Geology and Ground-Water Resources of Wallace County, Kansas

By Warren G. Hodson

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BULLETIN 161

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

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Geology and Ground-Water Resources of Wallace County, Kansas

ABSTRACT

Wallace County is a 910-square mile area in the High Plains section of west-central Kansas. Chalk and shale beds of Late Cretaceous age are the oldest rocks cropping out in the county. The Ogallala Formation of Tertiary age (Pliocene) unconformably overlies the Cretaceous rocks in most of the county and consists of fluviatile deposits that in places exceed 400 feet in thickness. As much as 50 feet of loess and 70 feet of alluvium constitute the youngest deposits and are Late Pleistocene in age.

In Wallace County, the number of irrigation wells has been increasing about 6 percent per year in recent years. Yields of most irrigation wells range from about 400 gpm (gallons per minute) to more than 2,000 gpm. Most ground water is obtained from the Ogallala Formation, which contains about 4 million acre-feet in storage. Aquifer tests in the Ogallala indicate transmissibilities of about 150,000 gpd (gallons per day) per foot and permeabilities of about 1,000 gpd per square foot. Movement of ground water is eastward at about 0.9 foot per day.

Alluvial deposits along the principal valleys yield moderate quantities of water, but the deposits are narrow and confined to the inner valleys. In areas of Cretaceous outcrops, ground-water supplies are meager and where available are obtained from thin surficial deposits and weathered zones.

Résumé: Le Wallace County est une aire de 2357 kilomètres carrés dans la partie de High Plains du Kansas ouest-central. Les couches de craie et de schiste de l'âge Late Cretaceous sont les roches les plus vieilles qui affleurent dans le county. L'Ogallala Formation de l'âge Tertiary (Pliocene) recouvre discordantement les roches Cretaceous dans la plupart du county et consiste en dépôts fluviatiles qui excèdent 120 mètres d'épaisseur. Autant que 15 mètres de loess et 21 mètres d'alluvion constituent les dépôts les plus jeunes et sont de l'âge Late Pleistocene.

Dans le Wallace County, le nombre de puits d'irrigation a augmenté à environ 6 pour cent dans les ans recents. Les productions de la plupart des puits d'irrigation varient d'environ 1,5 à plus de 7,5 mètres cubes par minute. On obtient la plupart de la nappe superficielle de l'Ogallala Formation qui contient environ 5 milliard de mètres cubes d'emmagasinage. Les essais aquifères dans l'Ogallala indiquent des transmissibilities d'environ 1850 mètres cubes par jour par mètre et des permeabilités d'environ 40 mètres cubes par jour par mètre carré. Le mouvement de la nappe superficielle est vers l'Est a environ 0,3 mètre par jour.

Les dépôts alluviens le long des vallées principales produisent des quantités modérées d'eau, mais les dépôts sont étroits et limités aux vallées interieures. Dans les aires d'affleurements Cretaceous, les approvisionnements sont faibles et on les obtient où ils sont accessibles des minces dépôts subaériens et des zones altérées.

Resumen: Wallace County tiene una área de 2.357 kilómetros cuadrados. Está situado en la sección High Plains de la parte occidental-central de Kansas. Mantos de tiza y lutita de edad Cretácico superior son las rocas más antiguas que afloran en el county. La Ogallala Formation de edad Terciario (Plioceno), que consiste de depósitos fluviátiles los cuales en ciertos lugares exceden 120 metros en espesor, cubre unconformablemente rocas de el Cretácico en la mayor parte del county. Los depósitos más recientes, de edad Pleistoceno superior, consisten hasta 15 metros de loess y 21 metros de depositos aluviales.

En Wallace County, el número de pozos de irrigación ha aumentado cerca de 6 por ciento por año durante los últimos años. La rendición de la mayoría de los pozos fluctúa entre 1,5 y 7,5 metros cúbicos por minuto. La mayor parte de las aguas subterráneas es obtenida de la Ogallala Formation, la cual contiene cerca de 5 mil millones de metros cúbicos en depósito. Pruebas acuíferas realizadas en la Ogallala indican transmisibilidades de cerca de 1.850 metros cúbicos por día por metro y permeabilidades de cerca de 4 metros cúbicos por día por metro cuadrado. El movimiento de las aguas subterráneas es hacia el este a 0,3 metros por día.

Depósitos aluviales a lo largo de los valles prin-

cipales rinden cantidades moderadas de agua, pero los depósitos son estrechos y están confinados a los valles interiores. En áreas donde aflora el Cretácico, los abastecimientos de aguas subterráneas son pobres y donde accesibles son obtenidos de depósitos superficiales delgados y de zonas meteorizada.

Aufzug: Wallace County ist ein 2357 Quadratkilometer grosses Gebiet in der High Plains-Gegend dest westlichen Zentral-Kansas. Kreide- und Tonschieferbetten aus dem Late Cretaceous Alters sind die ältesten Gesteine, die im County zu Tage streichen. Im grössten Teil des County werden Cretaceous Gesteine von der Ogallala Formation Tertiary Alters (Pliocene) diskordant überlagert, welche aus Flussablagerungen besteht, die an einigen Stellen mehr als 120 Meter dick sind. Bis zu 15 Meter dicker Lös und 21 Meter dickes Alluvium stellen die jüngsten Ablagerungen dar; sie sind Late Pleistocene Alters.

Die Zahl der Bewässerungsbrunnen im Wallace County ist in jüngster Zeit um etwa sechs Prozent pro Jahr angestiegen. Die Auschüttung der meisten Bewässerungsbrunnen beträgt etwa 1,5 bis zu mehr als 7,5 Kubikmeter pro Minute. Der grösste Teil des Grundwassers wird von der Ogallala Formation erhalten, in der etwa 5 Milliarden Kubikmeter gespeichert sind. Grundwasserleiter proben im Ogallala zeigen Transmissibilitäten von ungefähr 1850 Kubikmeter pro Tag pro Meter und Permeabilitäten von ungefähr 40 Kubikmeter pro Tag pro Quadratmeter an. Die Grundwasserbewegung findet nach Osten statt und beträgt etwa 0,3 Meter pro Tag.

Alluviale Ablagerungen entlang den Haupttälern ergeben bescheidene Mengen an Wasser; aber die Ablagerungen sind nur schmal und auf das Talinnere beschränkt. In den Gebieten, die Cretaceous-Ausbisse aufweisen, ist die Grundwasserversorgung gering und wird, wo sie vorhanden sind, aus dünnen Oberflächenablagerungen und verwitterten Zonen gespeist.

INTRODUCTION

Purpose and Scope of Investigation

This report gives the results of a study of the geology and the ground-water resources of Wallace County, Kansas. The study was designed to determine the quantity and quality of ground water in the county, to learn the geologic factors that control the occurrence of the water, and to serve as a guide to future ground-water development.

Nearly all water supplies in Wallace County are obtained from wells. Ground water is one of the county's principal natural resources, and although supplies are adequate for most uses in most of the county at the present rate of withdrawal, there is need for a better understanding of the quantity and quality of the available water supply in order to meet anticipated increases in water use.

According to Robert Hay (1891, p. 129), irrigation started in Wallace County when "in 1873 George Allman settled on the south bank of the Smoky Hill, a mile or two above Fort Wallace. One of the first improvements he made was to construct a ditch about a mile long, and by the aid of a small dam tap the first permanent water of that river. In proving up his claim, the dam, ditch, and laterals were among the improvements he described."

Irrigation has been practiced along the valley of the South Fork Smoky Hill River (referred to in this report as the South Smoky Hill River) and in the upland in the southern part of the county for several years, and interest in irrigation has greatly increased in recent years. In the summer of 1958 there were 86 irrigation plants in Wallace County, most of which were drilled after 1951. By the summer of 1960 there were 10 additional irrigation wells, all in areas of considerable pumping. Further increased use of ground water for irrigation can be expected.

This study was made as a part of the ground-water program begun in 1937 by the State Geological Survey of Kansas and the U. S. Geological Survey, in cooperation with the Division of Sanitation of the Kansas State Board of Health and the Division of Water Resources of the Kansas State Board of Agriculture. The present status of the program is shown in Figure 1.

Location and Extent of Area

Wallace County is in the High Plains of northwestern Kansas, in the first tier of counties east of the Colorado border, and in the third tier of counties south of the Nebraska border (Fig. 1). The county is about 30 miles square, with an area of approximately 910 square miles.

Previous Investigations

A report was prepared by Hay (1895) on the geology and ground water of the area along the Kansas-Colorado line, including the northwestern part of Wallace County. A report on the progress of the Division of Hydrography for 1893 and 1894 (Newell, 1895) contained records of 26 wells in Wallace County measured by Hay. Haworth contributed reports on the physiography of western Kansas (1897), on the physical properties of Tertiary rocks in Kansas (1897a), and on the geology of underground water and the possibilities of irrigation in western Kansas (1897b). Logan (1897) discussed the occurrence of Upper Cretaceous rocks in western Kansas. Williston (1897) described the Niobrara in western Kansas and also discussed (1897a) the Pleistocene deposits of Kansas. Johnson (1901, 1902) discussed the origin of the Tertiary of the High Plains and referred to the source, availability, and use of ground water in western Kansas. A report by Darton (1905) discussed the geology and ground-water resources of the central Great Plains, in which he treated the loess of

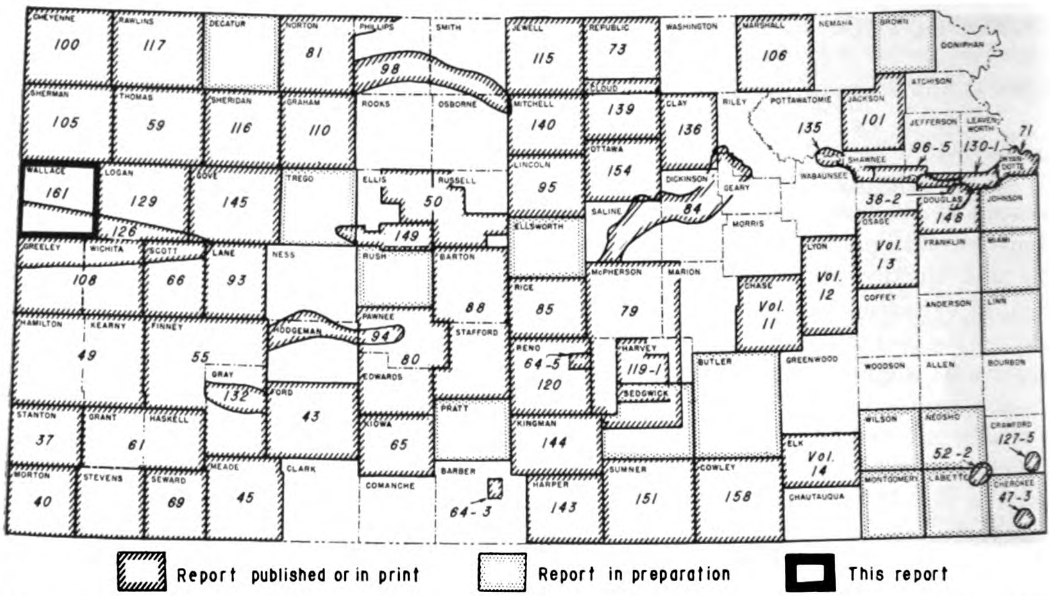

FIGURE 1.—Index map of Kansas showing area discussed in this report, and other areas for which ground-water reports have been published or are in preparation.

western Kansas as a distinctly separate formation from the underlying Tertiary deposits. Darton also briefly discussed (p. 320) the water resources of Wallace County and speculated on the possible water supply in the Dakota Formation in the county. A report by Parker (1911) on the quality of water supplies in Kansas contained a brief description of the geology of Wallace County and analyses of samples of ground water (p. 195-196). In a special report on well waters in Kansas, Haworth (1913) discussed the Tertiary of western Kansas and its water-bearing characteristics. The work of Elias (1931) on the geology of Wallace County was an important contribution to the geology of western Kansas, and his study of the Ogallala Formation and Upper Pleistocene deposits was the foundation for later studies. Frye and Leonard (1952) made a study of the Pleistocene geology of Kansas. Cardwell (1953) reported on irrigation-well development in the Kansas River basin of eastern Colorado. The southern part of the area considered in Cardwell's report borders part of Wallace County. Ground-water studies in areas of Kansas which border Wallace County or include parts of the county are Prescott (1953); Prescott, Branch, and Wilson (1954); Bradley and Johnson (1957); and Johnson (1958). An investigation of the geology and ground-water resources of Kit Carson County, Colorado, which borders about 6 miles of the northwestern edge of Wallace County, is in progress by George H. Chase of the U. S. Geological Survey district office in Colorado. Areas in Kansas where ground-water studies have been made, which have been published or are in preparation, are shown in Figure 1.

METHODS OF INVESTIGATION

The writer spent 4 months in the field during the summer and fall of 1957, about 2 months during the summer of 1958, and 1 month during the fall of 1960 gathering data upon which this report is largely based. The areal geology was mapped from field observations and from stereoscopic study of aerial photographs obtained from the U. S. Department of Agriculture. County maps prepared by the State Highway Commission of Kansas at a scale of 1 inch to the mile were used to record field data.

Data on 294 wells and 190 test holes were collected. Data on wells included the depth to water and the depth of the well. Most wells were measured by means of a steel tape graduated to hundredths of a foot. In a few wells measurements could not be made or were unreliable, and data on depth and water level for these wells were obtained from the owner or driller. Information concerning yield, adequacy of the supply, and quality of the water was obtained when possible from well owners. Drillers logs of wells and test holes were obtained when available from well owners and well drillers.

A total of 80 test holes were drilled in the county in conjunction with this investigation to determine the thickness and character of the Tertiary and Quaternary deposits. Of these test holes, 49 were drilled with a hydraulic rotary drilling machine and 31 with a jeep-mounted power auger, both owned by the State Geological Survey of Kansas. Well drillers and well owners provided logs of 51 irrigation wells, 1 domestic well, and 1 test hole. Logs of 32 shot holes were obtained from a seismograph party of Phillips Petroleum Company operating in the county during the summer of 1957.

Used in addition were logs of 18 test holes drilled and 4 test holes jetted in 1951 in conjunction with a ground-water investigation of the Ladder Creek area (Bradley and Johnson, 1957), and logs of 3 test holes near the Wallace-Sherman county line drilled in 1949 in conjunction with a ground-water investigation of Sherman County (Prescott, 1953).

Samples of water from representative wells were collected for analysis and were analyzed by Howard A. Stoltenberg, chemist, in the Sanitary Engineering Laboratory of the Kansas State Board of Health.

Locations of wells and test holes in the county were determined by means of an odometer and by aerial photographs. The altitudes of measuring points of wells and test holes were determined with a plane table and alidade. The base map used for Plate 1 was compiled from maps prepared by the State Highway Commission of Kansas.

Well-Numbering System

The locations of wells, test holes, and local features in this report are designated according to General Land Office surveys in the following order: township, range, section, quarter section, quarter-quarter section, and quarter-quarter-quarter section (10-acre tract). The quarter sections, quarter-quarter sections, and 10-acre tracts are designated a, b, c, or d in a counterclockwise direction beginning in the northeast quarter section. For example, well 11-41-25acb is in the NW¼ SW¼ NE¼ sec. 25, T. 11 S., R. 41 W. (Fig. 2).

If more than one well or test hole is located in the same 10-acre tract, the location letters are followed by serial numbers in the order in which they were inventoried. The location number of one inventoried well located in Colorado is preceded by the letter C.

Acknowledgments

The writer expresses appreciation to the many residents who gave permission to inventory their wells and supplied helpful information; to those who permitted their wells to be used for aquifer tests and who allowed access to their property for the study of rock exposures; and to the municipal officials who provided data concerning city water supplies. The following drillers furnished logs of wells and test holes and

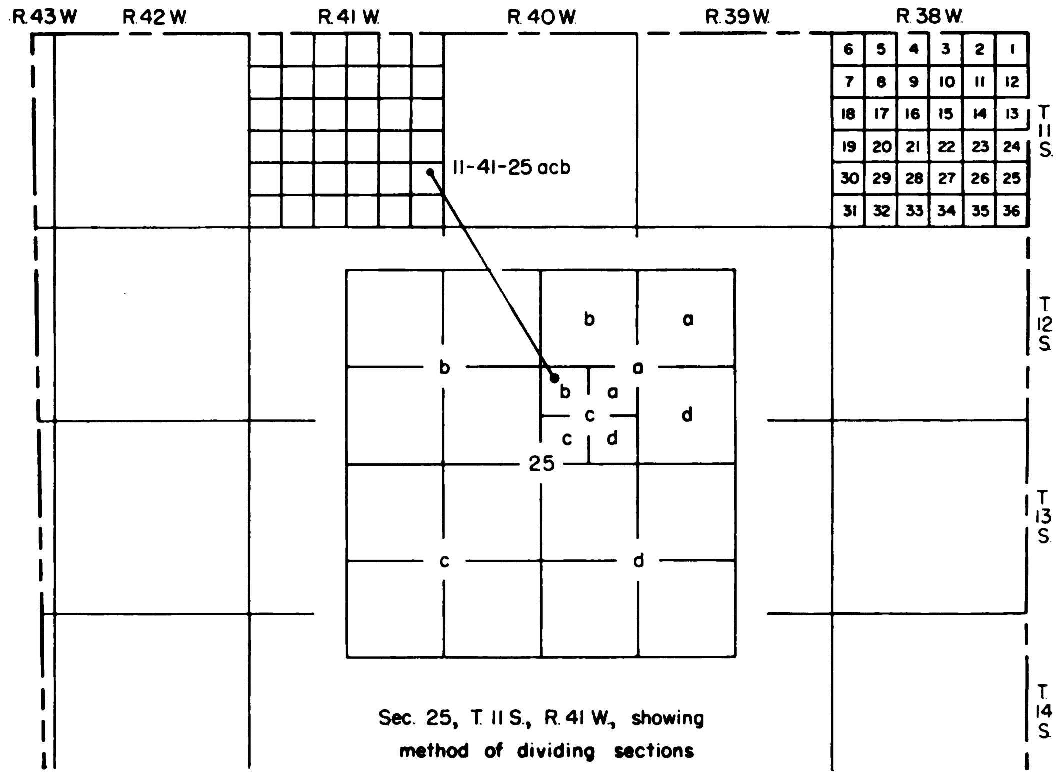

FIGURE 2.—Map of part of Wallace County illustrating the well-numbering system used in this report.

other information on wells in the county: Weishaar and Son, Scott City; Ben Hasz, Scott City; Jack Foust, Goodland; Kenneth Bogart, Goodland; and A. E. Agnew, Weskan. Logs of seismograph shot holes were obtained from a Phillips Petroleum Company seismograph crew. The staff of the Soil Conservation Service, U. S. Department of Agriculture, and Ray Mann, County Agent, gave helpful information.

E. L. and Carrie Reavis and William Gellinger of the U. S. Geological Survey and the State Geological Survey of Kansas gave assistance during field work. The illustrations were drafted by Mary J. Kummer.

The manuscript of this report has been reviewed by members of the U. S. Geological Survey and the State Geological Survey of Kansas; by Robert V. Smrha, chief engineer of the Division of Water Resources of the Kansas State Board of Agriculture; and by Dwight F. Metzler, chief engineer, and Willard O. Hilton, geologist, of the Division of Sanitation of the Kansas State Board of Health.

GEOGRAPHY

TOPOGRAPHY AND DRAINAGE

Wallace County lies within the High Plains section (Fig. 3) of the Great Plains physiographic province as designated by Schoewe (1949, p. 276). Physiographically much of the central part of the county differs somewhat from the High Plains of Kansas because the capping of unconsolidated sand, gravel, and silt of the Ogallala Formation (Tertiary) has been eroded by the South Smoky Hill River and its tributaries, exposing the older underlying Creta-

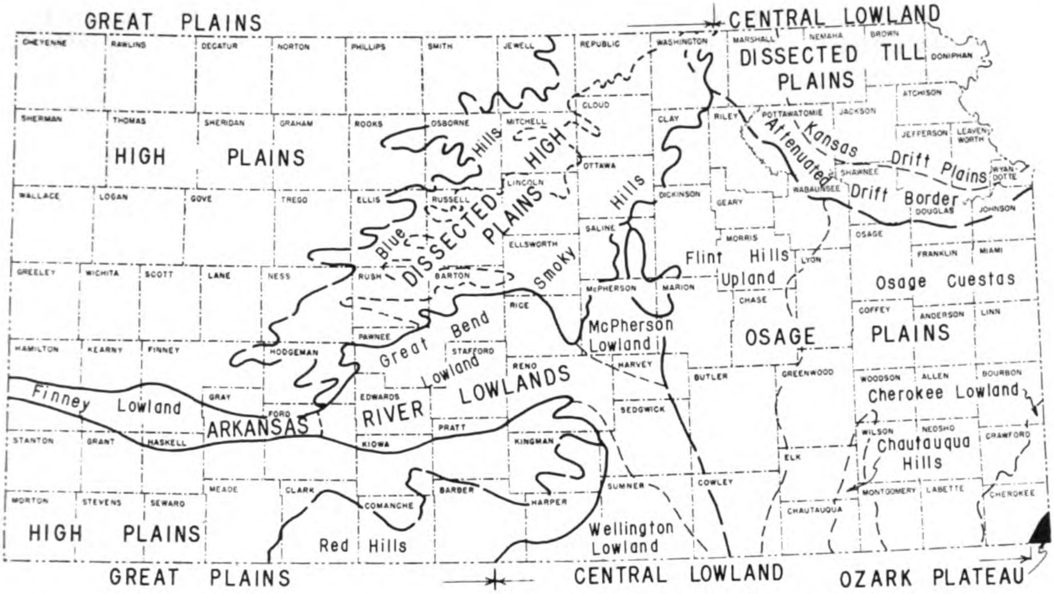

FIGURE 3.—Map of Kansas showing physiographic regions. (From Schoewe, 1949.)

ceous rocks. The southern, northwestern, and north-central parts of the county, however, consist of broad, flat, rolling uplands, characteristic of the High Plains.

The highest point in Kansas is in Wallace County. It is a knoll near the Kansas-Colorado border, about 11 miles north of U. S. Highway 40. The altitude is 4,038.7 feet above sea level, according to elevation levels run in April 1962 by William A. Long and Melvin H. Franz of the Ground Water Branch of the U. S. Geological Survey. The location is 0.3 mile north and 0.1 mile west of the SE cor. sec. 12, T. 12 S., R. 43 W. The second highest point, about 5 miles to the north, is approximately 4,022.7 feet above sea level and is about 200 feet east of the state line and 0.5 mile south of the NW cor. sec. 13, T. 11 S., R. 43 W.

The surface of the High Plains slopes gently eastward, and in Wallace County the average slope ranges from about 12 feet per mile in the southern part of the county to about 18 feet per mile in the northern part. The total topographic relief in Wallace County is about 885 feet. The lowest elevation, about 3,140 feet above sea level, is in the channel of the South Smoky Hill River on the eastern county line in the NE¼ sec. 25, T. 13 S., R. 38 W. Shallow valleys having inconspicuous bluffs are the rule, although the south wall of the South Smoky Hill Valley in the eastern part of the county is rough and very prominent. Stream tributaries enter major streams at angles of 60° to 90°.

The major stream in Wallace County is the South Smoky Hill River, which rises about 30 miles west of the Kansas-Colorado border in Cheyenne County, Colorado, and flows eastward across Wallace County. The stream has a gradient of about 22 feet per mile across Wallace County, dropping from about 3,800 feet above sea level at the state line to about 3,140 feet at the eastern edge of the county. The width of the floodplain and the adjacent low terraces is about half a mile along most of its course but varies from a quarter of a mile to more than a mile. North Ladder Creek and Sand Creek are the principal streams in the southern part of the county. The valleys of these streams are narrow and their floodplains and terraces are poorly developed. Sand Creek joins North Ladder Creek in northeastern Greeley County. North Ladder Creek joins the Smoky Hill River in eastern Logan County.

Most of the smaller streams in Wallace County are tributaries to the South Smoky Hill River. The more important of these are Lake Creek, which drains much of the north-central and northeastern parts of the county, and Goose Creek and Willow Creek, which drain the northwestern part of the county. Rose Creek and Eagle Tail Creek drain part of the south-central part of the county and are the only streams of any consequence entering the South Smoky Hill River in Wallace County from the south. The North Smoky Hill River cuts across the extreme northeast corner of the county and joins the South Fork in Logan County, where they form the main stem of the Smoky Hill River.

The headward parts of several streams have cut into the Ogallala Formation and these spring-fed streams flow, especially after frost, from contributions from the Ogallala. Rose Creek heads 4 or 5 miles south of Sharon Springs and flows about 8 miles to its junction with the South Smoky Hill River about 6 miles east of Sharon Springs. A considerable amount of ground water is drained from the Ogallala by Rose Creek. Table 1 shows mean monthly discharges 1 mile upstream from the mouth of Rose Creek for the period from May 1946 to September 1953. In addition, an undetermined amount of water from Rose Creek is diverted for irrigation. It is reported that Rose Creek usually flows even in the driest summers.

Several other small tributary streams have cut headward into the Ogallala Formation, from which they derive water, and flow especially after frost, when transpiration by plants and evaporation is reduced. The more notable of these are Eagle Tail Creek and Willow Creek.

Lakes

Common features of the High Plains are shallow, undrained depressions and intermittent natural lakes. Several deep, steep-sided basins resulting from abrupt sinking of the ground also occur. Most of the depressions are circular to subcircular, although some appear to be linear and others have no particular pattern and may be designated as irregular in shape.

Dozens of undrained depressions characteristic of the surface of the High Plains are present in Wallace County. They range in size from a few tens of feet to nearly a mile in diameter. Some of the depressions appear to be grouped together.

TABLE 1.—Monthly and yearly mean discharge, in cubic feet per second, 1 mile upstream from mouth of Rose Creek, for period of record.

Water year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Yearly mean
1946								3.52	2.98	1.79	0.69	2.46	
1947	4.10	4.24	4.35	4.0	4.56	9.15	5.72	7.98	5.18	2.77	2.31	2.54	4.7
1948	3.20	3.55	3.44	3.95	4.26	4.74	3.78	3.19	3.27	3.92	2.76	2.17	3.5
1949	2.6	3.4	3.5	3.1	3.4	3.1	5.8	7.1	15.5	2.8	18.1	7.9	6.4
1950	6.0	4.8	5.0	6.3	5.0	4.3	3.7	2.83	1.44	7.3	19.5	5.2	6.0
1951	4.4	4.3	4.7	5.5	4.8	3.3	5.2	4.8	10.6	7.5	4.7	3.9	5.3
1952	3.82	4.42	4.05	4.72	4.66	5.05	4.77	4.36	1.67	0.31	0.61	1.91	3.4
1953	2.44	2.38	3.70	3.92	3.70	3.41	4.16	2.79	0.94	0.22	6.67	0.56	2.9

At some localities there appears to be an alignment of depressions; in places the alignments are along shallow valleys. In general there are three types: small, shallow depressions; large, deep depressions; and smaller, steep-sided depressions.

Most of the depressions in Wallace County are small and shallow, ranging in size from less than an acre to several tens of acres. After heavy rains, storm runoff collects in these depressions, forming temporary lakes. The water generally evaporates or seeps into the ground after a few weeks. The shallow depressions are referred to locally as "lagoons" or "buffalo wallows."

There are also several large, deep depressions, which range up to several hundred acres in size and contain water for many weeks or months after heavy rains. The large depressions were mapped from aerial photographs and are shown on Plate 1. The two largest are in the east-central part of the county where Tertiary rocks are not present, the largest one being in the southeastern part of T. 12 S., R. 38 W.

An abrupt sinking of the land, resulting in deep, steep-sided holes, has also occurred at several places. Smoky Basin Cave-in, about 5 miles east of Sharon Springs in the SE¼ sec. 33, T. 13 S., R. 39 W., is an example of an abrupt subsidence that occurred in 1926. Another well-known cave-in, referred to as Old Maid's Pool, is in the NE cor. sec. 30, T. 12 S., R. 40 W. This basin is perfectly circular and generally contains water at about the same level.

Several theories have been offered as to the origin of the depressions of the High Plains. Darton and others (1915, p. 36-37) referred to some of the depressions as buffalo wallows and explained their origin by the combined action of buffaloes and wind. They believed that the depressions were started by buffaloes, either at wet spots or places of salt or alkali, and were enlarged by wind action and by the removal of mud by the animals after rains. Although this explanation might account for some of the small, shallow depressions in Wallace County, it does not seem adequate for the large depressions having depths of 10 feet or more.

Johnson (1901, p. 702, 712) considered the origin of the basins of the High Plains to be the result of solution of soluble beds followed by collapse in areas of Permian bedrock; however, he believed this hypothesis inadequate in areas of Cretaceous bedrock. He attributed the shallow undrained depressions of the uplands to rainwater accumulation in initially flat, uneven and undrained areas. The seepage of water beneath the pond caused settling of the underlying sediments by mechanical compaction and solution in the Tertiary rocks.

Johnson's ideas are supported by work done in Thomas County (Frye, 1945, p. 30), where test holes were drilled near the centers and rims of two depressions. The test holes disclosed that there was no reflection on the underlying Cretaceous bedrock of the surface depressions in the Tertiary rocks.

Russell (1929) observed the depressions in Wallace, Logan, and other counties in western Kansas and excluded the possibility of solution of the underlying Cretaceous rocks because of their relatively impervious nature. He explained the subsidences as resulting from collapse of cavities that developed between the walls of faults in the Niobrara Formation from late Pliocene and Early Pleistocene tensional faulting.

Elias (1931, p. 224-236) studied the subsidences and concluded that they were caused by solution of chalk along fault planes in the Niobrara Formation and subsequent collapse of cavities. He believed that some of the shallow depressions could be cave-ins of earlier origin, the surface expressions of which had been subdued by gradual filling and slumping of the walls.

Just as there is more than one type of

depression so there could be more than one origin. Some of the depressions in Wallace County that are small and shallow could be accounted for either by Darton's buffalo wallow theory or Johnson's theory of compaction. However, for those depressions that are large and deep, Johnson's theory of compaction and solution of the Tertiary rocks seems applicable. It would seem that where Tertiary rocks are missing the large and relatively deep depressions must be explained by solution of the underlying rocks. Small, steep-sided depressions, such as Smoky Basin Cave-in and Old Maid's Pool, are the results of either solution of the Niobrara Chalk, probably along faults and fractured zones, or collapse within the Niobrara of cavities formed by tensional faulting. The uppermost rocks below the Niobrara that would be subject to solution would be about 2,000 feet below the land surface. Solution sufficient for collapse of large areas seems unlikely that far below the surface.

Climate

The climate of Wallace County is semiarid, with low to moderate precipitation and a high rate of evaporation. The weather during spring and fall is mild and generally pleasant. Much of the summer is hot, although the summer heat is moderated by brisk winds and low humidity, and the nights are generally cool. As a rule the winters are reasonably mild; the periods of severe cold weather are short and the snowfall is relatively light. A large percentage of the winter days are clear, although snow flurries are common and occasionally the area is subjected to blizzard conditions. Ordinarily, snow remains on the ground only a short time.

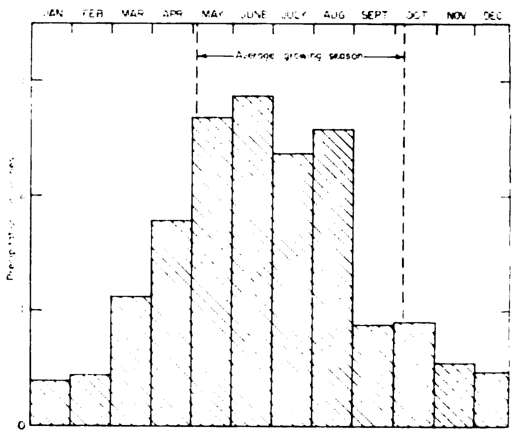

Figure 4.—Normal monthly precipitation and average growing season in Wallace County.

In Wallace County the amount of precipitation and its seasonal distribution are the controlling factors in crop growth. Rainfall is erratic, coming sometimes as storms of 4 inches or more, and at other times in no appreciable amount for several weeks. According to data compiled from published records of the U. S. Weather Bureau, about 65 percent of the annual precipitation in Wallace County falls during the growing season of about 5 months (Fig. 4). The mean annual precipitation at Sharon Springs is 17.03 inches. The greatest annual precipitation recorded was 34.00 inches, in 1880; the least was 7.45 inches, in 1873 (Table 2). The average length of the growing season is 157 days. The average date of the last killing frost in spring is May 3, and that of the first killing frost in fall is October 7.

Population

According to the census, Wallace County in 1960 had a population of 2,069. This is an average of 2.3 persons per square mile as compared to 26.6 person per square mile for the state as a whole. Sharon Springs, the county seat, had a population of 966. Other communities are Wallace, population 110, and Weskan, unincorporated.

TABLE 2.—Annual precipitation in Wallace County for period of record Measurements from 1870 to March 1923 at Wallace, subsequent measurements at Sharon Springs. From published records of the U. S. Weather Bureau.

Year	Precipitation, inches	Year	Precipitation, inches
1870	16.03	1916	10.60
1871	20.89	1917	11.95
1872	16.87	1918	20.37
1873	7.45	1919	17.86
1874	13.58	1920	14.85
1875	16.45	1921	16.15
1876	16.98	1922	12.58
1877	14.22	1923	25.03
1878	19.28	1924	10.93
1879	16.58	1925	11.77
1880	34.00	1926	10.32
1881	8.82	1927	17.02
1882	12.41	1928	22.27
1883	23.35	1929	16.69
1884	22.76	1930	23.49
1885	21.01	1931	10.87
1886	12.23	1932	15.71
1887	19.57	1933	25.67
1888	16.73	1934	9.40
1889	14.55	1935	12.13
1890	11.90	1936	11.12
1891	16.32	1937	12.36
1892	17.65	1938	22.47
1893	10.23	1939	13.02
1894	9.54	1940	17.17
1895	18.52	1941	24.35
1896	14.26	1942	24.01
1897	19.61	1943	13.39
1898	15.16	1944	18.81
1899	14.16	1945	15.89
1900	12.43	1946	17.65
1901	16.51	1947	17.49
1902	21.16	1948	18.74
1903	17.23	1949	31.05
1904	19.81	1950	13.92
1905	27.01	1951	22.65
1906	18.59	1952	15.01
1907	8.85	1953	17.05
1908	15.35	1954	12.53
1909	20.20	1955	13.06
1910	8.05	1956	8.16
1911	8.95	1957	25.75
1912	19.33	1958	20.74
1913	8.57	1959	17.56
1914	14.96	1960	17.35
1915	28.31		

TRANSPORTATION

The Union Pacific Railroad crosses east-west near the middle of the county and passes through the towns of Wallace, Sharon Springs, and Weskan. U. S. Highway 40 crosses the county east-west and parallels the Union Pacific Railroad much of the way. Kansas Highway 27 crosses north-south near the middle of the county and passes through Sharon Springs. In addition, the county maintains many miles of section-line roads.

AGRICULTURE

Agriculture is the dominant economic activity in Wallace County. According to the Kansas State Board of Agriculture (1959), the county in 1958 contained 327 farms, 283,000 acres in pasture, and 137,305 acres in crops harvested. Because of the practice of summer fallowing, only a part of the cropland is in cultivation each year. The total value of field crops in 1958 was $4,894,930, and of livestock and poultry produced was $1,526,770. In January 1959 there were 25,000 cattle, 4,260 sheep, and 2,300 hogs in Wallace County. The acreage, production, and value of crops in Wallace County are given in Table 3.

MINERAL RESOURCES

Mineral resources of Wallace County other than soil and ground water include sand and gravel, diatomaceous marl, natural gas, and volcanic ash.

SAND AND GRAVEL.—Sand and gravel are available in Wallace County from Pleistocene deposits along the South Smoky Hill Valley and from the Ogallala Formation in the uplands, where the deposits are extensive. The sand and gravel are used for concrete aggregate and for road construction and surfacing.

DIATOMACEOUS MARL.—Wallace County is the only county in Kansas where diatomaceous marl is mined. It is produced by the DeLore Division of the National Lead Company of St. Louis, Missouri. As described by the Kansas Geological Survey (1931), the diatomaceous marl is an impure variety of diatomite or diatomaceous earth, which is a hydrous or opaline form of silica

TABLE 3.—Acreage, production, and value of crops in Wallace County in 1958.

Use	Acres planted	Acres harvested	Production, bushels	Value
Wheat	81,000	70,000	1,820,000	$3,094,000
Sorghums	51,000	49,000	1,112,100	1,405,700
Barley	7,700	6,500	110,500	76,700
Hay		5,900	10,800[a]	124,700
Corn	4,000	4,000	160,000	174,600
Oats	2,100	1,000	14,000	8,500
Rye	1,500	900	11,700	9,700

[a] Tons

composed principally of skeletal remains of microscopic, one-celled, fresh-water plants called diatoms. The Wallace County deposits contain flaky calcium carbonate, sponge spicules, and minor amounts of sand. The marl consists of about 20 percent silica and 80 percent calcium carbonate by weight. Because of the box shape of empty tests of diatoms, the percentage of the volume occupied by the tests is much greater than the percentage by weight. About one-half the deposits by volume is estimated to consist of diatoms. The deposits, which are as much as 11 feet thick, are found in the Ogallala Formation of Tertiary age, along the south side of North Smoky Hill Valley near the northeast corner of the county, mainly in secs. 10, 11, and 12, T. 11 S., R. 38 W. The marl is snow white to grayish, light, and very fragile. The material is trucked to the company's processing plant at Edson in Sherman County, about 17 miles north of the mine, from where it is shipped by railroad cars. The deposits are estimated to exceed 1 million tons (Schoewe, 1959, p. 278). Kansas diatomaceous marl is used for a whiting substitute and as a paint filler.

OIL AND GAS.—Several wildcat wells have been drilled in Wallace County from time to time, but as yet oil in commercial quantities has not been produced. In 1956 gas was discovered on the Sexson lease in the SW¼ sec. 19, T. 13 S., R. 42 W. The production zone was in rocks of Morrowan age (Early Pennsylvanian) at 5,008 to 5,014 feet. The well was assigned an initial potential of more than 14 million cubic feet of gas per day and was named the discovery well of the Sexson field. Because no pipeline connections were available, the well was shut in and no production has been reported from the field.

VOLCANIC ASH.—A few deposits of volcanic ash occur in the Ogallala Formation in Wallace County. Although the ash is relatively clean, the deposits are not thick enough to be of commercial value. The thickest known deposit is in the SE cor. sec. 8, T. 14 S., R. 38 W., near the base of the Ogallala Formation. About 3 feet thick and fairly clean, the ash is exposed in a steep bluff under about 50 feet of overburden.

GEOLOGY

SUMMARY OF STRATIGRAPHY *

The rocks that crop out in Wallace County are sedimentary in origin and range in age from Cretaceous to Recent. Their areal distribution is shown on Plate 1; their stratigraphic relations are illustrated by cross sections on Plate 2. A generalized

* The classification and nomenclature of the rock units described in this report follow that of the State Geological Survey of Kansas and differ somewhat from the classification and nomenclature of the U. S. Geological Survey.

TABLE 4.—Outcropping rocks of Wallace County and their water-bearing properties.

System	Series	Stratigraphic unit	Maximum thickness, feet	Physical character	Water supply
Quaternary	Pleistocene	Alluvium	70	Stream-laid deposits ranging in composition from clayey silt to coarse sand and gravel occur along principal stream valleys. Thick, coarse deposits occur in the basal part of major valleys; finer deposits occur in smaller valleys.	Yields moderate to large quantities of water to wells in South Fork and North Fork Smoky Hill Valleys, moderate to small amounts in the smaller tributary valleys. Yields are as much as 1,000 gpm to irrigation wells in the major valleys.
		Peoria and Loveland Formations	50	Silt, mostly eolian, becoming sandy in lower part; locally contains a thin bed of gravel rubble near the base. Mantles most of the uplands, particularly in the southern part of the county, and masks much of the valley walls. Locally includes colluvial deposits in draws and headwaters of tributary streams.	Most of the deposits are above the water table, and hence yield no water to wells. In areas where ground-water supplies are meager, colluvial deposits overlying impervious bedrock in small upland creeks and draws serve as local catchment basins from which small amounts of ground water are available.
Tertiary	Pliocene	Ogallala Formation	400	Chiefly sand, gravel, silt, and clay; largely unconsolidated but cemented to various degrees, in places by calcium carbonate and locally by silica. The deposits are interbedded and admixed in various proportions, sand and limy silt being the dominant constituents.	Yields moderate to large quantities of water to wells in the southern and extreme western and northwestern parts of the county, and moderate to small quantities of water in much of the rest of the county. Yields are as much as 2,000 gpm to irrigation wells.
Cretaceous	Upper Cretaceous	Pierre Shale	600 ±	Fissile dark-gray shale, clayey and fossiliferous. Concretions of varied size and composition occur in zones, usually along bedding planes; thin beds of mottled grayish-green and brown bentonite are common. Iron pyrite and marcasite occur in fresh exposures; limonite and selenite crystals characterize weathered exposures.	Yields no water to wells.
		Smoky Hill Chalk Member of Niobrara Chalk	650 ±	Gray and light-gray chalk and chalky shale, thin bedded and platy. Contains thin beds of bentonite. Weathers to bright orange and cream yellow.	Do.

section of the outcropping rock units is given in Table 4.

The Smoky Hill Chalk Member, upper member of the Niobrara Chalk of Late Cretaceous age, is the oldest rock unit exposed in Wallace County. The Smoky Hill Chalk Member crops out along the south side of the South Smoky Hill Valley in the extreme east-central part of the county; in the rest of the county it is buried beneath younger rocks.

The Pierre Shale of Late Cretaceous age conformably overlies the Smoky Hill in Wallace County and crops out in the central and northern parts of the county. The Pierre is the dominant bedrock and is exposed chiefly along the valley walls of the larger streams, along the streambeds of the smaller streams, and in some of the upland draws.

The Ogallala Formation of Late Tertiary (Pliocene) age unconformably overlies the Pierre Shale in Wallace County. The Ogallala is present in approximately two-thirds of the county, and in the southern part of the county it underlies most of the upland plain. Erosion has removed much of the Ogallala along the streams in the central and northeastern parts of the county, and in much of these areas the Ogallala caps only the uplands.

Thin, dissected and isolated deposits of sand and gravel of Pleistocene age occur along the larger streams, chiefly the South Smoky Hill and North Smoky Hill Rivers. These deposits have been derived from the Ogallala Formation and lithologically are very similar to the Ogallala. Because of this similarity it is difficult to distinguish the Pleistocene gravels from the Ogallala. In general, however, the Pleistocene deposits tend to be better sorted and are not admixed with finer clastics, as is characteristic of the Ogallala.

Eolian silts of Late Pleistocene age mantle much of Wallace County and are shown on the geologic map (Pl. 1) as the Peoria and Loveland Formations. Colluvial deposits, consisting chiefly of reworked loess, but in many places containing sand and gravel derived from the Ogallala Formation and local bedrock fragments, constitute much of the thin surficial deposits on the slopes of the stream valleys and in the upland draws in the central and northeastern parts of the county. Where these deposits are thick enough to conceal the underlying rocks, they have been included with the Peoria and Loveland Formations in this report.

Alluvium believed to be Recent and late Wisconsinan in age occurs along the principal streams and constitutes the youngest geologic deposits in the county.

Cretaceous Rocks Not Exposed

Several rock units do not crop out in Wallace County but lie within a possible drilling depth for water wells.

The Dakota Formation of Early Cretaceous age is an important aquifer in some areas of Kansas and may be a potential source of small amounts of ground water in Wallace County. Generalized contours indicating the depth of the Dakota Formation below land surface in Wallace County are shown in Figure 5. So far as is known, no water wells have been drilled to the Dakota Formation in Wallace County.

The Graneros Shale and Greenhorn Limestone of Late Cretaceous age overlie the Dakota Formation. The Graneros Shale consists of about 60 feet of dark-gray clayey shale. The Greenhorn consists of about 100 feet of thin, alternating beds of chalky limestone and calcareous shale. Neither the Graneros Shale nor the Greenhorn Limestone can be considered an important source of ground water in Wallace County.

The Carlile Shale of Late Cretaceous age overlies the Greenhorn Limestone. The

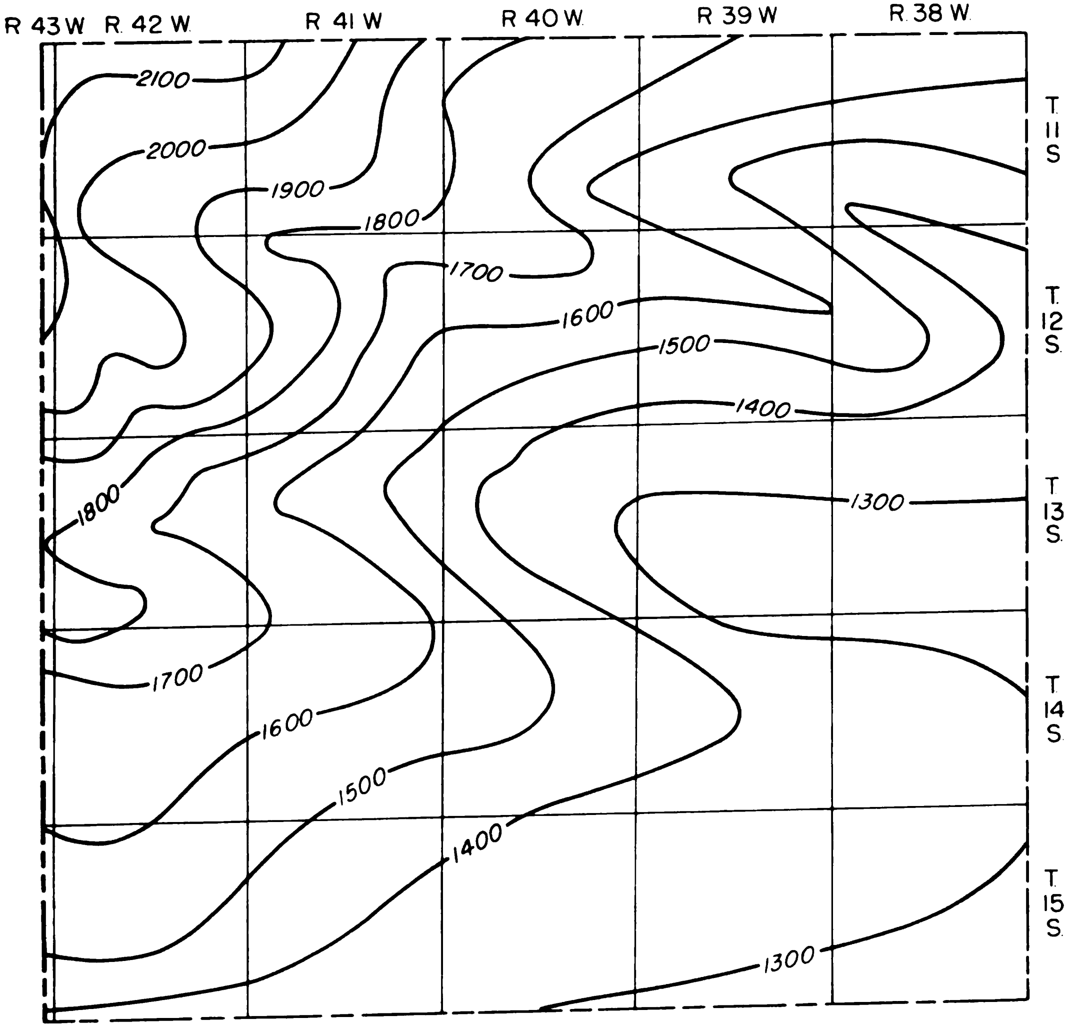

FIGURE 5.—Generalized contours showing depth to Dakota Formation below land surface in Wallace County. Interpolated from structural map of Dakota Formation by Merriam (1957) and from logs of oil and gas test wells. Contour interval 100 feet.

lower part of the Carlile consists of light-gray chalky shale; the upper part consists of dark-gray clayey shale. The Codell Sandstone Member, uppermost member of the Carlile, in much of Kansas consists of a thin bed of silty, fine-grained sandstone. Although the Codell tends to increase somewhat in thickness in the subsurface westward across Kansas, it is not considered an important source of ground water in Kansas except in local areas near outcrops, where small yields are characteristic. No wells derive water from the Codell in Wallace County.

