Geology and Ground-Water Resources of Kansas River Valley Between Wamego and Topeka Vicinity

By

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CONTENTS

ILLUSTRATIONS

TABLES

GEOLOGY AND GROUND-WATER RESOURCES OF KANSAS RIVER VALLEY BETWEEN WAMEGO AND TOPEKA VICINITY

By Henry V. Beck

ABSTRACT

The geography, geology, and ground-water resources of Kansas River valley from Kiro in Shawnee County to the west boundary of Range 10 East in Pottawatomie County are described in this report. The area comprises about 280 square miles, including parts of Shawnee, Wabaunsee, and Pottawatomie Counties. It is a major agricultural area and a potential industrial area.

The valley is asymmetrical, having steep bluffs on the south and gentle slopes on the north. The indurated rocks, limestone, shale, and sandstone of Pennsylvanian and Permian age, dip gently westward to the Nemaha Anticline, where the dip reverses. These rocks are the source of construction materials and small but important quantities of ground water.

Unconsolidated Pleistocene sediments blanket much of the area north of the river, and sediments representing all subdivisions of the Pleistocene Series are present. The principal deposits are till of Kansan age, terrace deposits formed during the Kansan, Illinoian, and Wisconsinan stages, loesses of Illinoian and Wisconsinan age, alluvium of Wisconsinan and Recent age, and dune sand of Recent age. The interglacial stages are represented by soils formed during times of ice retreat.

The Illinoian and Wisconsinan terrace deposits and Wisconsinan and Recent alluvium are the most prolific sources of ground water, yielding large supplies for irrigation and municipal wells. The till of Kansan age, found chiefly on divides, yields little water. The Kansan terrace deposits, which rest on bedrock that lies above the present valley surface, have been dissected by erosion; hence much of the water drains from them. The principal use of ground water is for irrigation, and the data indicate that the supply of ground water is sufficient for additional development of irrigation and industrial supplies.

Maps, cross sections, plates, and figures are used to present geologic and ground-water data. Well logs, water-level measurements, aquifer-test data, and chemical analyses are given.

INTRODUCTION

Kansas River valley has been studied from Kansas City to Kiro, near Topeka, and this investigation was begun in the summer of 1951 to extend the study upstream to Wamego. This investigation was made and the report was prepared to fulfill the requirements of a Doctorate thesis at the University of Kansas.

The increased use of ground water for irrigation in Kansas River valley from Kiro to Wamego has made it desirable to investigate the quantity, quality, and availability of ground water. This study was made to evaluate the present ground-water supply and to serve as a guide for future ground-water development.

LOCATION AND EXTENT OF THE AREA

The part of Kansas River valley described in this report extends from the east boundary of Range 14 East near Topeka to the west boundary of Range 10 East near Wamego, a distance of 30 miles. The north and south limits of the area are governed by the geology and drainage (Fig. 1). The drainage area of Kansas River in the western part of Shawnee County, in the eastern part of Pottawatomie County, and in the northeastern part of Wabaunsee County was studied. A total of about 280 square miles was mapped; the main valley floor contains approximately 140 square miles.

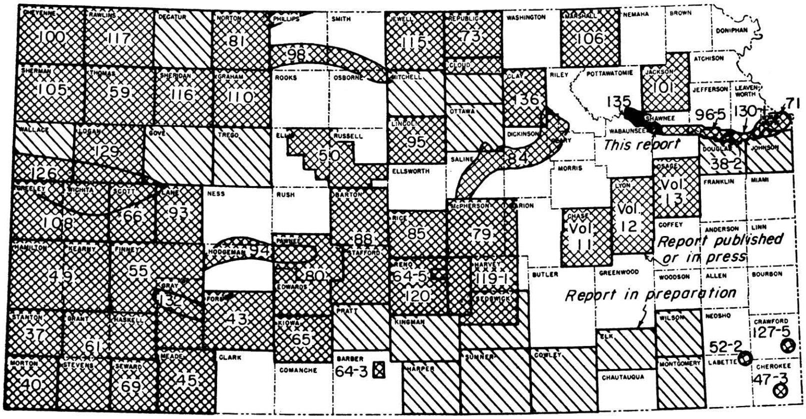


FIG. 1.—Index map of Kansas showing area described in this report.

PREVIOUS INVESTIGATIONS

The stratigraphy of the Pennsylvanian rocks in the Kansas Valley region was described by Moore (1936, 1949), and their distribution is shown on the geologic map of Kansas (Moore and Landes, 1937). The Upper Pennsylvanian and Lower Permian rocks have been reclassified by Moore and Mudge (1956). The outcropping rocks of Pennsylvanian and Permian age in Pottawatomie County were mapped by Glenn Scott of the U. S. Geological Survey during 1948 and 1949, and this map will be published in a circular describing the construction materials of that county.

The first mention of glaciation in Kansas was by Hay (1892). He described some of the glaciated areas and recognized the southern limit of the ice advance in Kansas as coinciding with the bluffs along the south side of Kansas River valley in Wabaunsee County. Haworth (1894) explained the glacial gravels composed of flint or chert as deposits derived from local limestones. Because these gravels were poorly sorted, he concluded that water had acted on them only slightly, if at all. A study of the glacial boulders by Swem (1896) showed that 75 percent of them are 1 to 3 feet in diameter and composed of Sioux Quartzite. The quartzite shows little weathering, whereas granite boulders are deeply weathered.

Smyth (1896) described a well-defined boulder belt extending from the southeastern corner of Shawnee County northwestward to Shunganunga Creek, thence west northwest, which in Pleistocene time temporarily dammed Kansas River south of Wamego. Later, Smyth (1898) described a series of possible lakes formed by damming of Kansas Valley by glacial ice. Kaw Lake was the greatest of these, extending from Wabaunsee westward to Salina.

Todd (1911, 1918, and 1920) described and mapped Pleistocene deposits in eastern Kansas. He interpreted the age of the topographically high chert gravels to be Pliocene, concluding that they were overridden in places by the advancing ice. He recognized some major drainage changes and pointed out that most drainage ways have been deepened since retreat of the ice front.

Schoewe (1922, 1930, 1938, 1939) described many glacial deposits and mapped the location of glacial striae in eastern Kansas. The glaciated area of Kansas was remapped, and revised borders were delineated along the west and south of the territory.

By means of mineralogical and grain-size analysis of glacial sediments in the vicinity of Manhattan, Harned (1938) concluded that field observations were not conclusive in establishing the origin of parent material of soils. Lill (1946) reported illite, a clay mineral, in glacial sediments, particularly in Marshall and Washington Counties, which lie to the west of the area of this report.

The first major attempt to correlate the nonglacial sediments of Pleistocene age in the central Great Plains with the glacial sediments was that of Frye, Swineford, and Leonard (1948). This correlation was based on petrographic and paleontological evidence. Frye and Leonard (1949) described the stratigraphic sequence in northeastern Kansas. Buried soils separating loess deposits were formed mainly during the interglacial stages. Frye (1949, p. 482) pointed out that fossil soils are perhaps the most usable lithologic criterion for stratigraphic correlation and classification of Pleistocene sediments in Kansas.

A subsurface reconnaissance of glacial deposits in northeastern Kansas was made by Frye and Walters (1950). That study disclosed a sag in the bedrock floor across southern Marshall and Nemaha Counties that was interpreted as a possible post-Nebraskan, pre-Kansan erosional feature. Their cross sections indicate that the surface traversed by the glaciers had less relief than the present surface.

Frye (1951) pointed out that all evidence seemed to indicate that interglacial intervals were times of soil formation and that glacial intervals were times of soil destruction or burial. The stratigraphic sequence in Kansas shows five major and several less distinct soil-forming intervals. The soils formed during these intervals, from oldest to youngest, are the Afton, Yarmouth, Sangamon, and Brady buried soils, and modern surface soil. The definition, description, and correlation of late Pleistocene loesses are included in a paper by Frye and Leonard (1951). The considerable difference between the early and late Pleistocene sediments throughout the state was pointed out.

Davis (1951) studied the gravels in the terrace deposits in Kansas River valley between Topeka and Lawrence. He concluded from the lithology that four principal gravels can be recognized: (1) pre-glacial gravels, (2) glacial outwash of Kansan age, (3) gravels from Kansas Till, and (4) gravels of Illinoian to Recent age. A report of the Pleistocene stratigraphy of Kansas by Frye and Leonard (1952) gives a history of the unit names and their present usage. Their report includes a summary of the Pleistocene geology of Kansas and a reconnaissance map that shows the areal distribution of Pleistocene sediments. The geology and ground-water resources of Kansas River valley between Lawrence and Topeka were described by Davis and Carlson (1952), who proposed the names Menoken, Buck Creek, and Newman for terraces along Kansas River.

METHODS OF INVESTIGATION

The geology of the area was mapped on aerial photographs having a scale of about 3 inches per mile and transferred to a base map (Pl. 1). Reconnaissance trips were made into adjacent areas to aid in comprehension of the regional geology. Rocks of principal interest in this study were those belonging to the Pleistocene Series. The sedimentary rocks of Pennsylvanian and Permian age were grouped into convenient units for mapping and for showing their relation to the Pleistocene sediments.

Wells were inventoried, and the depths to water, depths of wells, and other useful information are summarized in Table 7. Samples of water were collected from 15 wells, and chemical analyses of them were made by the State Board of Health (Table 4). The locations of wells inventoried, the depths to water, and the water-table contours are shown on Plate 2.

Information for three geologic cross sections (Pl. 3) was obtained from test drilling by the Federal and State Geological Surveys. Idealized geologic sections showing stages of development of Kansas River valley are given in Figure 4. Logs were prepared after examination of cuttings in the field, supplemented by microscopic examination of selected cuttings in the laboratory.

Samples of gravel were collected from various deposits in the area, and the size distribution of constituent particles was determined by mechanical analyses. The material retained on the 4-millimeter sieve was studied further to determine its composition, as was done by Davis (1951) to differentiate gravels of four different ages.

WELL-NUMBERING SYSTEM

The well-numbering system used in this report gives the location of wells according to General Land Office surveys and according to the following formula: township, range, section, 160-acre tract within the section, and 40-acre tract within the quarter section. If two or more wells are in the same 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 two examples illustrating the well-numbering system:

Well number	*General Land Office description*
10-12-20bc	SW¼ NW¼ sec. 20, T. 10 S., R. 12 E.
9-14-6da	NE¼ SE¼ sec. 6, T. 9 S., R. 14 E.

ACKNOWLEDGMENTS

Much information was received from R. Hofenstein, Alma, E. J. Jungmann, Topeka, A. O. Caylor and A. W. Hoerman, Manhattan, and G. Cox, Clifton, well drillers in the area. Special thanks are due Joe Campbell, Clyde Rodgers, and Louis Smith for use of irrigation wells on their farms for aquifer tests.

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

GEOGRAPHY

TOPOGRAPHY

The part of Kansas River valley between Topeka and Wamego is on the boundary between the Dissected Till Plains and Osage Plains sections of the Central Lowlands physiographic province as defined by Fenneman (1931) and Frye (1946, p. 276). Schoewe (1949, p. 276) includes this part of the valley in the Attenuated Drift Border of the Dissected Till Plains. He points out that the topography is more bold than the true Dissected Till Plains but less bold than the Osage Plains to the south because discontinuous deposits of till mask the bedrock topography.

Where Kansas River is close to the south side of the valley, an asymmetrical profile normal to the course of the river is produced. The south valley wall is more abrupt than the north valley wall, and the north-flowing tributaries have steeper gradients than the south-flowing ones. The main valley of Kansas River is divided topographically into the channel-scarred flood plain and a flat poorly drained terrace.

The total relief of the area is about 345 feet, and local relief is about 150 feet. The highest point in the area, on the divide between Kansas River and Mill Creek in Wabaunsee County, has an altitude of about 1,240 feet; the lowest point, along Kansas River at the eastern extremity of the area, has an altitude of about 895 feet.

CLIMATE

Kansas River valley is included in the area having a humid continental climate. According to the U. S. Weather Bureau, at Wamego the warmest months are July and August, which have monthly mean temperatures of 81.3° and 79.6°F, respectively, and daily maximums often in excess of 100°F. The summer of 1954 was unusually hot and the temperature was above 110°F for two days. The coldest months generally are December and January, which have monthly mean temperatures of 33.7° and 30.5°F, respectively. Winters are generally mild, but there are occasional cold waves during which the temperature is between 10° and -5°F for one to five days at a time. The annual mean temperature in the region is about 56°F, and the average length of the growing season is about 185 days.

Most of the precipitation is received from April through September. The normal annual precipitation is 31.73 inches at Willard, the recording station nearest the center of the area. Figure 2 gives the normal monthly precipitation at Willard, and Figure 3 gives the monthly precipitation and the cumulative departure from normal for the period April 1951 to January 1957.

TRANSPORTATION

The area is served by main lines of the Union Pacific Railway Co., which parallels Kansas River on the north side of the river, and the Chicago, Rock Island, and Pacific Railroad, which parallels the river on the south side from the east end of the area to the junction of Kansas River and Mill Creek, about 2 miles east of Maple Hill, where the railroad turns southwestward up Mill Creek valley.

Paved highways passing east-west through the area are U. S. Highways 24 and 40 and Kansas Highway 10. The last two are the principal highways on the south side of the river between Topeka and Junction City. U. S. Highway 24 parallels the river on the north side. Kansas Highway 63 is a paved highway north from St. Marys. The secondary roads in the area are all-weather gravelled roads maintained either by the townships or the counties.

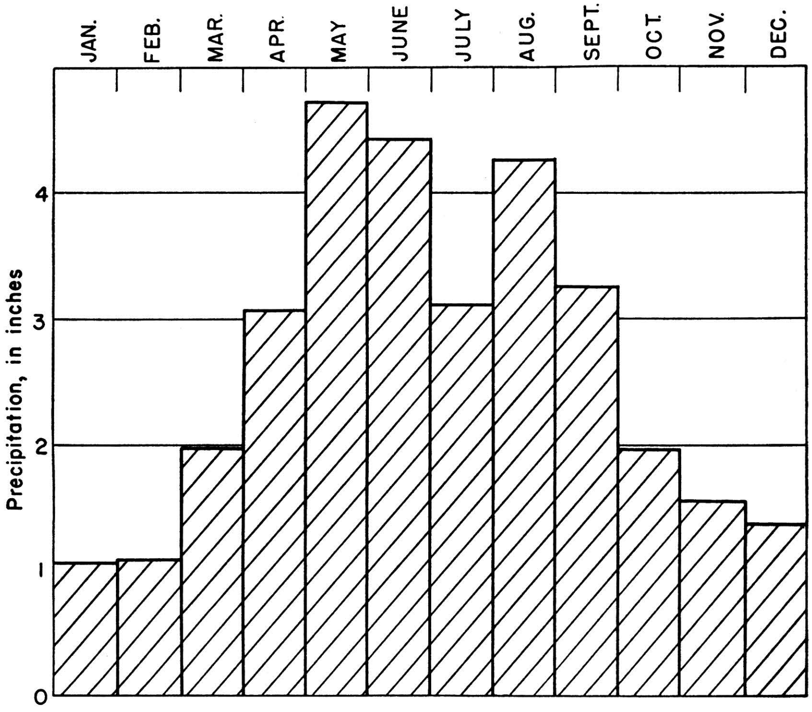


FIG. 2.—Normal monthly precipitation at Willard.

