Geology and Ground-Water Resources of Trego County, Kansas

By Warren G. Hodson

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ABSTRACT

Trego County is a 900-square-mile area in the High Plains section of west-central Kansas. The altitude ranges from about 2,000 to 2,600 feet above sea level. The climate is semiarid, and the mean annual rainfall is 21.40 inches. The population of the County in 1960 was 5,473. Farming and livestock raising are the chief occupations.

The Carlile Shale of late Cretaceous age is the oldest rock formation cropping out in the County. The Carlile is overlain by the Niobrara Chalk, the dominant bedrock formation in the County. The Ogallala Formation of Neogene (Pliocene) age unconformably overlies Cretaceous rocks in much of the County and consists principally of fluviatile deposits of sand, gravel, and silt. Terrace deposits of Pleistocene age occur along the principal valleys. Eolian silts that mantle the uplands and alluvium along stream valleys constitute the youngest deposits and are late Pleistocene in age.

The Ogallala Formation is the most widespread aquifer and yields water to many domestic and stock wells. Alluvium and terrace deposits yield moderate quantities of water, but these deposits are not of wide areal extent. In areas of Cretaceous outcrops, small quantities of ground water are obtained from the Dakota Formation of early(?) Cretaceous age and from the Codell Sandstone Member of the Carlile Shale of late Cretaceous age.

Hydrologic data are given in tables and include records of 280 wells, logs of 176 test holes and wells, and chemical analyses of 59 samples of water from wells.

INTRODUCTION

PURPOSE AND SCOPE OF INVESTIGATION

This report gives the results of a study of the geology and ground-water resources of Trego County, Kansas. Ground water, although often taken for granted, is one of the most vital natural resources of Kansas. The demand for water and for information concerning its availability has greatly increased in recent years because of an increasing population, accompanied by municipal, industrial, and irrigation expansion, and new water uses in the home and on the farm. The purpose of this investigation was to determine the occurrence, availability, movement, and chemical quality of ground water, and to relate the occurrence of the water to the character, thickness, and distribution of the geologic formations.

This study was made as a part of the cooperative ground-water program begun in 1937 by the State Geological Survey of Kansas and the U.S. Geological Survey, in cooperation with the Environmental Health Services of the Kansas State Department 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

Trego County is in west-central Kansas, in the third tier of counties south of the Nebraska border and in the fourth tier of counties east of the Colorado border (Fig. 1). It is almost square, extending approximately 30 miles east-west and 30 miles north-south and has an area of about 900 square miles. It contains 25 townships, from T 11 S to T 15 S, and from R 21 W to R 25 W.

PREVIOUS INVESTIGATIONS

Cretaceous rocks of Kansas have been a subject of study since the railway explorations and the Meek and Hayden surveys of the 1860's. Adams (1898) has given an historical summary of the early studies of the Cretaceous rocks in

Kansas. Haworth contributed reports on the physiography (1897a), the physical properties of Tertiary rocks (1897b), and the geology of underground waters (1897c) in western Kansas. Logan (1897) discussed Upper Cretaceous rocks in western Kansas, and Williston (1897a) described the Niobrara Chalk and discussed the Pleistocene deposits of Kansas (1897b). Johnson (1901, 1902) discussed the Tertiary rocks of the High Plains and ground water in western Kansas. Darton (1905) discussed the geology and ground-water resources of the central Great Plains, in which he treated the loess of western Kansas as a separate formation from the underlying Tertiary deposits. In a special report on well waters in Kansas, Haworth (1913) discussed the Tertiary deposits of western Kansas and their water-bearing characteristics. Russell (1929) studied the stratigraphy and structure of the Smoky Hill Chalk Member in Logan, Gove, and Trego counties and reported on the usefulness of bentonite layers in interpreting the strati-

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

graphy. Elias (1931) studied the geology of western Kansas with emphasis on the Pierre Shale, the Ogallala Formation, and the late Pleistocene deposits. Landes and Keroher (1939) briefly discussed the geology and petroleum resources of Logan, Gove, and Trego counties. A report by Byrne, *et al.* (1947) describes the occurrence of construction materials in the Cedar Bluff area in Trego County. Frye and Leonard (1952) discussed the Pleistocene geology of Kansas. Ground-water studies in Kansas which border Trego County, or include part of the County, were made by Prescott (1955), Hodson and Wahl (1960), and Leonard and Berry (1961). Areas in Kansas in which ground-water studies have been made, and which are published or are in preparation, are shown in Figure 1.

METHODS OF INVESTIGATION

The writer spent about three months during the summer and fall of 1959 and about three months during the summer and fall of 1960 in the field gathering data upon which this report is largely based. The areal geology was mapped from field observations and from stereoscopic study of areal photographs obtained from the U.S. Department of Agriculture. County maps prepared by the State Highway Commission of Kansas at a scale of one inch to the mile were used to record field data.

Data on 280 wells are given in Table 6 and include the depth to water and the depth of the well. Measurements were made with a steel tape graduated to hundredths of a foot. Measurements in a few wells could not be made and data on depth and water level for these wells were obtained from the owner or driller. Information concerning yield, adequacy of supply, and quality of water was obtained, if possible, from well owners. Drillers' logs of wells and test holes were obtained, if available, from well owners and well drillers.

Logs of 176 test holes and wells are given. Included are 145 sample logs of test holes, 19 logs of test holes obtained from the Bureau of Reclamation, and 4 logs obtained from the State Highway Department. Well drillers and well owners provided logs of 8 wells and test holes.

Locations of wells and test holes within the sections were determined by means of an odometer and from 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 Soil Conservation Service, U.S. Department of Agriculture.

Samples of water from representative wells were collected and were analyzed by Howard A. Stoltenberg, Chief Chemist, in the Sanitary Engineering Laboratory of the Kansas State Department of Health.

WELL-NUMBERING SYSTEM

The locations of wells, test holes, and local features are designated in this report 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 11-24-25acb is in the NW SW NE sec. 25, T 11 S, R 24 W (Fig. 2). If more than one well or test hole is located in the same 10-acre tract, the location numbers are followed by serial numbers in the order in which they were inventoried.

ACKNOWLEDGMENTS

Thanks and appreciation are expressed to the many residents who gave permission to inventory their wells and who allowed access to their property for the study of rock exposures, to those who permitted aquifer tests to be made using their wells, and to the municipal officials who provided data concerning city water sup-

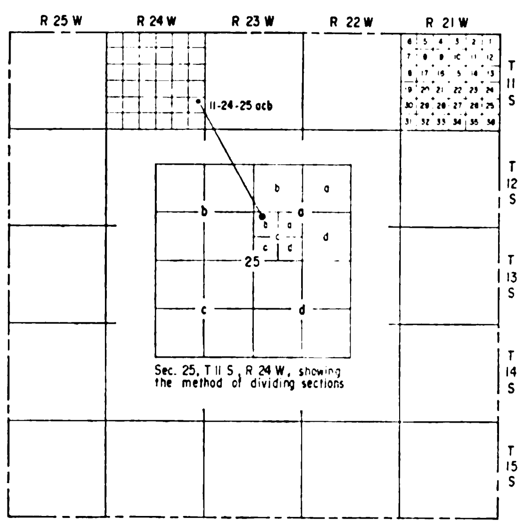

FIGURE 2.—Map of Trego County, Kansas, illustrating the well-numbering system used in this report.

plies. The Trego County office of the Soil Conservation Service, U.S. Department of Agriculture, located at WaKeeney, gave helpful information.

E. L. and Carrie Reavis and Melvin Franz, of the U.S. Geological Survey and the State Geological Survey of Kansas, gave assistance during field work. The illustrations were drafted by Judy Crissler and Larry Shelton.

The manuscript for 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 and Harris L. Mackey, Engineer, of the Division of Water Resources of the Kansas State Board of Agriculture; and by J. Lee Mayes, Chief Engineer, and Bruce F. Latta, Geologist, of the Environmental Health Services of the Kansas State Department of Health.

GEOGRAPHY

TOPOGRAPHY AND DRAINAGE

Most of Trego County lies within the High Plains section of the Great Plains physiographic province (Fig. 3) as designated by Schoewe (1949, p. 276). The southeastern corner of the County is in the Blue Hills division of the Dissected High Plains section. Gently rolling uplands that are moderately dissected by smaller drainageways characterize much of the County. Near the major streams, the slopes are quite steep and the topography is rough. Slopes along the north sides of the valleys of the larger streams are relatively more gentle and longer than along the south sides, whereas slopes along the southern sides tend to be cut into steep canyons and badlands. The Fort Hays Limestone Member of the Niobrara Chalk forms prominent escarpments in the southeastern part of the County and along the Smoky Hill Valley. One of the more prominent physiographic features along the Smoky Hill Valley is a high terrace. The surface of the terrace is about 50 feet above the level of the flood plain and about 200 feet below the general level of the upland. Loess and slope wash obscure the outer margin of the terrace in most places.

Three perennial streams cross the County, all flowing in an easterly direction, and are part of the Kansas River drainage system. The Smoky Hill River flows across the southern part of the County, Big Creek across the central part, and the Saline River along the northern edge of the County.

Pediment slopes are characteristic of the outer valleys of the major streams. Along the Smoky Hill River valley, long pediment slopes mask the prominence of the Fort Hays escarpment and grade into the high terrace. Along the Saline River Valley, the pediments are developed on the soft Cretaceous chalk beds and blend into

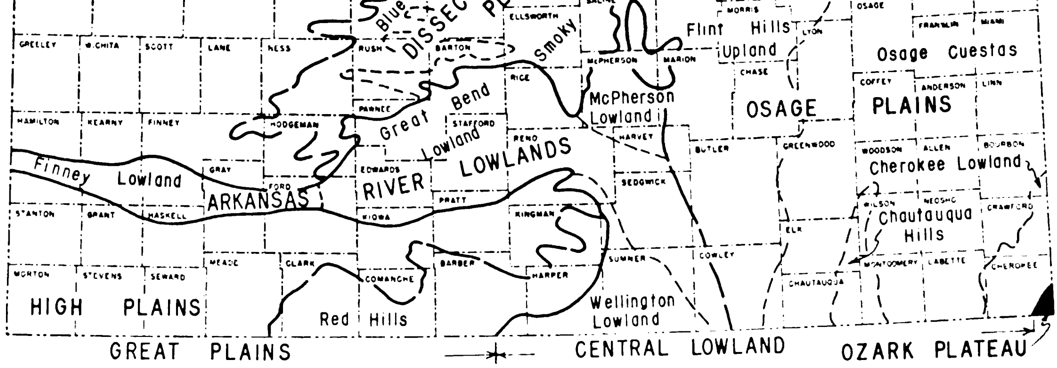

FIGURE 3.—Map of Kansas showing physiographic regions. (From Schoewe, 1949, fig. 22.)

the terrace surface so imperceptibly that the upland edge of the terrace cannot be mapped precisely without subsurface information.

The general slope of the land surface in Trego County is eastward. The total topographic relief is about 600 feet. The lowest elevation, about 2,000 feet above sea level, is in the channel of the Smoky Hill River on the eastern county line in the NE sec. 1, T 15 S, R 21 W. The highest elevations are in the uplands in the west-central and northwestern parts of the County and are about 2,600 feet above sea level.

CLIMATE

Trego County has a semiarid continental climate. Low to moderate precipitation, a high rate of evaporation, reasonably mild winters, and fairly hot summers are typical. The hot weather in summer is moderated by brisk winds and low humidity. As a rule the winters are moderate with only short periods of severe cold weather and relatively little snowfall. A large percentage of the winter days are clear, but snow flurries are common, and occasionally the area is subjected to blizzard conditions. In Trego 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.

The climatic data in this report were compiled from published records of the U.S. Weather Bureau (U.S. Department of Commerce). Approximately 70 percent of the annual precipitation in Trego County falls during the growing season of about 5½ months (Fig. 4). The mean annual precipitation at WaKeeney is 21.40 inches (based on period of record 1931-55). The greatest annual precipitation recorded was 37.37 inches in 1961; the least was 11.15 inches in 1888. The annual precipitation for the period of record and the cumulative departure from normal precipitation are shown in Figure 5. The average length of the growing season is 167 days, the average date of the last killing frost in spring being April 27, and the average date of the first killing frost in fall being October 11.

POPULATION

According to the U.S. Census Bureau, Trego County had a population of 5,473 in 1960, of which approximately 50 percent was urban and 50 percent rural. The County had an average of 6.1 persons per square mile as compared to a State average of 26.6 persons. WaKeeney, the county seat, had a population of 2,808. Other communities are Collyer, population 233, and Ogallah, unincorporated.

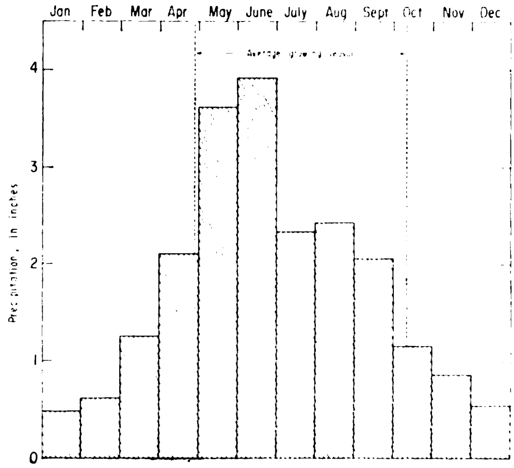

FIGURE 4.—Normal monthly precipitation at WaKeeney (1931-1955) and average growing season.

GENERAL GEOLOGY

SUMMARY OF STRATIGRAPHY[1]

The rocks that crop out in Trego County are sedimentary in origin and range in age from Cretaceous to Recent. Their areal distribution is shown on Plate 1; their stratigraphic relation is illustrated by cross sections on Plate 2 and in Figure 6. A generalized section of the rock units and their water-bearing properties are given in Table 1.

The Carlile Shale of late Cretaceous age is the oldest geologic formation exposed in Trego County. The Carlile crops out along the Smoky Hill Valley east of the junction of the Smoky Hill River and Hackberry Creek and is buried beneath rocks of younger age in the rest of the County.

The Niobrara Chalk of late Cretaceous age overlies the Carlile Shale. The Niobrara crops out along the outer valleys of the Smoky Hill and Saline rivers and their tributaries and along Big Creek valley in the eastern part of the County. The Niobrara Chalk is divided into two members, the Fort Hays Limestone below and the Smoky Hill Chalk above.

[1] The classification and nomenclature of 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.

The Ogallala Formation of Neogene age (Pliocene) unconformably overlies the Cretaceous rocks in much of the upland areas of the County. Erosion during the Pleistocene Epoch has removed the Ogallala along the Saline and Smoky Hill valleys and in the eastern part of the County along Big Creek valley. Along the Smoky Hill Valley, the Ogallala has been removed along a belt as much as two townships wide, exposing Cretaceous chalk and shale.

Unconsolidated deposits of both fluviatile and eolian origin represent the Pleistocene Series. Fluviatile deposits fill channels cut into Cretaceous bedrock along the principal streams. Eolian deposits mantle the uplands and in many places overlie older terrace deposits along stream valleys. Deposits belonging to the Pleistocene Series are the Grand Island and Sappa formations of Kansan age, the Crete and Loveland formations of Illinoisan age, the Peoria Formation of Wisconsinan age, and alluvium of Wisconsinan and Recent age.

In this report the Grand Island, Sappa, and Crete formations are shown in the illustrations and discussed as terrace deposits, and the Peoria and Loveland formations are discussed together

TABLE 1.—Geologic formations in Trego County, Kansas, and their water-bearing properties.

System	Series	Stratigraphic unit	Maximum thickness, feet	Physical character	Water supply
Neogene	Pleistocene	Alluvium (incl. Recent and late Wisconsinan terrace deposits)	70	Stream-deposited silt, sand, and gravel; thick, coarse deposits in major valleys, finer deposits in smaller valleys	Yields moderate to large quantities of water to wells along major valleys; lesser amounts along smaller valleys
		Peoria and Loveland formations	30	Silt, mostly eolian, sandy in lower part. Mantles most of uplands and masks much of valley walls	Yields small amounts of water to wells locally
		Grand Island, Sappa, and Crete formations (Terrace deposits)	100	Stream-deposited sand, gravel, and silt in a terrace position along major valleys. Locally contains Pearlette ash bed	Yields small to moderate quantities of water to wells along major valleys
	Pliocene	Ogallala Formation	150	Fluviatile deposits of sand, gravel, silt, and clay; mostly unconsolidated, but cemented at places to various degrees	Yields moderate quantities of water to wells in much of the County
Cretaceous	Upper Cretaceous	Niobrara Chalk: Smoky Hill Chalk Member	500	Chalk and chalky shale, thin-bedded and platy; bentonite beds throughout. Light gray to dark gray when fresh; weathers to brown and orange at outcrop	Yields no water to wells
		Niobrara Chalk: Fort Hays Limestone Member	55	Massive chalk beds separated by thin chalky shale partings, grayish-white, but may be yellow or light brown at outcrop	Yields small amounts of water to wells locally
		Carlile Shale	300	Lower part consists of gray calcareous shale and thin beds of chalky limestone; upper part consists of dark-gray clayey shale with silty fine-grained sandstone lenses in upper part	Yields small amounts of water to wells from Codell Sandstone Member
		Greenhorn Limestone	100	Alternating beds of chalky limestone and chalky shale	Yields no water to wells
		Graneros Shale	45	Noncalcareous dark-gray shale; persistent bentonite bed in upper part	Do
	Lower(?) Cretaceous	Dakota Formation	300	Clay, shale, siltstone, and sandstone; interbedded and varicolored. Sandstone fine- to medium-grained and lenticular. Lignite and "ironstone" common	Yields small amounts of water to wells

as loess deposits. Figure 6 illustrates the stratigraphic relation of Pleistocene deposits across the principal valleys. Deposits penetrated in test holes 13-21-5bbc and 13-21-8abb, along the north side of Big Creek valley, may be of Nebraskan age.

UNEXPOSED ROCKS

Geologic rock units below the Carlile Shale that do not crop out in Trego County but occur in the subsurface within a possible drilling depth for water wells consist of approximately 500 feet of Greenhorn Limestone, Graneros Shale, and Dakota Formation. The Greenhorn Limestone and Graneros Shale are not considered to be aquifers. The Dakota Formation is an important source of ground water for domestic and stock purposes in parts of Trego County. These formations will be discussed further in the section on geologic formations and their water-bearing properties.

ECONOMIC GEOLOGY

GROUND WATER

Source

Figure 7 is a diagram of the hydrologic cycle adapted from Piper (1953) showing the part of ground water in the circulation of water near the surface of the earth. The earth's water is constantly circulating from air to ground to air in a process called the hydrologic cycle. Water falls to the ground in the form of precipitation such as rain, snow, sleet, or hail. Part of this water vaporizes and returns to the air by evaporation, a part is removed as runoff via rivers to the ocean, a part percolates into the ground by infiltration, some of which is used by trees and vegetation and is returned to the air through a process called transpiration, and a very small part percolates downward through the soil and underlying strata until it reaches the water table, where it becomes ground water. The hydrologic cycle of rainfall, evaporation, runoff, infiltration and transpiration is continuous. It is this cycle which provides the source of our ground water. Figure 8 shows the generalized divisions of subsurface water.

Where a water-bearing formation 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 well, water will rise in the well to a height equal to the hydraulic head. The imaginary surface connecting this level in wells

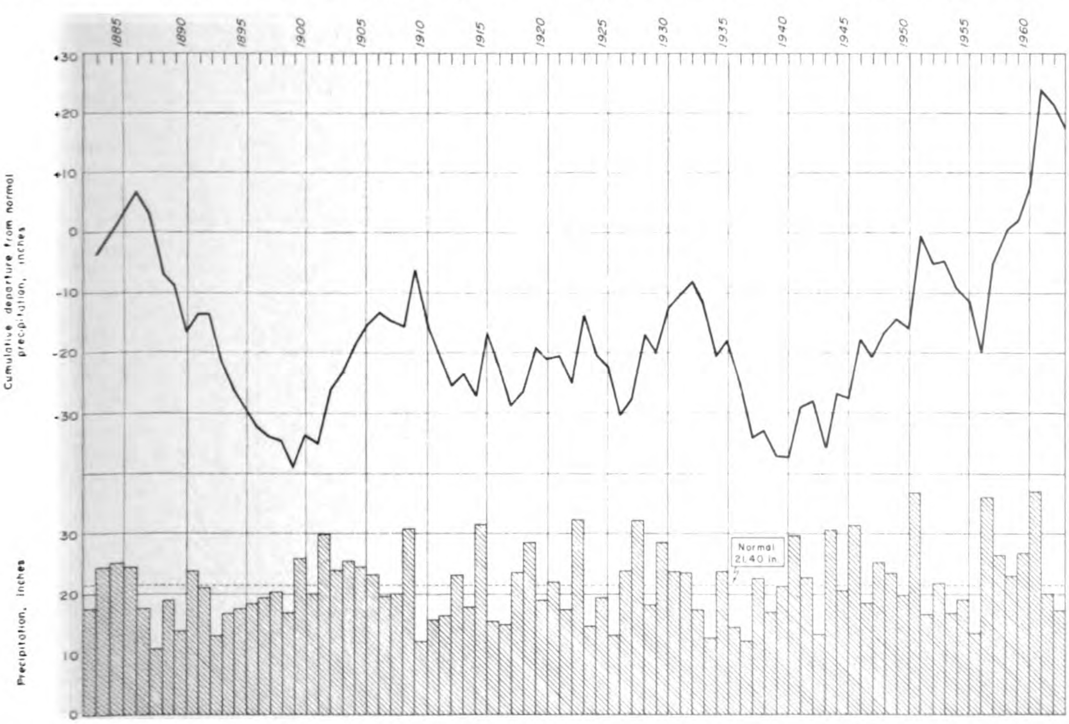

Figure 5.—Annual precipitation and cumulative departure from normal precipitation at WaKeeney.

is called the *piezometric surface*, which may or may not be above the land surface. Ground water in the Dakota Formation in Trego County is under artesian pressure, the water rising in some wells as much as 300 to 400 feet above the top of the Dakota. Water in the Codell Sandstone Member rises nearly 200 feet above the top of the Codell in some of the deeper wells in the County. Ground water in the Dakota and in the Codell is discussed further in the section on geologic formations and their water-bearing properties.

The Water Table and Movement of Ground Water

The water table fluctuates up and down in response to additions to or withdrawals from an aquifer. Fluctuations of the water table can be determined by periodic measurements of the depth to water in wells. The depth to water has been measured periodically since 1949 in several wells in the Smoky Hill Valley below the Cedar Bluff dam. These measurements have been published annually by the U.S. Geological Survey (1936-1959) and thereafter by the State Geologi-

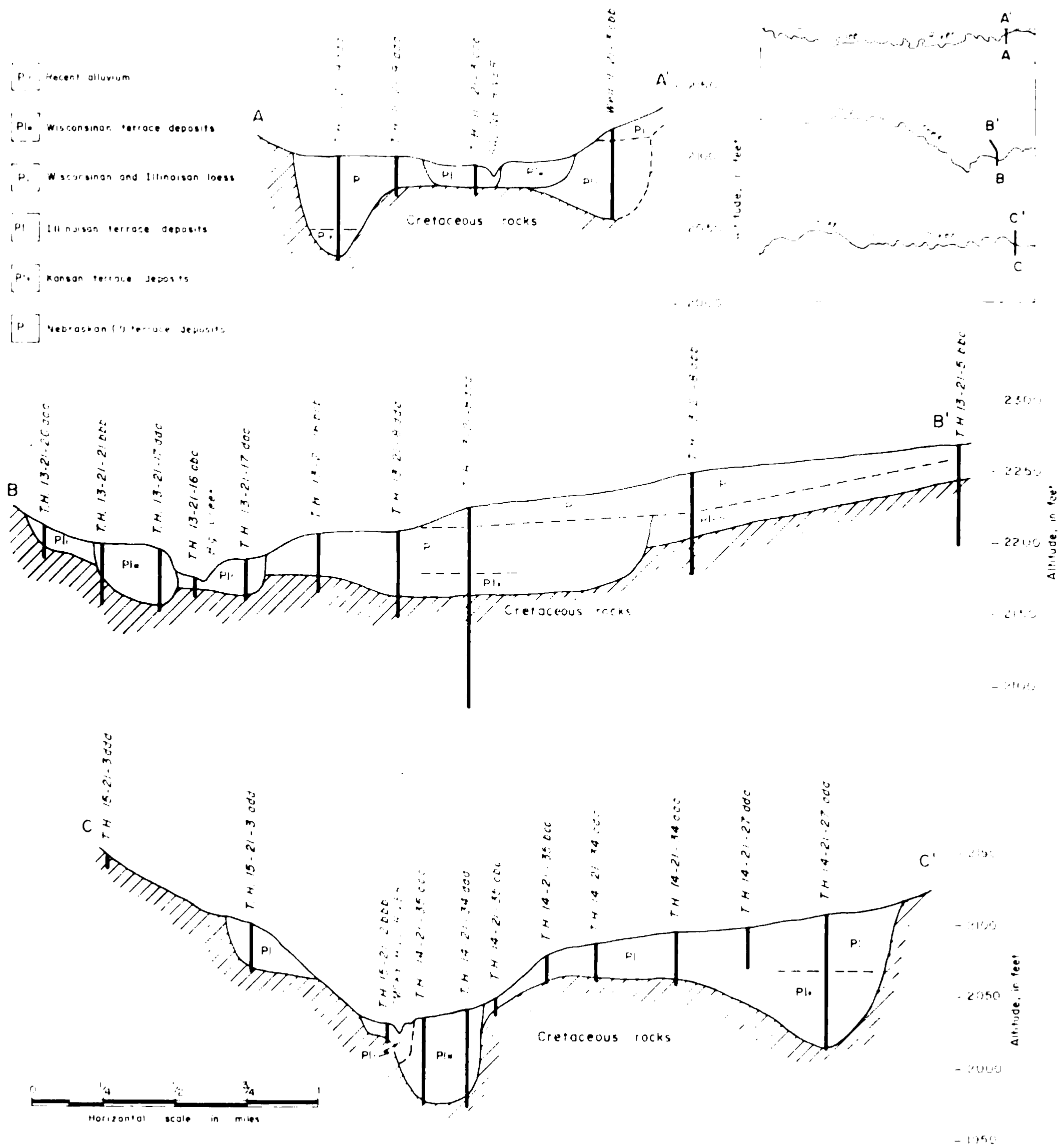

Figure 6.—Stratigraphic relation of Pleistocene deposits across Saline River (A-A'), Big Creek (B-B'), and Smoky Hill River (C-C') valleys.

cal Survey of Kansas (1958-1963). Hydrographs in Figure 9 show fluctuations of ground-water levels below the Cedar Bluff dam. The hydrograph of well 14-22-36aab, about a mile below the dam, reflects seepage from the reservoir which was filled in 1951.

The configuration of the water table in the Ogallala Formation in the northern part of the 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 downslope direction. The movement is generally eastward, but along the outer edges of the upland the contours bend back reflecting discharge along the edge of the upland. Local anomalies in the water-table contours along the edge of the upland indicate areas of greater recharge due to the predominance of sand and gravel near the land surface where the upland loess has been removed by erosion, exposing the coarser clastic deposits of the Ogallala.

Ground water in the alluvial valleys of the Smoky Hill and Saline rivers is not continuous with ground water in the Ogallala Formation in the uplands but is separated from it by impermeable Cretaceous rocks. Along Big Creek in the central and western parts of the County, however, the water table is continuous with the water table in the Ogallala, and water-table contours show that ground water from the Ogallala is discharging into terrace deposits and alluvium and from there into Big Creek (Pl. 1).

No long-term record of observation wells in the Ogallala Formation in Trego County is available. At the present rate of withdrawal, the water level is fairly stable and ground-water recharge and movement into the County is in equilibrium with discharge and movement from it.

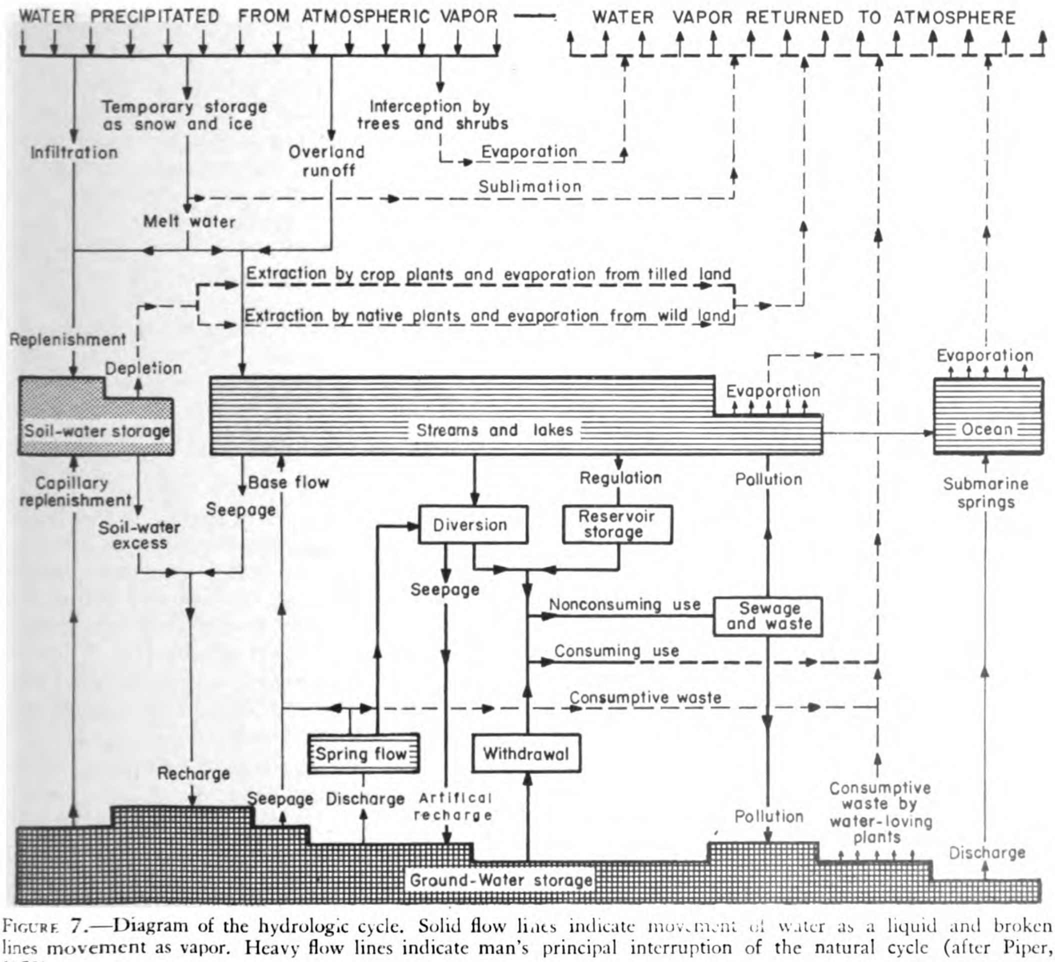

Figure 7.—Diagram of the hydrologic cycle. Solid flow lines indicate movement of water as a liquid and broken lines movement as vapor. Heavy flow lines indicate man's principal interruption of the natural cycle (after Piper, 1953).

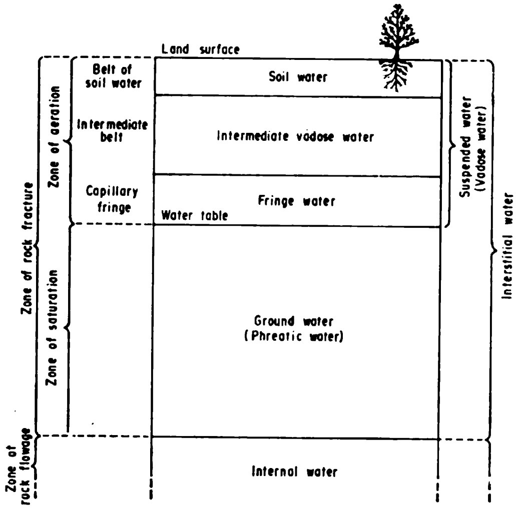

FIGURE 8.—Diagram showing generalized divisions of subsurface water (after Meinzer, 1923, fig. 2).

Additions of Ground Water

Additions to the ground-water reservoir may occur in several ways: by direct infiltration of precipitation, by seepage of water from streams, by subsurface inflow of water from adjacent areas, and by infiltration of irrigation water applied to the land.

INFILTRATION OF PRECIPITATION

Approximately 60 percent of the mean annual precipitation in Trego County falls during the 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 precipitation is returned to the atmosphere. Because much of the rainfall occurs during the growing season, a considerable part of the precipitation is returned to the atmosphere through transpiration of plants.

The topography, vegetative cover, and nature of the subsoil greatly affect the amount of water that will infiltrate below the land surface. The upland areas underlain by the Ogallala Formation are conducive to infiltration of rainfall in areas where sand and gravel crop out. Where thick loess deposits cover the Ogallala, infiltration is retarded.

The alluvium and terrace deposits along stream valleys are very conducive to infiltration because of the sandy nature of the deposits, the low relief, and the shallow depth to water. These deposits, however, are of relatively small areal extent. The annual quantity of recharge by infiltration of precipitation in Trego County is not known, but it is believed to be a small percentage of the total precipitation that falls in the County. Nevertheless, this recharge probably amounts to at least 10,000 acre-feet per year.

INFLUENT SEEPAGE FROM STREAMS

Smoky Hill River, Saline River, and Big Creek are effluent streams in Trego County. Their channels are cut below the water table and thus generally are receiving water from, rather than adding water to, the zone of saturation (Fig. 10). Deposits adjacent to the channels are recharged during flood stages, but the water represents temporary "bank" storage and returns to the stream soon after the flood. Smaller tributaries in the County lie above the water table and during periods of stream flow, contribute water to the underlying strata where the channel is underlain by deposits that are conducive to infiltration.

SUBSURFACE INFLOW

The quantity of subsurface inflow to the County is not known, but it is estimated that from 3 to 4 acre-feet of ground water per day moves into Trego County from the west through the Ogallala Formation (1 acre-foot equals 325,850 gallons). A small amount of ground water enters the County along the northern boundary, chiefly in valleys tributary to the Saline River valley. Some ground water also enters the County by movement in alluvium and terrace deposits along the major stream valleys. Because of the small cross-sectional area of the valley deposits, the amount of ground-water movement in them is relatively small.

INFILTRATION OF IRRIGATION WATER

Recharge from 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 and subsoils that are very permeable.

Irrigation in Trego County is confined chiefly to the Big Creek and Saline River valleys where the soils are sandy loam. The percentage of applied water that recharges the alluvium of these valleys is not known but probably is considerable in small local areas. Because irrigation is not practiced extensively and because the areal extent of the alluvial valleys is relatively small, the amount of recharge to the aquifer from infiltration of irrigation water is not significant.

In Trego County, much of the upland plain is thickly mantled by loess and has a relatively dense soil, and recharge probably does not exceed an average of 10 percent of the applied irrigation water. Because only a few irrigation wells obtain water from the Ogallala in Trego County, the amount of recharge to the aquifer from infiltration of irrigation water is considered to be negligible.

