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GEOLOGY AND GROUND-WATER RESOURCES OF THE KANSAS RIVER VALLEY BETWEEN LAWRENCE AND TOPEKA, KANSAS

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ABSTRACT

The Kansas River Valley between Lawrence and Topeka is an important industrial and agricultural area in eastern Kansas. Both Topeka and Lawrence are built principally on the south bluffs of the valley. The valley is divided topographically into flood plain and Newman terrace. An old dissected terrace is preserved in many places along the margins of the valley, and in other places steeper bedrock escarpments flank the valley.

Limestone, shale, siltstone, and sandstone of Pennsylvanian age crop out in the mapped area and dip gently westward. These rocks are the source for small but important quantities of domestic water. Unconsolidated Pleistocene sediments are the only other rocks exposed. Earliest Pleistocene sediments are small deposits of pre-Kansan and early Kansan sands and limestone-chert gravels. Till and outwash of Kansan age are widespread north of Kansas River. Till is impervious and adversely affects ground-water motion, but outwash gravel supplies water to a few wells and to two springs. Colluvium and terrace deposits of post-Kansan age are present along tributaries to the main valley but are not important sources of water. Late Wisconsinan and Recent alluvial fills are the only sources of large quantities of water. In the Kansas River Valley the alluvium reaches a maximum thickness of 89 feet.

Industry uses about 75 percent of the 12,852,000 to 15,552,000 gallons of water pumped from wells daily. Use for irrigation ranges from none to more than 2,500,000 gallons a day, quantity depending upon time of year and precipitation. Municipal use is about 3,000,000 gallons of water a day. Wells near the river receive direct recharge by river water, but the main alluvial fill is recharged by rain water and water draining from the uplands. No shortage of ground water exists and proper spacing of future wells will allow substantial increase in the amount of ground water available for utilization in the area. Quality of the water is generally good, the most objectionable property of the water being a high carbonate hardness which is a common constituent of most well water in central United States.

Well logs, water-table measurements, chemical analyses, and well yields are tabulated. Maps, cross sections, and profiles present other ground-water and geologic data.

INTRODUCTION

Purpose and scope of the report.—During the summers of 1950 and 1951 separate studies were made by us of the geology and ground-water resources of parts of Kansas River Valley between Lawrence and Topeka. These studies were sponsored by the State Geological Survey and were used to fulfill thesis requirements at the University of Kansas. The data collected for these two investigations have been combined in this report. Cooperative investigations of ground-water resources in Kansas were initiated in 1937 and this report conforms to the general procedures followed in the state-wide program. The cooperative investigations are carried out by the U.S. Geological Survey and the State Geological Survey of Kansas in cooperation with the Division of Sanitation of the State Board of Health and the Division of Water Resources of the State Board of Agriculture.

For many years there has been an increase in the use of ground water for industrial and municipal purposes in the Kansas River Valley in the vicinity of both Lawrence and Topeka. Owing to the constantly increasing demands for ground water in this area, it is necessary to have an adequate knowledge of the quantity and quality of the available supply, where and how additional supplies can be obtained, and what measures may be necessary to safeguard their continuance. These studies were made to guide future ground-water development and to better evaluate present ground-water problems.

Location and extent of the area.—The area covered by this report is in northeastern Kansas and includes the southern part of Jefferson County, the northwestern part of Douglas County, and the east-central part of Shawnee County (Fig. 1). It is approximately 9 miles wide and parallels Kansas River between the eastern edge of Lawrence and the community of Kiro which is 4 miles west of Topeka. It has an area of slightly more than 300 square miles.

Previous investigations.—The stratigraphy of Pennsylvanian rocks in eastern Kansas has been described by Moore (1936, 1949) and the distribution of these rocks has been shown on the State geologic map (Moore and Landes, 1937). More recently Lins (1950) described and mapped the Tonganoxie sandstone which is an important aquifer in the vicinity of Lawrence.

Todd (1909, 1911, 1923) mapped the glacial border in Kansas and described a number of Pleistocene drainage pattern changes. Schoewe (1930) remapped the glacial border south of Kansas River. A petrographic study of clayey soils developed on till and high terraces along Kansas River was made by Hoover (1936). Frye and Walters (1950) have made a subsurface reconnaissance of glacial deposits in northeastern Kansas.

Ground-water investigations in eastern Kansas were made by the Kansas Emergency Relief Committee in 1934 and by the Works Progress Administration in 1936. The work consisted primarily of locating ground-water supplies and constructing com-

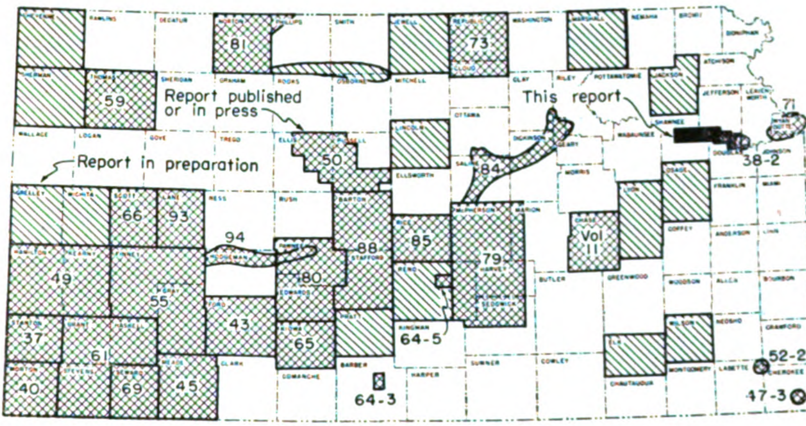


FIG. 1.—Index map of Kansas showing area covered by this report and areas for which cooperative ground-water reports have been published or are in preparation.

munity wells in upland areas. Typewritten reports summarized the work in many of the counties including Douglas County, but no reports were prepared for Jefferson and Shawnee Counties. A ground-water study of the Kansas River Valley in the vicinity of Lawrence was made by Lohman (1941). Fishel (1948) made a ground-water study of the Kansas River Valley in the vicinity of Kansas City.

A hydrologic study of Kansas River has been made by the Corps of Engineers, U.S. Army (Wyman, 1935).

Methods of investigation.—The geology of the area was studied and mapped (Pl. 1) during the summer and fall of 1950. Wells were inventoried and auger holes dug during six weeks in the spring and summer of 1950. The altitude of the measuring points of wells in the valleys and the ground surface at test-hole and auger-hole locations were measured with a plane table and alidade. Elevations of some measuring points on upland wells were determined from topographic maps and other elevations were measured by an altimeter. Location of wells inventoried, type of wells, depth to water, and ground-water contours are shown in Plate 2.

Information for three geologic cross sections (Pl. 3) was obtained by drilling 19 test holes through the water-bearing formations with the hydraulic rotary drilling machine owned by the

State Geological Survey of Kansas. The drilling was done during the summer of 1950 by William T. Connor and Lawrence Gnagy. Logs were prepared by us in the field and were later supplemented by microscopic examination of the well cuttings.

Samples of water from 15 wells in the area were collected by us in November and December 1950 and were analyzed by Howard Stoltenberg, chemist in the Water and Sewage laboratory of the Kansas State Board of Health.

The base map of the area used in Plates 1 and 2 was compiled from aerial photographs, U.S. Geological Survey topographic maps, and from county maps prepared by the State Highway Commission of Kansas. The geology was mapped in the field at a scale of 2.64 inches to the mile.

Well-numbering system.—The well and test-hole numbers used in this report give the location of wells according to general land office surveys and according to the following formula: township, range, section, 160-acre tract within that section, and the 40-acre tract within that quarter section. If two or more wells are located within a 40-acre tract the wells are numbered serially according to the order in which they were inventoried. The 160-acre and 40-acre tracts are designated a, b, c, and d in a counterclockwise direction, beginning in the northeast quarter. Below are given two examples illustrating the well-numbering system.

Well number	*General land office description*
11-15-12ab	NW¼ NE¼ sec. 12, T. 11 S., R. 15 E.
12-17-2cd	SE¼ SW¼ sec. 2, T. 12 S., R. 17 E.

Acknowledgments.—Appreciation is expressed for the friendly cooperation of the citizens of Topeka, Lawrence, and the surrounding communities. Well drillers, city engineers, industrial engineers, and individual owners gave freely of their time and knowledge. Among the industries supplying much useful information were the Westvaco Chemical Company; John Morrell and Company; Hill Packing Company; Beatrice Foods, Inc.; Atchison, Topeka, and Santa Fe Railway Company; and the Kansas Power and Light Company. Jungman Bros. of Topeka, J. S. Holmes of Lawrence, and Layne-Western Company of Kansas City gave generously of information concerning wells which they have drilled in the area.

Special thanks are due Ralph Button who allowed a test hole to be drilled on his property and Frank Baird who gave permission for his irrigation well to be used as an observation well.

GEOGRAPHY

Topography.—The Kansas River Valley between Lawrence and Topeka is on the boundary between the Dissected Till Plains and Osage Plains sections of the Central Lowlands physiographic province as defined by Fenneman (1931). More recently Schoewe (1949) has placed the area entirely within the Dissected Till Plains section. Locally the most striking topographic feature is the broad flat east-west trending Kansas River Valley.

Kansas River Valley can be divided topographically into a low flat terrace and a channel-scarred flood plain. A natural levee at the margin of the terrace hinders drainage on a large part of the terrace surface. Drainage ditches have largely eliminated the marshes which once occupied the area between the natural levee and the river bluffs. On the flood plain many small ponds and marshes fill old meander scars and have not been drained extensively.

The Kansas River Valley is asymmetrical due to the river cutting almost exclusively on the south side. This southward cutting increases the gradients and hence the erosional power of small tributaries on the south, which in turn produces rugged topography adjacent to the river. North of the river lessened stream gradients combined with the presence of terrace remnants and glacial till produce a much more subdued topography.

Bedrock topography typical of eastern Kansas is well developed south of the river. Prominent east-facing escarpments and rock benches are produced by the resistant westward-dipping limestone strata.

The total relief of the area is slightly more than 330 feet, and the local relief is commonly between 100 and 200 feet. The hills south of Topeka are the highest points in the area and have elevations in excess of 1,150 feet. The lowest point is along Kansas River in the eastern extremity of the mapped area.

Climate.—The Kansas River Valley is included within the area having a humid continental type of climate. Warmest months are July and August which have monthly mean temperatures above 75° F. with daily maximums often in excess of 100° F. but rarely in excess of 105°F. Winters are generally mild wtih occasional cold waves during which the temperature drops to between 10° F. and —5°F. for one to four days. The coldest month is January which has a mean monthly temperature of 29.9°F. in Lawrence and 29.4°F. in Topeka (Table 1). The mean annual temperature in the area is slightly more than 55° F. and the average length of growing season is about 195 days.

Most of the precipitation is during the spring and summer months. The normal annual precipitation is 35.40 inches at Lawrence, 34.9 inches at Lecompton, and 32.58 inches at Topeka. The lowest known annual precipitation in the area is below 25 inches and the highest known annual precipitation is more than 50 inches. Figure 2 gives the normal monthly precipitation at Lecompton.

Population.—The population within the mapped area is estimated from the 1948 census of the Kansas State Board of Agriculture to be about 130,000. The population of the larger cities and towns according to the 1950 census are: Topeka, 87,626; Lawrence, 18,638; Perry, 413; and Lecompton, 267. Towns which have stores and post offices but for which no population figures are available are Williamstown, Tecumseh, and Grantville. Other smaller communities are Kiro, Menoken, Midland, Big Springs, Newman, Thompsonville, and Lakeview.

Transportation.—The area is crossed in an east-west direction by main lines of the Union Pacific Railroad, Chicago, Rock Island, and Pacific Railroad, and the Atchison, Topeka, and Santa

TABLE 1.—*Normal monthly precipitation and temperature at Lawrence and Topeka*

	Temperature, degree F.		Precipitation, inches	
	Lawrence	Topeka	Lawrence	Topeka
Jan.	29.9	29.4	1.09	0.91
Feb.	32.7	32.1	1.34	1.30
March	44.4	43.7	2.16	1.98
April	55.1	54.7	3.14	2.90
May	64.7	64.6	4.88	4.42
June	73.9	74.3	4.67	4.00
July	79.1	79.7	3.75	3.41
Aug.	77.5	78.1	3.70	4.21
Sept.	69.8	70.0	4.44	4.10
Oct.	58.3	58.2	2.86	2.56
Nov.	44.7	44.3	2.20	1.76
Dec.	33.0	32.6	1.17	1.03

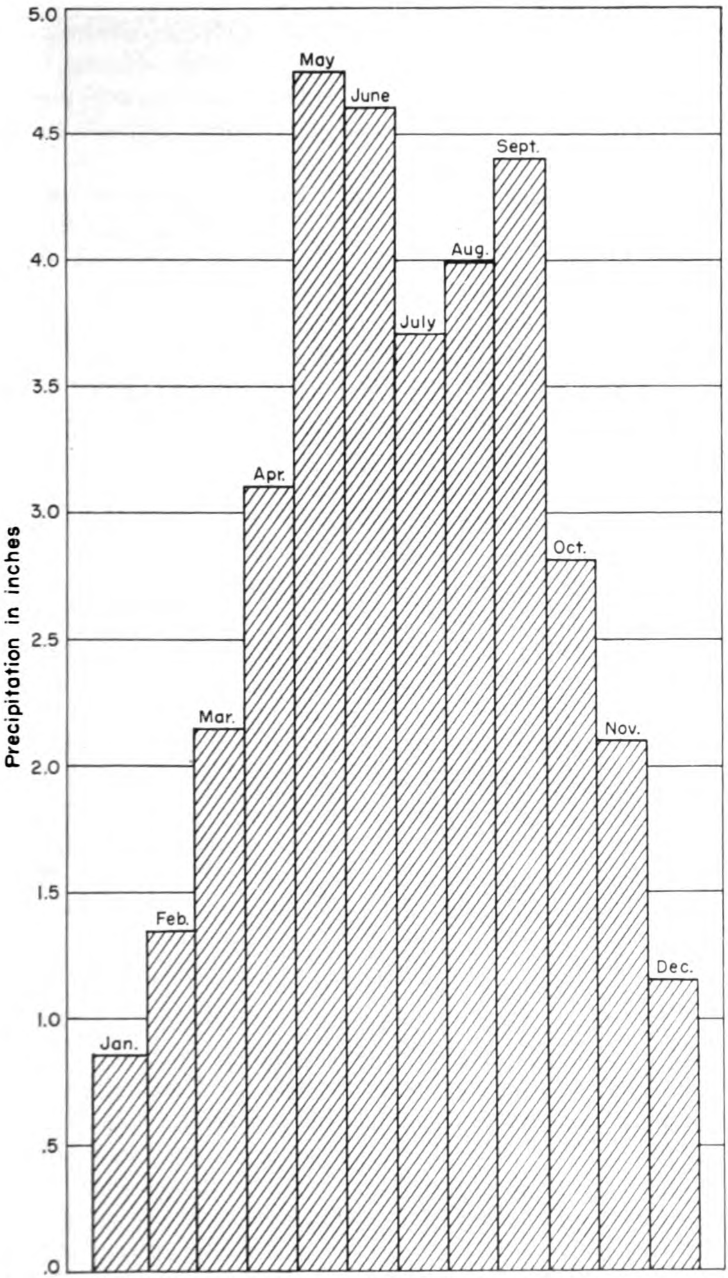


Fig. 2.—Graph showing normal monthly precipitation at Lecompton. (Data from U. S. Weather Bureau.)

Fe Railway. Branch lines of the Union Pacific Railroad, Atchison, Topeka, and Santa Fe Railway, and the Missouri Pacific Railroad also cross the area in a general north-south direction. Several bus lines serve Lawrence and Topeka as well as intermediate points and air lines also serve Topeka.

The hard-surface highways passing in an east-west direction through the area are U.S. 40, U.S. 24, and K-10. The hard-surfaced highways through the area in a north-south direction are U.S. 59 which passes through Lawrence, and U.S. 75 which passes through Topeka. K-4 merges with U.S. 75 north of Topeka and is parallel to K-10 west of Topeka.

Agriculture.—Corn is the principal crop raised in the area. Other important crops include wheat, oats, alfalfa hay, Irish potatoes, sorghum, soybeans, apples, and nursery stock. Much of the upland is used for grazing cattle, particularly land which is too stony or steeply sloping to be of other use.

Strawberries, garden vegetables, and nursery stock are the only crops which receive irrigation during years of normal precipitation. Generally, irrigation is most needed during the first two months of the growing season. Drought conditions could make irrigation desirable for other crops; however, few people maintain irrigation wells as insurance against dry years.

Industry.—Food processing is the leading industry in the area with flour, meat, poultry, dairy products, and canned vegetables being the principal items produced. Other important industrial products are tires, locomotives, freight cars, bearings, farm machinery, dog food, sand and gravel, serum, crushed limestone, sheetmetal and foundry products, cardboard boxes, and silos.

GEOMORPHIC DEVELOPMENT

Tertiary Time

Little evidence of a pre-Pleistocene surface remains in the mapped area. The closest known deposit of possible Tertiary age is a chert gravel 6 miles west of Kiro and north of Silver Lake which rests on a bedrock floor which in turn is more than 150 feet above the flood plain of Kansas River. Many late Tertiary chert gravels which once filled stream channels remain as isolated deposits on divides in Osage and Franklin Counties. The topographic position of the gravel suggests at least 150 feet of post-

Tertiary erosion in the major valleys. However, some of the uplands protected by underlying beds of resistant limestone may not have been greatly modified by erosion, solution, and loess deposition since late Tertiary time.

Pre-Kansan Pleistocene Time

North of the Kansas River Valley the till-mantled bedrock surface has a slope of about 90 to 100 feet in a distance of from 1 to 2 miles toward the present axis of the valley. The proximity of the glacial margin suggests that this slope was not caused by glacial scour and that a valley existed here prior to Kansan time. Several pre-Kansan gravels and pro-glacial gravels of Kansan age in the Kansas River Valley have been described (Davis, 1951) and probably represent material deposited by an eastward-flowing stream occupying essentially the same position as the present-day valley. The contact between early Pleistocene river deposits and Pennsylvanian rocks is everywhere at least 15 feet above the present flood plain of Kansas River which indicates that this early valley had a surface well above the present valley floor. This in turn indicates that the general topography which preceded glaciation was more subdued than at present since the approximate surface of the pre-glacial upland north of the river is mantled by a considerable thickness of till and was therefore lower than at present. As a result of test drilling in areas to the north which are buried under great thicknesses of till, Frye and Walters (1950) have also concluded that the pre-Kansan topography was more subdued than at present.

Kansan Time

The principal event of Kansan time was the advance into this area of the Kansan glacier which spread out from a center in Canada. Kansas River as it exists today is judged to have had its beginning during this glacial advance (Lohman and Frye, 1940) and was essentially an ice marginal river in the area studied. Wakarusa River may have served as a spillway for melt water during the time of a temporary ice dam (Todd, 1911).

The effect of the glacier on the topography was fourfold. (1) The pre-Kansan river valley was cut wider and a little deeper by melt water as the glacier advanced toward the area. (2) The uplands were stripped of some bedrock by the advancing ice (judged to be small due to the proximity of the ice margin). (3) Kansas River Valley was filled with glacial outwash which became progressively finer grained as the glacier was dissipated. (4) The uplands were mantled with as much as 40 feet of glacial drift after the glacier was gone from the area.

As the Kansan ice was dissipated, alluvial deposits continued to accumulate for some time in the ice-marginal Kansas River Valley, the surface of this fill being at least 80 feet above the present flood plain. Dissected remnants of this surface can be seen along Kansas River at many places between Holliday and Kiro. In Menoken Township (secs. 9, 10, and 11, T. 11 S., R. 15 E.) northeast of Topeka there is a large remnant of this terrace bordering the north side of the valley. Here accordant summits of the terrace are 90 feet above the flood plain and a number of deep erosional gullies expose the underlying material. The terrace has been subjected to a long period of erosion and therefore an exact accordance of summits within the terrace is not to be found.

This terrace is named the Menoken terrace from the township in which it is typically developed. It has been mentioned previously or described in Kansas River Valley by Newell (1935), Hoover (1936), Lohman (1941), Jewett (1949), and Frye and Walters (1950), but no name was proposed. Table 2 gives the elevation of the surface of the Menoken terrace at selected intervals between Kiro and Holliday.

Illinoian Time

Following the formation of the Menoken terrace there was a period of erosion in which the bedrock floor of Kansas River Valley was cut 50 to 60 feet below its former level. After this entrenchment the valley was again aggraded to about 35 feet above the present flood plain. The terrace surface formed by this aggradation is preserved at only a few places along the major valley but is found in many of the minor tributary valleys. The usual absence of this terrace along the valley is probably due to destruction by lateral river erosion. The Menoken terrace was preserved during this time because it has a much higher bedrock floor which has effectively resisted erosion.

TABLE 2.—*Altitude of terrace levels between Holliday and Kiro, Kansas**

Surface	Holliday	Lawrence	Buck Creek	Newman	Grantville	Topeka	Kiro
Menoken terrace	890	925	—	950	970	975	1,015
Buck Creek terrace	785**	—	880	—	—	920**	—
Newman terrace	775**	830	845	860	875	895	905
Kansas River	745	805	820	830	850	865	875

* Altitude given to the nearest 5 feet and obtained from U. S. Geological Survey topographic maps.
** Identity of these terraces is not certain.

This second terrace is named the Buck Creek terrace from a well-developed surface along Buck Creek in sec. 27, T. 11 S., R. 19 E. (Pl. 4A). Its age is judged to be Illinoian as the terrace fill truncates deposits of Kansan age and has a well-developed soil (Sangamon) at the surface which is discontinuously mantled by Peoria loess.

WISCONSINAN AND RECENT TIME

Newman terrace.—The youngest terrace in Kansas River Valley is extremely youthful and is still being aggraded by exceptionally severe floods. This terrace is virtually undissected except for minor gullying on the scarp, and has a well-developed natural levee from 3 to 6 feet high which slopes away from the scarp to a very level "backswamp" area. Small alluvial fans are being built on this terrace at the present time by intermittent streams which emerge from the bluffs along the valley. In the 6 test holes and 20 auger holes drilled into this terrace it was found that the first 10 to 25 feet is invariably a silt or silty clay except within a few hundred feet of the natural levee. These facts indicate that the terrace was formed by Kansas River being stabilized in a restricted portion of the flood plain while the rest of the valley floor was aggraded by flood-water deposition.

