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BULLETIN 94

GROUND-WATER RESOURCES OF
PAWNEE VALLEY, KANSAS

By V. C. FISHEL

*Prepared by the State Geological Survey of Kansas and the United States
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GROUND-WATER RESOURCES OF PAWNEE VALLEY, KANSAS

By V. C. Fishel

ABSTRACT

The report describes the ground-water resources of Pawnee Valley in Pawnee, Ness, and Hodgeman Counties in west-central Kansas. The hydrologic and geologic information was obtained in the field during the years 1944 to 1949, inclusive. The area consists of gently rolling upland plains together with relatively flat flood plains and terraces. The climate is subhumid, the average annual precipitation being between 20 and 24 inches. Farming and livestock raising are the principal occupations in the area. Irrigation from Pawnee River and from wells has been practiced extensively in Pawnee Valley.

The rocks that crop out in this area range in age from Cretaceous to Quaternary. The Cretaceous rocks are exposed in the uplands in northern Pawnee County and in the uplands adjacent to Pawnee Valley in Ness and Hodgeman Counties. The Ogallala formation crops out in the divide areas between Pawnee River and Buckner Creek and between Buckner Creek and Sawlog Creek. The alluvium and terrace deposits underlie the principal valleys and the adjacent areas. The alluvium yields large quantities of water to wells. Other formations generally yield only small to moderate quantities of water to wells.

In 1945 there were 132 irrigation wells in Pawnee Valley. These wells had yields ranging from about 400 to 1,900 gallons a minute. Pumping tests were made on nine wells to determine the yields of the wells and the permeability of the water-bearing materials. Data collected during the pumping tests and the analyses of the data from five of the tests are included in the report. Most of the wells constructed in recent years are single artificial gravel-pack or natural gravel-pack wells that penetrate all water-bearing materials above the Cretaceous bedrock. These wells are generally equipped with deep-well turbine pumps.

The saturated water-bearing materials of the alluvium have a maximum thickness of 120 feet. The volume of saturated water-bearing alluvium was determined for each township. A total of 1,145,000 acre-feet of water now in storage was estimated to be available for pumping. Records of ground-water levels and the stream flow of Pawnee River indicate that the available ground water exceeds the present withdrawal by pumping. The annual stream runoff in Pawnee Valley is about 36,000 acre-feet. If the water that is now discharged as stream flow is impounded and diverted to ground-water recharge, a maximum additional amount of 36,000 acre-feet could be available for pumping for irrigation.

Ground water in Pawnee Valley is usually hard, but is suitable for most uses. Waters from the Dakota formation generally contain large amounts of dissolved solids, but may be only moderately hard due to natural softening. The softer waters generally have a higher fluoride content. Water from the alluvium is hard but is of excellent quality for irrigation purposes.

The field data upon which this report is based are given in 22 tables. They include records of 316 wells, chemical analyses of water from 60 wells, and logs of 111 test holes.

INTRODUCTION

PURPOSE AND SCOPE OF THE INVESTIGATION

According to a survey made by Kenneth D. McCall and Milburn H. Davison of the Division of Water Resources, Kansas State Board of Agriculture, approximately 16,800 acres of land in Pawnee River Valley were under irrigation in 1939. Of the land under irrigation, about 8,700 acres were irrigated with water pumped from wells, about 6,000 acres were irrigated with water pumped from streams, and about 2,100 acres were irrigated with water pumped from wells and streams. There were 134 irrigation wells, 95 stream pumping plants, and 30 small dams in operation in 1939.

Irrigation with ground water in Pawnee Valley has been increasing for many years. That ground-water developments cannot be expanded indefinitely without causing overdevelopment is now recognized; hence, this investigation was made to determine the present utilization of ground water in the valley, under what conditions recharge and natural discharge occur, at what depth below the land surface water lies, the distribution of water-bearing materials beneath the surface of the land, the capacity of the water-bearing materials for storage and yield, the chemical character of the ground water, and many other pertinent facts.

The field work on the present investigation was begun in July 1945 by the United States Geological Survey and the State Geological Survey of Kansas in co-operation with the Division of Sanitation of the Kansas State Board of Health and the Division of Water Resources of the Kansas State Board of Agriculture.

The investigation was made under the general administration of A. N. Sayre, Chief of the Ground Water Branch of the U. S. Geological Survey.

LOCATION AND EXTENT OF THE AREA

The part of Pawnee Valley considered in this report is located in Ness, Hodgeman, and Pawnee Counties. It extends from the mouth of Pawnee River at Larned to 7 miles west of U. S. Highway 283. Consideration is given to some of the main tributaries of Pawnee River including Sawlog, Dry, Buckner, and Sawmill Creeks. The location of the area is shown by Figure 1.

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. Darton (1905), in describing the geology and ground-water resources of the Central Great Plains, discussed the general geology and stratigraphy of western Kansas. Records of water wells in Ness and Hodgeman Counties are included in his report. 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. A report by Rubey and Bass (1925) contains detailed descriptions and correlations of the Cretaceous strata and names a chalk member of the Greenhorn limestone for the town of Jetmore in Hodgeman County. Courtier (1934) mapped the geology of much of this area as a part of his study of south-central Kansas.

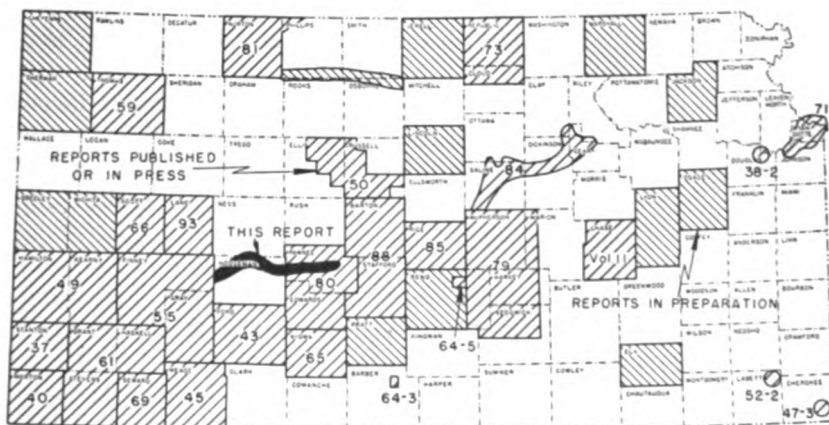


FIG. 1.—Area covered by this report and other areas for which co-operative ground-water reports have been published or are in preparation.

In 1932 Moss published a detailed description of the geology of Ness and Hodgeman Counties. Reports on geology and ground-water resources of Ford County (Waite, 1942), Finney and Gray Counties (Latta, 1944), and Barton and Stafford Counties (Latta, 1950) have been published. A report by McLaughlin (1949) gives the results of a detailed investigation of the geology and ground-water resources of Pawnee and Edwards Counties. That report includes the eastern one-half of the area described in this report.

METHODS OF INVESTIGATION

The field work for this report was begun in July 1945. An investigation of the geology and ground-water resources of Pawnee County which was started during the summer of 1944 by T. G. McLaughlin included that part of Pawnee Valley in Pawnee County. In July 1945 the study of the ground-water resources of Pawnee Valley was extended to include the valley area in Ness County and part of Hodgeman County. The geology of the valley was mapped by McLaughlin during the summer of 1945. A total of 316 wells in the valley area were visited, and the total depth and depth to water level below land surface in most of them were measured with a steel tape. The well inventory was made largely by J. Milton Sears, R. W. Ball, and Nels Florell. Well owners and drillers were interviewed regarding the nature and thickness of the water-bearing formations penetrated by the wells, and all available logs were collected. Information was obtained regarding the yield, draw-down, temperature of water, chemical character of the water, and the use of ground water.

Periodic measurements, generally monthly, of the water levels in eight observation wells in Pawnee Valley were started in August 1940. Measurements were discontinued on one well in December 1948 but they have been continued in the other seven wells since 1940.

Samples of water collected from 60 representative wells were analyzed by Howard A. Stoltenberg, chemist, in the Water and Sewage Laboratory of the Kansas State Board of Health at Lawrence.

During the fall of 1946 and the summer of 1947, 111 test holes were drilled in the area by O. S. Fent and Delmar W. Berry, geologists, and William T. Connor and Joseph Votaw using the hydraulic-rotary drilling machine owned by the State Geological Survey of Kansas. The locations of the test holes are shown on Plate 2. Samples of the material penetrated by the drill were collected and are described in the logs at the end of the report.

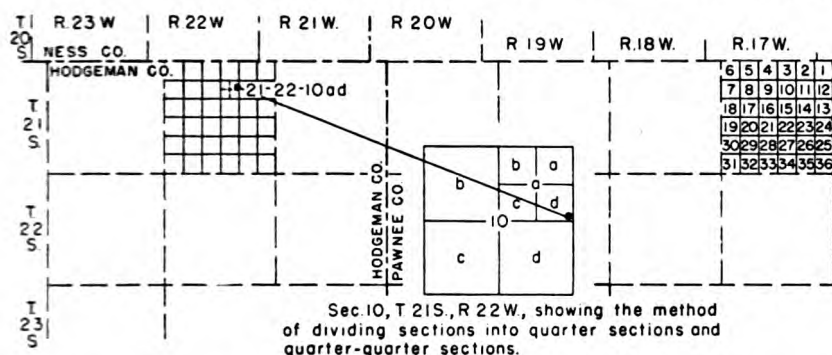
Altitudes of the measuring points were established by spirit leveling at each of the wells and the test holes. The levels were run by Charles K. Bayne and W. W. Wilson. The contours of the water table shown on Plate 2 are based on water-level altitudes in wells as referred to the altitudes of the measuring points.

Field data were compiled on a county map prepared by the State Highway Commission. Drainage data were taken from maps

prepared by the Soil Conservation Service and from aerial mosaics obtained from the United States Department of Agriculture, Agricultural Adjustment Administration.

WELL-NUMBERING SYSTEM

The well and test hole numbers used in this report give the locations of wells according to General Land Office surveys and according to the following formula: township, range, section, 160-acre tract within that section, and the 40-acre tract within that quarter section. This system of numbering wells is shown graphically on Figure 2. The 160-acre and 40-acre tracts are designated a, b, c,



or d in a counterclockwise direction beginning in the northeast quarter. For example, well 21-22-10ad is located in the SE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 10, T. 21 S., R. 22 W. If two or more wells are located within a 40-acre tract, the wells are numbered serially according to the order in which they were inventoried.

ACKNOWLEDGMENTS

The writer acknowledges the help of many residents of the area, especially those who gave permission to measure their wells, and who supplied helpful information regarding them. The operators of most of the irrigation wells were very co-operative and supplied much information regarding their wells. Special acknowledgment is given to the owners of nine irrigation wells for permitting us to make pumping tests on their wells and to Elias Hoagland, tenant on the Norris farm, for his helpful co-operation during the pumping test on the Norris irrigation well.

The geology was mapped by T. G. McLaughlin and the geologic map on Plate 1 was prepared by him. The manuscript for this

report has been critically reviewed by several members of the Federal and State Geological Surveys: George S. Knapp, Engineer, and Robert Smrha, Chief Engineer, of the Division of Water Resources of the Kansas State Board of Agriculture; and Dwight Metzler, Director, and Willard Hilton, Geologist, of the Division of Sanitation of the Kansas State Board of Health.

GEOGRAPHY

TOPOGRAPHY AND DRAINAGE

The area included in this report includes Pawnee River Valley and the main tributaries of Pawnee River—Sawlog Creek Valley, Buckner Creek Valley, and Sawmill Creek Valley. Flat bottomlands and terraces are the principal topographic features of the area. Pawnee Valley 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 locally is as much as a mile wide. Pawnee River has an average gradient of about 2 feet per mile.

CLIMATE

About 76 percent of the precipitation in this area falls during the 6-month period from April 1 through September 30. The U. S. Weather Bureau has maintained a precipitation gauge at Ness City since 1893, at Jetmore since 1901, and at Larned since 1880. The distribution of the normal precipitation at Ness City, by months, is given in Table 1. The annual precipitation and the cumulative departure from normal precipitation for the station at Ness City for the period of record beginning in 1893 are shown graphically in Figure 3. The precipitation has ranged from a minimum of 7.96 inches in 1894 to a maximum of 32.41 inches in 1944. The normal annual precipitation is 20.38 inches.

The normal annual precipitation recorded at Jetmore is 20.14 inches. The annual precipitation and the cumulative departure from normal precipitation at Jetmore for the period of record beginning in 1901 are shown graphically in Figure 4. The precipitation has ranged from a minimum of 11.93 inches in 1939 to a maximum of 32.09 inches in 1915.

The normal annual precipitation recorded at Larned is 23.48 inches. The precipitation at Larned has ranged from a minimum of 7.97 inches in 1872 to a maximum of 39.63 inches in 1915.

TRANSPORTATION

The Atchison, Topeka, and Santa Fe Railway Company has a spur line that extends from Larned to Jetmore. The communities served by this spur line are Frizell, Sanford, Rozel, Burdett, and Hanston.

The principal highways crossing Pawnee Valley are U. S. Highways 50 North, 183, 283, and Kansas Highway 45. U. S. Highway 50 North passes through or near Larned, Sanford, Rozel, Burdett, Hanston, and Jetmore. U. S. Highway 183 is a north-south highway that crosses the valley near Sanford and Rozel. U. S. Highway 283 is a north-south highway that passes through Ness City and Jetmore. State Highway 45 passes through Larned and follows the Arkansas River Valley in this area.

TABLE 1.—*Normal monthly precipitation at Ness City*

MONTH	Precipitation, inches	MONTH	Precipitation, inches
January.....	0.30	July.....	2.57
February.....	.79	August.....	2.50
March.....	.95	September.....	2.04
April.....	2.08	October.....	1.40
May.....	3.00	November.....	.82
June.....	3.33	December.....	.60

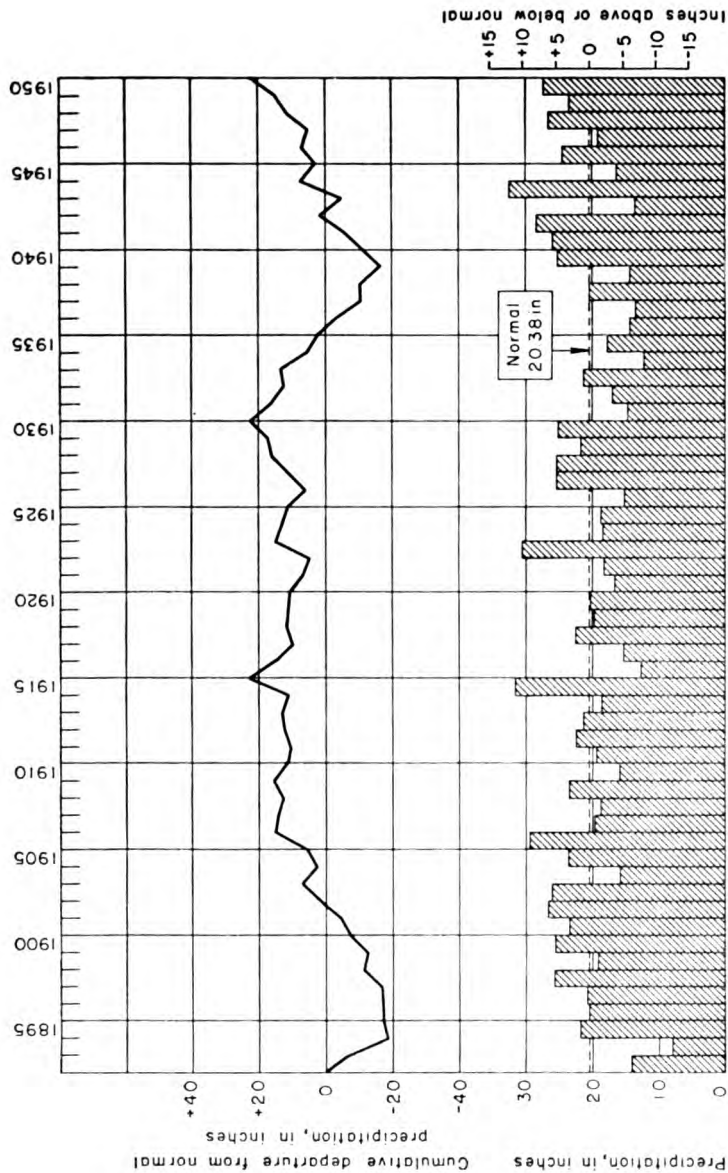


FIG. 3.—Annual precipitation and cumulative departure from normal precipitation at Ness City, Kansas. (Data from U. S. Weather Bureau.)

Pawnee Valley has many excellent county highways, some of which are hard-surfaced roads and others which have been surfaced with sand and gravel.

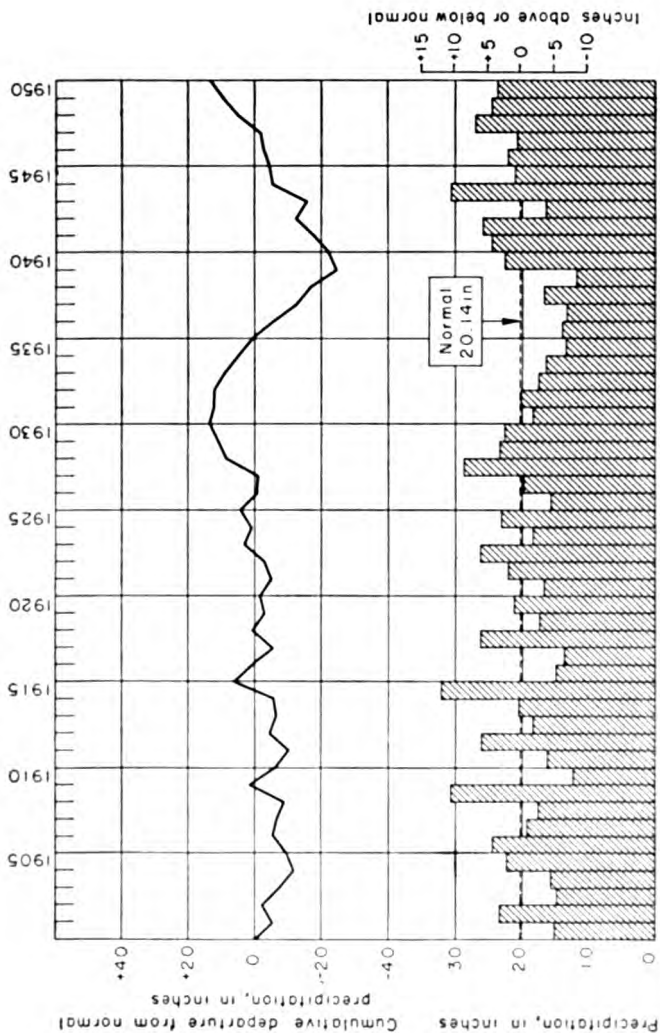


FIG. 4.—Annual precipitation and cumulative departure from normal precipitation at Jetmore, Kansas. (Data from U. S. Weather Bureau.)

GEOLOGY IN RELATION TO GROUND WATER

SUMMARY OF STRATIGRAPHY*

The rocks that crop out in Pawnee Valley are sedimentary and range in age from Cretaceous to Quaternary (Pl. 1). The oldest rocks exposed are Cretaceous and comprise the Dakota formation, Graneros shale, Greenhorn limestone, and Carlile shale. The Ogallala formation of Tertiary age caps the upland area in much of Hodgeman County. The terrace deposits that cover large areas adjacent to Pawnee River are believed to be Pleistocene in age but may be Tertiary in part. The alluvium in the principal valleys is Pleistocene.

A generalized section of the geologic formations of this area is given in Table 2.

CRETACEOUS SYSTEM

Cheyenne Sandstone

Character.—The Cheyenne sandstone does not crop out in Pawnee Valley; hence, little is known of its lithologic character in this area except as determined by the cuttings from test holes (McLaughlin, 1949, Pl. 3). The formation has been described in detail by Latta (1946, 1948) at the type locality near Belvidere which is about 20 miles south of the south line of Edwards County. Latta states (1946, p. 235):

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 flour-like 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 material 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.

* The stratigraphic classification used in this report is that of the State Geological Survey of Kansas.

TABLE 2.—Generalized section of the geologic formations in Pawnee Valley, Kansas

System	Series	Subdivision	Thickness (feet)	Physical character	Water supply
Quaternary	Pleistocene*	Alluvium	0-135	Coarse sand and gravel containing silt and clay. Sand and gravel generally overlain by 15 to 50 feet of silt and clay.	Yields large quantities of water to domestic, stock, and irrigation wells.
		Terrace deposits	0-150	Principally silt and clay but locally contains considerable sand and gravel.	Yields moderate supplies of water to domestic and stock wells and to a few irrigation wells.
Tertiary	Pliocene	Ogallala formation	0-100	Consists mainly of silt, sand, and gravel containing caliche.	Yields fair amounts of water for stock and domestic wells in parts of Ness and Hodgeman Counties.
		Carlile shale	0-100	Chalky shale containing thin beds of chalky limestone.	Yields small quantities of water to wells in adjacent area but not known to yield water to wells in this area.
Cretaceous	Gulfian*	Greenhorn limestone	0-125	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	20-36	Dark-gray shale containing sandy shale and lenses of sandstone.	Yields no water to wells in this area.
		Dakota formation	20-300	Consists principally of buff, yellow-brown, and brown sandstone and vari-colored clay and sandy clay.	Yields small to moderate quantities of water to domestic and stock wells.
	Comanche*	Kiowa shale	100-230	Dark-gray to black shale containing lenses of sandstone.	Yields no water to wells in this area.
		Cheyenne sandstone	15-50	Gray, tan, and white fine to medium-grained sandstone.	Yields no water to wells in this area due to its considerable depth. Water may be highly mineralized.

* Classification of the State Geological Survey of Kansas.

Distribution and thickness.—The Cheyenne sandstone probably underlies all or most of Pawnee Valley considered in this report (McLaughlin, 1949, Pl. 3) as well as large areas of southwestern Kansas except in some of the counties in the southern tier. It crops out in very few places in southwestern Kansas. The principal localities are in the Belvidere area in southeastern Kiowa County (Latta, 1946) and in adjacent areas in Comanche and Barber Counties.

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 ranges from 19 to 95 feet (McLaughlin, 1949) and averages about 27 feet.

Water supply.—In most places in Pawnee Valley adequate supplies of water of good quality can be obtained from younger formations above the Cheyenne sandstone. As few wells have been drilled into the Cheyenne, little information is available regarding the quality and quantity of the water. The Cheyenne is permeable enough in most places to supply water for stock and domestic purposes, but it occurs at a depth of more than 350 feet and quite frequently the water is highly mineralized so that it is undesirable in Pawnee Valley to drill wells to the Cheyenne. Chemical analyses of waters from two wells that tap the Cheyenne sandstone in Kiowa County are reported by Latta (1948, p. 86). The waters from both wells are highly mineralized, having, respectively, 9,235 and 3,138 parts per million of dissolved solids, 3,068 and 1,075 parts of sodium and potassium, 1,141 and 277 parts of sulfate, 4,588 and 1,560 parts of chloride, and 1,090 and 330 parts of hardness.

Kiowa Shale

Character.—The Kiowa shale does not crop out in Pawnee Valley. The lithologic character of the Kiowa shale 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 to 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 (McLaughlin, 1949). 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 Valley included in this report and much of southwestern Kansas where it is concealed in most places 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 125 feet in central Kansas and about 135 feet in southwestern Kansas. The thickness of the formation in Pawnee and Edwards Counties ranged from 133 to 222 feet and averaged about 180 feet (McLaughlin, 1949).

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

Dakota Formation

Character.—The Dakota 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 (McLaughlin, 1949, pl. 7).

Distribution and thickness.—The Dakota formation crops out in isolated areas in Pawnee County (Pl. 1) in the vicinity of Larned and Burdett; in Hodgeman County the formation crops out in large areas south of Buckner and Sawlog Creeks. The Dakota underlies all of Pawnee Valley considered in this report.

The Dakota is reported to attain a maximum thickness of about 275 feet in north-central Kansas (Plummer and Romary, 1942, p. 330). The average thickness of the Dakota in Pawnee and Edwards Counties is believed to be about 200 feet (McLaughlin, 1949). According to Moss (1932, pp. 32, 45) the Dakota formation has a thickness of more than 300 feet in Ness and Hodgeman Counties.

Water supply.—The Dakota formation yields small to moderate quantities of water to many wells in the Pawnee Valley area. Most of the domestic and stock wells in the Dakota have a small diameter and yield only small quantities of water. The large-diameter public-supply wells at Larned have yields ranging from 125 to 150 gallons a minute. The water supply for the City of Utica located northwest of this area is obtained from the Dakota and several years ago the water supply for Ness City was obtained from the Dakota.

The water in the Dakota is generally under artesian pressure. A flowing artesian well located southeast of Jetmore furnishes enough water for irrigating a large garden.

The Dakota supplies water to wells in the outcrop area and where it is overlain only by relatively impermeable materials such as those in the Graneros, Greenhorn, and Carlile formations. Where the Dakota is overlain by coarse water-bearing materials as in the Pawnee Valley, wells generally obtain an adequate supply of suitable water in the overlying materials.

Water from the Dakota formation generally contains a large amount of dissolved solids but is comparatively soft (Table 20). However, a sample of water collected from well 22-21-25aa contained only 111 parts per million of dissolved solids and had a hardness of 30 parts per million. Where the Dakota is overlain by a large thickness of younger deposits, the water may be highly mineralized.

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.

The thickness of the Graneros shale in the Pawnee Valley area 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 Valley area.

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. The shales contain thin beds of bentonitic clay. The formation has been divided into four units in this area, including the Pfeifer shale member at the top, the Jetmore chalk member, the Hartland shale member, and the Lincoln limestone member 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 bed, 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 crops out north of Pawnee Valley in northwestern Pawnee County, on both sides of Pawnee Valley in southern Ness County, and in the bluffs along Buckner and Sawlog Creeks in Hodgeman County. According to Moss (1932, p. 26)

The thickness of the formation is approximately 125 feet in Hodgeman County. The entire section is not exposed at any one place, and so measurements were made of the beds exposed in various places and correlated to obtain the total thickness. Part of the middle of the formation is not exposed in Ness or Hodgeman counties, so was measured in Ford county, just south of the Hodgeman county line.

Water supply.—Very few wells that receive their entire water supply from the Greenhorn limestone were observed in the Pawnee

Valley area. The water-yielding capacity of the formation is low, and very small supplies of comparatively hard water may be expected from wells penetrating this formation.

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 is the only part of the Carlile exposed in the area considered by this report. According to Moss (1932) the Blue Hill shale member crops out in a band 2 to 5 miles wide extending from the northeast to the southwest corner of Ness County and crosses the northwest corner of Hodgeman County.

The Fairport chalky shale member consists of thick beds of chalky shale alternating with thin beds of chalky limestone. The thick beds of chalky shale contain flat concretions and a few beds of bentonite. The lower, more resistant beds of chalky limestone form small terraces whereas the upper beds erode to smooth, rounded soil-covered hills.

Distribution and thickness.—The Fairport chalky shale member covers large areas in Ness and Hodgeman Counties but in Pawnee County it crops out only in the northern part. The Fairport caps the divide between Walnut Creek and Pawnee River and it crops out along both sides of Pawnee River and Buckner Creek in Hodgeman County.

Moss (1932, p. 23) reports that no measurement of the thickness of the Fairport chalky shale member could be made in Ness and Hodgeman Counties as there are no exposures of the upper part. McLaughlin (1949, p. 82) believes that the thickness of the Carlile shale in Pawnee County nowhere exceeds 100 feet.

Water supply.—Meager supplies of water are obtained from a few shallow dug wells in the Carlile shale. The water is obtained from the joints and bedding planes of chalky limestone in the lower part of the formation. Generally, if there are no overlying deposits which yield an adequate water supply, wells are drilled through the Carlile into the Dakota formation even though the Dakota water may be highly mineralized.

Water from the Carlile shale is hard but can be used for domestic and stock purposes.

TERTIARY SYSTEM

PLIOCENE SERIES

Ogallala Formation

Character.—The Ogallala formation consists mainly of silt, sand, and gravel containing caliche. The mortarlike appearance of the gritty beds that have been cemented has caused them to be called “mortar beds.” The “mortar beds” are the most conspicuous part of the formation because they are resistant to erosion and form benches and, in some cases, vertical bluffs. As the Ogallala formation is more resistant than most of the underlying Cretaceous strata, there is a distinct topographic break in most places at the contact. Moss (1932, p. 13) stated,

On the north-facing slopes the Ogallala beds form a steep slope, and along the northward-flowing streams they have been eroded into steep-walled valleys. Many of the northward-flowing tributaries of Buckner and Sawlog creeks are locally known as “canyons.” On the south-facing slopes the topographic break is usually not pronounced and in places may not be evident, so that there is a gentle, unbroken slope from the top of the Ogallala down across lower strata to the bottom of the valleys.

Distribution and thickness.—The Ogallala formation crops out in northwestern Edwards County and in a few scattered areas in Pawnee County (McLaughlin, 1949, p. 82). Thin patches of algal limestone overlie the Dakota formation at many places in Pawnee County. The Ogallala formation caps the plateau-like uplands that make up about a third of the area of Ness and Hodgeman Counties (Moss, 1932). The formation caps the divide areas between Pawnee River and Buckner Creek and between Buckner Creek and Sawlog Creek. It also covers most of the area to the east of Sawlog Creek in southeastern Hodgeman County.

The Ogallala formation is 66 feet thick at a test hole at the northwest corner of sec. 15, T. 23 S., R. 20 W. but may be nearly 100 feet thick at the Edwards-Hodgeman County line (McLaughlin, 1949, p. 82). Moss (1932, p. 13) reports a maximum thickness of 100 feet in Hodgeman County, and Waite (1942, p. 158) stated that it may be as much as 250 feet thick in Ford County.

Water supply.—The Ogallala formation yields moderate quantities of water for stock and domestic wells in many parts of Ness and Hodgeman Counties and yields small quantities to a few domestic and stock wells in the northwestern part of Edwards County (McLaughlin, 1949). The formation in this area is the eastern fringe

of the High Plains and in general is highly dissected. Also, the Ogallala overlies high areas of Cretaceous rocks so that much of the formation is largely drained of water. However, in local areas, properly constructed wells yield adequate supplies of water for stock and domestic use.

QUATERNARY SYSTEM

PLEISTOCENE SERIES

Terrace Deposits

Character.—The terrace deposits consist principally of light-tan to brown clay and silt containing some caliche and is interbedded with fine to coarse sand and some 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 sand and gravel is poorly sorted and generally occurs at the base of the deposits. The gravel pebbles consist principally of limestone, sandstone, and ironstone which probably were derived from the Greenhorn, Carlile, and Dakota formations. Locally, the terrace deposits contain thick deposits of gravel and sand which furnish adequate supplies of water for irrigation from wells.

Distribution and thickness.—The extent of the terrace deposits in Pawnee Valley is shown on the geologic map (Pl. 1) and their thickness and character are given by cross sections in Plate 3 and logs of test holes at the end of this report. Terrace deposits overlie the Cretaceous rocks on both sides of Pawnee River throughout most of Pawnee County and extend into Ness and Hodgeman Counties. Thick terrace deposits occur along the north side of Sawlog and Buckner Creeks to a point a few miles upstream from Hanston. Remnants of terraces have been observed farther upstream along Pawnee River and its tributaries, but owing to their small areal extent, discontinuous nature, and small importance as water-bearing material, the remnants of terraces in the upstream areas have been included with the alluvium on the geologic map.

According to McLaughlin (1949, p. 86):

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 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.

The thickness of the terrace deposits ranges from a feathered edge near their contact with the Cretaceous bedrock to more than 100

feet in some places. At test hole 21-21-14cb the terrace deposits have a thickness of 152 feet. The average thickness of the terrace deposits along Pawnee Valley in Pawnee County is about 60 feet (McLaughlin, 1949, p. 88).

Water supply.—Inasmuch as the terrace deposits consist primarily of clay and silt, the formation generally 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 places where the deposits contain 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.

Water from the terrace deposits is moderately hard but otherwise is of good quality.

Alluvium

Character.—The alluvium of Pawnee Valley consists of sand, gravel, silt, and clay. The upper part of the alluvium consists predominantly of clay and silt containing some sand. McLaughlin (1949, p. 89) found that this zone of silt and clay ranges in thickness from about 15 feet to 50 feet and has an average thickness of about 30 feet. These thick deposits of clay and silt retard and limit the quantity of ground-water recharge from local precipitation. Beneath the silt and clay there is, in most places, a thick deposit of gravel and sand that yields large quantities of water to wells in the valley.

Distribution and thickness.—Alluvium underlies the bottomland of Pawnee River and some of its larger tributaries. The extent of the alluvium is shown on the geologic map (Pl. 1) and its thickness and character are shown by cross sections in Plate 3 and by logs of test holes at the end of this report. The alluvium of Pawnee Valley has a width of as much as 3 miles in parts of Pawnee Valley and as much as 2 miles in Hodgeman and Ness Counties. The thickness of the alluvium in Pawnee County as determined by 15 test holes ranged from 65 to 138 feet and averaged 105 feet (McLaughlin, 1949, p. 89). In the cross sections shown on Plate 3 the alluvium in Ness and Hodgeman Counties has a maximum thickness of about 100 feet. The alluvium in Buckner and Sawlog Creeks generally has a thickness of not more than 70 feet, but in few places has a thickness of as much as 100 feet. The base of the alluvium is shown by the bedrock contour map (Fig. 5).

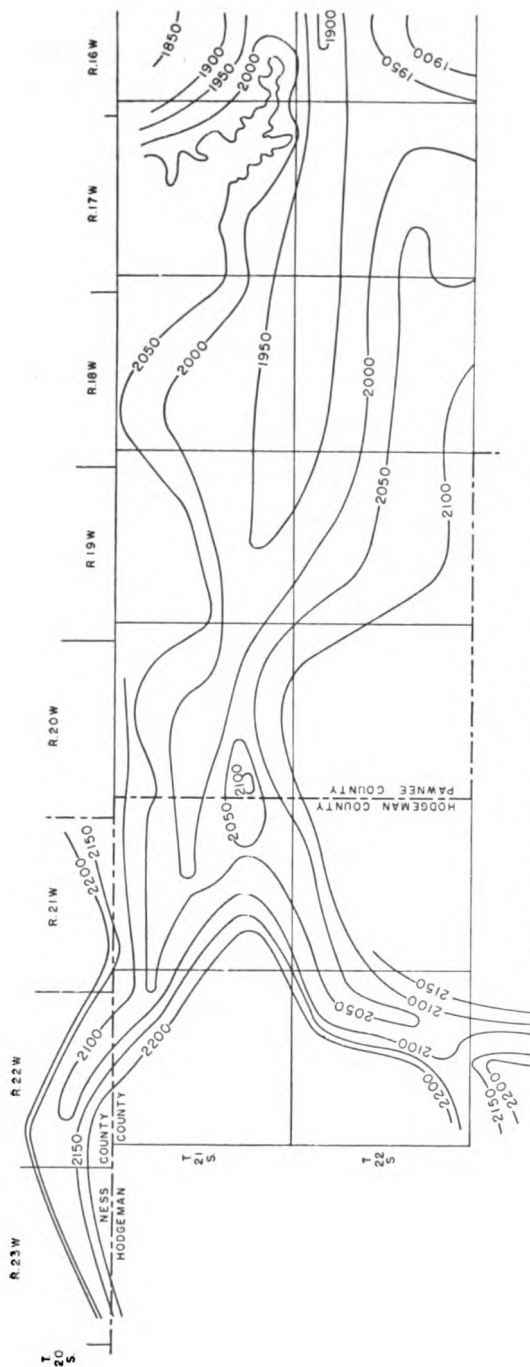


FIG. 5.—Contours on the bedrock in Pawnee Valley.

Water supply.—The alluvium of Pawnee, Buckner and Sawlog 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 the alluvium. A discussion of the large quantity of water pumped from the alluvium for irrigation is given in the section on irrigation. The water in the alluvium is hard but generally is suitable for most domestic, stock, and irrigation uses.