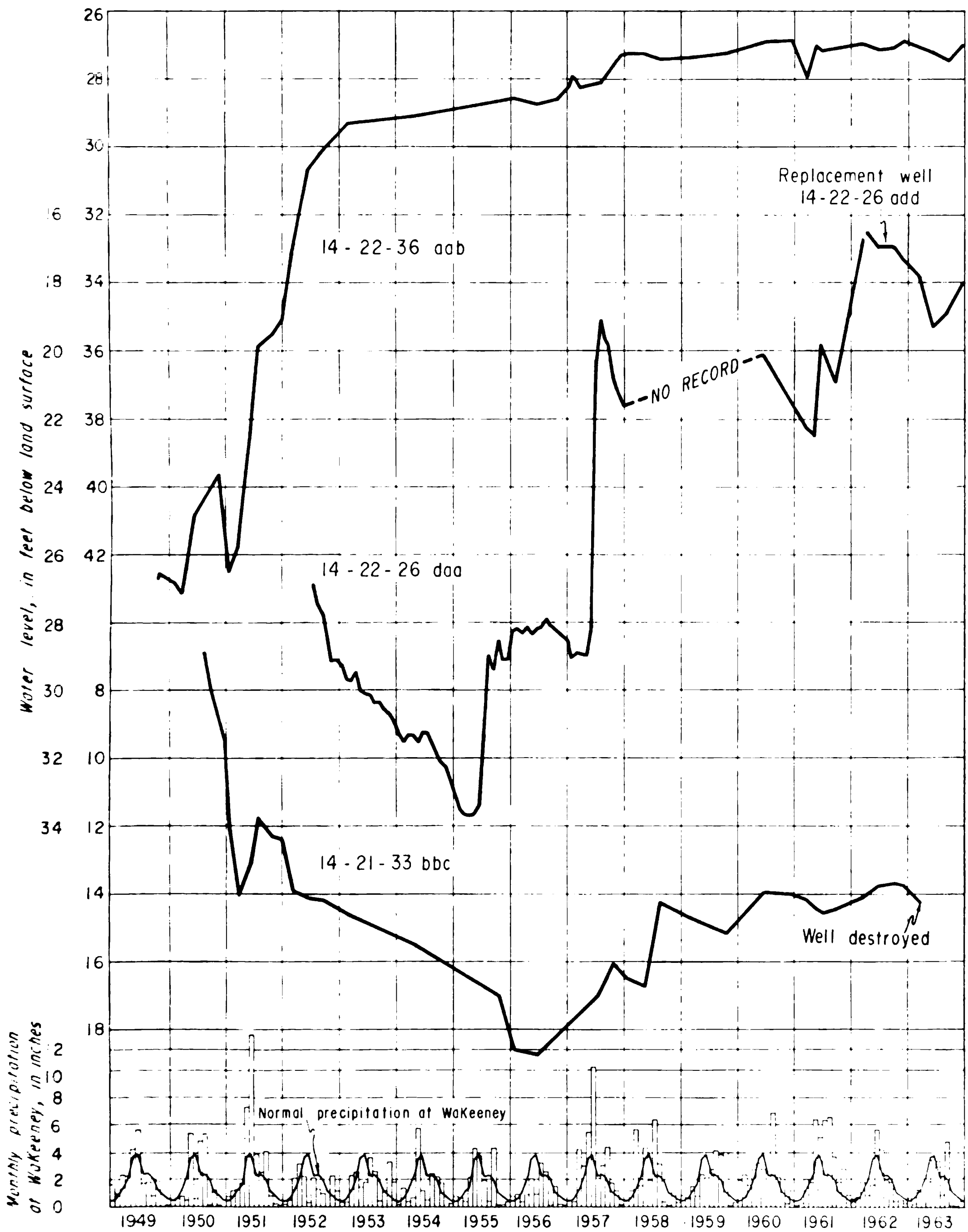

FIGURE 9.—Hydrographs showing fluctuations of water levels in the Smoky Hill Valley, and graphs showing monthly and normal precipitation at WaKeeney.

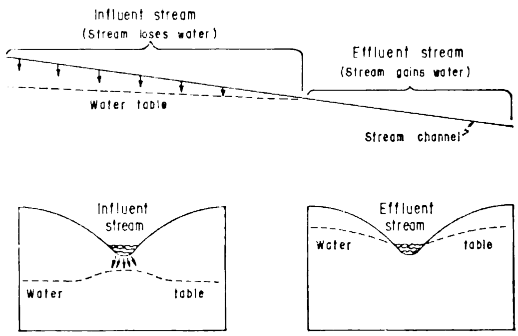

FIGURE 10.—Diagrammatic sections showing influent and effluent streams. *A*, Longitudinal section showing how a stream gains water (right) and how it loses water (left). *B*, Transverse section across influent part of a stream. *C*, Transverse section across effluent part of a stream. (After Meinzer,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

GROUND-WATER DISCHARGE

Subtractions from the ground-water reservoir in Trego County include discharge by effluent seepage into streams, discharge of springs, transpiration and evaporation, discharge from wells, and subsurface outflow.

SEEPS AND SPRINGS

Streamflow is maintained at low stages along the perennial streams in the County by ground-water discharge into the streams, mainly as seeps along stream channels. Discharge is chiefly from alluvial and terrace deposits, but along Big Creek, in the western and central parts of the County, the Ogallala Formation is in contact with the valley deposits and discharge occurs from the Ogallala into the valley deposits. Small springs occur at places where the contact of the Ogallala Formation and underlying Cretaceous rocks crop out. Springs also occur along the edges of the high terrace deposits in the Smoky Hill Valley. The amount of discharge of ground water by springs and seeps in Trego County is not known, but it is believed to be considerable.

TRANSPIRATION AND EVAPORATION

Shallow ground water along the major streams supports a heavy growth of vegetation, and during the growing season a significant amount of ground water is transpired by these plants. The quantity of ground water discharged in this manner is difficult to determine, but it probably exceeds the discharge by all other means combined. Transpiration reduces the ground-water discharge into a number of streams, and flow in these streams during the growing season is largely runoff from storms.

After the first killing frost in the fall, perennial streams show an appreciable increase in flow due to a decrease in plant transpiration. In the upland areas transpiration does not occur from the water table because of the greater depth of the water table. Soil moisture 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 in the County is restricted to the alluvial valleys and the amount is probably small compared to other means of ground-water discharge.

PHREATOPHYTES

Phreatophytes are plants that characteristically grow where they can send their roots down to the water table, or to the capillary fringe, and thus obtain their water supply. Most phreatophytes are of low economic value, and the water they transpire to the atmosphere is defined as "consumptive waste." More than 70 plant species have been classified as phreatophytes (Robinson, 1958, p. 1), some of the more common being pickleweed, rabbitbrush, salt grass, alfalfa, cottonwood, willow, greasewood, and salt cedar. Salt cedar *(Tamarix pentandra)* is a serious problem in many stream valleys in the southwestern and western United States. In places, salt cedar has developed a jungle-like growth, invading and choking overflow channels of streams, and producing serious flood hazards. The eradication or control of salt cedar is very difficult and expensive. The annual use of water by salt cedar in areas of heavy growth may be several acre-feet per acre.

Salt cedar has invaded some stream valleys in Kansas and is now found along the Cimarron and Arkansas valleys in southwestern Kansas, Smoky Hill and Saline valleys in west-central Kansas, and South Fork and North Fork Solomon valleys in north-central Kansas (Tomanek and Ziegler, 1963).

Salt cedar has been used extensively as a shelter belt in Trego County and is also found as an ornamental shrub in many farm yards in the County. A number of places around the Cedar Bluff reservoir have become heavily infested with salt cedar. Ecological studies of salt cedar in the Cedar Bluff area (Tomanek and Ziegler, 1963) show that the plant benefits from a drought or conditions that keep the water level falling or low for a long period of time.

DISCHARGE FROM WELLS

Ground water is pumped for municipal, domestic, stock, and irrigation use in Trego County. Municipal water departments in the County reported a total use of about 450 acre-feet of ground water in 1960. Records of the Division of Water Resources of the Kansas State Board of Agriculture show that 3,487 acre-feet of ground water per year were appropriated for irrigation in the County as of April, 1963. The amount of ground water reported as used for irrigation in 1962 was 333 acre-feet. This amount may vary considerably, depending upon rainfall. Most rural residents obtain water for domestic and livestock use from small-diameter drilled wells equipped with cylinder pumps powered by windmills. The yields of these wells are small and probably average about one gallon a minute. Because of their great number and long pumping periods, however, such wells represent an important withdrawal of ground water, estimated to be about 800 acre-feet per year for both household and stock purposes. Withdrawal of ground water from wells is increasing somewhat because of new water uses in the home and on the farm. There is also a small annual increase in the number of irrigation wells in the County, mostly in the alluvial valleys.

SUBSURFACE OUTFLOW

Ground-water contours on Plate 1 show the subsurface flow of ground water to be in a generally eastward direction in the northern part of the County. In most areas the contours bend westward along the edge of the uplands, indicating discharge from the uplands toward the stream valleys. The amount of outflow in the alluvial valleys is small because of the relatively small cross-sectional area of the alluvial valleys. It is estimated that about 700 acre-feet of ground water per year leaves Trego County by subsurface outflow.

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 the ability to transmit and to store water, which are measured by the coefficients of transmissibility and storage. Controlled aquifer tests in the field provide the data required to compute these coefficients.

The coefficient of transmissibility (T) may be expressed 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 ground-water temperature.

The coefficient of storage (S) may be expressed 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) may be expressed as the rate of flow of water, in gallons per day, through a cross-sectional area of 1 square foot, under a hydraulic gradient of 1 foot per foot, at the prevailing ground-water temperature. The field coefficient of permeability can be computed by dividing the coefficient of transmissibility by the aquifer thickness (m).

DETERMINATIONS OF TRANSMISSIBILITY AND PERMEABILITY

Aquifer tests were made using two irrigation wells, 12-23-20ccc, deriving water from alluvium in Big Creek valley, and 12-23-30acc, deriving water from terrace deposits along Big Creek valley. Details of the wells are given in the table of well records at the end of this report. Observation wells for drawdown measurements were constructed at appropriate distances from the pumped wells. Figures 11, 12, 13, and 14 give the results of these tests. Values of transmissibility were computed from the test data by the methods generally referred to as the Thiem formula, the Theis nonequilibrium formula, the Jacob modified nonequilibrium formula, and the Theis recovery formula. The theory of these formulas and their application are discussed by Ferris, *et al.* (1962).

The aquifer tests indicate that a coefficient of transmissibility of about 40,000 gpd per foot may be expected in the alluvium at localities where the saturated thickness is adequate and where reasonably good sand and gravel beds are in the saturated zone. Test drilling should disclose the more favorable well sites.

Although the aquifer test in the terrace deposits shows a coefficient of transmissibility of about 120,000 gpd per foot, the transmissibility is too high for most deposits shown as terrace deposits in this report. Deposits in the vicinity of well 12-23-30acc are thicker, better sorted, and have a greater saturated thickness than is characteristic of terrace deposits in most of the County. Also, in this area along the central and western reaches of Big Creek, terrace deposits are adjacent to, and in many places lithologically indistinguishable from, the Ogallala Formation. The water table in the terrace deposits is continuous with the water table in the Ogallala Formation and ground water moves from the Ogallala Formation into the terrace deposits. When pumping occurs in the terrace deposits, there is increased movement of ground water from the Ogallala into the terrace deposits toward the area of drawdown. In contrast, along the Saline River and Smoky Hill River valleys and along Big Creek valley in the eastern part of the County, the terrace deposits are separated from the Ogallala by wide areas of impermeable Cretaceous shale.

The coefficients of storage calculated in aquifer test 12-23-30acc (Fig. 13) show a change from artesian to water-table conditions as pumping continued. Logs of test holes in the alluvium and terrace deposits show that silt and clayey silt are characteristic of the upper part of the deposits and that sand and gravel generally occur in the lower part. The silt beds cause a slight artesian effect because of confinement of ground water below these less permeable silt beds.

Utilization of Ground Water

Data on 280 wells in Trego County are given in Table 6. 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. The principal uses of ground water in the County are listed below.

Domestic and Stock Supplies

One of the chief uses of ground water in Trego County is to supply domestic and stock needs. Nearly all domestic and stock supplies in the rural part of Trego County are obtained

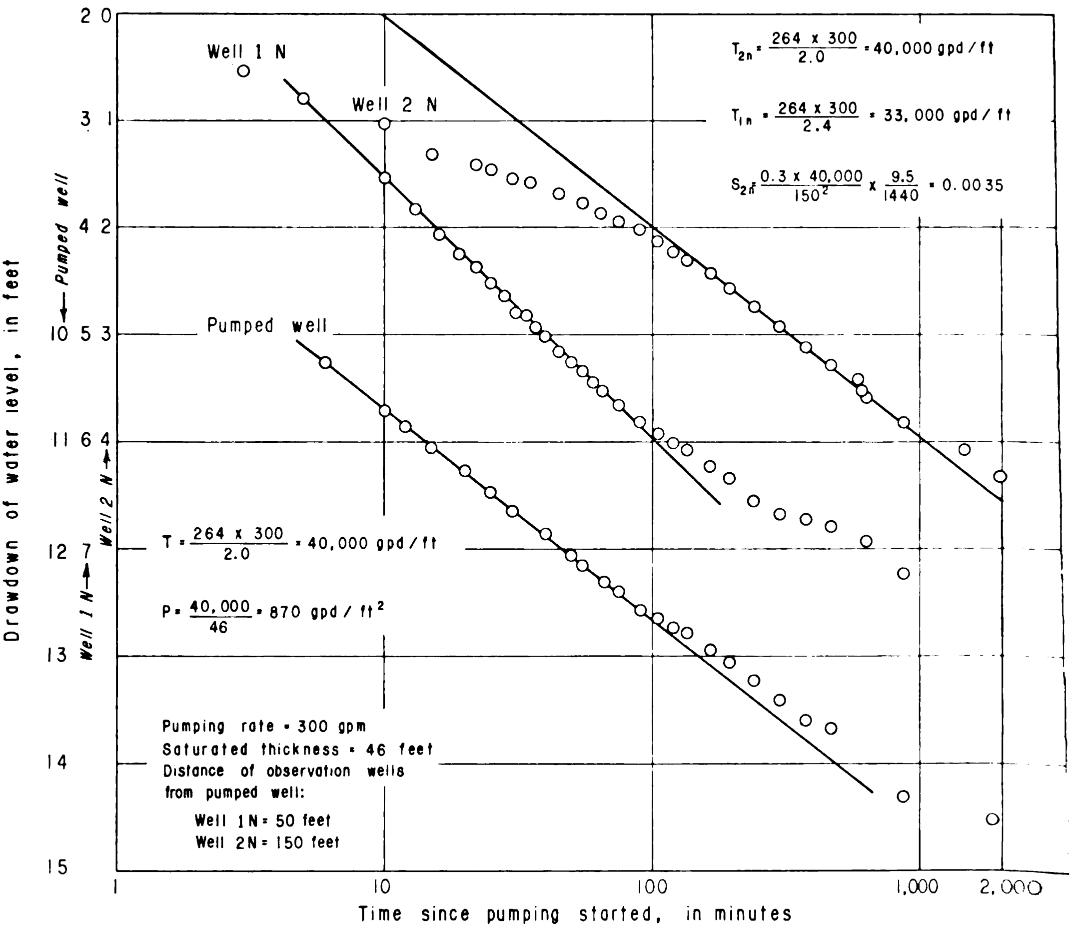

Figure 11.—Drawdown of water levels in pumped well and observation wells during aquifer test, plotted against time since pumping started (well 12-23-20ccc).

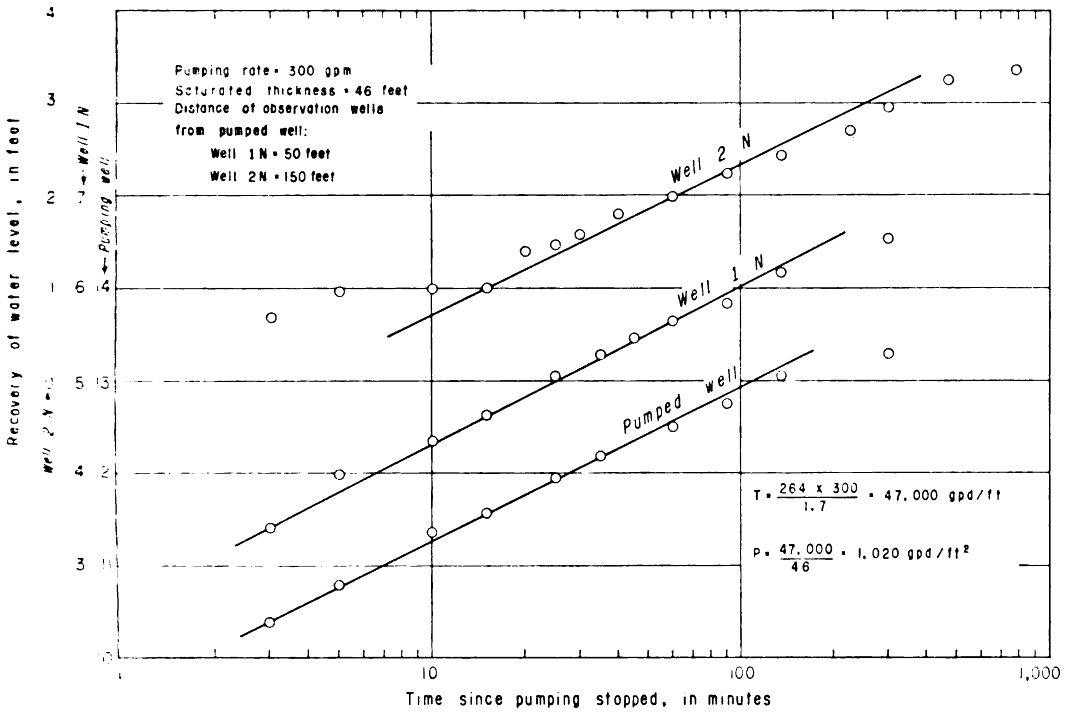

FIGURE 12.—Recovery of water levels in pumped well and observation wells during aquifer test, plotted against time since pumping stopped (well 12-23-20ccc).

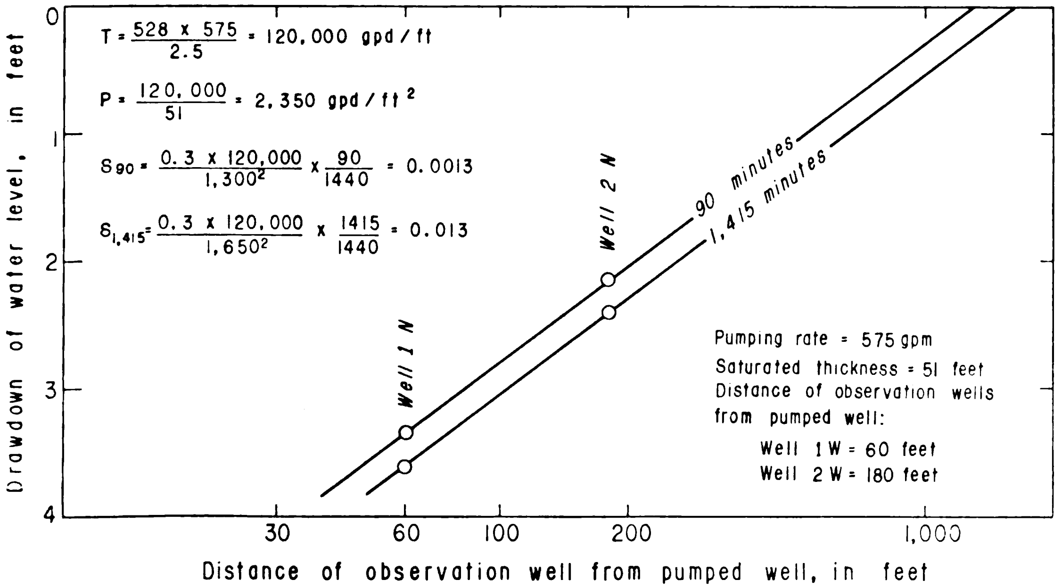

FIGURE 13.—Drawdown of water levels in observation wells during aquifer test at 90 and 1,415 minutes after pumping started, plotted against distance from pumped well (12-23-20ccc).

from wells, but in parts of the County where ground water is difficult to obtain, some stock supplies are provided by dams constructed across small watercourses. Most domestic and stock wells in the County are drilled wells in which 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; the others are operated by electric or gasoline motors, or by hand.

MUNICIPAL SUPPLIES

At the time of this investigation only the communities of WaKeeney and Collyer maintained municipal water-supply systems. Data regarding individual wells and details of well construction are given in Table 6.

WaKeeney.—The city of WaKeeney obtains its water supply from seven drilled wells in the alluvial deposits of Big Creek valley about 2 miles south of the city. The wells are equipped with electrically driven turbine pumps; yields range from about 100 to 500 gpm. A reserve well is also maintained at the east edge of town which derives water from the Ogallala Formation. Storage is provided by 2 elevated storage tanks with capacities of 250,000 and 75,000 gallons and 2 underground reservoirs with capacities of 200,000 and 100,000 gallons. Water used in 1960 was about 136 million gallons, as reported by the WaKeeney Water Department.

Collyer.—The city of Collyer obtains its water supply from two drilled wells in the Ogallala Formation at the southwest edge of the city. The wells are equipped with electrically driven turbine pumps; yields are about 100 gpm. Storage is provided by an elevated 55,000-gallon tank. An annual use of about 10 million gallons was reported by the Collyer Water Department.

IRRIGATION SUPPLIES

There were 22 irrigation plants in Trego County by the fall of 1960, most of which were in the alluvial valleys. Nearly all were single wells, but a few plants were pumping from batteries of two or more wells. Yields of the irrigation wells ranged from about 150 gpm to about 1,000 gpm. According to records of the Division of Water Resources of the Kansas State Board of Agriculture, 1,725 acres in Trego County were covered by ground-water rights, or

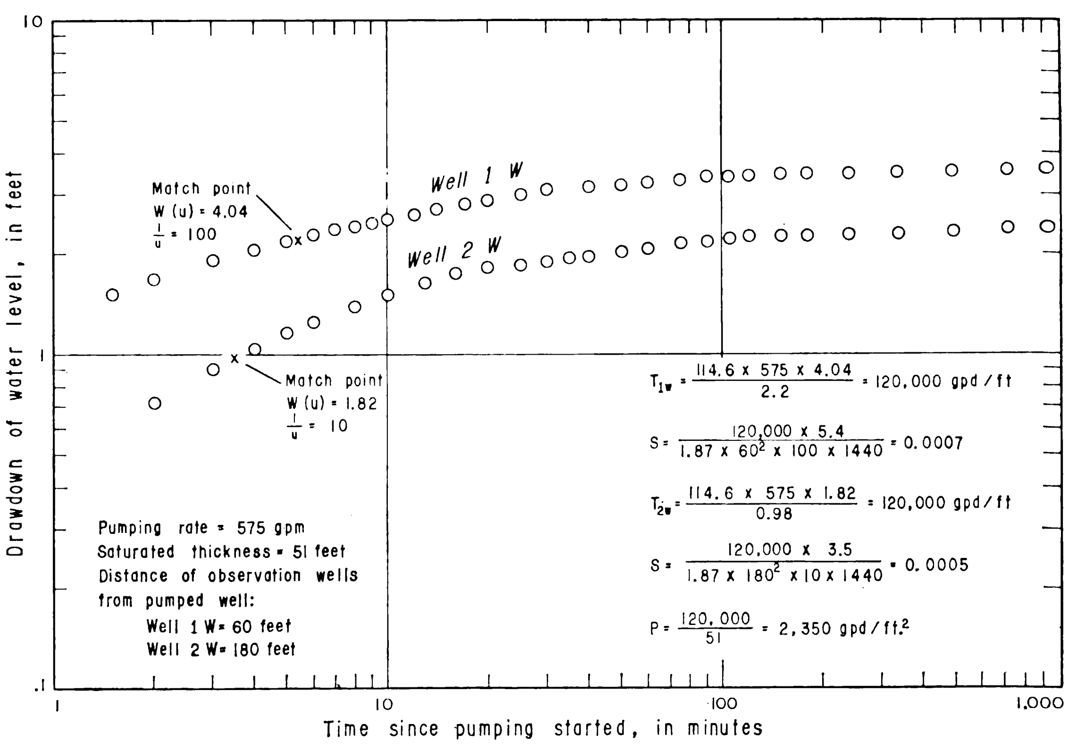

FIGURE 14.—Drawdown of water levels in observation wells during aquifer test, plotted against time since pumping started (well 12-23-30acc).

applications for rights, for which 3,487 acre-feet of ground water per year was appropriated, as of April 1963. Surface-water rights, or application for rights, totaled 1,105 acres, for which 2,119 acre-feet of surface water per year was appropriated. This does not include water released from Cedar Bluff reservoir for irrigation districts below the reservoir.

Possibilities of Developing Additional Supplies

Most of the land irrigated with ground water in Trego County is in Big Creek valley. On the assumption that the alluvium and Wisconsinan terrace deposits of Big Creek valley have an average width of a half mile, a length of 30 miles, an average thickness of saturated material of 20 feet, and a specific yield (ratio of the volume of water the saturated part of the aquifer will yield, by gravity, to its own volume) of 15 percent, there would be about 30,000 acre-feet of water in storage, which is 1,500 times the amount of water pumped for irrigation in Big Creek valley in 1962 (as reported to the Division of Water Resources of the Kansas State Board of Agriculture). If pumping were increased enough to lower the water table below stream level, the ground-water reservoir would be recharged from the stream instead of discharging into the stream as it does now. It is estimated that about equal amounts of ground water are in storage in each of the three principal valleys in the County—Smoky Hill Valley, Saline Valley, and Big Creek valley.

About 300 square miles in the northern and central parts of Trego County are underlain by the Ogallala Formation in which the estimated average saturated thickness is about 25 feet. Assuming a specific yield of 15 percent, the ground water in storage in this area would be about 700,000 acre-feet. Not all this water could be pumped from the aquifer, and yields from wells are only moderate to low, but it is an important source of water in the area.

Cedar Bluff Reservoir

Cedar Bluff Reservoir on the Smoky Hill River was filled in 1951 soon after construction of the dam was completed. The height of the dam is 134 feet above the river; its length is 12,560 feet. The reservoir is approximately 9 miles long and nearly 5 miles wide at its widest point. It has a shoreline of about 54 miles at irrigation-pool level. The reservoir has a flood-storage capacity of 191,800 acre-feet and an irrigation-storage capacity of 176,800 acre-feet.

MINERAL RESOURCES

Mineral resources of Trego County, other than soil and ground water, include oil, construction materials, and volcanic ash.

Oil

Trego County has been explored for oil since 1923. Oil was first discovered in May, 1929, in sec. 20, T 13 S, R 21 W. Production was from the basal conglomerate of Pennsylvanian age at a depth of 3,960 to 3,972 feet. Named the Rega pool, it was soon abandoned after producing about 15,000 barrels of oil. The pool was revived with a producer in 1947, but was abandoned again in 1950. The WaKeeney pool, discovered in 1934 in the northern part of the County, was the second pool discovered. Production was from the Lansing Group of Pennsylvanian age. The Gugler pool was discovered in 1936 about 4 miles northeast of the Rega pool. Production was from rocks of Pennsylvanian age and from Arbuckle rocks of Cambrian and Ordovician age. No new pools were discovered until 1941, when the Ogallah pool was opened about 4 miles north of the Gugler pool. Further development of the oil industry in Trego County is summarized in Table 2.

The 1963 production from 331 wells in 29 fields was 1,582,000 barrels of oil. Cumulative production to the end of 1963 was almost 19 million barrels. Gas in commercial quantities has not been produced in Trego County. Yearly data on production of oil and gas in Kansas are available in the files of the Oil and Gas Division of the State Geological Survey of Kansas and are published as bulletins of the State Geological Survey of Kansas.

Table 2.—Number of producing wells and producing fields, and annual production of oil from 1938 to 1963 in Trego County, Kansas.

Year	Producing wells	Producing fields	Production, thousands of barrels	Year	Producing wells	Producing fields	Production, thousands of barrels
1938	13	2	326*	1951	51	10	264
1939	13	2	43	1952	110	14	802
1940	8	2	48	1953	139	20	1,032
1941	9	3	45	1954	160	23	1,028
1942	8	2	23	1955	182	25	1,077
1943	6	1	42	1956	243	29	1,470
1944	9	2	33	1957	278	26	1,928
1945	11	3	64	1958	276	29	1,877
1946	11	3	74	1959	287	31	1,781
1947	14	5	88	1960	294	31	1,584
1948	17	5	97	1961	293	30	1,537
1949	18	7	107	1962	295	32	1,590
1950	18	7	90	1963	331	29	1,582

* Cumulative production to the end of 1938.
Data from Bulletins of the State Geological Survey of Kansas, annual oil and gas development reports.

Construction Materials

Mixed Aggregate

Deposits of sand and gravel suitable as road metal for light-traffic roads and in the construction of black-top roads are abundant in Trego County. The deposits are found chiefly along the Smoky Hill Valley as terrace deposits and in the Ogallala Formation in the upland areas. Terrace deposits along the Smoky Hill Valley are predominantly sand and gravel and are more suitable for mixed aggregate than are terrace deposits along other streams in the County, which in places contain considerably more silt with little or no sand and gravel.

Concrete Aggregate

Aggregate for concrete should be free from adherent coatings or silt and clay particles that would interfere with bonding. Arkosic sand and gravel in terrace deposits along the Smoky Hill Valley are generally suitable for concrete aggregate, although if silicious materials such as opaline or chalcedonic chert is present in significant quantities, a low-alkali cement may be necessary.

Structural Stone

The Fort Hays Limestone Member of the Niobrara Chalk has been quarried for structural stone at numerous localities in Trego County. The Fort Hays is relatively soft, although it hardens upon weathering. The Fort Hays also tends to absorb water and thus to deteriorate through freeze-and-thaw action and from spalling. Many farm buildings, city dwellings, and business houses in the area constructed of the Fort Hays Limestone seem to stand up well for many years, however. In a report by Risser (1960) the sources and characteristics of building stone in Kansas are discussed.

Volcanic Ash

Volcanic ash in Trego County consists predominantly of minute, platy or curved fragments of volcanic glass. The ash is generally white to light pearly-gray, but occasionally may show tints of yellow or red. The most common uses of volcanic ash are as an ingredient of ceramic glazes, as an additive to certain types of concrete, and as a mineral filler for bituminous-surfaced highways.

A small pit of volcanic ash has been opened in the SE sec. 36, T 14 S, R 21 W. About 10 feet of ash is present, with the lower 6 feet relatively free of impurities. The deposit becomes thinner laterally from the pit. Only a small amount of ash has been taken from the pit. Two other ash deposits were noted—one in the SE sec. 28, T 14 S, R 21 W, and another in the SW sec. 30, T 14 S, R 22 W. These deposits are small and have little commercial value.

QUALITY OF GROUND WATER

The chemical character of the ground water in Trego County is indicated by analyses of samples from wells deriving water from the principal aquifers (Table 3). The analyses of water were made by Howard A. Stoltenberg, Chief Chemist, in the Sanitary Engineering Laboratory of the Kansas State Department 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 4. 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 15.

Table 4.—Factors for converting parts per million to equivalents per million.

Mineral constituent	Chemical symbol	Conversion factor
Calcium	Ca^{++}	0.0499
Magnesium	Mg^{++}	.0822
Sodium	Na^{+}	.0435
Potassium	K^{+}	.0256
Carbonate	CO_3^{--}	.0333
Bicarbonate	HCO_3^{-}	.0164
Sulfate	SO_4^{--}	.0208
Chloride	Cl^{-}	.0282
Fluoride	F^{-}	.0526
Nitrate	NO_3^{-}	.0161

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

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

TABLE 3.—Analyses of water from typical wells in Trego County, Kansas (in parts per million, except as otherwise indicated*).
(Samples analyzed by H. A. Stoltenberg.)

Well no.	Date of collection	Depth of well, feet	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium and Potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 180° C)	Hardness as $CaCO_3$: Carbonate	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25° C)
10-25-34ddc	12-1-52	16.0	....	29	0.13	....	65	15	14	249	11	10	0.7	27	295	204	20	....
11-22-32bbc	6-14-60	87	....	36	.68	0.00	66	6.7	15	224	7.4	13	.4	17	272	184	8	410
11-23-6cdc	10-24-60	28.7	....	41	.07	.00	117	7.8	25	310	67	33	.3	9.3	453	254	70	800
11ccc	10-24-60	37.3	58	28	.53	.45	118	18	44	316	112	59	.6	4.4	540	259	109	970
26bcb	10-13-59	320	57	9.5	.78	....	24	18	163	344	121	51	2.8	1.1	560	134	0	955
11-24-29bcc	9-30-59	22.0	56	39	.06	....	76	18	10	246	12	22	.06	49	348	202	62	570
12-21-2bbb	9-26-60	54.0	....	31	.16	.00	82	12	10	283	11	9.0	.2	25	320	232	22	550
24cdc	10-12-59	665	....	8.0	.20	....	16	10	180	307	101	61	3.0	26	556	81	0	950
28aaa	10-12-59	48.0	60	13	.14	....	600	25	64	293	1,360	36	1.8	32	2,280	240	1,360	2,600
12-22-8bab	6-14-60	118.0	....	39	.14	.00	65	14	7.4	252	11	9.0	.4	4.9	275	206	14	450
12aab	10-12-59	65.0	60	25	.13	....	67	10	9.7	242	7.8	11	.2	8.0	258	198	10	415
28bba	6-14-60	......	....	33	.09	.00	62	10	16	239	16	9.0	.3	5.3	269	196	0	450
36ccb	6-14-60	269	....	15	.20	.00	28	15	219	346	150	95	2.8	33	728	132	0	1,270
36ccc	10-24-60	27.5	58	24	.20	.00	129	15	60	377	69	43	.6	88	614	309	75	1,070
12-23-12bab	6-14-60	103.0	....	43	.11	.00	66	13	21	264	14	9.0	.5	23	320	216	2	510
20ccc1	9-15-60	65	....	28	.96	.70	86	14	17	302	38	14	.3	1.5	347	248	24	640
30acc1	9-20-60	96	....	32	.05	.00	60	16	8.7	259	7.0	8.0	.4	3.5	263	212	4	460
33bcb	10-12-59	100.0	59	25	.07	....	74	9.6	12	246	14	13	.3	18	287	202	22	490
12-24-5cdc	10-25-60	67.5	58	41	.25	.00	89	15	13	295	19	17	.4	31	371	242	42	650
30dad	10-13-59	79.5	58	25	.13	....	70	13	13	264	5.3	14	.3	18	289	216	12	490
12-25-11aab	10-25-60	77.5	58	45	.48	.00	63	13	18	246	18	16	.6	8.0	303	202	8	510
12aaa	6-14-60	90	....	45	2.5	.00	91	19	13	244	20	41	.5	66	416	200	105	690

TABLE 3.—Analyses of water from typical wells in Trego County, Kansas.—*Concluded.*

Well. no.	Date of collection	Depth of well, feet	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium and Potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 180° C)	Hardness as $CaCO_3$ Carbonate	Hardness as $CaCO_3$ Noncarbonate	Specific conductance (micromhos at 25° C)
13-22-15daa	6-14-60	66	....	34	.54	.00	71	16	30	321	12	22	.4	1.2	345	243	0	600
22aaa	6-14-60	40	....	35	3.9	.17	114	17	17	405	30	20	.2	1.0	433	332	22	740
13-23-17aaa	10-10-59	107	....	27	.26	....	61	11	13	246	6.6	7.0	.2	6.6	253	197	0	415
22ccb	10-12-59	65.0	59	27	.12	....	170	26	45	283	21	91	.1	305	825	232	299	1,350
13-24-2aaa	10-12-59	106.5	59	25	.11	....	61	8.8	7.8	217	7.8	8.0	.2	9.3	235	178	10	385
36bbb	10-13-59	31.5	58	25	.39	....	110	14	36	285	99	27	.4	42	494	234	98	855
13-25-32cbb	9-27-60	21.0	59	24	.06	.00	100	8.4	11	278	46	14	.4	15	356	228	56	630
14-21-6aba	10-21-60	21.0	58	25	.16	.00	128	17	46	325	132	52	.5	15	575	266	124	1,000
30cab	10-29-49	29.2	59	32	4.7	....	156	29	39	284	262	29	.7	55	772	508	275	....
31cdb	10-29-49	13.2	62	39	.10	....	174	43	43	268	416	23	.6	22	938	610	390	....
34bad	10-29-49	20.9	58	36	.26	....	342	48	20	194	496	97	.4	348	1,480	1,050	890	....
35cab	10-22-49	19.1	59	27	.26	....	214	38	101	224	538	78	.5	69	1,180	690	510	....
35cca	10-22-49	19.8	59	45	.77	....	226	78	81	374	648	41	.3	26	1,330	884	576	....
14-22-6aba	9-29-60	27.5	59	29	.04	.00	85	11	26	259	44	26	.5	22	371	212	45	660
12ccc	6-14-60	87.0	....	15	.23	.00	73	40	42	288	142	32	.6	11	498	236	110	830
26ada	10-29-49	90.7	....	35	.19	....	76	11	20	248	53	9.0	.4	9.0	368	235	32	....
14-23-9aba	10-12-59	23.4	59	24	.62	....	97	8.3	11	267	21	20	.1	37	350	219	57	600
22aba	9-28-60	37.5	....	20	.14	.00	156	18	66	266	285	51	.4	25	752	218	245	1,170
14-24-19dda	10-19-59	300	57	9.5	.24	....	4.9	4.9	362	350	187	232	3.2	1.8	978	32	0	1,720
22baa	10-10-59	52.0	58	8.5	.18	....	82	11	13	259	28	10	.2	27	307	212	38	555
25ddd	10-10-59	29.0	60	25	.04	....	104	6.0	32	307	54	13	.1	32	417	252	32	720
14-25-25ccb	9-28-60	19.0	....	34	.07	.00	228	72	106	351	625	87	.7	42	1,370	288	577	1,950
15-21-5abb	10-29-49	11.1	63	36	.14	....	137	14	53	196	98	60	.1	208	780	400	239	....
16cbc	6-14-60	32	....	26	.07	.00	100	14	34	346	47	29	.7	8.0	429	284	23	745

25ddd	6-14-60	555	....	9.5	.49	.00	8.3	12	176	415	220	368	5.2	3.6	1,310	70	0	2,280
36ddd	6-14-60	45.0		21	.11	.00	110	16	19	300	33	50	.3	37	431	246	94	790
15-22-35aba	9-29-60	660	59	35	1.3	.00	68	9.4	13	246	13	12	.5	2.9	275	202	6	470
15-23-4bcb	10-12-59	18.0	60	16	.07	....	121	24	28	215	239	19	.5	10	564	176	224	860
14ccd	10-12-59	8.5	60	21	.31	....	281	37	87	307	628	68	.9	49	1,320	252	601	1,820
21ddc	10-12-59	47.4	58	18	.64	....	71	10	18	227	16	21	.4	31	297	186	32	520
35bcb	9-28-60	35.0	60	29	.11	.00	82	11	33	259	50	37	.3	5.3	375	212	38	660
15-24-15ccc	9-9-59	618	67	8.0	.62	....	9.1	7.7	398	312	174	336	3.2	.4	1,090	54	0	1,930
31ddc	9-28-60	72.5	59	31	1.8	.00	116	17	44	321	58	52	.2	71	547	263	97	970
35ccc	9-29-59	60	54	25	.89	....	102	25	23	246	47	64	.7	80	488	202	156	915
15-25-23dad	9-27-60	72.0	59	26	.30	.00	52	12	11	215	9.5	7.0	.5	5.3	229	176	3	400
29bba	9-27-60	35.0	....	21	.06	.00	115	14	10	315	33	27	.3	43	418	258	86	760
35cdc	10-13-59	93.0	57	25	.03	....	62	14	9.2	231	12	11	.4	17	264	190	22	465

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

contain enough of certain constituents to cause a noticeable taste or to make the water unsuitable in other respects.