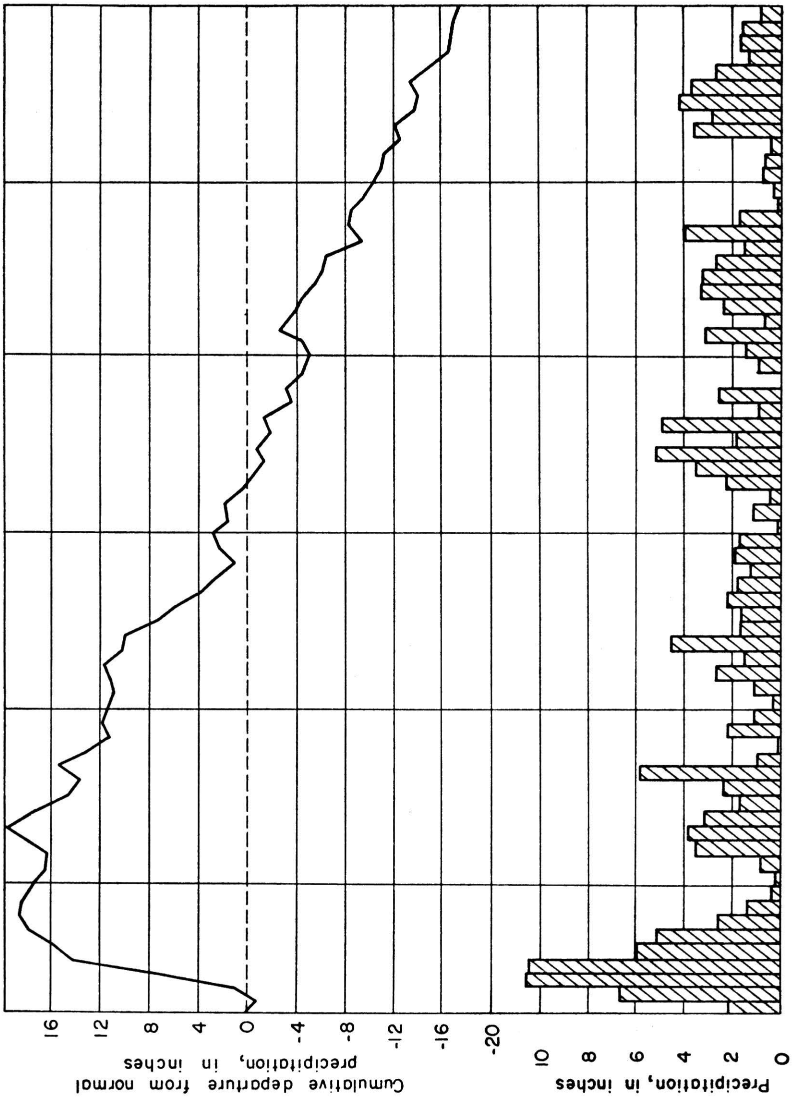


FIG. 3.—Monthly precipitation and cumulative departure from normal at Willard for the period April 1951 to January 1957.

AGRICULTURE AND INDUSTRY

The principal crop grown in the area is corn. Much seed corn is raised between Wamego and Silver Lake for the Kansas Farmers Union in St. Marys. Other major crops include wheat, alfalfa, and soybeans. The uplands are used chiefly for grazing livestock, as the land is generally too rough and stony to be cultivated. Some of the highest divide areas have been planted to wheat or milo.

There are very few industries in this part of Kansas River valley. Alfalfa-dehydrating plants operate seasonally at Belvue, Rossville, and Wamego. No quarries were active in 1956, but there are many inactive limestone and gravel quarries.

GEOLOGY IN RELATION TO GROUND WATER

Indurated rocks of Pennsylvanian and Permian age crop out along the sides of Kansas River valley. The regional dip is westward about 15 feet per mile from Kiro to the vicinity of Belvue. From the vicinity of Belvue westward, the buried Nemaha Anticline causes a reversal, and the rocks dip gently eastward. Unconsolidated sediments of Quaternary age blanket most of the area, however.

For convenience in mapping and description, the limestones, shales, and sandstones of the Pennsylvanian and Permian Systems were grouped into units larger than formations as defined by Moore and others (1951). With the exception of the Council Grove Group (Permian), which was arbitrarily divided into three unequal parts, subgroups and groups were mapped as units. A generalized geologic section of the Pennsylvanian, Permian, and Quaternary units mapped is given in Table 1.

PENNSYLVANIAN SYSTEM

VIRGILIAN SERIES

Wabaunsee Group

Sacfox Subgroup.—Strata of the Wabaunsee Group exposed below the base of the Burlingame Limestone were mapped as the Sacfox Subgroup. Only the Silver Lake Shale and Rulo Limestone are exposed. They crop out on the south side of the river at the base of the bluff east of Mission Creek (Pl. 1).

The Silver Lake Shale is blue gray and weathers gray to yellow (Pl. 4A). It is clayey and contains thin lenticular beds of impure platy limestone. The Rulo Limestone is blue gray and weathers

TABLE 1.—*Generalized section of outcropping rocks of Kansas River valley between Wamego and Topeka vicinity*

System	Series	Group	Subgroup or stage	Formation	Member	Thickness (feet)	Character	Water supply
Quaternary	Pleistocene	Sanborn	Recent	Dune Sand		0–10	Sand, silty and clayey, uniform throughout, light gray to tan.	Lies above the water table.
			Wisconsinan and Recent	Alluvium		18–85	Clay, silt, sand, and gravel, well-sorted in major valleys, generally fine-textured near top, grading downward into coarse sand and gravel.	Yields large amounts of water to irrigation, municipal, domestic, and stock wells. Water generally of good quality.
			Wisconsinan	Terrace deposits (Newman)		0–90	Silt and clay, gray in upper part, grades downward into coarse sand and gravel.	Yields large quantities of water to irrigation, municipal, domestic, and stock wells. Water generally of good quality.
				Peoria		0–10	Silt, eolian, well-sorted, light gray to gray tan. Thin mantle on uplands south of Kansas River.	Generally above water table, but may yield small quantities of water to shallow wells locally.
			Illinoian	Loveland		0–10	Silt, eolian, well-sorted reddish to pinkish brown. Thin mantle on upland north and south of Kansas River.	Generally above water table, yields little or no water.
				Terrace deposits (Buck Creek)		0–95	Sand, sandy silt, fine gravel in lower part grading upward into reddish-brown to reddish-tan silt, fluvial.	Locally, basal part yields moderate amounts of water to wells (as much as 625 gpm).
		Meade	Kansan	Terrace deposits (Menoken)		0–15	Silt and sandy silt, reddish tan to reddish brown.	Generally above water table, and does not yield water.
						0–20	Pebbles, cobbles, and boulders at the base; contains many lenses of arkosic sand.	May yield abundant amounts of water where in the zone of saturation.

				Kansas Till		0–84	Till, principally clay and silt, reddish brown to brown at surface, blue gray at depth; contains some pebbles, cobbles, boulders, and interstratified sands.	Generally a poor source of water. Sand lenses may contain small amounts of water.
			Nebraskan (?)	Undifferentiated preKansan gravels	Te	0–10	Chert-limestone gravel in clay matrix.	Too limited in extent to be of importance as an aquifer.
Permian	Wolfcampian	Council Grove		Beattie Limestone	Florena Shale	2–8	Shale, calcareous, silty, gray to tan.	Yields little or no water.
					Cottonwood Limestone	4–6	Limestone, massive, tan; contains flint nodules.	Locally, may yield water.
				Eskridge Shale		25–35	Shale, clayey, silty, calcareous, variegated.	Yields little or no water.
				Grenola Limestone	Neva Limestone	8–10	Limestone and interbedded shale, clayey, tan, weathers honeycombed.	Locally, the massive middle part may yield small amounts of water.
					Salem Point Shale	8–12	Shale, clayey, tan on weathered surface, dark gray on fresh exposures.	Yields little or no water.
					Burr Limestone	6–8	Limestone, tan to brown; two layers separated by shale.	Locally, may yield small amounts of water.
					Legion Shale	2–4	Shale, silty, clayey, tan to gray.	Yields little or no water.
					Sallyards Limestone	1	Limestone, gray.	Yields little or no water.
				Roca Shale		25–30	Shale, silty, clayey, calcareous, variegated.	Yields little or no water.
				Red Eagle Limestone	Howe Limestone	2–4	Limestone, dense; porous when weathered.	May yield small amounts of water.
					Bennett Shale	10–15	Shale, clayey, silty, calcareous, fossiliferous, gray to tan.	Yields little or no water.
					Glenrock Limestone	2–4	Limestone, argillaceous, thin bedded, gray.	Yields little or no water.

TABLE 1.—*Generalized section of outcropping rocks of Kansas River valley between Wamego and Topeka vicinity—Continued*

System	Series	Group	Subgroup or stage	Formation	Member	Thickness (feet)	Character	Water supply
Permian	Wolfcampian	Council Grove		Johnson Shale		15–20	Shale, clayey, silty, calcareous in part, gray to green.	Yields little or no water.
				Foraker Limestone	Long Creek Limestone	10	Limestone, porous, gray; contains celestite and quartz geodes.	Yields moderate quantities of water in other areas.
					Hughes Creek Shale	15–25	Shale, silty, calcareous, gray.	Yields little or no water.
					Americus Limestone	5	Limestone, dense; two layers separated by shale.	May yield small amounts of water.
		Admire		Hamlin Shale		40–50	Shale, clayey, gray in upper part, variegated in lower; limestone between members.	Yields little or no water.
				Five Point Limestone		4–6	Limestone, thin bedded, slightly porous.	May yield small amounts of water.
				West Branch Shale	Te	25–35	Shale, clayey, variegated; contains limestone lenses.	Yields little or no water.
				Falls City Limestone		2	Limestone, massive, gray to tan.	May yield some water.
				Hawxby Shale		6–15	Shale, clayey to sandy, gray to yellow.	Yields little or no water.
				Aspinwall Limestone		1–3	Limestone, massive to thin bedded, reddish brown.	May yield small amounts of water.
				Towle Shale		5–15	Shale, clayey, silty, calcareous; Indian Cave sandstone member present locally.	Sandy beds may yield moderate amounts of water.

Pennsylvanian	Virgilian	Wabaunsee	Richardson	Brownville Limestone		4	Limestone, massive, fossiliferous, brown.	Yields little or no water.
				Pony Creek Shale		15–25	Shale, clayey, silty, variegated; is siltstone in places.	Yields little or no water.
				Caneyville Limestone		10–12	Limestone, thin bedded to massive. gray; two beds separated by shale.	May yield small amounts of water.
				French Creek Shale		20–30	Shale, clayey and sandy, tan to light brown.	Yields little or no water.
				Jim Creek Limestone		1–2	Limestone, dense, massive, blue gray.	Yields little or no water.
				Friedrich Shale		25–30	Shale, clayey, sandy, contains lenses of limestone.	Sandy layers may yield small quantities of water.
				Grandhaven Limestone		4–6	Limestone, thin bedded to massive, blue gray; two beds separated by shale.	A possible source of small amounts of water.
				Dry Shale		10–15	Shale, clayey, sandy, variegated.	Yields little or no water.
				Dover Limestone		3	Limestone, thin bedded to massive, gray to tan.	May yield small quantities of water.
				Langdon Shale		25–30	Shale, clayey to sandy, blue gray to tan.	Sandy layers in upper part may yield small amounts of water.
				Maple Hill Limestone		2–4	Limestone, massive to thin bedded, gray to tan.	May yield small amounts of water.
				Pierson Point Shale		15–20	Shale, clayey, micaceous, blue gray to black, weathers tan.	May yield small amounts of water from sandy layers.
			Nemaha	Tarkio Limestone		3–5	Limestone, massive, fusulinid bearing; brown to tan.	May yield small amounts of water.
				Willard Shale		30–40	Shale, clayey, dark gray to brown; contains sandy layers.	Sandy layers may yield small amounts of water.
				Elmont Limestone		1–2	Limestone, massive, jointed, dark blue to gray.	Some water may be derived from joints and fractures.

TABLE 1.—*Generalized section of outcropping rocks of Kansas River valley between Wamego and Topeka vicinity—Concluded*

System	Series	Group	Subgroup or stage	Formation	Member	Thickness (feet)	Character	Water supply
Pennsylvanian	Virgilian	Wabaunsee	Nemaha	Harveyville Shale		15–20	Shale, clayey, sandy, blue to greenish brown.	The thin platy sandstones may yield some water.
				Reading Limestone		2–3	Limestone, weathers into three layers, dark gray to brown.	May yield small amounts of water.
				Auburn Shale		10–15	Shale, clayey, gray to tan; contains sandy and limy layers.	Sandy and limy layers may yield some water.
				Wakarusa Limestone		4–6	Limestone, fossiliferous, dark gray to brown; contains shale layers.	May yield small amounts of water.
				Soldier Creek Shale		15–20	Shale, clayey to sandy, blue gray to tan.	Sandy layers are possible sources of some water.
				Burlingame Limestone		4–6	Limestone, thick bedded, brown; contains shale partings.	May yield moderate amounts of water.
			Sacfox	Silver Lake Shale		±30	Shale, clayey, gray to yellow, contains impure limestone lenses.	Limestone lenses may yield small amounts of water.
				Rulo Limestone		±2	Limestone, bluish gray.	Yields little or no water.

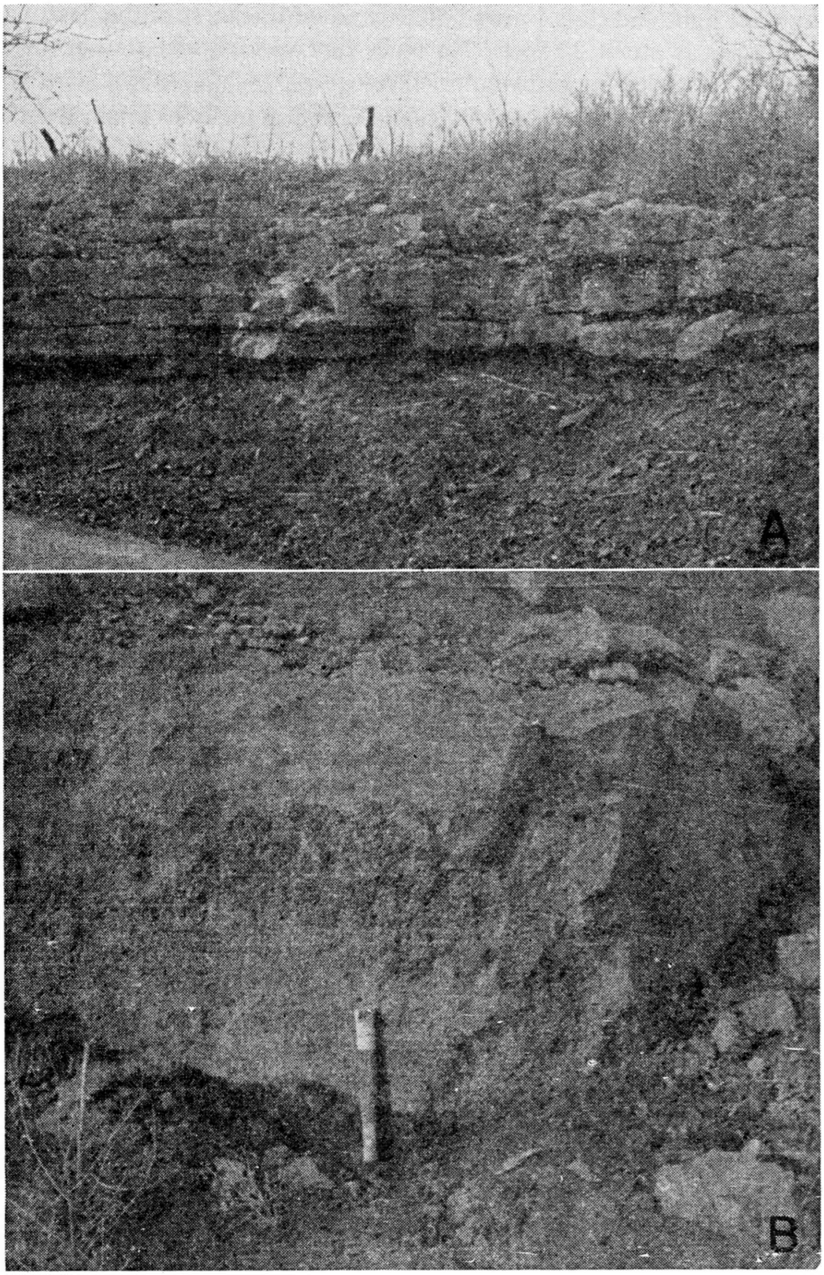


PLATE 4.—**A,** Silver Lake Shale and overlying Burlingame Limestone in road cut in SE¼ NE¼ sec. 36, T. 11 S., R. 14 E. **B,** Tarkio Limestone in quarry in sec. 29, T. 11 S., R. 14 E.

mottled light and dark brown. The exposed thickness of the Sacfox Subgroup is about 32 feet. No wells that yielded water from the Sacfox Subgroup were inventoried.