SOURCE, OCCURRENCE, AND MOVEMENT OF GROUND WATER

The discussion of the occurrence of ground water in Pawnee Valley has been based partly on the detailed treatment of the occurrence of ground water by Meinzer (1923), to which the reader is referred for more extensive consideration. A general discussion of the principles of ground-water occurrence, with special reference to Kansas, has been made by Moore and others (1940).

Throughout most, if not all, of Pawnee Valley, the rock formations below a certain level are saturated with water. The upper surface of the zone of saturation is known as the water table. The water in the upper part of the zone of saturation is generally replenished from precipitation, some of which reaches the water table by percolation downward through the soil. Normally the water that reaches the water table moves slowly toward Pawnee River or its tributaries and discharges into them. Before all the ground water above stream level can be drained away, more water is generally added from the surface; thus keeping the water table somewhat above stream level in the inter-stream tracts, though fluctuating as the recharge is temporarily more or less than the discharge. Owing to the continuous process of draining and the intermittent nature of recharge, the water table is in continuous fluctuation.

The ground water in Pawnee Valley consists largely of water that has fallen in the form of rain and snow and has percolated through the soil and subsoil materials to the water table. In areas of heavy pumping of ground water for irrigation the water table may be lower than the water surface in the river, and the aquifer may receive recharge from the river. On numerous occasions the Pawnee River has been observed to be dry along part of its course and to be flowing in parts. The dry parts were presumably caused by a lowering of the water table by pumping. Where the water table

was above the bed of the river, the river was a gaining stream and where it was below the river it was a losing stream.

The water in the alluvium occurs in the interstices between particles of clay, silt, sand, and gravel. The rate at which water moves through these materials depends on the hydraulic gradient, or slope of the water table, and on the size and shape of the interstices. The quantity of water available for pumping also depends on the thickness and areal extent of the saturated alluvium. Water moves freely through coarse gravels even under low hydraulic gradients, whereas it moves with extreme slowness through compact clay even under high hydraulic gradients. Although considerable quantities of water may move through beds of clay over very long periods of time, these deposits are regarded as being essentially impervious, and their importance with respect to ground water in some places is merely that they may serve as confining beds for water in adjacent beds of more permeable material.

The shape and slope of the water table in Pawnee Valley are shown on Plate 2 by contours drawn on the water table. Each contour line has been drawn through points on the water table having the same altitude. Ground water generally moves in the direction of maximum slope, which is at right angles to the contours. The contour map indicates that the water table slopes toward Pawnee River from both sides and that ground water is generally discharging into the river. Near the middle of the valley, the contours trend almost at right angles to the axis of the valley, and the spacing of the contours indicates an average hydraulic gradient or slope of about 4 feet to the mile.

The quantity of water flowing through a given cross-sectional area of water-bearing material is computed by the formula:

$$Q = pAv = PIA$$

in which Q is the quantity of water, p is the porosity of the material, A is the cross-sectional area, v is the average velocity of the ground water, P is the coefficient of permeability, and I is the hydraulic gradient. The approximate rate of movement of the water through the gravel, sand, and silt can be obtained by application of the above formula transposed as follows:

$$v = \frac{PI}{p}$$

If P is defined in Meinzer's units (gallons per day per square foot under a hydraulic gradient of 100 percent and a temperature of

60° F.), if I is given in feet per mile, and if p is given in percentage, v will be given in feet per day by the following formula:

$$v = \frac{PI}{395p}.$$

The average coefficient of permeability of four pumping tests (wells 21-21-35ba, 21-21-35cc, 22-22-23bc, and 23-22-11cc) is about 1,400. The hydraulic gradient is about 4 feet to the mile. For an assumed porosity of 30 percent for alluvial sediments in Pawnee Valley the average velocity of the ground water can be computed by the above formula as follows:

$$v = \frac{1,400 \times 4}{395 \times 30} = 0.5 \text{ foot per day.}$$

For silt having a coefficient of permeability of 10 gallons a day per square foot, a porosity of 30 percent, and a hydraulic gradient of 4 feet to the mile the ground water would have a velocity of about 0.04 inch per day.

HYDROLOGIC PROPERTIES OF THE WATER-BEARING MATERIALS

The quantity of ground water that a water-bearing formation will yield to wells depends upon the hydrologic properties of the material. The two hydrologic properties of greatest significance with respect to rate of yield are permeability and specific yield. Permeability is a measure of the ability of a formation to transmit water; specific yield is a measure of the quantity of water that will drain from the formation.

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

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

PUMPING TESTS

The permeability of the alluvium in Pawnee Valley was determined by five pumping tests. The results of all the tests were analyzed by the recovery method involving the formula developed by Theis (1935, p. 522) and also described by Wenzel (1942, p. 94) for computing the transmissibility of an aquifer. (The coefficient of transmissibility is equal to the average field coefficient of permeability, not corrected for temperature, multiplied by the saturated thickness of the aquifer.) The results of one test were analyzed by the distance-drawdown method described by Cooper and Jacob (1946, p. 527) for the determination of the coefficients of permeability and storage.

According to the recovery formula:

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

in which T = coefficient of transmissibility, in gallons per day per foot

q = pumping rate, in gallons per minute

t = time since pumping began, in minutes

t' = time since pumping stopped, in minutes

s = residual drawdown at the pumped well, in feet, at time t' .

The ratio $\log_{10} t/t'$ to s is equal to the ratio $\Delta \log_{10} t/t'$ to Δd where Δd is the change in the depth to the water level during the time interval $\Delta t'$. The ratio of $\Delta \log_{10} t/t'$ to Δd is determined graphically by plotting t/t' against corresponding values of d on semi-logarithmic paper with t/t' on the logarithmic co-ordinate. Over one cycle of the semi-logarithmic scale $\Delta \log_{10} t/t'$ becomes unity and the above formula reduces to:

$$T = \frac{264q}{\Delta d} \text{ where } \Delta d \text{ is the change in depth to the water level}$$

over one cycle of the semi-logarithmic scale.

According to the distance-drawdown method described by Cooper and Jacob (1946, p. 527, eq. 3):

$$s = - \left(\frac{2.303Q}{2\pi T} \right) \left[\log_{10} r - \frac{1}{2} \log_{10} \left(\frac{2.25Tt}{S} \right) \right]$$

The variables in this equation are the drawdown s , the distance r , and the time t . T is the coefficient of transmissibility

and S is the coefficient of storage. When t is constant, the above equation will be a straight-line plot of s against $\log_{10} r$. The slope of the straight-line plot is represented by the quantity on the outside of the brackets and the intercept of the straight line on the zero-drawdown line is represented by the second term within the brackets.

The drawdown at a time (t) after the discharge begins is plotted against r on semi-logarithmic paper with r on the logarithmic scale. Equating the quantity outside of the brackets in the above equation with the slope of the graph,

$$\frac{2.303Q}{2\pi T} = \frac{\Delta s}{\Delta \log_{10} r}$$

$$\text{Then } T = \frac{2.303Q}{2\pi} \frac{\Delta \log_{10} r}{\Delta s}$$

For convenience $\Delta \log_{10} r$ may be made unity by having it represent one logarithmic cycle, thus (Cooper and Jacob, eq. 6):

$$T = \frac{2.303Q}{2\pi \Delta s}$$

where Δs is the difference in drawdown over one logarithmic cycle.

The second term in brackets in the original equation can be equated with the intercept of the straight line on the zero-drawdown line and solved for the coefficient of storage (Cooper and Jacob, eq. 7):

$$S = \frac{2.25Tt}{r_o^2}$$

where r_o is the value of r at the $s = 0$ -intercept.

Alexander pumping test.—A pumping test was made by W. W. Wilson and D. C. Forrey on well 21-21-35cc on the farm of H. E. Alexander located in the SW¼ SW¼ sec. 35, T. 21 S., R. 21 W. The well was pumped on September 10, 1947, at an average rate of about 825 gallons a minute from 7:59 a. m. to 12:10 p. m. The static water level before pumping started was 31.35 feet below the land surface. The drawdown was about 14.4 feet and the specific capacity was about 57 gallons a minute per foot. The water-level measurements made during and following the pumping period are given in Table 3. The drawdown and recovery curves are shown in Figure 6.

TABLE 3.—*Water-level measurements in feet below the land surface in the Alexander irrigation well made during the pumping test on September 10, 1947*

TIME	Depth to water level, feet	Discharge, gallons a minute	Remarks
7:50 a. m.	31.35	.....	Static water level
7:59 .....	.....	.....	Pumping started
8:20	44.25	831	.....
8:50	44.90	825	.....
9:20	45.30	820	.....
9:50	45.65	818	.....
10:20	45.75	813	.....
10:50	45.98	807	.....
11:50	46.25	803	.....
11:55 .....	.....	1060	.....
12:10 p. m. ....	.....	.....	Pumping stopped
12:11	37.22	.....	.....
12:12	36.37	.....	.....
12:13	35.98	.....	.....
12:14	35.69	.....	.....
12:15	35.52	.....	.....
12:17	35.26	.....	.....
12:19	35.08	.....	.....
12:22	34.88	.....	.....
12:25	34.72	.....	.....
12:30	34.53	.....	.....
12:40	34.22	.....	.....
12:50	33.99	.....	.....
1:00	33.79	.....	.....
1:15	33.58	.....	.....
1:30	33.40	.....	.....
2:00	33.07	.....	.....
2:30	32.76	.....	.....
3:00	32.67	.....	.....
3:30	32.53	.....	.....
4:00	32.39	.....	.....

In applying the Theis recovery formula to the data given in Table 3, the value of T (coefficient of transmissibility) was found to be 139,000. The coefficient of transmissibility (139,000) divided by the thickness of saturated water-bearing material (48 feet) gives an average coefficient of permeability of 2,900.

Chilson pumping test.—A pumping test was made by W. W. Wilson and D. W. Berry on well 23-22-11cc on the farm of L. R. Chilson located in the SW cor. sec. 11, T. 23 S., R. 22 W. The well was pumped on November 15, 1946, at an average rate of about 685 gallons a minute from 10:10 a. m. to 2:19 p. m. The static water level before pumping started was 21.83 feet below the land surface. The drawdown was about 18.0 feet and the specific

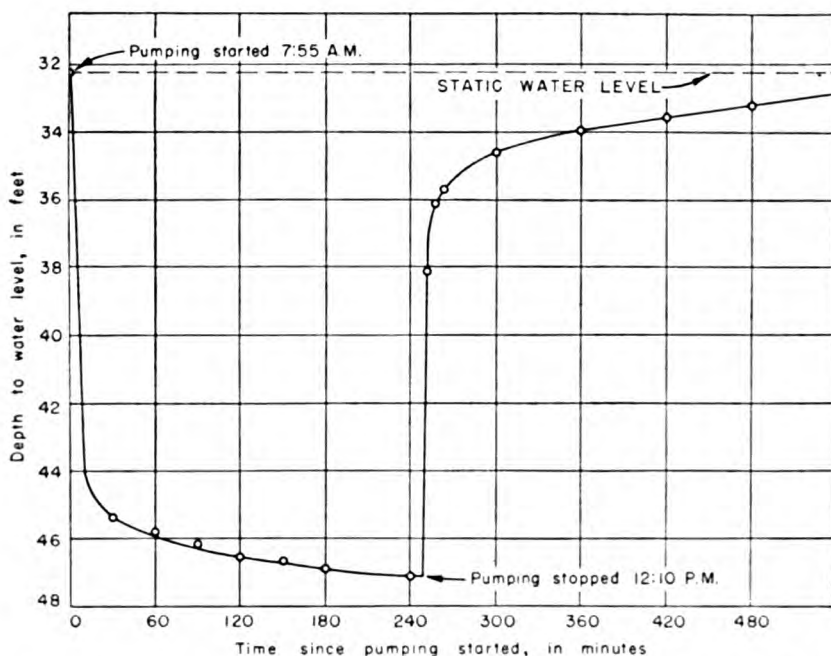


FIG. 6.—Drawdown and recovery curves for the Alexander well (21-21-35cc) during the pumping test on September 10, 1947.

capacity was about 38 gallons a minute per foot. The water-level measurements made during and following the pumping period are given in Table 4.

In applying the Theis recovery formula to the data given in Table 4, the value of T (coefficient of transmissibility) was found to be 44,800. The coefficient of transmissibility (44,800) divided by the thickness of water-bearing material (76 feet) gives an average coefficient of permeability of 590.

Hirschler pumping test.—A pumping test was made by W. W. Wilson and G. C. Prescott on May 20, 1948, on well 22-22-23bc on the farm of E. E. Hirschler located in the SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 23, T. 22 S., R. 22 W. The well was pumped at an average rate of about 1,210 gallons a minute from 8:04 a. m. to 11:52 a. m. The static water level before pumping started was 30.80 feet below the land surface. The drawdown was about 27.0 feet and the specific capacity was about 45 gallons a minute per foot. The water-level measurements

TABLE 4.—*Water-level measurements in feet below the land surface in the Chilson irrigation well (23-22-11cc) made during the pumping test on November 15, 1946*

TIME	Depth to water level, feet	Discharge, gallons a minute	Remarks
10:05 a. m.	21.83	.....	Static water level
10:10 .....	.....	.....	Pumping started
10:30	41.05	724	.....
11:00	40.13	695	.....
11:30	40.50	681	.....
12:00	40.60	682	.....
1:15 p. m.	41.00	677	.....
2:15	39.80	657	.....
2:19 .....	.....	.....	Pumping stopped
2:20	31.38	.....	.....
2:21	29.65	.....	.....
2:22	28.73	.....	.....
2:23	28.19	.....	.....
2:24	27.79	.....	.....
2:25	27.49	.....	.....
2:26	27.22	.....	.....
2:27	26.99	.....	.....
2:28	26.77	.....	.....
2:29	26.63	.....	.....
2:30	26.47	.....	.....
2:33	26.09	.....	.....
2:36	25.79	.....	.....
2:40	25.43	.....	.....
2:50	24.80	.....	.....
3:00	24.41	.....	.....
3:15	24.05	.....	.....
3:30	23.80	.....	.....
4:00	23.48	.....	.....
5:00	23.11	.....	.....

made during and following the pumping period are given in Table 5.

In applying the Theis recovery formula to the data given in Table 5, the value of T (coefficient of transmissibility) was found to be 51,000. The coefficient of transmissibility (51,000) divided by the thickness of water-bearing material (82 feet) gives an average coefficient of permeability of 620.

Lynam pumping test.—A pumping test was made by W. W. Wilson and D. C. Forrey on September 9, 1947, on well 21-21-21bc on the farm of W. A. Lynam located in the SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 21, T. 21 S., R. 21 W. The well was pumped at an average rate of 840 gallons a minute from 8:10 a. m. to 11:50 a. m. The static water level before pumping started was 33.21 feet below the land surface. The draw-

TABLE 5.—Water-level measurements in feet below the land surface in the Hirschler irrigation well (22-22-23bc) made during the pumping test on May 20, 1948

TIME	Depth to water level, feet	Discharge, gallons a minute	Remarks
8:00 a. m.	30.80		Static water level
8:04			Pumping started
8:45		1,234	
9:15		1,222	
9:45		1,220	
10:15		1,204	
10:45		1,213	
11:15		1,203	
11:45	58	1,190	
11:52			Pumping stopped
11:54	40.25		
11:55	39.20		
11:56	38.47		
11:57	37.88		
11:58	37.39		
11:59	36.97		
12:00	36.62		
12:01 p. m.	36.30		
12:02	35.99		
12:03	35.77		
12:04	35.53		
12:05	35.33		
12:06	35.13		
12:07	34.95		
12:08	34.78		
12:09	34.63		
12:10	34.48		
12:12	34.23		

down was about 14 feet and the specific capacity was about 60 gallons a minute per foot. The water-level measurements made during and following the pumping period are given in Table 6.

In applying the Theis recovery formula to the data given in Table 6, the value of T (coefficient of transmissibility) was found to be 460,000. The coefficient of transmissibility (460,000) divided by the thickness of water-bearing material (38.4 feet) gives an average coefficient of permeability of 12,000.

Norris pumping test.—A pumping test was made by W. W. Wilson, T. G. McLaughlin, and V. C. Fishel on October 6, 1949, on well 21-21-35ba on the farm of Clyde Norris located in the NE¼ NW¼ sec. 35, T. 21 S., R. 21 W. (Pl. 4A). The well was pumped at an average rate of 950 gallons a minute from 9:03 a. m. to 5:40 p. m. The static water level before pumping started was 30.74 feet

TABLE 6.—*Water-level measurements in feet below the land surface in the Lynam irrigation well (21-21-21bc) made during the pumping test on September 9, 1947*

TIME	Depth to water level, feet	Discharge, gallons a minute	Remarks
8:00 a. m.	33.21		Static water level
8:10			Pumping started
8:30	46.09	835	
9:00	46.48	845	
9:30	47.02	848	
10:00	47.05	845	
10:30	47.20	845	
11:00	47.36	845	
11:45	47.30	825	
11:50			Pumping stopped
11:51	34.79		
11:52	34.71		
11:53	34.57		
11:54	34.49		
11:56	34.41		
11:58	34.34		
12:01 p. m.	34.29		
12:05	34.23		
12:15	34.11		
12:25	34.04		
12:45	33.92		
1:00	33.86		
1:20	33.78		
1:40	33.73		

below the land surface. The drawdown was about 14.5 feet and the specific capacity was about 65 gallons a minute per foot.

Two 1½-inch observation wells having depths of 45 feet were constructed along the fence line east of the pumped well. The wells were located 100 and 300 feet respectively east of the irrigation well. The water levels in these observation wells and the pumped well were measured during and after the pumping period.

The measuring point of the pumped well was 99.43 feet above an assumed datum. The measuring point of the well 100 feet east was 99.46 feet above the datum and the measuring point of the well 300 feet east was 100.00 feet above the datum.

The discharge measurements made by a Hoff current meter (Pl. 4A) during the pumping period are given in Table 7. The water-level measurements made during the pumping period are given in Table 8 and the recovery measurements are given in Table 9.

The recovery measurements given in Table 9 for the pumped well are plotted on Figure 7. The ratio t/t' (time since pumping started divided by the time since pumping stopped) is plotted against the corresponding depth to water level. In applying the Theis recovery formula it is found that the change in depth to the water level (Δd) over one cycle of the semi-logarithmic paper is 0.68 foot. Then from the equation

$$T = \frac{264q}{\Delta d} = \frac{264 \times 950}{0.68} = 366,000$$

The drawdown of the water levels near the end of the pumping period in the observation wells are plotted in Figure 8 against the distance of the observation wells from the pumped well.

In applying the distance-drawdown formula given on page 31 it is found that the change in drawdown (Δs) over one cycle of the semi-logarithmic paper is 5.27 feet. The rate of pumping was about 950 gallons a minute or 2.12 cubic feet per second.

$$\begin{aligned} T &= \frac{2.303Q}{2\pi\Delta s} = \frac{2.303 \times 2.12}{2 \times 3.1416 \times 5.27} = 0.147 \text{ c. f. s./ft.} \\ &= 95,000 \text{ g. p. d./ft.} \end{aligned}$$

The coefficient of transmissibility (95,000) divided by the thickness of water-bearing material (61 feet) gives a coefficient of permeability of 1,550.

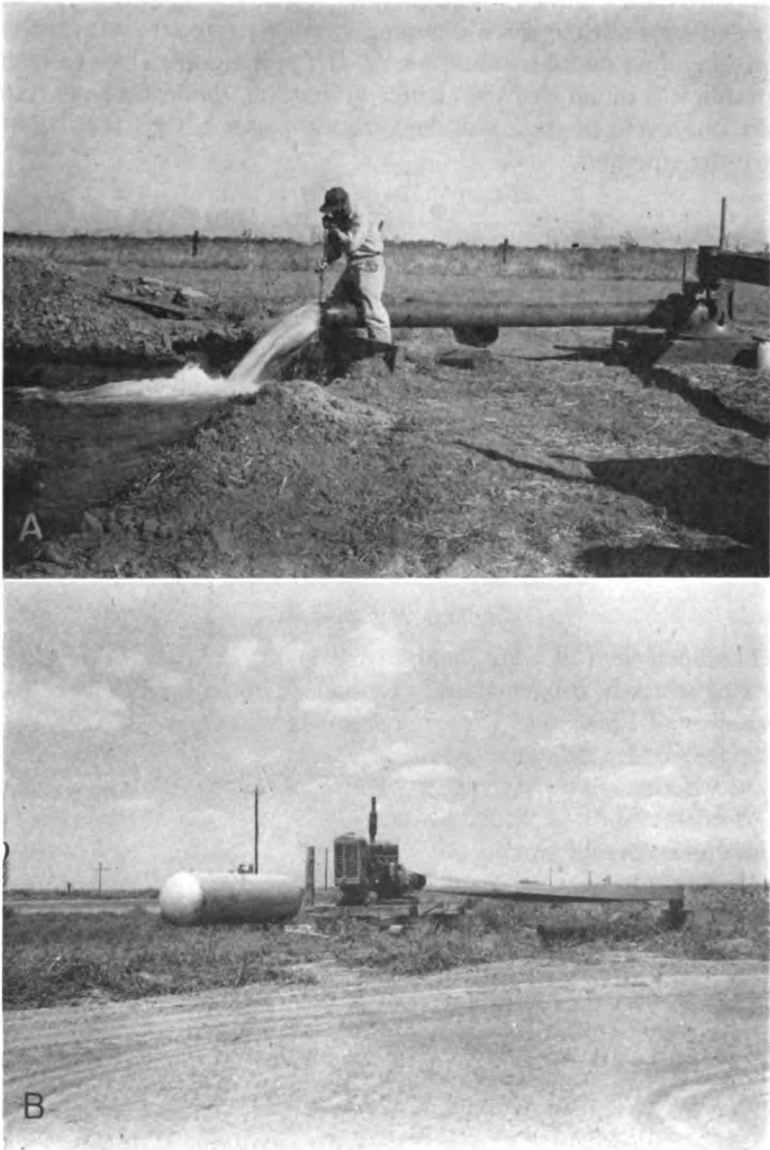


PLATE 4. A, Measuring the discharge of the Norris well (21-21-35ba) with a Hoff current meter. B, Irrigation well 22-22-23bc equipped with a turbine pump powered by an engine using butane gas.

TABLE 7.—Discharge measurements of the Norris irrigation well made during the pumping test on October 6, 1949

TIME	Discharge, gallons a minute	TIME	Discharge, gallons a minute
9:15 a. m.	976	2:35.	949
9:36.	955	3:10.	946
10:37.	959	3:38.	946
11:28.	935	4:32.	942
12:12 p. m.	939	5:12.	939
12:53.	946	5:29.	935
1:28.	952	5:40.	Pump stopped
2:08.	952		

TABLE 8.—Water-level measurements in feet below the measuring points in the Norris irrigation well and observation wells during the pumping period on October 6, 1949

Pumped well		Well 100 feet east		Well 300 feet east	
TIME	Depth to water level, feet	TIME	Depth to water level, feet	TIME	Depth to water level, feet
9:00 a. m.	31.34	9:00 a. m.	31.33	9:00 a. m.	32.70
9:16.	43.85	9:04.	32.50	9:28.	33.09
9:38.	44.57	9:06.	33.06	9:46.	33.46
9:53.	44.73	9:08.	33.35	9:59.	33.63
10:22.	44.98	9:23.	34.13	10:18.	33.80
11:30.	45.21	9:30.	34.30	10:47.	33.99
12:04 p. m.	45.29	9:43.	34.55	11:50.	34.26
12:54.	45.41	10:02.	34.70	12:20 p. m.	34.36
1:29.	45.50	10:15.	34.80	12:47.	34.44
2:09.	45.60	10:43.	34.94	1:31.	34.56
2:37.	45.64	11:03.	35.03	2:43.	34.69
3:11.	45.71	11:47.	35.18	3:10.	34.74
3:40.	45.72	12:17 p. m.	35.27	3:47.	34.80
4:34.	45.78	12:50.	35.36	4:27.	34.96
5:13.	45.83	1:29.	35.45	5:30.	34.95
5:31.	45.83	2:41.	35.60		
		3:08.	35.65		
		3:45.	35.63		
		4:25.	35.79		
		5:29.	35.87		
		5:37.	35.89		

TABLE 9.—*Recovery water-level measurements in feet below the measuring point in the Norris irrigation well and observation wells following the pumping period on October 6, 1949*

Pumped well		Well 100 feet east		Well 300 feet east	
TIME	Depth to water level, feet	TIME	Depth to water level, feet	TIME	Depth to water level, feet
5:42 p. m.	34.24	5:40½ p. m.	34.95	5:41 p. m. ...	34.94
5:43	34.08	5:41½	34.63	5:42	34.88
5:44	33.98	5:42½	34.45	5:43	34.84
5:45	33.91	5:43½	34.38	5:44	34.82
5:47	33.81	5:44½	34.30	5:45	34.80
5:50	33.74	5:45½	34.26	5:47	34.77
5:55	33.66	5:46½	34.20	5:49	34.73
6:05	33.54	5:47½	34.18	5:50	34.73
6:15	33.47	5:48½	34.15	5:51	34.72
6:30	33.35	5:49½	34.12	5:53	34.70
.....	.....	5:50½	34.11	5:55	34.67
.....	.....	5:55	34.04	5:57	34.66
.....	.....	6:00	33.99	5:59	34.63
.....	.....	6:10½	33.91	6:03	34.61
.....	.....	6:17	33.85	.....	.....

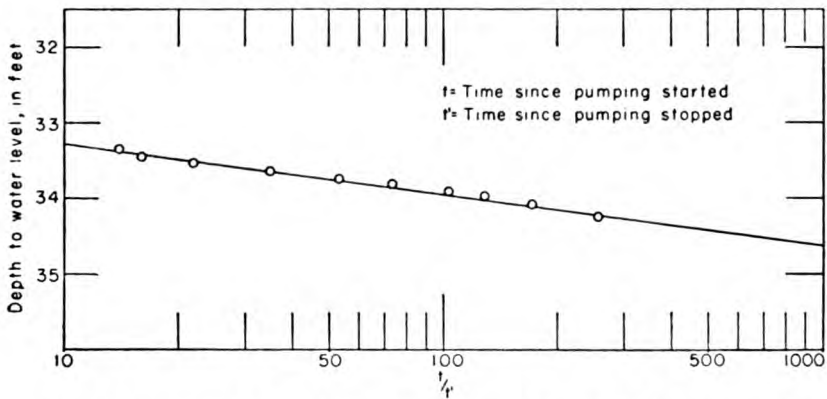


FIG. 7.—Pumping test on Norris well obtained by plotting the depth to the water level against t/t' (time since pumping started divided by the time since pumping stopped).

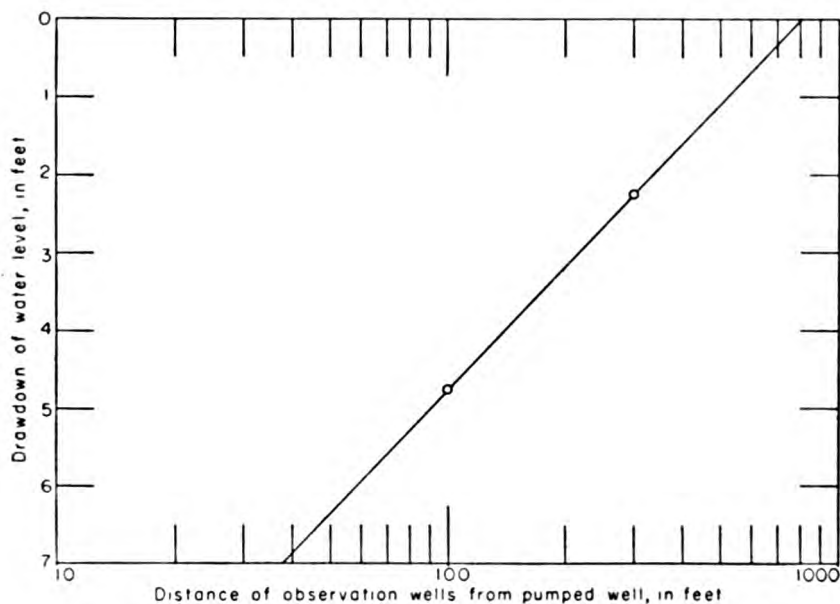


FIG. 8.—Drawdown of water levels plotted against the distance of the observation wells from the pumped well during the test on the Norris well.

From Figure 8 it is found that when $s = 0$, $r = 810$. Then applying the formula

$$S = \frac{2.25Tt}{r_o^2} = \frac{2.25 \times 0.149 \times 0.39 \times 86,400}{810^2} = 1.7 \text{ percent}$$

SUMMARY OF PERMEABILITY TESTS

Pumping tests were made on five wells in Pawnee Valley to determine the permeability of the water-bearing materials. Pumping tests were made on four additional wells to determine their yields. The results of the pumping tests are summarized in Table 10.

The test on the Lynam well indicated a coefficient of permeability of 12,000 which probably results from very favorable local conditions in the water-bearing material in Pawnee Valley. Neglecting this test and the recovery test on the Norris well, the other four tests gave an average of about 1,400 for the coefficient of permeability. These four permeability tests, two in Pawnee River Valley and two in Buckner Creek Valley, indicate that the alluvium in the

TABLE 10.—Results of pumping tests made on wells in Pawnee Valley

Well No.	OWNER	Depth of well, ft.	Yield, g.p.m.	Specific capacity g. p. m./ft.	Coefficient of transmissibility g. p. d./ft.	Coefficient of permeability g. p. d.
21-21-21bc	W. W. Lynam	72	840	60	460,000	12,000
21-21-33cc	Melvin Bryant	95	900	..	..	..
21-21-35ba	Clyde Norris	96	950	66	95,000	1,550
21-21-35cc	H. E. Alexander	80	825	57	139,000	2,900
22-21-3	Korf Brothers	87	1,070	65	..	..
22-21-4aa	Melvin Bryant	73	1,050	68	..	..
22-21-9cc	R. H. Thomson	67	750	..	..	..
22-22-23bc	E. E. Hirschler	114	1,210	45	51,000	620
23-22-11cc	L. R. Chilson	98	685	37	44,800	590

two valleys differs materially as to permeability. Also the test drilling indicates that the gravel and sand in Pawnee Valley is more coarse and generally has a greater thickness.

SUMMARY OF SPECIFIC YIELD TESTS

The analysis of the pumping test on the Norris irrigation well indicated a specific yield (storage coefficient) of 1.7 percent. The well is semi-artesian because the aquifer is confined by several feet of clay during nonpumping conditions. As a result of the semi-artesian conditions the specific yield obtained by this method was much too low for average conditions of the water-bearing material in Pawnee Valley.

Additional pumping tests and laboratory tests are planned in an attempt to determine a more correct value of the specific yield.

Pending these pumping tests and the laboratory tests a specific yield of 15 percent is being used, as the material in Pawnee Valley seems to be comparable to some material in other areas where the specific yield is about 15 percent.

GROUND-WATER LEVELS AND THEIR SIGNIFICANCE

The water table in Pawnee Valley is not a stationary surface, but a surface that fluctuates up and down much like the water level in a lake or reservoir. However, over a long period of time a condition of approximate equilibrium exists between the amount of water that is added annually to ground-water storage and the amount that is discharged annually by natural means. In general, the water table rises when the amount of recharge exceeds the amount of discharge and declines when the discharge is greater

than the recharge. Thus, changes in the water levels in wells indicate to what extent the ground-water reservoir is being depleted or replenished.

The factors controlling the rise of the water table in Pawnee Valley are (1) the amount of precipitation within the valley that passes through the soil and descends to the water table; and (2) the amount of influent seepage that reaches the underground reservoir from Pawnee River and its tributaries. The relation between the amount of precipitation and the level at which the water stands in wells is complicated by several factors. After a long dry period, the soil moisture becomes depleted through evaporation and transpiration; when a rain does occur the soil moisture must be replenished before any water can descend to the water table. During the winter when the ground is frozen the water falling on the surface is hindered from reaching the water table, and during the hot summer, some of the water that falls as rain is lost directly into the air by evaporation. Where the water table stands comparatively far below the surface, it fluctuates less in response to precipitation than it does where it is comparatively near the surface. In Pawnee Valley the water table is generally overlain by several feet of silt and clay (Pl. 3) which retards and limits the movement of water down to the water table.

The factors controlling the decline of the water table are (1) the quantity of water pumped from wells for irrigation, domestic, and stock use; (2) the quantity of water transpired directly from the water table by plants; (3) the quantity lost from the ground-water reservoir by evaporation; and (4) the quantity discharged as effluent seepage into the streams. Pawnee River has a deep channel; over most of the valley, the water table is more than 15 feet below the land surface and over much of the valley it is more than 20 feet below the land surface. Consequently the quantity of water discharged directly from the water table by evaporation and transpiration is small.

The ground-water levels in Pawnee Valley are an index of the extent of irrigation development in the valley. As irrigation from wells increases the water levels will decline until they are readjusted to the increased pumpage. If the irrigation developments reach the point where the pumpage exceeds the ground-water recharge, the water levels will continue to decline. Thus the ground-water levels give a close check on the relationship between the available water supply and its development.

OBSERVATION-WELL PROGRAM

In August 1940, eight wells in Pawnee Valley were selected as observation wells, and about monthly measurements of water level in them were begun to obtain information concerning the fluctuations in storage of the underground reservoir. Measurements on one well (21-19-27cc) were discontinued in December 1948. The descriptions of the wells and the water-level measurements for 1940 are given in Water-Supply Paper 908 which is the annual water-level report of the Federal Geological Survey for that year (Meinzer and Wenzel, 1942, pp. 124-125, 150-151). Subsequent water-level measurements have been published in ensuing water-level reports (Water-Supply Papers 938, 946, 988, 1018, 1025, and 1073). The descriptions of the wells are included in Table 22 of this report. The well numbers used in this report and in the water-supply papers are correlated in Table 11.

TABLE 11.—*Observation-well numbers used in this report and the corresponding numbers given in annual water-supply papers*

Well No. in this report	Well No. in water-supply papers	Well No. in this report	Well No. in water-supply papers
20-22-20cc.....	Ness 2	21-22-12bc.....	Hodgeman 3
20-23-32ca.....	Ness 1	22-16-6bb.....	Pawnee 8
21-19-27cc.....	Pawnee 6	22-17-18aa.....	Pawnee 7
21-21-36ab.....	Hodgeman 5	22-22-13cc.....	Hodgeman 4

IRRIGATION IN PAWNEE VALLEY

EXTENT OF IRRIGATION

The precipitation in Pawnee Valley averages about 20 inches a year. Good crops can ordinarily be grown without irrigation but do not yield as well without irrigation as when irrigated. In dry years crops may be almost failures. Although the precipitation for the year may be but a few inches below normal, a drought in July and August may seriously damage a crop which had promise of a satisfactory yield. Irrigation in Pawnee Valley has resulted in increased yields every year, and in some years the application of but a few inches of water at a critical period has saved a crop from serious injury by drought.

Irrigation by pumping water directly from the river and from wells was started in Pawnee Valley during the early part of this century. By 1925, about 35 irrigation wells were in operation. The

number of wells had increased to approximately 75 in 1935 and to 132 in 1945. From 1940 to 1948 the precipitation was above normal and labor was scarce; therefore, many of the irrigation wells were not used. Most of these wells are still available for use if needed, and many new wells are being drilled annually.

YIELDS OF IRRIGATION WELLS

Irrigation wells in Pawnee Valley yield from about 400 to 1,900 gallons a minute. The yields of nine wells were measured by W. W. Wilson and are given in Table 10. These nine wells have an average yield of about 900 gallons a minute. The yields of 108 additional wells were reported by the owners or drillers. The yields of the 117 wells are given in Table 22 and are summarized in Table 12.