The dissolved solids in the samples of water collected ranged from 229 to 2,280 ppm (Table 3). Most samples contained less than 500 ppm of dissolved solids. Eight samples contained more than 1,000 ppm of dissolved solids.

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 the washing process. Calcium and magnesium cause almost all the hardness of water and are the constituents that contribute to the incrustation that may develop when water undergoes changes in temperature and pressure.

The total hardness of water may be divided into 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, thereby causing precipitation of magnesium and calcium carbonate. Noncarbonate hardness is the difference between the total and the carbonate hardness and 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 effect of other minor con-

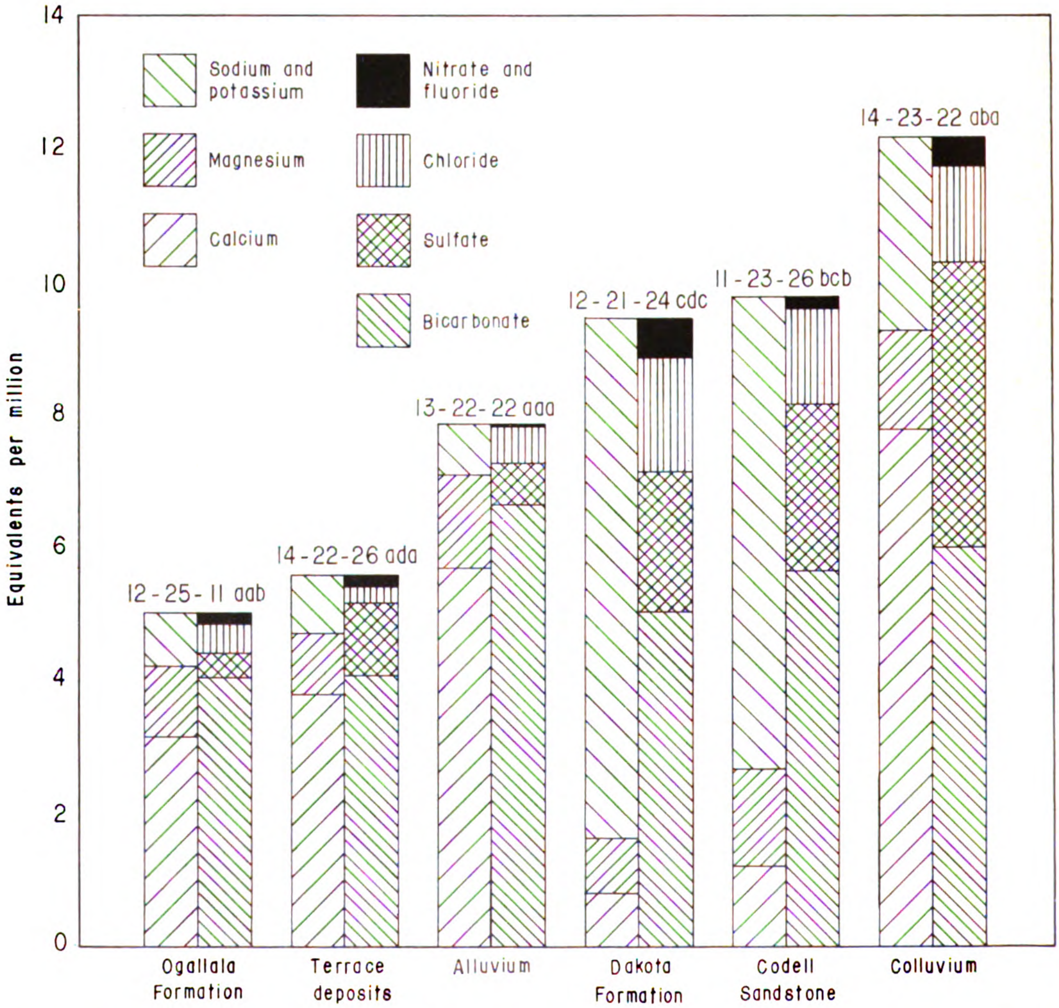

FIGURE 15.—Graphic representation of chemical constituents in samples of water from wells in principal aquifers in Trego County, Kansas.

stituents. Noncarbonate hardness cannot be removed by boiling.

Water that has a hardness of less than 60 ppm is classified as soft. Hardness of 60 to 120 ppm will cause an increase in the amount of soap required for washing but will not interfere with the use of the water for most purposes—although water in the upper part of this range will cause considerable scale in steam boilers. Hardness of 120 to 180 ppm will cause a hardness that is quite noticeable. Water that has a hardness of more than 180 ppm is considered very hard. Where municipal water supplies are softened, the hardness is generally reduced to about 100 ppm.

Most samples of the water collected were high in total hardness (carbonate and noncarbonate). Most of them ranged from 100 to 400 ppm, with the greatest proportion ranging from 200 to 300 ppm. Only four samples had a total hardness of less than 100 ppm (Table 3).

NITRATE

The nitrate content of natural water may vary greatly, and in many ground waters nitrates 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 due to other sources. Nitrates are dissolved readily from soils that contain nitrate concentrations derived from plants, nitrate fertilizer, animal waste, or nitrifying bacteria. High nitrate concentrations in water may be due to the flow of surface water into a well. In an area where 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 into the effects of nitrate on the human system have shown that too much nitrate in water may cause cyanosis in infants (so-called "blue babies") when the water is taken in directly or used in the preparation of the formula for feeding. Both the Kansas State Department of Health and the U.S. Public Health Service regard 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 seemingly are not harmful to older children or adults. Nitrate cannot be removed from water by boiling.

The nitrate content of the samples of water collected ranged from less than 1 ppm to 348 ppm (Table 3). Most samples were low in nitrate content although eight samples ranged between 45 and 90 ppm and three exceeded 150 ppm.

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 during the formation of permanent teeth, mottling of the enamel may result. If the fluoride content is as much as 4 ppm, about 90 percent of the children using the water may develop 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, *et al.*, 1941). The U.S. Public Health Service (1962) recommends the standards for content of mineral constituents in drinking water that are to be used on interstate carriers. The recommended ***maximum*** content for fluoride is 1.5 ppm.

The fluoride content of the samples of water collected ranged from 0.06 to 5.2 ppm (Table 3). Although most samples contained less than 1.0 ppm, seven samples exceeded 1.5 ppm. Of five analyses of water from the Dakota Formation, four exceeded 1.5 ppm of fluoride.

CHLORIDE

Chloride is 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 nonpotable 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 500 ppm has a disagreeable taste. However, animals can tolerate water with a much greater chloride concentration (*e.g.*, concentrations of as much as 4,000 to 5,000 ppm can be tolerated by cattle.)

The chloride content of the water samples collected ranged from 7 ppm to 368 ppm (Table 3). Most samples were low in chloride; all but three samples contained less than 100 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 and taste in the water. 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 recommended by the U.S. Public Health Service are that the iron content should not exceed 0.3 ppm and that the manganese content should not exceed 0.05 ppm.

The iron content of the water samples collected ranged from 0.03 to 4.7 ppm (Table 3). Most samples contained less than 0.3 ppm of iron, but three samples contained more than 1.0 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, impart a bitter taste to the water, and the water may act as a laxative on people not accustomed to drinking it. More than 250 ppm of sulfate in drinking water generally is undesirable.

Most water samples collected were low in sulfate, although nine samples exceeded 250 ppm and one exceeded 1,000 ppm of sulfate (Table 3).

SILICA

Silicon combined with oxygen in the form of SiO_2 is called silica. Silica is a mineral constituent in most ground waters. Except for the scale it may form, silica has little effect on the use 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 the water samples collected ranged from 8 to 45 ppm (Table 3). Analyses of water from both the Dakota Formation and the Codell Sandstone Member of the Carlile Shale were characteristically low in silica content.

BICARBONATE

Bicarbonate and carbonate cause alkalinity of ground water. The concentration of bicarbonate, the predominant anion in the samples of water from Trego County, ranged from 194 to 415 ppm (Table 3).

SODIUM

The sodium content of water used for irrigation is important because a large percentage of sodium (equivalents per million of sodium divided by total equivalents per million of sodium, potassium, calcium, and magnesium) has an adverse effect on soil, especially where leaching is not adequate. The effect of sodium in irrigation water is discussed in detail in U.S. Department of Agriculture Handbook 60 (U.S. Salinity Laboratory Staff, 1954).

Analyses of water samples from 10 wells deriving water from alluvium, terrace deposits, and the Ogallala Formation were used to illustrate the suitability of water for irrigation. The procedure is based upon methods outlined in U.S. Department of Agriculture Handbook 60.

Figure 16 shows sodium-adsorption ratios determined by plotting the sodium content (equivalents per million) on the left scale (A), and the calcium plus magnesium content (equivalents per million) on the right scale (B). The point at which a line connecting these two points intersects the sodium-adsorption-ratio scale (C) indicates the sodium-adsorption ratio

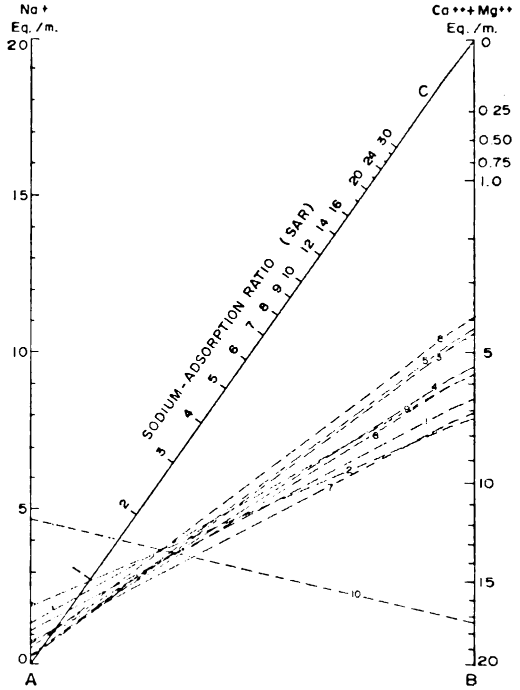

FIGURE 16.—Nomogram for determining the sodium-adsorption ratio of water.

TABLE 5.—Sodium-adsorption ratios (SAR), conductivities, sodium content, and calcium plus magnesium content of water samples from selected wells.

Well number	Sample used in Figures 16 and 17	Na (equivalents per million)	Ca + Mg (equivalents per million)	SAR	Conductivity (micromhos per centimeter at 25°C)
11-23-6cdc	1	1.09	6.48	0.60	800
11-23-11ccc	2	1.90	7.37	1.00	970
12-22-8bab	3	.32	4.39	.20	450
12-23-20ccc	4	.73	5.44	.40	640
12-23-30acc	5	.38	4.31	.20	460
12-24-5cdc	6	.57	5.67	.30	650
13-22-22aaa	7	.76	7.09	.40	740
13-23-17aaa	8	.55	3.94	.40	420
14-24-25ddd	9	1.37	5.68	.80	720
14-25-25ccb	10	4.63	17.30	1.60	1,950

of the water. Table 5 gives sodium-adsorption ratios, electrical conductivities, and values for sodium and for calcium plus magnesium of the water samples for which analyses were plotted.

The specific conductance of a water sample can be measured directly in the laboratory, or it can be approximated by multiplying the total equivalents per million of the cations (calcium, magnesium, sodium, and potassium) by 100, or by dividing the dissolved-solids content in parts per million by 0.64.

Sodium-adsorption ratios and electrical conductivities are plotted in Figure 17 to provide a classification of waters for irrigation use. Low-sodium water (S1) can be used for irrigation on most soils with little danger of development of harmful levels of exchangeable sodium. 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 techniques, such as good drainage, leaching, and additions of organic matter. Very high-sodium water (S4) generally is unsatisfactory for irrigation unless special practices are followed, 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. In Figure 17, all the waters were classified as low-sodium water (S1) and either medium-salinity water (C2) or high-salinity water (C3).

SANITARY CONSIDERATIONS

The analyses of water in Table 3 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 quite

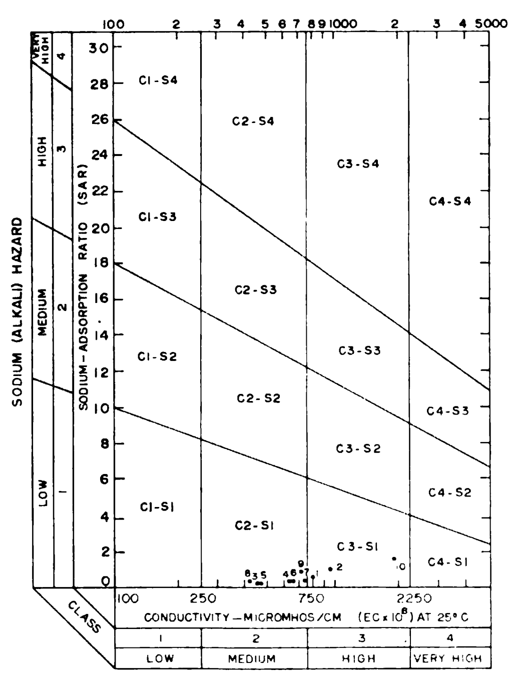

FIGURE 17.—Classification of water used for irrigation.

safe for drinking. Conversely, water that is 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—LOWER(?) CRETACEOUS SERIES

Dakota Formation

The Dakota Formation [Early(?) Cretaceous] does not crop out in Trego County, but it contains water within a practical drilling depth. In certain areas where shallow ground waters are scarce or not available, the Dakota is an important source of ground water.

The term "Dakota group" (Meek and Hayden, 1862) was first applied to the varicolored clay, sandstone, and lignite beds underlying the "Benton group" in exposures near Dakota City, Dakota County, Nebraska. The use of this grouping has been discontinued (Plummer and Romary, 1942), and the Dakota Formation now includes strata lying between the Kiowa Shale below and the Graneros Shale above. The Dakota Formation as defined by the State Geological Survey of Kansas has been variously referred to as "Dakota group" (Meek and Hayden, 1862); "Dakota sandstone" (Prosser, 1897); "Dakota formation" (Twenhofel, 1924); and "Cockrum sandstone" (Latta, 1941). Rubey and Bass (1925) referred to the upper 125 feet of the Dakota in Russell County as the "Rocktown channel sandstone member." Merriam (1957) used the term "Omadi formation" for the Dakota Formation in the subsurface of western Kansas.

CHARACTER AND SUBDIVISIONS

In Kansas the Dakota Formation has been divided into two members (Plummer and Romary, 1942), the lower called the Terra Cotta Clay Member and the upper called the Janssen Clay Member. Plummer and Romary described the Dakota Formation as consisting chiefly of varicolored clay containing irregular, lenticular beds of siltstone and sandstone. The lower member is dominantly gray and red mottled clay. A zone of siderite, limonite, and hematite pellets marks the base of the upper member. Gray clay containing siderite pellets and yellow-orange coloring matter dominates the upper member, with lignite common in the upper part. Lenticular beds of sandstone occur throughout the Dakota Formation.

The Dakota Formation is present in the subsurface throughout the County. The depth to the Dakota ranges from about 300 feet below the land surface in the southeastern part of the County to about 1,000 feet below the land surface in the northwestern part.

THICKNESS

The thickness of the Dakota Formation is not uniform, probably because of the disconformity at the base. Frye and Brazil (1943, table 3) gave the thickness of the Dakota Formation in Ellis and Russell counties as 200 to 300 feet. Swineford and Williams (1945) gave a thickness of 213 to 300 feet for the Dakota in southwestern Russell County. Latta (1950) indicated the Dakota was 200 to 300 feet thick in northern Barton County. Hodson (1959) gave a thickness of about 350 for the Dakota near the Mitchell-Cloud county line. Leonard and Berry (1961) indicated that in southern Ellis County the thickness of the Dakota was only 155 feet. Hodson and Wahl (1960) gave a thickness of about 250 feet for the Dakota in Gove County. A study of drillers' logs indicated a thickness of 150 to 250 feet for the Dakota Formation in Trego County.

WATER SUPPLY

In the east-central and southern parts of Trego County, a number of wells obtain water for domestic and stock use from the Dakota Formation. Information on eight wells ranging in depth from 500 to 670 feet that derive water from the Dakota is given in Table 6, and chemical analyses of five water samples from the Dakota are given in Table 3. Water from the Dakota is more mineralized than water in the unconsolidated rocks, but generally the water is soft.

Depth to the water level in wells ranged from about 200 feet to about 400 feet below the land surface for wells obtaining water from the Dakota that were inventoried in this investigation. The sandstone lenses in the Dakota contain ground water under artesian pressure, and, although locally there are differences in hydrostatic pressure from well to well (Leonard and

Berry, 1961, p. 26), ground-water investigations in much of Kansas suggest a connected hydrologic system among the sandstone lenses, for the most part.

Wells in the Dakota Formation in Trego County yield only quantities of water sufficient for domestic or stock supplies, although in some other areas in Kansas wells penetrating thick sandstones in the Dakota yield moderately large quantities of water, generally in areas nearer Dakota outcrops.

CRETACEOUS SYSTEM—UPPER CRETACEOUS SERIES

Graneros Shale

The Graneros Shale overlies the Dakota Formation and consists chiefly of dark-gray to black noncalcareous shale. The Graneros is present in the subsurface of Trego County where drillers' logs indicate it is 40 to 50 feet thick. It yields no water to wells in Trego County.

Greenhorn Limestone

The Greenhorn Limestone overlies the Graneros Shale and consists principally of about 100 feet of alternating thin beds of chalky limestone and calcareous shale. The Greenhorn Limestone is divided into four members, which, in ascending order, are the Lincoln Limestone, Hartland Shale, Jetmore Chalk, and Pfeifer Shale (Rubey and Bass, 1925; Bass, 1926). The chalky limestone and shale that comprise the Greenhorn are relatively impervious and do not yield water to wells in Trego County.

Carlile Shale

The Carlile Shale, consisting of the Fairport Chalk, the Blue Hill Shale, and the Codell Sandstone members, is the oldest formation exposed in Trego County. Only the upper part of the Carlile crops out, chiefly along the Smoky Hill Valley in the southern part of the County.

CHARACTER AND SUBDIVISIONS

The Carlile Shale was named by Gilbert (1896) from exposures of gray argillaceous shale west of Pueblo, in Pueblo County, Colorado. Logan (1897) correlated Gilbert's section with Cretaceous rocks in north-central Kansas. Rubey and Bass (1925) divided the Carlile Shale into two members, the "Fairport chalky shale" below and the "Blue Hill shale" above. The Codell Sandstone Member (upper part of the Carlile Shale) was named by Bass (1926) from exposures along the Saline River in Ellis County, Kansas.

The Fairport Chalk, lowermost member of the Carlile Shale, consists of alternating beds of calcareous shale and thin, nodular, chalky limestone. The Fairport does not crop out in Trego County.

The Blue Hill Shale, middle member of the Carlile Shale, is the oldest rock unit exposed in Trego County. The Blue Hill crops out along the Smoky Hill Valley eastward from the junction of the Smoky Hill River and Hackberry Creek. The Blue Hill is well exposed on the steep slopes below the escarpment made by the Niobrara Chalk. Because the shale is soft, however, good exposures are rare elsewhere.

The Blue Hill Member is a blocky to fissile, clayey shale that characteristically weathers into small, brittle flakes. The predominant color of the shale is dark blue-gray, but locally the shale is light to dark olive-gray. Drill cuttings from the Blue Hill may be very dark-gray to black as shown in several logs of test holes at the end of this report. Thin lenses of siltstone, fine-grained sandstone, and sandy shale are common in the upper part of the Blue Hill and become more abundant upward.

Concretions characterize outcrops of the Blue Hill. Most of the concretions are found in zones and become much more abundant in the upper part. Most of the concretions are calcareous septarian concretions, but noncalcareous clay-ironstone concretions are common, and, locally, calcareous sandstone concretions are found. The concretions range in diameter from a few inches to as much as 3 feet. Most are ellipsoidal or discoidal, but smaller concretions may be nearly spherical. The concretions contain intersecting veins of brown calcite that on weathering tend to stand out in relief.

The Codell Sandstone Member marks the top of the Carlile Shale. In Trego County, outcrops of the Codell consist of a zone of rust-brown fine sand, sandy silt, and clayey silt. It is generally very argillaceous; shark teeth and bone fragments are common in it. In fresh exposures, the Codell is light gray to gray. Specks of disseminated limonite cause an orange to yellowish-brown coloration in weathered outcrops. The contact between the Codell and the underlying Blue Hill Shale Member is gradational, whereas the contact between the Codell and the overlying Fort Hays Limestone Member of the Niobrara Chalk is generally sharp.

The thickness of the Codell Sandstone Member changes laterally in Trego County, but usually about 2 or 3 feet of Codell is present. Locally, however, as much as 5 feet of sandy silt representing the Codell was observed, while at a few localities, only a few inches was noted. A study of drillers' logs indicated that in the northeastern part of the County, the Codell may be as much as 20 feet in thickness. Hattin (1962) reported a thickness of nearly 20 feet in northern Ellis County, along the Saline Valley.

DISTRIBUTION AND THICKNESS

The Carlile Shale crops out along the Smoky Hill Valley eastward from the mouth of Hackberry Creek. Drillers' logs indicate that the Carlile is nearly 300 feet thick and that the Blue Hill Shale Member comprises about two-thirds of the formation.

WATER SUPPLY

The Codell Sandstone Member yields water to a number of wells in Trego County, mostly in the eastern and southern parts. Information on 19 wells ranging in depth from 31 feet to 320 feet below the land surface is given in Table 6, and chemical analyses of six water samples from the Codell are given in Table 3. The Codell yields only small amounts of water to wells, although the yield is generally adequate for domestic and stock supplies.

In the southern part of the County, where in much of the area only meager amounts of shallow ground water are available, small amounts of ground water are obtained from shallow wells dug or drilled into colluvium and into the underlying weathered shale and sandy shale of the upper part of the Blue Hill Shale Member.

Niobrara Chalk

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

The Niobrara Chalk consists chiefly of alternating beds of light-gray chalk, chalky limestone, and chalky shale. The total thickness of the Niobrara in west-central Kansas is about 700 feet, but only the lowermost 400 to 500 feet is present in Trego County, the upper part having been removed by erosion.

FORT HAYS LIMESTONE MEMBER

The Fort Hays Limestone Member is distinguished from the Smoky Hill, upper member of the Niobrara Chalk, by the relative predominance of massive beds of chalk and chalky limestone 50 to 60 feet in thickness. The chalky limestone beds in the Fort Hays generally range from 1 to 5 feet in thickness and are separated by thin partings of chalky shale. These beds contain large *Inoceramus* and small *Ostrea* shells. The Fort Hays is characteristically grayish-white, but locally may be stained yellow or light brown on the outcrop. The Fort Hays is more resistant to erosion than the overlying Smoky Hill Chalk Member and tends to form shoulders along slopes. Steep cliffs, in places nearly vertical, are typical of the Fort Hays along the Smoky Hill Valley. In the southeastern and extreme southern parts of the County, the Fort Hays forms prominent escarpments. The Fort Hays has been quarried at places along the outcrop for building stone and for road metal.

SMOKY HILL CHALK MEMBER

The Smoky Hill Chalk Member consists principally of thin-bedded chalk and chalky shale, with thin beds of bentonite throughout. Fresh exposures are platy and 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 when weathered. Thin veins of gypsum are characteristic of outcrops.

The Smoky Hill Chalk Member is noted for the abundant fossils it contains. Vertebrate fossils include bones of aquatic reptiles, such as mosasaurs and plesiosaurs, and numerous fish remains. Sharks' teeth are common. Invertebrate fossils characteristically include the phyla Mollusca and Echinodermata, 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 Textulariidae comprise much of the chalk.

The Smoky Hill 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 badlands type of topography.

WATER SUPPLY

The Niobrara Chalk is not important as an aquifer in Kansas and carries very little ground water in Trego County. The beds of shaly chalk are relatively impermeable, and water is transmitted chiefly through fractures and joints and is found only locally and in small quantities. Fractures filled with secondary calcite are indicative that water has circulated through the formation at some time in the past. Where the Niobrara was observed to be fractured, however, it was generally in the topographically higher parts of the County well above the water table. Fractures and bedding planes are more prevalent in the Fort Hays Limestone Member, and these may yield small amounts of ground water to a few wells.

NEOGENE SYSTEM— PLIOCENE SERIES

Ogallala Formation

The Ogallala Formation was named by Darton in 1899 (p. 732-734) from exposures in southwestern Nebraska. Darton (1920, p. 6) designated the type locality as being near Ogallala Station in western Nebraska. Since Darton's work, the most significant studies of the Ogallala in western Kansas have been by Elias (1931), Smith (1940), and Frye, Leonard, and Swineford (1956).

CHARACTER AND SUBDIVISIONS

The Ogallala Formation in Kansas is divided into three members which, in ascending order, are the Valentine, Ash Hollow, and Kimball. A thin, discontinuous pisolitic limestone, 1 to 3 feet thick, commonly occurs as the topmost bed of the Ogallala. No attempt was made to divide the Ogallala Formation in Trego County, and it is shown on Plate 1 as a single unit.

The Ogallala Formation constitutes a widespread mantle of fluvial deposits consisting predominantly of sand, gravel, silt, and clay. The Ogallala was deposited upon an erosional surface of Upper Cretaceous rocks by eastward-trending streams whose source of sediment was igneous rocks of the Rocky Mountains and sedimentary rocks of eastern Colorado. The deposits are comprised 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, with textures ranging from very coarse gravel and pebbles to clay and sorting ranging from good to poor. The lithology changes sharply both vertically and laterally. Lentils of volcanic ash, marl, or marly limestone, and bentonite contrast with the predominantly stream-laid clastics. Throughout this heterogeneous assortment of sediments there is virtually no distinctive bed that can be traced any appreciable distance.

The deposits are interbedded and admixed in various proportions and are largely unconsolidated, although cementation of beds occurs to some degree throughout the Formation. Calcium carbonate is a common constituent throughout almost all of the Ogallala. It is distributed both as fine material and as stringers of caliche and small- to medium-sized nodules. Calcium carbonate in many places binds the deposits so firmly as to produce a series of hard ledges, interbedded with beds that are only slighted cemented. 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 or small, irregular lenses and beds is occasionally seen.

Sand, the principal material within the Ogallala Formation, is present at all horizons and is typically light-gray or greenish in color. 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 limestones are common in the middle and uppermost parts of the Ogallala. Bluish-gray volcanic ash is found locally in the lower and middle parts of the Formation.

The Formation's topographic expression includes flat uplands, gentle erosional slopes, and nearly vertical cliffs. In spite of the diversity of deposits, the outcrop pattern of the Ogallala presents a uniformity of aspect that makes it readily identifiable. Typical outcrops are cemented to various degrees and are ash gray in color. 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 differ regarding the origin of the thin, discontinuous bed of pisolitic limestone, originally called the "algal limestone" by Elias (1931), which marks the stratigraphic top of the Ogallala Formation. Elias postulated a lacustrine origin for the capping limestone. Subsequent workers advanced an hypothesis of subaerial origin, such as a caliche zone. Smith

(1940) discussed the two hypotheses, and more recently Frye, Leonard, and Swineford (1956, p. 13-16) critically discussed the bed, postulating a mode of origin in which development of a mature to senile lime-accumulating soil was later modified by solution.

DISTRIBUTION AND THICKNESS

The Ogallala Formation, although generally mantled with eolian silts, underlies much of the interstream areas. The Ogallala is thickest and most extensive in the central and northwestern parts of the County. It crops out along the bluffs of Big Creek valley and locally is well exposed in many of the tributary canyons along the Saline River valley. The Ogallala is thin and discontinuous in the southern part of the County due to erosion by the Smoky Hill River and its tributaries. In Trego County, the Formation rests on an erosional surface of considerable relief, which slopes generally eastward (Fig. 18).

Logs of test holes show that the thickness of the Ogallala Formation in Trego County exceeds 150 feet in some of the thicker sections. The thickness is not uniform, however, because of unconformable contacts at the top and bottom of the Formation. The thickness and character of the Ogallala Formation are shown in 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 water-bearing formation in Trego County. It supplies water to most domestic and stock wells in the County. In much of the central and northwestern parts of the County, the saturated thickness of the Ogallala is great enough to store fairly large quantities of ground water, from which moderate yields of water are obtained. In the southern part of the County, the Ogallala is either missing or thin and contains little ground water.

A considerable amount of the Ogallala has been removed by erosion along the three principal streams—the Smoky Hill and Saline Rivers and Big Creek (Pl. 2). Few areas in the County have much more than 50 feet of saturated thickness and the saturated thickness of the Ogallala decreases toward the edge of the upland where the Ogallala has been completely drained of ground water. Nevertheless it is estimated that about 700,000 acre-feet of ground water is in storage in the Ogallala in Trego County. Although yields of wells in the Ogallala are not large, it is the most important aquifer in the County because of its wide areal extent.

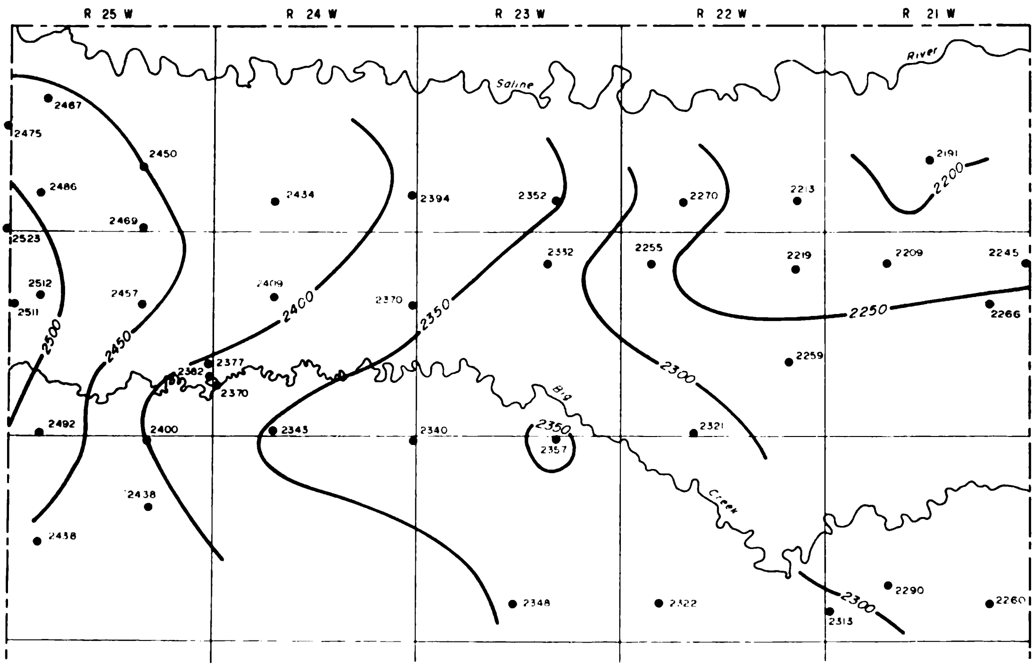

FIGURE 18.—Contours on base of Ogallala Formation in northern Trego County, Kansas (contour interval 50 feet).

NEOGENE SYSTEM—PLEISTOCENE SERIES

The classification of Pleistocene deposits by the State Geological Survey of Kansas is based on the classification of glacial deposits in the Midcontinent Region (Frye and Leonard, 1952). Although the nearest glacial deposits are more than 150 miles northeast of Trego County, correlations between the glaciated and nonglaciated areas have been made on the basis of continuous loess deposits, their molluscan fauna and buried soils, and petrologically distinctive volcanic ash (Condra, Reed, and Gordon, 1947; Frye, Swineford, and Leonard, 1948).

Deposits of Pleistocene age, although relatively thin, are the surficial materials in much of Trego County, as shown by the geologic map (Pl. 1) and cross sections (Pl. 2). Pleistocene deposits include the Grand Isand Formation and Sappa Formation of Kansan age, the Crete Formation and Loveland Formation of Illinoisan age, the Peoria Formation of Wisconsinan age, and terrace deposits and alluvium of Wisconsinan and Recent age. The Grand Island, Sappa, and Crete formations occur as terrace deposits along the valleys of the Smoky Hill and Saline rivers and along Big Creek valley. Alluvium of late Wisconsinan and Recent age occurs along the inner valleys of the larger streams. Eolian silts classified as the Peoria and Loveland formations cover much of the upland areas and extend along the outer valleys, masking the valley slopes. Pleistocene deposits have been treated in this report as terrace deposits (Crete, Sappa, and Grand Island formations), loess beds (Peoria and Loveland formations), and alluvium (late Wisconsinan and Recent deposits). Figure 6 shows the stratigraphic relation of Pleistocene deposits along the principal valleys.

Terrace Deposits

Terrace deposits shown on the geologic map accompanying this report (Pl. 1) consist chiefly of sand, gravel, and silt deposited during Kansan and Illinoisan times. Terrace deposits along the Smoky Hill Valley are predominantly sand and gravel, whereas terrace deposits along the Saline River and Big Creek valleys contain a relatively greater amount of finer clastic material with silt being predominant in the upper part. Included in the terrace deposits (Pl. 1) are the Grand Island Formation and Sappa Formation of Kansan age and the Crete Formation of Illinoisan age. The Crete and the Grand Island are lithologically similar, both consisting chiefly of arkosic sand and gravel. Stratigraphically, the Sappa Formation lies between the Crete and the Grand Island. The Sappa consists chiefly of silt and sandy silt but locally contains the Pearlette ash bed which identifies it as late Kansan in age. The Crete Formation of Illinoisan age constitutes most of what are called "terrace deposits" in this report. The Crete Formation is spread laterally over a much more extensive area than the underlying Kansan deposits, which are restricted to narrow channels.