The Fort Hays Limestone Member, lower member of the Niobrara Chalk, overlies the Carlile Shale. The Fort Hays Member consists of grayish-white chalk and chalky limestone beds separated by thin chalky shale partings. The Fort Hays is about 50 to 60 feet thick and ranges from about 900 feet below land surface in the southeastern part of the county to about 1,700 feet below in the northwestern part.

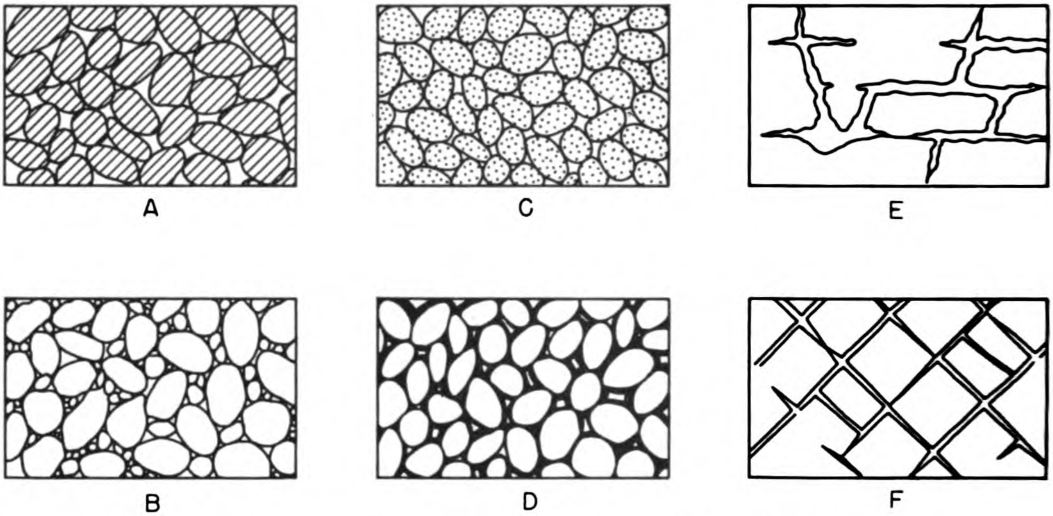

FIGURE 6.—Diagram showing several types of rock interstices and the relation of rock texture to porosity. (From Meinzer, 1923a.) **A**, Well-sorted sedimentary deposit having high porosity; **B**, poorly sorted sedimentary deposit having low porosity; **C**, well-sorted sedimentary deposit consisting 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.

GROUND WATER

PRINCIPLES OF OCCURRENCE

The fundamental principles governing the occurrence and movement of ground water were described by Meinzer (1923) and were summarized as they apply to Kansas by Moore (Moore and others, 1940). These principles will be discussed here briefly; for a more detailed discussion the reader is referred to the above-mentioned reports.

The rocks and surficial deposits that form the outer crust of the earth are not solid throughout, but contain many open spaces. These spaces range in size from minute openings between particles of silt or clay to larger openings between grains or pebbles in sandstone, sand, or gravel, to open joints and crevices formed by fractures and solution in consolidated rocks. A unit in which the openings are interconnected and large enough to allow water to move to a well is called an aquifer. Figure 6 shows several common types of rock interstices and the relation of texture to porosity.

Figure 7 is a diagram of the hydrologic cycle, adapted from A. M. Piper (1953), and shows the part of ground water in the circulation of water near the surface of the earth. In Wallace County ground water is derived almost entirely from precipitation. Part of the water that falls as precipitation becomes surface runoff, part of it evaporates into the atmosphere, and part of it is absorbed by plants and later transpired into the atmosphere. The rest, a very small part, percolates downward through the soil and underlying strata until it reaches the water table, where it becomes ground water. Figure 8 shows the generalized divisions of subsurface water.

Where a water-bearing unit is confined between relatively impermeable beds and water is supplied to it from an adjacent area of higher altitude, the water table is absent and the water is said to be confined or under artesian pressure. When an aquifer under artesian pressure is penetrated by a

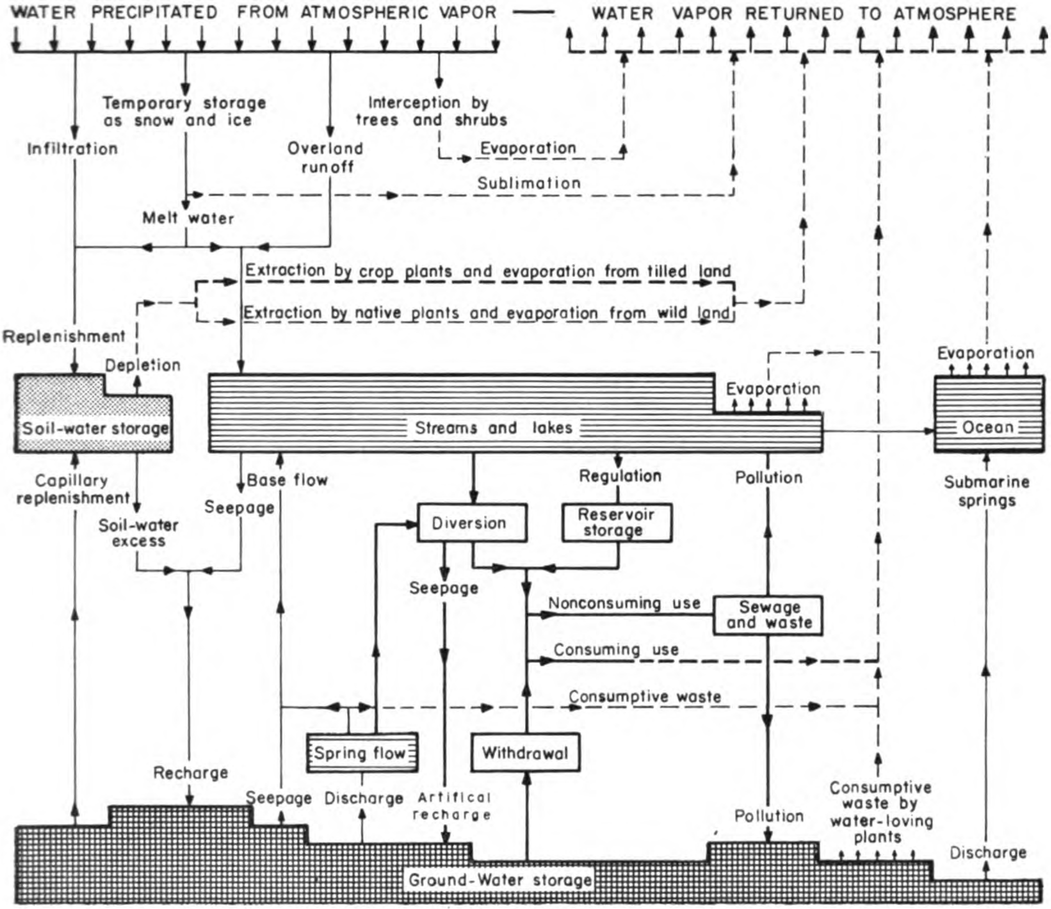

FIGURE 7.—Diagram of the hydrologic cycle. (After Piper, 1953.) Solid flow lines indicate movement of water as a liquid, and broken lines, movement as vapor. Heavy flow lines indicate man's principal changes in the natural cycle.

well, water will rise in the well until pressure of the column of water is equal to the hydraulic head. The imaginary surface connecting this level in wells is called the piezometric surface, which may or may not be above the land surface.

The Water Table and Movement of Ground Water

The water table may be defined as the upper surface of that part of the zone of saturation where water is free to move by gravity. The water table is not a static, level surface, but is a sloping surface having irregularities in the form of mounds, depressions, and ridges related to the topography, geology, and hydrology of the area. The configuration of the water table in Wallace County is shown on Plate 1 by means of contour lines. The direction of ground-water movement is at right angles to the contours and in a down-slope direction. In most of the county the movement is easterly. Because of frictional resistance of the small interstices through which the water must pass, this movement is very slow. The slope of the water table varies inversely with the permeability of the aquifer, the water-table contours being spaced

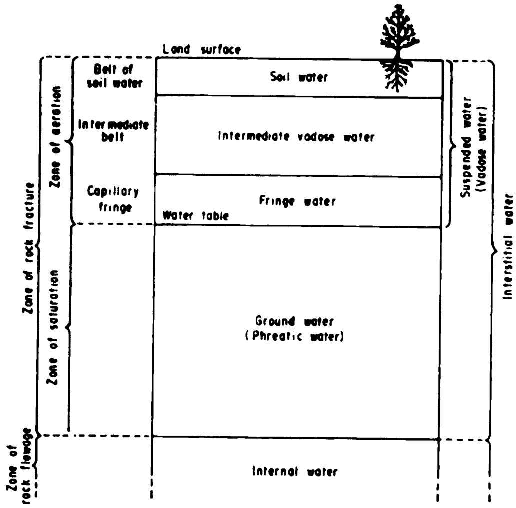

FIGURE 8.—Diagram showing generalized divisions of subsurface water. (After Meinzer, 1923a, fig. 2.)

farther apart in areas where the water-bearing beds are more permeable. The movement of ground water where aquifer tests were made in Wallace County is calculated elsewhere in this report, in the discussion of hydrologic properties of water-bearing materials.

Ground water that accumulates from recharge of the aquifer by precipitation moves eastward at a slope of approximately 11 feet per mile (Pl. 1), or at a hydraulic gradient of 0.002. The amount of ground water moving through that part of the aquifer shown on the southern part of the geologic cross section B-B′ (Pl. 2) is estimated by assuming a coefficient of permeability of 1,000 gpd per square foot (determined from aquifer tests in this general area). The total area of saturated material in the cross section is about 7,200,000 square feet. The quantity of ground water moving through a given cross-sectional area of water-bearing material can be calculated from the following formula:

$$Q = PIA$$

where Q = the quantity of water,
P = the coefficient of permeability,
I = the hydraulic gradient, and
A = the area.

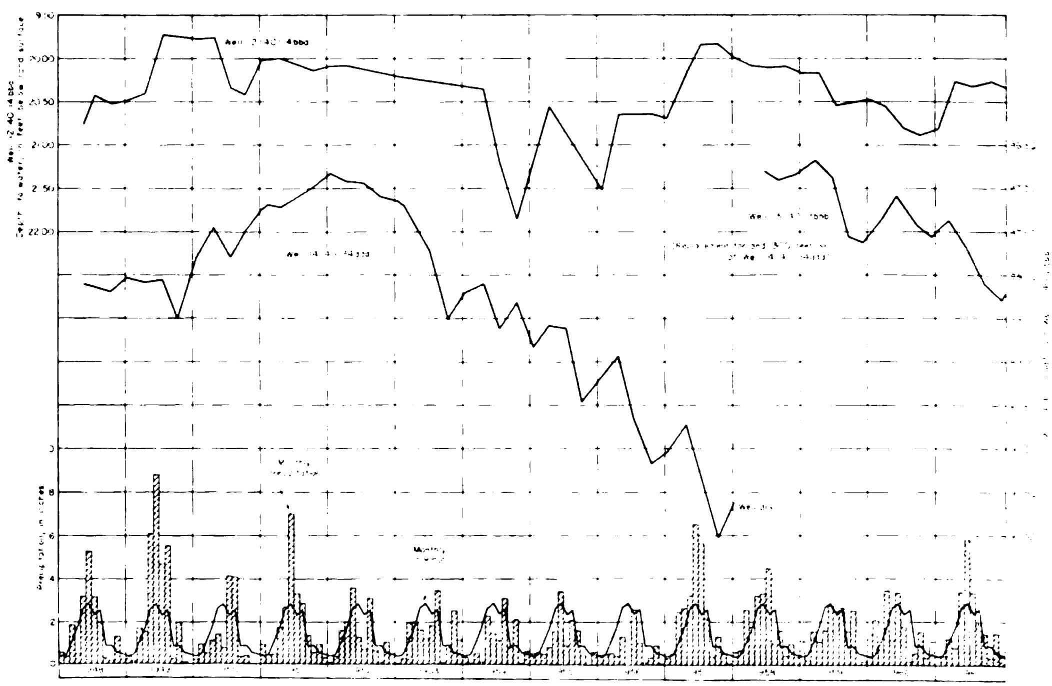

FIGURE 9.—Hydrographs showing fluctuations of water levels in the Ogallala Formation, and graphs showing monthly and normal precipitation at Sharon Springs.

Thus, the ground-water movement through the cross section is:

(1,000) (0.002) (7,200,000) =
14,400,000 gpd, or 16,000 acre-feet per year.
(One acre-foot equals 325,850 gallons.)

Fluctuations of the Water Table

The water table is not a stationary surface but one that fluctuates up and down in response to additions to or withdrawals from the aquifer. Hydrographs showing fluctuations of the water levels in two wells in Wallace County and the monthly precipitation at Sharon Springs are shown in Figure 9. Water levels in a number of irrigation wells in the southeastern part of the county were several feet lower in the fall of 1957, after many of the wells had been pumped during much of the summer and fall, than water levels in the same wells in the summer of 1958, when considerably less water had been pumped for irrigation because of ample rainfall.

Ground-Water Recharge

Ground water in Wallace County, as in other parts of the Great Plains, is derived almost entirely from local precipitation in the form of rain or snow. One inch of water falling on 1 square mile amounts to more than 17 million gallons. The mean annual precipitation of 17.03 inches amounts to nearly 300 million gallons per square mile and a total of more than 800 thousand acre-feet over the entire county. Only a small part of the annual precipitation, however, reaches the ground-water reservoir. As has been mentioned above, a very small part of the water that falls as precipitation in Wallace County is carried away as surface runoff by streams; part is evaporated into the atmosphere; part is absorbed by vegetation and later transpired into the atmosphere. The small amount of water that is not discharged by these processes percolates downward to the zone of saturation. After the water reaches the water table, it moves down gradient slowly toward points of discharge such as wells, springs, and streams, or to points of evaporation and transpiration.

More than 60 percent of the mean annual precipitation in Wallace County falls during the 4 months of May through August when the climate is characterized by brisk wind movement, high temperatures, and relatively low humidity. Consequently, evaporation is rapid, and much of the annual precipitation returns to the atmosphere. Moreover, because much of the rainfall occurs during the growing season, a large part of the precipitation is returned to the atmosphere through transpiration by plants.

Recharge, the addition of water to the ground-water reservoir, may occur in several ways. The original source of all recharge is precipitation; however, in addition to direct infiltration of precipitation, a ground-water reservoir may be recharged locally by the seepage of water from streams, by subsurface inflow of water from adjacent areas, and by the infiltration of irrigation water applied on the land surface.

Infiltration of Precipitation

The topography, type of soil, and nature of subsoil greatly affect the amount of water that will infiltrate below the land surface. A good vegetative cover will retard runoff and allow water to seep into the soil. Most of the southern part of Wallace County is much more conducive to infiltration of rainfall than is the northern part, and the relative lack of surface streams in the southern part of the county in contrast to the predominance of streams in the northern part attests to this difference between the two areas.

The rate of ground-water recharge in Wallace County is not known, but studies of recharge in other, similar areas in the High Plains indicate a recharge of about one-fourth inch per year. If the figure of one-fourth inch per year is applied to the area in Wallace County underlain by the Ogallala Formation, the annual addition to the ground-water reservoir from precipitation would be about 10,000 acre-feet.

Influent Seepage from Streams

Most streams in Wallace County are influent streams—that is, they have not cut their channels below the water table and thus add water to rather than receive water from the zone of saturation. Figure 10 illustrates influent and effluent streams. North Fork Ladder Creek, in the southern part of the county, probably contributes considerably more water to the ground-water reservoir than other streams in the county because of the sandy nature of the channel, its meandering course, and the permeable beds underlying the stream. Recharge from streams in the northern part of the county would tend to be minor because of the nearness of shale to the land surface in much of the area.

Subsurface Inflow

Subsurface inflow to an area results from the down-gradient movement of ground water from adjacent areas toward areas of discharge. Ground water moves into Wallace County along the western edge of the county. The quantity of subsurface inflow to the county is not known but is estimated to be approximately 100 acre-feet per day.

Infiltration of Irrigation Water

Recharge from the return of water applied to the land for irrigation has been estimated to approach 25 percent of the applied water in certain irrigated areas. In these areas, the irrigated water is distributed in relatively long ditches over soils

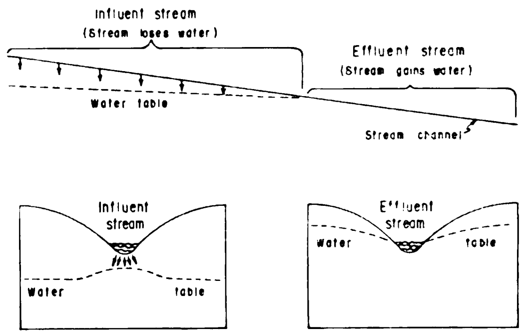

FIGURE 10.—Diagrammatic sections showing influent and effluent streams. A, Longitudinal section showing (right) how an effluent stream gains water and (left) how an influent stream loses water. B, Transverse section across influent part of a stream. C, Transverse section across effluent part of a stream. (After Meinzer, 1923a, fig. 26.)

and subsoils that are very permeable. The upland plain in Wallace County is thickly mantled by loess and has a relatively dense soil, and recharge probably does not average more than 10 percent of the applied water. On the irrigated land in the alluvial valleys, where the soils are more sandy, the percentage of applied water that recharges the aquifer probably is somewhat greater. However, the areal extent of the alluvial valleys is relatively small in Wallace County.

GROUND-WATER DISCHARGE

Ground-water discharge is the release of water from the zone of saturation. In Wallace County ground water is discharged by effluent seepage into streams, by springs, by transpiration and evaporation, by pumping from wells, and by subsurface outflow.

Springs and Seeps

Streamflow is maintained at low stages in Rose Creek, Eagle Tail Creek, and Willow Creek by ground-water discharge from the Ogallala Formation. Ground water is discharged into these streams mainly by seeps along stream channels, but there are many small springs along the valley walls where the stream channel intercepts the water table, and also at the contact of the Ogallala Formation and the underlying impermeable Pierre Shale. Many of the springs and seeps continue to discharge ground water during periods of drought, and the shallow ground water along the streams supports a heavy growth of vegetation. The amount of discharge of ground water by springs and seeps in Wallace County is not known but is believed to be considerable.

Transpiration and Evaporation

During the growing season, plants transpire a considerable amount of ground water in the major stream valleys in the area. The lowering of the water table by transpiration greatly reduces the ground-water discharge into streams, notably Rose Creek, Eagle Tail Creek, and Willow Creek, and in these streams the flow during the growing season is largely runoff from storms. The base flow increases markedly during the fall and winter when transpiration ceases. Transpiration does not occur from the water table underlying the upland areas of the county because of the greater depth of the water table. Soil mosture lost by transpiration on the uplands, however, must be replaced before any water can infiltrate downward to the water table.

Where the water table is within a few feet of the land surface, ground water may evaporate from the capillary fringe overlying the zone of saturation, or, if the water table is within a few inches of the land surface, water may evaporate directly from the zone of saturation. The evaporation of water from the ground-water reservoir is restricted to the alluvial valleys, and the amount is probably small compared to other ground-water discharge.

Wells

The effect of the pumping of wells upon an aquifer depends upon the extent and permeability of the aquifer as well as upon the quantity of water pumped. Withdrawal of ground water from wells in Wallace County is increasing. In 1960 there were 96 irrigation plants in the county using 16,234 acre-feet of water to irrigate 8,192 acres (as reported to the Division of Water Resources of the Kansas State Board of Agriculture). Withdrawal of ground water for domestic and stock supplies is small compared to withdrawal for irrigation. Sharon Springs and Wallace are the only towns in the county that derive municipal supplies from ground water.

Subsurface Outflow

Ground-water contours on Plate 1 show a subsurface outflow of ground water in the southeastern part of the county, where the movement is southeastward. A maximum of about 7,000 acre-feet of ground water per year leaves Wallace County by subsurface outflow. The amount of outflow in the alluvial valleys is considered negligible because of their relatively small areal extent.

Recovery of Ground Water

When water is pumped from a well, the water level becomes lower inside the well than outside, and water therefore moves toward the well. The water table or piezometric surface in the surrounding part of the aquifer is lowered, and a depression in the form of an inverted cone develops in the water table (Fig. 11). The lateral extent of this cone of depression is called the area of influence, and the vertical distance that the water level is lowered is called the drawdown. The size and shape of the cone of depression are determined by

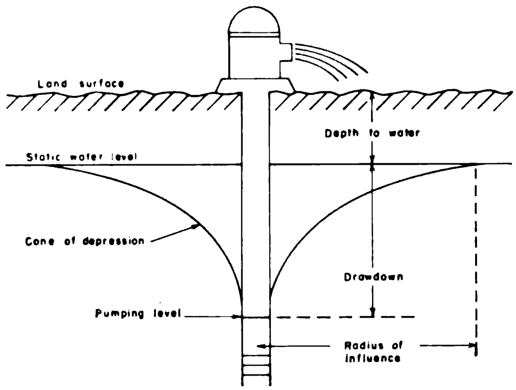

FIGURE 11.—Diagrammatic section of a well that is being pumped, showing its drawdown, cone of depression, and radius of influence.

the transmissibility of the aquifer, rate of pumping, length of pumping time, and extent to which the well penetrates the aquifer. The cone of depression around a pumped well will increase in depth and area until it intercepts enough recharge or reduces natural discharge sufficient to supply the demand of the well. After pumping stops, the water table or piezometric surface surrounding the well will in time return to its original position.

If wells are closely spaced, as in a well field or an intensively irrigated area, the cone of depression developed by each well may overlap those of adjacent wells, causing mutual interference (Fig. 12). When mutual interference occurs, the drawdown at any point within the radius of influence of the wells is the sum of the drawdowns caused by the individual wells at that point. When wells interfere, the pumping lift in each well is increased and the discharge is decreased. Also, to maintain a constant discharge from a pumped well would increase the drawdown and extend the cone of depression. In areas where many wells are pumping from the same aquifer, the large cone of depression resulting from mutual interference may not have sufficient time to recover between pumping periods and the water level may decline persistently.

UTILIZATION OF GROUND WATER

Data on 294 wells in Wallace County were obtained during the course of this investigation. Only part of the domestic and stock wells were visited, but records were made of all municipal and irrigation wells in the county at the time of this investigation (Table 11). The principal

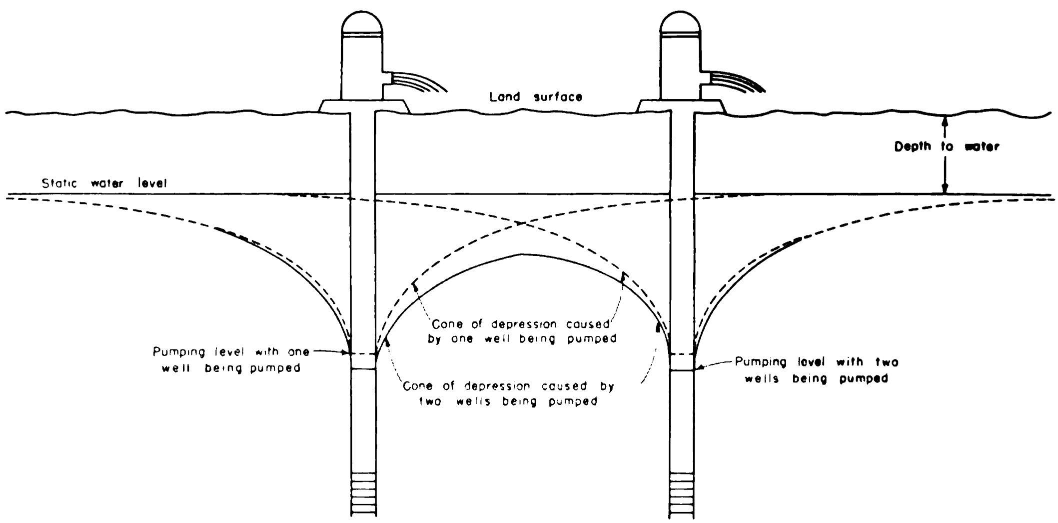

FIGURE 12.—Diagrammatic section of two closely spaced wells being pumped, showing mutual interference between wells and the resulting cone of depression.

uses of ground water in the county are listed below.

Domestic and Stock Supplies

One of the chief uses of ground water in Wallace County is to supply domestic and stock needs, although the amount so used is small as compared to the amount pumped for irrigation. Nearly all domestic and stock supplies in the rural part of Wallace County are obtained from wells, but in parts of the county where ground water is difficult to obtain, some stock supplies are provided by ponds created by dams across small watercourses. Most domestic and stock wells in the county are drilled wells in which standard-size casing has been set and which are equipped with displacement-type pumps in which the cylinder is below the water level. Most pumps are operated by windmills; others are operated by electric or gasoline motors, or by hand.

Municipal Supplies

At the time of this investigation only the communities of Sharon Springs and Wallace maintained municipal water-supply systems. Pertinent remarks regarding individual wells and details of well construction are given in Table 11.

SHARON SPRINGS.—Sharon Springs (population about 1,000) obtains its water supply from three drilled wells in Eagle Tail Creek valley in the southwestern part of town. The wells are equipped with electrically driven turbine pumps. Storage is provided by an elevated 50,000-gallon steel tank. An average daily use of about 100,000 gallons of water was reported by city officials.

WALLACE.—Wallace (population about 100) obtains its water supply from well 13-39-25daa drilled into alluvium of South Smoky Hill Valley. An electrically driven turbine pumps water directly into the mains, the excess going into an elevated 50,000-gallon steel tank. An average daily use of about 15,000 gallons of water was reported by city officials.

Irrigation Supplies

There were 96 irrigation plants in Wallace County in the fall of 1960. Nearly all were single wells, but a few plants in the valleys were pumping from batteries of two or more wells. Most of the irrigation wells are in the southern part of the county, chiefly in the lower two tiers of townships, where approximately 3 million acre-feet of water is in storage in the Ogallala Formation. Yields of irrigation wells range to more than 2,000 gpm. Figure 13 is a map of Wallace County showing the extent of land covered by water rights or applications for rights as of July 1961, according to records of the Division of Water Resources of the Kansas State Board of Agriculture. The acreage affected by these rights and applications totals 20,174 acres, of which 8,192 acres were reported to have been irrigated in 1960 by 45 appropriators. The authorized quantity of ground water appropriated totals 37,658 acre-feet, of which 16,234 acre-feet was reported to have been applied in 1960 by 49 appropriators. The acreages and quantities of water given above do not include data from surface-water irrigators, of whom there are several, mostly along Rose Creek.

HYDROLOGIC PROPERTIES OF WATER-BEARING MATERIALS

The quantity of ground water that an aquifer will yield to wells depends upon the hydrologic properties of the material forming the aquifer. The hydrologic properties of greatest significance are its ability to transmit and to store water, as measured by its coefficients of transmissibility and storage. Controlled aquifer tests in the field provide the data required to compute these coefficients.

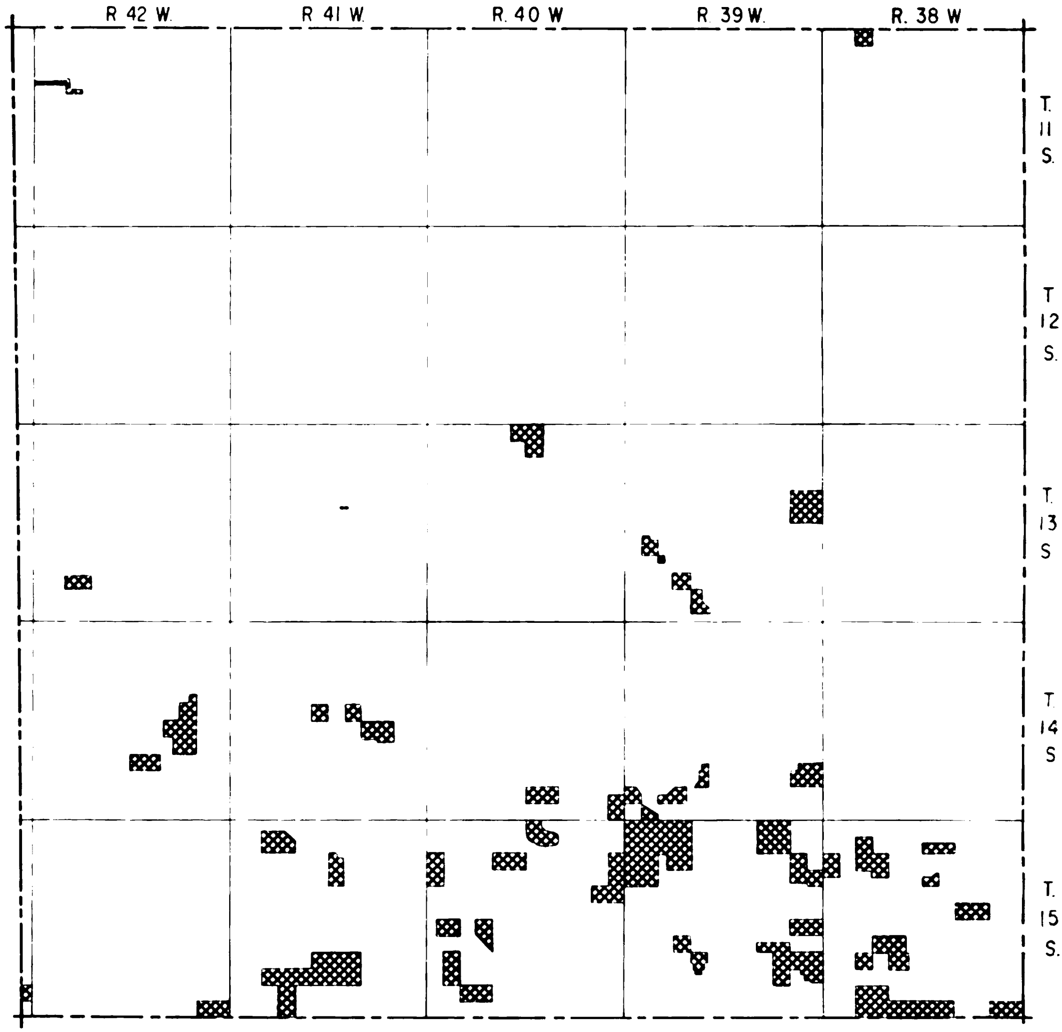

FIGURE 13.—Map showing areas in Wallace County covered by water rights to ground water.

The coefficient of transmissibility (T) may be defined as the rate of flow of water, in gallons per day, through a vertical strip 1 foot wide and extending the full height of the saturated thickness of the aquifer, under a hydraulic gradient of 1 foot per foot, at the prevailing temperature.

The coefficient of storage (S) may be defined as the change in the stored volume of water per unit surface area of the aquifer per unit change in the component of head normal to that surface.

The field coefficient of permeability (P) can be computed by dividing the coefficient of transmissibility by the aquifer thickness (m). The field coefficient of permeability of an aquifer may be defined as the rate of flow of water, in gallons per day, through a square foot of its cross section, under a hydraulic gradient of 1 foot per foot, at the prevailing temperature.

Determinations of Transmissibility and Permeability

Aquifer tests were made using two wells

deriving water from the Ogallala Formation to determine the coefficients of transmissibility and permeability of the Ogallala in Wallace County. Values of transmissibility were computed from the test data by the methods generally referred to as the Thiem method, the Theis nonequilibrium method, and the Jacob modified nonequilibrium method.

Thiem Method

The Thiem method of determining the coefficients of transmissibility and storage of a water-bearing material is based on the rate of discharge of a pumped well and the drawdown in two or more observation wells at different known distances from the pumped well. The Thiem equation (Wenzel, 1942, p. 81), expressed in terms of transmissibility instead of permeability, is

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

in which T is the coefficient of transmissibility, in gallons per day per foot
Q is the rate of discharge of the pumped well, in gallons per minute
r_1 and r_2 are distances of two observation wells from the pumped well, in any unit
s_1 and s_2 are drawdowns of water level at distances r_1 and r_2, in feet

To apply the Thiem equation, some convenient elapsed pumping time, t, is selected after the water levels in the observation wells reach a steady rate of decline. When the values of drawdowns, s, are plotted on the arithmetic scale of semilogarithmic paper and the values of distances, r, are plotted on the logarithmic scale, the data should form a straight line. From this line the change in drawdown per log cycle, Δs, is determined, and the Thiem equation is reduced to

$$T = \frac{528Q}{\Delta s}$$

Using this same line and extrapolating it to the zero-drawdown axis, the storage coefficient may be calculated by the following equation:

$$S = \frac{0.3Tt}{r_0^2}$$

where S is the coefficient of storage
T is as previously defined
t is the time since pumping started, in days
r_0 is the distance intercept on the zero-drawdown axis, in feet

The Thiem method of determining the coefficient of transmissibility is based on the theory that the aquifer is homogeneous throughout, but because aquifers are not perfectly homogeneous a probable error in the value of T is introduced. Some aquifers are so heterogeneous that the drawdown rate in aquifer tests is slowed in one or more of the observation wells and perhaps accelerated in others, thus giving a false slope to the line used in determining a value for Δs.

Theis Nonequilibrium Method

The Theis nonequilibrium method of determining the coefficients of transmissibility and storage is based on the rate of discharge of a pumped well and the rate of change of drawdown in one or more observation wells. The Theis nonequilibrium equation is

$$s = \frac{114.6Q}{T} \int_u^{\infty} \frac{e^{-u}}{u} du$$

$$\text{where } u = \frac{1.87 r^2 S}{Tt}$$

s is the drawdown in an observation well, in feet
r is the distance from pumped well to observation well, in feet
Q is the rate of discharge of the pumped well, in gallons per minute
T is the coefficient of transmissibility, in gallons per day per foot
S is the coefficient of storage expressed as a decimal fraction
t is the time since pumping began, in days

The integral expression is written symbolically as W(u) and is read as the "well function of u." The integral expression cannot be integrated directly, but its value is given by the series

$$W(u) = -0.5772 - \log_e u + u - \frac{u^2}{2.2!} + \frac{u^3}{3.3!} - \frac{u^4}{4.4!} + \ldots$$

Two unknowns and the nature of the integral expression make an exact analytical solution impossible, but Theis devised a graphical method of superposition that makes it possible to obtain a simple solution of the complex equation.

In this method a type curve is plotted on logarithmic paper with W(u) plotted along the vertical axis and $\frac{1}{u}$ along the horizontal axis to form a type curve (Wenzel, 1942, p. 88-89). If values of s obtained in one observation well are plotted against values of t on logarithmic paper of the same scale as the type curve, the curve of the observed data will conform to a part of the type curve. The data curve is superposed on the type curve, the axes of the two curves being held parallel and in a position that best fits the data curve to the type curve. The selection of a match point common to both curves provides the data needed to solve the Theis equation, which in simple form reduces to

$$T = \frac{114.6\, Q\, W(u)}{s}$$

and

$$S = \frac{Tt}{1.87 r^2 \left(\frac{1}{u}\right)}$$

For convenience a match point may be selected at the intersection of one of the major axes of the type curve, for example where $\frac{1}{u} = 10$, or where $\frac{1}{u} = 100$.

Jacob Modified Nonequilibrium Method

From the Theis equation, Cooper and Jacob (1946) developed the following formula:

$$T = \frac{264Q \left(\log_{10} \frac{t_2}{t_1}\right)}{s_2 - s_1}$$

where Q and T are as previously defined
t_1 and t_2 are two selected times since pumping started in any convenient units
s_1 and s_2 are the respective drawdowns, in feet, at the noted times

If the observed drawdowns for each well are plotted on the arithmetic scale and the values of t are plotted on the logarithmic scale of semilog paper, the resulting plot should form a straight line if enough time has elapsed since pumping began. If t_1 and t_2 are chosen one log cycle apart, the Jacob modified nonequilibrium equation reduces to

$$T = \frac{264Q}{\Delta s}$$

where Δs is the drawdown per log cycle.

The coefficient of storage can be determined from the same semilog plot of the observed data by the following equation:

$$S = \frac{0.3\, T t_0}{r^2}$$

where S, T, and r are as previously defined, and t_0 is the time intercept on the zero-drawdown axis, in days.

Aquifer Tests

Waugh Aquifer Test

An aquifer test was made in August 1960 using irrigation well 14-42-23dbb1, owned by E. M. Waugh. The well is 350 feet deep and yields water from the Ogallala Formation. A drillers log of the pumped well and a sample log of observation well 1W (14-42-23dbb2) are included with the logs of test holes and wells at the end of this report. Two observation wells were drilled at distances of 237 and 468 feet from the pumped well. The well was

Table 5.—Drawdown of water level in pumped well and observation wells during the Waugh aquifer test, August 1960.

Time since pumping started, minutes	Drawdown, feet		
	Pumped well	Well 1W	Well 2W
1		0.07	
4		0.46	
7		0.96	
8			0.30
9		1.24	
11		1.46	
13		1.64	0.60
15		1.81	
17		1.97	
18			0.80
19		2.09	
21		2.20	
23		2.28	
24			1.06
25	31.78	2.36	
27		2.44	
28			1.20
30	32.42	2.49	
33	32.49		
34			1.35
35		2.64	
36	32.54		
38			1.44
40		2.74	
42			1.52
45		2.83	
47	32.81		1.59
50		2.92	
52			1.62
53	33.00		
55		3.01	
57			1.75
60	33.10	3.08	
62			1.80
70		3.20	
72	33.31		1.90
80	33.44		
85		3.34	
87			2.02
90	33.52		
100		3.44	
102			2.10
106	33.64		
120	33.79	3.54	
130			2.23
140		3.63	
150			2.31
155	33.97		
160		3.71	
180		3.79	2.40
182	34.08		
210	34.15	3.87	2.49
240	34.22	3.92	2.55
270		3.98	2.60
287	34.26		
310		4.04	
315			2.65
330	34.33		
340		4.08	
345			2.69
390	34.47		
395		4.16	
398			2.75
450	34.50		
455		4.23	
457			2.82
473	34.55		
540	34.64		
545		4.29	
550			2.91
713	34.76		
720		4.50	
723			3.10
930	34.89		
940		4.70	
945			3.24

pumped at a rate of about 1,600 gpm, as measured frequently with a Hoff flow meter. Drawdown measurements in the pumped well and the two observation wells were made during the period of pumping and are given in Table 5.

The coefficients of transmissibility shown in Figure 14 were determined by the Jacob modified nonequilibrium method. The coefficients computed from data from the pumped well and observation well 1W are believed to be correct; the larger coefficient of transmissibility obtained from data from observation well 2W is believed to be too high and can probably be accounted for by insufficient time for the drawdown to attain the correct slope because of the greater distance from the pumped well. The coefficients of transmissibility, permeability, and storage shown in Figure 15 were determined by the Thiem method.

Holland aquifer test

An aquifer test was made in August 1960 using irrigation well 15-39-23cbc1 owned

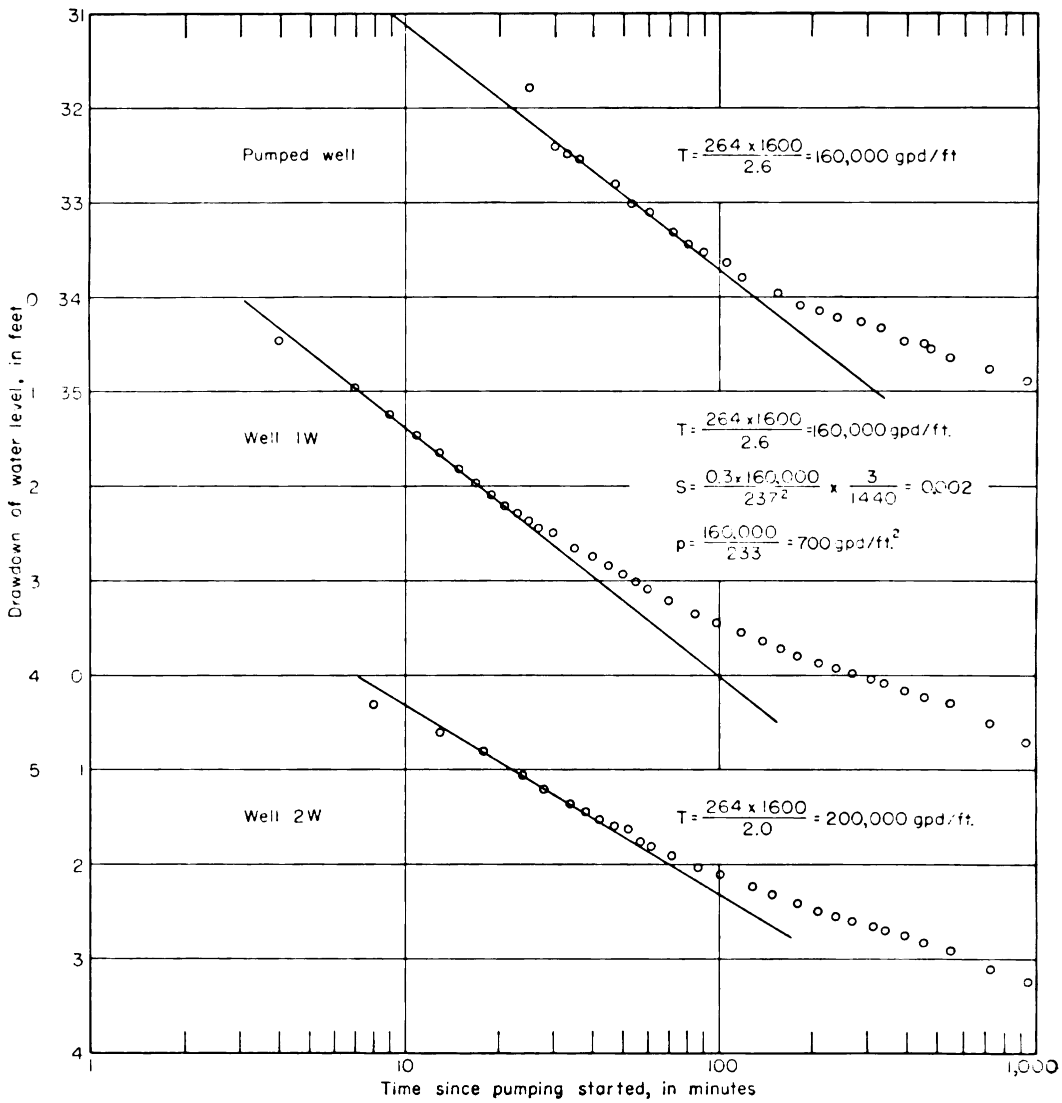

Figure 14.—Drawdown of water level measured in pumped well and observation wells during the Waugh aquifer test plotted against time since pumping started.

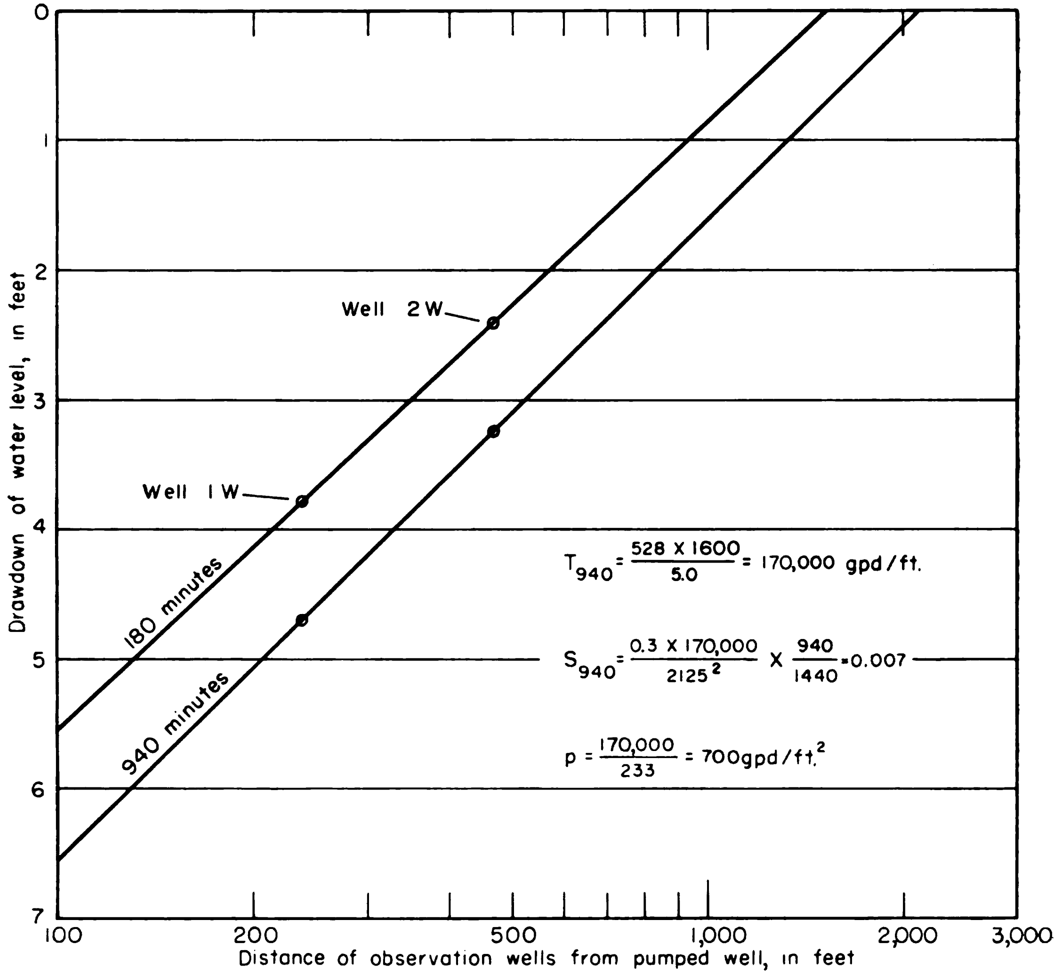

FIGURE 15.—Drawdown of water level in observation wells at 180 and 940 minutes during the Waugh aquifer test plotted against distance from pumped well.

by G. W. Holland. The well is 234 feet deep and yields water from the Ogallala Formation. A drillers log of the pumped well and a sample log of observation well 1S (15-39-23cbc2) are included in Table 11. Two observation wells were drilled at distances of 120 and 237 feet from the pumped well. The well was pumped at a rate of about 1,300 gpm, as measured frequently by a Hoff flow meter. Drawdown measurements were made in the two observation wells during the period of pumping and are given in Table 6.