This terrace is named the Newman terrace from the town of Newman, Kansas, where a large segment of the terrace is unmodified by tributary streams for almost a mile to the north and 2 miles to the east. The terrace surface at Newman was surveyed and the elevations plotted (Fig. 3). The profile shown is considered to be typical of the Newman terrace between Lawrence and Kiro. The scarp is accentuated by vertical exaggeration in the plotted profile; however, the normal configuration can be seen in Plate 4B.

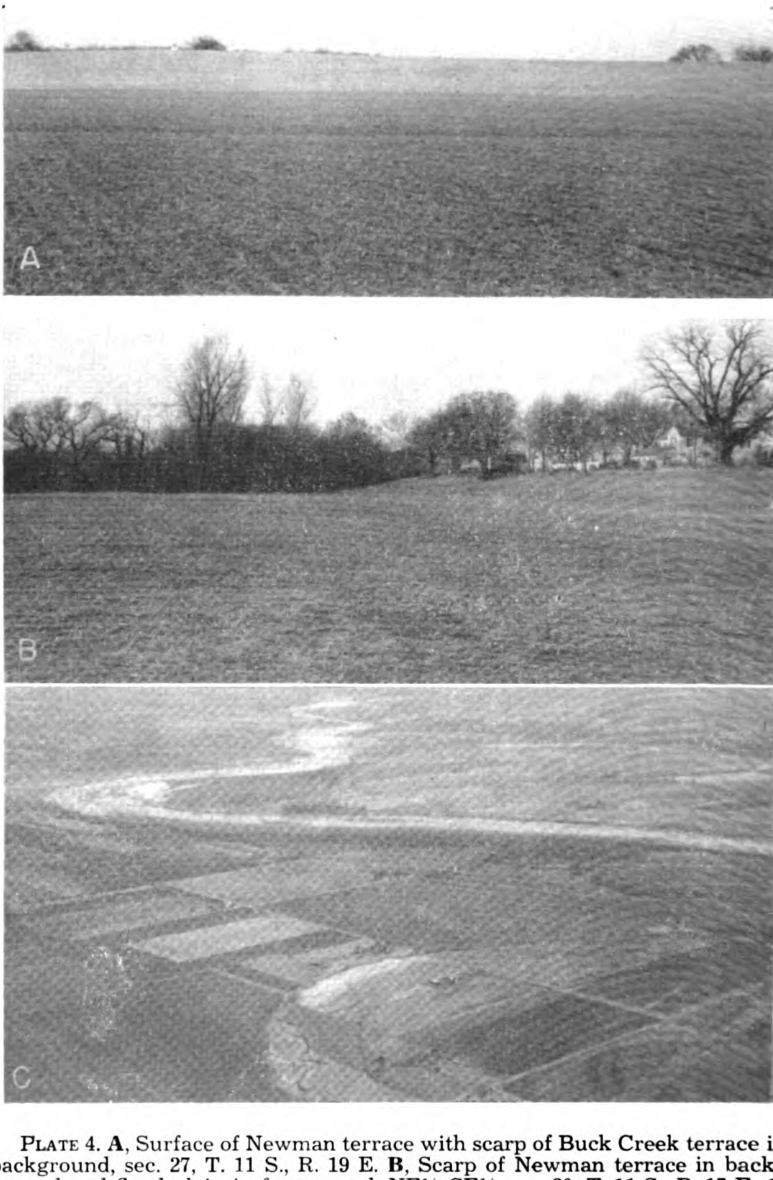


PLATE 4. **A**, Surface of Newman terrace with scarp of Buck Creek terrace in background, sec. 27, T. 11 S., R. 19 E. **B**, Scarp of Newman terrace in background and flood plain in foreground, NE¼ SE¼ sec. 20, T. 11 S., R. 17 E. **C**, Aerial view of Kansas River Valley looking southeast across Stone House Creek to Lakeview Lake in upper right of picture. Kansas River in center of picture.

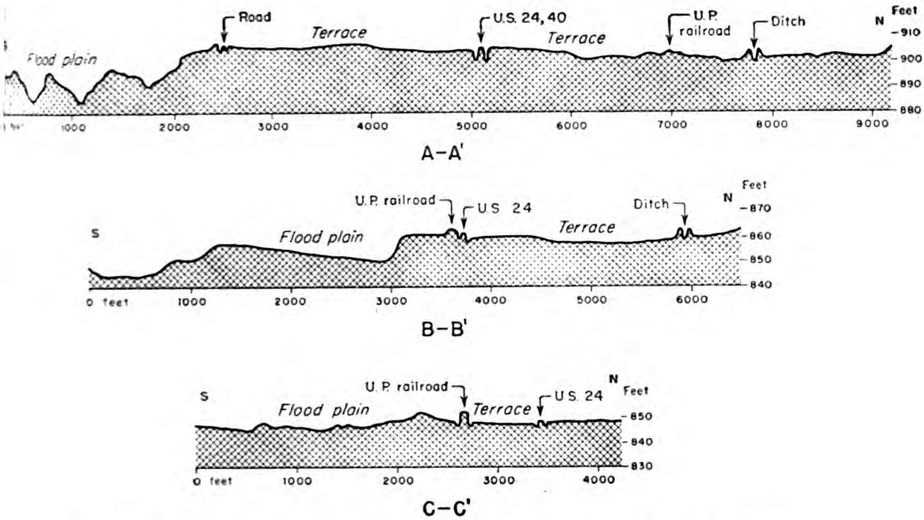


FIG. 3.—Transverse profiles of the Newman terrace and the flood plain.

Flood plain.—The flood plain as mapped in this report (Pl. 1) contains many surface irregularities and minor scarps which may be interpreted as representing one or more minor terraces. Two factors give the impression of a terrace younger than the Newman terrace. First, the point bar accretion slopes in abandoned meanders are so gentle that they appear horizontal and unless carefully surveyed could be easily mistaken for terraces (see the point bar accretion slope just south of Newman in Fig. 3). Second, it has been suggested that the radii of curvature of the meander scars have increased greatly during the last stages of flood-plain development (Harbaugh, 1950). Arcuate point bar accretionary patterns and abandoned meander loops of varying radii can be differentiated on aerial photographs (Pl. 4C).

Kansas River between Kiro and Lawrence is actively cutting on only the south, or right, bank except at a few points. This may be due partially to the operation of Ferrel's law. A more reasonable explanation seems to be that the Wakarusa River basin intercepts most of the stream run-off south of Kansas River, and north of the river the streams are larger and more numerous. Thus the sediment supply from northern tributaries is much greater and produces a delta effect in the Kansas River channel which forces the river to the south. It is significant that the river shifts to the northern bluff line only opposite points at which large northward-flowing tributaries enter the channel. The northward loop of Kansas River at Topeka is the most notable example and is the reflection of the entrance of Shunganunga Creek.

Minor upland cycles of erosion.—Two periods of alluviation and two periods of gullying are almost universally indicated in upland deposits. Bottoms of the oldest gullies are marked by local gravel accumulations and by an extremely well-developed soil zone. The oldest gullies are filled with 2 to 3 feet of black silt which has a weak central soil zone. Gullying in historical times has incised much deeper than formerly and has exposed the entire sequence to view. Gullies up to 20 feet in depth have developed in the soft till and terrace deposits. No effort was made to correlate these erosion cycles from one exposure to the next or to relate the upland cycles to changes in river erosion or alluviation.

GEOLOGY IN RELATION TO GROUND WATER

Paleozoic Rocks

GENERAL

The total thickness of Paleozic rocks increases from about 2,600 feet near Lawrence to more than 3,000 feet west of Topeka. Rocks from all the systems of the Palezoic except the Permian System are present, but only the Ordovician, Mississippian, and Pennsylvanian Systems are represented by more than 200 feet of sediments (Jewett, 1949a). Of the entire Paleozic sequence only the upper rocks of Pennsylvanian age crop out in northeastern Kansas. Although all the rocks are not conformable, the entire sequence dips gently westward.

Three groups of Pennsylvanian rocks were mapped—Douglas, Shawnee, and Wabaunsee. The formations included within the groups that were mapped and their general water-bearing characteristics are given in Table 3. Most of the information concerning the Pennsylvanian rocks is generalized from Moore (1940, 1949).

A detailed study of ground water in rocks of Pennsylvanian age was not attempted. Generally wells obtain water from solution openings in limestone and from sandstone. Except in weathered zones, shale and siltstone yield virtually no water to wells.

TABLE 3.—*Generalized section of the geologic formations of the Kansas River Valley between Lawrence and Topeka, Kansas*

System	Series	Subdivisions		Thickness, feet	Character	Water Supply
Quaternary	Pleistocene	Recent and Wisconsinan alluvium		40-90	Clay, silt, sand, and gravel, well sorted in major valleys; generally fine textured near the top and grading downward into coarse sand and gravel.	Alluvium of major valleys yields large amounts of water to industrial, irrigation, municipal, domestic, and stock wells. Quality of water is generally good.
		Sanborn formation	Peoria silt member	0- 9	Silt, well sorted, light yellow-gray to ash-gray. Thin mantle on uplands south of Kansas River.	Above water table, yields no water to wells.
			Loveland silt member	0- 2	Silt, well sorted, reddish-tan to reddish-brown. Locally present under Peoria silt on uplands.	Above water table, yields no water to wells.
			Crete and Loveland members undifferentiated	0-90	Sand, sandy silt, fine gravel in lower portion (Crete) grading upward into reddish-brown to reddish-tan silt (Loveland).	Locally basal portion yields moderate amounts of water to wells.
		Meade formation	Sappa member	20-50	Silt and sandy silt, reddish-tan to reddish-brown.	Generally above water table, yields no water to wells.
			Grand Island member	5-40	Pebbles, cobbles, and boulders at the base, locally cemented with calcite to form conglomerate; many lenses of sand.	Often above water table, yields abundant amount of water when in zone of saturation.
		Kansas till		0-40	Till, largely clay and silt with scattered pebbles, cobbles, and boulders. Yellowish-brown to reddish-brown at the surface; is blue-gray when not weathered. Contains interstratified sand and gravel in thick sections.	Generally a poor source for water.
		Atchison formation		0-30	Fine sand and coarse tan silt, well sorted; 6-15 feet of gravel at the base.	Too limited in extent to be of importance as an aquifer.
		Undifferentiated pre-Kansan gravel		0- 8	Chert-limestone gravel, well sorted.	Too limited in extent to be of importance as an aquifer.

TABLE 3.—*Generalized section of the geologic formations of the Kansas River Valley between Lawrence and Topeka, Kansas (continued)*

System	Series		Subdivisions	Thickness, feet	Character	Water Supply
Pennsylvanian*	Virgilian	Nemaha subgroup	Wakarusa ls.	3-15	Dark-bluish hard limestone that becomes brown when weathered.	Locally supplies water to upland domestic and stock wells.
			Soldier Creek sh.	6-10	Bluish-gray clayey to sandy shale.	Yields little water.
			Burlingame ls.	4-10	Brown, fine-grained, hard, thick-bedded, appearing mottled and brecciated in some exposures.	Yields small to moderate amounts of water to domestic and stock wells.
		Wabaunsee group, Sacfox subgroup	Silver Lake sh.	15-45	Gray and yellow clay shale, variably associated with platy, impure limestone, sandy shale, or sandstone.	Sandstone within the shale formation locally yields moderate amounts of water to wells.
			Rulo limestone	1- 4	Bluish-gray, locally mottled with light-brown when weathered; single massive bed with vertical jointing.	....
			Cedar Vale sh.	16-60	Bluish to yellowish-brown clayey and sandy shale and sandstone with coal bed near the top.	Small to moderate ground water yields from sandy portions.
			Happy Hollow ls.	1- 8	Single, persistent massive bed, pinkish-brown and characterized by large fusulines.	....
			White Cloud sh.	30-80	Bluish-gray to yellowish-brown clayey and sandy shale with local sandstone and conglomerate fill channels.	Yields moderate amounts of water in sandy portions.
			Howard limestone	8-20	Gray-blue, thin, dense, sandy limestones, alternating with bluish-gray to yellowish-brown sandy shale.	Solution openings in the limestones yield some water to wells.
			Severy shale	70-80	Yellowish-brown and bluish-gray shale and a minor amount of platy to massive sandstone	Sandstone yields a small quantity of water to wells.

Pennsylvanian	Virgilian	Shawnee group	Topeka ls.	35-45	Alternating light-gray to bluish-gray massive, nne-grained, dense limestones and bluish-gray to black sandy shales.	Yields moderate amounts of water to domestic and stock wells.
			Calhoun shale	40-50	Clayey and sandy dark-gray to tan shale containing plant fossils; minor limestone and coal beds.	Local massive sandstone yields moderate amounts of water.
			Deer Creek ls.	25-45	Alternating light-gray to bluish-gray, fine-grained limestones sometimes characterized by wavy bedding and by presence of chert nodules and gray or yellow fissile shale.	Yields moderate quantities of water of generally good quality to domestic and stock wells; is source for a number of springs.
			Tecumseh shale	45-65	Clayey and sandy shale, unfossiliferous, having a more or less discontinuous limestone in upper part.	Small amounts of water derived from sandstone in upper part of formation.
			Lecompton ls.	30-40	Consists of 4 limestone members commonly bluish-gray, dense, and fossiliferous and 3 shale members with included sandstone lenses.	Moderate amounts of water derived from solution openings in limestone.
			Kanwaka sh.	40-60	Yellowish-brown to bluish-gray sandy shale containing numerous plant fossils and an intervening bluish-gray, massive, vertical-jointed fossil-bearing limestone.	Moderate amounts of water derived from sandstone channel fills.
			Oread ls.	40-50	Four limestone members ranging from light-brownish-gray to bluish-gray, massive and dense to thin, wavy bedding and generally fossiliferous, and 3 shale members brown to black, calcareous to sandy, fossiliferous.	Moderate amounts of water derived from Toronto and Plattsmouth limestone members to domestic and stock wells.
		Douglas group	Lawrence sh.	250	Blue-gray and yellowish shale, tan-colored sandstone, and a minor amount of coal, limestone, and conglomerate.	Moderate supplies of water of varying quality derived from sandstone member to domestic and stock wells.
			Stranger formation	60-90	Light-tan to yellowish-gray sandstone and shale and a minor amount of limestone, coal, and conglomerate with marine and nonmarine fossils.	Large quantities of water of generally good quality derived from the lowest member of this formation, the Tonganoxie sandstone. Water supplies municipal, domestic, and stock wells.

*Pennsylvanian System generalized from Moore (1940, 1949).

The water table in the rocks of Pennsylvanian age is in general a subdued reflection of the topography and is commonly from 10 to 30 feet below the surface (Pl. 2); however, due to the importance of stratigraphic control, the water table is not everywhere continuous. Depth to the water table is not always an indication of the total depth needed for a well, particularly in shaly rock, because it is often necessary to drill wells much deeper in order to encounter rocks of higher permeability.

The depth to brackish water in the Paleozoic rocks is highly variable. In most cases drilling for fresh water to depths greater than 300 feet would seem inadvisable, and in many wells the depth to brackish water is reported to be less than 150 feet.

DOUGLAS GROUP

The Douglas group consists of massive or cross-bedded sandstone, siltstone with numerous carbonaceous layers, and thinly bedded shale. Two rather thin persistent limestone beds and several thin and discontinuous coal beds are minor constituents of the group.

Sandstones in the Douglas group generally yield adequate amounts of potable water near the outcrop areas, but the quality of water becomes progressively worse down dip. Wells which supply water for cooling, air conditioning, domestic, and stock uses have been drilled into these sandstones. Water from most of these wells is brackish (Lohman, 1941) and much of the water is of such poor quality that it is unfit for human consumption. Generally water of the best quality is pumped from wells which penetrate the Tonganoxie sandstone which is the lowest sandstone member of the Douglas group (Lins, 1950).

SHAWNEE GROUP

The Shawnee group is differentiated from the other units mapped by its thick persistent limestone members and by its well-defined megacyclothems. Where the rocks crop out they are characterized physiographically by prominent eastward-facing limestone escarpments and by a more rugged topography south of Kansas River. Limestone, sandstone, and shale beds of the upper portion of the Shawnee group are shown in Plate 5A.

Limestone and sandstone are both important water-bearing rocks within the Shawnee group. During periods of normal or greater than normal rainfall, wells in these rocks yield adequate supplies for domestic and stock needs; however, many wells failed to yield sufficient water during the exceptionally dry spring of 1950. A number of small springs issue from the various limestone members in the group. Most of the springs cease to flow during periods of little rainfall. The largest spring measured had a discharge of 50 gallons per minute during the summer of 1950, but was reported to have gone dry for brief periods during the severe droughts between 1930 and 1940.

WABAUNSEE GROUP

Sacfox subgroup.—Shale, sandstone, and siltstone are the most common rocks in the Sacfox subgroup. Three relatively thin limestone formations with two coal seams are also within the subgroup. The water-bearing capacity of the rocks in this subgroup is generally poor, although, when present, sandstone yields moderate amounts of water to wells.

Nemaha subgroup.—Only the lower 50 feet of this subgroup occurs in the area mapped. The lower part of this subgroup is dominated by two prominent limestone formations. Where sufficient solution openings are present the limestone beds are good sources of ground water.

QUATERNARY DEPOSITS

Pre-Kansan gravel.—Three deposits of gravel composed predominantly of chert were found along the north bluff of the Kansas River Valley. All deposits are overlain by Kansas till or outwash but contain less than 1 percent erratic material and more than 50 percent chert in the 4 to 8 mm size. This gravel lithology is considerably different than that of known glacial outwash (Davis, 1951), so it is judged that these gravels are either pre-Kansan gravels that have derived a small number of erratics from Nebraskan glacial outwash or are remotely pro-glacial gravels of early Kansan age. The distribution of these gravels is too limited to be of importance as a source of ground water.

Atchison formation.—Sand and gravel overlain by Kansas till and underlain by Pennsylvanian shale occur in at least three exposures. The best exposure found is in an old gravel pit in the SE¼ NW¼ sec. 16, T. 11 S., R. 16 E. Here till overlies 15 feet of well-sorted yellow-gray fine sandy silt which in turn overlies a moderately well-sorted limestone-chert gravel. The gravel contains about 60 percent well-rounded but slightly etched limestone pebbles, 20 to 30 percent chert, 5 to 10 percent shale and siltstone, and 2 percent granite and quartzite. Locally the gravel is cemented by calcite to form a very hard conglomerate, and even in the seemingly unconsolidated portions, the gravel is often partially cemented together. Interstitial space in the gravel is filled with medium to coarse quartz sand. With the exception of the upper part of the till, the gravel, sand, and till show only the slightest evidence of post-depositional weathering.

The age of these deposits is judged to be Kansan as their conformable relation to the overlying till suggests that they were deposited in front of the advancing ice and later overridden by the ice. This conclusion is strengthened by the persistent, but not abundant, fragments of northern erratics in the gravel. The high percentage of limestone precludes the possibility of the gravel having been deposited by a major pre-glacial stream since the limestone would be highly etched and secondary to chert in abundance (Davis, 1951). The Kansan pro-glacial outwash has been named the Atchison formation from exposures in the vicinity of Atchison, Kansas (Moore and others, 1951, p. 15).

Pro-glacial outwash seems to be too limited in distribution to be important as a source of ground water in the area studied. It is possible that deposits similar to the one described are present under parts of the till-mantled uplands, and if present in a saturated zone, would afford an excellent source of water.

Kansas till.—Uplands north of Kansas River are mantled by glacial till which ranges in thickness from a thin veneer of clayey soil to more than 40 feet of typical till. Owing to post-depositional erosion, the till is thickest and most persistent on crests of hills. In many places north of Kansas River it is thick enough and continuous enough to modify the usual bedrock topography. In an early soil survey the presence of glacial till was clearly recognized in Shawnee County and was classified as Shelby loam (Byers and Throckmorton, 1913). Although 16 percent of the county was mapped as Shelby loam, only a small fraction was found to be south of Kansas River. It was also noted that till was thickest and most common directly north of Kansas River and that the till thinned gradually to the north (Byers and Throckmorton, 1913, p. 19). These observations strongly suggest that the

Kansan ice sheet was stabilized for a considerable time directly north of Kansas River and that any advance across the present river valley by the ice was of relatively short duration.

The till is characterized at the surface by a clayey red soil thoroughly oxidized and leached and containing scattered cobbles and pebbles of quartz, chert, granite, and various metamorphic rocks. Satisfactory exposures of thick sections of till were very uncommon, but generalizations can be made from the few exposures found in this area and in areas to the north. Four zones which are caused by different degrees of weathering can be differentiated in the till; these are shown below.

Zones in the Kansas till

A. Red clay zone. Highly leached and oxidized zone, red in color and containing exclusively siliceous pebbles in the coarser fraction; commonly modified by colluvial action.

B. Mottled gray clay zone. Leached and oxidized, mottled gray and light brown in color, and contains almost entirely highly siliceous pebbles, limonitic shale fragments, and various metamorphic rocks; locally jointed.

C. Oxidized and unleached till. Yellow brown to green brown in color with abundant limestone, chert, shale, and granitic pebbles; ferromagnesian minerals in rock are altered near the rock surfaces and limestone is slightly etched; till is commonly jointed.

D. Unoxidized and unleached till. Dark blue-gray in color and has essentially the same pebble content as C; very hard and impervious as compared to other zones; may contain interstratified sand and gravel in thicker portions (Frye and Walters, 1950, p. 151).

Previous workers have emphasized the abundance of pink quartzite in the till; however, it was found by cobble and pebble studies that pink quartzite is only a minor constituent of the original till and that surface concentrations of quartzite are an indication of prolonged and selective weathering (Davis, 1951). Even in highly weathered till only the boulder size is more than 50 percent pink quartzite. A fine-grained femic quartzite is particularly abundant in the smaller sizes as are also chert, quartz, weathered granite, and various unclassified metamorphics.

