STATE GEOLOGICAL SURVEY OF KANSAS

FRANKLIN D. MURPHY, M. D.,
Chancellor of the University, and ex officio Director of the Survey

FRANK C. FOLEY, Ph. D.,
Director and State Geologist

Division of Ground Water

V. C. FISHEL, B. S.,
Engineer in Charge

BULLETIN 110

GEOLOGY AND GROUND-WATER RESOURCES OF GRAHAM COUNTY, KANSAS

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

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GEOLOGY AND GROUND-WATER RESOURCES OF GRAHAM COUNTY, KANSAS

By Glenn C. Prescott, Jr.

ABSTRACT

This report describes the geography, geology, and ground-water resources of Graham County, in northwestern Kansas. Records of 344 wells and springs and logs of 31 test holes are given. The outcropping rock formations were studied in the field and a geologic map and geologic cross sections were prepared. Samples of water from 21 wells were analyzed for dissolved mineral content.

Graham County is in the High Plains section of the Great Plains physiographic province. The county is moderately to well dissected and South Fork Solomon River, Bow Creek, Saline River, and tributaries to these rivers afford good drainage to the area. The most extensive flat lands in the county are the terrace surfaces in South Fork Solomon Valley. The climate of the area is subhumid, the average annual precipitation being about 21 inches. In addition to ground water, the principal mineral resources are oil and construction materials. Farming and livestock raising are the principal occupations of the county. A very small acreage is irrigated.

The outcropping rocks in Graham County are sedimentary and range from late Cretaceous to Recent in age. The oldest outcropping rock is the Smoky Hill chalk member of the Niobrara formation, which underlies the entire county. The Ogallala formation of Tertiary (Pliocene) age overlies the Smoky Hill chalk member, but in several areas erosion has removed the Ogallala and the Cretaceous bedrock is exposed. Along many of the valleys where the Ogallala has been removed, late Wisconsinan terrace deposits mantle the bedrock. Other older Pleistocene alluvial deposits are the Crete sand and gravel member of the Sanborn formation and the Meade formation. The wind-blown silt of the Sanborn constitutes the surficial material over much of the area, particularly in the uplands. The youngest deposits are Recent alluvium along the streams and scattered sand dunes.

The Ogallala formation is the most wide-spread water-bearing formation in the county and yields water to many wells. In stream valleys the late Wisconsinan terrace deposits supply water to many wells and also the Crete yields water to wells. Small amounts of water can be obtained from the Niobrara formation, and from the upper part of the Carlile shale, which underlies the Niobrara. The Dakota formation, which underlies the surface at depths ranging from about 500 to 1,100 feet, contains considerable amounts of water. However, this water is of questionable quality.

The body of ground water contained in the Pleistocene and Pliocene deposits is recharged principally by precipitation that falls in the county or in adjacent areas to the west. Ground-water recharge to the Niobrara formation probably takes place in a similar manner. Some recharge to the Carlile and Dakota formations may result from local precipitation but probably the greater part

of recharge to these aquifiers takes place in their areas of outcrop. Ground water is discharged from Pleistocene and Pliocene deposits through transpiration and evaporation, by discharge into streams, by subsurface movement into other areas, and by wells and springs. Discharge from Cretaceous aquifers is accomplished principally through subsurface movement.

The report contains a map showing the location of wells and springs for which information was obtained and showing the depth to water level at each well. The maximum measured depth to water was 229 feet in a well to the Dakota formation. A contour map showing the shape and slope of the water table indicates that ground water generally moves into the county from the west and out of the county to the east. Geologic cross sections indicate that the Pleistocene and Pliocene water-bearing materials are too thin over most of the county for the development of irrigation wells. The most promising areas for obtaining sufficient water for irrigation wells are in the northwestern part of the county from the Ogallala formation and in places along South Fork Solomon River from the Wisconsinan terrace deposits.

Analyses of 21 samples of ground water reveal that water from the Ogallala formation, although moderately hard, is suitable for most purposes. Water from alluvial materials and from the bedrock formations is more highly mineralized than water from the Ogallala formation. Water from the Carlile shale may be unfit for irrigation and water from the Dakota formation is unfit for irrigation and may be unfit for domestic and stock use.

INTRODUCTION

Purpose and Scope of the Investigation

The investigation upon which this report is based is part of a program of ground-water investigations in Kansas begun in 1937 by the United States Geological Survey and the State Geological Survey of Kansas in co-operation with the Division of Water Resources of the Kansas State Board of Agriculture and Division of Sanitation of the Kansas State Board of Health. The present status of investigations made under this program is shown in Figure 1.

The investigation of the geology and ground-water resources of Graham County was made to determine the availability and quality of ground water for domestic, stock, industrial, and irrigation supplies and to determine the geologic and hydrologic factors that control the occurrence of ground water, which is one of the principal natural resources of western Kansas. Although at the present rate of withdrawal, the danger of seriously depleting the ground-water supply seems very slight, there still is a definite need for an adequate understanding of the quantity and quality of the available supply, where additional supplies can be obtained, and what measures may be necessary to safeguard their continuance.

The investigation was made under the general direction of A. N.

Sayre, chief of the Ground Water Branch of the U. S. Geological Survey, and under the immediate supervision of V. C. Fishel, district engineer in charge of ground-water studies in Kansas.

Location and Extent of the Area

Graham County, which is near the eastern edge of the High Plains, is bordered on the north by Norton County, on the east by Rooks County, on the South by Trego County, and on the west by Sheridan County. It is in the second tier of counties south of the Kansas-Nebraska State line and is four counties east of the Kansas-Colorado State line. It includes 25 townships—Ts. 6 to 10 S. and Rs.

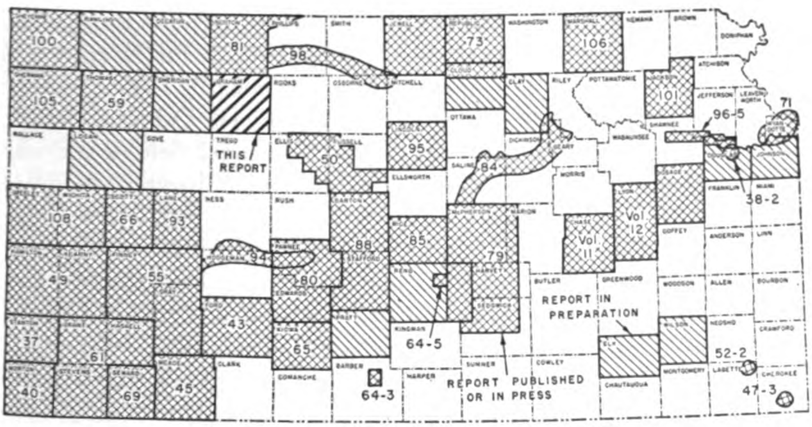


Fig. 1.—Index map of Kansas showing area included in this report and other areas for which ground-water reports have been published or are in preparation.

21 to 25 W. inclusive—and has an area of about 891 square miles. The location of the county is shown in Figure 1.

Previous Investigations

In 1897 several reports on the geology of western Kansas were published by the University Geological Survey of Kansas (Haworth, 1897, 1897a; Logan, 1897; Williston, 1897, 1897a). In the same year a report of the Board of Irrigation Survey and Experiment to the State Legislature of Kansas (Haworth, 1897b) contained a section on the principles of occurrence of ground water and a discussion of the water-bearing beds of western Kansas and included a geologic map of Kansas, geologic cross sections, and a reconnaissance hydrographic map of western Kansas. Johnson (1901, 1902) made special reference to the source, availability, and use of ground water in western Kansas. The first specific reference to Graham County was in a report by Darton (1905) in which he discussed briefly the geology and water supply of the county. Partial chemical analyses of samples of well water from Graham County were given in a report by Parker (1911). A chapter of a special report on well waters in Kansas (Haworth, 1913) was devoted to the Tertiary area of western Kansas, which includes Graham County.

A report on the geology of Wallace County (Elias, 1931) contained the results of detailed studies of Pleistocene, Pliocene, and Cretaceous deposits in the western Kansas area. A report by Landes (1937) briefly summarized the principal aquifers and mentioned the undeveloped mineral resources of the area. Reports on geology and ground-water resources have been published for Norton and northwestern Phillips Counties (Frye and Leonard, 1949) and for the North Fork Solomon River Valley in Mitchell, Osborne, Smith, and Phillips Counties (Leonard, 1952). In 1952 field work was completed and reports on the geology and ground-water resources are in preparation for Sheridan, Gove, Decatur, and Rawlins Counties. Byrne, Coombs, and Matthews (1951) give the results of an investigation of the construction materials in Graham County and prospecting for and development of petroleum in Graham County are summarized by Ver Wiebe (1940, 1941, 1942, 1943, 1944, 1945, 1946, 1947) and Ver Wiebe and others (1948, 1949, 1950, 1951, 1952, 1953, 1954). An important contribution to the literature on Pleistocene geology was made in 1952 by the publication of a report on the Peistocene geology of Kansas (Frye and Leonard, 1952).

Methods of Investigation

Approximately 4½ months in the summer and fall of 1952 were spent in the field collecting the data upon which this report is based. A total of 344 wells and springs was visited and total depth and depth to water of wells were measured where possible. Well owners and drillers were interviewed regarding the nature and thickness of the water-bearing formations, the yield and drawdown of the wells, and the quality and permanency of the water supply.

Samples of water from 18 wells were collected; they were later analyzed in the Water and Sewage Laboratory of the Kansas State Board of Health at Lawrence by Howard A. Stoltenberg. Three other analyses by Mr. Stoltenberg not made especially for this investigation have been used in the report.

During the course of the investigation the surficial geology was studied and mapped on aerial photographs and the geologic map (Pl. 1) was later prepared in the office. C. K. Bayne assisted in the mapping of geologic features in the valley of the South Fork Solomon River. To determine the character of the material beneath the surface, 29 test holes were drilled by Norman W. Biegler, William T. Connor, and William Gellinger using the hydraulic-rotary drilling rig owned by the State Geological Survey. Samples from the test holes were collected and studied in the field by Biegler, who also prepared logs of the holes.

The altitudes of the surface at the test holes and of the measuring point of wells were determined with a plane table and alidade by level parties headed by Edwin Rhine and Woodrow Wilson. The water-table contour map (Pl. 1) is based on these altitudes together with the measured depth to water in the wells. Wells shown on this map and the well-location map (Pl. 2) were located within the sections by use of an odometer. The base map used for Plates 1 and 2 was adapted from a map compiled by the United States Department of Agriculture, Soil Conservation Service. Road corrections were made by field observations or by use of aerial photographs. The drainage on Plates 1 and 2 was adapted from a map of the Soil Conservation Service.

Well-Numbering System

The well and test-hole numbers used in this report give the location of wells according to General Land Office surveys and according to the following formula: township, range, section, 160-acre tract (quarter section), 40-acre tract within that quarter section, and 10-acre tract. If two or more wells are within the same 10-acre tract the wells are numbered serially in the order in which they were inventoried. An example of this well-numbering system is given in Figure 2 where well 6-24-5bac, a well in the SW¼ NE¼ NW¼ sec. 5, T. 6 S., R. 24 W., is shown.

GEOGRAPHY

Topography and Drainage

Graham County is entirely in the High Plains section of the Great Plains physiographic province (Adams, 1903, p. 113). The area does not consist of the flat to gently rolling upland plains typical of the High Plains farther west (Frye, 1945, p. 12; Prescott, 1954) but rather is moderately to well dissected. Most of the county is well drained and sloping ground predominates. The most extensive areas of flat land are on the terrace surface that is in the valley of South Fork Solomon River. This terrace is thought to be the same age as the Almena terrace along Prairie Dog Creek (Frye and

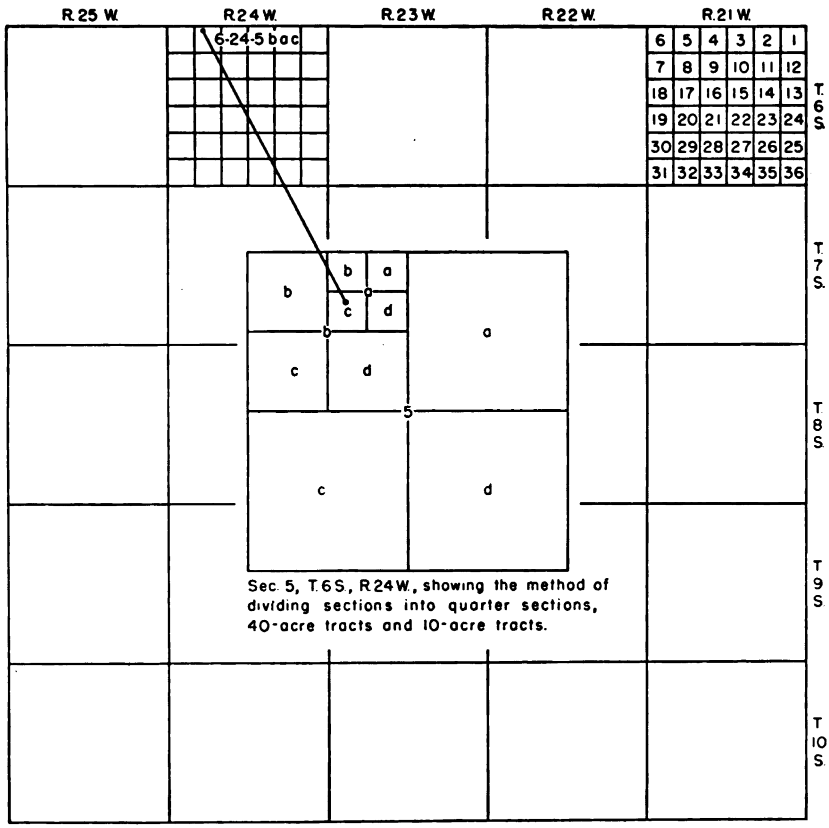


Fig. 2.—Map of Graham County illustrating the well-numbering system used in this report.

Leonard, 1949, p. 53) and the Kirwin terrace on North Fork Solomon River (Leonard, 1952, p. 14). The lowest point in the county, which is where South Fork Solomon River enters Rooks County, is about 1,900 feet above sea level. Several places on the west side of the county have altitudes of more than 2,600 feet, the maximum altitude recorded during the leveling of wells and test holes being 2,633 feet at the SE cor. sec. 18, T. 9 S., R. 25 W. Thus the maximum relief is more than 700 feet.

South Fork Solomon River is the principal stream in Graham County. It flows across the center of the County from west to east and drains about two-thirds of the area. Bow Creek, which is intermittent in the western half of Graham County, flows northeasterly across the northern part of the county and continues easterly until it meets North Fork Solomon River in eastern Phillips County. The North Fork continues easterly and southeasterly and joins South Fork Solomon River south of Cawker City in Mitchell County, where it becomes the Solomon. Saline River flows southeastward through sec. 31, T. 10 S., R. 25 W., which is in the extreme southwestern corner of the county. The tributaries to Saline River drain approximately one-fourth of the county. Most of the tributaries to these three major streams are ephemeral—that is, they flow only during and after periods of heavy rain. However parts of some of the tributaries are spring-fed and maintain a small perennial flow.

Climate

The climate of Graham County is subhumid and is characterized by abundant sunshine, moderate precipitation, and a high rate of evaporation. Days are hot during the summer but the nights are generally cool. The summer heat is alleviated by good wind movement and low relative humidity. Winters are moderate with only occasional short periods of severe cold and with relatively light snowfall. The normal annual mean temperature at Hill City is 53.9° F. The highest normal monthly mean temperature is 79.0° F. in July and lowest normal monthly mean temperature is 28.5° F. in January. The lowest temperature on record at Hill City is –24° F., which occurred on January 12, 1912. The highest temperature on record is 117° F., which occurred on July 24, 1936. The average length of the growing season is 165 days but extremes of from 128 to 196 days have occurred.

The norman annual precipitation at Hill City as determined by the U. S. Weather Bureau is 20.55 inches. The precipitation has ranged from a low of 9.65 inches in 1910 to a high of 39.38 inches in 1941. About 77 percent of the precipitation falls during the growing season from April through September when moisture is needed most. The annual precipitation and the cumulative departure from normal precipitation at Hill City for the period of record are shown in Figure 3 and the normal monthly precipitation is shown in Figure 4.

Population

The population of Graham County in 1890 was 5,029, which was 9 more than the number recorded by the Federal Census of 1950. By 1910 the population had increased to 8,700, the greatest number ever recorded. The population decreased from 1910 to 1920, increased slightly from 1920 to 1923, and had decreased steadily since 1930 until the time of the 1950 census. A decrease from 6,071 to 5,020, or a 17.3 percent decrease, was recorded between 1940 and 1950. Probably the population at the present time (1953) is slightly

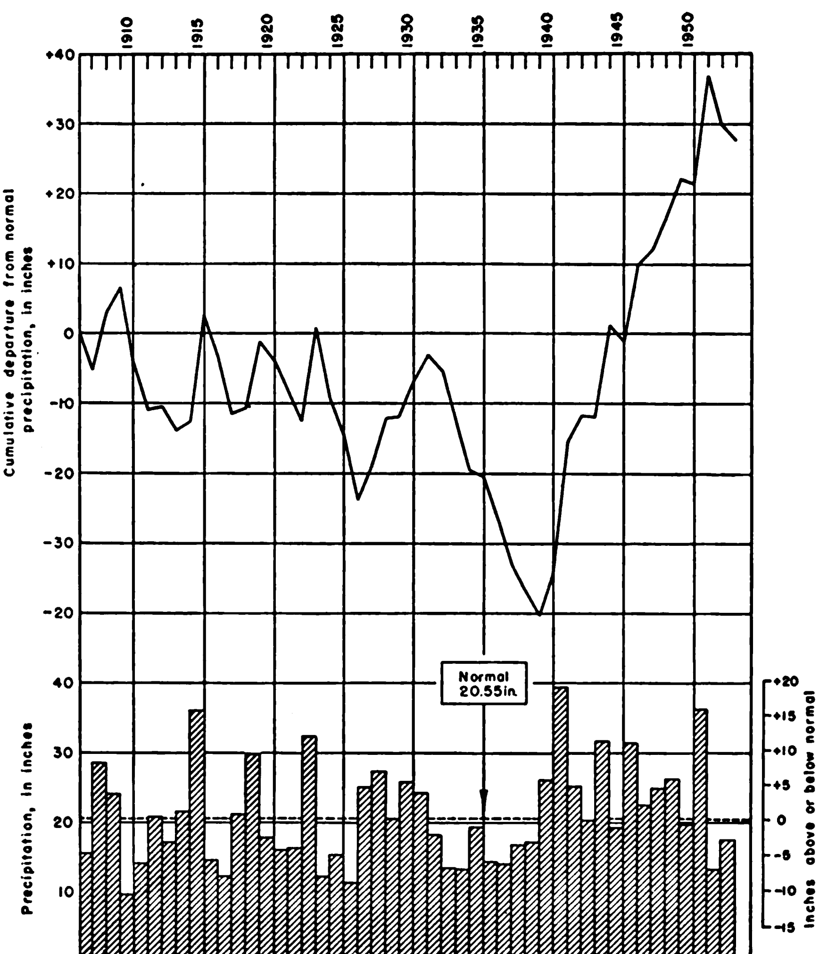


FIG. 3.—Graphs showing annual precipitation and cumulative departure from normal precipitation at Hill City.

greater than it was in 1950. The average density of population for the county in 1950 was 5.6 persons per square mile as compared to 23.2 for the State.

Hill City, the county seat of Graham County, had a population of 1,115 in 1940 and 1,432 in 1950. Bogue had 157 inhabitants in 1940 and 211 in 1950. Morland had 356 inhabitants in 1940 and 287 in 1950. Graham County ranks 84th in population among the 105 counties in Kansas.

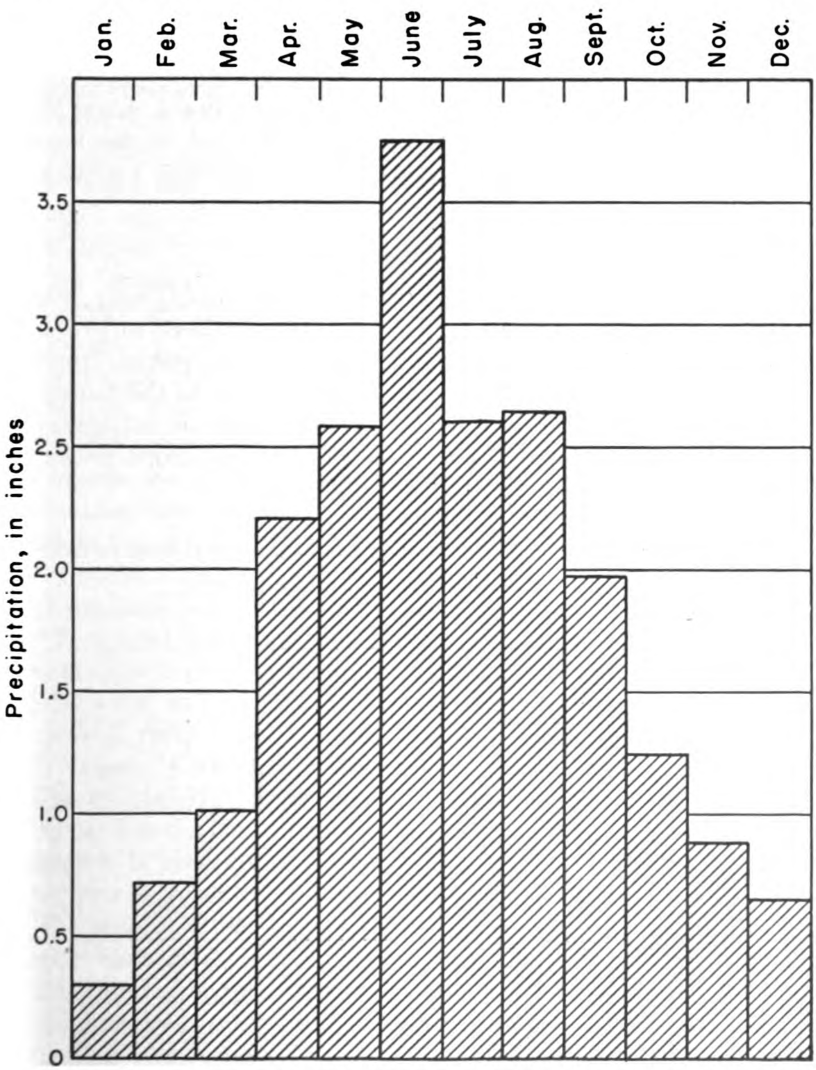


Fig. 4.—Graph showing the normal monthly precipitation at Hill City.

Transportation

Graham County is crossed by a branch line of the Union Pacific Railroad, which runs westward from Salina in Saline County to Colby in Thomas County. The railroad goes through Bogue, Hill City, Penokee, and Morland.

The county is traversed by two paved Federal highways—U. S. Highway 24 east-west just north of Bogue, Penokee, and Morland, and through Hill City and U. S. Highway 283 north-south through Hill City. State Highway 18, which is paved, parallels the railroad northwestward from the Rooks County line to Bogue where it turns northward to join U. S. Highway 24. Short sections of paved highway, State Highways 84 and 85, run north from Penokee and Morland, respectively, to U. S. Highway 24. Several of the county roads have been graded and graveled and many other county and township roads have been improved.

Agriculture

Agriculture is the principal occupation in Graham County, which according to a census of the State Board of Agriculture, in 1945 had 909 farms. In 1950 192,824 acres of crops were harvested, approximately 70 percent of the crop land being devoted to the raising of wheat. About 40 percent of the land is in pasture and cattle raising is a major occupation. The acreage of principal crops grown in 1950 is shown in Table 1.

Table 1.—*Acreage of principal crops grown in Graham County in 1950*

(Data from Kansas State Board of Agriculture)

Crop	Acres
Wheat	136,000
Corn	8,000
Oats	2,220
Barley	6,580
Rye	150
Sorghum	
For grain	22,280
For forage	12,060
For silage	2,190
All hay	3,320
Total	192,800

Mineral Resources

The principal mineral resources of Graham County in addition to ground water are oil and construction materials.

Oil.—The first well in Graham County to find oil in commercial quantities was drilled by the Continental Oil Company in 1938 in the southeastern part of the county in sec. 15, T. 9 S., R. 21 W. Subsequent development has proved this well to be the discovery well of the largest pool in the county, the Morel. To the end of 1953, the 210 Arbuckle producing wells of the Morel pool had produced 16,631,864 barrels of oil (Ver Wiebe and others, 1954, p. 160). The second largest oil pool in the county, the Cooper, which in 1953 had more than 100 Arbuckle producing wells, was discovered during 1950. During the first four years, 3,119,535 barrels of oil were produced from this pool. In 1953, production was from 37 pools, 7 of which were discovered in that year. To the end of 1953 a total of 22,212,816 barrels of oil had been produced from the 442 producing Graham County wells. The principal producing rocks in the county are the Lansing and Kansas City groups and the Arbuckle group. Data concerning the development and production of oil in the county are given by Ver Wiebe, 1940, 1941, 1942, 1943, 1944, 1945, 1946, and 1947 and Ver Wiebe and others, 1948, 1949, 1950, 1951, 1952, 1953, and 1954.

Construction materials.—Rocks from the Ogallala and Niobrara formations have been used to some extent for construction in Graham County. The lower part of the Ogallala in places contains a distinctive hard green rock consisting of sand and gravel cemented with opaline silica (Pl. 3A). This rock (which is called "quartzite," has been used to build several buildings in the county (Pl. 3B) and was used for riprap on the upstream face of Antelope Lake dam in the NE¼ sec. 9, T. 8 S., R. 25 W. Crushed quartzite has been used on several rural roads and was used in concrete pavement in Hill City (Byrne, Coombs, and Matthews, 1951, p. 13).

The Smoky Hill chalk member of the Niobrara formation has been used in the construction of buildings in Graham County. The formation is generally shaly but where it is more massive, building stone can be quarried (Pl. 4). Chalk has also been used on some of the roads. Other materials used in construction are ledges of mortar beds in the Ogallala formation which have been crushed and used on some roads and beds of unconsolidated sand and gravel which have been quarried at several localities from both the Ogallala formation and terrace deposits. Sand and gravel is obtained hy-

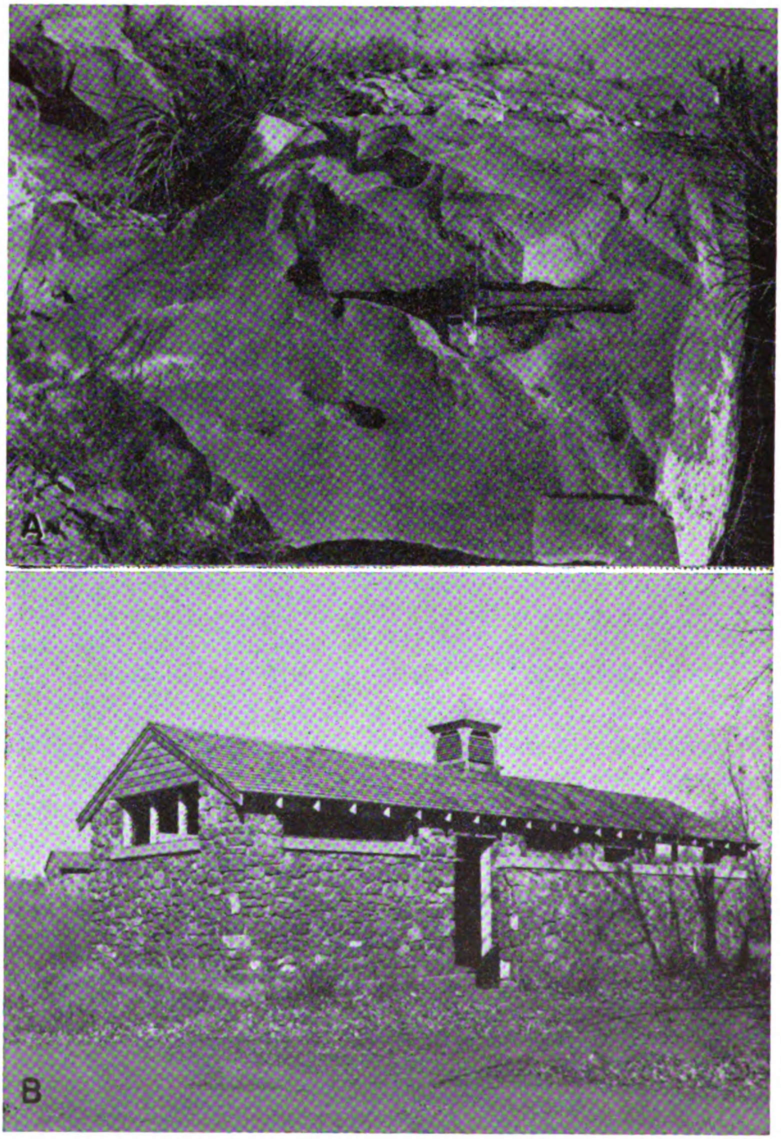


PLATE 3. Quartzite of the Ogallala formation. **A,** Bed of very hard, fine-grained, green quartzite in the SW¼ NW¼ sec. 6, T. 9 S., R. 21 W. **B,** Building constructed of quartzite in picnic ground at Antelope Lake, sec. 9, T. 8 S., R. 25 W.

draulically from the alluvium of the South Fork Solomon River. For a more complete discussion of these and other materials whose economic value is minor the reader is referred to Byrne, Coombs, and Matthews (1951).

