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BULLETIN 105

GEOLOGY AND GROUND-WATER RESOURCES OF SHERMAN COUNTY, KANSAS

By GLENN C. PRESCOTT, JR.
(U. S. Geological Survey)

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

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GEOLOGY AND GROUND-WATER RESOURCES OF SHERMAN COUNTY, KANSAS

By Glenn C. Prescott, Jr.

ABSTRACT

This report describes the geography, geology, and ground-water resources of Sherman County in northwestern Kansas. The county has an area of 1,055 square miles and in 1950 had a population of 7,373. Sherman County lies entirely within the High Plains section of the Great Plains physiographic province and consists of nearly flat to gently rolling upland plains dissected in several areas by relatively shallow valleys. The climate is semiarid, the average annual precipitation being about 18 inches. Farming and livestock raising are the principal occupations in the area. A small amount of irrigation is practiced in the county.

The outcropping rocks in Sherman County are sedimentary, ranging in age from late Cretaceous to Recent. Most of the county is underlain by deposits of Tertiary Ogallala formation, which in most places is covered by wind-blown silts of the Sanborn formation of Pleistocene age. The Pierre shale of late Cretaceous age has been exposed by erosion in a few localities in southern Sherman County. Deposits of Recent alluvium are along most of the stream valleys. The report contains a map showing the areal distribution of outcropping rocks; subsurface relations are shown in cross sections.

The Ogallala formation is the principal water-bearing formation in Sherman County, and in places large yields can be obtained from wells in permeable water-bearing beds in this formation. Alluvial deposits along parts of Beaver Creek and the North Fork Smoky Hill River yield water to wells in places where the deposits are below the water table.

The report contains a map of the county showing the locations of wells for which records were obtained and showing by means of shading the depths to water level. The water table ranges in depth from less than 10 feet in some stream valleys to more than 200 feet in one area in the southeastern part of the county. The depth to water level in most of the upland areas is more than 100 feet. Included in the report is a contour map showing the shape and slope of the water table. This map indicates that ground water moves in a general easterly or northeasterly direction; the average slope of the water table is about 15 feet per mile.

The ground-water reservoir is recharged principally by ground-water flow that enters Sherman County from the west and southwest and to a less extent by precipitation that falls within the area. Ground water is discharged by transpiration or evaporation, by springs, by seepage into streams, by subsurface movement into adjacent areas to the east, and by wells. Most of the domestic, stock, public, and irrigation supplies are obtained from wells.

Irrigation is not practiced extensively in Sherman County. With the exception of the southeastern part, much of the county is underlain by a considerable thickness of water-bearing beds. Depths to water are generally relatively

great and permeabilities of water-bearing beds are generally low. Some beds in the Ogallala are rather permeable; however, and moderately large yields can be obtained from wells penetrating these beds. That irrigation may increase in the future is probable; the most favorable area for future irrigation is along parts of Beaver Creek.

Analyses of 24 samples of ground water are given, together with a discussion of principal chemical constituents in relation to use. Analyses indicate that water from Ogallala and alluvial deposits is moderately hard, but is suitable for most purposes. Water from the Pierre shale contains a slightly higher concentration of dissolved solids than water from the Ogallala or alluvium. The field data upon which this report is based are given in tables; they include records of 326 wells, chemical analyses of 24 water samples from selected wells, and logs of 41 wells and test holes, including 29 test holes drilled as part of this investigation and 2 test holes drilled on the Sherman-Thomas County line as part of an investigation of the geology and ground-water resources of Thomas County.

INTRODUCTION

Purpose and Scope of the Investigation

A program of investigation of the ground-water resources of Kansas was begun in 1937 by the U. S. Geological Survey and State Geological Survey of Kansas with the co-operation of the Division of Sanitation of the State Board of Health and the Division of Water Resources of the State Board of Agriculture. The investigation upon which this report is based was begun in June 1949. It is similar to other investigations that have been completed or are being made in other counties in Kansas. The present status of investigations resulting from this program is shown in Figure 1.

Ground water is one of the principal natural resources of Sherman County as well as of much of western Kansas. Nearly all public, domestic, railroad, and stock water supplies are obtained from wells. Ground water is being used to some extent for irrigation, and that this use will increase in the future is probable. At the present rate of withdrawal, the danger of seriously depleting the water supply is slight; but there is a definite need for an adequate understanding of the quality and quantity of the available supply and where additional supplies can be obtained.

The investigation was made under the general administration of A. N. Sayre, Chief of the Ground-Water Branch of the U. S. Geological Survey and under the immediate supervision of V. C. Fishel, District Engineer in charge of ground-water investigations in Kansas.

Location and Extent of the Area

Sherman County is in the High Plains in northwestern Kansas. It is bounded on the north by Cheyenne and Rawlins Counties, on the east by Thomas County, on the south by Logan and Wallace Counties, and on the west by Kit Carson County, Colorado (Fig. 1). It contains all or part of 30 townships from T. 6 S. to T. 10 S. and from R. 37 W. to R. 42 W. and has an area of 1,055 square miles.

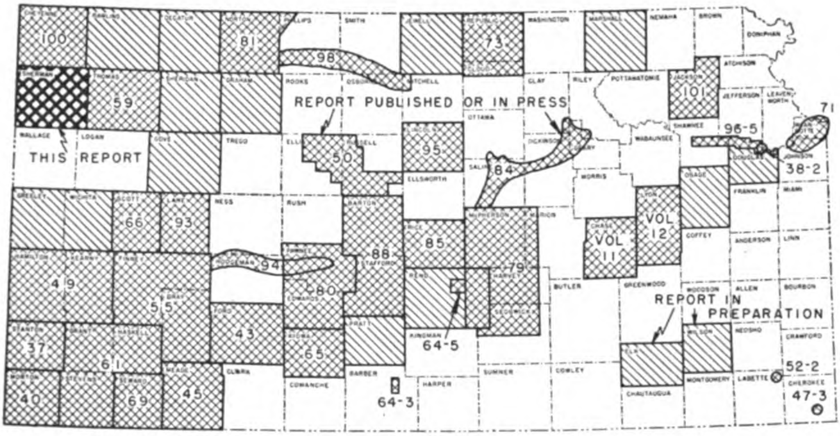


Fig. 1.—Index map of Kansas showing area covered by this report and areas for which co-operative ground-water reports have been published or are in preparation.

Previous Investigations

No detailed geologic reports on Sherman County have been published, but several reports that refer to the county either directly or in a general way have been published. As early as 1895, a comprehensive report on geology and ground water along the Kansas-Colorado State line was published by the U. S. Geological Survey (Hay, 1895). This report discussed the source and the quantity of ground water, geology, and water-bearing formations in the area. Several references to Sherman County were made. A report on the progress of the Division of Hydrography for 1893 and 1894 (Newell, 1896) contained records of 50 wells in Sherman County which were measured by Hay. In 1897 Haworth contributed reports on the physiography of western Kansas (Haworth, 1897), on the physical properties of Tertiary rocks in Kansas (Haworth, 1897a), and on the geology of underground water in western Kansas (Haworth, 1897b).

A report of the Board of Irrigation Survey and Experiment to the State Legislature of Kansas for the years 1895 and 1896 was concerned with history, irrigation law, and station reports; a State-financed experimental pumping station near Goodland was described in detail (Sutton, 1897, pp. 21-24). Johnson (1901, 1902) reported on the utilization of the High Plains with special attention being given to source, availability, and use of ground water in western Kansas. In 1905 a preliminary report on the geology and ground-water resources of the central Great Plains made brief reference to the geology and hydrology of Sherman County (Darton, 1905, p. 317). In 1911 in a report on the quality of water supplies in Kansas, Parker listed analyses of ground waters from Sherman County and made several references to the geology of the county. A report on a reconnaissance soil survey in western Kansas (Coffey and Rice, 1912) included Sherman County. A special report on well waters in Kansas by Haworth (1913, p. 98) contains a log of a deep well drilled at Goodland.

Adams and Martin (1929) described an important Pliocene fossil discovery in Sherman County. In 1931 the State Geological Survey of Kansas published a very detailed report on the geology of Wallace County (Elias, 1931), which borders Sherman County on the south. This report discussed the geologic formations in Wallace County and gave a brief summary of the water resources of each township. A report by Landes (1937) on the mineral resources of Kansas counties briefly mentioned the water supplies and undeveloped mineral resources in Sherman County. In the same year Elias (1937) reported on the geology of Rawlins and Decatur Counties with special reference to ground water. Rawlins County borders the northeastern edge of Sherman County. In 1940 Moore and others prepared a generalized report on the ground-water resources of Kansas and in 1945 Frye prepared a report on the geology and ground-water resources of Thomas County which borders Sherman on the east. In addition, reports by Ver Wiebe contain paragraphs summing up the results of test drilling for oil and gas in Sherman County (Ver Wiebe, 1940, p. 104; 1943, p. 86; 1946, p. 107).

Methods of Investigation

This report is based on about 5 months of field work done in the summer and fall of 1949. Data on 326 wells were obtained; most of these were measured with a steel tape to determine the depth of the well and the depth to water level. Well owners and drillers were interviewed regarding yield and drawdown of wells and the character of water-bearing materials. Pumping tests on irrigation wells were made by Woodrow W. Wilson and me to determine the yield of wells and the permeability of water-bearing materials. Samples of water from 24 representative wells in the county were collected; chemical analyses of the water were made in the Water and Sewage Laboratory of the Kansas State Board of Health at Lawrence by Howard A. Stoltenberg, chemist.

During the course of the investigation the surficial geology was studied and a geologic map (Pl. 1) was prepared. The character of the material beneath the surface was determined by the drilling of 29 test holes. These test holes were drilled with the portable hydraulic-rotary drilling machine owned by the State Geological Survey of Kansas and operated by William T. Connor and Max Yazza (Pl. 3A). Samples of the drill cuttings were collected and studied in the field and later examined in the office with a binocular microscope. The altitude of the surface at the test holes and of the measuring points of the wells were determined by level parties headed by William A. Carlson and Rex Huff, using a plane table and alidade.

The wells shown on Plates 1 and 2 were located within the sections by use of an odometer. The base map of the county used in these plates was prepared by Joseph C. Weakly from a county map compiled by the State Highway Commission of Kansas. Geologic mapping was done on a map obtained from the United States Department of Agriculture, Soil Conservation Service; drainage was adapted from maps issued by the Soil Conservation Service.

Well-Numbering System

The well and test-hole numbers used in this report 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, 40-acre tract within that quarter section, and 10-acre tract within the quarter-quarter section, if this subdivision can be determined precisely. The 160-acre, 40-acre, and 10-acre tracts are designated a, b, c, or d in a counterclockwise direction beginning in the northeast quarter. If two or more wells are located within a 10-acre tract, the wells are numbered consecutively as inventoried. An example of this well-numbering system is given in Figure 2.

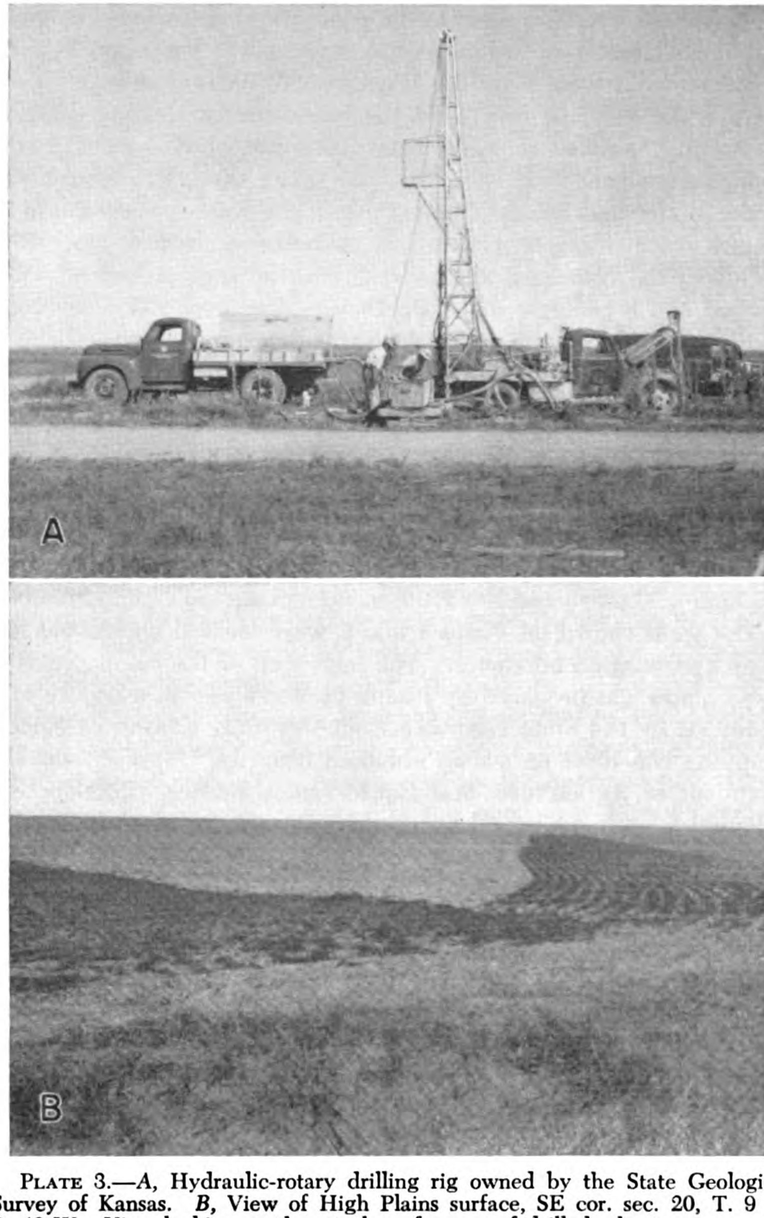


PLATE 3.—*A,* Hydraulic-rotary drilling rig owned by the State Geological Survey of Kansas. *B,* View of High Plains surface, SE cor. sec. 20, T. 9 S., R. 42 W. View looking northwest along furrows of drilled wheat.

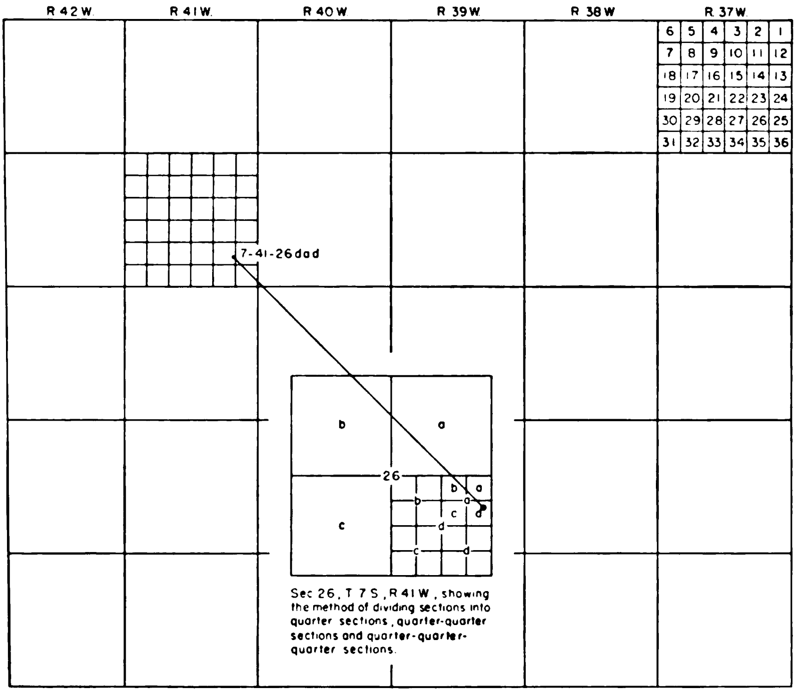


FIG. 2.—Map of Sherman County illustrating the well-numbering system used in this report.

ACKNOWLEDGMENTS

I am indebted to many residents of Sherman County who gave permission to measure their wells and supplied other helpful and pertinent information. Special thanks are extended to owners of irrigation wells who permitted pumping tests on their wells to be made. A. J. Foust of Goodland furnished logs of several irrigation wells and test holes and Dan Kramer, driller from Goodland, and Charles Harmon, driller from Kanorado, furnished information on wells in the county.

The manuscript for this report has been critically reviewed by several members of the Federal and State Geological Surveys: by Robert V. Smrha, Chief Engineer, and George S. Knapp, Engineer, of the Division of Water Resources of the Kansas State Board of Agriculture; and by Dwight F. Metzler, Director, and W. O. Hilton, Geologist, of the Division of Sanitation of the Kansas State Board of Health. The illustrations were drafted by Woodrow W. Wilson

and Joseph C. Weakly of the Federal Geological Survey. The manuscript was typed by Wanda H. Hansen.

GEOGRAPHY

Topography and Drainage

Sherman County lies entirely within the High Plains section of the Great Plains physiographic province. The county consists of nearly flat to gently rolling uplands (Pls. 3B, 4A) dissected in several areas by relatively shallow valleys. The upland plains surface slopes gradually eastward at the rate of about 13 feet to the mile. The maximum relief of the county is about 700 feet. The highest point is about 8 miles south of Kanorado where the altitude of the surface is about 4,000 feet. At several localities in southeastern Sherman County the altitude is approximately 3,300 feet.

Common features of the nearly flat upland plains are the numerous shallow undrained depressions (shown on Pl. 1 as intermittent ponds) which range from a few tens of feet to more than half a mile in diameter. After a heavy rain many of these depressions hold water, thus becoming temporary ponds. Some of the larger and deeper depressions contain water for many weeks or months after rains (Pl. 4). The relation of these depressions to ground-water recharge is discussed on page 43 and the theories of their origin are discussed on pages 28 and 29.

Sherman County contains the headwater areas of North and South Forks of Sappa Creek. The county is crossed by Beaver Creek, North Fork Beaver Creek, and North Fork Smoky Hill River. All streams drain northeastward or eastward with the exception of North Fork Smoky Hill River, which flows southeastward as it leaves the county. Most streams are intermittent, flowing only during and after rains. In 1949, a year of above average precipitation, the northeastern part of Beaver Creek had a continuous flow of a few gallons a minute as did North Fork Smoky Hill River in its eastern reaches in Sherman County.

Climate

The climate of Sherman County is of the semiarid type and is characterized by abundant sunshine, moderate precipitation, and a high rate of evaporation. During the summer the days are hot, but the nights are generally cool. The summer heat is relieved by good wind movement and low relative humidity. The winters

PLATE 4.—Undrained upland depressions in Sherman County. *A*, Small undrained upland depression of the "buffalo wallow" type in the NW¼ SW¼, sec. 11, T. 9 S., R. 42 W., looking north. *B*, Large undrained depression in sec. 2, T. 9 S., R. 40 W. View looking southwest. Depression is larger than typical undrained upland depressions and may have been formed by collapse of underlying beds.

generally are moderate with occasional severe cold periods of short duration and relatively little snowfall.

According to the U. S. Weather Bureau, the normal mean annual temperature at Goodland is 51.9° F. The lowest temperature on record is —23° F. on December 9, 1919, and the highest temperature recorded is 111° F. on July 25, 1940. The average length of the growing season is 161 days and has ranged from extremes of 131 to 190 days. Killing frosts have occurred as late as May 27 and as early as September 20.

The normal annual precipitation at Goodland reported by the U. S. Weather Bureau is 17.98 inches. The lowest annual precipitation reported is 10.52 inches in 1934 and the highest is 30.89 inches in 1915. About 77 percent of the precipitation falls during the 6 months from April through September when the growing season is at its height and moisture is needed. The annual precipitation from 1906 to 1950 and the cumulative departure from normal precipitation at Goodland are shown on Figure 3; the normal monthly precipitation is shown on Figure 4.

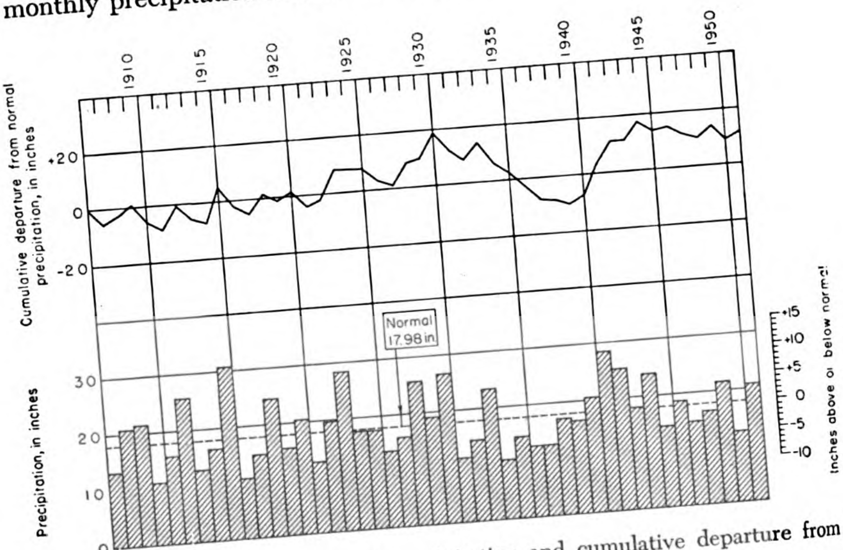


FIG. 3.—Graphs showing annual precipitation and cumulative departure from normal precipitation at Goodland.

POPULATION

According to the 1950 Federal census, the population of Sherman County was 7,373; and for 1946, the Kansas State Board of Agriculture reported a population of 6,402. In 1886, at its date of organization, the county had 2,820 inhabitants. By 1890 the population had risen to 5,632 but by 1900 had declined to 3,341. The population increased to 5,592 in 1920, to 7,400 in 1930, but dropped to 7,352 in 1940.

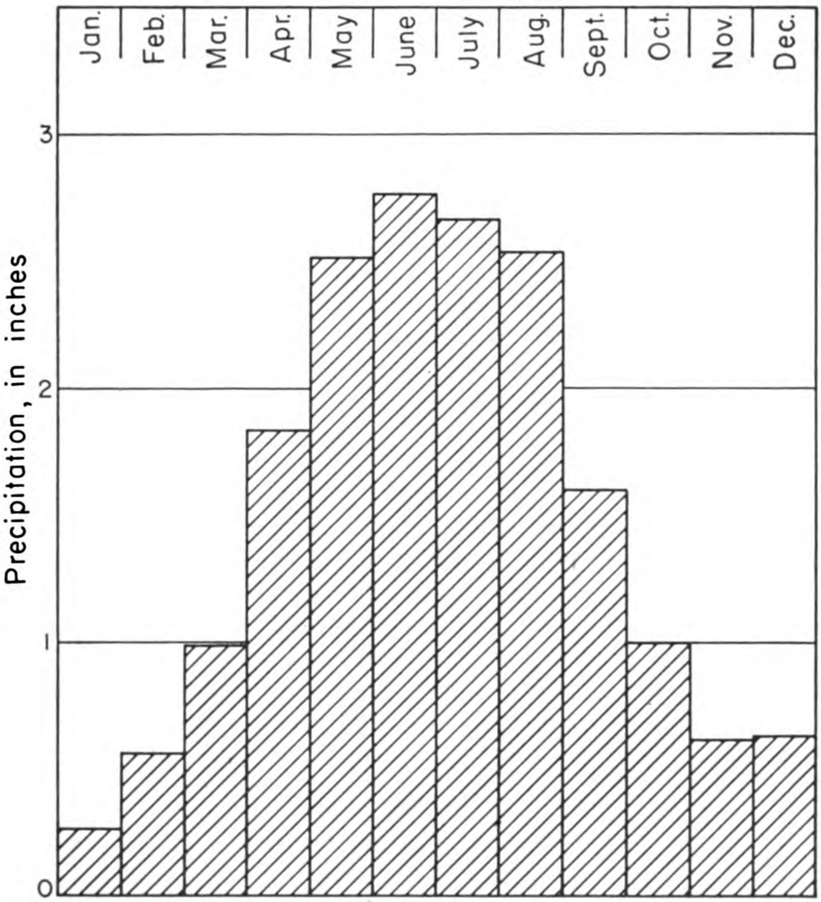


FIG. 4.—Graph showing the normal monthly precipitation at Goodland.

Goodland, the county seat of Sherman County, had a population of 3,306 in 1940, and 4,690 in 1950. Kanorado had 359 inhabitants in 1940 and 285 in 1950. Sherman County ranks 70th in population among the 105 counties within the State.

TRANSPORTATION

Sherman County is crossed by the main line of the Chicago, Rock Island and Pacific Railway Company, which crosses the county from east to west through Edson, Goodland, Ruleton, and Kanorado.

Two hard-surfaced highways traverse Sherman County. The east-west trending U. S. Highway 24 bisects the county and is roughly parallel to the railroad. State Highway 27 extends from north to south across the county and passes through Goodland. Most of the remainder of the county is served by improved county or township roads.

Agriculture

Agriculture is the chief occupation in Sherman County. According to the Thirty-sixth Biennial Report of the Kansas State Board of Agriculture, there were 584 farms in the county in 1948. The approximate acreage of the county is 675,200, most of which is in farmland. In 1948, major crops were harvested from 221,185 acres. Wheat was the principal crop, about 82 percent of the cultivated acreage being used for its production. The acreage of major crops grown in 1948 is shown in Table 1. A very small acreage is irrigated. A large percentage of the land area is in pasture.

Mineral Resources

Sherman County has no known mineral resources of great economic importance. Sand and gravel, used extensively for road-surfacing material, is obtained from alluvium along stream channels and from the Ogallala formation. There has been some exploration for oil and gas, but thus far it has been relatively unsuccessful. At Goodland a well owned by A. R. Tompkins yields enough gas from the lower part of the Pierre shale or upper Niobrara formation to supply one house. Gas is not known to occur in commercial quantities in the county.

GEOLOGY

Summary of Stratigraphy*

The rocks cropping out in Sherman County are of sedimentary origin and range in age from late Cretaceous (Gulfian) to Recent (Pl. 1). The Pierre shale (Cretaceous), oldest outcropping rock in Sherman County, crops out in a few places along the southern border and underlies the entire county.

Except where it has been removed by erosion and the Pierre is exposed, the Ogallala formation (Pliocene) overlies the Pierre shale throughout the county. It is exposed in bluffs along some of the

* The geologic classification and nomenclature of this report follow the usage of the State Geological Survey of Kansas and differ somewhat from those used by the U. S. Geological Survey.

TABLE 1.—*Acreage of major crops grown in Sherman county in 1948**

Crop	Acreage
Wheat	182,000
Corn	3,500
Oats	4,200
Barley	8,470
Rye	170
Sorghum:	
For grain	3,980
For forage	15,510
For silage	1,470
Potatoes	5
Hay (including alfalfa)	1,880
Total	221,185

* Data from 36th Biennial Report of the Kansas State Board of Agriculture (1948), p. 377.

stream valleys (Pl. 5A), but is commonly covered by a thick deposit of wind-blown silt (loess), which is the Sanborn formation (Pleistocene). Colluvial materials derived partly from the underlying Pliocene bedrock, but mainly from the loess mantle, cover some of the slopes. For convenience, these slope deposits are included with the Sanborn formation on the geologic map. The youngest deposits, Recent in age, consist of sand, gravel, and silt under the channels and flood plains of several of the streams that cross the county. The character and water-bearing properties of the geologic formations are described briefly in Table 2; more detail is given in the section on geologic formations and their hydrologic properties. The stratigraphic relations of the formations are shown in the geologic cross sections through Sherman County (Figs. 5 and 6).

Geologic History

PALEOZOIC ERA

In the earliest part of the Paleozoic Era, the part of the west-central United States in which Sherman County is situated was above sea level. Submergence of the land began in middle Cambrian time, and an interior sea covered the area until some time during the Ordovician Period when the area was uplifted. Rocks

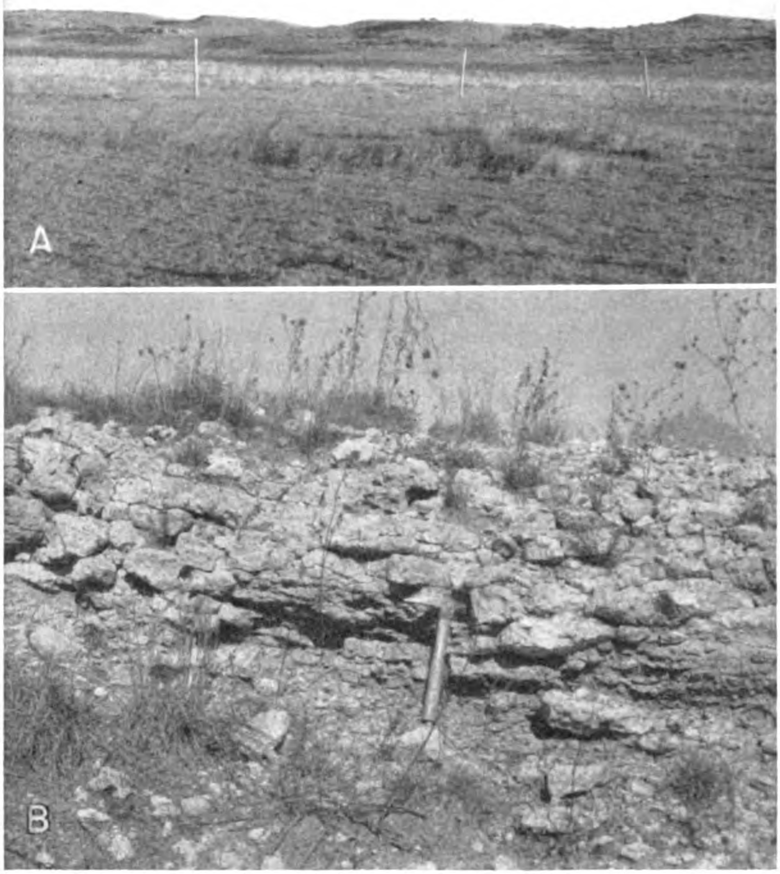


PLATE 5.—*A*, Bluffs formed by beds of the Ogallala formation in the SW¼ sec. 13, T. 10 S., R. 40 W., south of the North Fork Smoky Hill River. View looking southeast. *B*, "Algal limestone" of Ogallala formation in cut made by Chicago, Rock Island and Pacific Railway Company, SE¼ sec. 23, T. 8 S., R. 42 W.

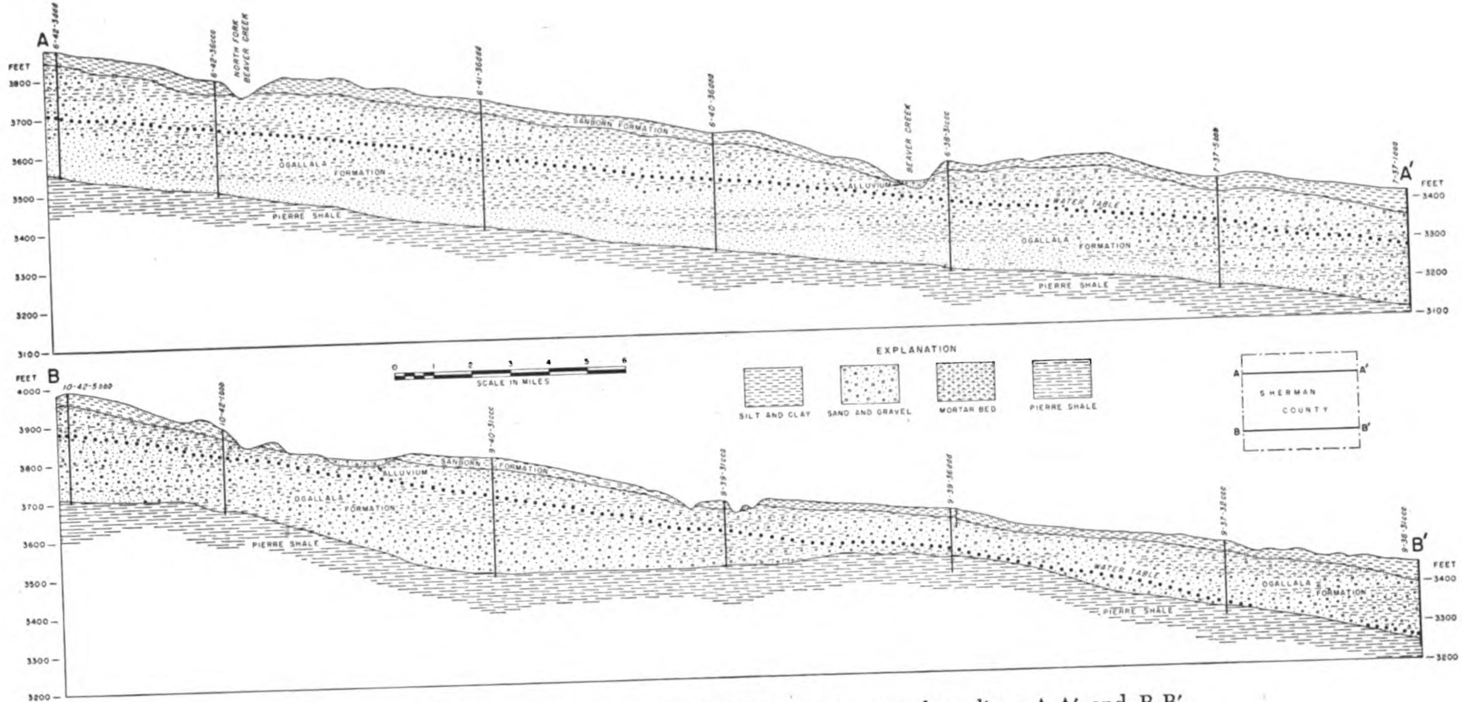


FIG. 5.—Geologic cross sections through Sherman County along lines A-A′ and B-B′.