The drawdown of the water level in the observation wells is plotted against time on logarithmic paper in Figure 16. The Theis type curve was applied to determine the coefficient of transmissibility. The plot of the data deviates from the type curve for the later measurements and probably indicates that vertical drainage is occurring from the confining beds, in which case T is probably correct but S is not. The coefficient of transmissibility computed from data obtained from observation well 2S is believed to be correct. Observation well 1S seemingly did not respond to the drawdown as quickly as it should have and probably was partially plugged, at least during the early part of the aquifer test. The coefficients of transmissibility, permeability, and storage shown in Figure 17 were determined by the Thiem method.

Theoretical Predictions of Drawdowns

In order to predict future drawdowns the assumptions have been made that all water pumped came from storage within the aquifer, that pumping is continuous at a rate of 1,000 gpm, and that the water-bearing material has a T of 150,000 gpd per foot and an S of 0.002. The predictions of future drawdowns are in error to the

Table 6.—Drawdown of water level in observation wells during the Holland aquifer test, August 1960.

Time since pumping started, minutes	Drawdown, feet	
	Well 1S	Well 2S
3	2.52	
5		0.29
7	3.34	
9		0.59
11	3.63	
13		0.90
15	3.80	
17		1.17
19	3.98	
21		1.44
23	3.99	
25		1.60
27	4.05	
29		1.74
31	4.09	
33		2.00
35	4.15	
37		2.14
39	4.18	
43		2.30
45	4.21	
47		2.44
50	4.26	
52		2.57
55	4.29	
57		2.69
60	4.31	
62		2.74
68	4.34	
70		2.91
75	4.37	
77		2.97
84	4.40	
88		3.09
96	4.45	
100		3.17
112	4.49	
115		3.24
134	4.54	
136		3.33
150	4.58	
153		3.36
173	4.62	
178		3.42
212	4.60	
214		3.46
242	4.66	
246		3.50
300	4.72	3.54
390	4.69	3.58
505	4.66	3.60
815	4.91	3.71
855	4.92	3.73
1200	5.01	3.77
1620	5.15	3.89
2370	5.26	3.95
2975	5.39	4.05
3810	5.50	4.10

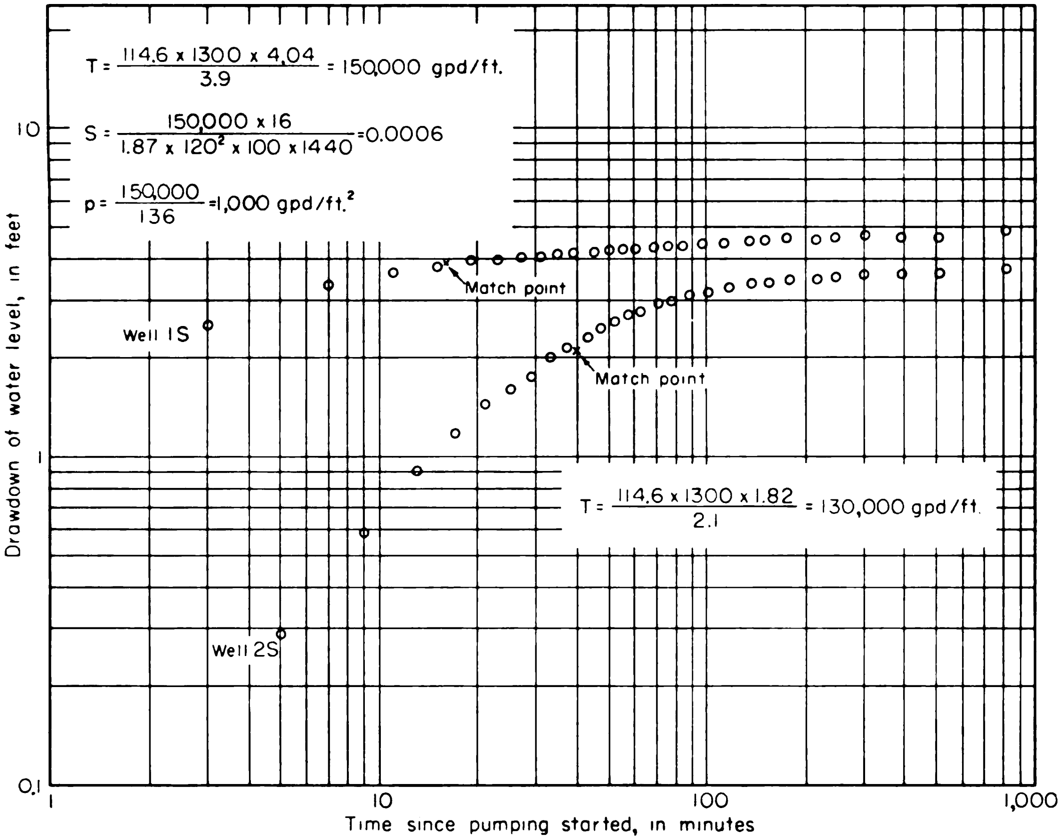

FIGURE 16.—Drawdown of water level in observation wells during the Holland aquifer test plotted against time since pumping started.

extent that these assumptions are in error, but the predictions are probably of the right order of magnitude.

Figure 18 shows, under the assumed conditions specified, the drawdown of water level at any distance from a pumped well after 1, 10, 100, 1,000, and 10,000 days. After 100 days of pumping at a rate of 1,000 gpm, the drawdown at a distance of 1,000 feet will be about 6 feet. Figure 19 shows the rate of decline caused by pumping. A well pumped at 1,000 gpm for 10 days will cause about 4 feet of decline at a distance of 1,000 feet, and after 100 days about 6 feet of decline. The data indicate that the cone of influence will spread rapidly in response to pumping. Large-yield wells can interfere with each other unless the wells are spaced at considerable distances. When wells mutually interfere, the drawdown at any one point will be the sum of the drawdowns produced by each well.

Movement of Ground Water

The quantity of ground water moving through a given cross-sectional area of water-bearing material can be calculated from the following formula:

$$Q = pAv = PIA$$

where Q = the quantity of water
p = the porosity of the material
A = the cross-sectional area
v = the velocity of the ground water
P = the coefficient of permeability, and
I = the hydraulic gradient.

The approximate rate of movement of water through the water-bearing materials

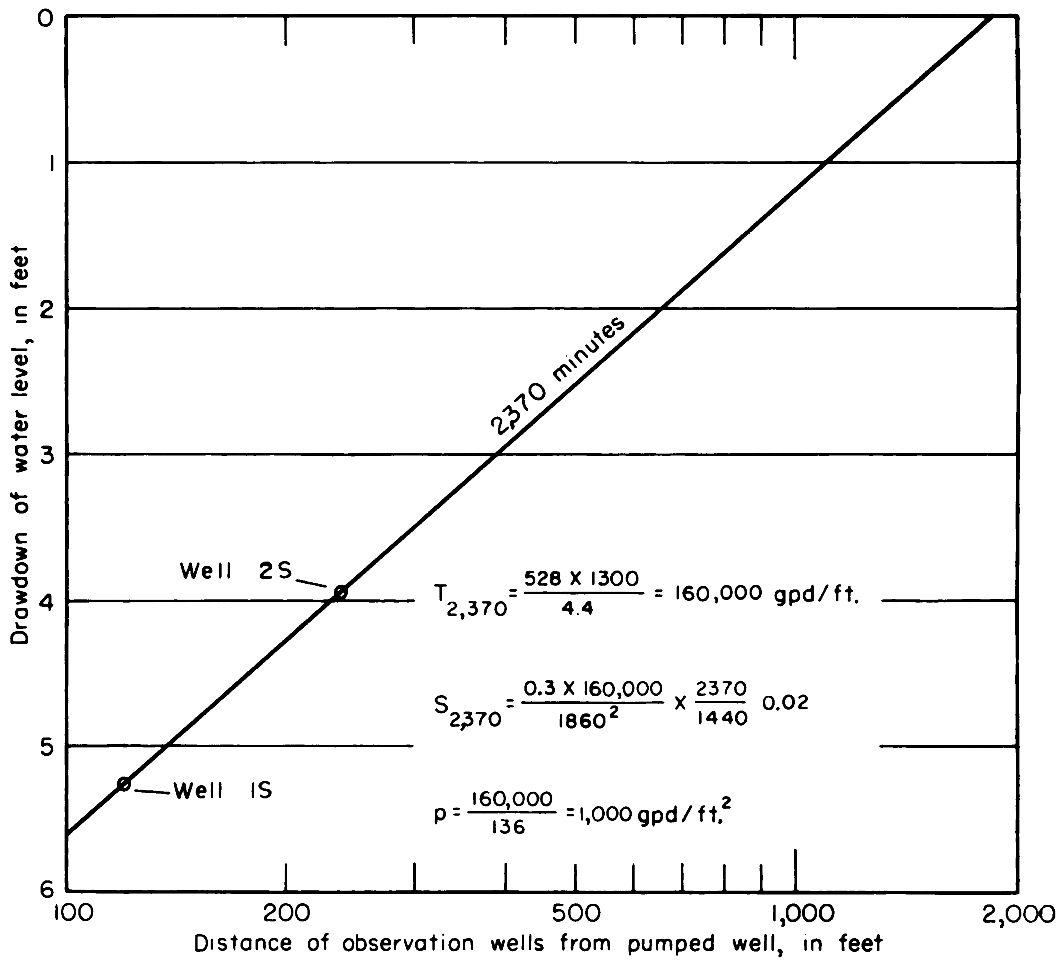

FIGURE 17.—Drawdown of water level in observation wells at 2,370 minutes during the Holland aquifer test plotted against distance from pumped well.

can be calculated by applying the above formula transposed as follows:

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

If P is expressed in gallons per day per square foot, I in feet per mile, and p in percent, then v, in feet per day, is given by the following formula:

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

The hydraulic gradient in the Ogallala Formation is approximately 12 feet per mile across the county. Aquifer tests indicate an average permeability of about 900 gpd per ft². With an assumed porosity of 30 percent, the average velocity of the ground water is calculated to be

$$v = \frac{900 \times 12}{395 \times 30} = 0.9 \text{ foot per day, or}$$

about 11 inches per day, or about 1 mile in 16 years.

QUALITY OF GROUND WATER

The chemical character of ground water in Wallace County is indicated by analyses

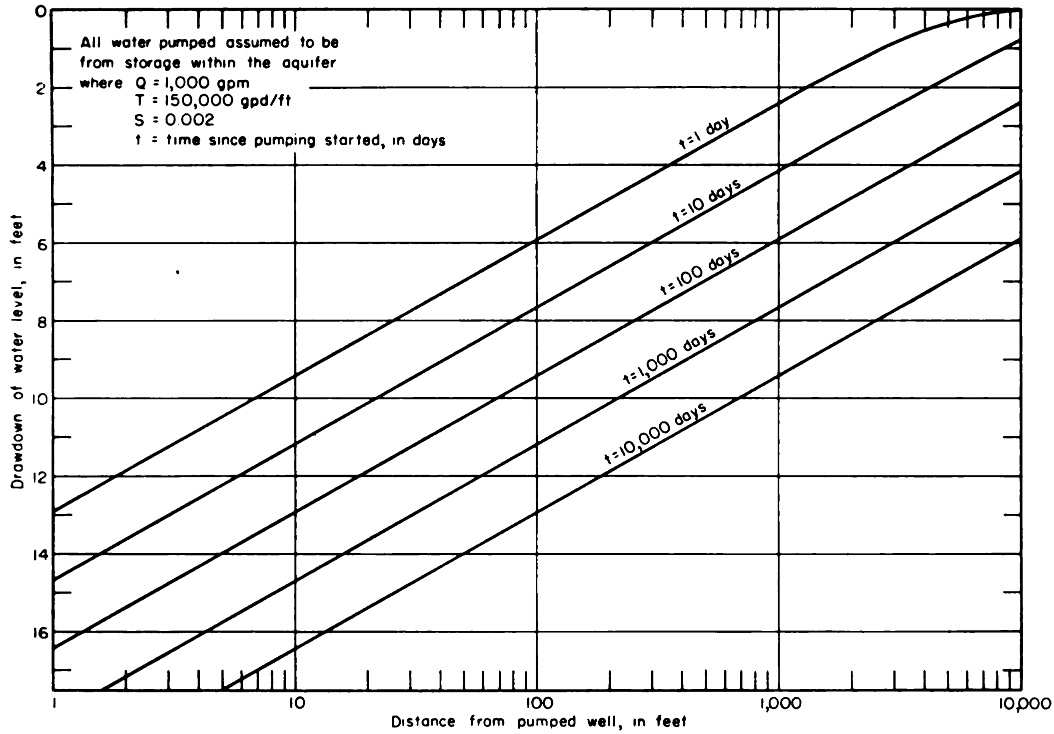

FIGURE 18.—Drawdown of water level at any distance from pumped well after pumping has begun.

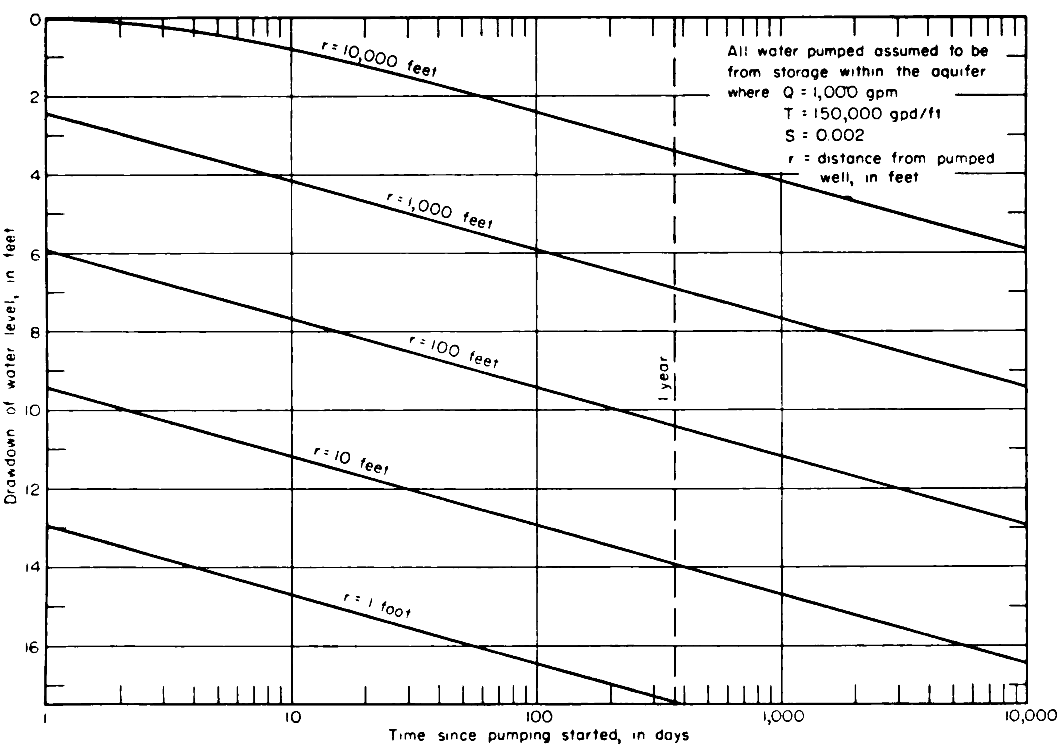

FIGURE 19.—Drawdown of water level at any time after pumping has begun.

TABLE 7.—Analyses of water from typical wells in Wallace County, Kansas. Analyses by H. A. Stoltenberg. Dissolved constituents given in parts per million.[a]

Well	Depth, feet	Geologic source	Date of collection	Temperature (°F)	Dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Hardness as $CaCO_3$ Total	Carbonate	Noncarbonate
11-38-5bbc	128.0	Alluvium and Ogallala Formation	7-31-58	57	396	25	0.03	76	17	44	342	44	16	1.0	5.3	260	260	0
11-38-18dca	81.0	Ogallala Formation	7-28-58	58	482	31	.82	107	25	22	320	84	40	.2	15	370	262	108
11-39-4cbc	65.5	do	7-28-58	58	305	27	.26	77	12	11	266	6.6	13	.2	27	242	218	24
11-39-28acc	19.5	Alluvium	7-29-58	59	425	25	.71	69	19	60	366	57	13	1.3	.8	250	250	0
11-40-1bcc	86.2	Ogallala Formation	10-31-49	58	579	33	.28	60	38	81	256	174	53	2.3	12	306	210	96
11-40-35aaa	124.5	do	8- 2-58	58	320	39	.36	44	11	49	234	36	15	1.3	9.3	155	155	0
11-41-2ccd	54.0	do	7-28-58	59	219	23	.07	44	13	13	196	10	7.0	1.0	11	164	160	4
11-42-7dad	148	do	7-28-58	58	199	21	.04	33	12	20	180	7.4	9.0	1.5	6.2	132	132	0
11-42-34abc	15.0	Colluvium	10- 5-60	58	435	21	.26	66	21	69	410	41	11	2.6	1.5	251	251	0
12-38-33bba	38.0	do	7-29-58	59	4,420	21	.17	357	144	827	231	2,760	103	1.2	84	1,480	190	1,290
12-39-2cdd	25.5	do	10- 6-60	..	567	29	.54	107	28	41	292	184	20	.6	14	382	240	142
12-40-15cdd	89.5	Ogallala Formation	7-29-58	59	287	25	.56	69	14	10	249	10	13	.2	23	230	204	26
12-41-11aad1	20.0	Alluvium	8- 2-58	58	730	28	.18	74	29	140	390	242	23	1.7	.4	304	304	0
12-42-15aaa	122.0	Ogallala Formation	7-28-58	58	484	50	.56	65	20	61	222	116	36	1.2	26	244	182	62
13-38-11bba	41.5	Colluvium	7-29-58	59	839	23	.71	84	27	154	210	358	63	.8	26	320	172	148
13-39-19dca	51.0	Alluvium	8- 4-58	58	374	26	.03	69	14	41	268	72	12	.7	7.1	230	220	10
13-39-25adb	20	do	9-20-51	57	...	..	...	..	..	..	...	1,270	48	..	...	...	...	..
13-40-7aac	76.0	do	7-31-58	58	316	24	.06	54	17	33	249	51	11	.9	2.3	204	204	0
13-42-24cca	16.0	do	9-20-51	58	324	31	1.2	57	12	33	227	19	13	.7	42	192	186	6
13-43-36abb	270.0	Ogallala Formation	8- 4-58	58	193	22	.06	34	9.5	20	173	6.2	7.0	.7	8.9	124	124	0
14-39-17dad	.....	Rose Creek	10-12-60	..	244	23	.35	47	12	22	217	22	6.0	1.2	3.8	166	166	0
14-39-25ccb	182.0	Ogallala Formation	7-31-58	58	247	25	.04	42	10	29	193	26	8.0	1.8	10	146	146	0
14-40-36dcc	226.0	do	7-31-58	59	224	24	.03	33	12	27	180	21	8.0	1.2	8.9	132	132	0
14-41-15dbb	217	do	8- 4-58	58	206	22	.05	34	13	19	177	15	6.0	1.0	9.3	138	138	0
14-42-23bca	180	do	9-20-51	58	230	31	.03	35	11	27	170	28	5.5	1.0	6.6	133	133	0
15-37-30cbb	73.0	do	9-21-51	56	258	27	2.3	37	14	33	204	29	5.5	1.8	8.8	150	150	0
15-38-30ccb	232.0	do	10-10-60	58	258	26	.04	40	17	23	198	36	8	1.2	8.9	170	162	8
15-38-34cbc	214.0	do	7-31-58	58	246	25	.02	36	26	10	195	31	11	1.3	10	197	160	37
15-39-1ccc	180.0	do	10-12-60	58	241	23	.06	36	16	24	190	28	7	1.7	11	156	156	0
15-39-11bbb	130	do	9-21-51	56	...	..	...	..	..	..	...	32	5.5	...	..	...	...	..
15-39-20dab	228.0	do	7-30-58	58	246	24	.17	38	16	23	188	33	8.0	1.0	11	161	154	7
15-39-25bbb	227.0	do	7-30-58	58	258	22	.04	39	14	31	195	33	11	1.3	11	155	155	0
15-40-19acb	265.0	do	8- 4-58	58	247	25	.02	40	17	21	205	24	10	1.1	8.0	170	168	2
15-40-27dcc	88.0	do	10-11-60	58	253	29	.16	47	17	12	190	13	15	.7	25	187	156	31
15-41-5acb	235	do	8- 2-58	..	249	24	.03	38	15	26	193	30	9.0	1.1	11	156	156	0
15-41-32aca	254.0	do	8- 1-58	60	243	24	.02	31	17	29	198	25	8.0	1.1	10	148	148	0
15-43-12dda	218.0	do	9-20-51	..	304	17	1.4	33	16	50	202	59	9.0	1.4	13	149	149	0

[a] One part per million is equivalent to 1 pound of substance per million pounds of water or 8.33 pounds per million gallons of water.

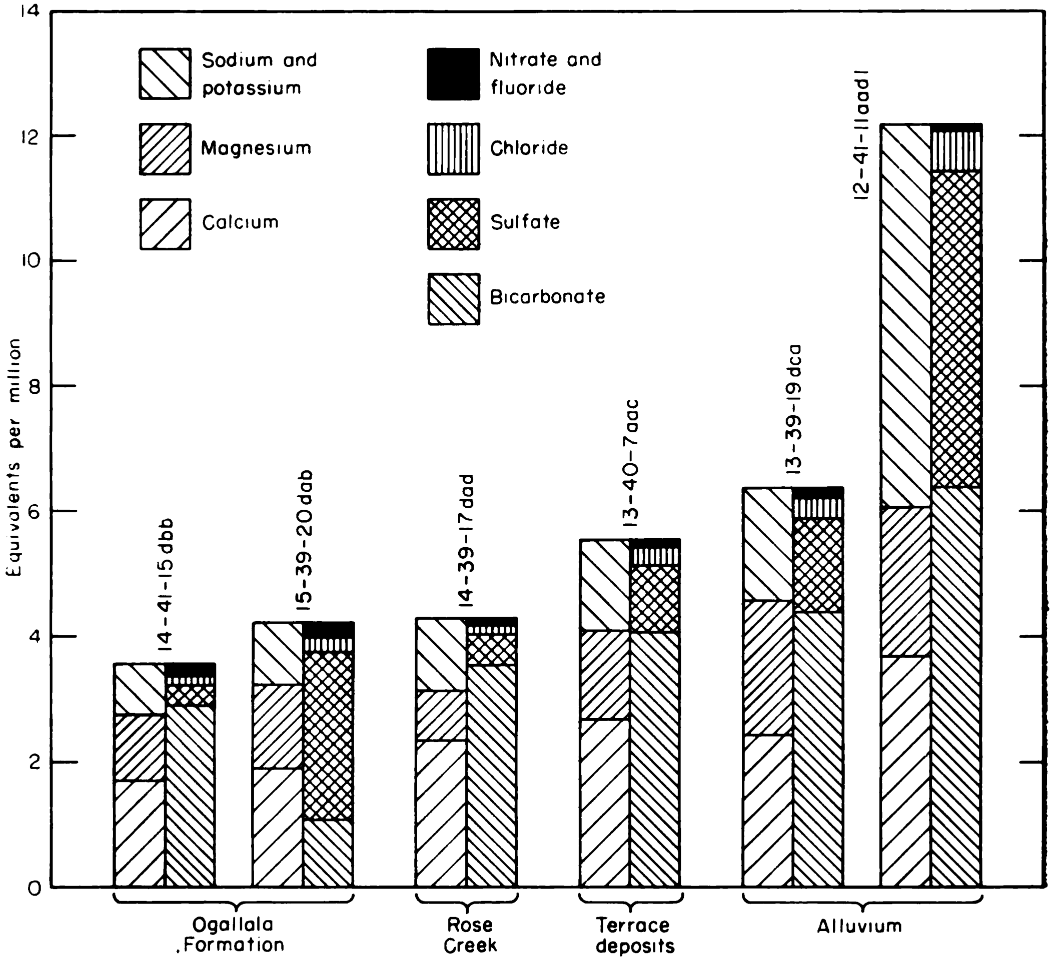

FIGURE 20.—Graphic representation of chemical constituents of samples of water from Wallace County.

of samples from wells deriving water from the principal aquifers (Table 7). The analyses of water were made by Howard A. Stoltenberg, chemist, in the Sanitary Engineering Laboratory of the Kansas State Board of Health. The results of the analyses are given in parts per million. Factors for converting parts per million of mineral constituents to equivalents per million are given in Table 8. The analyses show only the dissolved mineral constituents and do not indicate the sanitary condition of the water. Representative analyses of ground water from the principal aquifers are shown in Figure 20.

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 U. S. Geological Survey and the State Geological Survey of Kansas. (See Table 7 for chemical analyses of water from Wallace County.)

DISSOLVED SOLIDS.—The residue that is left after a sample of water has evaporated consists mainly of the dissolved minerals in the original sample, but may also include some organic material and water of crystallization. Water containing less than 500 ppm (parts per million) of dissolved solids generally is satisfactory for domestic and many industrial purposes. Water containing more than 1,000 ppm of dissolved solids is likely to contain enough of certain constituents to cause noticeable taste or to make the water unsuitable in other respects.

The dissolved solids in samples of water collected in Wallace County ranged from 193 to 4,420 ppm. Most of the samples were relatively low in dissolved solids; more than half contained less than 300 ppm. Only 5 samples contained more than 500 ppm, and only 1 sample contained more than 1,000 ppm.

HARDNESS.—Hardness of water is recognized most commonly by the amount of soap needed to produce a lather or suds and by an insoluble scum that forms during washing processes. Calcium and magnesium cause almost all the hardness of water and may be deposited as constituents of scale in heat-exchange equipment.

The hardness of water is of two types—carbonate hardness and noncarbonate hardness. Carbonate hardness includes that portion of the calcium and magnesium that would combine with the bicarbonate and the small amount of carbonate that are present. Carbonate hardness can be virtually removed by boiling the water, which causes the magnesium and calcium to precipitate. Noncarbonate hardness is caused by that portion of calcium and magnesium that would combine with the sulfate, chloride, and nitrate ions that are present, plus the slight hardness of other minor constituents. Noncarbonate hardness cannot be removed by boiling.

Water that has a hardness of less than 50 ppm is considered soft. A hardness of 50 to 150 ppm is satisfactory for most purposes, but the amount of soap needed increases with hardness, and water in the upper part of this range will cause considerable scale in steam boilers. Hardness of more than 150 ppm is obviously noticeable, and water that has a hardness of 200 or 300 ppm is considered undesirable for household purposes until it is treated by a softening process. Where municipal water supplies are softened, the hardness is generally reduced to about 100 ppm.

TABLE 8.—Factors for converting parts per million to equivalents per million.

Mineral constituents	Chemical symbol	Factor
Calcium	Ca^{++}	0.04990
Magnesium	Mg^{++}	.08220
Sodium	Na^{+}	.04350
Potassium	K^{+}	.02558
Carbonate	CO_3^{--}	.03333
Bicarbonate	HCO_3^{-}	.01639
Sulfate	SO_4^{--}	.02082
Chloride	Cl^{-}	.02820
Fluoride	F^{-}	.05263
Nitrate	NO_3^{-}	.01613

Hardness of the water samples collected in Wallace County ranged from 124 to more than 1,000 ppm. Only 9 samples had a hardness of 150 ppm or less. Six samples had a hardness of more than 300 ppm and 1 sample had 1,480 ppm.

NITRATE.—The nitrate content of natural water may vary greatly and frequently may seem unrelated to any geologic formation. Although some nitrate may be derived from nitrate-bearing rocks and minerals in the water-bearing formation, strong concentrations of nitrate probably are from other sources. Nitrates are dissolved readily from soils that contain nitrate concentrations derived from plants, nitrate fertilizer, animal waste, or nitrifying action. High nitrate concentrations in water from a well may be due to direct flow of surface water into the aquifer. Because privies, cesspools, and barnyards are sources of organic nitrogen, a large amount of nitrate in well water may indicate harmful bacteria or pollution.

In the last two decades investigations of the effects of nitrate have shown that too much nitrate in water may cause cyanosis in infants (blue babies) when it is used for drinking or in the preparation of the formula for feeding. The Kansas State Board of Health, as well as the U. S. Public Health Service, regards 45 ppm as the safe limit of nitrate (as NO_3^-). This amount of nitrate is equivalent to 10 ppm of nitrogen. Water containing as much as 90 ppm of nitrate generally is considered very dangerous to infants, and water containing as much as 150 ppm may cause severe cyanosis. Moderate nitrate concentrations are seemingly not harmful to older children or adults. Nitrate cannot be removed from water by boiling.

The nitrate content of samples of water collected in Wallace County ranged from less than 1 to 84 ppm (Table 7). Only one sample contained more than the 45 ppm limit set by the State Board of Health.

FLUORIDE.—Fluoride generally is present only in small amounts in ground water. However, the fluoride content of drinking water should be known, because if children drink water containing too much fluoride while their permanent teeth are forming, it may cause mottling of the tooth enamel. If the fluoride content is as much as 4 ppm, about 90 percent of the children using the water may have mottled tooth enamel (Dean, 1936). Although too much fluoride has a detrimental effect, a smaller amount in drinking water, about 1 ppm, lessens the incidence of tooth decay (Dean and others, 1941). The U. S. Public Health Service (1961) recommended standards for the content of mineral constituents in drinking water that is used on interstate carriers. The recommended maximum content of fluoride is 1.5 ppm.

Although the fluoride content of samples of water collected in Wallace County ranged from 0.2 to 2.6 ppm, most samples contained less than 1.5 ppm. (Table 7).

CHLORIDE.—Chloride is quite abundant in nature, and many rocks contain small to large amounts of chloride salts which may be dissolved by ground water. Chloride has little effect on the suitability of water for ordinary use unless present in such concentrations as to make the water unpotable or corrosive. Water that contains less than 150 ppm of chloride is satisfactory for most purposes. Water containing more than 250 ppm generally is objectionable for municipal supplies, and water containing more than 350 ppm is objectionable for most irrigation or industrial uses; water containing as much as 500 ppm has a disagreeable taste. However, animals can drink water with much greater chloride concentration; the upper limit in water consumed by cattle is believed to be as much as 4,000 to 5,000 ppm.

Most water samples collected in Wallace County were low in chloride content, which ranged from only 5.5 to 103 ppm. All but 3 samples contained less than 50 ppm.

IRON.—Iron and manganese in quantities that exceed a few tenths of a part per million are undesirable, as they stain fabrics and plumbing fixtures and produce an objectionable coloration in the water. The limit generally specified is 0.3 ppm. Water in the ground may contain considerable iron in the ferrous state, but upon exposure to air most of the iron is oxidized and precipitated as reddish-brown ferric hydroxide. Iron can be removed from most water by aeration and filtration, but some water requires additional treatment. Drinking-water standards of the U. S. Public Health Service (1961) recommend that the iron content should not exceed 0.3 ppm and the manganese 0.05 ppm.

The iron content of water samples collected in Wallace County ranged from 0.2 to 2.3 ppm; eleven out of 35 samples contained more than 0.3 ppm.

SULFATE—Sulfate (SO_4^{--}) in ground water is derived principally from gypsum or anhydrite (calcium sulfate) and from the oxidation of pyrite (iron disulfide). Magnesium sulfate (Epsom salt) and sodium sulfate (Glauber's salt), if present in sufficient quantities, will impart a bitter taste to the water, and the water may act as a laxative for people not accustomed to drinking it. More than 250 ppm of sulfate in drinking water generally is undesirable (U. S. Public Health Service, 1961). Most water samples collected in Wallace County were low in sulfate; only four samples exceeded 250 ppm, two of which exceeded 1,000 ppm.

SILICA.—Silicon combined with oxygen in the form of SiO_2 is called silica. Silica is a mineral constituent in most ground water. Except for the scale it may form, silica has little effect on the usefulness of water for most purposes. Silica may be deposited as scale with other incrustants, generally in the form of calcium or magnesium silicate. The silica content of water samples collected in Wallace County ranged from 17 to 50 ppm.

BICARBONATE.—Bicarbonate, the predominant anion in ground water in Wallace County, and carbonate cause alkalinity of ground water. The concentration of bicarbonate in samples of water from wells in Wallace County ranged from 170 to 410 ppm.

SODIUM.—The sodium content of water to be used for irrigation is important because a large percentage (equivalents per million of sodium divided by equivalents per million of sodium, potassium, calcium, and magnesium, expressed as a percentage) is undesirable. The effect of sodium in irrigation water is discussed on the following pages.

Suitability of Water for Irrigation

This discussion of the suitability of water for irrigation is based on Agriculture Handbook 60, U. S. Department of Agriculture (U. S. Salinity Laboratory Staff, 1954).

In areas of sufficient rainfall and ideal soil conditions, soluble salts in the soil or salts added to the soil with water are carried downward by percolation and ultimately reach the water table. Soil that was originally nonsaline and nonalkali may become unproductive if an excess of soluble salts or exchangeable sodium is allowed to accumulate as a result of improper irrigation and soil management. If the amount of water applied to the soil is not more than is needed by plants, water will not percolate downward below the root zone, and mineral matter will accumulate at that point. Likewise, impermeable soil zones near the surface can retard the downward movement of water and cause waterlogging of the soil and deposition of salts.

The characteristics that seem to be most important in determining the suitability of irrigation water are the dissolved-solids content and the concentration of sodium ions. For diagnosis and classification, the dissolved-solids content of irrigation water can be estimated from specific conductance, which is a measure of the capacity of the inorganic salts in solution to conduct an electrical current. The specific conductance can be measured accurately in the laboratory, or it can be approximated by multiplying the total equivalents per million of cations (calcium, magnesium, sodium, and potassium) by 100 or by dividing the dissolved-solids content in parts per million by 0.64.

Salt-sensitive crops such as strawberries, green beans, and red clover may be affected adversely by irrigation water having a specific conductance exceeding 250 micromhos per centimeter, but water having a specific conductance below 750 micromhos per centimeter is generally satisfactory for irrigation, insofar as salt content is concerned. Water in the range of 750 to 2,250 micro-

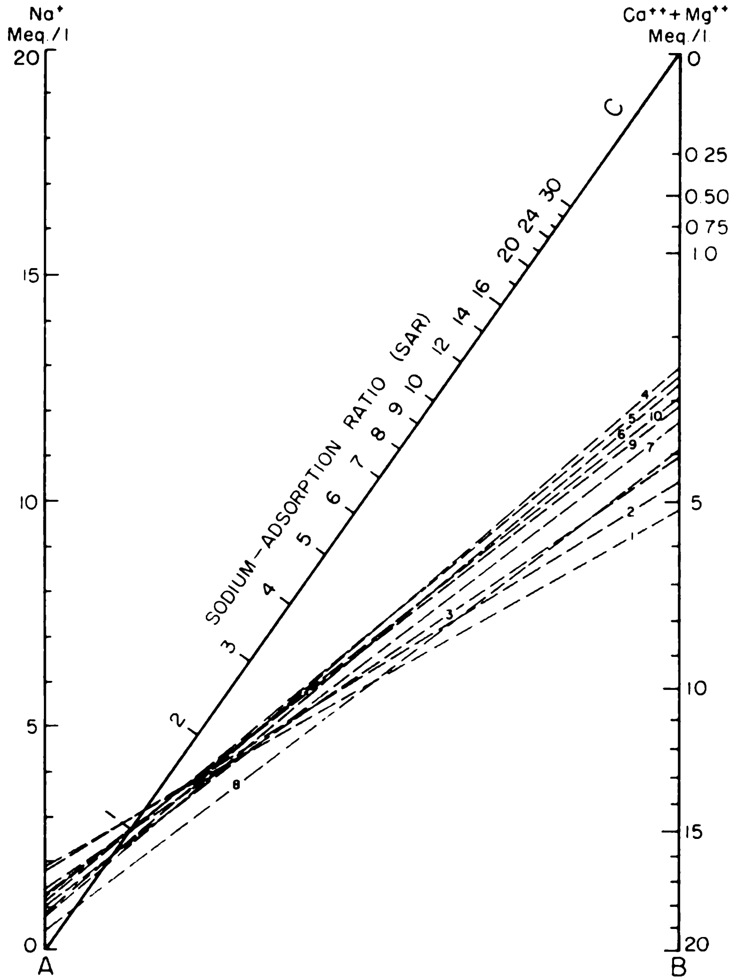

Figure 21.—Nomogram for determining the sodium-adsorption ratio of water.

mhos per centimeter is widely used, and satisfactory crop growth is obtained under good management and favorable drainage conditions, but saline conditions will develop if leaching and drainage are inadequate. Use of water having a conductivity of more than 2,250 micromhos per centimeter is the exception, and few cases can be cited where such water has been used successfully.

The sodium-adsorption ratio may be determined by the formula

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

where the ionic concentrations are expressed in equivalents per million. It may be determined also by use of the nomogram shown in Figure 21. In using the nomogram to determine the sodium-adsorption ratio of a water sample, the concentration of sodium expressed in equivalents per million is plotted on the left scale (A), and

TABLE 9.—Sodium-adsorption ratios (SAR), conductivities, sodium content, and calcium plus magnesium content of water samples from selected wells.

Sample number in Figures 21 and 22	Well	Na (equivalents per million)	Ca + Mg (equivalents per million)	SAR	Conductivity (micromhos per centimeter at 25°C)
1	11-38-5bbc	1.92	5.19	1.15	690
2	13-39-19dca	1.80	4.59	1.15	630
3	13-40-7aac	1.45	4.09	1.00	550
4	13-43-36abb	.87	2.48	.80	330
5	14-40-36dcc	1.17	2.64	1.00	380
6	14-41-15dbb	.81	2.77	.70	360
7	15-38-30ccb	1.02	3.40	.80	440
8	15-38-34cbc	.44	3.94	.35	430
9	15-39-25bbb	1.35	3.10	1.00	430
10	15-41-32aca	1.26	2.95	1.00	420

the concentration of calcium plus magnesium expressed in equivalents per million is plotted on the right scale (B). (In this report the concentrations of sodium and potassium are given together as sodium, but the amount of potassium is considered negligible.) A line connecting these two points intersects the sodium-adsorption-ratio scale (C) at the sodium-adsorption ratio of the water. Table 9 gives the wells and index numbers of samples for which analyses are plotted in Figures 21 and 22; also given are sodium-adsorption ratios, approximate electrical conductivities, and values for sodium and for calcium plus magnesium.

When the sodium-adsorption ratio and the electrical conductivity of a water are known, the suitability of the water for irrigation can be determined graphically by plotting these values on the diagram shown in Figure 22. Low-sodium water (S1) can be used for irrigation on almost all soils with little danger that harmful levels of exchangeable sodium will develop. Medium-sodium water (S2) may be used safely on coarse-textured or organic soils having good permeability, but S2 water will present an appreciable sodium hazard in certain fine-textured soils, especially under poor leaching conditions. High-sodium water (S3) may produce harmful levels of exchangeable sodium in most soils and will require special soil management such as good drainage, leaching, and additions of organic matter. Very high-sodium water (S4) generally is unsatisfactory for irrigation unless special action is taken, such as addition of gypsum to the soil.

Low-salinity water (C1) can be used for irrigation of most crops on most soils with little likelihood that soil salinity will develop. Medium-salinity water (C2) can be used if a moderate amount of leaching occurs. Crops that tolerate moderate amounts of salt, such as potatoes, corn, wheat, oats, and alfalfa, can be irrigated with C2 water without special practices. High-salinity water (C3) cannot be used on soils having restricted drainage. Very high-salinity water (C4) can be used only on certain crops and then only if special practices are followed.

Ten representative chemical analyses of water samples from irrigation systems were selected for determining the suitability of water in Wallace County for irrigation (Table 9). Specific conductance ranged from 330 to 690 micromhos. In Figure 22, all the water samples were classified as low-sodium (S1) and medium-salinity (C2) water.

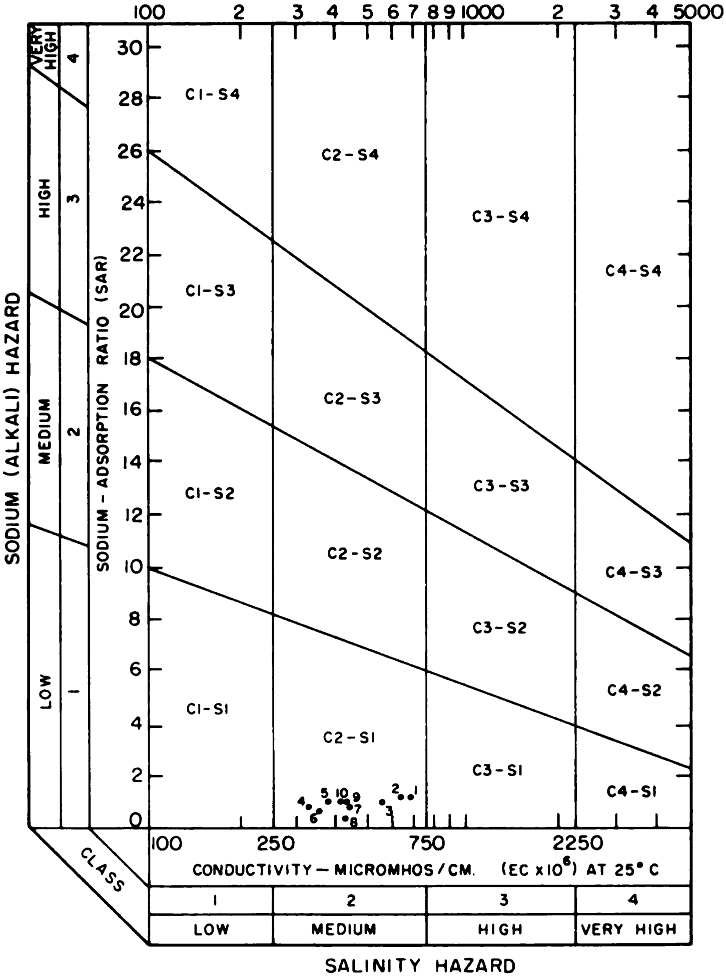

FIGURE 22.—Classification of water being used for irrigation in Wallace County.

SANITARY CONSIDERATIONS

The analyses of water in Table 7 give only the dissolved-solids content of the water and do not indicate the sanitary quality of the water, although a large amount of certain mineral constituents such as nitrate or chloride may indicate pollution. Water containing mineral matter that imparts an objectionable taste or odor may be free from harmful bacteria and safe for drinking. Conversely, water clear and pleasant to the taste may contain harmful bacteria. Great care should be taken to protect domestic and public water supplies from pollution. To guard against contamination, a well must be properly sealed to keep out dust, insects, vermin, debris, and surface water. Wells should not be placed where barnyards, privies, or cesspools are possible sources of pollution.

GEOLOGIC FORMATIONS IN RELATION TO GROUND WATER

Cretaceous System—Upper Cretaceous Series

Niobrara Chalk

The Niobrara Chalk consists chiefly of about 700 feet of alternating beds of light-gray chalk, chalky limestone, and chalky shale. The lower 50 to 60 feet of the Niobrara is massive-bedded chalk and chalky limestone called the Fort Hays Limestone Member. Most of the Niobrara consists chiefly of thin-bedded chalk and chalky shale called the Smoky Hill Chalk Member, upper member of the Niobrara Chalk.

The Niobrara was named by Meek and Hayden in 1862 from exposures of calcareous marl and chalky limestone near the mouth of the Niobrara River in northeastern Nebraska. Logan (1897, p. 219) described the Niobrara in north-central Kansas and divided it into the Fort Hays Limestone Member below and the Smoky Hill Chalk Member above. Williston (1897, p. 235) discussed the paleontology and stratigraphy of the Niobrara in western Kansas.

SMOKY HILL CHALK MEMBER

The oldest rocks that crop out in Wallace County consist of chalk and chalky shale of the Smoky Hill Chalk Member. Only the uppermost part of the member is exposed in Wallace County where it crops out along the south side of the South Smoky Hill Valley, in the east-central part of the county. In the rest of the county, these rocks occur in the subsurface.

The Smoky Hill consists principally of chalk and chalky shale, but thin beds of bentonite occur throughout. The Smoky Hill is characteristically thin-bedded and platy. Fresh exposures are light to dark gray but the beds weather colorfully to white, orange, and brown. Concretions of limonite and pyrite are common and they account for the bright colors of the Smoky Hill Chalk Member when weathered.

The Smoky Hill is noted for the abundant fossils it contains. Vertebrate fossils include bones of aquatic reptiles, such as mosasaurs and plesiosaurs, and many species of fish. Shark teeth are common. Invertebrate fossils characteristically include echinoderms and molluscs, the most numerous of which are the genera *Inoceramus*, a clam, and *Ostrea*, an oyster. Minute shells of foraminifers belonging mainly to the families Globigerinidae and Textularidae compose much of the chalk.

The Smoky Hill Chalk Member is also notable for its effect on topography. Soil development is either thin or absent, vegetation is sparse, and rainwash and gully erosion produce a badland type of topography.