GENERAL GEOLOGY

Summary of Stratigraphy *

The rocks that crop out in Graham County are sedimentary and range in age from late Cretaceous (Gulfian) to Recent. A generalized section of the geologic formations is given in Table 2, their areal distribution is shown on Plate 1, and their stratigraphic relationship is shown in Figure 5.

The oldest rocks exposed in the county belong to the Smoky Hill chalk member of the Niobrara formation. The entire county is underlain by this formation and a large part of the county is within the area of outcrop of the Niobrara. The lower member of the Niobrara formation, the Fort Hays limestone, does not crop out in the county. The Pierre shale, which reaches a thickness of about 1,400 feet in the northwestern part of the State (Elias, 1931, p. 50) has almost entirely been eroded away here and has been recognized in only a few outcrops in the western part of the county. The Ogallala formation of Tertiary (Pliocene) age overlies the Niobrara or Pierre over much of the area, but in many places the Ogallala has been completely removed and Cretaceous rocks are exposed. Eolian silt of the Sanborn formation of Pleistocene age mantles the uplands and valley walls over most of the county. Along many stream valleys this silt may be underlain by stream-deposited sand and gravel (Crete member of the Sanborn) in a terrace position with respect to the valley. Terrace deposits (Meade formation) of an earlier aggradational cycle lie in places along South Fork Solomon River and some of the other creeks, and late Wisconsinan to Recent deposits occur along many of the streams as alluvium or terrace deposits. In small local areas Recent winds have formed dunes of sand from alluvial deposits or from the Ogallala formation.

* The classification and nomenclature of the rocks described in this report follow that of the State Geological Survey of Kansas. They differ somewhat from the classification and nomenclature given in formal reports of the U. S. Geological Survey.

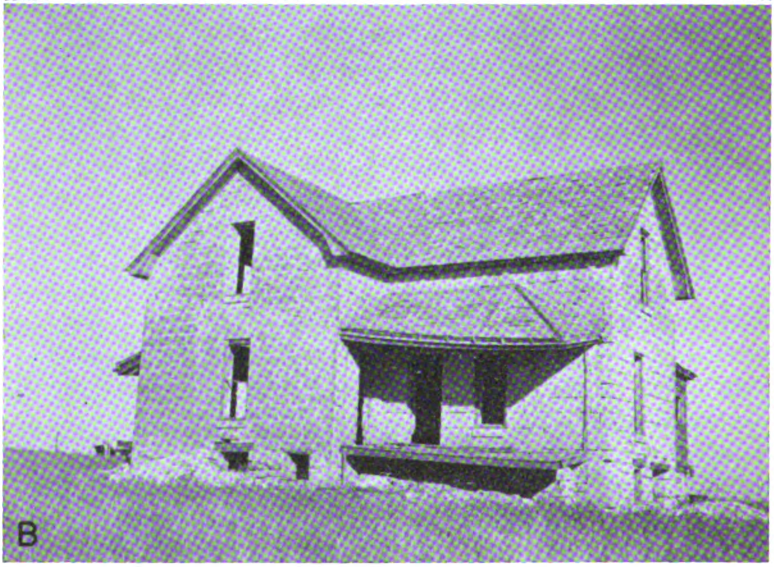


PLATE 4. Niobrara formation. **A,** Smoky Hill chalk member consisting of a bed of massive yellow-brown chalk lying above blue-gray shale. **B,** Old house constructed of massive Smoky Hill chalk member or Fort Hays limestone member.

Rocks Not Exposed

The Niobrara formation in Graham County is underlain by approximately 400 feet of deposits consisting principally of shale and limestone. Included herein are the Carlile shale, the Greenhorn limestone, and the Graneros shale. The Codell sandstone zone in the Blue Hill shale member of the Carlile is thought to supply water to a few wells in Graham County, but the Greenhorn limestone and Graneros shale are generally not aquifers. Beneath the Graneros shale is the Dakota formation, which is an important aquifer in some areas in Kansas and which may be a potential source of water for wells in Graham County. These formations will be discussed in more detail in the section on geologic formations and their water-bearing properties.

Geomorphology

The principal topographic features of Graham County are the result of events that happened during Pliocene and Pleistocene time. Near the end of Cretaceous time, the sea that had deposited a great thickness of sediments over the western Kansas area during late Cretaceous time withdrew, exposing the upper part of these beds to subaerial erosion. In early Tertiary time uplift occurred in the Rocky Mountain province and streams flowing eastward across the High Plains area of Kansas stripped off a considerable thickness of upper Cretaceous sedimentary rocks. The Pierre shale was completely removed except in an area in the western part of the county where seemingly the Pierre had been downfaulted or down folded and was therefore protected from erosion. Varying thicknesses of the underlying Niobrara formation were also lost to erosion. In Pliocene time streams from the Rockies deposited large quantities of sediments (Ogallala formation) over the High Plains of Kansas. As the stream valleys became filled, the streams topped the bedrock divides, shifted laterally, and developed an extensive almost featureless plain of alluvium, which merged with the erosional plain in the Rocky Mountain region. The broad alluvial plain was marked in many places with shallow water-table lakes in which the "Algal limestone" was formed.

In early Pleistocene time there was either uplift of the land to the west or a climatic change which caused streams to start cutting valleys below the surface of this vast constructional plain. The sequence of events during Nebraskan and Aftonian time in this area is not known because deposits of these ages have not been identified.

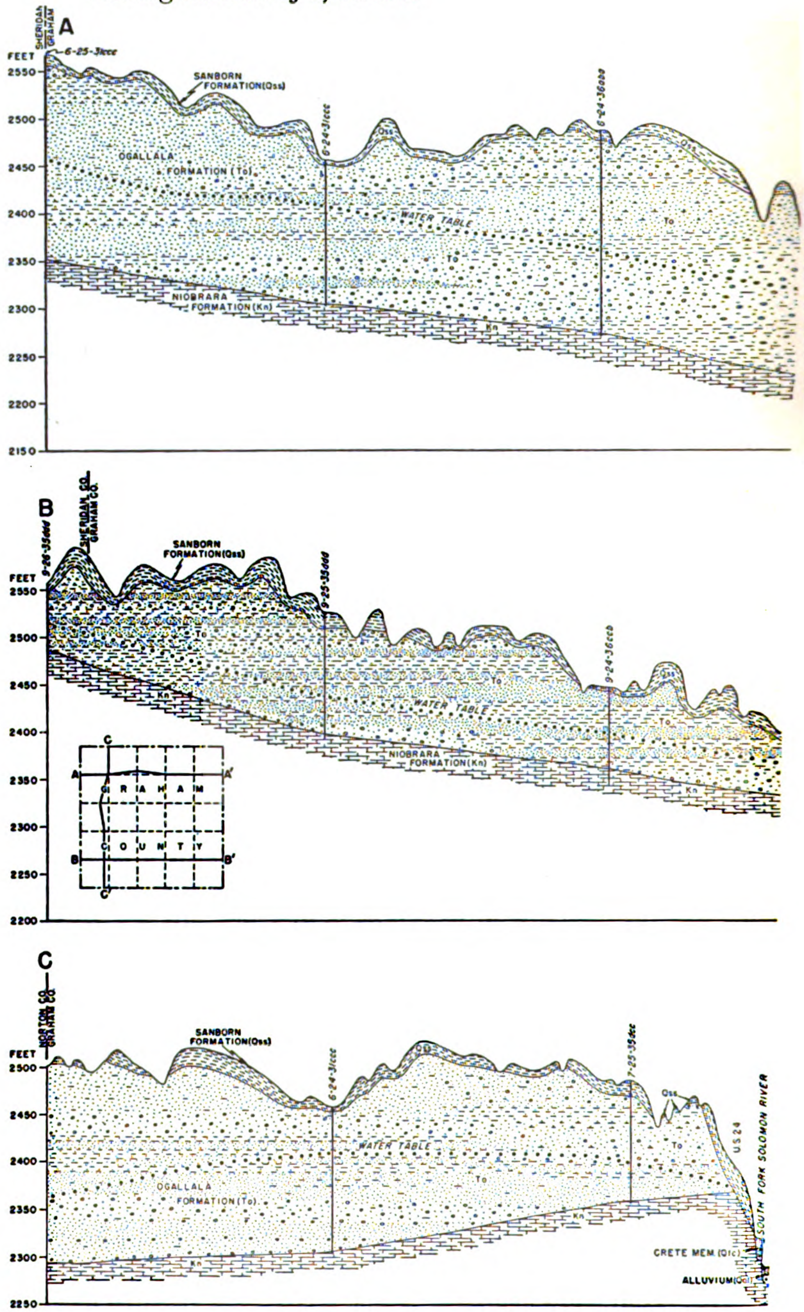
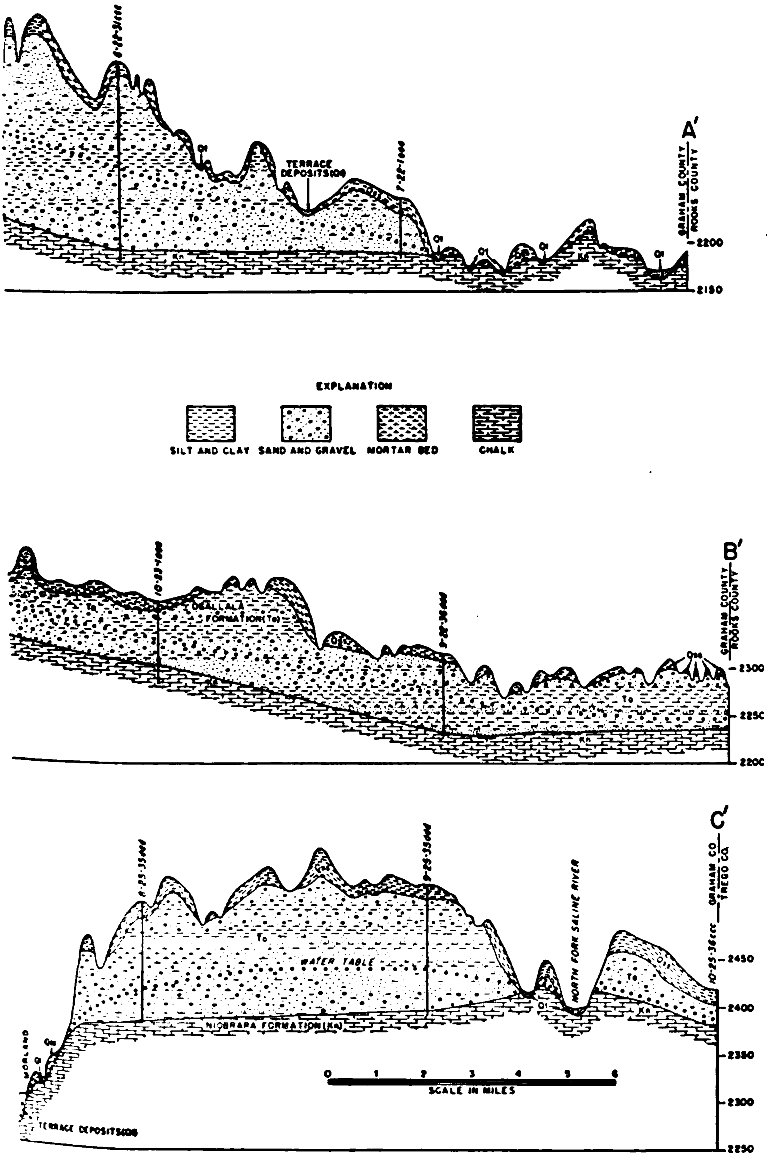


FIG. 5.—Geologic cross



sections in Graham County.

TABLE 2.—*Generalized section of geologic formations and their water-bearing properties*

System	Series	Formation	Member	Thickness, feet	Character	Water supply
Quaternary	Pleistocene*	Alluvium		0–20	Sand, gravel, and silt in stream channels and underlying the flood plains. Along minor streams it is poorly sorted and contains a greater percentage of fine materials.	Contains much water but generally restricted to stream channels and consequently yields water to few wells.
		Dune sand		0–20	Fine to course wind-deposited sand.	Generally lies above the water table and yields no water to wells. Serves as an intake area for ground-water recharge from local precipitation.
		Sanborn formation	Terrace deposits (late Wisconsinan)	0–55	Sand, gravel, silt and clay derived principally from older alluvial deposits and from the Ogallala formation. Deposits along Bow Creek are generally fine-textured in upper part. Deposits along tributary streams are generally poorly sorted and fine-textured.	Yields abundant supplies of water to wells along South Fork Solomon River and eastern Bow Creek. Yields smaller supplies to wells in trbutary valleys.
			Bignell silt member	0–4	Light-tan silt that occurs in scattered localities.	Lies above the water table and yields no water to wells.
			Peoria silt member	0–30	Light-tan to yellowish-gray silt that mantles the uplands in much of the area. In places is terminated upward by the Brady soil.	Lies above the water table and yields no water to wells.
			Loveland silt member	0–15	Massive tan to reddish-tan silt with thick Sangamon soil at top.	Lies above the water table and yields no water to wells.
			Crete sand and gravel member	0–25	Sand and gravel with some silt and clay. Generally overlain by loess of the Loveland or Peoria.	Yields water to some wells in valley areas where it lies below the water table.
		Meade formation	Sappa member*	0–15	Silt, clay, and fine sand. Contains the Pearlette volcanic ash bed. Occurs in only a few places.	Lies above the water table and yields no water to wells.
			Grand Island member*	0–15	Sand, gravel, silt, and clay. Occurs in only a few places.	Generally lies above the water table, but may yield water to a very few wells.

TABLE 2.—*Generalized section of geologic formations and their water-bearing properties—Concluded*

System	Series	Formation	Member	Thickness, feet	Character	Water supply
Tertiary	Pliocene	Ogallala formation	Kimball,* Ash Hollow,* and Valentine* members	0–215	Sand, gravel, silt, and clay, predominantly calcareous. May be consolidated or unconsolidated. Contains beds of limestone, caliche, and "quartzite."	Yields abundant supplies of water to wells in much of the county. Supplies water to springs in some areas where eroded below the water table.
Cretaceous	Gulfian*	Pierre shale	Sharon Springs (?) member	0–40	Soft, fissile blue-gray shale.	Yields no water to wells.
		Niobrara formation	Smoky Hill chalk member	100–550	Chalk and chalky shale, blue-gray, yellow, and tan. Contains a silicified zone and some bentonite.	Yields a small amount of water to wells.
			Fort Hays limestone member	40–60	Chalk and chalky limestone with some thin beds of chalky shale. Light to dark-gray. Not exposed in Graham County.	Yields a small amount of water to wells.
		Carlile shale	Blue Hill shale member	250 ±	Dark-gray noncalcareous shale. Contains a sandy zone called Codell sandstone zone at top. Not exposed in Graham County.	Codell sandstone zone yields a small amount of highly mineralized water.
			Fairport chalky shale member		Gray to blue-gray calcareous shale. Not exposed in Graham County.	Not known to yield water to wells in Graham County.
		Greenhorn limestone		90 ±	Gray chalky shale and chalky limestone. Not exposed in Graham County.	Not known to yield water to wells in Graham County.
		Graneros shale		40 ±	Dark-gray noncalcareous shale. Not exposed in Graham County.	Not known to yield water to wells in Graham County.
		Dakota formation		300 ±	Clay, shale, and siltstone with lenses of fine-grained sandstone. Underlies the surface at depths ranging from 500 to 1,100 feet.	Contains water of questionable quality. Two wells in Graham County contain water from the Dakota but are not used.

* Classification of the State Geological Survey of Kansas.

However, scattered terrace remnants of Kansan and Yarmouthian age indicate that by Kansan time the major valleys had become entrenched in approximately their present location and that they were later alluviated during Kansan and Yarmouthian time. During the period of erosion which followed, the ancestral South Fork Solomon River entrenched its valley considerably below the base of the Meade deposits (of Kansan and Yarmouthian age). During the period of alluviation which followed, the Crete sand and gravel member (of Illinoian age) of the Sanborn formation was deposited. The aggradational plain that was thus being formed at this time seemingly was subject to strong wind action and it is thought that the loess of the Loveland silt member of the Sanborn formation, which is spread over the upland area, was derived from this source. During late Sangamonian time very little erosion took place and a well-developed soil formed on the silt member of the Loveland loess.

During early Wisconsinan time erosion again took place and streams cut below the Crete member of the Sanborn. This period of erosion is thought to have been followed by rapid alluviation, which brought a large quantity of fine sediments into the valleys of the region. This is suggested by the extensive deposits of wind-blown silt which form a nearly continuous blanket over the upland areas and valley slopes and which are classed as the Peoria member of the Sanborn formation. Alluvial deposits of early Wisconsinan age have not been identified in Graham County and it is probable that they were removed during a period of erosion later in the Wisconsinan when the major streams did their last extensive downcutting. The period of alluviation that followed in late Wisconsinan or early Recent time produced deposits that are here referred to as late Wisconsinan terrace deposits. The surface of this terrace forms the principal flat area in the valley of the South Fork Solomon River. During late Wisconsinan time high winds again deposited a thin mantle of loess in upland areas. This loess, the Bignell silt member of the Sanborn formation, was deposited on the Peoria silt member, seemingly rather sporadically. In places the top of the Peoria is marked by the Brady soil that had developed prior to the deposition of the Bignell.

During Recent time, erosion in stream valleys has progressed and the modern streams have cut channels in the late Wisconsinan terrace deposits. Deposits of Recent alluvium occur along the stream channels. Other events that have occurred during Recent time have been the reworking of the sand of Ogallala and terrace and alluvial deposits into dunes and the erosion and slumping of silt of the Sanborn formation to form colluvial deposits that mantle some of the slopes.

GROUND WATER

Source and Occurrence

All the water beneath the surface of the earth is termed subsurface water. The part of subsurface water above the zone of saturation is called suspended water or vadose water, whereas water in the zone of saturation is called ground water. Ground water is the water that is available to wells or springs. In Graham County most of the ground water is derived from precipitation that falls as rain or snow either within the county or in near-by counties to the west. The greater part of the precipitation evaporates, is used by vegetation, or is carried away as surface runoff, but a small fraction enters the ground and eventually joins the body of ground water in the zone of saturation. Water that occurs in the deep-lying Dakota formation and Carlile shale (Codell sandstone zone of the Blue Hill member), neither of which crops out in the county, may be derived partially from local precipitation but probably the major part is obtained in outcrop areas of these two formations where they may receive direct precipitation or where streams flow over the outcrops. Some water may be obtained where the formations are overlain by other water-bearing formations.

The rocks underlying the surface in Graham County are not solid throughout, but rather they contain voids or interstices, which may contain air, natural gas, oil, or water. There are several different kinds of rocks in Graham County and they differ greatly in the number, size, shape, and arrangement of the interstices, and therefore in their water-holding and water-yielding capacities. The amount of water that can be stored in a rock depends on the porosity of the rock. The percentage of the volume of the rock consisting of interstices is its porosity. Although it is desirable when considering problems of ground-water supply to know the porosity, it is the permeability of the material that determines the rate at which ground water may move. The permeability of a rock is dependent on the size, shape, and interconnection of the interstices. Figure 6 illustrates several types of rock interstices that might occur in Graham County.

WATER IN SAND AND GRAVEL

Much of Graham County is underlain by deposits of unconsolidated or partially consolidated material that was laid down by streams during Pliocene and Pleistocene time. The sorting action

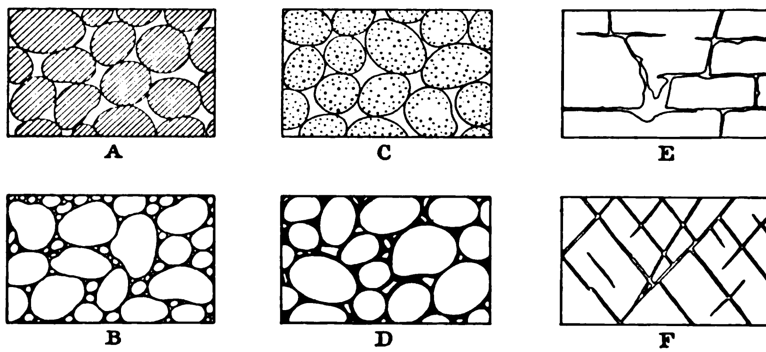


FIG. 6. Diagram showing several types of rock texture to porosity. **A,** Well-sorted sedimentary deposit having a high porosity; **B,** poorly sorted sedimentary deposit having a low porosity; **C,** well-sorted sedimentary deposit consisting of pebbles that are themselves porous so that the deposit as a whole have a very high porosity; **D,** well-sorted sedimentary deposit whose porosity has been diminished by the deposition of mineral matter in the interstices; **E,** rock rendered porous by solution; **F,** rock rendered porous by fracturing. (From O. E. Meinzer.)

of streams on the sediments in places resulted in the deposition of distinct beds of gravel, sand, silt, or clay. However, in Graham County well-sorted beds of sand or gravel are not common and in general sand and gravel occur together along with more or less silt and clay. Deposits of uniform coarse sand or gravel may have a high porosity and permeability, but deposits of sand and gravel containing silt and clay will be less porous and less permeable. Uniform deposits of silt, clay, or fine sand may be very porous, but because of the small interstices they will have a low permeability. Properly constructed wells in well-sorted uniform gravel or coarse sand yield large quantities of water.

Sand and gravel in the Ogallala formation and terrace deposits constitute the principal source of ground water in the county.

WATER IN LIMESTONE AND SHALE

Chalk, chalky limestone, and chalky shale are generally not important sources of water to wells but several wells in Graham County derive water from such beds in the Niobrara formation. In places the formation has undergone considerable folding, faulting, or fracturing, and water probably occurs in such openings caused or enlarged by water containing dissolved carbon dioxide. The occurrence of fractures and solution openings is irregular and it is generally impossible to predict where water may be found.

Shale is a very poor rock from which to obtain water. Shale is in places highly porous and may contain much water, but because of the small interstices most of the water will be retained by molecular attraction and will not be available to wells. Some water occurs in shale along joints and bedding planes but it is thought that fractures in the more massive beds yield more ground water to wells than the bedding planes and joints in the more shaly beds.

WATER IN SANDSTONE

Sandstone yields water to several wells in Graham County. The factors determining the water-bearing properties of a sandstone are the grain size, sorting, and cementation. A coarse-grained, well-sorted sandstone, if not too tightly cemented, will yield water freely, whereas a well-sorted, fine-grained sandstone will yield water less readily. Some sandstones are so tightly cemented they will not yield water from the original openings between the grains, but such sandstones may contain water in joints and fractures.

Details concerning the Codell sandstone zone of the Carlile shale and sandstone of the Dakota formation in Graham County are not available.

MOVEMENT

The water table is defined as the upper surface of the zone of saturation except where that surface is formed by an impermeable body (Meinzer, 1923, p. 32), in which case the water table is absent and artesian conditions exist. The water table is not a plane surface but is a sloping surface which has irregularities caused by differences in permeability of water-bearing material, by unequal additions or withdrawals of ground water, and by pronounced irregularities of the bedrock surface. The water table is not stationary but fluctuates in response to additions to or withdrawals from water in storage and to other factors such as changes in barometric pressure.

The configuration of the water table in Graham County where it can be drawn is shown on Plate 2 by means of contours. Water-table contour lines connect points of equal altitude and show the general shape of the water surface just as topographic maps show the shape of the land surface. The direction of movement of ground water is at right angles to the water-table contour lines.

Plate 2 indicates that ground water moves into Graham County generally from the west. It is not practical to draw water-table contours in much of the county because in places there is little or no Pleistocene or Pliocene water-bearing material. This does not necessarily indicate that no ground water can be obtained in such areas but it does mean that the water table is discontinuous and that ground water may be hard to obtain. In such areas some water can be obtained from alluvial or colluvial deposits in draws or from Cretaceous rocks.

ARTESIAN CONDITIONS

Water contained in the Dakota formation, the Codell sandstone zone of the Carlile shale, and generally the Niobrara formation, is under artesian conditions—that is, the water is contained under sufficient pressure to rise above the level at which it is encountered in wells. To be under artesian conditions water must be confined above and below by relatively impermeable beds that dip from the intake area to the area of ground-water discharge. Water entering the permeable bed percolates down gradient and will exert considerable pressure on the upper confining bed, and will rise in a well drilled through the confining layer. If the water is under sufficient pressure and the intake area is at a higher altitude than the surface of the well, the water may flow at the surface. Flowing artesian wells have been reported in Graham County, but none of these reports has been verified.

RECHARGE

Ground-water recharge is the addition of water to the ground-water reservoir and may be accomplished in several ways.

TO PLIOCENE AND PLEISTOCENE DEPOSITS

Recharge to Pliocene and Pleistocene deposits in Graham County is derived from water that falls as precipitation within the county or in adjacent areas to the west.

Although the average annual precipitation of Graham County is about 21 inches, actually only a very small fraction of this (probably less than half an inch) ever reaches the ground-water body. More than 75 percent of the precipitation falls during the months April through September during the height of the growing season when moisture is needed most. A considerable amount of the precipitation during this period is used by plants, some of it being used by the plant in the growth process and some being released to the atmosphere as water vapor by the process known as transpiration. During the same months temperatures are high, wind circulation is good, and consequently the rate of evaporation is high. According to the records of the U. S. Weather Bureau (1950) the rate of evaporation from a free water surface during the growing season as recorded at the Experimental Station at Hays, Ellis County, for the period from 1938 to 1948, is: April, 7.99 inches; May, 9.63 inches; June, 12.04 inches; July, 15.08 inches; August, 13.47 inches; and September, 11.13 inches. It is apparent that the rate of evaporation greatly exceeds the precipitation that falls during this period.

The amount of water from precipitation in Graham County that is lost to runoff is probably not very great. Data are not available for Graham County, but in the Pawnee River Valley in Ness and Hodgeman Counties, the average annual runoff has been computed to be 0.3 inch (Fishel, 1952, p. 58). In Cheyenne County the runoff for the area drained by South Fork Republican River was 0.68 inch (Prescott, 1953, p. 33). The runoff in Graham County is probably of a similar order of magnitude.

Part of the water that escapes the processes of runoff, evaporation, and transpiration percolates downward through the soil and underlying formations and eventually reaches the body of ground water. A larger amount of recharge will occur in the valleys where the surficial material is permeable and the depth to water is not great than in the upland areas where the surficial material is rather impermeable and the depth to water is great.

Probably the most important source of water in the Pliocene and Pleistocene deposits in Graham County is subsurface inflow (underflow). Plate 2 indicates that ground water enters the county from the west, which means that some of the water that reaches the water table in adjacent counties to the west moves laterally into Graham County as underflow.

Some recharge is obtained from the loss of water from ponds or from the channels of streams. Many ponds have been constructed in Graham County and, where they are above the water table and not too tightly sealed to prevent downward leakage, they constitute a source of ground-water recharge. Some of the streams lie above the ground-water level and flow only during and after heavy rains. During such periods they are a source of ground-water recharge. Many streams have cut below the base of the Ogallala formation, which is the base of the main zone of saturation, and consequently they cannot add water to the principal body of ground water. Data are too few and valleys too small to permit the drawing of water-table contour lines for other than the valley of the South Fork Solomon River.

TO BEDROCK FORMATIONS

Recharge to the Niobrara formation is similar to recharge of Pliocene and Pleistocene deposits. Some recharge is from precipitation that falls directly on the outcrop area, both within and without Graham County, and some is from streams that flow across the outcrop area. Some recharge also must take place directly from the Ogallala formation where the Ogallala formation contains water and where the upper surface of the Niobrara formation contains cracks or fractures.

Although it may be possible that some recharge to the Codell sandstone zone of the Carlile shale and the Dakota formation may result from downward seepage of local precipitation through overlying beds, probably most recharge to these aquifers takes place in areas where the formations crop out or where they are directly overlain by other water-bearing beds.

Discharge

Ground-water discharge is the discharge of water from the zone of saturation and in Graham County it is accomplished by transpiration and evaporation, by seepage into streams, and by discharge from wells and springs. Ground water also leaves the county by subsurface flow to the east.

Transpiration is one of the principal methods of ground-water discharge in Graham County. Water may be taken into the roots of plants directly from the zone of saturation and may be discharged from the plants by the process known as transpiration. The loss of ground water by transpiration is not significant in upland areas where the depth to water is great but it is of importance in the valleys where the depth to water is shallow and where water-loving plants (phreatophytes) such as alfalfa and cottonwood trees may send their roots deep in search of water. Direct evaporation from the zone of saturation also takes place in areas where the water table is shallow.