Kansas till is very high in clay and silt content. No complete size analysis of the till was made, but a separation of fragments larger than 1 mm was made and it was found that this coarse fraction was only about 5 percent of the total sample.

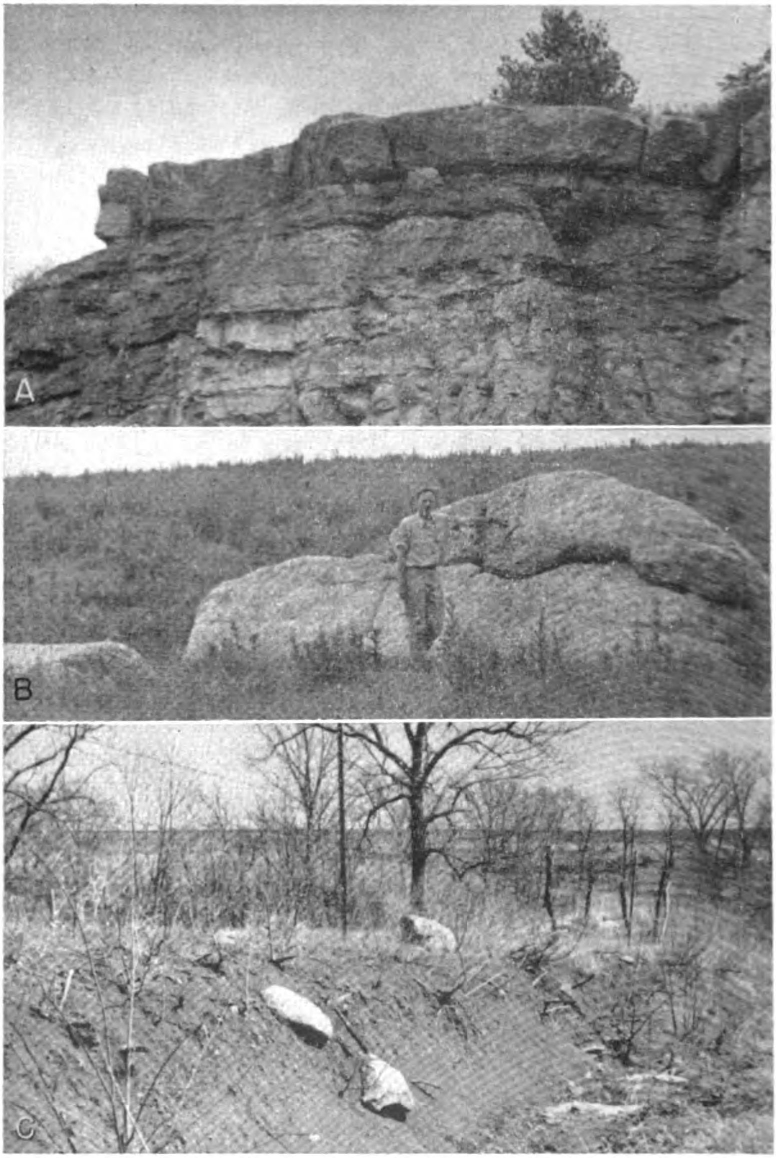


PLATE 5. **A**, Topeka limestone capping sandstone and minor amounts of shale and siltstone in the Calhoun shale, NE¼ SW¼ sec. 15, T. 11 S., R. 16 E. **B**, Large conglomeratic quartzite boulder transported by the Kansan ice, Cen. sec. 19, T. 10 S., R. 16 E. **C**, Weathered till 4 miles north of Perry, Jefferson County.

Boulders exceeding 5 feet in mean diameter are very uncommon in the till. The largest boulder observed is a few miles north of the mapped area in the Cen. sec. 19, T. 10 S., R. 16 E. This boulder is pink conglomeratic quartzite and is split into two pieces, the larger being 23 by 11 by 8 feet and the smaller being 18 by 7 by 2 feet. The measurements are only of that part exposed above the ground (Pl. 5B). This large boulder must have been transported a minimum of 200 miles, since the nearest outcrop of pink quartzite is in northeastern Iowa. Smaller and more typical glacial boulders are shown in Plate 5C.

The till transmits water very slowly due to its high clay content, which makes the till a poor source for ground water and also adversely affects the recharge. Thus if till is very thick in any locality, shallow wells are usually unsuccessful. All dug wells investigated in till-mantled areas were found to penetrate the till and to draw water from underlying Pennsylvanian rocks, or from the till-bedrock contact zone. Many small seeps were seen along till-bedrock contacts for as long as a month after heavy rains, but no perennial springs were found to derive water from till.

Meade formation.—Deposits which are classed as Meade formation occur along both the north and south bluffs of Kansas River Valley. The upper surface of these deposits forms a high terrace which is mapped as the Menoken terrace (Pl. 1), and which is discontinuously mantled with loess, eolian sand, and sand derived from slope wash. These thin surficial deposits range in age from Illinoian to Recent.

The Meade formation in Kansas River Valley has three well-defined zones which are usually, but not always, present. The lowest zone is a coarse gravel with abundant cobbles and boulders which in many localities attains a thickness of at least 30 feet (Pl. 6A). The percentage of rock types in the 4 to 8 mm size range was found to be about 60 percent limestone, 20 percent chert, 8 percent sandstone and shale, 5 percent granite, 3 percent metamorphic rocks, 2 percent quartz, 1 percent limonitic concretions, and 1 percent dark igneous rocks. In the thicker gravel deposits rocks are mostly unaltered except near the surface where only highly siliceous rocks are left in a red clayey soil. Commonly the gravel is roughly cross-bedded and is interstratified with coarse sand. Three facts indicate that the lowest zone

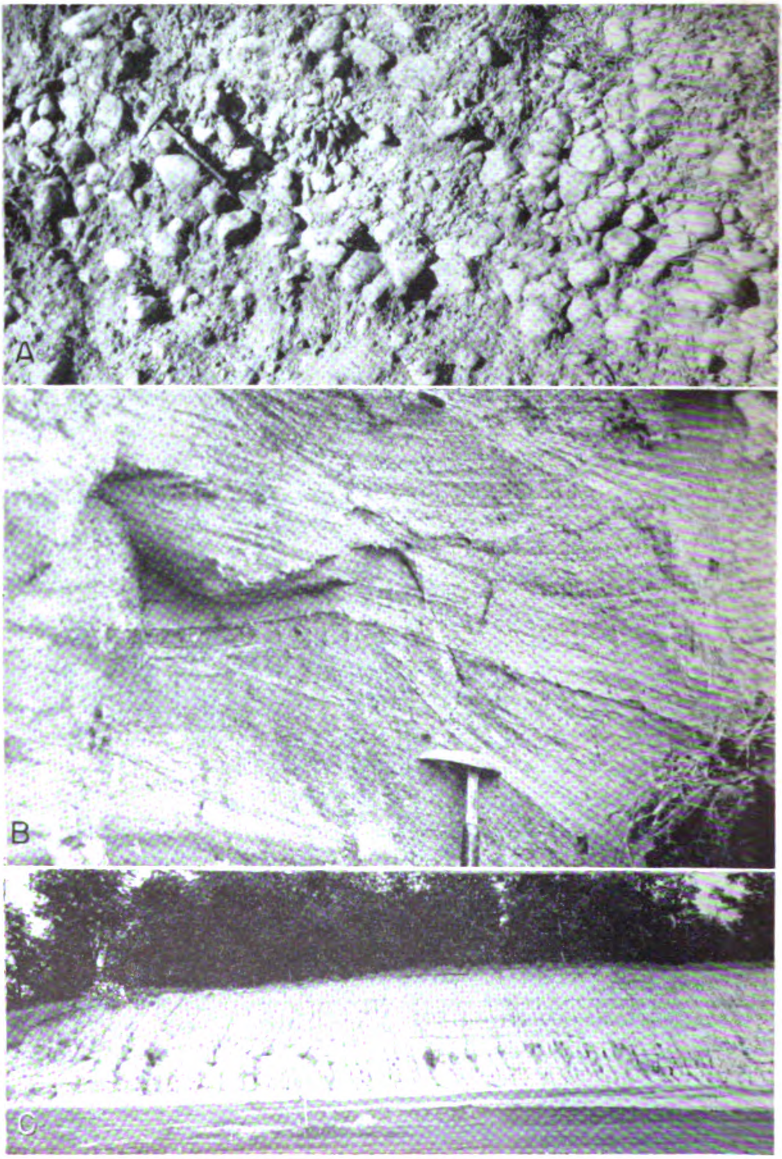


PLATE 6. Meade formation in Douglas County, Kansas. **A**, Coarse Grand Island gravel at the base of the Meade formation, SW¼ SW¼ sec. 9, T. 12 S., R. 20 E. **B**, Cross-bedded sands in the central part of the Meade formation, SE¼ sec. 14, T. 12 S., R. 19 E. **C**, Sand overlain by Sappa silt of the Meade formation, Cen. sec. 14, T. 12 S., R. 19 E.

is closely associated with the Kansan glacier. (1) Till was found to interfinger with the gravels northeast of Kiro (Cen. SW¼ sec. 9, T. 11 S., R. 15 E.). (2) Boulders with a mean diameter of about 500 mm are not unusual in the gravels, whereas the normal gradient of Kansas River is sufficient only to transport cobbles of about 60 mm mean diameter (Wyman, 1935, p. 230). This extreme difference in size is best explained by abnormal gradients which would exist along an ice front. (3) The gravels have a lithology almost identical to gravel in the glacial till but quite different from the present material being transported by Kansas River and the older pre-Kansan chert gravel (Davis, 1951). Overlying the lowest zone is a somewhat discontinuous zone of sand and silt containing a few lenses of gravel and granules (Pl. 6B). The top zone, which is the most distinctive of the three zones, is a reddish sandy silt which is 30 to 40 feet thick (Pl. 5C). The silt is massive and tends to weather with columnar jointing; however, a very weak stratification can sometimes be seen. The entire thickness is leached and unfossiliferous. Numerous pebbles scattered through the silt and a large percentage of sand in the silt preclude the possibility of the material being a loess. As noted by Hoover (1936), the surface of the deposits is roughly parallel with the present river profile, so lacustrine deposition of the silts also seems unlikely. It is believed that the silt represents the final stage of alluviation initiated by the coarser glacial outwash.

In some localities a clear differentiation can be made between the lower Atchison formation, representing pro-glacial outwash, and the overlying Grand Island member of the Meade formation, representing outwash from the retreating Kansan glacier. However, in many localities where this distinction cannot be made, outwash sand and gravel is, for convenience of mapping and description, considered as belonging to the Grand Island member of the Meade formation. The overlying sandy silt is classed as the Sappa member of the Meade formation.

The bedrock base of the Meade formation in this area is at least 10 feet above the present flood plain of Kansas River. This is evidenced by four test holes in the Topeka area, three test holes near Lawrence, and eight road-cut exposures between Lawrence and Kiro.

In general the Meade formation in this area is not a good aquifer, because ground water is easily drained from the lower part of the formation by deeply incised streams and by Kansas River Valley. Many people having houses in the area underlain by Meade formation use either cisterns or municipal water. Several houses near the bluff facing the valley are supplied by wells in the valley alluvium and water is brought to the houses by pressure systems. Northwest of Lawrence some wells drilled through the Meade formation draw water from the underlying Pennsylvanian sandstones.

Undifferentiated middle Pleistocene alluvial fill and colluvium.—In tributary valleys remnants of glacial outwash, a younger terrace, colluvium, and slope wash are all present and can generally be differentiated. However, in many places these were not mapped separately because individual units were often too small to be clearly shown on a map. The greater part of these undifferentiated deposits is a red clayey silt which is almost free of pebbles but locally contains sand and gravel in the basal part. Most clayey silt deposits at heads of tributary valleys (swales of Hoover, 1936, p. 144) seem to be slope wash or colluvium that has stabilized and is being dissected by gullying at the present time. Much of the red clayey silt is found in terrace deposits along the creeks. The terraces are somewhat dissected and stand from 15 to 25 feet above the flood plain; they are probably equivalent in age to the Buck Creek terrace.

Owing to low permeability, dissection, and small thicknesses, these deposits are a poor source of ground water. No wells were found to obtain water from these undifferentiated deposits.

Sanborn formation.—Loess and alluvial deposits which are classed as belonging to the Sanborn formation are widespread in the area mapped. The loess, the greater part of which is considered to be the Peoria silt member of the Sanborn formation, mantles most of the upland areas south of Kansas River but is generally too thin to map. The small areas that were mapped as loess (Pl. 1) are all south of Kansas River and all have maximum loess thicknesses of more than 5 feet. The greatest thickness of loess found in the area was in the northern part of Tecumseh in the SE¼ NE¼ sec. 36, T. 11 S., R. 16 E. At this locality there is exposed in a railroad cut 9.8 feet of Peoria silt overlying 10 feet of Loveland silt which has a well-developed Sangamon soil profile on top and grades downward into at least 12 feet of Crete gravel. The Loveland silt of this area is in part, if not entirely, an alluvial deposit, the upper surface corresponding to the Buck Creek terrace in both elevation and lithology. Elsewhere Peoria silt overlies residual bedrock soil and till and less commonly overlies a thin layer of eolian Loveland silt.

Alluvial deposits of the Sanborn formation have a maximum known thickness of 90 feet at the Buck Creek School in sec. 27, T. 11 S., R. 19 E. Here rotary drilling penetrated 90 feet of silt and fine silty sand which had only slight textural changes in the entire thickness. This silt is classed as the Loveland silt member of the Sanborn formation.

All loess found was above the water table and is important to considerations of ground-water supply only as it affects recharge. The alluvial deposits are generally of fine texture and constitute only a minor source of ground water. Local Crete gravels, if present in a saturated zone, may serve as a satisfactory source for moderate supplies of ground water. Only one well which obtained water from these deposits was inventoried.

Wisconsinan and Recent alluvium.—All river and major stream valleys in the area have deep alluvial fills which reach a maximum thickness of almost 90 feet in the Kansas River Valley. In general, the deeper alluvial fills grade upward from a coarse cobble fill in the deepest portion to a fine sand or silt at the surface. Sediments encountered while test drilling in Kansas River Valley indicate that the first 40 feet is similar to sediments transported by Kansas River at the present time while below this depth boulders are encountered which are much larger than the cobbles recovered from surface samples in the present river channel. The largest fragment of rock recovered by us weighed 77 grams; the largest fragments recovered by the U.S. Engineers from 34 samples of bed load did not exceed 64 mm in diameter (Wyman, 1935, pp. 229-230). The lower cobbles may be related to deposition by abnormal depths of scour during flood stages, or may be related to an earlier deposition at a time when the river flowed at a lower level.

The upper 30 feet of sediment grades laterally from a medium to fine sand near the river to a silty clay under the parts of the Newman terrace which are the greatest distance from the river. Much of the finer material near the bluffs is a "backswamp" deposit, the surface requiring artificial draining to allow cultivation. Even with this surface drainage many hundred acres of land were inundated during the summer months in 1950 and 1951. Adjacent to the pres-

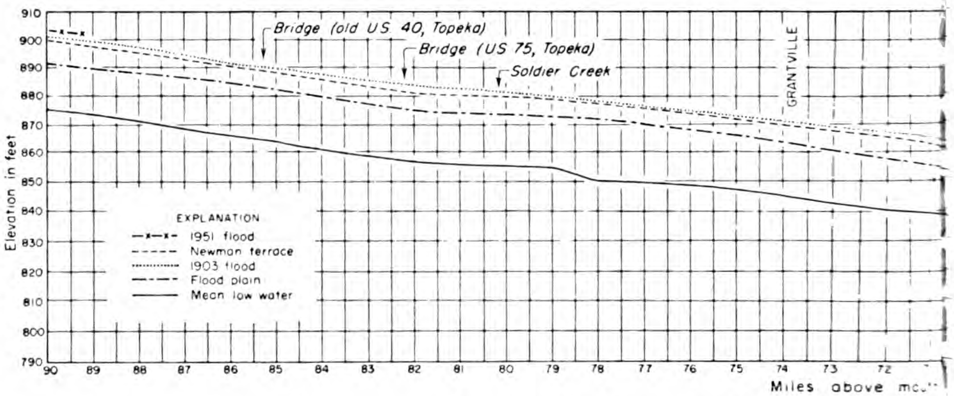
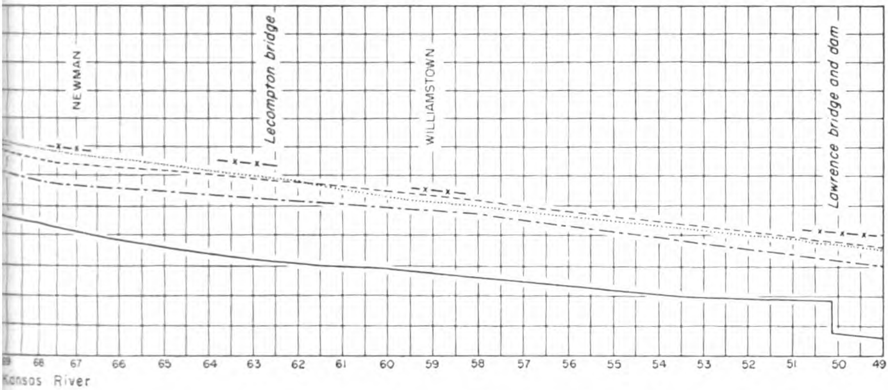


Fig. 4—Profile of Kansas River from Lawrence to Topeka showing
(River elevations from

ent river channel is a highly scarred flood plain surface over which the river has meandered in the last few hundred years. This section has coarse silt and fine sand at the surface which grades downward into fine to coarse gravel. On this flood plain the fine silts and clays are confined to channel scar fillings or "clay plugs." No test holes were drilled in the channel scars, but three auger holes were dug more than 8 feet into clay with no sign of coarser sediments.

The age of the alluvial fill ranges from Wisconsinan to Recent since these deposits truncate Illinoian terrace fills and alluviation on the flood plain and the Newman terrace has been observed within historical times. The three largest floods on record occurred in 1844, 1903, and 1951. The 1951 flood was the most severe of the three; all these floods deposited some material on the Newman terrace. The 1903 flood covered minor parts of the terrace (Fig. 4), and the 1844 and 1951 floods covered all but a few of the high areas along the natural levee.

A two-day reconnaissance was made two weeks after the 1951 flood to attempt to determine the amount of sediment deposited by the flood. Since much of the flood plain was inaccessible during this reconnaissance, only an approximation of the deposition on the Newman terrace could be made. A total of 32 thicknesses were measured at selected intervals between Lawrence and Kiro. The thicknesses were obtained by averaging several measurements in a single locality. Areas near fence lines, ditches, houses, and trees were avoided. The thickness of sediment deposited on the Newman



ionship of the 1903 flood to Newman terrace and the flood plain.
rmy Engineers, 1944.)

terrace was found to range from a minimum of less than 1 mm to a maximum of about 14 mm; the average was about 5 mm. The sediment deposited was a calcareous tan to light-brown silt which graded from a coarse silt at the natural levee to a silty clay in the "backswamp" areas. The silt was leached in areas in which the sediment was less than 2 mm thick and in which water had stood with a large amount of organic debris in it. Scouring by the flood water was evident only at the margins of the terrace and is considered to be negligible on the terrace.

In contrast to the thin silty clay on the Newman terrace, the flood plain has deposits of coarse silt which in many places near buildings and fences exceed 3 feet in thickness. Deposition on the flood plain seems to be controlled principally by the strength of the currents flowing through an area during a flood and by the amount of vegetation next to the ground which is effective in arresting the movement of the bed-load sediment. Large areas of scour were apparent along old meander scars and flood-overflow channels.

Valley alluvial deposits are the major water-bearing sediments in the entire region. In general, the larger the valley and the deeper the fill, the more satisfactory the water supply will be. The Kansas River Valley is by far the most favorable source for large quantities of water. The coarse gravels have a very high permeability and are excellent aquifers. Water temperature is uniformly from 56 to 58 degrees F. except near Kansas River where infiltration of river water causes a seasonal fluctuation of from 5 to 10 degrees F. The water is somewhat harder than that obtained from Kansas River, but has the advantages of constant temperature and little or no turbidity.

Recent sand dunes.—Two small sand-dune areas were found on the flood plain near Grantville. Several dunes are active at the present time and are adversely affecting crops at a number of points within the dune tract. The sand was seen moving in large quantities during the dust storms in the spring of 1950. Channels more than 10 feet deep were cut in the dunes during the 1951 flood.

The dune sand does not seem to be more than 20 feet thick. None of the wells inventoried obtained water from these sands; however, it is well sorted and permeable and is probably of local importance as an excellent recharge area.

GROUND WATER

The following discussion covers a number of aspects of ground-water hydrology as applied to northeastern Kansas. For a more extended discussion of the principles of ground-water hydrology, the reader is referred to a discussion of ground-water occurrence in the United States by O. E. Meinzer (1923) or to a summary of ground-water conditions in Kansas by R. C. Moore (1940).

Source, Occurrence, and Movement

During most periods of heavy precipitation part of the moisture enters the ground and part runs off in streams or evaporates. Much of the moisture entering the soil zone is utilized by plants and is returned to the atmosphere by transpiration, and a small amount continues to migrate downward until a zone of saturation is reached in which the available openings in the consolidated or unconsolidated rocks are filled with water. The upper surface of the zone of saturation is the water table, except where that surface is formed by an impermeable layer of rock. When water reaches the zone of saturation it commences to move towards a point of discharge which may be a spring, well, stream, pond, or an area in which plants send roots to the saturated zone and discharge the water to the air by transpiration. The ground-water movement is in the down-slope direction of the water table which is generally the same direction as the slope of the land surface. Thus the major areas of natural ground-water discharge are in the lowest topographic positions which are along Kansas River and its tributaries.

There is no regional circulation of ground water in the Pennsylvanian rocks near Topeka. Owing to the highly dissected nature of the upland topography it is doubtful if much ground water travels a lateral distance of more than 10 miles. Therefore, water-level fluctuations in upland wells are a direct result of only local additions or withdrawals of ground water. Water-level fluctuations in wells in the valley alluvium are somewhat more complex owing to the influence of flood stages in Kansas River and its tributaries which tend to reverse normal ground-water gradients.