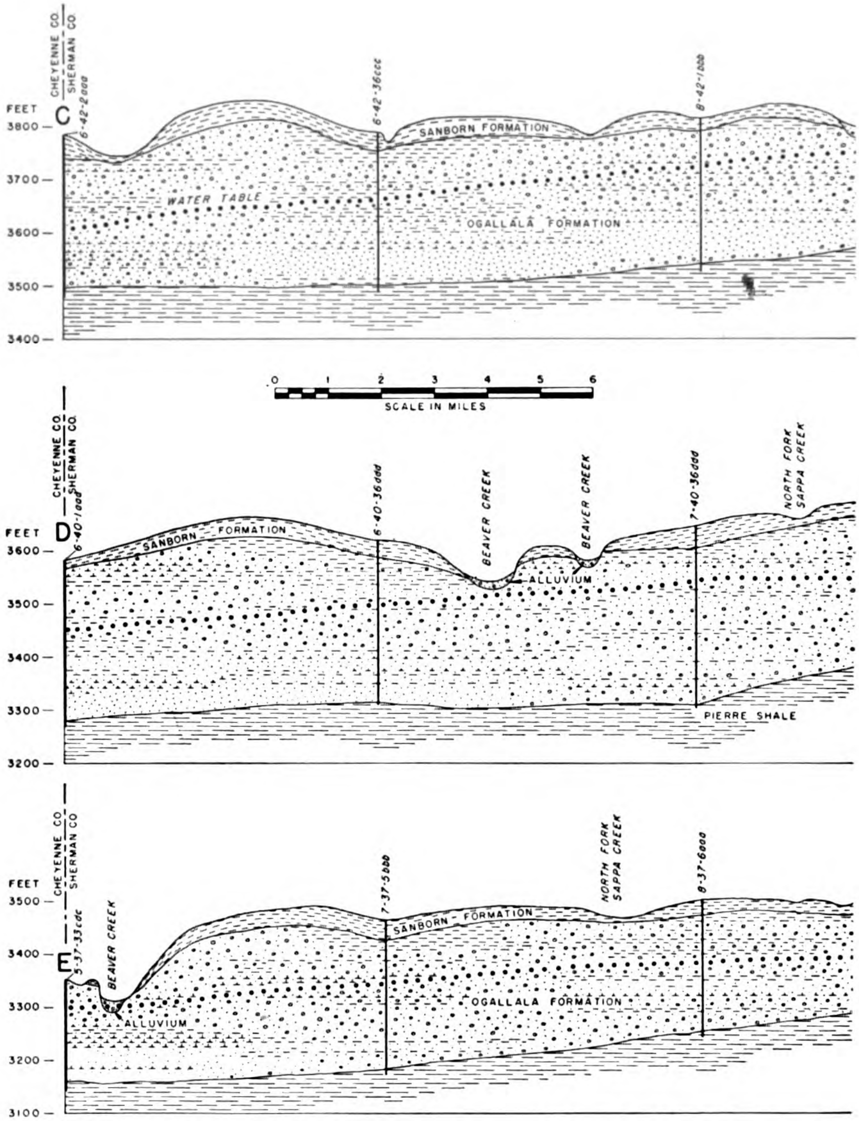
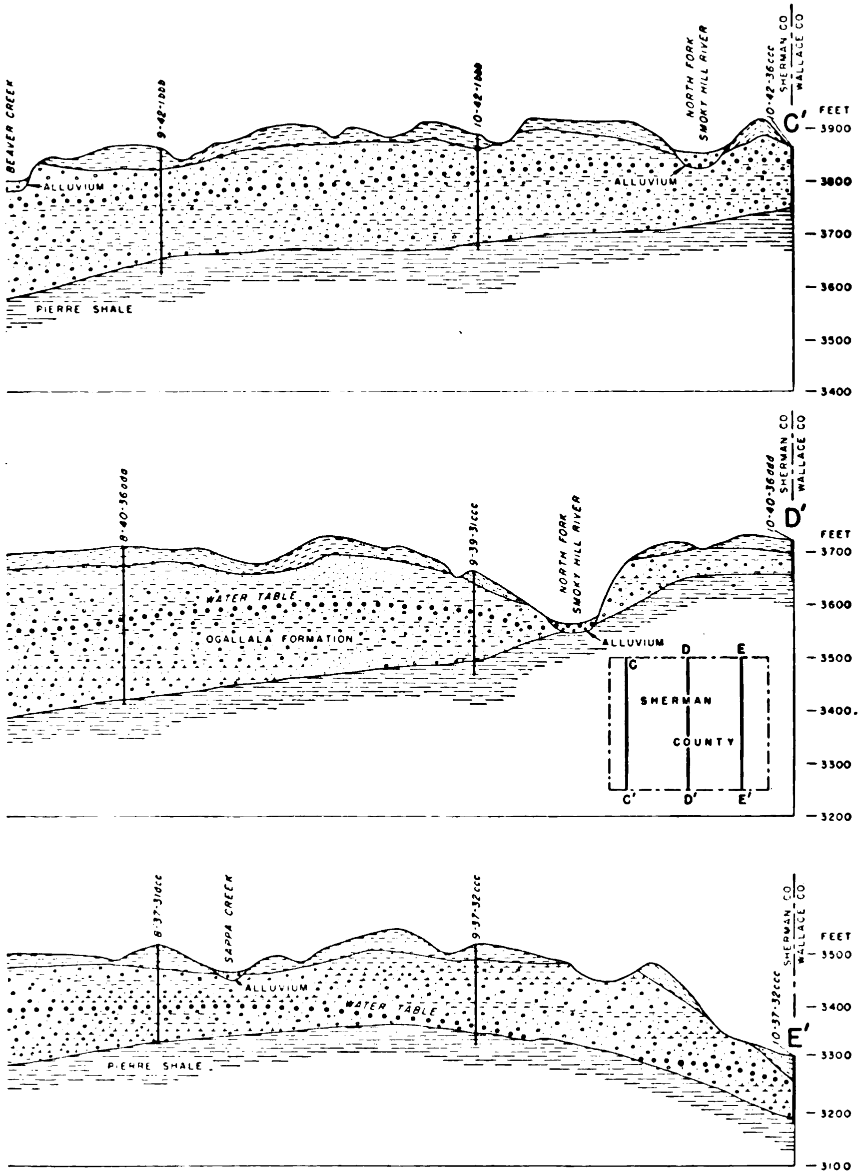


FIG. 6.—Geologic cross sections through



Sherman County along lines C-'C, D-'D, and E-E'.

TABLE 2.—*Generalized section of the geologic formations in Sherman county*

SYSTEM	Series	Formation	Thickness (in feet)	Character	Water supply
Quaternary	Pleistocene*	Alluvium	0–35	Sand, gravel, and silt along most of the stream valleys.	Commonly above water table except along parts of Beaver Creek and North Fork Smoky Hill River where it yields moderate quantities of water to wells.
		Sanborn formation	0–50	Silt, tan to reddish-brown, in places contains much very fine sand and locally contains sand and gravel at the base.	Lies above the water table and yields no water to wells in this area.
Tertiary	Pliocene	Ogallala formation	0–300	Sand, gravel, and silt, predominantly calcareous; may be consolidated or unconsolidated; contains limestone beds and a volcanic ash bed.	Yields moderate to large supplies of water to wells in most of the county.
Cretaceous	Gulfian*	Pierre shale	600–900 ±	Shale, dark-gray to black.	Yields a small quantity of water to a few wells in southern Sherman County

* The classification is that of the State Geological Survey of Kansas.

deposited during Cambrian and Ordovician time are represented in the subsurface of western Kansas by the Arbuckle group (Cambrian and Ordovician in age) and the Viola limestone (Ordovician). According to Ver Wiebe (1946, p. 107) an oil test drilled in the SW¼ sec. 20, T. 10 S., R. 38 W. encountered the Arbuckle group at 5,382 feet; at 5,640 feet, when drilling ceased, the Arbuckle had not been penetrated completely.

Silurian and Devonian rocks probably do not underlie Sherman County. A low land mass or a shallow sea may have been present, but so far as is known there was no deposition or erosion during this time. During early Mississippian time the land subsided, and deep-water marine deposition followed. Deposits of marine dolomitic limestone and shale were laid down in this area during early Mississippian time. In late Mississippian time the sea withdrew, and early Mississippian strata were eroded. In Pennsylvanian time, subsidence and uplift alternated, resulting in the deposition of both marine and continental rocks, consisting of sandstone, shale, limestone, and coal. During the Permian Period, emergence predominated over submergence and sediments were deposited in shallow basins or on low plains. The deposits consist of red shale and sandstone which contain beds of salt, anhydrite, and gypsum, indicating that arid conditions prevailed during the Permian.

MESOZOIC ERA

The Paleozoic Era in western Kansas was probably terminated by an uplift that brought the region above sea level where it remained during Triassic time and early Jurassic time. In late Jurassic time the land subsided and sediments which were deposited have been tentatively correlated with the Morrison formation. These deposits consist of about 60 feet of light-green, gray, and red shale which contains much rose to milky-white jasperlike chert in the lower part. Rocks of Jurassic age are not present in much of western Kansas, but have been identified in drill cuttings in Sheridan County (Ver Wiebe, 1940, p. 104) and in Logan, Gove, and Trego Counties (Landes and Keroher, 1939, p. 25). Deposition was ended by an uplift near the end of the Jurassic or in early Cretaceous time. This uplift was not of long duration and during late Comanchean time, the sandstones and shales of the Cheyenne sandstone were deposited either by streams or in a shallow sea.

The land was next submerged under a moderately deep sea and the Kiowa shale was deposited. Following the deposition of the Kiowa, conditions similar to those when the Cheyenne was deposited reoccurred, and the sandstones, shales, and clays of the Dakota formation were deposited. The Dakota is a fresh-water deposit that was laid down on a beach or near the shore during an uplift of the land. In earlier reports on Sheridan County (Ver Wiebe, 1940, p. 104) and on Logan, Gove, and Trego Counties (Landes and Keroher, 1939, p. 24) no attempts were made to distinguish the Cheyenne and Kiowa from the Dakota. A study of samples of cuttings from an oil-test well drilled in the SW cor. sec. 20, T. 10 S., R. 38 W., on the Cogswell ranch indicates that 450 feet of sediments, consisting mainly of sandstone, shale, and clay, are included in the interval between the Graneros shale, above, and the Morrison formation, below. Of this, 380 feet is considered to be Dakota formation and the remaining 70 feet is correlated with the Cheyenne and Kiowa formations.

During most of the remainder of the Cretaceous Period, marine conditions prevailed in this area and hundreds of feet of shale, limestone, and chalk were deposited. These formations in order of deposition are: the Graneros shale, the Greenhorn limestone, the Carlile shale, the Niobrara formation, and the Pierre shale. The presence of numerous thin beds of bentonitic clay in these formations indicates that at different times volcanic ash was blown into the seas in which sediments were being deposited. The ash settled in layers and was subsequently altered to bentonite.

CENOZOIC ERA

Tertiary Period

In early Tertiary time there was extensive uplift in the Rocky Mountain province. While streams from the mountains were laying down widespread sheets of sand, gravel, and silt in the region to the north, the land surface of western Kansas was being eroded and any sediments that might have been deposited in earliest Tertiary time together with varying thicknesses of Upper Cretaceous sediments were removed. The configuration of the land surface at the end of this early Tertiary erosion is shown by the contact between the Ogallala formation and Pierre shale in Figures 5 and 6 and by contours in Figure 7. In Pliocene time conditions were reversed, probably due to differential uplift of the land, and streams from the Rocky Mountains made extensive deposits of sand, gravel, silt, and clay that comprise the Ogallala formation over the High Plains surface. As deposition proceeded, bedrock divides were buried deeper and deeper, and by the end of deposition the erosional plain in the

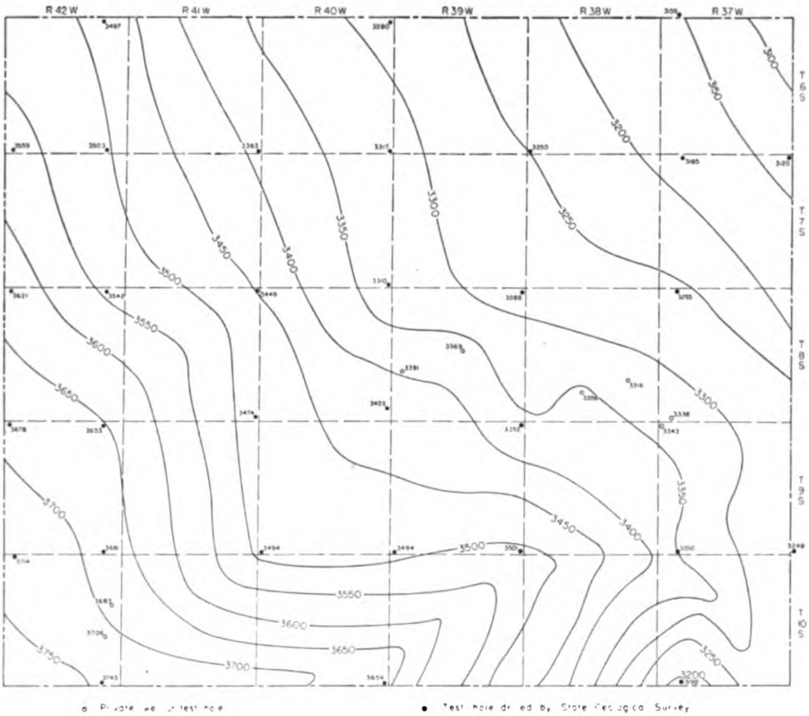


FIG. 7.—Map of Sherman County showing the configuration of the bedrock surface beneath Tertiary deposits by means of contours, and the locations of test holes.

Rocky Mountain region merged with the aggradational plain in the Great Plains.

At many localities there is a distinctive hard bed of limestone at the top of the Pliocene Ogallala formation. This limestone was described by Elias (1931, pp. 136-141) and named the "*Chlorellopsis* limestone" or "Algal limestone" from the presence of the abundant remains of the fossil alga, *Chlorellopsis bradleyi* (Pl. 5B). Elias (1931, p. 141) believed that the limestone was deposited on the bottom of a very large shallow lake near the close of Ogallala time. He advocated the lacustrine origin because living algae related to *Chlorellopsis* are not known to precipitate calcium carbonate in running waters. It is probable that no single large lake existed, but rather many small lakes. Near the end of Ogallala deposition stream gradients were low and stream channels became choked with sediments. This may have caused lateral shifting of channels and may have resulted in the formation of many lakes, for the most part disconnected and occupied by still water.

Quaternary Period

Pleistocene Epoch.—During early Quaternary time the land to the west was uplifted and streams in western Kansas began to cut through the Pliocene deposits. Later, sedimentation was resumed and alluvial deposits of sand and gravel were deposited along some of the major stream valleys. A history of successive periods of stream erosion and deposition is shown by the terraces of major valleys east of Sherman County (Frye, Leonard, and Hibbard, 1943; Frye and Leonard, 1949), but if there are alluvial deposits of more than one age in Sherman County, the different ages have not been determined. It is possible that some of the gravel beds to the south in Wallace County that Elias referred to as the basal part of the Sanborn formation (1931, p. 163) were laid down during this time. Later in Pleistocene time winds became strong. A layer of wind-blown silt (loess) was deposited over the area to depths of as much as 50 feet. The loess and underlying sand and gravel were named Sanborn formation by Elias (1931, p. 163).

During Recent time the county has undergone erosion that has formed much of its present topography. Streams have cut deeply into Pliocene deposits and along the eastern reach of North Fork Smoky Hill River the Ogallala formation has been removed and the Pierre shale is exposed. The loess mantle has been modified by the action of sheet and rill wash, and some slopes are covered by thick colluvial deposits that have moved down from the uplands by slope processes. In many places these slope deposits are contiguous with alluvium, which occupies the floors of most of the stream valleys, and the boundary between the two is usually indistinct.

During Recent time, many shallow depressions have developed on the upland areas in Sherman County and in many areas in the High Plains. The depressions range from a few tens of feet to about half a mile in diameter. Most of them hold water after periods of heavy rainfall until the water has evaporated or percolated into the soil.

The origin of the depressions has been a perplexing problem to geologists for many years; several theories of origin have been offered. Darton (1916, pp. 36-37) referred to some of these High Plains depressions as "buffalo wallows" and explained their origin by the action of buffaloes and wind. He believed that the depressions were started by buffaloes, either at wet, salty, or alkali spots, and that they were excavated by tramping hoofs and by mud sticking to the shaggy coats of the animals during wet periods. After breaking of the sod cover, wind scour became the dominant mode of erosion during dry periods. This hypothesis might account for some of the small depressions having depths of 10 feet or less (Pl. 3B), but seems inadequate for the larger, more extensive depressions (Pl. 3A).

For large depressions or basins in areas of Permian bedrock, Johnson (1901, pp. 702-712) advocated an origin by solution of soluble beds of the Permian followed by collapse of the overlying beds and development of surface depressions. This theory explains satisfactorily the origin of large sinks such as Salt Well in Meade County and Big Basin and St. Jacob's Well in western Clark County, but does not adequately explain the origin of depressions—especially small shallow depressions—in areas of thick Cretaceous bedrock. Johnson believed that a grain-by-grain process of compaction and readjustment within the Tertiary alone was responsible for the innumerable small upland depressions in areas of thick Cretaceous bedrock. Concerning the mechanics of the compaction process, he stated (1901, pp. 703, 704):

> Appearances indicate basining of the alluvial surface as a consequence, first, of rain water accumulation in initial faint unevenesses of the plain; second, of percolation of this ponded surface water downward to the ground water in largely increased amount from these small areas of concentration, rather than from over the whole surface uniformly, with the result that the alluvial mass is appreciably settled beneath the basins only. The inference is at once suggested that this settlement takes place as the combined effect of mechanical compacting of the ground particles and the chemical solution of the more soluble particles. Finally, these effects should be cumulative, resulting in the growth noted, since, with enlargement of the basins, concentration of rain water within them will be on an increased scale.

Hay in 1895 (pp. 555-556) described the development of sink holes in Sherman County, which were discovered after a very hard rain in May 1894. Hay remarked:

> The storm of last May probably only completed a process of widening natural channels that percolating waters had been busy performing for ages.

Hay's idea on the formation of sink holes is similar to Johnson's compaction hypothesis. This hypothesis seems to fit best several large depressions in Sherman County, especially those in the NW¼ sec. 26, T. 8 S., R. 42 W., and in the Cen. sec. 2, T. 9 S., R. 40 W. The former is about 35 feet deep and the latter is approximately 60 feet deep. The depressions are too large and deep to be explained by the "buffalo wallow" theory and the thickness of the Ogallala formation and Pierre shale are prohibitive to Johnson's theory of the solution of soluble beds. Many of the smaller depressions could have been caused by buffaloes but Johnson's compaction theory seems to be the most adequate explanation.

GROUND WATER

Principles of Occurrence

The following discussion of the occurrence of ground water has been adapted from Meinzer (1923, pp. 2-102) and the reader is referred to his report for a more detailed discussion.

All water beneath the surface of the earth is termed subsurface water. The part of subsurface water that is in the zone of saturation is termed ground water or phreatic water whereas subsurface water above the zone of saturation—that is, in the zone of aeration—is called suspended subsurface water or vadose water. Ground water is the water that is obtained from wells and springs.

The rocks that form the outer crust of the earth are seldom entirely solid, but have numerous open spaces, called voids or interstices, which may contain air, natural gas, oil, or water. The interstices in rocks range in size from microscopic openings to the large caverns that are found in some limestones. The open spaces are generally connected so that water may percolate from one to another, but in some rocks the interstices are isolated and the water has little or no chance to move. The occurrence of water in the rocks of any region is determined by the character, distribution, and structure of the rocks, that is, by the geological character of the region.

The porosity of a rock is its property of containing interstices. It is expressed quantitatively as the percentage of the total volume of the rock that is occupied by interstices. A rock is said to be saturated when its interstices are filled with water or other liquid and the porosity is practically the percentage of the total volume of rock that is occupied by the liquid. The porosity of a rock determines only the amount of water a given rock can hold, not the amount it may yield to wells. A rock may be very porous but may yield very little water to wells if interstices are small or disconnected. The specific yield of a water-bearing formation is defined as the ratio of the volume of water which, after being saturated, the formation will yield by gravity to its own volume. Specific yield is a measure of the yield of a water-bearing material when it is drained by a lowering of the water table. The permeability of a water-bearing material is defined as its capacity for transmitting water under hydraulic head and is measured by the rate at which the formation will transmit water through a given cross section under a given difference of head per unit of distance. A rock containing small interstices may be very porous, but water may pass through it with difficulty, whereas a coarser-grained rock, although perhaps less porous, is generally more permeable and allows water to pass through it more freely because the interstices are larger. A part of the water in all rocks is held by the force of molecular attraction, which, in fine-grained rocks, is great enough to hold most of the water against the force of gravity, thus resulting in a very low specific yield. Several common types of open spaces or interstices and the relation of texture to porosity are shown in Figure 8.

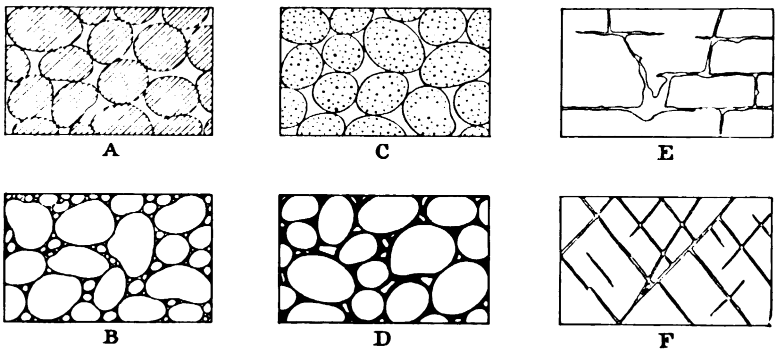


FIG. 8.—Diagram showing several types of rock interstices and the relation of rock texture to porosity. *A*, Well-sorted sedimentary deposit having a high porosity; *B*, poorly sorted sedimentary deposit having low porosity; *C*, well-sorted sedimentary deposit consisting of pebbles that are themselves porous so that the deposit as a whole has a very high porosity; *D*, well-sorted sedimentary deposit whose porosity has been diminished by the deposition of mineral matter in the interstices; *E*, rock rendered porous by solution; *F*, rock rendered porous by fracturing. (From O. E. Meinzer.)

The upper surface of the zone of saturation is called the ground-water table or more simply the water table. All the rocks above the water table are in the zone of aeration, which usually consists of three parts: the belt of soil water; the intermediate or vadose zone; and the capillary fringe.

The belt of soil moisture lies just below the land surface and contains water held by molecular attraction. The thickness of the soil-moisture zone is dependent upon the character and thickness of the soil and upon the precipitation and vegetation.

The intermediate zone lies between the belt of soil moisture and the capillary fringe. In this zone the interstices in the rocks contain some water held by molecular attraction but also may contain appreciable quantities of water while it is moving downward from the belt of soil water to the water table. In Sherman County the intermediate zone may be absent along some river valleys where the water table is near the surface, or it may be nearly 200 feet thick in some upland areas.

The capillary fringe lies directly above the water table where water rises from the saturated zone by capillary action. The water in the capillary fringe is not available to wells, and wells must be deepened to the saturated zone before water will enter them. The capillary fringe is thin in coarse-grained sediments, but it may be several feet thick in fine-grained sediments.

Gravel is an excellent water-bearing material. Gravel deposits of uniform texture have high porosity, high permeability, and high specific yield. In some deposits, clay, silt, or sand is mixed with the gravel, reducing its porosity, permeability, and specific yield. Most of the gravel deposits in Sherman County contain much silt and sand and some are cemented with calcium carbonate which also reduces yields of wells.

Sand ranks next to gravel as a water bearer. Sand differs from gravel in having smaller interstices; therefore it conducts water less readily and will give up a smaller proportion of water to wells. Sand consists of smaller particles than gravel and is more readily carried into wells by water, thus causing problems in connection with drilling and pumping.

Most of the ground water pumped in Sherman County comes from sand and gravel beds of the Ogallala formation with a lesser amount coming from alluvial sand and gravel. One well included in the inventory (well 11-40-1bcc, in Wallace County) is thought to derive water from the Pierre shale, which underlies the Ogallala. Shale is a very unfavorable material from which to obtain water. If not too tightly indurated, it may be highly porous and contain water. However, the interstices between individual particles are small and water is held by molecular attraction and is not readily available to wells. Some water is found in shale along joints and bedding planes.

Permeability of the Water-Bearing Materials

The rate of movement of ground water is determined by the size, shape, quantity, and degree of connection of the interstices, and by the hydraulic gradient. The capacity of a water-bearing material to transmit water under hydraulic head is its permeability. The coefficient of permeability in Meinzer's units may be expressed as the rate of flow of water in gallons a day through a cross-sectional area of 1 square foot under a hydraulic gradient of 100 percent at a temperature of 60° F. (Stearns, 1927, p. 148). The coefficient of transmissibility is defined as the number of gallons of water a day transmitted through each vertical 1-foot strip extending the saturated thickness of the aquifer under a unit gradient (Theis, 1935, p. 520). The coefficient of transmissibility also may be expressed as the number of gallons of water a day transmitted through each section 1 mile wide extending the saturated thickness of the aquifer under a hydraulic gradient of 1 foot to a mile. The coefficient of transmissibility is equivalent to the coefficient of permeability multiplied by the saturated thickness of the aquifer.

Pumping Tests

The transmissibility of water-bearing materials in Sherman County was determined by three pumping tests using the recovery method involving the formula developed by Theis (1935, p. 522) and later described by Wenzel (1942, pp. 94-96). The formula as stated by Theis is as follows:

$$T = \frac{264q}{s} \log_{10} \frac{t}{t_1}$$

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

q = pumping rate, in gallons a minute
t = time since pumping started, in minutes
t_1 = time since pumping stopped, in minutes
s = residual drawdown at the pumped well, in feet, at time t_1

The residual drawdown (s) is computed by subtracting the static water level measurement from depth to water level measurements made after pumping ceases. The ratio of $\log_{10} \frac{t}{t_1}$ to s is determined graphically by plotting $\log_{10} \frac{t}{t_1}$ against corresponding values of s. This procedure is simplified by plotting $\frac{t}{t_1}$ on the logarithmic co-ordinate and s on the arithmetic co-ordinate of semi-logarithmic paper (Fig. 9). If $\log_{10} \frac{t}{t_1}$ is taken over one log cycle it will become unity and s will be the difference in drawdown over one log cycle.

Well 7-39-20bad, an irrigation well on the Rhoads farm, was pumped for approximately 4 hours on July 29, 1949. Drawdown measurements, using the wetted tape method, were made during the period of pumping, and recovery measurements were made for 2¾ hours after the pump was shut down. The average pumping rate was 1,170 gallons a minute (determined by a Collins flow gage). The drawdown at the end of pumping was about 16 feet and the specific capacity (determined by dividing the yield by the drawdown) was about 73 gallons a minute for each foot of drawdown.

The computations for transmissibility and permeability are as follows:

$$T = \frac{264 \times 1{,}170 \times 1}{0.78} = 396{,}000 \text{ g.p.d./ft.}$$

$$P = \frac{396{,}000}{120} = 3{,}300 \text{ g.p.d./ft.}^2$$

The transmissibility is computed as 396,000 gallons per day per foot and the coefficient of permeability, determined by dividing the transmissibility by the thickness of the aquifer, which is 120 feet, is 3,300 gallons per day per square foot.

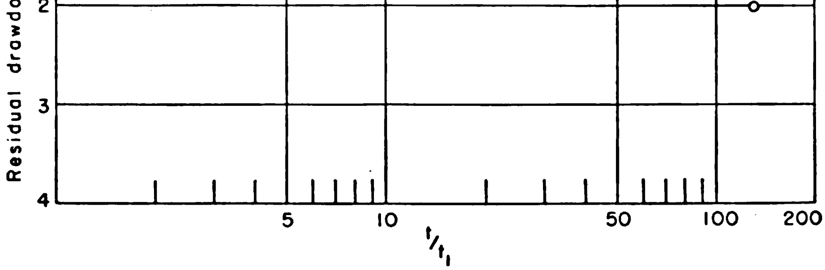


FIG. 9.—Curve for pumping test on well 7-39-20bad obtained by plotting residual drawdown against t/t_1.

The time versus drawdown curve for the pumping test on well 7-39-20bad is shown in Figure 9 and data that were plotted to obtain this curve are shown in Table 3. Data on two other pumping tests are given in Tables 4 and 5 and results of all three tests are given in Table 6.

TABLE 3.—*Data on pumping test of well 7-39-20bad, made on July 29, 1949*

Time since pumping started, minutes	Time since pumping stopped, minutes	t/t_1	Depth to water level, feet	Drawdown, feet
			22.23 (static water level)	
10	....	....	38.40	15.17
40	....	....	37.40	15.17
70	....	....	38.00	15.77
100	....	....	38.00	15.77
130	....	....	38.00	15.77
160	....	....	38.00	15.77
190	....	....	37.82	14.59
220	....	....	....	....
250	....	....	37.90	15.67
261	2	130.5	24.27	2.04
263	4	65.8	23.78	1.55
265	6	44.1	23.61	1.38
267	8	33.4	23.49	1.26
270	11	24.5	23.38	1.15
275	16	17.2	23.29	1.06
285	26	11.0	23.16	0.93
295	36	8.2	23.08	0.85
310	51	6.8	22.98	0.75
330	71	4.6	22.87	0.64
350	91	3.8	22.80	0.57
380	121	3.1	22.75	0.52
410	151	2.7	22.70	0.47

TABLE 4.—*Data on pumping test of well 8-39-15ccc, made on August 4, 1949*

Time since pumping started, minutes	Time since pumping stopped, minutes	t/t_1	Depth to water level, feet	Drawdown, feet
			127.78 (static water level)	
20	....	....	158.00	30.22
50	....	....	158.00	30.22
80	....	....	160.00	32.22
110	....	....	159.20	31.42
140	....	....	158.75	30.97
170	....	....	159.50	31.72
200	....	....	158.00	30.22
230	....	....	....	....
260	....	....	160.00	32.22
290	....	....	157.55	29.77
325	....	....	....	....
350	....	....	160.70	32.92
380	....	....	156.25	28.47
410	....	....	158.70	30.92
450	....	....	160.00	32.22
470	....	....	160.00	32.22
500	....	....	160.00	32.22
530	....	....	160.00	32.22
560	....	....	162.00	34.22
598	3	199.3	154.42	26.64
600	5	120.0	135.39	7.61
602	7	86.0	134.50	6.72
604	9	67.1	133.96	6.18
606	11	55.1	133.50	5.72
616	21	29.3	132.10	4.32
622	27	23.0	131.49	3.71
625	30	20.8	131.27	3.49
632	37	17.1	130.85	3.07
646	51	12.7	130.26	2.48
664	69	9.6	129.77	1.99
686	91	7.5	129.40	1.62
713	118	6.0	129.11	1.33
741	146	5.1	128.95	1.17

TABLE 5.—*Data on pumping test of well 8-40-12dba, made on July 27, 1949*

Time since pumping started, minutes	Time since pumping stopped, minutes	t/t_1	Depth to water level, feet	Drawdown, feet
			122.76 (static water level)	
19	....	....	132.00	9.24
49	....	....	132.00	9.24
84	....	....	131.72	8.96
109	....	....	128.70	5.94
139	....	....	131.90	8.14
169	....	....	135.00	12.24
199	....	....	131.66	8.90
229	....	....	131.63	8.87
259	....	....	131.00	8.24
267	3	89.0	126.29	3.53
269	5	53.8	125.35	2.59
271	7	38.7	124.85	2.09
277	13	21.3	124.12	1.36
284	20	14.2	123.76	1.00
294	30	9.8	123.48	0.72
315	51	6.1	123.28	0.52
349	85	4.1	123.12	0.36
412	148	2.8	123.00	0.24
484	220	2.2	122.94	0.18

TABLE 6.—*Results of pumping tests made on wells in Sherman County, using Theis recovery method for determining permeability*

Well number	Average discharge, gallons a minute	Drawdown, feet	Duration of pumping, minutes	Specific capacity (1)	Coefficient of transmissibility (2)	Approximate thickness of water-bearing material, feet	Coefficient of permeability (3)
7–39–20bad	1,170	16	259	73	396,000	120	3,300
8–39–15ccc	640	32	595	20	34,000	127	266
8–40–12dba	315	9	264	35	36,000	117	309

1. The specific capacity of a well is its rate of yield per unit of drawdown and is determined by dividing the tested capacity in gallons a minute by the drawdown in feet.
2. The coefficient of transmissibility is expressed as the number of gallons of water a day transmitted through each 1 mile wide section of the saturated thickness of the aquifer, under a hydraulic gradient of 1 foot to the mile.
3. Coefficient of transmissibility divided by thickness of saturated water-bearing material.

Graphical methods developed by Jacob (1944, 1946) for determining permeability were also used in determining permeability of water-bearing materials near wells 7-39-20bad and 8-39-15ccc. Near well 7-39-20bad, two observation wells were drilled at distances of 100 and 200 feet north of the pumped well, and water-level measurements were made during the period of pumping and after pumping ceased. Drawdown at any given time in each observation well was plotted against distance from the pumped well on semi-logarithmic paper and transmissibility was computed by use of the formula

$$T = 527.7\ Q\ \frac{(\log_{10} r_2 - \log_{10} r_1)}{s_1 - s_2}$$

Another method of analysis, in which time since pumping began is plotted against drawdown on semi-logarithmic paper, was also used. Only one observation well is needed for these calculations. Results obtained for well 7-39-20bad and well 8-39-15ccc (where only one observation well was drilled) were very similar to those obtained using the Theis recovery method. Values given by using the distance-drawdown method for well 7-39-20bad do not correspond with results determined by the other two methods and are thought to be in error, perhaps because the period of pumping was not long enough.

The Water Table and Movement of Ground Water

SHAPE AND SLOPE

The water table is defined as the upper surface of the zone of saturation except where that surface is formed by an impermeable body (Meinzer, 1923a, p. 32). The shape and slope of the water table are shown by the contour lines on Plate 1. Water-table contour lines connect points of equal altitude and these lines show the configuration of the water surface just as topographic maps show the shape of the land surface. As indicated by Plate 1, the water table is not a plane surface in all parts of the county, but rather has irregularities roughly comparable to the land surface although the water table is not as rugged. The water table does not remain stationary but fluctuates due to variations in discharge and recharge. Ground water moves at right angles to the water-table contour lines in the direction of greatest downward slope.

Plate 1 indicates that ground water is moving through Sherman County in a general easterly or northeasterly direction. In southeastern Sherman County, the water table slopes southeastward. The slope of the water table seems to be controlled to some extent by the slope of the bedrock surface, for in general, the water table slopes in the direction of the slope of the bedrock floor (Fig. 7). Other factors that influence the shape and slope of the water table include: local differences in the permeability of water-bearing deposits, discharge of ground water into streams, transpiration, evaporation, pumpage, and recharge of ground water by streams.

The slope of the water table varies from place to place, but the average slope is about 15 feet to the mile in a general northeasterly direction. Ordinarily, the slope of the water table varies inversely with the permeability of the water-bearing materials. In areas where the water-bearing beds are relatively impermeable, the slope of the water table steepens, but in areas of more permeable water-bearing beds, the slope of the water table is flatter.

The discharge of ground water into streams influences the slope of the water table in Sherman County only along the eastern part of the North Fork Smoky Hill River. Here the water table slopes downward to the stream level causing the upstream flexure of the contour lines shown in Plate 1.

Recharge of ground water by ephemeral streams is probably not an important factor in the formation of any permanent irregularities in the water table. Ephemeral or intermittent streams flow only after rains. Their channels lie above the water table and are dry most of the time. In Sherman County alluvial deposits contain much sand and gravel and after rains when ephemeral streams are flowing, it is probable that much water seeps into the stream bed and moves downward to the water table. This would cause a temporary mound or ridge on the water table, but such an irregularity would not be permanent and probably would not be evident on a small-scale map such as Plate 1. The movement of ground water from influent (losing) streams and to effluent (gaining) streams is shown by the diagrammatic sections in Figure 10.

FLUCTUATIONS IN THE WATER TABLE

The water table is not a static surface but a surface that fluctuates much like the surface of a lake. The water table rises when the amount of recharge exceeds the amount of discharge and declines when the discharge is greater than the recharge. The fluctuations of the water table indicate in part the extent to which the ground-water reservoir is being depleted or replenished.

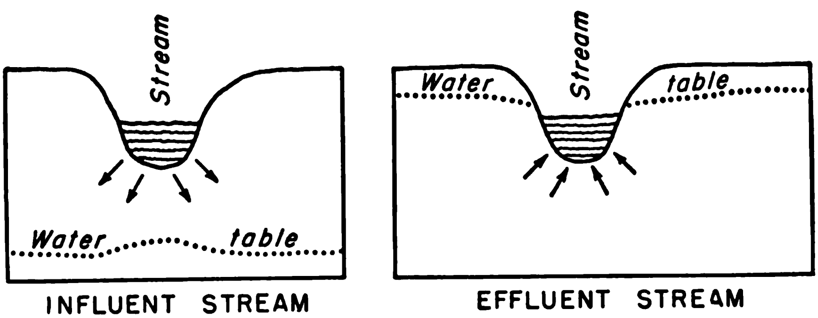


FIG. 10.—Diagrammatic sections showing influent and effluent streams.