The water-table contour lines on Plate 2 indicate that water is moving from the water table to the South Fork Solomon River where the stream level is generally below the level of the water table. Ground water also contributes to the flow of Bow Creek in its eastern reach in Graham County. Several other smaller creeks are spring-fed and contain flowing water. Springs are common in the county and generally occur in draws at or near the contact between the water-bearing beds of the Ogallala formation and the underlying impermeable Niobrara formation. The amount of water discharged by springs is not known.

The discharge of water from wells is another method of ground-water discharge. Most of the domestic, stock, municipal, and irrigation water supplies in the county are obtained from wells but no data on the annual pumpage are available.

Some ground water leaves the area through subsurface outflow principally to the east. This movement of water takes place primarily in the alluvium and terrace deposits of streams that leave the area. The Ogallala formation is generally absent or very thin along the eastern border of the county and only a small amount of water leaves the area as subsurface outflow from this formation.

Recovery

When water is standing in a well the pressure of water within the well is equal to the pressure of water outside the well. When water is withdrawn from a well, either by pumping or by some other lifting device, the pressure inside the well is reduced, allowing water to move into the well. When water is being discharged from a well the water level in the vicinity of the well declines, taking the approximate form of an inverted cone known as the cone of depression. The distance that the water level is lowered at any distance from the well is called the drawdown and the lateral extent of the cone of depression from the well is called the area of influence. In general, the greater the pumping rate, the greater will be the drawdown.

The character and thickness of the water-bearing materials largely determine what the yield and drawdown of a well will be. Drawdown increases the height that water must be lifted in pumping a well, thus increasing the cost of pumping. If the water-bearing material is coarse and uniform in size it will readily yield large quantities of water to a well with a relatively small drawdown; if the water-bearing material is fine or poorly sorted it will offer more resistance to the flow of water into a well, thereby decreasing the yield and increasing the drawdown. In general, the lower the transmissibility (average permeability multiplied by thickness of the aquifer) of the water-bearing material the greater will be the drawdown in the well.

The majority of ground water that is recovered in Graham County is obtained from wells. Most of the wells have been drilled by the cable-tool (percussion) method and cased with 5- or 6-inch galvanized iron casing. Many of the shallow wells in the valleys were bored with hand augers or post-hole diggers and some shallow wells were dug by hand and cased, generally with concrete or rock. Most wells of large capacity, such as irrigation and public-supply wells, were drilled by the hydraulic-rotary method.

Some ground water is recovered from springs, which generally occur at or near the contact between Pliocene or Pleistocene deposits and the nearly impermeable Niobrara formation, which prevents the downward movement of ground water. The location of and data on some of the springs visited during the investigation are given in Table 7, but several other springs have been developed for which records are not given.

Utilization

During this investigation information on 339 wells and 5 springs was obtained. Only a small percentage of the domestic and stock wells was visited, but records were made for all municipal wells and for most irrigation wells. Records of wells and springs are listed in Table 7 and the principal uses of ground water are listed below.

DOMESTIC AND STOCK SUPPLIES

Nearly all the domestic supplies in rural Graham County are obtained from wells, and domestic supplies in the towns of Penokee, Nicodemus, Morland, and St. Peter, which have no public water supply, also obtain water from wells. Several springs are used for domestic supplies. In general, ground water in Graham County is suitable for most domestic purposes, although it is slightly hard.

Most water for stock is also obtained from wells. The stock supply is supplemented by water from streams, springs, or stock ponds.

PUBLIC SUPPLIES

Public water supplies at Hill City and Bogue are obtained from wells. Data on the municipal wells at these cities are given in Table 7.

Hill City.—Hill City, the county seat of Graham County, obtains its water supply from five wells deriving water from the terrace deposits of South Fork Solomon River. The wells range in depth from about 31 to 54 feet and are drilled through the entire thickness of the water-bearing Pleistocene deposits into shale of Cretaceous age. Wells 8-23-13bdc1 and 8-23-13bdc2, located at the power plant, are dug wells and are about 28 and 15 feet in diameter, respectively. They are curbed with concrete. Wells 8-23-13cdb1, 8-23-13cdb2, and 8-23-13cdc are 18-inch drilled wells and are just north of the river south of town and east of the fair grounds. The wells pump into the mains with the excess going to an 80,000-gallon elevated water tank in the northwestern part of town. The average daily consumption of water at Hill City is from 300,000 to 500,000 gallons a day. The consumption during the summer is sometimes nearly 1 million gallons a day. An analysis of a sample of water from the Hill City water supply is given in Table 3. The water is chlorinated.

Bogue.—Bogue obtains its water from one well in the main section of town which is a dug well and is reported to be 55 feet deep. The well pumps directly into the mains with the excess going into an elevated 50,000-gallon tank at the south end of town. The average amount of water consumed at Bogue is about 20,000 gallons a day. An analysis of water from the Bogue water supply is given in Table 3. The water is chlorinated.

INDUSTRIAL SUPPLIES

At the time the field work for this report was done very little water was used for industrial purposes. In fact, only one well, a well owned by the Union Pacific Railroad at Morland, could be classified as an industrial well. This well was used principally for filling locomotive boilers. No data were obtained concerning the well or amount of water pumped. Probably ground water was used in the drilling of some oil wells in the county, but the principal source of drilling water was surface water. In 1952 the Rex Beach power plant of the Central Kansas Power Company was under construction at Hill City. When completed this plant will use a considerable amount of ground water.

IRRIGATION SUPPLIES

A relatively small amount of ground water is used for irrigation in Graham County. Although several of the wells visited were classified as irrigation wells, only one, well 7-22-10bcb, was used in 1952 (Pl. 5B). This well irrigated several acres of corn, milo, and alfalfa, by a sprinkler system (Pl. 5A). The yield of the well at the

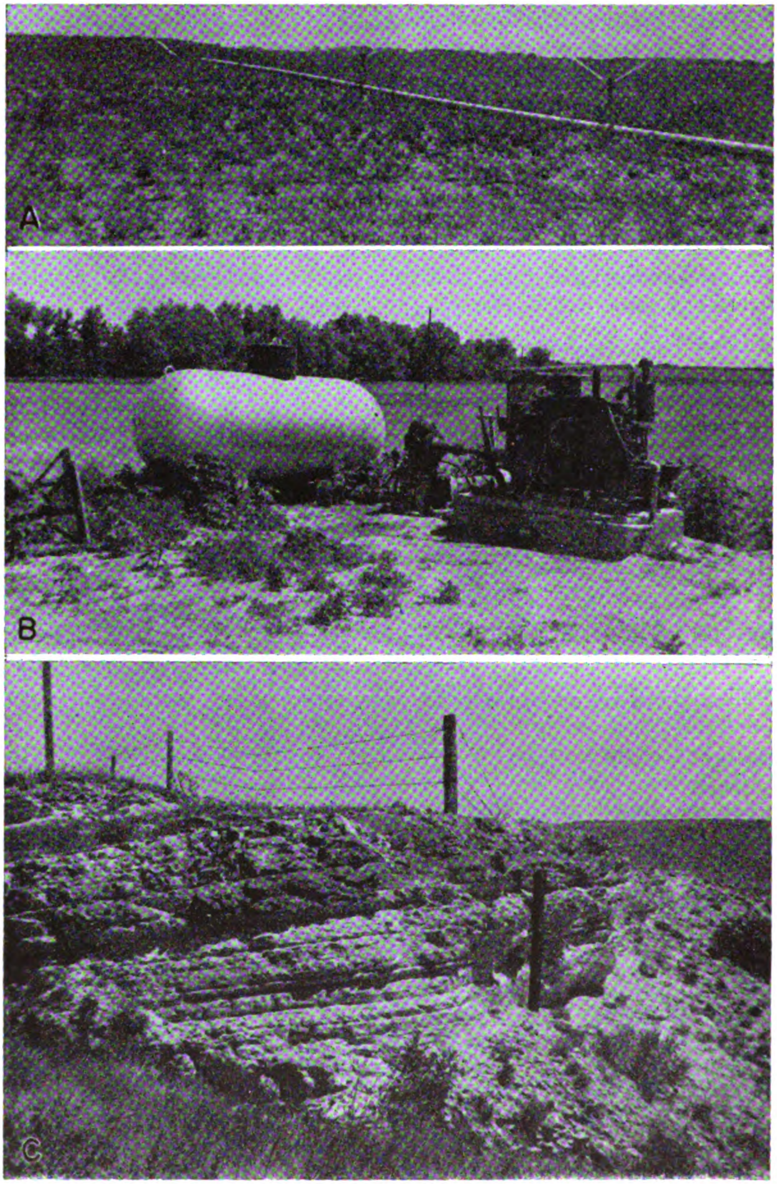


PLATE 5. A, Irrigating alfalfa by the sprinkler system from well 7-22-10bcb. B, Irrigation well 7-22-10bcb owned by M. E. Worcester. C, Tilted beds in the Smoky Hill chalk member of the Niobrara formation. View in the NW¼ NE¼ sec. 14, T. 8 S., R. 24 W. along U. S. Highway 24.

time it was first tested was 400 gallons a minute according to C. A. Robben, driller of the well.

It is possible that in certain areas in Graham County ground-water supplies sufficient for irrigation can be developed. The two most promising areas for the development of large supplies of ground water are in the valley of South Fork Solomon River and in the northwestern part of the county. The terrace deposits along the river in places are very permeable and would transmit large quantities of water to wells. In addition, the water table is relatively near the surface, which would tend to minimize the cost of drilling and pumping. The thickness and nature of water-bearing terrace deposits differ from place to place and it is advisable to drill test holes to determine the amount of saturated sand and gravel at any locality before an irrigation well is constructed there.

The Ogallala formation in northwestern Graham County contains a large amount of ground water that would be available to irrigation wells. The geologic cross sections shown in Figure 5 indicate that in places the thickness of water-bearing materials is more than 100 feet. Much of this material consists of sand and gravel and would contain much water. However, as in the valley of South Fork Solomon River the drilling of test holes to find the most favorable locations is advisable.

For data concerning the construction and development of irrigation wells the reader is referred to publications by Bennison (1947) and Rohwer (1940).

Chemical Character

The chemical character of ground water in Graham County is shown by the analyses of water from 21 wells (Tables 3 and 4). Table 3 includes analyses of the municipal water supplies of Bogue and Hill City. Figure 7 shows graphically the chemical character of water from the principal water-bearing formations. The water samples were analyzed by Howard A. Stoltenberg, chemist, in the Water and Sewage Laboratory of the Kansas State Board of Health at Lawrence. The analyses show only the dissolved mineral content and do not indicate the sanitary condition of the water.

CHEMICAL CONSTITUENTS IN RELATION TO USE

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

TABLE 3.—*Analyses of water samples from wells in Graham County*

Analyzed by H. A. Stoltenberg. Dissolved constituents given in parts per million.[a]

Well number	Depth (feet)	Geologic source	Date of collection, 1952	Temperature (°F)	Dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Hardness as $CaCO_3$ Total	Carbonate	Noncarbonate
T. 6 S., R. 21 W.																		
6-21-28ccb	42.0	Ogallala	Nov. 24	56	316	32	0.18	78	7.6	11	209	10	12	0.2	62	226	172	54
T. 6 S., R. 22 W.																		
6-22-5ddc	30.0	Terrace deposits	Nov. 24	......	228	39	0.08	52	7.0	13	205	8.6	5.0	0.2	2.6	158	158	0
T. 6 S., R. 24 W.																		
6-24-10add	128.5	Ogallala	Nov. 24	57	265	42	0.43	57	14	12	251	5.3	6.0	0.6	4.2	200	200	0
T. 7 S., R. 21 W.																		
7-21-2bcc1	380	Niobrara and/or Carlile	Dec. 2	......	768	14	0.21	50	17	215	453	163	75	3.2	7.5	195	195	0
7-21-2bcc2	100	Niobrara	Dec. 2	......	426	16	0.70	98	13	40	351	46	28	0.5	11	298	288	10
T. 7 S., R. 23 W.																		
7-23-10ccc	103.5	Ogallala	Nov. 24	57	288	38	3.1	66	12	16	273	6.6	8.0	0.4	6.6	214	214	0
T. 7 S., R. 24 W.																		
7-24-20cbb	125.0	do.	Nov. 24	......	290	39	0.10	70	12	10	264	6.6	7.0	0.3	15	224	216	8
T. 8 S., R. 21 W.																		
8-21-8dcc	30.0	Crete	Nov. 24	......	601	31	0.62	137	16	33	262	186	25	0.4	44	408	215	193
8-21-17acb[c]	55	do.	Jan. 28[e]	......	630	25	0.11	134	15	43	293	167	28	0.4	44	396	240	156
T. 8 S., R. 22 W.																		
8-22-3bbc[c]	164	Niobrara	Nov. 24	58	555	16	0.26	119	18	48	316	160	30	0.6	7.1	371	259	112
8-22-8bcc	35.0	Crete	May 29[e]	......	311	12	0.24	85	9.8	16	281	30	14	0.4	5.8	252	230	22
T. 8 S., R. 23 W.																		
8-23-2cdd	53.5	Niobrara	Nov. 24	......	784	19	0.18	155	18	74	327	91	71	0.4	195	460	268	192
8-23-9ccc	22.0	Terrace deposits	Nov. 24	58	550	25	0.15	126	21	27	288	191	16	0.6	1.1	401	236	165
8-23-13[d]	......	do.	Apr. 16	......	534	21	0.35	112	19	22	295	123	21	0.6	5.8	358	242	116
T. 8 S., R. 25 W.																		
8-25-14dcd	17.0	do.	Nov. 24	58	343	26	0.24	70	16	30	296	39	14	0.8	1.1	240	240	0
T. 8 S., R. 26 W.[b]																		
8-26-1ddd	119.0	Ogallala	Oct. 14	......	275	36	1.7	50	16	21	240	17	10	0.7	6.6	191	191	0
T. 9 S., R. 22 W.																		
9-22-27	88.0	do.	Dec. 2	......	259	31	0.62	67	8.2	11	240	4.5	12	0.4	6.6	200	197	3
T. 10 S., R. 21 W.																		
10-21-30abb	305	Niobrara	Dec. 2	56	887	26	0.20	159	22	107	326	335	65	0.9	12	487	268	219
T. 10 S., R. 23 W.																		
10-23-14add	49.5	Ogallala	Dec. 1	56	294	40	6.4	68	10	15	250	3.7	11	0.4	23	210	205	5
T. 10 S., R. 24 W.																		
10-24-23ccc	63.0	do.	Dec. 1	56	279	24	0.36	60	17	18	283	8.2	9.0	1.1	2.6	220	220	0
T. 10 S., R. 25 W.																		
10-25-34ddc	17.0	do.	Dec. 1	......	295	29	0.13	65	15	14	249	11	10	0.7	27	224	204	20

a. One part per million is equivalent to one pound of substance per million pounds of water or 8.33 pounds per million gallons of water.
b. Located in Sheridan County.
c. Sample of Bogue municipal supply.
d. Sample of Hill City municipal supply.
e. Collected in 1953.

TABLE 4.—*Summary of the chemical character of the water samples from 21 wells*

Range in: parts per million	Number of samples				
	Terrace deposits	Crete member of Sanborn formation	Ogallala formation	Niobrara formation	Niobrara formation and/or Carlile shale
Dissolved solids					
200–250	1				
251–300			8		
301–400	1	1	1		
401–500		1			
501–600	2			1	
601–700		1		1	
701–800				1	1
801–887				1	
Hardness					
151–200	1		3		1
201–300	1	1	6	1	
301–400	1	1		1	
401–487	1	1		2	
Calcium					
0–50			1		1
51–100	2	1	8	1	
101–150	2	2		1	
151–159				2	
Sodium					
0–50	4	3	9	2	
50–100				1	
101–150				1	
151–215					1
Bicarbonate					
0–200					
201–250	1		5		
251–300	3	3	4		
301–350				3	
351–453				1	1

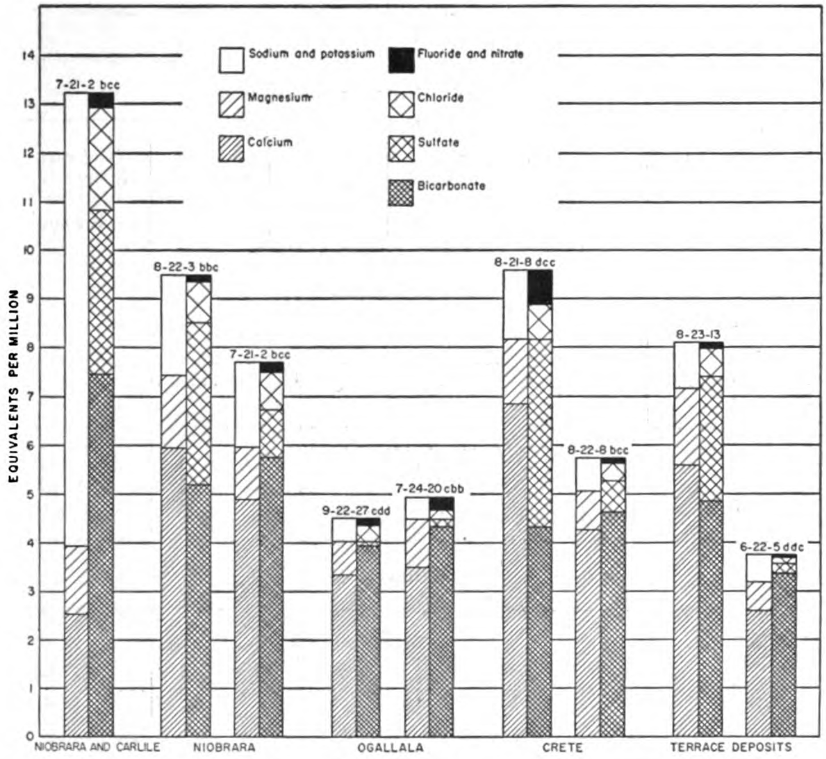


FIG. 7.—Graphical chemical analyses of samples of water from wells.

Dissolved solids.—Ground water dissolves some of the rock materials with which it comes in contact. After water has been evaporated, the residue consists of mineral matter, some water of crystallization and some organic material. The most important of these dissolved rock materials in the ground water of Graham County are shown in Table 3. The kind and quantity of dissolved constituents in water determine its suitability for various uses. Water containing less than 500 parts per million of dissolved solids is generally satisfactory for domestic use except for hardness or possibly high iron content. Water containing more than 1,000 parts per million dissolved solids is likely to contain enough of certain constituents to produce a noticeable taste or to be unsuitable in some other respect.

None of the 21 samples of ground water from Graham County contained more than 1,000 parts per million of dissolved solids. The maximum concentration was 887 and the minimum concentration

228 parts per million. Eight samples contained more than 500 parts per million of dissolved solids.

Hardness.—The hardness of water is a property that receives considerable attention and it is commonly recognized by the quantity of soap needed to produce a lather and by the curdy precipitate that forms during washing. Calcium and magnesium are the constituents that cause practically all hardness of ordinary water and are the active agents in the formation of the greater part of the scale formed in steam boilers and in other vessels in which water is heated or evaporated.

Hardness is of two types, carbonate and noncarbonate. Carbonate hardness, often called temporary hardness, is caused by calcium and magnesium bicarbonate and can be almost entirely removed by boiling. Noncarbonate or permanent hardness is caused by sulfate, chloride, nitrate, or fluoride of calcium and magnesium and cannot be removed by boiling. In use with soap there is no difference between carbonate and noncarbonate hardness, but in general noncarbonate hardness forms harder scale in steam boilers.

Water having a hardness of less than 50 parts per million is considered as soft. Hardness between 50 and 150 parts per million does not seriously interfere with the use of the water for most purposes but industries that use large amounts of soap, such as laundries, may find it profitable to reduce the hardness by a softening process. Water having a hardness of more than 150 parts per million may be treated by individual users for household use. The use of home water softeners was not observed in Graham County and there are no municipal softening plants in Graham County. Where municipal water supplies are softened the hardness is generally reduced to 100 parts per million or less.

No samples of water from Graham County can be considered as soft, as the minimum hardness was 158 parts per million. The maximum hardness was 487 parts per million. Only three samples contained less than 200 parts per million hardness.

Silica.—Silica is a mineral constituent of most ground water. Silica may be deposited with other scale-forming minerals in steam boilers, but otherwise it has no effect on the use of water for most purposes. The silica content of ground water in Graham County ranged from 14 to 42 parts per million.

Iron.—If water contains more than 0.2 or 0.3 part per million of iron, the excess may separate out and settle as a reddish sediment when exposed to air. Iron, which may be present in sufficient quantity to give a disagreeable taste, to discolor the water, or to stain plumbing fixtures or fabrics, may be removed from most water by aeration and filtration. However, some water requires additional treatment.

Fluoride.—Fluoride is generally present only in small concentration in ground water but it is desirable to know the amount of fluoride in water that is used by children. Fluoride in drinking water has been shown to be associated with the dental defect known as mottled enamel, which may appear on the teeth of children who habitually drink water containing excessive fluoride during the formation of the permanent teeth. Many dental authorities are now in agreement that fluoride in small quantities is a factor in reducing dental caries if the amount does not exceed about 1.5 parts per million. The fluoridation of municipal supplies in areas in the United States where the natural fluoride content of the water supply is low is increasing at the present time.

The fluoride content of water samples from Graham County ranged from 0.2 to 3.2 parts per million. Only two samples contained fluoride in excess of 1 part per million.

Nitrate.—The quantity of nitrate in ground water is commonly low, generally less than about 10 parts per million in natural water. Although some nitrate is obtained by ground water from nitrate-bearing rocks and minerals through which it percolates, high nitrate concentrations are thought to be obtained from direct flow of surface water into the well or to the percolation of surface water into the well through the top few feet of the well. Soils, especially during the fall and winter, contain large concentrations of readily soluble nitrate derived from plants or animal waste. Privies, barnyards, and cesspools are also sources of organic nitrogen and may be not only a source of nitrate to wells but a source of harmful bacteria as well.

Nitrate in concentrations of more than 45 parts per million (as NO_3) is undesirable because of the possible toxic effect that it may have on the blood circulatory system of infants. (Metzler and Stoltenberg, 1950). This effect, which is known as cyanosis, results when the water habitually consumed by an infant contains a large amount of nitrate. In cyanosis the baby becomes listless and drowsy and the skin becomes blue. If the water supply is not changed in time death may result. Nitrate in drinking water does not cause cyanosis in adults but may be responsible for certain digestive disorders.

Nitrate concentrations in water samples from Graham County ranged from 1.1 to 195 parts per million. Two samples contained

44 parts per million and another had 62, but all others contained considerably less than 45 parts per million nitrate with the exception of the one containing 195.

WATER FOR IRRIGATION

The suitability of water for irrigation is thought to be dependent principally on the total quantity of dissolved mineral matter and the percentage of sodium. The quantity of chloride may be large enough to affect the use of water and in some areas, boron may be present in sufficient amounts to be harmful to plants. Each factor must be considered with respect to other factors such as soil composition, permeability, drainage, and crop tolerances.

Continuous use of water high in dissolved solids may increase the salinity of the soil, which may ultimately affect the permeability of the soil and disturb plant growth. The total concentration of dissolved constituents may be expressed in terms of parts per million of dissolved solids, of total equivalents per million of anions and cations, or in terms of electrical conductivity. Electrical conductivity is a measure of the ability of inorganic salts in solution to conduct an electrical current, and it is related to the concentration of dissolved solids. Approximate values for electrical conductivity can be obtained by multiplying total equivalents per million of anions or cations by 100, or by dividing dissolved solids in parts per million by 0.7 (Wilcox, 1948, pp. 4-5).

Irrigation water containing a high percentage of sodium may cause dispersion of soil particles and may retard water and air movement through the soil. To find the percentage of sodium the results of the analyses must be reported in equivalents per million. The quantity of sodium in equivalents is divided by the sum of the quantities of calcium, magnesium, sodium, and potassium and the result is expressed as a percentage. In general, water containing more than about 60 percent sodium is undesirable for irrigation use. The classification of water for irrigation is shown in Table 5, and conversion factors to change parts per million to equivalents per million are given in Table 6.

Water samples from Graham County were not analyzed for boron content. However, water samples from wells in the valley of North Fork Solomon River contained only a small amount of boron (Leonard, 1952, pp. 74, 76) and it is probable that the quantity of boron in ground water in Graham County is insufficient to be harmful to plants.

TABLE 5.—*Percentage of sodium permissible in several classes of irrigation water (after Wilcox, 1948a, p. 27)*

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

TABLE 6.—*Factors for converting parts per million of mineral constituents to equivalents per million*

Cation	Conversion factor	Anion	Conversion factor
Ca^{++}	0.0499	HCO_3^-	0.0164
Mg^{++}	0.0822	SO_4^-	0.0208
Na^+	0.0435	Cl^-	0.0282
		NO_3^-	0.0161
		F^-	0.0526

Only one sample of water from Graham County, from well 7-21-2bcc1, is thought to be of questionable quality for irrigation. This well, which obtains water from the Niobrara formation and the Carlile shale, contains a high ratio of sodium to other cations as well as moderately high concentration of dissolved solids.

SANITARY CONSIDERATIONS

The analyses of water in Table 3 show only the amount of dissolved mineral matter in the water and do not necessarily indicate its sanitary quality. An abnormal amount of certain mineral constituents, such as chloride or nitrate, however, may indicate pollution of the water.

The entire population of Graham County is dependent on ground water and care should be taken to protect from pollution wells and springs that serve humans. Wells should be located away from possible sources of pollution such as barnyards and privies. If a well must be located near a possible source of pollution, the well should be upslope from such source so that rain water will not run from the source of pollution to the well. Wells should be properly sealed at the top to prevent the direct inflow of surface water. Water samples from two wells in Graham County were rather high in nitrate content. Both wells were poorly sealed at the top and it is thought that nitrate-bearing surface water ran directly into the wells. It is also possible that some harmful bacteria entered the wells at the same time.

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

Cretaceous System

GULFIAN SERIES

Dakota Formation

The Dakota formation does not crop out in Graham County but it contains considerable water within a practical drilling depth and should be considered in a discussion of the aquifers in the county. At the time of the investigation no wells were known to produce water from the Dakota but two of the wells visited had been drilled to the Dakota and contained water. In near-by Gove, Trego, and Rooks Counties, the Dakota is an important source of ground water in certain areas where shallow ground water is scarce.

The Dakota formation in Kansas consists predominately of clay, shale, and siltstone with lenses of fairly fine-grained sandstone. Many of the sandstone lenses are interconnected and some water-bearing sandstone is present at most localities. The percentage of sandstone in the Dakota formation in the subsurface of Graham County is not known. The thickness of the Dakota formation in Graham County averages about 300 feet. Its depth below land surface ranges from about 1,100 feet in the uplands on the west to about 500 feet in the valleys in the eastern part of the county.

The quality of the water in the Dakota formation in Graham County is not known. According to A. R. Leonard (1952, p. 28) water in the Dakota in Phillips County is so highly mineralized that it is unfit for domestic, stock, or irrigation use. However, according to W. D. Waterman (personal communication) the water in several Dakota wells in Gove County is suitable for domestic and stock use although too highly mineralized for irrigation.

Graneros Shale

The Dakota formation is overlain by a dark noncalcareous shale that is known as the Graneros shale. It averages about 40 feet in thickness in Graham County and is not known to yield water to wells.

Greenhorn Limestone

The Greenhorn limestone, which consists principally of a series of chalky limestones and calcareous shales, overlies the Graneros shale. The Greenhorn is on the average about 90 feet thick in Graham County and is not known to yield water to wells.

Carlile Shale

Above the Greenhorn limestone is the Carlile shale, which averages about 250 feet in thickness in Graham County. The lower part of the formation, which consists of gray to blue-gray calcareous shale and thin chalk beds, is known as the Fairport chalky shale member. The upper part of the formation consists principally of dark-gray noncalcareous shale and is known as the Blue Hill shale member. At the top of this member is a sandstone or sandy shale zone, which is the Codell sandstone zone. None of the test holes drilled in the area penetrated the Carlile, and logs of oil wells drilled in the county contain very little detailed information, so the character of the Codell in Graham County is not known. It is thought that the upper part of the Carlile shale, presumably Codell sandstone zone, is water-bearing, and one well, 7-21-2bcc1, is believed to obtain at least part of its water from this formation. The water from this well is highly mineralized but is not extremely hard. It would be unsuitable for irrigation because of a high percentage of sodium, and might be unsatisfactory for sustained drinking by children because of a relatively large amount of fluoride.

Niobrara Formation

The oldest rocks to crop out in Graham County consist of the chalk and chalky shale of the Smoky Hill chalk member of the Niobrara formation. The lower member of the Niobrara formation, the Fort Hays limestone member, is not exposed in Graham County.

Fort Hays limestone member.—The Fort Hays limestone member is composed of thick massive beds of chalk or chalky limestone separated by thin beds of chalky shale. The beds are light to dark gray when unweathered, but upon weathering they are white, tan, buff, or cream. The Fort Hays underlies the entire area and probably averages about 55 feet in thickness. It is thought that the Fort Hays limestone member contains water in fractures or along bedding planes and that it supplies water to some wells in the area. For example, wells 7-21-2bccl and 10-21-30abb probably obtain some water from the Fort Hays. Water from these wells is rather highly mineralized. Water from well 10-21-30abb is very hard, whereas water from well 7-21-2bccl is less hard, being similar to water from the Ogallala formation in that respect. In well 7-21-3bccl, water from the Fort Hays is thought to be modified by water from the Carlile shale.