No water-table contours were drawn in older alluvium and in Pennsylvanian rocks because a simple water table, such as is found in Recent to Wisconsinan alluvial fills, often does not exist. Water-table contours were drawn in the alluvium along Kansas River (Pl. 2), and the contours indicate that the general water motion is diagonally downstream and toward the river. This general direction of ground-water movement is modified near Lawrence owing to the effect of the dam across Kansas River which raises the level of the river water above that of the water table in the surrounding alluvium thus reversing the gradient and hence the direction of flow. Soldier Creek also affects the shape of the water table between Menoken and Topeka. The water table in this area is unusually flat owing to ground-water discharge into both Kansas River and Soldier Creek. Soldier Creek also intercepts the water normally moving into the valley from the north.

The water table was contoured on information gathered after an unusually wet summer, so in any subsequent drilling the water table may be lower than the elevation indicated on the map (Pl. 2). The normal water-table fluctuation at a distance of over 3,000 feet from the river is not greater than 5 feet a year unless it is affected by pumping or water flooding the entire valley. During the flood of 1951 water levels rose from 10 to 15 feet in many of the wells. Sufficient information was not gathered to contour the effect of small tributary streams which cross the valley alluvium. From measurements on five streams it is inferred that all the streams normally gain through ground-water discharge while crossing the valley alluvium.

As is shown in Figure 5 the water level in wells near the river fluctuates with the stage of the river; water levels in wells at a greater distance from the river seem to respond to a slow infiltration of rain water (Figs. 6 and 7); however, as the periods of high river stage correspond to the periods of heavy rainfall, it is difficult to separate the effects of the two at some distance from the river.

Recharge

The information collected was not sufficient to attempt an accurate quantitative measure of ground-water recharge. In eastern Kansas the annual recharge is estimated at about one-half inch of the total precipitation of more than 30 inches (Knapp and others, 1940, p. 18.) Calculations from the November base flow in Soldier Creek indicate a minimum possible recharge of one-fifth inch per year in the Soldier Creek drainage basin. Using the minimum flow

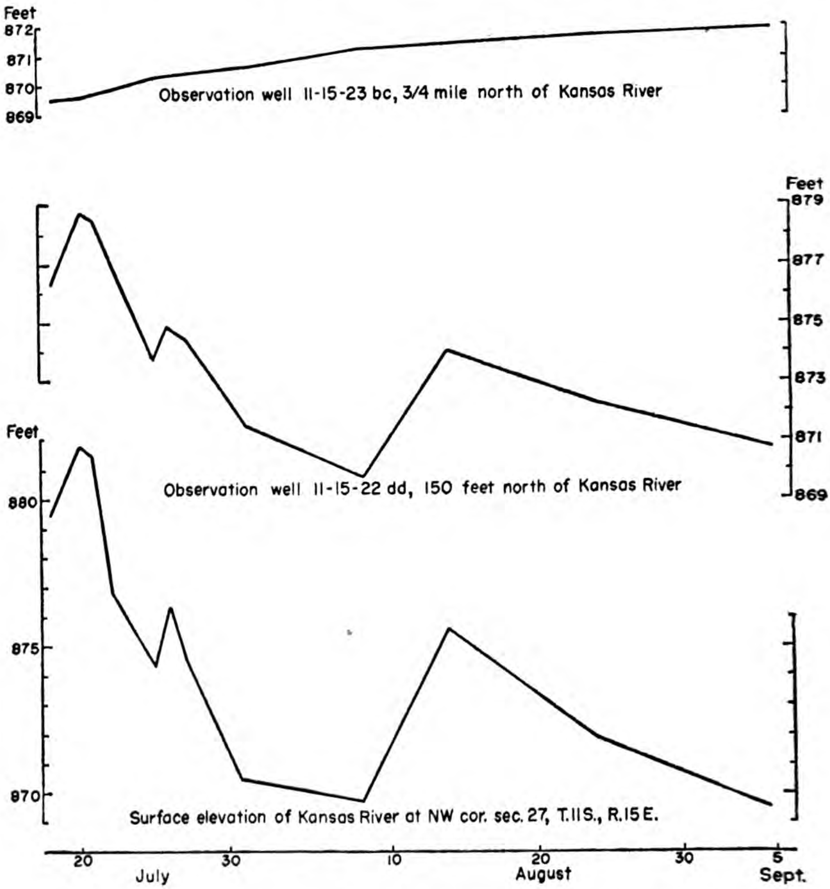


FIG. 5.—Hydrographs of two observation wells and Kansas River near Topeka showing influence of river stage on wells close to the river.

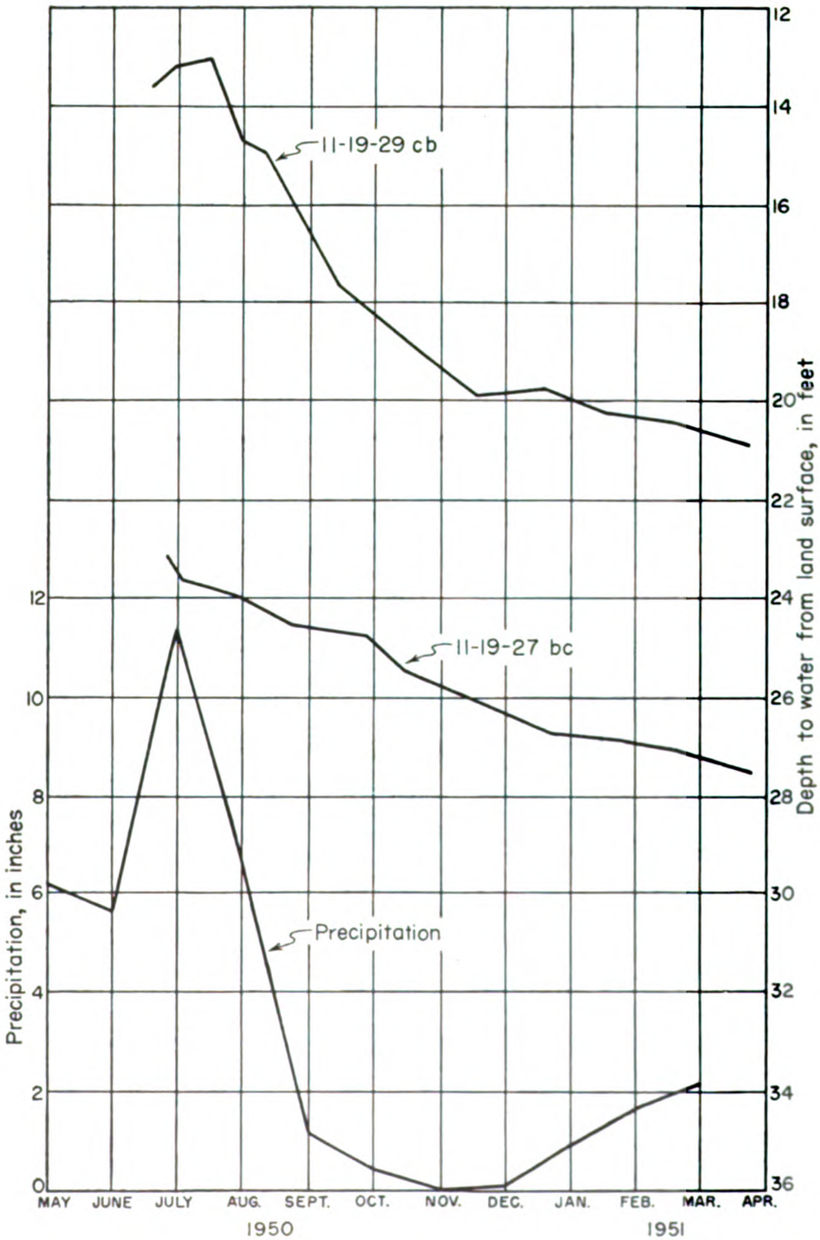


FIG. 6.—Hydrographs of two observation wells near Lawrence and monthly precipitation for 1950 at Lawrence. (Precipitation data from U. S. Weather Bureau.)

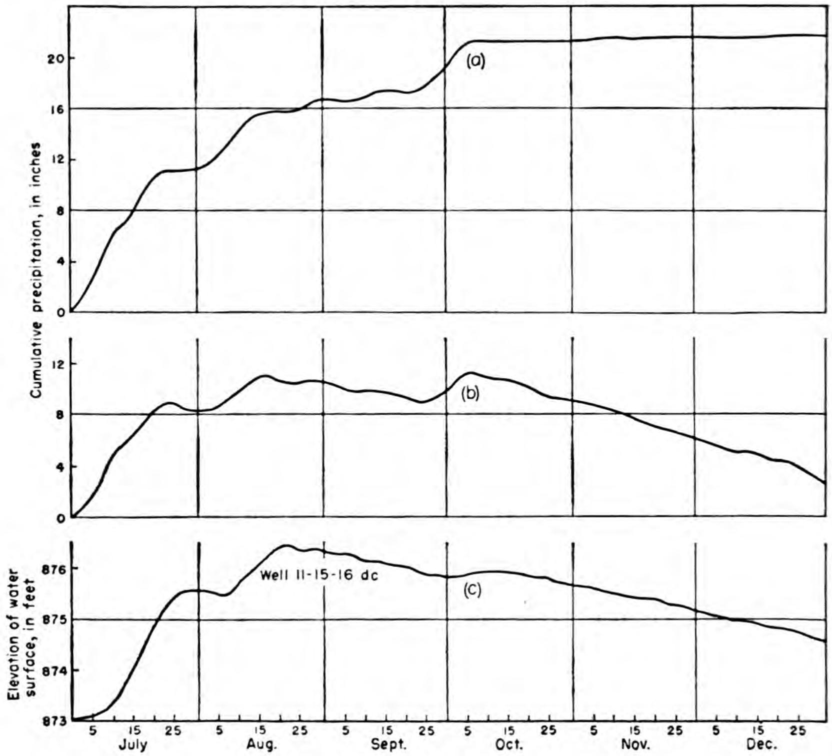


FIG. 7.—Hydrograph of an observation well near Topeka for the period July through December 1950 and cumulative precipitation. Well owned and operated by the Division of Water Resources, Kansas State Board of Agriculture; precipitation data from the U. S. Weather Bureau.

for each month during the year of 1946, the recharge was calculated to be 1 inch. The true amount of annual ground-water recharge in the Soldier Creek basin is probably somewhere between these two quantities. In considering a small area, such as in this report, it must be remembered that calculations of recharge on a regional basis will have little significance, as infiltration may be 100 times as great in an area underlain by limestone or sandy alluvium as an area underlain by shale.

In the Kansas River Valley the rate at which precipitation infiltrates to the zone of saturation is largely dependent on the clay content of the surficial material. During the spring of 1950 many ponds with surfaces well above the water table persisted through a three-month period of little rainfall. Most of these ponds occupy old meander scars which have silty clay fillings and through which very little water can pass. In contrast to this condition, some sandy areas only contain puddles of rain water for a few hours after heavy rainfall, indicating very favorable recharge conditions. An annual recharge of 2 inches of precipitation would maintain the existing ground-water mound between Kansas River and Soldier Creek. This estimate was based on permeability of 1,700 (Meinzer units) which was obtained from an average of 25 test wells in the vicinity of Lawrence (Lohman, 1941, pp. 34-37), water-table conditions obtained from observation wells, and the saturated thickness from test holes to the east. The principal area of recharge by precipitation is believed to be the flood plain with very little recharge occurring in old channel scars and on the "backswamp" deposits of the Newman terrace.

During as many as 30 days in the year, high stages in Kansas River and its tributaries will cause a reversal of the normal ground-water flow and the river will feed water to the alluvium. The effect of the river stage on ground-water levels is shown in Figures 5 and 8. Much of this water will be temporary bank storage which drains into the river again without becoming effective as recharge. However, it is possible that as much as 20 percent of the recharge in the valley between Menoken and Topeka is from the river. In the vicinity of the towns of Grantville, Perry, Newman, and Lakeview the normal recharge from the river should be much less. At Lawrence the dam across Kansas River causes water to flow into the alluvium during most of the year (Lohman, 1941).

Yields of Wells

Some of the more important factors affecting the yield of a well are: (1) permeability of the water-bearing material; (2) thickness of the water-bearing material penetrated by the well; (3) construction of the well; and (4) diameter of the well.

Lohman (1941) concluded that the permeability of the material penetrated by 25 test holes in the vicinity of Lawrence was about 1,700 (Meinzer units). It is considered likely that similar high permeabilities are to be found everywhere in the deeper parts of the Kansas River alluvium. During the investigation made for this report the permeability of several samples of sand and gravel recovered from test holes was determined. The permeability of the material tested was found to range from 186 to 10,753 (Meinzer

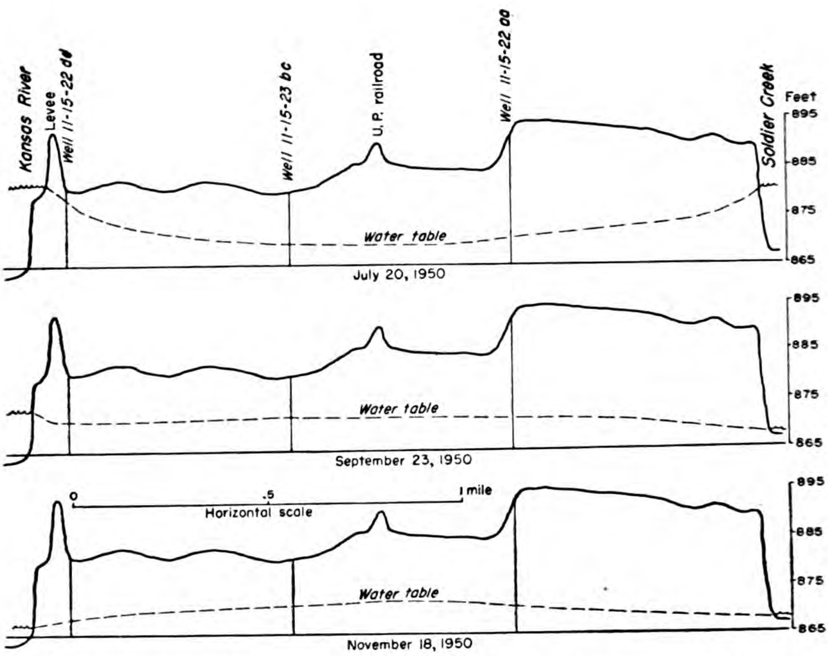


FIG. 8.—Water-table profiles near Topeka showing the influence of Kansas River and Soldier Creek stages on ground-water recharge and discharge.

units). Owing to fluviatile deposition there is no great degree of uniformity in the sediments. Discontinuous lenses of gravel, sand, and boulders which grade into one another characterize the lower part of the Kansas River alluvial fill. In general, however, the deeper the fill the coarser and more permeable the sediments.

In seeking to obtain the maximum yield for a well it is highly important that the greatest possible thickness of the water-bearing material is penetrated by the well. The saturated thickness of alluvium in the Kansas River Valley ranges from about 20 to about 65 feet. The maximum thickness of alluvium is confined to a relatively narrow bedrock channel which can be located only by test drilling as it has no surface expression or relation to the present river channel.

Well construction varies greatly with the quantity of water desired, geologic conditions, and individual well driller's practices. A general discussion of well construction is beyond the scope of this report, but the following are a number of the more important points which should be considered carefully: (1) size of slot opening used in the casing or screen; (2) size and type of gravel used if the well is gravel packed; (3) total open space in the casing which allows water to enter the well; (4) the method with which the well is developed; and (5) the distance of the constructed well from other wells.

The diameter of a well is not as important a factor in obtaining large yields as was once thought. A well having a 4-inch diameter would have to be enlarged to a well having a diameter in excess of 80 inches in order to double the yield, providing all other factors affecting yield remain constant. There are, however, some advantages in increasing well diameters. The greatest advantage in heavily pumped wells is that the velocity with which water enters the well is greatly reduced, which in turn reduces sand pumpage and incrustation and corrosion of well screens or casings. The advantage of large diameter wells in formations which yield small quantities of water is that the well serves as a reservoir and stores the slowly accumulating water during times when the well is not pumped.

Representative yields of industrial and irrigation wells in Kansas River alluvium are given in Table 4. The specific yields of these wells range from 10.8 to 133 gallons per foot of drawdown. The average specific yield of the wells is 53 gallons per foot of drawdown.

Utilization

Domestic.—Of the domestic wells in the alluvium about 95 percent are driven wells. The wells are usually constructed by augering to the first layer of sand in the zone of saturation, then driving the well point and pipe a desired distance into the sand or gravel. The wells are either started in basements or in small pits so the pump cylinders can be placed as near as possible to the water table. Driven wells are cheap and are usually satisfactory for small domestic supplies; however, if wells are to supply water for garden irrigation, air conditioning, or small dairies, larger and more expensive wells are usually necessary. In recent years most of the larger wells have been drilled by rotary or percussion methods and open-end, gravel-packed, or screened wells have been installed.

The older wells in Pennsylvanian rocks are mostly dug wells which range in diameter from 3 to 15 feet and in depth from 5 to 75

TABLE 4.—*Pumping tests on wells in Kansas River alluvium; data as reported by well drillers, industrial engineers, and private individuals*

Location of well	Owner	Local well number	Depth of well, feet	Pumping rate, gals. per min.	Drawdown, feet	Hours pumped
NW¼ NE¼ sec. 26, T. 11 S., R. 15E.	State Hospital	3	49	220	7.6	2
do	do	3	49	400	14.6	3
do	do	1	60	500	5.5	9
do	do	1	60	748	8.4	1
NE¼ NE¼ sec. 14, T.11S., R. 15E.	Howard Jackson	—	60	480	11.0	—
SE¼ NE¼ sec. 13, T.11S., R.15E.	Goodyear Tire and Rubber Company	3	75.7	602	5.7	1.2
do	do	3	75.7	350	3.5	6
do	do	4	71	510	6.7	6
SW¼ NE¼ sec. 13, T.11S., R.15E.	do	1	79.3	720	7.7	8
do	do	2	89	776	6.7	8
do	do	2	89	1,400	11.1	few minutes
NE¼ SW¼ sec. 30, T.11S., R.16E.	Beatrice Foods Inc.	1	70	430	13	14
do	do	2	70	425	19	—
SE¼ SW¼ sec. 29, T.11S., R.16E.	Hill Packing Co.	1	68.5	1,000	7.5	—
do	do	2	70	900	9.6	4
SW¼ NE¼ sec. 29, T. 12S., R.20E.	Westvaco Co.	1	54	260	8.0	8
do	do	2	51	290	11.0	8
do	do	3	75.5	260	15.0	8
SE¼ NE¼ sec. 29, T.12S., R.20E.	do	4	74	205	19.0	8
do	do	5	64	370	15.0	8

feet. Curbing is either brick or native limestone, and the upper part is often cemented to prevent entrance of polluted surface water. During the periods of drought from 1933 to 1939 many upland wells failed and several 15-foot diameter wells were dug under the supervision of the Kansas Emergency Relief Committee and by the Works Progress Administration. These wells were mostly located in alluvium along small streams.

Agricultural.—There are at least 10 wells in the area which are used entirely or in part for irrigation. The yield of these wells ranges from 20 to 500 gallons a minute; however, owing to small pumps the potential yield is often not attained. No estimate of daily pumpage of these wells was made, as the pumpage depends upon the distribution and quantity of rainfall during the growing season. Judging from the reported capacities of the wells it is estimated that the total daily pumpage is about 2,500,000 gallons during the exceptionally dry years, and that there is virtually no pumpage during exceptionally wet years.

An irrigation well that is typical of the type which could be installed in this section of the Kansas River Valley is the well owned by Howard T. Jackson. This well was drilled in 1933 under the sponsorship of the Topeka Chamber of Commerce. The well is 60 feet deep, has 24-inch perforated casing opposite coarse sand, and is capable of yielding 500 gallons a minute with a 12-foot drawdown. The plant irrigates 35 acres and in 1936 a total of 44.5 acre-feet of water was pumped at a cost of $3.17 per acre-foot. The total power consumed for 1936 was 4,096 kilowatt hours.

Industrial.—Use of ground water by industry exceeds 9,000,000 gallons a day (Table 5). Most ground water is used in industry for cooling, condensing, and cleaning. The daily pumpage reaches a

TABLE 5.—*Ground water use in the Kansas River Valley area between Topeka and Lawrence, Kansas, based on 1950 inventory*

Use	Consumption, gallons per day
Industrial	9,500,000
Municipal	2,500,000
State Hospital (Topeka)	500,000
Rural use, domestic and stock (estimated)	350,000
Irrigation (seasonal and highly variable)	2,500,000
Air conditioning in churches, homes, and stores (seasonal)	100,000
Total daily consumption, maximum	12,850,000

PLATE 7. **A**, Pumping test at Westvaco Chemical Co. near Lawrence, Douglas County. **B**, Water wells of the State Hospital at Topeka, NE¼ sec. 26, T. 11 S., R. 15 E. **C**, Pond on flood plain south of Kiro, Shawnee County, with water surface more than 3 feet above water table. Picture taken after three months of little rainfall.

maximum during summer months which greatly exceeds the yearly average given in Table 5.

Nearly 50 percent of the total quantity of ground water used for all purposes is pumped by industry from a small area near the south bank of Kansas River in Topeka. The only large industrial users of ground water not in this area are the Goodyear Tire and Rubber Company north of Topeka and the Westvaco Chemical Company northeast of Lawrence (Pl. 7A). Many of the wells in Topeka are so close to the river that water filters directly to the wells from the river and the temperature of water pumped from the wells varies directly with the temperature of the river water. Water from heavily pumped wells close to the river may have a temperature difference of as much as 20° F. during the year. Wells at a greater distance from the river will have a water temperature that remains between 56° F. and 58° F. throughout the year.

Perforated concrete casings, well screens, and perforated metal casings with gravel packing are all used in local well construction. Some perforated concrete casings have been used successfully for 18 years. These wells have been pumped only moderately.