Terrace deposits crop out extensively along the Smoky Hill Valley, but they also occur to a lesser degree along the Saline Valley and along Big Creek valley. These deposits are nearly 2 miles wide along much of the Smoky Hill Valley and in places little dissection has occurred in them, particularly along the south side of the valley in the western part of the County. Along the Saline Valley, terrace deposits are mostly remnants, since most of the deposits have been eroded. Along Big Creek valley in the central and western parts of the County, terrace deposits are of narrow width and tend to be obscured because of slope wash from the Ogallala. Along the north side of Big Creek valley in the eastern part of the County, terrace deposits are more than 2 miles wide in places. Where the terrace deposits have not been dissected by erosion, a thin cover of loess mantles them. Although the loess tends to mask the edge of the terrace deposits nearest the upland margin, these terrace deposits are a geomorphologically prominent feature in the major valleys.

GRAND ISLAND AND SAPPA FORMATIONS

The oldest Pleistocene deposits definitely recognized in Trego County are stream-deposited sand, gravel, and silt classified as the Grand Island Formation and Sappa Formation of Kansan age, although deposits penetrated in test holes 13-21-5bbc and 13-21-8abb may be Nebraskan in age. Along the Smoky Hill Valley, Kansan deposits fill a narrow channel about a quarter of a mile wide. This ancient channel, which has a meander pattern much like that of the modern river, underlies the widespread Crete Formation along much of the terrace extent of the valley, but crops out only locally. In a test hole in the SE cor. NE sec. 27, T 14 S, R 21 W, 93 feet of terrace deposits were penetrated, the lower 54 feet of which are classified as the Grand Island and Sappa Formations.

The Grand Island consists predominantly of sand and gravel containing cobbles as much as 4 inches in diameter. The sand and gravel are mostly arkosic but intermixed with the deposits are rounded chalk pebbles and shale fragments. The Sappa Formation consists mostly of silt and sandy silt, but thin lenticular beds of sand and gravel with pebbles of chalk are common. The Sappa is generally very calcareous. It is buff or light gray when fresh but characteristically weathers to very light gray. Locally, a lenticular bed of volcanic ash (Pearlette ash bed) ranging in thickness from a few inches to several feet is found within the Sappa. Outcrops of the Grand Island and Sappa formations occur in small areas along the Smoky Hill Valley.

No outcrops of Kansan deposits were found along the Saline Valley, but test drilling has shown that deposits of Kansan age underlie the Illinoisan terrace surface in a stratigraphic position analogous to that found along the Smoky Hill Valley. In a test hole drilled in the Saline Valley in the SE cor. NE sec. 9, T 11 S, R 21 W, 70 feet of terrace deposits were penetrated, the lower part of which is considered to be Kansan in age. Deposits considered to be of Kansan age were penetrated in test holes along Big Creek and underlie the Illinoisan terrace at least locally along Big Creek, especially along the north side of the valley in the eastern part of the County.

CRETE FORMATION

Deposits classified as the Crete Formation of Illinoisan age constitute most of the deposits that underlie the prominent terraces along the major valleys. The Crete Formation consists chiefly of arkosic sand and gravel. A small amount of chalk and shale pebbles and fragments are usually present but are not as common as in the Grand Island. Locally, the upper part of the Crete grades upward into yellow and buff silt and sandy silt classified as the Loveland Formation of late Illinoisan age.

WATER SUPPLY

Terrace deposits that border the principal stream valleys are generally continuous with the alluvial deposits that underlie the streams and fill the inner valleys, and the water table in the alluvium is continuous with the water table in the terrace deposits along much of the valleys. Because the terrace deposits overlie bedrock that was not cut as deeply as the incised valley of the present cycle, the saturated thickness of the terrace deposits is not as great as the saturated thickness of the alluvium of the inner valleys.

Terrace deposits yield water adequate for domestic and stock supplies at most places where they occur. In areas where the saturated material is sufficiently thick, moderately large yields from wells can be expected. Test drilling will disclose the more favorable well sites.

Peoria and Loveland Formations

CHARACTER, DISTRIBUTION, AND THICKNESS

Eolian silts (loess) of late Pleistocene age cover a considerable part of Trego County with a relatively thin mantle which tends to subdue the topography in much of the area. The loess caps the rolling hills and flat uplands and masks the gentle slopes of the valleys. It is generally thicker in the northwestern part of the County, where test-hole data indicate the loess may be 25 or 30 feet thick. The loess is shown on the geologic map (Pl. 1) as the Peoria and Loveland formations undifferentiated.

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 Trego County.

Colluvial deposits, consisting chiefly of reworked loess, local bedrock fragments, and, in many places, sand and gravel slope wash derived from the Ogallala Formation, constitute much of the surficial material on the slopes of stream valleys and upland draws. Where these colluvial deposits are of sufficient thickness to conceal the underlying rocks they have been included with the Peoria and Loveland formations in this report.

WATER SUPPLY

The deposits mapped as Peoria and Loveland formations consist mostly of relatively thin, wind-deposited silts which generally lie above the water table. In parts of Trego County, however, where the Ogallala Formation has been removed by erosion and shallow ground-water supplies are meager, 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, the best well sites generally prove to be in creek valleys and draws where thin alluvial and colluvial fill and unconsolidated material overlie the bedrock and serve as local catchment basins. In periods of ample rainfall these wells generally prove adequate for most domestic or stock supplies. During extended periods of dry weather, however, the water drains from much of this material and wells tend to become dry. Because ground water in colluvial 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.

Alluvium

Character, Distribution, and Thickness

Alluvium classified as late Wisconsinan and Recent in age occurs in relatively narrow deposits 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 from 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. Deposits in the smaller valleys grade headward into colluvium and slope deposits at the edge of the uplands. The lithology depends largely upon the type of rock into which the valley has been cut.

The alluvium that underlies the stream channels and the narrow floodplains along the principal streams is considered to be Recent in age. Low, relatively narrow terrace deposits, considered to be late Wisconsinan in age, border the floodplain. Although the narrow floodplain and the low terraces are best developed along Smoky Hill Valley, Saline Valley, and Big Creek valley, they are also found to a lesser extent along the smaller valleys. 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.

The width and thickness of the alluvium are greatest along Smoky Hill Valley, Saline Valley, and Big Creek valley. It reaches a maximum width of about a mile, but in most places it is less than a half mile in width. The alluvium generally has a thickness of 60 to 70 feet in the deepest part of the valley fill along the Smoky Hill Valley, although one test hole (14-24-35bcc) penetrated 95 feet of it. Alluvium along the Saline Valley and Big Creek valley 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 ground water in Trego County. Many domestic and stock wells obtain water from the alluvium, and most irrigation wells in the County obtain water from alluvium along the Saline River and Big Creek valleys. Moderate to moderately large yields of water can be expected from wells in alluvium along the Smoky Hill Valley.

Ground-water yields from wells in alluvium in the smaller valleys can be expected to be considerably less than in the larger valleys, because of the finer, less permeable material in the smaller valleys. Since the cross-sectional areas of the smaller valleys are small, 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 pertaining to wells is given in Table 6. Measured depths of wells 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 Table 6 is described on page 7 and illustrated in Figure 2.

TABLE 6.—Records of wells in Trego County, Kansas.

Well no.	Owner or tenant	Type of well†	Depth of well, feet	Diameter of well, in.	Type of casing‡	Principal water-bearing unit: Character of material	Principal water-bearing unit: Geologic source	Method of lift§	Use of water‖	Depth to water level below land surface, feet	Date of measurement	Height of land surface above mean sea level, feet	Remarks (Yield given in gallons per minute; drawdown in ft.)
10-25-33dcd	Christian Uhrich	Dr	41.5	5	GI	Sand, gravel	Terrace deposits	Cy, W	S	35.18	7-15-60	2,414.8	In Graham County.
34ddc*	do	Dr	16.0	5½	GI	do	Ogallala Formation	Cy, W	S	10.00	9-22-59	2,445.0	do
11-21-3cbb	School district	Dr	62.5	5½	GI	do	Terrace deposits	N	N	44.54	7-28-60	2,120.3	Abandoned school well.
6bbc	A. E. Armbrustes	Du	27.5	30	OB	do	do	Cy, W	N	25.06	8-7-59	2,148.6	Abandoned domestic and stock well.
16abb	W. M. Akers	Dr	42.0	6	GI	do	Ogallala Formation	Cy, G	D, S	17.48	7-28-60	2,155.1	
26dad	C. A. Baugher	Dr	75.0	6	GI	do	do	Cy, E	D, S	71.81	9-26-60	2,303.7	
27ada	C. A. Lynd	Dr	93.5	4½	GI	do	do	Cy, W	S	86.65	7-28-60	2,310.7	
29ddd	Barbara Denning	Dr	130.0	5½	GI	do	do	Cy, W	D, S	99.45	7-28-60	2,335.7	
30ccc	P. S. Wiesner	Dr	86.5	6	GI	do	do	Cy, W	S	75.52	8-7-59	2,312.8	
36add	J. F. Huck	Dr	45.8	5½	GI	do	do	Cy, W	S	37.04	8-8-59	2,273.3	
11-22-3cdc	Sophia Hillman	Dr	38.5	5½	GI	do	Terrace deposits	Cy, H	D, S	30.10	8-2-60	2,204.4	
4abb	Joe Faulker	Dr	60.0	6	GI	do	Ogallala Formation	Cy, W	S	43.00	8-2-60	2,253.2	
7cad	Herman Bucholz	Dr	64.0	16	S	do	Terrace deposits	T, P	I	40.25	10-25-60	2,218.0	Reported yield 400.
7ccc	do	Dr	70	18	S	do	Alluvium	T, P	I	24.36	10-25-60	2,190.2	Reported yield 700.
11ccc	School district	Dr	45.0	5½	GI	do	Terrace deposits	Cy, H	D	37.23	8-2-60	2,164.7	
13ddd	Joe Weismer	Dr	31.5	7½	GI	do	Ogallala Formation	Cy, W	S	23.97	8-8-60	2,258.1	
17bbb	Clarence Lemke	Dr	57.0	16	S	do	Alluvium	T, P	I	21.05	10-12-59	2,179.1	Reported yield 400.
17bbc	do	Dr	42	16	S	do	do	T, E	I	30	10-12-59	2,192.1	Reported yield 100.
19add	Ella Hixson	Dr	15.0	6	GI	do	Ogallala Formation	N	N	6.90	3-29-62	2,289.6	Abandoned stock well.
28aaa	C. V. Honas	Dr	66.5	5	GI	do	do	Cy, W	S	41.00	8-7-59	2,317.4	
29aad	C. M. Kline	Dr	75.0	6	GI	do	do	Cy, W	S	54.96	8-7-59	2,346.8	
32bbc*	Glen Spena	Dr	87	5½	GI	do	do	Cy, E	D, S	81	7-16-60	2,400.6	
33cbb	Reuben Flagler	Dr	97.0	5½	GI	do	do	Cy, W	S	68.67	7-16-60	2,368.7	
34aaa	A. M. Schumacher	Dr	91.0	5½	GI	do	do	Cy, W	S	79.58	7-16-60	2,346.8	
11-23-2aad	E. M. McCall	Du	14.5	42	R	Sand, silt	Colluvium	Cy, W	S	9.63	8-6-59	2,226.3	
4bcc	E. A. Osborn	Dr	73.5	5	GI	Sand, gravel	Terrace deposits	Cy, W	S	43.03	9-22-59	2,303.5	
5abc	do	Dr	75	16	S	do	do	T,T	I	30	7-15-60	2,301.3	Reported yield 400.
5abd	do	Dr	75	16	S	do	do	T, T	I	31.05	7-15-60	2,303.1	Reported yield 600.
6cdc*	Ralph Walker	Du	28.7	42	C	do	do	J, E	D, S	22.20	7-15-60	2,287.8	
9bcc	Oren Delaney	Dr	42.0	6	GI	do	do	Cy, W	N	24.75	9-21-60	2,256.7	Abandoned domestic well.
11ccc*	Edwin McCall	Dr	37.3	5½	GI	do	do	J, E	D, S	27.20	10-24-60	2,237.6	
20add	Fred Nemeckek	Dr	45.0	6	GI	do	Ogallala Formation	N	N	35.34	7-15-60	2,337.5	Abandoned domestic well.
26bbc	Worden R. Howat	Dr	320	6	OW	Sand	Codell Sandstone Member	Cy, G	S	300	8-6-59	2,409.4	
26bcb*	do	Dr	320	6	OW	do	do	Cy, E	D, S	300	8-6-59	2,403.6	
26cbb	do	Dr	672	6	OW	do	Dakota Formation	Cy, G	S	400	8-6-59	2,412.6	Water reported very soft.
33ddd	E. Hixon	Dr	64.0	5½	GI	Sand, gravel	Ogallala Formation	Cy, W	S	43.03	9-21-60	2,408.2	
35aaa	C. E. Howat	Du	11.2	30	R	do	do	Cy, W	S	10.14	8-6-59	2,340.8	
11-24-2bab	W. T. Littlechild	Dr	62.5	6	GI	do	Terrace deposits	Cy, W	D	51.80	9-21-60	2,350.3	
2cdd	E. Pearch	Dr	32.0	6	GI	do	do	Cy, H	N	23.20	8-5-59	2,294.0	Abandoned domestic well.
5bdc	Keith Garrett	Dr	31.5	5½	GI	do	do	Cy, W	S	24.25	9-21-60	2,337.5	
14aaa	J. Littlechild	Du	32.0	36	C	Sand, silt	Colluvium	Cy, W	S	27.23	9-21-60	2,309.6	

21ccc	Leo Malinowsky	Dr	90	5½	GI	Sand, gravel	Ogallala Formation	J, E	D, S	69.32	7-14-60	2,196.9	
22caa	C. F. Ivan	Dr	24.5	6	GI	do	do	Cy, E	D, S	18.80	7-14-60	2,428.1	
23ddd	C. M. Atherton	Dr	46.5	6	GI	do	do	Cy, W	D, S	40.52	9-28-59	2,436.5	
27ddd	A. L. Struss	Dr	63.0	6	OW	do	do	Cy, W	S	48.72	8-5-59	2,467.3	
29bcc*	L. Malinowsky	Dr	22.0	5½	GI	do	do	Cy, W	S	15.38	7-30-57	2,457.5	
36dcb	R. B. Osborn	Dr	50.0	5½	GI	do	do	Cy, W	N	34.40	8-5-59	2,440.2	Abandoned domestic well.
11-25-1bbc	J. Evers	Dr	63.5	5½	GI	do	do	Cy, W	S	54.90	9-22-59	2,427.2	
2ccb	A. C. Miller	Dr	29.4	5½	GI	do	Terrace deposits	Cy, W	S	20.73	9-22-59	2,373.5	
6bdc	W. D. Walsh	Dr	47.0	6	GI	do	Alluvium	N	N	33.85	9-22-59	2,446.7	Abandoned domestic well.
12cdc	A. Cochran	Dr	37.5	6	GI	do	do	Cy, W	D, S	25.28	7-15-60	2,375.3	
18aaa	Wendolin Scheck	Dr	75.0	6	GI	do	Ogallala Formation	Cy, W	S	68.10	9-22-59	2,544.9	
18ddc	Eva Spies	Dr	61.2	5	GI	do	do	Cy, W	S	42.10	8-4-59	2,522.6	
22ccc	Frank Dechant	Dr	100	6	GI	do	do	Cy, W	D, S	87.73	9-22-59	2,560.0	
23aab	Jess Connor	Dr	72.5	5½	GI	do	do	Cy, H	N	54.12	9-23-59	2,477.6	Well not used.
25ccc	A. Mollenkamp	Dr	95.1	5½	GI	do	do	Cy, W	N	71.38	8-1-57	2,529.9	do
30dcc	F. M. Dinkel	Dr	67.2	6	GI	do	do	Cy, W	S	58.35	8-4-59	2,571.7	
33add	Martin Weissbeck	Dr	93.0	5	GI	do	do	Cy, G	S	68.18	8-4-59	2,555.6	
12-20-31ccc	....	Dr	82.5	5½	GI	do	Terrace deposits	Cy, W	S	18.74	8-10-59	2,190.9	In Ellis County.
12-21-2bbb*	J. Cockrell	Dr	54.0	5	GI	do	Ogallala Formation	Cy, W	S	38.73	9-4-57	2,289.6	
5ddd2	L. A. Christopher	Dr	101.0	5½	GI	do	do	Cy, N	N	86.10	8-8-59	2,341.5	Abandoned school well.
12-21-12add	Willis Barnes	Dr	81.0	5½	GI	do	do	Cy, W	D, S	64.25	8-8-59	2,325.6	
12bcc	C. Christopher	Dr	81.0	5½	GI	do	do	Cy, W	S	64.52	9-26-60	2,342.6	
14bbc	R. Cotton	Dr	64.0	5½	GI	do	do	Cy, G	D, S	52.69	7-28-60	2,321.1	
18add	J. Aust	Dr	37.5	6	GI	do	do	Cy, W	S	28.28	8-8-59	2,288.9	
21aba	W. C. Baugher	Dr	52.0	5½	GI	do	do	Cy, W	S	46.15	8-8-59	2,313.0	
24cdc*	Fred J. Hamburg	Dr	665	6	OW	Sand	Dakota Formation	Cy, E	D, S	200	9-29-59	2,305.8	Must use moderately because of limited supply.
26ccc	Raymond Schoenthaler	Du	32	....	....	Sand, silt	Colluvium	J, E	D, S	28	9-26-60	2,215.0	
26ddd	R. C. Gugler	Dr	56.0	6	GI	do	do	Cy, W	S	5.25	8-10-59	2,204.4	
28aaa*	B. F. Staab	Du	48.0	48	R	Sand, gravel	Ogallala Formation	Cy, W	S	28.60	8-7-59	2,243.4	
30ddd	Lester Hillman	Dr	24.5	6	GI	do	do	J, E	D, S	16.30	9-26-60	2,262.2	
12-22-2aba	J. Kelsch	Dr	90.0	5½	GI	do	do	Cy, W	S	74.19	8-7-59	2,347.3	
8bab*	Frank Rinker	Dr	118.0	6	OW	do	do	Cy, E	D	100.96	7-12-60	2,404.7	
9dad	B. E. Babb	Dr	92.5	6	GI	do	do	Cy, W	S	54.30	8-8-60	2,347.5	
10aba	J. L. Hacker	Dr	115.0	5½	GI	do	do	Cy, W	S	86.22	9-26-60	2,372.8	
12aab*	Joe Kuhl	Dr	65.0	5	GI	do	do	Cy, W	S	58.78	8-7-59	2,327.9	
13bcc	W. S. Sherfeck	Dr	33.5	5	GI	do	do	Cy, H	N	25.25	8-7-59	2,281.0	Abandoned stock well.
19cbb	Miles Hubalek	Dr	130	18	S	do	do	T, D	I	97.94	8-12-59	2,411.3	Reported yield 300.
23dcb	....	Dr	108	5½	GI	do	do	Cy, W	N	80	7-25-58	2,371.9	Abandoned domestic well.
28bba*	J. A. Befort	Dr	....	6	GI	do	do	Cy, W	S	63.46	9-25-59	2,377.3	
31ddc	D. DeWald	Dr	44.0	6	GI	do	Terrace deposits	Cy, H	N	32.87	8-12-59	2,334.3	
34bda	O. & L. Deutscher	Dr	89.0	5	GI	do	Ogallala Formation	N	N	61.89	7-24-58	2,369.3	Abandoned stock well.
36ccb*	Ray Morton	Dr	269	6	GI	Sand	Codell Sandstone Member	Cy, G	D, S	60	6-8-58	2,293.2	Reported well pumps dry easily.
36ccc*	do	Dr	27.5	5½	GI	Sand, gravel	Ogallala Formation	Cy, W	S	8.22	10-21-60	2,272.5	Reported well to shale.
12-23-6ddc	Raymond Lemmons	Dr	74.5	6	GI	do	do	Cy, E	D, S	67.18	9-21-60	2,458.0	
10bbc	City of WaKeeney	Dr	107	10	S	do	do	T, E	P	....	10-19-60	....	Reported yield 90.
11bbb	B. D. Hixson	Dr	90.0	4	S	do	do	Cy, W	S	82.99	9-26-60	2,430.2	
12bab*	Dean Newcomer	Dr	103.0	6	GI	do	do	Cy, W	D, S	91.80	7-16-60	2,408.7	

TABLE 6.—Records of wells in Trego County, Kansas.—*Continued.*

Well no.	Owner or tenant	Type of well†	Depth of well, feet	Diameter of well, in.	Type of Casing‡	Principal water-bearing unit: Character of material	Principal water-bearing unit: Geologic source	Method of lift§	Use of water‖	Depth to water level below land surface, feet	Date of measurement	Height of land surface above mean sea level, feet	Remarks (Yield given in gallons per minute; drawdown in ft.)
12-23-17abb	M. Madden	Dr	75.0	5	GI	Sand, gravel	Ogallala Formation	Cy, H	N	65.56	8-11-59	2,443.1	Abandoned domestic well.
20abb	City of WaKeeney	Dr	43	....	....	do	do	T, E	P	....	10-19-60	....	Reported yield 120.
20caa1	do	Dr	65	16	S	do	Alluvium	T, E	P	....	10-19-60	....	Reported yield 100.
20caa2	do	Dr	74	19	C	do	do	T, E	P	....	10-19-60	....	Reported yield 130.
20cbd	do	Dr	69	16	S	do	do	T, E	P	....	10-19-60	....	Reported yield 100.
20ccb	H. & F. Keyser	Dr	85	18	S	do	Terrace deposits	T, D	I	30	8-11-59	2,386.6	Reported yield 150.
20ccc1*	do	Dr	65	16	S	do	Alluvium	T, P	I	19.22	9-14-60	2,373.6	Aquifer test using well.
20cdc	City of WaKeeney	Dr	69	16	S	do	do	T, E	P	....	10-19-60	....	Reported yield 100.
22aba	C. Deines	Dr	65.0	4	GI	do	Ogallala Formation	Cy, W	S	59.22	9-22-60	2,383.9	
27aaa	J. F. Strain	Dr	36.0	6	GI	do	do	Cy, W	S	22.45	8-29-59	2,343.7	
27aac	do	Dr	100	18	S	do	do	T, G	I	35	8-12-58	2,387.4	Reported yield 900.
28cbc	Roger Ewing	Dr	64	....	....	do	Alluvium	T, P	I	18	6-2-58	2,356.5	
29aaa	G. Miller	Dr	....	....	....	do	do	C, N	I	20	10-25-60	2,359.3	Not used for several years.
29baa	City of WaKeeney	Dr	87	18	S	do	do	T, E	P	....	10-19-60	....	Reported yield 450.
29bba	do	Dr	77	12	S	do	do	T, E	P	25	10-19-60	....	Reported yield 500.
30acc1*	Don Pearson	Dr	96	18	S	do	Terrace deposits	T, P	I	35	9-19-60	2,392.5	Aquifer test using well.
32baa	Pearl Sheets	Dr	125	5	GI	do	Ogallala Formation	Cy, W	S	100	7-27-58	2,454.0	
33bcb*	Anna Gregorcyk	Dr	100.0	6	GI	do	do	Cy, W	S	95.30	7-12-60	2,432.3	
12-24-5cdc*	Henry Dietz	Dr	67.5	6	GI	do	do	Cy, W	D, S	53.57	9-23-60	2,496.4	Reported 85 feet to shale in a nearby test hole.
6acc	Rudolph Radke	Dr	91.5	5	GI	do	do	Cy, W	N	70.95	9-2-59	2,521.7	Unused stock well.
7bbb	Martin Mohr	Dr	110.0	5½	GI	do	do	Cy, W	S	75.62	10-21-60	2,535.3	
8daa	L. G. Brown	Dr	56	6	GI	do	do	Cy, W	D, S	43	7-14-60	2,474.0	
10daa	A. C. Wolff	Dr	41.5	5½	GI	do	do	Cy, H	N	37.85	8-12-59	2,443.0	Abandoned domestic well.
11ddd	Fred H. Spena	Dr	96	6	GI	do	do	Cy, W	D, S	68.80	7-14-60	2,462.4	
12bbb	Philip Malinowsky	Dr	109.0	6	GI	do	do	Cy, E	D, S	95.75	8-3-60	2,498.0	
16ccc	School district	Dr	67.5	5	GI	do	do	Cy, H	D	56.13	8-12-59	2,471.0	
20bbb	M. H. Howatt	Dr	73.5	5	GI	do	do	Cy, W	N	50.12	8-12-59	2,475.9	Abandoned stock well.
23bbc	L. Schoenthaler	Dr	46.0	5	GI	do	do	Cy, G	S	44.40	8-7-57	2,434.9	
23ddc	E. Gross	Dr	54.0	5½	GI	do	Alluvium	Cy, W	S	37.96	7-14-60	2,415.0	
24baa	C. H. Keyser	Dr	60.0	5½	GI	do	Ogallala Formation	Cy, W	S	51.60	7-14-60	2,431.6	
27bcb	Leo Dolezal	Dr	40.0	6	GI	do	do	Cy, W	D, S	36.10	7-14-60	2,434.8	Reported plenty of good water.
30aab	Dale Oleson	Dr	54.0	18	S	do	Alluvium	T, G	I	10.85	8-11-58	2,438.9	
30bcc2	J. Leman	Dr	....	....	....	do	do	T, N	I	....	10-25-60	....	
30dad*	A. W. Hirsh	Dr	79.5	6	GI	do	Ogallala Formation	Cy, G	S	70.63	8-12-59	2,494.4	
32bdc	E. Bedashek	Dr	52.8	5	GI	do	do	Cy, W	N	49.21	8-7-57	2,469.0	Abandoned stock well.
36ada	H. Keyser	Dr	106.0	6	GI	do	do	Cy, W	S	85.87	8-29-59	2,455.5	
12-25-1bbb	J. F. Evers	Dr	90.0	5	GI	do	do	Cy, H	N	77.12	8-4-59	2,544.6	Unused domestic well.
5cdd	City of Collyer	Dr	120	12	S	do	do	T, E	P	80	10-19-60	2,592.0	
5dcc	do	Dr	120	12	S	do	do	T, E	P	80	10-19-60	2,592.1	Reported yield 85.
6dad	E. Morrell	Dr	84.2	6	GI	do	do	Cy, W	S	71.50	8-3-59	2,585.3	

9aaa	Julius Ulrich	Dr	70.0	5½	GI	do	do	Cy, W	S	17.56	9-23-60	2,541.4	
11aab*	Isadore Dreiling	Dr	77.5	5	GI	do	do	Cy, W	S	67.97	9-23-60	2,539.3	
11ddd	F. Hladek	Dr	54.0	5	GI	do	do	N	N	37.49	7-30-59	2,506.0	Abandoned school well.
12aaa*	Martin Mohr	Du	90	....	....	do	do	Cy, E	D, S	75	10-21-60	2,535.3	
15dad	A. Morell	Dr	66.0	....	....	do	do	N	N	52.62	8-13-57	2,531.3	Reported 81 feet to shale in nearby test hole.
16cbb	P. Lipp	Dr	90	5	GI	do	do	Cy, G	S	50.33	8-26-59	2,552.3	
18aaa	Yarrow Polkowsky	Du	72.0	42	R	do	do	Cy, E	D, S	64.10	9-22-60	2,578.9	
19dcb	G. H. O'Toole	Dr	44.5	5	GI	do	Terrace deposits	Cy, H	N	32.14	9-22-60	2,536.0	Unused stock well.
26bba	E. Hladek	Dr	37.3	5½	GI	do	do	Cy, W	S	23.54	7-30-57	2,490.5	
28cba	G. & J. O'Toole	Dr	39.0	5	GI	do	do	Cy, W	N	33.09	8-26-59	2,514.3	Abandoned domestic well.
31ccb	Tony Brown	Dr	80.3	6	GI	do	Ogallala Formation	Cy, W	N	72.65	8-26-59	2,577.8	do
13-21-2bcc	Barbary Helget	Dr	31.0	5½	GI	do	Alluvium	Cy, H	D	27.65	9-23-60	2,186.3	
25cda	Anna Storm	Du	36.0	36	R	do	Ogallala Formation	Cy, H	S	30.60	9-1-59	2,309.9	
28bbb	M. Locker	Du	15.0	36	C	do	do	Cy, W	S	4.99	8-4-58	2,287.7	
32abb	E. Moon	Du	14.0	70	C	do	do	Cy, W	S	6.27	8-2-60	2,276.9	
35aba	F. J. Graf	Du	12.0	36	R	do	do	Cy, W	S	11.28	9-1-59	2,289.6	
13-22-1bbb	J. C. Benson	Dr	40	6	GI	do	do	Cy, W	S	19	6-8-58	2,274.2	
8adc	Arthur Bliss	Dr	46	18	S	do	Alluvium	T, P	I	18.62	8-10-59	2,284.9	Reported yield 400. Shale at 44 feet.
13cbb	S. Y. Boarman	Dr	58.5	5	GI	do	Terrace deposits	Cy, G	S	37.24	9-28-59	2,268.6	
15daa*	Alfred Eberle	Dr	66	8	GI	do	do	Cy, E	D, S	51.60	10-25-60	2,291.8	
16aab	Bill Harvey	Dr	52.0	18	S	do	Alluvium	T, P	I	18.37	8-10-59	2,248.0	Reported yield 500.
19aba	J. Dietz	Dr	76	5	GI	do	Ogallala Formation	Cy, W	S	67.09	9-4-57	2,413.0	
22aaa*	Clifford Loflin	Dr	40	6	OW	do	Alluvium	J, E	D, S	20	6-14-60	2,257.7	
26aab	John Pearson	Dr	36	16	S	do	do	T, P	I	11	8-11-58	2,237.6	Reported yield 600.
33bab	W. R. Hall	Dr	70	6	GI	do	Ogallala Formation	Cy, W	D, S	40	6-9-58	2,359.6	
34ddd	C. Newcomer	Dr	11.0	4	OW	do	do	N	N	9.02	8-31-59	2,320.8	Abandoned domestic well.
13-23-3bcb	W. G. Dietz	Dr	75.3	5½	GI	do	do	Cy, W	S	66.05	9-25-59	2,429.8	
4bcc	M. A. Casey	Dr	86.5	5½	GI	do	do	Cy, W	S	61.45	9-1-59	2,435.2	Reported shale at 86 feet.
14aaa	School district	Dr	67.0	6	GI	do	do	Cy, H	D	59.60	8-12-59	2,408.3	
15aaa	Julia Hinkle	Dr	30.0	6	GI	do	do	Cy, W	N	14.25	7-12-60	2,380.4	Abandoned domestic well.
17aaa*	Bernhardt Bender	Dr	107	6	GI	do	do	Cy, E	D, S	84.40	10-3-62	2,470.0	
22ccb*	E. Hendrickson	Dr	65.0	6	GI	do	do	Cy, W	S	46.16	7-12-60	2,419.3	
28baa	Ernest Schneider	Dr	35	10	S	do	do	C, E	I	15	10-25-60	....	Series of 4 wells.
30aaa	School district	Dr	117.0	6	OW	do	do	J, E	D	83.45	8-29-59	2,473.9	Driller reported shale at 117 feet.
32baa	A. Honomickl	Dr	30.0	6	GI	do	do	Cy, W	S	19.23	8-4-60	2,399.3	
13-24-1ddd	School district	Dr	83.5	4	GI	do	do	Cy, H	D	78.15	8-11-59	2,472.1	
2aaa*	J. P. Sigler	Dr	106.5	5	GI	do	do	Cy, W	S	103.23	9-1-59	2,485.0	
3aaa	Clara M. Lessor	Dr	122.5	5	GI	do	do	Cy, W	S	108.98	9-1-59	2,498.6	
4ccb	J. E. Keller	Dr	84.0	5	GI	do	do	Cy, W	S	75.72	7-14-60	2,474.4	
7adc	V. V. Wedermeyer	Du	39.0	42	C	do	do	N	N	31.88	8-12-59	2,465.2	Abandoned domestic well.
14dad	Sol Mai	Dr	102.5	6	GI	do	do	Cy, W	S	87.60	9-28-59	2,490.3	
22dcc	F. Dietz	Dr	32.8	5½	GI	do	do	Cy, W	S	23.67	9-25-59	2,379.9	
24ddc	H. Schneider	Dr	34.0	10	S	do	do	Cy, W	S	27.50	9-25-59	2,423.0	
32aaa	Charles Surprise	Du	24.7	36	B	Sand, silt	Colluvium	N	N	12.75	7-13-60	2,354.0	Abandoned domestic well.
33dad	George Mai	Dr	40.0	5½	GI	do	do	Cy, E	D	33.80	8-4-60	2,340.3	Reported 9 feet of sand in bottom.