Nemaha Subgroup.—The Nemaha Subgroup includes strata from the base of the Burlingame Limestone to the top of the Tarkio Limestone. The contact between the Sacfox Subgroup and the Nemaha Subgroup is conformable. The outcrops of the subgroup are most extensive on the south side of the river east of Maple Hill (Pl. 1); there are less extensive outcrops on the north valley wall, where overlying Quaternary sediments have been removed by erosion.

The limestone formations in the Nemaha Subgroup range in thickness from 1 to 6 feet and the shales from 10 to 40 feet. The limestones are generally fossiliferous and brown and weather mottled brown. In limestone formations that contain two or more layers, the layers are separated by thin shale partings. The Tarkio Limestone (Pl. 4B) may be identified on the basis of large fusulinids and algal remains, and the Reading Limestone may be identified easily in a weathered exposure because it weathers into three or four layers of uniform thickness (Pl. 5A). The shales are generally dark gray or blue and weather gray or light tan. They are generally clayey and contain calcareous layers just below the limestones. Lenticular layers of clayey limestone are common in the Auburn Shale.

Good exposures of the Nemaha Subgroup may be seen in road cuts along Kansas Highway 10 and U. S. Highway 40 in Shawnee County. The total thickness of the subgroup may be as much as 117 feet, but is about 90 feet in the area mapped. Laterally the shales and limestones thicken and thin somewhat, making it difficult to trace formations on the basis of thickness alone. Wells of small yield may be developed locally in the weathered zones of the limestones and shales of the Nemaha Subgroup. Analyses of water from this subgroup in adjacent areas indicate that the water is hard.

Richardson Subgroup.—The Richardson Subgroup includes the limestone and shale formations from the top of the Tarkio Limestone to the top of the Brownville Limestone. The subgroup crops out generally on the sides of the valley from the vicinity of Willard west to Turkey and Bourbonais Creeks and from Wamego west to Range 9 East. In the central and western parts of the valley, much of the subgroup is covered by younger sediments.

The Richardson Subgroup is composed predominantly of clayey and sandy blue-gray shale, but parts of the Pony Creek and Dry Shales are variegated red and green. The sandy beds may be mi-

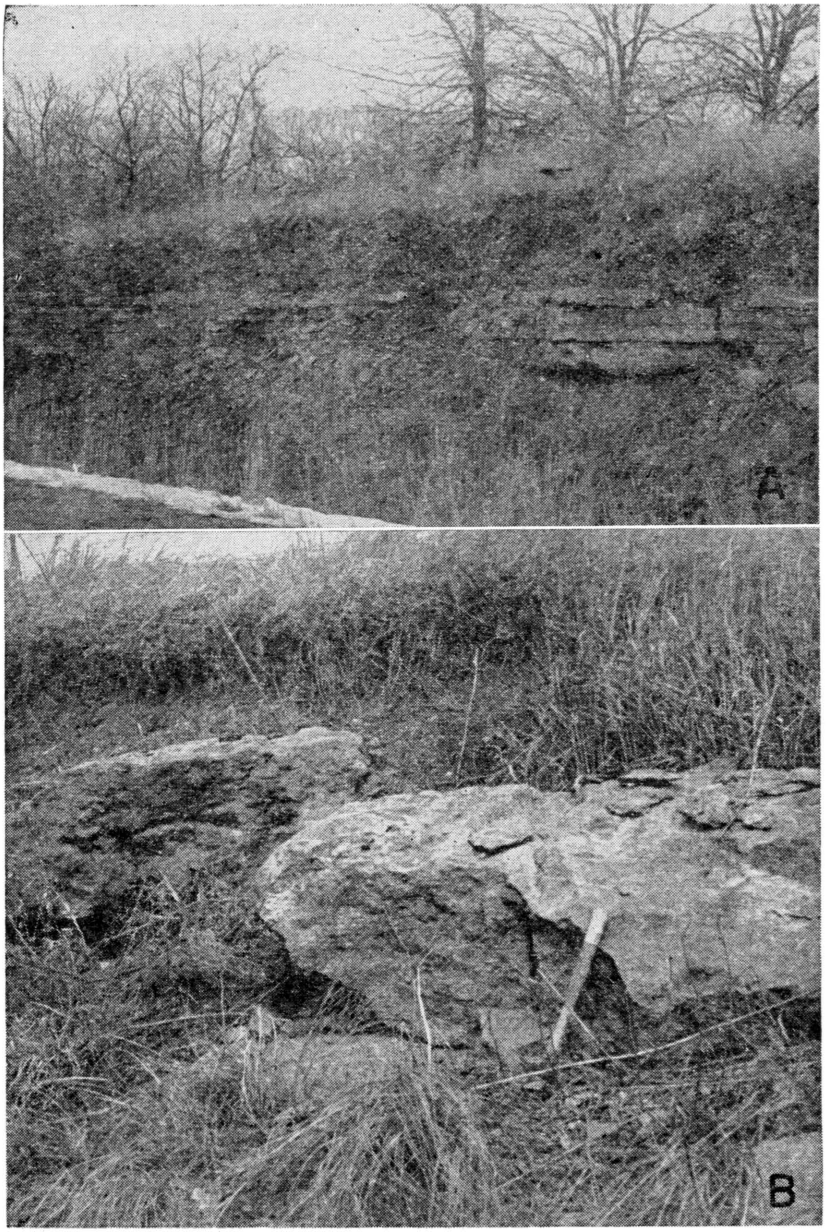


PLATE 5.—**A**, Reading Limestone underlying Harveyville Shale and overlying Auburn Shale in road cut in SW¼ SW¼ sec. 30, T. 11 S., R. 14 E. **B**, Brownville Limestone capping hill in SW¼ SW¼ sec. 18, T. 10 S., R. 13 E.

caceous, yellow or brown, loosely cemented sandstone. The Friedrich Shale locally contains sandstone-filled channels cut down as much as 25 feet into lower beds. Most of the shales in this unit contain thin coal beds a fraction of an inch to 2 inches thick. Some parts of the shales are calcareous or contain thin limestone.

The limestone formations are blue gray to gray and weather tan or brown. They generally contain one or two layers and may weather into platy limestones. Where the limestone formations are composed of two or more layers, the shale partings nowhere are more than a few inches thick. Characteristic fossils in the limestones are fusulinids, brachiopods, and pelecypods and other mollusks. *Meekopora* and *Chonetes* are distinctive in the Brownville Limestone, and local algal or algal-like deposits are prominent in the upper part of the Grandhaven and Dover Limestones. The most prominent outcropping limestones are the Brownville, Dover, and Maple Hill.

The thickness of the Richardson Subgroup is 150 feet. The individual shales range in thickness from 10 to 30 feet in this part of Kansas, and the limestones from 1 to 12 feet. The Grandhaven Limestone southeast of Maple Hill, consisting of two layers of limestone and an intervening shale layer, is about 6 feet thick. The Brownville Limestone (Pl. 5B) is the thickest single bed of limestone in this subgroup and is about 4 feet thick.

Some stock wells south of the river yield small supplies of water from one or more of the limestones of the Richardson Subgroup. Many ponds have been constructed in the outcrop region of the Richardson Subgroup to supplement the ground-water supply.

PERMIAN SYSTEM

WOLFCAMPIAN SERIES

All the Permian rocks exposed in Kansas River valley are included in the Wolfcampian Series. The base of the Permian System is the Indian Cave Sandstone member of the Towle Shale. The Indian Cave Sandstone was not observed in this area, but may be present locally. Permian rocks crop out from Cross and Mill Creeks westward, as shown on Plate 1.

Admire Group

The Admire Group is composed of four shale and three limestone formations and has been mapped as a single unit. The most extensive outcrops of the Admire Group are in the divide area between Mill Creek and Kansas River and northeast of St. Marys. In Roberts and Wells Creek valleys south of Kansas River, the group is covered extensively by a terrace deposited during the Illinoian Stage of the Pleistocene Epoch. Elsewhere, the group is concealed by thin deposits of weathered Kansas Till.

The shales of the Admire Group are chiefly clayey, but some are silty, calcareous, or sandy. The shales are very thin bedded to almost fissile. They are dark blue gray and weather light gray or tan. The Hawxby Shale contains many thin-bedded clayey limestone lenses.

The limestones are generally gray or light brown and weather tan or buff and are generally massive but weather thin bedded or platy. The Five Point Limestone, the upper limestone of this group, probably is the most porous.

The maximum thickness of the Admire Group is about 125 feet. About 115 feet of this thickness is shale and the other 10 feet is limestone. Individual limestone formations are 1 to 6 feet thick in this area. The Five Point Limestone consists of two limestone layers separated by a thin shale and its total thickness is about 6 feet; the Falls City Limestone is about 2 feet thick; and the Aspinwall Limestone is 1 to 3 feet thick.

A few stock wells probably obtain small supplies of ground water from the Five Point Limestone.

Council Grove Group

The Council Grove Group includes rocks from the base of the Foraker Limestone to the base of the Wreford Limestone. In Kansas River valley the lower seven formations of the group are exposed. These formations were divided into three units for convenience of mapping and description. The lower unit includes strata from the base of the Americus Limestone member of the Foraker Limestone to the base of the Burr Limestone member of the Grenola Limestone; the middle unit includes strata from the base of the Burr Limestone to the base of the Cottonwood Limestone member of the Beattie Limestone; and the upper unit includes the Cottonwood Limestone and Florena Shale members of the Beattie Limestone. The formations crop out from about 4 miles east of St. Marys to the vicinity of Wamego. Many of the limestones produce prominent topographic benches.

Lower unit.—The Americus Limestone is the basal member in the lower unit of the Council Grove Group and conformably overlies the Hamlin Shale of the Admire Group. The lower unit is exposed most extensively on the north side of the valley from St. Marys west, where it forms part of the north bluff of the valley. In the valleys of south-flowing tributaries to Kansas River, it has been covered by fills of Pleistocene age. Extensive areas northwest of Maple Hill are underlain by members of this unit. Terrace deposits cover all but the uppermost strata of the lower unit in the vicinity of Roberts and Wells Creeks.

The lower unit includes the Foraker Limestone, Johnson Shale, Red Eagle Limestone, Roca Shale, and the lower two members of the Grenola Limestone. The limestones in the Council Grove lower unit are generally massive and dense. The exception is the Long Creek Limestone, which is argillaceous, porous, and thin bedded. It contains many nodules and geodes of celestite and quartz, indicative of subsurface water action. The shales in the lower part of the unit are dark-gray to green clayey shales and contain lenses of very fossiliferous argillaceous limestone. One argillaceous limestone lens in the Hughes Creek Shale member contains very abundant fusulinids, and one in the Bennett Shale member contains an abundance of the brachiopods *Marginifera, Composita,* and *Orbiculoidea.* The Roca Shale is variegated red, green, and tan and is nonfossiliferous. Outcrops of the Sallyards Limestone and Legion Shale members of the Grenola Limestone are shown on Plate 6B.

The shales of this unit range in thickness from 2 to 30 feet. The Roca Shale generally is the thickest and the Legion Shale member the thinnest. Except the Long Creek Limestone member, which is commonly about 10 feet thick, the limestone strata range in thickness from 1 to 5 feet.

The weathered zones of the calcareous shales are possible sources of small quantities of ground water. Seeps from the calcareous parts of the Hughes Creek Shale and Bennett Shale are common, and some springs were observed issuing from the base of the Howe Limestone member. The best source of ground water from the lower unit is the Long Creek Limestone member, and some of the upland wells south of Belvue were reported to produce a maximum of about 10 gallons a minute from it.

Middle unit.—The Burr Limestone, Salem Point Shale, and Neva Limestone members of the Grenola Limestone and the Eskridge Shale are included in the middle unit of the Council Grove Group (Pl. 1). The Burr Limestone and Cottonwood Limestone members form prominent rock terraces. The unit underlies the divides both north and south of Kansas River and is covered by thin deposits of weathered till or residual mantle.

The predominant material of this unit is shale. The Eskridge Shale is clayey, variegated green, red, and tan, and weathers blocky (Pl. 6A). In some localities it contains thin argillaceous lime-

Plate 6.—**A**, Eskridge Shale capped by Cottonwood Limestone member of Beattie Limestone in SW¼ SW¼ sec. 16, T. 9 S., R. 12 E. **B**, Burr Limestone, Legion Shale, and Sallyards Limestone members of Grenola Limestone in road cut along Kansas Highway 63, north of St. Marys.

stones. A limestone layer in the upper part of the Eskridge Shale contains abundant pelecypods *Myalina* and *Aviculopecten.* The Salem Point Shale member between the Neva Limestone and the Burr Limestone is generally clayey and dark gray and weathers tan.

The limestone members present in the middle unit are the Burr and Neva Limestones. The Burr Limestone member (Pl. 6B) consists of two beds separated by a thin shale, and both beds are dense, massive, and tan. The bottom of the lowermost bed is oölitic and has a sandy appearance. The Neva Limestone member consists of three beds of limestone separated by thin shales, the middle limestone bed being much thicker than the lower and upper. Weathered outcrops of the middle limestone are thin bedded and locally honeycombed. The middle bed is light gray to tan, and the color is not altered by weathering.

The formations of the middle unit of the Council Grove Group have a combined thickness of about 65 feet. Thickness of the Eskridge Shale ranges from 25 to 35 feet, of the Neva Limestone member from 8 to 10 feet, of the Salem Point Shale member from 8 to 12 feet, and of the Burr Limestone member from 6 to 8 feet.

The Neva and Burr Limestone members are the best aquifers in the middle unit. Several domestic and stock wells in areas adjacent to Kansas River valley obtain small supplies of ground water from the Neva Limestone.

Upper unit.—The strata included in the upper unit of the Council Grove Group are the Cottonwood Limestone and Florena Shale members of the Beattie Limestone. They crop out on the crest of the divide north of St. Marys and in the upland southwest of Belvue.

The Cottonwood Limestone member is a massive tan limestone (Pl. 6A) and is recognizable because of an abundance of slender fusulinids in the upper part and flint nodules in horizontal layers at three or four levels in the massive layer. The lower 1 to 2 feet is fractured in an irregular pattern; otherwise, the member is a single massive layer about 5 feet thick.

The Florena Shale member is calcareous and silty, and its lower part is fossiliferous in most exposures. One of the most abundant fossils is *Chonetes.* The member is deeply weathered in exposures, is gray to tan, and is 2 to 8 feet thick.

The Cottonwood Limestone member is not an important aquifer in this area. Some seepage between the Florena Shale member and the overlying mantle was noted in the divide areas.

QUATERNARY SYSTEM

PLEISTOCENE SERIES

Quaternary deposits in Kansas River valley range in age from pre-Kansan to Recent and disconformably overlie the Paleozoic rocks of Permian and Pennsylvanian age. The oldest sediments are gravels that contain no material of glacial origin and are classed as pre-Kansan. The most recent deposits are sand dunes formed from the alluvial sands of the present river channel. The Quaternary deposits are the principal source of ground water in Kansas River valley and the adjacent upland. They are also the parent material from which most of the soils have developed.