The irrigation wells in Pawnee Valley differ greatly in yield and over-all efficiency. The yields of the measured wells range from 685 to 1,210 gallons a minute, and the specific capacities range from 37 to 68 gallons a minute per foot of drawdown. There are many factors that determine the yields of wells, including the methods of construction, the character and thickness of the water-bearing for-

TABLE 12.—*Reported or measured yields of irrigation wells in Pawnee, Ness, and Hodgeman Counties in Pawnee Valley*

Yield of wells, gallons a minute	Number of wells			
	Pawnee County	Ness County	Hodgeman County	Total
Less than 600	3	1	2	6
600-800	10	6	3	19
800-1,000	3	11	15	29
1,000-1,200	21	5	17	43
1,200-1,400	7	1	2	10
1,400-1,600	6	.....	2	8
More than 1,600	2	.....	.....	2
Totals	52	24	41	117

mation, the diameter of the casing, the material used for casing, the type of perforations, the quality of the water (whether harmless or corrosive or whether likely to form incrusting material readily), the type and placing of the screen, the development and finishing of the well, the age of the well, and the distance between pumping wells (effect of mutual interference).

CONSTRUCTION OF IRRIGATION WELLS

Several methods have been used in constructing irrigation wells in Pawnee Valley. Some wells have been constructed by the owners but most of the wells have been drilled by professional well drillers. The older irrigation wells in this area were constructed by digging a pit nearly to the water table, 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 some of these wells a centrifugal pump was placed at the top of the pit, but in most of the wells a centrifugal pump was placed at the bottom of the pit and connected by a belt to an engine at the surface.

Most of the newer plants consist of a single artificial gravel-pack or natural gravel-pack well that penetrates all water-bearing materials above the Cretaceous bedrock. These wells are equipped with deep-well turbine pumps (Pl. 4B).

The most common drilling methods used in this area are the orange-peel bucket method and the hydraulic rotary method. In constructing a well by the orange-peel bucket method, a hole of large diameter (48 to 60 inches) is excavated using an orange-peel bucket and temporarily cased. A well screen or perforated casing of a smaller diameter than the hole (12 to 25 inches) is then lowered into place and centered opposite the water-bearing beds. Blank casing extends from the screen to the surface. The annular space between the inner and outer casings then is filled with carefully sorted gravel—preferably of a grain size just slightly larger than the openings in the screen or perforated casing and also just slightly larger than that of the water-bearing material. The outer casing is then partly withdrawn in order to uncover the screen and allow the water to flow through the gravel packing from the water-bearing material.

In the hydraulic-rotary method, the hole is made by the rapid rotation of a bit on the bottom of a string of drill pipe. In this method removal of the cuttings is accomplished by circulating mud-laden fluid down through the drill pipe and up through the annular space between the drill pipe and the wall of the hole. The cuttings are brought to the surface as fragments suspended in the mud. In drilling a well by the hydraulic-rotary method no casing is used until the drilling has been completed, as the drilling mud prevents the walls of the hole from caving. A casing slightly smaller than the hole is placed in the well after the well has been drilled to the

desired depth. If the well is to be gravel-packed, the diameter of the hole is drilled much larger than the desired completed size of the well and the space between the hole and the casing is filled with gravel of the proper size.

DEPTH AND DIAMETER OF IRRIGATION WELLS

The depth and diameter of the irrigation wells in Pawnee Valley are given in Tables 13 and 14. Most of the irrigation wells in

TABLE 13.—*Irrigation wells in Pawnee, Ness, and Hodgeman Counties in Pawnee Valley classified according to depth*

Depth, feet	Number of wells			
	Pawnee County	Ness County	Hodgeman County	Total
Less than 40.....	10	.....	2	12
40-60.....	8	18	11	37
60-80.....	13	9	28	50
80-100.....	18	.....	8	26
More than 100.....	5	.....	2	7
Totals.....	54	27	51	132

TABLE 14.—*Irrigation wells in Pawnee, Ness, and Hodgeman Counties in Pawnee Valley classified according to diameter*

Diameter, inches	Number of wells			
	Pawnee County	Ness County	Hodgeman County	Total
Less than 16.....	1	5	2	8
16.....	6	3	.....	9
18.....	2	2	7	11
19.....	25	4	21	50
20.....	2	8	12	22
24.....	15	.....	4	19
More than 24.....	3	1	5	9
Totals.....	54	23	51	128

Pawnee Valley are less than 100 feet deep. About 58 percent of the wells are between 60 and 100 feet deep.

The diameter of the irrigation wells ranges from 10 inches to 60 inches but about 87 percent of the wells have a diameter of from 16 to 24 inches.

TYPES OF PUMPS USED ON IRRIGATION WELLS

The types of pumps used on irrigation wells in Pawnee Valley are given in Table 15. A preference is shown for centrifugal pumps in Pawnee and Ness Counties and for turbine pumps in Hodgeman County.

TYPES OF POWER USED FOR PUMPING IRRIGATION WELLS

The types of power used in 1945 to pump irrigation wells in Pawnee Valley are given in Table 16. The table shows that 16 wells in Pawnee County were equipped with electric motors, but at the time of this investigation, no wells in Ness and Hodgeman Counties had been equipped with electric motors. About half of the wells in each county were equipped with stationary gasoline engines. The other wells in Ness and Hodgeman Counties were equipped with tractors whereas in Pawnee County the other wells were equipped with tractors, electric motors, or butane-gas engines.

AVAILABILITY OF GROUND WATER

GENERAL FEATURES

The quantity of water that can be pumped from an underground reservoir without causing excessive permanent lowering of the water table depends on the amount of annual recharge to the reservoir. If the average annual quantity of water withdrawn from a ground-water reservoir is greater than the average annual recharge, water levels will decline. Such withdrawal, if long continued, may result in serious depletion of the ground-water reservoir. The quantity of water that can be withdrawn annually from the ground-water reservoir over a long period of years without causing depletion of the available supply is termed the safe yield of the reservoir. The

TABLE 15.—*Types of pumps used on irrigation wells in Pawnee, Ness, and Hodgeman Counties in Pawnee Valley*

Type of pumps	Number of wells			
	Pawnee County	Ness County	Hodgeman County	Total
Turbine.....	22	9	39	70
Centrifugal.....	28	18	13	59
Totals.....	50	27	52	129

TABLE 16.—*Types of power used as of 1945 for pumping irrigation wells in Pawnee, Ness, and Hodgeman Counties in Pawnee Valley*

Type of power	Number of wells			
	Pawnee County	Ness County	Hodgeman County	Total
Electric motor.....	16	.....	.....	16
Gasoline engine.....	28	14	25	67
Tractor.....	11	13	24	48
Butane-gas engine.....	1	.....	.....	1
Totals.....	56	27	49	132

feasibility of developing additional water supplies from wells for irrigation in Pawnee Valley is dependent upon the safe yield of the underground reservoir which is governed by geologic and hydrologic factors.

In a study of the availability of ground water for irrigation it is necessary to take into consideration the amount of precipitation, the amount of stream flow resulting from the precipitation, the amount of base flow, the amount of ground-water recharge and discharge, and the amount of available ground-water storage. The ground-water storage is a function of the areal extent, saturated thickness, and specific yield of the water-bearing materials.

STORAGE

Studies were made to determine the quantity of ground water now in storage in the alluvium and terrace deposits in Pawnee Valley. A map of Pawnee Valley was prepared showing the saturated thickness of the alluvium and terrace deposits (Fig. 9). The contour lines showing saturated thickness were prepared by superimposing the water-table contour map (Pl. 2) on the bedrock contour map (Fig. 5) and drawing the contours through points of equal thickness. The contour line showing zero thickness represents the line of contact where the water table passes from the alluvial deposits into the underlying Cretaceous rocks (Pl. 3). The zero contour in the southwestern part of T. 21 S., R. 20 W. is caused by an exposure of the Dakota formation.

The saturated water-bearing materials in Pawnee Valley have a maximum thickness of 120 feet in the vicinity of the Hodgeman-Pawnee County line about a mile north of Pawnee River. In the vicinity of Rozel, the saturated deposits have a thickness of 100

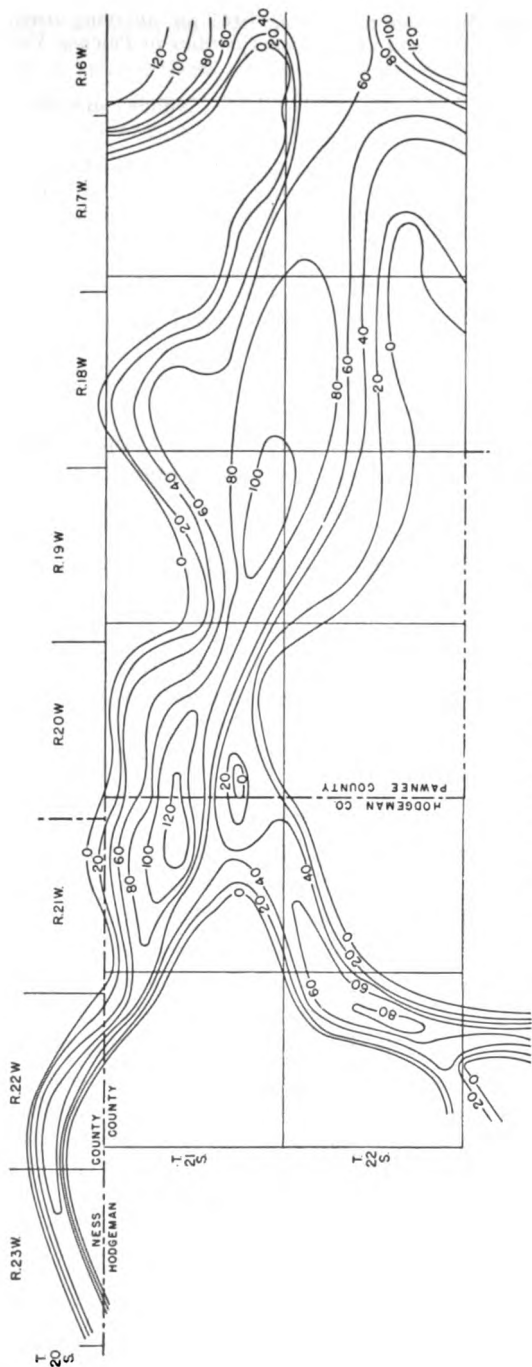


FIG. 9.—Saturated thickness of alluvium and terrace deposits.

feet. As shown by the north-south cross-section through Larned (L-L' on Pl. 3) and the contours on Figure 9, the saturated deposits have a thickness of about 20 feet near Pawnee River. The saturated deposits south of the river thicken, reaching a thickness of about 120 feet a mile south of Arkansas River. The saturated deposits become thinner to the north of Pawnee River at Larned as the Dakota formation crops out. About 2 miles north of the river they become thicker, reaching a thickness of 120 feet about 4 miles north of the river. The thick deposits located 4 miles north of the river were probably deposited by an ancestral tributary of the Arkansas River.

The area between each pair of contours was measured with a planimeter and was multiplied by the average saturated thickness to give the volume of saturated deposits. The volume of saturated deposits and the total volume of water available for pumping based on an assumed average specific yield of 15 percent is given by townships in Table 17.

The total volume of saturated water-bearing materials in the area under consideration, as measured, was 7,635,000 acre-feet. If the materials have a specific yield of 15 percent, a volume of water equal to 15 percent of the volume of saturated deposits would be

TABLE 17.—*Volume of saturated water-bearing materials in Pawnee Valley and the volume of water available for pumping based on a specific yield of 15 percent*

TOWNSHIP	Volume of water-bearing materials, acre-feet	Volume of water, acre-feet
T. 20 S., R. 21 W.....	1,000	150
T. 20 S., R. 22 W.....	202,000	30,300
T. 20 S., R. 23 W.....	163,000	24,500
T. 21 S., R. 17 W.....	149,000	22,400
T. 21 S., R. 18 W.....	1,051,000	157,700
T. 21 S., R. 19 W.....	976,000	146,400
T. 21 S., R. 20 W.....	920,000	138,000
T. 21 S., R. 21 W.....	1,059,000	158,800
T. 21 S., R. 22 W.....	92,000	13,800
T. 22 S., R. 17 W.....	1,047,000	157,000
T. 22 S., R. 18 W.....	875,000	131,200
T. 22 S., R. 19 W.....	541,000	81,100
T. 22 S., R. 20 W.....	3,000	400
T. 22 S., R. 21 W.....	139,000	20,800
T. 22 S., R. 22 W.....	417,000	62,500
Total volume.....	7,635,000	1,145,000

available for pumping. Thus, theoretically, from the total volume of 7,635,000 acre-feet of deposits, if completely drained, 1,145,000 acre-feet of water would be available. From a practical standpoint, much less than this quantity of water would be available for irrigation use. When less than half this quantity of water is used from storage, the yields of the wells will greatly diminish, and to irrigate may become economically unfeasible.

RECHARGE FROM PRECIPITATION

The mean annual precipitation in Pawnee Valley is about 22 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 zone of saturation.

The quantity of water added to or discharged from the ground-water reservoir is reflected in the fluctuations of the water levels in wells. The hydrographs of the water levels in seven wells which have been measured since 1940 are shown in Figure 10. A hydrograph of the average water level in the seven wells is shown in Figure 11.

The water levels in the wells in Pawnee Valley reflect the net effects of recharge from precipitation, pumping for irrigation, and in parts of the area the recharge from stream flow. Most of the fluctuations shown in Figures 10 and 11 and the general upward trend of the water levels in recent years are caused by recharge from precipitation. During the irrigation season the water table is temporarily lowered in local areas where irrigation wells are concentrated. An example is shown by the hydrograph for well 22-16-6bb for the period June to September in 1946. After the irrigation season, the water level recovered and then as a result of above-normal precipitation during September (2.13 inches above normal), October (5.55), and November (1.36), the water level rose to a level of about 2 feet higher than it was prior to the irrigation season.

The water levels have had a general upward trend since measurements were started in 1940 as shown by Figure 11. The water levels at the end of 1949 were a little over 3 feet higher than they were in 1940. On the basis of a specific yield of 15 percent a rise in water level of 3 feet would be equivalent to 5.4 inches of water added to storage since 1940. The net addition of 5.4 inches of water to the ground-water reservoir represents an increase in storage of 288 acre-feet per square mile.

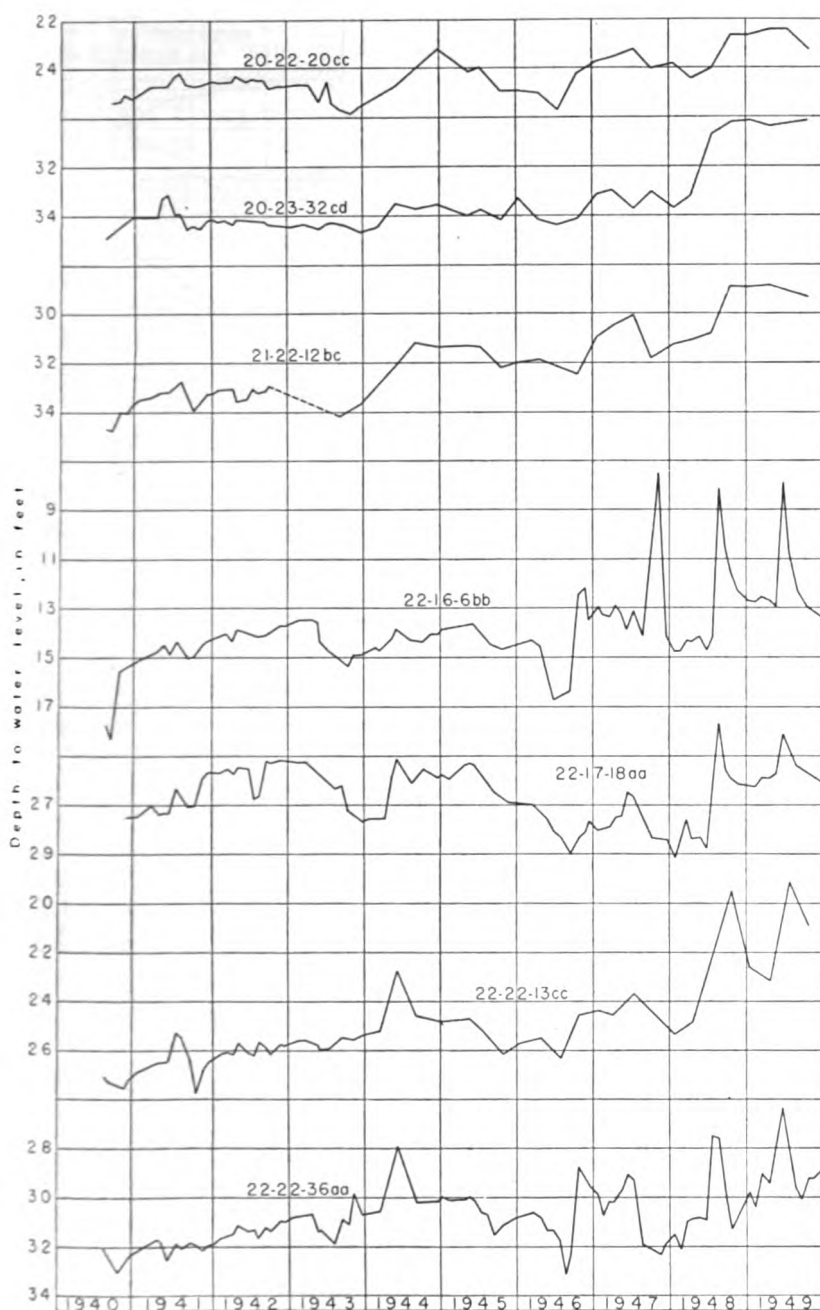


FIG. 10.—Hydrographs showing the fluctuations of the water levels in seven wells in Pawnee Valley.

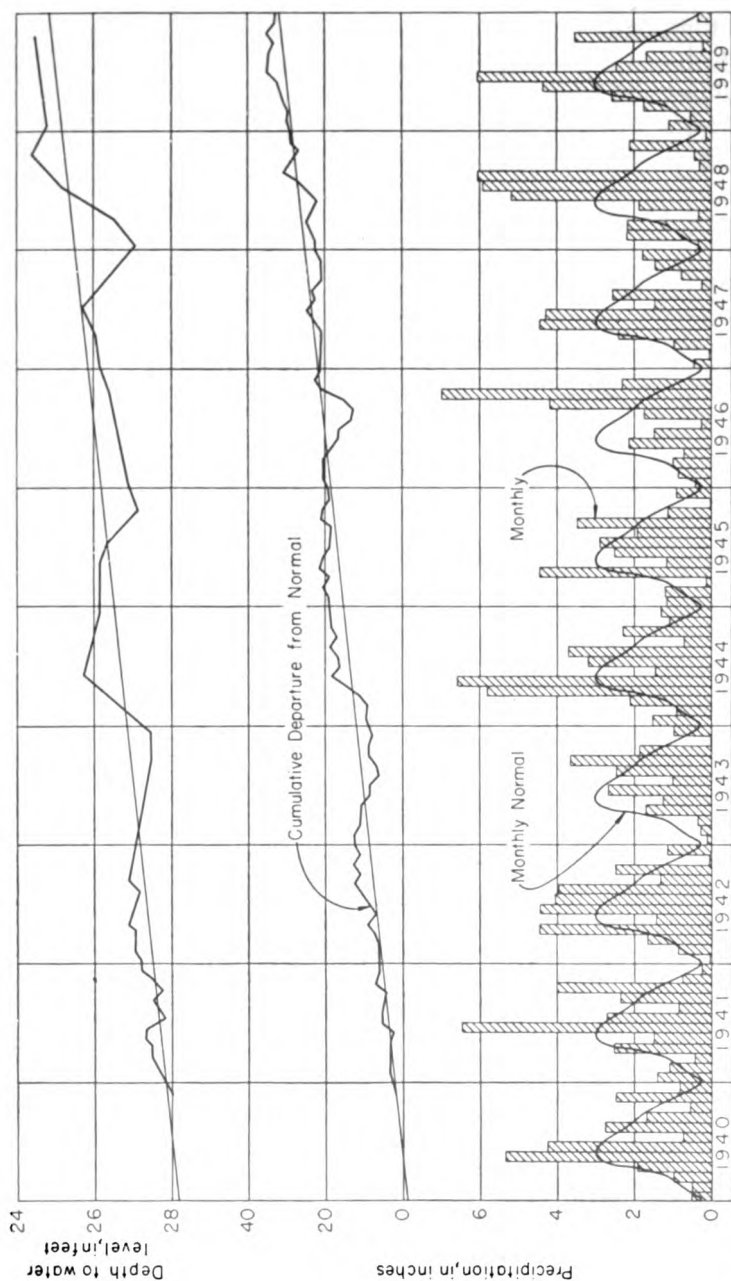


FIG. 11.—Hydrograph showing the fluctuations of the average water level in seven wells in Pawnee Valley, the cumulative departure from normal monthly precipitation at Jetmore, and the monthly precipitation at Jetmore.

Figure 11 shows a close relation between precipitation and the fluctuations of the water levels. A straight line was drawn through the curve for cumulative departure from normal precipitation. A straight line having the same slope was drawn through the hydrograph of the averages of the water levels in 7 wells. Thus the same slope fairly well defines the trends of the average water levels during the period 1940 to 1949. A cumulative departure of about 32 inches of precipitation has resulted in a net rise of the water levels of about 3 feet or on the average an annual cumulative departure of about 3 inches of precipitation has resulted in a net rise of the water levels of about 0.3 foot.

The dependence of the water levels on precipitation is illustrated by the calendar year 1943. The departure from normal precipitation, in inches, for the year is as follows: January, -0.16 ; February, -0.52 ; March, -0.59 ; April, -0.36 ; May, -1.75 ; June, -0.35 ; July, -1.69 ; August $+0.19$; September, $+1.60$; October, $+0.40$; November, -0.96 ; and December, -0.38 . Practically all the water levels declined from January through July. In some wells the decline continued the remainder of the year but in a few, the above-normal precipitation during August, September, and October caused the water levels to rise.

The logs of test holes in Pawnee Valley and the cross-sections in Plate 3 indicate that the material above the water table is not as permeable as that at greater depths. Much of the surficial material consists of silt and clay, and conditions for recharge from precipitation are not too favorable. Nevertheless the hydrographs in Figures 10 and 11 indicate considerable ground-water recharge from precipitation. In recent years the recharge has been more than adequate to supply the water pumped for irrigation and to supply the base flow of Pawnee River. The excess of recharge over the total discharge has resulted in raising the water table an average of about 0.3 foot per year.

RECHARGE FROM STREAM FLOW

Two factors determine whether a stream is capable of supplying water to the underground reservoir: (1) the water surface of the stream must be above the water table and (2) the material between the stream channel and the water table must be sufficiently permeable to permit water to percolate downward and outward from the stream. The water-table contours in Plate 2 indicate that in Pawnee Valley the water table as of 1945 was higher than the stream surface, and hence, the ground water was moving toward

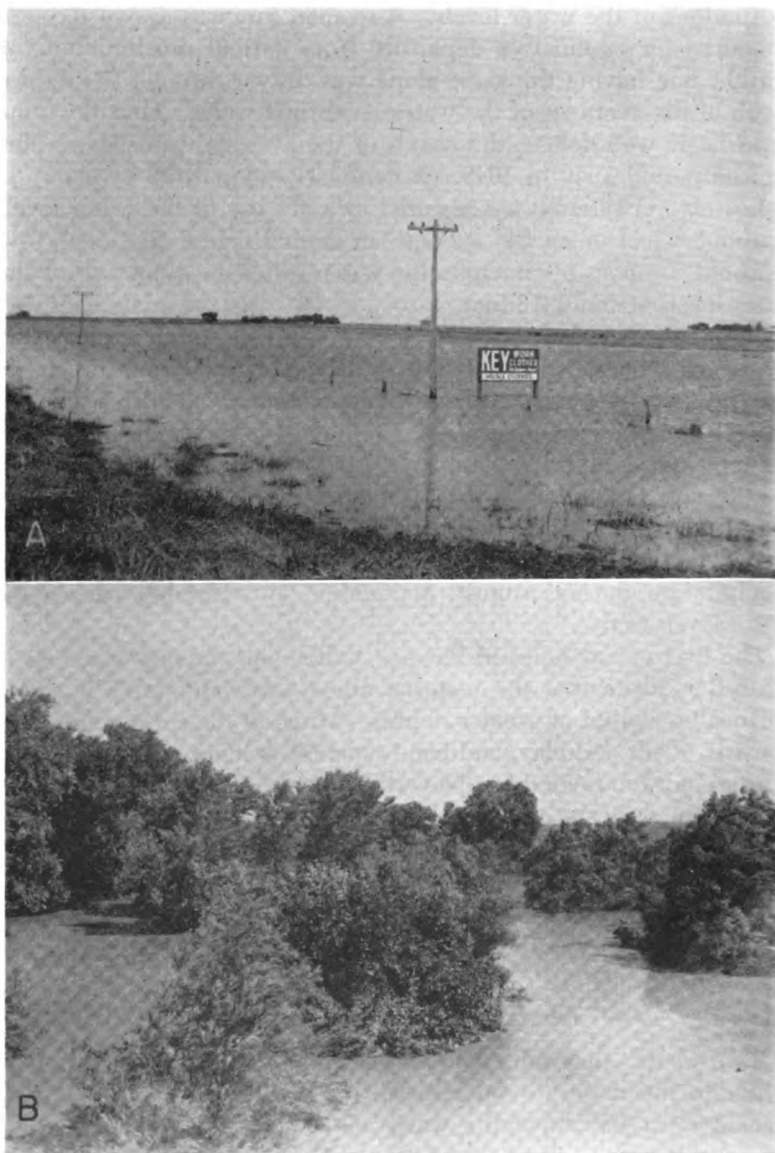


PLATE 5. A, Flood water in Pawnee Valley in the SE cor. SW $\frac{1}{4}$ sec. 27, T. 21 S., R. 17 W., facing northwest. B, Flood water in creek taken from bridge on highway in sec. 29, T. 21 S., R. 18 W., facing north. (Photos taken August 2, 1950.)

the river. However under conditions of heavy withdrawal of ground water resulting in a lowering of the water table below the stream surface, or during flood stages of the river (Pl. 5), the direction of movement of the ground water with respect to the river would be reversed and there would then be recharge from the river. In October, 1945, the water table was depressed locally by pumpage for irrigation. Some observations were made of the stream flow in Pawnee River which indicated that it was a gaining stream along part of its course and a losing stream along other parts. Some estimates of stream flow which were made at 11 points along the river by George S. Knapp, Milton Sears, and V. C. Fishel are given in Table 18.

The gradient of Pawnee Valley is approximately 2 feet to the mile. Thus a dam impounding water 2 feet deep at the dam will form a reservoir approximately a mile long. According to a survey by the Division of Water Resources of the State Board of Agriculture, there were 30 small dams in the river in 1939. As the stream level is raised by these reservoirs there will be a reversal of the normal direction of the movement of ground water. The water in the reservoir will recharge and back up the ground water until the slope of the water table is readjusted to the new stream level. The

TABLE 18.—*Estimates of stream flow of Pawnee River at 11 points on October 10, 1945*

LOCATION	Remarks
SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 29, T. 20 S., R. 23 W.	No flow; some pools
NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 28, T. 20 S., R. 23 W.	Flow estimated at 40 g. p. m.
NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 26, T. 20 S., R. 23 W.	No flow; some pools
NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 19, T. 20 S., R. 22 W.	No flow; pools west of road
NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 28, T. 20 S., R. 22 W.	Dry
SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 27, T. 20 S., R. 22 W.	Flow estimated at 75 g. p. m.
SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 36, T. 20 S., R. 22 W.	Flow estimated at 200 g. p. m.
SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 7, T. 21 S., R. 21 W.	Flow estimated at 15 g. p. m.
SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 20, T. 21 S., R. 21 W.	Flow estimated at 10 g. p. m.
SE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 27, T. 21 S., R. 21 W.	Small trickle
SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 25, T. 21 S., R. 21 W.	Flow estimated at 30 g. p. m.

reservoirs formed by the numerous small dams have undoubtedly contributed considerable ground-water recharge in Pawnee Valley. As additional dams are constructed, a greater percentage of the normal stream flow will be held back, some of which will be diverted to ground-water recharge and be available for irrigation pumpage.

That enough reservoir storage may be eventually constructed to hold all the normal stream flow is conceivable. Evaporation would remove a part of the water stored in the reservoirs but much would be contributed to ground-water recharge. Past records of discharge of Pawnee River would give an approximate idea of the maximum quantity of water that can be made available for irrigation in Pawnee Valley either by pumpage direct from the river or from wells. A stream gauging station has been maintained on Pawnee River since 1924 as a part of the co-operative stream-gauging program of the Federal Geological Survey and the Division of Water Resources of the State Board of Agriculture. The gauge is installed at the Moffet bridge, 300 feet downstream from the dam (Pl. 6) near Frizell, 11 miles west of Larned and 12 miles above Pawnee River confluence with Arkansas River. The drainage area above the dam is 2,300 square miles. Records of stream flow beginning in 1926 are given in Table 19. The runoff from the area has ranged from a minimum of 0.06 inch in 1926 to a maximum of 1.09 inches in 1935 and has averaged about 0.3 inch. The average annual precipitation in Pawnee Valley is about 22 inches. Of this amount 0.3 inch is discharged from the basin as stream flow and the remainder is discharged by evaporation and transpiration. A runoff of 0.3 inch is equivalent to about 36,000 acre-feet of water. Thus the water lost annually by stream flow of Pawnee River from the basin has

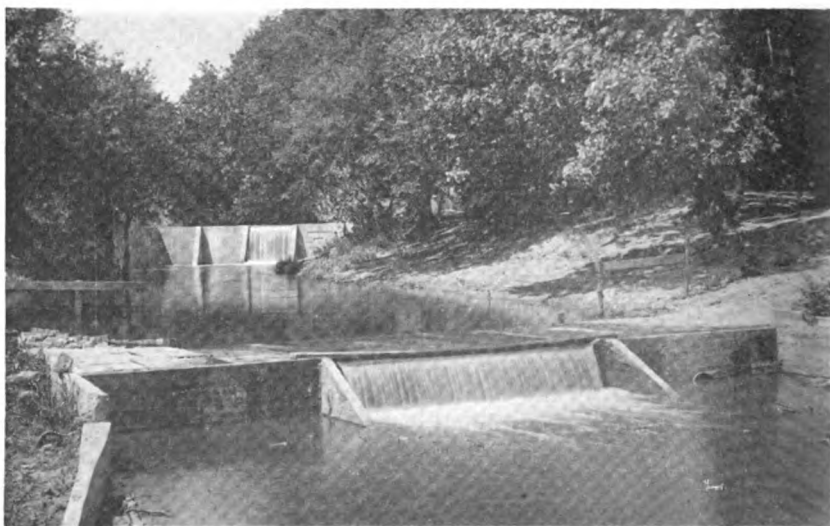


PLATE 6. Moffet dam on Pawnee River in the NW $\frac{1}{4}$ sec. 33, T. 21 S., R. 18 S., 11 miles west of Larned. (Photo by George S. Knapp.)

TABLE 19.—*Discharge of Pawnee River at the Moffet dam, 11 miles west of Larned and 12 miles above confluence with Arkansas River*

YEAR	Maximum discharge, second-feet	Minimum discharge, second-feet	Mean discharge, second-feet	Annual discharge, acre-feet	Annual discharge, inches
1926	582	0	10.0	7,250	0.06
1927	766	0	43.3	22,810	.18
1928	572	2	29.4	21,300	.17
1929	3,030	5	42.9	31,080	.25
1930	1,180	5	35.8	25,900	.21
1931	1,120	.4	20.0	14,490	.12
1932	880	.2	14.1	10,220	.08
1933	3,490	3	80.8	58,540	.48
1934	1,270	1	26.0	18,850	.15
1935	17,000	0	187	135,100	1.09
1936	2,040	0	38.4	27,860	.23
1937	981	0	20.8	15,090	.12
1938	2,070	0	57.0	41,310	.34
1939	2,690	0	34.2	24,740	.20
1940	9,900	0	105	76,260	.62
1941	1,330	0	30.8	22,300	.18
1942	2,960	0	34.7	25,110	.20
1943	7,280	0	58.0	42,000	.34
1944	3,810	3	129	93,420	.76
1945	653	0	11.9	8,600	.07

ranged from a minimum of about 7,250 acre-feet in 1926 to a maximum of about 135,100 acre-feet in 1935 and has averaged about 36,000 acre-feet. This water lost from the basin represents the maximum additional amount of water that can be utilized for irrigation unless it is found feasible to divert some discharge of ground water by useless phreatophytes to beneficial use.

POSSIBILITIES OF FURTHER DEVELOPMENT OF IRRIGATION SUPPLIES FROM WELLS

The quantity of water that can be pumped from an underground reservoir without causing excessive permanent lowering of the water table depends on the capacity of the reservoir and on the quantity of periodic recharge to the reservoir. If water is withdrawn from an underground reservoir by pumping faster than it enters, the water levels in wells will decline and the supply eventually will be depleted. The quantity of water that can be withdrawn annually from the ground-water reservoir over a long period of years without causing depletion of the available supply is termed the safe yield of the reservoir. The feasibility of developing additional water supplies from wells for irrigation in Pawnee Valley is dependent upon the safe yield of the underground reservoir and upon other geologic, hydrologic, and economic factors.

The estimate of ground water in storage in Pawnee Valley is more than one million acre-feet. In Table 17 the storage is given for each township. In a few townships the storage amounts to more than 150,000 acre-feet. The maximum amount of storage per township was estimated at 158,800 acre-feet which is about 4,400 acre-feet per square mile or 7 acre-feet per acre. The large quantity of ground water held in storage is available in part for pumping during dry seasons provided that conditions are favorable for replenishment by recharge from precipitation during successive seasons of abundant precipitation or by recharge from the river, or both. Although the above quantities of water may be available from storage, the rate at which the water could be pumped from storage would become progressively lower as the water table declined.

The records of water-level fluctuations in Pawnee Valley (Figs. 10 and 11) show: that the ground-water reservoir is recharged from precipitation; that precipitation was above normal between 1940 and 1949; and that, for the same period, water levels showed a net rise. Annual ground-water withdrawals for irrigation decreased during this period. Thus, it is indicated that ground-water discharge by wells and all natural discharge was less than the recharge for the period 1940 to 1949.

Records of stream flow also suggest that the pumpage for irrigation has been less than the available supply. For the 3-year period 1939 to 1941 the base flow was only about 35 percent of the average for the 24-year period from 1925 to 1948. Since 1941 the amount of base flow has had a sharp upward trend. For the 3-year period 1946 to 1948 the base flow was about 240 percent of the 24-year period.

Pawnee River is also a possible source of recharge of the ground-water reservoir in 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. Also, if additional small dams are constructed across Pawnee River, the reservoirs formed by the dams will contribute ground-water recharge until a new gradient of the water table is established at a higher level. As additional dams are constructed, a greater percentage of the normal stream flow will be impounded and made available for ground-water recharge. The average annual runoff in Pawnee Valley since 1926 has been about 36,000 acre-feet. If the water that is now discharged as stream flow is impounded and diverted to ground-water recharge, an additional amount equal to about 36,000 acre-feet a year would be available for pumping for irrigation.

CHEMICAL CHARACTER OF GROUND WATER

The general chemical character of the ground waters in Pawnee Valley is indicated by the analyses of water from 70 wells distributed as uniformly as practicable within the area and among the principal water-bearing formations (Table 20). Table 20 includes the analyses of 13 water samples from wells in the Dakota formation, 21 water samples from wells in the Greenhorn limestone, 9 water samples from wells in terrace deposits, 26 water samples from wells in alluvium, and 1 water sample from a well in the Permian rocks. The samples of water were analyzed by Howard A. Stoltenberg, chemist, in the Water and Sewage Laboratory of the Kansas State Board of Health.

CHEMICAL CONSTITUENTS IN RELATION TO USE

Dissolved solids.—When water is evaporated the residue that is left consists mainly of the mineral constituents listed in Table 20 and generally includes a small quantity of organic material and a little water of crystallization. Water containing less than 500 parts per million of dissolved solids generally is entirely satisfactory for domestic use, except for difficulties resulting from the hardness or an excessive content of iron. Water containing more than 1,000 parts per million is likely to include enough of certain constituents to produce a noticeable taste or to make the water unsuitable in some other respects.