Smoky Hill chalk member.—The Smoky Hill chalk member of the Niobrara formation consists principally of chalk and chalky shale beds, which are light to dark gray in unweathered beds but yellow, orange, tan, or pinkish in weathered exposures (Pls. 5C, 6). The Smoky Hill contains some massive chalk beds similar to beds of the Fort Hays limestone member. Thin bentonite beds and concretions of pyrite or limonite are common as are large fossil shells of *Inoceramus grandis* and small fossil shells of *Ostrea congesta*. The formation has undergone considerable deformation, and fractures, small faults, and tilted beds are common in outcrops of the Smoky Hill (Pls. 5C, 6B). Some of the fractures or fault lines are filled with crystalline calcite. In secs. 28, 29, and 32, T. 8 S., R. 25 W., is an area where considerable faulting has occurred. In this locality the Niobrara formation is above the younger Pierre shale in several places for horizontal distance of more than half a mile.

Beds of silicified chalk occur at or near the top of the Smoky Hill chalk member at several localities. Silicified chalk zones commonly occur near or are associated with the Ogallala formation. According to Frye and Leonard (1949 p. 30) the silicified zones in the chalk were formed by secondary silicification of the uppermost exposed chalk beds probably at the same time as the silicification of zones in the overlying Ogallala formation.

The entire county is underlain by the Smoky Hill chalk member and it crops out in a large part of the area (Pl. 1). The formation has undergone considerable dissection during Pleistocene time and its thickness is considerably different from place to place. In the upland areas in the northwestern part of the county where the Ogallala formation has protected the Smoky Hill from erosion, the Smoky Hill is as much as 550 feet thick but in the southeastern part of the county where there has been much erosion, it may not be more than 100 feet thick.

The Smoky Hill is generally not an important source of water, but in Graham County it yields water to several wells in areas where water is not available from Pleistocene or Pliocene deposits. The water in the Smoky Hill is thought to be contained in fractures along faults or along bedding planes. The success of a well pene-

PLATE 6. Smoky Hill chalk member of Niobrara formation. A, Chalky shale of the Smoky Hill with a mortar bed of the Ogallala formation at top; NW¼ SW¼ sec. 19, T. 10 S., R. 20 W., Rooks County. B, Small fault in Smoky Hill chalk member in sec. 29, T. 8 S., R. 25 W. Photograph by C. K. Bayne.

trating either the Smoky Hill or the Fort Hays depends on whether or not these openings are found. Yields of wells to the Niobrara generally are small.

Analyses of samples of water from four wells thought to derive part or all their water from the Smoky Hill are given in Table 3. The water is more highly mineralized and harder than water from the Ogallala but is satisfactory for stock use and most domestic uses.

Pierre Shale

The Pierre shale, which is the youngest formation of late Cretaceous age recognized in Kansas, consists principally of soft fissile blue-gray shale in Graham County. The formation has been studied and described in detail by Elias (1931) who separated the Pierre into six members. Outcrops of Pierre are too few and too thin in Graham County to determine what member is present, but it is probable that the Pierre shale in Graham County consists entirely of the lowermost member, the Sharon Springs shale member. Outcrops of Pierre shale are restricted to four small areas in the western part of the county (Pl. 1). The maximum thickness of the formation observed in outcrops was 18 feet. No Pierre shale was encountered in test drilling and it does not form a continuous layer in the upland areas. The maximum thickness of the Pierre is probably less than 40 feet. The Pierre yields no water to wells in Graham County.

TERTIARY SYSTEM

PLIOCENE SERIES

Ogallala formation

The Ogallala formation was named by Darton (1899, pp. 732, 734) from a locality in southwestern Nebraska and its age was considered as late Tertiary or Pliocene(?). In 1920 Darton (p. 6) designated the type locality as being near Ogallala Station in western Nebraska. Since the work of Darton, the most significant studies of Ogallala stratigraphy in western Kansas have been made by Elias (1931), Smith (1940), and Frye and Leonard (1949).

The Ogallala formation is now considered by the State Geological Survey of Kansas to range from early Pliocene or possibly late Miocene to late Pliocene in age. The Ogallala is subdivided into three members which, in ascending order, are: Valentine, Ash Hollow, and Kimball. No attempt to subdivide the Ogallala in Graham County was made.

Character.—The Ogallala formation in Graham County consists chiefly of silt, clay, sand, and gravel. Calcium carbonate is a common constituent and occurs as cementing material, as caliche beds, nodules, or stringers, or as layers of impure limestone. Silica occurs as cementing material or in places as beds of opaline sandstone or chert. Some beds of bentonitic clay are found in Graham County but beds of volcanic ash or diatomaceous marl, which occur in other areas, have not been identified in Graham County. The character of the Ogallala is shown in logs of test holes included near the end of the report. In spite of its diversity of rock types, the outcrop pattern of the Ogallala presents a uniformity of aspect that makes the formation readily identifiable.

Sand, the principal constituent of the Ogallala formation, occurs at all horizons. Beds of uniform sand may occur but generally the sand is mixed with gravel, silt or clay; sand grains also occur in beds of impure limestone. Gravel beds containing large amounts of sand, silt, or clay are fairly common but thick beds of uniform gravel are scarce. None were encountered in test drilling. Silt and clay, either mixed with deposits of sand and gravel or in layers, are common in the Ogallala. Beds of silty or sandy clay are greenish-gray, reddish-brown, tan, or gray. If the layers contain a large amount of calcium carbonate they are white. At some places layers contain nodules or stringers of calcium carbonate (caliche), calcium carbonate as cementing material, or calcium carbonate as disseminated particles.

Many of the beds in the Ogallala are cemented or partially cemented with calcium carbonate. At many places where sand and gravel deposits are cemented with calcium carbonate they form rough benches or scarps and are called "mortar beds" because of their resemblance to old mortar. Plate 7A shows a type of mortar bed that is common in the Ogallala of Graham County.

Perhaps the most distinctive rock type in the area is the so-called Ogallala "quartzite." This "quartzite" consists of sand and gravel zones cemented with opaline silica into a very hard rock. In places the sand is fine or medium, the interstices are seemingly filled with cement, and the rock resembles true quartzite. At other localities the rock contains coarse sand or gravel and has little resemblance to quartzite except in respect to hardness. The quartzite, which is typically green in Graham County, generally occurs very close to the base of Ogallala. Outcrops of quartzite are shown in Plates 3A and 7B. A more detailed description of the quartzite in this and other counties is given in a report by Frye and Swineford (1946).

PLATE 7. Ogallala formation. A, Mortar beds of the Ogallala formation in the SE¼ SE¼ sec. 31, T. 8 S., R. 24 W. B, Blocks of quartzite, most of which have broken from their original position and slumped down the hill; SE¼ sec. 31, T. 7 S., R. 22 W.

Another distinctive rock type in the Ogallala is the "Algal limestone," which is the uppermost bed in this formation. This limestone has a peculiar concentrically banded structure and was thought by Elias (1931, pp. 136-141) to have been precipitated in quiet water at least in part by the alga *Chlorellopsis*. Although the "Algal limestone" occurs in many areas in the High Plains and is recognized as far east in Kansas as Lincoln County, only one exposure was found in Graham County. This outcrop was at the bottom of a grader ditch near the SE cor. NE¼ sec. 34, T. 6 S., R. 24 W. Where not exposed in the ditch the "Algal limestone" is covered by 3 or more feet of loess in the locality. During the field work, several other limestone beds were found which lack the concentric algal features of the "Algal limestone" but which are otherwise similar and may be comparable. One such outcrop occurs at the top of a small hill about a quarter mile west of the SE cor. sec. 1, T. 7 S., R. 22 W.

Distribution and thickness.—The Ogallala formation at the end of Pliocene time probably covered the entire county with a mantle of sediments that generally were thinner to the east. At the present time the Ogallala still covers much of the area but in places it has been removed completely by erosion. The bedrock beneath the alluvium and terrace deposits of South Fork Solomon River is Niobrara formation, the Ogallala having been removed along the entire length of the stream in Graham County. North and south of the river are bluffs of the Niobrara formation. These bluffs are generally capped by beds of the Ogallala formation in the western part of the county. East of Hill City, however, the Ogallala crops out at a greater distance from the river as erosion of the Ogallala, which was probably originally very thin, has progressed farther in this area (Pl. 1). Some of the bluffs in the vicinity of the river are capped by quartzite of the Ogallala, which has retarded erosion to a considerable extent. For example quartzite outcrops occur in the NE¼ sec. 14, T. 8 S., R. 24 W., and in the NW¼ sec. 29, T. 8 S., R. 23 W.

In addition to South Fork Solomon River many other smaller streams have cut through the Ogallala formation and into the Niobrara. This has happened along North Fork Saline River and along the eastern part of Bow Creek, and along many other unnamed tributaries to Saline River, North Fork Saline River, and South Fork Solomon River. Good outcrops of the Ogallala occur along some of these streams. A particularly impressive exposure of the Ogallala occurs along the south bank of North Fork Saline River in the NW¼ sec 23, T. 10 S., R. 25 W. south of St. Peter (Pl. 8).

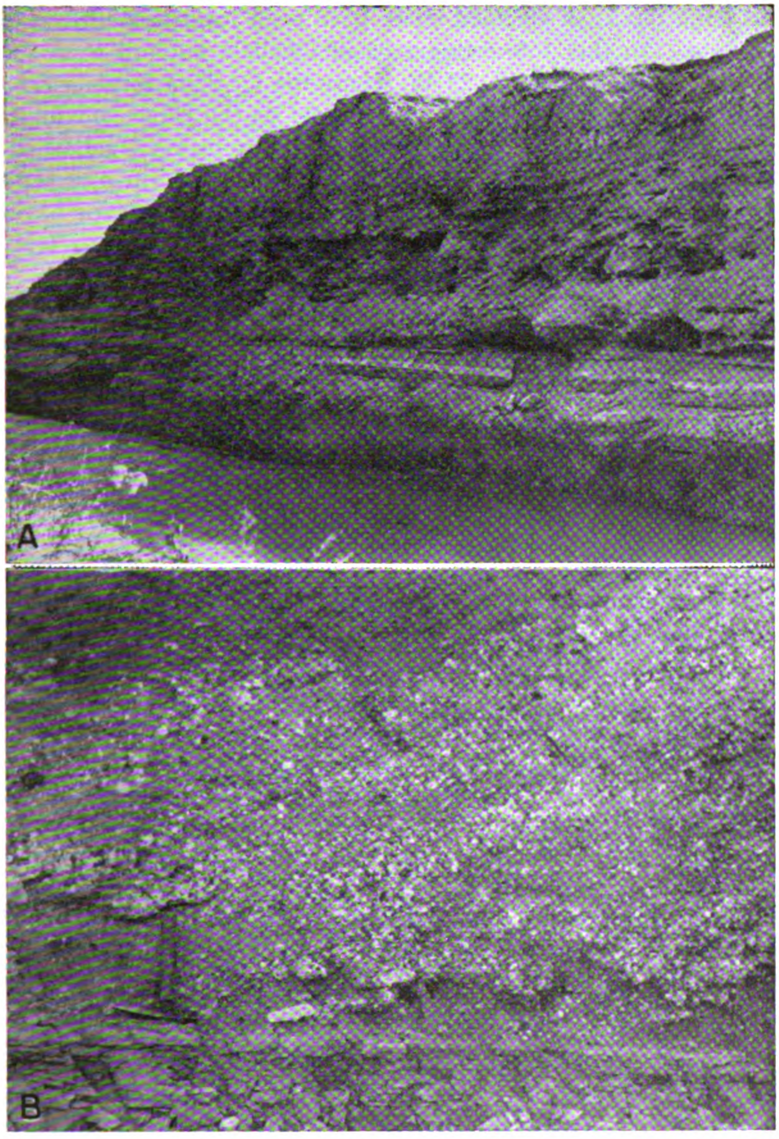


PLATE 8. Contact of the Ogallala and Niobrara formations. **A**, Ogallala formation in the NW¼ NW¼ sec. 23, T. 10 S., R. 25 W. in bluff on south side of North Fork Saline River. Coarse-textured Ogallala resting on silicified chalk of Niobrara formation. Large blocks of silicified chalk are incorporated in the Ogallala. **B**, Same locality showing the coarse texture of the Ogallala and the contact between the Ogallala and the silicified chalk.

At this locality the Ogallala overlies silicified chalk of the Niobrara and large blocks of silicified chalk have been incorporated into the Ogallala. Another interesting area of Ogallala outcrop is in secs. 22, 23, and 24, T. 7 S., R. 22 W. where the Ogallala forms a ridge. Quartzite caps some of the higher points on the ridge and mortar beds occur below. Sand, washed or blown from the Ogallala, has accumulated south and southeast of the ridge to form a series of low sand dunes. The entire area has the aspect of never having been covered with the loess of the Sanborn formation, which mantles the Ogallala in the uplands in much of the county.

Of the 29 test holes drilled in Graham County, 16 encountered the Ogallala formation. The maximum thickness of the Ogallala was 205 feet in test hole 6-25-31ccc. The thickness of the Ogallala is shown in the cross sections (Fig. 5) and in the logs of the test holes given in this report.

Water Supply.—The Ogallala is the most wide-spread water-bearing formation in Graham County. It supplies water to most of the domestic and stock wells in the upland areas and to the only irrigation well that was used in 1952. Many springs obtain water from the Ogallala but only a few of the springs are listed in Table 7. The yield of the wells ranges from a few gallons a minute for domestic and stock wells to about 400 gallons a minute for irrigation well 7-22-10bcb. Logs of test holes indicate that much of the water-bearing material consists of sand and gravel, which may store or yield large amounts of water. The geologic cross sections (Fig. 5) indicate that in most of the county, although water-bearing materials in the Ogallala may be relatively coarse and may contain sufficient water for domestic and stock purposes, they are generally too thin to permit the pumping of amounts of water sufficient for irrigation.

Water samples were collected from nine wells that derived their water from the Ogallala formation. The analysis listed in Table 3 indicate that the water from the Ogallala is fairly uniform in quality and is of better quality than water from the other formations. Although the water is moderately hard, it is generally of good quality both for domestic use and for irrigation.

Quaternary System

PLEISTOCENE SERIES

Deposits of Quaternary age constitute the surficial material in much of Graham County. Where they occur in the valleys they are an important source of ground water. The Quaternary deposits in

Graham County are the Meade formation, Sanborn formation, dune sand, and alluvium.

Meade Formation

Deposits of Kansan age (Meade formation) occur as remnants of a high terrace in scattered outcrops principally along South Fork Solomon River (for example, in road cuts along U. S. Highway 24 in the NW¼ sec. 18, T. 8 S., R. 24 W., the NW¼ sec. 14, T. 8 S., R. 23 W., and the SE¼ sec. 14, T. 8 S., R. 21 W.). Other exposures of the Meade formation have been identified in southwestern Graham County in the SW¼ sec. 18 and NW¼ sec. 19, T. 10 S., R. 24 W. along a tributary to North Fork Saline River and in sec. 35, T. 10 S., R. 23 W. along a tributary to Saline River. The Meade formation consists of two members, the Sappa member above and the Grand Island member. The Sappa member is composed principally of silt with small amounts of sand and gravel. In the SE¼ sec. 4, T. 8 S., R. 25 W., the combined thickness of the Sappa and Grand Island is about 25 feet. The Sappa at this locality consists chiefly of light-tan silt and fine sand. It also contains layers of greenish-gray clay. In the SW¼ SE¼ sec. 14, T. 8 S., R. 21 W. the Sappa consists of about 11 feet of light-tan fine sand and silt. In the NE¼ SW¼ sec. 11, T. 8 S., R. 25 W., the Sappa consists principally of silt but contains a 6-foot bed of volcanic ash, the Pearlette volcanic ash bed, which is an important marker bed and whose presence simplifies the identification of the Sappa member. The Pearlette volcanic ash bed has also been identified in the SW¼ sec. 18, T. 10 S., R. 24 W. (Pl. 9A). The Grand Island member has been identified in exposures in the SW¼ sec. 18 and NW¼ sec. 19, T. 10 S., R. 24 W.; SW¼ SE¼ sec. 14, T. 8 S., R. 21 W.; and SE¼ sec. 4, T. 8 S., R. 25 W. A test hole drilled at the SE cor. sec. 14, T. 8 S., R. 21 W. encountered 55 feet of deposits that are thought to be Meade formation. The Meade formation has been mapped with the Sanborn formation (Pl. 1). Outcrops of the Meade formation are small and generally lie above the water table in Graham County and yield no water to wells. However, one well that was inventoried (8-21-26dcd) obtained water from deposits that may be Meade formation. This well, located in a small draw tributary to the South Fork Solomon River, is thought to obtain water from beds that may have been deposited by tributary streams in Kansan time.

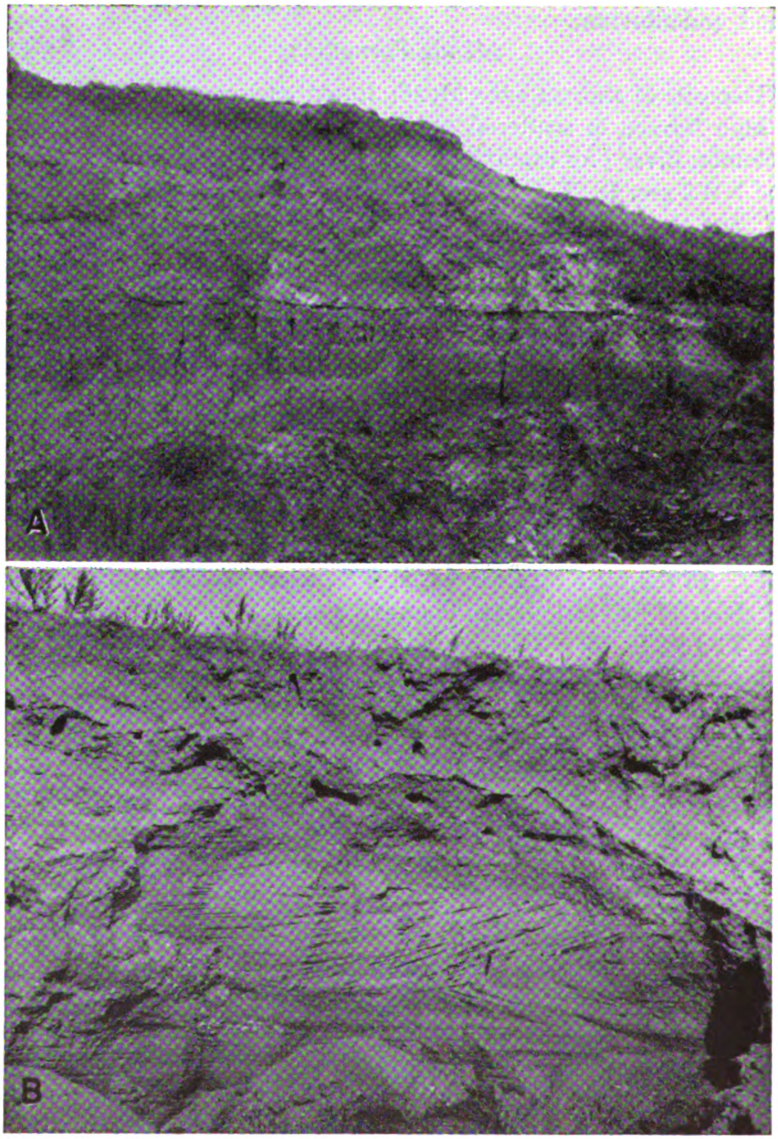


PLATE 9. **A,** Pearlette volcanic ash bed in Sappa member of Meade formation. Ash is the white bed near center of picture. Peoria silt member of the Sanborn formation at top of exposure and chalk of the Niobrara formation at base; NE¼ SW¼ sec. 18, T. 10 S., R. 24 W. **B,** Cross-bedded sand in the Crete sand and gravel member of the Sanborn formation; SW¼ SE¼ sec. 7, T. 8 S., R. 22 W.

Sanborn Formation

The name Sanborn formation was first used in 1931 by Elias (pp. 163-180) for unconsolidated Pleistocene deposits, consisting mainly of silt but with some sand and gravel at the base, that are widely distributed on the divides of western Kansas. The deposits were named for the town of Sanborn, Nebraska, which is just north of the type locality in northwestern Cheyenne County, Kansas. Since the work of Elias the formation has been more specifically defined and has been subdivided and expanded to include, in ascending order, the following members: (1) Crete sand and gravel member; (2) Loveland silt member, commonly containing the fossil Sangamon soil at its top; (3) unnamed early Wisconsinan alluvial deposits; (4) Peoria silt member, commonly containing the fossil Brady soil at its top; (5) unnamed late Wisconsinan alluvial deposits; and (6) the Bignell silt member (official classification of the State Geological Survey of Kansas, Frye and Leonard, 1952, p. 106). All subdivisions except early Wisconsinan alluvial deposits were recognized in Graham County.

Crete sand and gravel member.—The basal member of the Sanborn formation is the Crete sand and gravel member, which represents the major channel fills of Illinoian age. Deposits of the Crete are widespread throughout the county and occur in terrace position along many of the streams. In places the Crete is exposed in vertical banks and is overlain by either the Loveland silt member or the Peoria silt member. In the W½ sec. 15, T. 8 S., R. 25 W., the Crete lies on Pierre shale and Niobrara and is overlain by the Peoria silt member. The thickness of the Pleistocene section at this locality is approximately 30 feet. In the SE¼ SW¼ sec. 5, T. 8 S., R. 22 W. the Crete lies on Niobrara and is overlain by the Loveland silt member which in turn is covered by the Peoria silt member. Other good exposures of the Crete occur in the SE¼ sec. 7, T. 8 S., R. 22 W. (Pl. 9B) and in the SW¼ NW¼ sec. 9, T. 8 S., R. 23 W. Generally the Crete is mantled by varying thicknesses of silt of the Sanborn and does not crop out or consists of a narrow band of sand and gravel at the base of a vertical bank composed principally of loess. Outcrops of Crete shown on Plate 1 do not represent its maximum extent but rather are occurrences which are not covered by thick loess and which are mappable as Crete rather than Sanborn formation undifferentiated. The Crete was encountered in test holes 8-21-17dbb, 8-23-2ddd, and 8-23-12bcc, its maximum thickness being 17 feet in 8-23-12bcc.

Loveland silt member.—The Loveland silt member has been identified in outcrops in Graham County and has been recognized in drill cuttings but its occurrence is thought to be sporadic. Seemingly it does not form a continuous blanket over the divide areas as does the Peoria silt member, which overlies it. The loess of the Loveland is tan where unaffected by weathering, but generally it is identified by the Sangamon soil (formed at the top of the Loveland during Sangamonian time), which is dark brown and which contains a high percentage of clay. Some of the Loveland exposures in the county are in the NW¼ NE¼ sec. 7, T. 8 S., R. 21 W.; SE¼ SW¼ sec. 5, T. 8 S., R. 22 W.; and NW¼ sec. 14, T. 8 S., R. 23 W. Loveland was recognized in test holes 6-22-4aaa, 7-21-23add, and 7-22-1aaa. In test hole 6-22-4aaa the Loveland was 13 feet thick.

Peoria silt member.—The Peoria silt member is widespread in Graham County and has been recognized in all parts of the county where it overlies formations of Pliocene or Cretaceous age. The Peoria consists of a tan or yellowish-gray silt, which presumably was blown from the flood plains of the Platte and Republican Rivers during early Wisconsinan time (Swineford and Frye, 1951). The Peoria is in places terminated upward by the Brady soil, which is a dark-brown to black soil generally slightly thicker than the modern soil. Where the Brady soil occurs, it is overlain by the Bignell silt member, which is the uppermost silt member of the Sanborn (Pl. 10).

Bignell silt member.—The Bignell silt member, which consists of 3 to 4 feet of tan silt in a typical exposure in a road cut in the NE¼ NW¼ sec. 9, T. 10 S., R. 25 W., occurs sporadically throughout the area (Pl. 9B).

Terrace deposits.—Stream deposits underlie a broad low terrace that forms a considerable part of the floor of the South Fork Solomon River Valley throughout its length in Graham County. Alluvial deposits in terrace position also occur in valleys tributary to South Fork Solomon and Saline Rivers and in Bow Creek Valley. These deposits represent essentially a single cycle of terrace development although minor breaks in level suggest that the terraces were developed during several episodes of cut and fill. The terrace deposits are principally late Wisconsinan in age, although possibly some of the basal materials are early Wisconsinan and some of the uppermost material may be early Recent.

The terrace deposits along South Fork Solomon River consist principally of sand and gravel that has been derived from older alluvial

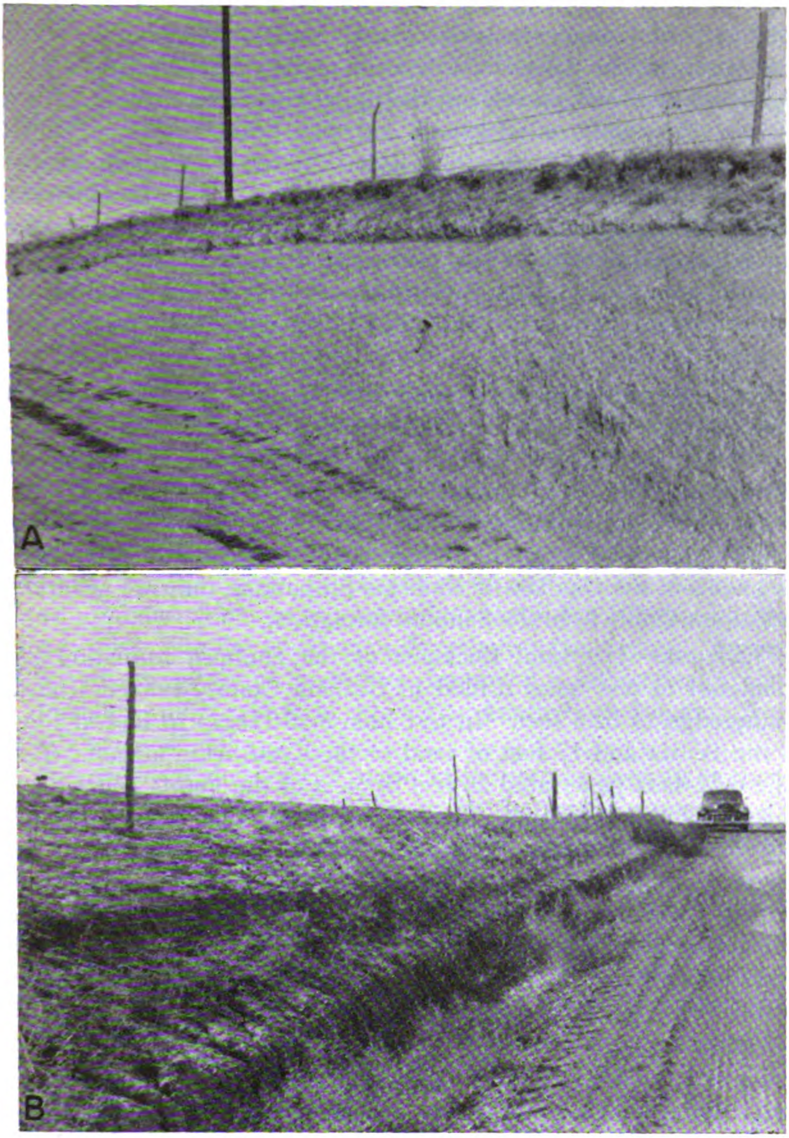


PLATE 10. Outcrops of the Sanborn formation A, Exposure of Peoria silt member of Sanborn formation in road cut; NW¼ SE¼ sec. 2, T. 8 S., R. 25 W. B, Bignell silt member and Peoria silt member of Sanborn formation separated by Brady soil. Soil is about 1 foot thick and is underneath hammer; NE¼ NW¼ sec. 9, T. 10 S., R. 25 W.

deposits or from the Ogallala formation. The deposits also contain fragments of Cretaceous bedrock and considerable sand and silt. The basal part of the terrace deposits of Bow Creek consists principally of sand and gravel, but the upper part is mostly silt. Some of this silt may be wind blown and may be correlated with the Bignell silt member as the Bignell and the terrace deposits are essentially of the same age. Some of the silt may also be colluvial. Upper Wisconsinan terrace deposits along the smaller streams contain a large percentage of fine materials. Included with the terrace deposits along the smaller streams are deposits of Recent alluvium which are too narrow to be shown on a map of the scale used in this report.

Slope deposits.—Included with the Sanborn formation on the geologic map (Pl. 1), although not properly classified as Sanborn, are colluvial materials mantling some of the slopes. The colluvium or slope deposits consist mainly of silt of the Sanborn formation that has been redeposited during Recent time by the action of wind, surface water, or soil creep. Although the slope deposits may include fragments of the Ogallala or Niobrara formations, they are generally indistinguishable from the Sanborn formation.