TABLE 6.—Records of wells in Trego County, Kansas.—*Continued.*

Well no.	Owner or tenant	Type of well†	Depth of well, feet	Diameter of well, in.	Type of Casing‡	Principal water-bearing unit: Character of material	Principal water-bearing unit: Geologic source	Method of lift§	Use of water‖	Depth to water level below land surface, feet	Date of measurement	Height of land surface above mean sea level, feet	Remarks (Yield given in gallons per minute; drawdown in ft.)
13-24-36bbb*	Ben Schneider	Dr	31.5	5	GI	Sand, gravel	Ogallala Formation	Cy, G	S	15.72	9-25-59	2,393.2	
13-25-1bab	Ed Kvasnick	Dr	110.5	5	GI	do	do	Cy, W	S	101.15	8-26-59	2,543.5	
3cbd	Frank Ziegler	Dr	78	18	S	do	do	T, P	I	27.09	8-26-59	2,483.7	Reported yield 420.
5dad	Warren Burbach	Dr	76.5	5½	GI	do	do	Cy, E	S	66.40	9-27-60	2,526.4	
9ccc	A. P. Billinger	Dr	29.2	10	GI	do	do	N	N	21.73	8-26-59	2,479.2	Abandoned school well.
13bbb	Tony Flax	Dr	53.0	5½	GI	do	do	Cy, W	D	45.56	10-24-60	2,510.9	
18bda	Louis Berens	Dr	32.0	5½	GI	do	do	Cy, W	S	22.86	9-27-60	2,468.3	
19ccc	H. A. Norman	Dr	17.5	5	GI	Sand, silt	Colluvium	Cy, N	N	7.81	7-30-57	2,403.5	Abandoned stock well.
20ddd	Lulu Harvey	Dr	60.0	5	GI	do	do	Cy, W	N	55.33	8-26-59	2,411.9	Abandoned domestic well.
21bcc	J. S. Dalby	Dr	39.5	5	GI	do	do	N	N	30.05	8-26-59	2,429.3	do
24ccc	E. Flagler	Dr	47.3	10	GI	Sand, gravel	Ogallala Formation	N	N	30.77	8-26-59	2,404.2	Abandoned school well.
32cbb*	L. W. Purinton	Dr	21.0	12	GI	do	Terrace deposits	J, E	D, S	11.62	9-27-60	2,331.4	
36bbb	V. C. Schoenberger	Dr	61.0	6	GI	Sand, silt	Colluvium	Cy, W	S	44.84	8-4-60	2,358.8	
14-21-3abb	I. Flax	Du	14.5	72	C	Sand, gravel	Ogallala Formation	Cy, G	S	6.88	9-1-59	2,279.4	
6aba*	Mary Locker	Du	21.0	60	C	do	do	Cy, W	D, S	13.60	8-2-60	2,257.7	
8cdd	John Honas	Du	13.0	48	C	Sand, silt	Colluvium	Cy, W	S	4.25	9-28-59	2,167.8	
10bcc	F. Wasinger	Du	20.0	48	C	do	do	Cy, H	S	2.83	8-15-58	2,197.1	
10dda	School district	Dr	82.0	5	GI	Sand	Codell Sandstone Member	Cy, H	D	22.30	8-25-59	2,223.3	
23aaa	Pius Gabel	Dr	31.5	6	GI	do	do	Cy, G	S	15.34	8-2-60	2,180.9	Reported blue shale at 20 feet.
25ddc	H. C. Waggoner	Dr	....	6	GI	Sand, silt	Colluvium	Cy, W	S	9.48	8-25-59	2,060.2	
28cbb	Bureau of Reclamation	Dr	40.2	1¼	P	Sand, gravel	Terrace deposits	N	O	35.80	7-7-61	2,118.2	Drillers log.
29dca	George Snyder	B	28.7	5½	GI	do	Alluvium	Cy, W	S	16.18	10-21-60	2,068.8	
30cab*	Tony Aschenburner	Du	29.2	42	C	do	do	N	N	14.93	9-15-59	2,071.8	Abandoned domestic well.
31cdb*	W. S. Spitsnau	Du	13.2	36	R	do	do	Cy, W	D, O	10.59	10-21-60	2,072.1	
33bbc	U.S. Geol. Survey	J	30.6	¾	P	do	do	N	O	15.18	10-9-59	2,057.7	
33bcc	Bureau of Reclamation	Dr	23.0	1¼	P	do	do	N	O	7.90	7-7-61	2,048.6	Drillers log.
33ccc	Jake Augustine	Du	11.8	33	C	Sand, silt	Colluvium	N	N	7.88	10-18-49	2,088.9	Well sealed shut and abandoned. Data from Leonard and Berry (1961).
34bad*	J. F. Wanamaker	Du	20.9	33	R	Sand, gravel	Alluvium	Cy, W	D, S	12.81	10-12-49	2,045.2	Data from Leonard and Berry (1961).
35bcc	Bureau of Reclamation	Dr	18.2	1¼	P	do	Terrace deposits	N	O	Dry	7-7-61	2,078.3	Drillers log.
35cab*	C. S. Holtzinger	Du	19.1	60	C	do	do	Cy, W	D, S	17.37	9-15-59	2,076.3	
35cbc2	Bureau of Reclamation	Dr	44.2	1¼	P	do	do	N	O	15.50	7-7-61	2,039.9	Drillers log.
35cca*	C. S. Holtzinger	B	19.8	6	GI	do	Alluvium	Cy, W	D, S	16.83	9-15-59	2,037.8	
35ccc	Bureau of Reclamation	Dr	23.0	1¼	P	do	do	N	O	11.40	7-7-61	2,035.2	Drillers log.
36aaa	do	Dr	51.2	1¼	P	do	Terrace deposits	N	O	46.90	7-7-61	2,107.1	Drillers log.
36bbb	do	Dr	16.0	1¼	P	do	do	N	O	10.90	7-7-61	2,072.6	Drillers log.
36bcc	do	Dr	58.2	1¼	P	do	do	N	O	46.00	3-17-61	2,075.7	Drillers log.
36ddd	do	Dr	23.1	1¼	P	do	Alluvium	N	O	8.50	7-7-61	2,019.3	Drillers log.
14-22-6aba*	A. H. Lawson	Dr	27.5	5	GI	Sand, silt	Colluvium	Cy, W	S	14.78	9-23-60	2,344.0	

12ccc•	J. Locker	Dr	87.0	5½	GI	Sand	Codell Sandstone Member	Cv, H	D	43.50	9-1-59	2,242.8	
18aaa	H. A. Geyer	Du	18.0	48	R	Sand, silt	Colluvium	N	N	15.30	8-31-59	2,270.0	Abandoned domestic well.
22ada	A. Kastner	Dr	27.0	8	GI	do	do	Cv, H	S	11.64	8-31-59	2,174.4	
26ada•	Bureau of Reclamation	Dr	90.7	6	GI	Sand, gravel	Terrace deposits	J, E	D	21.72	9-15-59	2,150.6	
26add	do	Dr	76.0	1¼	P	do	do	N	O	16.49	4-13-62	2,149.6	
26daa	do	Dr	50.0	6	GI	do	do	N	O	20.10	6-13-60	2,148.6	
30acd	M. W. Lecuyer	Dr	65.5	6	GI	Sand	Codell Sandstone Member	Cv, W	S	38.05	9-28-59	2,187.7	
33aad	Christian Church	Dr	35.0	6	GI	Sand, gravel	Terrace deposits	J, E	D	15.35	7-17-60	2,155.4	New well for youth camp.
36aab	U.S. Geol. Survey	Dr	68.5	1¼	P	do	do	N	O	27.20	10-9-59	2,114.7	
14-23-1bcb	Marvin Kuehn	Dr	81.5	6	GI	Sand	Codell Sandstone Member	Cv, W	S	24.85	9-23-60	2,310.2	
6cbd	Wilbur Duncan	Dr	27	....	....	Sand, silt	Colluvium	C, E	I	6	6-2-58	....	One pump on 11 wells in series.
9aba•	Rinehold Bender	Dr	23.4	5½	GI	do	do	Cv, W	S	16.54	8-29-59	2,294.0	
14abb	John Faulkner	Du	27.0	36	R	do	do	Cv, W	S	2.79	8-7-58	2,267.9	
18dcd	G. D. Deines	Dr	38.0	5½	GI	Sand	Codell Sandstone Member	Cv, W	S	20.76	9-28-60	2,271.3	
22aba•	School district	Dr	37.5	6	S	Sand, silt	Colluvium	J, E	D	25.87	9-28-60	2,266.9	
14-24-1bab	F. W. Deines	Dr	32.0	4½	S	Sand, gravel	Ogallala Formation	Cv, H	N	19.07	9-25-59	2,356.0	Abandoned stock well.
8abc	E. M. Schneider	Dr	41.0	5	GI	Sand, silt	Colluvium	Cv, H	N	27.60	9-22-60	2,306.4	Abandoned domestic well.
10aab	Olestine Pfannestiel	Dr	41.5	6	GI	do	do	Cv, W	S	28.27	9-22-60	2,306.9	
12ccc	William Kraus	Dr	30.5	6	GI	do	do	Cv, W	S	10.98	9-22-60	2,290.9	
17baa	Robert Park	Dr	42.0	6	GI	do	do	Cv, E	D, S	37	7-13-60	2,312.5	Reported lots of good water.
19dda•	C. Kline	Dr	500	2	P	Sand	Dakota Formation	Cv, W	S	225	8-4-58	2,316.2	
22baa•	A. W. Wolf	Dr	52.0	6	GI	do	Codell Sandstone Member	Cv, W	S	44.22	7-13-60	2,287.7	
25ddd•	R. M. Gaether	Dr	29.0	5½	GI	Sand, gravel	Terrace deposits	Cv, W	S	14.20	9-2-59	2,208.7	
32bcc	J. R. Koeppen	Dr	30.0	32	S	do	do	T, D	I	22.22	10-24-60	2,252.7	Reported yield 150; drawdown 4.
14-25-3bba	A. Krupp	Dr	54.0	5	GI	Sand, silt	Colluvium	Cv, W	S	44.05	7-23-58	2,364.3	
10ccc	Arthur O'Toole	Dr	18.0	6	GI	Sand, gravel	Alluvium	Cv, W	S	10.65	9-27-60	2,274.4	
25ccb•	do	Dr	19.0	6	GI	do	do	Cv, W	S	13.50	9-28-60	2,227.9	
32ddd	B. F. Schwindt	Dr	75.5	5½	GI	do	Terrace deposits	Cv, H	D	25.26	9-15-59	2,305.0	Drillers log
15-21-2acc	H. G. Waggoner	Dr	28.0	5	GI	do	do	Cv, W	S	22.33	7-23-58	2,087.2	
5abb•	A. B. Engel	Du	11.1	18	C	Sand, silt	Colluvium	Cv, E	D, S	8.42	10-21-60	2,090.4	
16cbc•	Clem Gaschler	Dr	32	48	R	Sand	Codell Sandstone Member	J, E	D	28	8-19-58	2,253.5	
20aad	C. F. Kutina	Dr	50.0	6	GI	Sand, silt	Colluvium	Cv, W	S	5.70	4-12-62	2,302.3	
25ddd•	D. K. North	Dr	555	4	OW	Sand	Dakota Formation	Cv, W	D, S	400	8-19-58	2,320.4	
26bcc1	John Rourke	Dr	650	2	P	do	do	Cv, E	D, S	....	9-2-60	....	
26bcc2	do	Dr	137.0	6	GI	do	Codell Sandstone Member	Cv, H	D	29.50	9-29-60	2,337.6	Penetrated blue shale at 90 ft; found water at 88 feet.
28dad	G. & M. North	Dr	33.0	5½	GI	Sand, gravel	Ogallala Formation	Cv, H	D	27.60	9-29-60	2,348.4	
36ddd•	Dewey North	Du	45.0	54	R	Sand	Codell Sandstone Member	Cv, W	S	26.38	9-29-60	2,277.0	
15-22-8daa	F. Bednasek	Du	18.6	36	R	Sand, silt	Colluvium	N	N	5.84	8-8-58	2,218.1	Abandoned stock well.
35aba•	C. & M. Beason	Dr	660	6	GI	Sand	Dakota Formation	Cv, W	S	....	9-29-60	2,404.2	
36bba	do	Dr	71.0	6	GI	Sand, gravel	Ogallala Formation	Cv, E	D	66.35	9-29-60	2,406.6	
36cdc	C. H. Beason	Dr	57.0	5	GI	do	do	Cv, W	S	45.19	7-23-58	2,398.7	
15-23-1cbc	U.S. Government	Dr	52.5	5	GI	do	Terrace deposits	Cv, W	S	24.83	8-29-59	2,169.3	
4bcb•	do	Dr	18.0	5½	GI	Sand, silt	Colluvium	Cv, W	S	3.41	8-8-58	2,157.4	

TABLE 6.—Records of wells in Trego County, Kansas.—*Concluded.*

Well no.	Owner or tenant	Type of well†	Depth of well, feet	Diameter of well, in.	Type of Casing‡	Principal water-bearing unit: Character of material	Principal water-bearing unit: Geologic source	Method of lift§	Use of water‖	Depth to water level below land surface, feet	Date of measurement	Height of land surface above mean sea level, feet	Remarks (Yield given in gallons per minute; drawdown in ft.)
15-23-8ddd	David Kraft	Dr	94.0	5½	GI	Sand	Codell Sandstone Member	Cy, W	D, S	29.50	9-28-60	2,286.4	Reported to have hit water at 55 feet.
13baa	H. McNinch	Du	28.6	36	C	Sand, silt	Colluvium	N	N	4.59	7-12-58	2,226.3	Abandoned stock well.
14ccd*	T. Lawrence	Du	8.5	48	R	do	do	Cy, W	S	2.08	7-12-58	2,255.0	
21ddc*	Horn Schneider	Dr	47.4	10	GI	Sand, gravel	Ogallala Formation	Cy, W	S	26.46	7-12-58	2,412.3	
31ddd	R. C. Alexander	Dr	71.0	4	GI	do	do	Cy, W	S	62.90	9-27-60	2,479.3	
35bcb*	Herman Kislinger	Dr	35.0	18	GI	do	do	Cy, W	D, S	30.35	9-28-60	2,419.6	
36ddc	Gus Hinnergardt	Du	15.0	48	C	Sand, silt	Colluvium	Cy, W	S	11.40	9-28-60	2,311.3	
15-24-7aaa	G. W. Mollenkamp	Dr	52.0	5½	GI	Sand	Codell Sandstone Member	N	N	25.45	9-2-59	2,352.3	Abandoned school well.
11ccc	J. Werth	Du	71.0	60	R	do	do	Cy, E	S	23.67	9-28-60	2,330.1	
15ccc*	Andy Montgomery	Dr	618	2	P	do	Dakota Formation	Cy, W	D, S	200	9-29-59	2,386.3	
16ddd	Bill Montgomery	Dr	640	7	OW	do	do	Cy, W	D, S	271.50	10-4-62	2,396.5	
20ddd	School district	Dr	125.0	....	....	do	Codell Sandstone Member	Cy, H	D	27.47	7-13-60	2,418.9	
24abb	M. Rauch	Dr	18.4	5	GI	Sand, silt	Colluvium	N	N	14.05	7-12-58	....	Abandoned domestic well.
26aaa	School district	Dr	99.0	5	GI	Sand	Codell Sandstone Member	Cy, H	D	34.20	9-2-59	2,340.6	
28bcb	E. Haug	Dr	16.5	5½	GI	Sand, silt	Colluvium	Cy, W	S	5.91	7-30-58	2,382.7	
31ddc*	Hugo Kraus	Dr	72.5	5½	GI	Sand, gravel	Ogallala Formation	Cy, W	S	64.05	9-28-60	2,512.3	
35ccc*	Carl Lutters	Dr	60	6	GI	do	do	Cy, W	D	27	9-29-59	2,469.2	Drilled through hard limestone and into sand where water was found.
15-25-1cdc	F. G. Nimz	Dr	124.0	6	GI	Sand	Codell Sandstone Member	Cy, W	S	29.15	9-28-60	2,367.3	
7aba	B. D. Paser	Dr	25.0	24	S	Sand, silt	Colluvium	Cy, W	S	18.24	7-30-58	2,296.5	
22bbd	Victor Splitter	Du	14.5	48	C	Sand, gravel	Alluvium	Cy, W	D, S	11.65	9-27-60	2,368.5	
23dad*	Carl Frye	Dr	72.0	6	GI	do	Ogallala Formation	Cy, E	D, S	56.45	9-27-60	2,513.0	
29bba*	Leonard Ochs	Dr	35.0	5½	GI	do	do	J, E	D, S	23.94	9-27-60	2,461.2	Reported lots of nearby springs.
31dcc	S. Deines	Dr	48.0	5	GI	do	do	Cy, W	S	34.92	9-15-59	2,556.2	
34ccc	D. Cooper	Dr	14.0	5½	GI	Sand, silt	Colluvium	Cy, W	S	10.00	7-29-58	2,449.1	
35cdc*	H. McNinch	Dr	93.0	5	GI	Sand, gravel	Ogallala Formation	Cy, W	S	76.56	7-13-60	2,549.9	
16-25-1bcc	....	Dr	52.8	6	GI	do	do	Cy, W	S	51.80	4-16-62	2,523.5	In Ness County.

* Chemical analysis given in Table 3.
† Type of well: *Dr*, drilled; *Du*, dug; *B*, bored; *J*, jetted.
‡ Type of casing: *GI*, galvanized iron; *OB*, oil barrel; *S*, steel; *R*, rock; *C*, concrete; *OW*, oil-well casing; *P*, pipe; *B*, brick.
§ Method of lift: *Cy*, cylinder; *W*, wind; *N*, none; *G*, gasoline engine; *E*, electric motor; *H*, hand; *T*, turbine; *P*, propane engine; *T*, tractor; *J*, jet; *D*, diesel; *C*, centrifugal.
‖ Use: *S*, stock; *N*, none; *D*, domestic; *I*, irrigation; *O*, observation; *P*, public.

LOGS OF TEST HOLES AND WELLS

Listed on the following pages are logs of 176 test holes and wells. 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.

10-24-34ddd.———Sample log of test hole in SE SE SE sec. 34, T 10 S, R 24 W, 50 feet west and 20 feet north of center of crossroads, Graham County (Prescott, 1955, p. 92); drilled September 1952. Altitude of land surface 2,357.2 feet; depth to water 35.4 feet.

	Thickness, feet	*Depth, feet*
NEOGENE		
Pleistocene		
Peoria and Loveland formations		
Silt and clay, dark-brown	4	4
Silt, tan; contains some gastropod shells	15.5	19.5
Pliocene		
Ogallala Formation		
Clay, sandy, tan-brown	3.5	23
Sand, gravel, and pebbles	2	25
Clay, sandy, tan; contains imbedded gravel	9	34
Sand, fine to coarse	6	40
Sand, fine to coarse; contains some gravel and pebbles	5.5	45.5
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Chalk, soft, white	2.5	48
Shale, gray	2	50

10-25-36ccc.———Sample log of test hole in SW SW SW sec. 36, T 10 S, R 25 W, 20 feet east and 15 feet north of center of crossroads, Graham County (Prescott, 1955, p. 92); drilled September 1952. Altitude of land surface 2,418.8 feet; depth to water 31.5 feet.

	Thickness, feet	*Depth, feet*
NEOGENE		
Pleistocene		
Peoria and Loveland formations		
Silt and clay, dark-brown (topsoil)	3	3
Silt and clay, tan-gray	6.5	9.5
Silt and clay, compact, tan; contains some sand near base	6.5	16
Pliocene		
Ogallala Formation		
Sand, fine to coarse and fine to coarse gravel; contains silt, sandy clay, and fragments of chalk	11	27
Clay, very sandy; contains gravel	5	32
Sand, fine to coarse, and fine to coarse gravel; contains some fragments of chalk	4.5	36.5
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Chalk, soft, yellow	1.5	38
Shale, calcareous, gray	2	40

11-21-3ccc.———Sample log of test hole in SW SW SW sec. 3, T 11 S, R 21 W, 50 feet NE of SW cor. sec. 3; drilled October 1957. Altitude of land surface 2,094.5 feet; depth to water 9.61 feet.

	Thickness, feet	*Depth, feet*
NEOGENE		
Pleistocene		
Alluvium		
Silt, sandy, dark-brown	4	4
Sand, fine to coarse; contains chalk gravel	3	7
Silt, brown	1	8
Sand, fine to coarse, silty, and arkosic gravel; contains small amount chalk gravel	6	14
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Fort Hays Limestone Member		
Shale, chalky, white	5	19
Shale, dark-gray	1	20

11-21-9ada.———Sample log of test hole in NE SE NE sec. 9, T 11 S, R 21 W, 0.3 mile south of NE cor. sec. 9, at edge of road; drilled October 1957. Altitude of land surface 2,101.1 feet.

	Thickness, feet	*Depth, feet*
NEOGENE		
Pleistocene		
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Silt, sandy, tan	4	4
Sand, fine to coarse; contains chalk gravel	17	21
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Fort Hays Limestone Member		
Shale, chalky, white	5	26
Shale, dark-gray	2	28

11-21-9add.———Sample log of test hole in SE SE NE sec. 9, T 11 S, R 21 W, 0.4 mile south of NE cor. sec. 9, at edge of road; drilled October 1957. Altitude of land surface 2,099.8 feet; depth to water 19.88 feet.

	Thickness, feet	*Depth, feet*
NEOGENE		
Pleistocene		
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Silt, dark-brown	4	4
Silt, tan	5	9
Sand, fine to coarse; contains arkosic and chalk gravel	8	17
Silt, blue-gray	2	19
Sand, fine to coarse; contains chalk gravel	8	27
Silt, blue-gray	13	40
Silt, sandy, gray; contains small amount chalk gravel	10	50
Sand, fine to coarse, very silty; contains small amount chalk gravel	10	60
Silt, very sandy, dark-gray	3	63
Sand, fine to coarse, and chalk gravel	7	70
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Fort Hays Limestone Member		
Shale, gray	3	73

11-21-22ccc.———Sample log of test hole in SW SW SW sec. 22, T 11 S, R 21 W, 10 feet north and 10 feet east of SW cor. sec. 22; drilled September 1960. Altitude of land surface 2,309.5 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Peoria and Loveland formations		
Silt, sandy, brown	5	5
Sand, fine to very coarse	7	12
Pliocene		
Ogallala Formation		
Silt, very limy, light tan	8	20
Silt, very sandy, limy, tan	10	30
Sand, medium to coarse, clean, well sorted, loose	10	40
Sand, medium to very coarse, clean, loose	10	50
Sand, medium to very coarse; contains streaks of silty clay in lower part	10	60
Silt, very limy; contains cemented streaks and thin layers of fine to coarse sand	5	65
Silt, clayey, tough, brown	5	70
Sand, fine to medium, loose	20	90
Sand, fine to coarse, loose	10	100
Sand, medium to very coarse, clean, loose	10	110
Gravel, fine; contains very coarse sand	8	118
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, light gray upper part, dark gray lower part	12	130

11-22-10dad.———Sample log of test hole in SE NE SE sec. 10, T 11 S, R 22 W, 250 feet north of bridge, 75 feet south of driveway to farm home, at edge of road; augered July 1960. Altitude of land surface 2,161.5 feet; depth to water 26.1 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Silt, sandy, tan	3.5	3.5
Silt, sandy, brown	5	8.5
Silt, brown	5	13.5
Silt, tan brown; contains small amount fine sand	5	18.5
Sand, fine, very silty	5	23.5
Silt, clayey; contains small amount fine sand	6.5	30
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, gray and brown	3.5	33.5

11-22-11ccb.———Sample log of test hole in NW SW SW sec. 11, T 11 S, R 22 W, 0.15 mile north of SW cor. sec. 11, 150 feet south of bridge, at edge of road; augered July 1960. Altitude of land surface 2,139.8 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Sand, fine to medium	5	5
Silt, very sandy, tan	4	9
Sand, fine to medium; contains small amount fine gravel	12	21
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, blue-gray	2.5	23.5

11-22-14bbb.———Sample log of test hole in NW NW NW sec. 14, T 11 S, R 22 W, 50 feet south and 25 feet east of center of crossroads, in grader ditch; augered July 1960. Altitude of land surface 2,171.5 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Silt, sandy, brown	3	3
Silt, sandy, light tan	6	9
Sand, fine, well sorted, clean	9	18
Silt, very sandy, light brown	7	25
Sand, fine to very fine	5	30
Sand, fine, clean	7	37
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, chalky, dark gray	1.5	38.5

11-22-32aaa.———Sample log of test hole in NE NE NE sec. 32, T 11 S, R 22 W, 40 feet west and 8 feet south of center of crossroads; drilled September 1960. Altitude of land surface 2,378.1 feet; depth to water 77.2 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pliocene		
Ogallala Formation		
Silt, very sandy, limy; contains cemented streaks in lower part	8	8
Sand, fine to very coarse; contains fine to medium gravel	6	14
Silt, very limy, sandy, light pink	6	20
Silt, very limy, cemented, light gray	10	30
Silt, very limy, sandy, light yellow to gray	10	40
Silt, very limy, very sandy; contains cemented streaks	6	46
Gravel, fine, and coarse to very coarse sand	4	50
Silt, very sandy; contains limy streaks	10	60
Sand, fine to very coarse, and fine gravel, loose	15	75
Silt, very limy, light greenish gray	5	80
Sand, fine to very fine, loose	20	100
Sand, fine to medium, loose	8	108
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, chalky, weathered light gray	16	120
Shale, chalky, gray	4	124

11-22-36bba.———Sample log of test hole in NE NW NW sec. 36, T 11 S, R 22 W, 0.2 mile east of NW cor. sec. 36, 150 feet west of bridge, at edge of road; drilled October 1957. Altitude of land surface 2,283.2 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pliocene		
Ogallala Formation		
Silt, dark brown	3	3
Sand, fine to coarse, and fine gravel, cemented	7	10
Silt, slightly sandy, tan	6	16
Sand, fine to coarse	7	23
Silt, grayish tan	3	26
Sand, fine	14	40
Silt, tan	1	41
Sand, fine to coarse	14	55
Sand, fine to coarse; contains cemented streaks	2	57
Sand, fine to coarse; contains thin layers of very limy silt	6	63
Silt, sandy, tan and pink	5	68
Silt, light tan	2	70
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, dark gray	6	76

11-23-7dad.———Sample log of test hole in SE NE SE sec. 7, T 11 S, R 23 W, 0.3 mile north of SE cor. sec. 7, 100 feet south of driveway to farm home, at edge of road; augered July 1960. Altitude of land surface 2,264.9 feet; depth to water 21.9 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Silt, dark brown	3.5	3.5
Silt, sandy, tan	9.5	13
Silt, slightly sandy, brown	7	20
Silt, sandy, light brown	5	25
Silt, clayey, tough, slightly sandy, light brown	3	28
Sand, fine to coarse, silty	5	33
Sand, medium to very coarse; contains small amount fine gravel	9	42
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, blue gray	1.5	43.5

11-23-8bbb.———Sample log of test hole in NW NW NW sec. 8, T 11 S, R 23 W, 30 feet east and 15 feet south of center of crossroads; augered July 1960. Altitude of land surface 2,290.6 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Silt, sandy, brown tan	5	5
Silt, brown, tan	3	8
Sand, fine to coarse	4	12
Sand, medium to very coarse, clean; contains small amount fine gravel	6.5	18.5
Gravel, fine to medium, and very coarse sand	5	23.5
Sand, fine to medium; contains thin layers of silt	5	28.5
Sand, fine to coarse; contains thin layers of limy silt	6.5	35
Sand, coarse to very coarse; contains small amount fine gravel	5	40
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, blue gray	3.5	43.5

11-23-8bcb.———Sample log of test hole in NW SW NW sec. 8, T 11 S, R 23 W, 0.3 mile south of NW cor. sec. 8, at edge of road; augered July 1960. Altitude of land surface 2,265.2 feet; depth to water 22.67 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Silt, sandy, brown	5	5
Silt, sandy, tan brown	7	12
Silt, heavy, brown	8	20
Silt, slightly sandy, light brown	8	28
Silt, very sandy, light brown	9	37
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, blue gray	6.5	43.5

11-23-8cbb.———Sample log of test hole in NW NW SW sec. 8, T 11 S, R 23 W, 0.4 mile north of SW cor. sec. 8, 150 feet south of bridge, at edge of road; augered July 1960. Altitude of land surface 2,249.4 feet; depth to water 7.0 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Sand, fine, silty	3.5	3.5
Sand, fine to medium, well sorted	5	8.5
Sand, medium, well sorted, clean	5	13.5
Sand, coarse to very coarse, clean; contains small amount chalk gravel	12.5	26
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, blue gray	2.5	28.5

11-23-8ccc.———Sample log of test hole in SW SW SW sec. 8, T 11 S, R 23 W, 0.1 mile north of SW cor. sec. 8, at edge of road; augered July 1960. Altitude of land surface 2,284.4 feet; depth to water 35.15 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Silt, sandy, dark brown	5	5
Silt, sandy, tan	18.5	23.5
Sand, medium to coarse, clean	6.5	30
Silt, very sandy, tan	5	35
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, blue gray	3.5	38.5

11-23-35bbb.———Sample log of test hole in NW NW NW sec. 35, T 11 S, R 23 W, 25 feet east and 25 feet south of NW cor. sec. 35; drilled September 1960. Altitude of land surface 2,417.6 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pliocene		
Ogallala Formation		
Silt, very sandy; contains limy streaks	10	10
Silt, sandy, very limy, light gray	10	20
Silt, very limy, cemented, light pink	10	30
Silt, very limy, sandy; contains cemented streaks	6	36
Sand, medium to coarse, clean, loose	4	40
Silt and fine sand, limy; contains cemented streaks	10	50
Sand, medium to very coarse; contains limy streaks	8	58
Sand, coarse to very coarse, and fine gravel, clean, loose	8	66
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, chalky, weathered, light gray	8	74
Shale, chalky, dark gray	6	80

11-24-10ada.———Sample log of test hole in NE SE NE sec. 10, T 11 S, R 24 W, at edge of road; drilled October 1957. Altitude of land surface 2,288.7 feet; depth to water 11.85 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Sand, fine to coarse; contains small amount gravel	5	5
Silt, dark brown	3	8
Sand, fine to coarse	8	16
Silt, sandy, tan	1	17
Sand, fine to coarse	5	22
Silt, dark brown	14	36
Sand, fine to coarse, silty; contains small amount chalk gravel	9	45
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale	5	50

11-24-10add.———Sample log of test hole in SE SE NE sec. 10, T 11 S, R 24 W, north of river in abandoned channel, at edge of road; drilled October 1957. Altitude of land surface 2,282.9 feet; depth to water 5.3 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Sand, silty; contains gravel in lower part	4	4
Sand, fine to coarse, and gravel	11	15
Sand, fine to coarse, silty, and gravel	3	18
Silt, light gray	3	21
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, dark gray	1	22

11-24-11bbc.———Sample log of test hole in SW NW NW sec. 11, T 11 S, R 24 W, 50 feet south of farm driveway, at edge of road; drilled October 1957. Altitude of land surface 2,290.2 feet; depth to water 12.8 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Silt, dark brown	5	5
Silt, tan	8	13
Sand, fine to coarse, silty; contains arkosic and chalk gravel	10	23
Sand, fine to coarse, and chalk gravel	10	33
Sand, medium to coarse, and gravel	7	40
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, dark gray	2	42

11-24-11cbb.———Sample log of test hole in NW NW SW sec. 11, T 11 S, R 24 W, at edge of road; drilled October 1957. Altitude of land surface 2,318.3 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Silt, dark brown	2	2
Sand, very silty	3	5
Sand, fine to coarse, and chalk gravel	4	9
Silt, dark tan	1	10
Sand, fine to coarse, and chalk gravel	6.5	16.5
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Silt, clayey, yellow	2	18.5
Shale, dark gray	3.5	22

11-24-25ddd.———Sample log of test hole in SE SE SE sec. 25, T 11 S, R 24 W, 400 feet north and 5 feet west of SE cor. sec. 25; drilled September 1957. Altitude of land surface 2,428.9 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Peoria and Loveland formations		
Silt, brown and tan	4	4
Silt, sandy, reddish tan	4	8
Pliocene		
Ogallala Formation		
Sand, fine to medium, and very limy silt	2	10
Sand, fine to coarse; contains layers of pink silt	3	13
Silt and sandy silt, limy, cemented hard	5	18
Sand and sandy silt; contains hard cemented layers	6	24
Sand, fine to coarse	2	26
Silt, sandy, limy, cemented hard	3	29
Sand, fine to coarse, and fine gravel; contains cemented limy silt layers	4	33
Gravel, fine to medium	2	35
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, white and yellow	5	40
Shale, yellow	6	46
Shale, white	4	50
Shale, brown and black	10	60

11-24-32aaa.———Sample log of test hole in NE NE NE sec. 32, T 11 S, R 24 W, 40 feet SW of center of crossroads; drilled September 1960. Altitude of land surface 2,519.4 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Peoria and Loveland formations		
Silt, sandy in lower part, brown	14	14
Pliocene		
Ogallala Formation		
Silt, sandy, very limy, light gray	4	18
Silt, very sandy, limy, light tan	5	23
Silt, very sandy, limy streaks, tan	12	35
Silt, very sandy, very limy; contains cemented streaks	8	43
Sand, fine to coarse, very silty; contains cemented limy streaks	7	50
Silt, sandy, very limy; contains layers of fine to medium sand and cemented streaks	10	60
Sand, fine to very coarse	4	64
Silt, clayey, very limy, gray green	8	72
Silt, very sandy, very limy; contains cemented layers	13	85
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, cream and brown upper part, gray lower part	15	100

11-25-2dda.———Sample log of test hole in NE SE SE sec. 2, T 11 S, R 25 W, 0.25 mile north of SE cor. sec. 2, at edge of road; augered July 1958. Altitude of land surface 2,401.2 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Silt, light tan	5	5
Silt, tan	5	10
Silt, reddish tan	5	15
Sand, fine to coarse	25	40
Sand, fine to coarse, silty	10	50
No sample	5	55

11-25-2ddd.———Sample log of test hole in SE SE SE sec. 2, T 11 S, R 25 W, 0.1 mile north of SE cor. sec. 2, at edge of road; augered July 1958. Altitude of land surface 2,391.6 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Silt, dark brown	5	5
Silt, brown and tan	5	10
Silt, tan	5	15
Silt, sandy, tan	5	20
Sand, fine, silty	5	25
Sand, fine	10	35
Sand, fine to coarse, and fine gravel	5	40
Sand and brown silt	5	45
Sand and tan silt	2	47
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale	1	48

11-25-5bbc.———Sample log of test hole in SW NW NW sec. 5, T 11 S, R 25 W, 0.2 mile south of NW cor. sec. 5, 500 feet north of bridge, at edge of road; augered July 1960. Altitude of land surface 2,423.0 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Sand, very fine, silty	4	4
Sand, fine	5	9
Silt, sandy, tan brown	2	11
Sand, coarse to very coarse, very clean	15	26
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, blue gray	2.5	28.5

11-25-5bcb.———Sample log of test hole in NW SW NW sec. 5, T 11 S, R 25 W, 0.25 mile south of NW cor. sec. 5, 50 feet north of bridge, at edge of road; augered July 1960. Altitude of land surface 2,414.5 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Sand, fine	5	5
Sand, medium to very coarse, clean	9	14
Sand, fine to very coarse; contains thin layers of brown silt	3	17
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, blue gray	11.5	28.5

11-25-6aaa.———Sample log of test hole in NE NE NE sec. 6, T 11 S, R 25 W, 250 feet south of NE cor. sec. 6, at edge of road; augered July 1960. Altitude of land surface 2,429.6 feet; depth to water 17.5 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Silt, sandy, brown	3.5	3.5
Silt, sandy, tan	5.5	9
Sand, very fine to fine, silty	8	17
Sand, fine, well sorted, clean	5	22
Sand, fine to coarse, silty	6.5	28.5
Sand, medium to very coarse	12.5	41
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, blue gray	7.5	48.5

11-25-6add.———Sample log of test hole in SE SE NE sec. 6, T 11 S, R 25 W, 0.4 mile south of NE cor. sec. 6, at edge of road across from driveway to field; augered July 1960. Altitude of land surface 2,434.5 feet; depth to water 24.2 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Silt, sandy, tan and brown	10	10
Silt, brown	3	13

	Thickness, feet	Depth, feet
Silt, sandy, light brown	7	20
Silt, sandy, light tan	15	35
Silt, very sandy, light tan	10	45
Silt and fine to medium sand	10	55
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, gray	3.5	58.5

11-25-11aaa.———Sample log of test hole in NE NE NE sec. 11, T 11 S, R 25 W, near NE cor. sec. 11; augered July 1958. Altitude of land surface 2,390.2 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Silt, brown and tan	5	5
Silt, tan	10	15
Sand, fine	10	25
Sand, fine to coarse	15	40
Sand and gravel	5	45
Sand and gravel; contains layers of silt	5	50
Sand and silt	17	67
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale	3	70

11-25-11aad.———Sample log of test hole in SE NE NE sec. 11, T 11 S, R 25 W, 0.15 mile south of NE cor. sec. 11, at edge of road; augered July 1958. Altitude of land surface 2,366.5 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Silt, brown	5	5
Silt, tan	7	12
Silt, dark gray	3	15
Sand, fine to medium	10	25
Sand, fine to medium, and dark silt	3	28
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, gray	12	40

11-25-11ada.———Sample log of test hole in NE SE NE sec. 11, T 11 S, R 25 W, 0.3 mile south of NE cor. sec. 11, at edge of road; augered July 1958. Altitude of land surface 2,352.4 feet; depth to water 17.85 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Silt, dark brown	5	5
Silt, tan	15	20
Sand, silty	5	25
No sample	10	35
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, gray	1	36

11-25-11add.———Sample log of test hole in SE SE NE sec. 11, T 11 S, R 25 W, 0.4 mile south of NE cor. sec. 11, at edge of road; augered July 1958. Altitude of land surface 2,338.3 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Silt	5	5
Sand, silty	10	15
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale	1	16

11-25-11bbb.———Sample log of test hole in NW NW NW sec. 11, T 11 S, R 25 W, 100 feet east of bridge, at edge of road; drilled September 1960. Altitude of land surface 2,363.9 feet; depth to water 6.3 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Silt, sandy, brown	7	7
Sand, fine to coarse	5	12
Sand, medium to very coarse, and fine gravel	8	20
Sand, medium, well sorted, clean	9	29
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, gray	11	40

11-25-12bcc.———Sample log of test hole in SW SW NW sec. 12, T 11 S, R 25 W, 70 feet south of bridge, at edge of road; augered July 1958. Altitude of land surface 2,338.7 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Silt	5	5
Sand	4	9
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale	1	10

11-25-17bbb.———Sample log of test hole in NW NW NW sec. 17, T 11 S, R 25 W, 40 feet east and 10 feet south of center of crossroads; drilled August 1960. Altitude of land surface 2,553.8 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Peoria and Loveland formations		
Silt, brown	5	5
Silt, sandy, tan	12	17
Pliocene		
Ogallala Formation		
Silt, sandy, very limy, cream tan	6	23
Sand, fine to very coarse	3	26
Silt, very sandy, limy, light tan	18	44
Silt, very limy, sandy, cemented	6	50
Silt, very sandy, limy; contains cemented streaks	13	63
Sand, medium to very coarse, loose;		

	Thickness, feet	Depth, feet
contains small amount fine gravel	9	72
Silt, very sandy, very limy, cream tan; contains thin layers of bentonite	6	78
Sand, fine to very coarse, and fine gravel, clean; contains cemented streaks	9	87
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, chalky, light yellow and brown	3	90

11-25-21aad.———Sample log of test hole in SE NE NE sec. 21, T 11 S, R 25 W, near west side of bridge; hand augered June 1958. Altitude of land surface 2,466.8 feet; depth to water 14.0 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pliocene		
Ogallala Formation		
Silt, sandy, dark	3	3
Sand, clean	1	4
Sand, silty	1	5
Sand, clean; contains caliche nodules	2	7
Sand and interbedded layers of silt	5.6	12.6
Sand, clean; contains layers of caliche 0.1 foot thick at top	2.3	14.9

11-25-27aaa.———Sample log of test hole in NE NE NE sec. 27, T 11 S, R 25 W, 30 feet SW of NE cor. sec. 27; drilled August 1960. Altitude of land surface 2,537.4 feet; depth to water 71.0 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Peoria and Loveland formations		
Silt, sandy in lower part, dark brown	8	8
Pliocene		
Ogallala Formation		
Sand, silty, very limy; contains cemented streaks	4	12
Sand, fine to coarse; contains cemented streaks in upper part	13	25
Sand, fine to very coarse; contains small amount fine gravel and cemented streaks	11	36
Silt, tough; contains limy streaks and streaks of bentonitic clay	8	44
Silt, very limy, sandy; contains cemented layers	8	52
Silt, sandy, compact, tan	8	60
Silt, blocky, tan; contains thin layers of fine to coarse sand	10	70
Sand, fine to coarse; contains cemented layers of limy silt	17	87
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, orange brown and dark gray	13	100

11-25-30ddd.———Sample log of test hole in SE SE SE sec. 30, T 11 S, R 25 W, 50 feet north and 10 feet west of center of crossroads; drilled August 1960. Altitude of land surface 2,528.6 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pliocene		
Ogallala Formation		
Silt, sandy, light brown	3	3
Silt, very sandy, very limy, cream tan	9	12
Silt, very sandy, tan; contains layers of fine to coarse sand	10	22
Sand, fine to very coarse; contains small amount fine gravel and streaks of cemented limy silt	8	30
Silt, sandy, very limy, cemented	5	35
Sand, medium to coarse, clean, loose	8	43
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, chalky, brown and white	7	50

11-25-34ddd.———Sample log of test hole in SE SE SE sec. 34, T 11 S, R 25 W, 50 feet north and 10 feet west of SE cor. sec. 34; drilled September 1957. Altitude of land surface 2,555.6 feet; depth to water 76.63 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Peoria and Loveland formations		
Silt, dark brown	1	1
Silt, reddish tan	12	13
Silt, heavy, dark brown	2	15
Silt, sandy, pink and tan; contains fine to coarse sand in lower part	5	20
Pliocene		
Ogallala Formation		
Sand, fine to coarse, and gravel	4	24
Silt, yellow tan	2	26
Silt, limy, gray	2	28
Sand, medium	1	29
Silt, limy, pink	6	35
Silt, very limy, gray	8	43
Silt, limy, pink	3	46
Silt, sandy, very limy, pink and white	7	53
Silt, very limy, white and light gray	5	58
Sand, fine to coarse, silty	7	65
Silt, limy, cemented hard	2	67
Silt, sandy, very limy; contains cemented streaks in lower part	10	77
Silt, sandy, very limy, cemented	10	87
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, yellow	3	90

11-26-13ddd.———Drillers log of shot hole in SE SE SE sec. 13, T 11 S, R 26 W, Gove County (Hodson and Wahl, 1960, p. 93); drilled June 1952 by Schaetfer Geophysics. Altitude of land surface 2,540.3 feet; depth to water 37.8 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Peoria and Loveland formations		
Silt	8	8
Pliocene		
Ogallala Formation		
Sand	12	20
Sand, clayey	29	49

	Thickness, feet	*Depth, feet*
Caliche	3	52
Lime, hard; contains flint layers	13	65
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, yellow	25	90
Shale, brown	5	95

11-26-36ddd.———Sample log of test hole in SE SE SE sec. 36, T 11 S, R 26 W, Gove County, 40 feet west and 11 feet north of center of crossroads (Hodson and Wahl, 1960, p. 97); drilled September 1952. Altitude of land surface 2,584.4 feet.