The Smoky Hill Chalk Member is not important as an aquifer in Kansas and is believed to carry but little ground water in Wallace County. As the beds of shaly chalk are relatively impermeable, water within the formation would be transmitted chiefly through fractures and joints and would be found only locally. Cave-ins such as the Smoky Hill Cave-in and the Old Maid's Pool attest to solution within the underlying chalk beds and are apparently associated with local faulted areas. Ground water from the Smoky Hill would tend to be more mineralized than other water at comparable depth below the land surface in Wallace County, owing to its association with minerals within the chalk. Although the water probably would be undesirable for household use, it could be used to water livestock.

Pierre Shale

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 detail by Elias (1931). He divided the Pierre 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 of about 500 or 600 feet, and the Beecher Island Shale. According to Elias, the lithology of the Pierre is fairly uniform and the breaks are based largely on fossils. Only the lower four members, which make up about the lower half of the Pierre, are present in Wallace County, the upper half having been removed by pre-Ogallala erosion. The Pierre Shale ranges in thickness from 0 southeast of the town of Wallace to approximately 600 feet in the northwestern part of the county.

The Pierre Shale conformably overlies the Niobrara Chalk in Wallace County and consists chiefly of dark-gray to black, thin-bedded shale which characteristically weathers to coffee brown and gray. Thin beds of greenish-gray, brown, and orange bentonite occur in much of the Pierre. Pyrite and marcasite are scattered throughout fresh exposures. Outcrops are characterized by limonite concretions and rusty spots, and by thin crystals of selenite, usually found in abundance along the cracks. Except for concretions, the Pierre Shale is noncalcareous, thus differing from the chalky shale of the underlying Niobrara Formation. Concretions of varied size and constituents occur commonly but generally consist of calcium carbonate, siderite, and limonite. The concretions characteristically occur in zones along bedding planes and form escarpments and prominent benches in places.

The contact of the Pierre Shale and the underlying Niobrara Formation may be seen southeast of the town of Wallace along the south side of the South Smoky Hill Valley. The Pierre Shale crops out at many localities in the central and northern parts of the county, particularly along stream valleys. It is typically soft and easily eroded, and low rolling slopes characterize its exposures. Because of the uniform hydrologic and lithologic character of the formation, the Pierre Shale is mapped as a single unit on Plate 1.

Following is a section of a part of the Pierre Shale, measured and described by C. R. Johnson and N. W. Biegler (Bradley and Johnson, 1957, p. 20).

Measured section of Pierre Shale in sec. 7, T. 14 S., R. 38 W.

	Thickness, feet
Ogallala Formation	
CRETACEOUS—Upper Cretaceous	
Pierre Shale	
Shale, yellow and brown, mottled; limestone concretions near contact; fish scales interspersed	10.5
Shale, gray, fissile, weathering lighter gray, having white, powdery material in fractures	11.6
Shale, gray and brown, fissile, containing lenticular silty limestone concretions as much as 7 inches in diameter	1.0
Shale, fissile, blue gray	6.5
Bentonite, having yellow limonitic shale partings	0.5
Shale, blue gray, containing lenticular limestone bodies as much as 0.5 foot thick and 6 feet long	3.5
Shale, blue gray, fissile, containing abundant bentonite stringers; a limonitic, resistant, persistent bed 0.5 inch thick lies at base	10.2
Shale, brown, limonitic, containing many limy concretions as much as 3 inches in diameter	0.6
Shale, blue gray, weathering yellow brown and earthy, fissile; bentonite stringers as much as 0.5 inch thick are common; contains fish scales. Gypsum crystals in platy aggregates are numerous	29.0
Total Pierre Shale measured	73.4

The Pierre Shale is of no consequence as as aquifer in Wallace County but serves as an impervious floor below the overlying water-bearing deposits and retards or prevents the downward percolation of water. Although the Pierre generally acts as an aquiclude, confining the ground water above it, at times a small amount of water probably moves along joints and bedding planes; the quantity of water is considered insufficient to supply wells.

Tertiary System—Pliocene Series

Ogallala Formation

The Ogallala Formation was named by Darton in 1899 (p. 732-734) from exposures in southwestern Nebraska. Darton in 1920 (p. 6) designated the type locality as being near Ogallala Station in western Nebraska. Since his work, the most significant studies of the Ogallala Formation in western Kansas have been by Elias (1931), Smith (1940), and Frye and others (1956). The Ogallala Formation in Kansas is divided by Frye and others into three members which, in ascending order, are the Valentine, Ash Hollow, and Kimball. A thin, discontinuous bed of pisolitic limestone, 1 to 3 feet thick, commonly occurs at the stratigraphic top of the Ogallala Formation.

The Ogallala Formation was deposited upon an erosional surface of Upper Cretaceous rocks, chiefly by eastward-flowing streams whose source of load was igneous and metamorphic rocks of the Rocky Mountains and sedimentary rocks of eastern Colorado. Its lithology varies sharply both vertically and laterally. The Ogallala consists chiefly of a series of valley fillings, overlapping laterally from the axes of the main drainageways onto the gentle erosional slopes of the valley sides.

Thus, the Ogallala Formation consists of a heterogeneous complex of predominantly clastic deposits, the texture ranging from very coarse gravel and pebbles to clay, and the sorting from good to poor. Lentils of volcanic ash, marl or marly limestone, and bentonite contrast with the predominant stream-laid clastics. Throughout this heterogeneous assortment of sediments there is virtually no distinctive bed that can be traced appreciable distances in the field. The formation's topographic expression includes flat uplands, gentle erosional slopes, and nearly vertical cliffs. Because of the uniform hydrologic character of the formation, no attempt was made to divide the Ogallala in Wallace County, and it is shown on Plate 1 as a single unit.

Character.—The Ogallala Formation in Wallace County is characteristically buff to pinkish in color. It constitutes a widespread mantle of fluvial deposits consisting predominantly of sand, gravel, silt, and clay. The deposits are interbedded and admixed to various proportions and are largely unconsolidated, although cementation of beds occurs to some degree throughout the formation. Also commonly present are thin beds of volcanic ash, fresh-water limestone, and bentonitic clay. Calcium carbonate is a common constituent in almost all the Ogallala. It is distributed both as fine material and as stringers of caliche and small to medium-size nodules. In many places calcium carbonate binds the deposits so firmly as to produce a series of hard ledges, interbedded with only slightly cemented beds. The hard ledges are usually unevenly cemented and form roughly weathered benches and cliffs which resemble mortar and accordingly are often referred to as "mortar beds." Silica also is present as a cementing material in beds of opaline sandstone or as chert deposits, and variously colored chert in the form of nodules and in small irregular lenses and beds is occasionally seen.

Sand is the principal material within the Ogallala Formation and is present at all horizons, the sand typically being light gray or greenish. Beds of uniform sand may occur but generally the sand ranges from fine to coarse and commonly is mixed with gravel, silt, or clay. Gravel beds containing lenses of sand, silt, and clay are common but thick beds of uniform gravel are rare. Beds of sand and gravel with distinct cross bedding occur in places. Silt, sandy silt, and clayey silt are present throughout the Ogallala and are greenish gray, pink, tan, and gray; if the beds contain a large amount of calcium carbonate, they are light gray or white.

Lenses and thin beds of white and pinkish limestone are common in the middle and uppermost parts of the Ogallala. Bluish-gray volcanic ash and light-gray to snow-white diatomaceous marl are locally found in the lower and middle parts of the formation.

Although relatively pure clay beds are not common within the Ogallala, fine plastic, bentonitic clays, greenish and reddish brown, are locally at or near the base of the Ogallala. Elias (1931, p. 153-158) discussed the occurrence of the clays and concluded that for the most part they were the product of weathering of volcanic ash that had been deposited on the surface of the Pierre Shale before Ogallala deposition began, or very early during Ogallala deposition. Subsurface samples of clay of similar appearance at the base of the Ogallala Formation in Thomas County were reported by Frye (1945, p. 67), who suggested that the clay might be a product of weathering of the underlying Pierre Shale. Bentonite lentils occur within the Ogallala, seemingly restricted to the lower member of the formation (Valentine Member). Bentonite was recognized in several test holes drilled in Wallace County, the thickest section being in test hole 14-42-13ccc, where 9 feet of grayish-green bentonite was recorded.

Following is a section of a part of the Ogallala Formation, measured and described by Frye and others (1956, p. 84).

Measured section of the Ogallala Formation in the SE¼ sec. 11, T. 13 S., R. 42 W.

	Thickness, feet
TERTIARY—Pliocene	
Ogallala Formation	
"Algal limestone"	0.5
Caliche, silt, fine sand, and a few pebbles, gray to ash gray, distinctly platy structure throughout	9
Sand, fine, some coarse sand and pebbles, massive, densely cemented with calcium carbonate, gray	13
Silt, fine sand, and clay, loose, massive to thin bedded, greenish gray to brown; contains nodules of caliche and small cemented lenses	11
Sand, pebbles of quartz and caliche, and cobbles of red silt, loosely cemented throughout; contains *Celtis willistoni*	10
Silt and fine sand, well sorted in thin beds, some cross-bedded zones; weathered volcanic ash shards abundant in basal part; discontinuous caliche zone at top	10
Sand, medium, some fine gravel, massive, gray, densely cemented; contains *Celtis willistoni*	7
Sand, fine to medium, loosely cemented, gray to pinkish tan	4
Sand and gravel, brown to tan, densely cemented; contains the following fossil seeds: *Berrichloa amphoralis, B. tuberculata, Biorbia fossilia, Krynitzkia auriculata, Stipidium intermedium, S. variegatum*	8
Silt and sand, loose, local cemented lenses, pinkish to reddish brown. (The Ogallala rests on Pierre Shale),	26
Total Ogallala Formation measured	98.5

Outcrops are characteristically cemented to various degrees and typically are ash gray in color. In spite of the diversity of deposits, the outcrop pattern of the Ogallala presents a uniformity of aspect that makes the formation readily identifiable. Many beds in the Ogallala are cemented or partially cemented with calcium carbonate. Because the cemented beds are more resistant to erosion, many outcrops of the Ogallala form rough benches, hard ledges, and cliffs; exposed surfaces commonly have a knobby, irregular aspect.

Opinions regarding the origin of the thin, discontinuous bed of pisolitic limestone—originally called "algal" by Elias (1931, p. 136-141)—that marks the stratigraphic top of the Ogallala Formation have been controversial. Elias postulated a lacustrine origin for the capping limestone. Later workers advanced a hypothesis of subaerial origin as a caliche zone. Smith (1940, p. 90-92) discussed the two hypotheses, and more recently Frye and others (1956, p. 13-16) critically discussed the bed, postulating as a mode of origin the development of a mature to senile lime-accumulating soil which was later modified by solution.

DISTRIBUTION AND THICKNESS.—The Ogallala Formation rests on a subaerially eroded surface developed on shales of Late Cretaceous age. This surface has a relief of several hundred feet in Wallace County and slopes generally eastward at a rate of about 10 to 15 feet per mile. Logs of test holes show that the thickness of the Ogallala Formation in Wallace County ranges from 0 to approximately 400 feet, but that the thickness is not uniform because of unconformable contacts at the top and bottom of the formation.

The Ogallala, although generally mantled with eolian silts, underlies the upland plain in the southern, west-central, and northwestern parts of the county. The Ogallala is thickest and most extensive in the southern part of the county, where it underlies the upland loess in nearly all the area. The Ogallala also occurs extensively in the west-central and northwestern parts of the county and it is locally quite thick. The Ogallala is thin and discontinuous in the central and northeastern parts of the county, where much of it has been removed by erosion. In many parts of this area it only caps the high interstream areas. The Ogallala crops out along the bluffs of the major valleys and locally is well exposed in many of the tributary canyons. The thickness and character of the Ogallala Formation are shown by the logs of test holes and wells at the end of this report and are illustrated in the cross sections on Plate 2.

WATER SUPPLY.—The Ogallala Formation is the most widespread and important water-bearing formation in Wallace County. It supplies water for most domestic and stock supplies, and 96 irrigation plants were obtaining water from it in the fall of 1960. The yields of the wells range from a few gallons per minute for domestic and stock wells to more than 2,000 gpm for several irrigation wells.

In much of the southern, the extreme western, and the northwestern parts of the county, the saturated thickness of the Ogallala, which yields moderate to large quantities of water, is great enough to store relatively large quantities of ground water. In much of the central and northeastern parts of the county, the Ogallala is either missing or too thin to carry more than a little ground water, if any.

Studies were made to determine the quantity of ground water in storage in the Pliocene and Pleistocene deposits. A contour map (Pl. 3) showing the saturated thickness of the deposits was prepared by superimposing a contour map of the water table upon a contour map of the bedrock surface and connecting points of equal saturated thickness. The area between each pair of contours was measured with a planimeter and was multiplied by the average saturated thickness to give the volume of saturated materials. The total volume of saturated materials and the volume of water, based on an assumed specific yield of

TABLE 10.—Volume of saturated water-bearing materials and volume of water available for pumping in Wallace County, based on a specific yield of 15 percent.

Township	Volume of water-bearing materials, acre-feet	Volume of water, acre-feet
T. 11 S., Rs. 38 and 39 W.	290,000	43,000
T. 11 S., R. 40 W.	970,000	145,000
T. 11 S., R. 41 W.	1,200,000	180,000
T. 11 S., Rs. 42 and 43 W.	1,300,000	195,000
T. 12 S., R. 40 W.	90,000	13,000
T. 12 S., Rs. 42 and 43 W.	1,200,000	180,000
T. 13 S., Rs. 41, 42, and 43 W.	2,000,000	300,000
T. 14 S., R. 38 W.	280,000	42,000
T. 14 S., R. 39 W.	1,000,000	150,000
T. 14 S., R. 40 W.	1,600,000	240,000
T. 14 S., R. 41 W.	2,300,000	345,000
T. 14 S., Rs. 42 and 43 W.	3,700,000	555,000
T. 15 S., R. 38 W.	1,900,000	285,000
T. 15 S., R. 39 W.	2,800,000	420,000
T. 15 S., R. 40 W.	3,700,000	555,000
T. 15 S., R. 41 W.	2,000,000	300,000
T. 15 S., Rs. 42 and 43 W.	500,000	75,000
Total volume	27,000,000	4,000,000

15 percent from the saturated material, are given by townships in Table 10.

The total volume of saturated water-bearing materials in Wallace County, as measured, is about 27 million acre-feet. If the materials have a specific yield of 15 percent, a volume of water equal to 15 percent of the total volume of saturated materials would be available for pumping. Thus, about 4 million acre-feet of water would be available if the deposits were completely drained. From a practical standpoint, much less water than this would be available for pumping.

Quaternary System—Pleistocene Series

Deposits of Quaternary age, although relatively thin, are the surficial materials in much of Wallace County, as shown by the geologic map (Pl. 1) and cross sections (Pl. 2). The deposits are both eolian and fluvial in origin and are assigned to the Pleistocene Series. The eolian deposits consist of the Peoria and Loveland Formations, and the fluvial deposits consist of alluvium.

Eolian silts cover much of the upland areas and typically extend along the valleys, masking the valley slopes. In places the loess is intermixed with reworked loess and slope wash, and in some areas the upland draws contain several feet of this colluvial material.

Fluvial deposits are associated with the drainage system and consist of alluvial deposits of sand, gravel, and silt along the inner valleys of the principal streams.

Peoria and Loveland Formations

CHARACTER AND THICKNESS.—Eolian deposits form the most extensive outcrops in Wallace County, blanketing much of the county with a cover of loess ranging from 0 to about 50 feet in thickness. The loess is apparently thicker in the northwestern part of the county. It caps the rolling hills and flat uplands and masks the gentle slopes of the valleys. The loess represents the Loveland Formation of Illinoisan age and the Peoria Formation of early Wisconsinan age. Locally, chiefly in the northwestern part of the county, about 1 or 2 feet of loess, largely incorporated within the modern soil profile and believed to represent the Bignell Formation of late Wisconsinan age, was observed overlying a buried soil believed to be the Brady soil.

The Loveland Formation is a reddish-tan silt, mostly eolian, which characteristically grades into sand in the lower part. The Sangamon buried soil marks the top of the Loveland Formation and separates it from the overlying Peoria Formation. The Peoria is a massive, eolian, tan to gray silt, which covers much of the upland areas of Wallace County and typically masks the valley slopes along the principal stream valleys.

Colluvium, material deposited by slope wash and consisting of reworked loess, sand and gravel derived from the Ogallala Formation, and Cretaceous bedrock fragments, mantles many slopes and characteristically fills the upland draws. Where the colluvium is thick enough to conceal the underlying bedrock it has been included with the Peoria and Loveland Formations on Plate 1.

WATER SUPPLY.—The deposits mapped as Peoria and Loveland Formations in this report consist mostly of relatively thin, wind-deposited silt, generally well above the water table. In parts of central and northeastern Wallace County, however, where in places ground-water supplies are meager, shallow domestic and stock wells obtain small amounts of ground water from colluvial and slope deposits which in this report are included with the Peoria and Loveland Formations. In these areas where ground-water supplies are meager and difficult to find, the best well sites generally prove to be creek valleys and draws where thin alluvial and colluvial fill

TABLE 11.—Records of wells in Wallace County.

Well (1)	Owner or tenant	Type of well (2)	Depth of well, feet (3)	Diameter of well, inches	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (5)	Use of water (6)	Depth to water level below land surface, feet (7)	Date of measurement	Altitude of land surface above mean sea level, feet	Remarks (Yield given in gallons a minute; drawdown in feet)
10-37-32dcc	J. S. Garvey	Dr	63.0	6	GI	Sand, Gravel	Ogallala Formation	Cy, W	S	59.13	7- 5-49	3,325.6	In Sherman County.
10-40-34ddc	J. A. Parker	B	33.0	5	GI	do	do	Cy, H	N	25.90	8-24-49	3,655.7	Do; abandoned well.
										25.95	7-25-58		
10-41-33daa	W. B. Hayden	Dr	129.0	5	GI	do	do	Cy, W	S	101.20	8-26-49	3,875.2	In Sherman County.
10-42-33bcd	Bertha Rivers et al.	Dr	51.4	6	GI	do	do	Cy, W	S	39.07	6-27-49	3,931.8	Do.
10-42-36bcc	C. A. Denton	Dr	114.5	6	GI	do	do	Cy, W	D, S	80.37	7- 9-49	3,913.6	Do.
11-37-30bbb	E. F. & E. A. Langdon	Dr	43.8	5½	GI	do	do	Cy, W	D, S	38.84	7-20-54	3,405.1	In Logan County.
11-38-1ddd	J. S. & W. W. Garvey	Dr	16.0	5½	GI	do	Alluvium	Cy, W	S	11.90	7-21-54	3,272.2	
*11-38-5bbc	John Cogswell et al.	Dr	128.0	16	S	do	Alluvium and Ogallala Formation	T, B	I	28.87	7-14-58	3,398.8	Reported yield 1,200.
11-38-10aaa	do	Dr	35.0	6	GI	do	Alluvium	Cy, W	D, S	24.27	7-23-58	3,328.6	
11-38-13ddd	C. Shurtz	Dr	44.0	5½	GI	do	Ogallala Formation	Cy, W	D, S	38.74	7-20-54	3,355.2	
										38.14	8-27-57		
11-38-16bcc	G. & F. Harrison	Dr	106.5	5	GI	do	do	Cy, W	D, S	101.25	8- 7-57	3,508.4	
*11-38-18dca	Berl Minnix	Dr	81.0	5½	GI	do	do	Cy, W	S	65.30	7-14-58	3,484.1	
11-38-19cdc	do	Dr	149.3	5½	GI	Sand, silt	Colluvium	Cy, W	S	71.54	8-27-57	3,380.5	
11-38-21ada	C. E. Taylor	Dr	86.0	5½	GI	Sand, gravel	Ogallala Formation	Cy, W	N	74.86	8- 9-57	3,458.3	
11-38-26ada	G. H. Smith	Dr	130.7	6	GI	do	do	Cy, N	N	126.84	8-12-57	3,451.7	
11-38-28aaa	W. L. Hoss	Dr	114.0	6	GI	do	do	Cy, H	N	104.52	10- 6-60	3,484.0	
11-38-32dcc	I. C. Harrison	Dr	43.0	6	GI	Sand, silt	Colluvium	Cy, W	N	32.00	10- 6-60	3,320.3	
11-38-35ccc	Lindy Bretz	Dr	111.0	6	GI	Sand, gravel	Ogallala Formation	Cy, W	D, S	78.04	8- 7-57	3,368.8	
11-39-2cda	Minnie Robidoux	Dr	108.0	5	GI	do	do	Cy, W	S	94.65	7-14-58	3,582.7	
*11-39-4cbc	F. G. Trablik	Dr	65.5	5	GI	do	do	Cy, W	S	56.55	7-14-58	3,559.8	
11-39-7bca	N. E. Parnell	Dr	110.5	5	GI	do	do	Cy, W	S	81.08	8- 8-57	3,615.7	
*11-39-28acc	C. C. Pearce	Dr	19.5	5	GI	do	Alluvium	Cy, W	S	13.65	7-23-58	3,425.7	
11-39-36aaa	School District	Dr	22.4	5	GI	do	do	Cy, E	D	11.75	7-14-58	3,337.7	
*11-40-1bcc	P. M. Piper	Dr	86.2	5	GI	do	Ogallala Formation	Cy, W	D, S	73.72	8-24-49	3,686.6	
										73.62	8- 9-57		
11-40-14acc	M. T. Smith	Dr	35.5	6	GI	do	do	Cy, W	S	19.05	6- 9-58	3,546.0	
11-40-15bbc	J. A. Parker	Dr	49.0	5	GI	do	do	Cy, W	S	38.55	10- 5-60	3,598.3	
11-40-15ddd1	do	Dr	57.0	6	GI	do	do	N	N	42.74	5-17-48	3,560.5	Well has been destroyed.
										42.38	4-24-51		
11-40-28dca	H. B. Rockwell	Dr	93.5	5	GI	do	do	Cy, G	D	56.36	7-25-57	3,606.1	
11-40-31bcc	John Stover	Dr	117.4	5½	GI	do	do	Cy, W	S	82.55	7-25-57	3,694.2	
*11-40-35aaa	R. D. Mills	Dr	124.5	6	GI	do	do	Cy, W	S	83.06	6- 9-58	3,566.8	
*11-41-2ccd	Willa Mather	Dr	54.0	5	GI	do	do	Cy, W	D, S	37.43	7-26-57	3,752.5	
11-41-4cda	M. L. Goings	Dr	101.0	5	GI	do	do	Cy, W	N	74.30	7-26-57	3,825.4	
11-41-6bbb	C. A. Duell	Dr	124.5	6	GI	do	do	Cy, W	D	107.76	8-26-49	3,884.3	
11-41-15ccc	School District	Dr	74.3	5	GI	do	do	Cy, H	D	55.80	7-23-57	3,790.8	
11-41-18ccc	G. W. & T. Agnew	Dr	74.8	5	GI	do	do	Cy, W	S	54.75	7-22-57	3,853.9	
†11-41-24add	R. C. Ward	Dr	91.0	5	GI	do	do	J, E	D, S	47.33	7-29-57	3,691.2	
11-41-26cbc	L. G. Mather	Dr	57.7	5	GI	do	do	J, E	D, S	31.14	8- 1-57	3,706.8	
11-41-32baa	B. Roy	Dr	36.0	6	GI	Sand, silt	Colluvium	N	N	29.05	10- 5-60	3,716.5	
11-41-33aab	Emma King	Dr	93.8	6	GI	Sand, gravel	Ogallala Formation	Cy, H	N	83.40	8-21-57	3,762.3	
11-42-4dcd	W. T. Niceschwander	Dr	116.5	5	GI	do	do	Cy, W	S	106.22	5-26-58	3,937.0	
*11-42-7dad	Walker Sivey	Dr	148	16	S	do	do	T, B	I	97.52	5-26-58	3,969.0	Reported yield 600.
11-42-11cda	O. L. Jones	Dr	93.3	5	GI	do	do	Cy, W	S	78.00	7-26-57	3,898.4	
11-42-16bbb	School District	Dr	120.0	5	GI	do	do	Cy, W	D	102.62	7-23-57	3,954.9	
11-42-19aac	Joe Van Laeys	Dr	48.5	6	GI	do	do	Cy, W	S	35.08	10- 5-60	3,909.8	
11-42-22abb	A. S. Waltz	Dr	110.0	6	GI	do	do	Cy, W	S	92.21	6-10-58	3,921.2	
*11-42-34abc	Paul Scott	Dr	15.0	5½	GI	Sand, silt	Colluvium	C, E	D, S	8.60	10- 5-60	3,759.5	

11-43-12aac	A. C. Sivey	Dr	74.4	5	GI	Sand, gravel	Ogallala Formation	Cy, W	D, S	61.30	7-30-57	3,956.7	
12-38-9add	J. S. & W. W. Garvey	Dr	32.8	5	GI	Sand, silt	Colluvium	Cy, W	D, S	25.38	8-12-57	3,258.9	
12-38-24aaa	G. E. Gfetter	Du	24.6	5½	GI	Sand, gravel	Alluvium	Cy, E	D	21.30	7-20-54	3,214.2	
•12-38-33bba	D. M. Bontrager	Dr	38.0	6	GI	Sand, silt	Colluvium	Cy, W	S	30.94	6- 6-58	3,334.1	
•12-39-2cdd	E. A. Hoss	B	25.5	8	GI	do	do	Cy, W	S	19.00	10- 6-60	3,437.6	Shale reported at 25 feet
12-39-6dcb	C. E. Madigan	Dr	104.0	5	GI	Sand, gravel	Ogallala Formation	N	N	98.90	8-20-57	3,655.9	
12-39-13ada	T. A. Harrison	Dr	24.5	6	GI	Sand, silt	Colluvium	Cy, W	S	18.35	6- 6-58	3,413.6	
12-39-15ddd	P. A. Adams	Du	20.0	48	R	Sand, gravel	Ogallala Formation	Cy, W	S	14.98	10-11-60	3,535.3	
12-39-33aba	G. Hileman	Dr	12.5	8	GI	do	Alluvium	Cy, W	S	6.50	7-23-58	3,378.5	
12-40-2cbb	R. D. Mills	Dr	130.5	5	GI	do	Ogallala Formation	Cy, W	S	109.26	8-14-57	3,667.6	
12-40-9aba	Raymond Stover	Dr	132.0	5	GI	do	do	Cy, W	S	118.75	10- 6-60	3,680.5	
12-40-14bba	W. P. Kirkham	Dr	20.5	6	GI	do	do	N	O	18.75	5-18-48	3,613.4	
										20.11	7-16-58		
•12-40-15cdd	R. D. Mills	Dr	89.5	6	GI	do	do	Cy, W	S	59.13	5-22-58	3,607.1	
12-40-24dad	C. L. Hubbs	Dr	14.0	14	GI	Sand, silt	Colluvium	Cy, W	D, S	10.40	7-23-58	3,470.5	
12-40-30bbc	W. D. Jones	Dr	35	18	S	Sand, gravel	Alluvium	C, G	I	11.87	6-24-58	3,502.6	Series of 4 wells; reported yield 450.
12-41-2dab	Raymond Stover	Dr	43.5	6	GI	do	Ogallala Formation	Cy, W	D, S	28.24	10- 5-60	3,641.9	
•12-41-11aad1	John Stover	Dr	20.0	5	GI	do	Alluvium	Cy, W	S	15.27	7- 7-58	3,571.1	
12-42-4ccc	G. N. Stewart	Dr	130.0	6	S	do	Ogallala Formation	Cy, W	S	109.46	7-25-57	3,961.0	
12-42-6bcb	do	Dr	80	5	GI	do	do	Cy, W	D, S	69.35	7-30-57	3,940.5	
12-42-10ccb	R. Harold	Dr	108.0	5½	GI	do	do	Cy, W	S	69.80	10- 5-60	3,920.5	
•12-42-15aaa	W. N. Botkin	Dr	122.0	5	GI	do	do	Cy, W	S	76.36	7-31-57	3,920.1	
12-42-18dad	Glen Cambridge	Dr	120.0	5	GI	do	do	Cy, W	D, S	81.65	7-25-57	3,924.1	
12-42-26cbc	Frank Goodwin	Dr	124.6	5	GI	do	do	Cy, W	D, S	108.13	7-31-57	3,893.8	
12-42-28acd	P. Carstensen	Dr	81.5	5	S	do	do	Cy, W	D, S	57.00	8-23-57	3,863.5	
12-42-32bcb	Clifton A. Smith	Dr	65.0	4½	S	do	do	Cy, E	D	16.31	10- 5-60	3,840.7	New well; shale reported at 63 feet.
12-43-36aab	G. E. Price	Dr	82.6	5	GI	do	do	Cy, W	S	66.07	7-30-57	3,878.3	
13-38-4aba	J. Benisch	Dr	22.4	6	GI	Sand, silt	Colluvium	Cy, W	D	15.62	6- 9-58	3,285.8	
13-38-6cbb	Joe Capper	Dr	15.5	5	GI	do	do	Cy, W	S	8.84	6- 5-58	3,298.3	
•13-38-11bba	A. Zebroski et al.	Dr	41.5	6	GI	do	do	Cy, W	D, S	28.72	6- 5-58	3,235.8	
13-38-13cdc	C. R. Holland	Dr	27.5	6	GI	do	do	Cy, G	S	22.08	6- 5-58	3,176.0	
13-38-17ddd	Joe Capper	Dr	33.5	6	GI	do	do	Cy, W	S	23.67	6- 6-58	3,245.3	
13-38-25bab	C. C. Lock	Dr	30	16	GI	Sand, gravel	Alluvium	C, D	I	3	7-25-58		Series of 3 wells; not used much.
13-38-25bbb	do	Dr	30	36	C	do	do	C, D	I	5.88	7-19-51	3,177.0	Series of 5 wells; not used.
13-38-26ada	do	Dr	32	16	GI	do	do	C, D	I	4	7-30-58		Series of 10 wells; yield 1,750.
12-38-27cad	F. Pearce	Dr	22.8	5½	GI	do	do	N	N	15.37	7-20-51	3,227.0	Well has been destroyed.
13-39-6cca	Gilbert Hileman	Dr	35.0	12	GI	Sand, silt	Colluvium	Cy, H	D	25.28	10-11-60	3,397.6	
13-39-16bda	G. H. Burris	Dr	21.3	6	GI	do	do	Cy, W	S	13.03	6- 9-58	3,331.3	
†13-39-19acb	John Finley	Dr	54.0	18	S	Sand, gravel	Alluvium	T, T	I	8.09	4-11-51	3,385.0	Cannot be measured; new concrete pump base; reported yield 1,100.
										7.43	7- 9-51		
13-39-19bad	do	Dr	54	10	S	do	do	C, T	I	9	9-26-57		Not used much.
13-39-19dba	do	Dr	54	10	S	do	do	C, T	I	9	9-26-57		Do.
•†13-39-19dca	do	Dr	51.0	16	S	do	do	T, T	I	10.48	9-26-57	3,349.8	Reported yield 1,000.
13-39-19ddd	do	Dr	43	8	GI	do	do	C, T	I	6.22	9-26-57	3,341.0	Reported yield 800.
13-39-25acc	M. W. Moore	Dr	30	18	S	do	do	T, T	I	5.36	7-17-51		Reported yield 400.
•13-39-25adb	do	Dr	20	18	S	do	do	C, E	I	5.00	7-17-51		Reported yield 400; draw-down 12.
13-39-25daa	City of Wallace	Dr	34	16	S	do	do	T, E	P	8	6- 4-58		
13-39-25dab	L. O. Stanley	Dr	53	16	S	do	do	T, G	I	8	6- 4-58	3,261.0	Reported yield 850.
13-39-26cbd	B. T. Armstrong	Dr		20	S	do	do	C, D	I	4.56	7-20-51	3,290.5	Series of 9 wells; not used.
13-39-28bcb	O. D. Duphorne	Dr	11	16	S	do	do	C, G	I	8	7-17-51	3,339.7	Series of 8 wells; reported yield 1,000.
										4.80	6- 4-58		
13-39-29bbb	Marshall Finley	Dr	42.0	12	S	do	do	C, G	I	6.75	6-12-58	3,338.7	Reported yield 700.
13-39-29dba	do	Dr	47	16	S	do	do	T, G	I	12	6-12-58		Reported yield 1,000.
13-39-33bbb	C. G. Tilton	Dr	62.2	12	S	do	do	T, G	I	18.53	7-17-51	3,334.3	Reported yield 700; draw-down 13.
										21.06	9-20-57		
†13-39-33bbd	do	Dr	66.0	18	S	do	do	T, B	I	21.10	6-12-58	3,321.9	Reported yield 900.
•†13-40-7aac	V. C. Morin	Dr	76.0	16	S	do	do	T, B	I	16.15	6-24-58	3,481.7	Reported yield 600

TABLE 11.—Records of wells in Wallace County—*Continued.*

Well (1)	Owner or tenant	Type of well (2)	Depth of well, feet (3)	Diameter of well, inches	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (5)	Use of water (6)	Depth to water level below land surface, feet (7)	Date of measurement	Altitude of land surface above mean sea level, feet	Remarks (Yield given in gallons a minute; drawdown in feet)
13-40-7dba	V. C. Morin	Du	16		N	Sand, gravel	Alluvium	C, B	I	8	10- 4-57		Bulldozed pit.
13-40-10abb1	Jesse Mumma	Dr	44.5	20	S	do	do	T, T	I, O	13.80	5-18-48	3,424.3	Not used much.
										16.10	6- 9-58		
†13-40-10abb2	do	Dr	48.0	24	S	do	do	T, E	I	15.72	6-24-58	3,423.1	Series of 3 wells; reported yield 1,000.
13-40-10bba	Tom Jackson	Dr	47	16	GI	do	do	T, T	I	15.85	7- 9-51	3,430.2	Reported yield 500.
										18.50	10- 4-57		
13-40-23aad	I. O. Miller	Dr	41.5	6	S	do	do	Cy, W	S	28.57	7- 9-51	3,398.9	
										30.86	5-21-58		
13-40-27ccd1	City of Sharon Springs	Dr	105	16	S	do	do	T, E	P	45	7-17-58		
13-40-27ccd2	do	Dr	129	16	S	do	do	T, E	P	40	7-17-58		
13-40-27cda1	do	Du	45	168	C	do	do	T, E	P	30	7-17-58		
13-40-27cda2	do	Du	38	168	B	do	do	T, E	P	23	7-17-58	3,433.4	
13-40-27cdb	do	Dr	85	16	S	do	do	T, E	P	18	7-17-58		
13-40-28daa	Guy Holland	Dr	29.2	5½	GI	Sand, silt	Colluvium	N	N	19.06	7-13-51	3,440.1	
										19.43	5-21-58		
13-40-36bbc	do	Dr	34.9	6	GI	do	do	Cy, W	S	28.09	7-13-51	3,414.5	
										25.84	9-20-57		
13-41-3aaa	David Ferguson	Dr	40.2	5½	GI	Sand, gravel	Ogallala Formation	N	N	33.22	8-15-57	3,587.5	
13-41-10dcb	Harmon Whitney	B	27.0	6	GI	Sand, silt	Colluvium	N	N	22.32	7- 9-51	3,571.7	Well has been destroyed.
13-41-12ccd	Ira Chisum	Dr	11.0	6	GI	Sand, gravel	Alluvium	Cy, W	S	6.59	7- 9-51	3,518.3	
										7.59	9-12-57		
13-41-14bcd	David Ferguson	Dr	35	16	S	do	do	C, G	I	5	7-24-58		Reported yield 450.
13-41-15acc	C. H. Walker	Dr	35	14	S	do	do	C, G	I	9	7-24-58		Reported yield 400.
13-41-20dcc	R. V. Baeler	Dr	54	6	GI	do	Ogallala Formation	Cy, W	S	30.53	7- 9-51	3,686.2	
										30.42	9-11-57		
13-41-32cbd	H. N. Holland	Dr	128.0	5½	GI	do	do	Cy, W	S	116.32	7- 9-51	3,788.3	
										113.76	9-17-57		
13-41-34abb	F. H. Biermann	Du			N	Sand, silt	Colluvium	N	N	22.2	7- 9-51		Well has been destroyed.
13-42-6aaa	M. S. Jellison	Dr	136.6	3½	S	Sand, gravel	Ogallala Formation	Cy, W	S	98.00	8-23-57	3,909.4	
13-42-14dbb	C. A. Tupper	Dr	130.2	5½	GI	do	do	Cy, W	D, S	108.07	7-30-57	3,800.2	
13-42-20add	David Paul	Dr	102.0	6	GI	do	do	Cy, W	S	89.84	7- 9-51	3,819.5	
										89.15	9-11-57		
13-42-22ada	L. E. Samuelson	Dr		6	GI	do	do	Cy, W	S	16.84	7- 9-51	3,707.3	
										15.48	9-11-57		
*13-42-24cca	L. Walker	Dr	16.0	6	GI	do	Alluvium	Cy, W	S	13.51	7- 9-51	3,678.5	
13-42-28dcc	R. B. Rigor	Dr	160.0	6	GI	do	Ogallala Formation	Cy, W	S	141.16	7- 9-51	3,857.7	
										141.37	9-11-57		
†13-42-29ccc	N. D. Sexson	Dr	217.0	16	S	do	do	T, D	I	150	10- 8-57	3,887.2	Reported yield 1,000.
13-42-31add	F. J. Armstrong	Dr	165.0	6	GI	do	do	Cy, W	D	143.19	7- 9-51	3,874.6	
										144.22	9-11-57		
13-43-24daa	F. Alford	Dr	58.0	6	GI	do	do	Cy, W	D	55.10	7- 9-51	3,813.4	
										54.39	9-11-57		
*†13-43-36abb	Iley Sexson	Dr	270.0	16	S	do	do	T, B	I	148.75	10- 8-57	3,893.5	Reported yield 1,400; reported drawdown 8.
14-37-30ccc	M. P. Surratt	Du	12.7	30	R	do	do	N	N	8.44	7-27-55		In Logan County.
14-38-9abb	C. F. Pearce	Dr	10.1	5½	GI	Sand, silt	Colluvium	N	N	4.88	7-18-51	3,333.0	Well has been destroyed.
14-38-21dcc	H. F. Schemm	Dr	93.5	6	GI	Sand, gravel	Ogallala Formation	Cy, W	S	81.91	7-18-51	3,525.0	
										81.62	9-23-57		
14-38-29ddc	do	Dr	76.0	5½	GI	do	do	N	N	72.70	7-17-51	3,529.4	Well has been destroyed
14-38-30ccc	Lyman Fry	Dr	120.0	5½	S	do	do	Cy, W	S	99.07	7-17-51	3,564.0	
										99.95	9-23-57		

14-38-33dcb	F. E. Buell	Dr	38.5	5½	GI	do	do	Cy, W	S	32.12	10-10-60	3,477.5	
14-39-9cbd	Glenn Nealis	Dr	20.0	6	S	do	Alluvium	Cy, H	D, S	16.34	7-17-51	3,410.4	Obstruction in casing.
14-39-17dcc	H. A. Clark Estate	Dr	19.5	5	GI	do	do	N	N	12.70	7-17-51	3,455.6	Well has been destroyed.
14-39-22daa	J. Severin	Dr	135.0	5	GI	do	Ogallala Formation	Cy, W	N	129.66	7-16-51	3,598.6	
										128.59	5-21-58		
14-39-24add	Lyman Fry	Dr	120.0	5½	GI	do	do	Cy, W	S	106.89	7-17-51	3,571.4	
										106.91	9-23-57		
*†14-39-25ccb	do	Dr	182.0	16	S	do	do	T, B	I	109.98	6-18-58	3,576.4	Reported yield 1,000.
14-39-28caa	Kenneth Buck	Dr	208	16	S	do	do	T, B	I	117	10- 3-57		Reported yield 850.
14-39-28cba	do	Dr	123.0	5	S	do	do	Cy, W	D, S	106.87	7-17-51	3,573.3	
										108.44	9-20-57		
†14-39-31bba	H. B. Kuehler	Dr	240.0	18	S	do	do	T, D	I	108.07	10- 2-57	3,623.1	Reported yield 1,200.
										106.90	7-24-58		
†14-39-32bdc	Glen Cloyd	Dr	240.0	16	S	do	do	T, B	I	111.05	10- 3-57	3,610.6	Reported yield 700.
										108.14	6-19-58		
14-39-36ddd	E. W. Artist	Dr	105.0	5½	GI	do	do	N	N	96.40	10-10-60	3,558.5	
14-40-5baa1	C. C. Pierce	Dr	15.8	5½	GI	Sand, silt	Colluvium	Cy, W	S	10.21	7- 9-51	3,485.8	
										11.28	5-20-58		
14-40-10cda	J. C. Heise	Dr	139.5	6	GI	Sand, gravel	Ogallala Formation	Cy, W	S	125.20	7-13-51	3,667.5	
										125.13	9-24-57		
14-40-13bdd	O. C. Walker	Dr	31.0	6	GI	do	do	Cy, W	S	18.05	7-13-51		
14-40-18cba	S. Hinkle	Dr	71.0	5½	GI	do	do	Cy, W	S	66.68	7-11-51	3,660.2	
										66.65	5-20-58		
14-40-21bdd	Paul Cutright	Dr	230	18	S	do	do	T, D	I	126.90	10- 7-60	3,689.6	Reported yield 1,400.
14-40-23add	O. C. Walker	Dr	220	18	S	do	do	T, D	I	118.44	6-19-58	3,644.6	Reported yield 1,150.
14-40-25acc	I. N. Bricker	Dr	44.4	6	GI	do	do	Cy, W	S	35.81	7-16-51	3,559.6	
										37.94	5-26-58		
14-40-28bab	Carl Forsbeck	Dr	140	6	GI	do	do	Cy, N	N	117.24	7-13-51	3,685.5	
										117.89	5-19-58		
14-40-32ccc	W. E. Barstow	Dr	173.0	6	GI	do	do	N	N	117.35	7-16-51	3,703.1	
										118.46	5-19-58		
14-40-34bda	P. L. Walker	Dr	290	18	S	do	do	T, D	I	108.76	10- 9-57	3,663.9	Reported yield 2,000
										106.70	6-24-58		
14-40-34ddd	A. Popp	Dr	91.0	6	GI	do	do	N	O	88.15	5-18-48	3,641.9	
										90.64	1- 8-58		
*†14-40-36dcc	H. B. Kuehler	Dr	226.0	18	S	do	do	T, B	I	104	10- 2-57	3,643.4	Reported yield 1,300.
14-41-8bcc	T. J. Reiss	Dr	125.0	5	GI	do	do	Cy, W	S	104.42	10-10-60	3,775.0	
14-41-9aad	C. C. Pierce	Dr	56.6	6	GI	do	do	Cy, W	S	45.28	7- 9-51	3,700.6	
*14-41-15dbb	M. J. Gauss	Dr	217	16	S	do	do	T, B	I	93.04	6-10-58	3,730.9	Reported yield 1,150.
14-41-15dbd	do	Dr	190	18	S	do	do	N	N	91	6-17-58		Not used.
14-41-16dbc	J. B. McReady	Dr	165	16	S	do	do	N	N	87.48	4- 3-51	3,741.4	Well has been destroyed.
14-41-16dcb	do	Dr	254	18	S	do	do	T, D	I	98	6-11-58		Reported yields 2,250.
14-41-17cbb	F. C. Minet	Dr	96.5	6	GI	do	do	Cy, W	S	87.10	6-26-58	3,758.3	
14-41-20cbb	G. E. Harper	Dr	85.0	5	GI	do	do	N	N	80.19	7-13-51	3,746.4	
										dry	9-17-57		
14-41-22bbb	D. M. Bontrager	Dr	218	26	S	do	do	T, D	I	84.30	6-11-58	3,728.8	Reported yield 2,000.
†14-41-23bbb	William Hagan	Dr	262.0	16	S	do	do	T, B	I	72	6-10-58	3,706.1	Reported yield 1,750.
14-41-26baa	M. F. Wallace	Dr	91.0	4	GI	do	do	Cy, W	D, S	75.55	7-13-51	3,698.0	
										76.74	7-22-58		
14-41-28dcd	L. E. Samuelson	Dr	115.0	5	GI	do	do	Cy, W	S	106.66	7-13-51	3,748.2	
										107.90	9-17-57		
14-42-2bbb	M. F. Powers	Dr	143.0	6	GI	do	do	Cy, W	D, S	125.68	10-10-60	3,828.3	
14-42-4ddd	John Welsh	Dr	145.0	5	GI	do	do	N	N	131.42	10-12-60	3,841.2	
14-42-7dda	A. E. Satterfield	Dr	200.0	6	GI	do	do	Cy, W	S	177.96	7- 9-51	3,899.8	
										178.46	9-12-57		
14-42-10aaa	A. J. Holsey	Dr	148.0	6	GI	do	do	Cy, W	D	135.91	7-11-51	3,839.7	
										136.48	9-12-57		
†14-42-14dbd	Harvey Doop	Dr	400.0	16	S	do	do	T, B	I	102.06	6-24-58	3,795.8	Reported yield 1,300.
14-42-16cdd	C. E. Waugh	Dr	164.0	6	GI	do	do	Cy, W	S	126.05	7-19-51	3,934.2	
										126.68	5-20-58		
*14-42-23bca	do	Dr	180	6	GI	do	do	Cy, W	D	110	7-22-58		
†14-42-23dbb1	E. M. Waugh	Dr	350.0	16	S	do	do	T, D	I	115.41	10- 8-57	3,808.6	Aquifer test using well.
										114.09	6-24-58		