Thickness.—The total thickness of the Sanborn formation encountered in test holes drilled in Graham County ranged from a featheredge to 52.5 feet. In test hole 8-23-12bcc, 16 feet of loess of the Peoria and 17 feet of sand of the Crete were logged. Test hole 6-22-4aaa penetrated 20 feet of loess of the Peoria and 13 feet of loess of the Loveland. Several test holes were drilled through late Wisconsinan terrace deposits. The maximum thickness of the deposits was 52.5 feet in test hole 6-21-7add drilled on the north side of Bow Creek in the northeastern part of the county. A test hole just northeast of the city light plant on the north side of the South Fork Solomon River drilled by C. A. Robben for Hill City penetrated 38 feet of terrace deposits and in irrigation well 8-21-7cbc 51 feet of terrace material was encountered.

Water supply.—The silt members of the Sanborn lie above the water table and yield no water to wells in Graham County. The Crete member, however, is a source of water to wells in some places where it occurs along the valleys. The municipal water supply at Bogue is obtained from Crete deposits and several other wells that were inventoried also obtain water from the Crete. Two water samples were collected from wells that tap the water-bearing beds of the Crete. Water from well 8-22-8bcc is of good quality, being similar to water from the Ogallala, but water from wells 8-21-8dcc and 8-21-17acb (the Bogue municipal well—for which an analysis is available) is more highly, although not excessively, mineralized.

The late Wisconsinan terrace deposits constitute an important source of ground water in Graham County. They yield water to a few irrigation wells, and to the municipal wells at Hill City. The lower water-bearing part of the deposits is commonly rather coarse-textured and contains a considerable amount of water, especially in the valley of South Fork Solomon River. In most places (most of Bow Creek excepted) where Wisconsinan terrace deposits occur, they lie on Cretaceous bedrock and are therefore below the base of the water-bearing zone in the Ogallala formation. Consequently, the water table in the terrace deposits is not connected with the water table in the Ogallala formation of the uplands. In places where the Crete member of the Sanborn carries water, water may move from the Crete into the terrace deposits, thus contributing to the recharge of the terrace deposits. The bulk of the recharge is probably received from precipitation directly on the terrace surfaces. Ground water moves laterally through the Wisconsinan terrace deposits into the alluvium or directly into the streams. Because of the narrow extent of the terrace deposits it is impractical to show water-table contour lines in other than South Fork Solomon River and Bow Creek valleys.

The chemical character of water in the terrace deposits is shown in Table 3 and Figure 7. The water is generally considerably harder and more highly mineralized than water in the Ogallala formation.

In general, water in the Crete member and in terrace deposits along South Fork Solomon River increases in dissolved solids content from west to east. The increase is due principally to the increased calcium sulfate content, which presumably is derived from the Niobrara formation.

Dune Sand

Deposits of dune sand occur in several places in the eastern part of South Fork Solomon Valley and in two other areas. One of these is located principally in sec. 25, T. 7 S., R. 22 W. but extends into several neighboring sections; the other area of dune sand is principally in sec. 6, T. 10 S., R. 21 W., and sec. 1, T. 10 S., R. 22 W. The dunes are composed predominantly of fine to coarse sand, which has been accumulated by the wind to form small hills. Most of the sand dunes are vegetated but in places areas of bare sand are being subjected to renewed wind action. The dune sand in the valley of South Fork Solomon River probably was derived from the alluvium and terrace deposits and was blown only a short distance. The sand in sec. 25, T. 7, S., R. 22 W. and neighboring sections was blown or washed from near-by Ogallala outcrops and accumulated by the wind to form dunes. The sand in sec. 6, T. 10 S., R. 21 W. and sec. 1, T. 10 S., R. 22 W. was probably derived principally from the Ogallala formation. The thickness of the dune sand in Graham County is not known but it probably does not exceed 15 or 20 feet.

No wells in Graham County are known to obtain water from the dune sand, but the dunes, because of their high permeability, serve as intake areas for ground-water recharge from local precipitation.

Alluvium

Deposits of Recent alluvium occur along the channel of South Fork Solomon River. Alluvium also exists in the channel of Bow Creek and many of the smaller streams. However, in these areas the alluvium cannot be shown on a map having the scale used in Plate 1 without great exaggeration, and consequently, the alluvium is included with the Wisconsinan terrace deposits. The alluvium of South Fork Solomon River consists principally of sand and gravel with lesser amounts of silt and clay. The alluvium of smaller streams contains a larger percentage of silt and contains materials derived from terrace deposits and fragments of Cretaceous bedrock. The alluvium of the smaller streams is more poorly sorted and less permeable than the alluvium of South Fork Solomon River.

The body of ground water in the alluvium is continuous with the body of ground water in the late Wisconsinan terrace deposits. Although the alluvium contains a considerable amount of ground water, very few wells obtain water from alluvium because it is generally restricted to the stream channels.

RECORDS OF WELLS AND SPRINGS

Descriptions of 339 wells and 5 springs visited in Graham County are given in Table 7. All information classed as reported was obtained from the owner or tenant. Depths of wells not classed as reported were measured and are given to the nearest half foot below the measuring point described in the table. Depths to water level not classed as reported were measured and are given to the nearest hundredth of a foot. An explanation of the well-numbering system used in this report is given on page 11.

TABLE 7.—*Record of wells and springs in Graham County*

Well number	Owner or tenant	Type of well (1)	Depth of well, (feet)	Diameter of well, (in.)	Type of casing (2)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (3)	Use of water (4)	Measuring point: Description	Measuring point: Distance above land surface, (feet)	Measuring point: Height above mean sea level, (feet) (5)	Depth to water level below measuring point, (feet)	Date of measurement 1952	Remarks
T. 6 S., R. 21 W.															
6-21-1ada	Henry Ehm	Dr	43.0	6	GI	Sand, gravel, or chalky shale	Crete or Niobrara	Cy, W	D, S	Top of casing	0.5	2,132.2	36.69	July 31	Not in use
6-21-3dcd	Joe White	Dr	19.0	6	GI	Sand, gravel	Terrace deposits	Cy,H,W	S	do	0.8	2,151.7	15.50	Sept 29	
6-21-8abb	School	Dr	43.5	6	GI	do	Ogallala	Cy,H,W	D	do	0.2	2,204.7	37.13	Aug. 16	
6-21-9abc	Louis Voss	Dr	48.5	8	GI	do	Terrace deposits	Cy,H,W	D, S	do	0.4	2,170.0	18.70	Sept. 29	
6-21-10bdb	M. B. Parker	Du	25.5	30	C	do	do	Cy, E	D, S	Top of concrete curb	1.5	2,162.5	22.23	Aug. 20	
6-21-11aaa	J. P. Holmquist	Du	29.5	36	C	do	do	Cy, G	S	do	0.4	2,120.0	16.26	Sept. 25	
6-21-13dbd	C. H. Kenyon	Dr	122.0	5	GI	do	Ogallala	Cy,H,W	S	do	0.4	2,275.2	114.25	Sept. 25	
6-21-14aab	J. P. Holmquist	Dr	40.0	8	GI	do	do	Cy, W	S	Top of hole in disc	0.8	2,191.7	37.18	Sept. 25	
6-21-15dcd	A. F. Brown	Dr	142.0	5	GI	do	do	Cy, W	D, S	Top of concrete curb	0.4	2,298.3	135.81	Sept. 25	
6-21-16bbb	Louis Voss	Dr	74.5	10	GI	do	do	N, N	N	Top of casing	0.6	2,243.4	72.77	Aug. 16	Abandoned .
6-21-18bad	G. Voss	Dr	145.0	5	GI	do	do	Cy, W	S	do	0.8	2,318.0	129.68	Sept. 29	
6-21-22ddd	John H. Drotts	Dr	94.0	5	GI	do	do	Cy,H,W	D, S	do	0.8	2,246.9	81.76	Sept. 25	
6-21-23aad	Lillie Fox	Dr	127.5	8	GI	do	do	Cy, N	N	do	0.2	2,284.0	124.64	July 31	Abandoned.
6-21-24ccd	K. A. Howard	Dr	100.0	5	GI	do	do	Cy, H	N	Top of board curb	1.4	2,250.4	92.65	Aug. 16	Not in use.
6-21-28ccb	C. J. Goff	Du	42.0	12	C	do	do	Cy, W	S	Top of tin cover	1.0	2,224.9	39.41	Aug. 20	Chemical analysis.
6-21-30baa	Maggie M. Wallace	Dr	87.5	5	GI	do	do	Cy,H,W	D, S	Top of casing	0.8	2,285.4	77.92	Aug. 20	
6-21-31bbb	Laura J. Frasca	Dr	19.8	5	GI	do	do	Cy, N	N	do	1.0	2,220.5	13.20	Aug. 28	Abandoned.
6-21-34ccc	R. Pennington	Dr	18.5	10	GI	do	Terrace deposits and Ogallala	Cy, W	S	do	1.3	2,184.9	13.23	Aug. 20	
T. 6 S., R. 22 W.															
6-22-1ddd	J. W. Henry	Dr	31.0	5	GI	do	Crete or Ogallala	Cy,H,W	D, S	do	0.3	2,209.5	25.29	Aug. 14	
6-22-5aaa	M. S. Spragg	Dr	71.5	5	GI	do	Ogallala	Cy,H,W	S	do	2.0	2,297.0	51.19	July 31	
6-22-5ddc	E. Rouback	Dr	30.0	8	GI	do	Terrace deposits	Cy, W	S	do	1.0	2,276.6	16.88	Aug. 15	Chemical analysis.
6-22-6cdc	C. C. Croffott estate	Dr	79.0	5	GI	do	Ogallala	Cy,H,W	D, S	do	1.8	2,333.4	58.72	July 30	Not in use.
6-22-8bbc	E. Rouback	Dr	40.0	6	GI	do	do	Cy, H	D, S	Top of plank cover	1.0	2,297.6	28.70	July 30	do
6-22-9bab	do	Dr	44.0	5	GI	do	Terrace deposits	N, N	N	Top of casing	2.0	2,266.8	14.60	Aug. 15	do
6-22-9daa	A. B. & David Rush	Dr	36.5	5	GI	do	Ogallala and/or terrace deposits	Cy,H,W	S	do	0.6	2,263.3	23.88	Sept. 29	
6-22-12bdd	J. C. Dwelly	Dr	24.5	6	GI	do	Terrace deposits	RB, H	S	do	2.5	2,215.0	20.55	Aug. 16	

6-22-12daa	J. S. Dwelly	Dr	20.5	5	GI	do	do	Cy, H	D, S	do	0.4	2,200.4	12.91	Aug. 14	
6-22-14ddd	D. Rush, et al.	Dr	137.0	5	GI	do	Ogallala	Cy, N	N	do	0.4	2,349.5	129.10	July 30	Abandoned.
6-22-16ddc	E. Broomfield	Dr	136.5	5	GI	do	do	Cy, W	S	do	1.0	2,387.3	134.30	July 30	
6-22-19bbb	J. D. Lerrick	Dr	124.0	5	GI	do	do	Cy, N	N	do	0.3	2,398.7	119.07	July 30	Abandoned.
6-22-26baa	Glenn Beecher	Dr	142.5	5	GI	do	do	N, N	N	do	0	2,369.7	141.22	July 30	do
6-22-27ddd	Etta Moore	Dr	59.5	5	GI	do	do	Cy,H,W	S	do	0.8	2,277.3	45.70	July 30	
6-22-28dad	V. Worcester	Dr	78.5	5	GI	do	do	Cy, W	S	Top of concrete curb	0.2	2,310.4	65.92	July 30	
6-22-29baa	J. L. Parks	Dr	119.5	5	GI	do	do	Cy,H,W	D, S	Top of casing	0.2	2,383.3	116.09	July 30	Not in use.
6-22-30ccb	V. O. Johnson	Dr	65.0	5	GI	do	do	Cy, W	D, S	do	0.8	2,347.7	61.70	Aug. 15	
6-22-32ccb	J. Walker	Du	26.0	18	I	do	do	Cy, W	S	do	0.3	2,291.8	20.72	Aug. 14	
6-22-32ddc	R. Trexler	Dr	55.0	5	GI	do	do	N, N	N	Top of concrete curb	1.0	2,297.5	41.18	Aug. 15	Abandoned.
T. 6 S., R. 23 W.															
6-23-2abb	A. T. Schuck	Dr	124.0	5	GI	do	do	Cy,H,W	S	Top of casing	0.5	2,377.3	110.16	July 23	
6-23-10bbb	R. G. McNeilley	Dr	139.5	5	GI	do	do	Cy,H,W	D, S	do	1.2	2,412.2	128.16	Aug. 4	Not in use.
6-23-10cdd	Edith M. Bower	Dr	130.5	4	GI	do	do	N, N	N	do	0.4	2,407.1	107.03	July 23	Abandoned school well.
6-23-12ccb	H. Hauser	Dr	70.0	5	GI	do	do	Cy, W	S, O	do	1.3	2,350.9	63.20	July 23	
6-23-17bcd	H. E. Webb	Dr	95.0	6	GI	do	do	Cy, W	D, S	Top of concrete curb	1.0	2,418.2	88.49	July 23	Not in use.
6-23-19bba	School district	Dr	50.8	5	GI	do	do	Cy, H	D	Top of casing	0.3	2,391.4	49.08	July 23	Not in use.
6-23-20dab	G. Gick	Du	41.5	6	GI	do	do	Cy, W	D, S	Bottom of board cover	1.0	2,368.6	37.43	July 25	Originally dug—later recased.
6-23-22dbc	H. W. & Marg Houser	Dr	112.0	4	GI	do	do	Cy,H,W	D, S	Top of casing	0.4	2,411.4	98.98	July 25	
6-23-24bbb	A. D. Barnett	Dr	40.0	6	GI	do	do	Cy, W	S	do	0.2	2,321.3	30.33	Aug. 26	
6-23-26ddc	Keiswetter, et al.	Dr	149.0	6	GI	do	do	Cy,H,W	D, S	Top of plank cover	0.8	2,435.1	134.17	Aug. 26	
6-23-30ccd	Fern Kaufman	Dr	124.5	5	GI	do	do	Cy, N	N	Top of casing	0	2,467.8	119.54	Aug. 7	Abandoned.
6-23-32ccc	R. Walters	Dr	143.5	5	GI	do	do	N, N	N	do	0	2,492.7	134.03	July 25	Abandoned school well.
6-23-33abd	W. H. Waggoner	Dr	144.0	5	GI	do	do	Cy, W	D, S	do	0.5	2,463.0	134.71	Aug. 26	
T. 6 S., R. 24 W.															
6-24-1caa	C. E. Long	Dr	109.0	5	GI	do	do	Cy, W	S	do	0.8	2,436.5	95.44	Aug. 4	
6-24-2bba	A. Wilcox	Dr	55.0	5	GI	do	do	Cy,H,W	D, S	do	0.2	2,381.7	39.20	Aug. 4	Not in use.
6-24-4ddd	Ruth Jamison	Dr	142.0	5	GI	do	do	Cy, W	S	do	0.9	2,497.8	138.88	Aug. 25	
6-24-5bad	Margaret Christiansen	Dr	51.5	5	GI	do	do	Cy,G,W	S	do	0	2,402.0	43.42	July 22	Not in use.
6-24-8ccc	Jacob B. Frye	Dr	158.5	5	GI	do	do	N, N	N	do	0.4	2,527.5	144.64	July 22	Abandoned school well.
6-24-10add	School district	Dr	128.5	5	GI	do	do	Cy,H,W	D	do	0	2,475.2	119.69	July 21	Chemical analysis.
6-24-13ada	C. O. Workman	Dr	90.5	5	GI	do	do	Cy, W	S	do	0	2,425.6	86.38	July 23	
6-24-15dcb	W. Deines	Dr	128.0	5	GI	do	do	Cy, W	S	do	0	2,461.4	93.23	July 21	
6-24-17ddd	Sylvia Olson	Dr	138.0	5	GI	do	do	Cy,H,W	D, S	do	-4.3	2,507.3	127.78	July 22	
6-24-19ccd	Joseph Smika	Dr	126.0	5	GI	do	do	N, N	N	do	1.1	2,523.2	122.61	July 21	Abandoned.
6-24-22cdc	M. F. Moffett, et al.	Dr	76.0	5	GI	do	do	Cy, H	N	Top of pump base	0.2	2,441.0	71.46	July 22	Not in use.
6-24-26abc	J. E. Hardman	Dr	67.5	5	GI	do	do	Cy,H,W	D, S	Top of casing	0.2	2,418.9	48.86	July 21	

Table 7.—*Records of wells and springs in Graham County—Continued*

Well number	Owner or tenant	Type of well (1)	Depth of well, (feet)	Diameter of well, (in.)	Type of casing (2)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (3)	Use of water (4)	Measuring point: Description	Measuring point: Distance above land surface, (feet)	Height above mean sea level, (feet) (5)	Depth to water level below measuring point, (feet)	Date of measurement 1952	Remarks
T. 6 S., R. 24 W.															
6-24-28dad	R. G. Allen, et al.	Dr	68.0	5	GI	Sand, gravel	Ogallala	Cy, W	D, S	Top of casing	0.2	2,447.6	66.08	July 21	Not in use.
6-24-29ccc	School district	Dr	122.0	5	GI	do.	do.	Cy, H	D	do.	0.4	2,498.5	103.09	July 21	
6-24-33dbb	Leo Wolf	Dr	87.0	5	GI	do.	do.	Cy,H,W	S	do.	0.4	2,463.4	78.87	Aug. 7	
6-24-35ddd	Alice Keith	Dr	157.0	5	GI	do.	do.	N, N	N	do.	0.5	2,501.5	139.05	July 21	Abandoned.
T. 6 S., R. 25 W.															
6-25-1abb	E. M. Coleman	Dr	27.0	4	GI	do.	do.	Cy,H,W	S	do.	2.0	2,384.9	17.85	Aug. 4	
6-25-3bbb	Gerhard Bruggeman	Dr	166.0	6	GI	do.	do.	Cy,H,W	D, S	do.	0.6	2,503.4	151.38	July 24	
6-25-6bda	V. J. Bell	Dr	50.0	5	GI	do.	do.	Cy,H,W	D, S	do.	0.2	2,445.4	26.43	Aug. 12	
6-25-8dab	S. Bangle	Dr	154.5	5	GI	do.	do.	Cy, N	N	do.	1.0	2,581.0	148.85	July 24	Abandoned.
6-25-11dde	F. K. Carpenter	Dr	135.0	5	GI	do.	do.	Cy, N	N	do.	0.8	2,493.8	132.08	July 22	Abandoned school well
6-25-15bab	C. Woodside	Dr	128.0	5	GI	do.	do.	Cy, W	D, S	do.	0.5	2,511.9	124.07	July 21	Not in use.
6-25-20bcb	W. Kline	Dr	152.0	4	GI	do.	do.	Cy, W	S	do.	0.2	2,591.9	143.42	July 24	
6-25-21ddd	C. E. McFadden	Dr	140.5	5	GI	do.	do.	Cy, W	D, S	do.	1.0	2,541.7	139.83	July 24	Not in use.
6-25-23ddc	P. C. Christiansen	Dr	99.5	5	GI	do.	do.	Cy, N	N	do.	0.8	2,511.9	98.75	Aug. 4	Abandoned.
6-25-30bab	T. M. Stuch	Dr	158.0	5	GI	do.	do.	Cy, W	S	do.	0.8	2,602.1	147.55	July 24	Not in use.
6-25-33abb	J. W. Yocum estate	Dr	102.5	5	GI	do.	do.	Cy, N	N	do.	0.3	2,508.8	98.10	July 24	Abandoned.
6-25-35ccc	V. D. Bashford, et al.	Dr	115.0	6	GI	do.	do.	N, N	N	do.	1.0	2,523.0	99.11	Aug. 12	do
6-25-36baa	J. H. Lutz	Dr	98.5	5	GI	do.	do.	Cy, W	N	do.	0.7	2,504.5	93.93	Aug. 7	Not in use.
T. 6 S., R. 26 W.															
6-26-12add	L. A. Teel	Dr	63.0	5	GI	do.	do.	Cy,H,W	S	do.	0.8	2,506.3	57.44	Aug. 11	
6-26-36daa		Dr	128.0	5	GI	do.	do.	Cy,H,W	D, S	do.	0.2	2,577.3	116.12	July 24	Not in use, located in Sheridan County.
T. 7 S., R. 21 W.															
7-21-2bcc*1*	C. B. Kenyon	Dr	380	6	GI	Chalky shale and/or sandstone	Niobrara and/or Carlile	Cy,H,W	S			2,185.5	50		Chemical analysis.
7-21-2bcc*2*	do.	Dr	265	6	GI	Chalky shale	Niobrara	Cy, W	S						

7-21-2bcc	C. B. Kenyon	Dr	100	6	GI	do.	do.	Cy, E	D		0.6	2,153.8	28.62		Chemical analysis.
7-21-5dcc	H. E. McKisson	Dr	58.5	5	GI	Sand, gravel	Terrace deposits	Cy,H,W	N	Top of casing	0.3	2,147.1	20.88	Sept. 15	Not in use.
7-21-9ada	J. A. Bundy	Dr	167.0	6	GI	Chalky shale	Niobrara	Cy, H	N	do.	0.3	2,147.1	20.88	Aug. 27	do
7-21-11bcb	C. B. Kenyon	Dr	218.0	6	GI	do.	do.	Cy,H,W	N	do.	0.5	2,156.7	32.50	Aug. 27	do
7-21-15aba	F. Holaman	Du	21.5	48	C	Sand, gravel	Terrace deposits	N, N	N	Top of concrete curb	0.5	2,104.4	12.26	Aug. 27	Abandoned.
7-21-15ddc	do.	Du	9.0	60	GI	do.	do.	Cy, W	S	do.	1.0	2,074.8	5.65	Sept. 15	
7-21-18aac	Sarah Bondy	Dr	63.0	5	GI	?	Niobrara (?)	Cy, H	N	Top of tin cover	0.3	2,162.4	39.53	Aug. 27	Not in use.
7-21-20ccb	Grace Gaylord, et al.	Dr	39.5	8	GI	?	Crete (?)	N, N	N	Top of casing	0.4		26.75	Sept. 15	Abandoned.
7-21-25ccc	J. C. Bibb	Dr	100	6	GI	Sand	Crete or Meade	Cy,H,W	D, S			2,046.8	60		Reported 65 ft. to shale.
7-21-33caa	H. White	Dr	125.0	5	GI	Chalky shale	Niobrara	N, N	N	Top of casing	2.2		64.86	Sept. 15	Abandoned.
7-21-36ccd	J. Capsene	Dr	62.0	5	GI	Chalky shale or sand, gravel	Niobrara or Crete	Cy, W	N	do.	1.5	2,015.4	56.14	Sept. 23	Not in use.
T. 7 S., R. 22 W.															
7-22-1cbd	Ola Ginther estate	Dr	51.0	5	GI	Sand, gravel	Ogallala	Cy,H,W	D, S	do.	1.0	2,252.2	45.09	July 31	do
7-22-2aaa	W. H. and B. Gibb	Dr	64.5	5	GI	do.	do.	N, N	N	do.	1.2	2,268.8	51.36	Aug. 28	Abandoned.
7-22-3aaa	Emma S. Post	Dr	15.5	6	GI	do.	do.	Cy,H,W	S	do.	1.0	2,234.8	13.02	Aug. 28	
7-22-6dad	Anton Smika	Dr	118.0	5	GI	do.	do.	Cy,H,W	D, S	do.	0.8	2,372.6	101.59	Aug. 15	
7-22-7ccc	I. Scott	Dr	113.5	5	GI	do.	do.	N, N	N	do.	1.3	2,366.0	88.55	July 30	Not in use.
7-22-10bbb	M. E. Worcester	Dr	45.0	7	S	do.	Ogallala and terrace deposits	N, N	N	do.	2.0	2,226.0	10.54	Aug. 14	do
7-22-10bcb	do.	Dr	84	16	S	do.	do.	T, T	I	Top of hole in pump base	0.3	2,227.2	12.50	Aug. 14	See log of well.
7-22-13bba	W. Stephenson	Dr	51.5	6	GI	Sand gravel or chalky shale	Crete or Niobrara	Cy, H	S	Hole in casing	0	2,185.3	39.58	Aug. 27	
7-22-14cdc	A. D. Worcester	Du	9.5	72	C	Sand	Colluvium	Cy, W C, G	S	Top of barrel	3.5	2,220.5	4.15	Aug. 28	
7-22-16cdd	Alex Fabricius	Dr	54.0	5	GI	Sand, gravel	Ogallala	Cy,H,W	N	Top of casing	0.4	2,287.3	44.20	Aug. 28	Not in use.
7-22-17bcc	Charles Worcester	Dr	70.5	5	GI	do.	do.	Cy, W	S	do.	0.6	2,307.7	49.50	Aug. 15	
7-22-17dba	Eugene Worcester	Dr	120.5	5	GI	do.	do.	Cy, G	S	do.	0.4	2,355.3	116.34	Aug. 15	
7-22-19ddd	R. K. Brumbaugh	S				do.	do.		S			2,221.6			
7-22-22daa	W. Polkowsky, et al.	Dr	37.0	5	GI	Sand, gravel and/or chalky shale	Ogallala and/or Niobrara	Cy, W	S	Top of casing	0.4	2,260.7	31.49	Aug. 27	
7-22-23bca	A. D. Worcester	Dr	848	8	S	Sandstone	Dakota	N, N	N	do.	0.3	2,281.3	228.93	Aug. 28	Not in use.
7-22-25ddc	C. Fabricius	S				Sand, silt	Colluvium		S						
7-22-26baa	Rachel Hall	Du	13.5	48	C	Sand, gravel	Ogallala	N, N	N	Top of concrete curb	0.3	2,241.4	12.67	Aug. 28	Abandoned.
T. 7 S., R. 23 W.															
7-23-2daa	B. E. and Susie Drury	Dr	150.0	5	GI	do.	do.	Cy,H,W	D, S	Top of casing	1.0	2,443.4	141.88	Aug. 26	
7-23-3cba	Don Himes	Dr	45.5	5	GI	do.	do.	Cy,H,W	S	Top of curb	0.2	2,369.0	44.27	July 29	Not in use.
7-23-7ddd	J. & J. & N. M. Clark	Dr	103.5	5	GI	do.	do.	Cy,H,W	S	Top of casing	0.9	2,438.6	93.82	July 25	
7-23-8dab	James S. Barrow	Dr	114.5	5	GI	do.	do.	Cy, H G, W	S	Top of concrete curb	0.8	2,446.3	108.51	Aug. 26	
7-23-10ccc	A. Scott	Dr	103.5	5	GI	do.	do.	Cy,H,W	S	Top of casing	0.4	2,421.2	100.71	Aug. 19	Chemical analysis.
7-23-20acc	J. P. Michaelis	Dr	58.0	5	GI	do.	do.	Cy,H,W	D, S	do.	0.5	2,368.6	44.60	Aug. 19	

TABLE 7.—*Records of wells and springs in Graham County—Continued*

Well number	Owner or tenant	Type of well (1)	Depth of well, (feet)	Diameter of well, (in.)	Type of casing (2)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (3)	Use of water (4)	Measuring point: Description	Measuring point: Distance above land surface, (feet)	Measuring point: Height above mean sea level, (feet) (5)	Depth to water level below measuring point, (feet)	Date of measurement 1952	Remarks
T. 7 S., R. 23 W.															
7-23-22dcd	Margaret S. Moore	Dr	49.0	5	GI	Sand	Ogallala	Cy,H,W	S	Hole, east side of pump	1.2	2,314.3	42.01	Aug. 19	
7-23-24bbc	H. Lindley	Dr	60.5	6	GI	Sand, gravel	do	Cy,H,W	S	Top of casing	0.5	2,309.8	54.78	Aug. 15	
7-23-33dad	M. J. Moore	Dr	52.5	6	GI	Sand	do	N, N	N	do	0	2,316.9	44.17	Aug. 20	
7-23-35ddd	Charles Stuchlik	Dr	800	8	S	Sandstone	Dakota	Cy, H	O	do	0.5	2,254.1	38.59	Aug. 15	Not in use.
7-23-36ccd	Hill City Cemetery	Du	54.0	42	R, N	Sand, gravel	Ogallala	Cy, W	O	Base of pump	0.7	2,245.2	30.98	Aug.15	do
T. 7 S., R. 24 W.															
7-24-2bbb	School district	Dr	158.0	6	GI	do	do	Cy,H,W	D	Top of casing	0.3	2,514.0	141.26	Aug. 19	
7-24-5cdc	A. W. Maferland	Dr	138.0	5	GI	do	do	Cy,W,G	D, S	do	0.5	2,525.4	132.10	Aug. 11	
7-24-9dda	V. Zohner	Dr	46.5	5	GI	do	do	Cy, W	S	do	0.8	2,432.2	33.54	July 29	Depth to water level, 41.10 feet, July 15, 1953. Not in use.
7-24-12cbb	Rettie L. and C. E. Chase	Dr	128.5	5	GI	do	do	Cy,H,W	D, S	do	0.3	2,474.7	113.68	Aug. 26	
7-24-15dad	F. Zohner	Dr	50.0	6	GI	do	do	Cy, W	S	do	2.0	2,401.0	22.48	July 29	
7-24-17bcb	A. J. Kooler	Dr	132.0	5	GI	do	do	Cy, H	N	do	0.6	2,509.7	119.70	Aug. 11	Abandoned.
7-24-20cbb	J. Clark	Dr	125.0	5	GI	do	do	Cy,H,W	S	do	0.8	2,506.2	117.88	Aug. 26	Chemical analysis.
7-24-25add	S. Hutton	Dr	14.0	5	GI	do	Ogallala or terrace deposits	J, E	D, S	do	—5.7	2,308.3	10.91	Aug. 19	
7-24-32acb	E. P. and K. L. Goddard	Dr	43.5	5	GI	do	Ogallala	Cy, H	N	Top of concrete curb	1.0	2,395.6	40.56	Aug. 12	
7-24-35abb	W. S. Heffelfinger, et al.	Dr	127.5	5	GI	do	do	Cy, H	N	Top of casing	2.0	2,438.0	112.58	Aug. 11	Abandoned.
T. 7 S., R. 25 W.															
7-25-4ccd	R. A. Nicholson	Dr	111.0	5	GI	do	do	Cy, W	S	do	0.2	2,533.4	97.49	July 24	
7-25-5cdc	S. Bangle	Dr	109.5	5	GI	do	do	Cy, W	S	do	0	2,551.4	108.14	Aug. 18	
7-25-7ccb	L. L. Huntington	Dr	112.5	5	GI	do	do	Cy,H,W	D, S	Top of concrete curb	1.6	2,558.5	100.72	Aug. 18	
7-25-10cbd	H. A. Moore	Dr	103.0	5	GI	do	do	Cy, W	S	Top of casing	0.6	2,519.8	82.52	Aug. 18	