Public supplies.—The State Hospital at Topeka obtains all water from wells adjacent to Kansas River (Pl. 7B). At the present time two wells are being pumped and a third well is drilled but not pumped as yet. Both the Topeka and the Lawrence municipal water supplies are regularly supplemented by water from wells on the south side of Kansas River. The Topeka water plant has two large-diameter dug wells and two gravel-packed wells which have a total capacity of 4,000,000 gallons of water a day and the Lawrence plant has three wells with a total capacity of 1,500,000 gallons of water a day. Both plants pump the well water at rates well below the total capacities of the systems. A fourth well to supplement the three existing wells will soon be constructed at Lawrence. In case of an emergency the entire municipal supply can be obtained from the four wells. The town of Perry obtains all municipal water from a well near the center of town.

Potential Development

No shortage of ground water was found to exist at the present time in the Kansas River Valley, and no shortage seems likely in the near future. There is, however, danger in spacing wells too close together. If it were not for rapid recharge by Kansas River, many industrial wells would experience serious mutual pumping interference at the present time.

Wells in upland areas are much less dependable than the wells in the major valleys. Many wells fail during exceptionally dry periods and water must be hauled for domestic and stock use. Conditions would be improved in many cases by a general deepening of the shallower wells and the location of new wells in more advantageous bedrock areas.

Considering the results of the pumping tests given in Table 4 it is quite certain that yields of as much as 1,000 gallons a minute can be obtained from the deeper alluvial fills in the Kansas River Valley and that yields of more than 200 gallons a minute can be obtained at most localities in the valley. In many places a general lowering of the water table from 3 to 8 feet would cause the river to recharge the alluvium continuously, thus greatly increasing the potential ground-water yield of the area as a whole.

Quality

The chemical character of the ground water in the Kansas River Valley and the adjacent uplands is shown by analyses of 24 samples of water collected from water wells and test holes. The analyses (Table 6) were made by Howard A. Stoltenberg in the Water and Sewage Laboratory of the Kansas State Board of Health and by the Kansas City Testing Laboratory, Inc. The analyses show only the dissolved mineral content of the water.

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

Dissolved solids.—The evaporation of natural water leaves a residue that consists essentially of mineral matter which may include some organic material and a small amount of water of crystallization. Water containing more than 1,000 parts per million of dissolved solids is sometimes used successfully for domestic or irrigation purposes; however, it is in most cases likely to contain certain constituents in quantities sufficient to make its use unsatisfactory. Water containing less than 500 parts per million of dissolved solids is generally suitable for most purposes unless containing excessive quantities of iron, fluoride, nitrate, or other less common constituents which are not subsequently discussed and are not regularly present in well water of eastern Kansas.

TABLE 6.—*Analyses of water from typical wells, test holes, and spring in Kansas River Valley in the Lawrence - Topeka area* (Dissolved constituents given in parts per million‡)

Location	Depth, feet	Geologic source	Date of collection	Temperature, °F.	Dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Hardness as $CaCO_3$: Total	Carbonate	Non-carbonate
10-14-36dd	56	Soldier Creek alluvium	1-24-50	57	828	6.8	13	113	27	174	587	48	169	0.1	1.2	393	393	0
11-15-18bc	34	Kansas River alluvium	1-24-50	58	449	26	0.06	118	15	17	354	54	16	0.4	29	356	290	66
11-15-21aa	35	do	1-24-50	57.5	412	2.4	3.9	113	8.4	23	344	57	16	0.3	1.3	316	282	34
11-15-26ab	51	do	6-13-45	—	508	15	0.94	94	17	50	266	98	60	0.3	9.7	304	218	86
11-16-20bc	46	do	1-24-50	56.5	641	25	1.7	156	28	32	429	81	93	0.2	13	509	352	157
11-16-13bc	33	Meade fm.	1-24-50	57	850	24	0.13	183	21	33	200	28	81	0.1	381	543	164	379
11-16-18bc	70	Kansas River alluvium	6-29-46	—	640	20	0.25	146	19	37	390	106	63	0.3	1.8	442	320	122
11-17-20bb	29	do	1-24-50	54	403	27	0.05	110	7.6	16	298	65	7.0	0.2	23	306	244	62
11-18-19bc	26	do	12- 2-50	56.5	346	24	0.18	90	11	19	315	35	9	0.6	2	270	258	12
11-19-27bc	33	Sanborn fm.	12- 2-50	57	230	12	0.35	61	5.4	11	181	12	9	0.1	30	174	148	26
11-19-31bc	27	Kansas River alluvium	12- 2-50	57.5	456	25	1.8	131	15	16	442	34	16	0.3	1.1	388	362	26
*12-17- 4db	—	Deer Creek ls.	1-24-50	58.5	358	14	0.05	108	8.6	13	348	30	8.0	0.1	4.9	305	286	19
12-19- 5dd	24	Kansas River alluvium	12- 2-50	56	424	27	4	113	19	17	425	14	22	0.5	2	360	348	12
12-19-14cd	216	Tonganoxie ss.	12- 2-50	57.1	545	16	1.9	75	16	78	244	11	43	0.2	186	253	200	53
12-19-15ba	22	Kansas River alluvium	12- 2-50	57.5	416	25	12	117	16	17	455	4.5	11	0.2	1.7	358	358	0
12-19-23ba	142	Tonganoxie ss.	12- 2-50	55.7	309	22	1.1	61	8.2	44	309	2.9	14	0.2	4.9	186	186	0
12-19-23dc	170	do	3-11-50	—	369	16	1.9	95	11	24	334	30	10	0.2	18	282	274	8
12-19-24db	39	Lawrence sh.	12- 2-50	56.1	1,695	19	0.5	350	89	85	627	587	154	0.2	102	1,239	514	725
12-19-26ab	190	Tonganoxie ss.	3-16-50	—	21,430	15	20	615	257	7,338	237	279	12,800	0.9	8.8	2,590	194	2,396
†12-20-29ac1	55	Kansas River alluvium	6-27-50	—	583	27.9	2.0	97.6	9.5	37	311.1	65.4	285	—	0	283	255	28
†12-20-29ac2	55	do	6-27-50	—	729	38.0	7.4	116.9	12.3	48.3	382	44	73	—	0	357	313	44

‡ 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.
* Spring.
† Test hole.

The dissolved solids in water derived from alluvium and terrace deposits ranged from 230 to 850 parts per million. With the exception of two wells, the dissolved solid content was under 650 parts per million. Water from wells tapping bedrock supplies showed generally a higher dissolved solid content, and water from one well in bedrock contained as high as 21,430 parts per million dissolved solids.

Hardness.—The hardness of water is generally the property that receives the most attention and is most commonly recognized by its effects when soap is used with the water. These constituents are also the active agents in the formation of the greater part of all the scale found in steam boilers and in other vessels in which water is heated or evaporated.

In addition to total hardness, the analyses indicate the carbonate hardness and the noncarbonate hardness. The carbonate hardness is that due to the presence of calcium and magnesium bicarbonate, and it is largely removed by boiling. In some reports this type of hardness has been called temporary hardness. The noncarbonate hardness is due to the presence of sulfates or chlorides of calcium and magnesium which cannot be removed by boiling, and has sometimes been called permanent hardness. With reference to use with soap, there is no difference between carbonate and noncarbonate hardness. In general the noncarbonate hardness forms a harder adhering scale in steam boilers.

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

Water samples collected from the alluvium of the Kansas River Valley ranged in hardness from 174 to 509 parts per million and averaged 357 parts per million. Water from bedrock sources ranged in hardness from 186 to 259 parts per million.

Iron.—Next to hardness, iron is the constituent of natural waters that receives the most attention. The quantity of iron in ground water may differ greatly from place to place, even though the water is from the same formation. If a water contains much more than 0.3 part per million of iron, the excess may separate out as a reddish sediment. Iron, which may be present in sufficient quantity to give a disagreeable taste and to stain clothing, porcelain ware, and cooking utensils, may be removed from most waters by simple aeration and filtration, but a few waters require the addition of lime or some other substance.

The iron content of the ground water in the area under investigation ranged from 0.05 to 20.0 parts per million (Table 6). The average iron content of the waters tested was 3.3 parts per million.

Chloride.—Water containing less than 150 parts per million of chloride is not objectionable for most uses but that containing more than 350 parts per million is often objectionable for irrigation or industrial use. Water containing more than about 500 parts per million becomes objectionable to the taste.

The chloride content of water in the alluvium of Kansas River Valley is generally less than 100 parts per million and is commonly less than 25 parts per million. The water from one well in the alluvium contained 169 parts per million chloride. Water from one well in bedrock had a chloride content of 12,800 parts per million.

Fluoride.—Although quantities of fluoride are relatively small as compared with other common constituents of natural water, it is desirable to know the amount of fluoride present in water that is likely to be used by children. Fluoride in water has been associated with the dental defect known as mottled enamel, which may appear on the teeth of children who drink water containing excessive quantities of fluoride during the period of formation of their permanent teeth. Water containing much more than 1.5 parts per million of fluoride is likely to produce mottled enamel. If the water contains as much as 4 parts per million of fluoride, 90 percent of the children exposed are likely to have mottled tooth enamel, and 35 percent or more of the cases will be classed as moderate or worse (Dean, 1936). Small quantities of fluoride, not sufficient to cause mottled enamel, are likely to be beneficial by decreasing dental cavities (Dean and others, 1941).

All the samples of water collected from this area contained less than 1.0 part per million fluoride. The average fluoride content of all the samples analyzed for this report is 0.28 part per million.

Nitrate.—An unusually large amount of nitrate in well water may cause cyanosis when the water is used in preparation of a baby's formula. The nitrate content for waters analyzed from each formation in the area covered by this report is shown in Table 6. The difference in nitrate content for the water is considerable and seemingly is not related to any geologic formation. A high nitrate content is probably due to the inflow of surface water around the well or to the movement of water through soil that contains more than a normal amount of nitrate. Wells near fields of alfalfa or other legumes might receive some of the nitrate which these plants have added to the soil. Shallow and poorly sealed wells allow more infiltration of surface seepage (Pl. 7C) than do deeper, more tightly cased wells. Thus shallow wells in alluvium or terrace deposits and dug wells that are not cemented in the top portion are more likely to have water of high nitrate content.

Water that contains more than 90 parts per million of nitrate is considered by the Kansas State Board of Health likely to cause infant cyanosis. Water containing less than 10 parts of nitrogen, or 45 parts of nitrate, is generally considered safe.

All the water samples analyzed with the exception of two contained some nitrate. Three samples exceeded the critical amount of 90 parts per million, ranging from 102 to 381 parts per million. The remainder of the samples had less than 30 parts per million.

RECORDS OF TYPICAL WELLS

Records of typical wells visited in the field are given in Table 7. Pertinent information about each is tabulated.

LOGS OF WELLS, TEST HOLES, AUGER HOLES, AND DESCRIPTION OF MEASURED SECTIONS

Listed in the following pages are the logs of 19 wells and 55 test holes in the reported area including 48 logs of test holes drilled by the State Geological Survey of Kansas and 26 logs of wells and test holes furnished by private drillers. The logs of the test holes drilled in 1940 are from Lohman (1941) and Lohman's numbers are indi-

TABLE 7.—*Records of wells in Kansas River Valley in Lawrence-Topeka area*

Well no.	Owner or Tenant	Type of well (1)	Depth of well, feet (2)	Diameter of well, in.	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Use of water (4)	Measuring point: Description	Measuring point: Feet above land surface	Measuring point: Feet above mean sea level	Depth to water level (5)	Date of measurement
10-14-36dd	C. L. Rogers	Du	35	30	R	Sand	Alluvium	D	S. edge of hole in conc.	0.5	914.4	15.45	8- 1-50
11-15-2ac	W. A. Lewis	Du	70	48	R	Limestone	Pennsylvanian	N	Land surface	0	892.6	12.2	9- 2-50
11-15-4dc	School district	Dr	41	5	I	do	do	D	W. edge of conc.	0.4	955.0	30.82	8- 1-50
11-15-9dd	Kirkpatrick	Du	65	49	R	Sand & Gravel	Alluvium	D, I	Iron pump base	0	905.5	26.71	7-27-50
11-15-10ad	Huckum	Du	18	72	B	Sand	Meade	D	Top conc. curb	3.0	935.0	10.74	8- 3-50
11-15-10da	Robinson	Du	8.3	30	C	do	do	S	Top of pipe	1.0	920.0	2.55	8- 3-50
11-15-14aa	Howard Jackson	Dr	60	24	I	Sand & Gravel	Alluvium	I	Hole, pump base	1.1	894.5	26.35	9- 5-50
11-15-21dc	W. D. Stover	Dn	22.6	1.5	GP	do	do	D	Top of pipe	2.4	882.2	14.86	9- 2-50
11-15-22aa	F. Baird	Dd	37.4	12	GI	do	do	I, O	Top of casing	—14.0	880.4	8.54	9- 5-50
11-15-22dd	U.S. Geol. Survey	Dn	17.1	1.25	GP	do	do	O	do	1.5	881.2	10.32	9- 5-50
11-15-23bc	do	Dn	17.5	1.25	GP	do	do	O	do	2.0	882.6	10.57	9- 5-50
11-15-24ab	S. Meier	Dd	—	24	I	do	do	I, D	Top, brick curb	2.3	888.0	21.30	9- 5-50
11-15-32da	G. L. Johnson	Du	—	60	B	Limestone	Pennsylvanian	D	Hole, conc. slab	3.8	—	8.05	8-10-50
11-16-5bd	R. F. Lucas	Du	24	36	R	do	do	D	do	0.5	975.0	5.30	8- 3-50
11-16-7bb	C. Gudenkauf	Du	16.2	72	B	do	do	N	Top conc. curb	1.5	930.	12.54	8- 3-50
11-16-10bb	M. E. Cathcart	Du	50	44	R	do	do	D	Top, well curb	1.0	960.0	6.40	8- 3-50
11-16-13bc	J. S. Givens	Du	33	36	B	Sand & Gravel	Meade	D	Top, conc. cover	0.5	930.0	17.35	8- 3-50
11-16-16bd	N. Olson	Dr	27	8	I	Sand	Calhoun	D	Land surface	0	885.3	8.56	8-11-50
11-16-20bc	Owen Sipes	Dd	42	10	I,B	Sand & Gravel	Alluvium	I, D	Top, wood rim	1.5	882.9	19.81	8-30-50
11-17-1cc	J. Hemme	Du	15.0	36	R	Till	Kansas	N	Top curb	1.3	—	1.5	8- 8-50
11-17-5cc	School district	Du	—	36	R	Limestone	Pennsylvanian	N	Top conc. curb	1.0	955.0	13.75	8- 8-50
11-17-10cc	F. Schultz	Du	—	40	R	do	do	D	Top of S. log	0.4	905.0	23.52	8- 8-50
11-17-16cb	Dewelde	Dd	—	60	C	Sand & Gravel	Alluvium	D	Top, conc. cover	0.5	876.1	20.6	9- 1-50
11-17-17bb	James Johnson	Du	22	30	R	do	Meade	D	Top, board cover	1.0	888.7	13.6	9- 1-50
11-17-18cd	Julius Brown	Du	25.7	87	B	Sand	Alluvium	N	Top of curb	0	875.1	20.95	9- 5-50
11-17-32ca	C. S. Hennessey	Du	42	64	R	do	Meade	D	S. edge of curb	0.5	920.0	34.58	8-11-50
11-18-8cd	T. Worthington	Du	40.8	48	R	do	Alluvium	S	Wood platform	0.8	867.1	12.5	6-23-50
11-18-18aa	Z. A. Enos	Du	40.0	48	R	Sand & Gravel	do	O	Land surface	0	861.0	13.6	8-29-50
11-18-22ac	City of Perry	Dr	80.0	10	I	do	do	P	do	0	848.0	15.0	10-28-50
11-18-26cd	———	Du	31.0	6	I	do	do	D, S	Wood platform	0.4	848.1	19.5	6-21-50
11-18-34cd	Fred Smith	Du	44.5	30	R	Sandstone	Lecompton	D	Land surface	0	960.0	26.1	6-27-50
11-19-14-cb	———	Du	32.0	48	R	Limestone	Oread	D	Top, ss. slab	0.2	1000.0	8.4	7-22-50
11-19-25db	H. W. Love	Du	23.8	48	R	Sand	Alluvium	D	Top, rock casing	0	872.5	20.25	10-15-50
11-19-25dc	E. L. Nottingham	Du	24.8	48	R	do	do	S	Conc. porch	2.0	872.1	19.4	10-15-50

TABLE 7.—*Records of wells in Kansas River Valley in Lawrence- Topeka area*

Well no.	Owner or Tenant	Type of well (1)	Depth of well, feet (2)	Diameter of well, in.	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Use of water (4)	Measuring point: Description	Measuring point: Feet above land surface	Measuring point: Feet above mean sea level	Depth to water level (5)	Date of measurement
11-19-27bc	Buck Creek School	Du	32.7	36	R	Silt	Sanborn	P	Top conc. curb	0.2	884.6	26.3	7- 6-50
11-19-27cc	Dora Amerine	Dr	58.1	10	C	Sand & Gravel	do	D	do	0	864.9	32.2	6-20-50
11-19-28ac	———	Du	32.6	36	R	Shale	Lawrence	N	do	0.3	923.5	30.2	7-22-50
11-19-28bc	Cemetary	Du	17.1	18	C	Limestone	Oread	P	do	0.6	901.0	8.9	6-20-50
11-19-29bc	———	Du	24.3	36	R	Sand	Alluvium	N	Top of casing	0	856.1	15.2	9- 5-50
11-19-30aa	M. E. Stallard	Du	25.5	60	R	do	do	D	Top wood platform	2.0	843.1	13.0	8-31-50
12-15-15ba	S. J. Shirley	Dr	70	6	I	Limestone	Pennsylvanian	D	Top casing	0.8	965.0	9.93	8-10-50
12-15-17bb	Grange No. 665	Du	—	70	R	Sand	Alluvium	D	Top conc. cover	1.0	—	9.59	8-10-50
12-16-12dc	J. Hafele	Du	35	60	R	Limestone	Pennsylvanian	D	do	0.8	965.0	7.52	8-10-50
12-16-20cc	F. E. Osborn	Du	20	36	B	do	do	D	Top curb	0.3	—	6.9	8-10-50
12-17-1da	Myron Nelson	Du	13	72	R	do	do	S	Top conc. cover	1.0	1065.0	4.3	8-24-50
12-17-2cc	R. C. Traxler	Du	40	60	R	do	do	D	Top of wood wall	6.0	1110.0	18.42	8-11-50
12-17-16bb	Shawnee County	Du	33.7	180	R	Sand	Alluvium	P	Top conc. cover	2.5	960.0	9.34	8-24-50
12-18-1bb	———	Du	46.2	60	R	Limestone	Deer Creek	D	Top, wooden platform	2.5	910.0	22.2	9-20-50
12-18-2ac1	M. J. Coleman	Du	17.2	36	C	do	do	D	Top, brick curb	2.3	995.0	16.7	9-20-50
12-18-2ac2	Anderson	Du	13.0	36	R	Shale-limestone	Jackson Park	N	Top casing	0	935.0	10.3	6-22-50
12-18-2bb	John Taylor	Du	27.1	48	B	Shale	Kanwaka	D	Top wood platform	0.9	1040.0	19.1	6-23-50
12-18-2db	———	Du	14.5	24	R	do	do	N	Top wood platform S. side	0	950.0	11.4	6-23-50
12-18-3bc	Joe Smith	Du	24.7	42	R	Limestone	Lecompton	D	Top wood planking	0.9	880.0	23.7	6-22-50
12-18-13cd	Winter School	Du	18.0	36	R	do	do	P	Top casing	0	1030.0	9.6	6-22-50
12-19-4dd	W. Brune	Dr	81.1	16	I	Sand & Gravel	Alluvium	I	do	0	831.0	12.0	6-25-50
12-19-6cd	———	Du	29.9	36	R	Shale	Lawrence	S	do	3.0	920.0	19.1	6-19-50
12-19-7ac	———	Du	19.2	48	R	Limestone	Oread	D, S	Top wood platform S. side	0.6	950.0	4.6	6-23-50
12-19-8ac	———	Du	9.6	48	R	do	do	N	Top wood platform	1.7	975.0	2.3	6-22-50
12-19-8bd	School District No. 69	Du	12.4	14	GI	Shale-limestone	Kanwaka	D	do	0.9	990.0	9.3	6-22-50

12-19-10cc	Cerophyl Lab., Inc.	Dr	52.0	8	I	Sand & Gravel	Alluvium	In	Top conc. curb	—0.6	832.5	13.3	6-22-50
12-19-10cd	Gun Trader's Club	Du	23.2	3	I	Sand	do	D	do	0	832.2	13.3	6-10-50
12-19-12aa	Emil Heck	Dr	48.7	7	I	do	do	In	Top casing	6.3	833.1	15.9	6-10-50
12-19-14bd1	Kansas Power and Light Company	Dr	52.0	8	I	Sand & Gravel	do	In	Land surface	0	—	8.7	8-13-50
12-19-14bd2	do	Dr	53.0	8	I	do	do	In	do	0	—	9.1	8-13-50
12-19-14cd	Ben Kowing	Dr	208.0	3	I	Sandstone	Tonganoxie	D, S	Top conc. curb	0.2	920.0	114.0	6-26-50
12-19-15bc	Lakeview Fishing Assoc.	Dr	92.0	8	I	Sand & Gravel	Alluvium	D	do	2.0	838.0	13.7	6-19-50
12-19-15cc	———	Du	31.8	36	R	Silt & Sand	do	N	do	0.4	840.0	20.0	6-27-50
12-19-16cc	Barker School	Du	21.8	36	R	Limestone	Oread	D	Top. conc. curb	1.0	987.0	16.8	6-24-50
12-19-17ac	C. Allen	Du	16.2	24	R	do	do	S	do	0.6	950.0	4.6	6-19-50
12-19-22ab	S. O. Gentry	Dr	90.0	6	I	Sand & Gravel	Meade	D, S	do	0.4	860.0	35.0	6-27-50
12-19-22dd	———	Du	11.0	48	R	Silt	do	S	do	0.8	900.0	4.6	6-27-50
12-19-23aa	Leonard Hills	Dr	52.0	6	I	Sand & Gravel	do	D, S	do	0.3	880.0	50.0	6-26-50
12-19-23ab	do	Dr	133.0	6	C	Shale lime-stone, sand stone	Lawrence	N	Top conc. curb S. side	1.5	890.0	74.5	6-26-50
12-19-23ba	N. W. Goff	Dr	130	6	I	Sandstone	Tonganoxie	D	Top wood platform	0.6	900.0	60.0	6-27-50
12-19-23cd	Oatman	Du	49.0	30	B	Sand & Gravel	Meade	D	Top conc. platform at manhole	0.9	890.0	40.1	6-26-50
12-19-23dc	A. C. Edwards	Dr	185.0	6	GI	Sandstone	Tonganoxie	D, S	Top of manhole	2.1	890.0	61.1	6-26-50
12-19-23dd	———	Du	20.0	48	R	Silt, sand	Meade	S	Top wood platform E. side	1.0	890.0	16.2	6-26-50
12-19-24bb1	J. A. Wingert	Dr	114.0	5	I	Shale, sandstone	Lawrence	D	Top conc. blocks	0.2	865.0	7.1	6-26-50
12-19-24bb2	do	Du	32.0	36	R	Silt, sand	Meade	N	Top conc. curb	0.7	865.0	29.5	6-27-50
12-19-24bd	Carl Miller	Dr	137.0	6	I	Sandstone	Tonganoxie	D	do	0.4	890.0	112.0	6-10-50
12-19-24ca	B. W. Bales	Du	50.5	36	C	Limestone	Lawrence	D	do	0.3	870.0	48.0	6-23-50
12-19-24db	———	Du	38.6	36	R	Shale	do	N	Top wood platform N. side	1.5	835.0	17.4	6-23-50
12-19-25cb	———	Du	21.2	36	R	do	do	N	Top conc. curb S. side	0	880.0	12.5	6-26-50
12-19-26ab	Farris	Dr	129.0	7	GI	Sandstone	Tonganoxie	D	Top casing	-5.5	885.0	76.7	6-25-50
12-20-17cd	W. H. Hayden	Dr	54.0	19	GI	Sand & Gravel	Alluvium	I	SE cor. tile wall	0.2	818.8	9.3	6-26-50
12-20-18ba	Fred Laptad	Dn	36.6	1.3	I	Sand	do	S	Top conc. curb S. side	0.8	827.9	10.0	6-27-50

1. Dd, dug and drilled well; Dn, driven well; Dr, drilled well; Du, dug well.
2. Reported depths below land surface given in feet, measured depths given in feet and tenths.
3. B, Brick; C, concrete; GI, galvanized sheet iron; GP, galvanized iron pipe; I, iron; N, none; R, rock.
4. D, Domestic; I, irrigation; In, industrial; N, not being used; O, observation; P, public supply; S, stock.
5. Measured depths to water level are given in feet, tenths, and hundredths; reported depths to water level are given in feet. All depths are below measuring point.

cated in parentheses at the top of each of his logs. In addition, logs of 2 auger holes and descriptions of 3 measured sections are included.