Pre-Kansan Gravels

Gravels classed as pre-Kansan (Nebraskan or Tertiary ?) occur in small isolated deposits high on the divides above Kansas River northeast of Rossville and northwest of Wamego. The gravels are composed principally of chert and limestone and contain very small quantities of erratic material. Davis (1951) concluded that their composition is considerably different from glacial outwash, and he classed them as pre-Kansan or remote Kansan proglacial gravels. The constituent particles of chert and limestone are subangular to subrounded fragments, which could have been derived from Paleozoic limestones cropping out west of this area.

The thickness of the gravels ranges from a featheredge to 10 feet and averages about 5 feet. The gravels cannot be traced laterally any great distance because they have been eroded since their deposition. They are embedded in a matrix of clay, which decreases the porosity and permeability of these deposits; hence the gravels are not an important source of ground water.

Kansas Till

Deposits consisting of clay, sand, gravel, and boulders are present over part of the area on the crests of the divides and on the sides of the valley. In two upland areas, east of Cross Creek and northwest of Wamego, the till is as much as 84 feet thick, but in places the till has been eroded and only a thin veneer remains.

Locally the Kansas Till mapped on Plate 1 includes stratified sand and gravel at the base or interbedded with the till. The stratified deposits probably are meltwater deposits associated with the ice front of the Kansan glacier.

The till is composed of clay containing some erratics and limestone fragments. A very heavy concentration of glacial boulders rests on the Permian bedrock southwest of Belvue. Much of the finer material has been removed from the till, resulting in a concentration of boulders forming stone stripes. Most exposures are either in road ditches or stream cuts; hence only a few feet of material can be observed. A typical exposure is a gully in the SE¼ SW¼ sec. 35, T. 11 S., R. 13 E. The till, composed principally of clay containing fragments of chert, quartzite, and greenstone ranging in size from granules to boulders, is blocky and mottled gray and rust brown. The till exposed in a road ditch in the NW¼ NW¼ sec. 1, T. 11 S., R. 14 E., is red to brown clay containing a mixture of granules of chert, quartzite, and dark igneous rock. Till that is well oxidized but only slightly leached is exposed in the center of sec. 3, T. 11 S., R. 14 E. It is very tight clay containing granules of limestone, chert, and igneous and metamorphic rocks, especially quartzite.

Quartzite and quartzite conglomerate are the two most common rock materials in areas where boulders are the only part of the till remaining; they are more resistant to chemical weathering than other kinds of rocks. In till that has not been leached and oxidized, cobbles of granite and some dark igneous rock are fairly abundant. Davis and Carlson (1952) described the zones of the Kansas Till from their work and that of Frye and Walters (1950) as follows:

A. Red clay zone. Deeply leached and oxidized zone, red, 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, containing almost entirely siliceous pebbles, limonitic shale fragments, and various metamorphic rocks; locally jointed.

C. Oxidized and unleached till. Yellow brown to green brown containing 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, 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.

Test hole 10-14-32cc penetrated 84 feet of interbedded sand, clay, and gravel. The lower 26 feet was medium to coarse sand and gravel composed of quartz and limestone. Such gravels are characteristic of the pro-Kansan gravels of Davis (1951) and may correlate with the Atchison Formation in the northeastern corner of the state. The upper 58 feet consisted of clay and fine sand interbedded with some pebbles of limestone, quartzite, and dark igneous rock typical of Kansas Till. Test hole 10-14-32bb penetrated about 72 feet of interbedded clay, sand, and gravel. These two test holes probably penetrated about the maximum thickness of till in the area. Colluvial and fluvial processes have removed much of the till from slopes of the valley walls, and in many places it was too thin to map on Plate 1.

The sandy layers in the till yield small supplies of ground water to wells. The clays are too impermeable to yield much water.

Menoken Terrace Deposits

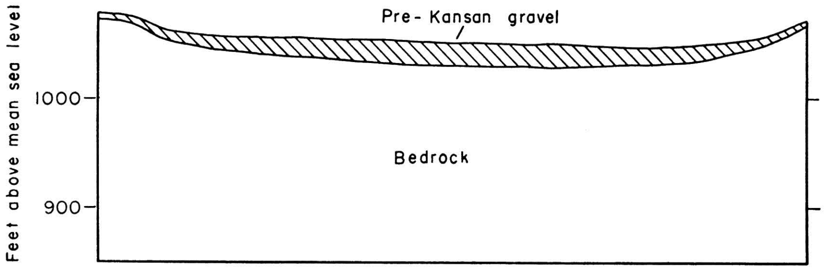
Material mapped as the Menoken Terrace deposits was deposited by meltwater from the retreating ice front and is Kansan in age. Originally these deposits probably were continuous in the valley (Fig. 4), but erosion has so dissected the surface that only remnants remain. They occupy a terrace position, and the most extensive deposits are on the north side of the valley east of Rossville. Other isolated deposits are on both sides of the valley as far west as Deep Creek. Menoken Terrace deposits are underlain either by bedrock of Paleozoic age or by gravels of Cenozoic age, and the floor of the Menoken Terrace deposits ranges from 20 to 40 feet above the present flood plain.

Gravels of the Menoken Terrace deposits can be distinguished from gravels at the base of the Kansas Till by their composition. About 10 percent of the gravel in the terrace deposits was derived from igneous or metamorphic rocks, whereas not more than 2 percent of the gravels at the base of the Kansas Till was derived from igneous or metamorphic rocks (Davis, 1951). The gravels of Illinoian and Wisconsinan age have a still greater percentage of granitic material, which distinguishes them from Kansan and pre-Kansan gravel deposits. Gravel about 7 feet thick, composed of limestone and chert, is exposed in a pit in the SE¼ SE¼ sec. 24, T. 11 S., R. 13 E. It is overlain by well-sorted arkosic gravel. A gravel composed of limestone and chert, containing less than 5 percent quartzite and dark igneous rock fragments, irregularly cemented with calcium carbonate to produce a conglomerate is exposed in a pit in the SW¼ SE¼ sec. 4, T. 10 S., R. 12 E. The deposit is overlain by fine arkosic sand and silt and overlies the Red Eagle Limestone of Permian age.

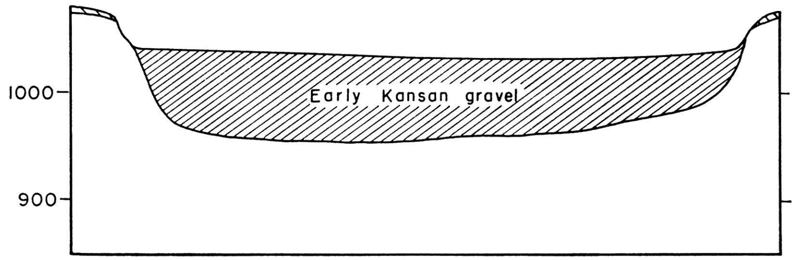
About 20 feet of sand and gravel overlying the Nemaha Subgroup is exposed in a sand and gravel pit in the NW¼ SE¼ sec. 12, T. 11 S., R. 14 E. The lower 6 feet of gravel consists of well-rounded limestone and quartzite fragments as much as 8 inches in diameter and some chert and micaceous shale fragments. This deposit grades upward into well-sorted medium-coarse arkosic sand. The uppermost part of the deposit consists of fine sand, stained brown or black, and silt and clay. Menoken Terrace deposits also are exposed in a large pit in the SW¼ SW¼ sec. 36, T. 10 S., R. 13 E. (Pl.

7A). This exposure shows much crossbedding and sorting of material, which suggest its water-laid origin. The reddish sandy silt at the top of the cut is 10 to 15 feet thick. The stream-deposited gravels in the lower part of the Menoken Terrace deposits may possibly correlate with the Grand Island Formation in western Kansas, and the reddish silt and clay may be equivalent to the Sappa Formation.

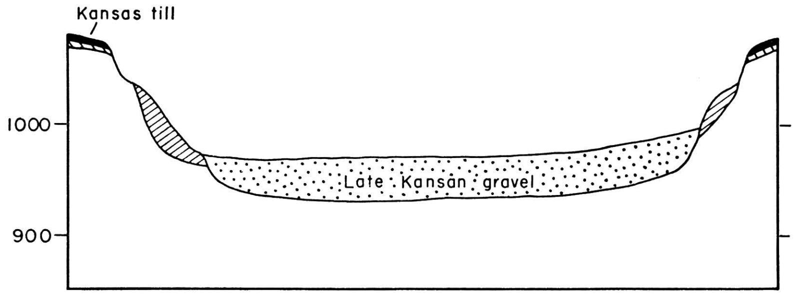
No wells were inventoried that produce water from the Menoken



A. PRE-KANSAN



B. EARLY KANSAN



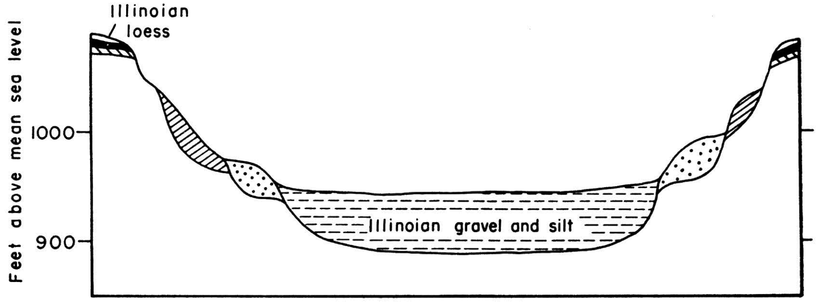
C. LATE KANSAN

FIG. 4.—Idealized geologic sections showing development of Kansas River valley.

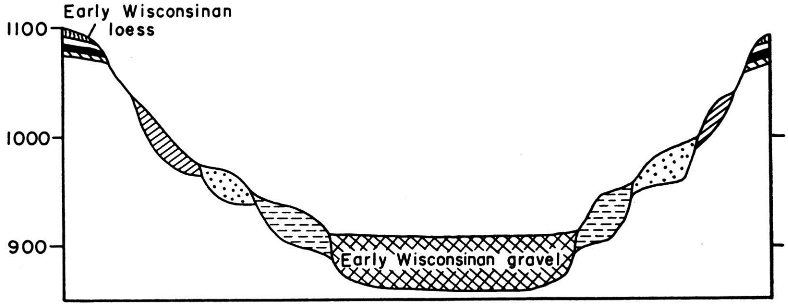
Terrace deposits. The terrace has been dissected by erosion, and permeable basal gravels are nearly drained.

Buck Creek Terrace Deposits

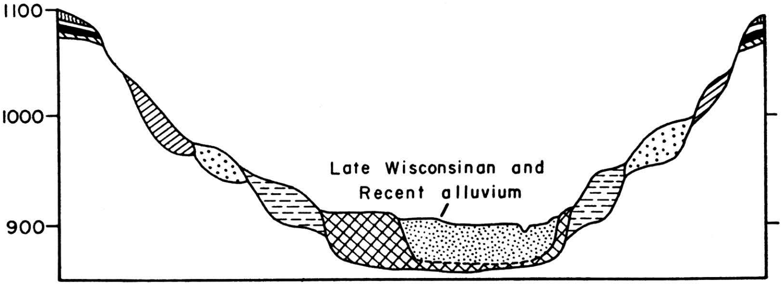
The Buck Creek Terrace deposits were laid down during the Illinoian Stage of the Pleistocene Epoch, and these deposits in Kansas River valley and its tributaries are topographically lower than the Menoken Terrace deposits (Pl. 1).



D. ILLINOIAN



E. EARLY WISCONSINAN



F. LATE WISCONSINAN AND RECENT

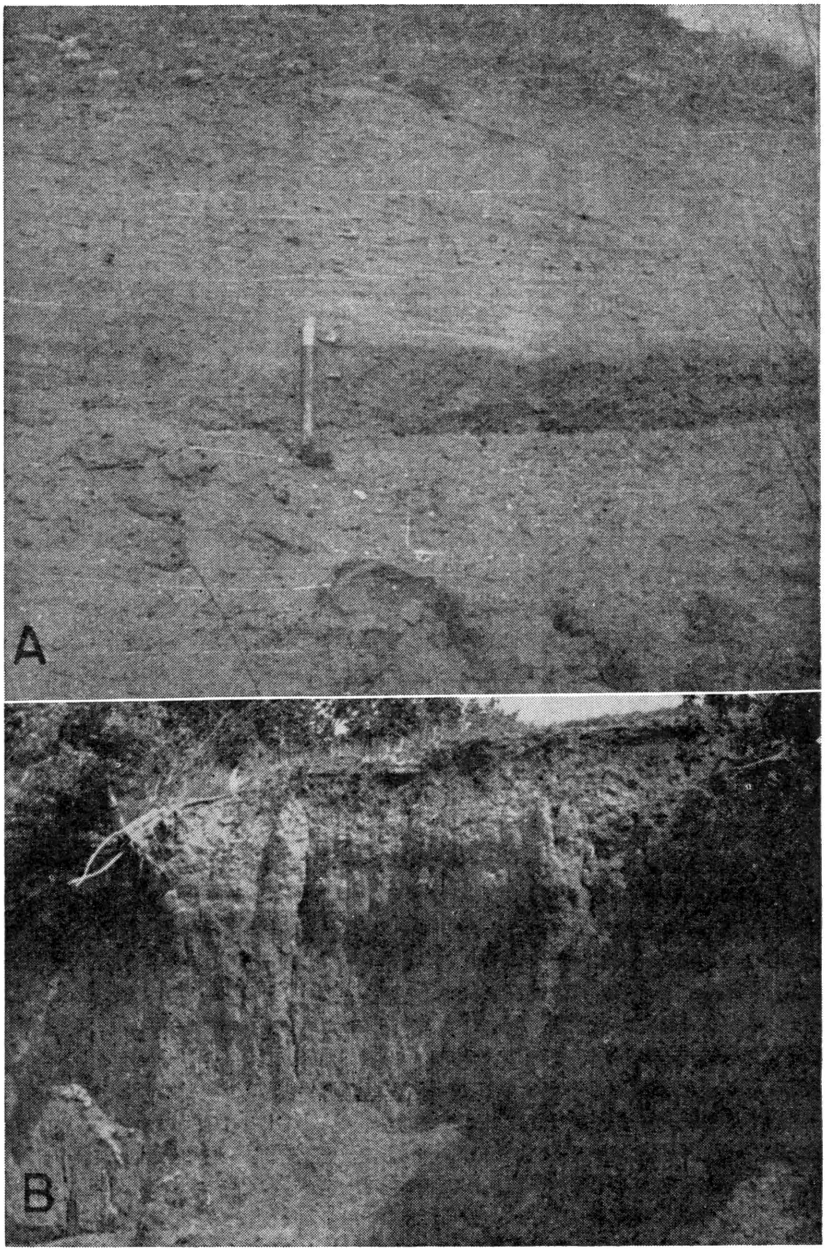


PLATE 7.—**A**, Sand and gravel deposits of Menoken Terrace in pit in SW¼ SW¼ sec. 36, T. 10 S., R. 13 E. **B**, Soil profile on Newman Terrace in NW¼ NW¼ sec. 33, T. 10 S., R. 12 E.

South of the river opposite Belvue a large remnant of the Buck Creek Terrace deposits shows features characteristic of alluvial terraces, and the terrace surface can be traced eastward to Mill Creek. Isolated deposits are present on the north side of the river, the largest remnant being on the west side of Cross Creek valley north of Rossville. Alluvial fills in many of the tributaries were mapped as Buck Creek Terrace deposits. The fills possibly contain material derived from the divides by colluvial action, but most of it is alluvium.

Buck Creek Terrace deposits contain sand and gravel in the lower part and grade upward into silt and clay. Test hole 11-12-12ad penetrated about 15 feet of coarse sand and gravel below the silt and clay. The sand and gravel is arkosic in Kansas River valley but contains a few fragments of locally derived limestone and chert. The gravel particles are principally quartz and granite fragments that are well rounded, indicating that they were transported for considerable distance before being deposited.

The silt and clay are characterized by a red-brown color and uniform texture; they weather blocky or columnar. The presence of pebbles in the silt in some localities suggests that the material is alluvial in origin.