The amount of dissolved solids in the samples of ground water collected in Pawnee Valley is indicated in Table 21. Of the 35 samples of water collected from wells in the alluvium and terraces the dissolved solids in 20 samples ranged between 300 and 400 parts per million. Only two samples from wells in the alluvium (wells 21-16-33cd and 22-16-4ca) contained more than 1,000 parts per million of dissolved solids.

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

TABLE 20.—*Analyses of water from typical wells in Pawnee Valley, Kansas*
Analyzed by H. A. STOLTENBERG. Dissolved constituents given in parts per million,* and in equivalents per million ^b (in italics)

WELL DESIGNATION (c)	Depth (feet)	Geologic source	Date of collection	Temper- ature (°)F	Dis- solved solids	Silica (SiO ₂)	Iron (Fe)	Calcium (Ca)	Mag- nesium (Mg)	Sodium and potas- sium (Na+K)	Bicar- bonate (HCO ₃)	Sulfate (SO ₄)	Chloride (Cl)	Fluoride (F)	Nitrate (NO ₃)	Hardness as CaCO ₃	
																Total	Car- bonate
20-19-26cc.....	160	Greenhorn.....	8-24-44	60	354	.....	4.3	49 <i>2.44</i>	20 <i>1.64</i>	57 <i>2.46</i>	284 <i>4.66</i>	58 <i>1.21</i>	21 <i>.59</i>	1 <i>.05</i>	2.1 <i>.03</i>	204	0
20-19-29dd.....	44.7	do.....	8-24-44	59	409	.....	4.7	116 <i>5.79</i>	11 <i>.90</i>	14 <i>.62</i>	340 <i>5.58</i>	14 <i>.29</i>	13 <i>.87</i>	.2 <i>.01</i>	.66 <i>1.06</i>	334	55
20-20-32cd.....	110	Dakota.....	10-11-44	59	972	.....	5.8	45 <i>2.25</i>	28 <i>2.30</i>	267 <i>11.60</i>	379 <i>6.22</i>	322 <i>6.70</i>	107 <i>3.02</i>	2.4 <i>.13</i>	5.3 <i>.08</i>	228	0
20-21-31ad.....	37	Alluvium.....	6-10-47	59	326	12	1.8	90 <i>4.49</i>	12 <i>.99</i>	13 <i>.55</i>	300 <i>4.92</i>	14 <i>.29</i>	16 <i>.45</i>	.5 <i>.03</i>	.21 <i>.34</i>	274	28
20-22-9bb.....	43.6	Greenhorn.....	6-10-47	58	652	5.8	14	156 <i>7.78</i>	20 <i>1.64</i>	37 <i>1.59</i>	290 <i>4.76</i>	218 <i>4.53</i>	42 <i>1.18</i>	1.4 <i>.07</i>	.29 <i>.47</i>	471	233
20-22-9ddd.....	27.3	do.....	6-10-47	58	396	18	.08	109 <i>5.44</i>	8.6 <i>.71</i>	12 <i>.51</i>	279 <i>4.58</i>	15 <i>.31</i>	16 <i>.45</i>	.6 <i>.03</i>	.80 <i>1.29</i>	308	79
20-22-20ca.....	48.4	Alluvium.....	7-6-46	58	386	31	.06	89 <i>4.44</i>	12 <i>.99</i>	28 <i>1.23</i>	301 <i>4.94</i>	54 <i>1.12</i>	16 <i>.45</i>	.4 <i>.02</i>	.8 <i>.13</i>	272	25
20-22-24dc.....	38.8	Terrace deposits	8-12-46	58	324	22	.03	86 <i>4.29</i>	9.2 <i>.76</i>	16 <i>.72</i>	289 <i>4.74</i>	22 <i>.46</i>	11 <i>.31</i>	.3 <i>.02</i>	.15 <i>.24</i>	252	15
20-22-27bb.....	28.5	Alluvium.....	6-10-47	57	365	20	.84	92 <i>4.59</i>	13 <i>1.07</i>	22 <i>.96</i>	315 <i>5.17</i>	40 <i>.83</i>	19 <i>.64</i>	.6 <i>.03</i>	.3 <i>.05</i>	283	25
20-23-14aa.....	28.9	Greenhorn.....	6-10-47	57	564	9.6	.68	125 <i>6.24</i>	15 <i>1.23</i>	45 <i>1.97</i>	312 <i>5.12</i>	80 <i>1.66</i>	38 <i>1.07</i>	.6 <i>.03</i>	.97 <i>1.56</i>	374	118
20-23-20ad.....	21.7	do.....	6-10-47	55	48	15	9.7	136 <i>6.79</i>	84 <i>.69</i>	14 <i>.61</i>	322 <i>5.28</i>	27 <i>.56</i>	16 <i>.45</i>	.2 <i>.01</i>	.11 <i>1.79</i>	374	110

20-23-224e.....	34.6	do.....	8-12-46	57	385	15	.05	108 6.39	7.4 61	14	205 4.84	17.35	12.34	.3 1.06	300	*
20-23-254b.....	37.6	Alluvium.....	7-5-46	58	359	33	.08	86 4.29	13 1.07	21	310 6.08	33.69	14.39	.3 5.3	208	254 14
20-23-32ca.....	69.6	do.....	8-3-46	58	324	30	.11	80 3.99	10 1.82	20	288 4.72	24.50	12.34	.3 5.3	240	236 4
20-23-36bb.....	42	Greenhorn.....	6-10-47	59	341	16	.05	92 4.59	8.8 1.72	17	287 4.71	26.64	13.37	.4 27.43	266	236 30
21-16-7dd.....	38.8	Terrace deposits	10-7-44	58	551	.....	2.7	89 4.44	14 1.15	102	269 4.44	27.56	15.10	.3 11	280	245 35
21-16-33cd.....	70	Alluvium.....	8-11-45	.....	1,480	.....	0	178 8.88	54 4.44	201	254 4.17	726	94	0	666	208 453
21-17-18dd.....	42.5	Terrace deposits	10-10-44	58	295	.....	2.5	76 3.79	9.8 1.81	25	311 5.10	7.4	10	.5 8.4	230	0
21-18-5ad.....	100	do.....	10-13-44	59	287	.....	13	75 3.74	11 1.90	19	317 5.80	0	6	.9 3.2	232	0
21-18-17ec.....	120	Alluvium.....	6-21-45	.....	272	.....	10	74 3.69	14 1.15	13	288 4.72	11.23	12.34	.5 5.3	242	236 6
21-18-29bb.....	110	do.....	6-21-45	.....	276	.....	9.4	76 3.79	14 1.15	13	300 4.92	8.2	11	.5 5.3	247	246 1
21-18-32bb1.....	418	Permian redbeds	6-22-45	.....	8,830	.....	6.1	628 37.34	284 23.34	2,049	116 1.90	2,990	2,820	1.8 3.5	2,730	95 2,640
21-18-32bb2.....	306	Dakota (?).....	6-13-45	.....	423	.....	17	56 2.79	17 1.40	86	293 4.80	37.77	80	1.1 2	210	0
21-18-32cc.....	120	Alluvium.....	9-25-44	.....	370	.....	.08	74 3.69	15 1.23	49	324 5.31	32.66	36	.8 1.4	246	0
21-19-27cb.....	42	do.....	8-24-44	59	319	.....	.52	80 3.99	14 1.15	26	340 5.68	13.27	13	.7 2	257	0
21-20-15da.....	45	do.....	9-25-44	58	403	.....	.24	122 6.09	14 1.15	11	405 6.64	19.40	11	.2 23.37	362	332 30
21-20-20ba1.....	55	do.....	9-21-44	60	331	.....	.05	80 3.99	13 1.07	28	299 4.90	38.79	17	.6 4.4	253	245 8

TABLE 20.—Analyses of water from typical wells in Pawnee Valley, Kansas—Continued

WELL DESIGNATION (c)	Depth (feet)	Geologic source	Date of collection	Temper- ature (°F)	Dis- solved solids (SiO ₂)	Iron (Fe)	Calcium (Ca)	Mag- nesium (Mg)	Sodium and potas- sium (Na+K)	Bicar- bonate (HCO ₃)	Sulfate (SO ₄)	Chloride (Cl)	Fluoride (F)	Nitrate (NO ₃)	Hardness as CaCO ₃		
															Total	Car- bonate	Noncar- bonate
21-20-28cd	126	Dakota	8-24-44	60	269	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	288	268	20
21-21-9cd	58.7	Terrace deposits	6-10-47	58	356	3.3	72 3.59	11 .90	46 1.98	298 4.89	42 .87	20 .56	1 .05	6.2 .10	224	224	0d
21-21-18aa	54.6	Alluvium	8-3-46	58	414	.15	97 4.84	15 1.23	31 1.35	356 5.84	52 1.08	16 .45	.4 .02	2 .03	304	292	12
21-21-22da	51.5	do.	6-10-47	58	407	.30	92 4.59	14 1.15	37 1.62	357 5.85	50 1.04	15 .42	.5 .03	1.4 .02	287	287	0e
21-21-36ab	93.5	do.	8-2-46	58	395	.23	71 3.54	13 1.07	55 2.41	332 5.44	42 .87	23 .65	.8 .04	1.1 .02	230	230	0f
21-22-3ab	62.7	Alluvium	7-1-46	58	379	.48	94 4.69	11 .90	24 1.04	321 5.26	40 .83	16 .45	.3 .02	4.3 .07	280	263	17
21-22-4ld	30.7	Greenhorn	6-10-47	57	380	11	99 4.94	13 1.07	25 1.09	359 5.89	18 .37	27 .76	.3 .02	4 .06	300	294	6
21-22-8bb	35.7	do.	6-10-47	57	329	27	78 3.89	8.9 .73	27 1.17	259 4.25	27 .56	13 .37	.5 .03	36 .58	231	212	19
21-22-15ac	35.2	do.	6-10-47	57	397	.11	124 6.19	8 .66	9.2 .40	372 6.10	18 .37	12 .34	.2 .01	27 .43	342	305	37
21-22-27cb	285	Dakota	8-12-46	61	622	.32	50 2.50	16 1.32	156 6.80	399 5.07	170 3.54	67 1.89	2 .10	1.5 .02	191	191	0g
22-16-4ca	12	Alluvium	10-6-44	59	1,020	.46	188 9.28	40 3.29	90 3.90	295 4.84	501 10.42	37 1.04	1 .05	14 .22	634	242	392
22-17-5ca		do.	10-10-44	59	795	7	128 6.39	28 2.30	128 5.58	418 6.86	118 2.45	171 4.82	.5 .02	5.3 .08	434	343	91

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22-17-11dd	30	do.	8-23-44	58	981		.72	109	34	102	239	492	38	1.07	7	25	561	196	365
22-17-10-b	215	Dakota	8-23-44	60	1,480		.58	42	26	491	337	120	610	17.80	2	5.8	212	212	0
22-18-9cc	26	Alluvium	10-11-44	58	316	.....	.16	88	12	18	331	7	12	.34	.3	13	269	269	0
22-18-28cc	82.5	Terrace deposits	10-10-44	59	391	.....	6.7	103	17	16	300	12	54	1.52	.3	32	327	246	81
22-18-35dd	56.5	do.	10-7-44	59	455	.....	20	116	18	29	454	15	25	.70	.4	4.2	364	364	0
22-19-8dd	40.5	do.	10-9-44	60	314	.....	.30	66	13	38	290	18	26	.73	1	7.1	218	218	0
22-19-29cc	100	Dakota	10-11-44	59	527	.....	34	42	22	118	351	76	54	1.52	2.6	2.5	196	196	0
22-20-4bb	210	do.	10-9-44	60	361	.....	5.5	64	27	32	310	63	11	.31	1.4	2.3	270	254	16
22-20-29ba	28.2	Terrace deposits	10-9-44	58	348	.....	.12	102	7.2	15	300	14	15	.42	44	.2	284	246	38
22-21-9cc	67.4	Alluvium	8-2-46	58	343	21	0	85	13	21	300	30	22	.62	.5	2.7	266	246	20
22-21-10cb	100	do.	6-11-47	58	315	4.6	6.9	96	9.4	12	303	19	23	.65	.3	2.1	278	248	30
22-21-12ab	70.4	Terrace deposits	8-11-46	59	343	7	.27	85	22	14	327	33	18	.51	1.1	2.2	302	268	34
22-21-14aa	67.2	Dakota	6-11-47	58	240	5.6	6.3	60	10	16	227	4.1	12	.34	.5	20	190	186	4
22-21-25aa	126.3	do.	6-11-47	59	111	2.4	18	5.6	3.8	33	72	9	16	.45	.8	.70	30	30	0h
22-22-13cb2	75.5	Alluvium	7-23-46	58	363	31	.29	86	12	26	321	26	16	.45	.3	8	264	263	1
22-22-27ca	106	do.	8-3-46	58	460	29	.25	87	13	59	327	67	42	1.18	.8	1.3	270	268	2

TABLE 20.—Analyses of water from typical wells in Pawnee Valley, Kansas—Concluded

WELL DESIGNATION (c)	Depth (feet)	Geologic source	Date of collection	Temper- ature (°F)	Dis- solved solids	Silica (SiO ₂)	Iron (Fe)	Calcium (Ca)	Mag- nesium (Mg)	Sodium and potas- sium (Na+K)	Bicar- bonate (HCO ₃)	Sulfate (SO ₄)	Chloride (Cl)	Fluoride (F)	Nitrate (NO ₃)	Hardness as CaCO ₃	
																Total	Car- bonate
22-22-31de.....	59.4	Alluvium.....	7-9-46	57	503	32	.05	106 5.29	15 1.23	51 2.20	366 6.00	75 1.56	36 1.02	.6 .03	7.1 .11	326	300
23-21-2bb.....	207.4	Dakota.....	6-11-47	59	337	6.4	5.2	47 2.34	27 2.22	44 1.90	303 4.97	44 .92	17 .48	1.4 .07	1.2 .02	228	228
23-22-11cc.....	98.1	do.....	8-13-46	58	409	30	.32	74 3.69	14 1.15	56 2.44	337 5.53	26 .54	40 1.13	1 .05	1.8 .03	242	242
23-22-20dd.....	248	do.....	8-12-46	61	1,610	5.4	.36	40 2.00	25 2.06	549 23.39	346 5.67	126 2.62	690 19.46	3 .16	2.2 .04	203	203
23-23-15cd.....	128.1	do.....	8-12-46	60	362	17	5.4	86 4.29	14 1.15	26 1.11	300 4.92	52 1.08	17 .48	.9 .05	1.1 .02	272	246

a. One part per million is equivalent to one pound of substance per million pounds of water or 8.33 pounds per million gallons of water.

b. An equivalent per million is a unit chemical equivalent weight of solute per million unit weights of solution. Concentration in equivalents per million is calculated by dividing the concentration in parts per million by the chemical combining weight of the substance or ion.

c. When the number is preceded by T, the sample was collected from a test hole.

d. Excess alkalinity, 20 parts per million.

e. Excess alkalinity, 3 parts per million.

f. Excess alkalinity, 42 parts per million.

g. Excess alkalinity, 63 parts per million.

h. Excess alkalinity, 37 parts per million.

i. Excess alkalinity, 20 parts per million.

j. Excess alkalinity, 34 parts per million.

k. Excess alkalinity, 81 parts per million.

TABLE 21.—Summary of the chemical characteristics of the samples of water collected from wells in Pawnee Valley, Kansas

Range in parts per million	Number of samples			
	Dakota	Greenhorn	Terraces	Alluvium
<i>Dissolved solids</i>				
Less than 200.....	1	.....	.....	.....
201-300.....	1	.....	2	2
301-400.....	4	7	5	15
401-500.....	2	2	1	4
501-1,000.....	3	2	1	3
More than 1,000.....	2	.....	.....	2
<i>Hardness</i>				
Less than 200.....	4	.....	.....	.....
201-300.....	9	3	6	19
301-400.....	.....	7	3	3
401-500.....	.....	1	.....	1
More than 500.....	.....	.....	.....	3
<i>Iron</i>				
Less than 0.1.....	.....	2	.....	8
0.1-1.0.....	4	3	6	13
1.1-5.0.....	1	2	0	1
5.1-10.0.....	5	1	1	4
More than 10.0.....	3	3	2	.....
<i>Chloride</i>				
Less than 10.....	.....	.....	1	.....
11-20.....	6	6	4	16
21-50.....	1	5	2	8
51-100.....	3	.....	1	1
101-500.....	1	.....	1	1
More than 500.....	2	.....	.....	.....

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

Water having a hardness of less than 50 parts per million is generally rated as soft, and its treatment for the removal of hardness is rarely justified. Hardness between 50 and 150 parts per million does not seriously interfere with the use of water for most purposes, but it does increase slightly the consumption of soap; removal of the hardness by a softening process is profitable for laundries or other industries that use large quantities of soap. Treatment for the prevention of scale is necessary for the successful operation of steam boilers using water in the upper part of this range of hardness. Hardness of more than 150 parts per million can be noticed by anyone, and where the hardness is 200 or 300 parts per million it is common practice to soften water for household use or to install cisterns to collect soft rain water.

The hardness of 59 of the samples of water that were analyzed is indicated in Table 20; distribution by ranges of hardness are indicated in Table 21.

Iron.—Next to hardness, iron is the constituent of natural waters that in general receives the most attention. The quantity of iron in ground waters may differ greatly from place to place, even in waters from the same formation. If a water contains much more than 0.1 part per million of iron, the excess may separate out after exposure to the air and settle as a reddish sediment. Iron, which may be present in sufficient quantity to give a disagreeable taste and to stain cooking utensils, may be removed from most waters by simple aeration and filtration, but a few waters require the addition of lime or some other substance. For the samples analyzed, 50 of the total of 60 contained more than 0.1 part per million of iron.

The iron content of the samples of ground water that were analyzed is shown in Table 21.

Water for irrigation.—The suitability of water for use in 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. Magistad and Christiansen (1944, pp. 8-9) makes the following statement concerning irrigation waters:

Plants in saline soils are adversely affected by high concentrations of salts in the soil solution and by poor physical condition of the soil. Both conditions are greatly affected by the type of irrigation water used. An irrigation water having a high sodium percentage will, after a time, give rise to a soil having a large proportion of replaceable sodium in the colloid, often designated as black alkali soil. Even on sandy soils with good drainage waters of 85 percent sodium or higher will give rise to impermeable soils after prolonged use. With higher total salt content there is a flocculating action that tends to counterbalance the poor physical condition caused by a high sodium concentration in the water. On a heavy soil already high in replaceable sodium, the poorest water that one could use would be one low in total salts but having a high sodium percentage.

Magistad and Christiansen proposed standards for irrigation waters which are helpful in appraising or evaluating supplies. A class 1 water which is considered as excellent to good should contain not more than 700 parts per million of salt and not more than 60 percent sodium. A class 2 water which is classed as good to injurious contains from 700 to 2,000 parts per million of salt and a sodium percentage between 60 and 75. A class 2 water is probably harmful to the more sensitive crops. A class 3 water which is generally unsatisfactory contains more than 2,000 parts per million salts and more than 75 percent sodium.

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 specific limits can be adopted. Most of the water in the alluvium and terrace deposits of Pawnee Valley can be used safely for irrigation. Two samples contained more than 1,000 parts per million dissolved solids (wells 21-16-33cd and 22-16-4ca). The wells from which these samples were collected are in the Arkansas Valley near the mouth of Pawnee River.

QUALITY IN RELATION TO WATER-BEARING FORMATIONS

The quality of water from the alluvium, Dakota formation, and Greenhorn limestone is indicated by the analyses in Table 20, is summarized in Table 21, and is shown graphically in Figure 12. The quality of water in these formations and in the Permian redbeds 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

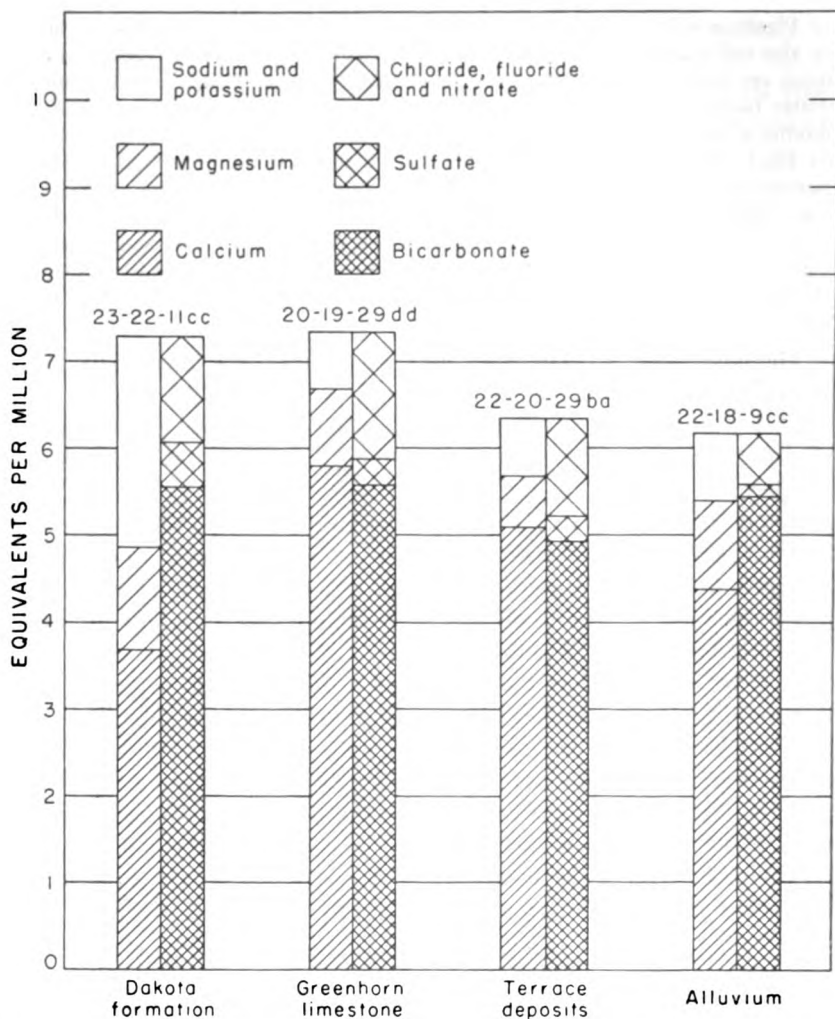


FIG. 12.—Analyses of waters from the principal water-bearing formations in Pawnee Valley.

artesian pressure in these deposits. Therefore, such wells and test holes must be effectively sealed to prevent contamination of water.

The analysis of one sample of water from the Permian redbeds is given in Table 20 (21-18-32bb1). This sample contained 8,834 parts per million dissolved solids, 2,991 parts per million of sulfate, and 2,820 parts per million of chloride.

Dakota formation.—Thirteen samples of water were collected from wells penetrating the Dakota formation. Seven of these samples contained more than 400 parts per million of dissolved solids, two of which had a dissolved solids content over 1,000 ppm. Water from the Dakota formation is moderately hard to hard. The 13 samples had an average hardness of 212. The maximum hardness was 288 and the minimum was 30 (well 22-21-25aa).

Greenhorn limestone.—Eleven samples of water were collected from wells penetrating the Greenhorn limestone. Seven of these samples contained between 300 and 400 parts per million of dissolved solids, two contained between 400 and 500 parts per million, and two contained between 500 and 1,000 parts per million. Seven of the samples had a hardness between 300 and 400. The chloride content of all samples was less than 50 parts per million.

Terrace deposits.—The dissolved solids in five of nine samples ranged from 300 to 400 parts per million. The hardness of six of the samples ranged from 200 to 300 parts per million. The other three samples had a hardness ranging from 300 to 400 parts. Seven samples had a chloride content of less than 50 parts per million, one had 54 parts per million, and one had 155 parts per million.

Alluvium.—Twenty-six samples of water from the alluvium were analyzed. A few of the samples were from wells in the Arkansas Valley near the mouth of Pawnee River. The water in the alluvium of Pawnee Valley is generally of good quality, but the water in Arkansas Valley may contain a fairly high amount of dissolved solids. The dissolved solids in the 26 samples ranged from 272 to 1,480. Nineteen samples had a hardness between 200 and 300 parts per million and 7 samples had a hardness of more than 300 parts.

RECORDS OF WELLS

Information pertaining to 316 water wells in Pawnee Valley is tabulated in the following pages (Table 22). The well-numbering system used in this table is described on page 11.

TABLE 22.—Records of wells in Pawnee Valley, Kansas

WELL DESIGNATION (1)	Owner or tenant	Type of well (2)	Depth of well (feet) (3)	Diam- eter of well (in.) (4)	Type of cas- ing (4)	Principal water-bearing bed		Method of lift (5)	Use of water (6)	Measuring point			Depth to water level meas- uring point (feet) (7)	Date of meas- ure- ment	REMARKS (Yield given in gallons a minute; drawdown in feet)
						Character of material	Geologic source			Description	Dis- tance above land surface (feet)	Height above mean sea level (feet)			
20-19-26ec. 20-19-28aa. 20-19-29ad.	F. M. Stephens. Howard Winkler. School District.	Dr 312 Dr	160 312 44.7	(?) 5 5	(?) GI GI	Limestone. Sandstone. Limestone.	Greenhorn. Dakota. Greenhorn.	Cy, W Cy, W, H Cy, H	S D, S D	Top of casing, north side	0	2,197.8 2,149.3 16.90	100 180 16.90	10-13-44 7-27-44	
20-20-20dd.	Charles Keller.	B	32	6	GI	(?)	Terrace deposits	Cy, W, H	D, S	Top of board platform under pump	0.5	2,151.3	12.51	2-9-45	
20-20-22dd.	N. L. Olsen.	Dr	42	6	GI	Limestone.	Greenhorn.	Cy, W	D, S	Top of casing, north side	1.6	2,161.5	18.47	2-9-45	
20-20-32cd. 20-20-34dad. 20-21-31ad.	J. H. Armstrong. Mr. Stokes. D. W. Turner.	Dr (?) Dr	110 27 37.1	5 6 (?)	I GI (?)	Sandstone. Sand. Sand and gravel	Dakota. Terrace deposits Alluvium.	Cy, W Cy, W, H Cy, W, D, S	S D, S D, S	do. Top of casing, east side Top of casing, north side	0.5 0.8 2,171.3	2,177.1 18.28 20.76	65.34 18.28 20.76	7-31-44 2-9-45 9-19-45	
20-22-6ec.	Mary L. McFadden	Dr	29.8	6	GI	do.	do.	Cy, W	D, S	Top of casing at pump base	1.0	2,174.9	28.65	9-22-45	
20-22-8dd. 20-22-9bb. 20-22-9dd. 20-22-16bb. 20-22-17da.	Henry De Chant. School District. H. Steeklen. Laurin De Laney. A. M. De Chant.	Du Dr Du Du Dr	20.1 43.6 27.3 21.7 22.4	(?) 6 (?) (?) 6	(?) GI (?) GI GI	Limestone. do. do. do. do.	Greenhorn. do. do. do. do.	Cy, W Cy, W, H Cy, H Cy, W Cy, G Cy, W	S S S S S S	Top of wooden curb. Top of casing. Top of wooden cover. Edge of tin cover. Top of carbide can cover	0.5 1.0 0.4 0.3 1.7	2,202.1 2,223.8 2,210.2 2,204.3 2,194.5	12.90 24.14 16.03 16.37 12.83	9-21-45 9-20-45 9-20-45 9-21-45 9-21-45	
20-22-18bc.	R. P. Warren.	Dr	55.2	6	GI	Sandstone.	Dakota.	Cy, W	N	Top of casing at pump base	0.4	2,228.6	36.39	9-20-45	Formerly a domestic well
20-22-19cc.	Mildred Brennan.	Dr	(?)	(?)	(?)	Sand and gravel	Alluvium.	T, T	I	do.					New well, reported yield, 1,100
20-22-20ca. 20-22-20cc. 20-22-20da. 20-22-20da.	G. C. Holmes. C. L. Whitley. G. C. Holmes.	Dr Dr Dr Dr	48.4 51.4 50.9	16 20 20	GI GI GI GI	do. do. do. do.	do. do. do. do.	C, G C, G C, G C, T	I I I I	Top of concrete curb. do. do. do.	1.1 0.5 0.6	2,191.6 2,193.9 2,190.2	27.06 24.77 27.40	8-21-45 8-21-45 8-21-45	Reported yield, 900 Reported yield, 700 Reported yield, 780; drawdown 16
20-22-20da2	G. C. Holmes.	Dr	54.9	(?)	(?)	do.	do.	C, G	I	do.	0.9	2,190.2	27.65	8-21-45	Reported yield, 880; drawdown 11.75
20-22-21de. 20-22-23ba.	J. H. Bowman. New Hampshire Savings Bank	Dr Dr	29.4 26	6 (?)	GI (?)	do. do.	do. Terrace deposits	Cy, W Cy, W	S S	Top of casing. Top of casing, east side	0 0.2	2,182.5 2,197.7	21.33 17.20	9-22-45 9-19-45	

20-23-29ad	L. B. Buellett	Du	21.7	(7)	(7)	Limestone	Greenhorn	Cy, W	S	Top of concrete curb...	0.8	2,242.1	15.23	9-20-45
20-23-22ab	H. H. Godfrey	Dr	34.6	6	GI	do.	do.	Cy, W	S	Top of casing, south side	0.4	2,212.0	27.17	9-19-45
20-23-23ad	Sam Beardslee	Dr	52.2	6	GI	do.	do.	Cy, W	D, S	Top of casing inside base pump	0.8	2,227.4	34.30	9-20-45
20-23-23ad	S. A. Whitley	Dr	34.4	6	GI	Sand and gravel	Alluvium	Cy, W	N	Top of casing, east side	0.3	2,209.7	30.61	9-19-45
20-23-24de	C. L. Whitley	Dr	55	20	GI	do.	do.	C, G	I	Top of 2-inch board...	1.1	2,205.3	27.37	9-20-45
20-23-25ac	H. A. Reinert	Dr	56	20	GI	do.	do.	T, T	I	Hole in pump base...	1.2	2,211.1	28.89	8-23-45
20-23-25cb	H. A. Reinert	Dr	55.6	20	GI	do.	do.	T, T	I	Top of pump base, west side	0.6	2,211.1	28.82	7-5-46
20-23-25db	H. A. Reinert	DD	57.6	80	GI	do.	do.	T, T	I	Bottom edge of pump base	1.3	2,204.6	31.20	8-20-45
20-23-27bb	School District	Dr	46.3	5	GI	do.	do.	Cy, H	D	Top of concrete curb...	0.4	2,223.8	30.18	8-23-45
20-23-32aa	J. E. Ficken	Dr	69.6	20	GI	do.	do.	T, G	I	Top of iron beam...	1.2	2,228.4	33.81	9-18-45
20-23-33aa	Joe Jedlicka	Dr	56.3	20	GI	do.	do.	C, G	I	Top of wooden curb...	0	2,224.6	33.67	8-20-45
20-23-33be	H. M. Fruisher	Dr	63.6	19	GI	do.	do.	T, G	I	Top of iron beam, east side	1.4	2,228.9	34.28	9-19-45
20-23-35cc	J. Fruisher	Dr	30.8	6	GI	Limestone	Greenhorn	Cy, H	N	Window sill	1.8	2,249.3	17.70	9-27-45
20-23-36aa	Lee Whitley	Dr	44.7	6	GI	do.	do.	Cy, W	S	Top of casing	0	2,206.5	33.55	9-27-45
20-23-36bb	E. H. Riehard	Dr	42	6	GI	do.	do.	Cy, W	N	At pump base	0	2,213.4	33.30	9-27-45
21-16-7dd	School District	Dr	38.8	5	GI	Sand	Terrace deposits	Cy, W	D	Top of casing, north-east side	0.35	2,003.4	21.69	7-22-44
21-16-20de	City of Larned	Dr	167	10	I	Sandstone	Dakota	T, E	P	Top of pit	0	2,006.5	30	2-20-45
21-16-27ab	Mr. Bell	DD	36	16	GI	Sand and gravel	Terrace deposits	C, E	I	At base of pump frame	0.8	1,980.5	16.81	5-9-45
21-16-27ba	Dr. C. E. Sheppard	Dr	82	24	C (7)	do.	do.	T, E	I	do.	0	2,006.1	30	...
21-16-28aa	City of Larned	Dr	123	10	I	Sandstone	Dakota	T, E	P	do.	0	2,005.0	30	...
21-16-28ab1	City of Larned	Dr	145	10	I	do.	do.	T, E	P	do.	0	2,006.5	30	...
21-16-28ab2	City of Larned	Dr	38.8	6	GI	Sand and gravel	Terrace deposits	Cy, H	D	Top of casing, east side	0.4	2,194.2	23.95	9-19-45
20-22-24de	J. A. Bandurant	Dr	28.9	(7)	(7)	do.	do.	Cy, W	D, S	Top of rock cover	1.8	2,178.8	18.28	9-22-45
20-22-25be	John J. Rohr	Du	28.5	6	GI	do.	do.	Cy, W	D, S	Top of concrete curb...	0.4	2,178.4	22.48	9-22-45
20-22-27bb	Harry McFarland	DD	59	16	GI	do.	do.	C	N	do.	0	2,187.2	22.48	...
20-22-28bb	Dale Bowman	DD	57	15	GI	do.	do.	C, T	I	Top of concrete curb, south side	0	2,189.0	28.21	8-24-45
20-22-28cb	J. L. McFadden	DD	56.7	20	GI	do.	do.	C, T	I	Top of wooden platform	0	2,190.0	30.15	8-24-45
20-22-28cc1	H. M. McFadden	DD	54	15	GI	do.	do.	C, T	I	Top of wooden curb...	0	2,190.4	28.75	8-24-45
20-22-28cc2	I. O. McFadden	DD	61.8	(7)	(7)	do.	do.	C, G	I	Top of wooden platform	0.4	2,185.3	28.17	8-25-45
20-22-28de	G. H. Cook	DD	56	16	GI	do.	do.	T, T	I	Top of pump base, south side	1.0	2,201.3	28.60	8-25-45
20-22-29bd	E. H. Uehling	DD	60.8	18	GI	do.	do.	T, T	I	do.	1.0	2,201.3	28.60	8-21-45
20-22-30ac	Harry Hall	Dr	60.8	18	GI	do.	do.	T, T	I	do.	1.0	2,201.3	28.60	8-21-45