The main factors controlling the rise of the water table in Sherman County are the amount of precipitation within the county that penetrates the ground and reaches the zone of saturation, the amount of seepage that reaches the underground reservoir from surface streams, and the amount that enters the county from the west. Factors controlling the decline of the water table are pumpage from wells, seeps and springs, evaporation and transpiration in areas where the water table is near the surface, seepage into streams, and movement of ground water from the county to adjacent areas.

Periodic water-level measurements were begun in three observation wells in Sherman County in 1948 to obtain information concerning the fluctuations of the water table. The water-level measurements will appear in forthcoming annual water-level reports of the U. S. Geological Survey.

GROUND-WATER RECHARGE

GENERAL FEATURES

Recharge, the addition of water to the ground-water reservoir, may be accomplished in several ways. All ground water available to wells in Sherman County is derived from precipitation falling as rain or snow within the area or within near-by areas to the west. Part of the water that falls as precipitation is carried away as surface runoff and is lost to streams, part evaporates, and some is absorbed by plants and returned to the atmosphere as water vapor by the process known as transpiration. Water that escapes runoff, evaporation, and transpiration, percolates slowly down through the soil and underlying strata, and part of it eventually reaches the zone of saturation.

The quantity of water that is carried away by surface runoff depends upon several factors: the intensity of rainfall, the slope of the land, the type of soil, the type and amount of vegetation, and the season.

In general, for a given amount of rainfall a greater percentage of the rainfall will enter the ground during a long gentle rain than during a torrential downpour when the percentage of runoff is large. The slope of the land is an important factor in determining the amount of runoff and the steeper the slope, the greater the amount of runoff. In much of Sherman County slopes are gentle, but there are fairly steep slopes along some of the streams. Runoff in the uplands is reduced considerably by drainage into many small basins.

The type of soil also affects the amount of runoff. In general, runoff is greater in places of tightly compacted, fine-grained soil than in places of loose sandy soil. Runoff from rainfall is greater in the winter when the frozen ground prevents infiltration.

The velocity of surface runoff is reduced by a suitable vegetative cover and water has a better chance to seep into the ground. Modern methods of land terracing and contour farming generally tend not only to retard the erosion of valuable soil but to reduce runoff and therefore increase the recharge of water to the soil and to the water table.

Most of the water from precipitation is evaporated or transpired, never having reached the water table. A large percentage of the precipitation falls during the period from May through September when temperatures are high, humidity is low, and wind movement is relatively high; consequently the rate of evaporation is high.

The water that escapes evaporation, transpiration, and runoff percolates downward into the soil zone. When the amount of water absorbed by the soil is greater than can be held by the capillary force opposing the pull of gravity, water will move from the soil zone to the saturated zone. During the growing season this downward percolation is greatly retarded by evaporation and by absorption and transpiration by plants, and at the end of the growing season moisture in the soil zone may be near depletion. During the fall and winter when evaporation and transpiration are at a minimum the soil zone may again become saturated and recharge to the water table may take place if precipitation is sufficient.

The average annual precipitation of Sherman County is about 18 inches; very little of this ever reaches the water table. The amount of annual recharge in Sherman County is not known but is very small. Frye (1942, p. 66) has estimated that in the High Plains in southwestern Kansas the average amount of ground-water recharge is about one-fourth inch, but marked differences between the geology of the two areas indicates that it is much less than this in Sherman County and is probably of the magnitude of one-tenth inch.

UPLAND AREAS

Ground-water recharge in the upland areas in Sherman County is probably very slight. The uplands are covered by a mantle of wind-blown silt (loess) which is as much as 50 feet thick in places. Although the loess generally is sandy, it is usually rather impermeable. The porosity of loess is fairly high but water percolates down through it at a very slow rate. Rodent burrows may furnish some avenues of recharge, and recharge may take place through sod cracks which develop during dry seasons. These sod cracks in places attain a width of several inches and extend along the surface for several hundred feet. Hay (1895) also considered that sod cracks were important in recharge of ground water. Several times during the test drilling in Sherman County, water circulation was lost while drilling in loess, indicating the presence of cracks or openings beneath the surface.

DEPRESSIONS

Shallow depressions are very common in the upland areas of Sherman County. The locations of some of these depressions are shown on Plate 1 as intermittent ponds. After heavy rains water collects in the depressions and forms temporary ponds. The water in some of these ponds disappears quickly, but in others it may remain for several weeks or months. Whether much ground-water recharge is derived from undrained depressions of this sort is problematical. A study of the character of deposits underlying similar depressions in the High Plains of Texas has revealed that subsurface conditions are quite varied. Several hundred test holes were drilled. It was found that some depressions were underlain by permeable beds, whereas others were underlain by relatively impermeable caliche or cemented beds (White, Broadhurst, and Lang, 1940, pp. 6-8). The floors of some depressions in Sherman County are traversed by mud cracks that develop during dry periods. It is possible that some recharge after rains may take place through these mud cracks until they are sealed over again. Other depressions have a soil cover that would seem to be an effective seal against recharge of ground water. In his hypothesis for the origin of High Plains depressions, Johnson (1901) assumed that significant quantities of water entered the ground from these depressional ponds.

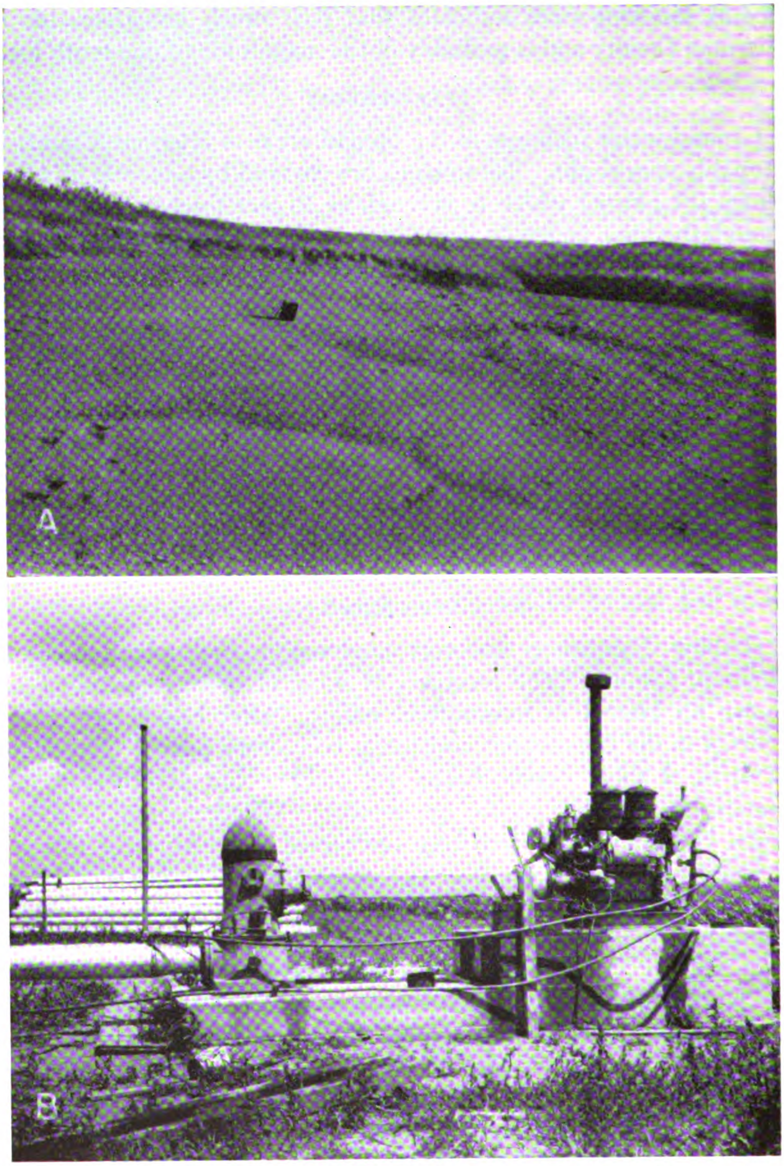


PLATE 6.—*A*, Deposits of alluvial sand and gravel along Beaver Creek. View looking east in the NE¼ SW¼ sec. 26, T. 7 S., R. 41 W. There probably is considerable ground-water recharge in such deposits during periods of stream flow. *B*, Deep-well pumping plant owned by Albert Vohs, SW cor. SE¼ sec. 28, T. 8 S., R. 38 W.

STREAMS

One of the principal sources of recharge of the ground-water reservoir in Sherman County is the loss of water from the channels of streams. With the possible exception of the southeastern part of the North Fork Smoky Hill River and the northeastern part of Beaver Creek, all streams in Sherman County are ephemeral, flowing only after periods of heavy rainfall. The alluvium in most of the stream valleys in Sherman County is rather permeable (Pl. 6A) and it is probable that during periods of stream flow, much water percolates down through the alluvium and eventually reaches the body of ground water.

SUBSURFACE INFLOW

The water-table map (Pl. 1) indicates that ground water in this area moves in a northeasterly direction. The bulk of ground water available to wells in Sherman County is derived from subsurface inflow. Estimates based on available data indicate that approximately 7 billion gallons of water enter the county annually from the west and southwest. This amount is much larger than that thought to join the water table from local precipitation in Sherman County.

Discharge of Subsurface Water

Meinzer (1923a, p. 48) has divided the discharge of subsurface water into vadose-water discharge (discharge of soil water not derived from the zone of saturation) and ground-water discharge (discharge from the saturated zone).

VADOSE-WATER DISCHARGE

The discharge of soil water not derived from the zone of saturation is called vadose-water discharge and includes the discharge of water directly from the soil by evaporation and discharge from growing plants by transpiration. The consumption of soil water by crops is large and is vitally important to agriculture. This consumption of water reduces recharge to ground water because the deficiency of soil moisture must be replenished before recharge can take place.

GROUND-WATER DISCHARGE

Ground-water discharge is discharge of water from the zone of saturation and may take place through evaporation and transpiration, by discharge from wells and springs, by seepage into streams, and by underground movement to adjacent areas.

Transpiration and evaporation.—Water may be taken into the roots of plants directly from the zone of saturation or from the capillary fringe and discharged from the plants by the process known as transpiration. The depth to which the roots of plants go for water varies with different kinds of plants and types of soil. Ordinary plants and grasses do not draw water from depths of more than a few feet; alfalfa may obtain ground water from as much as 20 or 30 feet below the surface and the roots of certain types of desert plants have been known to extend 50 or 60 feet below the surface to reach the water table (Meinzer, 1923, pp. 82-83).

Loss of ground water through direct evaporation and transpiration from the water table is probably not very great in Sherman County, where depths to water table in most areas are considerably below the roots of plants. The only places where transpiration is of much significance in ground-water discharge are in parts of the valley of the North Fork Smoky Hill River and in parts of the valley of Beaver Creek. Discharge of ground water by direct evaporation is also restricted to these areas where the water table is very shallow (Pl. 2).

Springs and seeps.—The amount of water discharged from springs in Sherman County is negligible. There are springs in some places along the North Fork Smoky Hill River where the water table intersects the ground surface. In the NE¼ sec. 33, T. 10 S., R. 39 W., a spring is at the contact between the Ogallala and Pierre formations. Water moving laterally at the base of the Ogallala formation on the top of the relatively impermeable Pierre shale flows or seeps out at the surface where the top of the Pierre is exposed.

Most of the streams in Sherman County are influent (or losing) streams, discharging water to the water table during periods of flow. However, parts of Beaver Creek and the North Fork Smoky Hill River receive water from the water table and are effluent (or gaining) streams in these areas.

Wells.—Ground water is also discharged by pumpage from wells. All domestic, railroad, and municipal water supplies and much of the livestock water supply in Sherman County are derived from wells. A relatively small quantity of ground water is pumped for irrigation. The amount of water discharge from wells for all purposes is estimated to be of the magnitude of 350 million gallons a year.

Subsurface outflow.—Before wells were drilled in Sherman County, the ground-water reservoir in the area was in a state of approximate equilibrium—that is, the average annual recharge was approximately balanced by the average annual discharge and the water table was moderately stable except for seasonal fluctuations. Ground water was added by underground movement from the west, by recharge from precipitation, and by seepage from streams. Discharge of ground water took place mainly by subsurface movement from the area with smaller amounts being discharged by evaporation and transpiration, and by seepage into streams. In spite of the additional discharge due to pumping, the dominant method of ground-water discharge in Sherman County is still by subsurface movement to adjacent areas. Measurements of ground-water discharge through subsurface outflow could not be made, but estimates based on available data indicate that subsurface outflow, predominantly to the east and north, is slightly more than 7 billion gallons a year.

Recovery of Ground Water

Principles of Recovery

When the water level in a well is at the static level there is an equilibrium between the pressure of water within the well and the pressure of water outside the well. When water is pumped from a well the pressure inside the well is reduced and water moves into the well. When water is being discharged from a well the water table in the vicinity of the well is lowered to form a depression resembling an inverted cone. This depression of the water table is called the cone of depression, and the distance that the water table is lowered is called the drawdown. In a well, the greater the pumping rate the greater will be the drawdown. When pumping stops, the cone of depression gradually fills with water from adjacent areas until equilibrium is reached again.

The capacity of a well is the rate at which it will yield water after the water stored in the well has been removed. The capacity depends upon the quantity of water available, the thickness and permeability of the aquifer, and upon the construction and condition of the well itself. The capacity of a well is usually expressed in gallons a minute.

When a well is pumped, the water level drops rapidly at first and then more slowly, but it may continue to decline for several hours or days. When pumping ceases the water level rises rapidly at first but recovery becomes progressively slower and may continue for some time after pumping has stopped.

DUG WELLS

Dug wells are wells that have been excavated, usually by hand with pick and shovel, or sometimes with power machinery. Some of the early wells in Sherman County were dug, but most of these have been replaced by drilled wells. Well 8-39-19bab, one of the Goodland municipal wells, was originally dug to slightly below the water table and later drilled to a depth of about 300 feet, the drilled part being cased with 12-inch iron casing. Well 8-39-19cad2, owned by the Chicago, Rock Island and Pacific Railway Company, was originally dug to a depth of 165 feet. The well was later drilled to about 255 feet, cased with 12-inch steel casing for its entire depth, and the dug part filled in. Several shallow irrigation wells in stream valleys were dug to the water table, then drilled deeper.

BORED WELLS

Bored wells are made by post-hole diggers or hand augers in unconsolidated sediments. Some of the shallow wells in valley areas were made in this way.

DRILLED WELLS

Most of the wells in Sherman County have been drilled by means of either a percussion or hydraulic-rotary drill. In the percussion method, a portable cable-tool drill mounted on a truck or trailer is used. This method of drilling uses a heavy bit which is lifted and dropped alternately to produce a cutting action at the bottom of the hole. The crushed material in the well is mixed with water added during the drilling and is removed by means of a bailer. In the hydraulic-rotary method a hollow drill stem equipped with a cutting bit is rotated in the hole; cuttings are removed by circulating muddy water under pressure down through the stem and up through the annular space between the drill pipe and the hole. The cuttings are brought to the surface as fragments suspended in the mud. The mud also serves to plaster the walls of the hole, thereby preventing caving until casing is installed. In the reverse-rotary method, which is sometimes employed in the drilling of large-diameter wells, direction of flow of water is reversed and the cuttings are carried up through the drill stem.

Most of the drilled wells in Sherman County obtain water from unconsolidated or only partly consolidated deposits of Pliocene age. Wells in these deposits are usually cased to the bottom with steel, iron, or galvanized iron casing to prevent caving of the walls. In some wells the water may enter only through the open end of the casing, but in most wells, the casing is perforated below the water table to increase the intake area. The size and shape of the perforations is an important factor in the construction of a well, and the capacity and even the life of the well may be determined by it. If the perforations are too large, fine material may filter through and fill the well; if the perforations are too small they may become clogged so that water is prevented from entering the well freely. A common practice is to select a slot size that will pass from 30 to 60 percent by size of the water-bearing material. The coarser particles that remain around the screen form a natural gravel packing that increases the effective diameter and therefore the capacity of the well.

Gravel-wall wells generally are effective for obtaining large supplies of water from relatively fine-grained unconsolidated deposits, and have been used for public supply and irrigation. In constructing a well of this type a hole of large diameter is first drilled and temporarily cased with unperforated casing. A well screen or perforated casing is centered in the hole opposite the water-bearing beds and enough unperforated casing is added to reach the surface. The space between the two casings is filled with sorted gravel, preferably of a grain size just a little larger than the openings in the screen or perforated casing, and also slightly larger than that of the water-bearing material. The outer casing is then withdrawn to uncover the screen and to allow the flow of water from the water-bearing material through the gravel packing. The envelope of select gravel that surrounds the well increases the effective diameter of the well and decreases the velocity of the water leaving the formation. This reduction in velocity reduces the movement of fine sand into the well. Due to the increased effective area offered by this type of construction, the entrance friction of the water is reduced and consequently the drawdown may be reduced. A reduction in drawdown at a given yield increases the specific capacity and reduces the cost of pumping.

McCall and Davison (1939, p. 29) have summarized the procedures, which when observed in drilling, will tend to minimize drawdown and thereby increase the efficiency of the well:

> First, the well should be put down through all valuable water-bearing material. Secondly, the casing used should be properly perforated so as to admit water to the well as rapidly as the surrounding gravel will yield the water. Third, the well should be completely developed so that the water will flow freely into the well.
>
> Increasing the diameter of the well will decrease the drawdown but little, all else remaining equal. . . . Increasing the depth of the well will have

a greater effect on reducing the drawdown than will increasing the diameter, so long as additional water-bearing formations are encountered.

METHODS OF LIFT AND TYPES OF PUMPS

Most of the domestic and stock wells in Sherman County are equipped with lift or force pumps. The cylinders or working barrels in lift pumps and force pumps are similar and for best results are placed at a level below the water table. A lift pump generally discharges water only at the pump head, whereas a force pump can force water above this level—such as to an elevated tank. A few wells are equipped with jet pumps and one shallow stock well that was inventoried had a pitcher pump. Domestic and stock wells in Sherman County are generally operated by windmills, but some are operated by hand and several are powered by electric motors or gasoline engines.

Irrigation wells in Sherman County are equipped with either horizontal centrifugal, or vertical turbine pumps (Pl. 6B). The horizontal centrifugal pumps in Sherman County are usually set in pits dug nearly to the water table. They can be used only where the depth to water plus the drawdown does not exceed the working suction limit. Turbine pumps are used for most of the irrigation wells and city wells. Well 8-42-20cdb, one of the municipal wells in Kanorado, is equipped with a double-action plunger pump.

The pumps in the municipal and railroad wells are powered by electricity, and most of the pumps in the irrigation wells are powered by gasoline or diesel engines. One irrigation well is near the natural gas line from Colby to Goodland, and the pump is powered by an engine using natural gas.

UTILIZATION OF GROUND WATER

Information on 326 wells in Sherman County was obtained during the course of the investigation. All known irrigation, public-supply, and industrial wells in the county were visited and all available data concerning them were collected. Only a small percentage of the domestic and stock wells in the county were visited. Records of wells are listed in Table 10, and the principal uses of water are described below.

DOMESTIC AND STOCK SUPPLIES

All domestic supplies in rural areas and domestic supplies in the towns of Ruleton and Edson, which have no municipal water supplies, are obtained from wells. Most of the water used by livestock also comes from wells, although some is obtained from undrained depressions, stock ponds, or creeks. In Sherman County ground water is generally moderately hard, but is satisfactory for most uses.

PUBLIC SUPPLIES

Public supplies of water are obtained from wells at Goodland and Kanorado in Sherman County.

Goodland.—Goodland, the county seat of Sherman County, obtains its water supply from three wells.* All the wells are about 300 feet deep and the depth to static water level in each well is nearly 150 feet. Data on the wells are given in Table 10. The wells are equipped with electrically driven deep-well turbine pumps. Storage is provided by an elevated tank having a capacity of 250,000 gallons and a standpipe holding 213,000 gallons. Well 8-39-19bab, at the fire station, pumps into the standpipe. Well 8-39-20cbc, at the power plant, pumps into the elevated tank. Well 8-39-19aaa, in Gulik Park, pumps directly into the mains. The estimated yield of each well is 300 gallons a minute. The daily average consumption of water at Goodland is not known. The water, of good quality, is chlorinated as an extra precaution against possible contamination.

Kanorado.—The City of Kanorado, on the western border of the county, obtains its water supply from two drilled wells approximately 180 feet deep. Well 8-42-20cdb, equipped with a double-action plunger pump, is reported to yield 100 gallons a minute. Well 8-42-29bac, which has a deep-well turbine pump, has an estimated yield of 250 gallons a minute. The wells pump directly into the mains, the excess water being stored in an elevated tank holding 55,000 gallons. The daily consumption of water is not known. The water is not treated.

INDUSTRIAL SUPPLIES

The largest industrial user of ground water in Sherman County is the Chicago, Rock Island and Pacific Railway Company at Goodland. The railroad has three wells, which supply water principally for filling locomotive boilers. Well 8-39-19cad2, pumped by an electrically driven submersible turbine, has been the principal source of water used by the railroad at Goodland. Well 8-39-19cad was drilled in 1949 and equipped with a deep-well turbine pump but had not been put into use at the time field work for this report was done. Well 8-39-19cad3, equipped with a piston pump, was used only for emergencies. Water is stored in two tanks having capa-

* In 1950, a new well was drilled to replace well 8-39-19bab, which had caved in. No information on this new well was obtained.

cities of 75,000 gallons and 150,000 gallons. According to L. W. Everetts, Water Service Superintendent, about 150,000 gallons of water a day is used by the railroad.

Some ground water is used in Goodland for air conditioning but much of it is purchased from the city. However, well 8-39-19adb owned by Commonwealth Theatres is used for air conditioning the Sherman Theatre. This well is 209 feet deep and is cased with 12-inch steel casing. Water is pumped by a deep-well turbine powered by an electric motor. The Goodland Boothroy Memorial Hospital also has a well used for air conditioning.

IRRIGATION SUPPLIES

Irrigation is not practiced extensively in Sherman County. Although 19 of the wells visited are classed as irrigation wells, only 5 wells (8-39-15ccc, 8-38-28acc, 7-40-11dcc, 9-41-18cbb, and 10-40-23bdc) pumped appreciable amounts of water in 1949. Well 8-40-12dba was pumped occasionally to fill a small pond, but most of the other wells were not pumped at all. Some of them had not been in use for several years. Well 6-42-26acc was a new well drilled in the summer of 1949; it had not been put into use at the time of the investigation. The total acreage under irrigation is not known, but it does not exceed a few hundred acres. The amount of water used for irrigation is not known. A few domestic wells equipped with windmills sometimes pump water to irrigate small garden plots, but the amount of water used for this purpose is negligible. In addition to pumpage from wells a small amount of water is pumped for irrigation from the North Fork Smoky Hill River. The water was pumped from the upper end of a pond formed by the damming of the river (Pl. 7A).

The yields of four irrigation wells were determined by pumping tests made by members of the Federal Geological Survey. Yields measured by the Collins flow gauge ranged from about 316 to slightly more than 1,170 gallons a minute. Drawdowns as measured by the wetted-tape method during the pumping ranged from about 10 feet to 30 feet. A chemical analysis of a sample of water taken from well 8-39-15ccc indicates that the water is excellent for irrigation.

Possibilities of further development of irrigation supplies.—The feasibility of further development of irrigation supplies from wells is dependent principally on geologic, hydrologic, and economic factors. The amount of water available for irrigation depends on the

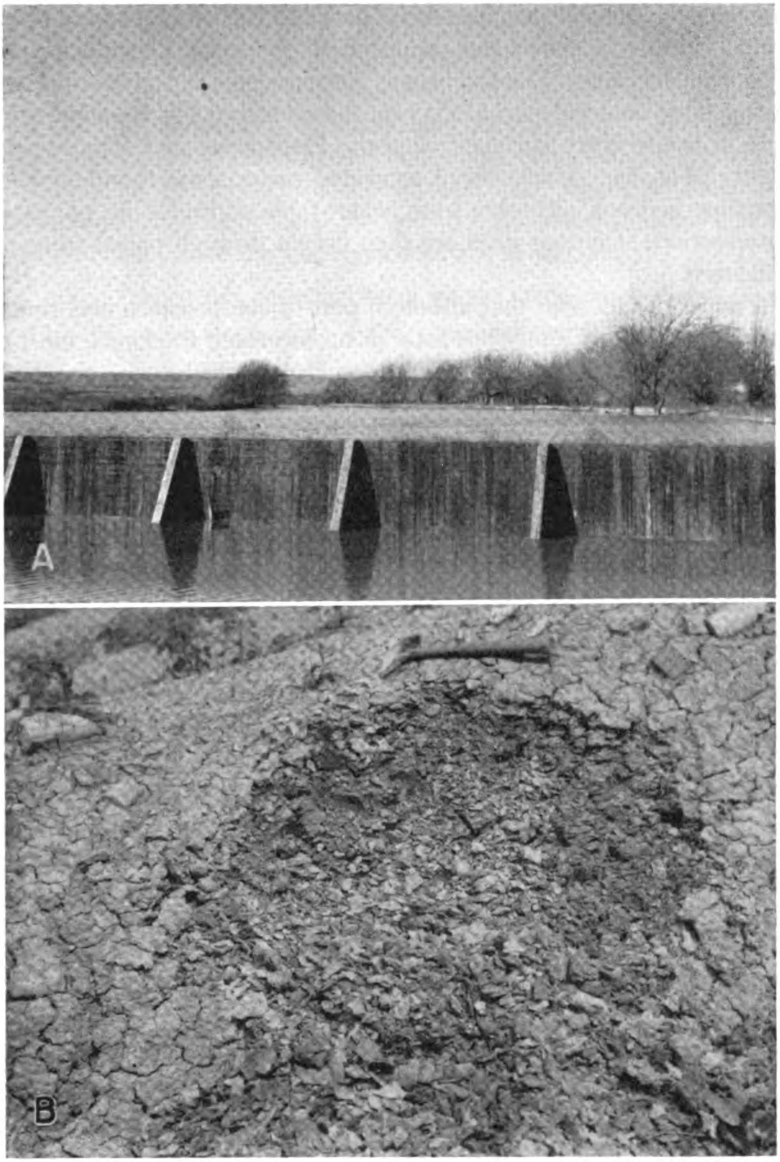


PLATE 7.—*A*, View of Smoky Lake, looking west; sec. 14, T. 10 S., R. 40 W. *B*, Exposure of Pierre shale in sec. 34, T. 10 S., R. 39 W.

thickness and extent of the water-bearing beds, the permeability of the material, and the amount of recharge to the ground-water reservoir. Figure 11 shows the saturated thickness of Pleistocene and Pliocene deposits. The figure was prepared by superimposing the water-table contour map (Pl. 1) on the map showing the configuration of the bedrock surface below the Pleistocene and Pliocene deposits (Fig. 7). Thickness of saturated materials is found by subtracting bedrock altitudes from water-table altitudes at points of intersection. Contour lines are then drawn through points of equal thickness.

Figure 11 indicates that although part of southeastern and south-central Sherman County has little or no saturated thickness, most of the county has a considerable amount of water-bearing material, the maximum being slightly more than 200 feet. Test drilling has indicated that the water-bearing beds in places are rather fine-grained, have low permeabilities, and would consequently yield water to wells slowly, but large yields can be obtained from wells where materials having high permeabilities are penetrated.

The cost of drilling and pumping is determined in part by the depth to water level. In areas where the water table is deep, the wells must also be deep and the pumping lift is great. Plate 2, which shows the depth to water level, indicates the depth to the water level in Sherman County ranges from a few feet to more than 200 feet. In much of the upland area where the contour of the land is suitable for irrigation the depth to water level is much more than 100 feet. As permeabilities of water-bearing formations are generally low in Sherman County, drawdowns in wells of large capacity would be large. The large drawdowns together with the relatively great depths to water result in a fairly high cost of irrigation. However, it is beyond the scope of this report to say what the greatest depth of profitable pumping will be because, as previously stated, so many other factors must be considered.

In some of the stream valleys the depths to water are not great and where water-bearing materials are relatively permeable, wells having high yields may be drilled and pumped economically. The creek bottoms generally are not very wide and commonly very little land is suitable for irrigation. The most promising area for future irrigation seems to be along Beaver Creek where depths to water level are not great, permeabilities are fairly high, and there is considerable land suitable for irrigation.

Chemical Character of Ground Water

The chemical character of ground water in Sherman County is shown by analyses of water from 24 representative wells (Table 7). Figure 12 shows graphically the chemical character of water from the Ogallala formation, alluvium, and Pierre shale. The samples were analyzed by Howard A. Stoltenberg, chemist, in the Water and Sewage Laboratory of the Kansas State Board of Health at Lawrence. The analyses show only the dissolved mineral content and do not indicate the sanitary condition of the water.

CHEMICAL CONSTITUENTS IN RELATION TO USE

The following discussion of the chemical constituents of ground water has been adapted in part from publications of the Federal Geological Survey and the State Geological Survey of Kansas.

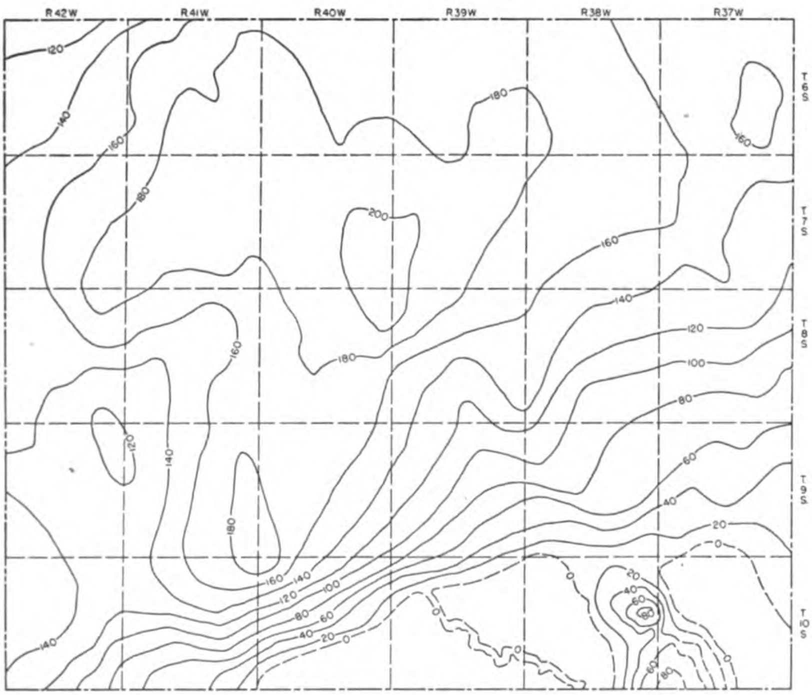


Fig. 11.—Map showing the saturated thickness of Tertiary and Quaternary deposits in Sherman County.

TABLE 7.—*Analyses of water from typical wells in Sherman County*

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

WELL NUMBER	Depth (feet)	Geologic source	Date of collection, 1949	Temperature (°F)	Dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Hardness as $CaCO_3$		
																Total	Carbonate	Noncarbonate
T. 6 S., R. 37 W. 6-37-11bcc	195.0	Ogallala	Oct. 26	......	268	24	5.4	37 *1.85*	16 *1.32*	36 *1.57*	229 *3.76*	26 *.54*	11 *.31*	1.8 *.09*	2.8 *.04*	158	158	0
T. 6 S., R. 38 W. 6-38-34cbb	152.0	do	Oct. 26	58	275	38	.05	37 *1.85*	16 *1.32*	33 *1.42*	222 *3.64*	19 *.40*	11 *.31*	1.2 *.06*	11 *.18*	158	158	0
T. 6 S., R. 39 W. 6-39-6dda	160.0	do	Oct. 26	57	285	44	1.1	39 *1.95*	16 *1.32*	30 *1.29*	205 *3.36*	30 *.62*	10 *.28*	1.8 *.09*	13 *.21*	164	164	0
T. 6 S., R. 41 W. 6-41-9bcb	205.0	do	Oct. 26	58	279	42	1.1	32 *1.60*	15 *1.23*	40 *1.74*	222 *3.64*	20 *.42*	9.0 *.25*	2.0 *.10*	10 *.16*	142	142	0
T. 6 S., R. 42 W. 6-42-4aac	167.5	do	Oct. 26	57	271	53	.06	44 *2.20*	16 *1.32*	17 *.73*	200 *3.28*	19 *.40*	11 *.31*	1.5 *.08*	11 *.18*	176	164	12
T. 7 S., R. 38 W. 7-38-36ada	144.5	do	Oct. 29	58	288	46	1.1	41 *2.05*	14 *1.15*	34 *1.46*	227 *3.72*	18 *.37*	11 *.31*	1.5 *.08*	11 *.18*	160	160	0
T. 7 S., R. 39 W. 7-39-35add	164.8	do	Oct. 29	58	282	49	1.8	34 *1.70*	14 *1.15*	38 *1.65*	221 *3.62*	17 *.35*	10 *.28*	1.8 *.09*	9.7 *.16*	142	142	0
T. 7 S., R. 41 W. 7-41-28aad	106.0	do	Oct. 26	58	254	38	.76	38 *1.90*	13 *1.07*	27 *1.18*	198 *3.25*	20 *.42*	10 *.28*	1.2 *.06*	8.8 *.14*	148	148	0
T. 7 S., R. 42 W. 7-42-10cbb	128.5	do	Oct. 26	57	266	42	.48	42 *2.10*	18 *1.48*	20 *.89*	232 *3.80*	12 *.25*	8.5 *.24*	1.0 *.05*	8.0 *.13*	179	179	0
T. 8 S., R. 37 W. 8-37-33baa	125.0	do	Oct. 29	57	279	32	.10	41 *2.05*	13 *1.07*	36 *1.58*	222 *3.64*	24 *.50*	11 *.31*	1.2 *.06*	12 *.19*	156	156	0

T. 8 S., R. 39 W. 8-39-3cbc	151.5	do	Oct. 29	58	273	46	.51	37 *1.85*	17 *1.40*	28 *1.20*	223 *3.66*	16 *.33*	8.0 *.23*	1.6 *.08*	9.3 *.15*	162	162	0
8-39-15ccc	254.0	do	Oct. 28	57	276	40	1.3	35 *1.75*	12 *.99*	40 *1.73*	215 *3.53*	20 *.42*	9.0 *.25*	1.6 *.08*	12 *.19*	137	137	0
8-39-30bcc	165.5	do	Oct. 31		259	32	.12	36 *1.80*	13 *1.07*	35 *1.53*	222 *3.64*	16 *.33*	8.5 *.24*	1.0 *.05*	8.8 *.14*	144	144	0
T. 8 S., R. 41 W. 8-41-22cbb	175.0	do	Oct. 26	59	267	36	.05	32 *1.60*	15 *1.23*	37 *1.63*	214 *3.51*	21 *.44*	10 *.28*	1.8 *.09*	8.8 *.14*	142	142	0
T. 9 S., R. 37 W. 9-37-30dad	174.5	do	Oct. 29	59	278	25	.64	35 *1.75*	15 *1.23*	43 *1.86*	232 *3.80*	23 *.48*	12 *.34*	1.3 *.07*	9.3 *.15*	149	149	0
T. 9 S., R. 38 W. 9-38-5dcc	136.5	do	Oct. 29	57	253	17	1.4	42 *2.10*	12 *.99*	32 *1.41*	212 *3.48*	22 *.46*	11 *.31*	1.1 *.06*	12 *.19*	154	154	0
T. 9 S., R. 42 W. 9-42-2cbb	80.0	do	Oct. 26	57	266	34	1.5	38 *1.90*	15 *1.23*	32 *1.37*	224 *3.67*	15 *.31*	8.5 *.24*	1.7 *.09*	12 *.19*	156	156	0
T. 10 S., R. 37 W. 10-37-13daa	168.5	do	Oct. 29	57	331	20	.24	79 *3.94*	18 *1.48*	12 *.53*	295 *4.84*	4.1 *.08*	12 *.34*	1.0 *.05*	40 *.64*	271	242	29
T. 10 S., R. 38 W. 10-38-19ccc	48.5	do	Oct. 29	57	294	20	.13	48 *2.40*	14 *1.15*	37 *1.61*	234 *3.84*	31 *.64*	15 *.42*	1.0 *.05*	13 *.21*	178	178	0
10-38-30dcc	23.5	Alluvium	Oct. 29	55	436	32	.10	72 *3.59*	22 *1.81*	48 *2.08*	311 *5.10*	86 *1.79*	15 *.42*	.9 *.05*	7.5 *.12*	270	255	15
T. 10 S., R. 39 W. 10-39-8bcc	24.0	Ogallala	Oct. 31	56	272	16	.18	42 *2.10*	13 *1.07*	37 *1.63*	212 *3.48*	34 *.71*	12 *.34*	1.2 *.06*	13 *.21*	158	158	0
T. 10 S., R. 41 W. 10-41-26ccc	91.0	do	Oct. 31		224	15	.14	36 *1.80*	11 *.90*	30 *1.31*	198 *3.25*	12 *.25*	9.0 *.25*	1.6 *.08*	11 *.18*	135	135	0
T. 10 S., R. 42 W. 10-42-9bba	93.0	do	Oct. 31	56	256	18	.84	53 *2.64*	10 *.82*	25 *1.07*	227 *3.72*	10 *.21*	9.0 *.25*	1.2 *.06*	18 *.29*	173	173	0
T. 11 S., R. 40 W. 11-40-1bcc	94.0	Pierre	Oct. 31	58	579	33	.28	60 *2.99*	38 *3.12*	81 *3.51*	256 *4.20*	174 *3.62*	53 *1.49*	2.3 *.12*	12 *.19*	306	210	96

a. One part per million is eqivalent 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.