A good soil profile has developed on the upper part of the Buck Creek Terrace deposits and is exposed in a road cut just south of Kansas River in the NW¼ NW¼ sec. 7, T. 11 S., R. 13 E. The upper 15 inches is dark brownish gray, leached, and friable. The lower 30 inches is lighter in color, oxidized, and only slightly leached.

Eight test holes were drilled in the Buck Creek Terrace deposits to determine the thickness of sand, gravel, silt, and clay and the altitude of the bedrock surface. The thickness of these deposits ranges from about 35 feet in test hole 10-11-7ad to 96 feet in test hole 9-11-19cd. Thickness of the sand and gravel in the lower part of the terrace deposit ranges from 3 feet in test hole 10-11-17aa to 57 feet in test hole 9-11-19cd, which was the only test hole to penetrate more than 20 feet of sand and gravel. Thickness of the sand and gravel is commonly 8 to 15 feet and that of the silt and clay ranges from 10 to 47 feet.

Six wells that produce water from sand and gravel of the Buck Creek Terrace deposits were inventoried. Well 10-10-30db is 59 feet deep and penetrates 14 feet of saturated material. The estimated yield was 475 gpm, but information was not available to determine the specific capacity. Well 10-10-28bc is 48 feet deep, penetrates 26 feet of saturated material, and by report yields 625 gpm.

Loveland and Peoria Formations Undifferentiated

The sediments mapped as the Loveland and Peoria Formations on Plate 1 are materials deposited on the upland by wind action. The Loveland and Peoria loesses are both present. The Loveland loess is the more widespread and was observed chiefly in the eastern third of the area, where it caps the upland northeast of Cross Creek and Kansas River. Some of the loess south of Willard on the divide area is probably Loveland, but it has been blanketed by the Peoria loess over most of the area south of the river. In much of the area the loesses have been removed by erosion, were never deposited, or were too thin to map.

Loveland loess is material blown from the major valleys and deposited on the upland during the Illinoian Stage of the Pleistocene Epoch. The material is mostly reddish to pinkish-brown friable silt and some clay. The loess becomes clayey and blocky where weathering has caused deflocculation of the clay. In some places there is a concentration of calcium carbonate in the lower part of the B zone and in the upper part of the C zone of the soil profile. The soil profile is similar to that developed on the Buck Creek Terrace deposits, and the two are thought to be about the same age.

Peoria loess is generally light gray or gray tan in contrast to the reddish to pinkish-brown color of Loveland loess. Peoria loess was observed on the divides south of Kansas River. Peoria loess about 5 feet thick overlying Kansas Till is exposed in a gully in the SE¼ SW¼ sec. 35, T. 11 S., R. 13 E. The underlying Kansas Till is less permeable than the loess, and a calichelike deposit is present near the contact.

Road ditch and stream exposures suggest that the loess is probably no more than 20 feet thick. No test holes were drilled in areas of thick loess. Maximum thickness north of the river is probably on the divide between Kansas River and Soldier Creek just northeast of the area studied. South of the river, along Kansas Highway 10 and U. S. Highway 40 near Willard, loess is estimated to be as much as 15 feet thick. Deposits in sec. 33 and 36, T. 10 S., R. 11 E., are about 10 feet thick.

Seeps were noted in several localities at the contact of the Kansas Till and overlying loess. Some shallow domestic and stock wells on the divide areas may obtain small supplies of ground water near the base of the loess.

Wisconsinan Terrace Deposits

Extensive alluvial deposits that were laid down during the Wisconsinan Stage of the Pleistocene Epoch cover or underlie Kansas River valley, forming a broad level surface a few feet above the present flood plain. The terrace thus produced was named the Newman Terrace (Davis and Carlson, 1952) from the town of Newman, where a large segment of the terrace surface is unmodified by tributary streams for almost 1 mile north and 2 miles east. The Newman Terrace is widespread throughout this section of the valley, and the broad flat surfaces in the valleys of Cross Creek, Mill Creek (Pl. 8A), and Mission Creek are continuations of the Newman Terrace surface from Kansas River valley.

The upper part of the Newman Terrace deposits is silty clay, and the A zone of the soil profile is well developed. Silt and clay of the B zone and C zone are generally gray to gray tan, and they contain many calcium carbonate nodules. Brown stains in the C zone indicate some iron oxidation. Silt and clay grade laterally and vertically into fine sand. The lower part of the terrace deposits is composed of sand and gravel, principally quartz, feldspar, and granite fragments but containing very small quantities of limestone fragments. Because the material is subrounded to rounded, it is judged to have been transported a great distance.

Two distinct soils are included in about 25 feet of silt and clay exposed in a stream cut in the NW¼ NW¼ sec. 33, T. 10 S., R. 12 E. (Pl. 7B). The topsoil is dark-gray silt that has been leached and is friable. This soil is younger than most soils on the Newman Terrace deposits. The other soil (buried) measures 2.2 feet thick and is underlain by about 20 feet of clayey silt that is very similar in texture, color, and other physical appearances to the silt and clay of the upper part of the Newman Terrace deposits.

Several test holes were drilled in the valley to determine the character and thickness of the Newman Terrace deposits. Logs of these test holes are given at the end of this report. Cobbles of limestone, granite, and quartzite were recovered at a depth of about 54 feet, just above bedrock, in the drilling of a water well in the SW¼ SE¼ sec. 1, T. 11 S., R. 13 E. The gravel in the upper part of the well was fairly well sorted and arkosic, as is most of the material in the valley. Gravel in the Newman Terrace deposits is similar to gravel in the lower part of the Buck Creek Terrace deposits.

The Newman Terrace deposits range in thickness from about 37 feet in well 10-13-30cc to about 90 feet in well 10-10-3db, being thickest, as a general rule, north of Kansas River. The part that comprises the sand and gravel ranges in thickness from 7 to 60 feet.

The Newman Terrace deposits provide large supplies of ground water in the area. In general, the wider the valley and the thicker the deposits, the more satisfactory the water supply will be. The coarse gravels are very permeable and are excellent aquifers. Water temperature is about 60°F, varying little except in wells near the river where seasonal infiltration of surface waters may cause fluctuation. Several new irrigation wells have been drilled in the New-

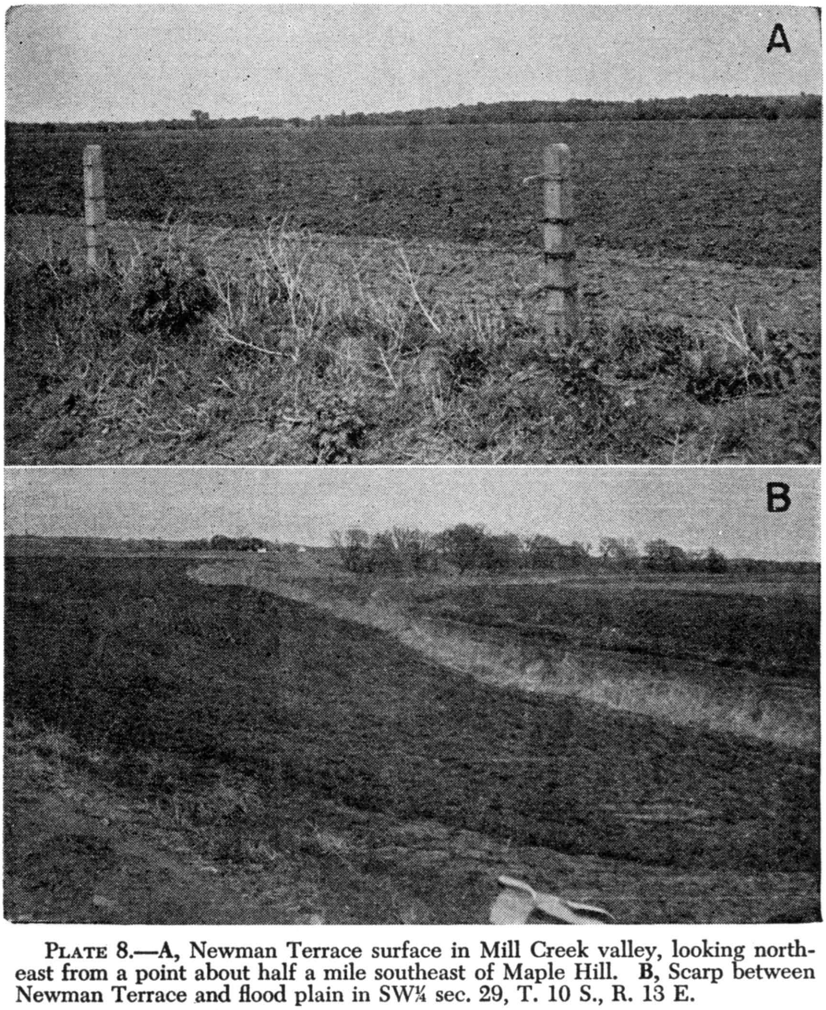


PLATE 8.—A, Newman Terrace surface in Mill Creek valley, looking northeast from a point about half a mile southeast of Maple Hill. B, Scarp between Newman Terrace and flood plain in SW¼ sec. 29, T. 10 S., R. 13 E.

man Terrace deposits; the yields range from 500 to 1,500 gpm. Specific capacities of some wells were determined and are given in Table 7.

Late Wisconsinan and Recent Alluvium

The alluvium shown on Plate 1 is late Wisconsinan and Recent in age and is the flood plain of Kansas River. In most places the alluvium is separated from the Newman Terrace by a scarp 4 to 8 feet high (Pl. 8B). In general, the alluvium is more extensive on the north side of Kansas River.

The alluvium is very sandy in the upper part in contrast to the Newman Terrace deposits. The lower part is generally coarse sand and gravel similar to that of the Newman Terrace deposits. The soil profile is very poorly developed on sandy parent material. Some alluvium was deposited by the 1951 flood, which over large areas covered or destroyed the soil that had developed; hence an A zone of 0.5 foot is about the thickest that can be observed. Material below the A zone is very fine, silty tan sand, which in many places contains disseminated carbonaceous material. Many of the meander scars contain blue or dark-gray clay, which is impermeable and causes water to collect and remain in the scars for a considerable period of time. Such clay deposits have been referred to as clay plugs and are characteristic of back swamp flood deposits.

Test hole 11-14-20bc, just west of Valencia on the south side of the river, penetrated only 18.5 feet of alluvium. Test hole 10-13-31cd penetrated 41 feet of sand and gravel. In test hole 9-11-31dc, near the junction of Kansas River and Vermillion Creek, the alluvium is 50 feet thick. The upper 10 feet consists of silt and clay, and the lower 40 feet consists of fine to coarse sand and medium gravel.

Many wells produce water from the sand and gravel of the alluvium (Table 7). The water table is near the surface and wells commonly are constructed by augering a hole to the water table and then driving a sand point into the saturated sediments. Many wells are of this type and are satisfactory for domestic and stock use. Hydrologic properties of these sediments are similar to those of the Wisconsinan Terrace deposits. Irrigation well 10-10-14bd, drilled in 1955, penetrated 46 feet of alluvium, 26 feet of which was saturated. After the well had been pumped at 300 gpm for 15 minutes, the drawdown was 2 feet; hence the specific capacity was 150 gpm per foot of drawdown.

Recent Dune Sand

There is active shifting dune sand in one locality in Kansas River valley. The dune tract parallels the river on the north side southwest of St. Marys and has a hummocky relief of 5 to 10 feet. The dunes are composed of light-gray to tan very fine quartz and feldspar sand of uniform size and some silt and clay. The dune sand is thin and lies on the surface of the present flood plain, above the water table.

GEOMORPHIC DEVELOPMENT

PRE-KANSAN TIME

Little evidence of a pre-Pleistocene surface remains in Kansas River valley. Chert and limestone gravels in a clay matrix high on the divide areas are the only known deposits of possible Tertiary or Nebraskan age. Topographic position, stratigraphic succession, and absence of glacial material were the criteria used in classifying the gravels.

The gravels are exposed in the divide areas about 125 to 150 feet above the present bedrock floor of the valley; they were deposited by streams in Tertiary or early Pleistocene time. Chert gravels are exposed in a pit in the NW¼ NE¼ sec. 31, T. 10 S., R. 14 E., in a road ditch in the SE¼ SE¼ sec. 26, T. 10 S., R. 13 E., in the SE¼ SW¼ sec. 29, T. 10 S., R. 12 E., and in the NE¼ sec. 5, T. 10 S., R. 10 E. (Pl. 1). They also are exposed in a pit in the SE¼ SW¼ sec. 7, T. 10 S., R. 13 E., and in the NE¼ sec. 5, T. 10 S., R. 12 E., but the exposures are too small to map. Till overlies the chert gravels in nearly all these exposures. The gravels are not extensive enough to permit reconstruction of a pre-Kansan surface.

KANSAN STAGE

The advance of the Kansan glacial ice front into this area from a center in Canada was the principal event of Kansan time. The present Kansas River had its beginning during this glacial advance (Lohman and Frye, 1940) and was an ice-marginal river.

Considerable erosion must have taken place prior to the invasion by the ice. The bedrock surface on which pro-Kansan sediments were deposited is 50 to 75 feet below the surface underlying the pre-Kansan gravels. Pro-Kansan sands and gravels occur locally below the Kansas Till in this section of the valley. Because of the proximity of this area to the glacial margin, the bedrock surface probably was not scoured by the glacier. Test holes shown on the north end of the cross sections (Pl. 3) penetrated 5 feet (10-14-32bb) to 26 feet (10-14-32cc) of sand and gravel beneath the till. The pro-Kansan gravels were deposited on a bedrock surface 15 to 25 feet above the present Newman Terrace surface.

The ice front continued to advance and extended beyond the present valley as indicated by the presence of pro-Kansan gravels in the valleys of some of the larger tributaries south of Kansas River, and the overriding of the pro-Kansan gravels by the ice covered them with thin sheets of till. Kansas River and many of its tributaries were dammed by the ice during its maximum advance in Kansan time. Ice damming caused accumulation of meltwater from the ice and also of water from the west, forming many lakes in the area. A concentration of gravel and till along Turkey Creek valley in Wabaunsee County indicates that Turkey Creek was a major tributary to Kansas River in early Kansan time. Turkey Creek may have been the main tributary to Kansas River and the outlet from Mill Creek into Kansas River, but the width of the present Mill Creek valley and the high bedrock divide between Turkey Creek and Mill Creek are evidence against this hypothesis.

Smyth (1898) and Todd (1911) recognized the evidence of a Kaw Lake, which drained to the south along the glacial ice margin into Mill Creek, thence into Mission Creek through Dry Creek south of Maple Hill, and into the headwaters of Shunganunga Creek. This drainage approximately parelleled the till deposits south of the river. The largest concentration of till boulders is southeast of Wamego in Wabaunsee County. The till is very thin on the south side of the river; most of the finer material has been removed by erosion, leaving the concentration of boulders.

The thickest till is north of the river. Cuttings from test holes indicate that the till mantle may be as much as 84 feet thick northwest of Silver Lake. The till is composed principally of clay interbedded with sand and gravel but containing sparse large boulders.

Kansas River valley was filled with glacial outwash as the glacier retreated. The Menoken Terrace deposits are the remnants of these deposits. The Menoken Terrace is about 60 feet above the Newman Terrace. Menoken Terrace deposits contain considerably more fragments of granitic and metamorphic rock than do the pre-Kansan gravels. The distinctive lithology of some of the pebbles indicates that they were derived from sources in the Rocky

Mountains and deposited by streams flowing across the Great Plains, the Flint Hills divide having been breached during Kansan time. As the glacier retreated, progressively finer grained material was deposited. The silt and clay in the upper part of the Menoken Terrace deposits may be in part eolian in origin, but they are so deeply weathered that they cannot be distinguished as such. During the subsequent Yarmouthian Stage, soil formation was the principal geologic process (Frye, 1951).