TABLE 22.—Records of wells in Pawnee Valley, Kansas—Continued

WELL DESIGNATION (1)	Owner or tenant	Type of well (2)	Depth of well (feet) (3)	Diam- eter of well (in.) (4)	Principal water-bearing bed		Method of lift (5)	Use of water (6)	Measuring point			Depth to water level below meas- uring point (feet) (7)	Date of meas- ure- ment	REMARKS (Yield given in gallons a minute; drawdown in feet)
					Character of material	Geologic source			Description	Dis- tance above land surface (feet)	Height above sea level (feet)			
20-22-30bc	Harry Hall	Dr	65	(?)	Sand and gravel	Alluvium	T, G	I	Top of board cover,	0	28	28	9-14-45	Reported yield, 1,200
20-22-30ca1	F. E. Roth	DD	68	80, 16	do.	do.	C, G	I	south side	0	25.20	25.20	8-23-45	Reported yield, 900
20-22-30ca2	F. E. Roth	DD	60	19	do.	do.	C, G	I	Top of board cover	0	2,200.9	29.05	7-6-46	Reported yield, 700;
20-22-30db	G. N. House	Dr	49.6	(?)	do.	do.	T, G	I	Top of casing, north-	1.3	2,200.9	28.90	9-14-45	drawdown 16
20-22-33ac	W. Barricklow	DD	55.1	19	do.	do.	C, T	I	west side	0.2	2,186.4	32.01	8-25-45	Reported yield, 900
20-22-33da	Ray McFadden	DD	41.5	15	do.	do.	C, G	I	Top of board cover	2.0	2,179.9	24.45	9-12-45	Reported yield, 400
20-22-34bc	W. G. McFadden	DD	60.4	15	do.	do.	C, T	I	Top of pulley frame,	0	2,186.1	32.46	8-25-45	Reported yield, 800
20-22-35ac	Tom Bowie	DD	58.4	19	do.	do.	C, G	I	west side	0.8	2,166.8	27.94	10-27-45	Reported yield, 850
20-22-35bc	A. Cox	DD	51.5	15	do.	do.	C, T	I	Top of concrete curb,	0.4	2,173.3	26.70	9-13-45	Reported yield, 800
20-22-35cc	W. H. Cox	DD	55.2	18	do.	do.	C, T	I	southeast side	0.2	2,173.8	28.76	9-12-45	Reported yield, 800
20-23-13ab	Pete Batz	Dr	34.9	6	Limestone	Greenhorn	C, W	S	Top of casing	0.6	2,231.0	29.75	9-21-45	Reported yield, 800
20-23-14aa	W. F. Hopper	Dr	28.9	6	do.	do.	C, W	D	do.	0.5	2,228.7	23.60	9-21-45	Reported yield, 800
21-16-32ca	City of Larned	Dr	140	10	Sandstone	Dakota	T, E	P	do.	0	2,004.6	30	9-12-45	Reported yield, 800
21-16-32dd	City of Larned	Dr	150	10	do.	do.	T, E	P	do.	0	1,999.8	30	9-12-45	Reported yield, 800
21-16-33ba	Don Burnett	Dr	47	16	do.	Terrace deposits	C, E	I	do.	0	1,996.3	10	9-12-45	Reported yield, 800
21-16-33cd	City of Larned	Dr	70	19	do.	Alluvium	T, E	P	do.	0	1,994.2	10	9-12-45	Reported yield, 800
21-16-34ab	Mr. Fairchild	DD	45	(?)	do.	do.	C, T	I	Top of wooden cover	0	1,993.7	17.08	6-17-45	Reported yield, 800
21-16-34ac	Warren Phinney	Dr	36	19	do.	do.	T, G	I	by discharge pipe	0	1,982.9	6.5	3-13-45	Reported yield, 1,100;
21-17-10dd	Walter M. Fox	Dr	53	6	do.	Dakota	N	N	Top of casing, south	0	2,048.0	36.55	3-13-45	drawdown 23.5
21-17-17de	School District	Dr	45.4	5	Sand	Terrace deposits	Cy, W, H	D	side	0.2	2,054.3	24.87	7-24-44	Abandoned, formerly a
21-17-18dd	Mary Prusa	Dr	42.5	6	do.	do.	Cy, H	P	Top of casing, west side	0.1	2,062.6	30.94	3-15-45	domestic well
21-17-33ba	C. Sweeney	Du, Dn	41.5	28	Sand and gravel	Alluvium	N, W	N	Top of concrete curb,	1.9	2,030.0	19.53	7-13-44	Abandoned, formerly a do- mestic and stock well

21-18-4cc	J. F. Johnson	Dr	87	6	GI	Sandstone	Dakota	Cy, W	S	Top of casing, west side	0.4	2,113.1	45.75	7-24-44	Reported yield, 1,000; drawdown 30
21-18-5ad	J. F. Johnson	Dr, Du	100	(?)	N	Sand	Terrace deposits	Cy, W	D, S	Top of wooden plat-	0	2,132.2	55	10-13-44	Reported yield, 1,400; drawdown 23
21-18-15cb	O. Mickelson	Dr	186	8	OW	Sandstone	Dakota	Cy, H	N	Top of concrete well	0	2,090.8	44.72	5-22-45	Abandoned, formerly an oil well supply well
21-18-17dd	Clara Bukman	DD	53	36	GI	Sand	Terrace deposits	Cy, W, H	D, S	Top of concrete well	0	2,088.8	33.48	5-22-45	Reported yield, 1,000; drawdown 50
21-18-31ca	A. H. Hall	DD	90	19	GI	Sand and gravel	Alluvium	C, T	I	Top of casing, north	0.9	2,085.3	15	7-22-44	Reported yield, 1,400; drawdown 23
21-18-32cc	A. B. Thomas	Dr	120	20	GI	do	do	T, G	I	Top of casing	0	2,148.9	36.90	2-13-45	Abandoned, formerly a domestic and stock well
21-19-1cb	Leo Hagerman	Dr	60	6	GI	Limestone	Greenhorn	N	N	Top of casing	0	2,152.5	65	2-10-45	Reported yield, 1,160
21-19-3cc	L. O. Bley	Dr	200	8	OW	Sandstone	Dakota	Cy, W, H	D, S	Top of concrete well	1.0	2,127.9	32.35	2-12-45	Reported yield, 1,485; drawdown 27
21-19-7ab	Wm. N. and M. L. Blackwell	(?)	52	6	GI	Sand	Terrace deposits	Cy, W	S	Base of pump, south-	1.5	2,086.2	30	2-12-45	Measured yield, 600±; drawdown 27
21-19-16dd	A. F. Bruntzel	Dr	65	6	GI	Sand and gravel	Alluvium	Cy, W	S	Top of casing, north	0.8	2,077.1	20.09	5-23-45	Reported yield, 1,000; drawdown 10
21-19-20cc	D. B. Wies	Dr	96	19	GI	do	do	T, E	I	Top of manhole, west	0.3	2,065.4	25	7-24-44	Reported yield, 1,300
21-19-23ab	H. W. Scott	Du, Du	43	30	Br	do	do	Cy, W, H	D, S	Below ground surface	-8.0	2,062.3	18	7-31-44	Reported yield, 1,900
21-19-27cb	W. W. Christian	Du	42	(?)	(?)	Sand and gravel	Alluvium	Cy, E	D	17 feet below base-	0.2	2,126.4	21.27	6-6-45	Abandoned, formerly a stock well
21-19-27cc	Frank Elmore	Dr	123	16	GI	do	do	T, G	I	Top of casing, north-	1.6	2,100.1	32	6-6-45	Reported yield, 1,200; drawdown 25
21-19-27cc2	Frank Elmore	DD	56	3	GI	do	do	C, E	I	Top of lath strip on	1.0	2,100.8	32	6-6-45	Abandoned, formerly an irrigation well
21-19-29cd	Ralph W. Cone	DD	60	24	GI	do	do	C, G	I	Top of 3- by 12-inch	1.0	2,108.9	29	9-21-44	Reported yield, 1,000; drawdown 50+
21-19-33bb	Cook Brothers	DD	61	24	GI	do	do	C, G	I	Top of board platform	0	2,110.2	30.44	9-10-44	Reported yield, 650
21-19-36ac	F. J. Finger	Dr	100	16	GI	do	do	T, G	I	Top of casing, north-	0.2	2,110.2	30.44	9-10-44	Reported yield, 650
21-19-36db	Nick Werner	Dr	104	(?)	(?)	do	do	T, E	I	Top of casing, east side	2.2	2,110.2	30.44	9-10-44	Reported yield, 650
21-20-9bc	C. Schwind	Dr	58	5	GI	Sand	Terrace deposits	Cy, W	N	Top of casing, east side	2.2	2,110.2	30.44	9-10-44	Reported yield, 650
21-20-15da	Nuckolls Brothers	Dr	45	5	I	Sand and gravel	Alluvium	Cy, W, H	D, S	Top of concrete curb,	0	2,109.7	29.61	6-6-45	Abandoned, formerly an irrigation well
21-20-15db	Nuckolls Brothers	DD	75	24	GI	do	do	C, T	I	Top of concrete well	0.2	2,106.3	18.56	7-24-44	Reported yield, 1,300
21-20-17cd	Mr. Schraeter	DD	(?)	24	GI	do	do	C, T	N	Top of concrete curb,	0	2,064.3	18.56	7-24-44	Reported yield, 1,300
21-20-20ab	Fred Brown	DD	87	28	GI	do	do	T, G	I	Top of concrete well	0.2	2,064.3	18.56	7-24-44	Reported yield, 1,300
21-20-20a1	George Smith	Du	55	(?)	N	do	do	Cy, W	D, S	Top of concrete curb,	1.4	2,062.3	18	7-31-44	Reported yield, 1,900
21-20-20a2	George Smith	DD	80	24	GI	do	do	C, G	I	Top of concrete curb,	1.4	2,126.4	21.27	6-6-45	Abandoned, formerly a stock well

TABLE 22.—Records of wells in Pawnee Valley, Kansas—Continued

WELL DESIGNATION (1)	Owner or tenant	Type of well (2)	Depth of well (feet) (3)	Diam- eter of well (in.) (4)	Principal water-bearing bed		Method of lift (5)	Use of water (6)	Measuring point			Depth to water level below meas- uring point (feet) (7)	Date of meas- ure- ment	REMARKS (Yield given in gallons a minute; drawdown in feet)
					Character of material	Geologic source			Description	Dis- tance above land surface (feet)	Height above mean sea level (feet)			
21-20-21cb.....	John Maur.....	Dr	64	19	Sand and gravel	Alluvium.....	C, T	I	Top of concrete curb, east side	.....	2,100.8	24.49	7-25-45	Reported yield, 1,250
21-20-24ab.....	Henry Peak.....	Dr	70	24	do.....	do.....	T, T	I	Top of 6- by 10-inch timber under pump,	0	2,093.9	31.57	5-25-45	Reported yield, 800; drawdown 28
21-20-26ab.....	Harold Bell.....	Dr	90	19	do.....	do.....	T, G	I	Top of concrete pump south side	0	2,091.5	30.28	5-7-45	Reported yield, 1,400;
21-20-26da.....	Lester Preston.....	DD	90	19	do.....	do.....	C, T	I	Top of steel pulley frame	0.4	2,094.7	33.58	5-23-45	Reported yield, 450; drawdown 20
21-20-28cd.....	Whiteway Cafe.....	Dr	126	6	Sandstone.....	Dakota.....	Cy, W E	D	Top of concrete curb...	0.3	2,107.8	30	6-6-45	Battery of three wells.
21-20-29bc1.....	Irving Brownlee.....	DD	53	19	Sand and gravel	Alluvium.....	C, G	I	Top of concrete curb...	.....	2,107.6	27.61	.....	Reported yield, 800; drawdown 14
21-20-29bc2.....	Irving Brownlee.....	Dr	94	19	do.....	do.....	T, G	I	.....	.....	.....	.....	.....	Reported yield, 1,000
21-20-30bc.....	Rex Lee.....	Du	93	24	do.....	do.....	C, G	I	At edge of 4- by 4-inch timber	1.1	2,115.1	34	9-20-45	.....
21-21-8dd.....	R. E. Mooney.....	Dr	92.2	6	do.....	Terrace deposits	Cy, W	S	.....	.....	2,107.7	42.50	.....	.....
21-21-9ed.....	R. E. Mooney.....	Dr	58.7	6	do.....	do.....	Cy, W	S	do.....	1.0	2,143.1	36.50	9-26-45	.....
21-21-14dc.....	M. E. Choat.....	Dr	64.8	6	do.....	do.....	Cy, W	S	do.....	0.4	2,160.4	35.40	9-26-45	.....
21-21-16cb.....	Dan Hogan.....	DD	59.9	20	do.....	Alluvium.....	C, G	I	Top of 6-inch angle iron	0.7	2,138.5	31.37	9-15-45	.....
21-21-17cb.....	Susie Bauer.....	DD	60	19	do.....	do.....	T, G	I	Bottom edge of cross timber	0.6	2,139.9	31	9-18-45	Reported yield, 900
21-21-18sa.....	O. W. Lynnam.....	DD	54.6	20	do.....	do.....	C, G	I	.....	.....	2,146.8	32.94	9-15-45	Reported yield, 900; drawdown 15
21-21-18bb.....	R. O. Croft.....	DD	65	19	do.....	do.....	T, G	I	Top of pump pulley...	3.4	2,152.3	37.63	9-15-45	Estimated yield, 1,200; drawdown 15
21-21-19bb.....	E. F. Frisell.....	Du	42.5	(?)	Limestone.....	Greenhorn.....	N	N	Top of rock curb.....	1.1	2,163.8	40.34	9-25-45	Formerly a domestic well
21-21-21bb.....	W. A. Lynnam.....	DD	77.7	19	Sand and gravel	Alluvium.....	T, T	I	Top of iron beam, north end	0	2,134.9	29.25	9-13-45	Reported yield, 1,000;
21-21-21bc.....	W. A. Lynnam.....	Dr	72	19	do.....	do.....	T, G	I	Base of pump, east side	0.5	2,136.8	29.54	7-10-46	drawdown 19
21-21-21bc.....	W. A. Lynnam.....	Dr	72	19	do.....	do.....	T, G	I	Bottom edge of cross timber	0	2,132.3	33.71	9-9-47	Measured yield, 840; drawdown 14
21-21-21db.....	Eakin Estate.....	DD	84.9	19	do.....	do.....	C	N	.....	.....	.....	28.34	9-13-45	Formerly an irrigation well

21-21-23da	Maude Blount	DD	51.5	6	GI	do.	do.	Cy, W	S	Top of casing	1.3	2,121.8	30.37	9-26-45
21-21-24ce	Dwight Eakin	Dr	30.6	6	GI	do.	do.	Cy, W	S	Top of 4- by 4-inch timber	0.5	2,114.5	31.57	9-26-45
21-21-26ce	J. Bauer	Dr	61.2	24	GI	do.	do.	T, T	I	Top of wooden beam, southwest side	1.0	2,113.1	30.98	8-22-45
21-21-26be	Dwight Eakin	Dr	68	25	GI	do.	do.	T, T	I	Bottom edge of pump base, east side	0.6	2,123.1	34.65	7-10-46
21-21-26cb	Dwight Eakin	Dr	66	18	GI	do.	do.	T, T	I	Top of pump base, south side	0	2,124.6	35.44	9-13-45
21-21-30cb	N. Rittenhouse	Dr	334.6	4	GI	Sandstone	Dakota	Cy, W	D	Top of casing	0.5	2,128.8	204.60	9-12-45
21-21-33cd	Clyde Mattoon	DD	71	19	GI	Sand and gravel	Alluvium	T, T	I	Top edge of casing	0.5	2,127.7	25.89	8-25-45
21-21-33de	Melvin Bryant	Dr	95	13	GI	do.	do.	T, T	I	Base of pump	0.5	2,122.7	29	10- 3-45
21-21-34db	C. W. Lyman	DD	70	24	GI	do.	do.	T, G	I	Top of casing	1.4	2,116.1	30.75	9-25-45
21-21-32ba	R. N. Norris	Dr	34.3	6	GI	do.	do.	Cy, W	S	Tractor frame rest	0.9	2,120.7	35.10	9-18-45
21-21-32ce	H. F. Alexander	DD	63.3	19	(?)	do.	do.	T, T	I	Top of casing, north side	0.9	2,114.2	32.83	8-27-46
21-21-32cb	Roy Klein	DD	93.5	20	GI	do.	do.	T, T	I	Top of casing, north side	0	2,157.9	32.05	7-10-46
21-21-36ab	J. A. Brown	DD	67.7	20	GI	do.	do.	T, T	I	Bottom of 2- by 6-inch timber	0	2,157.9	32.50	9-15-45
21-22-1ad	Leo Larson	DD	49.2	18	GI	do.	do.	C, T	I	Top edge of 6-inch angle iron	1.0	2,157.2	33.49	9-17-45
21-22-1db	W. L. Traver	DD	51	18	GI	do.	do.	T, T	I	Top of concrete curb	0.5	2,165.8	32.64	9-13-45
21-22-2bb	E. Kraker	Du	26.4	(?)	(?)	do.	do.	Cy, W	S	Top of wooden curb	0	2,172.1	33.74	9-25-45
21-22-2cb	Frank Moore	DD	62.7	19	GI	do.	do.	T, G	I	Top of iron beam, west side	0.5	2,172.1	33.74	8-24-45
21-22-3ab	Martha Tift	Dr	35.7	6	GI	do.	do.	Cy, W	S	Top of casing	0.4	2,179.0	30.40	9-24-45
21-24-4ad	L. Newport	Dr	27.7	6	GI	do.	do.	Cy, W	S	do.	0.6	2,181.0	17.90	9-24-45
21-22-4dd	C. E. Tift	Dr	30.7	(?)	(?)	Limestone	Greenhorn	Cy, W	S	Top of wooden curb	1.1	2,198.9	28.92	9-24-45
21-22-5dc	Lillie McFarland	Du	38.2	(?)	(?)	do.	do.	Cy, W	S	Top of rock	1.6	2,221.3	34.75	9-24-45
21-22-7aa	D. Nevore	Dr	34.3	(?)	(?)	do.	do.	Cy, W	S	Top of casing	0.6	2,235.7	27.67	9-24-45
21-22-8aa	Maggie Redder	Du	26.3	(?)	(?)	do.	do.	Cy, W	N	do.	0	2,233.0	27	9-24-45
21-22-8ba	J. Bower	Dr	35.7	6	GI	do.	do.	Cy, W	S	Top of casing	0	2,233.0	26.50	9-24-45
21-22-8bc	Harry Klinge	(?)	39.8	6	GI	do.	do.	Cy, W	S	do.	1.0	2,243.8	36.75	9-24-45
21-22-8be	George Cox	Du	43.5	(?)	(?)	do.	do.	Cy, G	N	Top of concrete curb	1.0	2,215.0	40.82	9-24-45
21-22-9bb	F. Kraker	Du	40.6	(?)	(?)	do.	do.	Cy, G	N	do.	1.5	2,183.6	35.60	9-24-45
21-22-10ba	Tom Bowie	DD	33.3	48	GI	Sand and gravel	Alluvium	C, G	I	Top of concrete curb, south side	0.5	2,153.8	32.03	9-17-45
21-22-12aa	Harold McFadden	DD	75.6	60	GI	do.	do.	C, T	I	Top of concrete curb, southwest side	1.0	2,157.6	35.69	8-28-40
21-22-12bc	Gus Lingenfelder	DD	40.7	48	GI	do.	do.	T, G	I	Top of 2- by 4-inch cross piece	0.7	2,155.7	35.40	8-22-45
21-22-12cb	Bowie Estate	DD	60	18	GI	do.	do.	T, G	I	Top of casing	0.4	2,188.5	40.80	9-25-45
21-22-12db	A. E. Watson	Dr	49.3	6	GI	Limestone	Greenhorn	T	N	Top of wooden curb	0.4	2,188.5	40.80	9-25-45
21-22-14bb	F. W. Wieland	Du	35.2	(?)	(?)	do.	do.	Cy, W	S	Top of casing, east side	4.1	2,248.6	99.18	10- 5-45
21-22-15ac	R. H. Clews	Dr	285	6	GI	Sandstone	Dakota	Cy, W	S	Top of casing, east side	4.1	2,248.6	99.18	10- 5-45

TABLE 22.—Records of wells in Pawnee Valley, Kansas—Continued

Well designation (1)	Owner or tenant	Type of well (2)	Depth of well (feet) (3)	Diameter of well (in.) (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 land surface (feet)	Height above mean sea level (feet)			
21-22-28aa.....	A. J. Halling.....	Dr	360.6	6	Sandstone.....	Dakota.....	Cy, W	S	Top of casing, north side	1.1	2,284.0	136.61	10- 5-45	
21-23-3ba.....	R. B. Frusher.....	Dr	22.7	(?)	Limestone.....	Greenhorn.....	Cy, W	S	Top of rock.....	0.7	.....	13.86	9-21-45	
21-23-6dc.....	J. B. Frusher.....	Dr	35.9	6	do.....	do.....	Cy, W	S	Top of casing.....	0.6	.....	31.67	9-21-45	
21-23-18dc.....	John Frusher.....	Dr	30	6	do.....	do.....	Cy, W	S	do.....	0.4	.....	21.00	10-30-45	
21-23-29cb.....	Esther Burns.....	Dr	48.3	6	do.....	do.....	Cy, W	D, S	do.....	0.8	.....	42.35	10-30-45	
21-23-33aa.....	R. P. Sloan.....	Dr	21.3	6	do.....	do.....	Cy, W	S	do.....	1.3	.....	13.60	10-30-45	
21-24-3ac.....	George Van Vleet.....	Dr	63.1	19	Sand and gravel	Alluvium.....	T, T	I	Top of casing, east side	0.9	.....	31.93	9-14-45	
21-24-36da.....	N. W. Goebel.....	Du	9.6	(?)	do.....	Oxallala (?)	Cy, W	S	Top of wooden cover.....	0.5	.....	31.50	7-24-46	
21-25-2dc.....	W. L. Love.....	Dr	218.9	6	Sandstone.....	Dakota.....	Cy, W	D, S	Top of concrete curb.....	0.4	.....	5.99	10-31-46	
21-25-3aa.....	E. Sinclair.....	Du	28.8	(?)	Limestone.....	Greenhorn.....	Cy, W	D, S	Top of concrete curb, northwest side	0	.....	90.76	10-22-45	Reported yield, 800
21-25-6ec1.....	T. W. Sinclair.....	Dr	67.5	6	do.....	do.....	Cy, W	S	Top of casing.....	1.5	.....	54.90	11-15-45	
21-25-6ec2.....	T. W. Sinclair.....	Dr	68.1	5	do.....	do.....	Cy, W	S	do.....	1.5	.....	55.80	10-20-45	
21-25-7ad.....	S. H. Pitts.....	Dr	49.8	5	do.....	do.....	Cy, W	S	Top of curb.....	0.5	.....	47.50	10-20-45	
21-25-16dd.....	School District.....	Dr	42.8	6	Sand and gravel	Alluvium.....	Cy, W	D	do.....	0.5	.....	29.69	10-22-45	
21-25-18lb.....	T. W. Sinclair.....	Du	(?)	(?)	do.....	do.....	Cy, W	D, S	do.....	0.9	.....	40.64	10-22-45	
21-25-32eb.....	R. A. Sinclair.....	B	26.6	5	do.....	Oxallala (?)	Cy, W	D, S	Top of casing.....	1.3	.....	25.90	10-19-45	
21-25-33ac.....	G. Sinclair.....	B	20.9	5	Shale.....	Carille (?)	Cy, W	N	Top of stone curb.....	0.8	.....	17.80	10-19-45	Formerly a domestic well
21-25-34ad.....	G. Sinclair.....	Dr	33.0	5	Sand and gravel	Oxallala (?)	Cy, W	S	Top of casing.....	2.0	.....	32.60	10-18-45	
22-16-3bc.....	Orville Baldwin.....	DD	65	19	do.....	Alluvium.....	C, T	I	Top of concrete foundation at window	1.0	1,992.0	7.58	6-17-45	Reported yield, 1,000
22-16-4ab.....	Mr. Handshaw.....	Dr	38	30	do.....	do.....	T, E	I	Top of pump base.....	0.5	1,995.4	10.91	6-17-45	Reported yield, 1,200; drawdown 16 to 18
22-16-4ba.....	Leo Myers.....	Dr	75	19	do.....	do.....	T, E	I	Hole in pump base.....	1.2	1,996.2	9.29	6-17-45	Reported yield, 1,500; drawdown 9+
22-16-4bb.....	Fred W. Freeland.....	DD	45	18	do.....	do.....	C, G	I	Top of 1-inch plank at discharge pipe	0.2	1,998.0	8.98	6-17-45	
22-16-4ca.....	Catherine L. Boyd.....	Dn	12	(?)	do.....	do.....	P, H	D	.....	.....	1,995.7	6	10- 6-44	Reported yield, 400; drawdown 6
22-16-4da.....	James Buster.....	DD	38	16	do.....	do.....	C, E	I	.....	.....	1,996.0	9	.....	

12-16-34d	City of Larned	Du.Dn	26	20	C	do.	do.	C, E	P	Top of concrete rim of hole in well fiber	-1.7	2,011.3	6.63	7-28-44	Reported yield, 600
12-16-46b	Harold Bell	Dr	33 5	19	(7)	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
12-16-47d	A. L. Stockwell	DD	33	19	GI	do.	do.	C, T	I	At top of casing	0	2,010.0	12.53	11-28-45	Reported yield, 700
12-16-6cd	A. L. Stockwell	DD	31.4	16	GI	do.	do.	C, T	N	Top of concrete curb, southwest side	0	2,014.7	14.23	7-13-44	Abandoned, formerly an irrigation well
12-16-7bb	F. Hoag	DD	32.9	16	GI	do.	do.	C, T	N	Base of 2-by 8-inch board over well	0.5	2,016.1	14.34	7-13-44	Abandoned, formerly an irrigation well
12-16-7ec	M. Christian	DD	35	20	GI	do.	do.	C, T	I				8		Reported yield, 1,000; drawdown 6. Not in use since 1938
12-16-8ba	John Beamer	DD	34	24	GI	do.	do.	C, G	I			2,008.1	7		Reported yield, 1,000; drawdown 10 to 12
12-16-18ac	Wm. Hiss, Jr.	Dn	12 3	1 25	GI	do.	do.	P, H	S	Bottom of check valve	1.8	2,015.1	4.85	2-16-45	Reported yield, 700
12-17-5bb1	E. E. Fizzell	Dr	66	24	GI	do.	do.	T, G	I	Top of steel pump support	0.1	2,036.4	15.74	7-22-44	Reported yield, 700
12-17-5bb2	E. E. Fizzell	Dr	66	24	GI	do.	do.	T, G	I	Base of pump, north side	0.9	2,037.8	16.93	5-14-45	Reported yield, 700
12-17-5bb3	E. E. Fizzell	Dr	66	24	GI	do.	do.	T, G	I	Base of pump	0.6	2,036.6	15.80	5-14-45	Reported yield, 700
12-17-5cc	School District	Dr	(7)	(7)	(7)	do.	do.	Cy, H	D	Top of casing, south side	0		12.16	5-14-45	
12-17-9cd	W. L. Brooks	DD	55	19	GI	do.	do.	C, G	I			2,046.1	20		Reported yield, 1,000
12-17-11dd	School District	Dn	20	(7)	N	do.	do.	Cy, H	D			2,020.6	12		Reported yield, 1,000; drawdown 8
12-17-12cc	Joe Smith	DD	52	19	GI	do.	do.	C, G	I			2,021.4	14		Reported yield, 1,000; drawdown 8
12-17-17ad	Henry C. Schnack	DD	35	19	GI	do.	do.	C, E	I	Top of 20-inch casing, southwest side	0.5	2,052.4	23	8-2-45	Reported yield, 1,000; drawdown 28
12-17-18aa	Ralph Luper	Dr	124	19	GI	do.	do.	T, E	I	Top of casing		2,056.1	27.13	11-17-45	Reported yield, 650
12-17-19ch	Mary Ekmeier	Dr	215	5	I	do.	do.	Cy, W	S	Top of board over casing over well		2,092.9	48.04	7-19-44	Abandoned, formerly an irrigation well
12-17-21ba	Faun Brothers	DD	44	16	GI	Sandstone	Dakota	C, G	I	Top of 1-inch board	0	2,060.5	12.92	8-2-44	Reported yield, 1,000
12-17-2cc	M. Ewing	Du	21 7	48	(7)	Sand and gravel	Alluvium	C, N	N	Top of metal rim around well	0	2,080.8	24.10	2-16-45	Reported yield, 1,000
12-17-32bh	D. B. Welch	Dr	151	(7)	(7)	Sandstone	Dakota	Cy, W	S	Top of casing	0.5	2,047.2	13.13	5-14-45	Reported yield, 1,000
12-17-3ccc	Elizabeth Karr	Du.Dn	(7)	11 4	GI	Sand and gravel	Meade	C, N	S	Top of pump base, south side	0.6	2,051.0	13.89	7-13-44	Reported yield, 1,000
12-18-3da	Irvin Whitmore	Du	26	60	Ba	do.	Alluvium	T, E	I	Top of casing	0.3	2,053.1	15.85	11-28-45	Reported yield, 1,000
12-18-4b	Dan Fox	Dr	98	19	GI	do.	do.	T, E	I	Top of oil-gauge hole in pump base	0.9	2,056.9	12.42	7-22-44	Reported yield, 1,000; drawdown 30 to 32
12-18-5fb	Frank Browlee	DD	74 5	19	GI	do.	do.	C, G	I	Top of casing		2,057.5	15	11-28-45	Reported yield, 2,000
12-18-6aa	N. D. Webster	Dr	100	19	GI	do.	do.	T, G	I	Top of casing	1.0	2,052.7	12.09	11-28-45	Reported yield, 1,100; drawdown 15.5
12-18-6bb	Lee Meador	Dr	96	24	GI	do.	do.	T, G	I			2,050.7	14		
12-18-8ce	J. Mackfresel	Dr	69 5	18	GI	do.	do.	T, G	I						
12-18-9db	Donald Younkun	Dr	100	19	GI	do.	do.	T, E	I						

TABLE 22.—Records of wells in Pawnee Valley, Kansas—Continued

WELL DESIGNATION (1)	Owner or tenant	Type of well (2)	Depth of well (feet) (3)	Diameter of well (in.) (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 land surface (feet)	Height above mean sea level (feet)			
21-22-28aa.....	A. J. Halling.....	Dr	360.6	6	Sandstone.....	Dakota.....	Cy, W	S	Top of casing, north side	1.1	2,284.0	136.61	10- 5-45	
21-23-3ba.....	R. B. Frusher.....	Dr	22.7	(?)	Limestone.....	Greenhorn.....	Cy, W	S	Top of rock.....	0.7	.....	13.86	9-21-45	
21-23-6dc.....	J. B. Frusher.....	Dr	35.9	6	do.....	do.....	Cy, W	S	Top of casing.....	0.6	.....	31.67	9-21-45	
21-23-18dc.....	John Frusher.....	Dr	30	6	do.....	do.....	Cy, W	S	do.....	0.4	.....	21.00	10-30-45	
21-23-29cb.....	Esther Burns.....	Dr	48.3	6	do.....	do.....	Cy, W	D, S	do.....	0.8	.....	42.35	10-30-45	
21-23-35aa.....	R. P. Sloan.....	Dr	21.3	6	do.....	do.....	Cy, W	S	do.....	1.3	.....	13.60	10-30-45	
21-24-3ac.....	George Van Vleet.....	Dr	63.1	19	Sand and gravel	Alluvium.....	T, T	I	Top of casing, east side	0.9	.....	31.63	9-14-45	Reported yield, 800
21-24-36da.....	N. W. Goebel.....	Du	9.6	(?)	do.....	Ogallala (?)	Cy, W	S	Top of wooden cover.....	0.5	.....	31.50	7-24-46	
21-25-2dc.....	W. L. Love.....	Dr	218.9	6	Sandstone.....	Dakota.....	Cy, W	D, S	Top of concrete curb.....	0.4	.....	90.76	10-22-45	
21-25-3aa.....	E. Sinclair.....	Du	28.8	(?)	Limestone.....	Greenhorn.....	Cy, W	D, S	Top of concrete curb, northwest side	0	.....	27.90	10-19-45	
21-25-6ec1.....	T. W. Sinclair.....	Dr	67.5	6	do.....	do.....	Cy, W	S	Top of casing.....	1.5	.....	54.90	11-15-45	
21-25-6ec2.....	T. W. Sinclair.....	Dr	68.1	5	do.....	do.....	Cy, W	S	do.....	1.5	.....	55.80	10-20-45	
21-25-8ad.....	S. H. Pitts.....	Dr	49.8	5	do.....	do.....	Cy, W	S	Top of curb.....	0.5	.....	47.50	10-20-45	
21-25-16dd.....	School District.....	Dr	42.8	6	Sand and gravel	Alluvium.....	Cy, W	D, S	do.....	0.5	.....	29.69	10-22-45	
21-25-18db.....	T. W. Sinclair.....	Du	(?)	(?)	do.....	do.....	Cy, W	D, S	do.....	0.9	.....	40.64	10-22-45	
21-25-32cb.....	R. A. Sinclair.....	Dr	26.6	5	Shale.....	Ogallala (?)	Cy, W	N	Top of casing.....	1.3	.....	25.90	10-19-45	Formerly a domestic well
21-25-33ac.....	G. Sinclair.....	B	20.9	5	do.....	do.....	Cy, W	S	Top of stone curb.....	0.8	.....	17.80	10-19-45	
21-25-34ad.....	G. Sinclair.....	Dr	33.0	6	Sand and gravel	Ogallala (?)	Cy, W	S	Top of casing.....	2.0	.....	32.60	10-18-45	Reported yield, 1,000
22-16-3bc.....	Orville Baldwin.....	DD	65	19	do.....	Alluvium.....	C, T	I	Top of concrete foundation at window	1.0	1,992.0	7.58	6-17-45	
22-16-4ab.....	Mr. Handshaw.....	Dr	38	30	do.....	do.....	T, E	I	Top of pump base.....	0.5	1,995.4	10.91	6-17-45	Reported yield, 1,200; drawdown 16 to 18
22-16-4ba.....	Leo Myers.....	Dr	75	19	do.....	do.....	T, E	I	Hole in pump base.....	1.2	1,996.2	9.29	6-17-45	Reported yield, 1,500; drawdown 9+
22-16-4bb.....	Fred W. Freeland.....	DD	45	18	do.....	do.....	C, G	I	Top of 1-inch plank at discharge pipe	0.2	1,998.0	8.98	6-17-45	
22-16-4ca.....	Catherine L. Boyd.....	Dn	12	(?)	do.....	do.....	P, H	D	.....	.....	1,995.7	6	10- 6-44	Reported yield, 400; drawdown 6
22-16-4da.....	James Buster.....	DD	38	16	do.....	do.....	C, E	I	.....	.....	1,996.0	9	.....	