7-25-11bbb	K. A. Von Maurhauser	Dr	83.5	5	GI	do	do	Cy,H,W	D, S	do	1.0	2,488.2	65.54	Aug. 11	
7-25-12dda	Livenia L. Anderson	Dr	128.5	5	GI	do	do	Cy, H	N	do	0	2,528.1	122.73	Aug. 11	Abandoned.
7-25-13bbb	J. Nesbitt	Dr	145.0	5	GI	do	do	Cy, H	N	do	0.8	2,537.9	126.44	July 29	Not in use.
7-25-19dcc	C. H. Goodrow	Dr	85.5	4	GI	do	do	N, N	N	do	0.1	2,530.9	80.50	Aug. 18	Abandoned.
7-25-20bba	C. E. McFadden	Dr	128.5	5	GI	do	do	Cy, W	S	do	0.5	2,565.3	119.73	Aug. 12	
7-25-22ccc	Harry Toll	Dr	93.5	5	GI	do	do	N, N	N	do	0.5	2,506.4	81.02	Aug. 18	Abandoned.
7-25-24dcc	C. W. Keith	Dr	66.5	5	GI	do	do	Cy, H	S	do	1.7	2,473.8	62.03	Aug. 7	
7-25-29dcd	C. G. And T. M. Krause	Dr	102.0	5	GI	do	do	Cy, W	S	do	0.8	2,520.8	97.10	Aug. 18	
7-25-31aba	R. Davis	Dr	69.5	5	GI	do	do	Cy,H,W	N	do	0.8	2,503.3	66.35	Aug. 18	Not in use.
7-25-33aaa	S. C. Dodd	Dr	99.0	5	GI	do	do	Cy, N	N	do	0.3	2,512.3	98.14	Aug. 18	Abandoned.
7-25-33dcc	John R. Sullivan	Dr	38.0	5	GI	do	do	N, N	N	do	1.6	2,428.7	28.08	Aug. 18	do
7-25-35aba	R. L. Hunsinger	Dr	93.0	5	GI	do	do	Cy, W	S	do	0.2	2,500.7	91.12	Aug. 7	
7-25-36ccc	A. T. Sanger	Dr	77.5	5	GI	do	do	Cy, W	S	do	0.3	2,456.8	60.69	Aug. 18	Not in use.
T. 8 S., R. 21 W.															
8-21-2aba	E. Buckner	Dr	42.0	5	GI	do	Terrace deposits	Cy,H,W	D, S	do	1.0	1,983.2	20.38	Sept. 25	
8-21-3cdc	Wilma Kenyon	Dr	22.0	6	GI	do	do	C, E	I	do	0.4	1,998.8	11.76	Sept. 25	Irrigates small garden.
8-21-7cbc	George Cooksey	Dr	51	18	S	do	do	T, G	I			2,033.4	8		See log of well.
8-21-8bac	B. C. Kenyon, et al.	Dr	15.5	5	GI	do	do	Cy, W	S	Top of casing	0.4	2,020.5	9.00	Sept. 25	
8-21-8dcc	Garold Napue	Dr	30.0	5	GI	do	Crete	Cy, H	D	do	0	2,035.0	22.10	Sept. 19	Chemical analysis.
8-21-9cdc	H. Young	Dr	15.5	5	GI	do	Terrace deposits	Cy, H	S	do	0.3	2,012.4	7.90	Sept. 19	
8-21-11abb	A. Williams	Dr	12.0	5	GI	do	do	Cy,H,W	D, S	do	0.5	1,967.7	8.78	Sept. 25	
8-21-13dbb	Joe Brin	Dr	42.0	6	GI	do	Crete (?)	Cy, W	D, S	Top of tile curb	0.3	2,045.6	36.07	Sept. 23	
8-21-14ccb	I. Benoit	Dr	29.5	6	GI	do	Terrace deposits	Cy, N	N	Top of concrete curb	0.2	1,998.4	22.39	Sept. 23	Not in use.
8-21-17acb	City of Bogue	Du	55	16	S	do	Crete	T, E	P			2,040.7	32		Reported 52 ft. to shale.
8-21-17bcd	E. R. Kenyon	Dr.	38.5	6	GI	do	do	Cy, H	N	Base of pump	0	2,062.4	27.09	Sept. 19	Abandoned.
8-21-18bcd	Earl Dohrman	Dr	18.0	5	GI	do	Terrace deposits	N, N	N	Top of concrete curb	0.5	2,041.3	7.98	Sept. 19	do
8-21-20aab	Adrian Brault	Dr	125.0	5	GI	Chalky shale	Niobrara	Cy, H	N	Top of casing	0		50.12	Sept. 19	Not in use.
8-21-21abb	Armund Brault	Dr	48.0	5	GI	?	Crete (?)	Cy,H,G	S	Bottom of hole, SE side of pump	2.2	2,068.3	34.26	Sept. 19	
8-21-25ddd	Simonreau	Dr	10.5	6	GI	Sand, silt	Terrace deposits	Cy, W	S	Top of pump base	1.2	2,028.8	8.20	Aug. 6	
8-21-26dcd	E. L. Grover	Dr	86	5	GI	Sand	Meade (?)	Cy, W	D, S			2,110.4	80		Reported 80 ft. to shale.
T. 8 S., R. 22 W.															
8-22-3bbc	F. Morris	Dr	165	5	GI	Chalky shale	Niobrara	Cy,H,W	D, S			2,155.3	25		Chemical analysis.
8-22-3dcd	F. O. Dunwody	Dr	24.5	8	GI	Sand, gravel	Terrace deposits	Cy, W	S, O	Top of casing	3.0	2,076.5	16.89	Aug. 14	
8-22-5cdd	L and F. Zohner	Dr	67.5	6	GI	Sand, gravel or chalky shale	Crete or Niobrara	N, N	N	do	0.8	2,159.1	63.80	Aug. 22	Abandoned.
8-22-8bcc	F. and C. Stuchlik	Dr	35.0	5	GI	Sand, gravel	Crete	Cy, H	D	do	0.2	2,127.6	22.17	Aug. 22	Chemical analysis.
8-22-8cad	W. J. Heffelfinger, et al.	Dr	26.0	5	GI	do	Terrace deposits	Cy, H	S	do	0.4	2,093.1	12.19	Sept. 26	
8-22-9dbb	Marie E. Shutts	Dr	30.0	5	GI	do	do	Cy, H	D, S	do	0.6	2,093.4	22.97	Sept. 26	
8-22-12acc	I. M. Gordon	Dr	14.0	5	GI	do	do	Cy, W	S	do	2.6	2,039.7	10.12	Sept. 26	

TABLE 7.—*Records of wells and springs in Graham County—Continued*

Well number	Owner or tenant	Type of well (1)	Depth of well, (feet)	Diameter of well, (in.)	Type of casing (2)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (3)	Use of water (4)	Measuring point: Description	Measuring point: Distance above land surface, (feet)	Measuring point: Height above mean sea level, (feet) (5)	Depth to water level below measuring point, (feet)	Date of measurement 1952	Remarks
T. 8 S., R. 22 W.															
8-22-12dda	John Luck	Dr	19.5	5	GI	Sand, gravel	Terrace deposits	Cy, H	N	Top of casing	1.0	2,040.6	11.32	Sept. 19	Not in use.
8-22-14cba	J. W. Hotham	Du	25.0	24	R	do.	Crete	Cy, E	S	Top of concrete curb	0	2,079.1	17.93	Sept. 19	
8-22-17daa	J. A. Lewis estate	Dr	44.0	5	GI	do.	do.	Cy, H, W, G	D, S	Top of casing	0.8	2,108.9	35.26	Sept. 23	
8-22-18bda	Rice estate	Dr	24.0	5	GI	do.	Terrace deposits	Cy,H,W	S	do.	1.3	2,124.8	15.65	Sept. 26	
8-22-19bbb	Mable A. Lloyd	Dr	24.5	5	GI	do.	do.	Cy,H,W	N	do.	0.4	2,126.6	22.15	Aug. 22	Not in use.
8-22-20bbb	E. L. Quint	Dr	44.0	5	GI	do.	Crete	Cy, H	D, S	Base of board cover	0	2,131.8	40.31	Sept. 18	
8-22-24dad	O. Gosselin	Dr	16.0	5	GI	do.	Terrace deposits	N, N	N	Top of casing	0.8	2,065.0	10.92	Sept. 19	Not in use.
T. 8 S., R. 23 W.															
8-23-2cdd	C. E. Wainwright	Dr	53.5	5	GI	Chalky shale	Niobrara	Cy, W	S	do.	0.1	2,220.7	24.30	Aug. 19	Chemical analysis.
8-23-9ccc	C. E. McFadden	Dr	22.0	6	GI	Sand, gravel	Terrace deposits	Cy,H,W	S	do.	1.0	2,185.1	11.80	Sept. 30	do
8-23-13bdc1	City of Hill City	Du	32.5	336	C	do.	do.	T, E	P	Land surface	0	2,126.6	18.09	Sept. 26	
8-23-13bdc2	do.	Du	31.0	180	C	do.	do.	T, E	P	do.	0	2,125.9	16.10	Sept. 26	
8-23-13cdb1	do.	Dr	46	18	S	do.	do.	T, E	P	.....	.....	2,122.5	10	.....	
8-23-13cdb2	do.	Dr	54.0	18	S	do.	do.	T, E	P	Hole, S. side of pump	6.0	2,120.6	13.96	Sept. 26	
8-23-13cdc	do.	Dr	45	18	S	do.	do.	T, E	P	.....	.....	2,116.8	8	.....	
8-23-19adc	O. L. Brinkmeyer	Dr	35.0	5	GI	do.	do.	N, N	N	Top of casing	0.8	2,206.8	25.68	Sept. 18	Abandoned.
8-23-19cbb	C. K. Brinkmeyer	Dr	41.5	5	GI	do.	Crete	Cy, W	N	do.	1.1	2,231.1	35.55	Sept. 18	Not in use.
8-23-21aaa	Carl Schmidt	Dr	24.0	5	GI	do.	Terrace deposits	Cy, H	S	do.	1.0	2,154.0	15.78	Sept. 30	do
8-23-21bcd	F. A. McCoy	Du	16.5	8	GI	do.	do.	Cy,H,W	D, S	do.	—3.0	2,163.0	12.60	Sept. 18	
8-23-22abd	E. M. Chipman, et al.	Dr	51.0	18	S	do.	Crete	Cy, G	I	do.	1.6	2,160.7	31.52	Sept. 18	Not used in 1952.
8-23-23bdb	L. Legere	Dr	30	18	S	do.	Terrace deposits	C, G	I	Base of pump	1.0	2,133.6	9.37	Sept. 18	do
8-23-24abc	Ray Law	Dr	.....	12	S	do.	do.	Cy, G	I	.....	.....	.....	.....	.....	do
8-23-24acc	R. and L. F. Law	Dr	32.5	5	GI	do.	Crete	Cy, W	D, S	Top of casing	0.5	2,154.0	27.90	Sept. 19	
8-23-26bcd	M. Blackford	Dr	32.5	6	GI	do.	do.	Cy,H,W	S	Top of concrete curb	0.3	2,165.7	19.80	Sept. 26	
8-23-31dcc	J. A. Miller	Dr	.....	5	GI	do.	Ogallala	Cy,H,W	D, S	Base of pump	0.8	2,313.9	21.60	Sept. 24	
8-23-33bcb	H. L. Tomson	Dr	20.5	5	GI	do.	do.	Cy, H	D, S	Top of casing	0.3	2,318.6	16.05	Sept. 5	

T. 8 S., R. 24 W.														
8-24-1abb	Sol. Hutton	Dr	42.5	6	GI	do.	do.	Cy, H	N	do.	1.8	2,347.1	38.13	Aug. 12	Abandoned.
8-24-14cdc		Dr	26.5	5	GI	do.	Terrace deposits	N, N	N	do.	0	2,224.1	12.10	Sept. 30	do
8-24-15ccb	L. and H. Herron	Dr	33.0	6	GI	do.	do.	Cy, H	N	do.	0.1	2,249.6	23.44	Sept. 30	Not in use.
8-24-16cdc	W. J. Keith	Dr	25.0	5	GI	do.	do.	Cy,H,W	D, S	do.	0.6	2,260.0	19.24	Sept. 17	
8-24-17add	J. D. McRae	Dr	24.0	5	GI	do.	do.	N, N	N	do.	0.7	2,270.0	19.42	Sept. 30	Abandoned.
8-24-18bdb	W. I. Covalt	Dr	18.5	5	GI	do.	do.	P, H	D, S	do.	1.2	2,289.0	16.00	Sept. 30	
8-24-19ccd	Ida Keith	Dr	67.0	5	GI	do.	Ogallala	Cy, W	S	do.	0.7	2,411.6	54.49	Sept. 17	
8-24-20bbb	W. J. Keith	Dr	14.0	6	GI	do.	Terrace deposits	Cy, W	S	Top of metal plate	0.1	2,272.1	12.93	Sept. 16	
8-24-22bcc	Emma D. Findley	Dr	34.5	4	GI	do.	Crete	Cy,H,W	D, S	Top of casing	0.4	2,268.3	33.87	Sept. 17	
8-24-24bcd	O. F. and C. L. Kobler	Du	22.0	48	C	do.	Terrace deposits	N, N	N	Top of wooden cover	0.6	2,219.5	17.38	Sept. 18	Abandoned.
8-24-29bad	E. Keith	Dr	12.5	6	GI	do.	do.	Cy, H	N	Top of casing	1.0	....	12.09	Sept. 17	Not in use.
8-24-36ccc	W. W. Keith	Dr	19.5	10	GI	do.	Ogallala	Cy, W	I	do.	0.8	2,353.0	12.22	Aug. 22	Irrigates small garden.
T. 8 S., R. 25 W.															
8-25-3adc	F. Hunter	Dr	11.0	6	GI	do.	do.	Cy, H	N	do.	0.5	2,391.1	8.44	Sept. 16	Not in use.
8-25-5acb	C. E. Heskett	Dr	35.5	5	GI	do.	do.	Cy, H	S	do.	1.3	2,434.3	26.79	Sept. 16	
8-25-9bba	H. Toll	Dr	34.5	5	GI	do.	Terrace deposits	Cy, H	N	do.	0.4	2,397.9	24.94	Sept. 16	Not in use.
8-25-14dcd	Farmers Lumber Co.	Dr	17.0	5	GI	do.	do.	Cy, H	D	do.	0.7	2,300.3	12.09	Sept. 17	Chemical analysis.
8-25-16acb	C. E. McFadden	Dr	36.5	4	GI	do.	Crete	Cy, H	N	Top of wooden platform	1.0	2,365.3	34.88	Sept. 30	Not in use.
8-25-18abb	Stella Pratt	S	......	......	......	do.	Ogallala	......	S	......	......	2,395.9	......	......	
8-25-18ccc		Dr	15.0	5	GI	do.	Terrace deposits	Cy, H	S	Top of casing	0.2	2,371.6	7.02	Sept. 16	
8-25-20baa	F. Schmied	Dr	33.5	5	GI	do.	Crete	N, N	N	Top of concrete curb	0.3	2,375.5	29.29	Sept. 16	Not in use.
8-25-21cab	Henry Schmied	Dr	18.5	5	GI	do.	Terrace deposits	Cy,H,W	S	Top of casing	0	2,362.5	14.90	Sept. 17	
8-25-22aab	do.	Dr	5.5	6	GI	do.	do.	Cy, H	D, S	do.	0.6	2,310.8	4.63	Sept. 17	
8-25-22bbc	do.	Dr	28.0	5	GI	do.	Crete	Cy, W	D, S	do.	0.5	2,333.4	13.38	Sept. 17	
8-25-23cda	B. St. John	Dr	27.5	5	GI	do.	Terrace deposits	Cy,H,W	S	do.	2.0	....	10.48	Sept. 2	
8-25-24aaa	G. H. Engleman	Dr	17.5	5	GI	do.	do.	Cy,H,E	D, S	do.	1.5	2,295.8	11.43	Sept. 17	
8-25-25cdd	George W. Stober estate	Dr	35.5	5	GI	do.	Ogallala	Cy, W	S	do.	1.0	2,392.4	32.66	Sept. 2	
8-25-29bdd	E. J. Rowe	Dr	11.0	5	GI	do.	do.	Cy, W	S	do.	2.5	2,420.4	8.87	Aug. 29	
8-25-30adb	D. G. Hansen	Dr	70.0	5	GI	do.	do.	Cy, H	N	do.	1.0	2,478.8	52.44	Aug. 29	Not in use.
8-25-34bdd	F. M. and W. L. Setchell	Dr	37.0	5	GI	do.	do.	Cy, H	D	do.	0.2	2,447.2	34.22	Sept. 2	
8-25-36acd	I. G. Bell	S	......	......	......	do.	do.	......	D, S	......	......	2,402.8	......	......	
T. 8 S., R. 26 W.															
8-26-1ddd	Frank Bretz, Jr.	Dr	119.0	5	GI	do.	do.	Cy,H,W	D, S	Top of casing	0.5	2,530.5	108.72	Sept. 16	Located in Sheridan Co. Chemical analysis.

TABLE 7.—*Records of wells and springs in Graham County*—*Continued*

Well number	Owner or tenant	Type of well (1)	Depth of well, (feet)	Diameter of well, (in.)	Type of casing (2)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (3)	Use of water (4)	Measuring point: Description	Measuring point: Distance above land surface, (feet)	Measuring point: Height above mean sea level, (feet) (5)	Depth to water level below measuring point, (feet)	Date of measurement 1952	Remarks
T. 9 S., R. 21 W.															
9-21-17cba	C. W. Cooley	Dr	88.0	6	GI	Sand, gravel	Ogallala	Cy,H,W	D, S	Top of casing	0.5	2,327.0	59.00	Sept. 10	
9-21-18adb	Eva Seefold	Du	9.5	36	I	Sand	Terrace deposits	N, N	N	Top of concrete cover	0	2,265.8	8.4	Sept. 10	Abandoned.
9-21-20cbc	W. C. Pricer	Dr	70.0	6	GI	do	Ogallala	Cy, H	N	Top of casing	1.0	2,338.7	62.18	Sept. 11	do
9-21-24bbc	Frank Balthazor	Dr	260	6	GI	Chalky shale or sandy shale	Niobrara or Carlile	Cy, E	D, S	......	......	2,229.3	50	......	
9-21-26aad	O. Cox	Dr	30.0	5	GI	Sand, gravel	Ogallala	Cy, H	D	Top of casing	0.2	2,257.2	24.98	Sept. 11	Not in use.
9-21-29ccd	C. Harrold	Dr	38.0	5	GI	do	do	Cy, W	D, S	do	0.2	2,309.2	32.00	Aug. 6	do
9-21-32ccd	B. B. Denning	Du	14.5	30	I	do	do	Cy, H	N	Top of board cover	0	2,270.8	11.43	Sept. 12	do
9-21-35aaa	H. J. and D. DeYoung, et al.	Dr	75.0	5	GI	do	do	Cy, W	S	Top of board base	0	2,305.4	64.66	Sept. 9	
T. 9 S., R. 22 W.															
9-22-3cbc	Robert Warland	Du	30.0	48	C	do	Terrace deposits	Cy, H	N	Top of concrete curb	0	......	18.70	Sept. 23	Not in use.
9-22-4cbc	W. Robertson	Dr	13.5	6	GI	do	Ogallala	Cy, H	N	Top of casing	1.0	......	10.30	Oct. 29	do
9-22-12cbb	Harold A. Vesper	Dr	294.0	5	GI	Chalky shale and/or sandy shale	Niobrara or Carlile	Cy,H,W	N	do	0.4	......	21.85	Sept. 8	do
9-22-13dac	C. E. Buss	Dr	18.0	5	GI	Sand, gravel	Ogallala	Cy,H,W	S	do	0.8	2,274.0	7.43	Sept. 8	do
9-22-15add	W. W. Justus	Dr	35.0	6	GI	do	do	Cy, H	D, S	do	0.5	2,296.0	32.37	Sept. 10	
9-22-16bab	L. H. Walker	Dr	36.0	6	GI	do	do	Cy,H,W	D, S	do	0.8	2,311.0	28.19	Sept. 8	
9-22-18ddd	Frank Ninemire	Dr	91.5	5	GI	do	do	Cy,H,W	N	do	0.5	2,385.6	68.62	Aug. 13	Not in use.
9-22-20aba	T. H. Denning	Dr	41.5	4	GI	do	do	Cy, N	N	do	0.1	2,349.0	38.52	Aug. 13	Abandoned.
9-22-23aba	B. B. Bomgardner	Dr	34.0	5	GI	do	do	Cy,H,W	D, S	Base of pump	0	2,308.7	30.22	Sept. 10	
9-22-26ada	P. Holzhauer	Dr	95.5	6	GI	do	do	Cy, H	N	Top of concrete cover	0.2	2,377.4	89.51	Sepr. 10	Not in use.
9-22-27cdd	J. D. Sandlain	Dr	88.0	5	GI	do	do	Cy,H,W	D, S	Top of casing	1.0	2,368.3	70.70	Sept. 8	Chemical analysis.
9-22-32aba	F. and G. Sturgeon	Dr	72.5	5	GI	do	do	Cy,H,W	D, S	Top of curb	0.4	2,366.7	56.30	Aug. 30	
9-22-35dda	Margaret S. Moore	Dr	45.5	5	GI	do	do	Cy, W	N	Top of casing	0.5	2,327.7	34.74	Sept. 8	Not in use.

T. 9 S., R. 23 W.															
9-23-2cbe	E. Mildrexter	Du	35.5	48	......	do.	Crete	Cy,H,W	S	Top of metal cover	2.0	....	31.24	Sept. 5	
9-23-12dda	L. A Ninemire	Dr	97.5	5	GI	do.	Ogallala	Cy,H,W	S	Top of casing	0.2	2,412.5	95.10	Aug. 13	
9-23-13cbb	Marshall Law	S	....	......	......	do.	do.		S	....	......	2,319.1	......	......	
9-23-16aab	C. H. Schweitzer	Dr	21.0	6	GI	do.	do.	J, E	D, S	Top of casing	—4.0	2,340.6	13.80	Sept. 5	
9-23-22cbe	E. Hildebrand	Dr	51.0	5	GI	do.	do.	Cy,H,W	D, S	do.	1.3	2,377.2	38.44	Sept. 13	
9-23-23cbb	E. A. Fabricius	Dr	17.0	6	GI	do.	do.	Cy, W	S	do.	1.2	2,336.5	7.62	Sept. 13	
9-23-26bcc	Order of Holy Cross	Dr	105.5	5	GI	do.	do.	Cy, H	N	do.	0	2,437.6	91.02	Aug. 13	Abandoned school well.
9-23-28bcb	L. Morris	Dr	101.0	5	GI	do.	do.	Cy,H,W	D, S	do.	0.5	2,463.2	97.40	Aug. 1	
9-23-30baa	F. L. Wiesner	Dr	44.5	5	GI	do.	do.	Cy, N	N	do.	0.4	2,420.5	25.49	Aug. 25	Not in use.
9-23-35aac	Clara F. Rice	Dr	75.5	4	GI	do.	do.	Cy,H,W	S	do.	0.2	2,398.2	55.33	Aug. 13	
T. 9 S., R. 24 W.															
9-24-1ddc	W. R. Engleman	Dr	34.5	5	GI	do.	do.	Cy, G	S	do.	0.6	2,379.1	28.27	Sept. 24	
9-24-3aaa	George Lovelady	Dr	63.5	5	GI	do.	do.	Cy, G	S	do.	0.2	2,409.9	46.38	Aug. 22	
9-24-4bbc	D. Keith	Dr	99.5	5	GI	do.	do.	Cy, W	S	do.	0.4	2,477.2	86.62	Sept. 6	
9-24-6aaa	A. McKinley	Dr	47.0	5	GI	do.	do.	Cy, H	N	do.	0.8	2,430.6	36.00	Sept. 2	Not in use.
9-24-8abb	School district	Dr	77.5	5	GI	do.	do.	Cy, H	D	do.	0.3	2,477.6	70.76	Sept. 2	do
9-24-8cbb	F. Keith	Dr	46.0	5	GI	do.	do.	N, N	S	do.	0.5	2,449.6	36.18	Sept. 4	A new well in 1952.
9-24-10bbb	Ida Keith	Dr	18.0	6	GI	do.	Ogallala and/or terrace deposits	Cy, W	S	do.	1.8	2,396.4	9.54	Sept. 4	
								Cy, W	S	do.	1.8	2,396.4	9.54	Sept. 4	
9-24-15cdd	Preachers Aid Assn.	Dr	94.0	5	GI	do.	Ogallala	N, N	N	do.	1.5	2,488.3	92.46	Sept. 2	Abandoned.
9-24-16ccc	Margaret S. Moore	Dr	111.0	4	GI	do.	do.	Cy, N	N	do.	0.1	2,513.3	107.28	Sept. 4	do.
9-24-17bbc	Clyde Keith	Dr	84.0	5	GI	do.	do.	Cy,H,W	S	do.	1.6	2,462.6	44.84	Sept. 4	
9-24-22dad	K. H. Boone	Dr	44.5	5	GI	do.	do.	Cy, W	S	do.	0.4	2,431.5	36.14	Sept. 6	
9-24-23aab	E. R. Nichelson	Dr	62.5	5	GI	do.	do.	Cy,H,W	N	do.	0.5	2,446.3	57.77	Sept. 2	Not in use.
9-24-29dda	G. Nichelson	Dr	149.0	5	GI	do.	do.	Cy, G	S	do.	0.4	2,541.3	127.73	Aug. 1	
9-24-30cdc	Andrew Riedel	Dr	95.5	5	GI	do.	do.	N, N	N	do.	0.3	2,521.6	92.51	Sept. 3	Abandoned.
9-24-34bbb	J. W. Kurtz	Dr	113.5	5	GI	do.	do.	Cy,H,W	D, S	do.	1.0	2,515.0	109.43	Sept. 6	
9-24-35cbc	E. E. Gano	Dr	93.0	5	GI	do.	do.	Cy, W	S	do.	0.8	2,491.6	89.05	Aug. 22	
9-24-35ddd	J. P. Sproul	Dr	85.5	5	GI	do.	do.	Cy, W	S	do.	1.0	2,453.1	52.98	Aug. 22	
T. 9 S., R. 25 W.															
9-25-1ddc	Albert Clark	Dr	96.0	5	GI	do.	do.	Cy,H,W	D, S	do.	1.1	2,510.4	87.51	Sept. 2	
9-25-2cdd	J. J. Richmeier	Dr	103.0	5	GI	do.	do.	Cy, E	D, S	do.	0.2	2,520.7	83.91	Sept. 2	
9-25-6acb	A. T. Sanger	Dr	95.0	5	GI	do.	do.	Cy, W	S	do.	0.2	2,556.0	86.37	Aug. 29	
9-25-8ccc	L. Messick	Dr	128.0	5	GI	do.	do.	Cy,H,W	S	do.	0.5	2,591.0	111.74	Aug. 29	
9-25-9aaa	J. C. Sparks	Dr	112.0	5	GI	do.	do.	Cy, G	S	do.	0	2,554.1	103.22	Sept. 2	
9-25-9bbb	W. P. Knoll	Dr	133.5	5	GI	do.	do.	Cy, H	N	do.	1.0	2,580.3	115.22	Sept. 2	Not in use.
9-25-11ddd	....	Dr	86.0	5	GI	do.	do.	Cy, W	S	do.	0.4	2,509.3	71.37	Sept. 4	
9-25-16daa	H. L. James	Dr	118.0	5	GI	do.	do.	Cy, W	S	do.	0.6	2,574.1	112.70	Sept. 3	Not in use.
9-25-18ddd	C. E. McFadden	Dr	152.0	4	GI	do.	do.	Cy, W	S	do.	0.5	2,633.9	145.39	Aug. 1	
9-25-20daa	J. Pfeifer	Dr	98.0	5	GI	do.	do.	Cy, W	S	do.	0.6	2,570.9	95.08	Sept. 3	