ILLINOIAN STAGE

Erosion was renewed near the beginning of Illinoian time after a long period of geologic stability. The Kansas Till and outwash were deeply dissected and in places removed by Kansas River and its tributaries. No deposits directly associated with ice of the Illinoian Stage are present in Kansas River valley. The bedrock surface on which Illinoian sediments were deposited is 25 to 50 feet below the surface on which Kansan sediments were deposited (Pl. 3, Fig. 4).

In the waning phase of Illinoian time, Kansas River and its main tributaries were heavily laden with sediment, and the valley again was alluviated to a level about 30 feet above the Newman Terrace. The remnants of these deposits are the Buck Creek Terrace deposits. The Buck Creek Terrace is prominent on the west side of the junction of Mill Creek and Kansas River, in Cross Creek valley, and on the south side of Kansas River south of Belvue and Wamego. Many of the smaller tributary valleys were choked by sediments of local origin. The upper part of the fill is reddish-brown silt and clay upon which the Sangamon soil developed.

Some of the finer material in the upper part of the Buck Creek Terrace deposits may be of eolian origin. The extensive cover of Loveland loess northeast of Rossville and Silver Lake was derived from Soldier Creek to the northeast. Loess derived from Kansas River valley is very thin on the upland south of the river.

After Illinoian glaciation, Kansas River valley again was stable geologically, and the Sangamon soil developed during the Sangamonian interval. The profile of this soil generally exhibits a thick A zone, a moderately thick B zone, and a thoroughly oxidized C zone.

Paleontological evidence for dating the Illinoian deposits is very meager, but the physical criteria are almost conclusive. Fossil mollusks reported from similar deposits in other parts of Kansas River valley are comparable to the Illinoian fauna of Leonard (1951).

WISCONSINAN AND RECENT STAGES

During the early Wisconsinan Stage, the alluvium forming the Newman Terrace deposits was laid down in Kansas River valley, and eolian loess was distributed on the upland. During the late Wisconsinan Stage, renewed entrenchment of Kansas River formed the Newman Terrace.

The surface of the Newman Terrace, which may be as much as 15 feet above the flood plain, is undissected except by minor gullying at the scarp. The nearly flat surface resulted from vertical accretion more than from lateral point-bar accretion. The bedrock surface on which the Newman Terrace deposits accumulated lies 50 to 80 feet below the terrace surface (Pl. 3). Deposits on the surface of the Newman Terrace are predominantly silt and silty clay.

During early Wisconsinan time the wind transported fine silt and clay from the flood plain of Kansas River to the upland. This loess is classed as the Peoria Formation; it differs from the Illinoian loess of the Loveland Formation in color and in degree of soil development. The Peoria Formation is light gray to gray tan and is less clayey than the Loveland Formation. Also, the degree of oxidation is greater in the Loveland Formation than in the Peoria Formation.

In parts of Kansas Valley the early Wisconsinan deposits have been eroded and late Wisconsinan and Recent sediments deposited (Pl. 3) as the flood plain of modern Kansas River. The flood plain is extensively scarred by old meanders of Kansas River, and in places minor terraces or pseudoterraces have formed by point-bar accretion. Soils on older parts of the flood plain have a weakly developed profile, whereas the younger parts have little or no soil. Deposits on the surface of the flood plain are predominantly fine sand and sandy silt, but some meander scars have clayey fillings. The channel of Kansas River is cut into the flood plain, and the normal water level of the stream is about 8 to 10 feet below the top of the channel.

Sand dunes are active in several localities in the valley, but only one area is extensive enough to map. Sand dunes generally are associated with recent channel changes; the wind moves sand before vegetation can become established to protect the unconsolidated material from deflation.

Small alluvial fans have been deposited along the north bluff of Kansas River valley by intermittent tributary streams. Reduction in gradient of these streams as they emerge on the Newman Terrace results in deposition of a part of the stream load.

GROUND WATER

OCCURRENCE AND MOVEMENT

The following discussion of ground-water hydrology has been adapted from Meinzer (1923) and Tolman (1937). Water beneath the surface of the earth is termed subsurface water. Below a certain level in the earth's crust, the permeable rocks generally are saturated with water. The saturated rocks are called "the zone of saturation" and the subsurface water in the zone of saturation is called "ground water". The subsurface water above the zone of saturation is called "suspended subsurface water", or "vadose water". The upper surface of the zone of saturation is the ground-water table or simply the water table.

The ground water that is available to wells in Kansas River valley is derived from precipitation that falls within the area or in areas upstream. Part of the precipitation that falls runs off the surface and is discharged as stream flow, part of it evaporates or is absorbed by growing vegetation and transpired into the atmosphere, and part of it that escapes runoff, evaporation, and transpiration percolates slowly downward until it joins the water table. Not all the water that infiltrates the soil reaches the water table; some of it adheres to the soil, and only the excess reaches the water table.

When water reaches the water table it moves down gradient toward a point of discharge. The water table generally slopes in the same direction as the land surface but less steeply. Water moves down grade at right angles to the water-table contours. In Kansas River valley (Pl. 2) the general movement is downstream and toward the river, and ground water is being discharged into Kansas River and its tributaries.

HYDROLOGIC PROPERTIES OF THE WATER-BEARING MATERIALS

Porosity.—The amount of water that can be stored in rock or unconsolidated sediment depends upon the porosity. Porosity is expressed quantitatively as the percentage of the total volume of the rock or sediment that is occupied by voids or interstices. The material is said to be saturated when all its interstices are filled with water.

Permeability.—Permeability is defined as the capacity of material to transmit a fluid and for water is measured by the rate at which the formation will transmit water through a unit cross section under a unit difference of hydraulic head per unit of distance. The coefficient of permeability is expressed in Meinzer's units as the rate of flow of water in gallons a day through a cross-sectional area of 1 square foot under a hydraulic gradient of 100 percent at a temperature of 60°F (Wenzel, 1942). The coefficient of permeability also may be defined as the number of gallons of water a day that is conducted laterally through each mile of the water-bearing bed under investigation, measured at right angles to the direction of flow, for each foot of thickness of the bed and for each foot per mile of hydraulic gradient at the prevailing temperature.

Transmissibility.—The coefficient of transmissibility may be expressed as the number of gallons of water a day, at the prevailing temperature, that is transmitted through each mile of the aquifer under a hydraulic gradient of 1 foot to the mile; hence, it is the average coefficient of permeability multiplied by the thickness of the aquifer and adjusted for temperature.

Specific yield.—The specific yield of water-bearing material is defined as the ratio of (1) the volume of water that, after being saturated, the formation will yield by gravity to (2) its own volume. The ratio is usually stated as a percentage. Specific yield is a measure of the yield of a water-bearing material when it is drained by a lowering of the water table.

FLUCTUATIONS OF THE WATER TABLE

The water table does not remain stationary but fluctuates in response to recharge to and discharge from the ground-water reservoir. The water-table contours shown on Plate 2 were based on water levels measured during a period of low precipitation (Fig. 3); hence the water table is at a low level. Davis and Carlson (1952) reported that water-table fluctuations at a distance of about 3,000 feet from Kansas River were no greater than 5 feet a year unless the water table was affected by pumping or by water flooding the valley. In August 1951, the water level in an auger hole in the SE¼ SE¼ sec. 29, T. 10 S., R. 13 E., was 2 feet below the surface. The depth to water level in observation well 10-13-19da on June 3, 1952, was 19 feet and on October 10, 1956, was 27.68 feet.

Two observation wells were drilled in Kansas River valley and one in Mill Creek valley during this investigation, and the water levels were measured at intervals from June 1952 through December 1956 (Fig. 5, 6). The rapid water-table decline after the wells were drilled was caused by drought that followed the 1951 flood; by February 1956 the water table was at least 5 feet below its former level. The rises shown in Figure 6 probably resulted from recharge from precipitation and from bank storage during periods of high water in the river. Discharge from the ground-water reservoir to Mill Creek would be reduced, and water levels in wells on the flood plain would rise in response to increase in stream level.

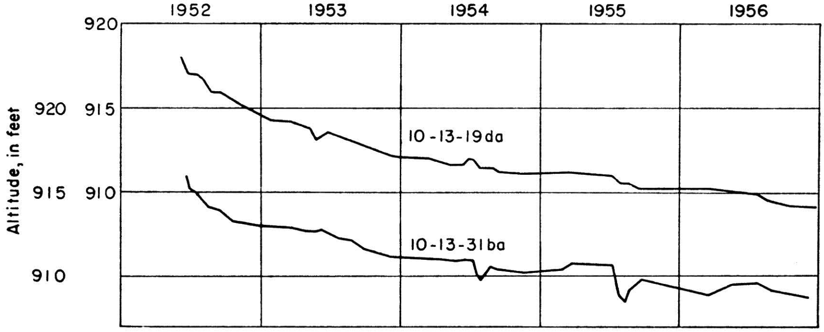


FIG. 5.—Hydrographs of observation well 10-13-19da, 3 miles north of Kansas River, and observation well 10-13-31ba, 1.5 miles north of Kansas River.

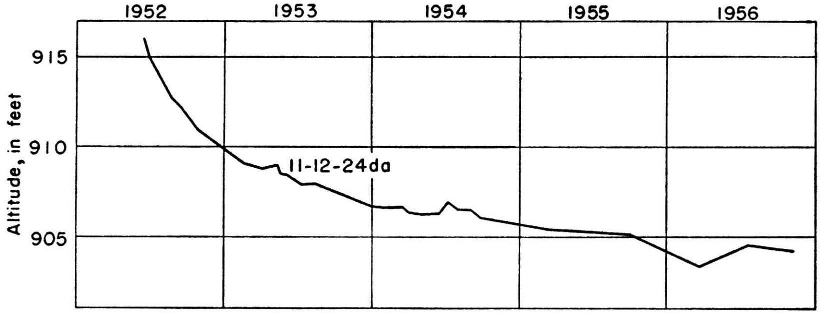


FIG. 6.—Hydrograph of observation well 11-12-24da, 0.5 mile north of Mill Creek.

RECHARGE

Recharge is the addition of water to the ground-water reservoir and may be accomplished in several ways. That part of precipitation that does not run off, evaporate, or transpire from plants may percolate down to the water table and recharge the reservoir. Also, if the river level is above the surrounding water table, the river may contribute ground-water recharge. The quantity of precipitation that infiltrates the soil depends upon several factors: the intensity of the rainfall, the slope of the land, the type of soil, the type and amount of vegetation, and the time of the year.

The amount of ground-water recharge in Kansas River valley was not determined in this investigation. Knapp and others (1940, p. 18) estimated that in Soldier Creek basin in eastern Kansas the annual recharge is about half an inch. According to Lohman (1941, p. 45), ground-water recharge from precipitation at Lawrence in Kansas River valley amounts to as much as 10 percent of the precipitation. The normal annual precipitation at Willard is 31.73 inches. On the basis of Lohman's estimate, the average recharge in this area would be about 3 inches, but in drought years there may be no recharge and in wet years the recharge may be much more than 3 inches.

In much of Kansas River valley the surface is fairly flat and surface runoff is small. Some precipitation accumulates in meander scars and other depressions in the valley, and if these scars are underlain by permeable material, the water soon infiltrates the surface. The scars on the Newman Terrace are underlain by clayey material having low permeability, and water is held in these scars for a long period of time and mostly evaporates.

The fact that the water table generally has sloped toward Kansas River during the period of this investigation (Fig. 7A, C), indicates that the river is receiving water from the ground-water reservoir. During high river stages, the slope of the water table near the river is reversed, and the river recharges the alluvium (Fig. 7B). Some of this recharge water from the river is temporary bank storage that soon drains back into the river. When the stage of the river is high, discharge from the ground-water reservoir is decreased or stopped.

Discharge

Ground-water discharge is the removal, by any method, of water from the zone of saturation. Ground water is discharged in Kansas River valley by transpiration and evaporation, by seepage into streams, by subsurface movement into adjacent areas, and by wells.

Transpiration is the process by which water is taken into the root system of plants and discharged into the atmosphere. Alfalfa is probably the only plant in Kansas River valley that has a root system that penetrates to the water table or capillary fringe. Most of the water discharged by transpiration and evaporation is from the soil zone, but some also is discharged from the zone of saturation.

Kansas River receives water by seepage from the ground-water reservoir in most of the valley. Kansas River has been at a low stage during the period of this investigation, permitting considerable

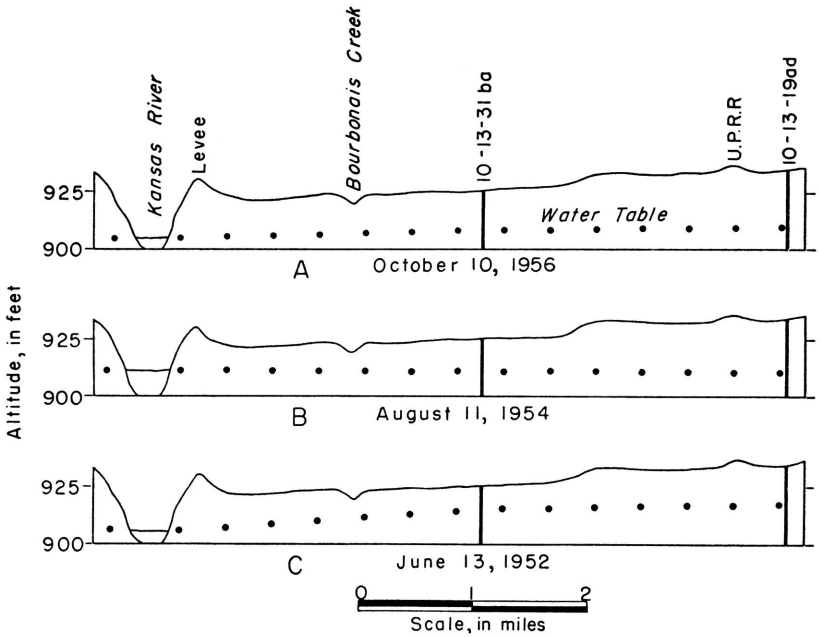


FIG. 7.—Water-table profiles near St. Marys showing the influence of Kansas River stages on recharge and discharge.

quantities of ground-water discharge from the reservoir. Some ground water is discharged by subsurface movement to the east from this section of the valley.

Supplies of domestic, stock, municipal, industrial, and irrigation water in Kansas River valley are derived from wells. The average pumping rate of an irrigation well in this valley is about 700 gpm, and when operating for 24 hours, such a well would remove about 1,000,000 gallons of water from the reservoir. Needed information for computing the total quantity of water pumped annually is not available, but in 1956 the pumpage was small compared to the total discharge. As irrigation increases in Kansas River valley, discharge by irrigation wells may exceed the annual recharge from precipitation.

RECOVERY

When water is standing in a well, there is equilibrium between the pressure of the water within the well and the pressure of the water outside the well. When water is pumped from a well, the pressure inside the well is reduced, and water moves into the well from the surrounding aquifer. When water is being discharged from the well, the water table in the vicinity of the well is lowered, and a depression is formed somewhat resembling an inverted cone. This depression of the water table is known as "the cone of depression", and the amount that the water level is lowered is called the "drawdown" (Fig. 8).

The capacity of a well can be defined as the maximum rate at which it will yield water after the water level during pumping becomes approximately stabilized. The capacity depends on the quantity of water available, the thickness and permeability of the aquifer, and the construction and condition of the well. The capacity of a well generally is expressed in gallons per minute. The specific capacity of a well is its rate of yield per unit of drawdown and is determined by dividing the capacity in gallons per minute by the drawdown in feet. The specific capacity of some of the irrigation wells in Kansas River valley was determined from information obtained from the drillers' tests and is stated under "Remarks" in Table 7.