11-15-11aa. *Sample log of test hole in the SE¼ NE¼ NE¼ sec. 11, T. 11 S., R. 15 E., Shawnee County; drilled 1950. Surface elevation, 981 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Kansas till		
Clay, sandy, red; contains scattered granules and pebbles of quartz	8	8
Clay, light blue-gray	4	12
Clay, silty, yellow; contains abundant pebbles of granite, quartz, and quartzite	12.5	24.5
Boulders, limestone; contains silty shale and clay	5.5	30
Sand, coarse to medium	3	33
PENNSYLVANIAN—Virgilian		
Limestone interbedded with soft shale	5	38
Shale, silty, blue	2	40

11-15-11da. *Sample log of test hole in the NE¼ NE¼ SE¼ sec. 11, T. 11 S., R. 15 E., Shawnee County; drilled 1950. Surface elevation, 953.4 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Meade formation		
Silt, sandy, red	4.5	4.5
Silt, clayey, red	5.5	10
Silt, clayey, reddish-brown; contains some sand	2	12
Silt, clayey, yellow-brown; contains some sand	16	28
Sand, coarse to medium; contains occasional pebbles scattered throughout and clay layers at bottom	13	41
Kansas till (?)		
Clay, silty, yellow; contains some sand	9	50
Clay, silty, light-gray	2.5	52.5
PENNSYLVANIAN—Virgilian		
Limestone, blue-gray	1.0	53.5

11-15-12cc. *Sample log of test hole in the SW¼ SW¼ sec. 12, T. 11 S., R. 15 E., Shawnee County; drilled 1950. Surface elevation, 885.0 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene to Recent		
Alluvium		
Clay, silty, dark-brown	5	5
Silt, coarse, brown	13.5	18.5
Sand, fine, tan; contains coarse silt	6	24.5
Sand, coarse; contains some pebbles	9.5	34
PENNSYLVANIAN—Virgilian		
Shale, silty, blue	1	35
Limestone, white	1	36

11-15-13bc. *Sample log of test hole in the SE¼ SW¼ NW¼ sec. 13, T. 11 S., R. 15 E., Shawnee County; drilled 1950. Surface elevation, 890.5 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Late Pleistocene to Recent		
Alluvium		
Silt, sandy, dark-brown	2	2
Clay, silty, brown	6	8
Silt, sandy, light-brown	3.5	11.5
Clay, silty, light-brown	11.5	23
Clay, silty, blue-gray	5	28
Sand, coarse; contains some granules	9	37
Gravel, sandy	31	68
Sand, fine to medium	7	75
Gravel, very coarse; contains chert and limestone cobbles	12	87
PENNSYLVANIAN—Virgilian		
Shale, silty, blue	3	90

11-15-13ad2. *Drillers log of Goodyear water well No. 4 in the SE¼ NW¼ sec. 13, T. 11 S., R. 15 E., Shawnee County; drilled 1944. Surface elevation, about 891 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Late Pleistocene to Recent		
Alluvium		
Black soil	3	3
Joint clay, hard	3	6
Clay	19	25
Clay, hard, blue	10	35
Clay, soft, blue	3	38
Sand	7	45
Clay, sandy (lots of wood)	5	50
Sand and gravel, coarse	15	65
Clay, blue	4	69
Sand, coarse, gravel, and lots of boulders	3	72

11-15-13ca. *Drillers log of Goodyear test hole No. 5 in the NE¼ NE¼ SW¼ sec. 13, T. 11 S., R. 15 E., Shawnee County; drilled 1944. Surface elevation about 890 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Late Pleistocene and Recent		
Alluvium		
Soil	1	1
Clay, black	3	4
Clay	26	30
Sand, fine	3	33
Sand, coarse, brown (loose)	20	53
Sand and gravel, few boulders	19	72
Sand, gravel, and boulders	17.5	89.5
PENNSYLVANIAN—Virgilian		
Rock	0	89.5

11-15-13cb. *Drillers log of Goodyear test hole No. 6 in the SW¼ NW¼ SW¼ sec. 13, T. 11 S., R. 15 E., Shawnee County; drilled 1944. Surface elevation, about 892 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Late Pleistocene to Recent		
Alluvium		
Soil	1	1
Clay	19	20
Fine sand	4	23
Sand, medium-coarse, brown	20	43
Sand, gravel, and some clay balls	32	75
Sand, gravel, and boulders	15.5	87.5
PENNSYLVANIAN—Virgilian		
Rock	0	87.5

11-15-13cd. *Sample log of test hole in the NW¼ SE¼ SW¼ sec. 13, T. 11 S., R. 15 E., Shawnee County; drilled 1950. Surface elevation, 890.2 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Late Pleistocene to Recent		
Alluvium		
Silt, dark-brown	5	5
Clay, silty, brown	8	13
Sand, very fine	9	22
Sand, coarse; contains some granules	22	44
Gravel; contains granite, quartz, chert, and some limestone	7	51
Sand, coarse; contains some gravel	15	66
Gravel; contains some granules	13	79
PENNSYLVANIAN—Virgilian		
Limestone, shaly, gray-white	1	80
Siltstone, yellow-brown	3.5	83.5
Shale, blue	1	84.5

11-15-14aa. *Drillers log of the Howard Jackson irrigation well in the SW¼ NE¼ NE¼ sec. 14, T. 11 S., R. 15 E., Shawnee County; drilled 1933. Surface elevation, 891.4 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Late Pleistocene to Recent		
Alluvium		
Top soil	5	5
Clay, sandy	7.5	12.5
Clay, brown	10.5	23
Clay, reddish	8	31
Sand, fine	7	38
Sand, clean, coarse	22	60
Sand, yellow, streaked with silt and clay	5	65
Sand, clean, coarse	15	80
Sand, yellow, streaked with silt and clay	4	84
Sand, clean, coarse	3	87

11-15-14cc. *Drillers log of Goodyear test hole No. 1 in the NW¼ SE¼ SE¼ sec. 14, T. 11 S., R. 15 E., Shawnee County; drilled 1944. Surface elevation, about 894 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Late Pleistocene to Recent		
Alluvium		
Soil	1	1

Clay, yellow	10	11
Joint clay	4	15
Clay	10	25
Sand, coarse, brown	2	27
Sand, coarse, uniform, loose, with some gravel	28	55
Sand, medium-fine to coarse	10	65
Sand and gravel; contains some fine sand with small boulders	17	82
PENNSYLVANIAN—Virgilian		
Shale	0	82

11-15-14cd. *Drillers log of Goodyear test hole No. 2 in the SW¼ SE¼ SW¼ sec. 14, T. 11 S., R. 15 E., Shawnee County; drilled 1944. Surface elevation, about 885 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Late Pleistocene to Recent		
Alluvium		
Soil	1	1
Clay	9	10
Sand, medium fine	15	25
Sand, coarse, loose, brown, and a few boulders	25	40
Sand, fine to coarse, with scattered clay balls, a few boulders, and gravel	22.8	62.8
PENNSYLVANIAN—Virgilian		
Shale	0	62.8

11-15-24bc. *Sample log of test hole near the SE cor. SW¼ NW¼ sec. 24, T. 11 S., R. 15 E., Shawnee County; drilled 1950. Surface elevation, 884.6 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Late Pleistocene to Recent		
Alluvium		
Clay, silty, brown	8.5	8.5
Sand, medium, quartz and feldspar	6.5	15
Clay, silty, light-brown	0.5	15.5
Granules; contains some sand and gravel	29.5	45
Gravel, coarse; contains many boulders of limestone	4	49
PENNSYLVANIAN—Virgilian		
Limestone, light-gray	1	50
Shale, calcareous, gray	0.5	50.5
Shale, silty, blue	3	53.5

11-15-25bb. *Sample log of test hole in the SE¼ NW¼ NW¼ sec. 25, T. 11 S., R. 15 E., Shawnee County; drilled 1950. Surface elevation, 883 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Late Pleistocene to Recent		
Alluvium		
Silt, coarse, brown; contains some sand	4	4
Silt, clayey, dark-brown; contains some sand and caliche nodules	4	8
Silt, clayey; contains abundant sticks, leaves, and twigs	2	10
Sand, medium, layers of clay, and silt toward bottom	18	28
Granules; contains some sand and gravel	8	36
Log, rotten	0.5	36.5
Sand, coarse	7.5	44
Gravel; contains some sand	4	48

PENNSYLVANIAN—Virgilian		
Shale, silty, light blue-gray	2	50
Siltstone, sandy	4	54
Shale, silty, light blue-gray	2	56

11-15-26ab. *Drillers log of State Hospital well No. 3 in the NW¼ NE¼ sec. 26, T. 11 S., R. 15 E., Shawnee County; drilled 1940. Surface elevation, about 885 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Late Pleistocene to Recent		
Alluvium		
Top soil	10	10
Sand, medium fine	15	25
Sand, fine, and some gravel	3	28
Sand, coarse	2	30
Sand, coarse, and clay balls	2	32
Sand, coarse	8	40
Sand, coarse, clean	5	45
Sand, coarse, and large gravel	3	48
Sand, coarse	3	51
PENNSYLVANIAN—Virgilian		
Shale	0	51

11-15-26bc. *Sample log of auger hole in the SW¼ NW¼ sec. 26, T. 11 S., R. 15 E., Shawnee County*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Peoria silt member		
Silt, slightly clayey, dark-brown	0.1	0.1
Silt, brown	0.9	1.0
Silt, tan; contains plant remains	4.7	5.7
Silt, tan; contains scattered caliche nodules 8 to 10 mm in diameter	0.4	6.1
Silt, mottled tan and reddish-brown	0.3	6.4
Loveland silt member		
Silt, clayey, light-reddish-brown	1.6	8.0
Kansas till		
Sand, clayey, red	1.4	9.4
Till, highly leached and oxidized, red; contains scattered pebbles of granite, chert, and pink quartzite	0.2	9.6

11-16-29cd. *Drillers log of Santa Fe water well No. 2 in the SE¼ SE¼ SW¼ sec. 29, T. 11 S., R. 16 E., Shawnee County; drilled 1928. Surface elevation, 886 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Late Pleistocene to Recent		
Cinders and fill	9.3	9.3
Alluvium		
Sand, fine, and clay	20	29.3
Sand, coarse, and gravel	38	67.3
PENNSYLVANIAN—Virgilian		
Bedrock	0	67.3

11-16-30ca. *Drillers log of Beatrice Foods, Inc., water well in the NE¼ SW¼ sec. 30, T. 11 S., R. 16 E., Shawnee County. Surface elevation, about 880 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Late Pleistocene to Recent		
Alluvium		
Soil and fill	7	7
Gumbo	8	15
Sand	13	28
Gravel and coarse sand	12	40
Sand, medium-coarse, and small gravel	5	45
Gravel, coarse	5	50
Sand, coarse	13	63
Gravel and coarse sand	8	71
PENNSYLVANIAN—Virgilian		
Limestone, buff	0	71

11-18-5da. *Sample log of test hole in the NE¼ SE¼ sec. 5, T. 11 S., R. 18 E., Jefferson County; drilled in 1950. Surface elevation, 855 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil, silty, black	2	2
Silt, clayey, dark-brown	12	14
Silt, clayey, light-brown	10	24
Clay, bluish-gray	3	27
Silt, clayey, light-brown	4	31
Sand, fine, dark-gray	6	37
Sand, medium to coarse, consisting mainly of quartz and feldspar, dark-gray	22	59
Gravel, coarse	7	66
Sand, fine, light-brown	2	68
Gravel, coarse	7	75
PENNSYLVANIAN—Virgilian		
Shale, bluish-gray	2	77

11-18-9bb. *Sample log of test hole in the NW¼ NW¼ sec. 9, T. 11 S., R. 18 E., Jefferson County; drilled 1950. Surface elevation, 877 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Meade formation		
Silt, clayey, pink to light-red	4	4
Silt, sandy, fine, brownish-gray to gray-green	9	13
Sand, medium to coarse, few quartz pebbles and some black carbonaceous remains	7	20
Same as above with fine pebbles of chert, sandstone, quartz, pink quartzite, and granite	5	25
PENNSYLVANIAN—Virgilian		
Siltstone, yellow	1	26
Shale, soft, blue	5	31
Siltstone, lime-cemented, yellow	1	32

11-18-16ba. *Sample log of test hole in the NW¼ NW¼ sec. 16, T. 11 S., R. 18 E., Jefferson County; drilled 1950. Surface elevation, 848 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Clay, silty to sandy, dark-brown	7	7

	Thickness, feet	Depth, feet
Silt, clayey, fine-grained, brown	3	10
Silt, sandy, fine, brown, with sandy limonite concretions	12	22
Sand, quartzose, medium-grained, dark blue-gray, some limestone, chert, and shale pebbles and a few wood fragments	18	40
Sand, fine to medium	6	46
Gravel, coarse, mostly chert, some limestone, quartz, and granite	12	58
Gravel, coarse	2	60
Sand, coarse, with quartz and feldspar	9	69
Clay, hard, yellow	1	70
Sand, coarse, with quartz and feldspar	5	75
PENNSYLVANIAN—Virgilian		
Alternate layers of limestone and shale	4	79
Shale, dark-gray	1	80

11-18-21ba. *Sample log of test hole in the NE¼ NW¼ sec. 21, T. 11 S., R. 18 E., Jefferson County; drilled 1950. Surface elevation, 853 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Silt, clayey, dark-brown	2	2
Clay, silty, brown to yellow	14	16
Sand, fine to medium	1	17
Clay, silty, yellow-brown	2	19
Sand, feldspar, medium to coarse	9	28
Clay, silty, yellow-brown	1	29
Sand, medium	7	36
Clay and sand, fine	2	38
Sand, feldspar and quartz, coarse	2	40
Sand, fine	6	46
Gravel, coarse, with some chert	1	47
PENNSYLVANIAN—Virgilian		
Limestone, soft, yellow	2	49
Shale, blue	1	50

11-18-22ac. *Drillers log of water well in the SW¼ NE¼ sec. 22, T. 11 S., R. 18 E., Jefferson County; drilled 1948. Surface elevation, 848 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil	3	3
Clay, black	27	30
Sand, fine, tan	6	36
Sand, medium, gray	9	45
Sand, medium to coarse, gray	7	52
Sand, coarse, and gravel	13	65
Sand, coarse, and gravel, with some quartzite boulders	15	80
PENNSYLVANIAN—Virgilian		
Limestone and shale		

11-18-28ba. *Sample log of test hole in the NE¼ NW¼ sec. 28, T. 11 S., R. 18 E., Jefferson County; drilled 1950. Surface elevation, 847 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Silt, sandy, fine, light-brown	5	5
Quartz and feldspar, fine to medium	5	10
Sand, medium to coarse, consisting of quartz and feldspar	18	28
Granules and gravel of feldspar and granite	5	33
Clay, silty	3	36
Sand, medium, feldspar	5	41
PENNSYLVANIAN—Virgilian		
Limestone chips, yellow	2	43

11-18-28cd. *Sample log of test hole in the SE¼ SW¼ sec. 28, T. 11 S., R. 18 E., Douglas County; drilled 1950. Surface elevation, 843 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Clay, silty, dark	3	3
Silt, clayey, brown	2	5
Sand, medium to coarse, feldspar and quartz	6	11
Clay, silty, dark-brown	1	12
Sand, medium, quartz and feldspar	11	23
Granules, coarse, and limestone boulder	1	24
Gravel, coarse, and granules	6	30
Gravel, coarse, and granules and cobbles	7	37
Sand, coarse, and boulders	11	48
PENNSYLVANIAN—Virgilian		
Shale, yellow-brown to light blue-gray	2	50
Shale, soft, blue, with thin layer of brown siltstone	5	55

11-19-27bc. *Sample log of test hole in the SW¼ NW¼ sec. 27, T. 11 S., R. 19 E., Jefferson County; drilled 1950. Surface elevation, 887 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Soil, black	2	2
Silt, clayey, red, sometimes gritty with caliche	38	40
Clay, silty, red, gritty with caliche	10	50
Clay and silt, reddish-brown	12	62
Clay and silt, red, with a few shale pebbles	28	90
PENNSYLVANIAN—Virgilian		
Shale, gray	7	97

11-19-33ad. *Sample log of test hole in the SE¼ NE¼ sec. 33, T. 11 S., R. 19 E., Jefferson County; drilled 1950. Surface elevation, 843 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Silt, clayey, fine, dark-brown	6	6
Silt, light to medium brown, with some clay	8.5	14.5
Clay, silty, light-brown	10.5	25
Clay, silty, brownish-gray with plant remains	8	33
Sand, quartzite, and granules of feldspar	7	40

Sand, coarse, quartzite	5	45
Sand, coarse, quartzitic, and gravels of feldspar	15	60
PENNSYLVANIAN—Virgilian		
Shale, blue	2	62

11-19-33dd. *Sample log of test hole in the SE¼ SE¼ sec. 33, T. 11 S., R. 19 E., Jefferson County; drilled 1950. Surface elevation, 834 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Road fill of fine gravel	1.5	1.5
Clay, silty, dark-gray	3.5	5
Clay, silty, dark-brown	9.5	14.5
Sand, silty, fine, with feldspar and quartz	21.5	36
Sand, coarse, and granules of feldspar and quartz	13	49
PENNSYLVANIAN—Virgilian		
Limestone	2.5	51.5

11-19-34cc. *Sample log of test hole in the SW¼ SW¼ sec. 34, T. 11 S., R. 19 E., Jefferson County; drilled 1950. Surface elevation, 833 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Silt, clayey, dark-brown	3	3
Clay, silty, brown	13	16
Clay, blue-gray, some silt	4	20
Silt, fine, and sand	13	33
Sand, coarse, and gravel of feldspar and quartz	7	40
Sand, fine to medium, quartz and feldspar	8	48
PENNSYLVANIAN—Virgilian		
Limestone, white	1	49

12-19-9ad. *Sample log of test hole in the SW¼ NE¼ sec. 9, T. 12 S., R. 19 E., Douglas County; drilled 1950. Surface elevation, 828 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Sand, fine to coarse, composed of quartz and feldspar	8	8
Sand, medium to coarse; contains snail shells	12	20
Sand, coarse, quartzitic	10	30
Sand, coarse, and granules of feldspar	18	48
Sand, coarse, and gravel containing limestone fragments	12	60
Gravel, coarse, and granules of quartz and feldspar with weathered shale	8	68
PENNSYLVANIAN—Virgilian		
Shale, blue-gray	2	70

12-19-14bd. (Lohman, p. 64) *Drillers log of water well in the SE¼ NW¼ sec. 14, T. 12 S., R. 19 E., Douglas County.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil	3	3
Clay, sandy	8	11

Sand, fine	4	15
Sand, medium to coarse	5	20
Sand, fine	3	23
Sand, medium to coarse	7	30
Clay	1	31
Gravel and sand	14	45
Gravel and sand, few boulders	7	52
PENNSYLVANIAN—Virgilian		
Lawrence shale		

12-19-14bd. (Lohman, p. 64) *Drillers log of water well in the SE¼ NW¼ sec. 14, T. 12 S., R. 19 E., Douglas County.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil	3	3
Clay	11	14
Sand, fine	4	18
Sand, coarse, some gravel	12	30
Clay	5	35
Sand, coarse, some gravel	10	45
Gravel and sand	8	53
PENNSYLVANIAN—Virgilian		
Lawrence shale		