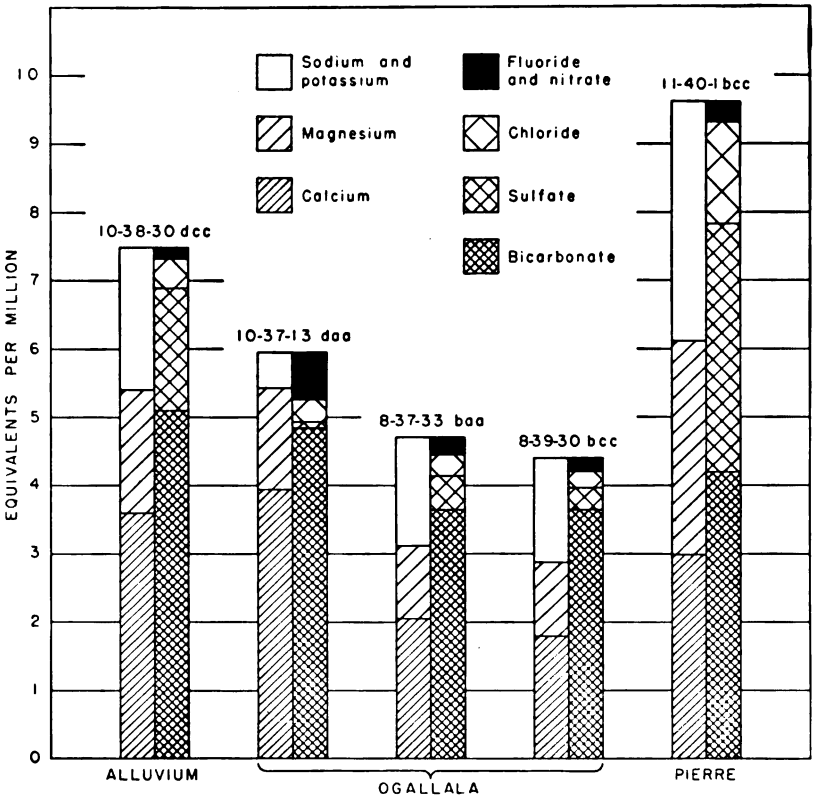


FIG. 12.—Chemical analyses of water from wells in Sherman County.

Dissolved solids.—When water is evaporated the residue consists of rock materials and sometimes a small quantity of water of crystallization and organic material. The kind and quantity of these soluble rock materials in the water determine its suitability for use. Water with less than 500 parts per million of dissolved solids generally is satisfactory for domestic use, except for the difficulties resulting from its hardness, and, in some areas, corrosiveness to iron. Water with more than 1,000 parts per million is likely to contain enough of certain constituents to produce a noticeable taste or to make the water unsuitable in some other respect.

The dissolved solids in samples of water from Sherman County ranged from 224 to 579 parts per million. Only one sample contained more than 500 parts per million (Table 8). The water therefore is suitable for most ordinary uses from the standpoint of dissolved solids.

TABLE 8.—*Summary of the chemical quality of the samples of water from typical wells in Sherman County*

Range in parts per million	Number of samples		
	Alluvium	Ogallala formation	Pierre shale
Dissolved solids			
200–250	....	1	....
251–300	....	20	....
301–350	....	1	....
351–400	....	....	....
401–600	1	....	1[a]
Total hardness			
100–150	....	8	....
151–200	....	13	....
201–250	....	....	....
251–300	1	1	....
301–350	....	....	1
Fluoride			
0.5–1.0	1	4	....
1.1–1.5	....	9	....
1.6–2.0	....	9	....
2.1–2.5	....	....	1
Iron			
0.0 .10	1	5	....
.11– .20	....	3	....
.21– .50	....	2	1
.51–1.0	....	4	....
1.1 –2.0	....	7	....
2.1 –5.5	....	1[b]	....

a. 579 parts per million.
b. 5.4 parts per million.

Hardness.—Hardness of water is most commonly recognized by the excessive quantity of soap needed with the water in washing and by the curdy precipitate that forms before a permanent lather is obtained. Calcium and magnesium cause practically all the hardness of ordinary water and are the active agents in the formation of the greater part of the scale formed in steam boilers and in other vessels in which water is heated or evaporated.

Hardness is of two types—carbonate and noncarbonate. Carbonate hardness is caused by calcium and magnesium bicarbonate, and because it can be removed almost entirely by boiling, is often called temporary hardness. Noncarbonate hardness, or permanent hardness, is caused by sulfates, chlorides, nitrates, and fluorides of calcium and magnesium and cannot be removed by boiling. With reference to use with soap, there is no difference between carbonate and noncarbonate hardness. In general noncarbonate hardness forms harder scale on steam boilers.

Water having a hardness of less than 50 parts per million is generally considered as soft and treatment to remove hardness is usually unnecessary. Hardness between 50 and 150 parts per million does not seriously interfere with the use of water for most purposes but does increase the consumption of soap and its removal by a softening process may be 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 is easily noticeable and water having more than 200 parts per million is sometimes treated to soften it. Where municipal water supplies are softened, the hardness is usually reduced to 60 to 80 parts per million.

Samples of water from Sherman County were moderately hard. Only three samples had more than 200 parts per million of hardness.

Iron.—If water contains much more than 0.3 part per million of iron, the excess may separate out and settle as a reddish sediment when exposed to the air. Iron, which may be present in sufficient quantity to give a disagreeable taste or to stain cooking utensils, may be removed from most water by aeration and filtration, but some requires additional treatment.

In water samples collected in Sherman County the iron content ranged from 0.05 to 5.4 parts per million. Six samples contained 0.1 part per million or less, 17 contained from 0.11 to 2.0 parts per million, and 1 sample contained more than 2.0 parts per million of iron.

However, it is believed that well 6-37-11bcc, from which the sample containing 5.4 parts per million of iron was obtained, may not have been pumped long enough to clear the pipes of rusty water and consequently the amount of iron in the sample may be greatly in excess of the amount normally expected.

Fluoride.—Although fluoride is usually present only in small quantities in ground water, it is desirable to know the amount of fluoride present in water used by children. Fluoride in water has been shown to be associated with the dental defect known as mottled enamel, which may appear on the teeth of children who drink water containing too much fluoride during the formation of the permanent teeth. Dean (1936) has described the effects of fluoride in drinking water on the teeth of children (p. 1270):

> . . . from the continuous use of water containing about 1 part per million, it is probable that the very mildest forms of mottled enamel may develop in about 10 per cent of the group. In waters containing 1.7 or 1.8 parts per million, the incidence may be expected to rise 40 or 50 per cent, although the percentage distribution of severity would be largely of the "very mild" and "mild" types. At 2.5 parts per million an incidence of about 75 to 80 per cent might be expected, with possibly 20 to 25 per cent of all cases falling into the "moderate" or severer type. A scattering few may show the "moderately severe" type.
>
> At 4 parts per million the incidence is, in general, in the neighborhood of 90 per cent, and as a rule, 35 per cent or more of the children are classified as "moderate" or worse. In concentrations of 6 parts per million or higher an incidence of 100 per cent is not unusual.

Recent studies have indicated that whereas more than 1.5 parts per million of fluoride may be detrimental to the teeth of children, less than 1.5 parts is definitely beneficial in helping to prevent tooth decay.

Of 24 water samples collected in Sherman County, 5 contained 1.0 or less part per million of fluoride; 9 samples contained from 1.1 to 1.5 parts per million, 9 contained from 1.6 to 2.0, and only 1 contained more than 2 parts per million of fluoride.

Nitrate.—The nitrate content of water used for drinking has been the object of a great deal of attention in the past few years since the discovery that high nitrate water may cause cyanosis of infants when the water is used in the preparation of the baby's formula. Although some nitrates are derived from nitrate-bearing rocks and minerals in the water-bearing formations, high nitrate concentrations are probably due to direct flow of surface water into the well or to percolation of nitrate-bearing water into the well through the top few feet of the well. Nitrates, very soluble, are readily dissolved from soils that have high concentrations of nitrate. Other sources of nitrogenous material are privies, cesspools, and barnyards; consequently a large amount of nitrate may also indicate that harmful bacteria are present in the water. Because they are usually poorly sealed, dug wells generally allow more contamination by surface seepage than drilled wells which are commonly deeper and usually tightly cased.

Ninety parts per million of nitrate as NO_3 in water is considered by the Kansas State Board of Health as dangerous to infants, and some authorities advocate that water containing more than 45 parts per million (as NO_3) should not be used for formula preparation. All water samples collected in Sherman County contained some nitrate, but none contained enough nitrate to be considered dangerous. Most of the wells in Sherman County are drilled, relatively deep, generally well cased and sealed, and are not readily contaminated. One water sample had 40 parts per million but all others had less than 20 parts per million of nitrate.

WATER FOR IRRIGATION

The suitability of a water for irrigation is dependent mainly on the concentration of dissolved constituents and the percentage of sodium. The quantity of chloride is sometimes large enough to affect use of water for irrigation and boron is sometimes present in sufficient amounts to be harmful to plants. The concentration of dissolved constituents may be expressed in terms of equivalents per million of anions or cations, of parts per million of dissolved solids, or in terms of electrical conductivity. Electrical conductivity is the measure of the ability of the inorganic salts in solution to conduct an electric current, and it is related to the concentration of dissolved solids. Electrical conductivity measurements are not shown in analyses of water from Sherman County, but an approximate value can be obtained by multiplying total equivalents per million of anions or cations by 100, or by dividing dissolved solids in parts per million by 0.7 (Wilcox, 1948, pp. 4-5). To find the percentage of sodium, the results of the analysis must be reported in equivalents per million. The quantity of sodium in equivalents is then divided by the sum of the quantities of calcium, magnesium, sodium, and potassium in equivalents, and the result expressed as a percentage.

The classification of water for irrigation use is shown in Table 9.

TABLE 9.—*Permissible limits for electrical conductivity and percentage sodium of several classes of irrigation water* (Wilcox, 1948a, p. 27)

Classes of water		Electrical conductivity (micromhos at 25° C)	Percent sodium
Rating	Grade		
1	Excellent	less than 250	less than 20
2	Good	250–750	20–40
3	Permissible	750–2,000	40–60
4	Doubtful	2,000–3,000	60–80
5	Unsuitable	more than 3,000	more than 80

This table shows that, in general, water containing more than 60 percent sodium or water having electrical conductance of more than 2,000 is unfit for irrigation. All samples of water from Sherman County that were analyzed are well within the safety limits suggested by Wilcox.

SANITARY CONDITIONS

The analyses of water given in the tables show only the amounts of dissolved mineral matter in the water and do not indicate the sanitary quality of the water. The water in a well may contain mineral matter that imparts an objectionable odor or taste and yet may be free from harmful bacteria and safe for drinking. On the other hand, the water in a well although clear and palatable may contain harmful bacteria. An abnormal amount of certain mineral constituents, such as nitrate or chloride, sometimes indicates pollution.

The entire population of Sherman County is dependent upon well-water supplies and every precaution should be taken to protect these supplies from pollution. Deep drilled wells on the uplands penetrate relatively impervious silt above the water table and are less subject to pollution than are shallow wells in valleys where pervious sandy material sometimes extends from the surface to the water table. Every well should be tightly sealed at the top and if possible should be located in a raised area so that surface water will run away from rather than into the well. Wells should not be located where barnyards, privies, or cesspools are possible sources of pollution.

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

Cretaceous System

GULFIAN SERIES

Pierre Shale

The oldest formation that crops out in Sherman County is the Pierre shale (late Cretaceous in age) (Pl. 7B). The Pierre shale was named by Meek and Hayden in 1862 from exposures at old Fort Pierre in South Dakota. The Pierre shale in northwestern Kansas has been studied and described in great detail by Elias (1931). He divided the Pierre shale into five named members and one unnamed unit. These are, in ascending order: Sharon Springs shale, Weskan shale, Lake Creek shale, Salt Grass shale, an unnamed shale interval, and the Beecher Island shale. Probably all but the Beecher Island shale member are present under most of Sherman County. The Lake Creek shale is thought to be the only member of the Pierre shale to crop out in Sherman County. The Lake Creek shale consists of dark-gray and black shale. It contains many limonite concretionary zones and small concretions of calcium carbonate. The Lake Creek shale member differs from the Weskan shale member below and the Salt Grass shale member above by the absence or scarcity of the large limestone concretions that are so common in the members above and below (Elias, 1931, p. 93). The maximum thickness of the Lake Creek shale member is about 200 feet in Wallace County but its thickness is not known in Sherman County. The total thickness of the Pierre shale in Sherman County ranges from about 600 feet in the southern part of the county to perhaps as much as 900 feet in the north.

The Pierre shale is not known to yield water to wells in Sherman County, but well 11-40-1bcc on the northern border of Wallace County obtains its water from the Pierre. Shale is a poor aquifer but locally may contain water in joints and along bedding planes. The sample from this well indicates that water from the Pierre shale is of poorer quality than water from the Ogallala formation. It contains more dissolved solids, is harder, and has a slightly higher fluoride content than Ogallala water in Sherman County. P. M. Piper reported that when his well (11-40-1bcc) is allowed to stand for a day or two without pumping, the water acquires a peculiar odor. This may be due to the high sulfate content of the water.

Tertiary System

PLIOCENE SERIES

Ogallala Formation

The Ogallala formation was named by Darton in 1899 (pp. 732-734) from a locality in southwestern Nebraska. In 1920 Darton (p. 6) referred to the type locality as near Ogallala station in western Nebraska. Elias (1931) made a detailed study of the Ogallala formation in Wallace County, and in 1937 he briefly described Ogallala deposits in Rawlins and Decatur Counties. In 1945 the Ogallala formation in Thomas County was described by Frye, and in 1949 Frye and Leonard described the character and occurrence of the Ogallala in Norton and Phillips Counties.

Character.—The Ogallala formation in Sherman County consists of clastic sediments of diverse character. It contains chiefly sand and gravel, silt, clay, some limestone, and beds of volcanic ash and bentonitic clay. To the south in Wallace County it contains diatomaceous marl and in other areas it contains hard silicified beds resembling chert or quartzite. The character of the Ogallala is shown by the logs of test holes included in this report. There are no exposures that permit an extensive examination of any considerable thickness of these strata in Sherman County and for this reason no stratigraphic sections were measured. The following stratigraphic section was measured in eastern Rawlins County. (Frye 1945, pp. 63-64).

Measured section of the Ogallala formation, SE¼ sec. 30, T. 5 S., R. 32 W., Rawlins County. (Measured by John C. Frye and August Lauterbach.)

Bed no.		Thickness, feet
13	Mostly covered, capped by nodular mortar bed, irregular, hard, gray	6.0
12	Mortar bed, coarse gravel to sand cemented by calcium carbonate; weathers irregularly cavernous	5.5
11	Silt, sand, and gravel; massive; poorly sorted; red-tan	7.0
10	Mortar bed, sand and some fine gravel; loosely cemented by calcium carbonate; friable; gray	1.5
9	Silt, sand, and gravel; massive; poorly sorted; red-tan	17.8
8	Mortar bed, hard, massive, gray	4.0
7	Sand, fine, and some silt; tan to red-buff; partly covered	7.5
6	Mortar bed, hard, gray	3.5
5	Sand, fine to medium, tan to buff, partly covered	6.0
4	Mortar bed, sand and coarse gravel; hard; gray	2.2
3	Sand and gravel; tan	9.5
2	Caliche and mortar bed; massive; having thin lenses of clay and silt interbedded; light-gray to light gray-tan	8.0
1	Silt and fine sand; massive; gray; covered in lower part	13.7
	Total thickness of beds measured	92.2

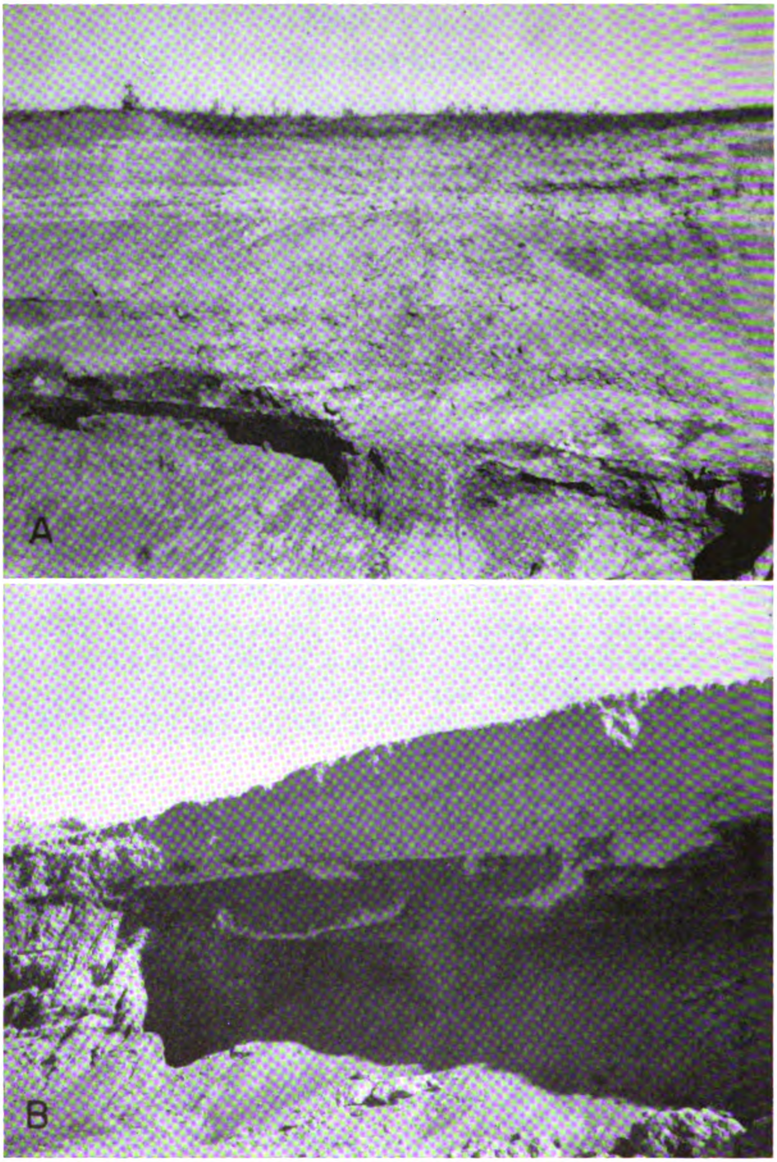


PLATE 8.—Views of Ogallala deposits in gravel pit in the NE¼ SE¼ sec. 30, T. 8 S., R. 40 W. *A,* Cross-bedded sands resting on mortar bed. *B,* Bed of caliche at top resting on brown silt and sand, which in turn rests on partly cemented sand and gravel.

The materials composing the formation are usually poorly sorted and may grade from one rock type to another within short distances both laterally and vertically. Individual beds are characteristically lenticular, and with the exception of a limestone member at the top, they cannot be traced very far.

Sand is the most common constituent of the Ogallala formation. It is composed predominantly of quartz but contains subordinate amounts of feldspar and other minerals. Test drilling has indicated that in some places beds of uniform well-sorted sand are found, but generally the sand is poorly sorted, being mixed with silt, clay, or gravel (Pl. 8).

Beds of uniform gravel are not common, especially at depth. Generally gravel deposits contain large amounts of sand and silt, thus causing the formation to have a fairly low permeability.

Beds of sandy silt are very common in the Ogallala. The silt is gray, brown, red, tan, or buff; where it contains much calcium carbonate, it may be white. Silt layers generally contain nodules or stringers of caliche (calcium carbonate).

Many of the beds in the Ogallala formation are cemented, usually with calcium carbonate. Sand and gravel deposits cemented with calcium carbonate may form rough benches or scarps and are called "mortar beds" because of their resemblance to mortar (Pl. 9A).

The most distinctive bed in the Ogallala is the "Algal limestone" (Pl. 5B) which is at the top of the formation. This limestone has a peculiar concentrically banded structure and was thought by Elias (1931, pp. 136-141) to have been at least partly precipitated by the alga *Chlorellopsis.* It is usually reddish and weathers to a knobby, irregular surface. Outcrops of "Algal limestone" are fairly common in Sherman County and have been found in several different localities (NW¼ sec. 3, T. 8 S., R. 41 W.; SW¼ NE¼ sec. 27, T. 6 S., R. 41 W.; NW¼ sec. 19, T. 7 S., R. 36 W. on the border of Thomas County; and NW¼ sec. 1, T. 10 S., R. 41 W.).

Another distinctive bed found in one locality is a bed of white limestone that contains casts and molds of fossil snails. A similar formation crops out in Norton County (Frye and Leonard, 1949, p. 39) and in Wallace County where in places it overlies beds of diatomaceous marl (Elias, 1931, p. 162).

In a few localities in southern Sherman County the Ogallala contains layers of brown, tan, or greenish bentonitic clay. It is probable that this clay represents the "Woodhouse clay" described by Elias in Wallace County (1931, pp. 155-158).

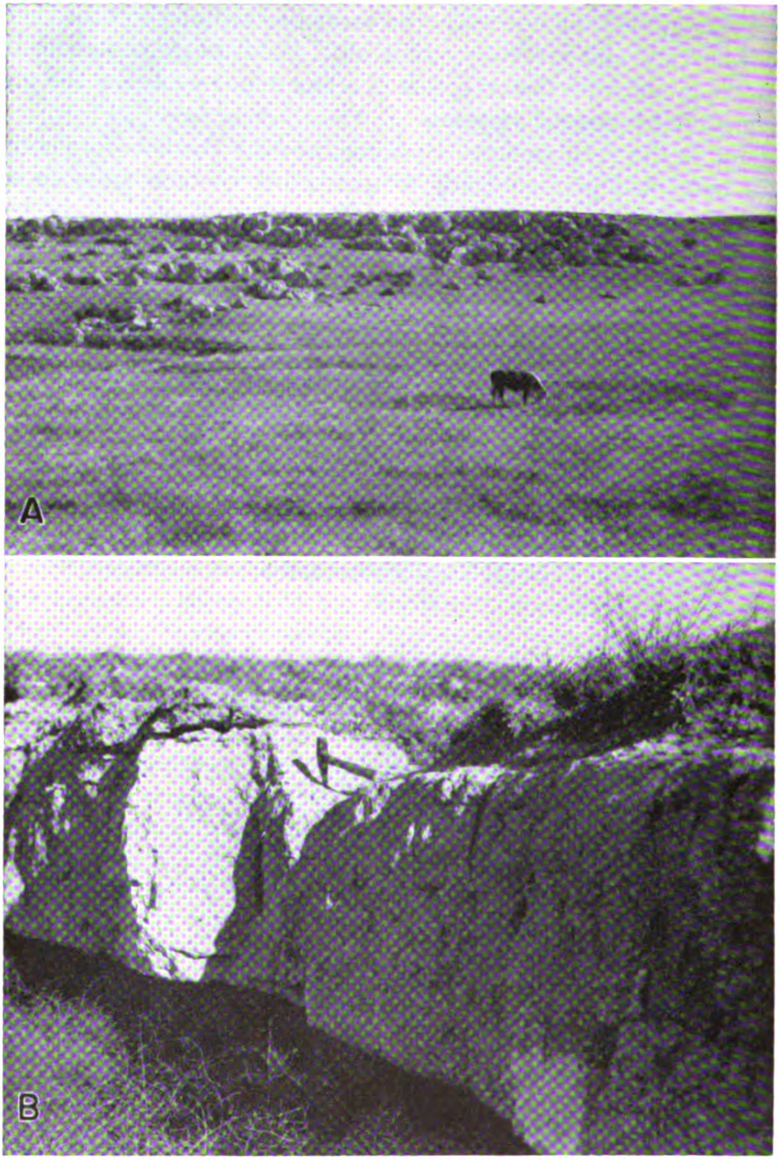


PLATE 9.—*A*, Mortar beds of the Ogallala formation. View looking eastward in NW¼ sec. 21, T. 10 S., R. 39 W. *B*, Bed of volcanic ash in Ogallala formation in the SW¼ NE¼ sec. 16, T. 8 S., R. 40 W. White spot at bottom right is a fresh exposure of ash.

Distribution and thickness.—The Ogallala formation underlies all of Sherman County except for small areas in the southern part of the county where Pierre shale crops out or where alluvium of the North Fork Smoky Hill River lies directly on Pierre shale. The Ogallala is overlain in most of the county by the Sanborn formation, slope deposits, or alluvium, but the Ogallala crops out along most of the streams in places where it has been exposed by stream erosion, wind, or by soil creep. The thickness of the Ogallala ranges from a few feet to about 300 feet. The thickness of Ogallala sediments encountered in test hole drilling ranged from 296 feet in test hole 7-40-36ddd to 40 feet in test hole 10-40-36ddd. The thickness of the formation is shown in the cross sections (Figs. 5 and 6) and in the logs of test holes given in this report.

Origin.—The sediments of the Ogallala formation were deposited largely by streams that flowed from the Rocky Mountains. During the early stages of deposition the main valleys were probably occupied by through-flowing streams from the Rockies. As time went by, stream channels became filled with deposits and stream gradients decreased. This led to overflow of streams and the building of broad flood plains. Channels themselves became choked and shifted laterally and probably anastomosing stream patterns developed. As deposition progressed, relief was lowered, valleys became filled, divides were covered, and the depositional zones of individual streams overlapped and coalesced.

However, not all the Ogallala deposits were laid down by running water. It is thought that at various times during Ogallala deposition there were small shallow lakes, probably formed by damming of stream channels. This is substantiated by the beds of volcanic ash (Pl. 9B), which must have been deposited in still water, in the Ogallala of this county and other counties (Frye and Leonard, 1949, p. 39; Elias, 1937, p. 24). As previously discussed in the section on geologic history, it is thought that the "Algal limestone" was also formed in quiet water. Whereas the coarse materials in the Ogallala were undoubtedly deposited by streams, some of the deposits of structureless silt and fine sand may have been deposited by wind action.

Most of the materials of the Ogallala were derived from the Rocky Mountains. The silts and clays were derived from soils and weathered rocks in the mountain area. Sand and gravel was derived from the weathering of igneous rocks and clastic sedimentary rocks. Much of the calcareous matter that is so abundant in the Ogallala was derived from the weathering of Paleozoic limestones and calcic minerals in the igneous rocks. Some of the limy material may have been deposited by percolating subsurface water or ground water after the deposition of the rocks.

Age and correlation.—In 1899 Darton (pp. 732, 734) applied the name Ogallala formation to deposits formerly called "Tertiary grit" and considered to be of Miocene age by Hay (1895, p. 570). Darton considered these deposits to be of Pliocene age. The formation now is generally considered to be of Pliocene age. The State Geological Survey of Kansas classes the Ogallala as a formation with three units, the Valentine, Ash Hollow, and Kimball, as members. The thickness of these members has not been determined in Sherman County, but all three members are undoubtedly present.

Fossil seeds and other plant remains from Tertiary rocks in the Great Plains have been described by Elias (1932, 1942) and Chaney and Elias (1936). The recognition of the Valentine, Ash Hollow, and Kimball members is based primarily on plant fossils because the Ogallala has few distinctive lithologic types. Elias (1942) considers *Stipidium commune* to be the most common grass seed in the Valentine member. Lower Ash Hollow contains abundant remains of *Krynitzkia coroniformis,* and the remainder of the Ash Hollow is characterized by the occurrence of *Biorbia fossilia.* The most diagnostic form found in the Kimball member is *Prolithospernum johnstoni.* However, because of the occurrence of the "Algal limestone" at the top of the Kimball, this member is often identifiable without recourse to fossil evidence.

Beds of volcanic ash are sometimes useful stratigraphically. However, the only ash deposit found in Sherman County, in sec. 16, T. 8 S., R. 40 W., is thought to be a new ash not previously identified in Kansas. It probably is in the upper part of the Ash Hollow or the lowest part of the Kimball.

A large number of Pliocene vertebrate fossils have been found in Ogallala deposits in Sherman County. The main source of these fossils is the "Edson Quarry" or "Edson beds" in secs. 25 and 26, T. 10 S., R. 38 W. This quarry was originally opened by Martin and described by Adams and Martin (1929). Several subsequent papers describing new species found in the "Edson Quarry" have been published (Hibbard, 1934; Taylor, 1941; Lane, 1945). The "Edson beds" are thought to occur low in the Ogallala, probably in the Valentine member.

Water supply.—The Ogallala formation is the principal water-bearing formation in Sherman County. Most of the domestic and stock wells, all industrial and municipal wells, and the irrigation wells that were used in 1949 derive their water from the Ogallala formation. The Ogallala also yields water to a few springs in the county. The yields of wells deriving water from the Ogallala formation range from a few gallons a minute for domestic and stock wells to about 1,200 gallons a minute for one irrigation well. The irrigation wells that obtain water from this formation yield from 20 to 73 gallons a minute per foot of drawdown. Figures 5, 6, and 11 indicate that water-bearing materials, principally the Ogallala, reach a thickness of more than 200 feet in Sherman County and that most of the area is underlain by a considerable thickness of water-bearing material. However, although there is much ground water in storage in the Ogallala formation, logs of test holes indicate that in places the water-bearing beds may be fine-grained and would not yield water to wells without excessive drawdowns.

Water samples were collected from 22 wells that obtain water from the Ogallala formation. Chemical analyses indicate that the water is moderately hard but is of good quality both for domestic use and for irrigation. The quantity of fluoride in nine of the samples was slightly more than the amount considered to be the optimum fluoride content of water consumed by children, but probably, only very mild cases of mottled enamel would result from continuous drinking of this water.

Quaternary System

PLEISTOCENE SERIES

Sanborn Formation

Character.—In 1931 Elias (pp. 163-181) described unconsolidated Pleistocene deposits consisting mostly of silt in northwestern Cheyenne County, Kansas, and named these deposits Sanborn formation from the town of Sanborn, Nebraska, just north of the type area.

According to Elias (1931, pp. 179-180) there are three types of loess in Wallace County. These are: loess of the divides, loess of the valley slopes, and valley-bottom loess. He believed that only the loess of the divides could be considered of Pleistocene age, the loess of the valley slopes and valley bottoms having been redeposited from the divide areas. Probably only the loess of the divides should be termed loess and the loess of the valley slopes should be called colluvium or slope deposits. Elias acknowledged that the valley-bottom loess graded downward into alluvial sand and gravel and should be regarded as part of the alluvial deposits.

Slope deposits similar to those described in Wallace County are extensive in Sherman County where they cover the slopes of most of the valleys. The slope deposits in Sherman County consist mainly of loess of the Sanborn formation that has been redeposited by the action of wind, surface water, or slope processes, but deposits may also include fragments of the underlying Ogallala formation. Where the source material consists entirely of the Sanborn formation, slope deposits are indistinguishable from the Sanborn. Mechanical analyses of samples of Sanborn deposits and slope deposits in Thomas County indicate that where the slope deposits are derived from the upper massive silt of the Sanborn formation, they cannot be distinguished from it on the basis of grain size and sorting (Frye, 1945, p. 77). On the geologic map (Pl. 1) slope deposits are included with the Sanborn formation because of the similarity of the two formations and because of difficulties involved in trying to differentiate between the two.

In Sherman County two members of the Sanborn formation, the Peoria silt member and the Loveland silt member, have been recognized. The Loveland silt member, the lower member, consists of dark-brown silt; at its top is a buried soil (Sangamon) which developed during a period of subaerial erosion that occurred between the deposition of the two silt members. The soil is colored reddish brown by organic material and oxidation. The upper part of the soil has been leached of calcium carbonate which has been redeposited below as caliche. This soil is not well developed in Sherman County, but it has been observed in outcrops and in test holes (Pl. 10).

The Peoria silt member consists of tan to light-brown silt and in a few places contains large amounts of very fine sand. The Brady soil, which is at the top of the Peoria silt and the Bignell silt member have not been found in Sherman County.

According to Elias (1931, p. 163) the basal part of the Sanborn formation in Wallace County contains coarse gravel, and boulders up to 2.5 feet in diameter were observed. Rocks found in the gravel deposits of Wallace County include arkose, granite, quartz, quartzite, basalt, porphry, flint, and jasper. Pieces of wood petrified into flint were common. The gravel was undoubtedly transported from the Rocky Mountain area. Although the Ogallala contains gravel of these same rocks, Elias considered that the "Sanborn" gravel was Pleistocene in age because of the occurrence of scratched cobbles and large boulders of arkose, both of which he had never observed in the Ogallala. The presence of heavy boulders and scratched

PLATE 10.—Exposures of loess in the Sanborn formation in Sherman County. *A,* Loess of the Peoria silt member overlying loess of the Loveland silt member. Ogallala formation beneath Loveland. View in road cut along U. S. Highway 24 in the SW cor. sec. 21, T. 8 S., R. 40 W. *B,* Loess of the Peoria silt member overlying loess of the Loveland silt member. Indistinct contact is marked by position of hammer in picture. SW cor. sec. 21, T. 8 S., R. 40 W.

cobbles suggested transportation by ice, probably by river or flood ice. Further evidence that this gravel is Pleistocene rather than Pliocene (Ogallala) is that in one location a few arkose boulders were observed to be clearly above the "Algal limestone," the topmost bed of the Ogallala (Elias, 1931, p. 178).