TABLE 11.—Records of wells in Wallace County—*Continued.*

Well (1)	Owner or tenant	Type of well (2)	Depth of well, feet (3)	Diameter of well, inches	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (5)	Use of water (6)	Depth to water level below land surface, feet (7)	Date of measurement	Altitude of land surface above mean sea level, feet	Remarks (Yield given in gallons a minute; drawdown in feet)
†14-42-23dbb2	E. M. Waugh	Dr	170.0	1¼	P	Sand, gravel	Ogallala Formation	N	O	118.16	8-18-60		
14-42-24bba	A. Waugh	Dr	109.0	5½	GI	do	do	Cy, W	D	102.85	7-11-51	3,792.7	
										103.60	6-26-58		
14-42-26dba	A. W. Hunt	Dr	108.0	5	GI	do	do	Cy, H	N	95.55	7-13-51	3,783.6	
										97.27	10-13-57		
14-42-27bba	L. B. Hambleton	Dr	285	16	S	do	do	T, B	I				Was not drilled to shale; reported yield 1,000.
14-42-28cdd	J. E. Ely	Dr	143.0	5	GI	do	do	Cy, W	D	123.59	7-13-51	3,832.2	
										124.41	9-13-57		
14-42-32cbb	Lee Wandling	Dr	137.0	6	GI	do	do	Cy, W	N	131.37	7-13-51	3,853.8	Well has been abandoned.
										dry	9-12-57		
15-37-18cdc	H. Burk	Dr	69.0	5½	GI	do	do	Cy, W	S	59.26	6-14-51	3,459.6	In Logan County.
										59.28	7-25-58		
*15-37-30cbb	Ben Atkisson	Dr	73.0	6	GI	do	do	Cy, W	S	48.73	6- 8-51	3,434.8	Do.
15-37-31bcc	C. E. Brown	Dr	96.0	5½	GI	do	do	Cy, W	S	64.74	7-22-54	3,443.2	Do.
15-38-3dcb1	F. E. Buell	Dr	110	16	S	do	do	T, G	I	80	6-23-58		
†15-38-3dcb2	do	Dr	120.0	12	S	do	do	T, G	I	78.37	6-23-58	3,503.8	
15-38-3dcb3	do	Dr	112	10	S	do	do	T, G	I	78	6-23-58		
†15-38-5ccb	Lester Bolen	Dr	152.0	18	S	do	do	T, B	I	76.90	6-13-58	3,530.9	Reported yield 1,000.
15-38-6cdc	H. Bolen	Dr	105.0	5½	GI	do	do	Cy, W	N	89.06	6-14-51	3,548.0	
										90.15	9-23-57		
†15-38-7bbb	L. W. Pilger	Dr	178.0	16	S	do	do	T, B	I	91.62	9-25-57	3,551.4	Reported yield 650.
										90.55	6-17-58		
†15-38-8bbb	Harlon Bogenhagen	Dr	148.0	16	S	do	do	T, B	I	90.71	9-25-57	3,531.9	Reported yield 530.
										77.87	6-17-58		
15-38-9bbb	Clarence Bolen	Dr	93.5	5½	GI	do	do	Cy, W	N	74.20	6-14-51	3,522.6	
										74.95	9-23-57		
†15-38-10cbd	Fredrik Hedstrom	Dr	116.0	16	S	do	do	T, B	I	82.65	6-23-58	3,511.4	Reported yield 225.
†15-38-14ccd	O. E. Young	Dr	150.0	18	S	do	do	T, B	I	72.97	6-14-58	3,485.9	Reported yield 550.
15-38-15bbb	School District	Dr	93.5	6	GI	do	do	Cy, H	N	82.31	6-14-51	3,510.0	
										83.11	9-25-57		
15-38-20cbb	F. T. Pilger	Dr	93.5	5½	GI	do	do	N	N	89.17	6-14-51	3,531.5	
										92.00	7-11-58		
†15-38-20dba	Clarence Bolen	Dr	187.0	18	S	do	do	T, B	I	93.50	10- 7-57	3,517.8	Reported yield 1,000.
										88.90	6-18-58		
†15-38-21cbc	G. E. Shields	Dr	180.0	18	S	do	do	T, B	I	90.60	10- 7-57	3,513.2	Do.
										85.88	6-17-58		
15-38-21cdd	do	Dr	97.0	6	GI	do	do	Cy, W	N	79.63	6-14-51	3,508.5	
										84.68	9-25-57		
15-38-26bcc	E. M. & G. A. Proffitt	Dr	98.0	6	GI	do	do	N	N	68.46	6-14-51	3,478.0	
										71.10	5-21-58		
†15-38-28bcc	J. J. Bauch	Dr	200.0	18	S	do	do	T, B	I	90	10- 7-57	3,511.7	Reported yield 1,800.
†15-38-28dbb	Selma Nelson	Dr	202.0	18	S	do	do	T, B	I	85.70	10- 7-60	3,502.0	Reported yield 1,450.
†15-38-29abc	Leigh Post	Dr	198.0	18	S	do	do	T, B	I	83	10- 7-57	3,520.2	Reported yield 1,200.
*†15-38-30ccb	John Larson	Dr	232.0	16	S	do	do	T, B	I	95	10- 7-60	3,538.6	Reported yield 2,000.
15-38-31cda	C. L. Reimer	Dr	61.0	6	GI	do	do	Cy, H	N	48.19	5-20-51	3,488.9	
										49.50	9-20-57		
†15-38-32baa	John Lake	Dr	235.0	16	S	do	do	T, B	I	96.32	10- 4-57	3,522.8	Reported yield 1,800.
										93.60	6-18-58		
†15-38-32dbb	C. L. Reimer	Dr	230.0	18	S	do	do	T, B	I	83	10- 4-57	3,511.7	Do.
†15-38-33cbb	Lloyd Brown	Dr	225.0	18	S	do	do	T, B	I	80	10- 4-57	3,505.5	Reported yield 1,600

*†15-38-34cbc	Harold Brown	Dr	214.0	18	S	do	do	T, B	I	78	10- 7-57	3,491.6	Reported yield 1,000.
†15-38-36cbb	E. L. Brown	Dr	153.0	16	S	do	do	T, B	I	70.81	6-19-58	3,461.4	Do.
*†15-39-1ccc	C. A. Myers	Dr	180.0			do	do	T, B	I			3,569.0	Reported yield 700.
15-39-2bcc	Frazier Farms	Dr	121.5	6	GI	do	do	Cy, N	N	108.98	7- 2-51	3,587.0	
										109.29	9-23-57		
†15-39-2bcd	do	Dr	195.0	30	C	do	do	T, B	I	112.22	6-23-58	3,584.6	Reported yield 700.
†15-39-2cca	do	Dr	204.0	30	C	do	do	T, B	I	110.14	6-23-58	3,582.0	Reported yield 850.
15-39-4abb	Marvin Sides	Dr	133.0	6	GI	do	do	Cy, E	D, S	111.20	10- 8-60	3,602.1	
15-39-5bcc	William Pletcher	Dr		16	S	do	do	T, B	I	109.62	10-11-60	3,618.2	
†15-39-5ccc	do	Dr	227.0	18	S	do	do	T, B	I	114.01	10- 2-57	3,622.4	Reported yield 800.
										110.40	6-17-58		
15-39-6cad	H. & F. Theis	Dr	220	18	S	do	do	T, D	I	98.07	7-20-51	3,617.0	Cannot be measured; new pump base; reported yield 1,200.
†15-39-7dab	William Mai	Dr	239.0	18	S	do	do	T, B	I	119.28	10- 2-57	3,637.2	Reported yield 2,000.
										117.51	6-18-58		
†15-39-8acc	do	Dr	222.0	18	S	do	do	T, D	I	113.24	7-16-51	3,615.5	Reported yield 1,000.
										115.90	6-18-58		
15-39-10daa	H. L. Wieland	Dr	136.0	6	GI	do	do	Cy, W	S	98.38	7- 2-51	3,579.5	
										98.86	9-23-57		
*15-39-11bbb	D. M. Washburn	Dr	130	6	GI	do	do	Cy, W	S				
†15-39-12abb	Lester Bolen	Dr	180.0			do	do	T, B	I	100	10- 7-60	3,558.1	
15-39-12bdc	Frazier Farms	Dr				do	do	T, B	I				
15-39-16bbb	do	Dr	125.0	5½	GI	do	do	Cy, G	S	111.98	10-10-60	3,609.5	
*†15-39-20dab	Frank Mangold	Dr	228.0	16	S	do	do	T, B	I	102	10- 7-57	3,601.1	Reported yield 1,600.
†15-39-23cbc1	G. W. Holland	Dr	234.0	18	S	do	do	T, D	I	100	10- 3-57	3,571.3	Aquifer test using well.
†15-39-23cbc2	do	Dr	130.0	1¼	P	do	do	N	O	98.66	8-13-60		
†15-39-24bbc	C. A. Myers	Dr	218.0	16	S	do	do	T, D	I	101.63	6-13-58	3,561.5	Reported yield 1,000.
†15-39-24cbb	do	Dr	218.0	16	S	do	do	T, D	I	100	6-13-58	3,559.1	Do.
*†15-39-25bbb	John Larson	Dr	227.0	18	S	do	do	T, B	I	98.28	10- 3-57	3,555.7	Reported yield 1,200.
										94.65	6-18-58		
†15-39-26acc	do	Dr	239.0	16	S	do	do	T, B	I	98.93	10- 7-60	3,561.6	Reported yield 1,800.
15-39-26bbb	Elva Hinds	Dr	92.0	6	GI	do	do	N	N	89.91	7- 2-51	3,567.3	
										dry	9-20-57		
†15-39-28bbd	Roy Mangold	Dr	200.0	16	S	do	do	T, B	I	65.32	6-18-58	3,564.9	Reported yield 1,200.
15-39-29aaa	H. C. Wilson	Dr	67.5	6	GI	do	do	N	N	64.43	7- 2-51	3,571.6	
										65.15	6-18-58		
15-39-32ccd	Oscar Bearce	Dr	87.0	6	GI	do	do	Cy, W	S	81.36	7- 2-51	3,583.7	
										81.00	5-22-58		
15-40-2bbb	C. Popp	Dr	112.0	5	GI	do	do	Cy, H	O	86.81	6-25-58	3,642.9	
15-40-3bab	J. C. Heise	Dr	254	16	S	do	do	T, B	I	75.37	10- 9-57	3,636.3	Reported yield 1,400.
										74.56	6-19-58		
15-40-4cdd	Heise & Heise	Dr	93.4	6	GI	do	do	Cy, W	N	91.68	7-13-51	3,659.3	
										89.53	9-19-57		
†15-40-7bbb	J. C. Heise	Dr	260.0	16	S	do	do	T, B	I	108	6-12-58	3,706.2	Reported yield 1,200.
15-40-8adc	C. M. Patterson	Dr	87.0	5½	GI	do	do	N	N	83.65	10-12-60	3,661.4	
15-40-12daa	I. M. Bricker	Dr	232	18	S	do	do	T, D	I	105.50	7-16-51	3,628.5	Reported yield 1,200.
										107.10	6-17-58		
†15-40-13baa	Henry Klinge	Dr	242.0	16	S	do	do	T, B	I	101.36	6-18-58	3,641.6	Reported yield 1,250.
15-40-15daa	J. C. Heise	Dr	101.0	6	GI	do	do	Cy, H	N	82.16	7- 2-51	3,640.7	
										83.35	9-19-57		
15-40-18ccc	R. Sterrett	Dr	118.0	5½	GI	do	do	Cy, W	D, S	103.95	10-12-60	3,692.6	
*†15-40-19acb	Ralph Kuehler	Dr	265.0	16	S	do	do	T, D	I	110	6-24-58	3,695.1	Reported yield 1,500.
15-40-20aba1	W. H. McNeil	Dr	115.0			do	do	N	N	103.60	7-13-51	3,681.7	Well has been destroyed.
15-40-20aba2	do	Dr	235	16	S	do	do	T, D	I				Reported yield 1,200.
15-40-22dda	William Mai	Dr	98.5	6	GI	do	do	Cy, W	S	88.02	7- 2-51	3,641.0	
										88.89	5-16-58		
15-40-23bbb	School District	Dr	80.5	6	GI	do	do	N	N	76.97	5-18-48	3,634.8	Well has been destroyed.
										75.82	4-10-52		
15-40-24bbb	Henry Klinge	Dr	97.0	6	GI	do	do	Cy, H	N	59.27	7- 2-51	3,609.0	
										59.56	9-19-57		
*15-40-27dcc	William Mai	Dr	88.0	5½	GI	do	do	Cy, W	S	68.95	10-11-60	3,628.4	

TABLE 11.—Records of wells in Wallace County—*Concluded.*

Well (1)	Owner or tenant	Type of well (2)	Depth of well, feet (3)	Diameter of well, inches	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (5)	Use of water (6)	Depth to water level below land surface, feet (7)	Date of measurement	Altitude of land surface above mean sea level, feet	Remarks (Yield given in gallons a minute; drawdown in feet)
†15-40-30dbb	Keith Niswanger	Dr	265.0	16	S	Sand, gravel	Ogallala Formation	T, D	I	111.40	10- 7-60	3,694.3	Reported yield 1,500.
15-40-31bcc	Harry Voth	Dr	265			do	do	T, B	I	110.45	10- 7-60	3,694.7	Do.
15-40-32aaa	E. M. Shuman	Dr	115.5	6	GI	do	do	Cy, W	N	93.00	7-13-51	3,656.5	
										95.40	9-19-57		
15-40-32bda	do	Dr	176	18	S	do	do	T, B	I	105.59	10- 9-57	3,679.8	Reported yield 1,250.
										103.32	6-23-58		
15-40-35dad	Ethel Burnett	Dr	92.8	6	S	do	do	Cy, W	S	59.69	7-16-51	3,600.5	
										59.44	9-24-57		
15-41-2aaa1	H. R. Lewis	Dr	177.0	5	GI	do	do	Cy, W	D, S	157.20	7-24-58	3,762.5	
•15-41-5acb	Fred Mignerey	Dr	235	16	S	do	do	T, B	I	145.03	6-11-58	3,794.5	Reported yield 800.
15-41-6add	Herman Gebhards	Dr	148.0	5½	GI	do	do	Cy, W	D, S	128.85	7-13-51	3,792.5	
										131.26	9-13-57		
†15-41-10bab	G. A. Branberg	Dr	264.0	16	S	do	do	T, D	I	161.16	6-11-58	3,787.3	Reported yield 1,500.
15-41-10bba	do	Dr	165	5	GI	do	do	Cy, W	D, S	151.24	6-11-58	3,778.0	
15-41-12daa	Fred Klaassen	Dr	120.0	5½	GI	do	do	N	N	107.69	7-17-51	3,694.2	
										109.24	9-19-57		
15-41-14cac	F. H. Barstow	Dr	116.0	5½	GI	do	do	Cy, W	S	99.30	7-17-51	3,707.8	
										98.93	5-22-58		
15-41-18caa	C. A. Westerberg	Dr	156	5½	GI	do	do	Cy, W	S	144.50	9-13-57	3,794.9	
15-41-21bab	W. H. Akers	Dr	142.0	5½	GI	do	do	Cy, W	S	137.33	7-13-51	3,758.5	
										136.85	5-19-58		
15-41-25aaa	Ethel Akers	Dr	131.0	5½	GI	do	do	Cy, W	S	108.77	7-17-51	3,698.1	
										110.86	9-17-57		
15-41-27acc	N. & H. Smith Estate	Dr	257	16	S	do	do	T, B	I	148.80	7-12-58	3,753.0	Reported yield 1,200.
15-41-28cdd	Dale Simonson	Dr	171.0	5	GI	do	do	Cy, W	S	149.31	9-13-51	3,760.6	
										148.37	5-22-58		
15-41-28dca	do	Dr	270	16	S	do	do	T, B	I	160	7-12-58		Reported yield 1,000.
•†15-41-32aca	Laverne Kuder	Dr	254.0	18	S	do	do	T, B	I	160	7-12-58	3,777.8	Reported yield 1,400.
15-41-36ddb	F. R. Potter	Dr	123.0	6	GI	do	do	N	N	103.52	7-13-51	3,691.8	Well has been destroyed.
15-42-2bbb	W. H. Charles	Dr	225	18	S	do	do	T, B	I	153	10- 8-57	3,852.2	Reported yield 900.
15-42-2cbc	do	Dr	156.0	6	GI	do	do	Cy, W	D, S	151.23	7-13-51	3,841.7	
										153.01	9-13-57		
15-42-16adc	Alvin Goering	Dr	163.0	6	GI	do	do	Cy, W	N	153.10	7-13-51	3,863.2	Shale reported at 166 feet.
										153.12	5-20-58		
15-42-30bcc	M. Miller	Dr		6	GI	do	do	Cy, W	S	197.97	7-18-51	3,902.8	
15-42-32abb	W. T. Miller	Dr	200	6	GI	do	do	Cy, W	S	192.30	7- 9-58	3,862.2	
15-42-34bcd	do	Dr	225.0	5½	GI	do	do	Cy, W	S	199.11	7-18-51	3,847.4	
										199.65	5-20-58		
15-42-36cdc	W. O. Smothermon	Dr	270			do	do	T, D	I	193.93	4- 3-51	3,843.9	Reported yield 1,200.
										214.76	10- 7-57		
										210.59	6-23-58		
•15-43-12dda	Elmer Akers	Dr	218.0	6	GI	do	do	Cy, W	D	206.35	7-13-51	3,922.9	
										205.88	9-12-57		
16-38-2abb	H. C. Wines	Dr	87.0	6	GI	do	do	Cy, W	D	64.10	7- 8-48	3,432.6	In Wichita County; well has been destroyed.
16-38-5bcd	Mary Johnson	Dr		6	GI	do	do	Cy, W	S	70.55	5-20-51	3,474.1	In Wichita County.
16-39-1bdc	J. F. Weaver	Dr		6	GI	do	Alluvium	Cy, W	S	13.55	5-20-51	3,434.5	In Greeley County.
16-39-3daa	do	Dr	100.0	6	GI	do	Ogallala Formation	N	N	72.91	5-20-51	3,512.4	Do.
16-39-4ada	do	Dr	75.5	6	GI	do	do	Cy, W	N	62.29	5-20-51	3,517.4	Do.
										61.60	7-18-58		
16-39-6ebb	E. Bates	Dr	68.0	6	GI	do	do	Cy, W	S	42.37	5-28-51	3,539.4	Do.

16-40-2cba	A. Sell	Dr	51.5	6	GI	do	do	N	N	38.12	7-13-51	3,567.0	Do.
16-40-2dad	T. M. Boulware	Dr	53.2	6	GI	do	do	Cy, W	S	35.72	7-22-47	3,550.1	Do.
										36.09	5-28-51		
16-40-6bbb	H. Hoffman	Dr	112.0	6	GI	do	do	N	N	102.83	7-13-51	3,672.2	Do.
16-41-5caa	R. Murphy	Dr	135.7	6	GI	do	do	Cy, W	S	118.0	7-22-48	3,741.0	Do.
16-42-6aaa	E. K. Beedy	Dr	181.5	6	GI	do	do	N	N	178.0	7-30-48	3,836.5	Do.; well has been destroyed.
C 14-41-19adb		Dr	182.0	6	GI	do	do	Cy, W	N	166.23	7-13-51	3,899.3	In Colorado.

* Chemical analysis given in Table 7.
† Drillers log given at back of report.
(1) Well-numbering system described in text.
(2) B, bored well; Dr, drilled well; Du, dug well.
(3) Measured depths of wells given in feet and tenths below land surface; reported depth given in feet.
(4) B, brick; C, concrete; GI, galvanized sheet iron; N, none; P, pipe; R, rock; S, steel.
(5) Method of lift: C, centrifugal; Cy, cylinder; J, jet; N, none; T, turbine.
Type of power: B, butane engine; D, diesel engine; E, electric motor; G, gasoline engine; H, hand operated; N, none; T, tractor; W, windmill.
(6) D, domestic; I, irrigation; N, none; O, observation; P, public; S, stock.
(7) Measured depths to water level given in feet, tenths, and hundredths; reported depths given in feet.

and unconsolidated material overlie the bedrock and thus serve as local catchment basins. In periods of ample rainfall these wells generally prove adequate for most domestic or stock use. During extended periods of dry weather, however, the water drains from many of these deposits and wells tend to become dry.

Because ground water in these deposits is generally in contact with the underlying Cretaceous bedrock and with bedrock fragments that are incorporated within the deposits, the water obtained from these wells is generally of inferior chemical quality (Fig. 20).

Alluvium

CHARACTER.—Alluvium believed to be of late Wisconsinan and Recent age occurs in narrow belts along the principal streams in the county. Thick, coarse alluvial deposits of sand and gravel are restricted to the larger valleys and are derived mostly by erosion of older alluvial deposits and the Ogallala Formation. Thin, poorly-sorted deposits of alluvium lie in the smaller valleys and contain relatively less coarse material, the deposits being predominantly silt and fine sand. These deposits grade headward into colluvium and slope deposits at the edge of the uplands. Their lithology depends chiefly upon the type of rock into which the valley has been incised.

In the South Smoky Hill Valley, the alluvium that underlies the braided stream channel and the narrow floodplain is considered to be Recent in age. Low, relatively narrow terraces, believed to be late Wisconsinan in age, border the floodplain. Although the narrow Recent floodplain and the low terraces are best developed along South Smoky Hill Valley, they are also found to a lesser extent along most of the other principal streams. The alluvium of Recent age and the alluvial deposits of late Wisconsinan age underlying the low terraces are lithologically indistinguishable and are shown together as alluvium on Plate 1.

DISTRIBUTION AND THICKNESS.—Alluvium occurs in narrow belts along the principal valleys. The width and thickness of the alluvium are greatest along the South Smoky Hill Valley, where the alluvium reaches a maximum width of about a mile, averaging about half a mile, and a maximum thickness of 70 feet in the central and eastern parts of the county. Alluvium in the valleys of the North Smoky Hill River and Lake Creek is 40 to 50 feet thick. Alluvium in the smaller valleys is thin and of narrow extent, and headward these deposits grade into colluvium and slope wash.

WATER SUPPLY.—Alluvial deposits constitute an important source of water in parts of Wallace County where other ground-water supplies are meager or not available. Many domestic and stock wells obtain water from the alluvium, and several irrigation wells obtain water from alluvium along the South Smoky Hill Valley. One irrigation well obtains water from alluvium in the North Smoky Hill Valley and one irrigation plant obtains water from alluvium in the Goose Creek valley.

Moderate to moderately large yields of water can be expected from wells in alluvium along the South Smoky Hill Valley. The areal extent of the alluvium is not great, however, averaging only about half a mile in width. Ground-water yields from wells in alluvium in the smaller valleys can be expected to be considerably less than from those in the larger valleys, because of the finer, less permeable material in the smaller valleys. Since the cross-sectional areas of the smaller valleys also are less, water levels tend to fluctuate more in response to rainfall. Declining water levels, with subsequent drying up of wells in the smaller valleys and upland draws, can be expected during extended periods of below-normal rainfall. In addition, because of the relatively shallow depth to water in the alluvium, transpiration by deep-rooted plants during the growing season often results in a decline of water levels.

RECORDS OF WELLS

Information on 294 inventoried wells in Wallace County and adjoining areas is given in Table 11 (see p. 52). Measured well depths are given to the nearest tenth of a foot; reported depths are given in feet. Measured depths to water are given to the nearest hundredth of a foot; reported depths are given in feet. The well-numbering system used in this table is described on page 9 and illustrated in Figure 2.

LOGS OF TEST HOLES AND WELLS

Listed on the following pages are logs of 190 test holes and wells in Wallace County and adjoining areas. Of these test holes, 70 are drilled, 31 are augered, and 4 are jetted, all by the State Geological Survey of Kansas. Also included are drillers logs of 51 irrigation wells, 32 seismograph shot-holes, 1 domestic well, and 1 test hole. Logs designated "sample logs" describe test holes from which samples were collected. The logs are numbered according to the well-numbering system illustrated in Figure 2. Locations of wells and test holes are shown on Plate 1. Plate 2 illustrates the character of material penetrated by the test holes. Water-level measurements are stated in feet below land surface.

10-37-32ccc.—Sample log of test hole in SW SW SW sec. 32, T. 10 S., R. 37 W., Sherman County (Prescott, 1953, p. 118); drilled August 1949. Altitude of land surface, 3,307.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, dark brown	9	9
Silt, light brown; contains snail shells; sandy 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 cemented layers from 60 to 70 feet	14	70
Sand, fine to coarse, and fine gravel; contains a little medium to coarse gravel	10	80
Sand, fine to coarse; contains cemented layers of sand and gravel	17	97
Mortar bed	5	102
Sand, medium to coarse; contains a little gravel; partially cemented	6	108
Sand, fine to medium	4	112
Gravel, medium to coarse	4	116
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, light gray to red brown	4	120
Shale, light gray	3	123
Shale, dark blue	7	130

10-40-36ddd.—Sample log of test hole in SE SE SE sec. 36, T. 10 S., R. 40 W., Sherman County (Prescott, 1953, p. 121); drilled September 1949. Altitude of land surface, 3,721.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, dark brown	1	1
Silt, tan	24	25
Silt, red 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, fine to coarse, and coarse sand; contains some pebbles 1 inch in diameter,	12	52
Clay and silt, gray	13	65
Clay and silt, white	2	67
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Clay, yellow brown and greenish	3	70
Shale, yellow brown	10	80

10-42-36ccc.—Sample log of test hole in SW SW SW sec. 36, T. 10 S., R. 42 W., Sherman County (Prescott, 1953, p. 124); drilled September 1949. Altitude of land surface, 3,868.8 feet; depth to water 36.7 feet, October 1, 1949.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
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

	Thickness, feet	Depth, feet
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, fine to coarse, 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 a little medium to coarse gravel and yellow clay	26	126
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, yellow brown to light gray	14	140

11-38-13aaa.—Sample log of test hole in NE NE NE sec. 13, T. 11 S., R. 38 W., 50 feet south of NE cor. sec. 13; drilled August 1960. Altitude of land surface, 3,376.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, brown	10	10
Silt, sandy, brown	10	20
Silt, sandy, light tan	10	30
TERTIARY—Pliocene		
Ogallala Formation		
Silt, sandy, limy	12	42
Sand, fine to very coarse, and small amount fine gravel; contains thin layer cemented limy silt	8	50
Silt, very sandy, and fine to coarse sand; contains cemented streaks	10	60
Silt, limy; contains thin layers of sand	32	92
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, brown and light gray	8	100

11-38-15ccc.—Sample log of test hole in SW SW SW sec. 15, T. 11 S., R. 38 W., 25 feet NE of SW cor. sec. 15; drilled August 1960. Altitude of land surface, 3,482.3 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, brown	5	5
Silt, sandy, light brown	12	17
TERTIARY—Pliocene		
Ogallala Formation		
Silt, sandy, limy, light tan	6	23
Sand, fine to very coarse; contains thin layers of sandy silt	12	35
Sand, fine to medium, loose	15	50
Sand, medium to coarse, clean, well sorted, loose	10	60
Sand, medium to coarse and fine gravel, loose	10	70
Sand, medium to very coarse, and fine to medium gravel, loose	11	81
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, brown and light gray	9	90

11-38-18ccc.—Sample log of test hole in SW SW SW sec. 18, T. 11 S., R. 38 W., 35 feet east and 25 feet north of SW cor. sec. 18; drilled October 1957. Altitude of land surface, 3,431.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, sandy, loose, brown	14	14
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, gray	6	20

11-38-23bbb.—Log of test hole in NW NW NW sec. 23, T. 11 S., R. 38 W.; 40 feet SE of NW cor. sec. 23; augered July 1958. Altitude of land surface, 3,445.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, eolian, tan	16	16
Silt, very sandy, tan	2	18
TERTIARY—Pliocene		
Ogallala Formation		
Sand, fine to coarse; contains cemented layers	2	20
Sand, fine to medium	2	22
Silt, sandy, limy; contains cemented layers	4	26
Silt, very sandy, tough	9	35
Sand, very silty; contains cemented layers	14	49

11-38-25ddd.—Log of test hole in SE SE SE sec. 25, T. 11 S., R. 38 W., 40 feet NW of SE cor. sec. 25; augered July 1958. Altitude of land surface, 3,441.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, eolian, tan	10	10
TERTIARY—Pliocene		
Ogallala Formation		
Sand, medium to coarse	5	15
Sand, fine to medium	3	18
Silt, clayey, tan	3	21
Sand, medium to very coarse, clean	4	25
Sand, fine to very coarse; contains thin layers of sandy silt,	3	28
Gravel, fine to coarse	2	30
Sand, medium to coarse, cemented	2	32

	Thickness, feet	Depth, feet
Sand, fine to coarse	10	42
Sand, fine to medium; contains thin layers of silt	4	46
Silt, sandy, tan	4	50
Gravel, medium to very coarse,	5	55
Sand, fine to medium; contains thin layers of silt	2	57
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, weathered, brown and gray	12	69

11-39-1ccc.—Sample log of test hole in SW SW SW sec. 1, T. 11 S., R. 39 W., 75 feet NE of SW cor. sec. 1; drilled August 1960. Altitude of land surface, 3,562.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, brown	10	10
Silt, sandy, light brown	10	20
Silt, slightly sandy, light brown,	10	30
TERTIARY—Pliocene		
Ogallala Formation		
Silt, sandy; contains limy streaks	5	35
Silt, clayey, very limy; contains streaks of bentonite	20	55
Sand, fine to coarse; contains streaks of limy silt	5	60
Sand, fine to medium, well sorted	8	68
Sand, medium to very coarse; upper part contains thin layers of silt	12	80
Sand, medium to very coarse, and fine gravel, clean, loose,	20	100
Sand, fine to coarse; contains small amount fine to medium gravel	10	110
Sand, fine to very coarse, and fine gravel; lower part contains streaks of limy silt	10	120
Sand, medium to very coarse, clean, loose	29	149
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, brown and gray	11	160

11-39-6ccc.—Sample log of test hole in SW SW SW sec. 6, T. 11 S., R. 39 W., near edge of road near sec. line; drilled August 1960. Altitude of land surface, 3,640.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, light brown	8	8
Silt, very sandy, light tan	12	20
Silt, sandy, tan	8	28
TERTIARY—Pliocene		
Ogallala Formation		
Silt, very limy, light gray	4	32
Silt, very limy, light tan; contains thin layers of sand	11	43

	Thickness, feet	Depth, feet
Sand, medium to very coarse, and fine to medium gravel, loose	12	55
Silt, sandy, light tan	3	58
Sand, fine to very coarse, and fine gravel; contains cemented streaks	12	70
Gravel, fine to medium, and very coarse sand; contains cemented layers	9	79
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, brown and gray	6	85

11-39-9abb.—Log of test hole in NW NW NE sec. 9, T. 11 S., R. 39 W., 0.4 mile west near edge of road; augered July 1958. Altitude of land surface, 3,523.2 feet; depth to water, 20.0 feet, July 1, 1958.

	Thickness, feet	Depth, feet
TERTIARY—Pliocene		
Ogallala Formation		
Silt, sandy, red brown	3	3
Silt, very sandy, light tan	4	7
Gravel, medium to coarse	3	10
Sand, fine to coarse	10	20
Sand, fine to coarse, and medium gravel	7	27
Silt, very sandy	8	35
Sand, fine to coarse, silty	7	42
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, brown and gray	17	59

11-39-18cbb.—Drillers log of shothole in NW NW SW sec. 18, T. 11 S., R. 39 W.; drilled by Phillips Petroleum Co., 1957. Altitude of land surface, 3,601 feet.

	Thickness, feet	Depth, feet
Pleistocene and Pliocene (undifferentiated)		
Surface silt	4	4
Sand and gravel	71	75
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Clay, yellow	15	90

11-39-31baa.—Drillers log of shothole in NE NE NW sec. 31, T. 11 S., R. 39 W.; drilled by Phillips Petroleum Co., 1957. Altitude of land surface, 3,533 feet.

	Thickness, feet	Depth, feet
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, brown	30	30

11-40-9add.—Drillers log of shothole in SE SE NE sec. 9, T. 11 S., R. 40 W.; drilled by Phillips Petroleum Co., 1957. Altitude of land surface, 3,660 feet.

	Thickness, feet	Depth, feet
Pleistocene and Pliocene (undifferentiated)		
Surface silt	10	10
Silt, brown and red	75	85
Sand and gravel	115	200

CRETACEOUS—Upper Cretaceous Pierre Shale	Thickness, feet	Depth, feet
Clay, yellow	5	205
Blind	20	225

11-40-15ddd2.—Sample log of test hole in SE SE SE sec. 15, T. 11 S., R. 40 W., 60 feet south of SE cor. of schoolhouse; drilled October 1957. Altitude of land surface, 3,560.2 feet; depth to water, 38.22 feet, November 2, 1957.

TERTIARY—Pliocene Ogallala Formation	Thickness, feet	Depth, feet
Silt, sandy, red brown	4	4
Sand, fine to coarse, loose	4	8
Sand, fine to medium; contains layers of limy silt	7	15
Sand, fine to coarse, silty	10	25
Silt, sandy, tan	9	34
Sand, medium, clean	5	39
Silt, clayey, gray	2	41
Gravel, fine, and very coarse sand, clean	4	45
Silt, sandy, limy, light tan	3	48
Sand, medium to coarse, gray and brown	9	57
Silt, sandy, tan	8	65
Silt, sandy, very limy, gray and light tan	9	74
Sand, fine to coarse; contains thin layers of limy silt	14	88
Gravel, fine to medium	9	97
Silt, sandy, light tan; contains limy cemented streaks	22	119
Sand, medium to very coarse; contains fine gravel in lower part	18	137
CRETACEOUS—Upper Cretaceous Pierre Shale		
Shale, gray and brown; upper 9 feet silicified, hard	13	150

11-40-17ddd.—Sample log of test hole in SE SE SE sec. 17, T. 11 S., R. 40 W., 50 feet north and 30 feet west of SE cor. sec. 17; drilled August 1960. Altitude of land surface, 3,644.3 feet.

QUATERNARY—Pleistocene Peoria and Loveland Formations	Thickness, feet	Depth, feet
Silt, brown	10	10
Silt, sandy, tan	10	20
CRETACEOUS—Upper Cretaceous Pierre Shale		
Shale, brown and gray	10	30

11-40-21cbb.—Drillers log of shothole in NW NW SW sec. 21, T. 11 S., R. 40 W.; drilled by Phillips Petroleum Co., 1957. Altitude of land surface, 3,631 feet.

Pleistocene and Pliocene (undifferentiated)	Thickness, feet	Depth, feet
Surface silt	4	4
Sand	66	70
Silt, clayey, red	70	140

CRETACEOUS—Upper Cretaceous Pierre Shale	Thickness, feet	Depth, feet
Clay, yellow	35	175

11-40-26bbb.—Log of test hole in NW NW NW sec. 26, T. 11 S., R. 40 W., 50 feet east of highway and 15 feet south of farm driveway; augered July 1958. Altitude of land surface, 3,575.7 feet.

QUATERNARY—Pleistocene Peoria and Loveland Formations	Thickness, feet	Depth, feet
Silt, sandy, tan	4	4
TERTIARY—Pliocene Ogallala Formation		
Sand, fine to coarse, and fine to medium gravel	10	14
Gravel, cemented, hard	10	24

11-40-26bcb.—Log of test hole in NW SW NW sec. 26, T. 11 S., R. 40 W., 0.3 mile south of sec. line and 200 feet east of highway; augered July 1958. Altitude of land surface, 3,525.1 feet; depth to water, 10.90 feet, July 2, 1958.

QUATERNARY—Pleistocene Alluvium	Thickness, feet	Depth, feet
Silt, sandy, light tan	2	2
Sand, fine to coarse, and fine gravel	8	10
Sand, fine to very coarse, and fine to medium gravel	6	16
TERTIARY—Pliocene Ogallala Formation		
Sand, medium to coarse, wet,	9	25
Sand, fine to coarse, silty	16	41
Silt, sandy, tough	2	43
Sand, fine to coarse, silty	7	50
Silt, very sandy, tan	15	65
CRETACEOUS—Upper Cretaceous Pierre Shale		
Shale, gray and brown	4	69

11-40-26cbb.—Log of test hole in NW NW SW sec. 26, T. 11 S., R. 40 W., 0.45 mile north of sec. line and 50 feet east of highway; augered July 1958. Altitude of land surface, 3,532.7 feet; depth to water, 15.80 feet, July 2, 1958.

QUATERNARY—Pleistocene Alluvium	Thickness, feet	Depth, feet
Silt, sandy, brown	10	10
Sand, fine to medium	5	15
Sand, medium to coarse, clean	3	18
Silt, sandy, tan	2	20
Gravel, medium to coarse	4	24
TERTIARY—Pliocene Ogallala Formation		
Sand, fine to coarse, very silty,	6	30
Silt, very sandy	5	35
Silt, tough, brown	5	40
Sand, fine to coarse	7	47
Silt, sandy, brown	21	68
CRETACEOUS—Upper Cretaceous Pierre Shale		
Shale, tough, tan and brown	1	69

11-40-29cdd.—Drillers log of shothole in SE SE SW sec. 29, T. 11 S., R. 40 W.; drilled by Phillips Petroleum Co., 1957. Altitude of land surface, 3,662 feet.

Pleistocene and Pliocene (undifferentiated)	Thickness, feet	Depth, feet
Sand and red silt	75	75
Sand	55	130
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Clay, yellow	40	170

11-40-34ddd.—Sample log of test hole in SE SE SE sec. 34, T. 11 S., R. 40 W., 35 feet north and 25 feet west of SE cor. sec. 34; drilled August 1960. Altitude of land surface, 3,704.0 feet.

QUATERNARY—Pleistocene Peoria and Loveland Formations	Thickness, feet	Depth, feet
Silt, brown	8	8
Silt, sandy, light tan	12	20
Silt, very sandy, tan	3	23
TERTIARY—Pliocene		
Ogallala Formation		
Silt, very limy, sandy	7	30
Sand, medium to very coarse, and fine gravel, clean	18	48
Silt, clayey, light tan	6	54
Sand, medium to very coarse, and fine gravel, clean loose,	16	70
Sand, medium to very coarse, well sorted, loose	10	80
Silt, sandy, light tan	4	84
Sand, medium to very coarse, and fine gravel	16	100
Sand, fine to coarse; contains hard cemented streaks	15	115
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, brown and dark gray	15	130

11-41-24add.—Drillers log of domestic well in SE SE NE sec. 24, T. 11 S., R. 41 W.; drilled by Kenneth Bogart, July 1957. Altitude of land surface, 3,691.2 feet; depth to water, 47.33 feet, July 29, 1957.

QUATERNARY—Pleistocene Peoria and Loveland Formations	Thickness, feet	Depth, feet
Silt	10	10
TERTIARY—Pliocene		
Ogallala Formation		
Silt, sandy; contains cemented layers	8	18
Sand, silty, red tan	10	28
Sand, fine to coarse; contains layers of sandy silt and cemented streaks	32	60
Silt, very limy, light gray	5	65
Sand, medium to coarse, and gravel	16	81
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Clay, yellow	8	89
Shale, brown and gray	2	91

11-41-24bbb.—Sample log of test hole in NW NW NW sec. 24, T. 11 S., R. 41 W., 45 feet south and 10 feet east of NW cor. sec. 24; drilled October 1957. Altitude of land surface, 3,742.1 feet; depth to water 65.43 feet, November 2, 1957.

QUATERNARY—Pleistocene Peoria and Loveland Formations	Thickness, feet	Depth, feet
Silt, loose, brown	10	10
Silt, light brown	14	24
TERTIARY—Pliocene		
Ogallala Formation		
Silt, sandy, cemented	7	31
Silt, sandy, very limy; contains cemented layers	11	42
Sand, fine to coarse; contains silt layers	23	65
Silt, sandy, limy, tan	9	74
Sand, fine to medium	4	78
Silt, sandy, gray	6	84
Sand, fine; contains layers of limy silt and cemented streaks	26	110
Silt, limy, cemented, hard, light gray	8	118
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, gray and brown	2	120

11-41-25ddd.—Sample log of test hole in SE SE SE sec. 25, T. 11 S., R. 41 W., 30 feet north and 20 feet west of SE cor. sec. 25; drilled August 1960. Altitude of land surface, 3,694.0 feet.

QUATERNARY—Pleistocene Peoria and Loveland Formations	Thickness, feet	Depth, feet
Silt, brown; contains streaks of sand in lower part	12	12
TERTIARY—Pliocene		
Ogallala Formation		
Silt, sandy, very limy, light gray	13	25
Silt, very sandy, tan	10	35
Silt, sandy, compact, rust tan	8	43
Sand, fine to coarse, silty	12	55
Sand, fine to medium; upper part contains thin layers of limy cemented streaks	7	62
Sand, fine to coarse; contains cemented streaks	11	73
Sand, fine, loose	7	80
Silt, very limy, cemented hard,	10	90
Sand, fine to coarse; contains layers of cemented limy silt,	10	100
Sand, very coarse, and fine gravel, clean	15	115
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, brown and light gray	10	125

11-42-5bab.—Sample log of test hole in NW NE NW sec. 5, T. 11 S., R. 42 W., 75 feet east of fence and 15 feet south of road center; drilled October 1957. Altitude of land surface, 3,933.6 feet; depth to water, 61.60 feet, November 4, 1957.

QUATERNARY—Pleistocene Peoria and Loveland Formations	Thickness, feet	Depth, feet
Silt, loose, brown	10	10

	Thickness, feet	Depth, feet
Silt, compact, light brown	10	20
TERTIARY—Pliocene		
Ogallala Formation		
Silt, sandy, limy, tan	7	27
Gravel, fine to medium, and very coarse sand, clean	16	43
Silt, sandy, tan	12	55
Silt, and fine sand; contains limy layers	6	61
Silt, sandy, limy; contains cemented layers, white and tan,	15	76
Sand, coarse to very coarse, and fine gravel, clean	14	90
Silt, and fine to medium sand; contains limy cemented layers	27	117
Sand, fine to coarse; contains thin silt layers	8	125
Silt, very limy, white and light gray; contains cemented layers in lower part	13	138
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, gray and brown	12	150

11-42-20bbc.—Sample log of test hole in SW NW NW sec. 20, T. 11 S., R. 42 W., 0.18 mile south and 12 feet east of NW cor. sec. 20; drilled October 1957. Altitude of land surface, 3,946.6 feet; depth to water, 76.15 feet, November 2, 1957.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, compact, light tan	8	8
Sand, fine to coarse, silty; contains caliche	9	17
TERTIARY—Pliocene		
Ogallala Formation		
Sand, medium to coarse, and fine gravel; contains layers of limy silt	11	28
Sand, fine, cemented, gray	9	37
Silt, limy, light gray	6	43
Sand, fine, cemented, gray	5	48
Gravel, fine to coarse, and fine sand	15	63
Sand, fine to coarse; contains layers of limy silt	15	78
Silt, sandy, cemented	2	80
Sand, coarse, and fine gravel	12	92
Silt, sandy, limy, yellow and tan; contains cemented layers	15	107
Sand, medium to coarse, clean,	19	126
Gravel, fine to medium, and coarse sand; contains layers of limy silt	6	132
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, greenish gray and tan	8	140

11-42-24aaa.—Sample log of test hole in NE NE NE sec. 24, T. 11 S., R. 42 W., 135 feet south and 5 feet west of NE cor. sec. 24; drilled October 1957. Altitude of land surface, 3,848.2 feet; depth to water, 48.22 feet, November 4, 1957.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, loose, brown; sandy in lower part	14	14
TERTIARY—Pliocene		
Ogallala Formation		
Silt, clayey, limy, light gray	6	20
Sand, fine to coarse, tan	15	35
Silt, very sandy, light tan; contains limy streaks	13	48
Silt, and fine to coarse sand; contains cemented layers	12	60
Gravel, fine to medium, and fine to coarse sand; contains limy silt layers and cemented streaks	8	68
Sand, coarse, and fine gravel, clean	20	88
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, gray and brown	2	90

11-42-29cbb.—Sample log of test hole in NW NW SW sec. 29, T. 11 S., R. 42 W., near edge of road near ½-mile line; drilled August 1960. Altitude of land surface, 3,931.9 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, brown	12	12
Silt, sandy, brown	11	23
TERTIARY—Pliocene		
Ogallala Formation		
Silt, sandy, very limy, light tan,	7	30
Sand, fine to very coarse	10	40
Sand, fine to very coarse; contains layers of cemented limy silt	20	60
Silt, limy, cemented; contains layers of fine to coarse sand,	10	70
Sand, medium to very coarse, clean, loose; contains small amount of fine gravel	8	78
Silt, sandy, limy; contains streaks of sand	12	90
Silt, sandy; contains thin layers of fine to coarse sand	10	100
Sand, medium to coarse, clean, loose	8	108
Clay, bentonitic, greenish gray,	7	115
Sand, fine to coarse; contains cemented streaks	9	124
Silt, very sandy, tight, reddish tan	21	145
Clay, bentonitic, greenish gray,	3	148
Silt, very sandy; contains cemented streaks and thin layers of fine to medium sand	12	160

	Thickness, feet	Depth, feet
Sand, fine to coarse; contains layers of sandy red-tan silt	10	170
Sand, fine to coarse; contains limy streaks and thin layers of sandy silt	13	183
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, brown and gray	17	200

12-38-10cdc.—Log of test hole in SW SE SW sec. 10, T. 12 S., R. 38 W., 250 feet south of Lake Creek near edge of farm road; augered June 1958. Altitude of land surface, 3,245.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Silt, sandy, brown	2	2
Sand, fine, silty	2	4
Sand, fine to medium, red tan	6	10
Silt, clayey, tough, gray tan	2	12
Sand, coarse, and fine gravel	5	17
Sand, fine to medium, silty, wet	8	25
Silt, very sandy, tan	10	35
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, blue gray	9	44

12-38-27aaa.—Log of test hole in NE NE NE sec. 27, T. 12 S., R. 38 W., 50 feet SW of NE cor. sec. 27; augered June 1958. Altitude of land surface, 3,286.3 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, loose, eolian, light tan	10	10
Silt, eolian, tan	10	20
Silt, compact, eolian, tan; sandy in lower part	8	28
Silt, clayey, tough, gray tan	4	32
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, weathered, gray	7	39

12-39-1abb.—Drillers log of shothole in NW NW NE sec. 1, T. 12 S., R. 39 W.; drilled by Phillips Petroleum Co., 1957. Altitude of land surface, 3,447 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Surface silt	4	4
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Clay, yellow	41	45

12-39-3cbb.—Drillers log of shothole in NW NW SW sec. 3, T. 12 S., R. 39 W.; drilled by Phillips Petroleum Co., 1957. Altitude of land surface, 3,550 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Surface silt	4	4
TERTIARY—Pliocene		
Ogallala Formation		
Sand	26	30
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Clay, yellow	15	45

12-39-12cdd.—Drillers log of shothole in SE SE SW sec. 12, T. 12 S., R. 39 W.; drilled by Phillips Petroleum Co., 1957. Altitude of land surface, 3,480 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Surface silt	4	4
TERTIARY—Pliocene		
Ogallala Formation		
Clay, sandy	21	25
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Clay, yellow	30	55

12-39-18add.—Drillers log of shothole in SE SE NE sec. 18, T. 12 S., R. 39 W.; drilled by Phillips Petroleum Co., 1957. Altitude of land surface, 3,553 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Sand	8	8
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, brown	62	70

12-39-22cdd.—Drillers log of shothole in SE SE SW sec. 22, T. 12 S., R. 39 W.; drilled by Phillips Petroleum Co., 1957. Altitude of land surface, 3,510 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Surface silt	4	4
TERTIARY—Pliocene		
Ogallala Formation		
Sand and clay	16	20
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Clay, yellow	30	50

12-40-2cdd.—Drillers log of shothole in SE SE SW sec. 2, T. 12 S., R. 40 W.; drilled by Phillips Petroleum Co., 1957. Altitude of land surface, 3,661 feet.