	Thickness, feet	*Depth, feet*
NEOGENE		
Pleistocene		
Peoria and Loveland formations		
Silt, clayey, tan gray; contains gravel in lower part	7	7
Pliocene		
Ogallala Formation		
Clay, very sandy, tan to tan white	3	10
Sand and gravel, fine to coarse, silty to clayey, red brown; loosely cemented sand below 27 feet	18	28
Clay, sandy, tan to light tan	4	32
Sand and gravel, fine to coarse, silty	10.5	42.5
Clay, sandy and limy, light tan to white	2.5	45
Sand and gravel, fine to coarse, clayey	3.5	48.5
Clay, sandy, tan gray to gray brown	12.5	61
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Chalk, silicified, yellow to white	2.5	63.5

12-21-1ddd.———Sample log of test hole in SE SE SE sec. 1, T 12 S, R 21 W, 50 feet NW of SE cor. sec. 1; drilled October 1957. Altitude of land surface 2,284.5 feet.

	Thickness, feet	*Depth, feet*
NEOGENE		
Pliocene		
Ogallala Formation		
Silt, sandy, limy; lower part cemented	15	15
Sand, fine to coarse, and gravel; contains cemented streaks	4	19
Sand, fine to coarse	1	20
Sand, fine to coarse; contains layers of yellow silt	3	23
Sand, fine to coarse	4	27
Silt, sandy, yellow	1	28
Sand, fine to coarse, and gravel	5	33
Sand, medium to coarse, and gravel; contains thin layers of silt	5	38
Silt, tan brown	2	40
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, pink	10	50
Shale, gray and tan	5	55
Shale, dark gray	5	60

12-21-5ddd1.———Sample log of test hole in SE SE SE sec. 5, T 12 S, R 21 W, 150 feet north of SE cor. sec. 5, at edge of school yard; drilled October 1957. Altitude of land surface 2,341.2 feet.

	Thickness, feet	*Depth, feet*
NEOGENE		
Pleistocene		
Peoria and Loveland formations		
Silt, sandy, brown	4	4
Pliocene		
Ogallala Formation		
Sand, fine to coarse, and gravel	2	6
Sand, very silty, limy, cemented	5	11
Silt, very limy, white to light gray	3	14
Silt, pink	2	16
Sand, silty, limy, cemented hard	2	18
Silt and fine to coarse sand, limy, cemented hard	11	29
Silt, sandy, dark tan	4	33
Sand, fine to coarse, very silty; contains small amount fine gravel	3	36
Silt, sandy, limy, cemented hard	12	48
Sand, silty, limy; contains cemented layers	5	53
Silt, sandy, tan	3	56
Sand, fine to coarse	1	57
Silt, sandy, pink and white; contains limy streaks	5	62
Silt, sandy, gray	7	69
Sand, fine to coarse	2	71
Silt, sandy, gray and pink	14	85
Sand, fine to coarse	2	87
Silt, sandy, pink	7	94
Sand, fine to coarse, and fine gravel	7	101
Silt, sandy, gray	1	102
Sand, fine to coarse, and fine gravel	8	110
Silt, very sandy, tan	8	118
Silt and fine to coarse sand	9	127
Silt and fine sand	5	132
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, yellow	2	134
Shale, brown	6	140

12-21-14aaa.———Sample log of test hole in NE NE NE sec. 14, T 12 S, R 21 W, 60 feet west and 10 feet south of NE cor. sec. 14; drilled September 1960. Altitude of land surface 2,338.5 feet; depth to water 51.36 feet.

	Thickness, feet	*Depth, feet*
NEOGENE		
Pleistocene		
Peoria and Loveland formations		
Silt, sandy, light brown	3	3
Silt, very sandy, light tan	9	12
Pliocene		
Ogallala Formation		
Silt, sandy; contains layers of fine to coarse sand and cemented streaks	8	20
Silt, very limy, sandy, cemented	4	24
Sand, fine to coarse; contains cemented limy streaks	6	30
Silt, very sandy, limy; contains cemented streaks	4	34
Sand, fine to very coarse, and fine gravel, loose	8	42
Gravel, fine, and very coarse sand, clean	11	53
Silt, clayey, tough, greenish gray	5	58
Sand, fine to medium, contains cemented limy streaks	4	62

	Thickness, feet	Depth, feet
Silt, very sandy, very limy, cemented	10	72
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, cream brown upper part, dark gray lower part	8	80

12-22-6ddd.———Sample log of test hole in SE SE SE sec. 6, T 12 S, R 22 W, 100 feet north and 20 feet west of SE cor. sec. 6, at edge of road; drilled October 1957. Altitude of land surface 2,399.1 feet; depth to water 91.09 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Peoria and Loveland formations		
Silt, brown and tan	4	4
Silt, reddish tan	8	12
Pliocene		
Ogallala Formation		
Silt, very limy, white	1	13
Silt and fine sand	6	19
Sand, silty, limy, cemented	2	21
Sand, fine to coarse, silty	2	23
Silt, sandy, gray	5	28
Sand and gravel, silty, limy, cemented hard	11	39
Sand, fine to coarse, and pink silt; contains cemented layers	11	50
Sand, silty, limy, cemented hard	7	57
Sand, fine to coarse, silty; contains cemented streaks	3	60
Sand and gravel, silty, limy; contains cemented streaks	3	63
Silt, sandy, limy, gray; contains cemented streaks	7	70
Silt, sandy, yellow brown	5	75
Sand, fine to coarse; contains small amount medium gravel	5	80
Silt, limy, gray; contains cemented layers	6	86
Silt, sandy, gray tan	5	91
Silt, gray	3	94
Sand, fine to medium	22	116
Sand and silt, cemented hard	3	119
Silt, sandy, tan	5	124
Sand, fine; contains thin layers of gray silt	14	138
Sand, fine, very silty, limy	6	144
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, chalky, white	6	150
Shale, chalky, brown and yellow	5	155
Shale, dark gray	2	157

12-22-12bbb.———Sample log of test hole in NW NW NW sec. 12, T 12 S, R 22 W, 350 feet south and 5 feet east of center of crossroads; drilled October 1957. Altitude of land surface 2,340.4 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Peoria and Loveland formations		
Silt, dark brown	3	3
Pliocene		
Ogallala Formation		
Sand, fine to coarse; contains small amount fine gravel	2	5
Sand and gravel, silty, cemented hard	8	13
Silt, sandy; contains cemented streaks	6.5	19.5
Sand, fine to coarse, and gravel	1	20.5
Silt, sandy, very limy; contains cemented streaks	3.5	24
Sand, fine to coarse, and gravel	14	38
Sand, fine to coarse, and gravel; contains cemented layers of very limy silt	4	42
Sand, fine to coarse	6	48
Sand, fine to coarse, and gravel; contains layers of sandy silt and limy streaks	8	56
Sand, fine to coarse; contains streaks of yellow sandy silt	3	59
Sand, fine, cemented at top	6	65
Sand, fine, silty; contains a small amount of medium to coarse sand	8	73
Sand, fine, very silty; contains a small amount of medium to coarse sand	10	83
Silt, tan; contains a small amount of sand	6	89
Sand, fine to coarse; contains streaks of tan silt	6	95
Sand, fine to coarse	11	106
Sand, fine to coarse; contains layers of tan very limy silt	15	121
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, brown and dark gray	1	122

12-22-23dda.———Sample log of test hole in NE SE SE sec. 23, T 12 S, R 22 W, between highway and railroad, near fence line 90 feet north of highway; drilled October 1957. Altitude of land surface 2,366.8 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Peoria and Loveland formations		
Silt, heavy, brown	2	2
Silt, gray	2	4
Silt, reddish tan	5	9
Silt, reddish tan; contains caliche nodules	3	12
Pliocene		
Ogallala Formation		
Silt, sandy, limy; contains cemented streaks	2	14
Silt, sandy, pink	2	16
Silt, sandy, limy, cemented	4	20
Silt, sandy; contains cemented layers	10	30
Silt, sandy, cemented hard	6	36
Silt, slightly sandy, limy, gray; contains hard cemented layers	12	48
Sand, medium to coarse, and gravel	2	50
Silt, sandy, limy, tan and pink; contains a hard cemented layer at top	15	65
Silt, sandy, light tan	8	73
Sand, fine to coarse	3	76
Silt, light tan; contains a small amount of fine to coarse sand	14	90
Sand, fine, silty	7	97

	Thickness, feet	Depth, feet
Silt, pink	6	103
Silt, light tan	2	105
Silt, sandy, light tan	2	107
Silt, sandy, limy, cemented hard	1	108
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, yellow	2	110
Shale, dark gray	2	112

12-22-33ccc.———Sample log of test hole in SW SW SW sec. 33, T 12 S, R 22 W, 250 feet north of SW cor. sec. 33, at edge of road; drilled September 1960. Altitude of land surface 2,356.0 feet; depth to water 32.75 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Peoria and Loveland formations		
Silt, sandy lower part, brown and tan	11	11
Pliocene		
Ogallala Formation		
Sand, medium to very coarse; contains small amount fine gravel	9	20
Sand, medium to very coarse, and fine gravel	9	29
Silt, sandy, very limy, light gray; contains layers of fine to coarse sand in lower part	6	35
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, cream and brown upper part, dark gray lower part	15	50

12-23-3ddd.———Sample log of test hole in SE SE SE sec. 3, T 12 S, R 23 W, 250 feet north and 8 feet west of SE cor. sec. 3; drilled October 1957. Altitude of land surface 2,427.4 feet; depth to water 78.34 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Peoria and Loveland formations		
Silt, heavy, brown	2	2
Silt, tan	11	13
Pliocene		
Ogallala Formation		
Sand and caliche nodules; contains a small amount of gravel	9	22
Sand and gravel	3	25
Silt, pink	2	27
Silt, very limy, white	1	28
Sand and gravel	10	38
Silt, sandy, very limy, light gray; contains thin layers of sand	5	43
Silt, sandy, cemented hard	7	50
Silt, sandy, and fine sand, cemented	10	60
Sand, fine	3	63
Silt, sandy, limy, cemented hard	3	66
Silt, sandy, gray and pink	10	76
Sand, fine, and pink and light gray limy silt	4	80
Sand, fine to coarse, and gravel; contains thin layers of yellow silt	6	86
Silt, limy, white to yellow; sandy in upper part	9	95
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, dark gray	5	100

12-23-5bbb.———Sample log of test hole in NW NW NW sec. 5, T 12 S, R 23 W, 120 feet south of bridge; hand augered July 1958. Altitude of land surface 2,385.0 feet; depth to water 7.1 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pliocene		
Ogallala Formation		
Soil and silt, dark brown	5.8	5.8
Sand, coarse, and interbedded dark silt	1.5	7.3
Sand, coarse, silty	3.1	10.4

12-23-7bbb.———Drillers log of test hole in NW NW NW sec. 7, T 12 S, R 23 W, 2 miles west of WaKeeney; drilled July 1954 by Elmer Corder.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene and Pliocene (undifferentiated)		
Top, dark	4	4
Clay	6	10
Limestone, soft	9	19
Sand, fine	1	20
Limestone, soft	25	45
Limestone, hard	1	46
Sand	1	47
Limestone, hard	2	49
Limestone, soft	3	52
Limestone, hard	4	56
Limestone, soft	1	57
Clay	9	66
Sand	1	67
Limestone, hard	7	74
Sand and clay	1	75
Clay	2	77
Clay and sand	2.5	79.5
Rock, cemented hard	1	80.5
Limestone, hard	3	83.5
Limestone and sand	3	86.5
Limestone, hard	0.5	87
Sand	1.5	88.5
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Ochre	5	93.5

12-23-20ccc2.———Sample log of test hole in SW SW SW sec. 20, T 12 S, R 23 W, 75 feet north and 30 feet east of SW cor. sec. 20; drilled September 1960. Altitude of land surface 2,373.1 feet; depth to water 19.03 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Silt, dark brown	5	5
Silt, sandy, light brown	5	10
Silt, sandy; contains limy streaks	5	15
Silt, sandy, tough	7	22

	Thickness, feet	Depth, feet
Sand, medium to coarse, well sorted, clean, loose	5	27
Sand, very coarse, and fine gravel, clean, loose	3	30
Silt, dark blue gray	2	32
Sand, fine to coarse, loose; contains small amount fine gravel	6	38
Silt, clayey; contains streaks of sandy silt	13	51
Sand, fine to very coarse, loose	14	65
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, chalky, weathered, light gray	3	68

12-23-21ddd.———Drillers log of test hole in SE SE SE sec. 21, T 21 S, R 23 W, drilled July 1954 by Elmer Corder.

	Thickness, feet	Depth, feet
NEOGENE		
Pliocene		
Ogallala Formation		
Top, dark	5	5
Clay	21	26
Silt, black	5	31
Clay, sandy	27	58
Clay and sand	2	60
Limestone	8	68
Clay	2	70
Clay, sandy	4	74
Sand	25	99
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Clay, yellow	4	103
Shale, dark gray	10	113

12-23-22bcc.———Drillers log of test hole in SW SW NW sec. 22, T 12 S, R 23 W, by 3rd R.E.A. pole north of Erickson house; drilled July 1954 by Elmer Corder.

	Thickness, feet	Depth, feet
NEOGENE		
Pliocene		
Ogallala Formation		
Clay	10	10
Limestone, soft	2	12
Limestone and sand	4	16
Clay	2	18
Sand	7	25
Limestone and sand	44	69
Clay	5	74
Sand	16	90
Clay, sandy	20	110
Sand	8	118
Clay and limestone	3	121
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Ochre	2	123

12-23-22cbb.———Drillers log of test hole in NW NW SW sec. 22, T 12 S, R 23 W, NW of pasture south of Erickson house; drilled July 1954 by Elmer Corder.

	Thickness, feet	Depth, feet
NEOGENE		
Pliocene		
Ogallala Formation		
Top, dark to light	19	19
Clay, gray	7	26
Limestone, sandy	9	35
Clay, sandy	8	43
Sand, medium, good	24	67
Sand, cemented	5	72
Clay	4	76
Clay, light	2	78
Clay, sandy, brown	4	82
Limestone and sand	6	88
Sand, medium, good	19	107
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Ochre and gray shale	6	113

12-23-25ccc.———Sample log of test hole in SW SW SW sec. 25, T 12 S, R 23 W, 50 feet north and 10 feet east of center of crossroads; augered July 1960. Altitude of land surface 2,333.7 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Silt, brown	3.5	3.5
Silt, sandy, brown	6.5	10
Silt, sandy, and fine to medium sand	7	17
Silt, sandy, tan	7	24
Silt, sandy, brown	6	30
Silt, very sandy, gray brown	5	35
Silt, sandy, gray brown	10	45
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, blue gray	3.5	48.5

12-23-27ccc.———Sample log of test hole in SW SW SW sec. 27, T 12 S, R 23 W, 50 feet east and 10 feet north of center of crossroads; drilled October 1957. Altitude of land surface 2,331.5 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Silt, sandy, light brown	2	2
Sand and gravel	2	4
Silt, gray	2	6
Sand and gravel	1	7
Silt, gray	1	8
Sand and gravel; contains layers of dark blue-gray silt	10	18
Sand and gravel	4	22
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, weathered, white to tan	12	34
Shale, dark brown	2	36

12-23-28aad.———Drillers log of test hole in SE NE NE sec. 28, T 12 S, R 23 W, near 3rd telephone pole south of Dietz house; drilled July 1954 by Elmer Corder.

	Thickness, feet	Depth, feet
NEOGENE		
Pliocene		
Ogallala Formation		
Clay, yellow	13	13
Clay, brown	27	40
Sand	3	43
Clay, sandy	5	48
Sand	24	72
Clay, sandy, brown	4	76
Sand, fine to medium	31	107
Limestone	1	108
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Ochre	4	112
Shale, brown	11	123

12-23-28dda.———Sample log of test hole in NE SE SE sec. 28, T 12 S, R 23 W, 100 feet south of bluff on north side of valley; drilled October 1957. Altitude of land surface 2,335.1 feet; depth to water 12.15 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Silt, sandy, dark brown; contains thin layers of sand and gravel in lower part	10	10
Silt, sandy, light brown	2	12
Silt, sandy, limy, gray	1	13
Sand, fine to coarse, and gravel	3	16
Silt, dark blue gray	2	18
Silt, dark blue gray; contains thin layers of fine to coarse sand	5	23
Sand, fine to coarse, and gravel	9	32
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, weathered, white	16	48
Shale, brown and dark gray	2	50

12-23-28ddd.———Sample log of test hole in SE SE SE sec. 28, T 12 S, R 23 W, halfway between valley bluff and creek, at edge of road; drilled October 1957. Altitude of land surface 2,333.6 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Silt, very sandy, dark brown	7	7
Sand, fine to coarse, and gravel	19	26
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, weathered, white	19	45
Shale, dark gray	2	47

12-23-30acc2.———Sample log of test hole in SW SW NE sec. 30, T 12 S, R 23 W, 60 feet west of irrigation well; drilled September 1960. Altitude of land surface 2,389.0 feet; depth to water 30.95 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Silt, very sandy, tan	2	2
Sand, fine to very coarse, loose; contains small amount fine gravel	9	11
Silt, clayey, light brown	14	25
Sand, fine to very coarse, loose; contains small amount fine gravel	5	30
Silt, sandy, tan; contains cemented limy layers	4	34
Silt, dark blue gray	5	39
Sand, fine to very coarse, and fine to medium gravel, loose	11	50
Sand, fine; contains small amount medium to coarse sand and streaks of sandy silt	10	60
Sand, fine to very coarse, loose; contains small amount fine gravel	22	82
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, cream and brown upper part, gray lower part	8	90

12-23-34bbc.———Sample log of test hole in SW NW NW sec. 34, T 12 S, R 23 W, 700 feet south of Big Creek, at edge of road; drilled October 1957. Altitude of land surface 2,329.5 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Silt, dark brown	3	3
Sand, fine to coarse, and gravel, clean	18	21
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, dark brown	9	30

12-23-35daa.———Sample log of test hole in NE NE SE sec. 35, T 12 S, R 23 W, 0.45 mile north of SE cor. sec. 35, 300 feet north of bridge, at edge of road; augered July 1960. Altitude of land surface 2,316.9 feet; depth to water 18.0 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Silt, sandy, tan	10	10
Silt, brown	5	15
Silt, sandy, tan brown	5	20
Silt, clayey, tough	5	25
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, blue gray	3.5	28.5

12-23-35dda.———Sample log of test hole in NE SE SE sec. 35, T 12 S, R 23 W, 0.2 mile north of SE cor. sec. 35, at edge of road; augered July 1960. Altitude of land surface 2,318.0 feet; depth to water 15.7 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Silt, brown	5	5
Silt, sandy, brown	7	12
Silt, clayey; contains limy streaks	3	15

	Thickness, feet	Depth, feet
Sand, silty, limy	5	20
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, blue gray	3.5	23.5

12-23-36bbc.———Sample log of test hole in SW NW NW sec. 36, T 12 S, R 23 W, 0.25 mile south of NW cor. sec. 36, at edge of road near driveway to field; augered July 1960. Altitude of land surface 2,337.7 feet; depth to water 18.5 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Silt, brown	3.5	3.5
Silt, sandy, light brown	6.5	10
Silt, sandy, clayey, tan	8	18
Clay, silty, tough	4	22
Sand, fine to medium; contains thin layers of silt	11	33
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, blue gray	5.5	38.5

12-23-36cbc.———Sample log of test hole in SW NW SW sec. 36, T 12 S, R 23 W, 0.32 mile north of SW cor. sec. 36, 50 feet south of bridge, at edge of road; augered July 1960. Altitude of land surface 2,301.5 feet; depth to water 3.95 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Silt, sandy, brown	3	3
Sand, medium to coarse	13	16
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, blue gray	2.5	18.5

12-24-1dcc.———Drillers log of test hole in SW SW SE sec. 1, T 12 S, R 24 W, 2.5 miles west of WaKeeney; drilled July 1954 by Elmer Corder.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene and Pliocene (undifferentiated)		
Top, dark	5	5
Clay, brown	10	15
Clay, sandy	11	26
Clay, gray	17	43
Limestone, soft	4	47
Clay	16	63
Clay, sandy	3	66
Limestone	1	67
Sand	3	70
Limestone and sand	1	71
Limestone, cemented hard	4	75
Sand, cemented hard	5	80
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Ochre	3	83

12-24-8ddc.———Sample log of test hole in SW SE SE sec. 8, T 12 S, R 24 W, 0.23 mile west of SE cor. sec. 8, at edge of road; drilled September 1957. Altitude of land surface 2,507.2 feet; depth to water 77.47 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Peoria and Loveland formations		
Silt, reddish brown	8	8
Silt, sandy	3	11
Pliocene		
Ogallala Formation		
Sand, fine to coarse; contains thin layers of very limy silt	4	15
Sand, fine to coarse, and gravel; contains thin layers of silt	5	20
Sand, fine to coarse; contains a hard cemented layer 25 to 26 feet	11	31
Silt, gray and pink	6	37
Silt, pink; contains cemented streaks	9	46
Silt, limy, gray; contains cemented streaks	11	57
Sand and gravel; contains thin layers of silt and cemented streaks	4	61
Silt and sand, cemented hard	4	65
Sand, fine, and limy silt; contains cemented layers	6	71
Sand, fine, and gray silt	8	79
Silt and sand, limy, cemented hard	2	81
Sand, fine, silty	17	98
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, weathered, white	1	99
Shale, weathered, yellow and white	6	105
Shale, yellow and brown	4	109
Shale, brown and gray	5	114

12-24-9bcc.———Drillers log of test hole in SW SW NW sec. 9, T 12 S, R 24 W, drilled by Kansas Highway Department. Depth to water 19.8 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene and Pliocene (undifferentiated)		
Silt and clay	6.8	6.8
Sand and clay	3.7	10.5
Sand and caliche	1.5	12.0
Sand	2.7	14.7
Clay and sand	10.3	25.0
Sand; contains clay and caliche	2.7	27.7
Sand and clay; contains limy layers	14.8	42.5
Sand and limy silt	7.2	49.7
(Lost circulation)	2.6	52.3

12-24-13aaa.———Sample log of test hole in NE NE NE sec. 13, T 12 S, R 24 W, 75 feet south and 8 feet west of NE cor. sec. 13; drilled September 1957. Altitude of land surface 2,462.1 feet; depth to water 74.0 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Peoria and Loveland formations		
Silt, dark brown	1	1
Silt, gray and tan	4	5
Silt, reddish tan	4	9
Silt, dark tan, and fine to medium sand	1	10

	Thickness, feet	*Depth, feet*
Silt, sandy, light tan	5	15
Pliocene		
Ogallala Formation		
Silt, very limy, light gray, and fine to coarse sand	3	18
Sand, fine to coarse, and tan silt	5	23
Silt, very limy, sandy, white	2	25
Sand, medium to coarse	2	27
Sand and silt, very limy, cemented hard	13	40
Sand and silt, cemented very hard	3	43
Sand, medium to coarse, and gravel	5	48
Silt, sandy, light tan	2	50
Sand, fine to coarse, silty	2	52
Silt and sand, very limy, cemented	6	58
Silt, gray to tan	2	60
Silt, sandy, gray to tan	10	70
Sand, fine; contains thin layers of tan silt	18	88
Sand, fine, and green silt	4	92
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, weathered, gray and white	5	97
Shale, brown and dark gray	3	100

12-24-30bcc1.———Sample log of test hole in SW SW NW sec. 30, T 12 S, R 24 W, 0.48 mile south of NW cor. sec. 30, at edge of road; drilled August 1960. Altitude of land surface 2,445.4 feet; depth to water 7.6 feet.

	Thickness, feet	*Depth, feet*
NEOGENE		
Pleistocene		
Alluvium		
Silt, sandy lower part, dark brown	8	8
Sand, fine to very coarse; silty streaks upper 2 feet, very clean lower part	12	20
Sand, medium to coarse, well sorted, clean, loose	8	28
Silt, sandy, compact, tan	12	40
Silt, sandy; contains thin layers of fine to medium sand	8	48
Sand, fine to medium, loose	3	51
Pliocene		
Ogallala Formation		
Sand, fine to medium; contains cemented layers of sandy silt	9	60
Sand, fine to medium, cemented	15	75
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, dark gray	5	80

12-24-32ddd.———Sample log of test hole in SE SE SE sec. 32, T 12 S, R 24 W, 50 feet north and 10 feet west of center of crossroads; drilled August 1960. Altitude of land surface 2,512.9 feet.

	Thickness, feet	*Depth, feet*
NEOGENE		
Pleistocene		
Peoria and Loveland formations		
Silt, dark brown	10	10
Pliocene		
Ogallala Formation		
Silt, very sandy, limy, cemented	6	16
Sand, fine to coarse, clean	8	24
Silt, sandy, very limy; contains bentonitic clay streaks	6	30
Silt, tough, limy; contains thin layers of fine to coarse sand and cemented streaks	10	40
Silt, limy, cemented, lower part very sandy	10	50
Silt, very limy, cemented; contains thin layers of fine to very coarse sand	13	63
Gravel, fine, and very coarse sand, clean, loose	7	70
Sand, coarse to very coarse, and fine gravel, very clean, loose	30	100
Sand, fine to coarse, clean, loose	10	110
Sand, fine to medium, clean, loose	16	126
Sand, fine to medium; contains cemented layers	14	140
Sand, fine to coarse, clean	10	150
Sand, fine, loose	10	160
Sand, fine to coarse, clean, loose	10	170
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, blue gray and black	20	190

12-25-7ddd.———Sample log of test hole in SE SE SE sec. 7, T 12 S, R 25 W, 50 feet north and 10 feet west of center of crossroads; drilled August 1960. Altitude of land surface 2,581.8 feet.

	Thickness, feet	*Depth, feet*
NEOGENE		
Pleistocene		
Peoria and Loveland formations		
Silt, very sandy lower part, brown and tan	12	12
Pliocene		
Ogallala Formation		
Silt, sandy, limy, very limy lower part	8	20
Silt, sandy, tan; contains limy streaks	15	35
Sand, fine to very coarse, and fine gravel, loose	15	50
Silt, sandy, very limy; contains streaks of bentonite and hard cemented layers	7	57
Sand, fine to very coarse; contains cemented limy silt layers	13	70
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, brown and orange tan	4	74

12-25-9add.———Drillers log of test hole in SE SE NE sec. 9, T 12 S, R 25 W; drilled by Kansas Highway Department. Altitude of land surface 2,544.1 feet.

	Thickness, feet	*Depth, feet*
NEOGENE		
Pleistocene and Pliocene (undifferentiated)		
Soil and silt	12.2	12.2
(no sample)	3.9	16.1
Sand and caliche	2.5	18.6
Sand and gray clay	1.7	20.3
Sand and caliche	6.2	26.5
Caliche and clay	1.0	27.5

	Thickness, feet	Depth, feet
Sand	9.5	37.0
Sand and gravel	1.3	38.3
Sand and clay	10.2	48.5
Sand; contains caliche nodules	2.4	50.9
Sand, caliche, and limy silt	1.3	52.2

12-25-9bcc.———Drillers log of test hole in SW SW NW sec. 9, T 12 S, R 25 W, drilled by Kansas Highway Department. Altitude of land surface 2,496.5 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene and Pliocene (undifferentiated)		
Silt and clay	12.6	12.6
Sand and clay	6.0	18.6
Sand and caliche	2.1	20.7
(no sample)	6.6	27.3
Mortar bed	8.4	35.7
Sand	4.2	39.9
Sand and clay	8.8	48.7
Mortar bed	7.2	55.9
Sand and clay; contains cemented layers	36.8	92.7

12-25-10adc.———Drillers log of test hole in SW SE NE sec. 10, T 12 S, R 25 W; drilled by Kansas Highway Department. Altitude of land surface 2,539.2 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene and Pliocene (undifferentiated)		
Silt, clay, and caliche nodules	23.3	23.3
Sand, coarse, and clay layers	2.5	25.8
Sand, coarse, and gravel; contains clay layers	1.2	27.0
Sand, medium to coarse; contains caliche nodules	14.9	41.9
Sand and gray clay	0.4	42.3

12-25-15aaa.———Sample log of test hole in NE NE NE sec. 15, T 12 S, R 25 W, 20 feet south and 10 feet west of NE cor. sec. 15; drilled September 1957. Altitude of land surface 2,534.6 feet; depth to water 54.7 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Peoria and Loveland formations		
Silt, brown and gray	6	6
Silt, reddish tan	8	14
Silt, reddish; contains limy streaks	1	15
Pliocene		
Ogallala Formation		
Sand, silty, very limy	8	23
Silt, very limy, white, and fine sand	6	29
Sand, fine to coarse	11	40
Silt, sandy, very limy, light tan and pink	8	48
Silt, sandy, very limy, white; contains cemented streaks	8	56
Sand, medium to coarse	1	57
Sand, limy, cemented hard	2	59
Sand, fine, and very limy silt	11	70
Sand, medium to coarse, and very limy silt	8	78
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, yellow	21	99
Shale, brown and dark gray	4	103

12-25-18bbb.———Sample log of test hole in NW NW NW sec. 18, T 12 S, R 25 W; drilled September 1957. Altitude of land surface 2,583.5 feet; depth to water 57.68 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Peoria and Loveland formations		
Silt, dark brown	2	2
Silt, reddish tan	12	14
Silt, very sandy, reddish brown; contains a very limy layer at 16 feet	4	18
Pliocene		
Ogallala Formation		
Silt, very limy, and fine to coarse sand	6	24
Silt, sandy, limy; contains cemented streaks	6	30
Sand, fine, and pink silt	4	34
Silt, very limy, and fine sand	4	38
Silt, pink, and fine sand	3	41
Silt, limy, pink and white, and fine sand	5	46
Sand, fine to coarse	1	47
Silt, sandy, limy, brown and white; contains cemented streaks	2	49
Sand and silt, cemented very hard	3	52
Sand, fine to coarse, and limy silt	4	56
Sand, fine to coarse, limy; contains cemented streaks	6	62
Sand and gravel, very limy, cemented	9	71
Silt, sandy, red tan and white	1	72
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, weathered, yellow and white	6	78
Shale, brown and dark gray	2	80

12-25-24ddd.———Sample log of test hole in SE SE SE sec. 24, T 12 S, R 25 W, 40 feet north and 10 feet west of center of crossroads; drilled August 1960. Altitude of land surface 2,449.1 feet; depth to water 14.6 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Silt, sandy, lower part, brown and tan	10	10
Silt, sandy, heavy, tough	5	15
Sand, fine to very coarse	5	20
Sand, medium to very coarse, clean, loose	10	30
Sand, fine to very coarse, loose; contains small amount fine gravel	10	40
Sand, fine to medium, well sorted, clean, loose	18	58
Pliocene		
Ogallala Formation		
Silt, sandy, very limy; contains thin layers of fine to coarse sand and cemented streaks	14	72

	Thickness, feet	*Depth, feet*
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, brown and gray	8	80

12-25-25ada.———Sample log of test hole in NE SE NE sec. 25, T 12 S, R 25 W, 0.3 mile south of NE cor. sec. 25 and 20 feet west of road center; drilled August 1960. Altitude of land surface 2,445..5 feet; depth to water 10.7 feet.

	Thickness, feet	*Depth, feet*
NEOGENE		
Pleistocene		
Alluvium		
Silt, dark brown	10	10
Silt, sandy, light brown	7	17
Sand, medium to very coarse, and fine gravel, clean, loose	8	25
Sand, fine to very coarse, clean, loose	9	34
Sand, fine to medium, loose; contains brown blocky silt from 34 to 36 feet and from 46 to 47 feet; lower part contains cemented layers	14	48
Pliocene		
Ogallala Formation		
Silt, sandy, tan	12	60
Silt, very limy	2	62
Sand, fine to medium	2	64
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, brown and gray	6	70

12-25-31ddd.———Sample log of test hole in SE SE SE sec. 31, T 12 S, R 25 W, 50 feet north and 10 feet west of center of crossroads; drilled August 1960. Altitude of land surface 2,568.2 feet.

	Thickness, feet	*Depth, feet*
NEOGENE		
Pleistocene		
Peoria and Loveland formations		
Silt, sandy, light tan	9	9
Pliocene		
Ogallala Formation		
Silt, very sandy, tough; contains limy streaks	11	20
Silt, sandy, limy; contains layers of fine to coarse sand	15	35
Sand, fine to very coarse; contains thin layers of cemented silt	12	47
Silt, sandy, very limy, cemented hard	3	50
Sand, fine to very coarse, and fine gravel; contains cemented streaks of limy silt	5	55
Silt, very limy, cemented hard	3	58
Sand, medium to very coarse, and fine gravel, clean, loose	9	67
Silt, very limy, cemented hard	2	69
Gravel, fine and very coarse sand, clean, loose	7	76
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, chalky, orange and cream tan	14	90

13-21-5bbc.———Drillers log of test hole in SW NW NW sec. 5, T 13 S, R 21 W, drilled June 1961 by Bureau of Reclamation. Altitude of land surface 2,268.7 feet; depth to water 20.2 feet.