In some places in Sherman County deposits of gravel are found beneath loess and above mortar beds of the Ogallala. Boulders as large as 1 foot in diameter were noted in Sherman County. However, no evidence that these gravel deposits were of other than Pliocene age was found. No gravel deposits were found above the "Algal limestone" and scratched pebbles were not observed. Although it is possible that some of these gravel beds were deposited during Pleistocene time, until further investigation produces more definite evidence, these gravel deposits in Sherman County are being classed as gravels of the Ogallala which have been loosened from underlying cemented beds by leaching of calcium carbonate and by mechanical erosion. Plate 11A is a photograph of a gravel deposit that is considered to have been weathered directly from a bed of coarse, partly cemented gravel of the Ogallala such as that shown in Plate 11B.

Distribution and thickness.—Most of the surface of Sherman County is underlain by the Sanborn formation and associated slope deposits. All the test holes drilled in the county encountered loess or slope deposits which ranged in thickness from 1 to about 46 feet. The greatest thickness of the Loveland silt member was 8 feet; the Peoria silt member was more than 40 feet thick in Sherman County.

Age and correlation.—The name Sanborn formation was first used by Elias (1931, p. 163) to replace such terms as "Tertiary marl" and "Plains marl" which were used by Hay (1895) and other early workers in the central Great Plains region for deposits later recognized as consisting mainly of loess. Elias considered these deposits to be Pleistocene in age. In 1937 in Decatur County, Kansas, Elias (1937, p. 7) noted the occurrence of a dark-brownish ("red") loess that underlay the light yellowish-buff loess of the Sanborn. This "red" loess he classified as equivalent to the Loveland formation of Nebraska.

The Loveland, Peoria, and Bignell silt members of the Sanborn formation in Kansas have been correlated with the Loveland, Peorian, and Bignell loesses of the Nebraska classification (Frye and Fent, 1947). To retain Sanborn as a stratigraphic unit of formational

PLATE 11.—*A*, Loose gravel of the Ogallala overlying consolidated Ogallala deposits, NW¼ sec. 1, T. 10 S., R. 40 W. *B*, Coarse, partly cemented gravel in the Ogallala formation, SW¼ NE¼, sec. 6, T. 10 S., R. 39 W.

rank in Kansas is desirable because it is a convenient mapping unit and because members of the Sanborn are difficult to delineate in sufficient detail to be usable mapping units.

In Nebraska the Peorian loess has been found above Iowan till and has been established as post-Iowan glaciation in age. The Loveland loess underlies the Iowan till in places and is Illinoian in age. The Bignell loess is considered to be late Wisconsinan.

Water supply.—The Sanborn formation in Sherman County lies above the water table and therefore does not yield water to wells. The primary importance of the Sanborn with respect to water supply is its retarding effect on ground-water recharge due to the fine texture and low permeability of the silts.

Alluvium

General features.—Alluvial deposits of Pleistocene age occur along the valleys and underlie the flood plains of the major streams in Sherman County. The alluvium consists predominantly of sand and gravel with lesser amounts of silt and clay. Materials comprising the alluvium were derived mainly from the Ogallala formation and from slope deposits. The streams for the most part are not actively eroding but during periods of flow are merely serving as lines of transportation for sediments. The boundary between the slope deposits and alluvium is not distinct and the field mapping of the alluvium was somewhat arbitrary in some places. The thickness of alluvial deposits is not known as no test holes were drilled in the alluvium, but it probably does not exceed about 35 feet.

Water supply.—Along most of the valleys in Sherman County, the alluvium is above the water table and contains no water available to wells. Along the eastern segments of Beaver Creek and the North Fork Smoky Hill River part of the alluvium is below the water table. Several wells along these streams obtain water from the alluvium. Wells 6-38-20acc and 10-40-10acd, irrigation wells in the valleys of Beaver Creek and North Fork Smoky Hill River, respectively, obtain water from the alluvium but are drilled into the underlying Ogallala formation to insure a larger yield. A water sample was collected from well 10-38-30dcc which obtains water from the alluvium of the North Fork Smoky Hill River. The chemical character of this water does not differ essentially from that of typical Ogallala water although the water from alluvium contained a larger amount of dissolved solids and was somewhat harder.

RECORDS OF WELLS

Descriptions of wells visited in Sherman County are given in Table 10. All information classed as reported was obtained from the owner or tenant. Depth of wells not classed as reported were measured and are given to the nearest tenth of a foot below the measuring point described in the table. Depths to water level not classed as reported were measured and are given to the nearest hundredth of a foot. The well-numbering system used in this table is described on page 11.

TABLE 10.—*Records of wells in Sherman County, Kansas*

WELL NUMBER	Owner or tenant	Type of well (1)	Depth of well (feet) (2)	Diameter of well (inches) (3)	Type of casing	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Distance above land surface (feet)	Measuring point: Height above mean sea level (feet) (6)	Depth to water level below measuring point (feet) (7)	Date of measurement, 1949	REMARKS (Yield given in gallons a minute; drawdown in feet)
T. 5 S., R. 38 W.															
5-38-31ccc	E. M. Brown	Dr	175.5	6	GI	Sand, gravel	Ogallala	Cy, W	N	Top of casing, north side	1.0	3,560.6	162.74	July 15	Located in Cheyenne County
5-38-36cdc	M. B. Hanley	Dr	156.0	6	GI	do	do	Cy, W	D, S	Top of concrete curb	0.8	3,473.5	147.21	July 8	do
T. 5 S., R. 39 W.															
5-39-32ccb	T. J. Ruder	Dr	108.0	5	GI	do	do	Cy, W	S	Top of casing	0.7	3,560.3	102.05	Oct. 26	do
T. 6 S., R. 37 W.															
6-37-1bcc	R. Tovrea	Dr	198.0	6	GI	do	do	Cy, W	D, S	do	0.4	3,434.2	179.30	Aug. 22	
6-37-6ada	L. C. Hazen	Dr	58.5	6	GI	do	do	Cy, W	S	Top of board cover	0.8	3,345.9	43.07	July 8	
6-37-8dcb	F. G. Cooper	Dr	174.5	6	GI	do	do	Cy, N	N	Hole in casing	—2.5	3,465.8	161.76	July 19	Abandoned
6-37-8bbb	Minnie Johnson	Dr	20.5	6	GI	do	Alluvium	N, N	N	Top of casing	1.5	3,324.6	19.86	July 8	do
6-37-9ada	M. H. Van Dyke	Dr	143.5	6	GI	do	Ogallala	Cy, W	N	do	0	3,424.2	128.00	July 19	do
6-37-11bcc	C. P. Jones	Dr	195.0	6	GI	do	do	Cy, W	S	Top of concrete curb	0.5	3,454.6	183.90	Nov. 3	Chemical analysis
6-37-15aad	W. Briney	Dr	184.0	6	GI	do	do	Cy, N	N	do	1.5	3,456.2	173.54	June 29	Abandoned
6-37-18bcc	Sarah Stanley	Dr	66.5	5	GI	do	do	Cy, W	S	do	0.2	3,364.3	36.60	July 21	
6-37-22ada	D. H. Downing	Dr	162.5	5	GI	do	do	N, N	N	Top of casing, east side	0.5	3,442.9	150.79	June 29	Abandoned
6-37-28ccc	Nellie E. Bunten	Dr	167.0	5	GI	do	do	N, N	N	Top of concrete curb	0	3,464.6	146.57	July 21	do
6-37-31bbb	Rolla Ackerman	Dr	175.5	6	GI	do	do	Cy, W	S	Top of casing	0.3	3,493.3	149.25	July 8	
6-37-35bcb	Bob Rawson	Dr	148.5	6	GI	do	do	Cy, W	D, S	do	0.4	3,447.9	134.36	June 29	
T. 6 S., R. 38 W.															
6-38-1cdc	R. Pemberton	Dr	66.0	6	GI	do	do	Cy, W	D, S	do	1.2	3,381.5	55.26	July 8	Not used much
6-38-6ccc	J. Mosbarger	Dr	180.0	6	GI	do	do	Cy, W	D, S	do	0.4	3,569.2	168.20	July 15	
6-38-9bcc	F. R. Cooper	Dr	156.0	6	GI	do	do	Cy, W	S	do	0.5	3,513.9	139.23	July 15	Not in use
6-38-10bac	C. E. Jones	Dr	109.5	6	GI	do	do	Cy, W	S	do	0.4	3,462.6	107.85	July 8	
6-38-14bad	F. S. Miller	Dr	80.5	5	GI	do	do	Cy, W	S	do	0.3	3,393.9	48.16	July 21	
6-38-20acc	August Busse	Dr	52.0	18	S	do	Alluvium, Ogallala	T, G	I	do	1.0	3,408.1	12.84	July 18	Not used in 1949
6-38-23bbb	Ida D. Sparks	Dr	23.5	5	GI	do	do	Cy, H, W	S	Top of board curb	0	3,372.5	18.09	July 18	
6-38-30dbd	Carl Tellessen	Dr	20.5	6	GI	do	Alluvium	Cy, W	S	Top of casing	1.5	3,424.5	10.66	July 18	
6-38-34cbb	E. E. Euwer	Dr	152.8	6	S	do	Ogallala	Cy, W	S	do	0.8	3,515.1	125.37	July 13	Chemical analysis

T. 6 S., R. 39 W.														
6-39-3dcc	August Busse	Dr	183.0	5	GI	do.	do.	Cy, W	S	do.	1.6	3,596.6	180.16	July 22	Not in use
6-39-4add	Wilhelmina C. Hitch	Dr	187.5	6	GI	do.	do.	Cy, W	D, S	do.	1.3	3,561.2	139.76	July 15	
6-39-6dda	Walter M. Jones	Dr	160.0	6	GI	do.	do.	Cy, W	D, S	do.	1.6	3,596.9	144.03	July 15	Chemical analysis
6-39-9ddd	School district	Dr	160.0	6	GI	do.	do.	Cy, H	D	do.	0.5	3,578.8	146.05	July 6	
6-39-14dad	Charles E. Sherrod	Dr	149.0	6	GI	do.	do.	Cy, W	D, S	Top of concrete curb	0.9	3,536.4	120.40	July 15	
6-39-17ccc	R. A. Hardin	Dr	171.5	6	GI	do.	do.	N, N	N	Top of casing, southeast side	0.8	3,628.7	163.43	June 8	Abandoned
6-39-21cba	C. E. Eklund	Dr	136.0	6	GI	do.	do.	Cy, W	S	Top of concrete curb	1.0	3,553.5	102.71	July 6	
6-39-23cca	E. A. Rhoads	Dr	90.5	6	GI	do.	do.	Cy, W	S	Top of casing	1.1	3,478.6	44.35	July 15	
6-39-24daa	Orville Bogenhagen	Dr	48.5	6	GI	do.	do.	Cy, W	D, S	Top of curb	0.3	3,465.1	43.85	July 15	
6-39-25cdd	S. D. Nichols	Du,Dr	61.0	18	S	do.	Ogallala, Alluvium	HC, G	I	Top of concrete curb	2.8	3,453.0	18.55	July 18	Not used in 1949
6-39-25cbb	do.	Du,Dr	42.0	6	GI	do.	do.	HC, G	I	Base, plank platform	3.2	3,439.2	12.50	July 18	Irrigates garden
6-39-29ccd	Jerry Barnes	Dr	146.0	6	GI	do.	Ogallala	Cy, W	D, S	Top of casing	0.6	3,597.7	118.29	July 15	
6-39-36bbc	Robert Coon	Dr	21.0	6	GI	do.	Alluvium	Cy, W	S	do.	0.6	3,445.6	15.54	July 18	
T. 6 S., R. 40 W.															
6-40-3add	Emil Peter	Dr	169.0	6	GI	do.	Ogallala	Cy, W	S	Top of curb	0.6	3,637.5	155.75	Oct. 17	
6-40-4abb	H. K. Loyd	Dr	124.5	6	GI	do.	do.	Cy, W	D	do.	1.7	3,605.8	111.08	Oct. 17	
6-40-6bab	L. E. Harrison	Dr	153.0	5	GI	do.	do.	Cy, W	S	Top of casing	0.5	3,661.5	142.35	Oct. 17	
6-40-7cdd	Harold Bair	Dr	176.5	5	GI	do.	do.	Cy, W	D, S	Top of concrete curb	0.7	3,697.8	164.30	Oct. 17	
6-40-16bdd	P. N. Scofield	Dr	160.0	6	GI	do.	do.	Cy, W	D, S	Top of casing	0.8	3,667.9	149.60	Oct. 17	Not frequently used
6-40-22add	J. S. Stoskopf et al	Dr	151.5	6	GI	do.	do.	Cy, W	D, S	do.	1.5	3,646.7	147.32	June 20	do
6-40-25ada	Minnie L. Downing	Dr	182.2	5	GI	do.	do.	N, N	N	Top of concrete curb	2.2	3,657.1	170.21	July 15	Abandoned
6-40-31bcd	J. W. Harkins	Dr	168.5	5	GI	do.	do.	Cy, N	N	do.	0.3	3,719.1	147.50	Oct. 17	do
6-40-33bbb	J. G. Curry	Dr	160.0	6	GI	do.	do.	Cy, W	D, S	Top of casing	0.6	3,690.3	154.73	June 20	
6-40-35bcc	J. W. Peter	Dr	167.0	6	GI	do.	do.	Cy, W	D	do.	1.1	3,658.3	145.95	July 6	Not used frequently
T. 6 S., R. 41 W.															
6-41-2bcb	Fred Boll	Dr	188.5	6	GI	do.	do.	Cy, H, W	D, S	Top of concrete curb	1.0	3,718.6	172.73	June 11	
6-41-9bcb	LeRoy Fortmeyer	Dr	205.0	6	GI	do.	do.	Cy, W	D, S	Top of casing	0.8	3,759.5	179.60	July 6	Chemical analysis
6-41-14abb	Wm. Rieb, Jr.	Dr	157.5	6	GI	do.	do.	Cy, H	S	Hole in pump base	0.2	3,704.5	144.97	June 11	Not used
6-41-21aaa	School district	Dr	143.0	6	GI	do.	do.	N, N	D	Top of casing	1.3	3,716.4	133.32	Oct. 20	New well
6-41-23bbb	Bessie E. Jones	Dr	112.0	5	GI	do.	do.	Cy, W	S	do.	1.2	3,662.0	92.08	Oct. 21	Not in use
6-41-27bcd	Oscar Roulier	Dr	175	6	S	do.	do.	Cy, W	S			3,753.8	149	June 11	
6-41-29baa	John G. Duckworth	Dr	162.5	6	GI	do.	do.	Cy, W	S	Top of casing	1.1	3,764.7	143.47	July 11	
6-41-31cca	W. Kirby	Dr	159.0	5	GI	do.	do.	Cy, W	S	do.	1.1	3,787.6	139.20	July 11	
6-41-34ddd	Lenna Hobbs	Dr	186.0	6	GI	do.	do.	Cy, H, W	D, S	Top of concrete curb	1.1	3,753.9	149.64	June 11	Not used frequently
T. 6 S., R. 42 W.															
6-42-1ccc	W. A. Wolfe	Dr	133.0	6	GI	do.	do.	Cy, W	S	Top of casing	0.6	3,743.2	123.15	July 6	do
6-42-4aac	Rufus Stephens	Dr	167.5	6	GI	do.	do.	Cy, W	D, S	do.	1.3	3,773.7	155.25	June 30	Chemical analysis
6-42-6aaa	B. V. Kellner	Dr	172.0	5	GI	do.	do.	Cy, W	S	Top of discharge pipe	—2.0	3,796.4	167.65	July 23	
6-42-10bcb	I. G. Roscoe	Dr	138.0	6	GI	do.	do.	Cy, W	D, S	Top of casing	0.8	3,765.2	128.00	June 30	
6-42-13aaa	Jesse James	Dr	170.5	6	GI	do.	do.	Cy, W	S	do.	0	3,798.0	158.75	July 11	

TABLE 10.—*Records of wells in Sherman County, Kansas—Continued*

WELL NUMBER	Owner or tenant	Type of well (1)	Depth of well (feet) (2)	Diameter of well (inches) (3)	Type of casing	Principal water-bearing bed		Method of lift (4)	Use of water (5)	Measuring point			Depth to water level below measuring point (feet) (7)	Date of measurement, 1949	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) (6)			
T. 6 S., R. 42 W.															
6-42-17cbb	B. R. Graybill	Dr	164.0	6	GI	Sand, gravel	Ogallala	Cy, W	D, S	Top of casing	0.2	3,819.1	149.45	July 16	
6-42-22ccd	School district	Dr	192.0	6	GI	do	do	Cy, W	D	do	0.6	3,851.7	188.40	June 30	
6-42-23bcb	Charlie Pizel	Dr	235.0	6	GI	do	do	Cy, W	S	do	0.6	3,837.5	194.13	June 30	
6-42-25dda	M. Kirby	Dr	150.5	6	GI	do	do	Cy, W	D, S	Top of concrete curb	1.3	3,786.0	146.00	July 11	Unable to measure water level accurately
6-42-26acc	Curtis James	Dr	338.0	16	S	do	do	T, G	I	Top of casing	0.7	3,837.5	183.29	Sept. 17	Drilled in 1949
6-42-30abb	Nellie Anderson	Dr	202.0	6	GI	do	do	Cy, W	D, S	Top of floor	0.7	3,870.1	176.32	July 16	
6-42-33aad	Harold Daise	Dr	180.0	6	GI	do	do	Cy, W, G	D, S	Top of casing	0.6	3,845.4	170.00	June 30	
6-42-36ccc		Dr	163.5	6	GI	do	do	Cy, W	D, S	do	0.6	3,721.2	156.27	July 16	Not in use. Located in Kit Carson County, Colo.
T. 7 S., R. 37 W.															
7-37-1dcc	T. F. Carpenter	Dr	123.0	6	GI	do	do	Cy, W	D, S	do	0.2	3,400.8	113.33	June 29	
7-37-4bcb	D. H. Downing	Dr	....	4	GI	do	do	Cy, W	D	do	0.5	3,472.7	139.80	Aug. 22	Unable to get past cylinder to measure depth
7-37-11bba	Minna Dillinger	B	154.0	5	GI	do	do	Cy, W	D, S	Top of concrete curb	0.5	3,446.7	147.10	July 22	
7-37-12cdd	L. E. Hazen	Dr	140.0	6	GI	do	do	Cy, W	N	Top of casing	0.6	3,415.2	121.75	June 29	Abandoned
7-37-16aaa	W. Briney	Dr	136.0	5	GI	do	do	N, N	N	Top of casing, west side	0.3	3,448.6	128.28	July 21	do
7-37-18cbc	W. W. Bear	Dr	146.0	6	GI	do	do	Cy, H, W	S	Top of casing	0.6	3,501.9	128.10	July 11	Not in use
7-37-19ddd	Congregational Christian church	Dr	133.8	6	GI	do	do	Cy, W	D	do	0.3	3,481.6	105.00	June 29	
7-37-21aaa	Federal Land Bank	Dr	119.0	6	GI	do	do	Cy, H	N	Top of casing, east side	0.7	3,440.5	112.03	July 21	Abandoned
7-37-25daa	V. C. Eddy	Dr	142.3	6	GI	do	do	Cy, H	N	Top of casing	0.6	3,428.9	132.07	June 29	do
7-37-26ccc	Antydony Deane	Dr	142.0	6	GI	do	do	Cy, H, W	D, S	Top of concrete curb	0.8	3,473.7	137.10	July 21	
7-37-28cbc	Rosa M. O'Neal	Dr	87.0	6	GI	do	do	Cy, G	S	Top of casing	0.3	3,449.3	81.66	June 29	
7-37-36cdd	B. A. Hutton	Dr	135.5	6	GI	do	do	Cy, W	D, S	do	1.1	3,443.7	133.17	June 29	Not used frequently

T. 7 S., R. 38 W.														
7-38-2bab	L. S. McIntire	Dr	160.0	6	GI	do.	do.	Cy, W	D, S	do.	0.5	3,534.8	155.90	July 19	
7-38-7dcd	J. C. Woods	Dr	147.0	6	GI	do.	do.	Cy, W	D, S	Top of plate holding pipe	0.3	3,568.1	136.40	June 14	
7-38-9ccc	F. P. Brubaker	Dr	152.0	6	GI	do.	do.	Cy, W	D, S	Top of concrete curb	0.3	3,555.5	137.61	June 14	Not used often
7-38-11acd	Robert Hartley	Dr	177.0	6	GI	do.	do.	Cy, W	D, S	Top of casing	0.8	3,540.9	157.15	July 19	
7-38-34cbc	F. G. Chambers	Dr	114.0	6	GI	do.	do.	Cy, W	S	Top of concrete curb	0	3,513.1	97.44	July 13	
7-38-36ada	Wm. Seick	Dr	144.5	6	GI	do.	do.	Cy, W	S	Top of casing	0.6	3,519.6	127.00	July 8	Chemical analysis
T. 7 S., R. 39 W.															
7-39-2bdd	L. D. Coon	Dr	44.0	6	GI	do.	do.	Cy, H, W	D, S	do.	0.6	3,477.8	28.55	July 18	Not in use
7-39-7ccb	James Krayca	Dr	39.0	6	GI	do.	do.	Cy, W	S	do.	1.1	3,549.2	33.43	June 13	
7-39-7daa	J. H. Shaver	Dr	107.5	6	GI	do.	do.	Cy, H, W	D, S	Top of concrete curb	2.4	3,586.0	92.50	June 8	
7-39-9adb	G. W. Forney	Dr	108.0	6	GI	do.	do.	Cy, W	S	Top of casing	0.7	3,570.2	94.55	July 6	
7-39-14ccc	E. W. Morton	Dr	138.0	6	GI	do.	do.	N, N	N	do.	1.4	3,592.8	121.64	June 14	Abandoned stock well
7-39-16bcd	W. T. Wickwar	Dr	66.3	5	GI	do.	do.	N, N	D, S	do.	1.7	3,544.1	47.90	July 6	New well
7-39-20bad	W. O. Rhoads	Dr	140.0	18	GI	do.	do.	T, T	I	Top of hole, base of pump	0.8	3,532.6	22.24	July 6	Measured yield 1180
7-39-30dad	Bernard Borgmann	Dr	61.0	6	GI	do.	do.	Cy, W	D, S	Top of casing	0.8	3,580.4	59.82	June 13	
7-39-32cdd	I. A. Ihrig	Dr	159.0	6	GI	do.	do.	Cy, W	D, S	do.	0.9	3,642.4	136.73	June 15	
7-39-33ada	O. H. Andrew	Dr	140.0	5	GI	do.	do.	Cy, W	D, S	do.	1.2	3,622.2	133.25	June 15	Not used frequently
7-39-35add	Don Weick	Dr	164.8	6	GI	do.	do.	Cy, W	D, S	Top of concrete curb	0.2	3,610.1	148.76	June 14	Chemical analysis
T. 7 S., R. 40 W.															
7-40-6ddc	Paul Roeder	Dr	149.5	6	GI	do.	do.	Cy, W	D, S	do.	1.0	3,718.8	144.31	June 15	
7-40-11dcc	Wm. Mangus	Du, Dr	79.0	16	S	do.	do.	T, G	I	Base of board cover	0	3,568.5	43.27	June 18	Dug to 41 feet; 36 inch concrete casing; measured yield 427
7-40-16bdd	H. C. Tagtmeyer	Dr	78.0	18	S	do.	do.	T, N	I	Base of pump	0.2	3,620.0	54.54	June 20	Old irrigation well; not in use
7-40-20add	H. S. Brinkmeier	Dr	100.0	6	GI	do.	do.	Cy, W	D, S	Top of casing	1.1	3,670.9	97.25	June 20	
7-40-26cdd	Nick Walker	Dr	119.0	6	GI	do.	do.	N, N	N	Top of casing, south side	1.5	3,636.1	89.35	June 20	Abandoned
7-40-29bbb	W. Curry	Dr	157.0	16	GI	do.	do.	T, N	I	Top of casing, east side	0	3,707.0	121.85	June 20	Not in use
7-40-29dda	J. F. Jenson	Dr	134.0	6	GI	do.	do.	Cy, W	D, S	Top of concrete curb	1.2	3,693.9	115.10	June 15	
7-40-32cdd	P. H. Rossener et al.	Dr	122.0	5	GI	do.	do.	N, N	N	Top of casing, east side	1.0	3,707.9	112.90	June 20	Abandoned
7-40-36ccd	T. F. Skelton	Dr	132.8	6	GI	do.	do.	Cy, G	N	Top of concrete curb	1.0	3,673.3	131.88	June 15	do
T. 7 S., R. 41 W.															
7-41-2add	J. Roth	Dr	172.0	6	GI	do.	do.	N, N	N	Top of casing	0.6	3,752.5	156.90	Oct. 24	do
7-41-4baa	F. D. Elliott	Dr	159.5	6	GI	do.	do.	Cy, W	D	Top of casing, west side	—4.0	3,779.0	153.06	July 20	
7-41-5ddc	Wilber Tubbs	Dr	174.5	6	GI	do.	do.	Cy, W	D, S	Top of casing	0.3	3,801.4	160.50	July 20	
7-41-7bcb	F. F. Bair	Dr	182.0	6	GI	do.	do.	Cy, W	D, S	do.	1.5	3,843.3	178.14	July 20	
7-41-11ddd	do.	Dr	135.0	6	GI	do.	do.	N, N	N	Top of concrete curb	1.8	3,734.7	127.50	July 20	Abandoned
7-41-16cdd	A. L. Rinck	Dr	127.5	6	GI	do.	do.	Cy, G	N	Top of casing	1.0	3,770.1	118.82	July 20	Not in use

TABLE 10.—*Records of wells in Sherman County, Kansas—Continued*

Well Number	Owner or tenant	Type of well (1)	Depth of well (feet) (2)	Diameter of well (inches) (3)	Type of casing	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Distance above land surface (feet)	Measuring point: Height above mean sea level (feet) (6)	Depth to water level below measuring point (feet) (7)	Date of measurement, 1949	REMARKS (Yield given in gallons a minute; drawdown in feet)
T. 7 S., R. 41 W.															
7-41-21bba	R. E. Amos	Dr	146.0	5	GI	Sand, gravel	Ogallala	Cy, W	D, S	Top of casing	0.5	3,792.9	124.00	July 20	
7-41-22cbb	Adolph Evert	Dr	93.6	6	GI	do	do	Cy, W	S	Top of board cover	0.5	3,728.3	79.73	June 11	
7-41-26dad	J. W. Kaiser	Dr	58.0	6	GI	do	do	Cy, W	S	Top of casing	1.0	3,683.4	55.86	July 20	
7-41-28aad	Adolph Evert	Dr	106.0	6	GI	do	do	Cy, W	D, S	do	0.8	3,754.4	102.20	June 11	Chemical analysis
7-41-28dda	do	Dr	99.0	6	GI	do	do	N, N	N	Top of casing, north side	1.0	3,743.9	84.40	June 11	Abandoned
7-41-31ccb	H. F. Swayne	Dr	133.5	6	GI	do	do	Cy, H, W	S	Top of casing	0.9	3,813.7	103.69	Oct. 18	
7-41-36bcc	C. W. White	Dr	112.5	6	GI	do	do	Cy, W	D, S	Top of concrete curb	1.3	3,742.6	111.40	July 20	
T. 7 S., R. 42 W.															
7-42-1bbc	E. M. Anderson	Dr	183.0	6	S	do	do	Cy, W	S	Top of casing	1.2	3,797.0	131.89	July 20	
7-42-7add	J. Waltz	Dr	166.0	6	GI	do	do	Cy, W	N	do	0.9	3,891.8	163.90	July 16	Not in use
7-42-10cbb	Wm. Mack Currens	Dr	128.5	6	GI	do	do	Cy, W	D, S	Top of plank cover	0.6	3,828.0	124.17	Oct. 18	Chemical analysis
7-42-16dcd	Arthur B. Richardson	Dr	184.5	6	GI	do	do	Cy, W	D, S	Top of concrete curb	0.9	3,872.5	157.00	June 11	Not in use
7-42-18dad	Fay Christenson	Dr	137.5	6	GI	do	do	Cy, W	D, S	Top of casing	1.0	3,872.4	128	July 16	Unable to obtain accurate water level measurement
7-42-22add	A. J. Cook	Dr	170.0	6	GI	do	do	Cy, W	S	Hole in top of plate	0.2	3,858.8	146.13	June 30	
7-42-24cdb		Dr	168.0	6	GI	do	do	Cy, W	S	Top of concrete curb	0.2	3,874.8	156.59	July 30	Not in use. Located in Kit Carson County, Colo.
7-42-31add	T. B. Wright	Dr	141.0	6	GI	do	do	Cy, H	D	Hole, side of pump	0.7	3,906.9	137.48	July 16	Not used often
7-42-34bda	Walter Wright	Dr	164.5	6	GI	do	do	Cy, W	S	Top of casing	1.1	3,882.2	146.92	Oct. 18	
T. 8 S., R. 37 W.															
8-37-9dcc	Moise Roulier	Dr	92.0	4	GI	do	do	Cy, W	D, S	Top of concrete curb	0.6	3,456.6	78.10	June 10	Not in use
8-37-10ddc	L. F. Horney	Dr	108.8	6	GI	do	do	Cy, N	N	do	0.3	3,452.9	89.69	June 10	Abandoned
8-37-11cdc	W. E. Roulier	Dr	84.0	6	GI	do	do	Cy, W	S	do	0.2	3,421.6	72.64	June 10	
8-37-12ada	Wm. Guise	Dr	78.0	6	GI	do	do	Cy, W	S	Top of casing	1.9	3,379.0	66.88	June 29	
8-37-13add	Cemetery	Dr	125.5	6	GI	do	do	Cy, W	P	do	0.4	3,430.6	112.20	June 10	
8-37-14add	W. L. Wright	Dr	137.5	6	GI	do	do	Cy, H, W	D, S	Top of concrete curb	0.8	3,455.2	124.93	June 10	Abandoned
8-37-17aac	R. H. Harvey	Dr	130.5	6	GI	do	do	Cy, W	N	Top of casing	0.5	3,488.7	99.70	July 21	Not in use

8-37-26dad	John Brooks	Dr	68.3	6	GI	do.	do.	N, N	N	do.	0.6	3,404.8	63.67	June 10	Abandoned stock well
8-37-28abc	Albert Vohs	Dr	125.0	6	GI	do.	do.	N, N	S, O	Top of casing, west side	0.3	3,479.1	107.89	May 17	Measured in 1948
8-37-32cbb	L. D. Golden	Dr	109.2	6	GI	do.	do.	N, N	N	Top of casing	0.6	3,494.9	98.23	June 17	Abandoned
8-37-33baa	Nellie Brochinski	Dr	125.0	6	GI	do.	do.	Cy, H, W	D	do.	0.7	3,462.9	88.66	June 17	Chemical analysis
8-37-36bcb	J. M. Brooks	Dr	56.0	4	GI	do.	do.	N, N	N	Bend in casing	0	3,390.6	48.69	Aug. 22	Abandoned stock well
T. 8 S., R. 38 W.															
8-38-5ddc	L. H. Simmons	Dr	108.0	6	GI	do.	do.	Cy, W	S	Top of casing	0.5	3,519.8	87.92	July 22	
8-38-6abc	J. A. Glasco	Dr	166.0	6	S	do.	do.	Cy, W	S	do.	0.9	3,581.0	134.46	July 13	
8-38-9daa	John Kuhlman	Dr	152.2	5	GI	do.	do.	Cy, W	S	do.	1.4	3,570.1	146.28	June 10	
8-38-12ccc	George C. Krotter	Dr	115.0	6	GI	do.	do.	Cy, W	S	Top of concrete curb	0.3	3,516.9	112.50	June 10	
8-38-15dda	Chris Sporsel	Dr	120.5	6	GI	do.	do.	Cy, W	S	Top of casing	0.6	3,539.0	111.34	July 21	
8-38-17abb	G. Ashcraft	Dr	136.0	5	GI	do.	do.	N, N	N	do.	0.5	3,579.9	134.95	July 21	Abandoned
8-38-18bcc	L. S. C. Runnells	Dr	144.0	6	GI	do.	do.	Cy, W	D, S	do.	1.0	3,603.8	131.88	June 16	
8-38-19ccc	Henry Northdurft	Dr	125.0	6	GI	do.	do.	Cy, W	D, S	do.	0.7	3,607.7	118.67	June 29	
8-38-25dcc	Charles Bateman	Dr	122.5	6	GI	do.	do.	Cy, W	D, S	Top of concrete curb	0.5	3,523.5	109.33	June 17	
8-38-26aba	Albert P. Vohs	Dr	240.0	16	S	do.	do.	T, G	I	Top of casing	1.1	3,553.9	129.40	June 17	
8-38-28acc	do.	Dr	215.0	16	S	do.	do.	T, D	I	Top of concrete curb	1.1	3,587.7	132.87	June 17	
8-38-31ccd	A. M. Dautel	Dr	139.0	6	GI	do.	do.	Cy, W	S	Top of casing	1.1	3,613.2	126.63	June 16	
T. 8 S., R. 39 W.															
8-39-3abb	Mrs. John Diebolt	Dr	160	6	GI	do.	do.	Cy, W	D, S			3,630.5	156	June 14	
8-39-3cbc	John Harding	Dr	151.5	6	GI	do.	do.	Cy, W	D, S	Top of casing	0.6	3,622.3	125.05	June 15	Chemical analysis
8-39-7add	L. L. Crosby	Dr	120.5	6	S	do.	do.	Cy, W	S	do.	0.9	3,642.1	101.70	June 13	
8-39-11aad	H. M. Armstrong	Dr	135.0	6	GI	do.	do.	Cy, W	S	do.	0.3	3,585.2	112.28	July 13	Not in use
8-39-15ccc	Tom Cebula	Dr	254	18	S	do.	do.	T, NG	I	Top of observation pipe	1.3	3,643.0	127.78	Aug. 4	Measured yield, 650; Chemical analysis
8-39-19aaa	City of Goodland	Dr	295	18	S	do.	do.	T, E	P				150	Aug. 29	Reported yield, 350
8-39-19adb	Commonwealth Theaters	Dr	209.0	12	S	do.	do.	T, E	A	Top of casing	1.0	3,689.6	149.27	June 14	
8-39-19bab	City of Goodland	Du,Dr	295	12	S	do.	do.	T, E	P				150	Aug. 29	Dug to 157 feet (about 7 feet in diameter) and drilled remainder; Reported yield about 300
8-39-19caa	Wm. Hall	Dr	165.5	6	GI	do.	do.	N, N	O	Top of casing	0.4	3,694.5	150.33	June 8	
8-39-19cad	Chicago, Rock Island and Pacific Railroad	Dr	299	12	S	do.	do.	T, E	R				150	Oct. 20	
8-39-19cad2	do.	Du,Dr	255	12	S	do.	do.	T, E	R				150	Oct. 20	Reported yield, 165. Originally dug to 165 feet, later filled in
8-39-19cad3	do.	Dr	190	12	S	do.	do.	Cy, E	R				150	Oct. 20	
8-39-20cbc	City of Goodland	Dr	295	12	S	do.	do.	T, E	P				150	Aug. 29	Reported yield, 325
8-39-20cdd	Susie Beal	Dr	149.5	6	GI	do.	do.	Cy, W	D	Top of concrete curb	0.3	3,675.5	136.20	July 21	
8-39-25bab	Edward Gard	Dr	154	6	GI	do.	do.	Cy, E	D			3,621.8	130	June 10	
8-39-26cbd	R. R. Weick	Dr	124.0	6	GI	do.	do.	Cy, W	D, S	Top of casing	0.8	3,624.6	115.26	July 13	Not in use
8-39-30bcc	E. A. Rockwell	Dr	160.0	6	S	do.	do.	Cy, E	D	Top of curb	—5.5	3,695.9	132.59	June 8	Chemical analysis