12-19-15cd. *Sample log of test hole in the SE¼ SW¼ sec. 15, T. 12 S., R. 19 E., Douglas County; drilled 1950. Surface elevation, 860 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Soil, clayey, black	3	3
Silt and clay, brown	4	7
Silt, clayey, red	33	40
Silt, clayey, red, with some fine sand	12	52
Sand, medium, to gravel	1	53
PENNSYLVANIAN—Virgilian		
Shale, blue-gray	1	54

12-19-24. (Lohman, T-11) *Sample log of test hole in the Cen. sec. 24, T. 12 S., R. 19 E., Douglas County; drilled 1940. Surface elevation, 856.1 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Meade formation		
Soil, clay, silty, dark	3	3
Clay, silty, yellow-brown	6	9
Clay, silty, light-gray	3	12
Sand, fine to coarse, dirty	4.5	16.5
Sand and gravel, poorly sorted, orange-brown	3.5	20
PENNSYLVANIAN—Virgilian		
Lawrence shale		
Shale, and sandstone, yellow-green to gray	5.5	25.5
Shale, dark blue-gray	4.5	30

12-19-24a. (Lohman, T-10) *Sample log of test hole in the Cen. NE¼ sec. 24, T. 12 S., R. 19 E., Douglas County; drilled 1940. Surface elevation, 821.4 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil, silty, dark	11	11
Sand, coarse to fine, and fine gravel	9	20
Sand, coarse, and fine gravel	2	22
Sand, coarse to fine, and fine gravel	8	30
Sand, coarse to medium	10	40
Sand, coarse	9	49
PENNSYLVANIAN—Virgilian		
Lawrence shale		
Shale, sandy, light-gray, and sandstone	1	50

12-19-24ad. (Lohman, T-8) *Sample log of test hole in the SE¼ NE¼ sec. 24, T. 12 S., R. 19 E., Douglas County; drilled 1940. Surface elevation, 819.2 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil, sandy, brown	1	1
Soil, black	7	8
Sand, medium to fine, brown	2	10
Sand, medium to fine	9	19
Sand, medium to coarse, gray	11	30
Gravel, coarse to fine, and coarse to medium sand	10	40
Gravel, fine, and coarse sand	6	46
PENNSYLVANIAN—Virgilian		
Lawrence shale		
Shale, sandy, light-gray	4	50

12-19-24ad. (Lohman, T-9) *Sample log of test hole in the SE¼ NE¼ sec. 24, T. 12 S., R. 19 E., Douglas County; drilled 1940. Surface elevation, 821.6 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Sand, fine, earthy	10	10
Sand, coarse, and fine gravel	13	23
Sand, coarse	7	30
Sand, coarse to medium	10	40
Sand, medium	7.5	47.5
PENNSYLVANIAN—Virgilian		
Lawrence shale		
Shale, sandy, light-gray, and sandstone	2.5	50

12-19-24dac. (Lohman, T-6) *Sample log of test hole in the SW¼ NE¼ SE¼ sec. 24, T. 12 S., R. 19 E., Douglas County; drilled 1940. Surface elevation, 817.7 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil, sandy, dark	4	4
Sand, medium, brown	16	20
Sand, medium to coarse	4	24
Sand, medium, to fine gravel	6	30

	Thickness, feet	Depth, feet
Sand, coarse	10	40
Gravel, medium and coarse, some fine	7.5	47.5
PENNSYLVANIAN—Virgilian		
Lawrence shale		
Shale, sandy, gray, and sandstone	2.5	50

12-19-25aa. (Lohman, T-1) *Sample log of test hole in the NE¼ NE¼ sec. 25, T. 12 S., R. 19 E., Douglas County; drilled 1940. Surface elevation, 815.5 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil, silty, dark; contains some sand and gravel	2.5	2.5
Soil, silty, dark	3.5	6
Soil, silty clay, dark-brown	7	13
Sand, coarse, and fine gravel	7	20
Gravel, medium, and coarse sand	10	30
Gravel, medium and fine	10	40
Gravel, coarse to fine	5.5	45.5
PENNSYLVANIAN—Virgilian		
Lawrence shale		
Shale, sandy, light-gray, and sandstone	4.5	50

12-19-25ad. (Lohman, T-2) *Sample log of test hole in the SE¼ NE¼ sec. 25, T. 12 S., R. 19 E., Douglas County; drilled 1940. Surface elevation, 815.8 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil, earthy, black	10.5	10.5
Clay, dark-blue to gray	10.5	21
Gravel, fine, and coarse sand	9	30
Gravel, medium to fine	10	40
Gravel, medium to fine	4.5	44.5
PENNSYLVANIAN—Virgilian		
Shale, sandy, gray, and sandstone	5.5	50

12-20-7adc. (Lohman, W-1) *Drillers log of water well in the SW cor. SE¼ NE¼ sec. 7, T. 12 S., R. 20 E., Douglas County.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Sand, fine to medium, gray	40	40
Sand, coarse, and fine gravel; brown	10	50
Sand, medium, and coarse gravel; brown	5	55
Gravel, coarse, and some sand; brown	8	63
Sand, medium, and coarse gravel	4	67
Gravel, coarse, and brown sand	3	70
Sand, medium, and coarse gravel	4	74
Gravel, medium, and fine sand	3	77
Gravel, coarse, and medium sand	3	80
Gravel, coarse, and fine sand; iron-stained and contains limonite concretions	3	83
PENNSYLVANIAN—Virgilian		
Lawrence shale		
Shale, silty	1	84

12-20-9cdd. (Lohman, T-19) *Sample log of test hole in the SE cor. SW¼ sec. 9, T. 12 S., R. 20 E., Douglas County; drilled 1940. Surface elevation, 883.0 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Meade formation		
Clay, silty, reddish	3	3
Clay, silty, light-gray and brown	4	7
Clay, silty, yellow	2	9
Clay, silty, orange-yellow and light-gray	5.5	14.5
Sand, fine to coarse, yellow-brown	6.5	21
Clay, silty; contains concretions of limonite	4	25
Clay, silty, orange-yellow and light-gray	2	27
Gravel, poorly sorted, orange-brown; contains concretions of limonite	6.5	33.5
Sand and gravel, brown, and some cobbles	10	43.5
PENNSYLVANIAN—Virgilian		
Lawrence shale		
Shale, gray	6.5	50

12-20-9da. *Sample log of test hole in the NE¼ SE¼ sec. 9, T. 12 S., R. 20 E., Douglas County; drilled 1949.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Meade formation		
Clay, slightly sandy, red-brown	1.5	1.5
Clay, sandy, buff, tan, and brown	5.5	7
Clay, sandy, dark-tan	5	12
Clay, tan to buff; thin hard ferruginous bands	4	16
Clay, sandy, soft, tan	7	23
Clay, very fine sand, tan	9.5	32.5
Clay and very fine sand, tan; thin ferruginous sandstone-like beds	19.5	52
Sand, coarse, and fine gravel; mostly igneous material and chert	6	58
Gravel, fine to medium; igneous material and chert	4.5	62.5
PENNSYLVANIAN—Virgilian		
Limestone, hard, gray, with shell fragments	0.5	63

12-20-17add. (Lohman, T-18) *Sample log of test hole in the SE cor. NE¼ sec. 17, T. 12 S., R. 20 E., Douglas County; drilled 1940. Surface elevation, 829.4 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil, silty, dark-brown	3	3
Soil, silty, clayey, dark	5	8
Clay, silty, dark	4	12
Clay, silty, light-brown	8	20
Clay, silty, light-yellow	6	26
Clay, silty, dark	3.5	29.5
Sand, medium, and some coarse sand	5.5	35
Sand, medium to coarse	4	39
Gravel, coarse to fine	11	50
Gravel, fine to coarse, and some coarse sand	12	62
Gravel, coarse to fine, and some coarse sand	8	70
Gravel, coarse to fine	9	79

	Thickness, feet	Depth, feet
PENNSYLVANIAN—Virgilian		
Lawrence shale		
Sandstone, yellow-green	1	80

12-20-17cd. (Lohman, W-3) *Drillers log of water well in the SE¼ SW¼ sec. 17, T. 12 S., R. 20 E., Douglas County.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Clay, brownish-yellow	13.5	13.5
Sand, fine, white	0.5	14
Clay, yellow-brown	12	26
Sand, coarse, and fine gravel	12	38
Clay, black	1	39
Gravel, coarse; contains boulders	3.5	42.5
Clay, black	4.5	47
Gravel, coarse, gray	7	54

12-20-17d. (Lohman, T-17) *Sample log of test hole in the Cen. SW¼ sec. 17, T. 12 S., R. 20 E., Douglas County; drilled 1940. Surface elevation, 815.7 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil, silty, sandy, dark	8	8
Soil, silty; contains abundant shell fragments	1	9
Sand, fine, brown	5	14
Sand, coarse to medium; and some fine gravel	7	21
Sand, coarse to medium, brown to green	5	26
Gravel, coarse, to medium sand	4	30
Gravel, coarse to fine	30	60
Gravel, coarse to medium	7.5	67.5
PENNSYLVANIAN—Virgilian		
Lawrence shale		
Sandstone, light-gray and brown	2.5	70
Sandstone, fine-grained, light-gray	10	80

12-20-19ba. (Lohman, T-29) *Sample log of test hole in the NE¼ NW¼ sec. 19, T. 12 S., R. 20 E., Douglas County; drilled 1940. Surface elevation, 817.5 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil, silty, dark (gumbo at top)	7	7
Sand, fine to coarse, interbedded with silty clay	4	11
Sand, coarse to medium, and fine to coarse gravel	10	21
Gravel, fine to coarse, and coarse to medium sand	9	30
Sand, coarse, and fine to coarse gravel	10	40
Gravel, fine to coarse, and fine to medium sand	5	45
PENNSYLVANIAN—Virgilian		
Lawrence shale		
Sandstone, hard, light-gray	4	49

12-20-19bcc. (Lohman, T-7) *Sample log of test hole in the SW cor. NW¼ sec. 19, T. 12 S., R. 20 E., Douglas County; drilled 1940. Surface elevation, 817.2 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil, sandy, dark	10	10
Sand, medium to coarse	10	20
Gravel, fine, and coarse sand	10	30
Sand, coarse, and fine gravel	10	40
Sand, coarse	3.5	43.5
PENNSYLVANIAN—Virgilian		
Lawrence shale		
Sandstone, hard, light-gray	5.5	49

12-20-19bd. (Lohman, T-28) *Sample log of test hole in the SE¼ NW¼ sec. 19, T. 12 S., R. 20 E., Douglas County; drilled 1940. Surface elevation, 822.5 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil, dark	1	1
Sand, fine, light-tan, and medium sand	15	16
Sand, coarse, gray, to medium gravel	14	30
Gravel, fine to coarse, and coarse sand	10	40
Gravel, coarse to fine, and some coarse sand	9.5	49.5
PENNSYLVANIAN—Virgilian		
Lawrence shale		
Clay, silty, light-gray, and sandy shale	0.5	50

12-20-19ca. (Lohman, T-27) *Sample log of test hole in the NE¼ SW¼ sec. 19, T. 12 S., R. 20 E., Douglas County; drilled 1940. Surface elevation, 815.9 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil, dark	1.5	1.5
Sand, medium, brown	9.5	11
Gravel, fine, and coarse sand	9	20
Gravel, fine to coarse, and coarse sand	10	30
Sand, coarse, and fine to coarse gravel	13.5	43.5
PENNSYLVANIAN—Virgilian		
Lawrence shale		
Clay, silty, light-gray, and shale	1.5	45

12-20-19cb. *Drillers log of Lawrence municipal well No. 3 in the NW¼ SW¼ sec. 19, T. 12 S., R. 20 E., Douglas County; drilled 1947.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Top soil	1	1
Rock ballast and chat	4	5
Clay, sandy	10	15
Sand, medium	8	23
Sand, muddy	4	27
Sand, coarse	16	43
Clay	1.5	44.5
Sand, coarse, and clay balls	9.9	54.4

12-20-19cc. *Drillers log of Lawrence municipal well No. 2 in the SW¼ SW¼ sec. 19, T. 12 S., R. 20 E., Douglas County; drilled 1945.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Fill	10	10
Clay, sandy	10	20
Sand, fine to medium	12	32
Sand, fine, well-packed	4	36
Sand, coarse	9	45
Sand, coarse, and gravel	6	51

12-20-19cc. (Lohman, T-5) *Sample log of test hole in the SW¼ SW¼ sec. 19, T. 12 S., R. 20 E., Douglas County; drilled 1940. Surface elevation, 818.0 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Sand, medium, brown	11	11
Sand, medium to coarse, brown	4	15
Sand, medium	5	20
Gravel, fine, to medium sand	10	30
Gravel, fine to coarse	10	40
Sand, coarse to medium	5.5	45.5
PENNSYLVANIAN—Virgilian		
Lawrence shale		
Shale, sandy, gray, and sandstone	4.5	50

12-20-19cd. (Lohman, T-26) *Sample log of test hole in the SE¼ SW¼ sec. 19, T. 12 S., R. 20 E., Douglas County; drilled 1940. Surface elevation, 820.0 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil; contains some sand and cinders	8	8
Clay soil, silty, gray	5	13
Sand, coarse to medium, and some fine gravel	17	30
Gravel, coarse to fine, and some coarse sand	10	40
Gravel, coarse to fine, and coarse sand	5	45
PENNSYLVANIAN—Virgilian		
Sandstone, light-gray, and sandy shale	5	50

12-20-19da. (Lohman, T-20) *Sample log of test hole in the NE¼ SE¼ sec. 19, T. 12 S., R. 20 E., Douglas County; drilled 1940. Surface elevation, 813.1 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil, sandy dark	3	3
Soil, clayey, silty, muddy gray	9	12
Gravel, fine to coarse, and coarse sand	9	21
Gravel, fine to coarse, and coarse sand	20.5	41.5
PENNSYLVANIAN—Virgilian		
Lawrence shale		
Sandstone, medium-grained, light-gray	3.5	45

12-20-20baa. (Lohman, T-16) *Sample log of test hole in the NE cor. NW¼ sec. 20, T. 12 S., R. 20 E., Douglas County; drilled 1940. Surface elevation, 821.5 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil, silty, dark	6	6
Soil, silty, brown	2	8
Sand, coarse, brown, and some medium sand	2	10
Sand, medium to coarse	10	20
Sand, coarse to medium, and some fine gravel	5	25
Sand, coarse, to coarse gravel	5	30
Sand, coarse to medium, and some fine gravel	9	39
Sand, coarse, to coarse gravel	4	43
Gravel, fine, and coarse sand	7	50
Gravel, fine to coarse, and coarse sand	10	60
Sand, coarse; contains boulders	12	72
PENNSYLVANIAN—Virgilian		
Lawrence shale		
Shale, sandy, gray, and sandstone	8	80

12-20-20bcc. (Lohman, T-15) *Sample log of test hole in the SW cor. NW¼ sec. 20, T. 12 S., R. 20 E., Douglas County; drilled 1940. Surface elevation, 829.4 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil, black	3	3
Clay, silty, light-brown	8	11
Sand, very fine to medium, tan	11	22
Sand, coarse, and some fine gravel	8	30
Sand, coarse, and fine to medium gravel	10	40
Sand, medium to coarse, and fine gravel	10	50
Sand, coarse to medium, and fine gravel	7	57
PENNSYLVANIAN—Virgilian		
Lawrence shale		
Shale, sandy, light-gray, and some hard brown sandstone	3	60

12-20-20da. (Lohman, W-14) *Drillers log of water well in the NE¼ SE¼ sec. 20, T. 12 S., R. 20 E., Douglas County.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil	6	6
Sand, fine, white	8	14
Sand and gravel, brown	3	17
Sand, fine, white	4	21
Gravel and sand, coarse, brown	14	35
Clay, black	1	36
Gravel, coarse, and brown sand	14	50

12-20-29ac. *Drillers log of test hole No. 1 at Westvaco Chemical Company in the SW¼ NE¼ sec. 29, T. 12 S., R. 20 E., Douglas County; drilled 1950. Surface elevation, 820 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Top soil, sandy, black	8	8
Clay, sandy, brown	4.6	12.6
Sand, fine, with clay streaks	3.3	15.9
Sand, medium, with clay streaks	4.1	20
Sand, coarse, with clay streaks	4.6	24.6
Sand, coarse, and gravel with clay balls	25.4	50
PENNSYLVANIAN—Virgilian		
Sandstone	4.9	54.9

12-20-29ac. *Drillers log of Westvaco Chemical Company well No. 1 in the SW¼ NE¼ sec. 29, T. 12 S., R. 20 E., Douglas County; drilled 1951.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Surface silt and loam	3	3
Sand, silty, fine, brown	15	18
Sand, fine to medium, brown	6	24
Sand, coarse, brown, with some silt streaks	4	28
Sand, medium to coarse, gray	6	34
Sand, coarse, gray, with streaks of heavy thick silt and lenses of gravel	10	44
Gravel, gray, with streaks of blue-gray silt and and fine to coarse sand	7	51
Clay and silt, blue, grading into sandstone	3	54

12-20-29ac. *Drillers log of test hole No. 2 at Westvaco Chemical Company in the SW¼ NE¼ sec. 29, T. 12 S., R. 20 E., Douglas County; drilled 1950. Surface elevation, 819 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Top soil, sandy, black	4.6	4.6
Sand, clayey, fine	4	8.6
Clay, black	1.1	9.7
Sand, fine, with clay streaks	14.3	24
Sand, medium, with clay streaks	6	30
Sand, coarse, with a few clay balls	11.6	41.6
Clay, gray	0.7	42.3
Sand, coarse, and gravel, with a few clay balls	11.1	53.4
PENNSYLVANIAN—Virgilian		
Sandstone	1.5	54.9

12-20-29ac. *Drillers log of Westvaco Chemical Company well No. 2 in the SW¼ NE¼ sec. 29, T. 12 S., R. 20 E., Douglas County; drilled 1951.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil, silt, and loam	3	3
Sand, silty, fine, yellowish-brown	11	14
Sand, fine, brownish-yellow	12	26

	Thickness, feet	Depth, feet
Sand, fine, gray, some silt streaks	11	37
Sand, coarse, gray	4	41
Sand, coarse, gray, and gravel, with lenses of blue silt	8	49
Sand, fine, grading to sandstone	2	51

12-20-29ac. *Drillers log of Westvaco Chemical Company well No. 3 in the SW¼ NE¼ sec. 29, T. 12 S., R. 20 E., Douglas County; drilled 1951.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil, silty loam	4	4
Sand, silty, fine	13	17
Sand, fine, yellow	9	26
Sand, medium to coarse	5	31
Sand, coarse, with silt lenses; clay at 43 feet	15	46
Sand, coarse, and gravel, with thin lenses of silt	11	57
Sand, coarse, and gravel, with silt streaks	11	68
Clay, black, with lenses of sand	7	75
PENNSYLVANIAN—Virgilian		
Shale, blue	0.5	75.5

12-20-29ad. *Drillers log of Westvaco Chemical Company well No. 4 in the SE¼ NE¼ sec. 29, T. 12 S., R. 20 E., Douglas County; drilled 1951.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil with yellow clay	5	5
Sand, fine, yellow, with much clay	10	15
Sand, fine, yellow	6	21
Sand, medium to coarse, gray	5	26
Sand, coarse, gray	26	52
Sand, coarse, gray, some gravel and clay streaks	16	68
Clay, dark-blue with some silt streaks and shale at base	6	74

12-20-29ad. *Drillers log of Westvaco Chemical Company well No. 5 in the SE¼ NE¼ sec. 29, T. 12 S., R. 20 E., Douglas County; drilled 1951.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil	2	2
Sand, fine, yellow, with some clay	14	16
Sand, yellow	5	21
Sand, coarse, yellow, with clay lenses	7	28
Sand, medium to coarse, gray	3	31
Sand, fine, with some clay	5	36
Sand, coarse, gray	5	41
Sand, coarse, and gravel	10	51
Sand, coarse, gray, and gravel, with lenses of clay	7	58
Clay, blue	3	61
Clay, grading into sandy shale	3	64

12-20-30aa. (Lohman, T-13) *Sample log of test hole in the NE¼ NE¼ sec. 30, T. 12 S., R. 20 E., Douglas County; drilled 1940. Surface elevation, 816.9 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Road fill, soil, and rock	6	6
Soil, silty, dark-brown	4	10
Sand, coarse and medium, and some fine gravel	10	20
Sand, coarse, and fine gravel	10	30
Sand, medium, to coarse gravel	10	40
Sand, medium, and some coarse sand	8	48
PENNSYLVANIAN—Virgilian		
Lawrence shale		
Coal, black, and sandy light-gray shale	2	50

12-20-30abb. (Lohman, T-14) *Sample log of test hole in the NW cor. NE¼ sec. 30, T. 12 S., R. 20 E., Douglas County; drilled 1940. Surface elevation, 816.6 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil, silty, sandy, brown	13	13
Sand, coarse to medium, and some fine gravel	7	20
Gravel, coarse to fine, and coarse to medium sand	10	30
Gravel, fine to coarse, and coarse sand	13.5	43.5
PENNSYLVANIAN—Virgilian		
Lawrence shale		
Sandstone, light-gray, a hard boulder bed just above it	6.5	50

12-20-30ba. (Lohman, T-12) *Sample log of test hole in the NE¼ NW¼ sec. 30, T. 12 S., R. 20 E., Douglas County; drilled 1940. Surface elevation, 816.2 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil, sandy, dark-brown	14	14
Sand, coarse, and medium sand	6	20
Gravel, medium and coarse, and coarse and medium sand	10	30
Sand, coarse, and fine to coarse gravel	10	40
Gravel, fine, and coarse sand	8	48
PENNSYLVANIAN—Virgilian		
Lawrence shale		
Shale, sandy, light-gray, and sandstone	2	50

12-20-30ba. (Lohman, T-21) *Sample log of test hole in the NE¼ NW¼ sec. 30, T. 12 S., R. 20 E., Douglas County; drilled 1940. Surface elevation, 811.0 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil, sandy, dark	8	8
Sand, medium to coarse, brown	4	12
Gravel, coarse to medium, and coarse to medium sand	8	20