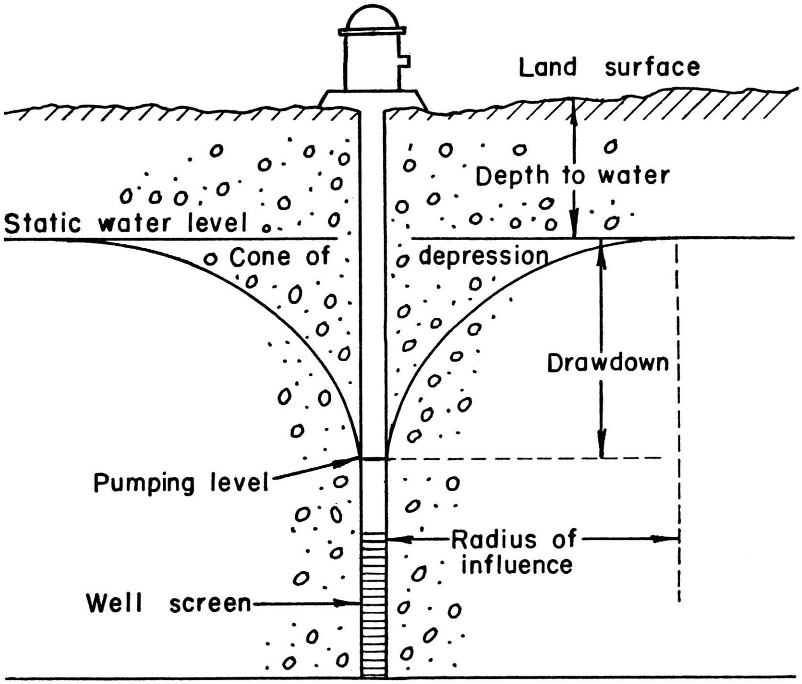


FIG. 8.—Diagrammatic section through a well being pumped.

UTILIZATION

Domestic and stock wells.—About 90 percent of the domestic and stock wells in the valley are driven wells. Many farms have two or more wells, one for domestic supply and the other for stock. The lack of consolidation of the water-bearing material and the shallowness of the water table favor construction of driven wells. The farm wells in the upland are either dug or drilled. Dug wells are walled or curbed with native stone masonry to decrease the possibility of pollution by surface water. Most drilled wells are cased through the unconsolidated material and have a concrete platform at the surface to keep out the surface water.

Irrigation wells.—When this investigation started in 1951, no irrigation wells were in use in Kansas River valley between Kiro and Wamego. By the summer of 1954, however, 10 irrigation wells were operating and an old one was being repaired. By July 1956, 52 irrigation wells were in operation. The drought from 1952 through 1956 caused many farmers to irrigate. The estimated yields of irrigation wells range from 500 to 1,500 gpm, and specific capacities range from 40 to 156 gpm per foot of drawdown. Most irrigation wells in Kansas River valley are drilled 30 inches in diameter, have 16- to 18-inch casing, are gravel packed, and penetrate all the water-bearing materials. Most of the irrigation systems are equipped with turbine pumps driven by engines using gasoline, propane, or natural gas for fuel.

Industrial wells.—Industry is probably the smallest user of ground water in this section of the valley. The alfalfa-dehydrating industry is the only one using ground water, and its process requires very little water.

Public wells.—All public water supplies in this area of the valley are obtained from wells in the sand and gravel underlying the Newman Terrace or the flood plain of Kansas River. The wells are drilled and gravel packed. Wamego, the largest town in the area, pumped an average of 291,600 gallons per day in 1955 from three wells. St. Marys, the next largest town, has four wells approximately 35 feet apart aligned in a northeast-southwest direction. Average daily consumption is about 100,000 gallons. Rossville has two wells that supply 30,000 gallons per day, and Silver Lake has two that supply 35,000 gallons per day.

AQUIFER TESTS

Three aquifer tests were made in Kansas River valley to determine the ability of the aquifer to transmit water and to yield water from storage. Procedures for analyzing aquifer test data have been summarized by Brown (1953), and methods of determining permeability have been summarized by Wenzel (1942).

Campbell aquifer test.—An aquifer test was made on August 10, 1953, using irrigation well 10-10-30ab owned by J. C. Campbell. The data collected during the test have not been included in this report. An analysis of the data by G. J. Stramel, of the U. S. Geological Survey, is summarized as follows:

> The test, in general, was too short to give good results, particularly for the storage coefficient. After analyzing the data by various methods I conclude that the coefficient of transmissibility is about 120,000 gallons per day per foot.

Smith aquifer test.—An aquifer test using well 10-11-2ca was made July 9, 1956. The well, an irrigation well owned by Louis Smith, is equipped with a turbine pump powered by a gas engine and is 70.4 feet deep. The alluvium at this site was 86.4 feet thick, and the water level was 27.5 feet below the surface. Three observation wells, 1E, 2E, and 3E, about 50 feet deep were installed in a line east of the pumped well at distances of 29, 60, and 90 feet respectively. Well 10-11-2ca was pumped for 21 hours and 15 minutes. The rate of discharge was 550 gpm as estimated from the discharge of gates along the irrigation pipe. Depth to water in the pumped well and observation wells was measured at selected intervals during the pumping period (Table 2).

The coefficient of transmissibility (T) of an aquifer can be determined by plotting the time since pumping started (t) in minutes, divided by the square of the distance to the observation well (r) in feet, on a logarithmic scale and the drawdown (s) in feet on an arithmetic scale, and applying the Theis (1935) nonequilibrium formula as modified by Cooper and Jacob (1946, eq. 8) and restated and adjusted for change in units:

$$T = \frac{264\ Q}{s} \log_{10} \frac{t}{r^2}$$

where T is the coefficient of transmissibility, in gpd/ft
Q is the discharge, in gallons per minute,
s is the drawdown of the water level at any distance r from the pumped well, in feet.

TABLE 2.—*Water levels measured in pumped well 10-11-2ca and in observation wells 1E, 2E, and 3E during Smith aquifer test, July 9, 1956*

Time	Time (t) since pumping started, in minutes	Depth to water, in feet			
		Well 10-11-2ca	1E	2E	3E
12:10 p.m.	Static	28.10	...	...	...
1:30	Static	...	29.20	...	...
2:15	Static	...	...	29.29	...
2:16	Static	...	...	...	29.43
3:00	Pump started	...	...	...	...
3:00:30	0.5	...	...	29.43	...
3:01	1	...	29.95	...	...
3:01:30	1.5	...	...	29.27	30.22
3:03	3	...	30.24	29.65	...
3:04	4	...	30.30	30.33	...
3:05	5	...	30.32	...	30.35
3:06	6	...	...	30.00	...
3:07	7	...	30.36	...	30.34
3:08	8	...	...	30.35	...
3:09	9	...	...	...	30.32
3:10	10	...	30.39	30.35	...
3:12	12	...	...	...	30.35
3:13	13	31.32	...	...	...
3:15	15	...	30.42	30.35	...
3:16	16	...	...	...	30.33
3:18	18	31.34	...	...	...
3:20	20	...	30.43	30.35	30.42
3:25	25	...	30.44	30.35	...
3:26	26	...	...	...	30.40
3:28	28	31.26	...	...	...
3:30	30	...	30.44	30.35	...
3:31	31	...	...	...	30.40
3:37	37	31.40	...	...	...
3:40	40	...	30.45	30.40	30.45
3:45	45	31.46	...	...	...
3:50	50	...	30.46	30.40	...
3:51	51	...	...	...	30.45
3:55	55	31.47	...	...	...
4:00	60	...	30.45	30.41	30.45
4:30	90	...	30.49	30.42	30.45
4:32	92	31.49	...	...	...
5:00	120	...	30.50	30.44	30.46
5:02	122	31.50	...	...	...
5:30	150	...	30.50	30.45	30.46
5:32	152	31.51	...	...	...
6:15	195	31.53	30.51	30.46	30.50
7:30	270	31.57	30.53	30.48	30.55
9:00	360	31.59	30.55	30.50	30.57
12:00 a.m.	540	31.61	30.59	30.54	30.60
4:00	780	31.65	30.60	30.55	30.61
8:00	1,020	31.62	30.60	30.55	30.61
11:00	1,200	31.62	30.60	30.55	30.60
12:15 p.m.	Pump stopped	...	...	...	...

Data collected from the observation wells have been plotted on semilogarithmic paper (Fig. 9). The change in water level over one log cycle (Δs) in the three observation wells was 0.22. By applying the modified Theis nonequilibrium formula, the coefficient of transmissibility for the test was computed to be 660,000 gpd/ft.

The drawdown in the pumped well at the end of the pumping period was 3.52 feet, and the specific capacity of the well was 156 gallons per foot of drawdown.

The coefficient of transmissibility (T) of an aquifer can be determined also by use of drawdown data from two or more observation wells. The distance (r) of each observation well from the pumped well is plotted on a logarithmic scale and the drawdown (s) of each

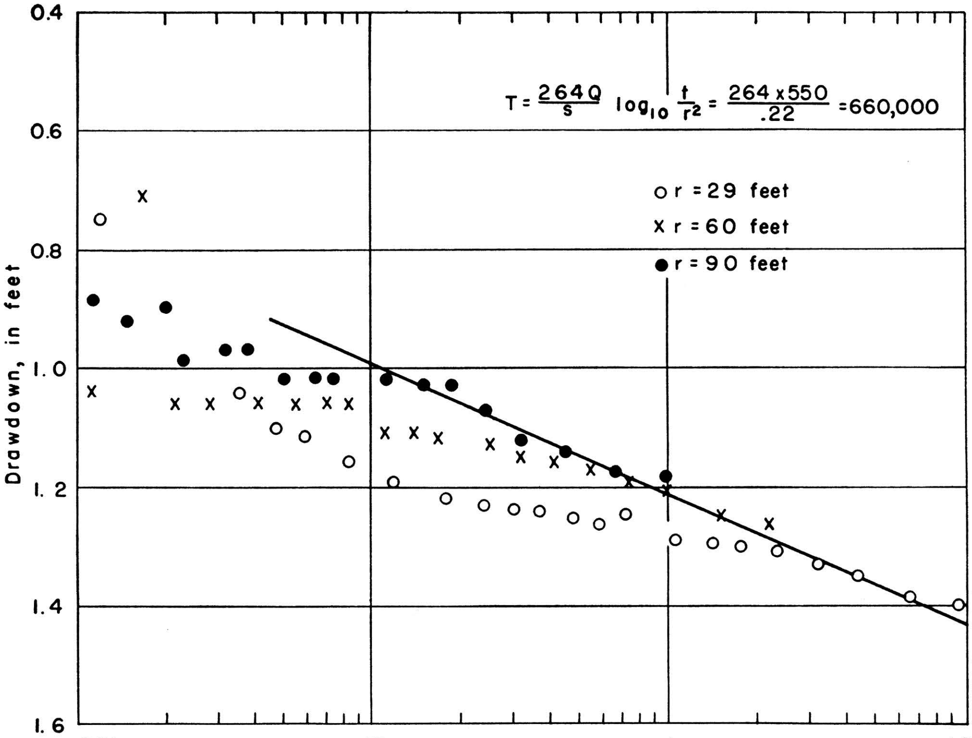


FIG. 9.—Drawdown in observation wells 1E, 2E, and 3E plotted against $\log_{10} t/r^2$ (time in minutes, divided by square of distance between observation well and pumped well, in feet), Smith aquifer test.

observation well on an arithmetic scale. The Thiem formula given by Wenzel (1942) can be reduced to the following formula:

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

where T is the coefficient of transmissibility, in gpd/ft
Q is the discharge, in gallons per minute,
Δs is the drawdown in water level per log cycle of distance of the observation well from the pumped well, in feet.

The drawdown data from observation wells 1E, 2E, and 3E were plotted at 20, 40, 90, 195, and 780 minutes (Fig. 10). The values of Δs, as determined from Figure 10, and the coefficients of transmissibility are as follows:

Time since pumping started, minutes	Δs	*Coefficient of transmissibility, gpd/ft.*
20	0.52	558,000
40	0.51	569,000
90	0.51	569,000
195	0.51	569,000
780	0.46	631,000

Rodgers aquifer test.—An aquifer test using well 11-13-3db was made July 26, 1956. The well, an irrigation well owned by Clyde Rodgers, is equipped with a turbine pump powered by electricity, and is 57 feet deep. The well penetrates about 26 feet of saturated material and does not penetrate the total saturated thickness. Two observation wells, 1N and 2N, were installed in a line north of the pumped well at distances of 60 and 90 feet respectively. Well 11-13-3db was pumped for 24 hours at a rate of about 850 gpm as determined from curves of the Berry Irrigation Supply Company. Depth to water was measured in the pumped well and in the observation wells at selected intervals during the pumping period (Table 3).

The rate of discharge of the well varied during the aquifer test, hence the water-level measurements did not plot as a straight line on semilogarithmic paper and no plot of the measurements has been included in this report. Coefficients of transmissibility ranging from 182,000 to 218,000 were determined from a plot of measurements made during the latter part of the test.

The drawdown in the pumped well at the end of the pumping period was 8.6 feet, and the specific capacity of the well was 99 gallons per foot of drawdown.

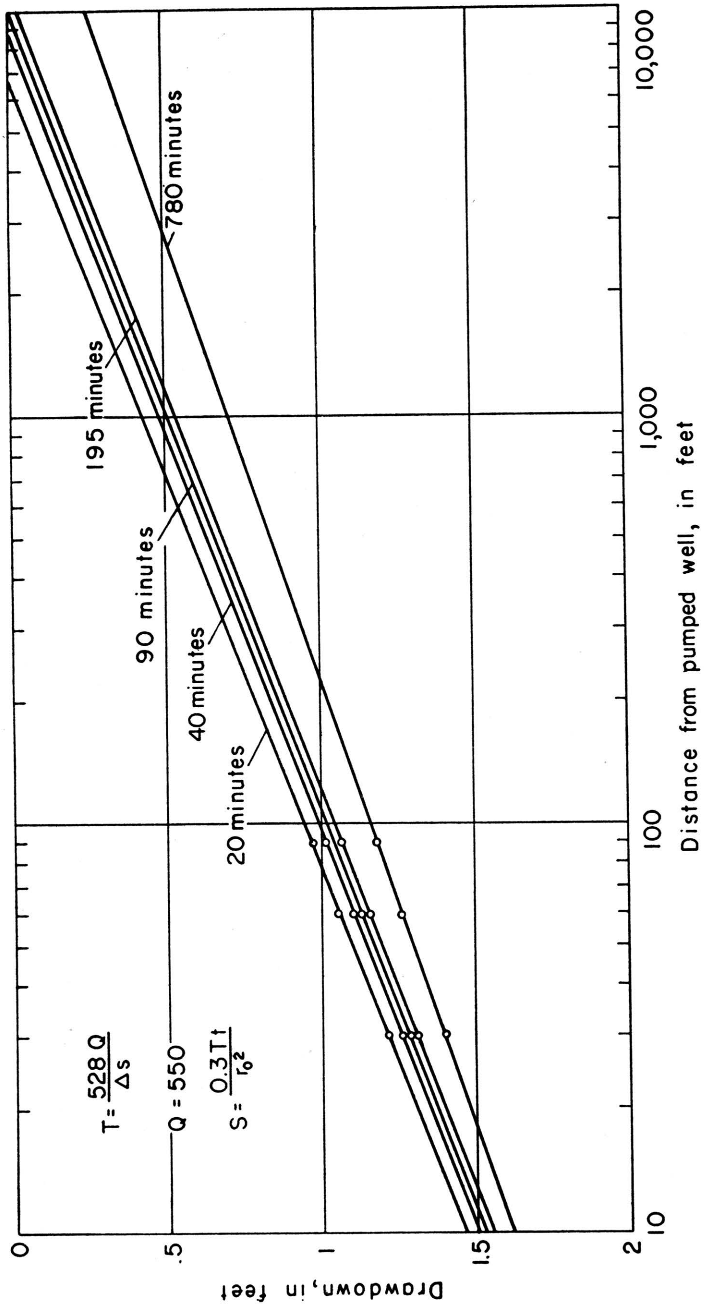


FIG. 10.—Drawdown of water level in observation wells 1E, 2E, and 3E at 20, 40, 90, 195, and 780 minutes plotted against distance from pumped well 10-11-2ca in Smith aquifer test.