	Thickness, feet	Depth, feet
Pleistocene and Pliocene (undifferentiated)		
Surface silt	8	8
Silt, yellow	37	45
Sand	25	70
Blind	55	125
Sand	35	160
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Clay, yellow	5	165

12-40-15aaa.—Sample log of test hole in NE NE NE sec. 15, T. 12 S., R. 40 W., 50 feet west and 5 feet south of NE cor. sec. 15; drilled October 1957. Altitude of land surface, 3,672.6 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, sandy, light brown	7	7
Sand, fine to medium, silty, tan,	5	12
TERTIARY—Pliocene		
Ogallala Formation		
Gravel, fine to medium, and very coarse sand, clean	4	16
Silt, limy, gray	1	17
Sand, medium to coarse	13	30
Sand, medium to coarse; contains thin cemented silt layers	6	36
Sand, medium to very coarse	20	56
Sand, medium to very coarse; contains cemented silt layers,	11	67
Sand, fine to coarse, and interbedded layers of limy silt	6	73
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, gray and brown	7	80

12-40-23cbb.—Drillers log of shothole in NW NW SW sec. 23, T. 12 S., R. 40 W.; drilled by Phillips Petroleum Co., 1957. Altitude of land surface, 3,609 feet.

	Thickness, feet	Depth, feet
Pleistocene and Pliocene (undifferentiated)		
Surface silt	6	6
Sand	19	25
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, brown	35	60

12-41-11aad2.—Log of test hole in SE NE NE sec. 11, T. 12 S., R. 41 W., 120 feet north of Goose Creek near gate to farm driveway; augered July 1958. Altitude of land surface, 3,558.6 feet; depth to water, 10.55 feet, July 8, 1958.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Silt, sandy, brown	2	2
Sand, fine to coarse	8	10
Silt, sandy, tan	4	14
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, blue gray	5	19

12-41-11add.—Log of test hole in SE SE NE sec. 11, T. 12 S., R. 41 W., near ½-mile line near edge of road; augered July 1958. Altitude of land surface, 3,568.4 feet; depth to water, 15.0 feet, July 8, 1958.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Silt, sandy, tan	10	10
Silt, heavy, brown	5	15
Silt, sandy, wet, tan	10	25
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, blue gray	4	29

12-41-11dda.—Log of test hole in NE SE SE sec. 11, T. 12 S., R. 41 W., 20 feet west of road center near gate to pasture; augered July 1958. Altitude of land surface, 3,555.4 feet; depth to water, 15.83 feet, July 8, 1958.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, sandy, light tan	3	3
Silt, sandy, tan	9	12
Silt, brown	5	17
Silt, sandy, wet, tan	3	20
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, blue gray	4	24

12-41-12bbb.—Log of test hole in NW NW NW sec. 12, T. 12 S., R. 41 W., 20 feet east and 8 feet south of NW cor. sec. 12; augered July 1958. Altitude of land surface, 3,572.0 feet; depth to water, 15.0 feet, July 8, 1958.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Silt, light tan	10	10
Silt, tan	10	20
Silt, sandy	6	26
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, blue gray	3	29

12-41-18add.—Sample log of test hole in SE SE NE sec. 18, T. 12 S., R. 41 W., near edge of road about 25 feet north of ½-mile line; drilled August 1960. Altitude of land surface, 3,786.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, brown	5	5
Silt, sandy, brown	4	9
TERTIARY—Pliocene		
Ogallala Formation		
Sand, fine to very coarse; upper part contains streaks of limy silt	11	20
Sand, very coarse, and fine gravel; contains layers of cemented limy silt	12	32
Gravel, fine to medium, and very coarse sand, clean, loose,	10	42
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, brown and gray	18	60

12-41-23aaa.—Sample log of test hole in NE NE NE sec. 23, T. 12 S., R. 41 W., 70 feet west of road center and 15 feet south of fence; drilled October 1957. Altitude of land surface, 3,586.3 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, loose, brown	8	8
Silt, compact, light tan	7	15
Silt, clayey, light gray	10	25
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, gray and brown	10	35

12-42-5bbb.—Sample log of test hole in NW NW NW sec. 5, T. 12 S., R. 42 W., 80 feet east and 10 feet south of NW cor. sec. 5; drilled October 1957. Altitude of land surface, 3,940.4 feet; depth to water, 74.75 feet, November 2, 1957.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, tan	10	10
Silt, compact, light tan	10	20
TERTIARY—Pliocene		
Ogallala Formation		
Silt, limy, tan and light gray	10	30
Silt, sandy, limy, light tan	7	37
Sand, medium to coarse, and fine gravel	6	43
Silt, sandy, limy, tan and brown,	7	50
Silt and caliche, white and gray	6	56
Gravel, fine to medium, and very coarse sand	6	62
Silt, sandy; contains limy streaks	14	76
Sand, coarse, and fine gravel	12	88
Silt, sandy, tan, very limy 95 to 98 feet	10	98
Sand, fine to medium; contains layers of limy silt	9	107
Bentonite, green and orange	4	111
Sand, fine to medium	2	113
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, greenish gray and tan	17	130

12-42-14aaa.—Sample log of test hole in NE NE NE sec. 14, T. 12 S., R. 42 W., 35 feet west and 10 feet south of NE cor. sec. 14; drilled October 1957. Altitude of land surface, 3,856.2 feet; depth to water, 40.78 feet, November 4, 1957.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, loose, brown	14	14
Silt, clayey, light brown	11	25
TERTIARY—Pliocene		
Ogallala Formation		
Silt, limy, light gray	7	32
Sand, medium, red and brown,	14	46
Silt, limy, cemented, light gray,	2	48
Sand, medium, gray, clean	3	51
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, gray and brown	9	60

12-42-18ddd.—Sample log of test hole in SE SE SE sec. 18, T. 12 S., R. 42 W., 75 feet west and 5 feet north of SE cor. sec. 18; drilled October 1957. Altitude of land surface, 3,938.5 feet; depth to water, 100.75 feet, November 2, 1957.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, dark brown	10	10
Silt, tan	13	23
Silt, sandy, light tan	5	28
TERTIARY—Pliocene		
Ogallala Formation		
Sand, fine to coarse, silty; contains caliche streaks	8	36
Sand, fine to coarse, very silty,	8	44
Silt, sandy, light tan; contains caliche streaks	14	58
Sand, medium to very coarse, and fine gravel, clean	5	63
Silt, very sandy, tan	15	78
Silt and caliche, light gray and white; contains hard cemented streaks	11	89
Gravel, fine to coarse, and coarse sand	11	100
Sand, medium to coarse	5	105
Gravel, fine to coarse	9	114
Silt, sandy, tan; contains caliche streaks	13	127
Gravel, fine to coarse, and coarse sand	9	136
Sand, fine to coarse, and fine gravel; contains hard cemented limy streaks	10	146
Silt, sandy; contains hard cemented limy streaks	8	154
Bentonite, greenish gray	3	157
Sand, medium to very coarse, loose, clean	17	174
Sand, medium to coarse; contains hard cemented limy streaks	9	183
Sand, medium to coarse, and fine gravel	20	203
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, green gray and tan	7	210

12-42-29bcc.—Sample log of test hole in SW SW NW sec. 29, T. 12 S., R. 42 W., near edge of road near ½-mile line; drilled August 1960. Altitude of land surface, 3,916.6 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, brown	10	10
Silt, sandy, brown	10	20
Silt, sandy, tan	7	27
TERTIARY—Pliocene		
Ogallala Formation		
Silt, sandy, limy, light tan	15	42
Silt, sandy, very limy, light gray; contains cemented layers	8	50
Silt, sandy, cemented hard, light tan	7	57
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, gray and brown	23	80

12-42-30aaa.—Log of test hole in NE NE NE sec. 30, T. 12 S., R. 42 W., 60 feet south of creek bridge and 15 feet west of road center; augered July 1958. Altitude of land surface, 3,886.2 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, brown	3	3
Silt, sandy, tan	14	17
TERTIARY—Pliocene		
Ogallala Formation		
Silt, limy, light tan	7	24

12-42-34ddd.—Sample log of test hole in SE SE SE sec. 34, T. 12 S., R. 42 W., 35 feet north and 10 feet west of SE cor. sec. 34; drilled August 1960. Altitude of land surface, 3,854.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, brown	10	10
Silt, sandy, tan	8	18
TERTIARY—Pliocene		
Ogallala Formation		
Silt, limy, sandy, gray and tan,	13	31
Sand, medium to very coarse, and fine gravel, clean, loose,	7	38
Silt, sandy, red tan; contains limy streaks	12	50
Sand, fine to very coarse; contains cemented streaks and thin layers of sandy red-brown silt	10	60
Sand, medium to very coarse, and fine gravel; lower part contains cemented limy streaks	10	70
Sand, medium, clean, well sorted	10	80
Silt, limy, light tan	10	90
Silt, light tan; contains streaks of sand	10	100
Silt, blocky, tan; middle part contains streaks of bentonite,	15	115
Sand, fine to coarse; contains streaks of silt	7	122
Sand, fine to medium, loose	8	130
Sand, fine to coarse; contains streaks of limy silt	10	140
Sand, medium to coarse, loose,	10	150
Sand, very coarse, and fine gravel, clean, well sorted, loose	16	166
Sand, fine to coarse, and fine gravel; contains thin layers of silt and cemented streaks	7	173
Sand, medium to very coarse, clean, well sorted, loose	7	180
Sand, fine to medium, silty	10	190
Sand, medium to coarse, clean, loose	8	198
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, brown and gray	12	210

13-38-8ddd.—Log of test hole in SE SE SE sec. 8, T. 13 S., R. 38 W., 40 feet NW of SE cor. sec. 8; augered June 1958. Altitude of land surface, 3,284.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, sandy, brown	3	3
Silt, eolian, light tan	6	9
Silt, eolian, tan	11	20
Silt, eolian, tough, tan	10	30
TERTIARY—Pliocene		
Ogallala Formation		
Clay, silty, tough, tan; contains embedded gravel	5	35
Silt, and fine to coarse sand, tan	5	40
Clay, silty, tough	2	42
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale	4	46

13-38-22ddd.—Log of test hole in SE SE SE sec. 22, T. 13 S., R. 38 W., 30 feet west and 10 feet north of SE cor. sec. 22; augered July 1958. Altitude of land surface, 3,184.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Silt, tan	3	3
Silt, heavy, brown	8	11
Sand, medium to coarse, and fine gravel	7	18
Gravel, fine to medium, and coarse sand; contains layers of silt	15	33
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, blue gray	1	34

13-39-5bbb.—Log of test hole in NW NW NW sec. 5, T. 13 S., R. 39 W., 50 feet east and 20 feet south of NW cor. sec. 5; augered June 1958. Altitude of land surface, 3,429.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, eolian, light tan	10	10
Silt, sandy, eolian, tan	4	14
Silt, sandy, tough	4	18
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, gray brown	6	24

13-39-10ccc.—Log of test hole in SW SW SW sec. 10, T. 13 S., R. 39 W., 40 feet NE of SW cor. sec. 10; augered June 1958. Altitude of land surface, 3,341.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, brown	4	4
Silt, eolian, light tan	5	9
Silt, eolian, tan	3	12
TERTIARY—Pliocene		
Ogallala Formation		
Silt, clayey	4	16
Gravel, medium	3	19
Silt, clayey, tough, brown	2	21
Clay, tough	3	24
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, weathered, brown and gray	5	29

13-39-19acb.—Drillers log of irrigation well in NW SW NE sec. 19, T. 13 S., R. 39 W.; drilled by Jack Foust, March 1946. Altitude of land surface, 3,385.0 feet; depth to water, 7.43 feet, July 9, 1951.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Top soil	3	3
Clay	7	10
Gravel	30	40
Clay, sandy	3	43
Gravel	11	54
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale	1	55

13-39-19dca.—Drillers log of irrigation well in NE SW SE sec. 19, T. 13 S., R. 39 W.; drilled by Jack Foust. Altitude of land surface, 3,349.8 feet; depth to water, 10.48 feet, September 26, 1957.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Surface silt	8	8
Gravel	25	33
Silt, blue gray	7	40
Gravel	11	51
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale	1	52

13-39-25dad.—Sample log of test hole in SE NE SE sec. 25, T. 13 S., R. 39 W. (Bradley and Johnson, 1957, p. 117); jetted November 1951. Altitude of land surface, 3,252.8 feet; depth to water, 7.19 feet, November 28, 1951.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Silt, fine, light brown; contains some sand	0.5	0.5
Sand, quartz, fine to coarse; contains some silt	1.5	2.0
Sand and gravel, quartz with a few mafic minerals	10.8	12.8
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, chalky, hard, gray; contains finely disseminated black flecks	0.1	12.9

13-39-25dda.—Sample log of test hole in NE SE SE sec. 25, T. 13 S., R. 39 W. (Bradley and Johnson, 1957, p. 117); jetted November 1951. Altitude of land surface, 3,250.1 feet; depth to water, 6.11 feet, November 29, 1951.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Silt, sandy, light brown	1.5	1.5
Sand, quartz, medium to coarse	5.5	7
Sand, quartz, and some gravel with gray clay streak in upper part	13.0	20
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
(no sample obtained)	0	20

13-39-33bbd.—Drillers log of irrigation well in SE NW NW sec. 33, T. 13 S., R. 39 W.; drilled by Jack Foust. Altitude of land surface, 3,321.9 feet; depth to water, 21.10 feet, June 12, 1958.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Silt	11	11
Clay, sandy	4	15
Sand and gravel	4	19
Gravel, coarse	25	44
Silt	14	58
Gravel, coarse	7	65
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale	1	66

13-39-36aaa.—Sample log of test hole in NE NE NE sec. 36, T. 13 S., R. 39 W. (Bradley and Johnson, 1957, p. 117); jetted November 1951. Altitude of land surface, 3,251.0 feet; depth to water, 6.21 feet, November 28, 1951.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Clay, sandy, light brown	2	2
Sand, quartz, very fine to very coarse	5	7
Gravel, fine to coarse with some silt; large quartz pebbles at base	3	10
Sand and gravel, quartz, poorly sorted	5	15
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
(no sample obtained)	0	15

13-39-36ada.—Sample log of test hole in NE SE NE sec. 36, T. 13 S., R. 39 W. (Bradley and Johnson, 1957, p. 118); jetted November 1951. Altitude of land surface, 3,273.6 feet; depth to water, 34.85 feet, November 28, 1951.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Clay, silty, dark brown	1.5	1.5
Sand, quartz, poorly sorted; contains silt and gray to buff calcareous clay streaks,	8.5	10
Sand, quartz and grains of mafic minerals	10	20
Sand, coarse, and fine gravel; contains mostly quartz, but mafic minerals are common,	13	33
Sand, coarse, and gravel, largely quartz with scattered mafic minerals	8	41
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
(no sample obtained)	0	41

13-40-3aaa.—Log of test hole in NE NE NE sec. 3, T. 13 S., R. 40 W., 30 feet south of road intersection near edge of road; augered June 1958. Altitude of land surface, 3,480.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, sandy, brown	3	3
Silt, eolian, light tan	6	9

	Thickness, feet	Depth, feet
Silt, eolian, tan	6	15
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, gray	4	19

13-40-3aca.—Log of test hole in NE SW NE sec. 3, T. 13 S., R. 40 W., 0.3 mile south of road intersection near edge of road; augered June 1958. Altitude of land surface, 3,466.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, sandy, brown	2	2
Silt, eolian, light tan	18	20
Silt, clayey, tough, tan	3	23
Sand, coarse	2	25
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, gray and brown	10	35

13-40-3cdd.—Sample log of test hole in SE SE SW sec. 3, T. 13 S., R. 40 W., 50 feet west and 30 feet north of center of road intersection; drilled November 1957. Altitude of land surface, 3,424.9 feet; depth to water, 16.99 feet, November 2, 1957.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Silt, sandy, brown	12	12
Silt, sandy, very limy	3	15
Sand, medium to coarse, and fine gravel, clean	5	20
Sand, coarse, and fine to medium gravel, clean	10	30
Clay, greenish gray, tough	2	32
Silt, sandy, blue gray	11	43
Sand, coarse, and fine gravel	2	45
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, dark gray	5	50

13-40-3dbc.—Log of test hole in SW NW SE sec. 3, T. 13 S., R. 40 W., 0.3 mile north of section line near edge of road near driveway to field; augered June 1958. Altitude of land surface, 3,435.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, sandy, brown	10	10
Silt, clayey, gray brown	3	13
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, brown gray	6	19

13-40-7aac.—Drillers log of irrigation well in SW NE NE sec. 7, T. 13 S., R. 40 W.; drilled by Jack Foust, March 1957. Altitude of land surface, 3,481.7 feet; depth to water, 16.15 feet, June 24, 1958.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Silt	39	39
Gravel	13	52
Clay	2	54
Gravel	5	59
Clay	4	63
Gravel	13	76
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale	4	80

13-40-10abb2.—Drillers log of irrigation well in NW NW NE sec. 10, T. 13 S., R. 40 W.; drilled by Jesse Mumma, 1937. Altitude of land surface, 3,423.1 feet; depth to water, 15.72 feet, June 24, 1958.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Silt	15	15
Sand, fine to medium	5	20
Gravel	28	48
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale	2	50

13-40-10acb.—Log of test hole in NW SW NE sec. 10, T. 13 S., R. 40 W., 0.3 mile south of sec. line and 50 feet east of highway; augered June 1958. Altitude of land surface, 3,421.5 feet; depth to water, 14.65 feet, June 27, 1958.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Silt, sandy, tan	14	14
Sand, medium to coarse, and medium gravel	3	17
Gravel, medium to coarse	3	20
Sand, fine to coarse; contains layers of silt	3	23
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, blue gray	4	27

13-40-10acc.—Log of test hole in SW SW NE sec. 10, T. 13 S., R. 40 W., 75 feet north of bridge near edge of road; augered June 1958. Altitude of land surface, 3,411.7 feet; depth to water, 5.50 feet, June 27, 1958.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Sand, fine to coarse, silty	4	4
Sand, coarse, and medium coarse gravel	8	12
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, blue gray	7	19

13-40-10dbc.—Log of test hole in SW NW SE sec. 10, T. 13 S., R. 40 W., 200 feet south of bridge near edge of farm driveway; augered June 1958. Altitude of land surface, 3,412.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Silt, sandy, brown	2	2
Sand, medium to coarse, and fine gravel	4	6
Gravel, fine to medium	6	12

	Thickness, feet	Depth, feet
Gravel, fine to coarse	4	16
Gravel, medium to coarse	9	25
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale	3	28

13-40-10dcc.—Log of test hole in SW SW SE sec. 10, T. 13 S., R. 40 W., 300 feet north of sec. line near edge of road; augered June 1958. Altitude of land surface, 3,446.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, sandy brown	5	5
TERTIARY—Pliocene		
Ogallala Formation		
Sand, fine to coarse	5	10
Sand, medium to coarse, and fine gravel	5	15
Sand, coarse, and fine gravel,	5	20
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, dark blue gray	29	49

13-40-11aaa.—Log of test hole in NE NE NE sec. 11, T. 13 S., R. 40 W., 40 feet west and 15 feet south of NE cor. sec. 11; augered June 1958. Altitude of land surface, 3,464.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, brown	3	3
Silt, light tan	11	14
Silt, clayey, brown	3	17
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, gray	2	19

13-40-15abc.—Log of test hole in SW NW NE sec. 15, T. 13 S., R. 40 W., 0.15 mile south of sec. line and 45 feet east of highway center near field driveway; augered June 1958. Altitude of land surface, 3,470.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, sandy, dark brown	2	2
Silt, loose, eolian, light tan	12	14
Silt, clayey, tough, gray and brown	6	20
TERTIARY—Pliocene		
Ogallala Formation		
Silt, sandy, tan	10	30
Sand, medium to very coarse, and fine gravel	5	35
Silt, sandy, brown	5	40
Sand, fine to coarse	5	45
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, gray and brown	10	55

13-40-15dbc.—Log of test hole in SW NW SE sec. 15, T. 13 S., R. 40 W., 0.3 mile north of sec. line and 45 feet east of highway center near edge of road; augered June 1958. Altitude of land surface, 3,524.3 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, dark brown	2	2
Silt, loose, eolian, light tan	13	15
Silt, tight, sandy, red tan	7	22
TERTIARY—Pliocene		
Ogallala Formation		
Silt, clayey, tough, gray	3	25
Gravel, coarse	3	28
Silt, sandy, loose, gray	4	32
Sand, coarse, and fine gravel	4	36
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, clayey, tough, gray	14	50

13-41-5bbb.—Sample log of test hole in NW NW NW sec. 5, T. 13 S., R. 41 W., 50 feet south and 5 feet east of NW cor. sec. 5; drilled October 1957. Altitude of land surface, 3,784.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, compact, light tan	12	12
Silt, sandy, tan	10	22
TERTIARY—Pliocene		
Ogallala Formation		
Silt, limy, white and light gray,	3	25
Sand, medium to coarse, gray,	5	30
Silt, clayey, limy, light gray	2	32
Sand, medium to coarse, clean,	6	38
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, gray and brown	2	40

13-41-16ccc.—Sample log of test hole in SW SW SW sec. 16, T. 13 S., R. 41 W., near side of road about 35 feet north of SW cor. sec. 16; drilled August 1960. Altitude of land surface, 3,615.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, sandy, brown	5	5
Sand, fine to medium	7	12
Silt, clayey, light greenish gray,	9	21
Sand, medium to very coarse,	4	25
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, brown and black	5	30

13-41-27abb.—Sample log of test hole in NW NW NE sec. 27, T. 13 S., R. 41 W., near ½-mile line 20 feet south of road center; drilled August 1960. Altitude of land surface, 3,619.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, sandy, brown	8	8
Silt, clayey, light tan	7	15
Silt, sandy, tan	10	25
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, brown and dark gray	5	30

13-41-28ddd.—Drillers log of shothole in SE SE SE sec. 28, T. 13 S., R. 41 W.; drilled by Phillips Petroleum Co., 1957. Altitude of land surface, 3,736 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Sand	25	25
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, brown	55	80

13-42-5bbb.—Sample log of test hole in NW NW NW sec. 5, T. 13 S., R. 42 W., 35 feet east and 5 feet south of NW cor. sec. 5; drilled October 1957. Altitude of land surface, 3,919.8 feet; depth to water, 107.72 feet, November 2, 1957.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, sandy, dark gray	9	9
Sand, medium to coarse; contains caliche streaks	4	13
TERTIARY—Pliocene		
Ogallala Formation		
Sand, coarse, and medium gravel; contains caliche and cemented streaks	7	20
Sand, medium to coarse; contains cemented layer at 24 to 26 feet	7	27
Gravel, fine to medium, clean,	2	29
Sand, medium to very coarse,	14	43
Sand, fine to coarse; contains abundant caliche and thin cemented layers	9	52
Sand, fine to medium, silty, red brown	12	64
Sand, fine to medium, and thin silt layers; contains caliche streaks	15	79
Silt, compact, tan	3	82
Sand, fine to coarse, and silt layers; contains caliche streaks	11	93
Sand, coarse to very coarse, and fine gravel	14	107
Sand, fine to coarse; contains thin layers of very limy silt,	14	121
Sand, medium to coarse; contains cemented streaks	8	129
Sand, medium to coarse; contains thin layers of very limy silt	11	140
Sand, medium to coarse, clean,	9	149
Silt, sandy, red brown	2	151
Sand, fine to coarse, silty, limy, cemented	2	153
Sand, medium to very coarse, loose	12	165
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, light greenish gray	5	170

13-42-7add.—Sample log of test hole in SE SE NE sec. 7, T. 13 S., R. 41 W., in ditch near ½-mile line; drilled August 1960. Altitude of land surface, 3,876.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, sandy, brown	12	12
TERTIARY—Pliocene		
Ogallala Formation		
Sand, fine to very coarse; contains small amount fine gravel and streaks of rust-brown silt	10	22
Silt, sandy, limy, light gray	6	28
Gravel, fine to medium, and very coarse sand, clean	12	40
Sand, medium to very coarse, and fine gravel	17	57
Silt, sandy, tan	2	59
Sand, fine to medium	11	70
Sand, medium to very coarse,	10	80
Sand, medium to very coarse, and fine gravel	5	85
Silt, compact, hard, brown	3	88
Gravel, fine and very coarse sand	12	100
Gravel, fine to coarse	11	111
Silt, sandy, tan	7	118
Sand, fine to very coarse, and fine to medium gravel	7	125
Silt, sandy, tan	3	128
Sand, very coarse, and fine gravel	12	140
Sand, very coarse, and fine gravel; contains thin layers of silt	18	158
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, brown and gray	8	166

13-42-17cbb.—Log of test hole in NW NW SW sec. 17, T. 13 S., R. 42 W., 500 feet north of river bridge and 60 feet east of road center; augered July 1958. Altitude of land surface, 3,794.6 feet.

	Thickness, feet	Depth, feet
TERTIARY—Pliocene		
Ogallala Formation		
Sand, fine to coarse	4	4
Sand, medium to very coarse, and fine gravel	8	12
Silt, sandy, tan	1	13
Sand, fine to very coarse, silty	3	16
Silt, clayey, compact, brown	4	20
Sand, fine, hard	4	24
Sand, fine to coarse, silty	8	32
Sand, fine to very coarse, and fine gravel, loose	8	40
Gravel, fine to very coarse, and coarse sand	10	50
Silt, sandy, wet, loose	4	54
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, blue gray	10	64

13-42-17ccb.—Log of test hole in NW SW SW sec. 17, T. 13 S., R. 42 W., 20 feet south of river bridge and 10 feet east of road center; augered July 1958. Altitude of land surface, 3,767.2 feet; depth to water, 3.20 feet, July 8, 1958.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Sand, medium, clean	4	4
Gravel, fine to medium, and coarse sand	6	10
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, blue gray	4	14

13-42-17ccc.—Sample log of test hole in SW SW SW sec. 17, T. 13 S., R. 42 W., 18 feet east of road center and 122 feet south of power pole on south bank of river (Bradley and Johnson, 1957, p. 118); drilled September 1951. Altitude of land surface, 3,764.2 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Sand, fine to coarse; contains some fine to medium gravel and clay stringers	10	10
Sand, fine to coarse	2	12
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, gray	8	20

13-42-20bcb.—Log of test hole in NW SW NW sec. 20, T. 13 S., R. 42 W., 0.3 mile south of sec. line near edge of road; augered July 1958. Altitude of land surface, 3,798.1 feet.

	Thickness, feet	Depth, feet
TERTIARY—Pliocene		
Ogallala Formation		
Silt, very sandy, tan	5	5
Silt, sandy, tan	10	15
Silt, sandy, brown	9	24
Gravel, medium to coarse	4	28
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, gray	6	34

13-42-20cbb.—Log of test hole in NW NW SW sec. 20, T. 13 S., R. 42 W., 20 feet east of road center near ½-mile line; augered July 1958. Altitude of land surface, 3,837.3 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, sandy, tan	3	3
Sand, fine to medium, clean	9	12
Silt, sandy, tan	2	14
Sand, fine, silty	2	16
TERTIARY—Pliocene		
Ogallala Formation		
Silt, clayey, tan	2	18
Sand, fine to medium, red tan,	6	24
Silt, sandy, tan	5	29
Sand, fine to medium; contains cemented streaks	7	36
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, gray	8	44

13-42-27aaa.—Sample log of test hole in NE NE NE sec. 27, T. 13 S., R. 42 W., near edge of road 200 feet west of NE cor. sec. 27; drilled August 1960. Altitude of land surface, 3,732.0 feet; depth to water, 40.90 feet, October 10, 1960.

	Thickness, feet	Depth, feet
TERTIARY—Pliocene		
Ogallala Formation		
Sand, fine, silty	10	10
Sand, fine to medium, clean, loose	10	20
Sand, medium to very coarse; contains cemented layers of very limy silt	10	30
Silt, very limy; contains thin layers of sand	10	40
Silt, very sandy, limy; contains cemented streaks	10	50
Silt, sandy, compact, rust tan,	10	60
Sand, fine to very coarse, and fine gravel; contains thin layers of limy silt	10	70
Sand, fine to very coarse; contains small amount fine gravel and cemented limy streaks,	12	82
Silt, compact, blocky, brown; contains limy streaks	11	93
Sand, fine to medium, loose,	7	100
Sand, medium to very coarse, clean, loose	10	110
Sand, medium to very coarse, and fine gravel; upper part contains thin layers of silty clay	10	120
Sand, medium to very coarse, and fine gravel; contains layers of limy silt	12	132
Sand, medium to very coarse; upper part contains thin layers of silt	8	140
Sand, medium to very coarse, and fine gravel, clean	8	148
Sand, fine to very coarse; upper 3 feet contains cemented streaks	10	158
Sand, fine; upper part contains thin layers of silt	12	170
Sand, medium to very coarse, and fine gravel; contains limy streaks	15	185
Silt, very sandy; contains streaks of fine to coarse sand	12	197
Sand, medium to very coarse; contains small amount fine gravel	18	215
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, brown and dark gray,	5	220

13-42-29ccc.—Drillers log of irrigation well in SW SW SW sec. 29, T. 13 S., R. 42 W.; drilled by Jack Foust, 1953. Altitude of land surface, 3,887.2 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Surface silt	10	10

	Thickness, feet	Depth, feet
TERTIARY—Pliocene		
Ogallala Formation		
Sand, cemented	9	19
Gravel	4	23
Clay, sandy	11	34
Gravel	10	44
Clay, sandy	6	50
Gravel	6	56
Clay, sandy	4	60
Gravel	19	79
Clay, sandy	34	113
Gravel	25	138
Clay	12	150
Gravel	1	151
Clay	4	155
Gravel	24	179
Clay	2	181
Gravel	8	189
Clay	9	198
Gravel	9	207
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Soapstone	7	214
Shale	3	217

13-42-30daa.—Sample log of test hole in NE NE SE sec. 30, T. 13 S., R. 42 W., 12 feet west of road center and 3 feet south of fence line (Bradley and Johnson, 1957, p. 118); drilled September 1951. Altitude of land surface, 3,874.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Soil, silt, and clay, black	3	3
Clay and silt, tan gray	4	7
TERTIARY—Pliocene		
Ogallala Formation		
Clay, limy, silty, light tan to tan brown	10	17
Clay, sandy, brown	4	21
Clay, limy, light tan	12	33
Clay, sandy, tan	2	35
Clay, very limy, light tan	3	38
Clay, very sandy, tan brown	2	40
Clay, limy, light tan	9	49
Clay, light tan; contains imbedded fine to coarse sand	11	60
Sand, fine to coarse, very clayey, tan brown	7	67
Sand, fine to medium, clayey, tan	5	72
Sand, medium to coarse, and fine to coarse gravel; contains some clay	19	91
Clay, very sandy, light tan to brown	7	98
Sand, medium to coarse, and fine gravel; contains some clay	10	108
Sand and gravel, medium to coarse, and some clay	10	118
Sand, medium to coarse, and fine to medium gravel	10	128
Sand, medium to coarse, and fine to coarse gravel	10	138
Sand, medium to coarse, and fine to coarse gravel; contains some silty clay	8	146
Clay, sandy, tan	10	156
Sand, fine to coarse, clayey, tan,	8	164
Clay, sandy, tan brown	11	175
Clay, tan brown and light gray,	5	180
Sand, medium to coarse, and fine gravel; contains some clay	10	190
Sand, medium to coarse; contains some clay	10	200
Sand, fine to coarse; contains sandy clay stringer at 205 feet	10	210
Clay, sandy, tan	10	220
Clay, sandy, tan to gray; contains interbedded layers of fine to coarse sand	10	230
Clay, sandy, tan to gray; contains layers of fine to coarse sand and fine gravel	30	260
Clay, sandy, tan	40	300
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, yellow gray to yellow green	6	306
Shale, gray	4	310

13-42-31ddd.—Sample log of test hole in SE SE SE sec. 31, T. 13 S., R. 42 W., 40 feet west and 10 feet north of SE cor. sec. 31; drilled August 1960. Altitude of land surface, 3,880.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, brown	5	5
Sand, fine, silty	12	17
Silt, sandy, light brown	6	23
TERTIARY—Pliocene		
Ogallala Formation		
Gravel, fine, and very coarse sand; contains streaks of cemented red silt	15	38
Silt, very sandy, rust red; lower part contains streaks of bentonite	16	54
Silt, very sandy, limy; upper part contains streaks of bentonite	16	70
Silt, very sandy, limy; contains streaks of caliche	14	84
Sand, medium to coarse, loose,	6	90
Sand, fine to coarse; contains layers of silt	10	100
Sand, medium to very coarse, clean	12	112
Sand, fine to coarse, and fine gravel; contains layers of very limy silt and cemented streaks,	8	120
Sand, medium to very coarse; contains small amount fine gravel and streaks of limy silt	10	130
Silt, sandy, very limy; contains streaks of sand	10	140
Silt, sandy, limy; contains thin beds of sand	10	150
Sand, fine to very coarse; con-		

	Thickness, feet	Depth, feet
tains small amount fine gravel and thin layers of silt	10	160
Sand, very coarse, and fine gravel, clean, well sorted, loose	10	170
Gravel, fine to medium, and very coarse sand, clean, loose,	10	180
Sand, medium to very coarse, and fine gravel; contains thin layers of silt	10	190
Sand, fine to very coarse, and fine gravel, contains layers of silt	10	200
Sand, medium to very coarse, and fine gravel, loose	8	208
Sand, fine to coarse; contains streaks of silt	12	220
Gravel, fine, and very coarse sand, clean, loose	10	230
Gravel, fine to medium, and very coarse sand, clean, loose,	10	240
Gravel, fine to medium, well sorted, loose	12	252
Silt, sandy, limy, tan	6	258
Sand, very coarse, and fine gravel, clean	12	270
Gravel, fine, and very coarse sand, clean, loose	17	287
Silt, sandy; contains layers of fine to coarse sand	8	295
Sand, very coarse, and fine gravel	15	310
Sand, coarse to very coarse, and fine gravel; contains streaks of cemented limy silt	10	320
Sand, very coarse, clean, loose; contains small amount fine gravel	10	330
Gravel, fine, clean, well sorted,	10	340
Gravel, fine, and very coarse sand, clean	30	370
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, gray and dark gray	10	380

13-43-36abb.—Drillers log of irrigation well in NW NW NE sec. 36, T. 13 S., R. 43 W.; drilled by Jack Foust, 1957. Altitude of land surface, 3,893.5 feet; depth to water 148.75 feet, October 8, 1957.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Surface silt	8	8
TERTIARY—Pliocene		
Ogallala Formation		
Sand, cemented	4	12
Gravel	5	17
Sand, cemented	6	23
Sand	8	31
Sand, cemented	6	37
Gravel	65	102
Sand, cemented	4	106
Gravel	34	140
Sand, cemented	8	148
Gravel	13	161
Sand	8	169
Sand, cemented	8	177
Gravel	53	230
Clay	5	235
Gravel	8	243
Clay	7	250
Sand	7	257
Clay	3	260
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Soapstone	10	270

14-38-17ddd.—Sample log of test hole in SE SE SE sec. 17, T. 14 S., R. 38 W., 125 feet west and 20 feet north of SE cor. sec. 17; drilled November 1957. Altitude of land surface, 3,545.0 feet; depth to water, 78.30 feet, November 14, 1957.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, dark brown	10	10
Silt, light brown	10	20
TERTIARY—Pliocene		
Ogallala Formation		
Silt, sandy, limy, light tan	8	28
Silt, sandy, very limy, cemented	4	32
Sand, fine, very silty	11	43
Sand, medium to very coarse, clean	5	48
Silt and fine to coarse sand, very limy, cemented hard	17	65
Silt, limy, tan	10	75
Sand, fine to medium, and limy silt	7	82
Silt, sandy, tan	11	93
Bentonite, gray green	2	95
Sand, fine to coarse, very silty,	7	102
Sand, medium to coarse, silty	6	108
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, gray and yellow	8	116

14-38-33ccc.—Sample log of test hole in SW SW SW sec. 33, T. 14 S., R. 38 W., 55 feet north of sec. line and 11 feet east of road center (Bradley and Johnson, 1957, p. 120); drilled October 1951. Altitude of land surface, 3,526.2 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, tan gray, and tan clay	16	16
TERTIARY—Pliocene		
Ogallala Formation		
Clay, silty, limy, tan	2	18
Clay, silty, very limy, light tan to white	3	21
Silt and fine sand, limy, cemented, tan	3.5	24.5
Sand, fine to medium, silty, light tan to gray white	4.5	29
Clay, silty, limy, light tan to light gray	2	31
Silt and fine sand, cemented, tan brown	6	37
Sand, fine to coarse, and brown silty clay, limy	7	44
Clay, limy, gray to tan gray; contains some imbedded sand	12	56
Sand, fine to medium, silty, tan gray; contains a little clay	9	65

	Thickness, feet	Depth, feet
Sand, fine to coarse, and fine to medium gravel; contains a little light-tan clay	18	83
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, bentonitic, clayey, green to gray	8	91
Shale, silty, yellow	14	105
Shale, gray	5	110

14-38-34aaa.—Sample log of test hole in NE NE NE sec. 34, T. 14 S., R. 38 W., 25 feet west and 10 feet south of NE cor. sec. 34; drilled August 1960. Altitude of land surface, 3,512.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, dark brown	5	5
Silt, sandy, brown	5	10
Silt, sandy, light tan	10	20
Silt, very sandy, tan	5	25
TERTIARY—Pliocene		
Ogallala Formation		
Silt, sandy, very limy; contains cemented layers	15	40
Silt, very sandy, cemented hard,	10	50
Sand, fine to coarse, silty, cemented hard	8	58
Sand, medium to very coarse, and fine gravel; contains cemented streaks	7	65
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, brown and gray	5	70

14-39-21bbb.—Sample log of test hole in NW NW NW sec. 21, T. 14 S., R. 39 W., 18 feet south and 9 feet east of NW cor. sec. 21; drilled November 1957. Altitude of land surface, 3,453.0 feet; depth to water, 12.18 feet, November 14, 1957.

	Thickness, feet	Depth, feet
TERTIARY—Pliocene		
Ogallala Formation		
Silt, sandy, light brown	17	17
Silt, limy, gray brown	5	22
Sand, medium to very coarse; contains some medium gravel,	7	29
Silt, sandy, tough, brown	4	33
Clay, tough, yellow tan	2	35
Sand, fine to coarse, silty	8	43
Sand, medium to coarse, silty	8	51
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale	19	70

14-39-25ccb.—Drillers log of irrigation well in NW SW SW sec. 25, T. 14 S., R. 39 W.; drilled by Jack Foust, March 1956. Altitude of land surface, 3,576.4 feet; depth to water, 109.98 feet, June 18, 1958.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Surface silt	18	18
TERTIARY—Pliocene		
Ogallala Formation		
Sand, cemented	32	50
Clay	7	57
Sand	13	70
Clay	11	81
Sand, cemented	7	88
Clay, sandy	16	104
Sand	15	119
Gravel	10	129
Sand, cemented	1	130
Gravel	5	135
Sand, cemented	3	138
Sand	6	144
Clay	3	147
Gravel	17	164
Clay	1	165
Gravel	9	174
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Soapstone	5	179
Shale	3	182

14-39-31bba.—Drillers log of irrigation well in NE NW NW sec. 31, T. 14 S., R. 39 W.; drilled by Ben Hasz, April 1955. Altitude of land surface, 3,623.1 feet; depth to water, 106.90 feet, July 24, 1958.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Topsoil and silt	11	11
TERTIARY—Pliocene		
Ogallala Formation		
Sand and clay; cemented from 94 to 97 feet	88	99
Sand, very coarse	31	130
Clay	4	134
Sand, coarse	5	139
Sand and sandy clay	6	145
Sand	8	153
Clay, sandy	8	161
Sand, coarse	6	167
Clay, sandy	7	174
Sand, fine; contains clay from 188 to 189 feet	16	190
Clay, sandy	3	193
Sand, coarse	5	198
Clay, sandy; contains cemented layers	6	204
Sand	11	215
Clay, sandy	4	219
Sand	6	225
Clay, sandy	2	227
Sand	7	234
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Clay, yellow	4	238
Shale	2	240

14-39-32bdc.—Drillers log of irrigation well in SW SE NW sec. 32, T. 14 S., R. 39 W.; drilled by Ben Hasz, October 1955. Altitude of land surface, 3,610.6 feet; depth to water, 108.14 feet, June 19, 1958.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Topsoil and silt	9	9

TERTIARY—Pliocene Ogallala Formation	Thickness, feet	Depth, feet
Sand and clay; contains cemented layers	138	147
Sand	5	152
Clay; contains cemented layers,	6	158
Sand, coarse, loose	4	162
Clay, sandy	2	164
Sand	2	166
Clay; contains cemented layers,	3	169
Sand	10	179
Sand; contains cemented layers,	4	183
Sand, coarse	20	203
Clay and sandy clay; contains cemented layers	9	212
Clay, sandy; contains cemented layers	13	225
Rock, hard	4	229
Clay	3	232
Sand	7	239
Clay, tight, sticky	15	254
Clay; contains cemented layers	3	257
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Soapstone	5	262

14-39-33ddd.—Sample log of test hole in SE SE SE sec. 33, T. 14 S., R. 39 W., 70 feet north and 6 feet west of SE cor. sec. 33; drilled November 1957. Altitude of land surface, 3,599.9 feet.

QUATERNARY—Pleistocene Peoria and Loveland Formations	Thickness, feet	Depth, feet
Silt, compact, light brown	15	15
Silt, limy, light gray	9	24
TERTIARY—Pliocene		
Ogallala Formation		
Silt, dense, cemented, light gray	12	36
Silt, sandy, tan; contains limy streaks in lower part	9	45
Sand, medium to coarse, and fine gravel; contains 2 feet of silt at base	15	60
Sand, fine to coarse, silty	8	68
Silt, sandy, limy, light tan	10	78
Sand, medium to coarse, and fine gravel	7	85
Silt, sandy, gray	8	93
Sand, fine, silty	7	100
Silt, sandy, gray	7	107
Sand, medium to coarse, and fine gravel; contains silt layers from 112 to 115 and 120 to 122 feet	23	130
Silt, sandy, tan	8	138
Sand, medium to coarse; contains cemented limy silt from 147 to 149 and 152 to 154 feet	16	154
Sand, fine to very coarse; contains limy silt layers	12	166
Silt, sandy, tan; contains limy streaks	9	175
Sand, fine to medium, and limy silt; contains thin cemented layers	15	190
Sand, medium to coarse, silty	9	199

CRETACEOUS—Upper Cretaceous Pierre Shale	Thickness, feet	Depth, feet
Shale, yellow and gray	11	210

14-40-5baa2.—Drillers log of shothole in NE NE NW sec. 5, T. 14 S., R. 40 W.; drilled by Phillips Petroleum Co., 1957. Altitude of land surface, 3,491 feet.

Pleistocene and Pliocene (undifferentiated)	Thickness, feet	Depth, feet
Surface silt	5	5
Sand and gravel	22	27
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale	78	105

14-40-11dcc.—Drillers log of shothole in SW SW SE sec. 11, T. 14 S., R. 40 W.; drilled by Phillips Petroleum Co., 1957. Altitude of land surface, 3,639 feet.

TERTIARY—Pliocene Ogallala Formation	Thickness, feet	Depth, feet
Sand; contains cemented layers,	30	30
Sand and silt	55	85
Sand	85	170
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Clay, yellow	20	190

14-40-15dcc.—Sample log of test hole in SW SW SE sec. 15, T. 14 S., R. 40 W., 42 feet east of highway center and 13 feet north of sec. line (Bradley and Johnson, 1957, p. 121); drilled October 1951. Altitude of land surface, 3,660.0 feet.

QUATERNARY—Pleistocene Peoria and Loveland Formations	Thickness, feet	Depth, feet
Soil, black	1	1
Silt, clayey, tan to tan gray	14.5	15.5
Sand, fine to coarse; contains silty to clayey limy nodules	2.5	18
TERTIARY—Pliocene		
Ogallala Formation		
Limestone, silty, medium hard, white	2	20
Sand, fine to coarse; contains silt and clay, tan to light gray	5	25
Sand, fine, silty, cemented, tan brown; contains a little coarse to medium sand	10	35
Sand, fine to coarse, silty, cemented, tan brown	16	51
Sand, fine to coarse; contains fine to coarse gravel and silty clay	9	60
Sand, fine to coarse; contains clay layers	4	64
Clay, silty, gray tan; contains limy streaks	6	70
Clay, sandy, brown; contains a little sand	8.5	78.5
Sand, fine to coarse, and fine gravel; contains yellow-tan silt and clay	16.5	95
Clay, silty, blue gray and tan green	4	99

	Thickness, feet	Depth, feet
Clay, sandy, tan yellow	5	104
Sand, fine to coarse, and fine gravel; contains a little tan-yellow clay	14	118
Clay, silty, tan yellow to tan brown; contains embedded sand and fine to coarse gravel	10	128
Sand and clay, interbedded, brown to tan yellow	10	138
Sand, fine to coarse; contains a little tan-brown clay	19	157
Clay, sandy, tan brown	11	168
Sand, fine to coarse; contains a little clay	16	184
Clay, gray brown; contains a little sand	11	195
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, yellow	8	203
Shale, dark gray	3	206

14-40-20dcc.—Sample log of test hole in SW SW SE sec. 20, T. 14 S., R. 40 W., 35 feet east of ½-mile line and 25 feet north of road center; drilled August 1960. Altitude of land surface, 3,699.5 feet.

QUATERNARY—Pleistocene	Thickness, feet	Depth, feet
Peoria and Loveland Formations		
Silt, sandy, tan brown	10	10
Silt, very sandy, tan brown	5	15
TERTIARY—Pliocene		
Ogallala Formation		
Silt, sandy, very limy, light gray	5	20
Sand, medium, tan	10	30
Sand, coarse to very coarse	8	38
Silt, very sandy, limy, tan	15	53
Sand, very coarse, and fine gravel	5	58
Sand, fine to coarse; contains thin layers of cemented limy silt	15	73
Sand, coarse to very coarse, and fine gravel, clean	11	84
Silt, sandy, limy, tan	6	90
Sand, fine to coarse, and fine gravel; contains layers of limy silt and a thin layer of bentonite at 105 feet	20	110
Sand, medium to very coarse, cemented	10	120
Sand, medium, clean	10	130
Sand, medium to very coarse, and fine gravel, clean	20	150
Sand, fine to coarse	10	160
Sand, medium to coarse; contains cemented layers	10	170
Sand, medium to very coarse, clean	10	180
Sand, medium to very coarse, and fine gravel; contains layers of cemented silt	10	190
Sand, medium to very coarse, clean, loose	10	200
Sand, medium to very coarse, and fine gravel; lower part contains layers of sandy silt,	10	210
Sand, medium to very coarse, and fine gravel	11	221
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, orange and brown	10	231
Shale, black	4	235

14-40-35ccc.—Sample log of test hole in SW SW SW sec. 35, T. 14 S., R. 40 W., 90 feet east and 35 feet north of SW cor. sec. 35; drilled November 1957. Altitude of land surface, 3,639.3 feet; depth to water, 86.72 feet, November 12, 1957.