Gravel, coarse to fine, and some coarse sand	10	30
Gravel, fine to coarse, and coarse sand	10	40
Sand, coarse, and fine to coarse gravel	2	42
PENNSYLVANIAN—Virgilian		
Lawrence shale		
Shale, sandy, light-gray	3	45

12-20-30ba. (Lohman, T-25) *Sample log of test hole in the NE¼ NW¼ sec. 30, T. 12 S., R. 20 E., Douglas County; drilled 1940. Surface elevation, 814.8 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil, dark	1.5	1.5
Silt, brown, and fine sand	6.5	8
Gravel, fine to coarse, and coarse to medium sand	6	14
Sand, coarse to medium, and fine to coarse gravel	6	20
Gravel, coarse to fine, and coarse sand	21	41
PENNSYLVANIAN—Virgilian		
Lawrence shale		
Sandstone, light-gray	4	45

12-20-30bb. *Drillers log of Lawrence municipal well No. 1 in the NW¼ NW¼ sec. 30, T. 12 S., R. 20 E., Douglas County; drilled 1944.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Sandy soil	1	1
River fill	4	5
Clay, soft, blue	13	18
Sand, fine, blue	7	25
Sand, medium to coarse	9	34
Sand, fine	3	37
Clay, blue, and rotten wood	0.5	37.5
Sand, fine	1.5	39
Sand, medium to coarse	3	42
Sand, coarse, and gravel; small rock	5	47

12-20-30bb. (Lohman, T-3) *Sample log of test hole in the NW¼ NW¼ sec. 30, T. 12 S., R. 20 E., Douglas County; drilled 1940. Surface elevation, 814.9 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil, dark	1	1
Sand, fine, light-tan	2	3
Clay, soft, dark	11	14
Gravel, fine to coarse, and coarse sand	6	20
Gravel, fine, and coarse sand	10	30
Sand, coarse, and fine gravel	10	40
Gravel, fine, and coarse sand	5	45
PENNSYLVANIAN—Virgilian		
Lawrence shale		
Shale, sandy, light-gray	5	50

12-20-30bc. (Lohman, T-4) *Sample log of test hole in the SW¼ NW¼ sec. 30, T. 12 S., R. 20 E., Douglas County; drilled 1940. Surface elevation, 814.4 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Meade formation		
Soil, earthy, black	5	5
Clay, dark-blue to gray	8	13
Sand, coarse to medium	7	20
Gravel, fine, and coarse to medium sand	7	27
Clay or sand (sample contained too much drilling mud to determine)	2	29
Sand, medium	5	34
Gravel, fine, and coarse sand	6	40
Sand, coarse, and fine gravel	4	44
PENNSYLVANIAN—Virgilian		
Lawrence shale		
Shale, sandy, light-gray	3	47

12-20-30bc. (Lohman, T-22) *Sample log of test hole in the SW¼ NW¼ sec. 30, T. 12 S., R. 20 E., Douglas County; drilled 1940. Surface elevation, 821.7 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Sand, fine, brown	9	9
Silt, soft, plastic, brown	2	11
Sand, coarse to medium	9	20
Sand, coarse to medium, and fine gravel	8	28
Clay, silty, dark-gray	10	38
Gravel, fine to coarse, and coarse to medium sand	12	50
Sand, coarse to medium, and some fine gravel	2.5	52.5
PENNSYLVANIAN—Virgilian		
Lawrence shale		
Sandstone, light-gray, and sandy shale	2.5	55

12-20-30bc. (Lohman, T-23) *Sample log of test hole in the SW¼ NW¼ sec. 30, T. 12 S., R. 20 E., Douglas County; drilled 1940. Surface elevation, 814.8 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil, sandy, brown	5	5
Sand, fine, brown	2	7
Clay, silty, dark	3	10
Sand, coarse, and fine gravel	10	20
Sand, coarse to medium, and some fine gravel	2.5	22.5
Clay, silty, dark blue-gray	13.5	36
Sand, coarse, and fine gravel	4	40
Sand, coarse to medium	6.5	46.5
PENNSYLVANIAN—Virgilian		
Lawrence shale		
Shale, sandy, light-gray, and sandstone	1.5	48

12-20-30bc. (Lohman, T-24) *Sample log of test hole in the SW¼ NW¼ sec. 30, T. 12 S., R. 20 E., Douglas County; drilled 1940. Surface elevation, 818.2 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil, sandy, brown	10.5	10.5
Sand, coarse to medium, brown	6.5	17
Sand, coarse, and fine gravel	3	20
Sand, coarse to medium, and fine gravel	10	30
Sand, coarse to medium, and fine to coarse gravel	10	40
Gravel, fine to coarse, and some coarse sand	9.5	49.5
PENNSYLVANIAN—Virgilian		
Lawrence shale		
Shale, sandy, light-gray, and sandstone	2.5	52

13-20-5cb. *Sample log of auger hole in the NW¼ SW¼ sec. 5, T. 13 S., R. 20 E., Douglas County.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Peoria silt member		
Silt, clayey, dark-brown, leached	1.0	1.0
Silt, mottled gray and brown, leached	2.0	3.0
Silt, mottled gray and brown, leached; contains small caliche nodules	0.5	3.5
Silt, mottled reddish-brown and gray, leached	1.5	5.0
Loveland silt member		
Silt, yellow-brown, leached; contains caliche nodules 2 mm in size	1.0	6.0
Silt, clayey, yellow-brown, slightly mottled, leached	0.5	6.5
Kansas till		
Clay, brown to reddish-brown, leached; contains MnO_2 stains, chert granules, and limonite nodules	1.5	8.0
Clay, silty, light reddish-brown; contains some chert and feldspar grains	1.8	9.8

11-16-16. *Section measured in abandoned gravel pit in the SE¼ NW¼ sec. 16, T. 11 S., R. 16 E., Shawnee County.*

	Thickness, feet
QUATERNARY—Pleistocene	
Kansas till	
6. Till, oxidized and leached, yellowish-brown; many parts reworked colluvially	4.5
5. Till, unleached, blue-gray; contains a high percentage of clay and large limestone boulders	5.9
Atchison formation	
4. Caliche, thin layer, white; absent in many places	0.1
3. Silt, coarse, light-gray to yellow; contains occasional oblate spheroidal concretions of coarse silt cemented with calcite, 30 to 100 mm. in diameter	15.0
2. Gravel, partially cemented with calcite; contains limestone and chert with about 2 percent glacial erratics	2.7

PENNSYLVANIAN—Virgilian	
Calhoun shale	
1. Shale, silty, yellowish-brown	6.5
Total measured	34.7

11-15-12. *Section measured along creek bank in the Cen. SW¼ sec. 12, T. 11 S., R. 15 E., Shawnee County.*

	Thickness, feet
QUATERNARY—Pleistocene	
Eolian sand	
5. Sand, fine, light-gray; contains considerable silt	2.1
Meade formation	
Sappa member	
4. Silt, sandy, reddish-yellow; contains scattered pebbles, is leached, and has columnar jointing	25.0
Grand Island member	
3. Sand with interbedded silt and small gravel	6.5
2. Gravel, coarse; contains abundant glacial erratics	3.0
PENNSYLVANIAN—Virgilian	
Severy shale	
1. Shale, thinly bedded, light-brown	2.5
Total measured	39.1

11-15-9. *Section measured in gravel pit in the Cen. SW¼ sec. 9, T. 11 S., R. 15 E., Shawnee County.*

	Thickness, feet
QUATERNARY—Pleistocene	
Meade formation—Grand Island member	
5. Sand, coarse to medium, reddish-brown; contains scattered siliceous pebbles	4.1
4. Conglomerate, calcareous cement; contains limestone, chert, granite, and various metamorphic rocks	1.0
3. Gravel, coarse; contains large quartzite and limestone boulders up to 2 feet in mean diameter and scattered lenses of sand	12.9
Kansas till	
2. Till, unleached, gray; interstratified with unsorted gravel and boulders	3.0
Atchison formation	
1. Gravel, cross-bedded; contains mostly limestone with less than 1 percent glacial erratics	8.1
Total measured	29.1

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Geologic Map of Kansas River Valley, Lawrence to Topeka

By Stanley N. Davis and William A. Carlson

1952

State Geological Survey of Kansas

Bulletin 96, Part 5, Plate 1

GENERALIZED STRATIGRAPHIC COLUMNS

EXPLANATION

QUATERNARY — PLEISTOCENE — Recent / Wisconsinan

Qd — Dune sand

Fine quartz sand. Not known to yield water to wells.

Qal — Alluvium

Silt and fine to medium sand grading downward into coarse sand and gravel in the deeper alluvial fill of Kansas River. Yields large amounts of water to wells in the Kansas River Valley. Water is hard but otherwise of good quality.

Qtn — Newman terrace

Terrace in the valleys is underlain by silt and silty clay which grades downward into sand and gravel. Yields large amounts of water to wells in the Kansas River Valley. Water is hard but otherwise of good quality.

Qs — Sanborn formation

Loess of Peoria and possibly Loveland members. Yields no water to wells.

QUATERNARY — PLEISTOCENE — Illinoian / Kansan

Qtb — Buck Creek terrace

Terrace is underlain by silt and sandy silt of the Sanborn formation. Local lenses of coarse silt and fine gravel in basal portion of terrace fill. Yields small amounts of water to wells.

Qtu — Undifferentiated middle Pleistocene colluvium and terraces

Fine silt and silty clay. Yields little water to wells.

Qtm — Menoken terrace

Terrace is underlain by silt, sand, and gravel of the Meade formation and by minor amounts of Kansas till and silt, sand, and gravel of the Atchison formation. Basal portion is usually gravel which yields moderate amounts of water of fair quality where it is in the zone of saturation.

Qk — Kansas till

Silt and clay with minor amounts of intermixed sand, gravel, and boulders. Yields virtually no water to wells and adversely affects ground-water recharge.

PENNSYLVANIAN — VIRGILIAN

IPvw — Wabaunsee group

Limestone interbedded with shale, siltstone, and sandstone. Limestone and sandstone locally yield moderate amounts of water to wells.

IPvs — Shawnee group

Limestone interbedded with shale, siltstone, and sandstone. Sandstone and solution channels in limestone locally yield moderate quantities of water to wells.

IPvd — Douglas group

Shale, siltstone, and sandstone with a few beds of limestone and coal. Sandstone in lower part of group yields moderate to large quantities of water to wells near Lawrence. Water from these rocks varies greatly in quality but is generally fair to good in the basal sandstone.


Map of Kansas River Valley, Lawrence to Topeka
GENERALIZED CONTOURS ON THE WATER TABLE
LOCATION OF WATER WELLS AND TEST HOLES
By Stanley N. Davis and William A. Carlson
1950
State Geological Survey of Kansas
Bulletin 96, Part 5, Plate 2
R.15 E.
R.16 E.
R.17 E.
R.18 E.
R.19 E.
R.20 E.
TOPEKA
TECUMSEH
GRANTVILLE
NEWMAN
PERRY
WILLIAMSTOWN
LECOMPTON
BIG SPRINGS
LAWRENCE
MENOKEN
KIRO
Kansas River
Shunganunga Creek
Lake Shawnee
Topeka municipal airport
Lawrence municipal airport
JEFFERSON CO.
DOUGLAS CO.
Base adapted from topographic quadrangles, U.S. Geological Survey
Topeka area served by municipal water system
Limit of area served by municipal water
Ground-water use (gallons per day):
2,000,000 - 2,500,000
1,500,000 - 2,000,000
1,000,000 - 1,500,000
500,000 - 1,000,000
100,000 - 500,000
Seasonal use—irrigation and air conditioning
County boundary
Township boundary
Section line
Federal or State highway
Graded road
Ungraded road
Railroad
Perennial stream
Intermittent stream
Lake or pond
Dam
EXPLANATION
Spring
Altitude of normal low water level in stream
Upper number refers to altitude of water table
Lower number is the depth to water level (from measuring point)
Brackets indicate water analysis
Logs from Lohman, 1940
Profiles and geologic sections
Scale in miles

GEOLOGIC CROSS SECTIONS

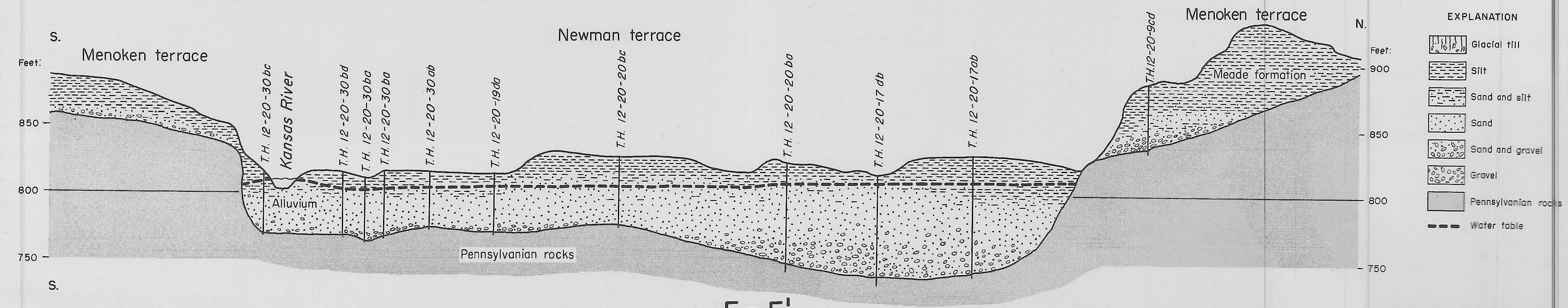
Kansas River Valley, Lawrence to Topeka

By Stanley N. Davis and William A. Carlson

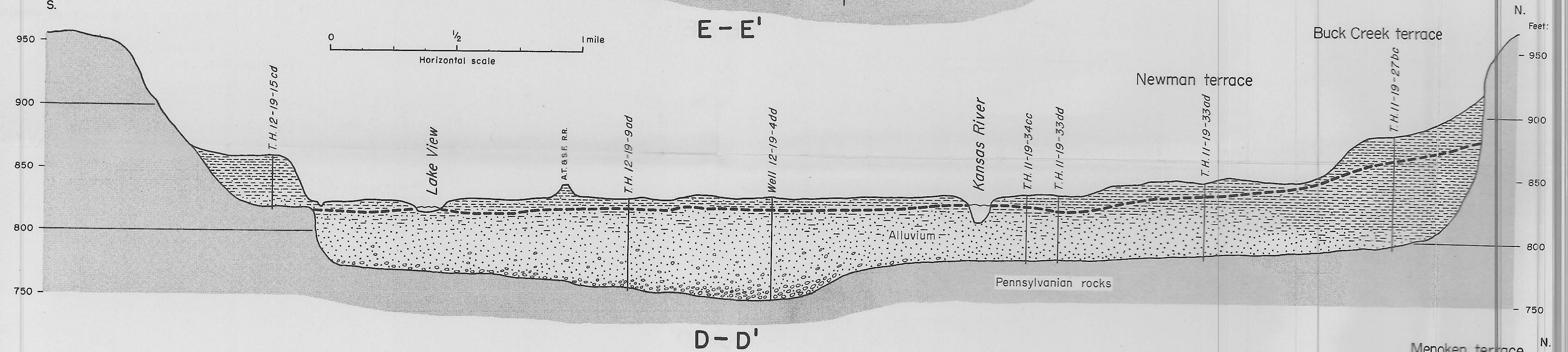
1952

State Geological Survey of Kansas

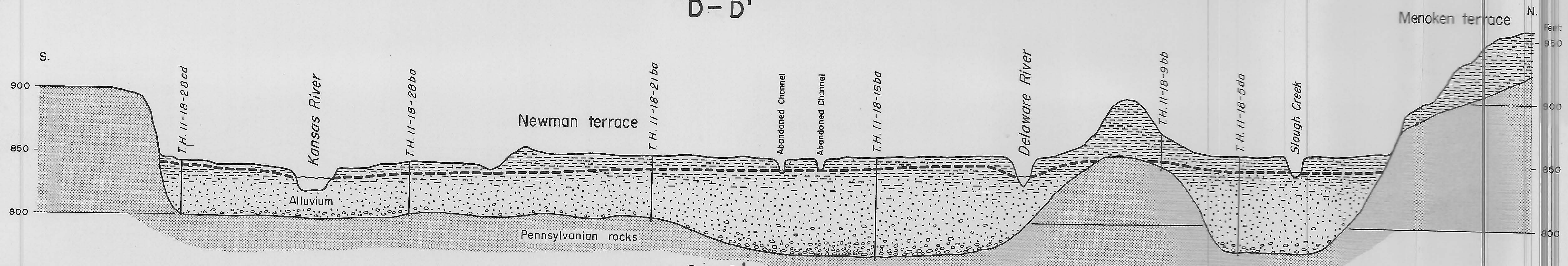
Bulletin 96, Part 5
Plate 3



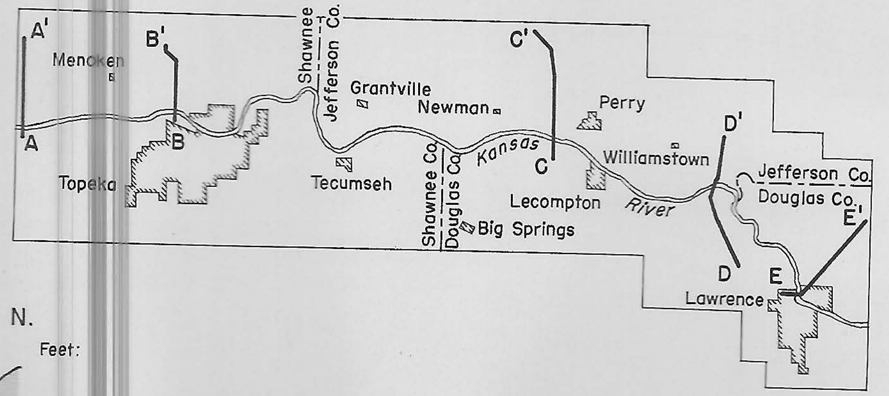
E–E'

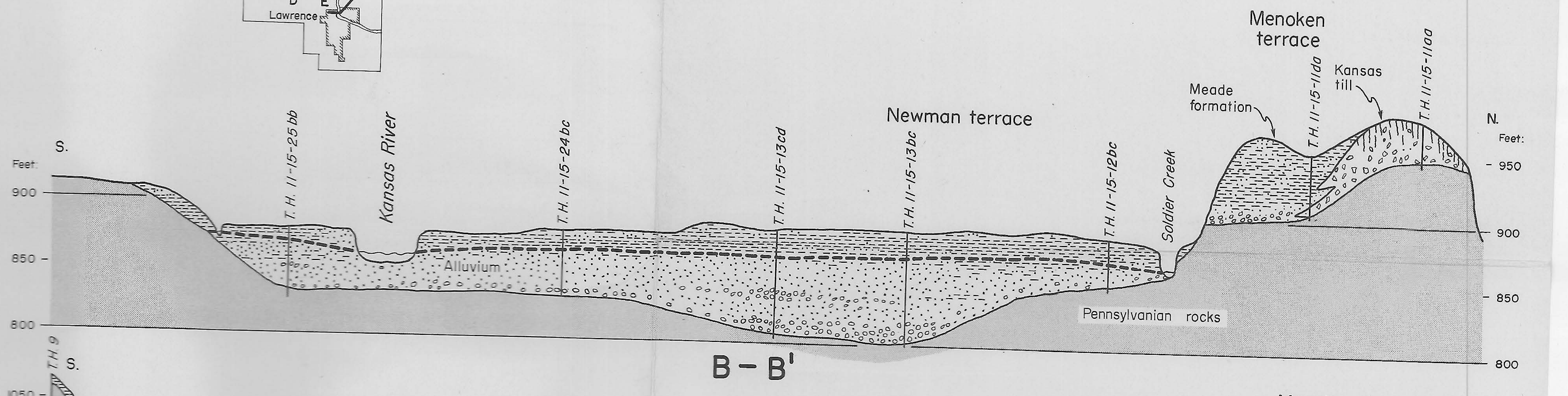


D–D'

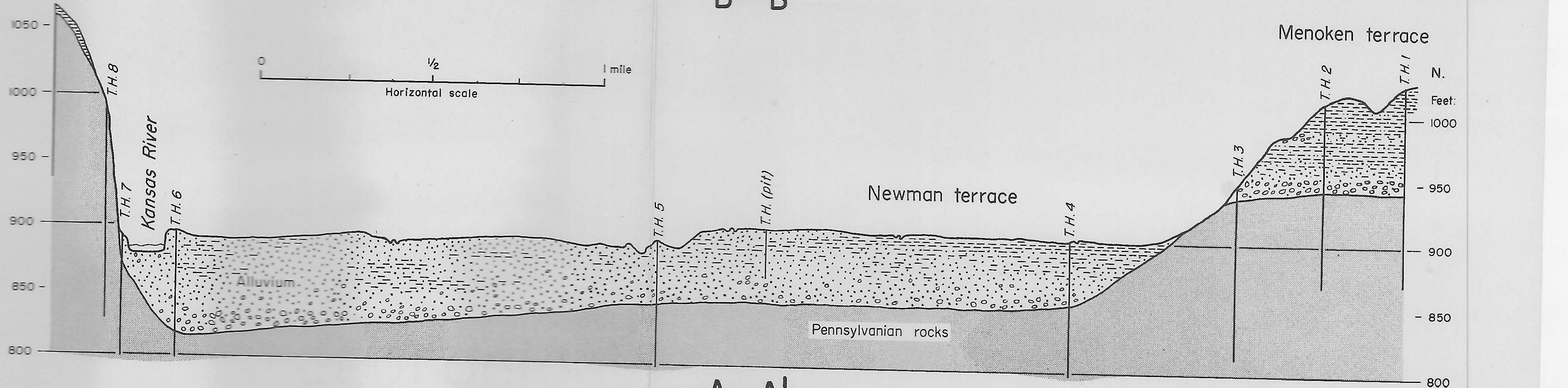


C–C'





B–B'



A–A'