22-16 8bd.	City of Larned.....	Du,Dn	26	20	C	do.	do.	do.	C, E	P	Top of concrete rim of hole in well fiber curb, south side	-1.7	6 63	7-28-44	Reported yield, 600
22-16 6bb	Harold Bell.....	Dr	33 5	19	(f)	do.	do.	do.	C, E	I	Top of round concrete curb, south side	1.5	19 29	8-28-40	Reported yield, 300±; drawdown 10 after several hours of pumping
22-16 6bd	A. L. Stockwell.....	DD	33	19	GI	do.	do.	do.	C, T	I	At top of casing.....	0	12 53	11-29-45	Reported yield, 700
22-16 6cd	A. L. Stockwell.....	DD	31 4	16	GI	do.	do.	do.	C, N	N	Top of concrete curb, southwest side	0	14 23	7-13-44	Abandoned, formerly an irrigation well
22-16 7bb	F. Hoag.....	DD	32 9	16	GI	do.	do.	do.	C, T	N	Base of 2- by 8-inch board over well	0.5	14 34	7-13-44	Abandoned, formerly an irrigation well
22-16 7cc	M. Christian.....	DD	35	20	GI	do.	do.	do.	C, T	I	.....	.....	8	.....	Reported yield, 1,000; drawdown 6. Not in use since 1938
22-16 8ba	John Beamer.....	DD	34	24	GI	do.	do.	do.	C, G	I	.....	.....	7	.....	Reported yield, 1,000; drawdown 10 to 12
22-16 18aac	Wm. Hass, Jr.....	Dn	12 3	1 25	GI	do.	do.	do.	P, H	S	Bottom of check valve	1.8	4 85	2-16-45	Reported yield, 700
22-17 5bb1	E. E. Friell.....	Dr	66	24	GI	do.	do.	do.	T, G	I	Top of steel pump support	0.1	15 74	7-22-44	Reported yield, 700
22-17 5bb2	E. E. Friell.....	Dr	66	24	GI	do.	do.	do.	T, G	I	Base of pump, north side	0.9	16 93	5-14-45	Reported yield, 700
22-17 5bb3	E. E. Friell.....	Dr	66	24	GI	do.	do.	do.	T, G	I	Base of pump.....	0.6	15 80	5-14-45	Reported yield, 700
22-17 5ca	School District.....	Dr	(f)	(f)	(f)	do.	do.	do.	Cy, H	D	Top of casing, south side	0	12 16	5-14-45	Reported yield, 1,000
22-17 9cd	W. L. Brooks.....	DD	55	19	GI	do.	do.	do.	C, G	I	.....	.....	20	.....	Reported yield, 1,000
22-17 11dd	School District.....	Dn	20	(f)	N	do.	do.	do.	Cy, H	D	.....	.....	12	.....	Reported yield, 1,000; drawdown 8
22-17 12cc	Joe Smith.....	DD	52	19	GI	do.	do.	do.	C, G	I	.....	.....	14	.....	Reported yield, 1,000; drawdown 25
22-17 17ad	Henry C. Schnack.....	DD	35	19	GI	do.	do.	do.	C, E	I	Top of 20-inch casing, southwest side	0.5	23 13	8- 2-45	Reported yield, 1,000
22-17 18aa	Ralph Lupfer.....	Dr	124	19	GI	do.	do.	do.	T, E	I	Top of casing.....	.....	27 13	11-17-45	Reported yield, 650
22-17 19cb	Mary Ekmeier.....	Dr	215	5	I	Sandstone	do.	do.	Cy, W	S	Top of casing.....	.....	48 04	7-10-44	Abandoned, formerly an irrigation well
22-17 21ba	Fagen Brothers.....	DD	44	16	GI	Sand and gravel	do.	do.	C, G	I	Top of board over casing	0	24 10	8- 2-44	Reported yield, 1,000
22-17 28cc	M. Ewing.....	Du	21 7	48	(f)	do.	do.	do.	C, N	N	Top of 1-inch board over well	0	12 92	2-16-45	Reported yield, 1,000; drawdown 30 to 32
22-17 32bb	D. B. Welsh.....	Dr	151	(f)	(f)	Sandstone	do.	do.	Cy, W	S	Top of board over casing	0	24 10	11-29-45	Reported yield, 2,000
22-17 36cc	Elizabeth Krarr.....	Du,Dn	(f)	1 1/4	GI	Sand and gravel	do.	do.	C, N	S	Top of metal rim around well	0	13 13	.....	Reported yield, 1,000; drawdown 15.5
22-18 3da	Irvin Whitmore.....	Du	26	60	Bs	do.	do.	do.	C, G	I	Top of casing.....	0.5	13 89	5-14-45	Reported yield, 1,000
22-18 4cb	Dan Fox.....	Dr	98	19	GI	do.	do.	do.	C, E	I	Top of pump base, south side	0.6	14	7-13-44	Reported yield, 1,000
22-18 5db	Frank Brownlee.....	DD	74 5	19	GI	do.	do.	do.	C, G	I	Top of casing.....	0.3	15 85	11-28-45	Reported yield, 1,000
22-18 6aa	N. D. Webster.....	Dr	100	19	GI	do.	do.	do.	T, E	I	Top of oil-gauge hole in pump base	0.9	12 42	7-22-44	Reported yield, 1,000; drawdown 30 to 32
22-18 6bb	Lee Meador.....	Dr	96	24	GI	do.	do.	do.	T, G	I	Top of casing.....	1.0	12 09	11-29-45	Reported yield, 2,000
22-18 8bc	J. Markfessel.....	Dr	69 5	18	GI	do.	do.	do.	T, G	I	.....	.....	14	.....	Reported yield, 1,000; drawdown 15.5
22-18 9bb	Donald Younkun.....	Dr	100	19	GI	do.	do.	do.	T, E	I	.....	.....	14	.....	Reported yield, 1,000; drawdown 15.5

TABLE 22.—Records of wells in Pawnee Valley, Kansas—Continued

WELL DESIGNATION (1)	Owner or tenant	Type of well (2)	Depth of well (feet) (3)	Diameter of well (in.) (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 land surface (feet)	Height above mean sea level (feet)			
22-18-9cb	Ernest Mackfessel	Dr	102	19	Sand and gravel	Alluvium	T, G	I			2,051.0	16		Reported yield, 1,500; drawdown 20
22-18-9cc	Ernest Mackfessel	Du	26	60	do	do	Cy, W, H	D, S			2,062.7	23	10-11-44	
22-18-10bb	Warren Charles	Dr	110	19	Dr	do	T, E	I			2,048.3	16		Reported yield, 1,200;
22-18-10cb1	A. L. Stockwell	Dr	100	19	do	do	T, G	I	Top of casing	0.5	2,047.3	13.63	11-27-45	drawdown 38
22-18-10cb2	A. L. Stockwell	Dr	100	24	do	do	T, G	I				13		Reported yield, 700; drawdown 68
22-18-11cd	Elmer Williams	Dr	96	19	do	do	T, G	I	Top of casing, east side		2,042.5	10		Reported yield, 1,200
22-18-14ab	G. L. Eddy	Dr	81	19	do	do	T, G	I		0	2,044.5	12.48	11-27-45	Reported yield, 750; drawdown 40 to 45
22-18-15ac	E. Easley	DD	86	10	do	do	C, T	I	Top of 1/2-inch hole in steel pipe clamp	1.6	2,047.3	12	8-2-44	Reported yield, 700
22-18-27aa	P. O. Palmer	Dr	53.5	5	Sandstone	Dakota	Cy, W	S	Top of casing, west side		2,070.0	17.27		Abandoned, formerly domestic and stock well
22-18-28cc	T. B. Price	Dr	82.5	5	Sand	Terrace deposits	Cy, W	N	Top of 5-inch hole in concrete base, east side	0.2	2,100.3	25.16	8-2-44	Abandoned, formerly domestic and stock well
22-18-35dd	E. A. Shumway	Dr	56.5	5	do	do	Cy, W	N		0.5	2,111.3	46.15	8-2-44	Abandoned, formerly domestic and stock well
22-19-8dd	I. E. Tebbel	Dr	40.5	5	do	do	Cy, W	S	Top of casing, east side	0.3	2,097.7	22.96	8-3-44	Abandoned, formerly domestic and stock well
22-19-10dd	G. E. Bartlett	Dr	38.6	6	do	do	Cy, W, H	D, S	Top of casing	1.2	2,087.1	24.38	3-20-45	Abandoned, formerly domestic and stock well
22-19-26ddc	J. A. Boyd	Du	67.5	28	Sandstone	Dakota	N	N	Top of 2- by 12-inch plank over well	0.4	2,138.9	43.77	3-20-45	Formerly an oil-well supply well
22-19-29cc	School District	Dr	100	6	do	do	Cy, W, H	D	Top of casing, south side	0.5	2,102.0	47	7-31-44	Abandoned, formerly domestic and stock well
22-20-4bb	Burdette Cemetery	Dr	210	4	do	do	Cy, W	I	Top of casing	0.3	2,208.1	117.66	3-14-45	Formerly an oil-well supply well
22-20-9adb	G. R. Norris	Dr	167	8	do	do	N	N			2,165.2	65.04	3-15-45	Abandoned, formerly domestic and stock well
22-20-13cb	A. A. Smith	Dr	120	5	do	do	Cy, W	S	Top of casing, south side	1.3	2,087.1	41.75	3-15-45	Abandoned, formerly domestic and stock well
22-20-19ba	J. E. Mooney	Dr	125.5	6	do	do	Cy, W	S	Top of casing, north side	0.5	2,239.6	91.60	7-31-44	Abandoned, formerly stock well
22-20-29ba	B. W. Klein	Dr	28.2	8	Sand	Terrace deposits	Cy, W	S	do	1.4	2,185.1	17.60	7-30-44	Abandoned, formerly stock well
22-20-30ad	L. O. Bley	Dr	35.2	6	do	do	Cy, W, H	N	do	0.2	2,192.4	18.91	3-20-45	Abandoned, formerly stock well

22-21-2ca	R. M. Norris	Dr	47 4	5	GI	Sand and gravel	Alluvium	C ₁ T	W	S	Top of casing, west side	0	2, 131.8	32.84	7-20-46	Reported yield, 1,125; drawdown 17
22-21-3aa	O. C. Shuck	Dr	87	13	I	do.	do.	T, T	I	I	Top of casing	0.8	2, 123.2	31.96	9-12-47	
22-21-3bc	J. H. Lingenfelder	DD	78 9	24	GI	do.	do.	T, T	I	I	Top of angle iron	0.5	2, 120.3	28.76	7-20-46	
22-21-4aa	McViv Bryant	DD	73 2	16	GI	do.	do.	T, T	I	I	Top of casing, west side	0	2, 127.3	28.45	10-3-45	
22-21-4bd	W. C. Myers	DD	59 5	24	GI	do.	do.	T, G	I	I	Top of pump support	0.4	2, 130.1	27.70	7-20-46	Reported yield, 900
22-21-6ad	John Schmit	DD	57	6	GI	do.	do.	C ₁ H	N	N	Top of casing	0.5	2, 140.3	26.72	7-20-46	
22-21-7ad	N. Hahn	DD	71	(?)	(?)	do.	do.	T, T	I	I	Bottom edge of pump base	0.4	2, 138.7	27.33	7-20-46	Reported yield, 1,000
22-21-7ec	Albert Neufeld	DD	58 7	20	GI	do.	do.	C, T	I	I	Top of 2- by 6-inch pump support	0.5	2, 144.4	24.22	7-9-46	
22-21-8bb	Chas. Dovell	Dr	70 4	19	GI	do.	do.	T, T	I	I	Top of concrete curb	0.2	2, 136.8	25.17	7-23-46	Reported yield, 900
22-21-9ad	Chas. Jones	Dr	60 1	19	GI	do.	do.	T, G	I	I	Top edge of pump base	0.3	2, 136.0	24.33	7-23-46	Reported yield, 800
22-21-9ca	R. H. Thomson	(?)	64 8	54	GI	do.	do.	T, T	I	I	Top of pump support	1.3	2, 138.7	32.52	7-20-46	Reported yield, 1,000
22-21-9ec	R. H. Thomson	DD	67 4	19	GI	do.	do.	T, G	I	I	do.	1.0	2, 143.6	33.30	7-20-46	Reported yield, 1,000
22-21-10bc	R. M. Norris	Dr	100	6	GI	do.	do.	C ₁ W	N	N	Top of concrete curb	0.4	2, 145.8	34.80	7-20-46	Formerly a stock well
22-21-12ab	B. H. Speck	Dr	70 4	6	GI	Sand	Terrace deposits	C ₁ W	D, S	D, S	Top of casing, north side	0.6	2, 162.3	37.40	7-20-46	
22-21-14aa	R. M. Norris	Dr	67 2	6	GI	Sandstone	Dakota	C ₁ W	S	S	Top of wooden clamp	1.2	2, 175.5	49.02	7-27-46	
22-21-15cb	C. H. Hesel	Du	40 4	48	B	Sand and gravel	Alluvium	C ₁ W	N	N	Top of wooden platform	0	2, 159.7	48.60	7-26-45	Formerly a stock well
22-21-20aa	Long Savings Bank	Dr	123 3	8	GI	Sandstone	Dakota	C ₁ W	D, S	D, S	Top of casing, south side	0.4	2, 245.6	30.72	7-29-46	
22-22-30a	John Salmons	D	42 1	6	GI	do.	Greenhorn	C ₁ W	S	S	do.	1.6	2, 288.4	20.57	10-9-45	
22-22-12cc	M. G. Pitts & Sons	DD	83 1	19	GI	Sand and gravel	Alluvium	T, G	I	I	Top of concrete curb	0	2, 147.7	32.98	10-8-45	Reported yield, 1,200
22-22-12db1	M. G. Pitts & Sons	DD	64	19	GI	do.	do.	C, G	I	I	Top of wooden cover	1.2	2, 144.3	33.70	7-23-46	Reported yield, 1,100
22-22-12db2	M. G. Pitts & Sons	DD	81.5	19	GI	do.	do.	T, G	I	I	Top of concrete curb	3.0	2, 144.1	30.13	7-23-46	Reported yield, 1,250
22-22-13bc	E. Kuhn	DD	(?)	(?)	(?)	do.	do.	N	I	I	Top of casing, north side	5.2	2, 155.7	31.20	7-12-46	Drilled in 1946
22-22-13cb	Buck Webster	Dr	74	18	GI	do.	do.	T, T	I	I	Top of pump plate	1.6	2, 152.7	27.60	10-8-45	Reported yield, 900
22-22-13cb2	Buck Webster	Dr	75.5	20	GI	do.	do.						23.00	28.40	7-23-46	
22-22-13cc	Bill Macey	Dr	50 3	20	(?)	do.	do.	T, G	I	I	Top of iron sill	1.0		25.03	8-28-40	
22-22-23ad	L. R. McLean	DD	(?)	(?)	(?)	do.	do.	T, T	I	I	Top of casing, south side	0	2, 160.4	31.66	7-10-46	Reported yield, 1,000;
22-22-23cb	E. E. Hirschler	DD	114	18	GI	do.	do.	T, G	I	I	Top of pump base, west side	1.2	2, 158.1	23.12	8-25-45	drawdown 16.7
22-22-23dd	C. S. Ruff	DD	54 3	19	GI	do.	do.	T, G	I	I	Edge of hole in pump base	0.5	2, 167.3	35.37	7-33-46	Reported yield, 1,000
22-22-27ca	A. L. Goller	Dr	106	20	GI	do.	do.	T, T	I	I	Bottom edge of rail	0.4	2, 172.6	29.35	7-11-46	Reported yield, 600
22-22-27cc	A. L. Goller	DD	53 8	19	GI	do.	do.	C, T	I	I				31.65	10-8-45	
													29.70	7-11-46		

TABLE 22.—Records of wells in Pawnee Valley, Kansas—Concluded

WELL DESIGNATION (1)	Owner or tenant	Type of well (2)	Depth of well (feet) (3)	Diam- eter of well (in.) (4)	Principal water-bearing bed		Method of lift (5)	Use of water (6)	Measuring point			Depth to water level below meas- uring point (feet) (7)	Date of measur- ement	REMARKS (Yield given in gallons a minute; drawdown in feet)
					Character of material	Geologic source			Description	Dis- tance above land surface (feet)	Height above mean sea level (feet)			
22-22-31cb.....	Sarah A. Abbott.....	DD	(?)	19	Sand and gravel	Alluvium.....	T, G	I	Top of pump support.....	0.6	2,211.4	34.61	10-6-45	
22-22-31dc.....	Ed Sebes.....	DD	59.4	20	do.....	do.....	C, G	I	Bottom edge of 8- by 8-inch timber	0.5	2,199.5	35.05	7-9-46	
22-22-34ab.....	A. J. Humel.....	DD	64.3	36	do.....	do.....	T, T	I	Top of angle iron.....	0.6	2,165.9	26.85	10-8-45	
22-22-34bc.....	Etta Preston.....	DD	(?)	19	do.....	do.....	C, N	N				29.00	7-23-46	
22-22-35cc.....	Cleland Koontz.....	Dr	47.8	18	do.....	do.....						23.70	10-9-45	
22-22-35da.....	School District.....	Dr	49.5	6	Limestone	Greenhorn.....	N	I	Top of casing, west side	2.4	2,172.8	24.22	7-12-46	
22-22-35dd.....	Jake Reed.....	Du	41.5	(?)	Sand and gravel	Ogallala.....	C, H	D	do.....	0		35.25	10-30-45	
22-22-35fe.....	Dan Ewy.....	Dr	67.3	6	Sandstone	Dakota.....	C, W	S	Top of wooden cover.....	0.7		37.30	10-31-45	
22-22-36bc.....	Jake Reed.....	Dr	279	6	do.....	do.....	C, W	S	Top of casing.....	0.7		28.99	10-29-45	
22-22-36bb.....	A. A. Doer.....	Dr	316.90	6	do.....	do.....	C, W	D, S	do.....	0		211.44	10-31-45	
22-22-32cc.....	John Courtney.....	Dr	176.55	6	do.....	do.....	C, W	D, S	Top of concrete curb.....	0.5		200.05	10-29-45	
22-22-35db.....	W. Billings.....	Dr	(?)	(?)	Sand and gravel	Alluvium.....	T, G	I	Top of casing.....	2.5		83.47	10-10-45	
22-22-14cc.....	E. Beta.....	Dr	54	5	Sandstone	Ogallala.....	N	D	do.....	0.6		42.00	10-18-45	Completed in Oct., 1945
22-22-27dd.....	W. Walter.....	Dr	282.8	6	do.....	Dakota.....	C, W	D, S	do.....	0.6		251.89	10-22-45	
22-22-22ba.....	Virgil Glunt.....	Dr	336.5	4	Shale	do.....	C, W	N	do.....	0.8		179.5	10-17-45	
22-21-22ba.....	Howard Dixon.....	Dr	207.4	4	Sandstone	Carlile.....	C, W	N	Top of casing, west side	0.8		27.20	10-16-45	Formerly a stock well
22-21-22bb.....	R. L. Hogan.....	Dr	194.1	6	do.....	Dakota.....	C, W	D, S	Top of casing, north side	2.313.0		149.43	7-31-46	
22-21-18ab.....	Nary Hogan.....	Dr	154.2	8	do.....	do.....	C, W	D, S	Top of casing, east side	0.2		2,232.2	7-31-46	
22-21-28cc.....	John Burke.....	Dr	71.6	6	Sand and gravel	Ogallala.....	C, W	D, S	Top of concrete curb.....	0.2		2,317.2	7-30-46	
22-22-1cc.....	C. I. Housman.....	Dr	144.5	6	Sandstone	Dakota.....	C, W	D, S	Top of casing, south side	0.1		2,358.4	7-29-46	
22-22-5bc.....	E. R. Housman.....	DD	75	15	Sand and gravel	Alluvium.....	N	N	Top edge of 4- by 4-inch timber	0.6		71.01	10-12-45	
22-22-5bc.....	Wilbur F. Housman.....	DD	75	15	do.....	do.....	C, G	N						Formerly an irrigation well
22-22-5ab.....	C. I. Housman.....	DD	(?)	(?)	do.....	do.....	C, T	I						
22-22-6ba.....	O. T. Sebas.....	Dr	(?)	20	do.....	do.....	T, G	I	Top of casing, east side	0.8		118.00	7-31-46	
22-22-10b1.....	Charles Housman.....	Dr	294.8	6	Sandstone	Dakota.....	C, W	S	Top of casing.....	0.8		26.72	10-19-45	
22-22-10bb.....	School District.....	Dr	31	4	Sand and gravel	Alluvium.....	C, H	D	Top of concrete curb.....	0.7		2,253.9	10-12-45	
22-22-11aa.....	L. R. Chilson.....	Dr	102.4	4	do.....	do.....	C, W	D, S	Top of concrete curb.....	0.8		22.92	10-12-45	
22-22-11cc.....	L. R. Chilson.....	Dr	98.1	19	do.....	do.....	T, G	I	Top of pump base.....	0.8		22.91	7-12-46	
												22.64	11-14-46	

23-22-22aa	John Querebach.	Dr	46	18	GI	do.	do.	T, G	I	Top of casing, north side	1 6	2, 107 0	22 00	7-12-46	Well drilled in 1946
23-22-22ab	L. C. Koontz.	Dr	71.4	20	GI	do.	do.	T, G	I	Bottom edge of iron beam	2, 215 5	28 05	10-12-45	Reported yield, 1,000	
23-22-22ac	W. K. Stambaugh	DD	85.8	20	GI	do.	do.	C	I	do.	0	2, 210 1	27 33	10-12-45	Reported yield, 1,000
23-22-22ad	Herb Ziesch.	Dr	41.3	(7)	(7)	do.	do.	N	I	Top of casing, north side	0	2, 209 4	29 17	7-12-46	Well drilled in 1946
23-22-22ae	Daisy Welch.	Dr	146	(7)	GI	do.	do.	C, W	I	do.	0	2, 274 5	28 00	10-23-45	
23-22-22af	Leo Gleason.	Dr	248	5½	GI	do.	do.	C, W	S	Top of wooden pipe clamp	0.8	2, 285 6	04 92	7-31-46	
23-22-22ag	Mrs. Allen Miller	Dr	65.3	6	GI	do.	do.	C, W	N	Top of casing, north side	0.5	2, 394. 2	55 34	7-31-46	Abandoned, formerly a domestic well
23-22-22ah	Carrie L. Dunegan.	Du	36.2	6	GI	Sand and gravel	Alluvium	C, W	N	Top of wooden curb.	1.4	2, 206 4	29 05	10-11-45	Formerly a stock well
23-22-22ai	W. G. Billings Estate	DD	(7)	(7)	(7)	do.	do.	C, W	N	do.					Well caved in; formerly an irrigation well
23-22-22aj	Norman Winget.	DD	33.2	19	GI	do.	do.	C, G	I	Top of wooden cover.	0	2, 213 7	19 35	10-10-45	Reported yield, 900
23-22-22ak	Jacob Hubin	Du	35.9	(7)	(7)	do.	do.	N	N	Top of 2- by 6-inch board	0.9	2, 232. 5	32 80	10-10-45	Formerly a domestic well
23-22-22al	W. L. Mayberry.	Dr	33.9	6	GI	do.	do.	C, W	N	Top of wooden curb.	0 6	2, 243 5	30 17	10-10-45	
23-22-22am	C. Salanons	Dr	40.9	6	GI	do.	do.	C, W	D, S	Top of concrete curb.	0 4	2, 260 9	30 66	10-10-45	
23-22-22an	Lee Hoagland	Dr	85.1	6	GI	do.	do.	C, W	D, S	Top of casing	0.7	2, 269 6	28 57	10-10-45	
23-22-22ao	A. Drumm	Dr	164.2	5	I	Sandstone	Dakota.	C, W	S	do.	1.8	105 85	8-1-46		
23-22-22ap	E. J. Andrew	Dr	128.1	6	GI	do.	do.	C, W	S	Top of casing, south side	2.0	79 9	8-1-46		
23-22-22aq	J. C. Lappin	Dr	65.8	6	GI	do.	do.	C, W	S	do.	0.4	57 36	8-2-46		
23-22-22ar	Stanley Lappin	Dr	198.8	6	C, W	do.	do.	C, W	N	do.					
23-22-22as	C. A. Thresher	DD	43.5	40	N	do.	do.	N	N	Top of pump base	0.4	70 56	8-1-46		Formerly a stock well
23-22-22at	W. J. Elliott	Dr	42.5	(7)	(7)	Sand and gravel	Ogallala	C, W	D, S	Top of wooden curb.	0.5	85 10	37-45		Well has not been used
23-22-22au	H. Gibbs	Dr	71.1	6	GI	do.	do.	C, W	N	Top of casing.	1.5	52 55	8-16-45		New well
23-22-22av	H. Borteson	Dr	24.4	6	GI	do.	do.	C, W	D, S	do.	0.5	16 77	10-24-45		
24-24-22aa	Mary Miller	Dr	18.4	6	GI	do.	do.	C, W	N	do.	3 6	10 77	10-24-45		
24-24-22ab	C. Miller	Dr	63.7	6	GI	do.	do.	C, W	D, S	Top of concrete curb, south side	0.6	61 90	10-24-45		
24-25-22ad	School District	Dr	71.9	6	GI	do.	do.	C, W	D	Top of casing, west side	0.2	53 80	10-24-45		
24-26-22aa	J. L. Burr	Dr	40.6	6	GI	do.	do.	C, W	D	Top of casing, north side	1.4	34 66	10-15-45		
24-26-22ab	Sch. 1 District	Dr	63.9	5	GI	do.	do.	C, W	D	Top of casing, north side	0.2	62 45	10-12-45		
24-26-22ac	M. Horner	Dr	64	6	GI	do.	do.	C, W	S	do.	0.1	60 94	10-15-45		

1. Location number: Well numbers give the location of wells according to General Land Office surveys and according to the following formula: Township—Range—Section, 160-acre tract within that section, and the 40-acre tract within the quarter section. If two or more wells are located within a 40-acre tract, the wells are numbered serially according to the order in which they were inventoried. The 160-acre and 40-acre tracts are designated a, b, c, or d in a counter-clockwise direction beginning in the northeast quarter. For example: well 20-19-26c is located in SW $\frac{1}{4}$ sec. 26, T. 20 S., R. 19 W.

2. B, bored well; DD, dug and drilled well; Dr, driven well; Dr, drilled well; Du, dug well.
3. Reported depths below the land surface are given in feet; measured depths are given in feet and tenths below measuring points.
4. Br, brick; Bs, boiler steel; C, concrete; GI, galvanized iron; I, iron; N, none; OW, oil well casing; R, rock.
5. Method of lift: C, centrifugal; CY, cylinder; N, none; P, pitcher; pump; T, turbine. Type of power: E, electric; G, gas engine; H, hand operated; T, tractor; W, windmill.
6. D, domestic; I, irrigation; N, not being used; 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. Minus preceding figure indicates measuring point below land surface.

LOGS OF TEST HOLES AND WELLS

The logs of 119 test holes and wells in Pawnee Valley are given on the pages that follow. The logs of 8 wells were furnished by private drillers, and the 111 test holes were drilled by the State Geological Survey with a hydraulic-rotary drill rig. The test hole and well-numbering system is described on page 11.

Sample log of test hole 20-20-34cd in the SE cor. SW¼ sec. 34, T. 20 S., R. 20 W., drilled by the State Geological Survey, May, 1945. Surface altitude, 2,132.1 feet.

	Thickness, feet	Depth, feet
Soil, silty, brown	3	3
QUATERNARY—Pleistocene		
Terrace deposits		
Clay, silty, tan	5	8
Clay, silty, light-yellowish tan	1 5	9 5
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, containing a few fragments of limestone and yellow limonitic stains	5 5	15

Sample log of test hole 20-21-26dd in the SE¼ SE¼ sec. 26, T. 20 S., R. 21 W., drilled by the State Geological Survey, November, 1947. Surface altitude, 2,187.3 feet.

	Thickness, feet	Depth, feet
Soil, black	2	2
Soil, clayey, dark-gray	1	3
QUATERNARY—Pleistocene		
Terrace deposits (?)		
Clay and silt, tan	4	7
Silt, brown	1	8
Clay, limy, light-tan	4	12
Silt, clayey, limy, light-brown	7	19
CRETACEOUS—Gulfian		
Greenhorn limestone		
Clay, limy, light-tan	5	24
Limestone, yellow-brown and some white	9	33

Sample log of test hole 20-22-20bc in the SW¼ NW¼ sec. 20, T. 20 S., R. 22 W., drilled by the State Geological Survey, November, 1947. Surface altitude, 2,192.5 feet; depth to water level, 23.8 feet, November 28, 1947.

	Thickness, feet	Depth, feet
Top soil, black silt	2	2
QUATERNARY—Pleistocene		
Alluvium		
Silt, dark-brown	21	23
Silt and very fine sand	2	25
Sand, coarse, and fine to coarse gravel	19	44

	Thickness, feet	Depth, feet
Silt, clayey, white	2	46
Sand, medium to coarse, and fine to coarse gravel; contains fine sand	14	60
Sand, coarse, and fine to coarse gravel; contains yellow clay at 68 to 70 feet	10	70
Sand, medium to coarse, and fine to coarse gravel; contains yellow silt	12	82
CRETACEOUS—Gulfian		
Dakota formation		
Shale, blue-gray	18	100

Sample log of test hole 20-22-20cc in the SW¼ SW¼ sec. 20, T. 20 S., R. 22 W., drilled by the State Geological Survey, November, 1947. Surface altitude, 2,192.5 feet; depth to water level, 24.0 feet, November 28, 1947.

	Thickness, feet	Depth, feet
Road fill, black silt	2	2
QUATERNARY—Pleistocene		
Alluvium		
Silt, tan	17	19
Silt, dark-brown	9	28
Silt, sandy, light-brown	4	32
Clay, limy, green	5	37
Sand, coarse, and coarse to fine gravel	9	46
Clay, blue; contains brown clay at 46 to 47 feet	7	53
Gravel, coarse to fine, and coarse sand; finer material at 57 to 65 feet	12	65
Clay, limy, sandy, yellow-brown	10	75
Clay, limy, yellow, and blue-black clay shale	5	80

CRETACEOUS—Gulfian

Dakota formation

Shale, blue-gray; contains yellow clay	20	100
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Sample log of test hole 20-22-29bc in the SW¼ NW¼ sec. 29, T. 20 S., R. 22 W., drilled by the State Geological Survey, November, 1947. Surface altitude, 2,194.6 feet; depth to water level, 27.2 feet, November 29, 1947.

	Thickness, feet	Depth, feet
Road fill, black silt	2	2
QUATERNARY—Pleistocene		
Alluvium		
Silt, tan	9	11
Silt, dark-tan	4	15
Silt, light-tan	2	17
Sand, medium to coarse, and light-tan silt	3	20
Sand, medium to coarse, and fine gravel	12	32
Sand, coarse, and fine to coarse gravel	8	40

	Thickness, feet	Depth, feet
Gravel, coarse to fine; contains yellow-brown clay at 48 to 49 feet	10	50
Clay, limy, light-gray	12	62
Clay, greenish-gray	6	68
Sand, medium to coarse, and fine to coarse gravel; contains gray clay at 70 to 90 feet	22	90
CRETACEOUS—Gulfian		
Dakota formation		
Sandstone, fine	1	91
Shale, blue-gray	9	100

Sample log of test hole 20-23-31ada in the SE¼ NE¼ sec. 31, T. 20 S., R. 23 W., drilled by the State Geological Survey, November, 1947. Surface altitude, 2,232.3 feet; depth to water level, 29.7 feet, November 25, 1947.

	Thickness, feet	Depth, feet
Road fill, black silt	1	1
QUATERNARY—Pleistocene		
Alluvium		
Silt, tan	14	15
Sand, medium to coarse, and fine to coarse gravel	2	17
Silt, tan	8	25
Silt, dark-brown	3	28
Silt, clayey, light-tan	8	36
Clay, greenish-gray	3	39
Sand, medium to coarse, fine to coarse gravel, and many pebbles one-half to one inch; contains brownish-gray clay at 49 to 50 feet	11	50
Clay, light blue-gray	5	55
Sand, coarse, and fine to medium gravel	5	60
Sand, coarse, and fine to coarse gravel	5	65
CRETACEOUS—Gulfian		
Dakota formation		
Shale, hard, limy, gray	7	72

Sample log of test hole 20-23-32cbb in the NW¼ SW¼ sec. 32, T. 20 S., R. 23 W., drilled by the State Geological Survey, November, 1947. Surface altitude, 2,230.5 feet; depth to water level, 29.9 feet, November 26, 1947.

	Thickness, feet	Depth, feet
Top soil, black silt	1	1
QUATERNARY—Pleistocene		
Alluvium		
Silt, tan	26	27
Silt and fine sand	7	34
Sand, medium to coarse, fine to coarse gravel, and some tan clay; contains blue clay at 38 to 40 feet	6	40
Gravel, coarse to fine, and some coarse sand; contains gravel 1 inch in diameter	8	48
Clay, green	9	57

	Thickness, feet	Depth, feet
Clay, gritty, dark-green	8	65
Silt, light-tan	7	72
Gravel, coarse to fine, and coarse sand	8	80
Gravel, medium to coarse	12	92

CRETACEOUS—Gulfian

Dakota formation

Shale, blue-gray, and some pyrite	8	100
Shale, noncalcareous, blue-gray; contains brown clay at 108 to 110 feet	10	110

*Sample log of test hole 21-16-17aa in the NE cor. sec. 17, T. 21 S., R. 16 W.,
drilled by the State Geological Survey, May, 1945. 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 me- dium sand	15	58
Silt, light-gray to buff, and fine to medium sand; con- tains 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 silt, light-gray to buff	5	145

CRETACEOUS—Gulfian

Dakota formation

Sandstone, medium- to fine-grained, white, yellow, and brown; contains yellow and light-gray clay	15	160
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*Sample log of test hole 21-16-20aa in the NE cor. sec. 20, T. 21 S., R. 16 W.,
drilled by the State Geological Survey, May, 1945. 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

	Thickness, feet	Depth, feet
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, containing fine sand and caliche	25	100
Silt, brown and greenish-gray, and fine sand; in part cemented by caliche; contains gravel	10	110
Sand, very fine to fine, and silt; brown; friable	10	120
Silt, buff and light-gray, and fine to medium sand; con- tains gravel	12	132
Sand, coarse to fine, and silt; yellow-buff; contains fine to coarse gravel	4	136
CRETACEOUS—Gulfian		
Dakota formation		
Sandstone, medium-grained, white	14	150

*Sample log of test hole 21-16-29aa in the NE cor. sec 29, T. 21 S., R. 16 W.,
drilled by the State Geological Survey, May, 1945. 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 silt; buff	3	10
Silt, buff, tan, and light-gray	10	20
Silt, buff, containing caliche and some pebbles de- rived from cretaceous rocks	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

*Driller's log of well 21-16-29aa 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

	Thickness, feet	Depth, feet
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

Driller's log of well 21-16-29ab1 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

Driller's log of well 21-16-29ab2 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
Sandstone, light	20	127
Shale, black	1	128
Sandstone, coarse	2	130
Sandstone, light	6	136
Shale, blue	4	140

*Driller's log of well 21-16-32da 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		
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
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

*Driller's log of well 21-16-32dd 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		
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

	Thickness, feet	Depth, feet
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

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

QUATERNARY—Pleistocene

Alluvium	Thickness, feet	Depth, feet
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

Sample log of test hole 21-17-6cc in the SW cor. sec. 6, T. 21 S., R. 17 W., drilled by the State Geological Survey, May, 1945. 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

Sample log of test hole 21-17-18bb at the NW cor. sec. 18, T. 21 S., R. 17 W., drilled by the State Geological Survey, June, 1945. 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

Sample log of test hole 21-17-19bb at the NW cor. sec. 19, T. 21 S., R. 17 W., drilled by the State Geological Survey, June, 1945. 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

Sample log of test hole 21-17-19cc at the SW cor. sec. 19, T. 21 S., R. 17 W., drilled by the State Geological Survey, June, 1945. 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

Sample log of test hole 21-18-4cc at the SW cor. sec. 4, T. 21 S., R. 18 W., drilled by the State Geological Survey, June, 1945. 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 sample 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.		