TABLE 7.—*Records of wells and springs in Graham County—Concluded*

Well number	Owner or tenant	Type of well (1)	Depth of well, (feet)	Diameter of well, (in.)	Type of casing (2)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (3)	Use of water (4)	Measuring point: Description	Measuring point: Distance above land surface, (feet)	Measuring point: Height above mean sea level, (feet) (5)	Depth to water level below measuring point, (feet)	Date of measurement 1952	Remarks
T. 9 S., R. 25 W.															
9-25-22cdd	L. N. Dreiling	Dr	157.0	5	GI	Sand, gravel	Ogallala	Cy,H,W	N	Top of casing	1.0	2,602.1	147.05	Sept. 3	Not in use.
9-25-24bbb	Marie Dinkle	Dr	89.0	6	GI	do	do	Cy, W	S	do	2.0	2,524.0	83.00	Sept. 3	
9-25-25ccc	A. E. Riedel	Dr	105.5	5	GI	do	do	Cy,H,W	D, S	do	1.0	2,542.1	96.09	Aug. 1	
9-25-32cbb	Riedel	Dr	111.0	5	GI	do	do	Cy,H,W	S	do	0.7	2,585.7	95.69	Sept. 24	
9-25-33ddd	D. Hartle	Dr	70.5	5	GI	do	do	Cy,H,W	S	do	0.5	2,525.5	57.83	Sept. 3	
9-25-35ccd	P. P. Rome	Dr	57.0	5	GI	do	do	Cy,H,W	S	do	1.0	2,498.2	51.98	Aug. 22	
T. 10 S., R. 21 W.															
10-21-2baa	Frank Noah	Dr	55.0	5	GI	do	do	Cy,H,W	S	do	0.3	2,298.5	51.97	Sept. 11	
10-21-4baa	R. Towns	Dr	84.0	6	GI	Sand, gravel, and/or chalky shale	Ogallala and/or Niobrara	Cy,H,W	N	do	0.5	2,299.2	35.46	Sept. 11	Not in use.
10-21-9baa	Roy E. Martin	Du	25.0	48	C	Sand, gravel	Ogallala	N, N	N	Top of board cover	0.3	2,272.5	21.13	Sept. 12	Abandoned.
10-21-20baa	R. E. Teal	Du	20.5	36	T	do	do	N, N	N	do	0.6	....	17.37	Sept. 13	do
10-21-30abb	Frank Hayes	Dr	305	6	GI	Chalky shale	Niobrara	Cy,H,W	S	Base of board cover	0.6	....	50.03	Oct. 25	Chemical analysis.
10-21-34ada	L. E. Rathbun	Du	29.0	36	C	Sand, gravel	Terrace deposits	Cy,H,W	S	Top of board cover	0.8	....	24.46	Sept. 9	
T. 10 S., R. 22 W.															
10-22-2cdc	Adrian Tremblay	Dr	50.0	5	GI	do	Ogallala	Cy, H	D	Top of casing	1.0	2,331.1	42.59	Sept. 8	
10-22-4cbd	E. E. Mullaney	Dr	29.0	5	GI	do	do	Cy, H	N	do	1.0	2,321.2	21.27	Aug. 30	Not in use.
10-22-8bbd	W. A. Allen	Dr	53	5	GI	Sand, silt	do	Cy,H,W	S	do	0.2	2,339.8	33.03	Aug. 30	
10-22-17dcc	R. F. Fritts, et al.	Dr	46.5	5	GI	Sand, gravel	do	Cy,H,W	S	do	1.0	2,348.8	36.75	Sept. 8	
10-22-18bba	O. L. Robinson	Dr	56.0	5	GI	do	do	Cy,H,W	D, S	do	—5.0	2,379.8	51.25	Sept. 12	
10-22-23bbb	J. Faulkner	Dr	110.0	4	GI	Chalky shale	Niobrara	N, N	N	do	3.5	....	13.50	Sept. 12	Not in use.
10-22-25bbb	William L. Iwan, et al	Dr	20.5	8	GI	Sand, gravel	Terrace deposits	Cy, N	N	do	0.5	....	12.05	Sept. 12	do
10-22-28ccc	R. E. Custer	Dr	16.0	5	GI	Chalky shale	Niobrara	N, N	N	do	0.2	....	9.85	Aug. 25	Abandoned.
10-22-28dda	Leo W. Faulkner	Dr	35.0	6	GI	do	do	Cy,H,W	S	do	1.6	....	28.10	Aug. 30	
T. 10 S., R. 23 W.															
10-23-3add	A. and E. Klenk	Dr	86.0	5	GI	Sand, gravel	Ogallala	Cy,H,W	D, S	do	—4.4	2,423.5	74.86	Sept. 12	
10-23-4bcb	Ben Law estate	Dr	102.5	5	GI	do	do	Cy,H,W	N	do	0.3	2,455.5	89.70	Aug. 25	Not in use.
10-23-6cdd	School district	Dr	59.0	5	GI	do	do	Cy, H	D	do	0.2	2,426.9	45.27	Aug. 2	

T. 10 S., R. 23 W.														
10-23-9ada	F. Johnson	Dr	80.5	5	GI	do.	do.	N, N	N	do.	0.5	2,430.1	73.57	Aug. 13	Abandoned.
10-23-9ccd	F. Hoof, et al.	Dr	32.7	5	GI	do.	do.	N, N	N	do.	2.5	2,383.0	26.50	Aug. 25	do
10-23-14add	F. B. Walker	Dr	49.5	5	GI	do.	do.	Cy,H,W	S	Base of board cover.	0	2,376.6	42.70	Oct. 30	Chemical analysis.
10-23-14bcc	J. Diebolt	Dr	40.0	4	GI	do.	do.	Cy, H	O	Top of casing	0	2,369.9	29.35	Aug. 13	Not in use.
10-23-18ada	N. Gano	Dr	55.5	5	GI	do.	do.	Cy,H,W	S	do.	0.4	2,412.4	48.80	Sept. 6	
10-23-19ccc	W. M. Klenk	Dr	68.0	5	GI	do.	do.	Cy,H,W	S	do.	1.0	2,417.6	45.05	Sept. 6	
10-23-20ada	C. Brown	Dr	41.5	5	GI	do.	do.	Cy,H,W	S, D	do.	0.4	2,391.2	36.75	Aug. 25	
10-23-28aba	S. Nemecheck	Du	27.5	36	C	do.	do.	Cy, N	N	Base of pump	0	2,362.7	16.75	Aug. 25	Abandoned.
10-23-32dab	Guy Dorman	Dr	30.0	4	GI	do.	do.	Cy, H	N	Top of casing	0.6	2,326.8	17.91	Aug. 2	do
10-23-34aad	C. J. Klenk, et al.	Dr	25.0	6	GI	do.	Terrace deposits	N, N	N	do.	—4.5	2,280.1	13.17	Aug. 13	Not in use.
T. 10 S., R. 24 W.															
10-24-2ccb		Dr	99.5	5	GI	do.	Ogallala	Cy, N	N	do.	1.5	2,489.2	84.37	Sept. 4	do
10-24-4bab	G. Nickelson	Dr	102.0	6	GI	do.	do.	Cy, W	S	do.	1.8	2,512.0	96.03	Sept. 6	
10-24-7 cab	Frank Riedel	Dr	23.0	5	GI	do.	do.	Cy,H,W	S	Hole in base of pump	1.5	2,445.5	21.91	Sept. 24	
10-24-10cdd	F. Herman	Dr	82.0	5	GI	do.	do.	Cy,H,W	S	Top of casing	0.8	2,468.6	68.42	Aug. 22	
10-24-11dcd	E. E. Gano	Dr	98.0	5	GI	do.	do.	Cy, W	S	do.	1.1	2,476.8	87.04	Aug. 22	
10-24-15dda	F. R. Sproul	Dr	18.0	5	GI	do.	do.	Cy, W	S	do.	0.4	2,395.2	9.61	Aug. 2	
10-24-17abd	H. Schamberger	Dr	54.0	5	GI	do.	do.	Cy, W	S	do.	0.8	2,439.3	36.26	Aug. 22	
10-24-23ccc	School district	Dr	63.0	6	GI	do.	do.	Cy, H	D	do.	1.1	2,423.5	48.24	Aug. 2	Chemical analysis.
10-24-28cdb	Robert Kirk	Dr	33.0	5	GI	do.	Terrace deposits	Cy,H,W	D, S	do.	1.0	2,351.0	19.38	Sept. 5	Not in use.
10-24-32cbb	Eugenia Rome	Du	33.0	6	GI	Sand and/or chalky shale	Ogallala and/or Niobrara	Cy, W	S	do.	0.5	2,420.2	17.25	Sept. 4	
T. 10 S., R. 25 W.															
10-25-1add	J. J. Richmeier	Dr	27.5	5	GI	Sand, gravel	Ogallala	Cy, W	S	Base of pump	0.6	2,462.6	26.90	Sept. 24	Not in use.
10-25-3cda	Joseph Kuhn	Dr	54.0	5	GI	do.	do.	Cy,H,W	D, S	Top of casing	0.6	2,496.0	43.50	Sept. 24	
10-25-7ddd	Wm. McGuire	Dr	22.0	5	GI	do.	do.	Cy, W	S	do.	0.8	2,499.6	15.50	Sept. 5	
10-25-8aad	F. Brungardt	Dr	92.0	5	GI	do.	do.	Cy,H,W	S	do.	0.8	2,543.3	69.00	Aug. 1	
10-25-13baa	A. Knoll	Dr	47.5	5	GI	do.	do.	Cy, H	N	do.	0.6	2,463.5	40.25	Sept. 3	Not in use.
10-25-20bbb	C. E. McFadden	Dr	102.0	6	GI	do.	do.	Cy, W	D	do.	1.2	2,556.7	83.91	Aug. 1	
10-25-21cab	C. LaCerte	Dr	96.0	5	GI	do.	do.	Cy, W	S	do.	1.6	2,540.9	87.22	Aug. 29	
10-25-25bbb	D. Hobbs	Dr	77.0	5	GI	do.	do.	Cy,H,W	N	do.	0.6	2,492.3	74.50	Sept. 5	Not in use.
10-25-26aab	W. P. Knoll	Dr	100.0	5	GI	do.	do.	Cy, W	S	do.	0.4	2,502.3	83.50	Sept. 5	
10-25-28ddd	R. J. Weiser	Dr	66.5	5	GI	do.	do.	Cy, W	S	do.	0.6	2,483.2	58.35	Aug. 29	
10-25-29bcc	B. Brungardt, et al.	Dr	65.0	5	GI	do.	do.	Cy, W	S	do.	0.8	2,508.0	51.62	Aug. 1	
10-25-33dcd	Christian Uhrich	Dr	42	5	GI	do.	Crete	Cy,H,W	D, S	......	......	......	38	......	
10-25-34aaa	John Weissbeck	Dr	60.5	5	GI	do.	Ogallala	Cy,H,W	S	Top of casing	0.3	2,466.2	46.10	Aug 29	
10-25-34ddc	Edwin and Edith Jarbol	Dr	17.0	5	GI	do.	do.	Cy,H,W	S	do.	0.3	2,398.1	11.43	Aug. 29	Chemical analysis.

1. Dr, drilled; Du, dug; S, spring.
2. C, concrete; GI, galvanized iron; I, iron; N, none; R, rock; S, steel; T, tile.
3. Type of pump: C, centrifugal; Cy, cylinder; J, jet; N, none; P, pitcher; RB, rope and bucket; T, turbine.
   Type of power: E, electricity; G, gasoline; H, hand; N, none; T, tractor; W, wind.
4. D, domestic; I, irrigation; N, none; O, observation; P, public supply; S, stock.
5. Where no measuring point is given, altitude is that of land surface at well.

LOG OF WELLS AND TEST HOLES

Listed on the following pages are logs of 31 test holes drilled by the State Geological Survey and logs of 4 test holes drilled by C. A. Robben of Norton. The location of test holes drilled by the State Geological Survey is shown on Plate 2. Samples from test holes drilled by the State Geological Survey in 1952 were studied in the field by Norman W. Biegler, who supervised the drilling and prepared logs of the holes. The samples were subsequently studied microscopically by me. Logs entitled sample logs are those drilled by the State Geological Survey and for which samples were collected. Depth to water measurements obtained from test holes are included in the headings of the logs. Test holes 5-23-34dd and 5-21-33cc were drilled in 1946 as part of the study of the geology and ground-water resources of Norton and northwestern Phillips Counties and test holes 6-25-6bbb and 6-25-31ccc were drilled in 1952 to assist in the study of the geology and ground-water resources of Sheridan County.

6-21-7aa. *Sample log of test hole in the NE cor. sec. 7, T. 6 S., R. 21 W., 14 feet west of road center and 30 feet south of intersection; drilled October 1952. Surface altitude, 2,198.5 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation—Peoria silt member		
Silt and clay, black (topsoil)	2.5	2.5
Silt and clay, brown to tan-gray	6.5	9
Clay, silty to compact, tan to light-gray	12	21
TERTIARY—Pliocene		
Ogallala formation		
Sand, fine to coarse, and fine gravel; contains some fragments of chalk	14	35
Clay, yellow-gray, with stringers of sand	4	39
Sand, fine to coarse, and fine to coarse gravel	15	54
Sand, gravel, and pebbles; contains a few thin stringers of yellow clay	23.5	77.5
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Chalk, clayey, yellow and white to pink	12.5	90

6-21-7add. *Sample log of test hole in the SE cor. NE¼ sec. 7, T. 6 S., R. 21 W., 6 feet west of road center and 10 feet north of half-section line fence to east; drilled September 1952. Surface altitude, 2,189.4 feet.*

	Thickness, feet	Depth, feet
Road fill	2	2
QUATERNARY—Pleistocene		
Sanborn formation—Terrace deposits (late Wisconsinan)		
Silt, clayey, tan-gray	10	12

	Thickness, feet	Depth, feet
Silt, tan-gray; ranges from clayey in upper part to sandy in lower part	6	18
Sand, fine to coarse, and fine to coarse gravel	10	28
Sand, fine to coarse, and fine to coarse gravel; contains pebbles and yellow-gray silt with some fragments of chalk from 30 to 38 feet; contains less gravel and pebbles from 48 to 52.5 feet	24.5	52.5
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Chalk, clayey, light-yellow and white	5.5	58
Shale, calcareous, gray-brown	2	60

6-21-8cbb. *Sample log of test hole in the NW¼ NW¼ SW¼ sec. 8, T. 6 S., R. 21 W., 110 feet east of road in pasture and about 300 feet south of bridge; drilled September 1952. Surface altitude, 2,186.9 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation—Terrace deposits (late Wisconsinan)		
Silt, black (topsoil)	2	2
Clay, silty and sandy, gray-brown to tan-gray	4	6
Sand, fine to coarse	2.5	8.5
Clay, gray; ranges from compact to sandy	2	10.5
Sand and gravel; contains thin lenses of gray silt or clay	9.5	20
Sand, fine to coarse, and some gravel; is silty in zones	10	30
Sand, fine to coarse, and some fine to medium gravel; contains a cemented layer from 38 to 38.5 feet	18.5	48.5
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Chalk, clayey, yellow and white	3.5	52
Shale, calcareous, gray to gray-brown	8	60

6-22-4aaa. *Sample log of test hole in the NE cor. sec. 4, T. 6 S., R. 22 W., 6 feet west of fence line and 18 feet south of road center; drilled September 1952. Surface altitude, 2,327.4 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Peoria silt member		
Silt and clay, black (topsoil)	2	2
Clay, gray-brown	1	3
Silt, tan-gray; contains a few grains of imbedded gravel	17	20
Loveland silt member		
Clay, blocky, brown to dark-brown (Sangamon soil)	2	22
Clay, sandy, tan to light-tan; calcareous in upper part	11	33
TERTIARY—Pliocene		
Ogallala formation		
Clay, light-tan to tan-white; sandy in lower part	7	40

	Thickness, feet	Depth feet
Silt and very fine sand, partly cemented, tan; calcareous from 60 to 67 feet	27	67
Sand, fine to coarse, loosely cemented; contains a clayey zone from 72 to 74 feet and contains a little fine to coarse gravel	12	79
Sand, medium; contains some fine to coarse sand and clay; contains less clay from 92 to 96 feet	20	99
Sand, fine to medium; partly cemented from 116 to 119 feet	20	119
Sand, fine to medium, cemented	20	139
Sand, fine to medium, clayey, light-gray	6	145
Clay, sandy	4	149
Sand, clayey, ranging to sandy clay; tan	19	168
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Chalk, clayey, yellow and white to pink	12	180

6-22-31ccc. *Sample log of test hole in the SW cor. sec 31, T. 6 S., R. 22 W., 6 feet east of road center and 80 feet north of intersection; drilled October 1952. Surface altitude, 2,394.2 feet.*

	Thickness, feet	Depth, feet
Road fill	1	1
QUATERNARY—Pleistocene		
Sanborn formation—Peoria silt member		
Silt, tan-gray	13	14
TERTIARY—Pliocene		
Ogallala formation		
Sand, fine to medium, partially cemented, light-gray; contains a very hard layer from 28.5 to 29 feet	29.5	43.5
Sand, fine to medium; contains white calcareous cement	6	49.5
Clay, tan-white, and gray-green sandy clay	3.5	53
Sand, fine to medium, loosely cemented; contains some yellow-brown silt from 63 to 67 feet	14	67
Clay, sandy, yellow-brown	10	77
Sand, fine to coarse, and fine gravel; contains clay layer from 86 to 87 feet	10	87
Clay, sandy, gray-brown	35	122
Gravel; contains sand and clay	10	132
Sand, fine to medium; contains sandy clay	15	147
Clay, sandy, gray-green	6	153
Sand, fine to coarse, and fine to coarse gravel; partly cemented	20	173
Sand and gravel, partly cemented; contains some fragments of weathered chalk	25	198
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Shale, calcareous, gray to black	12	210

6-24-31ccc. *Sample log of test hole in the SW cor. sec. 31, T. 6 S., R. 24 W., in field on edge of road ditch, 120 feet east of intersection and 15 feet north of road center; drilled October 1952. Surface altitude, 2,460.0 feet. Depth to water level, 48.8 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Silt and clay, black to dark-brown	5	5
TERTIARY—Pliocene		
Ogallala formation		
Sand, fine to coarse, tan-gray; contains clay from 5 to 6 feet	7	12
Sand, fine to coarse, and fine to coarse gravel; contains some pebbles from 22 to 27 feet	15	27
Clay, sandy, gray-green; contains some imbedded gravel and pebbles at top; contains more sand from 33 to 38 feet	11	38
Sand, fine to medium, silty, calcareous	6	44
Clay, sandy, gray-white	4	48
Sand, clayey, yellow-green	9	57
Sand, fine to medium, silty	3	60
Clay, sandy, yellow-green	6	66
Clay, yellow-green to green; contains some compact gray-green clay	3.5	69.5
Sand, fine to medium, with layers of yellow-green sandy clay	15.5	85
Sand, fine to coarse; contains silt in upper part	10	95
Sand, fine to coarse, with some fine to coarse gravel	21	116
Gravel and pebbles with yellow-brown clay	3	119
Sand and gravel, silty, yellow-brown	10	129
Sand, fine to coarse	11	140
Sand and gravel with light-tan to light-brown clay	5	145
Sand, fine to coarse, and fine to coarse gravel	8	153
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Chalk, clayey to silicified	1.5	154.5

6-24-36aba. *Sample log of test hole in the NE¼ NW¼ NE¼ sec 36, T. 6 S., R. 24 W., in yard near north side of building, 200 feet south of road; drilled October 1952. Surface altitude, 2,490.2 feet. Depth to water level 128.6 feet.*

	Thickness, feet	Depth, feet
Fill	4.5	4.5
QUATERNARY—Pleistocene		
Sanborn formation—Peoria silt member		
Silt, tan-gray; contains some imbedded gravel	6.5	11
TERTIARY—Pliocene		
Ogallala formation		
Clay, soft, sandy, tan-brown	8	19
Clay, sandy, light-tan; contains some imbedded gravel	6	25

	Thickness, feet	Depth, feet
Sand, fine to coarse, and fine to coarse gravel	3	28
Clay, sandy, tan and brown; contains beds of clayey sand and gravel	17	45
Clay, sandy, tan	15	60
Sand, fine to medium, cemented, tan-gray; contains some hard caliche	10	70
Sand, cemented with siliceous cement; contains beds of sandy clay	10	80
Sand, fine to medium, calcareous, cemented, light-gray	20	100
Gravel, fine to coarse, and fine to coarse sand, silty, cemented	8	108
Clay, sandy, light-tan; contains a few thin stringers of cemented sand	27.5	135.5
Sand, fine to coarse, and fine to coarse gravel; silty, cemented from 138 to 148 feet	12.5	148
Sand and gravel and some pebbles, loosely cemented	26	174
Sand, fine to coarse, and fine to coarse gravel; clayey, yellow-tan	5	179
Sand, fine to medium, silty to clayey; contains a little coarse sand and fine gravel	18	197
Clay, sandy, tan-gray; contains a few thin stringers of sand	10	207
Sand, fine to coarse; contains silt and clay	8	215
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Chalk, clayey to silicified, yellow and white	1	216

6-25-6bab. *Sample log of test hole in the NW¼ NE¼ NW¼ sec. 6, T. 6 S., R. 25 W., 200 feet south of county line and 15 feet east of road; drilled August 1952. Surface altitude, 2,492.9 feet.*

	Thickness, feet	Depth, feet
Road fill	0.5	0.5
TERTIARY—Pliocene		
Ogallala formation		
Sand, fine to coarse, silty; cemented with calcium carbonate	6.5	7
Silt, calcareous, hard, and fine to medium sand	5	12
Silt to fine sand, calcareous, white	3	15
Clay, sandy, tan-yellow	3	18
Sand, fine to medium, silty, light-tan	3	21
Sand, fine to coarse, silty, green	6	27
Sand, fine to coarse, and fine to coarse gravel; contains cemented stringers	6	33
Sand and gravel, cemented with silty lime	3	36
Clay, sandy, tan-green to gray-green	3	39
Clay, sandy, tan-gray to yellow-gray	7	46
Sand, fine to medium, silty; contains some coarse sand and fine gravel	8	54

	Thickness, feet	Depth, feet
Clay, tan to yellow-gray	2	56
Clay, light-gray	4	60
Clay, light-tan; contains much sand	8	68
Sand, fine to medium, clayey, tan-brown	8	76
Clay, sandy, tan-brown	10	86
Clay, tan-brown; contains stringers of sand	15	101
Sand, fine to medium; contains a lens of clay	10	111
Sand, fine to medium, silty	10	121
Sand, fine to medium	6.5	127.5
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Chalk, silicified, yellow-brown	.5	128

6-25-31cc. *Sample log of test hole in SW cor. sec. 31, T. 6 S., R. 25 W., 300 feet north and 15 feet east of intersection; drilled August 1952. Surface altitude, 2,571.9 feet.*

	Thickness, feet	Depth, feet
Road fill	3	3
QUATERNARY—Pleistocene		
Sanborn formation—Peoria silt member		
Silt, tan-gray to gray-green; contains snail shells	10	13
TERTIARY—Pliocene		
Ogallala formation		
Sand, fine to coarse, and fine to coarse gravel	9	22
Sand, fine to coarse; contains tan-gray clay stringers	5	27
Clay, sandy, tan-gray	18	45
Sand, cemented, light-tan	14	59
Sand, fine to coarse	4	63
Sand, cemented, clayey	15	78
Clay, sandy, light-gray	15	93
Sand, fine to coarse; contains stringers cemented with calcium carbonate	15	108
Sand, fine to coarse, clayey, yellow-gray	19	127
Sand, fine to coarse, silty	7	134
Sand, fine to coarse; contains interbedded silty clay stringers	5.5	139.5
Sand, clayey, partly cemented	24.5	164
Clay, yellow, compact; contains thin clayey stringers	6	170
Sand, fine to medium, cemented	20	190
Sand, fine to medium, and some weathered chalk cemented	19	209
Sand, fine to coarse, with fragments of silicified chalk,	9	218
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Chalk, silicified at top, and yellow to orange chalky shale	21	239

7-21-23add. *Sample log of test hole in the SE cor. NE¼ sec. 23, T. 7 S., R. 21 W., 100 feet west of road center and 30 feet north of fence line; drilled September 1952. Surface altitude, 2,093.6 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Peoria silt member		
Silt and clay, black (topsoil)	2	2
Silt, clayey, tan-gray	9	11
Loveland silt member		
Clay, compact, brown (Sangamon soil); contains a few grains of gravel	2	13
Clay, tan-brown	2	15
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Chalk, clayey, light-gray to light-yellow	38	53
Shale, calcareous, dark-gray to black	3	56

7-21-36cbb. *Sample log of test hole in the NW cor. SW¼ sec. 36, T. 7 S., R. 21 W., 60 feet south of half-section line and 10 feet east of road center; drilled September 1952. Surface altitude, 2,032.2 feet.*

	Thickness, feet	Depth, feet
Road fill	2	2
QUATERNARY—Pleistocene		
Sanborn formation—Crete sand and gravel member (?)		
Clay, sandy, compact, brown	5	7
Sand, fine to coarse, partly cemented	5	12
Clay, sandy, calcareous, light-gray to light-tan	10	22
Clay, sandy, light-gray to light-tan; contains thin stringers of sand and some limonite staining	4	26
Sand, fine to coarse; contains a clay stringer from 29 to 31 feet and some fragments of chalk	9	35
Clay, sandy, brown; contains gray-brown to dark-brown clay balls in interbedded clayey sand lenses; contains fragments of chalk and thin stringers of white calcareous clay from 45 to 49 feet	14	49
Sand, fine to coarse, calcareous, clayey, gray-white; contains thin stringers of white calcareous clay; contains some gravel from 59 to 68 feet	19	68
Sand, fine to coarse, and gray-white clay; contains some gravel and fragments of chalk	5	73
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Shale, calcareous, dark-gray	3	76

7-22-1aaa. *Sample log of test hole in the NE cor. sec. 1, T. 7 S., R. 22 W., 50 feet south of intersection and 7 feet west of road center; drilled September 1952. Surface altitude, 2,248.8 feet. Depth to water level, 47.1 feet.*

	Thickness, feet	Depth, feet
Road fill	1.5	1.5

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Peoria silt member		
Silt, tan-gray	8.5	10
Loveland silt member		
Clay, compact to silty, brown to tan-brown	8	18
TERTIARY—Pliocene		
Ogallala formation		
Sand, fine to medium; contains some clay	10	28
Sand, fine to medium; contains a cemented zone from 28 to 29 feet	9	37
Sand, fine to medium, silty to loosely cemented	8	45
Sand, fine to coarse, silty, yellow-brown; contains fragments of chalk	13	58
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Chalk, clayey, yellow and white	6	64
Shale, clayey, calcareous, dark-gray	1	65

7-22-10bcb. *Driller's log of irrigation well of M. E. Worcester in the NW¼ SW¼ NW¼ sec. 10, T. 7 S., R. 22 W. Drilled by C. A. Robben.*

	Thickness, feet	Depth, feet
QUATERNARY AND TERTIARY—Pleistocene and Pliocene		
Sand and gravel	10	10
Gravel	26	36
Ochre or joint clay	2	38
Gravel and sand	12	50
Sand, fine	1	51
Sand and gravel	3	54
Rock, soft	1	55
Sand	5	60
Sand, fine	24	84
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		

7-22-13c. *Driller's log of test hole in the NW¼ sec. 13, T. 7 S., R. 22 W. Drilled by C. A. Robben.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Peoria silt member		
Soil, black	1	1
Clay, yellow	18	19
Loveland silt member (?)		
Clay, brown	5	24
Crete sand and gravel member		
Clay, sandy	7	31
Magnesia rock mixed with sand	9	40
Magnesia rock	2	42

	Thickness, feet	Depth, feet
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Ochre	1	43
Shale	1	44