	Thickness, feet	*Depth, feet*
NEOGENE		
Pleistocene		
Peoria and Loveland formations		
Silt, reddish brown	10	10
Terrace deposits of Nebraskan(?) age		
Sand, fine to medium; contains small amount coarse sand and fine gravel	16	26
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Chalk, weathered, yellow	24	50
Niobrara Chalk—Fort Hays Limestone Member		
Chalk, gray	21	71

13-21-7aaa.———Sample log of test hole in NE NE NE sec. 7, T 13 S, R 21 W, near bridge; hand augered June 1958. Altitude of land surface 2,233.4 feet; dry hole.

	Thickness, feet	*Depth, feet*
NEOGENE		
Pleistocene		
Peoria and Loveland formations		
Silt, sandy, dark brown	2.5	2.5
Silt, sandy, tan	1.1	3.6
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Sand, fine to coarse, silty	3.6	7.2
Silt, light tan	0.1	7.3
Sand, fine to coarse, silty	0.7	8.0
Silt, very sandy	1.6	9.6
Sand, fine, clean	0.3	9.9
Sand, silty, tan	0.3	10.2
Sand, fine to medium, clean	1.0	11.2
Sand, fine, and grayish-green silt	1.7	12.9
Sand, medium to coarse, slightly cemented	3.0	15.9
Sand, medium to coarse, and coarse gravel; contains cemented layers	0.9	16.8
Silt, sandy, dark brown	1.4	18.2

13-21-8abb.———Drillers log of test hole in NW NW NE sec. 8, T 13 S, R 21 W, drilled June 1961 by Bureau of Reclamation. Altitude of land surface 2,249.3 feet.

	Thickness, feet	*Depth, feet*
NEOGENE		
Pleistocene		
Peoria and Loveland formations		
Silt, light brown	7	7
Silt, dark brown	3	10
Silt, reddish brown	8	18
Silt, sandy, reddish brown	12	30
Terrace deposits of Nebraskan(?) age		
Sand, medium to coarse, clean	2	32
Clay, brown	1	33
Sand, medium, clean	2	35
Clay, light brown	2	37
Sand, medium, silty	1	38
Sand, clean	4	42
Sand, fine to coarse, clean	5	47
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		

	Thickness, feet	Depth, feet
Chalk, weathered, yellow	47	58
Niobrara Chalk—Fort Hays Limestone Member		
Chalk, gray	15	73

13-21-8dad.———Drillers log of test hole in SE NE SE sec. 8, T 13 S, R 21 W, drilled June 1961 by Bureau of Reclamation. Altitude of land surface 2,223.2 feet; depth to water 43.0 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Silt, light brown	4	4
Silt, reddish brown	20	24
Sand, fine to medium, clean	2	26
Sand, very fine, silty	1	27
Sand, fine to medium, clean	5	32
Sand, medium to coarse, clean	1	33
Silt, sandy, brown	4	37
Sand, fine, silty	5	42
Sand, fine to medium, clean	3	45
Sand, fine, silty	4	49
Volcanic ash, very light gray; lower 0.2 foot contains brown clay	1	50
Sand, fine to medium, clean	12	62
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Fort Hays Limestone Member		
Chalk, hard, gray	48	110
Carlile Shale		
Shale, very dark gray	31	141

13-21-8ddd.———Sample log of test hole in SE SE SE sec. 8, T 13 S, R 21 W, 50 feet west and 10 feet north of center of crossroads; drilled September 1960. Altitude of land surface 2,205.9 feet; depth to water 28.2 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Silt, sandy, brown; lower part light brown	9	9
Silt, heavy, dark brown	3	12
Silt, clayey, tough, light brown	13	25
Sand, medium to very coarse, clean, loose; contains small amount fine gravel	11	36
Silt, heavy, dark blue gray	6	42
Gravel, fine to medium, and very coarse sand	3	45
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, light gray upper part, gray lower part; contains hard cemented layer upper 2 feet	15	60

13-21-16bab.———Drillers log of test hole in NW NE NW sec. 16, T 13 S, R 21 W, drilled July 1961 by Bureau of Reclamation. Altitude of land surface 2,213.4 feet; depth to water 49.7 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Silt, light brown	8	8
Silt, reddish brown	7	15
Sand, fine to medium, clean	6	21
Silt, compact	8	29
Sand, fine to medium, clean	19	48
Silt, light brown	20	68
Sand, clean	1	69
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Fort Hays Limestone Member		
Limestone, shaly, gray	34	103
Carlile Shale		
Shale, very dark gray	22	125

13-21-16bcb.———Sample log of test hole in NW SW NW sec. 16, T 13 S, R 21 W, 0.27 mile south of NW cor. sec. 16, at edge of driveway to farm home; drilled September 1960. Altitude of land surface 2,203.0 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Silt, sandy lower part, light brown	10	10
Silt, very sandy, light tan	10	20
Sand, medium to very coarse, and fine gravel; upper part contains limy silt layers; lower 2 feet cemented	8	28
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, gray	12	40

13-21-16cbc.———Sample log of test hole in SW NW SW sec. 16, T 13 S, R 21 W, 0.3 mile north of SW cor. sec. 16, 35 feet south of bridge, at edge of road; augered July 1960. Altitude of land surface 2,173.0 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Sand, medium to coarse, clean	3	3
Sand, coarse to very coarse, clean	5	8
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, blue gray	5.5	13.5

13-21-16dad.———Drillers log of test hole in SE NE SE sec. 16, T 13 S, R 21 W, drilled August 1961 by Bureau of Reclamation. Altitude of land surface 2,190.3 feet; depth to water 29.8 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Silt, brown	6	6
Silt, sandy, brown; contains small amount of chalk gravel at base	2	8

	Thickness, feet	Depth, feet
Silt, sandy, brown	17	25
Sand, fine to medium, and chalk gravel	2	27
Sand, fine, silty	5	32
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Fort Hays Limestone Member		
Chalk, weathered, light yellow	34	66
Carlile Shale		
Shale, very dark gray; contains 0.5 foot fine sand at top	3	69

13-21-16dbb.———Drillers log of test hole in NW NW SE sec. 16, T 13 S, R 21 W, drilled July 1961 by Bureau of Reclamation. Altitude of land surface 2,183.9 feet; depth to water 20.6 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Silt, clayey	2	2
Silt, light brown	5	7
Silt, very dark brown	4	11
Silt, dark gray	9	20
Silt, dark brown	7	27
Silt, very dark brown	4	31
Sand, fine to medium, clean	9	40
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Fort Hays Limestone Member		
Chalk, yellow and light gray	28	68
Carlile Shale		
Shale, very dark gray	23	91

13-21-16dda.———Drillers log of test hole in NE SE SE sec. 16, T 13 S, R 21 W, drilled August 1961 by Bureau of Reclamation. Altitude of land surface 2,187.3 feet; depth to water 26.0 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Silt, dark brown	2	2
Silt, brown	25	27
Silt, sandy, light brown	3	30
Silt, brown	4	34
Silt, dark brown	3	37
Silt, brown	3	40
Silt, sandy, very dark brown	7	47
Sand, fine to medium, clean	13	60
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Fort Hays Limestone Member		
Chalk, weathered, dark gray	2	62
Carlile Shale		
Shale	2	64

13-21-17daa.———Sample log of test hole in NE NE SE sec. 17, T 13 S, R 21 W, 0.45 mile north of SE cor. sec. 17, 500 feet north of bridge, at edge of road; augered July 1960. Altitude of land surface 2,186.0 feet; depth to water 15.35 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Sand, very fine, silty	3.5	3.5
Sand, fine to medium, silty	6.5	10
Silt, heavy, tan brown	2	12
Sand, medium to coarse, clean	4	16
Sand, medium to very coarse, clean	9	25
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, chalky, light gray	3.5	28.5

13-21-17dda.———Sample log of test hole in NE SE SE sec. 17, T 13 S, R 21 W, 0.18 mile north of SE cor. sec. 17, 250 feet south of driveway to farm home, at edge of road; augered July 1960. Altitude of land surface 2,193.3 feet; depth to water 20.1 feet.

	Thickness, feet	Depth, feet
Road fill	5	5
NEOGENE		
Pleistocene		
Alluvium		
Silt, tan brown	8.5	13.5
Silt, light tan	5	18.5
Silt, sandy, tan; contains streaks of silty clay	1.5	20
Sand, fine to coarse, silty	5	25
Silt, clayey, tan	2	27
Sand, medium to very coarse, clean	13	40
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, chalky, light blue gray	3.5	43.5

13-21-20aad.———Sample log of test hole in SE NE NE sec. 20, T 13 S, R 21 W, 0.2 mile south of NE cor. sec. 20, at edge of road; augered July 1960. Altitude of land surface 2,209.6 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Silt, brown	5	5
Silt, sandy, tan brown	2	7
Silt, clayey, tan; contains small amount sand	8	15
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Clay, limy, pink and gray (weathered chalk)	5	20
Shale, chalky, blue gray	3.5	23.5

13-21-21bbb.———Sample log of test hole in NW NW NW sec. 21, T 13 S, R 21 W, 25 feet south and 8 feet east of center of crossroads; augered July 1960. Altitude of land surface 2,197.6 feet; depth to water 22.65 feet.

	Thickness, feet	Depth, feet
Road fill	3.5	3.5
NEOGENE		
Pleistocene		
Alluvium		
Silt, tan brown	5	8.5
Silt, slightly sandy, tan	6.5	15
Silt, tough, tan brown	10	25

	Thickness, feet	Depth, feet
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Clay (weathered chalk)	10	35
Chalk, light gray	8.5	43.5

13-21-26ddd.———Sample log of test hole in SE SE SE sec. 26, T 13 S, R 21 W, 150 feet north of SE cor. sec. 26, at edge of road; drilled September 1960. Altitude of land surface 2,308.2 feet; depth to water 23.65 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pliocene		
Ogallala Formation		
Silt, sandy, light brown	10	10
Sand, fine to coarse; contains limy layers	5	15
Silt, sandy, limy, cemented	5	20
Sand, fine, very silty, limy	10	30
Sand, fine to medium, silty, cemented	10	40
Sand, fine to coarse, limy, cemented	8	48
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, dark gray	7	55

13-21-29ada.———Drillers log of test hole in NE SE NE sec. 29, T 13 S, R 21 W, drilled July 1961 by Bureau of Reclamation. Altitude of land surface 2,384.0 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pliocene		
Ogallala Formation		
Limestone, hard, light gray	5	5
Silt, sandy, lightly cemented	7	12
Sand, fine to medium, loose	11	23
Sand, fine, and silt; contains limy layers	5	28
Sand, fine; contains cemented limy layers	18	46
Limestone, sandy, hard, very light gray	6	52
Silt, sandy; contains cemented layers	4	56
Limestone, sandy, hard, gray	4	60
Silt, limy, gray	2	62
Silt, sandy; contains cemented layers	5	67
Sand, fine to medium	1	68
Silt, sandy, gray	1	69
Silt, light yellow	3	72
Silt, sandy, light green	6	78
Sand, fine to medium, loose	16	94
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Chalk, gray to white	46	140

13-21-31bbb.———Sample log of test hole in NW NW NW sec. 31, T 13 S, R 21 W, 25 feet east and 10 feet south of center of crossroads; drilled September 1960. Altitude of land surface 2,360.0 feet; depth to water 28.5 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pliocene		
Ogallala Formation		
Sand, fine to very coarse, and fine gravel; upper 2 feet silty, lower part cemented	10	10
Silt, limy, sandy, cemented	10	20
Sand, medium to very coarse, and fine to medium gravel	10	30
Silt, clayey, tough	10	40
Sand, fine to very coarse, and fine gravel; contains limy streaks	7	47
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, clayey, weathered, light tan	13	60
Shale, chalky, light gray	10	70
Shale, chalky, gray	5	75

13-22-8aad.———Sample log of test hole in SE NE NE sec. 8, T 13 S, R 22 W, near edge of terrace, at edge of road; drilled October 1957. Altitude of land surface 2,280.6 feet; depth to water 15.6 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Silt, brown	3	3
Silt, tan	4	7
Silt, dark brown	1	8
Silt, tan	4	12
Sand, fine to coarse, and gravel	3	15
Silt, brown	7	22
Silt, blue gray	3	25
Silt, brown	3	28
Silt, blue gray	6	34
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Limestone, shaly, gray	6	40

13-22-8ada.———Sample log of test hole in NE SE NE sec. 8, T 13 S, R 22 W, 200 feet south of bridge, at edge of road; drilled October 1957. Altitude of land surface 2,277.3 feet; depth to water 9.05 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Silt, sandy, dark brown	5	5
Sand, fine, silty	5	10
Sand, fine to coarse	6	16
Silt, blue gray	9	25
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Limestone, shaly, gray	5	30

13-22-8add.———Sample log of test hole in SE SE NE sec. 8, T 13 S, R 22 W, at edge of road; drilled October 1957. Altitude of land surface 2,273.9 feet; depth to water 8.94 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Sand, fine, and dark tan silt	4	4

	Thickness, feet	Depth, feet
Silt, dark tan; contains thin layers of chalk gravel	7	11
Sand, fine to coarse	8	19
Sand, fine to coarse, and chalk gravel; contains layer of blue-gray silt	11	30
Sand, fine to coarse; contains a small amount of blue-gray silt	7	37
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, dark gray	8	45

13-22-12bbb.———Sample log of test hole in NW NW NW sec. 12, T 13 S, R 22 W; drilled October 1957. Altitude of land surface 2,281.0 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Peoria and Loveland formations		
Silt, dark brown	3	3
Silt, tan	6	9
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Sand and gray silt, limy; contains cemented streaks	4	13
Silt, sandy, tan	4	17
Sand, fine to coarse	2	19
Silt, sandy, tan	2	21
Silt, sandy, tan; contains cemented limy layers	4	25
Sand, fine to medium, and tan silt; contains cemented limy layers	4	29
Silt, sandy, light tan; contains cemented limy layers	7	36
Sand, coarse, and yellow silt	1	37
Sand, fine to coarse, and chalk gravel; contains cemented limy silt	5	42
Gravel, chalk, and medium to coarse sand	5	47
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, weathered, yellow	1	48
Shale, dark gray	2	50

13-22-29ccc.———Sample log of test hole in SW SW SW sec. 29, T 13 S, R 22 W, 25 feet east and 10 feet north of center of crossroads; drilled September 1960. Altitude of land surface 2,412.0 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pliocene		
Ogallala Formation		
Silt and fine to coarse sand, limy	10	10
Sand and limy silt, cemented	10	20
Gravel, fine, and very coarse sand	15	35
Silt, very limy, cemented	5	40
Silt, sandy, limy	10	50
Sand, fine to coarse, limy, cemented	10	60
Gravel, medium to fine, and coarse sand	10	70
Sand, medium to very coarse, clean	10	80
Sand, fine to coarse, clean	10	90
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, weathered, light gray	14	104
Shale, dark gray	6	110

13-23-2bbb.———Sample log of test hole in NW NW NW sec. 2, T 13 S, R 23 W, 40 feet east of NW cor. sec. 2, at edge of road; drilled September 1960. Altitude of land surface 2,400.0 feet; depth to water 42.0 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pliocene		
Ogallala Formation		
Silt, limy, light brown	6	6
Silt, very limy, light gray to white	5	11
Sand, fine, silty	9	20
Silt and fine sand, limy; contains cemented streaks	9	29
Sand, fine to very coarse, loose; contains small amount fine gravel	14	43
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, clayey, tough, light gray and brown	7	50
Chalk, white and light gray	8	58
Shale, chalky, gray	7	65

13-23-28ddd.———Sample log of test hole in SE SE SE sec. 28, T 13 S, R 23 W, 35 feet west and 15 feet north of center of crossroads; drilled September 1960. Altitude of land surface 2,369.5 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pliocene		
Ogallala Formation		
Silt, light brown	10	10
Sand, fine to coarse, silty, limy	12	22
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, dark gray	8	30

13-24-1aaa.———Sample log of test hole in NE NE NE sec. 1, T 13 S, R 24 W, 500 feet west and 5 feet south of NE cor. sec. 1; drilled October 1957. Altitude of land surface 2,437.2 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pliocene		
Ogallala Formation		
Silt, tan	3	3
Silt and fine sand; contains limy streaks	3	6
Silt, tan	2	8
Silt, tan, and fine to medium sand	2	10
Sand and gravel	2	12
Silt, very limy, and medium to coarse sand; contains a small amount of gravel	4	16
Silt, white, yellow, and dark gray; contains limy layers	8	24
Sand, fine to coarse, and gray and white silt; contains a small amount of gravel	6	30
Sand, fine to coarse; contains a small amount of gravel	10	40
Sand, fine to coarse, and gravel	14	54
Silt, yellow and dark gray	4	58
Gravel, contains layers of silt	2	60
Sand, fine to coarse; contains layers of silt and a small amount of gravel	10	70

	Thickness, feet	Depth, feet
Sand, fine to coarse, and tan and gray silt	15	85
Silt, sandy, limy, white and tan	12	97
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, dark gray	3	100

13-24-29ccc.———Sample log of test hole in SW SW SW sec. 29, T 13 S, R 24 W, 50 feet east and 25 feet north of center of crossroads; drilled August 1960. Altitude of land surface 2,393.4 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Peoria and Loveland formations		
Silt, heavy, dark brown	5	5
Silt, light tan	5	10
Silt, sandy, tan	8	18
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, chalky, cream tan	12	30

13-24-36aaa.———Sample log of test hole in NE NE NE sec. 36, T 13 S, R 24 W, 75 feet west and 20 feet south of center of crossroads; drilled September 1960. Altitude of land surface 2,371.8 feet; depth to water 9.3 feet.

	Thickness, feet	Depth, feet
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Silt, dark brown	7	7
Shale, weathered, light gray	4	11
Shale, dark gray	9	20

13-25-2bbb.———Sample log of test hole in NW NW NW sec. 2, T 13 S, R 25 W, 30 feet east and 8 feet south of NW cor. sec. 2; drilled September 1957. Altitude of land surface 2,518.5 feet; depth to water 65.8 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pliocene		
Ogallala Formation		
Silt, brown upper part and tan lower part	5	5
Sand, fine to coarse	1	6
Silt, limy streaks, tan	1.5	7.5
Sand, fine to coarse, limy streaks	1	8.5
Silt, tan	5.5	14
Sand, fine to coarse	4	18
Sand and silt, limy, cemented hard; contains a very hard cemented limy bed at top	6	24
Sand, fine to coarse	5	29
Silt and fine to coarse sand, limy; contains thin cemented layers	9.5	38.5
Sand, fine to coarse, and limy silt, cemented	6.5	45
Silt, sandy, limy streaks, tan and white	3	48
Sand, fine, and tan to pink silt	15	63
Sand, fine, limy streaks; contains cemented layers	16	79
Silt, yellow tan	7	86
Silt, sandy, very limy, white	6	92
Silt, and fine sand, limy	5	97
Limestone, hard	1	98
Silt, soft, reddish	5	103
Silt, sandy, reddish tan	5	108
Silt, sandy, gray	6	114
Sand, medium to coarse	5	119
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, weathered, light tan to white in upper part, brownish in lower	11	130
Shale, brown	7	137

13-25-14bbb.———Sample log of test hole in NW NW NW sec. 14, T 13 S, R 25 W, 30 feet south and 5 feet east of NW cor. sec. 14; drilled September 1957. Altitude of land surface 2,489.6 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Peoria and Loveland formations		
Silt, brown	2	2
Silt, dark gray	3	5
Silt, reddish tan	7	12
Pliocene		
Ogallala Formation		
Sand, medium to coarse, and gravel, limy streaks	3	15
Sand, medium to coarse, and light tan to yellow silt; contains a small amount of gravel	6	21
Sand, fine to coarse, and fine gravel; contains thin layers of tan to yellow silt	12	33
Sand, fine to coarse, and gravel	2	35
Silt, tan, white and dark gray	9	44
Sand, fine to coarse, and very limy silt; contains cemented layers	8	52
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, weathered, tan and white	12	64
Shale, tan and brown	6	70
Shale, brown and dark gray	10	80

13-25-14ccc.———Sample log of test hole in SW SW SW sec. 14, T 13 S, R 25 W, 25 feet north and 5 feet east of SW cor. sec. 14; drilled August 1957. Altitude of land surface 2,458.4 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Peoria and Loveland formations		
Silt, brown	2	2
Silt, tan; contains a thin layer of gravel and sand at base	3	5
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Chalk, weathered, shaly	2	7
Chalk, hard	3	10

13-25-19aaa.———Sample log of test hole in NE NE NE sec. 19, T 13 S, R 25 W, 30 feet west and 10 feet south of center of crossroads; drilled September 1960. Altitude of land surface 2,450.4 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Peoria and Loveland formations		
Silt, dark brown	5	5
Pliocene		
Ogallala Formation		
Silt, sandy, very limy	7	12
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, creamy tan	8	20

14-20-31ccc.———Sample log of test hole in SW SW SW sec. 31, T 14 S, R 20 W, Ellis County (Leonard and Berry, 1961, p. 116); jetted September 1950. Altitude of land surface 2,018.1 feet; depth to water 8.2 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Silt, calcareous, dark gray	1	1
Clay, silty, soft, calcareous, light gray	7	8
Sand, medium to coarse; contains some gravel	6	14
Gravel and sand	4	18

14-21-25ccc.———Sample log of test hole in SW SW SW sec. 25, T 14 S, R 21 W (Leonard and Berry, 1961, p. 120); jetted September 1950. Altitude of land surface 2,073.4 feet; depth to water 12.9 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Peoria and Loveland formations		
Silt, clayey to sandy, calcareous, dark brown	6	6
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Sand, medium	5	11
Sand and gravel	5	16

14-21-25ddd.———Sample log of test hole in SE SE SE sec. 25, T 14 S, R 21 W (Leonard and Berry, 1961, p. 120); jetted September 1950. Altitude of land surface 2,106.2 feet; depth to water 12.2 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Peoria and Loveland formations		
Silt, calcareous, tan	1	1
Silt, calcareous, dark gray	8	9
Silt, clayey, blocky, calcareous, dark brown	18	27

14-21-26daa.———Sample log of test hole in NE NE SE sec. 26, T 14 S, R 21 W (Leonard and Berry, 1961, p. 120); jetted September 1950. Altitude of land surface 2,100.6 feet; dry hole.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Peoria and Loveland formations		
Soil, silty, black	2	2
Silt, loose, dark gray	3	5
Silt, hard, blocky, dark brown	2	7
Silt, loose, clayey and sandy, tan	12	19

14-21-27add.———Sample log of test hole in SE SE NE sec. 27, T 14 S, R 21 W, 0.48 mile south of NE cor. sec. 27, at edge of road (Leonard and Berry, 1961, p. 121); drilled October 1949. Altitude of land surface 2,108.4 feet; depth to water 76.7 feet.

	Thickness, feet	Depth, feet
Silt, black, dark brown (road fill)	2	2
NEOGENE		
Pleistocene		
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Silt, brown, and angular limestone gravel	2	4
Silt, plastic, tan to brown	6	10
Silt, sandy, rusty brown	3	13
Silt, plastic, buff	8	21
Gravel (limestone pebbles), and brown silt	4	25
Silt, plastic, clayey, gray	3	28
Gravel, medium to fine; contains some coarse arkosic sand	7	35
Gravel, medium to coarse	2	37
Gravel, medium to coarse, arkosic	2	39
Silt, calcareous, gray white	6	45
Silt, calcareous, gray white to buff	5	50
Silt, calcareous, gray white to cream color	5	55
Silt, calcareous, white	8	63
Gravel (limestone pebbles); contains some gray silt	4	67
Clay, gray, and silt; contains limestone gravel	3	70
Gravel, fine to medium, pebbles of limestone and quartz	4	74
Gravel, medium to coarse, pebbles of limestone and quartz, and gray silt	4	78
Gravel, fine to coarse, pebbles of limestone and quartz	6	84
Gravel, coarse, pebbles of limestone and quartz	5	89
Gravel, medium to fine, pebbles of igneous rock	2	91
Gravel, coarse to fine, pebbles of igneous rock and limestone	2	93
CRETACEOUS		
Upper Cretaceous		
Carlile Shale		
Shale, pliable, plastic, calcareous, blue	2	95

14-21-27dda.———Sample log of test hole in NE SE SE sec. 27, T 14 S, R 21 W (Leonard and Berry, 1961, p. 121); jetted September 1950. Altitude of land surface 2,099.5 feet; depth to water 27.3 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Silt, calcareous, light gray	3	3
Clay, calcareous, light tan; contains coarse sand	14	17
Sand, coarse to very coarse, poorly sorted; contains some gravel	13	30

14-21-28cbb.———Drillers log of observation well in NW NW SW sec. 28, T 14 S, R 21 W, drilled March 1961 by Bureau of Reclamation. Altitude of land surface 2,118.2 feet; depth to water 35.8 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Silt, light reddish brown	5	5
Silt, sandy, fine to medium, light brown	3.5	8.5
Sand, fine to coarse, light brown; contains chalk pebbles	10.5	19
Sand, fine to coarse, silty, gray brown	18	37
CRETACEOUS		
Upper Cretaceous		
Carlile Shale		
Shale, firm, blue gray	1.6	38.6

14-21-28ccb.———Sample log of test hole in NW SW SW sec. 28, T 14 S, R 21 W (Leonard and Berry, 1961, p. 122); jetted August 1950. Altitude of land surface 2,096.7 feet; depth to water 12.5 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Silt, calcareous, tan	1	1
Clay, calcareous, tan to gray; contains some sand	6	7
Sand, very coarse; contains gravel	12	19
Driven from 19 to 25 feet	6	25

14-21-30cdd.———Sample log of test hole in SE SE SW sec. 30, T 14 S, R 21 W (Leonard and Berry, 1961, p. 122); jetted July 1950. Altitude of land surface 2,065.4 feet; depth to water 13.08 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Silt, dark brown	1	1
Sand, silty, tan	15	16
CRETACEOUS		
Upper Cretaceous		
Carlile Shale		
Shale, blue	0.8	16.8

14-21-30dad.———Sample log of test hole in SE NE SE sec. 30, T 14 S, R 21 W (Leonard and Berry, 1961, p. 122); jetted September 1950. Altitude of land surface 2,122.7 feet; dry hole.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Silt, black	3	3
Silt, sandy, tan	5	8
Sand, coarse to very coarse; contains a few pebbles	13	21

14-21-30ddd.———Sample log of test hole in SE SE SE sec. 30, T 14 S, R 21 W (Leonard and Berry, 1961, p. 122); jetted July 1950. Altitude of land surface 2,112.9 feet; dry hole.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Silt, black; contains some very coarse sand	3	3
Sand, very coarse; contains some gravel	7	10
Gravel	0.5	10.5
Sand, medium	1.5	12
Sand, very coarse; contains some gravel	2	14

14-21-32add.———Sample log of test hole in SE SE NE sec. 32, T 14 S, R 21 W (Leonard and Berry, 1961, p. 123); jetted August 1950. Altitude of land surface 2,049.1 feet; depth to water 6.5 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Silt, calcareous, light tan	2	2
Sand, very coarse, clayey	0.5	2.5
Clay, calcareous, dark gray; contains some sand	4.5	7
Sand, very coarse; contains some fine gravel	9	16
Clay, sandy, soft, calcareous, blue-gray	5	21
CRETACEOUS		
Upper Cretaceous		
Carlile Shale		
Shale, weathered, calcareous, black to dark gray	..	21

14-21-33bbc.———Sample log of test hole in SW NW NW sec. 33, T 14 S, R 21 W (Leonard and Berry, 1961, p. 123); jetted August 1950. Altitude of land surface 2,057.7 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Silt, calcareous, tan	1	1
Clay, calcareous, dark gray; contains some sand	4	5
Clay, sandy, calcareous, tan	18	23
Sand, very coarse	5	28
CRETACEOUS		
Upper Cretaceous		
Carlile Shale		
Shale, weathered, clayey, calcareous, dark gray to black	..	28

14-21-33bcc.———Drillers log of observation well in SW SW NW sec. 33, T 14 S, R 21 W, 560 feet north of ½-mile line and 30 feet east of section line, drilled March 1961 by Bureau of Reclamation. Altitude of land surface 2,048.6 feet; depth to water 7.9 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Silt, brown	1.5	1.5
Silt, sandy, light brown	3	4.5
Sand, fine to coarse	3	7.5

	Thickness, feet	Depth, feet
Sand, fine to coarse; contains chalk pebbles	7.5	15
Sand, fine to coarse; contains layers of silt	9	24
CRETACEOUS		
Upper Cretaceous		
Carlile Shale		
Shale, blue gray	0.7	24.7

14-21-34aaa.———Sample log of test hole in NE NE NE sec. 34, T 14 S, R 21 W, 25 feet south and 35 feet west of center of crossroads (Leonard and Berry, 1961, p. 123); drilled October 1949. Altitude of land surface 2,095.4 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Silt, friable, slightly sandy, brown	1	1
Silt, clayey, slightly sandy, brown to gray buff	1.5	2.5
Silt, clayey, sandy, buff	2.5	5
Silt, sandy, rusty brown; contains buff silt	2	7
Sand, coarse, and fine quartz and feldspar gravel; contains some clay	3	10
Sand, fine to coarse; contains some fine gravel	5	15
Sand, medium to coarse; contains some fine to medium gravel	2	17
Gravel, fine to coarse, quartz and feldspar pebbles	8	25
Gravel, medium to coarse, limestone pebbles	7	32
CRETACEOUS		
Upper Cretaceous		
Carlile Shale		
Shale, plastic, weathered, yellow to gray	2	34
Shale, noncalcareous, blue black	3	37

14-21-34ada.———Sample log of test hole in NE SE NE sec. 34, T 14 S, R 21 W, 0.35 mile south of NE cor. sec. 34, at edge of road (Leonard and Berry, 1961, p. 124); drilled October 1949. Altitude of land surface 2,087.3 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Silt, plastic, clayey, calcareous, buff	2	2
Silt, sandy, calcareous, tan	3	5
Gravel, fine to coarse, pebbles of igneous rock and limestone; contains silt	4	9
Gravel, fine to medium, quartzose, and coarse sand	5	14
Gravel, coarse to fine, pebbles of quartz, claystone, and ironstone	2	16
Sand, coarse to medium, quartz and feldspar grains	2	18
Sand, coarse, and fine to medium quartz gravel	3	21
Gravel, fine to medium	2	23
CRETACEOUS		
Upper Cretaceous		
Carlile Shale		
Shale, pliable, plastic, noncalcareous, blue gray to black	3	26

14-21-34dad.———Sample log of test hole in SE NE SE sec. 34, T 14 S, R 21 W, 0.3 mile north of SE cor. sec. 34, at edge of road (Leonard and Berry, 1961, p. 124); drilled October 1949. Altitude of land surface 2,041.4 feet; depth to water 16.9 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Sand, fine to coarse; contains silt	3	3
Silt, fine, sandy, buff	6	9
Silt, buff to gray buff; contains fine to coarse gravel	6	15
Silt, buff to brown; contains medium to coarse sand	3	18
Clay, plastic, gray; contains fine to coarse sand and gravel	7	25
Clay, plastic, gray; contains some gravel and sand	5	30
Clay, plastic, gray; contains fine and coarse sand	5	35
Clay, gray; contains fine to coarse gravel	5	40
Clay, sandy, gray; contains some coarse sand	4	44
Clay, pliable, plastic, slightly sandy, gray	6	50
Gravel, fine to medium, and coarse sand	6	56
Gravel, fine to coarse, pebbles of igneous rock, limestone, and shale	7	63
CRETACEOUS		
Upper Cretaceous		
Carlile Shale		
Shale, calcareous, gray black	5	68

14-21-34ddd.———Sample log of test hole in SE SE SE sec. 34, T 14 S, R 21 W, 300 feet north and 20 feet west of SE cor. sec. 34 (Leonard and Berry, 1961, p. 125); drilled October 1949. Altitude of land surface 2,028.4 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Sand, fine to coarse quartz and feldspar grains; contains some silt	3	3
Sand, fine to coarse; contains some silt	2	5
Sand, medium to coarse, and fine gravel	5	10
Gravel, medium to coarse	2	12
Gravel, medium to coarse; contains some shale fragments	1	13
CRETACEOUS		
Upper Cretaceous		
Carlile Shale		
Shale, fissile, calcareous, black	5	18

14-21-35bcc.———Drillers log of observation well in SW SW NW sec. 35, T 14 S, R 21 W, 185 feet north of

½-mile line and 30 feet east of section line; drilled March 1961 by Bureau of Reclamation. Altitude of land surface 2,078.3 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Silt, clayey, light brown	6.5	6.5
Sand, fine to coarse	9.8	16.3
CRETACEOUS		
Upper Cretaceous		
Carlile Shale		
Shale, blue gray	3.3	19.6

14-21-35cbc1.———Sample log of test hole in SW NW SW sec. 35, T 14 S, R 21 W (Leonard and Berry, 1961, p. 125); jetted August 1950. Altitude of land surface 2,047.4 feet; dry hole.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Silt; contains very coarse sand	1	1
Sand, very coarse, poorly sorted	5	6
CRETACEOUS		
Upper Cretaceous		
Carlile Shale		
Shale, clayey, calcareous, dark gray; weathers tan	5	11

14-21-35cbc2.———Drillers log of observation well in SW NW SW sec. 35, T 14 S, R 21 W, 1,130 feet south of ½-mile line and 30 feet east of section line; drilled March 1961 by Bureau of Reclamation. Altitude of land surface 2,039.9 feet; depth to water 15.5 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Silt, clayey, dark brown	2	2
Silt, clayey, light brown	14	16
Silt, clayey, brown	14	30
Silt, gray	9	39
Silt, sandy, gray	19.8	58.8
CRETACEOUS		
Upper Cretaceous		
Carlile Shale		
Shale, blue gray	0.7	59.5

14-21-35ccc.———Drillers log of observation well in SW SW SW sec. 35, T 14 S, R 21 W, 600 feet north and 30 feet east of SW cor. sec. 35; drilled March 1961 by Bureau of Reclamation. Altitude of land surface 2,035.2 feet; depth to water 11.4 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Silt, dark brown	1	1
Silt and fine sand, light brown	10	11
Sand, fine to medium, silty	3	14
Sand, fine to coarse	20	34
Sand, fine to coarse; contains chalk pebbles	24	58
CRETACEOUS		
Upper Cretaceous		
Carlile Shale		
Shale, blue gray	1.7	59.7

14-21-36aaa.———Drillers log of observation well in NE NE NE sec. 36, T 14 S, R 21 W, at edge of road intersection; drilled March 1961 by Bureau of Reclamation. Altitude of land surface 2,107.1 feet; depth to water 46.9 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Peoria and Loveland formations		
Silt, dark brown	0.6	0.6
Silt, light reddish brown	23.4	24
Silt, clayey, light grayish brown	5	29
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Sand, fine to coarse; contains small amount chalk pebbles	17.8	46.8
CRETACEOUS		
Upper Cretaceous		
Carlile Shale		
Shale, blue gray	2	48.8

14-21-36bbb.———Drillers log of observation well in NW NW NW sec. 36, T 14 S, R 21 W, at edge of road intersection; drilled March 1961 by Bureau of Reclamation. Altitude of land surface 2,072.6 feet; depth to water 10.9 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Peoria and Loveland formations		
Silt, sandy, dark brown	4.5	4.5
Sand, fine to medium, silty	1.5	6
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Sand, fine to coarse; contains small amount chalk pebbles	6.7	12.7
CRETACEOUS		
Upper Cretaceous		
Carlile Shale		
Shale, blue gray	1.7	14.4

14-21-36bcc.———Drillers log of observation well in SW SW NW sec. 36, T 14 S, R 21 W, 20 feet north of ½-mile line and 23 feet east of section line; drilled March 1961 by Bureau of Reclamation. Altitude of land surface 2,075.7 feet; depth to water 46.0 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Silt, dark brown	1	1
Silt and fine sand, light brown	5	6
Sand, fine to medium, silty	2.5	8.5
Sand, fine to coarse, rusty brown	14.5	23
Silt, clayey, light brown	18	41
Sand, fine to medium, silty	15	56
Sand, fine to coarse	4.2	60.2
CRETACEOUS		
Upper Cretaceous		
Carlile Shale		
Shale, blue gray	4.2	64.4

14-21-36ddd.———Drillers log of observation well in SE SE SE sec. 36, T 14 S, R 21 W; drilled March 1961 by Bureau of Reclamation. Altitude of land surface 2,019.3 feet; depth to water 8.5 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Silt, sandy, dark brown	2.7	2.7
Sand, fine to medium, silty	5.3	8.0
Sand, fine to coarse, light brown	2	10
Sand, fine to coarse, grayish brown	19	29
CRETACEOUS		
Upper Cretaceous		
Carlile Shale		
Shale, blue gray	0.5	29.5