Sample log of test hole 21-18-5bb at the NW cor. sec. 5, T. 21 S., R. 18 W., drilled by the State Geological Survey, June, 1945. 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

Sample log of test hole 21-18-7aa at the NE cor. sec. 7, T. 21 S., R. 18 W., drilled by the State Geological Survey, June, 1945. 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 tan gravel	5	33
Clay, silty, tan	17	50

	Thickness, feet	Depth, feet
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, Clay, silty; contains fine to medium gravel; tan	5 5	73 5
Gravel, fine to coarse; contains silt; tan	7 5	81
Silt, tan to buff	10 5	91 5
Gravel, fine to coarse, tan; contains tan silt and frag- ments of brown "ironstone"	3 5	95
CRETACEOUS—Gulfian	8	103
Dakota formation		
Sandstone, fine- to medium-grained, tan to brown ..	7	110
<i>Sample log of test hole 21-18-7dd at the SE cor. sec. 7, T. 21 S., R. 18 W., drilled by the State Geological Survey, June, 1945. Surface altitude, 2,086.0 feet.</i>		
Road fill	Thickness, feet	Depth, feet
	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
<i>Sample log of test hole 21-18-10aa at the NE cor. sec. 10, T. 21 S., R. 18 W., drilled by the State Geological Survey, June, 1945. Surface altitude, 2,092.0 feet.</i>		
Road fill	Thickness, feet	Depth, feet
	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
<i>Sample log of test hole 21-18-12bb at the NW cor. sec. 12, T. 21 S., R. 18 W., drilled by the State Geological Survey, June, 1945. Surface altitude, 2,096.8 feet.</i>		
Road fill	Thickness, feet	Depth, feet
	5	5
QUATERNARY—Pleistocene		
Terrace deposits		
Clay, silty, grayish-tan and brown	3	8
Clay, silty, brown	3	11

	Thickness, feet	Depth, feet
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
<i>Sample log of test hole 21-18-17cc at the SW cor. sec. 17, T. 21 S., R. 18 W., drilled by the State Geological Survey, June, 1945. Surface altitude, 2,075.4 feet.</i>		
	Thickness, feet	Depth, feet
Road fill and dark-gray silty soil	7	7
QUATERNARY—Pleistocene		
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
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
<i>Sample log of test hole 21-18-29bb at the NW cor. sec 29, T. 21 S., R. 18 W., drilled by the State Geological Survey, June, 1945. Surface altitude, 2,063.6 feet.</i>		
	Thickness, feet	Depth, feet
Soil, silty; contains fine sand; brown	3 5	3 5
QUATERNARY—Pleistocene		
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	Thickness, feet	Depth, feet
Clay, silty, yellow; contains fine tan sand and brown fine-grained sandstone	4	105
Clay, silty, bluish-gray with faint red mottle	5	110

*Sample log of test hole 21-18-32bb at the NW cor. sec. 32, T. 21 S., R. 18 W.,
drilled by the State Geological Survey, June, 1945. Surface altitude,
2,059.6 feet.*

	Thickness, feet	Depth, feet
Soil, dark gray	3	3

QUATERNARY—Pleistocene

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
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 silt and fine to coarse sand	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

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 ma- terial	66 5	306

	Thickness, feet	Depth, feet
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
<i>Sample log of test hole 21-18-36aa at the NE cor. sec. 36, T. 21 S., R. 18 W., drilled by the State Geological Survey, June, 1945. Surface altitude, 2,040.3 feet.</i>		
	Thickness, feet	Depth, feet
Road fill	3	3
QUATERNARY—Pleistocene		
Alluvium		
Silt, gray and tan	15	18
Silt, light-gray	4	22
Clay, silty; contains fine sand; tan	5	27
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
<i>Sample log of test hole 21-19-17dd at the SE cor. sec. 17, T. 21 S., R. 19 W., drilled by the State Geological Survey, May, 1945. Surface altitude, 2,085.6 feet.</i>		
	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

	Thickness, feet	Depth, feet
Clay, silty, light-brown	2	32
Clay, silty; contains medium sand and small frag- ments of "ironstone"; brown to tan	4	36
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, contains fine sandstone; yellow and light- gray	4	40
<i>Sample log of test hole 21-19-18dd at the SE cor. sec. 18, T. 21 S., R. 19 W., drilled by the State Geological Survey, July, 1945. Surface altitude, 2,095.6 feet.</i>		
	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
<i>Driller's log of well 21-19-20cc in the SW¼ SW¼ sec. 20, T. 21 S., R. 19 W., Surface altitude, 2,086.2 feet.</i>		
	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
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
<i>Sample log of test hole 21-19-28bb at the NW cor. sec. 28, T. 21 S., R. 19 W., drilled by the State Geological Survey, May, 1945. Surface altitude, 2,079.5 feet.</i>		
	Thickness, feet	Depth, feet
Road fill	2	2
QUATERNARY—Pleistocene		
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

	Thickness, feet	Depth, feet
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 silt; tan and gray	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
<i>Sample log of test hole 21-19-32aa at the NE cor. sec. 32, T. 21 S., R. 19 W., drilled by the State Geological Survey, May, 1945. Surface altitude, 2,077.2 feet.</i>		
	Thickness, feet	Depth, feet
Soil, sandy, dark brownish-gray	3	3
QUATERNARY—Pleistocene		
Alluvium		
Silt and sand, very fine to fine; gray to tan	7	10
Silt and sand, fine; 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 tan to gray quartz	4	36
Gravel, fine to medium; contains a few limy zones; tan,	4	40
Gravel, fine to coarse, contains caliche, fossil bone, and fragments of shells; tan	10	50
Gravel, fine to coarse; contains caliche; tan	10	60
Gravel, fine to medium; contains caliche; tan	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, gray to tan; contains caliche and minor amounts of fine tan sand	8	100
Silt and sand, fine to coarse; contains fine to medium gravel; brown	10	110

	Thickness, feet	Depth, feet
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
<i>Sample log of test hole 21-19-32dd at the SE cor. sec. 32, T. 21 S., R. 19 W., drilled by the State Geological Survey, May, 1945. Surface altitude, 2,079.0 feet.</i>		
	Thickness, feet	Depth, feet
Soil, dark gray	3	3
QUATERNARY—Pleistocene		
Alluvium		
Clay, silty, brown to gray; contains fragments of gas- tropods	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 medium to coarse sand; 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 "iron- stone"	10	90
Gravel, fine to coarse, tan	12	102
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, bluish-gray; contains yellow limonitic stains	8	110
<i>Sample log of test hole 21-20-9aa at the NE cor. sec. 9, T. 21 S., R. 20 W., drilled by the State Geological Survey, May, 1945. Surface altitude, 2,132.8 feet.</i>		
	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 "iron- stone"; tan	8	38
Gravel, fine to medium; contains silt; tan	9	47
Silt, buff	17	64

	Thickness, feet	Depth, feet
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; contains limonitic concretions; mottled red and tan	3	103
<i>Sample log of test hole 21-20-9dd at the SE cor. sec. 9, T. 21 S., R. 20 W., drilled by the State Geological Survey, May, 1945. Surface altitude, 2,111.4 feet.</i>		
	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 silt and caliche; tan ..	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
<i>Sample log of test hole 21-20-15cc at the SW cor. sec. 15, T. 21 S., R. 20 W., drilled by the State Geological Survey, May, 1945. Surface altitude, 2,097.1 feet.</i>		
	Thickness, feet	Depth, feet
Soil, silty, brown	3	3
QUATERNARY—Pleistocene		
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

	Thickness, feet	Depth, feet
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
<i>Sample log of test hole 21-20-17dd at the SE cor. sec. 17, T. 21 S., R. 20 W., drilled by the State Geological Survey, July, 1945. Surface altitude, 2,103.7 feet.</i>		
	Thickness, feet	Depth, feet
Road fill	3	3
QUATERNARY—Pleistocene		
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 frag- ments 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
<i>Sample log of test hole 21-20-18cc at the SW cor. sec. 18, T. 21 S., R. 20 W., drilled by the State Geological Survey, July, 1945. Surface altitude, 2,121.8 feet.</i>		
	Thickness, feet	Depth, feet
Soil, dark gray	7	7
QUATERNARY—Pleistocene		
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

	Thickness, feet	Depth, feet
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
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Sample log of test hole 21-20-18dd at the SE cor. sec. 18, T. 21 S., R. 20 W., drilled by the State Geological Survey, July, 1945. Surface altitude, 2,113.1 feet.

QUATERNARY—Pleistocene

Alluvium

	Thickness, feet	Depth, feet
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
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
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Sample log of test hole 21-20-19dcc in the SW¼ SE¼ sec. 19, T. 21 S., R. 20 W., drilled by the State Geological Survey, November, 1947. Surface altitude, 2,115.7 feet; depth to water level, 41.1 feet, November 6, 1947.

	Thickness, feet	Depth, feet
Road fill, dark-brown silt	2	2
QUATERNARY—Pleistocene		
Alluvium		
Silt, dark-brown	5	7
Silt, clayey, limy, light-tan	13	20
Clay, tan, and some gray clay	19	39
Clay, dark blue-gray	10	49
Clay, light-gray	9	58
Sand, medium to coarse	2	60
Sand, medium to coarse, and fine to coarse gravel	17	77
Clay, blue-gray	6	83
Sand, medium to coarse	7	90
Sand, medium to coarse, and fine to coarse gravel	12	102
Gravel, coarse	3	105
Silt, brown	5	110
Silt, brown, and fine to coarse sand	20	130
Sand, coarse, and fine to coarse gravel	5	135
Gravel, coarse to fine, and gray clay	5	140
CRETACEOUS—Gulfian		
Dakota formation		
Shale, limy, hard, blue-gray, and some brown to light-gray clay	23	163

Sample log of test hole 21-20-23bb at the NW cor. sec. 23, T. 21 S., R. 20 W., drilled by the State Geological Survey, July, 1945. Surface altitude, 2,094.8 feet.

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

Sample log of test hole 21-20-24aa at the NE cor. sec. 24, T. 21 S., R. 20 W., drilled by the State Geological Survey, July, 1945. Surface altitude, 2,094.9 feet.

	Thickness, feet	Depth, feet
Road fill	3	3
QUATERNARY—Pleistocene		
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

Sample log of test hole 21-20-24bb 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		
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 "iron-stone" and fine sand	2	80

Sample log of test hole 21-20-27cc at the SW cor. sec. 27, T. 21 S., R. 20 W., drilled by the State Geological Survey, June, 1945. 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; contains a few lime-cemented zones; buff,	11	41
Clay, silty; contains coarse sand; tan	3	44
CRETACEOUS—Gulfian		
Dakota formation		
Sandstone, fine to medium, tan to brown	4	48

Sample log of test hole 21-20-28aa at the NE cor. sec. 28, T. 21 S., R. 20 W., drilled by the State Geological Survey, June, 1945. Surface altitude, 2,096.4 feet.

	Thickness, feet	Depth, feet
Road fill	3	3
QUATERNARY—Pleistocene		
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
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Sample log of test hole 21-21-2bbb in the NW¼ NW¼ sec. 2, T. 21 S., R. 21 W., drilled by the State Geological Survey, November, 1947. Surface altitude, 2,167.8 feet; depth to water level, 27.0 feet, November 4, 1947.

	Thickness, feet	Depth, feet
Soil, black	2	2
QUATERNARY—Pleistocene		
Terrace deposits (?)		
Clay and silt, limy; light-brown	25	27
Clay and silt, limy; dark-brown	4	31
Clay and silt; light-brown; contains a few limestone pebbles at 47 to 48 feet	24	55

CRETACEOUS—Gulfian

Dakota formation

Shale, clayey, gray; contains yellow clay	5	60
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Sample log of test hole 21-21-3ddd in the SW¼ SW¼ sec. 3, T. 21 S., R. 21 W., drilled by the State Geological Survey, October, 1947. Surface altitude, 2,152.7 feet; depth to water level, 26.8 feet, November 1, 1947.

	Thickness, feet	Depth, feet
Road fill, hard black silt	2	2
QUATERNARY—Pleistocene		
Terrace deposits		
Soil, silty, hard brown	5	7
Silt, dark brown	2	9
Silt, clayey, brown	3	12

	Thickness, feet	Depth, feet
Clay and silt, limy; tan	48	60
Clay, tan to gray	5	65
Sand, coarse, and fine to coarse gravel	4	69
Clay, tan	7	76
Silt and clay, sandy; yellow-brown	27	103
CRETACEOUS—Gulfian		
Dakota formation		
Clay, gray, and red clay	2	105
<i>Sample log of test hole 21-21-6abb in the NW¼ NE¼ sec. 6, T. 21 S., R. 21 W., drilled by the State Geological Survey, November, 1947. Surface alti- tude, 2,182.1 feet.</i>		
	Thickness, feet	Depth, feet
Soil, silty, black	2	2
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, light-brown	2	4
Silt, dark-brown	5	9
Silt, light-brown	3	12
CRETACEOUS—Gulfian		
Greenhorn limestone		
Limestone, yellow	3	15
<i>Sample log of test hole 21-21-6bcc in the SW¼ NW¼ sec. 6, T. 21 S., R. 21 W., drilled by the State Geological Survey, November, 1947. Surface alti- tude, 2,156.7 feet.</i>		
	Thickness, feet	Depth, feet
Road fill, black silt	3	3
QUATERNARY—Pleistocene		
Alluvium		
Silt, brown	5	8
Silt, tan	2	10
Silt, clayey, light tan; contains thin rusty zone at 18 to 19 feet	18	28
Sand, medium to fine; contains limestone pebbles at 34 to 35 feet	7	35
CRETACEOUS—Gulfian		
Dakota formation		
Clay, light-gray	1	36
Clay and shale, limy; blue-black	4	40
Clay, light-tan	5	45
Clay, reddish-brown	7	52
Clay, sandy; contains rusty material	18	70
Clay, sandy; contains mottled red to gray clay	10	80
Clay, mottled red to gray	5	85

Sample log of test hole 21-21-14cb in the SW cor. NW¼ SW¼ sec. 14, T. 21 S., R. 21 W., drilled by the State Geological Survey, December, 1946. Surface altitude, 2,140.5 feet.

QUATERNARY—Pleistocene

Terrace deposits	Thickness, feet	Depth, feet
Silt, sandy, loose, dark-brown	2	2
Silt, brown to tan; contains very fine sand	3	5
Silt, sandy, tan to buff; contains caliche	5	10
Silt, tan	8	18
Silt, tan to light-brown; contains very fine sand and some caliche	9	27
Silt, sandy, reddish-brown; contains calcium carbonate fragments and nodules	15	42
Silt, sandy, buff; contains fine gravel	13	55
Silt, slightly sandy, buff	17	72
Sand, medium to coarse; contains fine to medium gravel	10	82
Silt, blue-gray	11	93
Sand, medium to coarse; contains fine to coarse gravel,	9	102
Silt, sandy, buff	15	117
Sand, fine to coarse	18	135
Gravel, fine to coarse; contains coarse sand	17	152

CRETACEOUS—Gulfian

Dakota formation

Clay and shale, gray	18	170
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Sample log of test hole 21-21-15aaa in the NE¼ NE¼ sec. 15, T. 21 S., R. 21 W., drilled by the State Geological Survey, October, 1947. Surface altitude, 2,134.0 feet; depth to water level, 24.0 feet, November 1, 1947.

	Thickness, feet	Depth, feet
Soil, black	2	2
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, dark-brown	11	13
Clay, brown	17	30
Clay, silty, brown	37	67
Sand, coarse, and fine gravel; contains silty brown clay	3	70
Sand, coarse, and fine to medium gravel; contains limestone grains	10	80
Gravel, fine to coarse, and some medium to coarse sand; contains silty brown clay	11	91
Clay, sandy, brown	17	108
Sand, coarse, and fine to medium gravel; contains silty brown clay	2	110
Sand, coarse, and fine to coarse gravel; contains silty brown clay	10	120

CRETACEOUS—Gulfian

Dakota formation

	Thickness, feet	Depth, feet
Clay, brown; contains gray clay at 129 to 130 feet . .	10	130
Clay, brown and gray	10	140

Sample log of test hole 21-21-15dd in the SE cor. SE¼ SE¼ sec. 15, T. 21 S., R. 21 W., drilled by the State Geological Survey, December, 1946. Surface altitude, 2,135.4 feet.

QUATERNARY—Pleistocene

Terrace deposits

	Thickness, feet	Depth, feet
Silt, sandy, dark-gray to black	1 5	1 5
Silt, sandy, brown	1	2 5
Silt, sandy, grayish-brown	1 5	4
Silt, sandy, reddish-brown; contains caliche	2	6
Silt, yellow to tan	11	17
Silt, sandy, tan to brown	13	30
Silt, sandy, dark-brown to brown	7	37
Silt, sandy, buff with reddish-brown streaks	5	42
Silt, sandy, tan; contains brown sandy fragments	13	55
Silt, sandy, tan to gray; contains cemented sand and shell fragments	7	62
Gravel, fine to medium; contains sand and shell fragments	3	65
Gravel, fine to coarse, dark blue-gray to green; contains dark-gray silt	5	70
Silt, dark-gray	15	85
Sand, fine, and light-gray silt	2	87
Sand and gravel, fine to coarse	13	100
Gravel, fine to coarse; contains fragments of sandstone	15	115
Gravel, fine to coarse, contains one-half inch pebbles	7	122

CRETACEOUS—Gulfian

Dakota formation

Clay and shale; gray	8	130
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Sample log of test hole 21-21-22ad in the NE cor. SE¼ NE¼ sec. 22, T. 21 S., R. 21 W., drilled by the State Geological Survey, December, 1946. Surface altitude, 2,130.6 feet; depth to water level, 37.7 feet, December 13, 1946.

QUATERNARY—Pleistocene

Terrace deposits

	Thickness, feet	Depth, feet
Silt, sandy, dark-brown	2	2
Silt, sandy, tan	4	6
Silt, sandy, brown; contains caliche	2	8
Silt, sandy, tan	7	15
Silt, yellowish-tan to tan; contains caliche	7	22
Silt, sandy, buff; contains fragments of sandstone	14	36
Silt, sandy, grayish-tan to buff; contains fragments of sandstone	4	40

	Thickness, feet	Depth, feet
Silt, sandy, light-gray with reddish-brown streaks . . .	8 5	48 5
Silt, sandy, grayish-brown with reddish-brown streaks, . . .	5 5	54
Sand, very fine to fine; contains sandstone fragments and very sandy silt	6	60
Sand, fine to coarse; contains fine gravel	7	67
Silt, very sandy, clayey, gray	8	75
Silt, dark-gray	9	84
Sand, fine to coarse; contains fine to medium gravel and silt	8	92
Gravel, fine to coarse; contains coarse sand	5	97
Silt, sandy, brown	13	110
Silt, buff, and fine to coarse gravel	2	112
Gravel, fine to coarse; contains pebbles	8	120
Sand, fine to coarse; contains fine to medium gravel . .	9	129
CRETACEOUS—Gulfian		
Dakota formation		
Clay and shale, light-gray to white; contains lignite in upper part	11	140
<i>Sample log of test hole 21-21-22da in the SE cor. NE¼ SE¼ sec. 22, T. 21 S., R. 21 W., drilled by the State Geological Survey, December, 1946. Sur- face altitude, 2,128.7 feet; depth to water level, 35.6 feet, December 13, 1946.</i>		
	Thickness, feet	Depth, feet
Top soil, silty, dark-gray to black	2	2
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, buff	4	6
Silt, sandy, tan to brown; contains caliche	8	14
Silt, sandy, buff; contains caliche	3 5	17 5
Silt, tan; contains very fine sand and some gravel . . .	2 5	20
Silt, sandy, buff; contains caliche	6 5	26 5
Silt, light-brown; contains caliche	7 5	34
Silt, grayish-brown	2	36
Silt, dark-gray	4	40
Silt, sandy, light-gray	8	48
Sand, fine to coarse; contains shell fragments	7	55
Sand, medium to coarse, and fine to medium gravel . .	5	60
Sand, fine to coarse	13 5	73 5
Silt, dark blue-gray; contains sand and gravel	9	82 5
Sand, fine to coarse; contains fine gravel	7 5	90
Gravel and sand, fine to coarse	5	95
CRETACEOUS—Gulfian		
Dakota formation		
Sandstone, buff to dirty white	5	100

Sample log of test hole 21-21-23cc in the SW cor. SW¼ sec. 23, T. 21 S., R. 21 W., drilled by the State Geological Survey, December, 1946. Surface altitude, 2,120.5 feet; depth to water level, 27.6 feet, December 12, 1946.

QUATERNARY—Pleistocene

Alluvium	Thickness, feet	Depth, feet
Silt, dark-gray	1.5	1.5
Silt, sandy, tan	3.5	5
Silt, yellowish-tan; contains caliche and sandstone fragments	7	12
Silt, tan; contains sand from 16 to 20 feet	8	20
Silt, sandy, brown	5	25
Sand, fine to coarse	3	28
Silt, gray	2	30
Silt, dark-gray	4	34
Silt, sandy, light-gray; contains sandstone fragments	2	36
Gravel, fine to coarse, yellowish	3	39
Gravel, fine to coarse; contains coarse sand and sandstone fragments	2	41
Sand, fine to coarse; contains fine to medium gravel and sandstone	7	48
Gravel, fine to coarse; contains coarse sand and pebbles up to one-fourth inch	2	50
Sand, coarse; contains fine to medium gravel	8	58
Gravel, medium to coarse, and one-half inch pebbles; contains yellow and gray silt and clay	3	61
Silt, sandy, dark-gray; contains gravel	5	66
Silt, very sandy, gray to light-gray; contains gravel	5.5	71.5
Sand, fine to coarse; contains tan, buff, and gray silt	6.5	78
Gravel, fine to coarse; contains medium to coarse sand	8.5	86.5

CRETACEOUS—Gulfian

Dakota formation

Clay and silt; yellow	1	87.5
Clay and shale; light-gray to gray	2.5	90

Sample log of test hole 21-21-26bcc in the SW cor. SW¼ NW¼ sec. 26, T. 21 S., R. 21 W., drilled by the State Geological Survey, December, 1946. Surface altitude, 2,122.6 feet.

	Thickness, feet	Depth, feet
Road fill, silty, dark-brown to dark-gray and black; contains particles of gravel	2	2

QUATERNARY—Pleistocene

Alluvium

Silt, tan to buff	2.5	4.5
Silt, sandy, dark-gray	4	8.5
Silt, sandy, tan	4.5	13
Silt, sandy, grayish-brown	6	19
Silt, sandy, tan and reddish-brown mottled	5	24
Silt, sandy, dark-gray	3	27
Silt, sandy, light-tan to buff	3	30

	Thickness, feet	Depth, feet
Silt, sandy, dark-gray to black; contains shell fragments	3	33
Silt, sandy, light-gray to white	5	38
Silt, sandy, light blue-green; contains shell fragments	6	44
Sand and gravel, fine to coarse	16	60
Sand, fine to coarse; contains fine to coarse gravel and tan silt	7	67
Gravel, medium to very coarse; contains some one-half inch pebbles	3	70
Sand, fine to coarse, and fine to medium gravel; contains sandstone fragments	4	74
CRETACEOUS—Gulfian		
Dakota formation		
Shale, dark blue-gray	6	80

Sample log of test hole 21-21-26cb1 in the NW cor. NW¼ SW¼ sec. 26, T. 21 S., R. 21 W., drilled by the State Geological Survey, December, 1946. Surface altitude, 2,108.1 feet; depth to water level, 9.0 feet, December 11, 1946.

QUATERNARY—Pleistocene		
Alluvium		
Silt, dark-gray to black	2	2
Silt, dark-brown; contains fine to medium gravel	5	7
Silt and sand; contains shell fragments and gravel	1 5	8 5
Sand, fine to coarse; contains shell fragments and gravel	5 5	14
Silt, black; contains shell fragments	2 5	16 5
Silt and clay, light greenish-gray	6 5	23
Gravel, fine to coarse; contains medium to coarse sand	7	30
Sand, fine to coarse; contains very fine to fine gravel	10	40
Sand, very fine to fine, yellow	5	45
Gravel, fine to coarse; contains coarse sand	10	55
Silt, sandy, dark gray; contains shell fragments	1	56
Gravel, fine to coarse, and fine to coarse sand	11	67
CRETACEOUS—Gulfian		
Dakota formation		
Sandstone, gray	10	77

Sample log of test hole 21-21-26cb2 in the SW cor. NW¼ SW¼ sec. 26, T. 21 S., R. 21 W., drilled by the State Geological Survey, December, 1946. Surface altitude, 2,122.9 feet; depth to water level, 31.7 feet, December 11, 1946.

QUATERNARY—Pleistocene		
Alluvium		
Silt, sandy, dark-brown to dark-gray and black	3	3
Silt, sandy, buff	2	5
Silt, dark-brown to dark-gray	2	7
Silt, sandy, brown with reddish-brown streaks	3	10
Silt, sandy, buff	2	12
Silt, sandy, brown	3	15

	Thickness, feet	Depth, feet
Silt, sandy, tan	11	26
Silt, sandy, grayish-brown; contains few caliche nodules	4	30
Silt, sandy, gray; contains Recent shell fragments	4	34
Silt, sandy, buff to gray; contains sand and gravel	2	36
Silt, sandy, buff to light-tan	2	38
Silt, sandy, blue-green	2	40
Sand, fine to coarse; contains fine to medium gravel	14	54
Gravel, fine to medium; contains coarse sand	5	59
Sand, very fine to medium	8	67
Sand and dark blue-gray silt	3	70
Sand, very fine to medium; contains fine gravel	8	78
Silt, sandy, buff	8	86
Sand and gravel; contains sandstone fragments	7	93
Sandstone, reddish-brown	5 5	98 5

CRETACEOUS—Gulfian

Dakota formation

Clay and shale, gray to blue-gray	1 5	100
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Sample log of test hole 21-21-26cc in the SW¼ SW¼ sec. 26, T. 21 S., R. 21 W., drilled by the State Geological Survey, December, 1946. Surface altitude, 2,120.2 feet; depth to water level, 27.4 feet, December 3, 1946.

	Thickness, feet	Depth, feet
Road fill, silty, dark-gray to black; contains sand and gravel	1 5	1 5

QUATERNARY—Pleistocene

Alluvium

Silt, dark-gray	1 5	3
Silt, dark-brown to grayish-brown	2	5
Silt, buff; contains caliche	2	7
Silt, sandy, buff to brown	6	13
Silt, light grayish-brown to tan	7	20
Silt, brownish-gray to gray	3	23
Silt, sandy, buff	2 5	25 5
Silt, dark-gray to black	1 5	27
Silt, gray; contains shell fragments	3	30
Silt, blue-gray to greenish-gray; contains sand at 35 feet	7	37
Sand, very fine to medium; contains fine gravel	8	45
Gravel, fine to medium; contains medium to coarse sand	10	55
Gravel, fine to coarse; contains coarse sand	4	59
Silt, buff, and medium to coarse gravel	6	65
Gravel, fine to coarse, and coarse sand	10	75
Gravel, fine to very coarse, yellow, and sand, con- tains fine to coarse sandstone	13 5	88 5

CRETACEOUS—Gulfian

Dakota formation

Sandstone, white to light-buff	6 5	95
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Sample log of test hole 21-21-34dd in the SE cor. SE¼ SE¼ sec. 34, T. 21 S., R. 21 W., drilled by the State Geological Survey, November, 1946. Surface altitude, 2,118.9 feet; depth to water level, 27.8 feet, November 21, 1946.

QUATERNARY—Pleistocene

Alluvium	Thickness, feet	Depth, feet
Silt, sandy, dark-gray to black	3	3
Silt, sandy, brown	3	6
Silt, sandy, tan to light-brown	10	16
Silt, sandy, grayish-brown	4	20
Silt, dark brownish-gray	6	26
Silt, sandy, gray to light-gray	2	28
Sand, fine to coarse; contains fine to medium gravel, gray to dark-gray silt, and Recent shell fragments	2	30
Gravel, fine to medium, yellow to tan; contains medium to coarse sand and shell fragments	6	36
Gravel, fine to medium, and medium to coarse sand; green; contains shell fragments	11	47
Sand, medium to coarse, and fine gravel; gray; contains gray silt	3	50
Sand, medium to coarse, and fine to medium gravel; yellow; contains shell fragments	6	56
Clay and silt	6	62
Clay and silt, dark-gray	3	65
Clay and silt; light blue-gray; contains shell fragments and gravel	10	75
Sand and gravel, fine to coarse	5	80
Sand and gravel, fine to coarse; contains sandstone fragments	10	90
Sand, very fine to medium	12	102

CRETACEOUS—Gulfian

Dakota formation		
Clay, light-gray to white	8	110
Sandstone, gray to white; contains fragments of charcoal	20	130

Sample log of test hole 21-21-35bc in the NW cor. SW¼ NW¼ sec. 35, T. 21 S., R. 21 W., drilled by the State Geological Survey, November, 1946. Surface altitude, 2,117.8 feet; depth to water level, 26.8 feet, November 27, 1946.

QUATERNARY—Pleistocene

Alluvium	Thickness, feet	Depth, feet
Silt, sandy, dark-brown	3	3
Silt, sandy, brown to tan	7	10
Silt, grayish-brown; contains sand	8	18
Silt, sandy, tan to brown	2	20
Silt, dark-gray	2	22
Silt, sandy, gray	2	24
Silt, dark-gray	4	28
Silt, gray	2	30

	Thickness, feet	Depth, feet
Silt, blue-gray; contains sand	3	33
Sand, fine to coarse; contains fine to medium gravel ..	7	40
Gravel, fine to coarse; contains silt and coarse sand ..	5	45
Sand and gravel, fine to coarse	10	55
Sand, dark-gray; contains fine to medium gravel and gray silt	5	60
Gravel, fine to coarse; contains medium to coarse sand and fragments of limestone and sandstone	5	65
Clay, shaly, blue-gray	6 5	71 5
Gravel, fine to coarse; contains pebbles and medium to coarse sand	10 5	82
CRETACEOUS—Gulfian		
Dakota formation		
Sandstone, white to tan	8	90

Sample log of test hole 21-21-35cb in the SW cor. NW¼ SW¼ sec. 35, T. 21 S., R. 21 W., drilled by the State Geological Survey, November, 1946. Surface altitude, 2,116.5 feet; depth to water level, 24.9 feet, December 2, 1946.

QUATERNARY—Pleistocene

Alluvium

	Thickness, feet	Depth, feet
Silt, dark-gray to black	3	3
Silt, sandy, dark-brown	2	5
Silt, sandy, brown to tan; contains caliche	5	10
Silt, dark-brown	3	13
Silt, sandy, tan to buff	3	16
Silt, grayish-brown	2	18
Silt, sandy, reddish-brown	2	20
Silt, gray; contains sand	3	23
Silt, sandy, light-gray	3	26
Sand, very fine to fine, tan	9	35
Gravel, fine to medium; contains coarse greenish sand and shell fragments	5	40
Sand, fine to coarse, and fine to medium gravel; con- tains silt	10	50
Sand, medium to coarse, and fine to medium gravel; contains shell fragments	12	62
Sand, very fine to medium, gray; contains gray silt and shell fragments	4	66
Sand, very fine to medium, tan; contains shell frag- ments	8	74
Sand, fine to coarse, and fine to medium gravel; con- tains sandstone and "ironstone"	16	90
Sand, fine to very fine; contains gravel	10	100

CRETACEOUS—Gulfian

Dakota formation

Clay, white, gray, and red	16	116
Clay, sandy, white to light-gray	4	120

Sample log of test hole 21-22-11dcc in the SW¼ SE¼ sec. 11, T. 21 S., R. 22 W., drilled by the State Geological Survey, November, 1947. Surface altitude, 2,189.4 feet.

	Thickness, feet	Depth, feet
Soil, dark-brown	1	1
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, brown	9	10
Silt, clayey, light-tan	7	17
Silt, clayey, yellow-brown; contains Greenhorn pebbles,	3	20
CRETACEOUS—Gulfian		
Greenhorn limestone		
Limestone, hard and soft layers	6	26

Sample log of test hole 21-22-12baa in the NE¼ NW¼ sec. 12, T. 21 S., R. 22 W., drilled by the State Geological Survey, November, 1947. Surface altitude, 2,150.0 feet; depth to water level, 28.7 feet, November 18, 1947.

	Thickness, feet	Depth, feet
Road fill, black silt	2	2
QUATERNARY—Pleistocene		
Alluvium		
Silt, dark-brown	4	6
Silt, brown	14	20
Silt, tan	12	32
Clay, greenish-gray	5	37
Gravel, fine to coarse, and medium to coarse sand.	3	40
Sand, medium to coarse, and fine to coarse gravel; contains greenish clay	12	52
Sand, medium to coarse, fine gravel, and light-green clay; contains medium to coarse gravel	18	70
Sand, medium to coarse, fine and some medium to coarse gravel and yellow-brown to light-green clay; contains mottled red to gray clay at 98 to 100 feet ..	30	100
CRETACEOUS—Gulfian		
Dakota formation		
Clay, red to gray; contains coarse gravel	5	105
Clay, mottled red to gray	5	110

Sample log of test hole 21-22-12cbb in the NW¼ SW¼ sec. 12, T. 21 S., R. 22 W., drilled by the State Geological Survey, November, 1947. Surface altitude, 2,156.3 feet; depth to water level, 29.5 feet, November 13, 1947.

	Thickness, feet	Depth, feet
Soil, black	3	3
QUATERNARY—Pleistocene		
Alluvium		
Silt, brown	22	25
Silt, light-tan	4	29
Sand, coarse, and fine to medium gravel; contains medium sand and coarse gravel	11	40
Sand, coarse, and fine to coarse gravel	13	53

	Thickness, feet	Depth, feet
Sand, medium to coarse, and fine gravel.....	7	60
Gravel, fine to coarse; contains gray clay at 65 to 70 feet	10	70
CRETACEOUS—Gulfian		
Dakota formation		
Clay, gritty, gray	10	80
Clay, gray, and some yellow clay	20	100
Clay, sandy, gray	7	107
Sandstone, fine, brown	5	112
Sandstone, fine, and clay; gray	6	118
Clay, light-gray; contains brown clay at 122 to 130 feet	12	130
<i>Sample log of test hole 21-23-6bbb in the NW¼ NW¼ sec. 6, T. 21 S., R. 23 W., drilled by the State Geological Survey, November, 1947. Surface altitude, 2,233.0 feet; depth to water level, 30.8 feet, November 26, 1947.</i>		
QUATERNARY—Pleistocene		
Alluvium		
Silt, black	1	1
Silt, clayey, tan	4	5
Silt, clayey, olive drab	17	22
Silt, tan	5	27
Sand, very fine, and silt	6	33
Sand, coarse, fine to coarse gravel, and some one-half to one inch gravel; contains yellow-brown clay at 38 to 40 feet	7	40
Gravel, coarse to fine, and coarse sand; contains white clay	11	51
Silt and sand, fine, limy, white	11	62
Silt and sand, fine, light-gray	3	65
Sand, fine, and silt	7	72
Silt and sand, fine, white	3	75
Gravel, coarse to fine, and coarse sand; contains white clay at 78 to 80 feet	7	82
Sand, coarse, and fine to coarse gravel	1	83
CRETACEOUS—Gulfian		
Dakota formation		
Shale, noncalcareous, blue-gray; contains lignite and pyrite	7	90
Shale, blue-gray; contains lignite	10	100
<i>Sample log of test hole 22-16-4cc at the SW cor. sec. 4, T. 22 S., R. 16 W., drilled by the State Geological Survey, May, 1945. Surface altitude, 2,000.3 feet.</i>		
QUATERNARY—Pleistocene		
Dune sand		
Sand, fine to medium; contains silt; tan to gray	2	2
Meade formation		
Gravel, fine to coarse, tan; contains medium to coarse sand and silt	18	20

	Thickness, feet	Depth, feet
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
<i>Sample log of test hole 22-16-5aa in the NE¼ NE¼ sec. 5, T. 22 S., R. 16 W., drilled by the State Geological Survey, May, 1945. Surface altitude, 1,999.6 feet.</i>		
	Thickness, feet	Depth, feet
Soil, dark-gray	3	3
QUATERNARY—Pleistocene		
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
<i>Sample log of test hole 22-16-9cc at the SW cor. sec. 9, T. 22 S., R. 16 W., drilled by the State Geological Survey, May, 1945. Surface altitude, 2,010.4 feet.</i>		
QUATERNARY—Pleistocene		
Alluvium		
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
<i>Sample log of test hole 22-16-21bb at the NW cor. sec. 21, T. 22 S., R. 16 W., drilled by the State Geological Survey, May, 1945. Surface altitude, 2,031.9 feet.</i>		
	Thickness, feet	Depth, feet
Soil, dark-gray	3	3
QUATERNARY—Pleistocene		
Meade formation		
Clay, silty, light-gray; contains very fine sand.....	5	8

	Thickness, feet	Depth, feet
Sand, very fine to coarse; contains silt; tan	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 sand 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
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*Sample log of test hole 22-16-33bb at the NW cor. sec. 33, T. 22 S., R. 16 W.,
drilled by the State Geological Survey, May, 1945. Surface altitude,
2,041.2 feet.*

QUATERNARY—Pleistocene

Meade formation

	Thickness, feet	Depth, feet
Sand, fine to coarse; contains silt; tan	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 silt; tan	2	28
Sand, fine to coarse; contains fine gravel and tan and white caliche	12	40
Sand, fine to coarse, yellow-tan; contains limonitic ce- mented 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
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*Sample log of test hole 22-17-7bb 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		
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

*Sample log of test hole 22-17-7cc at the SW cor. sec. 7, T. 22 S., R. 17 W.,
drilled by the State Geological Survey, June, 1945. Surface altitude,
2,040.0 feet.*

	Thickness, feet	Depth, feet
Road fill	2	2
QUATERNARY—Pleistocene		
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 fine gray and tan 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

	Thickness, feet	Depth, feet
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Clay, silty, light-gray with red stains	9	90
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Sample log of test hole 22-17-19bb at the NW cor. sec. 19, T. 22 S., R. 17 W., drilled by the State Geological Survey, June, 1945. 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

	Thickness, feet	Depth, feet
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Clay, silty, tan and gray mottled red	3	60
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Sample log of test hole 22-17-30bb at the NW cor. sec. 30, T. 22 S., R. 17 W., drilled by the State Geological Survey, June, 1945. 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

CRETACEOUS—Gulfian

Dakota formation

	Thickness, feet	Depth, feet
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Clay, silty, tan, white, and yellow; contains very fine-grained sandstone	3	15
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Sample log of test hole 22-17-31cc at the SW cor. sec. 31, T. 22 S., R. 17 W., drilled by the State Geological Survey, June, 1945. Surface altitude, 2,074.8 feet; depth to water level, 9.2 feet, June 6, 1945.