QUATERNARY—Pleistocene	Thickness, feet	Depth, feet
Peoria and Loveland Formations		
Silt, sandy, loose, light brown,	15	15
Silt, sandy, limy, light gray	6	21
TERTIARY—Pliocene		
Ogallala Formation		
Sand, medium to coarse, clean,	14	35
Sand, fine to medium; contains thin layers of limy silt and cemented streaks	12	47
Silt, sandy, limy, light tan	7	54
Sand, medium to very coarse	8	62
Sand, medium, silty	5	67
Sand, very coarse; contains interbedded layers of silt in lower 5 feet	16	83
Sand, fine to medium	11	94
Silt, very sandy, tan	8	102
Sand, medium to coarse, silty in lower part	10	112
Silt and fine sand, limy, light tan	18	130
Sand, fine, and sandy silt; contains interbedded cemented limy layers	20	150
Sand, fine to coarse, and limy silt; contains cemented layers in lower part	27	177
Silt, sandy, limy, light tan	3	180
Sand, fine, silty	15	195
Sand, medium to coarse; contains thin limy silt layers	10	205
Silt, sandy, tan	2	207
Sand, fine to coarse, silty	21	228
Sand, very coarse, and fine gravel; contains limy silt from 235 to 237 and 242 to 247 feet	23	251
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, orange and gray	9	260

14-40-36dcc.—Drillers log of irrigation well in SW SW SE sec. 36, T. 14 S., R. 40 W.; drilled by Ben Hasz, 1956. Altitude of land surface, 3,643.4 feet.

Pleistocene and Pliocene (undifferentiated)	Thickness, feet	Depth, feet
Soil and silt	5	5
Sand and clay	23	28
Sand	40	68
Sand and coarse gravel	7	75

	Thickness, feet	Depth, feet
Silt, sandy, cemented	2	77
Clay, sandy	8	85
Sand and sandy clay	3	88
Gravel	13	101
Clay; contains cemented layers,	5	106
Sand	10	116
Silt, sandy, cemented	2	118
Sand and sandy clay	11	129
Sand, coarse, clean, loose	11	140
Clay	3	143
Sand	7	150
Sand and clay; contains cemented layers	6	156
Sand	9	165
Clay; contains cemented layers,	5	170
Gravel, good	37	207
Silt, sandy, cemented	3	210
Sand, clean	6	216
Sand	10	226
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Soapstone	3	229

14-41-7add.—Sample log of test hole in SE SE NE sec. 7, T. 14 S., R. 41 W., 35 feet north of ½-mile line and 35 feet west of road center; drilled August 1960. Altitude of land surface, 3,771.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, sandy, light brown	12	12
TERTIARY—Pliocene		
Ogallala Formation		
Sand, fine to medium, silty, limy; contains cemented streaks	8	20
Sand, medium to very coarse; contains cemented streaks	23	43
Sand, silty, limy, cemented hard	5	48
Sand, medium to very coarse; contains cemented layers	12	60
Sand, fine to medium; contains layers of sandy silt	10	70
Sand, silty, limy, cemented	7	77
Sand, medium to very coarse, clean, loose; contains small amount fine gravel	13	90
Sand, fine to medium, loose	10	100
Sand, coarse to very coarse, clean	10	110
Sand, coarse to very coarse and fine gravel, clean	10	120
Sand, coarse to very coarse; contains cemented limy streaks,	10	130
Sand, medium to very coarse, clean	19	149
Silt, limy, cemented hard	1	150
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, gray and brown	6	156

14-41-13ccc.—Sample log of test hole in SW SW SW sec. 13, T. 14 S., R. 41 W., 30 feet north and 10 feet east of SW cor. sec. 13; drilled November 1957. Altitude of land surface, 3,735.2 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, sandy in lower part, light tan	15	15
Silt, sandy, very limy, light gray and white	12	27
TERTIARY—Pliocene		
Ogallala Formation		
Sand, medium to coarse, silty	5	32
Sand, fine to coarse	6	38
Silt, limy, cemented, light gray,	5	43
Sand, fine to coarse	12	55
Silt and interbedded fine to medium sand, cemented	7	62
Sand, fine; contains thin layers of limy silt in lower part	12	74
Sand, medium to coarse	11	85
Silt, sandy, light gray	4	89
Sand, medium to coarse, silty	6	95
Silt, sandy, very limy	3	98
Sand, medium to coarse; contains sandy silt layers	17	115
Sand, fine to coarse, silty	15	130
Sand, medium to coarse, clean,	14	144
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, dark gray and gray brown,	6	150

14-41-13daa.—Drillers log of shothole in NE NE SE sec. 13, T. 14 S., R. 41 W.; drilled by Phillips Petroleum Co., 1957. Altitude of land surface, 3,719 feet.

	Thickness, feet	Depth, feet
Pleistocene and Pliocene (undifferentiated)		
Surface silt	4	4
Sand	94	98
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Clay, yellow	44	142

14-41-19bcc.—Drillers log of shothole in SW SW NW sec. 19, T. 14 S., R. 41 W.; drilled by Phillips Petroleum Co., 1957. Altitude of land surface, 3,766 feet.

	Thickness, feet	Depth, feet
Pleistocene and Pliocene (undifferentiated)		
Surface silt	4	4
Sand	272	276
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale	4	280

14-41-20ddd.—Sample log of test hole in SE SE SE sec. 20, T. 14 S., R. 41 W., 75 feet north and 20 feet west of SE cor. sec. 20; drilled August 1960. Altitude of land surface, 3,727.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, sandy, brown	4	4
Silt, very sandy, tan	4	8
Sand, medium to coarse, clean,	12	20
TERTIARY—Pliocene		
Ogallala Formation		
Sand, medium to very coarse, and fine gravel, clean	15	35
Silt, sandy, very limy, light gray	5	40
Sand, fine to very coarse, silty,	10	50
Silt, very sandy, very limy, cemented	10	60
Sand, fine to coarse; contains layers of cemented limy silt,	10	70
Sand, coarse to very coarse, and fine gravel, clean	7	77
Bentonite, greenish gray	3	80
Sand, medium to very coarse	7	87
Bentonite, greenish gray	3	90
Sand, coarse to very coarse, and fine gravel	10	100
Sand, coarse to very coarse, and fine gravel; contains layers of silt	10	110
Sand, fine, limy, cemented hard,	10	120
Sand, fine to coarse; contains thin layers of silt	10	130
Sand, fine to medium	10	140
Sand, fine to coarse	10	150
Sand, medium to coarse, and fine gravel	10	160
Sand, medium to coarse	10	170
Sand, medium to very coarse, clean	10	180
Sand, medium to very coarse, and fine gravel; contains a thin layer of bentonite	10	190
Sand, medium to coarse, clean,	10	200
Sand, medium to very coarse, and fine gravel	10	210
Sand, medium to very coarse, clean; contains a thin layer of bentonite in lower part	20	230
Sand, medium to very coarse; contains thin layers of bentonitic clay	12	242
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, orange and tan upper part, black lower part	8	250

14-41-23bbb.—Drillers log of irrigation well in NW NW NW sec. 23, T. 14 S., R. 41 W.; drilled by Ben Hasz. Altitude of land surface, 3,706.1 feet.

	Thickness, feet	Depth, feet
Pleistocene and Pliocene (undifferentiated)		
Top and subsoil	10	10
Clay	9	19
Sand	15	34
Clay	3	37
Sand	12	49
Clay	21	70
Sand, good, and sandy clay	9	79
Clay	19	98
Clay, sandy, and interbedded layers of sand	7	105
Sand and a little sandy clay	11	116
Clay, sandy	13	129
Sand and sandy clay	5	134
Sand, coarse, loose	18	152
Sand and clay; contains cemented streaks	8	160
Sand, coarse, loose	13	173
Clay and sandy clay	8	181
Sand	5	186
Mortar bed	1	187
Clay	9	196
Sand	5	201
Mortar bed	1	202
Sand	4	206
Sand and mortar bed	3	209
Sand	4	213
Mortar bed	2	215
Sand	2	217
Clay	3	220
Sand	3	223
Sand and clay	14	237
Sand, good, loose	25	262
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Soapstone	3	265
Shale	3	268

14-41-31ccc.—Sample log of test hole in SW SW SW sec. 31, T. 14 S., R. 41 W., 26 feet north of road center and 8 feet east of section line (Bradley and Johnson, 1957, p. 122); drilled October 1951. Altitude of land surface, 3,809.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Soil, silt, and clay, black	2.5	2.5
Silt, tan to tan gray; contains a little clay	7	9.5
TERTIARY—Pliocene		
Ogallala Formation		
Clay, silty to sandy; contains limy streaks and embedded gravel	8.5	18
Sand, fine to coarse, and fine to medium gravel, silty	3	21
Sand, fine, clayey; contains soft limy streaks	14	35
Clay, limy, tan gray; contains layer of sand from 41 to 43 feet	10	45
Clay, silty, limy, tan to gray brown	9	54
Clay, red brown; contains thin layers of sand	11	65

	Thickness, feet	Depth, feet
Sand, fine to coarse; contains interbedded layers of limy clay	18	83
Clay, tan to gray, and interbedded layers of sand	18	101
Sand, fine to coarse, and fine to medium gravel; contains thin layers of tan silt	19	120
Sand, coarse, and fine to coarse gravel	12	132
Clay, silty, sandy, brown	5	137
Sand, fine to coarse, and fine to medium gravel; contains layer of clay from 146 to 147 feet	10	147
Sand, fine to coarse, and fine to medium gravel	10	157
Sand, fine to coarse, and fine to medium gravel; contains sandy clay from 161 to 164 feet	10	167
Sand, coarse, and fine to coarse gravel	29	196
Clay, limy, gray, and interbedded layers of sand	10	206
Sand, medium to coarse, and fine gravel; contains thin layers of gray clay	9	215
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, clayey, yellow	2	217
Shale, dark gray	3	220

14-42-2ccc.—Sample log of test hole in SW SW SW sec. 2, T. 14 S., R. 42 W., in ditch 50 feet NE of SW cor. sec. 2; drilled August 1960. Altitude of land surface, 3,838.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, sandy, light brown	10	10
Silt, sandy, brown	5	15
TERTIARY—Pliocene		
Ogallala Formation		
Silt, very sandy, limy, light tan,	5	20
Silt, sandy, very limy, light gray	12	32
Sand, fine to coarse, silty; contains limy streaks	8	40
Sand, medium to very coarse, and fine gravel, clean	10	50
Sand, coarse to very coarse, clean	5	55
Bentonite, gray green	2	57
Sand, medium to very coarse, and fine gravel, clean	13	70
Sand, very coarse, and fine gravel, clean	10	80
Sand, medium to very coarse; contains layers of cemented limy silt	10	90
Sand, medium to very coarse, and fine gravel, clean	15	105
Sand, fine to coarse, and fine to medium gravel; contains cemented layers of limy silt	7	112
Sand, medium to very coarse, and fine gravel	8	120
Sand, medium to very coarse, and fine gravel; lower part contains cemented limy streaks	10	130
Sand, medium to very coarse, and fine to medium gravel	10	140
Sand, fine to very coarse; contains cemented streaks	10	150
Sand, medium to very coarse, and fine to medium gravel, clean	18	168
Sand, fine to medium, limy, cemented	12	180
Silt, sandy, limy, cemented	10	190
Sand, fine to coarse; contains cemented limy streaks	10	200
Sand, medium to very coarse; contains small amount fine gravel	24	224
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, brown and gray	14	238

14-42-8cbc.—Sample log of test hole in SW NW SW sec. 8, T. 14 S., R. 42 W., 0.3 mile north of sec. line and 7 feet east of road center (Bradley and Johnson, 1957, p. 123); drilled September 1951. Altitude of land surface, 3,900.2 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt and clay, tan gray	10	10
Silt, clayey, tan gray	11	21
TERTIARY—Pliocene		
Ogallala Formation		
Clay, silty, blocky, limy; contains a little embedded sand,	4	25
Clay, silty to sandy, gray brown; contains embedded fine to medium sand	6	31
Sand, and interbedded layers of clay and sandy silt	8	39
Sand and gravel, fine to coarse; contains layers of clay in lower part	11	50
Sand and gravel, fine to coarse; contains layers of clay from 56 to 59 feet	10	60
Sand, coarse, and fine to coarse gravel; contains layers of clay from 62 to 65 feet	10	70
Sand and gravel, fine to coarse; contains a little silty clay	10	80
Sand and gravel, fine to coarse; contains interbedded thin layers of silty clay and limy silt	5	85
Clay, silty, tan	7	92
Sand, fine to medium; contains a little brown silt	10	102
Sand, fine to coarse, and fine gravel, silty	14	116
Clay, sandy, tan gray; contains interbedded layers of coarse sand and fine gravel	11	127
Sand, medium to coarse, and fine gravel; contains a few thin layers of clay	15	142

	Thickness, feet	Depth, feet
Clay, silty and sandy, tan brown	4	146
Sand, medium to coarse, and fine to medium gravel; contains layer of clay from 149 to 151 feet	10	156
Sand, fine to coarse; contains a little gravel and interbedded layers of brown sandy clay	10	166
Clay, sandy, brown; contains interbedded layers of sand	17	183
Sand, medium to coarse, and fine gravel	32	215
Clay, silty, and interbedded layers of sand	13	228
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, clayey, yellow gray	19	247
Shale, gray	3	250

14-42-13ccc.—Sample log of test hole in SW SW SW sec. 13, T. 14 S., R 42 W., 40 feet east and 35 feet north of SW cor. sec. 13; drilled November 1957. Altitude of land surface, 3,791.2 feet; depth to water, 100.05 feet, November 14, 1957.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, sandy, light brown	16	16
Sand, medium, silty	4	20
Silt, very sandy, tan	5	25
TERTIARY—Pliocene		
Ogallala Formation		
Sand, medium to coarse, and fine gravel, clean	12	37
Silt, sandy, limy, light tan; contains cemented layers in lower part	17	54
Silt, sandy, red brown; very limy in lower 3 feet	11	65
Silt and fine to medium sand; contains limy streaks	11	76
Sand, fine to medium, silty	8	84
Sand, coarse to very coarse, clean	5	89
Bentonite, gray green	9	98
Sand, fine, and limy silt	12	110
Sand, medium to coarse, silty,	10	120
Silt, sandy, light tan	8	128
Sand, fine to coarse; contains layers of limy silt and cemented streaks	7	135
Silt, very sandy, limy, light tan	12	147
Sand, medium to very coarse, and fine gravel	18	165
Sand, medium to coarse, clean,	13	178
Silt, sandy, tan	6	184
Sand, medium	6	190
Sand, very coarse, clean	6	196
Sand, fine, and interbedded layers of limy silt; contains cemented streaks	16	212
Sand, medium to coarse; contains thin layers of cemented silt	13	225
Sand, fine to medium, silty in lower 5 feet	10	235
Sand, medium to coarse	8	243
Sand, fine, silty in top 3 feet,	7	250
Sand, medium to very coarse,	5	255
Silt, very sandy, light brown,	11	266
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Clay, tough, yellow	4	270
Shale, dark gray	10	280

14-42-14dbd.—Drillers log of irrigation well in SE NW SE sec. 14, T. 14 S., R. 42 W.; drilled by Ben Hasz, April 1956. Altitude of land surface, 3,795.8 feet; depth to water, 102.06 feet, June 24, 1958.

	Thickness, feet	Depth, feet
Pleistocene and Pliocene (undifferentiated)		
Top and subsoil	8	8
Sand and clay	93	101
Sand	2	103
Clay and sandy clay; contains cemented layers	19	122
Sand, fine, loose	24	146
Clay, sandy, and interbedded layers of sand	20	166
Sand; contains a little sandy clay	12	178
Clay; contains cemented layers,	19	197
Sand; contains a little sandy clay	11	208
Clay and sandy clay	3	211
Sand, coarse, loose	10	221
Clay, sandy	4	225
Sand; contains a little sandy clay	7	232
Clay, sandy; contains cemented layers	6	238
Sand, coarse, loose	6	244
Clay, sandy; contains thin layers of sand	13	257
Sand, coarse, loose	10	267
Clay and sandy clay	11	278
Sand, coarse, loose	10	288
Clay, sandy; contains thin layers of sand	11	299
Sand, coarse, loose	10	309
Clay and sandy clay	3	312
Sand, coarse, loose	18	330
Clay	6	336
Sand, coarse, loose	8	344
Clay and sandy clay; contains cemented layers	23	367
Sand, coarse, loose	3	370
Mortar bed	2	372
Sand, coarse, loose	4	376
Clay, sandy	2	378
Sand and a little sandy clay,	14	392
Sand, coarse, loose	6	398
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Soapstone	2	400

14-42-20ccb.—Sample log of test hole in NW SW SW sec. 20, T. 14 S., R. 42 W., 33 feet south of bridge and 13 feet east of road center (Bradley and Johnson, 1957, p. 124); drilled September 1951. Altitude of land surface, 3,837.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Soil and sandy silt, gray brown to black	4	4
Clay, silty, tan brown	2	6
TERTIARY—Pliocene		
Ogallala Formation		
Clay, limy, tan; contains thin layers of sand	2	8
Clay, very limy, light tan	3	11
Clay, silty to sandy, tan brown,	10	21
Clay, very sandy, tan brown; contains layer of limy clay from 28 to 29 feet	18	39
Silt, very limy, cemented, white	2	41
Silt and clay, sandy, cemented, tan	9	50
Sand, fine to coarse, and fine to medium gravel; contains thin layers of silt and clay	14	64
Clay, sandy, tan; contains cemented layer from 68 to 69 feet	7	71
Sand, medium to coarse, and fine gravel; contains interbedded layers of clay	11	82
Clay, silty to sandy, tan gray	3	85
Clay, sandy, brown	9	94
Sand, fine to coarse	50	144
Sand and tan clay, interbedded	7	151
Sand and gravel, fine to coarse; contains layers of clay at 152, 158, and 167 feet	22	173
Clay, tan gray	6	179
Sand, fine to medium	7	186
Clay, silty to sandy	7	193
Sand, fine to coarse; contains streaks of clay	10	203
Sand, fine to coarse, and fine gravel; contains interbedded thin layers of clay	70	273
Sand, fine to coarse, and tan silty clay, interbedded	12	285
Sand, coarse, and fine to medium gravel	12	297
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, clayey, yellow tan	6	303
Shale, dark gray	4	307

14-42-22acc.—Drillers log of test hole in SW SW NE sec. 22, T. 14 S., R. 42 W.; drilled by Ben Hasz, October 1955. Altitude of land surface, 3,833.7 feet.

	Thickness, feet	Depth, feet
Pleistocene and Pliocene (undifferentiated)		
Top and subsoil	6	6
Sand and clay; contains cemented layers	100	106
Sand, fine; contains a little red clay and sandy clay	9	115
Clay	4	119
Sand and red clay	7	126
Clay, sandy, and red clay	10	136
Sand and red clay	18	154
Clay, sandy, and red clay	11	165
Sand	4	169
Clay, sandy	4	173
Sand, good, loose	12	185
Clay, sandy	4	189
Sand, fine	4	193
Clay and sandy clay; contains cemented layers	10	203
Sand	7	210
Clay, sandy; contains thin interbedded layers of sand	15	225
Sand, good, loose	6	231
Clay, sandy; contains cemented layers	9	240
Sand, coarse, loose	10	250
Clay, sandy	8	258
Sand, coarse, loose	12	270
Clay and sandy clay	6	276
Sand	9	285
Clay and sandy clay	15	300
Sand, coarse, loose	24	324
Clay	3	327
Sand	3	330
Clay and sandy clay; contains cemented layers	18	348
Sand, coarse, loose	16	364
Clay, sandy; contains cemented layers	6	370
Sand	4	374
Clay	4	378
Sand	7	385
Clay, sandy	4	389
Sand	5	394
Clay and sandy clay	4	398
Clay, sandy	6	404
Sand	4	408
Clay, sandy	2	410
Sand, coarse, loose	22	432
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Soapstone	3	435
Shale	3	438

14-42-23dbb1.—Drillers log of irrigation well in NW NW SE sec. 23, T. 14 S., R. 42 W.; drilled by Ben Hasz, October 1955. Altitude of land surface, 3,808.6 feet; depth to water, 114.09 feet, June 24, 1958.

	Thickness, feet	Depth, feet
Pleistocene and Pliocene (undifferentiated)		
Top and subsoil	8	8
Sand and clay	87	95
Clay and sandy clay	19	114
Clay and sandy clay; contains cemented layers	7	121
Sand and sandy clay	9	130
Clay, sandy; contains thin cemented layers	17	147
Sand and sandy clay	3	150
Clay and sand; contains cemented layers	9	159
Sand	6	165
Clay	3	168

	Thickness, feet	Depth, feet
Sand and gravel	12	180
Clay	9	189
Sand and gravel	13	202
Clay	4	206
Sand, coarse, loose	13	219
Clay, sandy; contains thin layers of sand	4	223
Clay	8	231
Sand, coarse, loose	10	241
Clay	11	252
Sand; cemented from 257 to 258	11	263
Clay	8	271
Sand	8	279
Clay	4	283
Sand	4	287
Clay and sandy clay	9	296
Sand	6	302
Clay; contains cemented layers	3	305
Sand, coarse, loose	30	335
Clay, sandy	6	341
Sand	2	343
Clay, sandy	2	345
Sand	3	348
Clay	2	350
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Soapstone	7	357

14-42-23dbb2.—Sample log of test hole in NW NW SE sec. 23, T. 14 S., R. 42 W., observation well for pumping test, 237 feet NW of irrigation well; drilled August 1960. Depth to water, 118.19 feet, August 18, 1960.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, light brown	10	10
Silt, lower part very sandy, tan,	10	20
TERTIARY—Pliocene		
Ogallala Formation		
Sand, medium, clean, well sorted	16	36
Sand, fine to coarse, very limy,	6	42
Sand, medium to very coarse, clean, loose	8	50
Sand, medium to very coarse, and fine gravel, clean, loose,	8	58
Sand, fine to very coarse; contains cemented streaks	18	76
Silt, sandy, limy, light tan	9	85
Silt, very sandy, very limy, light gray	10	95
Sand, medium to very coarse; contains cemented limy silt streaks	15	110
Silt, very sandy, tan	5	115
Silt, very limy, cemented, light gray	15	130
Silt, limy, and streaks and thin layers of fine to medium sand, cemented hard; contains streaks of caliche	10	140
Sand, fine to medium; contains cemented limy silt streaks,	10	150
Sand, fine to coarse, clean	8	158
Silt, light tan	2	160
Sand, medium to coarse, and fine gravel; contains thin layers of limy silt	10	170

14-42-29cbb.—Sample log of test hole in NW NW SW sec. 29, T. 14 S., R. 42 W., 30 feet east of road center and 20 feet south of ½-mile line; drilled August 1960. Altitude of land surface, 3,854.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, sandy, tan	10	10
Silt, very sandy, tan	15	25
TERTIARY—Pliocene		
Ogallala Formation		
Silt, very sandy, limy	7	32
Sand, fine to very coarse; lower part contains layers of limy silt	8	40
Sand, fine to very coarse, and fine gravel; upper part contains layers of silt	10	50
Sand, fine to very coarse; contains silt layers	3	53
Silt, very limy	6	59
Gravel, fine to medium, and coarse sand; contains layers of limy silt	11	70
Gravel and coarse sand; contains layers of very limy silt,	10	80
Sand, fine to coarse, loose	15	95
Silt, sandy, very limy	5	100
Sand, fine to coarse; contains cemented limy layers	10	110
Sand, coarse to very coarse, very clean; contains small amount fine gravel	10	120
Gravel, fine to medium, and coarse sand, clean, loose	10	130
Sand, fine to coarse; contains cemented limy layers	10	140
Sand, medium to very coarse, and fine gravel; contains streaks of limy silt	10	150
Sand, coarse to very coarse, and fine gravel; contains cemented hard streaks	18	168
Silt, sandy, tan	4	172
Sand, medium to very coarse, and fine to medium gravel; contains thin layers of silt,	8	180
Sand, medium to very coarse, and fine to medium gravel, clean, loose	10	190
Sand, very coarse, and fine to medium gravel, clean	7	197
Silt, light tan	2	199
Sand, coarse to very coarse, and fine gravel	9	208
Silt, sandy, limy	7	215
Sand, fine to very coarse; contains thin layers of silt	15	230
Sand, fine to medium; contains cemented limy streaks	10	240
Sand, fine to very coarse, and fine gravel, clean	10	250

	Thickness, feet	Depth, feet
Sand, medium to very coarse, clean, loose	10	260
Sand, medium to very coarse, and fine gravel, clean; contains cemented streaks	10	270
Sand, fine to coarse; contains cemented limy streaks	10	280
Sand, medium to very coarse, clean	10	290
Sand, very coarse, and fine gravel, clean	10	300
Sand, medium to very coarse, clean	15	315
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, gray and brown	10	325
Shale, black	15	340

14-42-32ccc.—Sample log of test hole in SW SW SW sec. 32, T. 14 S., R. 42 W., 50 feet north and 37 feet east of road intersection (Bradley and Johnson, 1957, p. 125); drilled September 1951. Altitude of land surface, 3,876.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Soil, silt, and clay, black	3	3
Silt, tan gray	9	12
Sand, fine to coarse	7	19
TERTIARY—Pliocene		
Ogallala Formation		
Clay, sandy, limy, tan to light gray	8	27
Clay, sandy, tan brown	2	29
Sand, fine to coarse, and fine gravel	8	37
Clay, sandy, limy, tan gray	2	39
Sand, fine to medium	11	50
Sand, fine to coarse	3	53
Clay, tan brown; contains cemented sandy and limy silt from 57 to 58 feet	9	62
Gravel, fine to coarse, and very coarse sand	6	68
Bentonite, white	7.5	75.5
Clay, sandy, gray brown	4.5	80
Sand, fine to coarse; contains thin layers of clay	8	88
Clay, silty, brown	3	91
Sand, fine to coarse, and fine gravel	16	107
Clay, sandy, tan gray and brown	11	118
Sand, fine to coarse, and fine gravel	7	125
Clay, silty, limy, tan to light gray	10	135
Clay, silty, limy, tan to light gray, and interbedded brown sandy clay	12	147
Sand, fine to coarse	19	166
Clay, silty, tan gray	5	171
Sand, fine to coarse, and fine gravel	22	193
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, clayey, yellow	2	195
Shale, dark gray	3	198

15-38-3dcb2.—Drillers log of irrigation well in NW SW SE sec. 3, T. 15 S., R. 38 W., drilled by Kenneth Bogart, 1957. Altitude of land surface, 3,503.8 feet; depth to water, 78.37 feet, June 23, 1958.

	Thickness, feet	Depth, feet
Pleistocene and Pliocene (undifferentiated)		
Topsoil and silt	22	22
Sand and limy silt; contains cemented layers	20	42
Clay and sand; contains hard cemented layers	14	56
Clay	7	63
Clay, very sandy	3	66
Clay	4	70
Sand	28	98
Mortar bed	1	99
Sand	21	120
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale	5	125

15-38-5ccb.—Drillers log of irrigation well in NW SW SW sec. 5, T. 15 S., R. 38 W., drilled by Ben Hasz, September 1957. Altitude of land surface, 3,530.9 feet; depth to water, 76.90 feet, June 13, 1958.

	Thickness, feet	Depth, feet
Pleistocene and Pliocene (undifferentiated)		
Top and subsoil	2	2
Sand and clay	17	19
Clay and sand; contains hard cemented layers	24	43
Sand and clay; contains cemented streaks	33	76
Clay, green; contains cemented layers	8	84
Sand, medium to coarse, loose,	6	90
Clay, cemented	1	91
Sand, medium to coarse, loose,	4	95
Sand; contains thin cemented layers	10	105
Sand and gravel, loose	6	111
Sand, cemented	2	113
Sand and sandy clay; contains cemented layers	9	122
Sand, fine to medium, and interbedded layers of sandy clay	12	134
Sand and gravel, loose	5	139
Clay, pink; contains cemented streaks	5	144
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Clay, yellow	7	151
Shale	6	157

15-38-7bbb.—Drillers log of irrigation well in NW NW NW sec. 7, T. 15 S., R. 38 W.; drilled by Ben Hasz. Altitude of land surface, 3,551.4 feet; depth to water, 90.55 feet, June 17, 1958.

	Thickness, feet	Depth, feet
Pleistocene and Pliocene (undifferentiated)		
Soil and silt	17	17

	Thickness, feet	Depth, feet
Sand; contains cemented layers	32	49
Clay	6	55
Gravel	10	65
Sand, cemented	2	67
Gravel	5	72
Clay	2	74
Gravel	5	79
Clay	6	85
Gravel	19	104
Sand, cemented	4	108
Sand	12	120
Sand, cemented	1	121
Gravel	16	137
Sand; contains cemented layers	16	153
Gravel	14	167
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Soapstone	8	175
Shale	3	178

15-38-8bbb.—Drillers log of irrigation well in NW NW NW sec. 8, T. 15 S., R. 38 W., drilled by Ben Hasz, May 1958. Altitude of land surface, 3,531.9 feet; depth to water, 77.87 feet, June 17, 1958.

	Thickness, feet	Depth, feet
Pleistocene and Pliocene (undifferentiated)		
Top and subsoil	10	10
Clay	14	24
Clay; contains cemented layers	21	45
Sand, clay; contains a few cemented layers	19	64
Clay and sandy clay	20	84
Sand	1	85
Clay, sandy	4	89
Sand	8	97
Clay, sandy	4	101
Mortar bed	2	103
Sand, coarse	14	117
Clay, sandy, and sand	7	124
Sand, fine, and sandy clay	11	135
Sand, coarse	11	146
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale	2	148

15-38-10cbd.—Drillers log of irrigation well in SE NW SW sec. 10, T. 15 S., R. 38 W.; drilled by Jack Foust. Altitude of land surface, 3,511.4 feet; depth to water, 82.65 feet, June 23, 1958.

	Thickness, feet	Depth, feet
Pleistocene and Pliocene (undifferentiated)		
Soil and silt	36	36
Sand, contains cemented layers,	18	54
Gravel	6	60
Sand	9	69
Clay, sandy	4	73
Sand	14	87
Sand; contains cemented layers,	9	96
Sand	6	102
Sand, cemented	4	106
Sand	10	116
Clay; contains hard cemented layers	12	128
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Soapstone	5	133
Shale	2	135

15-38-14ccd.—Drillers log of irrigation well in SE SW SW sec. 14, T. 15 S., R. 38 W.; drilled by Weishaar & Son. Altitude of land surface, 3,485.9 feet; depth to water, 72.97 feet, June 14, 1958.

	Thickness, feet	Depth, feet
Pleistocene and Pliocene (undifferentiated)		
Clay	20	20
Clay, limy	29	49
Sand	23	72
Sand; contains clay streaks	8	80
Clay, sandy	14	94
Sand	29	123
Sand; contains clay streaks	9	132
Clay, sandy	10	142
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Clay, yellow	6	148
Shale	2	150

15-38-17daa.—Sample log of test hole in NE NE SE sec. 17, T. 15 S., R. 38 W., 42 feet south of bridge and 7 feet west of road center (Bradley and Johnson, 1957, p. 128); drilled October 1951. Altitude of land surface, 3,508.7 feet; depth to water, 66.56 feet, October 20, 1951.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Soil, silt, and clay, black	5.5	5.5
Silt, clayey, tan gray	8.5	14
Silt, and fine sand, brown	5	19
TERTIARY—Pliocene		
Ogallala Formation		
Clay, sandy, tan	5	24
Sand and gravel, fine to coarse; contains thin layers of tan clay	6	30
Sand, fine to coarse, and fine gravel; contains cemented streaks	18	48
Clay, sandy, limy, light tan; contains interbedded thin layers of fine to coarse sand,	5	53
Clay, sandy, gray green	3	56
Clay, sandy, limy, light tan to brown	9	65
Clay, silty, very sandy, tan brown	6	71
Sand, fine to coarse, and fine to medium gravel	8	79
Sand and interbedded light-tan limy clay	8	87
Clay, silty, gray	4	91
Sand, fine, and interbedded tan to gray limy clay	6	97
Clay, silty, sandy, brown	5	102
Sand, fine	16	118
Sand, fine, and interbedded layers of clay	4	122
Sand, fine to coarse; contains thin layers of yellow and tan clay	12	134

CRETACEOUS—Upper Cretaceous Pierre Shale	Thickness, feet	Depth, feet
Shale, clayey, yellow	7	141
Shale, dark gray	3	144

15-38-20dba.—Drillers log of irrigation well in NE NW SE sec. 20, T. 15 S., R. 38 W., drilled by Jack Foust, 1956. Altitude of land surface, 3,517.8 feet; depth to water, 88.90 feet, June 18, 1958.

Pleistocene and Pliocene (undifferentiated)	Thickness, feet	Depth, feet
Soil and silt	17	17
Sand; contains cemented layers,	21	38
Gravel	5	43
Sand; contains cemented layers,	7	50
Gravel	4	54
Sand; contains cemented layers,	18	72
Gravel	6	78
Sand; contains cemented layers,	13	91
Gravel	9	100
Clay	7	107
Gravel	5	112
Clay	8	120
Gravel	23	143
Clay	3	146
Gravel	15	161
Clay	3	164
Gravel	11	175
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Soapstone	12	187
Shale	3	190

15-38-21cbc.—Drillers log of irrigation well in SW NW SW sec. 21, T. 15 S., R. 38 W.; drilled by Weishaar & Son. Altitude of land surface, 3,513.2 feet; depth to water, 85.88 feet, June 17, 1958.

Pleistocene and Pliocene (undifferentiated)	Thickness, feet	Depth, feet
Clay	26	26
Clay, limy	21	47
Sand	3	50
Clay, sandy	47	97
Sand, fine; contains thin layers of clay	7	104
Sand; contains thin layers of clay	9	113
Sand	4	117
Sand; contains thin layers of clay	4	121
Sand	5	126
Sand and gravel	11	137
Sand, cemented	3	140
Sand and gravel	7	147
Sand; contains thin layers of clay	5	152
Sand	13	165
Sand, cemented	2	167
Clay, sandy	5	172
Sand and gravel	7	179
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Clay, yellow	7	186
Shale	4	190

15-38-27aaa.—Sample log of test hole in NE NE NE sec. 27, T. 15 S., R. 38 W., 30 feet west and 28 feet south of NE cor. sec. 27; drilled November 1957. Altitude of land surface, 3,469.2 feet; depth to water, 58.08 feet, November 13, 1957.

QUATERNARY—Pleistocene Peoria and Loveland Formations	Thickness, feet	Depth, feet
Silt, light tan, becoming limy in lower part	15	15
TERTIARY—Pliocene		
Ogallala Formation		
Sand, medium to coarse, very silty	7	22
Silt, sandy, gray	3	25
Sand, medium to coarse, silty	3	28
Silt, sandy, very limy, light tan to light gray	7	35
Sand, fine to coarse, very silty,	7	42
Silt, sandy, limy; contains cemented layers	14	56
Sand, medium to coarse; contains thin layers of limy silt	4	60
Silt, sandy, limy; contains cemented layers	4	64
Sand, medium, gray	4	68
Silt, very sandy, tan; contains thin interbedded layers of fine to coarse sand	10	78
Sand, medium to very coarse; contains thin cemented layers	14	92
Silt, sandy, very limy, cemented, light gray	13	105
Silt and fine to coarse sand	10	115
Sand, fine to coarse, very silty,	7	122
Sand, fine; contains layers of limy silt at 128 to 130 feet	9	131
Sand, medium to coarse	12	143
Silt, sandy, cemented, yellow and tan	4	147
Sand, fine to coarse, silty	7	154
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale	11	165

15-38-28bcc.—Drillers log of irrigation well in SW SW NW sec. 28, T. 15 S., R. 38 W.; drilled by Weishaar & Son. Altitude of land surface, 3,511.7 feet.

Pleistocene and Pliocene (undifferentiated)	Thickness, feet	Depth, feet
Clay	19	19
Clay, limy	24	43
Sand	14	57
Clay	6	63
Sand; contains clay streaks	9	72
Sand	10	82
Sand; contains clay streaks	11	93
Sand and interbedded layers of clay	21	114
Sand	7	121
Clay	7	128
Sand	8	136
Sand, fine, cemented; contains clay streaks	9	145

	Thickness, feet	Depth, feet
Sand, medium	8	153
Sand, cemented	9	162
Sand	36	198
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Clay, yellow	7	205
Shale	5	210

15-38-28dbb.—Drillers log of irrigation well in NW NW SE sec. 28, T. 15 S., R. 38 W.; drilled by Weishaar & Son, February 1957. Altitude of land surface, 3,502.0 feet; depth to water, 91.70 feet, October 7, 1960.

Pleistocene and Pliocene (undifferentiated)	Thickness, feet	Depth, feet
Clay	19	19
Clay; contains limy layers	11	30
Clay, limy, tight; contains streaks of sand	17	47
Clay, sandy; contains limy layers	8	55
Sand and clay	8	63
Clay, sandy	15	78
Sand and clay	6	84
Clay, sandy	12	96
Sand; contains streaks of clay	5	101
Clay	15	116
Sand, good	11	127
Sand and clay	3	130
Sand, fine to medium	8	138
Cemented layer	2	140
Sand, fine; contains a few streaks of clay	11	151
Sand and clay	4	155
Sand, good	7	162
Sand and clay	4	166
Sand, good	13	179
Sand and gravel, good	16	195
Clay	2	197
Sand and gravel	4	201
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, yellow	7	208
Shale	2	210

15-38-29abc.—Drillers log of irrigation well in SW NW NE sec. 29, T. 15 S., R. 38 W.; drilled by Weishaar & Son, February 1957. Altitude of land surface, 3,520.2 feet.

Pleistocene and Pliocene (undifferentiated)	Thickness, feet	Depth, feet
Clay	23	23
Clay, limy	25	48
Sand; contains limy streaks	11	59
Clay	21	80
Sand and interbedded clay	13	93
Clay	14	107
Sand	9	116
Sand, good	10	126
Sand; contains clay streaks	7	133
Sand, medium	11	144
Sand	5	149
Clay, sandy	7	156
Sand; contains clay streaks	8	164
Sand	15	179
Sand and gravel	17	196

CRETACEOUS—Upper Cretaceous	Thickness, feet	Depth, feet
Pierre Shale		
Clay, yellow	4	200
Shale	5	205

15-38-30bbb.—Sample log of test hole in NW NW NW sec. 30, T. 15 S., R. 38 W., 30 feet east and 8 feet south of NW cor. sec. 30; drilled November 1957. Altitude of land surface, 3,539.1 feet; depth to water, 92.10 feet, November 13, 1957.

QUATERNARY—Pleistocene	Thickness, feet	Depth, feet
Peoria and Loveland Formations		
Silt, light tan, clayey in lower part	15	15
TERTIARY—Pliocene		
Ogallala Formation		
Silt, very limy, white and light tan; contains cemented layers in lower part	19	34
Silt, sandy, limy, light tan, very limy in lower part	22	56
Silt, clayey, gray	12	68
Sand, medium to very coarse, silty	10	78
Silt, sandy, limy, light tan	15	93
Silt, sandy, very limy, light gray and white; contains cemented layers	9	102
Sand, medium to coarse, and fine gravel; contains thin layers of silt	17	119
Silt, sandy, light tan	6	125
Sand, fine to coarse, very silty,	15	140
Sand, medium to coarse, very silty	12	152
Silt, sandy, very limy, light gray and white	13	165
Sand, fine, silty	17	182
Silt, very sandy, light tan	13	195
Silt and fine sand	10	205
Sand, fine to coarse, silty	11	216
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, orange yellow and gray,	9	225

15-38-30ccb.—Drillers log of irrigation well in NW SW SW sec. 30, T. 15 S., R. 38 W.; drilled by Weishaar & Son, August 1959. Altitude of land surface, 3,538.6 feet.

Pleistocene and Pliocene (undifferentiated)	Thickness, feet	Depth, feet
Clay	30	30
Cemented limy layer	6	36
Clay	14	50
Cemented limy layer	7	57
Sand, fine, and clay	8	65
Clay	6	71
Sand, coarse	11	82
Sand, fine, and clay	12	94
Sand, fine, tight	3	97
Sand, coarse	9	106
Sand, fine, and clay	8	114
Sand, good	21	135
Sand, fine, and clay	8	143
Sand, good	4	147
Sand, fine, and clay	6	153
Sand, medium, good	7	160

	Thickness, feet	Depth, feet
Sand, fine, and clay	8	168
Sand, good	6	174
Sand, fine, tight	4	178
Sand, fine, and clay	3	181
Sand, medium, good	8	189
Sand, good	17	206
Clay	4	210
Sand and gravel, good	19	229
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, yellow	3	232
Shale	8	240

15-38-32baa.—Drillers log of irrigation well in NE NE NW sec. 32, T. 15 S., R. 38 W.; drilled by Weishaar & Son. Altitude of land surface, 3,522.8 feet; depth to water, 93.60 feet, June 18, 1958.

Pleistocene and Pliocene (undifferentiated)	Thickness, feet	Depth, feet
Clay	24	24
Clay, limy	37	61
Sand	11	72
Sand, fine; contains clay streaks,	11	83
Sand	9	92
Clay, sandy	11	103
Clay	3	106
Clay, sandy	22	128
Sand, fine to medium	7	135
Sand	26	161
Sand, fine	11	172
Sand and gravel	34	206
Sand and clay	4	210
Sand and gravel	16	226
Clay	4	230
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale	5	235

15-38-32dbb.—Drillers log of irrigation well in NW NW SE sec. 32, T. 15 S., R. 38 W.; drilled by Weishaar & Son. Altitude of land surface, 3,511.7 feet.

Pleistocene and Pliocene (undifferentiated)	Thickness, feet	Depth, feet
Clay	19	19
Clay, limy	33	52
Clay	21	73
Sand	11	84
Sand; contains clay streaks	14	98
Sand	9	107
Sand; contains clay streaks	8	115
Sand, fine to medium	15	130
Sand	9	139
Sand, fine to medium	7	146
Sand; contains cemented limy streaks	7	153
Sand, fine; contains clay streaks,	6	159
Sand	9	168
Sand, cemented	4	172
Sand	17	189
Sand, cemented	4	193
Sand	11	204
Sand, fine to medium	7	211
Sand	16	227

CRETACEOUS—Upper Cretaceous	Thickness, feet	Depth, feet
Pierre Shale		
Clay, yellow	2	229
Shale	6	235

15-38-33cbb.—Drillers log of irrigation well in NW NW SW sec. 33, T. 15 S., R. 38 W.; drilled by Weishaar & Son. Altitude of land surface, 3,505.5 feet.

Pleistocene and Pliocene (undifferentiated)	Thickness, feet	Depth, feet
Clay	17	17
Clay, limy	9	26
Clay, limy; contains cemented streaks	25	51
Sand; contains thin layers of limy clay	9	60
Sand and interbedded clay	15	75
Sand	9	84
Clay	6	90
Sand, cemented	22	112
Sand	7	119
Clay, sandy	5	124
Mortar bed	1	125
Sand	25	150
Mortar bed	3	153
Sand, fine to medium	7	160
Sand	60	220
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Clay, yellow	3	223
Shale	2	225

15-38-33cdd.—Sample log of test hole in SE SE SW sec. 33, T. 15 S., R. 38 W., 3 feet north of fence line and 180 feet west of ½-mile line; (Bradley and Johnson, 1957, p. 128); drilled October 1951. Altitude of land surface, 3,505.2 feet; depth to water, 80.60 feet, October 20, 1951.

QUATERNARY—Pleistocene	Thickness, feet	Depth, feet
Peoria and Loveland Formations		
Soil, silt, and clay, black	2	2
Silt, tan gray	15	17
Clay, silty, tan gray	1	18
Clay, silty, tan brown to light tan	11	29
TERTIARY—Pliocene		
Ogallala Formation		
Silt, very limy, light gray to white	10	39
Silt and silty clay, tan brown	8	47
Clay, very silty, light gray; contains interbedded layers of fine to coarse sand	9	56
Sand, fine to coarse, silty, cemented	11	67
Sand, fine to coarse, and gravel; contains layer of clay from 74 to 76 feet	10	77
Sand, fine to very coarse	17	94
Clay, brown, and interbedded layers of sand	10	104
Clay, sandy, light gray	2	106
Sand, fine to coarse, and fine to medium gravel	11	117
Clay, silty, tan gray	18	135

	Thickness, feet	Depth, feet
Sand, fine to coarse; contains interbedded thin layers of silt and clay	10	145
Sand, fine to coarse; contains a few thin layers of limy clay,	25	170
Clay, limy, blocky, light gray	5	175
Sand, fine to coarse; contains thin layers of tan clay	20	195
Sand, fine to coarse	31	226
CRETACEOUS—Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Clay, yellow to white	3.5	229.5
Shale, gray	3.5	233

15-38-34cbc.—Drillers log of irrigation well in SW NW SW sec. 34, T. 15 S., R. 38 W.; drilled by Weishaar & Son. Altitude of land surface, 3,491.6 feet.

Pleistocene and Pliocene (undifferentiated)	Thickness, feet	Depth, feet
Clay	19	19
Clay, limy	13	32
Clay, limy; contains cemented layers	17	49
Clay and interbedded layers of limy clay	8	57
Clay	14	71
Sand and interbedded clay	9	80
Sand	12	92
Sand; contains clay streaks	7	99
Sand	9	108
Sand, cemented	3	111
Sand, fine; contains clay streaks,	31	142
Sand	19	161
Sand, fine, cemented	5	166
Sand	22	188
Clay	3	191
Sand	21	212
CRETACEOUS—Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Clay, yellow	4	216
Shale	4	220

15-38-36cbb.—Drillers log of irrigation well in NW NW SW sec. 36, T. 15 S., R. 38 W.; drilled by Weishaar & Son. Altitude of land surface, 3,461.1 feet; depth to water, 70.81 feet, June 19, 1958.