Table 10.—*Records of wells in Sherman County, Kansas—Continued*

Well Number	Owner or tenant	Type of well (1)	Depth of well (feet) (2)	Diameter of well (inches) (3)	Type of casing	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Distance above land surface (feet)	Measuring point: Height above mean sea level (feet) (6)	Depth to water level below measuring point (feet) (7)	Date of measurement, 1949	REMARKS (Yield given in gallons a minute; drawdown in feet)
T. 8 S., R. 40 W.															
8-40-4ddd	Thomas W. Taylor	Dr	109.0	4	GI	Sand, gravel	Ogallala	N, N	N	Top of concrete curb	1.6	3,680.8	103.53	June 15	Abandoned
8-40-5ddb	C. E. Taylor	Dr	133.0	6	GI	do.	do.	Cy, W	S	Top of casing	1.2	3,722.8	125.13	June 15	
8-40-10ada	T. L. Reamer	Dr	162.0	6	GI	do.	do.	Cy, H, W	D, S	do.	1.3	3,714.4	148.30	June 15	
8-40-12dba	John Hevner	Dr	230	16	S	do.	do.	T, G	I	Hole, base of pump	0.5	3,670.9	122.70	June 15	Measured yield, 316
8-40-15ccd	J. W. Isernhagan	Dr	143.0	6	GI	do.	do.	Cy, W	S	Top of casing, south side	1.0	3,730.9	131.77	June 20	Not in use
8-40-17baa	H. F. G. Darnauer	Dr	109.0	6	GI	do.	do.	Cy, W	S	Top of casing	0.3	3,698.6	82.20	June 20	
8-40-20ddd	F. L. Dimmitt	Dr	40.5	6	GI	do.	do.	N, N	N	Top of casing, west side	1.8	3,664.6	37.09	June 13	Abandoned stock well
8-40-24baa	Victoria Van Drasek est.	Dr	164.0	6	GI	do.	do.	N, N	O	do.	0.7	3,698.4	137.19	May 17	Measured in 1948
8-40-26bab	Radio station KWGB	Dr	176.0	6	GI	do.	do.	Cy, E	D	Top of casing	1.5	3,719.7	130.54	July 4	
8-40-30aad	H. Mueller	Dr	98.8	6	S	do.	do.	Cy, W	S	Top of concrete curb	1.0	3,711.0	73.20	June 13	
8-40-30cbb	Ralph Topliff	Dr	62.0	6	GI	do.	do.	Cy, W	S	Top of casing	1.0	3,704.6	50.02	June 22	
8-40-36ada	Mrs. J. A. Keeran	Dr	156.0	6	GI	do.	do.	Cy, G	D, S	do.	1.0	3,711.4	140.80	June 9	
T. 3 S., R. 41 W															
8-41-4ddc	C. O. Duell	Dr	90.0	6	GI	do.	do.	Cy, W	S	do.	1.2	3,756.8	78.09	June 11	
8-41-8dbc	Opal Errington	Dr	70.0	5	GI	do.	do.	Cy, W	S	do.	0.7	3,763.8	59.68	Oct. 20	
8-41-12aba	W. F. Foster	Dr	138 0	6	GI	do.	do.	Cy, W	S	do.	2.7	3,752.5	119.30	July 20	Not in use
8-41-22cbb	Ruleton school	Dr	170	8	S	do.	do.	T, E	D			3,811.1	121	Oct. 26	Chemical analysis
8-41-22cbb2		Dr	137.0	8	S	do.	do.	Cy, H, W	S	Top of board cover	1.6	3,811.6	123.03	Oct. 26	
8-41-26aba	Rudolph Meinen	Dr	108	6	GI	do.	do.	Cy, W	D	Top of casing	1.2	3,759.3	94.35	June 13	
8-41-29aaa	Benjamin B. Foster	Dr	105.0	6	GI	do.	do.	Cy, W	S	Top of concrete curb	0.5	3,804.0	94.76	June 13	
8-41-32bbb	R. J. Hayden	Dr	97.0	6	GI	do.	do.	Cy, W	S	Top of casing	0.2	3,818.3	86.60	June 22	Not in use
8-41-34ccc	Tom Hayden	Dr	117.5	6	GI	do.	do.	Cy, W	D, S	Top of concrete curb	0.7	3,804.6	104.24	June 22	
T. 8 S., R. 42 W.															
8-42-2cbb	H. L. Pizel	Dr	124.0	5	GI	do.	do.	N, N	N	Top of casing, west side	1.2	3,851.2	109.43	June 30	Abandoned
8-42-3ccc	Charley Behl	Dr	123.0	6	GI	do.	do.	Cy, H	D, S	Top of casing	1.1	3,869.2	114.95	Oct. 18	Not in use

8-42-10ddd	W. Zeibig	Dr	135.0	6	GI	do	do	Cy, W	D, S	do	0.1	3,855.0	100.79	June 30	
8-42-13cbb	Lillie M. Wren	Dr	96.0	5	GI	do	do	Cy, W	S	Top of concrete curb	1.0	3,835.3	86.91	Nov. 5	
8-42-20cbb	Kanorado cemetery	Dr	160.0	6	GI	do	do	Cy, W	P	Top of concrete platform	0	3,913.5	110.16	July 16	
8-42-20cdb	City of Kanorado	Dr	186	8	S	do	do	Cy, E	P	....	....	....	100	Oct. 19	Reported yield, 100, drawdown, 11
8-42-23bcc	Hy. Pettibone	Dr	87.8	5	GI	do	do	N, N	N	Top of casing, west side	1.6	3,846.8	80.87	June 30	Abandoned
8-42-26bbb	W. B. Taylor	Dr	61.5	5	GI	do	do	Cy, W	D	Top of casing	0.8	3,828.5	59.57	June 27	
8-42-29bac	City of Kanorado	Dr	179	8	S	do	do	T, E	P	....	....	....	93	Oct. 19	Reported yield, 250 with 7 foot drawdown
8-42-30add	Bernice H. Platt	Dr	104.5	6	GI	do	do	Cy, W	S	Top of casing	0	3,908.1	94.22	Aug. 13	
8-42-33dcd	Ethel Nelson	Dr	141.0	5	GI	do	doz	Cy, W	S	do	0.5	3,830.3	129.31	Oct. 19	
8-42-35ddd	L. F. Thompson	Dr	113.0	5	GI	do	do	Cy, W	D, S	Top of concrete curb	1.7	3,868.4	98.36	June 27	
T. 9 S., R. 37 W.															
9-37-1dad	R. F. Craige	Dr	94.5	6	GI	do	do	Cy, W	D, S	Top of casing	0.7	3,411.7	76.67	July 22	Not used frequently
9-37-3aab	Albert Smith	Dr	70.0	6	GI	do	do	Cy, H, W	D, S	Top of concrete curb	0.6	3,419.6	54.59	June 17	
9-37-5ccc	F. N. Owens	Dr	78.0	6	GI	do	do	Cy, W	D, S	Top of casing	0.6	3,472.0	70.85	June 17	
9-37-15bab	W. T. Rooney	Dr	144.0	5	GI	do	do	Cy,H,W,G	D, S	do	0.6	3,497.7	136.58	Aug. 22	
9-37-21bbc	R. H. Garvey	Dr	112.0	6	GI	do	do	N, N	N	do	1.8	3,480.8	106.83	June 17	Abandoned
9-37-24daa	A. Richard	Dr	152.0	6	GI	do	do	Cy, W	S	do	0	3,441.6	143.26	July 5	
9-37-30dad	Florence Beatty et al.	Dr	174.5	6	GI	do	do	Cy, W	S	do	0.2	3,542.8	162.77	June 17	Chemical analysis
9-37-31dad	I. H. Mueller	Dr	145.0	6	GI	do	do	Cy, W	D, S	Top of concrete curb	0.7	3,508.2	137.45	June 17	
9-37-33aaa	T. H. Watters	Dr	203.5	6	GI	do	do	Cy, W	D, S	do	0.5	3,514.0	194.55	June 17	
9-37-36baa	C. and P. Falconer	Dr	208.5	5	GI	do	do	N, N	N	Top of casing	3.3	3,484.6	204.36	July 22	Abandoned
T. 9 S., R. 38 W.															
9-38-2bba	C. Tiede	Dr	142.1	6	GI	do	do	Cy, H	D, S	do	0.5	3,554.5	117.26	June 7	Not frequently used
9-38-5dcc	F. Bergsma	Dr	136.5	6	GI	do	do	Cy, W	D, S	do	0.9	3,591.6	116.43	June 28	Chemical analysis
9-38-11ddd	C. L. Elliott	Dr	119.5	6	GI	do	do	Cy, W	D, S	do	0.8	3,546.8	112.67	June 28	
9-38-24cbb	Leonard Musil	Dr	104.0	6	GI	do	do	Cy, W	D, S	do	0.3	3,528.1	84.00	June 28	
9-38-27bcb	H. E. Mann	Dr	109.5	6	S	do	do	Cy, W	S	Top of base plate	0.9	3,562.3	93.50	Aug. 23	
9-38-30bdb	Herman Burk	Dr	100.5	5	GI	do	do	Cy, W	S	Top of casing	1.9	3,588.2	82.50	Aug. 23	
9-38-31acc	Jake Van Donge	Dr	129.0	6	GI	do	do	Cy, W	S	do	0.7	3,626.0	120.60	Aug. 1	
T. 9 S., R. 39 W.															
9-39-3daa	J. F. Chambers	Dr	149.0	5	GI	do	do	N, N	N	Top of casing, east side	0.8	3,658.1	139.11	July 13	Abandoned
9-39-6aad	A. R. Tompkins	Dr	138.0	6	GI	do	do	N, N	N	Top of casing, south side	0.6	3,688.6	124.85	July 13	do
9-39-13bcb	J. Walschmidt	Dr	129.0	6	GI	do	do	Cy, H, W	D, S	Top of casing	—5.5	3,627.5	115.75	June 16	
9-39-16ccb	Ora West	Dr	122.0	6	GI	do	do	Cy, W	D, S	do	0.6	3,667.7	106.25	Aug. 23	
9-39-18aad	F. J. Armstrong	Dr	168.3	6	GI	do	do	Cy, W	D	do	0.9	3,702.4	129.25	July 12	Not frequently used
9-39-28bcc	W. Peter	Dr	140.0	5	GI	do	do	Cy, W	D, S	Top of curb	0.9	3,697.0	131.80	Aug. 23	Not in use
9-39-30cbb	Charles Glenn	Dr	145.0	6	GI	do	do	Cy, W	S, O	Top of casing, south side	0	3,711.5	118.68	May 17	Measured in 1948
9-39-32baa	Anne Cotter	Dr	155.0	5	GI	do	do	N, N	N	Top of casing	0	3,700.4	129.07	Aug. 23	Abandoned
9-39-36cdc	Lillian Briney	Dr	145.0	6	GI	do	do	Cy, W	N	Top of concrete curb	0.4	3,646.9	124.69	June 16	do

TABLE 10.—*Records of wells in Sherman County, Kansas—Continued*

Well Number	Owner or tenant	Type of well (1)	Depth of well (feet) (2)	Diameter of well (inches) (3)	Type of casing	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Distance above land surface (feet)	Measuring point: Height above mean sea level (feet) (6)	Depth to water level below measuring point (feet) (7)	Date of measurement, 1949	REMARKS (Yield given in gallons a minute; drawdown in feet)
T. 9 S., R. 40 W.															
9-40-1dad	G. E. Mercer	Dr	132.0	6	GI	Sand, gravel	Ogallala	Cy, W	D, S	Top of casing	1.2	3,705.4	122.04	June 23	
9-40-4baa	Robert J. Hayden	Dr	108.0	6	GI	do	do	Cy, W	S	do	0.4	3,726.5	98.56	June 7	
9-40-7daa	Wilfred E. Taylor	Dr	139.5	6	GI	do	do	Cy, W	S	do	0.8	3,768.9	113.50	June 21	
9-40-10dad	G. G. Topliff	Dr	129.5	5	GI	do	do	Cy, W	D, S	Top of concrete curb	0.1	3,719.2	104.02	June 22	
9-40-16ddd	Nelle J. Shutte	Dr	137.5	6	GI	do	do	Cy, W	D, S	Top of casing	0.3	3,762.7	128.62	June 21	
9-40-18dad	George A. McClelland	Dr	129.5	6	GI	do	do	Cy, H, W	D, S	do	0.6	3,781.6	120.90	June 21	Not in use
9-40-23bbb	E. Irvin	Dr	123.0	6	GI	do	do	Cy, W	N	do	0.2	3,734.4	115.09	June 23	Abandoned
9-40-28dad	E. S. House	Dr	130.8	5	GI	do	do	Cy, W	S	do	0.9	3,746.6	112.32	June 21	Not in use
9-40-30daa	M. W. Townsend	Dr	124	6	GI	do	do	Cy, W	D, S			3,769.5	100	June 23	
9-40-32daa	Peter N. Emig	Dr	117.0	6	GI	do	do	Cy, W	S	Top of board cover	1.2	3,769.2	115.00	June 23	
9-40-35bbb	E. S. House	Dr	139.0	6	GI	do	do	Cy, W	S	Top of casing	0.4	3,735.4	114.00	June 9	
T. 9 S., R. 41 W.															
9-41-7adb	Oren Parish	Dr	205	8	GI	do	do	T, N	I	Top of 2x4, west side	0.4	3,854.2	105.00	June 26	Reported 205 feet deep by driller; Not in use
9-41-11bba	E. H. Veselik	Dr	77.0	5	GI	do	do	Cy, W	S	Top of concrete curb	1.3	3,754.6	63.65	Aug. 30	
9-41-15bcc	Cecelia E. Veselik	Dr	78.0	6	GI	do	do	Cy, H, W	N	Top of casing	0.7	3,798.6	65.35	June 22	Abandoned
9-41-17dcc	Howard Underwood	Dr	82.0	5	GI	do	do	Cy, G	S	Top of curb	0.5	3,800.4	59.18	Nov. 5	
9-41-18cbb	Reuben Parish	Dr	245	16	S	do	do	T, D	I			3,862.3	90	June 22	16 inch casing to 200 feet 12 inch casing to 245 feet
9-41-19dda	V. W. Taylor	Dr	126.0	5	GI	do	do	N, N	N	Top of casing	0.1	3,876.8	117.54	Aug. 30	Abandoned
9-41-21ddc	F. Musalek	Dr	143.0	5	GI	do	do	Cy, W	S	Top of concrete curb	0	3,862.3	133.19	June 22	
9-41-24bbb	George F. Hayden	Dr	140.0	5	GI	do	do	Cy, W	S	Top of casing	0.7	3,801.8	114.98	Aug. 30	
9-41-27dad	V. W. Taylor	Dr	106	6	GI	do	do	Cy, W	D, S			3,830.6	102	June 21	
9-41-28cbb	E. J. Wilkinson	Dr	131.5	6	GI	do	do	Cy, W	N	Top of casing	1.1	3,870.5	125.44	June 23	Not in use
9-41-33ccb	Frank Petracich	Dr	79.0	6	GI	do	do	Cy, W	S	do	0.4	3,817.6	62.00	June 23	
T. 9 S., R. 42 W.															
9-42-2cbb	Andrew C. Carlson	Dr	80.0	5	GI	do	do	Cy, W	S	do	0.3	3,860.6	71.80	Aug. 30	Chemical analysis
9-42-9cbb	Leon L. Livengood	Dr	99.0	6	GI	do	do	Cy, W	S	do	0.8	3,911.3	87.99	Oct. 18	
9-42-13bbb	E. Irvin	Dr	120.0	6	GI	do	do	Cy, H, W	D, S	do	0.7	3,900.1	117.36	July 9	

9-42-18aaa	C. H. Briggs	Dr	91.5	5	GI	do.	do.	Cy, W	S	do.	2.0	3,919.2	88.70	Oct. 19	
9-42-21cbb	Myrtle E. Wilson	Dr	117.5	6	GI	do.	do.	Cy, W	S	do.	0.3	3,956.2	116.82	June 27	
9-42-23bcb	E. Blystone	Dr	104.5	6	GI	do.	do.	Cy, W	S	do.	0.6	3,901.4	91.54	June 27	
9-42-26add	R. W. Livengood	Dr	99.5	6	GI	do.	do.	Cy, W	S	do.	2.2	3,890.1	86.43	June 23	
9-42-32aad	John C. Jones	Dr	103.5	4	GI	do.	do.	Cy, W	D, S	Top of plank	0.2	3,965.0	99.06	Aug. 30	Reported 119 feet deep Weight probably caught on cylinder on depth measurement
T. 10 S., R. 37 W.															
10-37-10aaa	Vera F. Rasmussen	Dr	179.0	5	GI	do.	do.	Cy, N	N	Top of casing	0.7	3,440.0	165.02	July 22	Abandoned
10-37-13daa	Cellie Emel	Dr	168.5	6	GI	do.	do.	Cy, W	S	do.	0.8	3,387.6	140.65	July 5	Chemical analysis
10-37-20bab	H. H. Goetsch	Dr	138.0	6	GI	do.	do.	Cy, W	S	do.	0.8	3,428.2	137.60	June 28	
10-37-22cdd	H. Miller	Dr	101.0	6	GI	do.	do.	Cy, W	D, S	Top of concrete curb	2.5	3,376.3	99.00	Aug. 22	
10-37-23dab	Irvin R. Miller	Dr	174.0	6	GI	do.	do.	Cy, W	S	do.	1.6	3,412.9	164.00	Aug. 22	
10-37-30ccc	Rachel Cogswell	Dr	82.5	6	GI	do.	do.	Cy, W	N	Top of casing	1.0	3,404.4	81.05	July 5	Abandoned
10-37-32dcc	J. S. Garvey	Dr	63.0	6	GI	do.	do.	Cy, W	S	Top of concrete curb	1.2	3,326.8	60.33	July 5	
10-37-34add	George Knox	Dr	155.0	6	GI	do.	do.	Cy, H, W	S	Top of casing	1.0	3,395.7	149.41	July 5	Not in use
10-37-36abb	R. Emel	Dr	88.5	5	GI	do.	do.	Cy, W	S	do.	1.2	3,326.7	80.20	Aug. 22	
T. 10 S., R. 38 W.															
10-38-7bbb	Floyd Pickett	Dr	97.5	6	GI	do.	do.	Cy, W	D, S	do.	1.4	3,592.9	95.50	June 16	
10-38-13acc	Rachel Cogswell	Dr	57.0	6	GI	do.	do.	N, N	N	do.	1.0	3,456.4	18.98	Aug. 23	Abandoned stock well
10-38-18ccd	H. T. Hewett	Dr	117.5	6	GI	do.	do.	Cy, G, W	D, S	do.	0.4	3,576.6	104.87	June 16	Abandoned
10-38-19ccc	W. T. Connolly	B	48.5	6	GI	do.	do.	Cy, W	D, S	do.	0.4	3,494.5	46.55	June 16	Chemical analysis
10-38-22cdc	J. W. Baughman	Dr	90.0	5	GI	do.	do.	Cy, W	S	do.	0.5	3,454.5	86.50	Aug. 23	
10-38-24ddc	Rachel Cogswell	Dr	105.0	6	GI	do.	do.	Cy, W	S	do.	0.7	3,426.6	99.24	Aug. 23	
10-38-30cab	do.	Du,Dr	30.2	60	C	do.	Alluvium	HC, G	I	Top of concrete curb	1.0	3,452.7	10.15	July 25	Not in use
10-38-30dcc	Minnie Smith	Dr	23.5	6	GI	do.	do.	Cy, W	S	do.	0.9	3,452.2	14.90	June 16	Chemical analysis
10-38-32aca	Rachel Cogswell	B	15.5	6	GI	do.	do.	Cy, W	S	Top of tin cover	0	3,418.6	7.40	July 25	
10-38-35abb	do.	Dr	89.0	5	GI	do.	Ogallala	Cy, W	S	Top of concrete curb	0	3,388.3	68.62	July 24	
T. 10 S., R. 39 W.															
10-39-4ccc	Effie B. Lasley	Dr	88.0	5	GI	do.	do.	N, N	N	Top of casing	1.0	3,635.2	85.90	July 12	Abandoned
10-39-6add	A. R. Tompkins	Dr	62.5	6	GI	do.	do.	Cy, W	S	do.	1.5	3,617.6	47.20	July 12	
10-39-8bcc	Hoyt Tompkins	Dr	224.0	6	GI	do.	do.	Cy, W	D, S	do.	0	3,569.7	16.20	July 12	Chemical analysis
10-39-10aaa	Dave Laughlin	Dr	110.0	6	GI	do.	do.	Cy, W	D, S	do.	0.9	3,644.4	103.25	July 13	
10-39-14aab	do.	Dr	95.5	6	GI	do.	do.	Cy, W	S	do.	1.9	3,592.6	77.64	July 12	
10-39-14cbb	Catherine Bradshaw et al.	Dr	105.5	6	GI	do.	do.	Cy, W	D, S	do.	0.5	3,604.4	94.50	June 16	
10-39-16bba	E. H. Lorens	Dr	25.0	6	GI	do.	do.	Cy, W	D, S	do.	0	3,542.2	17.50	July 12	
10-39-25bdc	John Cogswell	Dr	59.0	18	GI	do.	Alluvium, Ogallala	T, N	I	Top of pump base	2.4	3,471.1	13.80	July 25	Not in use in 1949
10-39-26ab	do.	Du,Dr	36.0	18	GI	do.	Alluvium	HC, G	I	Top of casing	3.0	3,498.3	11.10	July 25	Not in use in 1949 A battery of two wells
10-34-32abb	Otis Todd	Dr	93	4	GI	do.	Ogallala	Cy, W	D, S			3,705.3	90	Aug. 24	

TABLE 10.—*Records of wells in Sherman County, Kansas—Concluded*

WELL NUMBER	Owner or tenant	Type of well (1)	Depth of well (feet) (2)	Diameter of well (inches) (3)	Type of casing	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Distance above land surface (feet)	Measuring point: Height above mean sea level (feet) (6)	Depth to water level below measuring point (feet) (7)	Date of measurement, 1949	REMARKS (Yield given in gallons a minute; drawdown in feet)
T. 10 S., R. 40 W.															
10-40-1aaa	Harry H. Miller	Dr	91.5	6	GI	Sand, gravel	Ogallala	Cy, W	S	Top of concrete curb	0.5	3,666.5	81.04	June 9	
10-40-4add	W. Darnauer	Dr	76.5	6	GI	do.	do.	Cy, W	S	do.	0.1	3,688.2	56.64	June 23	
10-40-8bcc	G. Townsend	Dr	115.0	5	GI	do.	do.	N, N	D	Top of casing	3.0	3,759.4	81.79	Nov. 12	New well
10-40-10acd	Tom Watters	Dr	49.5	18	S	do.	Alluvium, Ogallala	T, G	I	do.	1.2	3,635.6	21.83	June 23	
10-40-12aad	Phil Trablik	Dr	32.5	6	GI	do.	Ogallala	Cy, H	D	do.	1.5	3,576.1	23.11	June 9	
10-40-12aad2	do.	B	13.5	6	GI	do.	Alluvium	P, H	S	do.	2.0	3,566.3	6.06	June 9	
10-40-14bab	Sherman County	Dr	72.5	6	GI	do.	Ogallala	Cy, W	D, S	Top of curb	1.0	3,652.9	52.84	June 9	
10-40-16bab	Carl Smith	Dr	63.0	6	S	do.	do.	Cy, W	S	Top of casing	0.4	3,693.9	43.62	Aug. 25	
10-40-21ccc	do.	Dr	145.0	6	S	do.	do.	Cy, W	S	do.	0.7	3,784.2	120.50	Aug. 24	
10-40-23bdc	do.	Dr	104.5	6	S	do.	do.	Cy, W	S	do.	0.8	3,728.2	92.30	Aug. 24	
10-40-32bcb	do.	Dr	95.0	6	S	do.	do.	Cy, W	S	do.	1.0	3,757.9	76.89	Aug. 24	
10-40-34ddc	Junius A. Parker	B	33.0	5	GI	do.	do.	Cy, H	N	do.	0	3,655.7	25.90	Aug. 24	Abandoned
T. 10 S., R. 41 W.															
10-41-2bbb	Charles Wilkinson	Dr	103.5	6	GI	do.	do.	Cy, W	D, S	Top of concrete curb	0.7	3,804.4	80.90	June 21	
10-41-3ddd	School district	Dr	116.0	6	GI	do.	do.	Cy, W	D	Top of casing	0.5	3,807.7	76.24	June 21	
10-41-6add	J. E. Lawrence	Dr	128.5	5	GI	do.	do.	N, N	N	do.	0.3	3,876.7	97.66	Aug. 26	Abandoned
10-41-8bca	do.	Dr	63.5	6	GI	do.	do.	Cy, W	S	do.	0.8	3,834.7	52.10	June 22	
10-41-12add	E. L. Moore	Dr	82.0	6	GI	do.	do.	Cy, W	N	do.	1.0	3,762.6	65.85	Aug. 25	Not in use
10-41-13aac	Percy Murray	Dr	30.5	6	GI	do.	do.	Cy, W	S	do.	1.6	3,732.8	28.63	Aug. 26	
10-41-14ccc	Mae E. Purvis	Dr	18.5	6	GI	do.	Alluvium	Cy, H	S	Top of concrete curb	0.8	3,753.2	12.42	June 21	
10-41-22daa	do.	Dr	40.5	6	GI	do.	Ogallala	Cy, W	S	Top of hole, west side of casing	1.5	3,774.3	27.08	June 21	
10-41-24dbb	I. J. Waits	Dr	115.0	5	GI	do.	do.	Cy, W	D, S	Top of casing	1.3	3,816.3	110.56	Aug. 26	
10-41-26ccc	E. L. Hayden	Dr	91.0	6	GI	do.	do.	Cy, W	D, S	Top of plate	0.6	3,819.6	70.90	Aug. 26	Chemical analysis
10-41-28bab	F. Hayden	Dr	111.0	6	GI	do.	do.	Cy, W	S	Top of hole in plate	0.4	3,850.4	92.93	Aug. 26	
10-41-29bac	Reed Golden	Dr	122.0	6	GI	do.	do.	Cy, W	S	Top of casing	0.3	3,820.9	50.00	Aug. 26	
10-41-33daa	W. B. Hayden	Dr	129.0	5	GI	do.	do.	Cy, W	S	do.	0.3	3,875.5	101.50	Aug. 26	

T. 10 S., R. 42 W.														
10–42–1bbb	Reed Golden	Dr	83.0	5	GI	do	do	N, N	N	Top of casing, south side	0	3,884.0	69.43	June 23	Abandoned
10–42–6dab	Eula M. Cramer	Dr	114.0	6	GI	do	do	Cy, W	D, S	Top of concrete curb	0.5	3,993.2	103.67	Aug. 30	Not in use
10–42–9bba	E. B. Williams	Dr	93.0	5	GI	do	do	Cy, H, W	D, S	Top of casing	0.8	3,963.0	87.92	June 27	Chemical analysis
10–42–11dda	G. Adolph Johnson	Dr	101.0	6	GI	do	do	Cy, H	N	do	0	3,912.0	89.00	July 9	Abandoned
10–42–13acc	Golden brothers	Dr	112.0	6	GI	do	do	N, N	S	do	1.0	3,896.5	79.46	June 27	New well. Drilled as irrigation test well
10–42–21bbb	H. Nagel et al.	Dr	140	18	S	do	do	T, N	I	Ground surface	0	3,973.0	82.70	Oct. 31	Not pumped for several years
10–42–22baa	Ernest Notz	Dr	75.5	6	GI	do	do	Cy, W	W			3,920.7	58	Oct. 31	
10–42–24cdb	Golden brothers	Dr	47.0	6	N	do	Alluvium, Ogallala	N, N	N	Ground surface	0	3,857.1	32.40	June 27	Drilled 155 feet as irrigation test well
10–42–26bab	Ernest Notz	Dr	69.3	6	GI	do	Ogallala	Cy, H, W	N	Top of casing	0.2	3,916.0	60.76	June 27	Not in use
10–42–33bcd	Berth Rivers et al.	Dr	51.4	6	GI	do	do	Cy, W	S	Top of board cover	0.5	3,932.3	39.57	June 27	
10–42–36bcc	C. A. Denton	Dr	114.5	6	GI	do	do	Cy, W	D, S	Top of casing	0.9	3,914.5	81.27	July 9	
T. 11 S., R. 40 W.															
11–40–1bcc	P. M. Piper	Dr	94.0	5	GI	Shale	Pierre	Cy, W	D, S	do	0	3,687.0	73.72	Aug. 24	Located in Wallace County. Chemical analysis
T. 11 S., R. 41 W.															
11–41–6bbb		Dr	124.5	6	GI	Sand, gravel	Ogallala	Cy, W	D	Top of concrete curb	0.9	3,885.2	108.66	Aug. 26	Located in Wallace County

1. B, bored; Dr, drilled; Du, dug.
2. Reported depths below land surface given in feet; measured depths given in feet and tenths below measuring point.
3. C, Concrete; GI, galvanized iron; N, none; S, steel.
4. Type of pump: Cy, cylinder; HC, horizontal centrifugal; N, none; P, pitcher; T, turbine. Type of power: D, diesel; G, gasoline; H, hand; N, none; NG, natural gas; T, tractor; W, wind.
5. A, air conditioning; D, domestic; I, irrigation; N, not in use; O, observation; P, public supply; R, railroad; S, stock.
6. Where no measuring point is given, altitude is that of land surface at well.
7. Measured depths to water level are given in feet, tenths, and hundredths; reported depths to water level are given in feet.

LOGS OF TEST HOLES AND WELLS

Listed on the following pages are logs of 31 test holes drilled by the State Geological Survey, logs of 9 test holes or irrigation wells, and the log of 1 railroad well. The locations of test holes drilled by the State Geological Survey are shown in Figure 7.

Sample logs are given for holes drilled by the State Geological Survey and from which samples were collected. Test holes 7-37-1aaa and 9-36-31ccc were drilled in 1943 as part of an investigation of the geology and ground-water resources of Thomas County. Logs of these holes were prepared by Oscar S. Fent and samples were studied by him and John C. Frye. The remainder of the State-drilled test holes were drilled in 1949; I collected samples of the cuttings and prepared the logs of the holes.