14-22-26aca.———Drillers log of test hole in NE SW NE sec. 26, T 14 S, R 22 W; drilled by Bureau of Reclamation. Altitude of land surface 2,162.0 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Silt, sandy	24	24
Sand, fine to medium	30	54
Silt, clayey	13	67
Sand; contains thin layers of clay	29	96
Silt	4	100
Sand, medium; contains pebbles	10	110
CRETACEOUS		
Upper Cretaceous		
Carlile Shale		
Shale	3	113

14-22-33aac.———Sample log of test hole in SW NE NE sec. 33, T 14 S, R 22 W, 0.2 mile SW of NE cor. sec. 33; augered July 1960. Depth to water 21.0 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Silt, sandy, tan	3.5	3.5
Silt, sandy, heavy, tan	5	8.5
Silt and fine to medium sand	6.5	15
Silt, heavy, brown	3.5	18.5
Sand, fine to medium	5	23.5
Sand, fine to coarse	5	28.5
Sand, medium to coarse, very clean	6.5	35
CRETACEOUS		
Upper Cretaceous		
Carlile Shale		
Shale, tough, blue gray	3.5	38.5

14-22-36aab.———Sample log of test hole in NW NE NE sec. 36, T 14 S, R 22 W, 0.2 mile west of NE cor. sec. 36, at edge of road (Leonard and Berry, 1961, p. 126); drilled October 1949. Altitude of land surface 2,114.7 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Silt, dark brown; contains fine to coarse gravel and some coarse sand	1	1
Gravel, fine to coarse, quartzose, rusty brown	1	2
Gravel, fine quartz and feldspar pebbles	3	5
Gravel, fine to coarse, pebbles of quartz, feldspar, and limestone	2	7
Gravel, fine to medium, quartzose; contains some coarse sand	3	10
Gravel, fine to coarse, quartzose	4.5	14.5
Silt, soft, plastic, gray white	5.5	20
Silt, clayey, calcareous, gray white	6	26
Silt, sandy, tan to cream color	6	32
Gravel, fine to medium, and medium to coarse sand; contains some limestone fragments	6	38
Silt, clayey, calcareous, gray white	7	45
Silt, calcareous, gray to gray white	5	50
Silt, gray to gray white	8	58
Gravel, fine to medium, pebbles of igneous rock	7	65
Gravel, fine and coarse quartz sand	3	68
CRETACEOUS		
Upper Cretaceous		
Carlile Shale		
Shale, calcareous, blue black; contains limy material at 68 feet.	6.5	74.5

14-22-36acb.———Drillers log of test hole in NW SW NE sec. 36, T 14 S, R 22 W; augered by Bureau of Reclamation. Altitude of land surface 2,133.3 feet; depth to water 28.0 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Silt, sandy, compact	9	9
Sand, fine, silty	3	12
Sand, coarse, rusty	5	17
Sand, medium to coarse	11	28
CRETACEOUS		
Upper Cretaceous		
Carlile Shale		
Shale	2	30

14-22-36ada.———Sample log of test hole in NE SE NE sec. 36, T 14 S, R 22 W (Leonard and Berry, 1961, p. 127); jetted September 1950. Altitude of land surface 2,069.2 feet; depth to water 6.95 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Silt, dark brown	1	1
Silt, very sandy; contains some gravel	4	5
Clay, calcareous, light brown; contains some very coarse sand	7	12
Sand, coarse; contains some pebbles of quartz and limestone	4	16
Sand, very coarse; contains some fine gravel	8.4	24.4

14-22-36dad.———Sample log of test hole in SE NE SE sec. 36, T 14 S, R 22 W (Leonard and Berry, 1961, p. 127); jetted September 1950. Altitude of land surface 2,068.3 feet; depth to water 6.5 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Sand, fine; contains some silt	3	3
Sand, very coarse	9	12
Gravel; contains some sand and limestone pebbles	2	14
Sand, very coarse; contains some gravel	3.4	17.4

14-22-36dda.———Sample log of test hole in NE SE SE sec. 36, T 14 S, R 22 W (Leonard and Berry, 1961, p. 127); jetted September 1950. Altitude of land surface 2,063.4 feet; depth to water 3.85 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Silt, sandy, brown	0.5	0.5
Sand, very coarse	4.5	5
Gravel, very coarse; contains pebbles of quartz and limestone	5	10
Sand and gravel	1.6	11.6

14-23-28ccc.———Sample log of test hole in SW SW SW sec. 28, T 14 S, R 23 W, 35 feet east and 10 feet north of SW cor. sec. 28; augered July 1960. Altitude of land surface 2,218.2 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Peoria and Loveland formations		
Silt, brown and light brown	3.5	3.5
Silt, light brown	6.5	10
Silt and sandy silt, light brown	6	16
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Sand, medium, well sorted	9	25
Clay, limy, tough, light gray	1.5	26.5
CRETACEOUS		
Upper Cretaceous		
Carlile Shale		
Shale, black	3.5	30

14-23-32ada.———Sample log of test hole in NE SE NE sec. 32, T 14 S, R 23 W, 0.33 mile south of NE cor. sec. 32, at edge of road; augered July 1960. Altitude of land surface 2,200.2 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Silt, light gray	8	8
Silt, sandy, heavy, light brown	2	10
Sand, medium, well sorted, clean	7	17
Sand, medium to coarse, and coarse gravel, clean	3	20
Sand, medium to very coarse, and fine to very coarse gravel	3	23
Gravel, coarse to very coarse	10	33
CRETACEOUS		
Upper Cretaceous		
Carlile Shale		
Shale, blue gray	5.5	38.5

14-23-32daa.———Sample log of test hole in NE NE SE sec. 32, T 14 S, R 23 W, 0.6 mile south of NE cor. sec. 32, at edge of road; augered July 1960. Altitude of land surface 2,164.9 feet; depth to water 17.05 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Silt, sandy, light tan	8.5	8.5
Silt, sandy, tan	1.5	10
Sand, fine	8	18
Silt, heavy, dark brown	2	20
Silt, heavy, limy, brown and gray	3	23
CRETACEOUS		
Upper Cretaceous		
Carlile Shale		
Shale, dark gray	7	30

14-23-32dad.———Sample log of test hole in SE NE SE sec. 32, T 14 S, R 23 W, 0.65 mile south of NE cor. sec. 32, 250 feet north of bridge and 35 feet west of road center; drilled September 1960. Altitude of land surface 2,161.8 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Sand, very fine to medium, red tan	3.5	3.5
Silt, heavy, greenish brown	6.5	10
Sand, very fine to fine, tan	8.5	18.5
Sand, fine to coarse; contains small amount fine gravel	5	23.5
Sand, fine to very coarse; contains small amount chalk pebbles	6.5	30
Sand, medium to very coarse	5	35
CRETACEOUS		
Upper Cretaceous		
Carlile Shale		
Shale, chalky, dark gray	8.5	43.5

14-23-33cbc.———Sample log of test hole in SW NW SW sec. 33, T 14 S, R 23 W, 0.3 mile north of SW cor. sec. 33, 50 feet north of bridge, and 30 feet east of center of highway; augered July 1960. Altitude of land surface 2,158.9 feet; depth to water 12.6 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Silt, sandy, tan	3.5	3.5
Silt, sandy, brown	5	8.5
Silt, very sandy, tan brown	7.5	16
Silt, clayey, sandy, tough, tan	3	19
Silt, sandy, loose	8	27
Silt, clayey, tough, tan brown	11	38
CRETACEOUS		
Upper Cretaceous		
Carlile Shale		
Shale, blue gray	10.5	48.5

14-24-27dda.———Sample log of test hole in NE SE SE sec. 27, T 14 S, R 24 W, 0.23 mile north of SE cor. sec. 27, at edge of road; augered July 1960. Altitude of land surface 2,252.5 feet.

NEOGENE
Pleistocene
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)

	Thickness, feet	*Depth, feet*
Silt, brown	3.5	3.5
Silt, sandy, tough, brown	10	13.5
Silt, sandy, tan brown	6.5	20
Sand, coarse, and arkosic gravel, clean	5	25
Sand, fine to medium, rust tan	5	30
CRETACEOUS		
Upper Cretaceous		
Carlile Shale		
Shale, blue gray	3.5	33.5

14-24-27ddd.———Sample log of test hole in SE SE SE sec. 27, T 14 S, R 24 W, 50 feet north and 15 feet west of center of crossroads; augered July 1960. Altitude of land surface 2,250.2 feet.

	Thickness, feet	*Depth, feet*
NEOGENE		
Pleistocene		
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Silt, light brown	3.5	3.5
Silt, sandy, tan	8.5	12
Sand, medium to very coarse, and fine gravel, clean	8	20
Clay, tough, gray	1	21
Sand, medium to coarse, and fine to medium arkosic gravel	9	30
CRETACEOUS		
Upper Cretaceous		
Carlile Shale		
Shale, blue gray	5	35

14-24-29bcb.———Sample log of test hole in NW SW NW sec. 29, T 14 S, R 24 W, 650 feet north of river, at edge of road; drilled October 1957. Altitude of land surface 2,205.7 feet; depth to water 5.94 feet.

	Thickness, feet	*Depth, feet*
NEOGENE		
Pleistocene		
Alluvium		
Silt, tan, and fine to medium sand	2	2
Sand, fine to coarse	8	10
Sand and gravel	8	18
Sand, fine to coarse; contains thin layers of dark brown silt	4	22
Silt, dark gray; contains thin layers of sand and gravel	8	30
CRETACEOUS		
Upper Cretaceous		
Carlile Shale		
Shale, weathered, dark gray	10	40

14-24-29bcc.———Sample log of test hole in SW SW NW sec. 29, T 14 S, R 24 W, 50 feet north of river, at edge of road; drilled October 1957. Altitude of land surface 2,205.3 feet; depth to water 5.93 feet.

	Thickness, feet	*Depth, feet*
NEOGENE		
Pleistocene		
Alluvium		
Silt, dark brown, and fine to coarse sand; contains a small amount of chalk gravel	2	2
Sand, fine to coarse, and chalk gravel, silty	5	7
Silt, very sandy, dark	5	12
Sand, medium to coarse, and coarse chalk gravel	15	27
Sand, fine to medium	5	32
Silt, dark gray, and fine to medium sand	14	46
Silt, dark	7	53
Silt, dark, and fine sand	7	60
Sand, fine to coarse, and dark silt; contains a small amount of arkosic and chalk gravel	10	70
Sand, fine to coarse, and arkosic and chalk gravel, silty	10	80
Sand, fine to coarse, and dark silt; contains a small amount of arkosic and chalk gravel	15	95
CRETACEOUS		
Upper Cretaceous		
Carlile Shale		
Shale, dark gray	5	100

14-24-30bbc.———Sample log of test hole in SW NW NW sec. 30, T 14 S, R 24 W; drilled August 1947. Altitude of land surface 2,213.4 feet; depth to water 9.0 feet.

	Thickness, feet	*Depth, feet*
NEOGENE		
Pleistocene		
Alluvium		
Sand and fine gravel	10	10
Silt	4	14
Sand, coarse	6	20
Sand and chalk gravel	5	25
Sand	5	30
Sand, fine; contains thin layers of blue-gray silt in lower part	9	39
Sand, coarse, and fine gravel	5	44
Gravel, fine	6	50
CRETACEOUS		
Upper Cretaceous		
Carlile Shale		
Shale, weathered, black	25	75
Shale, hard	6	81
Shale, noncalcareous, black	15	96

14-24-30bcb.———Sample log of test hole in NW SW NW sec. 30, T 14 S, R 24 W; drilled August 1947. Altitude of land surface 2,212.6 feet; depth to water 6.2 feet.

	Thickness, feet	*Depth, feet*
NEOGENE		
Pleistocene		
Alluvium		
Sand, medium, clean	2	2
Gravel, fine, and coarse sand	5	7
Sand, medium, clean	13	20
Sand, fine	4	24
Silt	1	25
Sand, fine	5	30
Sand and silt	10	40
Sand and gravel, coarser in lower part	7	47
CRETACEOUS		
Upper Cretaceous		
Carlile Shale		
Shale, weathered, blue gray	3	50
Shale, noncalcareous, blue gray	5	55

14-24-30bcc.———Sample log of test hole in SW SW NW sec. 30, T 14 S, R 24 W; drilled August 1947. Altitude of land surface 2,211.6 feet; depth to water 5.1 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Soil and silt, dark	4.5	4.5
Sand, medium to fine	4.5	9
Sand, coarse, and fine gravel; contains chalk pebbles	1	10
Sand, medium	7	17
Silt	1	18
Sand, medium	3.5	21.5
CRETACEOUS		
Upper Cretaceous		
Carlile Shale		
Shale, noncalcareous, black	5.5	27

14-24-30ccc.———Sample log of test hole in SW SW SW sec. 30, T 14 S, R 24 W; drilled August 1947. Altitude of land surface 2,275.9 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Soil and silt, black	2	2
Silt, clayey	5.5	7.5
Sand, medium	7.5	15
Sand, fine	2.5	17.5
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Fort Hays Limestone Member		
Chalk, soft, white	9.5	27
Chalk, hard	12	39
Carlile Shale		
Shale, soft, noncalcareous, black	11	50

14-24-31cbb.———Sample log of test hole in NW NW SW sec. 31, T 14 S, R 24 W; drilled August 1947. Altitude of land surface 2,288.6 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Soil and clayey silt	4	4
Silt, clayey, brown	15	19
Sand, fine, silty	1	20
Sand, medium, silty	7	27
Sand, coarse, and fine gravel	8	35
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Fort Hays Limestone Member		
Chalk, fairly hard, white	7.5	42.5
Carlile Shale		
Shale, soft, gray	12.5	55

14-24-34aaa.———Sample log of test hole in NE NE NE sec. 34, T 14 S, R 24 W, 0.1 mile south of NE cor. sec. 34, at edge of road; augered July 1960. Altitude of land surface 2,234.3 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Silt, sandy, brown	5	5
Sand, fine to coarse, and quartz gravel	5	10
Sand, medium to very coarse, and quartz gravel; contains small amount chalk gravel	11	21
CRETACEOUS		
Upper Cretaceous		
Carlile Shale		
Shale, blue gray	2.5	23.5

14-24-34ddd.———Sample log of test hole in SE SE SE sec. 34, T 14 S, R 24 W, 50 feet north of SE cor. sec. 34, at edge of road; augered July 1960. Altitude of land surface 2,195.3 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Silt, sandy, tan	3.5	3.5
Silt, heavy, brown	5	8.5
Silt, sandy, tan brown	7.5	16
Silt, sandy, tan gray	4	20
Silt, tan brown	10	30
CRETACEOUS		
Upper Cretaceous		
Carlile Shale		
Shale, blue gray	3.5	33.5

14-24-35bcb.———Sample log of test hole in NW SW NW sec. 35, T 14 S, R 24 W, 0.3 mile south of NW cor. sec. 35, at edge of road; augered July 1960. Altitude of land surface 2,200.4 feet; depth to water 14.37 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Silt, sandy, brown	3.5	3.5
Silt and fine to medium sand	5	8.5
Silt, sandy, brown	5.5	14
Sand, coarse to very coarse, and fine gravel	4	18
CRETACEOUS		
Upper Cretaceous		
Carlile Shale		
Shale, blue gray	5.5	23.5

14-24-35bcc.———Sample log of test hole in SW SW NW sec. 35, T 14 S, R 24 W, 0.48 mile south of NW cor. sec. 35, at edge of road; drilled September 1960. Altitude of land surface 2,182.2 feet; depth to water 7.8 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Sand, fine to very coarse, loose; contains small amount fine gravel	10	10
Sand, medium to very coarse, and fine gravel, clean, loose	10	20
Sand, fine to very coarse, clean, loose	10	30

	Thickness, feet	Depth, feet
Sand, medium to very coarse, and fine gravel	16	46
Silt, dark blue gray	5	51
Sand, medium to very coarse, and fine gravel, clean, loose	9	60
Gravel, fine, and very coarse sand, clean, loose	10	70
Sand, medium to very coarse; contains small amount fine gravel	10	80
Sand, medium to very coarse, well sorted, clean, loose	8	88
Sand, medium to coarse, well sorted; contains cemented streaks	7	95
CRETACEOUS		
Upper Cretaceous		
Carlile Shale		
Shale, dark blue gray	15	110

14-24-35cbc.———Sample log of test hole in SW NW SW sec. 35, T 14 S, R 24 W, 0.3 mile north of SW cor. sec. 35, at edge of road across from farm home; augered July 1960. Altitude of land surface 2,182.3 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Silt, sandy, tan	3.5	3.5
Sand, fine to medium, clean	5	8.5
Sand, medium to coarse, and chalk gravel	21.5	30
CRETACEOUS		
Upper Cretaceous		
Carlile Shale		
Shale, blue gray	3.5	33.5

14-25-9ddd.———Sample log of test hole in SE SE SE sec. 9, T 14 S, R 25 W, 150 feet north of SE cor. sec. 9, at edge of road; augered July 1960. Altitude of land surface 2,273.5 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Silt, sandy, brown	4	4
Silt, sandy, light brown	4	8
Silt, very sandy, light brown	7	15
Sand, fine to medium, silty	5	20
Sand, medium to very coarse, clean	6	26
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, blue gray	2.5	28.5

14-25-15bbb.———Sample log of test hole in NW NW NW sec. 15, T 14 S, R 25 W, 500 feet south of NW cor. sec. 15, at edge of road; augered July 1960. Altitude of land surface 2,271.6 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Silt, sandy, upper part, very sandy lower part, brown and tan	4	4
Sand, medium to very coarse, clean	4.5	8.5
Sand, very coarse, and fine chalk gravel	8.5	17

	Thickness, feet	Depth, feet
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, blue gray	1.5	18.5

14-25-15bcb.———Sample log of test hole in NW SW NW sec. 15, T 14 S, R 25 W, 75 feet south of bridge, at edge of road; augered July 1960. Altitude of land surface 2,276.2 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Silt, very sandy, tan	3.5	3.5
Silt, sandy, light brown	6.5	10
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, blue gray	3.5	13.5

14-25-15bcc.———Sample log of test hole in SW SW NW sec. 15, T 14 S, R 25 W, 0.6 mile north of SW cor. sec. 15, at edge of road; augered July 1960. Altitude of land surface 2,306.2 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Silt, brown	3	3
Silt, clayey, yellow	2	5
Silt, sandy, light tan	4	9
Sand, fine, silty	6	15
Sand, fine to coarse, silty	5	20
Sand, fine to coarse, silty, rust brown	2	22
Silt, light brown	3	25
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Smoky Hill Chalk Member		
Shale, dark gray	3.5	28.5

14-25-32ddd.———Drillers log of domestic well in SE SE SE sec. 32, T 14 S, R 25 W, 30 feet west and 10 feet north of SE cor. sec. 32. Altitude of land surface 2,305.0 feet; depth to water 25.26 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Silt	22	22
Silt, sandy; contains layers of sand	21	43
Sand, silty, cemented	5	48
Sand, fine	2.5	50.5
Sand, fine; contains limy silt layers	6.5	57
Sand, fine, and interbedded silt layers	26	83
CRETACEOUS		
Upper Cretaceous		
Niobrara Chalk—Fort Hays Limestone Member		
Shale, white, pink, and yellow	2	85

15-21-2bbb.———Sample log of test hole in NW NW NW sec. 2, T 15 S, R 21 W, 90 feet south and 30 feet east of center of crossroads (Leonard and Berry, 1961,

p. 148): drilled October 1949. Altitude of land surface 2,031.4 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Silt, brown	1	1
Sand, fine to coarse; contains some brown silt	4	5
Gravel and sand, fine to coarse	3	8
Gravel, fine to coarse, and medium sand	3	11
CRETACEOUS		
Upper Cretaceous		
Carlile Shale		
Shale, black and blue black to dark gray	3	14

15-21-3add.———Sample log of test hole in SE SE NE sec. 3, T 15 S, R 21 W, 0.45 mile south of NE cor. sec. 3, at edge of road (Leonard and Berry, 1961, p. 148): drilled October 1949. Altitude of land surface 2,100.7 feet.

	Thickness, feet	Depth, feet
Silt, brown to gray (road fill)	3	3
NEOGENE		
Pleistocene		
Grand Island, Sappa, and Crete formations, undifferentiated (terrace deposits)		
Silt, slightly sandy, reddish brown	9	12
Silt, sandy, tan, and medium sand	3	15
Sand, medium to coarse, and fine gravel	5	20
Sand, fine to coarse; contains silt at 25.5 feet	5.5	25.5
Gravel, fine, and coarse sand	2.5	28
Gravel, medium to coarse	2	30
CRETACEOUS		
Upper Cretaceous		
Carlile Shale		
Shale, gray, blue black, and black	4	34

15-21-3ddd.———Sample log of test hole in SE SE SE sec. 3, T 15 S, R 21 W, 100 feet north and 7 feet west of center of crossroads (Leonard and Berry, 1961, p. 148): drilled October 1949. Altitude of land surface 2,148.8 feet.

	Thickness, feet	Depth, feet
CRETACEOUS		
Upper Cretaceous		
Carlile Shale		
Silt, clayey, tan	2	2
Silt, sandy, buff	2	4
Clay, pliable, plastic, tan to light gray	2.5	6.5
Shale, plastic, gray to blue gray; contains bentonite	3.5	10

15-22-1abb.———Sample log of test hole in NW NW NE sec. 1, T 15 S, R 22 W (Leonard and Berry, 1961, p. 149); jetted July 1950. Altitude of land surface 2,068.6 feet; depth to water 8.3 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Silt, clayey, dark brown	9	9
Sand, medium to coarse	6	15
CRETACEOUS		
Upper Cretaceous		
Carlile Shale		
Shale, blue	0.5	15.5

15-23-5aaa.———Sample log of test hole in NE NE NE sec. 5, T 15 S, R 23 W, 50 feet west and 10 feet south of NE cor. sec. 5; augered July 1960. Altitude of land surface 2,158.5 feet; depth to water 10.57 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene		
Alluvium		
Silt, sandy, tan	3.5	3.5
Sand, silty	6.5	10
Sand, fine, silty, wet	8.5	18.5
Sand, fine to coarse; contains small amount chalk gravel	5	23.5
Sand, medium to coarse, and fine chalk gravel	6.5	30
Sand, fine to medium, clean	5	35
CRETACEOUS		
Upper Cretaceous		
Carlile Shale		
Shale, tough, blue gray	8.5	43.5

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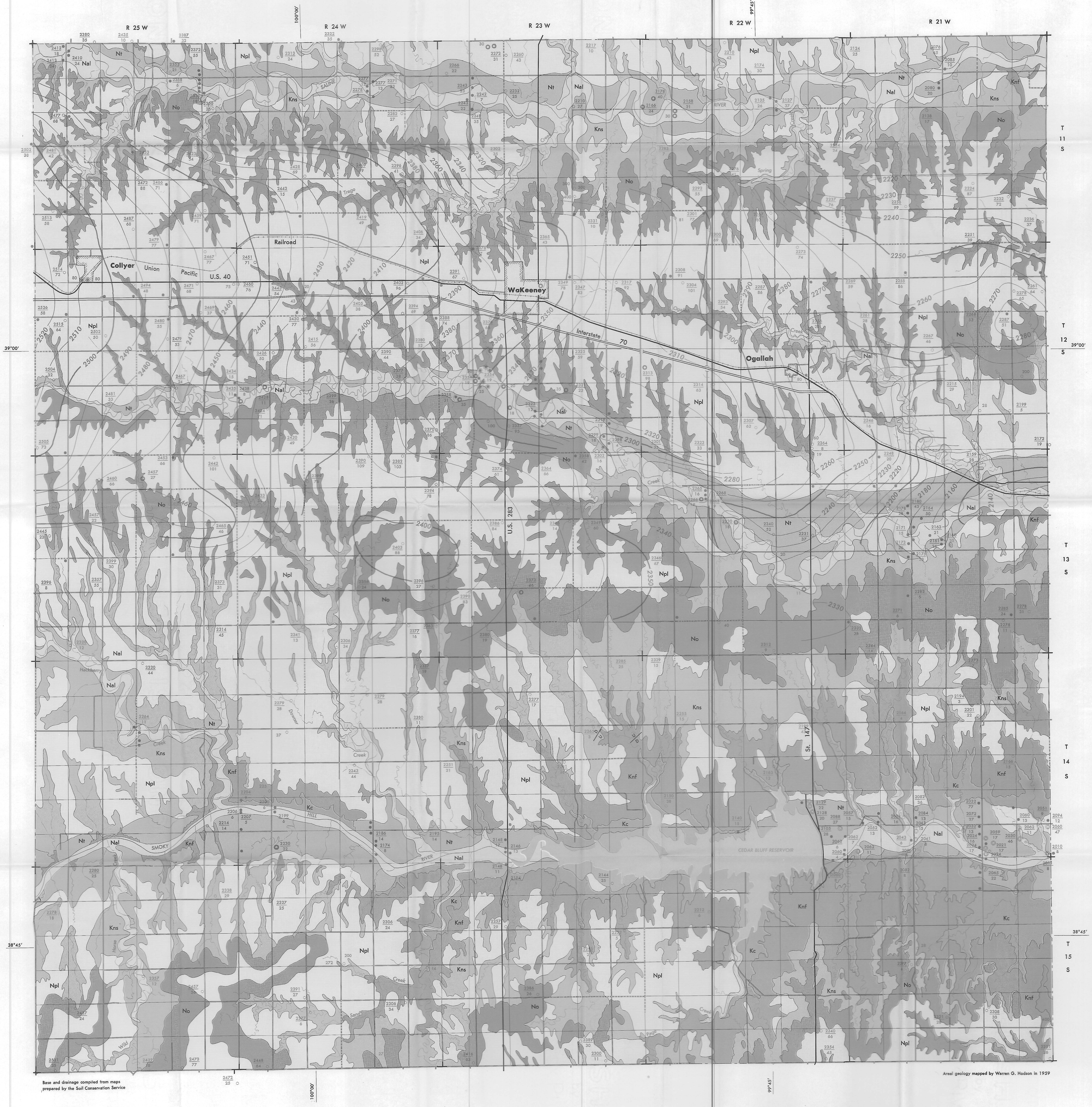
MAP OF TREGO COUNTY, KANSAS

showing areal geology, water-table contours, and location of wells and test holes for which records are given

By Warren G. Hodson

1965

Bulletin 174
Plate 1



Base and drainage compiled from maps prepared by the Soil Conservation Service

Areal geology mapped by Warren G. Hodson in 1959

EXPLANATION

NEOGENE

Pleistocene

Nal

Alluvium

Stream-laid deposits ranging in composition from clay to coarse sand and gravel. Occurs along principal stream valleys. Yields moderate to moderately large quantities of water to wells along larger valleys, lesser amounts along smaller valleys.

Npl

Peoria and Loveland Formations, undifferentiated

Silt, mostly eolian; sandy in lower part. Mantles most of the uplands and masks much of the valley walls. Includes slope wash derived from the Ogallala Formation along the edge of the uplands. Yields small quantities of water to wells locally.

Nt

Grand Island, Sappa, and Crete Formations (Terrace deposits).

Stream-deposited sand, gravel, and silt in a terrace position along the major valleys. Mostly continuous, but locally consists of remnants. Yields moderate quantities of water to wells.

Pliocene

No

Ogallala Formation

Consists chiefly of sand, gravel, silt, and clay, generally very calcareous. Mostly unconsolidated, but cemented at places to various degrees. Occurs in the uplands, chiefly in the northern and central parts of the county. Yields moderate quantities of water to wells.

CRETACEOUS

Upper Cretaceous

Niobrara Chalk

Kns

Smoky Hill Chalk Member

Chalk and chalky shale, thin-bedded and platy; bentonite beds occur throughout. Light gray to dark gray when fresh; weathers to brown and orange at outcrop. Yields no water to wells.

Knf

Fort Hays Limestone Member

Massive beds of chalk, separated by thin partings of chalky shale. Generally grayish-white, but may be yellow or light brown at outcrop. Yields small amounts of water to wells locally.

Kc

Carlile Shale

Lower part consists of calcareous shale and thin beds of chalky limestone; upper part consists of dark-gray clayey shale with lenses of silty, fine-grained sandstone near top. Yields small quantities of water to wells from Codell Sandstone Member at top of the formation.

2430

Contour connecting points of equal altitude of water table, based on instrumental levels (omitted where water table is discontinuous). Contour interval 10 feet.

2515
65

Upper number, altitude of water table above mean sea level, in feet; lower number, depth to water below land surface, in feet. (Single set of numbers indicates depth to water).

Domestic well
Irrigation well
Municipal well
Observation well
Test hole
Four-lane Interstate Highway
Federal or State Highway
Graded road
Ungraded road
Railroad
County line (no road)
Section line (no road)
Township corner
Approximate geologic contact
Intermittent stream
Fault

0 1 2 3 4
Scale in miles

State Geological Survey
of Kansas

GEOLOGIC CROSS SECTIONS IN TREGO COUNTY, KANSAS

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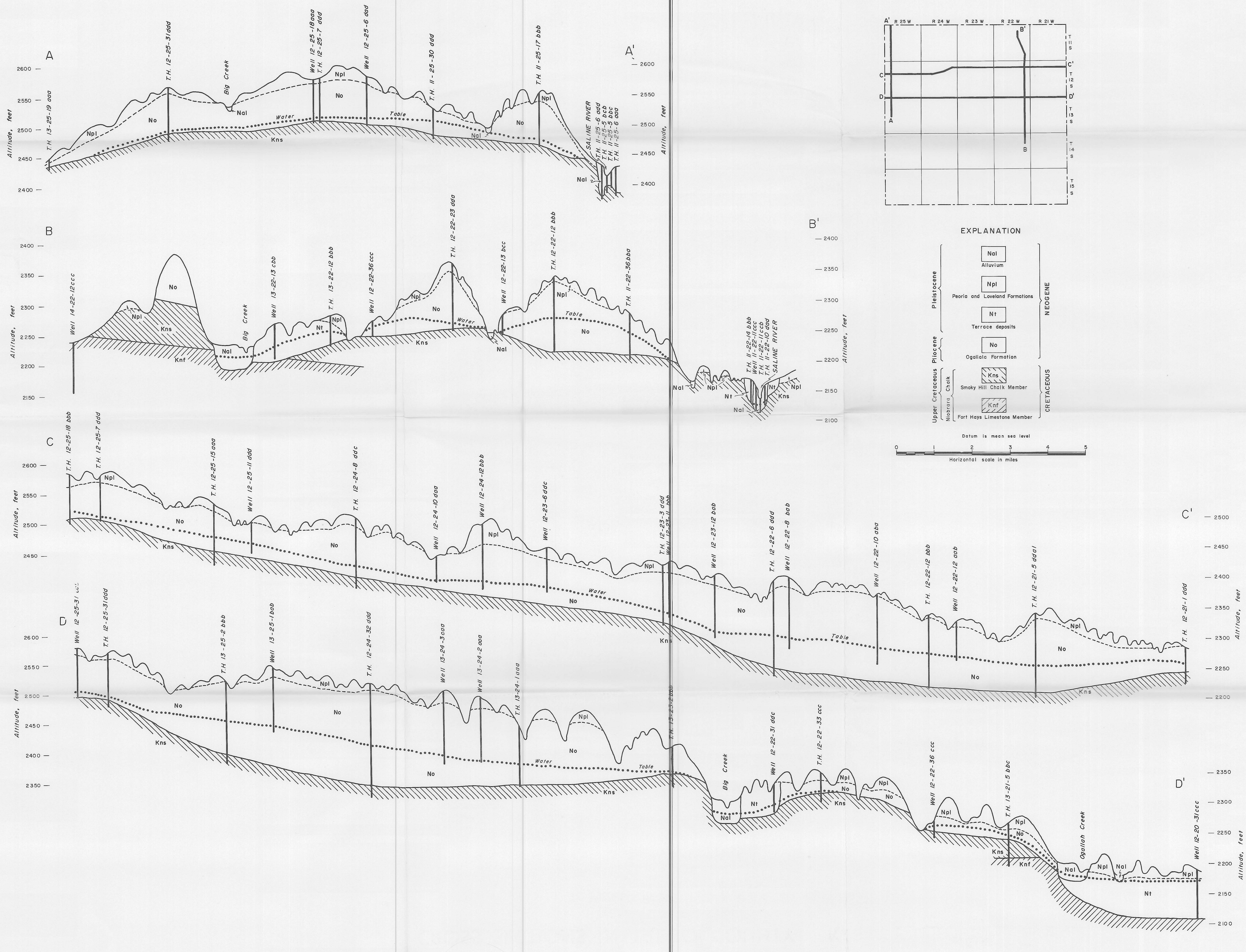

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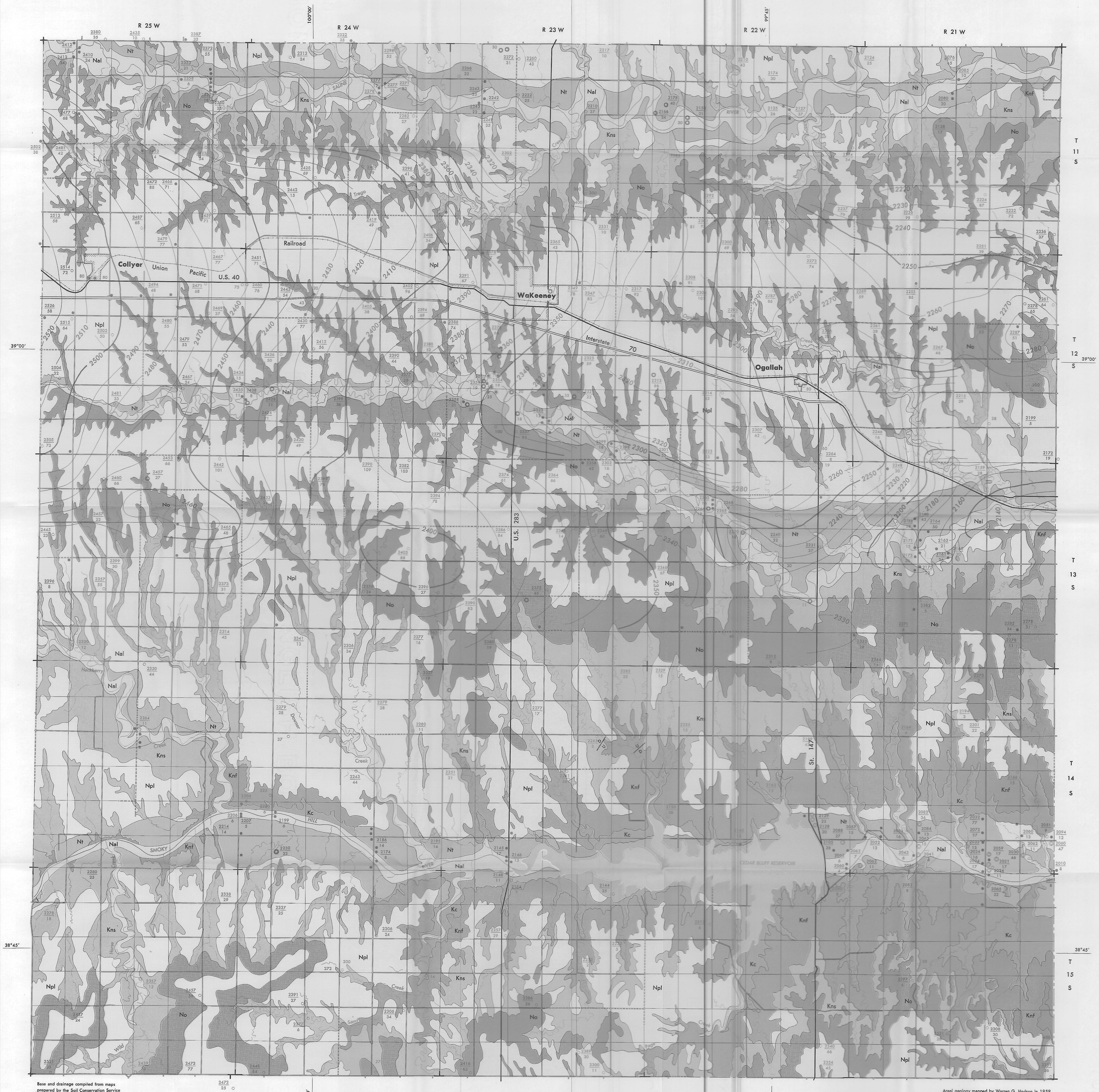

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