7-25-35dcc. *Sample log of test hole in the SW cor. SE¼ sec. 35, T. 7 S., R. 25 W., 15 feet north of intersection and 10 feet east of power line; drilled October 1952. Surface altitude, 2,486.6 feet. Depth to water level, 87.4 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation—Peoria silt member		
Silt and clay, black (topsoil)	2.5	2.5
Silt, tan; contains some caliche	7.5	10
Silt, tan; contains some caliche and imbedded gravel	6	16
TERTIARY—Pliocene		
Ogallala formation		
Sand and gravel, loosely cemented; contains a few thin stringers of fine sand	11	27
Silt and fine sand, cemented, tan-gray	6	33
Clay, blocky, tan-gray; some limonite staining	4	37
Sand, fine to medium, clayey to partly cemented, tan-brown	17	54
Sand, fine to coarse, silty	5	59
Sand, fine to coarse, loosely cemented; contains some fine gravel	10	69
Sand, fine to coarse, and fine to coarse gravel; clayey; contains a few stringers of tan blocky clay	16	85
Clay, sandy, calcareous, gray-white	4	89
Sand, fine to medium, silty; contains calcium carbonate near base	5	94
Clay, sandy, gray to yellow-green	8	102
Sand, fine to coarse	25	127
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Shale, calcareous, clayey, yellow and gray	2	129
Shale, calcareous, clayey, dark-gray to black	1	130

8-21-7cbc. *Driller's log of irrigation well of George Cooksey in the SW¼ NW¼ SW¼ sec. 7, T. 8 S., R. 21 W. Drilled by C. A. Robben.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Soil, black	2	2
Clay, sandy, light	3	5
Sand	3	8
Sand and medium gravel	11	19
Sand, coarse, and road gravel	5	24
Mud, black	6	30
Sand and medium gravel	9	39
Mud, black	2	41
Sand, coarse, and gravel	10	51

CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Rock and shale		

8-21-8baa. *Sample log of test hole in the NE cor. NW¼ sec. 8, T. 8 S., R. 21 W., in triangle, 25 feet west of road center and 250 feet south of U. S. Highway 24; drilled September 1952. Surface altitude, 2,024.1 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation—Terrace deposits (late Wisconsinan)		
Sand, fine to coarse, silty, gray	3	3
Sand, fine to coarse; contains silt, gravel, and pebble-sized fragments of chalk; includes rubble of weathered chalk, cemented sand, and limonite-stained fragments	2	5
Sand, fine to coarse; contains gravel and pebbles of chalk and weathered shale; contains a cemented stringer from 17 to 17.5 feet	14	19
Sand, fine to coarse, and fine to coarse gravel; silty, dark-gray	13.5	32.5
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Shale, clayey, gray to dark gray	4.5	37

8-21-8cdd. *Sample log of test hole in the SE cor. SW¼ sec. 8, T. 8 S., R. 21 W., in ditch west of State Highway 18, 10 feet east of fence line and 40 feet north of east-west fence line; drilled September 1952. Surface altitude, 2,029.3 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation—Terrace deposits (late Wisconsinan)		
Sand, fine to coarse; contains dark-brown to black silt at top	10	10
Sand, fine to coarse, and some fine to medium gravel,	30	40
Sand, fine to coarse; contains some gravel and fragments of chalk and weathered shale	8	48
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Shale, clayey, blue to blue-gray	2	50

8-21-14ddd. *Sample log of test hole in the SE cor. sec. 14, T. 8 S., R. 21 W., 20 feet west of intersection and 8 feet north of road center; drilled September 1952. Surface altitude, 2,096.5 feet.*

	Thickness, feet	Depth, feet
Road fill	1.5	1.5
QUATERNARY—Pleistocene		
Meade formation—Sappa and Grand Island members		
Silt, clayey, tan-gray	1.5	3
Sand, cemented, tan to light-tan	2	5
Sand, fine to coarse; contains fragments of chalk	17	22

	Thickness, feet	Depth, feet
Clay, sandy, brown, interbedded with fine to coarse partly cemented sand	9	31
Sand, fine to coarse, silty; contains clay in the lower part and some fragments of chalk	10	41
Clay, compact, light-gray; contains a few thin stringers of sand	9	50
Sand, fine to coarse; contains some fragments of chalk,	5	55
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Chalk, soft, tan-white	2	57
Shale, calcareous, gray to blue-gray	3	60

8-21-17dbb. *Sample log of test hole in the NW cor. SE¼ sec. 17, T. 8 S., R. 21 W., 4 feet east of intersection and 10 feet south of road center; drilled September 1952. Surface altitude, 2,057.8 feet.*

	Thickness, feet	Depth, feet
Road fill	1	1
QUATERNARY—Pleistocene		
Sanborn formation—Terrace deposits (late Wisconsinan)		
Silt, clayey, tan-brown	3	4
Sand, fine to coarse; contains a little fine gravel and a few thin stringers of clay	4	8
Sand, fine to medium, silty, dark-brown	2	10
Sand, fine to coarse, and fine to coarse gravel; contains a few stringers of clay	8	18
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Chalk, yellow and white; contains some imbedded gravel at surface and pebbles of silicified chalk and weathered shale	3	21
Shale, blue-gray	5	26

8-23-2ddd. *Sample log of test hole in the SE cor. sec. 2, T. 8 S., R. 23 W., 90 feet west of U. S. Highway 283 and 8 feet north of center of road; drilled October 1952. Surface altitude, 2,217.0 feet.*

	Thickness, feet	Depth, feet
Road fill	4	4
QUATERNARY—Pleistocene		
Sanborn formation		
Peoria silt member		
Clay, calcareous, tan-gray to light-tan	2.5	6.5
Silt, and clay, tan-gray to gray-brown	4.5	11
Silt, clayey, brown; contains a few grains of gravel,	4	15
Crete sand and gravel member		
Sand, fine to medium, very clayey	2	17
Clay, sandy, tan to tan-gray	7	24

	Thickness, feet	Depth, feet
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Chalk, yellow and white	6	30

8-23-12bcc. *Sample log of test hole in the SW cor. NW¼ sec. 12, T. 8 S., R. 23 W., 60 feet east of U. S. Highway 283 and 30 feet north of half-section line road; drilled October 1952. Surface altitude, 2,198.9 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Peoria silt member		
Silt and clay, black to dark-brown (topsoil)	2	2
Silt, gray-tan	8	10
Silt, sandy, tan-brown	6	16
Crete sand and gravel member		
Sand, silty, fine to coarse	3	19
Clay, tan-gray; contains sand and gravel	5	24
Sand, fine to coarse, clayey to loosely cemented	5	29
Clay, yellow-tan; contains some gravel	4	33
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Chalk, yellow	4.5	37.5
Shale, calcareous, dark-gray	2.5	40

8-23-13b. *Driller's log of test hole in the NW¼ sec. 13, T. 8 S., R. 23 W. Drilled by C. A. Robben.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Soil, black	4	4
Clay, yellow	15	19
Mud, light-blue	3	22
Clay, sandy	1	23
Sand, fine	6	29
Gravel	9	38
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Shale	1	39

8-23-14dda. *Sample log of test hole in the NE¼ SE¼ SE¼ sec. 14 T. 8 S., R. 23 W., 130 feet south of railroad tracks and 30 feet west of highway; drilled October 1952. Surface altitude, 2,124.3 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation—Terrace deposits (late Wisconsinan)		
Sand, silty to clayey, dark-brown	2	2
Clay, sandy, dark-brown	4	6
Sand, fine to coarse, silty	10	16
Sand, fine to coarse, and fine gravel	11	27
Sand, gravel, and pebbles, including fragments of chalk	5	32

	Thickness, feet	Depth, feet
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Shale, calcareous, gray	8	40

8-23-23-daa. *Sample log of test hole in the NE cor. SE¼ sec. 23, T. 8 S., R. 23 W., 30 feet south of half-section line road and 30 feet west of center of U. S. Highway 283; drilled October 1952. Surface altitude, 2,132.2 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation—Terrace deposits (late Wisconsinan)		
Silt and clay, black (topsoil)	1	1
Sand, fine to coarse, silty, dark-brown to black	4	5
Sand, fine to coarse, and fine to coarse gravel; contains fragments of chalk	9	14
Clay, dark-brown to black, and imbedded gravel	6	20
Clay, black, with some imbedded gravel; contains stringers of gravel and weathered shale	4	24
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Chalk, broken, light-gray	4.5	28.5
Shale, dark gray	1.5	30

8-24-36ccb. *Sample log of test hole in the NW¼ SW¼ SW¼ sec. 36, T. 8 S., R. 24 W., 0.15 mile north of intersection, 20 feet south of fence, and 14 feet east of road center; drilled September 1952. Surface altitude, 2,349.8 feet. Depth to water level, 11.4 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation—Terrace deposits (late Wisconsinan)		
Silt and clay, black (topsoil)	3.5	3.5
Sand, fine to coarse; contains a clayey stringer from 12 to 12.5 feet	13.5	17
Clay, sandy, dark-gray to black	3	20
Sand, fine to coarse, and fine to coarse gravel; contains a few thin stringers of clay	6	26
Sand and gravel, silty, yellow	2	28
Clay and silt, tan	4	32
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Shale, calcareous, blue-black	3	35

8-25-35ddd. *Sample log of test hole in the SE cor. sec. 35, T. 8 S., R. 25 W., 120 feet north of section line and 8 feet west of road center; drilled September 1952. Surface altitude, 2,510.5 feet. Depth to water level, 90.9 feet.*

	Thickness, feet	Depth, feet
Road fill	1	1
QUATERNARY—Pleistocene		
Sanborn formation—Peoria silt member		
Silt and clay, compact, tan-gray	2	3
Silt, tan-gray to gray-green	13	16

	Thickness, feet	Depth, feet
TERTIARY—Pliocene		
Ogallala formation		
Sand, fine to coarse, calcareous, cemented; contains stringers of tan-gray blocky clay	4.5	20.5
Sand, fine to coarse, and fine to coarse gravel; contains some pebbles	4.5	25
Sand, fine to coarse, cemented to partly cemented	3	28
Clay, sandy, and calcareous clay; tan-brown to tan-gray	11	39
Sand, fine to coarse, cemented	10	49
Sand, fine to coarse, cemented; contains stringers of clay	16	65
Sand, fine to coarse, and fine to medium gravel; principally fine to medium sand from 71 to 74 feet	9	74
Sand, calcareous, clayey to cemented, white	18	92
Limestone, very hard, white	3	95
Sand, fine, cemented	2	97
Sand, fine to coarse, and fine to coarse gravel; contains some chalk fragments; contains a stringer of clay at 107 feet	16	113
Sand, fine to medium, silty	6	119
Clay, sandy, light-tan	6.5	125.5
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Chalk, silicified, hard, yellow-brown	.5	126

9-22-36ddd. *Sample log of test hole in the SE cor. sec. 36, T. 9 S., R. 22 W., 60 feet west of intersection and 30 feet north of road center; drilled September 1952. Surface altitude 2,315.7 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation—Peoria silt member		
Silt and clay, light-gray	0.5	0.5
Silt, light-tan	6.5	7
TERTIARY—Pliocene		
Ogallala formation		
Sand, fine to coarse	2	9
Sand, calcareous, cemented, light-tan	7	16
Sand, fine to coarse; contains some gravel and a few thin stringers of clayey sand; contains a larger percentage of gravel from 26 to 32 feet	16	32
Clay, ranging to clayey sand; tan-brown to gray-green	8	40
Clay, compact, tan	3	43
Clay, sandy, calcareous, white; consists principally of clayey sand from 46 to 52 feet	9	52
Sand, cemented, light-tan to light tan-gray	4	56
Sand, fine to coarse	7	63
Clay, noncalcareous, light-gray	7	70
Clay, noncalcareous, light-brown	3	73

	Thickness, feet	Depth, feet
Clay, sandy, light-green; contains a hard stringer from 74 to 74.5 feet	2	75
Clay, noncalcareous, light-gray	4	79
Sand, fine to medium	.5	79.5
Sand, fine to medium; contains a very hard cemented layer from 79.5 to 80 feet	4	83.5
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Shale, calcareous, gray-brown	4.5	88

9-24-36ccb. *Sample log of test hole in the NW¼ SW¼ SW¼ sec. 36, T. 9 S., R. 24 W., in pasture opposite windmill to west, 0.15 mile north of intersection and 25 feet east of fence; drilled September 1952. Surface altitude, 2,528.9 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Peistocene		
Sanborn formation—Peoria silt member		
Silt and clay, gray-brown (topsoil)	1	1
Silt, tan-gray; contains gastropod shells	4	5
TERTIARY—Pliocene		
Ogallala formation		
Sand, fine to coarse, silty	4.5	9.5
Sand, fine to medium; contains interbedded gravel stringers, each about 1 foot thick	9.5	19
Clay, sandy, ranging to cemented clayey sand; light-gray	3	22
Clay, compact, light-tan to tan-white	5	27
Clay, sandy; contains stringers of sand	7	34
Clay, and silt, sandy, cemented, tan	4	38
Clay, gray and light-tan; contains stringers of sand	5.5	43.5
Sand, fine to coarse	11.5	55
Clay, sandy, gray	3	58
Clay, grading to cemented clayey sand	10	68
Sand, fine, calcareous, cemented, grading to a sandy silty limestone	12	80
Clay, sandy, red-brown	2	82
Clay, sandy to bentonitic, gray-green	4	86
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Chalk, soft, yellow	3.5	89.5
Chalk, silicified, yellow to yellow-brown	.25	89.75
Chalk, soft, yellow to white	4.25	94
Shale, calcareous, gray-brown to brown	9	103

9-25-35ddd. ***Sample log of test hole in the SE cor. sec. 35, T. 9 S., R. 25 W., in corner of field 15 feet west and 15 feet north of intersection; drilled September 1952. Surface altitude, 2,448.4 feet. Depth to water level, 87.97 feet.***

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation—Peoria silt member		
Silt and clay, dark-gray (topsoil)	3	3
Silt, light-tan	13.5	16.5
TERTIARY—Pliocene		
Ogallala formation		
Sand, fine to coarse, and fine to coarse gravel	3.5	20
Clay, sandy, tan-white; contains stringers of cemented sand	8	28
Sand, fine to coarse, and fine to coarse gravel	3	31
Sand, fine to coarse; contains silt and clay	7	38
Silt and fine sand, calcareous, cemented, gray-white	1.5	39.5
Clay, sandy, tan; contains stringers of light-tan to light-gray calcareous cemented fine sand	9.5	49
Silt and fine sand, calcareous, cemented, light-gray	2	51
Sand, fine to coarse	5	56
Clay, sandy, bedded, tan to tan-gray	22	78
Sand, fine to coarse; contains silt	9	87
Clay, sandy, tan-gray; contains a few stringers of fine to coarse sand and has some limonite staining	4	91
Sand, fine to coarse, clayey, calcareous, light-tan; contains a few thin layers of clay	10	101
Clay, calcareous, light-tan; contains imbedded gravel and pebbles	9	110
Sand, fine to coarse, yellow-tan; contains silt and clay and stringers of sandy clay	10	120
Sand, fine to coarse, silty; contains some fine gravel	8	128
Sand, gravel, and pebbles; contains some chalk fragments and some silt	4.5	132.5
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Chalk, soft, yellow, white, pink, and red	4.5	137

10-23-1aaa. ***Sample log of test hole in the NE cor. sec. 1, T. 10 S., R. 23 W., 80 feet west of road intersection and 5 feet south of road center; drilled September 1952. Surface altitude, 2,378.0 feet. Depth to water level, 47.2 feet.***

	Thickness, feet	Depth, feet
Road fill	3	3
TERTIARY—Pliocene		
Ogallala formation		
Silt and clay, sandy, tan-white; contains imbedded gravel	11	14
Clay, tan-brown; contains fine to medium sand and a few thin layers of clayey sand	11	25
Sand, fine to coarse; contains some fine to coarse gravel	4.5	29.5

	Thickness, feet	Depth, feet
Sand, fine to coarse, tan-brown; contains clay and silt; contains less silt from 36 to 40 feet	10.5	40
Sand, fine to coarse, and fine to coarse gravel	12.5	52.5
Sand and gravel, partly cemented; contains some pebbles and some tan-gray clay	5.5	58
Silt, tan-gray; contains sand and gravel	4	62
Sand, fine to coarse, and fine to coarse gravel; contains layers of brown clay	11	73
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Chalk, soft, white to light-yellow	4	77
Shale, olive to gray-green	16	93

10-24-34ddd. *Sample log of test hole at SE cor. sec. 34, T. 10 S., R. 24 W., 50 feet west of intersection and 20 feet north of road center; drilled September 1952. Surface altitude, 2,357.2 feet. Depth to water level, 35.4 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation—Peoria silt member		
Silt and clay, dark-brown	4	4
Silt, tan; contains some gastropod shells	15.5	19.5
TERTIARY—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—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Chalk, soft, white	2.5	48
Shale, gray	2	50

10-25-36ccc. *Sample log of test hole in the SW cor. sec. 36, T. 10 S., R. 25 W., 20 feet east of road center and 15 feet north of intersection on edge of field; drilled September 1952. Surface altitude, 2,418.8 feet. Depth to water level, 31.5 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation—Peoria silt member		
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
TERTIARY—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

	Thickness, feet	Depth, feet
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Chalk, soft, yellow	1.5	38
Shale, calcareous, gray	2	40

5-21-33cc. *Sample log of test hole in the SW¼ SW¼ sec. 33, T. 5 S., R. 21 W., Norton County; drilled 1946. Surface altitude, 2,306.3 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Peoria silt member		
Silt, loose, dark gray-brown	3	3
Silt, loose, tan; contains snail shells	10	13
Loveland silt member		
Silt, loose, tan	14	27
Sand, fine to very fine, and tan silt	7	34
TERTIARY—Pliocene		
Ogallala formation		
Sand, fine, light-tan to gray; contains gravel and silt	17	51
Sand, well-cemented with calcium carbonate	1	52
Sand and silt, light-gray to green-gray, and caliche	24	76
Silt, compact; contains some dull-red sand	21	97
Sand, fine, and dull-red silt; contains caliche	26	123
Sand, fine to very fine, and silt, and some gray and brown clay	55	178
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Shale, calcareous, fissile, gray; contains a few thin bentonite zones	12	190

5-23-34dd. *Sample log of test hole at the SE cor. sec. 34, T. 5 S., R. 23 W., Norton County; drilled 1946. Surface altitude, 2,397.3 feet.*

	Thickness, feet	Depth, feet
QUARTERNARY—Pleistocene		
Sanborn formation		
Silt, brown	2	2
Silt, tan; contains snail shells	5	7
TERTIARY—Pliocene		
Ogallala formation		
Sand, fine and very fine, silty, white	12	19
Sand and silt, cemented with calcium carbonate; contains fossil seeds	17	36
Sand, fine to coarse; contains silt, gravel, and caliche	49	85
Sand, with some silt; contains zones cemented with calcium carbonate	40	125
Sand, very fine to coarse, and silt	17	142
Silt, sand, and caliche; contains cemented zones	17	159
Sand and gravel, fine to coarse	24	183
Silt, soft, brown and gray	8	191
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Shale, chalky, fissile, brown, yellow, and gray; contains bentonite	9	200

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Areal Geology of Graham County, Kansas

By Glenn C. Prescott, Jr.

1952

State Geological Survey of Kansas

Bulletin 110
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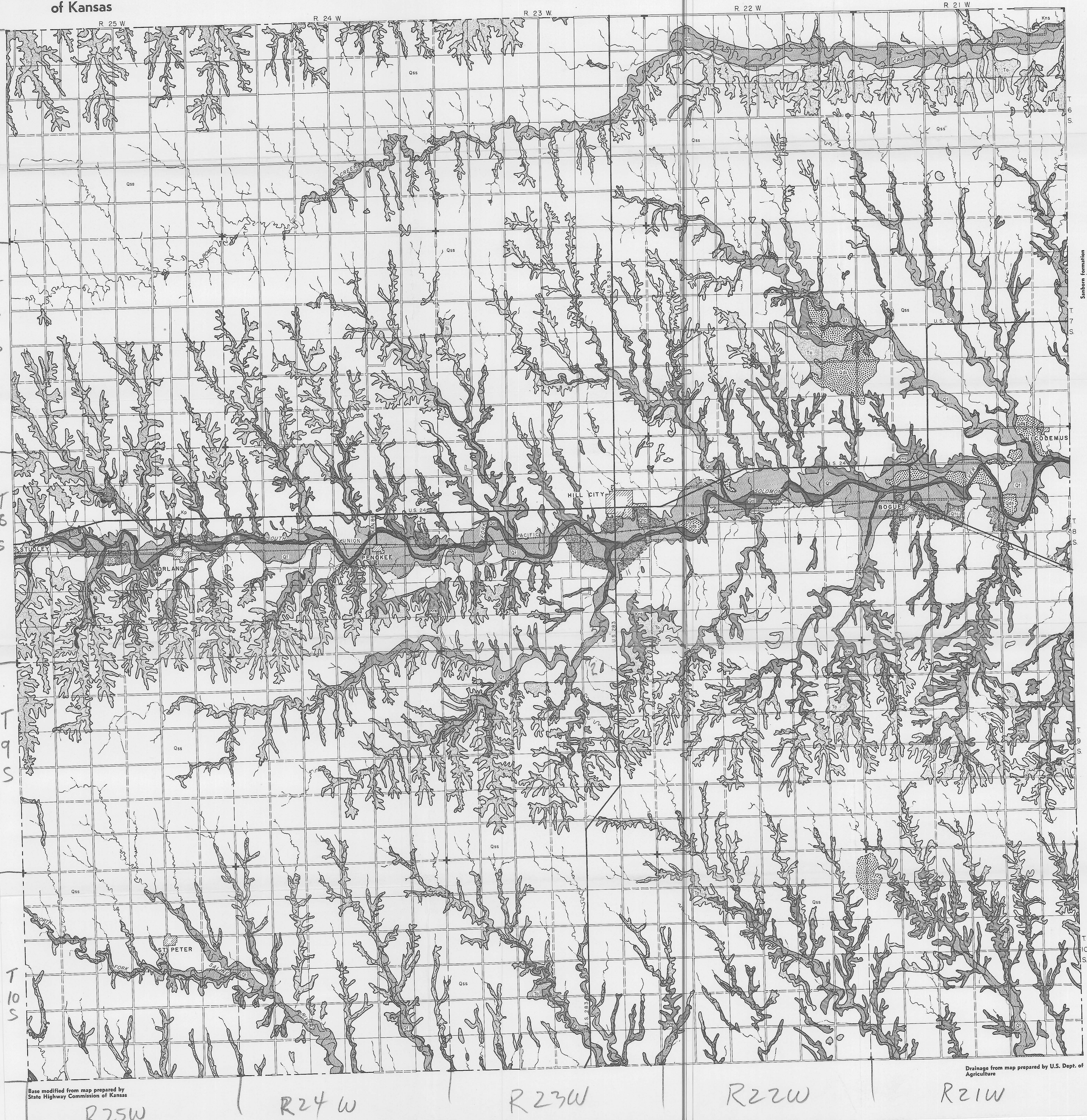


EXPLANATION

QUATERNARY — PLEISTOCENE

Qal — Alluvium

Sand, gravel, and silt in stream channels in major valleys. Contains much water in larger valleys but supplies water to few wells because it is generally restricted to stream channels.

Qds — Dune sand

Fine to coarse wind-deposited sand. Lies above the water table but serves as intake for ground-water recharge.

Sanborn formation

Qt — Terrace Deposits (late Wisconsinan)

Sand, gravel, silt and clay. Fine-grained along smaller streams. Includes some Recent alluvium along small streams and some coluvium. Yields abundant supplies of water in valleys of South Fork Solomon River and Bow Creek. Yields smaller supplies in tributary valleys.

Qss — Bignell, Peoria and Loveland silt members

(Includes Crete sand and gravel member where covered by silt along some streams; also includes coluvium and a few outcrops of Meade formation.) Massive wind-blown silt; contains water-laid sand and gravel (Crete) at base in some valleys. Silt members are above water table but Crete member yields moderate supplies of water where below water table.

Qtc — Crete sand and gravel member

(Where not mantled by thick deposits of loess.) Sand and gravel with some silt and clay. Yields water to wells in some areas where below the water table.

TERTIARY — PLIOCENE

To — Ogallala formation

Sand, gravel, silt, clay. May be consolidated or unconsolidated. Contains beds of limestone, caliche and "quartzite." The most widespread aquifer in Graham County. Yields abundant supplies of water in many areas.

CRETACEOUS — GULFIAN

Kp — Pierre shale

Soft, fissile blue-gray shale. Yields no water to wells.

Kns — Niobrara formation, Smoky Hill chalk member

Blue-gray, yellow or tan chalk and chalky shale. Yields a small amount of water to wells.

Federal or State Highway

Graded road

Ungraded road

Railroad

County line (no road)

Township line (no road)

Section line (no road)

Intermittent stream

0 1 2 3 4
SCALE IN MILES

Base modified from map prepared by State Highway Commission of Kansas

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

Map of Graham County, Kansas

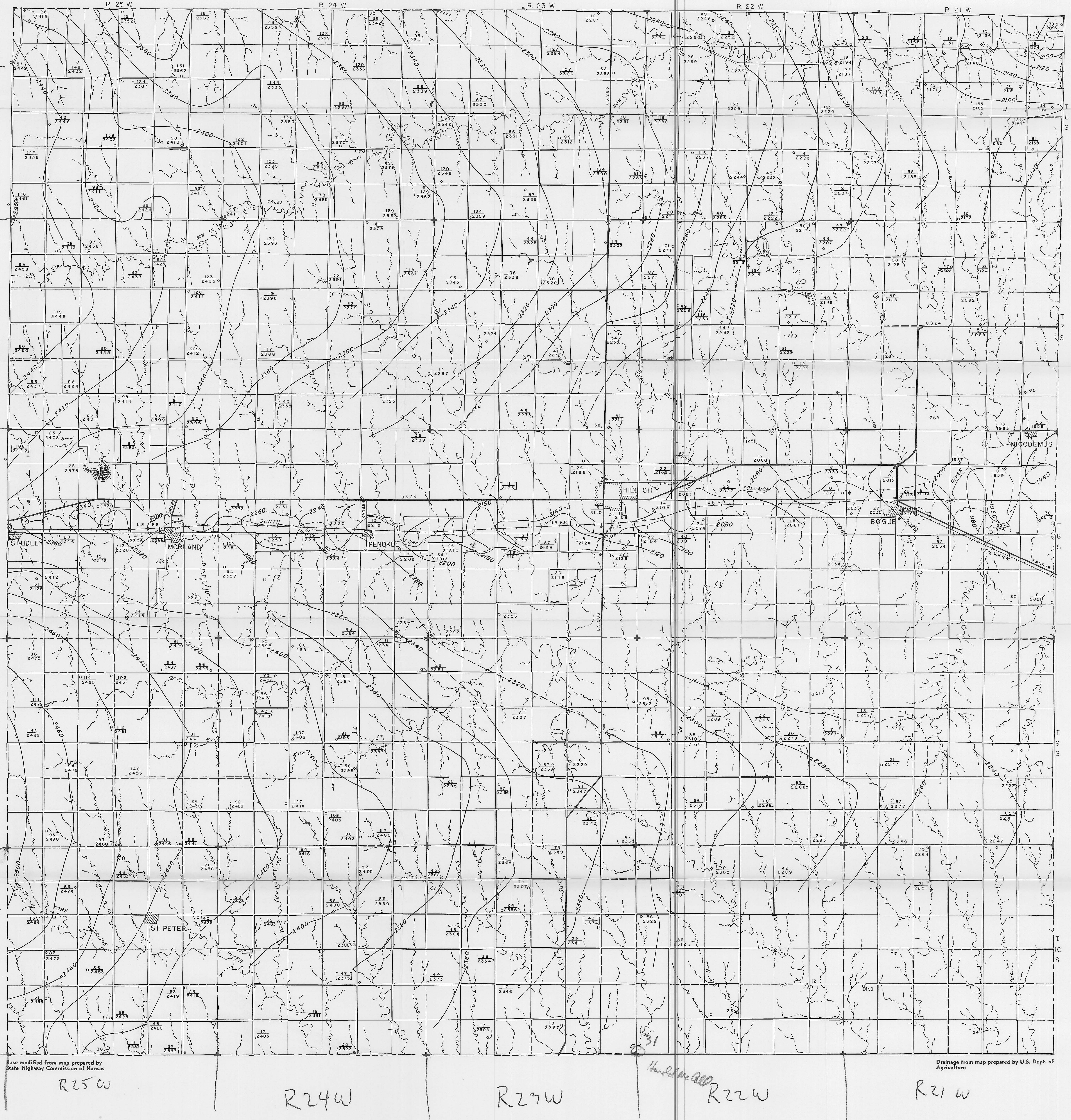
Showing the Depths to Water Level, the Location of Wells, Springs, and Test Holes for which Records are given, and Water-table Contours

By Glenn C. Prescott, Jr.

1952

State Geological Survey of Kansas

Bulletin 110
Plate 2



Base modified from map prepared by State Highway Commission of Kansas

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

EXPLANATION

Well location. Upper number refers to depth to water level; lower number refers to altitude of water level

Brackets indicate that water analysis is given.

Water-table contours

Domestic and stock wells

Irrigation well

Public supply well

Observation well

Test hole

Spring

Federal or State Highway

Graded road

Ungraded road

Railroad

County line (no road)

Township line (no road)

Section line (no road)

Intermittent stream

SCALE IN MILES