	Thickness, feet	Depth, feet
Road fill	2	2
QUATERNARY—Pleistocene		
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

	Thickness, feet	Depth, feet
Sandstone, fine yellow and tan, interbedded with tan and yellow clay	5	30

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

QUATERNARY—Pleistocene

Alluvium

	Thickness, feet	Depth, feet
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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*Sample log of test hole 22-18-7aa at the NE cor. sec. 7, T. 22 S., R. 18 W.,
drilled by the State Geological Survey, June, 1945. Surface altitude,
2,053.4 feet.*

	Thickness, feet	Depth, feet
Road fill	4	4

QUATERNARY—Pleistocene

Alluvium

Clay, silty, dark-gray to tan	7	11
Clay, silty, tan to brown; contains tan fine to me- dium sand	19	30
Clay, silty; contains very fine-grained sand; buff and tan	7	37
Gravel, fine to coarse; contains silt and fine to coarse sand; tan and gray	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, Clay, silty, dark-gray	4	64
Sand, fine to coarse, tan to brown	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
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Sample log of test hole 22-18-7dd at the SE cor. sec. 7, T. 22 S., R. 18 W., drilled by the State Geological Survey, June, 1945. 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

Sample log of test hole 22-18-18dd at the SE cor. sec. 18, T. 22 S., R. 18 W., drilled by the State Geological Survey, June, 1945. 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

Sample log of test hole 22-18-19dd at the SE cor. sec. 19, T. 22 S., R. 18 W., drilled by the State Geological Survey, June, 1945. 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

CRETACEOUS—Gulfian

Dakota formation

	Thickness, feet	Depth, feet
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Clay, silty, tan and yellow	2	38
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Sample log of test hole 22-18-25dd at the SE cor. sec. 25, T. 22 S., R. 18 W., drilled by the State Geological Survey, June, 1945. 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

	Thickness, feet	Depth, feet
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Clay, silty, mottled yellow and tan	6 5	50
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Sample log of test hole 22-18-31dd at the SE cor. sec. 31, T. 22 S., R. 18 W., drilled by the State Geological Survey, July, 1945. 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		
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

	Thickness, feet	Depth, feet
Clay, silty, gray, tan, yellow, and red; contains fragments of "ironstone"	15	157
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, containing interbedded tan sandstone ..	14	419
Shale, gray to grayish-green; contains interbedded tan and white sandstone	10	429
PERMIAN (Undifferentiated)		
Shale, gray and tan; contains interbedded sandstone ..	6	435
Shale, gray; contains interbedded brown sandstone ..	15	450
Shale, sandy, reddish-tan	5	455

Sample log of test hole 22-19-4cc at the SW cor. sec. 4, T. 22 S., R. 19 W., drilled by the State Geological Survey, May, 1945. 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 caliche; tan	10	40
Clay, silty, buff	10	50
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

Sample log of test hole 22-19-8dd at the SE cor. sec. 8, T. 22 S., R. 19 W., drilled by the State Geological Survey, May, 1945. 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

Sample log of test hole 22-19-20dd at the SE cor. sec. 20, T. 22 S., R. 19 W., drilled by the State Geological Survey, May, 1945. 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

	Thickness, feet	Depth, feet
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
<i>Sample log of test hole 22-19-32dd at the SE cor. sec. 32, T. 22 S., R. 19 W., drilled by the State Geological Survey, May, 1945. Surface altitude, 2,154.3 feet.</i>		

	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 fine to coarse gravel; contains caliche and many fragments of "ironstone" having the appearance of illmenite; tan	3	60
Silt and medium to coarse sand; 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
<i>Sample log of test hole 22-20-3cc at the SW cor. sec. 3, T. 22 S., R. 20 W., drilled by the State Geological Survey, June, 1945. Surface altitude, 2,164.7 feet.</i>		

	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

Sample log of test hole 22-20-4aa at the NE cor. sec. 4, T. 22 S., R. 20 W., drilled by the State Geological Survey, June, 1945. 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
Clay, silty, tan	15	25
Clay, silty; contains fine-grained sand and fine "iron-stone" gravel; tan and rust red	1	26
CRETACEOUS—Gulfian		
Dakota formation		
Sandstone, fine grained; contains silt and fine fragments of "ironstone"; reddish-brown to tan	2	28

Sample log of test hole 22-20-15bb at the NW cor. sec. 15, T. 22 S., R. 20 W., drilled by the State Geological Survey, June, 1945. 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 caliche; tan	6	12
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, yellow and tan	2	14

Sample log of test hole 22-20-28aa at the NE cor. sec. 28, T. 22 S., R. 20 W., drilled by the State Geological Survey, June, 1945. Surface altitude, 2,163.1 feet.

	Thickness, feet	Depth, feet
Road fill and soil; brown	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

Sample log of test hole 22-20-28dd at the SE cor. sec. 28, T. 22 S., R. 20 W., drilled by the State Geological Survey, June, 1945. 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
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

Sample log of test hole 22-21-2bb in the NW¼ NW¼ sec. 2, T. 22 S., R. 21 W., drilled by the State Geological Survey, November, 1946. Surface altitude, 2,111.8 feet; depth to water level, 20.7 feet, November 26, 1946.

QUATERNARY—Pleistocene		
Alluvium		
	Thickness, feet	Depth, feet
Silt and very fine sand	1.5	1.5
Sand, very fine to fine, tan; contains Recent shell fragments and coarse sand	10.5	12
Silt, sandy, brown to buff; contains shell fragments	6	18
Sand, very fine to fine, tan	4	22
Sand and gravel, fine to coarse, tan to blue and green	8	30
Sand and gravel, fine to coarse, yellowish-brown	5	35
Sand and gravel, fine to coarse, gray; contains silt	10	45
Sand, fine to coarse; contains fine gravel. Layer of gray silt at 45 feet	7	52
Sand, very fine to coarse; contains fine gravel and gray and tan silt	10	62
Gravel, fine to coarse, green; contains fine to coarse sand	10.5	72.5
Gravel, fine to coarse; contains one-half inch pebbles, sandstone, fine sand, and silt	11.5	84
Sand, fine to medium; contains gravel and broken fragments of sandstone	9	93

CRETACEOUS—Gulfian

Dakota formation

	Thickness, feet	Depth, feet
Clay, light-gray to white	3	96
Clay, shaley, gray to light-gray	4	100
Clay, sandy, light blue-gray	10	110
Clay, white	8	118
Clay, gray, reddish-brown	4	122
Clay and shale, dark gray-red	8	130

Sample log of test hole 22-21-2bc in the NW cor. SW¼ NW¼ sec. 2, T. 22 S., R. 21 W., drilled by the State Geological Survey, November, 1946. Surface altitude, 2,133.1 feet.

	Thickness, feet	Depth, feet
Top soil, silty, dark-brown	1	1
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, sandy, brown	1	2
Silt, light buff; contains caliche	2.5	4 5
Silt, buff to light-buff	4.5	9
Silt, buff; contains caliche and layers of sandy silt	10	19
Silt, grayish-brown; contains sand	9	28
Silt, grayish-brown; contains reddish-brown sandy streaks	6	34
Silt, gray; contains reddish-brown sandy streaks	4	38
Silt, sandy, gray and brown	2	40
Silt, dark-gray to black	6	46
Sand, fine to medium; contains coarse dark-gray silt, yellow-brown silt, and Recent shell fragments	4	50
Gravel and sand, fine to coarse; contains gray silt	5	55
Gravel and sand, fine to coarse; contains gray silt	10	65
Gravel and sand, fine to coarse; contains yellow-brown silt	5	70
Gravel, fine to coarse; contains sandstone fragments and silt	6	76
Gravel; contains fine to coarse sand and silt	18	94
Silt, tan to brownish-gray; contains sand and gravel	5	99
Silt, clayey, gray	8	107
Silt, tan to grayish-tan	5	112

CRETACEOUS—Gulfian

Dakota formation

Clay and shale; gray to light-blue; contains lignite ..	6	118
Clay and shale, gray to white	6	124
Clay and shale, solid, gray	6	130

Sample log of test hole 22-21-2cc in the SW cor. SW¼ SW¼ sec. 2, T. 22 S., R. 21 W., drilled by the State Geological Survey, November, 1946. Surface altitude, 2,141.6 feet; depth to water level, 29.8 feet, November 13, 1946.

	Thickness, feet	Depth, feet
Top soil, silty, dark-gray to black	1	1
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, sandy, dark-brown	1	2
Silt, sandy, tan	3	5
Silt, light-tan; contains caliche	2	7
Silt, buff to white mottled; contains caliche	1	8
Silt, buff	2	10
Silt, sandy, reddish-brown	3	13
Silt, sandy, buff	7	20
Silt, sandy, brown	5	25
Silt, buff; contains layers of caliche	11	36
Silt and clay; tan, buff, and pink; contains gravel	2	38
CRETACEOUS—Gulfian		
Dakota formation		
Clay, yellow	2	40
Sandstone, very fine, light-gray to white	1	41
Sandstone, coarse, consolidated, reddish-brown	3	44

Sample log of test hole 22-21-3da in the SE cor. NE¼ SE¼ sec. 3, T. 22 S., R. 21 W., drilled by the State Geological Survey, November, 1946. Surface altitude, 2,129.9 feet; depth to water level, 29.2 feet, November 14, 1946.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, dark-brown to black	1	1
Silt, sandy, light-brown; contains caliche	2	3
Silt, sandy, reddish-brown	3	6
Silt, buff; contains white caliche	6	12
Silt, light buff; contains layers of caliche nodules	10	22
Silt, tan to brown; contains sand	7	29
Silt, grayish-brown; contains reddish-brown sandy streaks	7	36
Silt, dark-gray to black	4	40
Sand, fine to medium; contains dark-gray sandstone, silt, and Recent shell fragments	6	46
Gravel, fine to coarse, yellow	4	50
Sand and gravel, fine to coarse	12 5	62 5
Clay, gray and yellow, and gravel; contains silt	1	63 5
CRETACEOUS—Gulfian		
Dakota formation		
Sandstone, dark reddish-brown	3.5	67

Sample log of test hole 22-21-19ab in the NE cor. NW¼ NE¼ sec. 19, T. 22 S., R. 21 W., drilled by the State Geological Survey, December, 1946. Surface altitude, 2,192.9 feet.

QUATERNARY—Pleistocene

Terrace deposits

	Thickness, feet	Depth, feet
Silt, sandy, dark-brown	2	2
Silt, sandy, tan to buff	2	4
Silt, light-buff to white	5	9
Silt and gravel; tan to buff; contains sandstone and shale fragments	3	12

CRETACEOUS—Gulfian

Dakota formation

Clay, sandy, blue-gray	1	13
Clay and shale, light-gray and yellow	2	15

Sample log of test hole 22-21-20bc in the NW cor. SW¼ NW¼ sec. 20, T. 22 S., R. 21 W., drilled by the State Geological Survey, December, 1946. Surface altitude, 2,182.1 feet.

	Thickness, feet	Depth, feet
Road fill, silty, sandy, brown, containing gravel	2	2
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, sandy, dark-gray	4	6
Silt and gravel	7	13
CRETACEOUS—Gulfian		
Dakota formation		
Clay, shaly, sandy, gray	1	14
Clay and shale, gray, tan, and red	6	20

Sample log of test hole 22-22-2dcc in the SW¼ SE¼ sec. 2, T. 22 S., R. 22 W., drilled by the State Geological Survey, November, 1947. Surface altitude, 2,115.7 feet; depth to water level, 23.4 feet, November, 12, 1947.

	Thickness, feet	Depth, feet
Soil, black	2	2
Soil, silty, dark-brown	5	7
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, clayey, light-brown	7	14
Silt, light-tan	7	21
CRETACEOUS—Gulfian		
Dakota formation		
Clay, sandy, brown	3	24
Clay, mottled red and gray	6	30

Sample log of test hole 22-22-12cbb in the NW¼ SW¼ sec. 12, T. 22 S., R. 22 W., drilled by the State Geological Survey, November, 1947. Surface altitude, 2,168.5 feet; depth to water level, 49.5 feet, November 11, 1947.

QUATERNARY—Pleistocene		
Terrace deposits	Thickness, feet	Depth, feet
Silt, sandy, dark-brown	3	3
Silt, light-tan	1	4
Sand, medium to coarse, and fine to coarse gravel	3	7
Silt, sandy, light-tan	42	49
Sand, fine to coarse, and fine gravel	17	66
Sand, medium to coarse, and fine to medium gravel; contains white clayey layer at 75 to 77 feet	14	80
Sand, fine to coarse, and brown silt; contains greenish clay at 93 to 97 feet	20	100
Sand, fine to coarse, and greenish clay; contains fine to coarse gravel	10	110
Sand, medium to coarse, some greenish clay and brown silt; contains coarse gravel at 128 to 130 feet	25	135
CRETACEOUS—Gulfian		
Dakota formation		
Clay, greenish	3	138
Sand, medium to coarse; contains much black carbona- ceous material and some gray clay	12	150
Clay, limy, light-gray	7	157
Siltstone, gray with black streaks, and some lignite; contains brown clay	3	160
Clay, gray; contains lignite	10	170

Sample log of test hole 22-22-12dcc in the SW¼ SE¼ sec. 12, T. 22 S., R. 22 W., drilled by the State Geological Survey, November, 1947. Surface altitude, 2,140.1 feet; depth to water level, 21.7 feet, November 10, 1947.

	Thickness, feet	Depth, feet
Soil, black	3	3
QUATERNARY—Pleistocene		
Alluvium		
Silt, brown	20	23
Sand and gravel	7	30
Sand, medium to coarse, and fine to medium gravel; contains fine sand	10	40
Sand, fine to coarse, and fine gravel; contains gray clay layer at 53 to 54 feet	20	60
Sand, medium to coarse, and fine to coarse gravel	25	85
CRETACEOUS—Gulfian		
Dakota formation		
Siltstone, light-gray	25	110
Sandstone, fine, gray	24	134

Sample log of test hole 22-22-13daa in the NE¼ SE¼ sec. 13, T. 22 S., R. 22 W., drilled by the State Geological Survey, November, 1947. Surface altitude, 2,144.7 feet; depth to water level, 20.9 feet, November 7, 1947.

	Thickness, feet	Depth, feet
Soil, black	2	2
QUATERNARY—Pleistocene		
Alluvium		
Silt, clayey, brown	14	16
Sand, fine to coarse	10	26
Clay, gray	3	29
Clay, silty, tan	1	30
Sand, medium to coarse, and fine to coarse gravel ..	18	48
CRETACEOUS—Gulfian		
Dakota formation		
Clay, gray, with red streaks	5	53

Sample log of test hole 22-22-31da in the center east side NE¼ SE¼ sec. 31, T. 22 S., R. 22 W., drilled by the State Geological Survey, December, 1946. Surface altitude, 2,193.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Silt, sandy, brown	3	3
Silt, sandy, grayish-brown	4	7
Silt, sandy	3	10
Silt, sandy, tan to buff	10	20
Silt, sandy, grayish-brown mottled	10	30
Silt, sandy, dark-gray	4	34
Silt, sandy, blue-green	2	36
Gravel, fine to coarse, gray and blue-green	4	40
Gravel, fine to coarse; contains medium to coarse sand and shell fragments	6	46
CRETACEOUS—Gulfian		
Dakota formation		
Clay and shale, sandy, gray; contains consolidated sand	3	49
Clay and shale, gray; contains sand	6	55

Sample log of test hole 22-22-32bc in the SW¼ NW¼ sec. 32, T. 22 S., R. 22 W., drilled by the State Geological Survey, December, 1946. Surface altitude, 2,250.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, sandy, brown	4	4
Silt, buff to light-tan; contains caliche	2	6
Silt and limestone, unconsolidated, yellowish-white ..	2	8
CRETACEOUS—Gulfian		
Greenhorn limestone		
Limestone, shaly; yellow to reddish-brown	2 5	10 5
Limestone and shale, weathered, reddish-brown and yellow	1	11 5

	Thickness, feet	Depth, feet
Limestone and shale, buff to yellow	2 5	14
Limestone and shale, yellow to brownish-yellow	2	16
Limestone and shale; contains calcite	3	19
Shale and clay, yellow to blue-gray	1	20

Sample log of test hole 23-22-5bc in the NW cor. SW¼ NW¼ sec. 5, T. 23 S., R. 22 W., drilled by the State Geological Survey, December, 1946. Surface altitude, 2,192.5 feet.

QUATERNARY—Pleistocene

Alluvium

	Thickness, feet	Depth, feet
Silt, dark-gray to white	3	3
Silt, grayish-brown; contains caliche	5	8
Silt, sandy, brown to tan	6	14
Sand and gravel, fine to coarse; contains tan to light-brown silt	5	19
Silt, sandy, tan	9	28
Silt, gray to gray-brown	5	33
Sand, fine to medium, and silt, blue-gray	7	40
Gravel, fine to coarse; contains medium to coarse sand	20	60
Silt, sandy, light-gray	5	65
Gravel, fine to coarse, yellow; contains medium to coarse sand	5	70

CRETACEOUS—Gulfian

Dakota formation

	Thickness, feet	Depth, feet
Clay and shale, grading to sandy, light-gray	7	77
Sandstone, gray to dark-gray; contains lignitic material, clay, and shale	3	80

Sample log of test hole 23-22-5cb1 in the NW¼ SW¼ sec. 5, T. 23 S., R. 22 W., drilled by the State Geological Survey, November, 1946. Surface altitude, 2,222.5 feet; depth to water level, 49.5 feet, December 23, 1946.

	Thickness, feet	Depth, feet
Road fill, silty, sandy, brown, buff	3	3
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, sandy, tan to buff	5	8
Silt, sandy, reddish-brown; contains caliche	4	12
Silt, tan	13	25
Silt, sandy, tan	13	38
Silt, sandy, brown	16	54
Silt, sandy, and medium to coarse gravel	4	58
Silt, sandy, tan	4	62
Silt, dark-gray to black	8	70
Silt, sandy, gray-green	7	77
Gravel, fine to coarse; contains blue and green gravel at 77 feet and medium to coarse sand	13	90
Silt, sandy, brown	7	97

	Thickness, feet	Depth, feet
Silt, grayish tan, and gravel	8	105
Gravel, fine to coarse, apparently Cretaceous derived . .	5	110
CRETACEOUS—Gulfian		
Dakota formation		
Clay and shale; varicolored and some mottled gray and red	10	120
<i>Sample log of test hole 23-22-5cb2 in the NW¼ SW¼ sec. 5, T. 23 S., R. 22 W., drilled by the State Geological Survey, December, 1946. Surface altitude, 2,176.4 feet.</i>		

QUATERNARY—Pleistocene		
Terrace deposits		
Silt, sandy, brown	5	5
Sand, fine to medium; contains fine to medium gravel and limestone pebbles	7 5	12 5
Silt, dark-gray	1 5	14
Sand, fine to medium, gray-green; contains coarse sand, Sand, fine to coarse, gray; contains Recent shell fragments	6	20
	11	31
CRETACEOUS—Gulfian		
Dakota formation		
Clay and shale, gray to highly colored	9	40
Clay and shale, varicolored	10	50
Clay and shale, varicolored; contains blue-gray fragments at 59 feet	10	60

Sample log of test hole 23-22-7aa in the NE cor. NE¼ NE¼ sec. 7, T. 23 S., R. 22 W., drilled by the State Geological Survey, December, 1946. Surface altitude, 2,199.4 feet; depth to water level, 14.0 feet, December 23, 1946.

QUATERNARY—Pleistocene		
Terrace deposits		
Silt, sandy, dark-brown	2	2
Silt, sandy, brown; contains caliche	2 5	4 5
Sand, fine to coarse; contains Cretaceous fragments of gravel	2	6 5
Gravel and silt; contains Cretaceous appearing material, gray silt, and clay	6 5	13
Gravel, fine to coarse; contains limestone fragments and coarse sand	7	20
Gravel, medium to coarse; contains one-half inch pebbles and coarse sand	12	32
Silt, sandy, buff and reddish-brown	1	33
CRETACEOUS—Gulfian		
Dakota formation		
Clay and shale, varicolored	7	40

Sample log of test hole 23-22-8bc in the SW cor. SW¼ NW¼ sec. 8, T. 23 S., R. 22 W., drilled by the State Geological Survey, December, 1946. Surface altitude, 2,234.1 feet; depth to water level, 29.5 feet, December 21, 1946.

QUATERNARY—Pleistocene

Terrace deposits

	Thickness, feet	Depth, feet
Silt, sandy, dark-brown	8	8
Silt, sandy, brown; contains gravel	11	19
Silt, sandy, dark-gray	10	29
Silt, sandy, gray-brown; contains caliche	3	32
Gravel, fragments composed of sandstone, "ironstone," and limestone; contains medium to coarse sand ..	7	39
Silt, sandy, tan; contains iron-stained streaks	7	46
Gravel, fragments composed of sandstone, limestone, "ironstone," and quartz	5	51

CRETACEOUS—Gulfian

Dakota formation

Clay and shale, yellow and brownish-gray, grading to gray sandy shale and clay	9	60
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Sample log of test hole 23-22-10cd in the SW cor. SE¼ SW¼ sec. 10, T. 23 S., R. 22 W., drilled by the State Geological Survey, December, 1946. Surface altitude, 2,199.0 feet; depth to water level, 34.9 feet, December 20, 1946.

QUATERNARY—Pleistocene

Alluvium

	Thickness, feet	Depth, feet
Silt, sandy, dark-brown to dark-gray	3	3
Silt, dark-brown	3	6
Silt, sandy, red-brown; contains caliche	11	17
Sand, fine to coarse; contains fine to medium gravel and buff silt	5	22
Silt, sandy, red-brown; contains sandstone fragments at 30 feet	15	37
Silt, sandy, gray-brown	3	40
Silt, light-gray	5	45
Silt, buff to tan, and fine to coarse sand; contains me- dium gravel ..	3	48
Sand, fine to coarse; contains fine to coarse gravel and Recent shell fragments	8	56
Gravel, fine to coarse; containing medium to coarse sand	11	67
Gravel, fine to coarse; contains yellow clay and silt ..	1	68

CRETACEOUS—Gulfian

Dakota formation

Clay and shale, sandy, light-gray	2	70
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Sample log of test hole 23-22-10dc in the SE cor. SW¼ SE¼ sec. 10, T. 23 S., R. 22 W., drilled by the State Geological Survey, December, 1946. Surface altitude, 2,191.0 feet; depth to water level, 26.6 feet, December 20, 1946.

QUATERNARY—Pleistocene

Alluvium

	Thickness, feet	Depth, feet
Silt, sandy, dark-brown	4	4
Silt, sandy, dark-gray	3	7
Silt, gray-brown; contains consolidated, some iron-stained, fragments	2	9
Silt, sandy, tan; contains caliche	3	12
Silt, gray-brown; contains caliche	3	15
Silt, sandy, tan	2	17
Silt, sandy, reddish-brown	6	23
Silt, sandy, buff, and very fine to fine sand	10	33
Sand, fine to medium; contains shell fragments	12	45
Gravel, fine to coarse; contains coarse sand, sandstone, and "ironstone"	10	55
Gravel, fine to coarse; contains yellow silt and clay	2	57

CRETACEOUS—Gulfian

Dakota formation

Clay and shale, sandy, light-gray, grading to solid, gray, yellow, and reddish-brown shale	3	60
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Sample log of test hole 23-22-10dd in the SW cor. SE¼ SE¼ sec. 10, T. 23 S., R. 22 W., drilled by the State Geological Survey, December, 1946. Surface altitude, 2,190.3 feet; depth to water level, 24.4 feet, December 19, 1946.

QUATERNARY—Pleistocene

Alluvium

	Thickness, feet	Depth, feet
Silt, sandy, dark-brown	3	3
Silt, sandy, dark-gray to black	1	4
Silt, sandy, brown	3	7
Silt, sandy, buff; contains caliche	3	10
Silt, sandy, buff to tan	4 5	14 5
Silt, sandy, buff	3	17 5
Sand, very fine to fine, and silt, buff	15 5	33
Sand, fine to coarse; contains fine to coarse gravel	7	40
Gravel, fine to coarse; contains coarse sand	7	47
Sand, medium to coarse	5	52
Gravel, fine to coarse; contains limestone and sandstone	2	54

CRETACEOUS—Gulfian

Dakota formation

Clay and shale, yellow-gray to dark-gray	6	60
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Sample log of test hole 23-22-11cc in the SW cor. SW¼ SW¼ sec. 11, T. 23 S., R. 22 W., drilled by the State Geological Survey, December, 1946. Surface altitude, 2,190.2 feet; depth to water level, 22.3 feet, December 18, 1946.

QUATERNARY—Pleistocene

Alluvium

	Thickness, feet	Depth, feet
Silt, sandy, dark-brown	3	3
Silt, sandy, tan to light-brown	5	8
Silt, sandy, brown	4	12
Silt, sandy, grayish-tan	6	18
Silt, sandy, tan to buff	7	25
Sand, very fine to fine; contains silt	11	36
Gravel, fine to coarse; contains medium to coarse sand,	9	45
Silt, gray; contains sand and gravel	1 5	46 5
Sand, fine to coarse	6 5	53
Silt, sandy, buff	10	63
Silt, sandy, grayish-tan; contains caliche	9	72
Silt, sandy, tan and light-brown	14 5	86 5
Sand, fine to coarse; contains fine gravel	8 5	95
Sand, fine to coarse; contains shell fragments	5	100
Sand and gravel, fine to coarse; contains sandstone fragments	4	104

CRETACEOUS—Gulfian

Dakota formation

Clay and shale, light-gray	16	120
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Sample log of test hole 23-22-11cd in the SW cor. SE¼ SW¼ sec. 11, T. 23 S., R. 22 W., drilled by the State Geological Survey, December, 1946. Surface altitude, 2,187.6 feet; depth to water level, 20.8 feet, December 19, 1946.

QUATERNARY—Pleistocene

Alluvium

	Thickness, feet	Depth, feet
Silt, sandy, fine, dark-brown	1	1
Silt, sandy, dark-gray	1 5	2 5
Silt, sandy, brown	4	6 5
Silt, brown to tan; contains sand and caliche	6 5	13
Silt, sandy, light-brown	8	21
Silt, dark-gray	16	37
Silt, light blue-green; contains shell fragments	4	41
Sand, fine to coarse; contains fine to medium gravel	8	49

CRETACEOUS—Gulfian

Dakota formation

Clay and silt, sandy; white	2	51
Clay and shale, sandy to solid; gray	9	60

Sample log of test hole 23-22-16aa in the NE¼ NE¼ sec. 16, T. 23 S., R. 22 W., drilled by the State Geological Survey, December, 1946. Surface altitude, 2,220.2 feet; depth to water level, 30.5 feet, December 20, 1946.

QUATERNARY—Pleistocene

Terrace deposits

	Thickness, feet	Depth, feet
Silt, sandy, dark-brown	2	2
Silt, sandy, buff	2	4
Silt, sandy, tan to brown	2	6
Silt, brown; contains caliche	3	9
Silt, buff; contains caliche	8	17
Gravel, fragments composed of sandstone and limestone	5	22
Silt, sandy, buff to light-tan	4	26
Gravel, fragments composed of brown sandstone, contains buff silt	4	30

CRETACEOUS—Gulfian

Dakota formation

Sandstone, yellow to tan	10	40
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Sample log of test hole 23-22-16ab in the NE cor. NW¼ NE¼ sec. 16, T. 23 S., R. 22 W., drilled by the State Geological Survey, December, 1946. Surface altitude, 2,231.2 feet; depth to water level, 17.3 feet, December 21, 1946.

QUATERNARY—Pleistocene

Terrace deposits

	Thickness, feet	Depth, feet
Silt, sandy, dark-brown	2	2
Silt, sandy, gray-brown	2	4
Silt, sandy, reddish-brown	3	7
Silt, brown to reddish-brown; contains caliche	3	10
Silt, sandy, tan	5	15
Gravel, fragments composed of sandstone and "ironstone," and buff silt	7	22
Gravel, fragments composed of sandstone, "ironstone," and limestone	4 5	26 5

CRETACEOUS—Gulfian

Dakota formation

Clay and silt, sandy, yellow	1 5	28
Clay and shale, yellow and red to gray	7	35

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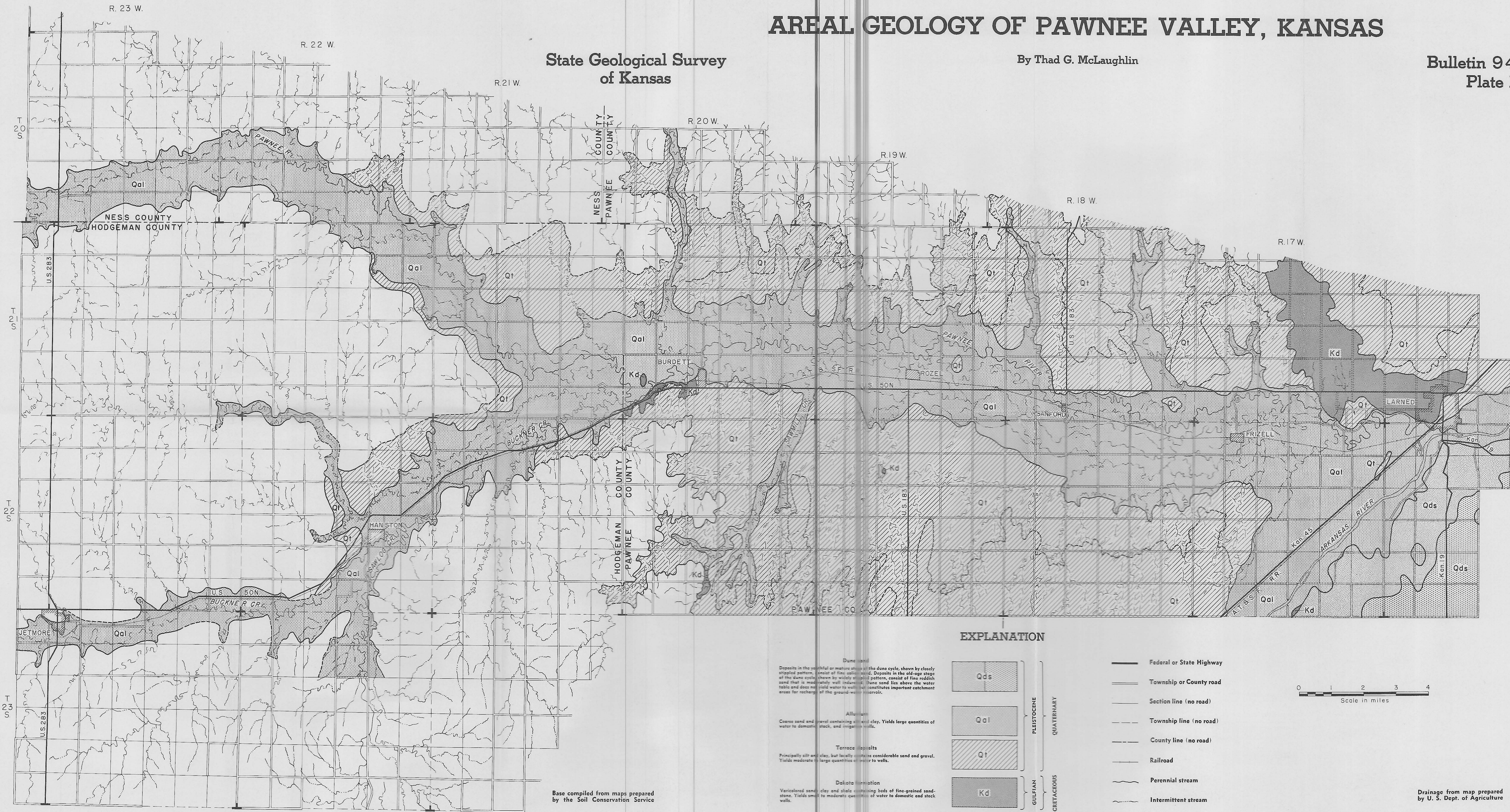
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AREAL GEOLOGY OF PAWNEE VALLEY, KANSAS

State Geological Survey
of Kansas

By Thad G. McLaughlin

Bulletin 94
Plate 1

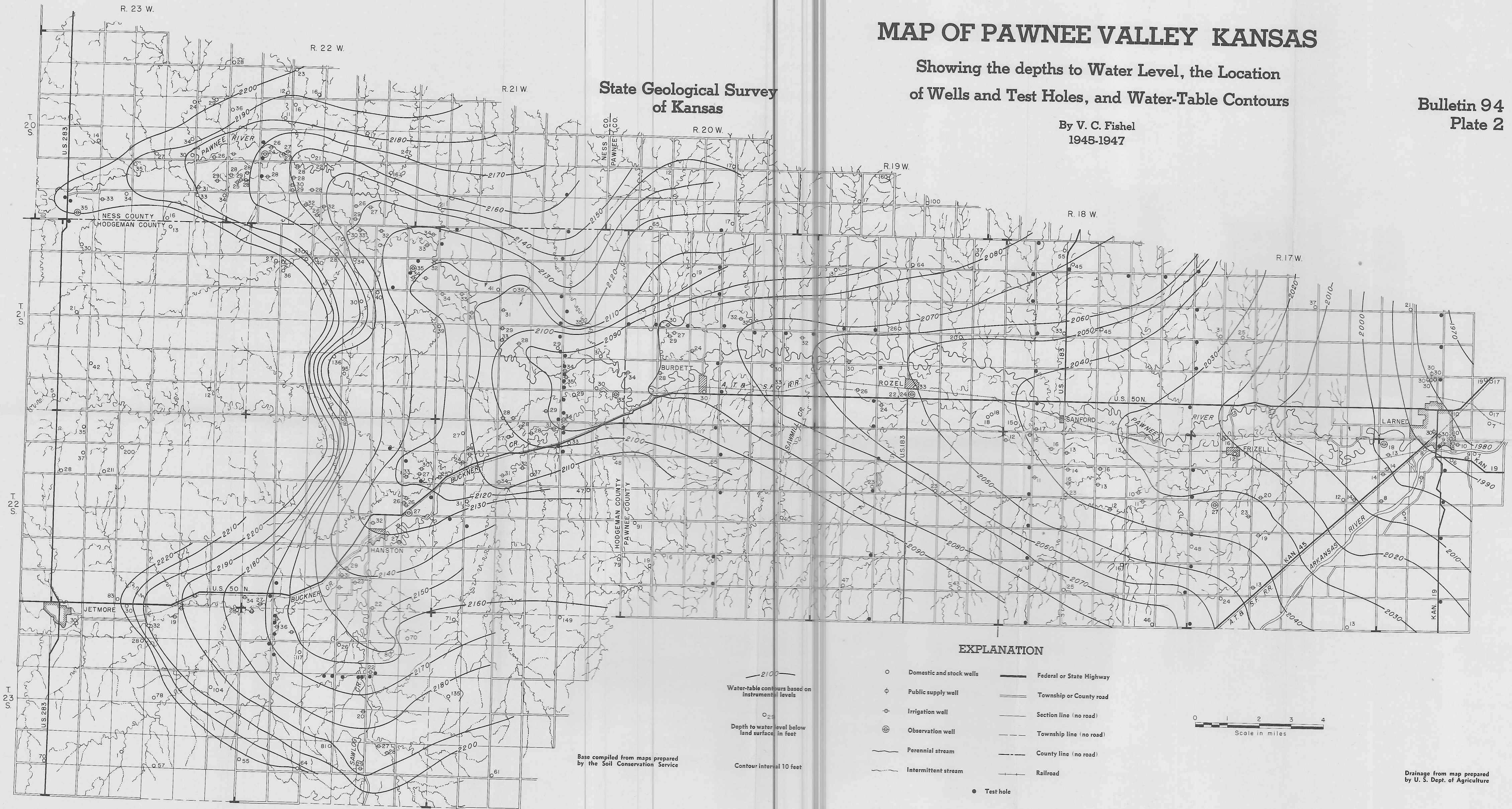


MAP OF PAWNEE VALLEY KANSAS

Showing the depths to Water Level, the Location
of Wells and Test Holes, and Water-Table Contours

By V. C. Fishel
1945-1947

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Plate 2



GEOLOGIC CROSS SECTIONS OF PAWNEE VALLEY, KANSAS

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Bulletin 94, Plate 3