5-37-33cdc. *Sample log of test hole in the SW¼ SE¼ SW¼ sec. 33, T. 5 S., R. 37 W., Cheyenne County; drilled August 1949. Surface altitude, 3,350.7 feet; depth to water level August 14, 1949, 50.0 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation—Peoria silt member		
Silt, tan	1	1
TERTIARY—Pliocene		
Ogallala formation		
Sand, medium to coarse, and fine gravel	9	10
Sand, medium to coarse, and fine to coarse gravel; contains a large amount of coarse gravel	10	20
Gravel, coarse to fine; contains a small amount of coarse sand	11	31
Sand, medium to coarse, and fine gravel; contains greenish-brown clay	14	45
Sand, fine to coarse, and fine to medium gravel; contains some brownish silt and clay	15	60
Gravel, coarse to fine, and medium to coarse sand	17	77
Mortar bed	16	93
Silt and clay, brown	4	97
Mortar bed containing much calcium carbonate; contains less calcium carbonate and is softer from 128 to 130 feet	33	130
Sand, fine to medium; contains some calcium carbonate cement	12	142
Sand, fine to medium	8	150
Sand, fine to medium; contains some green clay	15	165
Mortar bed; contains much lime cement	5	170
Sand, fine to medium; contains very little cement	22	192
CRETACEOUS—Gulfian		
Pierre shale		
Shale, weathered, yellow-brown	5	197
Shale, blue-black	13	210

6-38-31ccc. *Sample log of test hole in the SW cor. sec. 31, T. 6 S., R. 38 W.; drilled August 1949. Surface altitude, 3,527.5 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation—Peoria silt member		
Silt, dark-brown	2	2
Silt and fine to very fine sand; contains stringers of soil caliche, 10 to 25 feet	23	25
TERTIARY—Pliocene		
Ogallala formation		
Silt and clay, sandy, light-brown	8	33
Gravel, coarse, and some plastic silt and clay	8	41
Silt and fine sand, plastic, brown; contains sand and gravel at base	9	50
Gravel, coarse; contains a little silt and fine sand	3	53
Silt and fine sand, plastic, brown; contains sand and gravel	8	61
Mortar bed, soft	18	79
Sand, medium to coarse, and fine to coarse gravel	15	94
Sand, fine, and plastic silt	3	97
Sand, fine to coarse; contains some fine gravel	6	103
Sand, fine to coarse, and fine to coarse gravel	4	107
Sand, fine to coarse, and fine to coarse gravel; contains brown plastic silt and clay	6	113
Silt and clay, sandy, brown	17	130
Sand, fine to coarse, and fine gravel, partially cemented; contains some silt and very fine sand	25	155
Silt and very fine sand, plastic, brown; contains more sand from 165 to 170 feet	15	170
Silt and very fine sand, plastic, brown; contains much sand	20	190
Sand, fine to coarse; contains silt and clay	20	210
Sand, fine to medium; contains silt and clay	68	278
CRETACEOUS—Gulfian		
Pierre shale		
Shale, yellow-brown to greenish	1	279
Shale, dark blue-black	9	288

6-40-1aaa. *Sample log of test hole in the NE cor. sec. 1, T. 6 S., R. 40 W.; drilled September 1949. Surface altitude, 3,584.1 feet; depth to water level September 6, 1949, 129 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation—Peoria silt member		
Silt, dark-brown to tan	15	15
TERTIARY—Pliocene		
Ogallala formation		
Limestone, light-tan; "Algal limestone" at the top	13	28
Clay and silt, sandy, red	3	31
Mortar bed	9	40
Silt and clay, sandy, reddish-brown	18	58
Sand, fine to coarse	10	68

	Thickness, feet	Depth, feet
Gravel, coarse	12	80
Sand, fine to coarse	10	90
Sand, very fine to medium	5	95
Silt, sandy, brown	5	100
Silt and very fine sand, brown	40	140
Sand, fine to coarse, and fine gravel	18	158
Silt and clay, sandy, light-tan	12	170
Sand, fine to coarse, and fine gravel; contains silt and clay	20	190
Silt and very fine sand, brown	10	200
Silt and very fine to fine sand, light-brown	20	220
Sand, very fine to fine	15	235
Mortar bed	5	240
Sand, medium to coarse	64	304
CRETACEOUS—Gulfian		
Pierre shale		
Shale, weathered, greenish- to yellowish-brown	6	310
Shale, dark-blue to black	5	315

6-40-36ddd. *Sample log of test hole in the SE cor. sec. 36, T. 6 S., R. 40 W.; drilled September 1949. Surface altitude, 3,620.0 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation—Peoria silt member		
Silt, dark-brown	4	4
Silt, tan	28	32
TERTIARY—Pliocene		
Ogallala formation		
Silt and clay, calcareous, cream-colored; contains fragments of "Algal limestone"; hard layer from 38 to 39 feet	12	44
Gravel, fine to coarse, cemented	4	48
Silt and very fine sand, brown	2	50
Silt and very fine sand, brown; contains some medium to coarse sand and fine to coarse gravel	15	65
Silt and very fine sand, compact, tan to brown; greenish from 78 to 82 feet	17	82
Sand, fine to coarse; contains silt and very fine sand and a little gravel	8	90
Sand, fine to coarse; contains a little silt and a little fine gravel	17	107
Gravel, fine to coarse; contains some plastic brown silt and very fine sand	3	110
Sand, fine to coarse; contains a small amount of fine gravel	8	118
Silt and very fine sand, compact, brown; contains a small amount of fine to coarse gravel	12	130
Sand, fine to coarse; contains some fine gravel	5	135
Sand, fine to coarse; contains fine to coarse gravel	5	140

	Thickness, feet	Depth, feet
Sand, fine to coarse, and fine to coarse gravel; a little finer from 145 to 150 feet	10	150
Sand, medium to fine; contains a little coarse sand from 156 to 160 feet	15	165
Sand, medium to fine, light-brown	7	172
Sand, fine to coarse; contains a little fine to medium gravel	18	190
Sand, fine to coarse; contains a little very fine sand and silt	10	200
Silt and very fine sand, brown, compact	10	210
Sandstone, fine	8	218
Sand, fine to medium; contains white calcium carbonate cement; contains a little coarse sand and fine gravel from 218 to 220 feet	12	230
Sand, fine to medium, cemented; contains white silt and very fine sand from 238 to 246 feet	16	246
Silt and very fine sand, green	2	248
Sand, fine to medium; partially cemented from 268 to 270 feet	22	270
Sand, fine to medium	33	303
CRETACEOUS—Gulfian		
Pierre shale		
Shale, blue-black; contains a little greenish-gray clay at top	7	310

6-41-36ddd. *Sample log of test hole in the SE cor. sec. 36, T. 6 S., R. 41 W.; drilled September 1949. Surface altitude, 3,723.4 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation—Peoria silt member		
Silt, dark-brown	4	4
Silt, light-tan	33	37
TERTIARY—Pliocene		
Ogallala formation		
Silt, sandy, light-tan	17	54
Sand, coarse, and fine to coarse gravel; contains reddish-brown silt and clay	21	75
Sand, coarse, and fine to medium gravel	10	85
Gravel, fine to coarse	10	95
Sand, coarse, and fine to coarse gravel; contains brown silt and clay	12	107
Sand, fine to coarse, and fine gravel; partially cemented	6	113
Silt, sandy, brown	18	131
Sand, medium to coarse; contains much silt and very fine sand	9	140
Sand, coarse, and fine to coarse gravel; contains silt and very fine sand	10	150
Sand, medium to coarse	10	160

	Thickness, feet	Depth, feet
Sand, coarse, and fine to medium gravel	10	170
Mortar bed	21	191
Sand, medium to coarse	10	201
Mortar bed	56	257
Sandstone, medium-grained	13	270
Sand, fine to medium	56	326
Sand, coarse, and fine gravel	4	330
CRETACEOUS—Gulfian		
Pierre shale		
Shale, yellowish-green	3	333
Shale, dark-blue to black	7	340

6-42-2aaa. *Sample log of test hole in the NE cor. sec. 2, T. 6 S., R. 42 W.; drilled September 1949. Surface altitude 3,784.7 feet; depth to water level September 17, 1949, 184.8 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Peoria silt member		
Silt, dark-brown	2	2
Silt, tan	38	40
Loveland silt member		
Silt, red-brown	4	44
TERTIARY—Pliocene		
Ogallala formation		
Silt and clay, calcareous, cream-colored	11	55
Sand, fine to coarse, with silt and clay binder	5	60
Mortar bed	4	64
Sand, fine to coarse, and fine to coarse gravel	6	70
Sand, fine to coarse, and fine gravel	7	77
Sand, medium to coarse, and fine to coarse gravel; contains compact brown clay and silt	3	80
Sand, fine to coarse, reddish	6	86
Sand, fine to coarse, and a little fine to coarse gravel	14	100
Sand, fine to coarse, partly cemented	8	108
Sand, fine to coarse, and fine to coarse gravel	6	114
Silt and clay, gray to brown	6	120
Sand, fine to coarse, with brown silt and very fine sand,	13	133
Sand, fine to coarse, and fine to coarse gravel; contains compact silt and very fine sand	7	140
Sand, fine to coarse, and fine gravel; contains very fine sand and silt	7	147
Sand, fine to coarse, and fine to coarse gravel	14	161
Sand, fine to coarse	3	164
Sand, fine to coarse, and fine to coarse gravel	6	170
Sand, fine to coarse; contains silt and very fine sand	6	176
Sand, fine to coarse, and fine to coarse gravel	8	184
Sand, fine to coarse, partially cemented; contains a little fine to coarse gravel	5	189
Mortar bed	18	207

	Thickness, feet	Depth, feet
Sand, fine to medium, brown	7	214
Mortar bed	4	218
Sand, fine to coarse, and fine to coarse gravel, partially cemented	6	224
Mortar bed	6	230
Sand, fine to coarse, and fine gravel	10	240
Sand, fine to coarse, and fine to coarse gravel; contains silt and very fine sand as binder	10	250
Sand, fine to coarse, and fine to coarse gravel, partially cemented	10	260
Sand, fine to coarse, and fine gravel; contains a small amount of medium to coarse gravel	15	275
Gravel, coarse to fine, and medium to coarse sand	5	280
Sand, coarse to medium, and a small amount of fine gravel	6	286
Gravel, coarse to fine, and coarse sand	2	288
CRETACEOUS—Gulfian		
Pierre shale		
Shale, clayey, yellow-brown to tan	12	300
Shale, blue-black	6	306

6-42-31ddd. *Sample log of test hole in the SE cor. sec. 31, T. 6 S., R. 42 W.; drilled September 1949. Surface altitude, 3,880.8 feet; depth to water level September 17, 1949, 171.3 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation—Peoria silt member		
Silt, black	2	2
Silt, tan	24	26
Silt, light-tan	7	33
TERTIARY—Pliocene		
Ogallala formation		
Clay, calcareous, white; contains chips of "Algal limestone"; limestone layer from 36 to 37 feet	7	40
Clay and caliche	4	44
Sand, fine to coarse, and fine to coarse gravel	6	50
Sand, fine to coarse; contains a little fine to coarse gravel; lower part contains silt and very fine sand as binder	10	60
Sand, medium to coarse, and fine gravel; contains a little medium to coarse gravel	9	69
Silt and very fine sand, brown	2	71
Mortar bed	8	79
Gravel, coarse	2	81
Clay, silt, and very fine sand, gray	7	88
Mortar bed	9	97
Sand, medium to coarse, and fine to coarse gravel	3	100
Gravel, coarse to fine, and coarse to medium sand	23	123
Sand, fine to coarse, and fine to coarse gravel; finer than the preceding 23 feet	10	133

	Thickness, feet	Depth, feet
Silt and very fine sand, brown; contains a little gravel,	7	140
Sand, fine to medium, brown	4	144
Silt, and very fine to fine sand, brown	7	151
Sand, fine to coarse; contains gray silt and gravel from 154 to 158 feet	13	164
Sand, fine to coarse, and fine to coarse gravel; contains a little brown silt	11	175
Sand, fine to coarse, brown	16	191
Mortar bed	7	198
Sand, fine to coarse, and fine to coarse gravel; cemented from 207 to 210 feet	12	210
Mortar bed	6	216
Sand, fine to coarse, brown; cemented with calcium carbonate	10	226
Sand, fine to coarse, and fine to coarse gravel; contains brown silt and very fine sand binder	4	230
Sand, fine to coarse, and fine gravel; contains brown silt and very fine sand binder	12	242
Silt, and very fine to fine sand, compact	3	245
Sand, fine to coarse, red-brown; contains a little fine gravel	22	267
Sand, fine to coarse; contains a little fine gravel; cemented with calcium carbonate	2	269
Sand, fine to medium, greenish	31	300
Sand, fine to medium; contains a little coarse sand from 310 to 322 feet	22	322
CRETACEOUS—Gulfian		
Pierre shale		
Shale, weathered, yellow-brown	2	324
Shale, blue-black	6	330

6-42-36ccc. *Sample log of test hole in the SW cor. sec. 36, T. 6 S., R. 42 W.; drilled September 1949. Surface altitude, 3,791.1 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation—Peoria silt member		
Silt, black	1	1
Silt, tan	34	35
Silt and very fine sand, tan	1	36
TERTIARY—Pliocene		
Ogallala formation		
Silt, calcareous, light-tan	18	54
Sand, coarse, and fine to coarse gravel	6	60
Gravel, coarse to fine, and a little coarse sand	11	71
Gravel, fine to coarse, and medium to coarse sand	21	92
Silt and very fine sand, compact, brown	5	97
Sand, fine to coarse, and fine to coarse gravel; contains brown silt and very fine sand	3	100
Silt, clay, and very fine sand, light-brown; cream-colored from 120 to 123 feet	23	123

	Thickness, feet	Depth, feet
Sand, fine to coarse, and fine to coarse gravel	20	143
Sand, very fine to coarse; contains a little brown silt	9	152
Sand, very fine to medium, partially cemented; contains silt and clay	6	158
Mortar bed	2	160
Sand, fine to medium, with white silt and very fine sand binder	12	172
Sand, fine to medium; contains silt, very fine sand, and a small amount of coarse gravel	3	175
Silt and very fine to fine sand, brown	13	188
Sand, fine to medium, brown	5	193
Mortar bed	25	218
Sand, very fine to coarse	6	224
Sand, very fine to coarse; contains calcium carbonate cement	6	230
Sand, very fine to medium	20	250
Sand, very fine to medium; contains a little coarse sand,	28	278
Clay, yellow-green	8	286
Sand, very fine to coarse	2	288
CRETACEOUS—Gulfian		
Pierre shale		
Clay, yellowish-green	2	290
Clay, yellow	4	294
Shale, blue-black	6	300

7-37-1aaa. *Sample log of test hole in the NE cor. sec. 1, T. 7 S., R. 37 W.; drilled September 1943. Surface altitude, 3,417.5 feet; depth to water level October 1943, 140.0 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Soil, dark gray-brown	4	4
Silt, soft, yellow-gray; contains some very fine sand	33	37
Silt, partly clayey, compact, light brown-gray and light-buff; contains a little fine sand; contains a little coarse sand near 50 feet	13	50
Silt, clayey, cream and light-buff; contains a little caliche and fine to medium gravel	10	60
Silt, white to tan; contains much caliche, a little fine gravel, and fine to coarse sand	7	67
TERTIARY—Pliocene		
Ogallala formation		
Gravel, coarse to fine, cemented	3	70
Gravel, coarse to fine, and sand; contains a little caliche	3	73
Silt, greenish-gray downward to buff; contains some medium to fine gravel, coarse to fine sand, and a little caliche	15	88

	Thickness, feet	Depth, feet
Gravel, coarse to fine, and sand; contains a little light-buff silt; contains caliche from 97 to 98 feet	12	100
Gravel, medium to fine, and sand; contains some coarse gravel	7	107
Silt, buff and white; contains much fine gravel, coarse to fine sand, and caliche	23	130
Gravel, fine, and sand, partly cemented by caliche	6	136
Silt, gray-green and buff; contains some coarse to fine sand and a little caliche	4	140
Silt, soft, light brown-green and gray; contains a little caliche and a little coarse to fine sand	13	153
Gravel, fine, and sand; contains a little caliche	4.5	157.5
Silt, soft, light green-gray and light-brown; contains a little caliche	1.5	159
Gravel, coarse to fine, and sand; mostly firmly cemented	11	170
Gravel, medium to fine, and sand; contains some caliche	7	177
Silt, light-gray and tan; contains much coarse to fine sand and caliche and some fine to medium gravel	13	190
Silt, buff and white, and caliche; contains some fine to medium sand	6	196
Gravel, medium to fine, and sand	4	200
Sand, coarse to fine, buff silt, and caliche	7	207
Gravel, medium to fine, and sand; contains much gray and buff silt and a little caliche	15	222
Silt, yellow-gray, and caliche	4	226
Sand, coarse to fine; contains a little fine gravel and caliche	24	250
Sand, coarse to fine; contains some medium to fine gravel and silt; light gray-green	13	263
Clay, light gray-green and white; contains some medium to fine sand and some caliche	9	272
Gravel, fine, and sand; light-gray	9	281
Silt, light gray-green; contains much medium to fine sand	3	284
Gravel, fine, and sand; light-gray	6	290
Gravel, medium to fine, and sand; gray	8	298
CRETACEOUS—Gulfian		
Pierre shale		
Shale, clayey, light blue-gray and yellow	2	300
Shale, dark-gray and light-green	10	310

7-37-5bbb. *Sample log of test hole in the NW cor. sec. 5, T. 7 S., R. 37 W.; drilled August 1949. Surface altitude, 3,465.7 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation—Peoria silt member		
Silt, black	5	5
Silt, tan	33	38

	Thickness, feet	Depth, feet
TERTIARY—Pliocene		
Ogallala formation		
Clay, calcareous, light-tan	7	45
Silt and fine sand, brown to light-tan	12	57
Sand, medium to coarse, and fine to coarse gravel	3	60
Sand, fine to coarse, and fine gravel; contains some medium to coarse gravel	12	72
Sand, medium to coarse, and fine to coarse gravel; contains clay layer from 75 to 76 feet	6	78
Sand, medium to coarse, and fine to coarse gravel; contains brown silt and fine sand	13	91
Sand, medium to coarse, and fine to coarse gravel; contains little silt and clay	11	102
Mortar bed	11	113
Silt and fine sand, gray	6	119
Sand, medium to coarse, and fine to coarse gravel; contains brown silt and fine sand from 138 to 141 feet	22	141
Mortar bed, poorly cemented	9	150
Sand, medium to coarse, and fine to medium gravel	6	156
Sand, medium to coarse, and fine to medium gravel; contains much brown plastic silt and fine sand	4	160
Sand, fine to coarse; contains some silt and clay	15	175
Sand, medium to coarse, and fine to coarse gravel; contains some silt and clay	5	180
Sand, fine to coarse; contains clay and silt and some gravel at the base	10	190
Sand, medium to coarse	9	199
Sand, medium to coarse; contains some cemented layers and a little gravel	16	215
Sand, medium to coarse, partially cemented; contains silt and clay	10	225
Silt and clay, sandy, brown	4	229
Sand, fine to medium; contains some silt and clay from 240 to 250 feet	21	250
Sand, fine to medium; contains greenish-clay and a little fine to medium gravel	20	270
Sand, fine to coarse; contains some fine gravel	11	281
CRETACEOUS—Gulfian		
Pierre shale		
Shale, weathered, light-green to yellow-brown	4	285
Shale, blue-black	5	290

7-39-20bad. *Driller's log of irrigation well in the SE¼ NE¼ NW¼ sec. 20, T. 7 S., R. 39 W.; drilled by Reddig and Hubalek, 1940. Surface altitude, 3,531.8 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Soil	25	25

	Thickness, feet	Depth, feet
TERTIARY—Pliocene		
Ogallala formation		
Sand and gravel	57	82
Rock	1	83
Gravel, large, and clay	7	90
Clay, sand, and rock	35	125
Gravel, excellent	17	142

7-40-36ddd. *Sample log of test hole in the SE cor. sec. 36, T. 7 S., R. 40 W.; drilled August 1949. Surface altitude, 3,647.9 feet; depth to water level, August 20, 1949, 111.60 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation—Peoria silt member		
Silt, dark-brown	6	6
Silt, tan	28	34
Silt, light reddish-brown	8	42
TERTIARY—Pliocene		
Ogallala formation		
Clay and silt, calcareous, cream to light-brown; contains a little sand	8	50
Sand, fine to medium, partially cemented, reddish	7	57
Mortar bed	13	70
Sand, fine to coarse, and fine gravel; partially cemented at base	10	80
Sand, fine to coarse, partially cemented	20	100
Sand, fine to coarse, and fine gravel	20	120
Clay, calcareous, cream-colored	5	125
Sand, medium to coarse, and fine to medium gravel; contains silt and clay	15	140
Sand, medium to coarse, and fine to medium gravel; contains some coarse gravel, silt, and clay	19	159
Gravel, coarse	6	165
Gravel, fine to coarse, and medium to coarse sand	15	180
Sand, fine to coarse, and fine gravel; contains brown silt and very fine sand	10	190
Sand, very fine to coarse, with some silt	10	200
Sand, fine to coarse; contains some fine gravel	10	210
Sand, fine to coarse; contains fine to coarse gravel and some cemented layers	15	225
Sand, fine to coarse; contains a little very fine sand and silt; contains a little yellowish clay from 246 to 250 feet	41	266
Sand, fine to coarse; contains a little gravel and clay	4	270
Sand, fine to coarse; contains silt and a little clay	12	282
Mortar bed; contains much calcium carbonate cement,	8	290
Sand, fine to coarse; contains fine gravel from 320 to 338 feet	48	338
CRETACEOUS—Gulfian		
Pierre shale		
Shale, blue-black	7	345

8-37-6aaa. *Sample log of test hole in the NE cor. sec. 6, T. 8 S., R. 37 W.; drilled August 1949. Surface altitude, 3,503.2 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation—Peoria silt member		
Silt, dark-brown	3	3
Silt, tan	24	27
TERTIARY—Pliocene		
Ogallala formation		
Silt and clay, sandy	3	30
Silt and clay; contains much sand and gravel	9	39
Sand, coarse, and fine to coarse gravel; contains clay layer from 46 to 48 feet	18	57
Gravel, coarse; contains brown plastic silt and clay	11	68
Silt and clay, plastic, brown; contains much fine sand; contains gravel from 80 to 85 feet	17	85
Sand, medium to coarse, and fine to medium gravel	9	94
Clay, silt, and fine sand; contains medium to coarse sand and fine to coarse gravel	13	107
Gravel, fine to coarse, and medium to coarse sand	23	130
Gravel, fine to coarse, and medium to coarse sand; contains brown plastic silt and fine sand	10	140
Sand, medium to coarse, and fine to coarse gravel	5	145
Silt, fine sand, and clay; plastic, light-tan to brown; contains much fine to medium sand from 150 to 162 feet	7	162
Sand, fine to medium; contains much silt and clay	7	169
Sand, fine to medium, compact	9	178
Sand, fine to medium; contains a little clay and gravel,	3	181
Mortar bed	17	198
Sand, medium to coarse, and fine to medium gravel; contains a little coarse gravel	4	202
Sand, medium to coarse, and fine to coarse gravel, partially cemented	6	208
Clay, yellow	4	212
Sand, medium to coarse, and fine to medium gravel; contains streaks of yellow clay	8	220
Sand, medium to coarse, and fine to medium gravel; contains a little coarse gravel	20	240
Sand, medium to coarse, and fine to coarse gravel	8	248
CRETACEOUS—Gulfian		
Pierre shale		
Clay, yellow-brown	4	252
Shale, sticky, light-gray	4	256
Shale, dark blue-black	4	260

8-37-31dcc. *Driller's log of irrigation test hole in SW cor. SE¼ sec. 31, T. 8 S., R. 37 W.; drilled by A. J. Foust, 1949. Surface altitude, 3,519.3 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Surface soil and clay	50	50

	Thickness, feet	Depth, feet
TERTIARY—Pliocene		
Ogallala formation		
Gravel and sand	13	63
Clay, sandy	20	83
Sand and gravel	16	99
Pack sand	7	106
Clay, sandy	3	109
Sand, fine	7	116
Rock, white	2	118
Sand, fine	6	124
Clay, sandy, red	7	131
Sand and gravel	5	136
Clay, sandy, red and white	7	143
Gravel and sand, heavy	6	149
Sand rock	2	151
Sand and gravel, with heavy clay	9	160
Pack sand, with shells and rock	21	181
CRETACEOUS—Gulfian		
Pierre shale		
Soapstone	1	182

8-38-26aba. *Driller's log of irrigation well in the NE¼ NW¼ NE¼ sec. 26, T. 8 S., R. 38 W.; drilled by A. J. Foust, 1948. Surface altitude, 3,552.8 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Surface soil	38	38
TERTIARY—Pliocene		
Ogallala formation		
Clay	19	57
Sand and gravel, heavy	5	62
Clay, red	11	73
Clay, sandy; 1 foot thick shell rock at 82 feet	11.5	84.5
Gravel and sand, heavy, sandy, red	4.5	89
Clay, sticky	2	91
Clay, firm, white	7	98
Clay, sandy, red, carrying shell rocks	28	126
Sand and gravel	5	131
Clay, sandy	1	132
Sand and gravel, heavy	10.5	142.5
Clay, sandy	16.5	159
Gravel and sand	7	166
Clay, sandy	20	186
Sand, fine, red	3	189
Clay, sandy	44	233
Sand	4	237
CRETACEOUS—Gulfian		
Pierre shale		
Soapstone	1.5	238.5
Shale	1.5	240

8-38-28acc. *Driller's log of irrigation well in the SW cor. NE¼ sec. 28, T. 8 S., R. 38 W.; drilled by A. J. Foust, 1949. Surface altitude, 3,586.6 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Surface soil and clay	66	66
TERTIARY—Pliocene		
Ogallala formation		
Sand and gravel	12	78
Clay, sandy	4	82
Gravel, heavy	11	93
Clay, sandy	4	97
Sand and gravel	4	101
Clay, sandy	9	110
Gravel, heavy	16	126
Clay, sandy, red	5	131
Gravel, heavy	5	136
Clay, red	9	145
Gravel, heavy	14	159
Sand rock and clay	14	173
Gravel, heavy	11	184
Clay, sandy	9	193
Gravel, heavy	14	207
Rock, sandy, soft	3	210
Gravel, medium	4	214
Clay, white	1	215
Rock, hard	3	218
Clay, sandy	2	220
Rock, hard	9	229
Clay, sandy	2	231
CRETACEOUS—Gulfian		
Pierre shale		
Soapstone	4	235

8-39-1aaa. *Sample log of test hole in the NE cor. sec. 1, T. 8 S., R. 39 W.; drilled August 1949. Surface altitude, 3,583.2 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation—Peoria silt member		
Silt, black	2	2
Silt, sandy, tan	26	28
TERTIARY—Pliocene		
Ogallala formation		
Clay, sandy, calcareous	2	30
Limestone, white to cream; "Algal limestone" at top,	8	38
Silt and clay, calcareous, brown to cream	4	42
Caliche, sandy, red-brown	4	46
Mortar bed	4	50
Sand, medium to coarse, and fine to coarse gravel; contains a little silt and clay	19	69
Sand, fine to coarse, and fine to coarse gravel; partially cemented	11	80

	Thickness, feet	Depth, feet
Sand, fine to coarse; contains some coarse to fine gravel and silt; partially cemented from 92 to 94 feet	14	94
Gravel, fine to coarse	10	104
Gravel, fine to coarse; contains medium to coarse sand,	20	124
Silt and fine sand, plastic, brown	6	130
Mortar bed	8	138
Sand, fine to coarse, brown	4	142
Sand, fine to coarse, partially cemented	9	151
Sand, fine to coarse, and fine to coarse gravel	9	160
Sand, fine to coarse; contains a little fine to coarse gravel and silt and clay binder	10	170
Sand, fine to coarse; contains silt and clay; cemented from 205 to 210 feet	55	225
Sand, fine to coarse; contains a little fine to coarse gravel	3	228
Sand, fine to coarse; contains much white silt and clay,	2	230
Sand, fine to coarse; contains a little fine gravel	8	238
Gravel, fine to coarse, and fine to coarse sand, partially cemented	2	240
Mortar bed, well cemented	10	250
Sand, fine to coarse; contains fine gravel from 280 to 290 feet	40	290
Sand, fine to coarse; contains fine to medium gravel	5	295
CRETACEOUS—Gulfian		
Pierre shale		
Clay, yellow-brown	2	297
Shale, blue-black	3	300

8-39-15ccc. *Driller's log of irrigation well in the SW cor. sec. 15, T. 8 S., R. 39 W.; drilled by C. A. Robben. Surface altitude, 3,640.9 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Soil	40	40
TERTIARY—Pliocene		
Ogallala formation		
Gravel	21	61
Clay, light	5	66
Rock	1	67
Molding sand	10	77
Rock	2	79
Gravel	9	88
Sandrock	7	95
Clay, light	2	97
Molding sand	21	118
Gravel	7	125
Rock	2	127
Gravel, porous rock	6	133

	Thickness, feet	Depth, feet
Gravel	6	139
Molding sand, hard	7	146
Rock, porous, hard	5	151
Gravel	5	156
Sandrock	2	158
Sand	8	166
Sandrock	5	171
Gravel	10	181
Rock, porous	4	185
Sandrock, hard	4	189
Molding sand	4	193
Magnesia rock, hard	30	223
Sandrock	4	227
Magnesia rock	2	229
Gravel	4	233
Sandrock	3	236
Rock, porous, soft	11	247
Sand, coarse	3	250
Rock	7	257
Rock, porous	4	261
Rock, hard	1	262
Sandrock, hard	9	271
Sand	1	272
CRETACEOUS—Gulfian		
Pierre shale		
Ochre clay	3	275
Shale	..	..

8-39-19cad. *Driller's log of railroad well at Goodland in the SE¼ NE¼ SW¼ sec. 19, T. 8 S., R. 39 W.; drilled by Air Made Well Company, 1949.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Top soil	2	2
Clay, sandy	39	41
TERTIARY—Pliocene		
Ogallala formation		
Sand, hard, packed, or sand rock	55	96
Clay, sandy, hard	18	114
Sand, fine, loose	5	119
Sand, coarse, and gravel	13	132
Clay, sandy, hard	47	179
Sand, fine	5	184
Clay, sandy, hard	13	197
Sand	8	205
Clay, with streaks of hard sand	37	242
Clay	20	262
Sand, coarse	12	274

	Thickness, feet	Depth, feet
Clay	2	276
Sand, fine	23	299
CRETACEOUS—Gulfian		
Pierre shale		
Shale	..	..

8-40-36ada. *Sample log of test hole in the NE¼ SE¼ NE¼ sec. 36, T. 8 S., R. 40 W.; drilled August 1949. Surface altitude, 3,711.4 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation—Peoria silt member		
Silt, dark-brown	3	3
Silt, tan	28	31
Silt, light-tan	9	40
TERTIARY—Pliocene		
Ogallala formation		
Caliche	10	50
No sample recovered	20	70
Silt, clay, and fine sand, brown; contains some gravel,	10	80
Sand, fine to coarse, partially cemented, brown; contains a little fine gravel	9	89
Gravel, fine to coarse; contains silt and clay	6	95
Silt, clay, and very fine sand; plastic, light-brown	11	106
Sand, fine to coarse, and fine gravel	4	110
Sand, medium to coarse, and fine to coarse gravel	6	116
Clay and silt, brown; contains a small amount of sand and gravel	9	125
Sand, fine to coarse; contains silt and clay; contains a small amount of gravel from 130 to 135 feet	15	140
Gravel, fine to coarse	5	145
Silt, clay, and very fine sand, brown; contains some gravel and fine to coarse sand	12	157
Sand, fine to coarse, red	3	160
Sand, fine to coarse, and fine to medium gravel	10	170
Sand, fine to coarse; contains a little fine gravel	11	181
Gravel, coarse; contains a little fine to medium gravel; contains medium to coarse sand from 190 to 196 feet and a clay layer from 196 to 198 feet	19	200
Sand and gravel; contains much silt and clay	10	210
Sand, fine to coarse, and fine to coarse gravel; contains much silt and clay binder	10	220
Mortar bed	11	231
Sand, fine to coarse; contains a little fine gravel and a little clay	12	243
Mortar bed	7	250
Sand, fine to coarse, containing a little gravel; partially cemented	11	261
Sand, fine to coarse; contains fine gravel	19	280
Sand, fine to coarse, and a little fine gravel, partially cemented	9	289

	Thickness, feet	Depth, feet
CRETACEOUS—Gulfian		
Pierre shale		
Clay, yellow	3	292
Shale, blue-black	8	300

8-41-1aaa. ***Sample log of test hole in the NE cor sec. 1, T. 8 S., R. 41 W.; drilled September 1949. Surface altitude 3,713.7 feet; depth to water level September 17, 1949, 94.3 feet.***

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation—Peoria silt member		
Silt, dark-brown	2	2
Silt, and very fine sand	6	8
TERTIARY—Pliocene		
Ogallala formation		
Clay, cream-colored; contains fine sand	3	11
Mortar bed, cream-colored	5	16
Sand, fine to coarse, cemented, brown; contains pipes and nodules of caliche	22	38
Sand, fine to coarse, and fine to coarse gravel	20	58
Gravel, coarse	2	60
Sand, fine to coarse, and fine to coarse gravel	6	66
Silt, and fine to very fine sand, compact, brown; contains a little coarse gravel	4	70
Silt and fine to very fine sand, compact, brown; contains medium to coarse sand and fine to medium gravel	4	74
Silt and clay, reddish-brown	3	77
Sand, coarse to fine, and fine to coarse gravel	8	85
Caliche	2	87
Silt and clay, gray	3	90
Sand, fine to coarse, brown; partially cemented from 95 to 102 feet	12	102
Sand, fine to coarse; contains much calcium carbonate cement	6	108
Sand, fine to coarse, brown	8	116
Sand, fine to coarse, cemented; contains a little reddish fine to coarse gravel from 125 to 136 feet	20	136
Sand, fine to coarse; contains a little fine gravel	4	140
Sand, medium to coarse, and fine gravel	9	149
Sand, fine to coarse, brown	3	152
Sand, fine to coarse, cemented; contains a little fine to coarse gravel	17	169
Silt and clay, brown; contains a little sand and gravel,	17	186
Sand, fine to coarse	9	195
Sand, fine to coarse; contains a little fine to medium gravel and silt and clay binder	5	200
Sand, fine to coarse; contains a little silt and very fine sand	20	220
Sand, fine to coarse; contains much silt and very fine sand	15	235

	Thickness, feet	Depth, feet
Sand, fine to coarse	5	240
Sand, fine to coarse; contains yellowish clay from 248 to 253 feet	13	253
Sand, fine to coarse; contains fine to coarse gravel and yellow clay	7	260
Sand, medium to coarse, and fine to coarse gravel; contains yellow to greenish-yellow clay	5	265
CRETACEOUS—Gulfian		
Pierre shale		
Clay, yellow to greenish-yellow	5	270
Shale, blue-black	4	274

8-41-36ddd. *Sample log of test hole in the SE cor. sec. 36, T. 8 S., R. 41 W.; drilled September 1949. Surface altitude, 3,762.5 feet; depth to water level October 1, 1949, 104.1 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Peoria silt member		
Silt, dark-brown	2	2
Silt, tan	30	32
Loveland silt member		
Silt, hard, red-brown	5	37
TERTIARY—Pliocene		
Ogallala formation		
Caliche, cream-colored	13	50
Silt, clay, and fine sand, gray to brown	10	60
Sand, fine to coarse, and fine to coarse gravel	12	72
Sand, very fine to fine, and brown compact silt	8	80
Silt, clay, and very fine sand, gray	10	90
Sand, fine to coarse, and fine gravel; contains a little medium gravel	12	102
Sand, very fine, and brown silt	5	107
Sand, fine to coarse, and fine gravel; contains a little medium to coarse gravel	7	114
Silt and very fine sand, brown	4	118
Sand, fine to coarse	2	120
Sand, very fine, and reddish-brown silt	11	131
Sand, fine to coarse, and fine to coarse gravel	16	147
Sand, very fine to coarse, and fine gravel	3	150
Sand, fine to coarse; contains silt and very fine sand	14	164
Sand, fine to coarse; contains silt, clay, and very fine sand as binder	6	170
Sand, fine to coarse, and fine to medium gravel; contains a little coarse gravel	10	180
Sand, fine to coarse, and fine gravel	12	192
Sand, fine to coarse, and fine gravel; has silt and clay binder	14	206

	Thickness, feet	Depth, feet
Clay, silt, and very fine sand; contains medium to fine sand	4	210
Sand, fine to coarse; contains silt, clay, and very fine sand	14	224
Sand, very fine to coarse, cemented	26	250
Sand, very fine to medium; contains white clay from 269 to 270 feet	20	270
Sand, fine, well cemented; contains yellow clay layer from 274 to 275 feet	14	284
Gravel, fine to coarse	4	288
CRETACEOUS—Gulfian		
Pierre shale		
Clay, yellow-brown	4	292
Shale, black	4	296

8-42-1bbb. *Sample log of test hole in the NW cor. sec. 1, T. 8 S., R. 42 W.; drilled September 1949. Surface altitude, 3,817.4 feet; depth to water level, September 23, 1949, 93.9* feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation—Peoria silt member		
Silt, dark-brown	2	2
Silt, tan	22	24
TERTIARY—Pliocene		
Ogallala formation		
Sand, fine to coarse, and fine gravel; contains medium to coarse gravel from 28 to 33 feet	9	33
Sand, fine to coarse; contains a little fine to coarse gravel and brown silt and clay	9	42
Sand, fine to coarse, and fine to coarse gravel; contains smaller amount of coarse gravel from 50 to 60 feet,	18	60
Sand, fine to coarse, and fine to coarse gravel	21	81
Mortar bed	7	88
Sand, fine to coarse; contains a little fine to coarse gravel	8	96
Mortar bed	8	104
Sand, fine to coarse, and fine to medium gravel; contains a little coarse gravel	5	109
Gravel, coarse	2	111
Mortar bed	9	120
Sand, fine to coarse, and fine gravel; contains silt and very fine sand as binder	12	132
Sand, fine to coarse; contains a little fine to medium gravel	13	145
Sand, fine to coarse, cemented	7	152
Sand, fine to coarse; contains a little gravel and some silt and clay as binder	8	160
Sand, fine to coarse; contains fine to coarse gravel from 165 to 170 feet and silt and clay from 168 to 170 feet	10	170

	Thickness, feet	Depth, feet
Mortar bed	5	175
Sand, fine to coarse; contains a little fine to coarse gravel and clay	5	180
Mortar bed	5	185
Sand, fine to coarse; contains a little calcium carbonate cement	13	198
Sand, fine to coarse; contains a little gravel and compact silt and very fine sand	2	200
Sand, very fine to medium; contains a little coarse sand from 210 to 220 feet	20	220
Sand, fine to coarse; contains a little fine gravel from 230 to 240 feet	20	240
Sand, very fine to coarse, partially cemented	20	260
Sand, very fine to coarse	13	273
Sand, fine to coarse, and fine to coarse gravel; contains a little yellow clay	2	275
CRETACEOUS—Gulfian		
Pierre shale		
Clay, yellow-brown	7	282
Shale, blue-black	8	290