Pleistocene and Pliocene (undifferentiated)	Thickness, feet	Depth, feet
Clay	19	19
Clay, limy	24	43
Mortar bed	2	45
Clay and limy clay	9	54
Clay, sandy	15	69
Sand, medium	9	78
Clay; contains thin beds of fine sand	24	102
Clay	5	107
Sand, fine to medium	12	119
Sand, coarse	34	153

CRETACEOUS—Upper Cretaceous Niobrara Chalk—Smoky Hill Chalk Member	Thickness, feet	Depth, feet
Clay, yellow	4	157
Shale	3	160

15-39-1ccc.—Drillers log of irrigation well in SW SW SW sec. 1, T. 15 S., R. 39 W.; drilled by Ben Hasz. Altitude of land surface, 3,569.0 feet.

Pleistocene and Pliocene (undifferentiated)	Thickness, feet	Depth, feet
Topsoil	2	2
Sand and sandy clay; contains cemented layers	103	105
Sand, fine to coarse, loose; contains a few streaks of sandy clay	24	129
Clay, sandy, red	4	133
Sand, medium to coarse, loose; contains hard cemented streaks	10	143
Clay, sandy	3	146
Sand	3	149
Clay, sandy	3	152
Sand, fine to medium, loose	11	163
Sand; contains streaks of sandy clay	4	167
Sand, loose	3	170
Sand and clay, cemented hard,	4	174
Sand, medium to coarse, loose,	4	178
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, yellow	4	182
Shale	5	187

15-39-2bcd.—Drillers log of irrigation well in SE SW NW sec. 2, T. 15 S., R. 39 W.; drilled by Gustav Thieszen, November 1957. Altitude of land surface, 3,584.6 feet; depth to water, 112.22 feet, June 23, 1958.

Pleistocene and Pliocene (undifferentiated)	Thickness, feet	Depth, feet
Topsoil and clay	106	106
Clay, limy	6	112
Sand	6	118
Sand and gravel	14	132
Clay	4	136
Sand	4	140
Clay	6	146
Sand and gravel	2	148
Clay	4	152
Sand and gravel	36	188
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale	8	196

15-39-2cca.—Drillers log of irrigation well in NE SW SW sec. 2, T. 15 S., R. 39 W.; drilled by Gustav Thieszen, November 1957. Altitude of land surface, 3,582.0 feet; depth to water, 110.14 feet, June 23, 1958.

Pleistocene and Pliocene (undifferentiated)	Thickness, feet	Depth, feet
Topsoil, sand, and cemented sand	88	88

	Thickness, feet	Depth, feet
Sand and gravel	4	92
Sand, coarse	12	104
Sand, cemented, and clay	2	106
Sand	6	112
Sand, medium, and gravel	16	128
Sand and gravel, cemented hard	1	129
Sand, coarse	7	136
Clay and sand	2	138
Sand, medium, and gravel	16	154
Clay	2	156
Sand and gravel	14	170
Sand	2	172
Sand, medium, and gravel	12	184
Clay	12	196
Sand and gravel	6	202
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Clay	2	204

15-39-5ccc.—Drillers log of irrigation well in SW SW SW sec. 5, T. 15 S., R. 39 W., drilled by Ben Hasz, February 1957. Altitude of land surface, 3,622.4 feet; depth to water, 110.40 feet, June 17, 1958.

Pleistocene and Pliocene (undifferentiated)	Thickness, feet	Depth, feet
Top and subsoil	3	3
Sand, clay, and limy clay	89	92
Clay, sandy; contains cemented layers	12	104
Sand, medium to coarse, loose,	6	110
Clay, sandy	2	112
Sand, coarse, loose	14	126
Clay, sandy, soft	12	138
Sand, medium, loose	3	141
Clay and sandy clay; contains cemented streaks	8	149
Sand and sandy clay; contains cemented streaks	12	161
Sand, coarse, loose	12	173
Sand, fine, and sandy clay, soft,	7	180
Mortar bed	2	182
Sand, fine to medium, fairly loose	3	185
Clay, sandy, and cemented sand	4	189
Sand, coarse, loose; sandy clay from 197 to 198 feet	14	203
Clay, sandy	2	205
Sand, coarse, loose	12	217
Clay, sandy	1	218
Sand, coarse, very loose	7	225
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Soapstone	7	232

15-39-7dab.—Drillers log of irrigation well in NW NE SE sec. 7, T. 15 S., R. 39 W.; drilled by Ben Hasz, February 1957. Altitude of land surface, 3,637.2 feet; depth to water, 117.51 feet, June 18, 1958.

Pleistocene and Pliocene (undifferentiated)	Thickness, feet	Depth, feet
Top and subsoil	2	2
Clay and sand; contains cemented streaks	80	82
Sand and sandy clay; contains cemented streaks	15	97
Sand, gravel, and streaks of clay	12	109
Clay; contains cemented layers,	4	113
Clay and sandy clay	9	122
Sand, coarse, fairly loose	13	135
Clay, sandy, and a little sand,	8	143
Sand; contains cemented layers	4	147
Sand, coarse, loose	5	152
Mortar bed	1	153
Sand and sandy clay, soft	15	168
Sand, fine; contains cemented streaks	6	174
Clay; contains cemented streaks	10	184
Sand and sandy clay, soft	5	189
Sand, medium to coarse, loose,	6	195
Clay	2	197
Sand, medium to coarse, loose,	8	205
Clay; contains cemented layers,	4	209
Sand, fine, cemented; contains a little sandy clay	15	224
Sand, medium to coarse, loose,	4	228
Clay, sandy	1	229
Sand, medium to coarse, loose,	8	237
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Soapstone	4	241
Shale	3	244

15-39-8acc.—Drillers log of irrigation well in SW SW NE sec. 8, T. 15 S., R. 39 W.; drilled by Ben Hasz, April 1948. Altitude of land surface, 3,615.5 feet; depth to water, 113.24 feet, July 16, 1951.

Pleistocene and Pliocene (undifferentiated)	Thickness, feet	Depth, feet
Topsoil	35	35
Sand and clay; contains cemented layers	15	50
Clay and interbedded layers of sand	4	54
Sand	8	62
Sand, cemented	13	75
Sand and clay	9	84
Sand, cemented	8	92
Clay	2	94
Sand; contains cemented layers,	4	98
Mortar bed	5	103
Sand and clay	2	105
Sand	20	125
Clay	2	127
Sand and clay	3	130
Sand	10	140
Sand and clay	6	146
Sand; contains cemented layers,	7	153
Sand and clay	8	161
Sand	2	163
Sand and clay	3	166
Sand	4	170
Clay	15	185
Sand	7	192
Sand and clay	3	195
Sand	2	197
Clay and sandy clay	12	209

	Thickness, feet	Depth, feet
Sand	4	213
Sand and clay	5	218
Sand, good	3	221
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Clay	1	222

15-39-12abb.—Drillers log of irrigation well in NW NW NE sec. 12, T. 15 S., R. 39 W.; drilled by Weishaar & Son, September 1959. Altitude of land surface, 3,558.1 feet.

Pleistocene and Pliocene (undifferentiated)	Thickness, feet	Depth, feet
Clay	29	29
Cemented limy layers	4	33
Clay	5	38
Cemented limy layers	8	46
Clay	15	61
Sand, coarse	8	69
Clay	13	82
Sand	5	87
Clay	3	90
Sand, good	12	102
Sand, fine, tight	6	108
Sand, good	17	125
Sand, fine	26	151
Sand, cemented	5	156
Sand, good	10	166
Sand, cemented	2	168
Sand, good	9	177
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, yellow	4	181

15-39-20dab.—Drillers log of irrigation well in NW NE SE sec. 20, T. 15 S., R. 39 W.; drilled by Weishaar & Son, September 1957. Altitude of land surface, 3,601.1 feet.

Pleistocene and Pliocene (undifferentiated)	Thickness, feet	Depth, feet
Clay	18	18
Clay, limy	16	34
Clay, sandy	7	41
Sand, cemented	7	48
Clay; contains limy streaks	14	62
Clay	7	69
Clay, sandy	14	83
Sand	9	92
Clay, limy	6	98
Clay	5	103
Clay, sandy	17	120
Sand, good	21	141
Clay, sandy	4	145
Sand	10	155
Sand, fine; contains thin layers of clay	15	170
Sand, cemented	6	176
Clay, sandy	3	179
Sand	10	189
Sand; contains thin layers of clay	4	193
Sand	11	204
Mortar bed	1	205
Sand and gravel	22	227

CRETACEOUS—Upper Cretaceous	Thickness, feet	Depth, feet
Pierre Shale		
Shale, yellow	5	232

15-39-20ddd.—Sample log of test hole in SE SE SE sec. 20, T. 15 S., R. 39 W., 55 feet north and 35 feet west of road intersection (Bradley and Johnson, 1957, p. 129); drilled October 1951. Altitude of land surface, 3,572.8 feet; depth to water, 65.90 feet, October 20, 1951.

QUATERNARY—Pleistocene	Thickness, feet	Depth, feet
Peoria and Loveland Formations		
Soil, silt, and clay, black	3	3
Silt, clayey, tan gray	11	14
TERTIARY—Pliocene		
Ogallala Formation		
Clay, tan to tan brown	8	22
Clay, tan, and interbedded layers of fine to coarse sand	6	28
Clay, limy, green blue and gray,	1.5	29.5
Sand, fine to coarse	3.5	33
Clay and limy silt, light tan and light gray	4	37
Sand, fine to medium, and interbedded tan to light-tan clay	11	48
Clay, sandy, tan brown	7	55
Sand, very fine, silty, tan gray,	12	67
Sand, fine to coarse, and fine gravel	26	93
Sand and interbedded tan clay	4	97
Sand, fine to coarse, and fine gravel	12	109
Sand and interbedded tan clay,	16	125
Sand, fine to coarse, and fine gravel	14	139
Clay, limy, tan	9	148
Sand, fine to coarse; contains layer of clay from 151 to 154 feet	10	158
Sand, fine to coarse, and fine gravel; contains interbedded layers of tan clay	20	178
Sand, fine to coarse, and fine to medium gravel; contains interbedded layers of tan clay	24	202
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, clayey, yellow	5	207
Shale, clayey, dark gray	3	210

15-39-23cbc1.—Drillers log of irrigation well in SW NW SW sec. 23, T. 15 S., R. 39 W.; drilled by Ben Hasz. Altitude of land surface, 3,571.3 feet.

Pleistocene and Pliocene (undifferentiated)	Thickness, feet	Depth, feet
Top and subsoil	4	4
Clay, and sandy clay; contains limy streaks	64	68
Sand	8	76
Clay, sandy	25	101
Sand and sandy clay	2	103
Clay, sandy	3	106
Sand and sandy clay	4	110

	Thickness, feet	Depth, feet
Clay, sandy	5	115
Cemented layer	1	116
Sand, coarse	8	124
Clay, sandy; contains cemented layer from 124 to 125 feet,	7	131
Sand	2	133
Clay, sandy; contains cemented layer from 137 to 138 feet	10	143
Sand	8	151
Clay, sandy; contains cemented streaks	13	164
Sand, coarse	8	172
Sand, and sandy clay; contains cemented layers	8	180
Sand	2	182
Cemented layer	1	183
Clay	5	188
Sand	16	204
Clay, sandy	13	217
Sand, coarse, loose	14	231
Clay	3	234
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale	9	243

15-39-23cbc2.—Sample log of test hole in SW NW SW sec. 23, T. 15 S., R. 39 W., observation well for pumping test 119 feet south of irrigation well; drilled August 1960. Depth to water, 98.66 feet, August 13, 1960.

QUATERNARY—Pleistocene	Thickness, feet	Depth, feet
Peoria and Loveland Formations		
Silt, dark brown	5	5
Silt, light brown	5	10
Silt, sandy, tan	10	20
TERTIARY—Pliocene		
Ogallala Formation		
Silt, sandy, very limy, light gray	8	28
Sand, medium to coarse	2	30
Silt, sandy, limy, cemented, and caliche	20	50
Gravel, fine to medium, and very coarse sand	6	56
Bentonite, gray green	3	59
Silt, very sandy, red tan	11	70
Gravel, medium, and very coarse sand	5	75
Silt, very sandy, limy, tan	5	80
Sand, medium	5	85
Silt, very sandy, limy, tan; contains cemented streaks	5	90
Sand, medium to coarse, and fine gravel, clean	10	100
Sand, coarse to very coarse, clean; contains small amount fine gravel	30	130

15-39-24bbc.—Drillers log of irrigation well in SW NW NW sec. 24, T. 15 S., R. 39 W.; drilled by Ben Hasz, October 1955. Altitude of land surface, 3,561.5 feet; depth to water, 101.63 feet, June 13, 1958.

Pleistocene and Pliocene (undifferentiated)	Thickness, feet	Depth, feet
Top and subsoil	7	7
Sand and clay; contains cemented layers	48	55
Sand	13	68
Clay, sandy	6	74
Sand	12	86
Clay, sandy	11	97
Sand, coarse, loose	17	114
Clay, sandy	10	124
Clay	3	127
Sand and sandy clay, very soft,	10	137
Sand	2	139
Clay and sandy clay	8	147
Sand; contains streaks of sandy clay	10	157
Clay	3	160
Sand and sandy clay	8	168
Sand	5	173
Sand and sandy clay; contains cemented layers	7	180
Sand; contains sandy clay from 185 to 186 feet	13	193
Sand and sandy clay; contains cemented layers	2	195
Sand, good, loose	21	216
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Soapstone	4	220
Shale	2	222

15-39-24cbb.—Drillers log of irrigation well in NW NW SW sec. 24, T. 15 S., R. 39 W.; drilled by Ben Hasz, October 1957. Altitude of land surface, 3,559.1 feet.

Pleistocene and Pliocene (undifferentiated)	Thickness, feet	Depth, feet
Top and subsoil	2	2
Sand and clay; contains cemented limy layers	72	74
Sand; contains a little sandy clay	9	83
Clay, sandy; contains cemented layers	2	85
Sand and sandy clay; contains cemented layers	2	87
Clay, sandy, soft	5	92
Sand	1	93
Clay, sandy, soft, green and brown; contains thin layers of sand	9	102
Sand, fine to medium, loose,	8	110
Sand, coarse, loose	13	123

	Thickness, feet	Depth, feet
Clay	5	128
Sand, medium, loose	4	132
Sand, coarse, loose	9	141
Sand; contains a little sandy clay	7	148
Sand, medium to coarse; contains streaks of sandy clay,	10	158
Clay	1	159
Clay, sandy, soft	9	168
Sand; contains a little sandy clay	4	172
Sand, medium, loose	2	174
Sand and sandy clay; contains thin cemented layers	7	181
Sand, coarse, loose	4	185
Sand, and sandy clay; contains thin cemented layers	5	190
Sand; contains a little sandy clay	3	193
Sand, coarse, loose	9	202
Sand and sandy clay; contains cemented layers	3	205
Sand, coarse, loose; contains a little sandy clay	3	208
Sand and gravel, very loose	8	216
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Soapstone	4	220
Shale	5	225

15-39-25bbb.—Drillers log of irrigation well in NW NW NW sec. 25, T. 15 S., R. 39 W.; drilled by Weishaar & Son, October 1956. Altitude of land surface, 3,555.7 feet; depth to water, 94.65 feet, June 18, 1958.

Pleistocene and Pliocene (undifferentiated)	Thickness, feet	Depth, feet
Clay	22	22
Clay, contains cemented streaks	29	51
Sand	10	61
Clay, sandy	8	69
Sand; contains clay streaks	11	80
Clay; contains sandy layers	13	93
Sand	8	101
Clay, sandy	12	113
Sand	14	127
Sand; contains clay streaks	6	133
Sand, good	6	139
Sand, medium	10	149
Sand, good	8	157
Clay	7	164
Sand, fine	7	171
Sand	5	176
Sand, medium	6	182
Sand	8	190
Sand, cemented	8	198
Clay, sandy	3	201
Sand, fine	11	212
Sand and gravel	15	227
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Clay, yellow	5	232
Shale	3	235

15-39-26acc.—Drillers log of irrigation well in SW SW NE sec. 26, T. 15 S., R. 39 W.; drilled by Weishaar & Son, December 1958. Altitude of land surface, 3,561.6 feet; depth to water, 98.93 feet, October 7, 1960.

Pleistocene and Pliocene (undifferentiated)	Thickness, feet	Depth, feet
Clay	32	32
Cemented limy layers	20	52
Hard cemented rock	4	56
Clay	5	61
Sand and gravel	6	67
Sand, fine, and clay	25	92
Sand, fine, tight	5	97
Sand, fine, and clay	3	100
Sand and gravel, good	9	109
Sand, fine, and clay	43	152
Sand, good	11	163
Sand, tight	2	165
Sand, good	9	174
Sand, fine, and clay	21	195
Sand, good	10	205
Sand, cemented	1	206
Sand, good	8	214
Sand, tight	1	215
Sand, good	3	218
Sand, hard	2	220
Sand and gravel, good	14	234
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, yellow	2	236

15-39-28bbd.—Drillers log of irrigation well in SE NW NW sec. 28, T. 15 S., R. 39 W.; drilled by Weishaar & Son, September, 1957. Altitude of land surface, 3,564.9 feet; depth to water, 65.32 feet, June 18, 1958.

Pleistocene and Pliocene (undifferentiated)	Thickness, feet	Depth, feet
Clay	17	17
Clay, limy	22	39
Sand	6	45
Clay	16	61
Clay, sandy	11	72
Sand	16	88
Sand and clay	6	94
Sand	6	100
Sand, medium	5	105
Clay, limy, cemented	2	107
Clay and sand	13	120
Sand	7	127
Sand, fine; contains clay streaks,	8	135
Sand, fine to medium	12	147
Clay, sandy	4	151
Sand	11	162
Clay	2	164
Sand	20	184
Sand and gravel	14	198
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Clay, yellow	5	203
Shale	7	210

15-40-1aba.—Drillers log of shothole in NE NW NE sec. 1, T. 15 S., R. 40 W.; drilled by Phillips Petroleum Co., 1957. Altitude of land surface, 3,638 feet.

	Thickness, feet	Depth, feet
Pleistocene and Pliocene (undifferentiated)		
Sand, gravel, and red silt	120	120
Sand	95	215
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Clay, yellow	10	225

15-40-4ccc.—Drillers log of shothole in SW SW SW sec. 4, T. 15 S., R. 40 W.; drilled by Phillips Petroleum Co., 1957. Altitude of land surface, 3,658 feet.

	Thickness, feet	Depth, feet
Pleistocene and Pliocene (undifferentiated)		
Surface silt	4	4
Silt, very limy	51	55
Sand	215	270
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Clay, yellow	13	283

15-40-7bbb.—Drillers log of irrigation well in NW NW NW sec. 7, T. 15 S., R. 40 W.; drilled by Jack Foust, April 1955. Altitude of land surface, 3,706.2 feet.

	Thickness, feet	Depth, feet
Pleistocene and Pliocene (undifferentiated)		
Soil and silt	22	22
Sand, cemented	27	49
Gravel	11	60
Clay	6	66
Gravel	11	77
Clay, sandy	9	86
Sand, cemented	14	100
Gravel	2	102
Clay	6	108
Gravel	6	114
Clay	4	118
Gravel	3	121
Clay	2	123
Gravel	6	129
Sand, cemented	9	138
Gravel	10	148
Clay	5	153
Sand	12	165
Clay, sandy	9	174
Sand	26	200
Sand, cemented	5	205
Gravel	19	224
Clay	6	230
Gravel	24	254
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Soapstone	6	260
Shale	3	263

15-40-11bba.—Drillers log of shothole in NE NW NW sec. 11, T. 15 S., R. 40 W.; drilled by Phillips Petroleum Co., 1957. Altitude of land surface, 3,621 feet.

	Thickness, feet	Depth, feet
Pleistocene and Pliocene (undifferentiated)		
Surface silt	4	4
Sand	76	80
Blind	130	210
Sand	20	230
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Clay, yellow	7	237

15-40-11bbb.—Sample log of test hole in NW NW NW sec. 11, T. 15 S., R. 40 W., 40 feet east of highway center and 28 feet south of sec. line (Bradley and Johnson, 1957, p. 130); drilled October 1951. Altitude of land surface, 3,614.6 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Soil, silt, and clay, black	1	1
Silt, clayey, tan gray	4	5
Sand, fine to medium, silty	9	14
TERTIARY—Pliocene		
Ogallala Formation		
Clay, silty, tan gray	2	16
Sand, fine to coarse	8	24
Clay and silt, sandy, tan to white	5	29
Clay and sand, tan brown	2	31
Clay, sandy, gray green	2	33
Sand, fine to coarse, and thin layers of clay	3	36
Sand, fine to coarse, and fine gravel; contains layer of limy silt from 45 to 46 feet	20	56
Clay, silty, limy, tan gray to light gray	4	60
Clay, sandy to very sandy, brown	8	68
Sand, fine to coarse; contains a little clay	13	81
Sand, fine to medium, and interbedded gray clay	11	92
Sand and gravel, fine to coarse,	9	101
Clay, limy, tan to light tan; cemented from 103 to 105 feet,	6	107
Sand, fine to coarse, and fine to medium gravel; contains a few thin layers of clay	24	131
Clay, silty, sandy, tan	5	136
Sand, fine to coarse	17	153
Clay, limy, light tan to tan	5	158
Clay, silty to very silty, limy, light; contains interbedded fine to medium sand	10	168
Sand, fine to medium, and interbedded limy clay	20	188
Sand, fine to coarse	39	227
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, clayey, yellow	5	232
Shale, clayey, gray	3	235

15-40-13baa.—Drillers log of irrigation well in NE NE NW sec. 13, T. 15 S., R. 40 W.; drilled by Ben Hasz, October 1957. Altitude of land surface, 3,641.6 feet; depth to water, 101.36 feet, June 18, 1958.

	Thickness, feet	Depth, feet
Pleistocene and Pliocene (undifferentiated)		
Clay, sandy, and cemented limy clay	70	70
Sand, coarse, loose	4	74
Clay	4	78
Clay, sandy; contains thin layers of cemented sand	15	93
Clay, sandy	6	99
Sand, medium to coarse, loose,	9	108
Sand, loose	3	111
Sand and sandy clay	9	120
Sand, loose, coarse	3	123
Sand	3	126
Mortar bed	1	127
Sand, medium to coarse; contains cemented streaks	9	136
Clay, sandy	2	138
Clay, sandy	4	142
Sand, fine to medium, fairly loose	4	146
Clay, sandy	4	150
Clay, brown	3	153
Sand, fine, and sandy clay, tight	15	168
Sand and sandy clay, tight	3	171
Sand, fine to medium, loose; contains streaks of clay	12	183
Sand, loose	3	186
Sand and sandy clay	3	189
Sand, medium to coarse, very loose	24	213
Sand, medium to coarse, loose,	24	237
Cretaceous—Upper Cretaceous		
Pierre Shale		
Soapstone	3	240
Shale, blue gray	2	242

15-40-16ccc.—Sample log of test hole in SW SW SW sec. 16, T. 15 S., R. 40 W., 50 feet north and 20 feet east of SW cor. sec. 16; drilled August 1960. Altitude of land surface, 3,668.5 feet.

	Thickness, feet	Depth, feet
Quaternary—Pleistocene		
Peoria and Loveland Formations		
Silt, sandy, light brown	2	2
Sand, medium, tan	6	8
Sand, fine to medium	12	20
Silt, very sandy, tan	8	28
Tertiary—Pliocene		
Ogallala Formation		
Silt, sandy, very limy, light gray	7	35
Sand, fine to coarse, very limy; contains thin layers of cemented limy silt	10	45
Silt, very sandy, very limy; pink tan; contains cemented layers,	10	55
Silt, sandy, very limy, light pink tan; contains hard cemented layers	13	68
Sand, fine to coarse; contains cemented layers	12	80
Sand, coarse to very coarse, and fine to medium gravel	10	90
Gravel, fine to medium, and very coarse sand	10	100
Gravel, fine to medium; contains layers of limy silt	10	110
Silt, very sandy, limy, tan	10	120
Sand, fine to coarse; contains cemented silt layers	10	130
Sand, medium to very coarse, clean	10	140
Sand, fine to medium; contains layers of green clayey silt	10	150
Sand, medium, clean	8	158
Sand, medium; upper part cemented	12	170
Sand, medium, clean	10	180
Gravel, fine to medium; contains a few thin layers of green clayey silt	10	190
Sand, medium to very coarse	10	200
Sand, medium to coarse; contains small amount fine gravel	20	220
Sand, medium to very coarse, clean	10	230
Sand, coarse to very coarse, clean	10	240
Sand, medium to very coarse; contains small amount fine gravel	37	277
Cretaceous—Upper Cretaceous		
Pierre Shale		
Shale, weathered, yellow and white	5	282
Shale, black	4	286

15-40-19acb.—Drillers log of irrigation well in NW SW NE sec. 19, T. 15 S., R. 40 W.; drilled by Ben Hasz, October 1955. Altitude of land surface, 3,695.1 feet.

	Thickness, feet	Depth, feet
Pleistocene and Pliocene (undifferentiated)		
Top and subsoil	6	6
Clay; contains cemented layers,	60	66
Sand and gravel	7	73
Gravel; contains cemented layers	6	79
Clay	10	89
Sand; contains cemented layers,	9	98
Sand and sandy clay; contains cemented layers	10	108
Sand and sandy clay	19	127
Sand, coarse, loose	18	145
Clay, sandy	6	151
Mortar bed	3	154
Clay and sandy clay	2	156
Sand, good, loose	8	164
Clay, sandy, soft	3	167
Clay	2	169
Sand; contains cemented streaks,	6	175
Sand and sandy clay	4	179
Sand, good, loose	8	187
Clay and sandy clay	6	193
Mortar bed	4	197
Sand; contains cemented layers,	2	199
Sand, good, loose	12	211

	Thickness, feet	Depth, feet
Clay	6	217
Sand, good, loose	27	244
Clay, sandy	1	245
Sand, good, loose	10	255
Sand, clay, and sandy clay	6	261
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Soapstone	4	265
Shale	3	268

15-40-23ccc.—Sample log of test hole in SW SW SW sec. 23, T. 15 S., R. 40 W., 30 feet north of sec. line and 25 feet east of highway center (Bradley and Johnson, 1957, p. 131); drilled October 1951. Altitude of land surface, 3,646.0 feet; depth to water, 94.70 feet, October 20, 1951.

QUATERNARY—Pleistocene	Thickness, feet	Depth, feet
Peoria and Loveland Formations		
Soil, silt, and clay, black	2.5	2.5
Silt, tan gray	11	13.5
TERTIARY—Pliocene		
Ogallala Formation		
Clay, silty, tan gray	5.5	19
Clay, limy, tan; becoming sandy in lower part	10	29
Silt and fine sand, limy, cemented white to tan	5	34
Silt and clay, very sandy, cemented tan to light tan	17	51
Clay, green gray	1.5	52.5
Sand, fine to coarse, and fine to coarse gravel	23.5	76
Clay and sandy clay, tan gray,	10	86
Sand, fine to coarse; contains a little clay	10	96
Clay, tan to tan brown, and interbedded medium to coarse sand	11	107
Sand, fine to coarse; contains a little clay	7	114
Clay, sandy, tan gray	4	118
Sand, fine to coarse; contains a little clay	10.5	128.5
Clay, sandy, tan gray	4.5	133
Clay and interbedded fine sand,	17	150
Sand, fine to coarse, and fine gravel	17	167
Sand, fine to medium, and sandy silt	9	176
Sand, fine to coarse; contains a little tan to light-tan clay	66	242
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, clayey, yellow	6	248
Shale, gray to dark gray	9	257

15-40-30dbb.—Drillers log of irrigation well in NW NW SE sec. 30, T. 15 S., R. 40 W.; drilled by Vern Litton, June 1960. Altitude of land surface, 3,694.3 feet; depth to water, 111.40 feet, October 7, 1960.

Pleistocene and Pliocene (undifferentiated)	Thickness, feet	Depth, feet
Top	90	90
Sand	2	92
Cemented layer	1	93
Clay, sandy	18	111
Sand	1	112
Clay, sandy	14	126
Sand and gravel	3	129
Clay, sandy	21	150
Sand and gravel	2	152
Clay, sandy	1	153
Sand and gravel	1	154
Clay, sandy	3	157
Sand and gravel	9	166
Clay, sandy	10	176
Sand and gravel	8	184
Clay, sandy	3	187
Sand and gravel	16	203
Clay, sandy	3	206
Sand and gravel	4	210
Clay, sandy	4	214
Sand, fine, and sandy clay	4	218
Clay, sandy	14	232
Sand and gravel	10	242
Clay, sandy	7	249
Sand and gravel	3	252
Clay, sandy	12	264
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale	6	270

15-41-2aaa2.—Sample log of test hole in NE NE NE sec. 2, T. 15 S., R. 41 W., 16 feet south of sec. line and 10 feet west of road center (Bradley and Johnson, 1957, p. 131); drilled October 1951. Altitude of land surface, 3,758.3 feet.

QUATERNARY—Pleistocene	Thickness, feet	Depth, feet
Peoria and Loveland Formations		
Soil, silt, and clay, black	2.5	2.5
Silt, tan gray; contains a little clay	8	10.5
TERTIARY—Pliocene		
Ogallala Formation		
Clay, silty, limy, light tan to light brown	16.5	27
Silt and fine sand, cemented, tan and brown	11	38
Sand and gravel, fine to coarse; contains interbedded cemented sand and silt	18	56
Sand, fine to coarse, silty	6	62
Sand, fine to coarse, and fine gravel; contains thin layers of tan clay	12	74
Clay, sandy, brown	7	81
Sand and gravel, fine to coarse,	11	92
Clay, silty, tan brown	8	100
Clay, sandy, brown	10	110
Clay and sand, interbedded, limy	7	117
Sand, coarse, and fine to medium gravel; contains thin layers of silt and clay	20	137
Sand, coarse, and fine to medium gravel	20	157
Sand, coarse, and fine to medium gravel; contains thin layers of clay	17	174
Clay, silty, limy, tan white	5	179

	Thickness, feet	Depth, feet
Clay, sandy, gray brown; contains interbedded sand and gravel	10	189
Sand, fine to coarse, and fine gravel; contains a little sandy clay	30	219
Sand, fine to coarse, and fine gravel	40	259
Sand, fine to coarse; contains a little fine gravel and thin layers of brown silt	30.5	289.5
Sand, fine to coarse, and interbedded gray sandy clay	5	294.5
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, clayey, dark gray	5.5	300

15-41-2abb.—Drillers log of shothole in NW NW NE sec. 2, T. 15 S., R. 41 W.; drilled by Phillips Petroleum Co., 1957. Altitude of land surface, 3,756 feet.

	Thickness, feet	Depth, feet
Pleistocene and Pliocene (undifferentiated)		
Surface silt	4	4
Sand	270	274
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale	1	275

15-41-6abb.—Drillers log of shothole in NW NW NE sec. 6, T. 15 S., R. 41 W.; drilled by Phillips Petroleum Co., 1957. Altitude of land surface, 3,783 feet.

	Thickness, feet	Depth, feet
Pleistocene and Pliocene (undifferentiated)		
Surface silt	4	4
Clay, sandy	106	110
Sand	83	193
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale	1	194

15-41-10bab.—Drillers log of irrigation well in NW NE NW sec. 10, T. 15 S., R. 41 W.; drilled by Jack Foust. Altitude of land surface, 3,787.3 feet; depth to water, 161.16 feet, June 11, 1958.

	Thickness, feet	Depth, feet
Pleistocene and Pliocene (undifferentiated)		
Top and subsoil	13	13
Sand, limy, cemented	11	24
Sand, cemented	9	33
Gravel and cemented sand	5	38
Sand, limy, cemented	3	41
Gravel	13	54
Sand, cemented	5	59
Sand and gravel	7	66
Sand, cemented	9	75
Gravel	4	79
Clay, sandy	6	85
Gravel	4	89
Clay, sandy	9	98
Sand, limy, cemented	2	100
Gravel	4	104
Clay, sandy	5	109
Sand, limy, cemented	5	114
Clay, sandy	24	138
Sand	8	146
Gravel	8	154
Clay, sandy	6	160
Sand, limy	3	163
Clay, sandy	2	165
Gravel	5	170
Sand, limy, cemented	2	172
Sand	3	175
Sand, limy, cemented	2	177
Sand	3	180
Sand, limy, cemented	1	181
Clay, sandy	12	193
Sand	8	201
Clay, sandy	4	205
Sand, limy, cemented	3	208
Clay, sandy	11	219
Sand	7	226
Clay, sandy	5	231
Gravel	17	248
Clay, sandy	9	257
Sand	2	259
Clay, sandy	4	263
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale	1	264

15-41-18ccc.—Drillers log of shothole in SW SW SW sec. 18, T. 15 S., R. 41 W.; drilled by Phillips Petroleum Co., 1957. Altitude of land surface, 3,828 feet.

	Thickness, feet	Depth, feet
Pleistocene and Pliocene (undifferentiated)		
Surface silt	4	4
Sand	154	158
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Clay, yellow	12	170

15-41-19ccc.—Sample log of test hole in SW SW SW sec. 19, T. 15 S., R. 41 W., 50 feet east of sec. line and 10 feet north of road center (Bradley and Johnson, 1957, p. 132); drilled October 1951. Altitude of land surface, 3,840.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt and silty clay, tan	9	9
TERTIARY—Pliocene		
Ogallala Formation		
Clay, very limy, light tan to white	7	16
Sand and gravel, fine to coarse,	6	22
Clay and limy silt, sandy, tan to light tan	22.5	44.5
Sand, medium to coarse, and fine gravel; contains a little brown sandy clay	7.5	52
Sand and interbedded sandy clay	16	68
Sand and gravel, fine to coarse; contains a little brown sandy clay	7	75

	Thickness, feet	Depth, feet
Clay, silty and limy, gray brown; contains limy layer at 83 feet	21	96
Clay, sandy, tan brown; contains thin layers of limy silt at 96 and 105 feet	12	108
Clay and interbedded fine to medium sand	7	115
Sand, fine to coarse	4	119
Sand, fine to coarse; contains interbedded light-gray limy clay	4	123
Clay, limy, silty and sandy, tan gray to light tan	8	131
Sand, fine to medium; contains a little tan clay	9	140
Sand, fine to coarse; contains a little tan-brown clay, limy from 146 to 148 feet	10	150
Sand and interbedded sandy and limy clay	10	160
Sand, fine to coarse, and fine gravel; contains interbedded gray-brown sandy clay	10	170
Sand, fine to coarse, and fine gravel	17.5	187.5
Bentonite	.5	188
Clay, limy and sandy, brown to gray	4	192
Clay, sandy, brown, and interbedded fine to coarse sand	34	226
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, clayey, yellow	11	237
Shale, dark gray	3	240

15-41-21add.—Drillers log of shothole in SE SE NE sec. 21, T. 15 S., R. 41 W.; drilled by Phillips Petroleum Co., 1957. Altitude of land surface, 3,762 feet.

Pleistocene and Pliocene (undifferentiated)	Thickness, feet	Depth, feet
Sand, gravel, and red silt	205	205
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale	1	206

15-41-23ddd.—Sample log of test hole in SE SE SE sec. 23, T. 15 S., R. 41 W., 40 feet west and 40 feet north of road intersection (Bradley and Johnson, 1957, p. 133); drilled October 1951. Altitude of land surface, 3,714.9 feet; depth to water, 123.50 feet, October 8, 1951.

QUATERNARY—Pleistocene	Thickness, feet	Depth, feet
Peoria and Loveland Formations		
Soil, silt, and clay, dark gray to black	2	2
Silt, tan to tan gray; contains a little tan clay	8	10
TERTIARY—Pliocene		
Ogallala Formation		
Silt, and clay, sandy, limy, tan to light tan	12	22
Silt, fine to medium, silty, cemented, brown	6	28
Silt and sand, limy, tan and gray white	10	38
Clay, silty, limy, light tan	2	40
Sand, silty, limy, tan	20	60
Clay, silty, and interbedded fine to medium sand	8	68
Sand and gravel, fine to coarse,	15	83
Silt, sandy, brown to gray brown	16.5	99.5
Silt, clayey, gray tan to tan brown; contains interbedded sand	20.5	120
Sand, fine to medium, silty, tan,	10	130
Sand, fine to medium, and interbedded tan clay	12	142
Sand, fine to coarse, and fine gravel, silty	10	152
Sand, fine to coarse; contains layers of limy silt	9	161
Sand, fine to coarse, and fine to medium gravel	29	190
Sand, fine to coarse, and interbedded tan clay	20	210
Sand, fine to coarse, and fine gravel; contains a few thin layers of clay	20	230
Sand, fine to medium, silty	10	240
Sand, fine to coarse, silty	7	247
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, clayey, yellow	10	257
Shale, dark gray	3	260

15-41-32aca.—Drillers log of irrigation well in NE SW NE sec. 32, T. 15 S., R. 41 W.; drilled by Weishaar & Son, November 1956. Altitude of land surface, 3,777.8 feet.

Pleistocene and Pliocene (undifferentiated)	Thickness, feet	Depth, feet
Clay	9	9
Clay, limy, tight	20	29
Sand	9	38
Clay, sandy	29	67
Sand and interbedded clay	12	79
Clay	23	102
Sand and interbedded clay	12	114
Sand, fine; contains clay streaks,	33	147
Sand, fine to medium	18	165
Clay; contains interbedded layers of fine sand	14	179
Sand	12	191
Sand and interbedded clay	6	197
Clay	7	204
Sand, medium	15	219
Sand, fine to medium; contains streaks of clay	6	225
Sand	24	249
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Clay, yellow	5	254
Shale	6	260

15-41-32add.—Drillers log of shothole in SE SE NE sec. 32, T. 15 S., R. 41 W.; drilled by Phillips Petroleum Co., 1957. Altitude of land surface, 3,760 feet.

	Thickness, feet	Depth, feet
Pleistocene and Pliocene (undifferentiated)		
Surface silt	8	8
Sand, gravel, and red silt	237	245
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale	1	246

15-42-3baa.—Drillers log of shothole in NE NE NW sec. 3, T. 15 S., R. 42 W.; drilled by Phillips Petroleum Co., 1957. Altitude of land surface, 3,865 feet.

	Thickness, feet	Depth, feet
Pleistocene and Pliocene (undifferentiated)		
Sand, gravel, and red silt	110	110
Sand	100	210
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale	1	211

15-42-7daa.—Sample log of test hole in NE NE SE sec. 7, T. 15 S., R. 42 W., near edge of road near ½-mile line; drilled August 1960. Altitude of land surface, 3,900.3 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, light brown	10	10
Silt, sandy, light brown	10	20
Sand, medium, silty	5	25
TERTIARY—Pliocene		
Ogallala Formation		
Sand, medium, clean, well sorted	15	40
Sand, medium to coarse, limy, cemented	10	50
Sand, medium to very coarse, clean	10	60
Sand, medium to very coarse; contains silty streaks	10	70
Gravel, fine, and very coarse sand	10	80
Gravel, fine to medium, and very coarse sand	7	87
Clay, bentonitic, greenish gray,	3	90
Bentonite, greenish gray and gray	10	100
Sand, fine to very coarse, and fine gravel; contains limy streaks	10	110
Sand, medium to very coarse, clean, loose; contains small amount fine gravel	10	120
Sand, coarse to very coarse, and fine gravel, clean, loose	10	130
Sand, medium to very coarse, clean, loose; contains small amount fine gravel	30	160
Sand, coarse to very coarse, and fine gravel, clean, loose	17	177
Silt, sandy, tan	5	182
Sand, medium to coarse; contains limy streaks	13	195
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, black	5	200

15-42-15aaa.—Sample log of test hole in NE NE NE sec. 15, T. 15 S., R. 42 W., 35 feet west and 25 feet south of NE cor. sec. 15; drilled August 1960. Altitude of land surface, 3,852.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, sandy near base, light brown	10	10
Sand, fine to very coarse; contains thin cemented streaks near base	10	20
TERTIARY—Pliocene		
Ogallala Formation		
Sand, fine to coarse; contains layers of cemented limy silt,	10	30
Sand, medium to coarse; contains streaks of limy silt	10	40
Sand, fine to coarse, loose, clean	10	50
Sand, fine, well sorted	6	56
Silt, sandy, tan	3	59
Sand, medium to very coarse, clean, loose	11	70
Sand, medium to very coarse, clean, loose; contains small amount fine gravel	16	86
Silt, sandy, and streaks of fine sand; limy in lower part	17	103
Gravel, fine to medium, and very coarse sand, loose	13	116
Silt, sandy, tan	4	120
Silt, sandy, tan and gray; contains limy streaks and thin layers of bentonitic clay	10	130
Sand, fine to very coarse, and fine gravel; contains thin layers of limy silt and cemented streaks	5	135
Sand, medium to very coarse, and fine to medium gravel	5	140
Silt, sandy, tan	3	143
Sand, medium to very coarse, and fine to medium gravel	4	147
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, brown and gray	13	160

15-42-20bbb.—Sample log of test hole in NW NW NW sec. 20, T. 15 S., R. 42 W., 50 feet east of fence line and 16 feet south of sec. line (Bradley and Johnson, 1957, p. 134); drilled October 1951. Altitude of land surface, 3,904.9 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Soil, silt, and clay, gray tan	1.5	1.5
Silt, clayey, tan gray	12.5	14
TERTIARY—Pliocene		
Ogallala Formation		
Silt, limy, and interbedded sand and gravel	4	18
Sand, medium to coarse, and fine to medium gravel	10	28

	Thickness, feet	Depth, feet
Gravel, very coarse; contains coarse sand	9	37
Silt, sandy, limy, tan to light gray	10	47
Silt, sandy	10	57
Silt, very sandy	15	72
Sand, coarse to fine, silty	8	80
Sand, coarse, and fine to medium gravel, silty	3	83
Silt, sandy, tan to tan gray	9	92
Sand, fine, and interbedded tan silt	19	111
Sand, fine, silty, limy	12	123
Silt, sandy, limy	4	127
Sand, fine to coarse, and fine to medium gravel	19	146
Sand, fine to coarse, and fine to medium gravel, silty	24	170
Sand, fine to coarse, and fine to coarse gravel; contains interbedded tan silt	10	180
Silt, limy, tan to light gray	7	187
Sand, fine to coarse, and fine to medium gravel, silty	20	207
Sand, fine to coarse, and fine to medium gravel; contains yellow silty clay	18	225
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, clayey, dark gray	2	227

15-42-21daa.—Drillers log of shothole in NE NE SE sec. 21, T. 15 S., R. 42 W.; drilled by Phillips Petroleum Co., 1957. Altitude of land surface, 3,889 feet.

	Thickness, feet	Depth, feet
Pleistocene and Pliocene (undifferentiated)		
Surface silt	6	6
Sand, gravel, and red silt	194	200
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale	1	201

15-42-32dcd.—Sample log of test hole in SE SW SE sec. 32, T. 15 S., R. 42 W., 0.3 mile west and 30 feet north of SE cor. sec. 32 (Bradley and Johnson, 1957, p. 135); drilled October 1951. Altitude of land surface, 3,882.6 feet; depth to water, 202.70 feet, October 12, 1951.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Soil, silt, and clay, tan gray to dark gray	2.5	2.5
Silt and clayey silt, tan to tan gray	6.5	9
Sand, fine to medium, silty	8	17
TERTIARY—Pliocene		
Ogallala Formation		
Silt, sandy, clayey, limy, tan brown	11	26
Clay, medium hard, gray tan	2	30
Sand, fine to coarse, silty	6	36
Silt, clayey, limy, and interbedded sand	21	57
Sand and gravel, fine to coarse,	8	65

	Thickness, feet	Depth, feet
Sand, fine to coarse, and interbedded tan silt	6	71
Sand, fine to coarse, and fine to coarse gravel	7	78
Silt, clayey, brown	6	84
Silt, clayey, sandy, tan brown	4	88
Silt and silty sand, limy	13	101
Silt, very sandy, brown to red brown	4	105
Sand, fine to coarse	2	107
Silt, sandy, limy, tan and gray,	4	111
Sand, fine to coarse, silty	6	117
Silt, clayey, limy, light gray	4	121
Sand, fine to coarse; contains a little gravel and tan limy silt,	10	131
Sand, fine to coarse, and fine to coarse gravel; contains tan limy silt	15	146
Silt, sandy, limy, tan	11	157
Sand, coarse, and fine to medium gravel; contains limy silt	14	171
Sand, coarse, and fine to medium gravel, silty	8	179
Silt, sandy, limy, tan gray	7	186
Sand, fine to coarse, and fine to medium gravel; contains tan, gray-green silt	11	197
Silt, sandy, tan gray	11	208
Sand, very fine	6	214
Sand and clayey silt, interbedded	13	227
Sand, fine to coarse, and fine to medium gravel	25	252
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale, clayey, yellow	3	255
Shale, gray	3	258

15-42-34cbb.—Drillers log of shothole in NW NW SW sec. 34, T. 15 S., R. 42 W.; drilled by Phillips Petroleum Co., 1957. Altitude of land surface, 3,856 feet.

	Thickness, feet	Depth, feet
Pleistocene and Pliocene (undifferentiated)		
Surface silt	4	4
Sand, gravel, and red silt	104	108
Sand and gravel	112	220
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale	1	221

15-43-1dcd.—Drillers log of shothole in SE SW SE sec. 1, T. 15 S., R. 43 W.; drilled by Phillips Petroleum Co., 1957. Altitude of land surface, 3,929 feet.

	Thickness, feet	Depth, feet
Pleistocene and Pliocene (undifferentiated)		
Surface silt	4	4
Clay	136	140
Sand	90	230
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Clay, yellow	8	238

15-43-24aba.—Drillers log of shothole in NE NW NE sec. 24, T. 15 S., R. 43 W.; drilled by Phillips Petroleum Co., 1957. Altitude of land surface, 3,944 feet.

	Thickness, feet	Depth, feet
Pleistocene and Pliocene (undifferentiated)		
Surface silt	6	6
Sand and red silt	89	95
Sand	125	220
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Shale	1	221

15-43-36dcd.—Drillers log of shothole in SE SW SE sec. 36, T. 15 S., R. 43 W.; drilled by Phillips Petroleum Co., 1957. Altitude of land surface, 3,920 feet.

	Thickness, feet	Depth, feet
Pleistocene and Pliocene (undifferentiated)		
Surface silt	4	4
Clay	146	150
Sand	93	243
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Clay, yellow	8	251

16-42-1bbb.—Drillers log of shothole in NW NW NW sec. 1, T. 16 S., R. 42 W., Greeley County; drilled by Phillips Petroleum Co., 1957. Altitude of land surface, 3,796 feet.

	Thickness, feet	Depth, feet
Pleistocene and Pliocene (undifferentiated)		
Surface silt	6	6
Sand, gravel, and red silt	239	245
CRETACEOUS—Upper Cretaceous		
Pierre Shale		
Clay, yellow	5	250

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