8-42-6aaa. *Sample log of test hole in the NE cor. sec. 6, T. 8 S., R. 42 W.; drilled September 1949. Surface altitude, 3,912.3 feet; depth to water level September 23, 1949, 138.5 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation—Peoria silt member		
Silt, dark-brown	2	2
Silt, tan	30	32
TERTIARY—Pliocene		
Ogallala formation		
Clay and silt, cream-colored	11	43
Sand, fine to coarse, and fine gravel; contains a little medium to coarse gravel	10	53
Silt, clay, and very fine sand, brown; contains a little fine to coarse sand and gravel	9	62
Sand, fine to medium, brown; contains silt and clay	8	70
Sand, fine to coarse; contains a little fine to coarse gravel	12	82
Gravel, coarse	5	87
Sand, fine to coarse, and fine gravel	3	90
Sand, fine to coarse, and fine gravel; contains a little medium to coarse gravel	7	97
Clay, silt, and very fine sand, cream-colored	7	104
Sand, fine to coarse, and fine to coarse gravel; contains brown silt and very fine sand as binder from 117 to 120 feet	16	120
Silt and very fine sand, brown; contains a little sand and gravel	18	138

	Thickness, feet	Depth, feet
Sand, fine to medium, brown	7	145
Sand, fine to coarse; contains a little fine to coarse gravel from 150 to 163 feet	18	163
Sand, fine to coarse, brown	3	166
Sand, fine to coarse; contains a little fine to medium gravel and a little silt and clay	4	170
Sand, fine to coarse, and fine to coarse gravel	14	184
Gravel, fine to coarse, partially cemented	3	187
Sand, fine to coarse, and fine to medium gravel, partially cemented	2	189
Sand, fine to coarse, and fine to coarse gravel	13	202
Clay, silt, and very fine sand; contains a little sand and gravel	8	210
Mortar bed	12	222
Sand, fine to medium, partially cemented	13	235
Sand, fine to medium; contains very little cement	15	250
Sand, very fine to medium	10	260
Sand, fine to coarse	10	270
Sand, very fine to medium; contains a little silt and clay	10	280
Sand, very fine to medium	11	291
CRETACEOUS—Gulfian		
Pierre shale		
Clay, yellow-brown	6	297
Shale, blue-black	3	300

9-36-31ccc. *Sample log of test hole in the SW cor. sec. 31, T. 9 S., R. 36 W., Thomas County; drilled October 1943. Surface altitude, 3,450.2 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation—Peoria silt member		
Soil, dark-gray, grading downward to light-gray	3	3
Silt, yellow-gray; contains much very fine sand	24	27
Silt, light-buff; contains some fine sand and a few caliche nodules	1.5	28.5
Silt, yellow-gray; contains much very fine sand	1.5	30
Silt, light-buff; contains some fine to medium sand and a small amount of fine to medium gravel	10	40
Silt, compact, light-buff	10	50
TERTIARY—Pliocene		
Ogallala formation		
Silt, compact, gray; contains some coarse to fine sand and a little fine gravel	9	59
Gravel, fine to medium, and sand; contains a little coarse gravel	5	64
Silt, gray and tan; contains some fine gravel and coarse to fine sand. (Sand increases downward)	23	87
Gravel, medium to fine, and sand; contains a little coarse gravel	15	102

	Thickness, feet	Depth, feet
Silt, light-buff; contains some fine to coarse sand and sandy caliche	8	110
Silt, compact, tan, contains much coarse to fine sand	8	118
Gravel, coarse to fine, and yellow-gray sand; contains some buff silt and a little caliche and yellow clay	14	132
Clay, silty, yellow-gray and white; contains much hard, sandy, white to translucent caliche	12	144
Gravel, medium to fine, yellow to gray, containing much mortar; contains yellow clay	6	150
Gravel, medium to fine, and sand; yellow and gray; contains some coarse gravel and yellow clay	10	160
Gravel, medium to fine, and sand; yellow and gray; contains interbedded dull-yellow silt from 166 to 170 feet	10	170
Silt, clayey, dull-yellow; contains some coarse to fine sand and caliche	9	179
Gravel, medium to fine, and sand, gray; contains a little yellow and buff clay	23	202
CRETACEOUS—Gulfian		
Pierre shale		
Shale, clayey, light yellow-green grading downward to light and dark gray	8	210
Shale, dark-gray	10	220

9-37-6bbb. *Driller's log of irrigation test hole in the NW cor. sec. 6, T. 9 S., R. 37 W.; drilled by A. J. Foust, 1949. Surface altitude, 3,520.0 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Surface soil and clay	49	49
TERTIARY—Pliocene		
Ogallala formation		
Gravel, heavy	12	61
Clay, sandy	5	66
Clay, red	24	90
Gravel, heavy	4	94
Clay, sandy	18	112
Sand, fine	10	122
Clay	6	128
Gravel and sand	8	136
Clay, red	9	145
Sand and gravel	2	147
Clay, sandy	18	165
Pack sand, hard	10	175
Gravel, heavy	2	177
CRETACEOUS—Gulfian		
Pierre shale		
Soapstone	2	179
Shale	2	181

9-37-32ccc. *Sample log of test hole in the SW cor. sec. 32, T. 9 S., R. 37 W.; drilled August 1949. Surface altitude, 3,518.0 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation—Peoria silt member		
Silt, dark-brown	3	3
Silt, tan	25	28
TERTIARY—Pliocene		
Ogallala formation		
Silt, sandy, light-tan	3	31
Mortar bed, poorly cemented	6	37
Sand, medium to coarse, and fine gravel	6	43
Gravel, medium to coarse	4	47
Silt and fine sand, plastic, light-brown	3	50
Mortar bed, varying in hardness and amount of cementing material	25	75
Sand, coarse, and fine to coarse gravel; poorly cemented	5	80
Sand, coarse to medium, and fine to coarse gravel; contains white plastic silt and very fine sand	20	100
Gravel, coarse, and a small amount of sand and fine to medium gravel	10	110
Sand, medium to coarse, and fine to medium gravel; contains much plastic silt and very fine sand	7	117
Clay, yellow	2	119
Sand, medium to coarse, and fine to medium gravel; contains much plastic silt and very fine sand	13	132
Sand, coarse, and fine to medium gravel; contains very little silt and fine sand	8	140
Sand, coarse, and fine to medium gravel; contains some clay and silt	10	150
Sand, medium to coarse, and fine to coarse gravel; contains less coarse gravel from 160 to 168 feet	18	168
CRETACEOUS—Gulfian		
Pierre shale		
Clay, light-green to brown	2	170
Shale, soft, light-brown to tan	10	180
Shale, clayey, yellow-brown to blue	10	190

9-39-1aaa. *Sample log of test hole in the NE cor. sec. 1, T. 9 S., R. 39 W.; drilled September 1949. Surface altitude, 3,616.5 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation—Peoria silt member		
Silt, dark-brown	1	1
Silt, tan	23	24
TERTIARY—Pliocene		
Ogallala formation		
Silt and clay, cream-colored	9	33
Clay and caliche, cream-colored; sandy at base; contains a few "Algal limestone" fragments	9	42

	Thickness, feet	Depth, feet
Caliche, light-brown	6	48
Sand, coarse, and fine to coarse gravel	2	50
Mortar bed	12	62
Sand, coarse, and fine to coarse gravel, partially cemented	5	67
Sand, coarse, and fine to coarse gravel	23	90
Silt and very fine sand, compact, red	7	97
Sand, coarse, and fine to medium gravel	6	103
Mortar bed	15	118
Sand, fine to coarse, and a little coarse gravel	12	130
Sand, coarse, and fine to coarse gravel	10	140
Sand, medium to coarse, and fine to coarse gravel	9	149
Mortar bed	11	160
Silt and fine to very fine sand, red	10	170
Sand, fine to coarse; contains a little fine gravel	10	180
Sand, fine to coarse, and fine to coarse gravel; contains brown silt and very fine sand	11	191
Mortar bed; contains much calcium carbonate cement,	13	204
Sand, fine to coarse, and fine gravel, cemented	21	225
Sand, fine to coarse, with brown silt and clay	9	234
Sand, fine to coarse; contains yellow clay and silt; contains a little fine gravel from 240 to 250 feet	16	250
Sand, fine to coarse; contains yellow silt and clay; contains fine to coarse gravel from 260 to 264 feet,	14	264
CRETACEOUS—Gulfian		
Pierre shale		
Clay, yellow-brown	4	268
Shale, black	2	270

9-39-31ccc. *Sample log of test hole in the SW cor. sec. 31, T. 9 S., R. 39 W.; drilled August 1949. Surface altitude, 3,661.5 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation—Peoria silt member		
Silt, tan, sandy at base	10	10
Silt, sandy, tan	13	23
TERTIARY—Pliocene		
Ogallala formation		
Clay and silt, calcareous, cream to light-brown	12	35
Sand, and gravel; contains much silt and clay	4	39
Sand, fine to coarse, and fine gravel	9	48
Clay, light-gray	7	55
Sand, medium to coarse, and fine to coarse gravel; contains much gravel, ¼-inch in diameter	5	60
Gravel, coarse	9	69
Sand, medium to coarse, and fine to coarse gravel	8	77
Silt and very fine sand, plastic, brown	24	101
Sand, medium to coarse, and fine to medium gravel; contains brown silt and very fine sand	9	110

	Thickness, feet	Depth, feet
Silt and very fine sand, compact, brown	13	123
Sand, coarse, and fine to coarse gravel	10	133
Silt, clay, and fine to very fine sand, plastic, light-brown; contains a little sand and gravel	7	140
Sand, medium to coarse, and fine to coarse gravel; contains a small amount of plastic silt and clay	23	163
Gravel, coarse	4	167
CRETACEOUS—Gulfian		
Pierre shale		
Clay, yellow-brown	3	170
Shale, yellow-brown to light-gray	22	192
Shale, light-gray to dark blue-black	4	196

9-39-36ddd. *Sample log of test hole in the SE cor. sec. 36, T. 9 S., R. 39 W.; drilled August 1949. Surface altitude, 3,626.0 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation—Peoria silt member		
Silt, dark-brown	3	3
Silt, tan	20	23
TERTIARY—Pliocene		
Ogallala formation		
Silt, sandy, light-tan	8	31
Sand, medium to coarse, and fine to coarse gravel	17	48
Mortar bed	2	50
Sand, fine to very fine	5	55
Sand, medium to coarse, and fine to medium gravel	7	62
Sand, fine to coarse, and fine gravel; partially cemented	8	70
Sand, fine to coarse, and fine to medium gravel	25	95
Mortar bed; contains many white limestone fragments from 110 to 125 feet	30	125
CRETACEOUS—Gulfian		
Pierre shale		
Clay, greenish to yellow-brown	5	130
Shale, greenish to yellow-brown	20	150
Shale, dark blue-black	20	170

9-40-31ccc. *Sample log of test hole in the SW cor. sec. 31, T. 9 S., R. 40 W.; drilled September 1949. Surface altitude, 3,790.6 feet; depth to water level, October 1, 1949, 101.6 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation—Peoria silt member		
Silt, dark-brown	3	3
Silt, tan	26	29
TERTIARY—Pliocene		
Ogallala formation		
Caliche, cream-colored	13	42

	Thickness, feet	Depth, feet
Sand, fine to coarse, and fine to medium gravel; contains much silt, very fine sand, and a little coarse gravel	20	62
Sand, fine to coarse, and fine to medium gravel; contains a small amount of coarse gravel	8	70
Sand, fine to coarse, and fine to coarse gravel	20	90
Silt, clay, and very fine sand, white to brown; contains fine to medium sand, 110 to 122 feet	32	122
Sand, fine to medium; contains a little coarse sand	8	130
Sand, fine to coarse, and fine gravel	10	140
Sand, fine to coarse; contains green silt and clay from 145 to 154 feet	14	154
Sand, fine to coarse; contains a little fine to coarse gravel, silt and clay	15	169
Sand, fine to coarse; contains a little fine to medium gravel with silt and very fine sand binder	16	185
Silt and very fine sand, compact, cream to light-brown,	5	190
Sand, fine to coarse, and fine gravel; contains silt, clay, and very fine sand	12	202
Sand, fine to coarse, and fine gravel; contains some medium gravel	8	210
Sand, medium to coarse, and fine to coarse gravel	10	220
Gravel, fine to coarse	7	227
Clay and silt, brown	9	236
Sand, fine to medium	8	244
Sand, fine to coarse, and fine to coarse gravel; contains a little yellow clay from 247 to 250 feet	6	250
Sand, fine to coarse; contains much yellow clay, silt, and a little fine to coarse gravel	16	266
Sand, fine to coarse	8	274
Sand, medium to coarse, and fine to medium gravel; contains a little coarse gravel	16	290
Sand, coarse, and fine to coarse gravel	7	297
CRETACEOUS—Gulfian		
Pierre shale		
Shale, yellow-brown to gray	3	300
Shale, yellow-brown to dark blue-gray	10	310

9-42-1bbb. *Sample log of test hole in the NW cor. sec. 1, T. 9 S., R. 42 W.; drilled September 1949. Surface altitude, 3,863.2 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation—Peoria silt member		
Silt, dark-brown	3	3
Silt, tan; contains very fine sand from 35 to 42 feet	39	42
TERTIARY—Pliocene		
Ogallala formation		
Sand, fine to coarse; contains a little fine to coarse gravel	8	50

	Thickness, feet	Depth, feet
Sand, fine to coarse, and fine to medium gravel; contains a little coarse gravel	10	60
Sand, medium to coarse, and fine to coarse gravel	26	86
Sand, very fine to coarse; contains silt and clay; contains a little gravel from 90 to 100 feet	14	100
Sand, fine to coarse; contains silt, clay, and much gravel	15	115
Silt and very fine sand, compact, brown	5	120
Sand, very fine to medium, and silt	12	132
Mortar bed	5	137
Sand, fine to coarse; contains a little fine gravel	8	145
Silt and very fine sand, reddish-brown	15	160
Sand, fine to medium; contains brown silt and very fine sand	10	170
Sand, fine to medium; contains much silt and very fine sand	17	187
Silt and very fine sand; contains light-green clay	8	195
Sand, fine to coarse; contains silt and clay	10	205
Sand, fine to coarse; contains a little fine to coarse gravel and yellow clay	5	210
CRETACEOUS—Gulfian		
Pierre shale		
Shale, weathered, yellow; contains fragments of limonite concretion	10	220
Shale, yellow-brown	15	235
Shale, black	5	240

9-42-6aaa. *Sample log of test hole in the NE cor. sec. 6, T. 9 S., R. 42 W.; drilled September 1949. Surface altitude, 3,937.3 feet; depth to water level September 23, 1949, 116 feet.*

	Thickness, feet	Depth, feet
Road fill	1	1
QUATERNARY—Pleistocene		
Sanborn formation		
Peoria silt member		
Silt, tan	9	10
Loveland silt member		
Silt, red-brown	5	15
TERTIARY—Pliocene		
Ogallala formation		
Silt and clay, light cream-colored; contains "Algal limestone" fragments	5	20
Caliche, sandy, white	7	27
Mortar bed	5	32
Sand, fine to coarse; contains a little fine to coarse gravel	5	37
Silt and clay; contains fine to very fine sand	3	40
Mortar bed	8	48

	Thickness, feet	Depth, feet
Sand, very fine to medium; contains silt and clay	4	52
Sand, very fine to coarse	8	60
Sand, fine to coarse, and fine to medium gravel; contains a little coarse gravel	10	70
Sand, medium to coarse, and fine to coarse gravel; some pebbles 1½ inches in diameter	11	81
Silt and very fine to fine sand, compact, brown	14	95
Gravel, coarse	5	100
Sand, medium to coarse, and fine to coarse gravel; contains silt and very fine sand from 105 to 115 feet	15	115
Silt and very fine sand, compact, brown	7	122
Sand, fine to coarse	8	130
Sand, fine to coarse; contains fine to coarse gravel	10	140
Sand, fine to coarse; contains white calcium carbonate cement from 145 to 148 feet	10	150
Sand, fine to coarse, and fine gravel	7	157
Sand, fine to coarse, and fine gravel; contains silt and very fine sand	3	160
Sand, very fine to coarse; contains silt and clay from 178 to 185 feet	25	185
Sand, very fine to medium; contains cement from 190 to 195 feet	15	200
Sand, very fine to coarse	59	259
CRETACEOUS—Gulfian		
Pierre shale		
Shale, clayey, yellow-brown	9	268
Shale, black	2	270

10-37-32ccc. *Sample log of test hole in the SW cor. sec. 32, T. 10 S., R. 37 W.; drilled August 1949. Surface altitude, 3,307.8 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation—Peoria silt member		
Silt, dark-brown	9	9
Silt, light-brown; contains snail shells; contains sand from 40 to 44 feet	35	44
Silt, black; contains many snail shells	2	46
TERTIARY—Pliocene		
Ogallala formation		
Sand, coarse, and fine to coarse gravel	7	53
Mortar bed	3	56
Sand, fine to medium; contains some cemented layers from 60 to 70 feet	14	70
Sand, fine to coarse, and fine gravel; contains some medium to coarse gravel	10	80
Sand, fine to coarse; contains cemented layers of sand and gravel	17	97
Mortar bed	5	102

	Thickness, feet	Depth, feet
Sand, medium to coarse; contains some gravel; partially cemented	6	108
Sand, fine to medium	4	112
Gravel, medium to coarse	4	116
CRETACEOUS—Gulfian		
Pierre shale		
Shale, light-gray to red-brown	4	120
Shale, light-gray	3	123
Shale, dark-blue	7	130

10-38-20cc. *Driller's log of oil test drilled in SW cor. sec. 20, T. 10 S., R. 38 W., by Sinclair-Prairie Oil Co. in 1944 and 1945.*

	Depth, feet
Sand-gravel-shale	130
Shale, dark	1,325
Lime, chalky	1,450
Shale and shells	1,570
Shale and lime shells	1,770
Lime, brown	1,845
Lime and shale	2,080
Lime, broken	2,100
Lime, gray, hard	2,145
Lime, gray	2,160
Shale and lime shells	2,180
Shale, gray	2,200
Lime and shale	2,225
Gypsum and shale	2,305
Shale, sandy	2,315
Gypsum and shale	2,345
Gypsum	2,370
Shale, red	2,395
Gypsum	2,415
Salt	2,435
Shale, red	2,660
Lime and gypsum	2,685
Shale, red	2,775
Gypsum, hard	2,915
Gypsum and shale	2,955
Lime, gray, hard	3,020
Lime and shale	3,060
Lime, light, hard	3,085
Shale and lime shells	3,160
Lime, broken	3,200
Lime and shale	3,335
Shale, red; lime shells	3,530
Lime and shale	3,555
Lime, gray, hard	3,570
Lime, sandy, hard	3,610

	Depth, feet
Lime, white, hard	3,660
Lime, gray, hard	3,685
Lime and shale, brown	3,714
Lime and shale	3,725
Lime, gray, hard	3,825
Shale, black	3,830
Lime, gray, hard	3,900
Shale, brown	3,910
Lime, white-gray, hard	3,935
Lime, soft	3,937
Lime, gray, hard	4,008
Lime, soft	4,040
Lime, gray, hard	4,060
Lime, gray	4,132
Lime, gray, hard	4,200
Lime, broken	4,210
Lime, gray, hard	4,305
Lime, gray, medium	4,415
Lime, gray, hard	4,520
Lime, gray, medium	4,527
Lime, gray, hard	4,685
Lime, cherty, hard	4,689
Lime, gray, hard	4,879
Sand, white, hard	4,885
Lime and shale	4,970
Shale and lime	5,000
Lime, white, hard	5,030
Lime and chert	5,049
Lime, white, hard	5,135
Lime, gray, hard	5,180
Lime, white, hard	5,200
Lime and chert	5,255
Lime, brown, hard	5,275
Lime, light, medium	5,315
Lime, gray, hard	5,363
Lime, light, soft	5,371
Lime, gray, medium	5,415
Lime, (Arbuckle group) hard	5,425
Lime, gray, medium	5,445
Lime, gray, hard	5,476
Lime, gray, medium	5,510
Lime, gray, medium	5,580
Lime, soft	5,610
Lime, gray, hard	5,640
Tops: Lansing—Kansas City group	4,450
Cherokee group	4,876
"Mississippi limestone"	4,997
Arbuckle group	5,382

10-40-36ddd. *Sample log of test hole in the SE cor. sec. 36, T. 10 S., R. 40 W., drilled September 1949. Surface altitude, 3,721.1 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation—Peoria silt member		
Silt, dark-brown	1	1
Silt, tan	24	25
Silt, reddish-brown	2	27
TERTIARY—Pliocene		
Ogallala formation		
Clay and silt, cream-colored; sandy from 30 to 35 feet	8	35
Sand, fine to coarse, and fine to coarse gravel	5	40
Gravel, coarse to fine; contains coarse sand; contains some pebbles 1 inch in diameter	12	52
Clay and silt, gray	13	65
Clay and silt, white	2	67
CRETACEOUS—Gulfian		
Pierre shale		
Clay, yellow-brown to greenish	3	70
Shale, yellow-brown	10	80

10-42-1bbb. *Sample log of test hole in the NW cor. sec. 1, T. 10 S., R. 42 W.; drilled September 1949. Surface altitude, 3,887.9 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Silt, dark-brown	2	2
Silt, tan	25	27
TERTIARY—Pliocene		
Ogallala formation		
Caliche, sandy, light-tan	10	37
Sand, fine to coarse, and fine to coarse gravel	5	42
Silt and very fine sand, reddish; contains a little sand and gravel	8	50
Sand, fine to coarse, and fine to coarse gravel; contains red silt and very fine sand	15	65
Sand, fine to coarse, and fine to coarse gravel	7	72
Sand, very fine to fine, and silt, brown	8	80
Sand, fine to coarse, and fine gravel; contains silt and very fine sand	10	90
Sand, fine to coarse, and fine gravel; contains much silt and clay and a little medium to coarse gravel	10	100
Sand, fine to coarse; contains very fine sand and silt	10	110
Sand, fine to coarse, and fine to coarse gravel	10	120
Gravel, coarse to fine, and coarse sand	15	135
Sand, fine to coarse; contains some fine to coarse gravel, silt, and very fine sand	6	141
Mortar bed	11	152
Sand, very fine, and silt, red; contains a little fine to medium gravel	30	182

	Thickness, feet	Depth, feet
Sand, fine to coarse; contains a little gravel, silt, and very fine sand	18	200
Silt and very fine sand, gray; contains much fine sand,	7	207
CRETACEOUS—Gulfian		
Pierre shale		
Clay, yellow-brown	5	212
Shale, greenish to yellow-brown	8	220

10-42-5bbb. *Sample log of test hole in the NW cor. sec. 5, T. 10 S., R. 42 W.; drilled September 1949. Surface altitude, 3,992.0 feet; depth to water level October 1, 1949, 108.70 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Peoria silt member		
Silt, dark-brown	2	2
Silt, tan	24	26
Loveland silt member		
Silt, reddish	6	32
TERTIARY—Pliocene		
Ogallala formation		
Clay, calcareous, cream-colored	5	37
Sand, fine to coarse, and fine to medium gravel; contains a little coarse gravel; contains more coarse gravel from 50 to 58 feet	21	58
Sand, fine to coarse, and fine to medium gravel; contains a little coarse gravel and a little cementing material	10	68
Gravel, fine to coarse	7	75
Silt, and very fine sand, brown; contains a little gravel,	5	80
Sand, fine to coarse, and fine gravel, partially cemented	23	103
Sand, fine to coarse, and fine to medium gravel; contains a little coarse gravel, silt, and very fine sand	7	110
Sand, fine to coarse, and fine to medium gravel, partially cemented; contains a small amount of coarse gravel	11	121
Sand, fine to coarse; contains some very fine sand and silt	9	130
Sand, fine to coarse	13	143
Sand, very fine to coarse, and fine to medium gravel; contains a little silt and clay as binder	7	150
Sand, fine to coarse, brown	14	164
Sand very fine to coarse; contains a little fine gravel, silt, and clay	23	187
Sand, fine to coarse; contains fine to coarse gravel	5	192
Mortar bed	5	197
Sand, fine to medium, brown	8	205
Sand, fine to coarse, greenish	7	212

	Thickness, feet	Depth, feet
Sand, fine to coarse	17	229
Sand, fine to coarse, containing calcium carbonate cement	8	237
Sand, fine to coarse; contains silt and very fine sand	3	240
Sand, fine to coarse; contains a small amount of gravel from 270 to 278 feet	38	278
CRETACEOUS—Gulfian		
Pierre shale		
Shale, soft, gray to yellow-brown	4	282
Shale, black	5	287

10-42-13acc. *Driller's log of irrigation test hole in the SW cor. NE¼ sec. 13, T. 10 S., R. 42 W.; drilled by A. J. Foust, 1949. Surface altitude, 3,895.5 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Surface soil and clay	48	48
TERTIARY—Pliocene		
Ogallala formation		
Sand and gravel	7	55
Clay, sandy, red	9	64
Sand, fine	3	67
Clay, sandy, red	20	87
Water gravel	9	96
Clay, sandy	10	106
Sand and gravel	11	117
Clay, sandy	26	143
Caliche rock	2	145
Gravel, heavy	9	154
Shell rock	1	155
Clay, sandy	5	160
Sandrock	2	162
Clay, sandy	3	165
Pack sand and gravel	8	173
Sand and gravel	12	185
Clay, sandy	13	198
Sand and gravel	15	213
CRETACEOUS—Gulfian		
Pierre shale		
Soapstone and shale	1	214

10-42-24cdb. *Driller's log of irrigation test hole in the NW¼ SE¼ SW¼ sec. 24, T. 10 S., R. 42 W., drilled by A. J. Foust in 1949. Surface altitude 3,857.1 feet.*

	Thickness, feet	Depth, feet
QUATERNARY and TERTIARY		
Surface soil	12	12
Sand and gravel	20	32
Clay, sandy	18	50
Gravel, heavy	3	53

	Thickness, feet	Depth, feet
Clay, sandy	16	69
Gravel, heavy	7	76
Clay, sandy	6	82
Gravel, heavy	12	94
Clay, sandy	10	104
Rock, hard	2	106
Clay, sandy	6	112
Gravel, heavy	10	122
Pack sand and shell rock	9	131
Sandy clay, showing of soapstone	7	138
Sand and gravel	13	151
CRETACEOUS—Gulfian		
Pierre shale		
Soapstone	3	154
Shale	1	155

10-42-36ccc. *Sample log of test hole in the SW cor. sec. 36, T. 10 S., R. 42 W.; drilled September 1949. Surface altitude, 3,868.8 feet; depth to water level October 1, 1949, 36.7 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Slope deposits		
Silt, sandy, brown	3	3
TERTIARY—Pliocene		
Ogallala formation		
Gravel, fine to coarse; contains coarse sand from 10 to 17 feet	14	17
Gravel, fine to coarse; contains silt and very fine sand,	7	24
Silt, clay, and very fine sand	7	31
Sand, fine to coarse, and fine to coarse gravel; contains a little silt and very fine sand	9	40
Sand, fine to coarse, and fine to medium gravel; contains silt, very fine sand, and a little coarse gravel,	10	50
Sand, fine to coarse, and fine gravel; contains much silt and very fine sand	14	64
Sand, fine to coarse, and fine to medium gravel; contains a little coarse gravel	11	75
Gravel, medium to coarse	5	80
Gravel, coarse to fine, and coarse sand	8	88
Silt and very fine sand, brown	2	90
Clay, yellow-brown	7	97
Sand, fine to coarse, and fine gravel	3	100
Sand, fine to coarse, and fine gravel; contains some medium to coarse gravel and yellow clay	26	126
CRETACEOUS—Gulfian		
Pierre shale		
Shale, yellow-brown to light-gray	14	140

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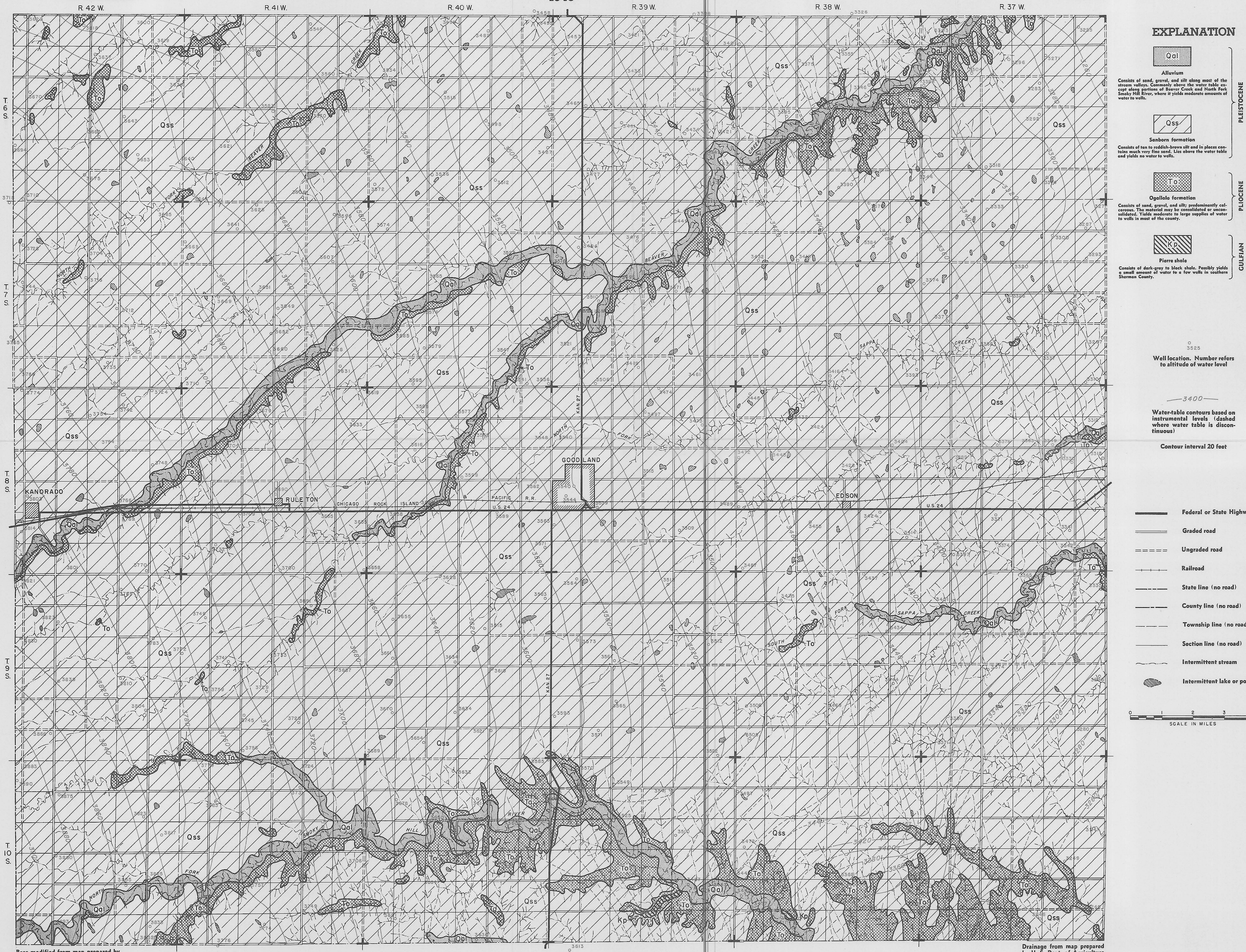
AREAL GEOLOGY OF SHERMAN COUNTY, KANSAS

With Water-Table Contours

By Glenn C. Prescott, Jr.
1949

State Geological Survey of Kansas

Bulletin 105
Plate 1



Base modified from map prepared by State Highway Commission of Kansas

Drainage from map prepared by U. S. Dept. of Agriculture

MAP OF SHERMAN COUNTY, KANSAS

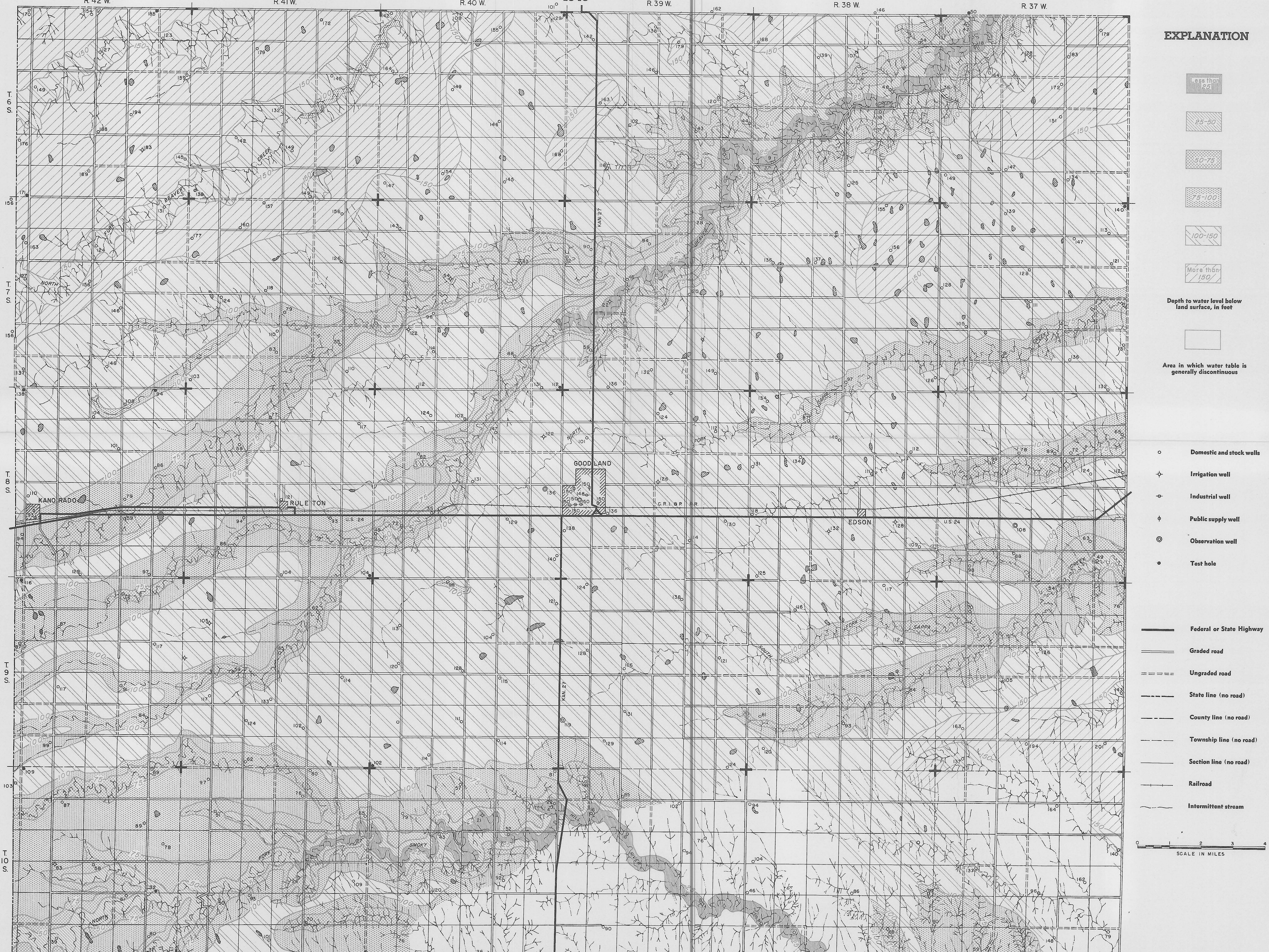
Showing the depths to Water Level and the Location of Wells for which Records are given

By Glenn C. Prescott, Jr.

1949

State Geological Survey of Kansas

Bulletin 105
Plate 2



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