TABLE 3.—*Water levels measured in pumped well 11-13-3db and in observation wells 1N and 2N during Rodgers aquifer test, July 26, 1956*

Time	Time (t) since pumping started, in minutes	Depth to water, in feet		
		Well 11–13–3db	1N	2N
6:50 a.m.	Static	31.73		
6:55	Static		31.23	
6:57	Static			31.47
7:00	Pump started			
7:00:30	0.5	35.20		
7:01	1	37.00		
7:02	2	40.10		
7:03	3	40.20		
7:05	5		31.63	
7:07	7	40.20		
7:09	9	40.20		
7:10	10		31.68	
7:13	13	40.25		
7:15	15	40.90		
7:18	18		31.76	
7:20	20	40.59		
7:22	22		31.76	
7:23	23			31.57
7:25	25	40.35		
7:27	27		31.69	
7:28	28			31.72
7:30	30	40.05		
7:32	32		31.72	
7:33	33			31.82
7:40	40	40.38		
7:42	42		31.77	
7:45	45			31.83
7:50	50	40.64		
7:52	52		31.74	
7:54	54			31.85
8:00	60	40.65		
8:02	62		31.75	
8:03	63			31.87
8:15	75	40.65		
8:17	77		31.85	
8:18	78			31.90
8:30	90	40.39		
8:32	92		31.94	
8:33	93			32.01
8:45	105	40.02		
8:47	107		31.82	
8:48	108			31.93
9:00	120	40.02		
9:01	121		31.89	
9:02	122			31.99
9:30	150	39.93		
9:32	152		32.07	
9:34	154			32.05
10:00	180	39.90		
10:05	185		32.11	
10:06	186			32.07
11:00	240	40.20		

TABLE 3.—*Water levels measured in pumped well 11-13-3db and in observation wells 1N and 2N during Rodgers aquifer test, July 26, 1956—Concluded*

Time	Time (t) since pumping started, in minutes	Depth to water, in feet		
		Well 11-13-3db	1N	2N
11:01	241	....	32.25	....
11:02	242	....	....	32.18
12:32 p.m.	332	40.55	....	....
12:35	335	....	32.40	....
12:37	337	....	....	32.30
9:00	840	40.50	....	....
9:02	842	....	32.80	....
9:03	843	....	....	32.87
6:52 a.m.	1,432	40.35	....	....
6:55	1,435	....	33.34	....
6:57	1,437	....	....	33.27
7:00	Pump stopped	....	....	....

QUALITY

The chemical quality of ground water in Kansas River valley is shown by the analyses of 18 samples of water collected from wells (Table 4). The analyses, made in the Water and Sewage Laboratory of the Kansas State Board of Health, show the dissolved mineral content of the water and not the sanitary conditions 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.—Evaporation of natural water leaves a residue that consists chiefly of mineral matter, and generally of some organic material and a small amount of water of crystallization. Water containing more than 1,000 parts per million of dissolved solids may be used for domestic and irrigation purposes, but it is likely to contain certain constituents in quantities sufficient to make its use unsatisfactory. Water containing less than 500 ppm of dissolved solids generally is suitable for most purposes unless it contains excessive quantities of iron, fluoride, nitrate, or less common constituents that are not discussed subsequently and are not present regularly in well water in eastern Kansas.

The dissolved solids in water derived from alluvium and terrace deposits ranged from 307 to 917 ppm. Water samples from two wells contained more than 600 ppm, and two had less than 400 ppm. Water from wells in the bedrock was not sampled, but Davis and Carlson (1952) reported that water in bedrock wells generally contains more dissolved solids than does the water from alluvium.

TABLE 4.—*Analysis of water from typical wells in Kansas River valley between Topeka and Wamego*

Dissolved constituents given in parts per million [a] and in equivalents per million [b] (in italics)

WELL NUMBER	Depth (feet)	Geologic source	Date of collection	Dissolved solids	Silica (SiO₂)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO₃)	Sulfate (SO₄)	Chloride (Cl)	Fluoride (F)	Nitrate (NO₃)	Hardness as CaCO₃		
															Total	Carbonate	Noncarbonate
9-10-26db...	50.0	Newman Terrace deposits..	5-22-53	493	14	1.0	130 *6.49*	29 *2.38*	19 *0.83*	533 *8.74*	17 *0.35*	21 *0.59*	0.1 *.01*	0.97 *.02*	444	437	7.0
9-11-33ca...	27	do......................	4-28-53	457	23	0.05	124 *6.04*	16 *1.32*	21 *.91*	433 *7.10*	33 *.69*	15 *.42*	0.1 *.01*	12 *.19*	376	355	21
10-10-3cd....	30	do......................	4-22-53	307	24	0.28	62.0 *3.09*	10 *.82*	24 *1.04*	144 *2.36*	64 *1.33*	34 *.96*	0.2 *.01*	18 *.29*	196	118	78
10-10-11dc...	31	Alluvium................	5-22-53	488	12	0.29	131 *6.54*	16 *1.32*	22 *.96*	386 *6.33*	65 *1.35*	24 *.68*	0.3 *.02*	28 *.45*	393	316	77
10-10-16ac...	30	do......................	5-21-53	413	14	0.14	109 *5.44*	14 *1.15*	25 *1.09*	394 *6.46*	38 *.79*	10 *.28*	0.4 *.02*	8.8 *.14*	330	323	7.0
10-11-2aa....	29	Newman Terrace deposits..	4-22-53	481	20	0.94	130 *6.49*	20 *1.64*	15 *.65*	412 *6.76*	78 *1.62*	13 *.37*	0.3 *.02*	1.5 *.02*	406	338	68
10-11-5dd....	24	Alluvium................	4-22-53	496	21	7.4	138 *6.89*	24 *1.97*	14 *.61*	522 *8.56*	32 *.67*	8.0 *.23*	0.2 *.01*	1.3 *.02*	443	428	15
10-11-15ac...	44	Buck Creek Terrace deposits	5- 9-53	489	3.2	0.06	105 *5.24*	21 *1.73*	51 *2.22*	429 *7.04*	48 *1.00*	27 *.76*	0.1 *.01*	23 *.37*	348	348	0.0
10-12-7aa....	25	Alluvium................	4-22-53	766	23	0.65	196 *9.78*	25 *2.06*	34 *1.48*	544 *8.92*	77 *1.60*	41 *1.16*	0.2 *.01*	102 *1.64*	592	446	146
10-12-16db...	25	Newman Terrace deposits..	4-22-53	469	20	1.2	116 *5.79*	17 *1.40*	32 *1.39*	410 *6.72*	47 *.98*	24 *.68*	0.3 *.02*	11 *.18*	360	336	24
10-12-28cc...	55.7	do......................	5- 9-53	552	11	12.0	107 *5.34*	22 *1.81*	73 *3.18*	471 *7.72*	0 *0.0*	86 *2.43*	0.1 *.01*	18 *.29*	358	358	0.0
10-13-20cb...	30	do......................	4-28-53	570	29	0.05	148 *7.39*	18 *1.48*	18 *.78*	381 *6.25*	46 *.95*	35 *.99*	0.1 *.01*	88 *1.41*	443	312	131

10-13-31bb...	41	Alluvium................	4-25-53	445	19	4.9	124 *6.19*	15 *1.23*	19 *.83*	418 *6.86*	49 *1.02*	12 *.34*	0.2 *.01*	0.97 *.02*	371	343	28
11-13-1dd....	30	Newman Terrace deposits..	4-28-53	471	22	0.07	128 *6.39*	7.0 *.58*	10 *.44*	229 *3.76*	49 *1.02*	27 *.77*	0.2 *.01*	115 *1.85*	348	188	160
11-13-5da....	34.3	Alluvium................	4-25-53	494	20	0.05	134 *6.69*	15 *1.23*	24 *1.04*	432 *7.08*	46 *.95*	18 *.51*	0.3 *.02*	24 *.39*	396	354	42
11-14-20db...	27	do......................	5- 9-53	493	24	0.33	156 *7.78*	14 *1.15*	8.3 *.36*	522 *8.56*	14 *.29*	10 *.28*	0.1 *.01*	9.3 *.15*	446	428	18
11-14-21ab...	26	do......................	4-25-53	917	17	0.10	219 *10.93*	28 *2.30*	33 *1.44*	382 *6.26*	137 *2.85*	65 *1.83*	0.3 *.02*	230 *3.70*	662	313	349
11-14-23ab...	28	Newman Terrace deposits..	4-25-53	397	25	0.06	105 *5.24*	13 *1.07*	19 *.83*	349 *5.72*	44 *.92*	14 *.39*	0.3 *.02*	4.9 *.08*	316	286	30

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

[b] An equivalent per million is a unit chemical equivalent weight of solute per million unit weights of solution. Concentration in equivalents per million is calculated by dividing the concentration in parts per million by the chemical combining weight of the substance or ion.

Factors for converting parts per million of mineral constituents to equivalents per million are given in Table 5.

Hardness.—Hardness of water is generally the property that receives the most attention and is recognized most commonly by its effect when soap is used with the water. Hardness constituents are also the active agents in the formation of the greater part of the scale 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 due to the presence of calcium and magnesium bicarbonate, and it is considerably reduced by boiling. This type of hardness has been called temporary hardness. Noncarbonate hardness is due to sulfates and chlorides of calcium and magnesium and cannot be removed by boiling. This type of hardness has 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 scale in steam boilers than does carbonate hardness.

Water having a hardness of less than 50 ppm generally is regarded as soft, and its treatment for removal of hardness is not necessary under ordinary circumstances. Hardness between 50 and 150 ppm does not interfere seriously with the use of water for most purposes, but it does increase slightly the consumption of soap, and removal of part of the hardness 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 exceeding 150 ppm is noticeable, and if the hardness is more than 200 ppm, water for household use commonly is softened, or cisterns are installed to collect soft rain water.

In 18 water samples collected for analyses, the total hardness ranged from 196 to 662 ppm. Of the 662 ppm hardness, 349 ppm was noncarbonate hardness. The noncarbonate hardness exceeded 100 ppm in only 3 samples. Water that had the greatest hardness also contained the most dissolved solids.

Iron.—Next to hardness, iron is the constituent of water 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 water contains more than 0.3 ppm of iron, the iron may precipitate as a reddish sediment. Iron, 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 aeration and filtration, but a few waters require the addition of lime or some other substance.

Iron content of the ground water from alluvium ranged from 0.05 to 12.0 ppm. Three of the 18 samples contained more than 4 ppm and 8 contained more than 0.3 ppm.

Chloride.—Water containing less than 150 ppm of chloride is not objectionable for most uses, but water containing more than 500 ppm has an objectionable taste and generally is unsatisfactory for irrigation or industry.

Chloride content of the water samples analyzed ranged from 8 to 86 ppm. In none of the wells inventoried did the water have a salty taste. Insofar as chloride content is concerned, the ground water seems to be satisfactory for domestic and irrigation use.

Fluoride.—Although the quantity of fluoride is relatively small compared with other common constituents of water, the amount of fluoride in water that is likely to be used by children should be known. Fluoride in water has been associated with the dental defect known as mottled enamel, which may appear on the teeth of children who, during the formation of their permanent teeth, habitually drink water containing excessive fluoride. Water containing more than 1.5 ppm of fluoride is likely to produce mottled enamel. If the water contains as much as 4 ppm 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, prove beneficial by decreasing tooth decay. Fluoride content of water from the alluvium of Kansas River valley ranged from 0.1 to 0.4 ppm and averaged about 0.3 ppm.

Nitrate.—The nitrate content of water from wells in the area ranged from 0.97 to 230 ppm. Three of the 18 samples contained more than 90 ppm of nitrate; the rest had less than 30 ppm. The difference in nitrate content of the water is considerable, but seemingly is not related to any geologic condition.

A large amount of nitrate in water may cause cyanosis when the water is used in preparation of a baby's formula. Water that contains more than 90 ppm of nitrate is regarded by the Kansas State Board of Health as likely to cause infant cyanosis, whereas water containing less than 45 ppm generally is considered safe.

WATER FOR IRRIGATION

This discussion of suitability of water for irrigation is adapted from Agriculture Handbook No. 60 of the U. S. Department of Agriculture.

Successful irrigation depends not only upon the supplying of irrigation water to the land but also the control of the salinity and alkalinity of the soil. Quality of irrigation water, irrigation practices, and drainage are involved in salinity and alkalinity control. Soil that was originally nonsaline and nonalkali may become unproductive if excessive soluble salts or exchangeable sodium are allowed to accumulate because of improper irrigation and soil-management practices or inadequate drainage.

In areas of sufficient rainfall and ideal soil conditions the soluble salts originally present in the soil or added to the soil by water are carried downward by the water and ultimately reach the water table. This process of dissolving and transporting soluble salts by the downward movement of water through the soil is called leaching. If the amount of water applied to the soil is not in excess of the amount needed by plants, there will be no downward percolation of water below the root zone, and mineral matter will accumulate. Likewise, impermeable soil zones near the surface can retard the downward movement of water, resulting in water-logging of the soil and deposition of salts. Leaching requires the free passage of water through and away from the root zone, hence, unless drainage is adequate, attempts at leaching may not be successful.

The characteristics of an irrigation water that seem to be most important in determining its quality are: (1) total concentration of soluble salts; (2) relative proportion of sodium to other cations (magnesium, calcium, and potassium); (3) concentration of boron or other elements that may be toxic; and (4) under some conditions, the bicarbonate concentration as related to the concentration of calcium plus magnesium.

For purposes of diagnosis and classification of irrigation water, the total concentration of soluble salts can be adequately expressed in terms of electrical conductivity, which is a measure of the ability of the inorganic salts in solution to conduct an electrical current, and which in soils work usually is expressed in terms of micromhos per centimeter. The electrical conductivity can be determined in the laboratory, or an approximation of the electrical conductivity may be obtained by multiplying the total equivalents per million (Table 5) of calcium, sodium, magnesium, and potassium by 100, or by dividing the total dissolved solids in parts per million by 0.64.

In general, waters having electrical conductivity values below 750 micromhos are satisfactory for irrigation insofar as salt content is concerned, although salt-sensitive crops such as strawberries, green beans, and red clover may be affected adversely by irrigation water having an electrical conductivity value in the range of 250 to 750 micromhos. Waters in the range of 750 to 2,250 micromhos are widely used, and satisfactory crop growth is obtained under good management and favorable drainage, but saline conditions will develop if leaching and drainage are inadequate. Use of waters having conductivity values above 2,250 micromhos is the exception, and very few projects can be cited where such waters have been used successfully.

In the past the relative proportion of sodium to other cations in irrigation water usually has been expressed simply as percent sodium. According to the U. S. Department of Agriculture, however, the sodium-adsorption ratio (SAR), used to express the relative activity of sodium ions in exchange reactions with soil, is a much better measure of the suitability of water for irrigation. The sodium-adsorption ratio may be determined by use of the nomogram shown in Figure 11. In using the nomogram to determine the sodium-adsorption ratio of a water, the concentration of sodium expressed in equivalents per million (Table 5) is plotted on the left-hand scale (A), and the concentration of calcium plus magnesium expressed in equivalents per million is plotted on the right-hand scale (B). The point where the line connecting these two points intersects the sodium-adsorption-ratio scale (C) is the sodium-adsorption ratio of the water. When the sodium-adsorption ratio and the electrical conductivity of a water are known, the suitability of the water for irrigation can be determined by plotting these values on the diagram shown in Figure 12. Low-sodium water (S1) can be used for irrigation on almost all soils with little

TABLE 5.—*Factors for converting parts per million of mineral constituents to equivalents per million*

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

danger of the development of harmful levels of exchangeable sodium. Medium-sodium water (S2) will present an appreciable sodium hazard in certain fine-textured soils, especially under low-leaching conditions. This water may be safely used on coarse-textured or organic soils having good permeability. High-sodium

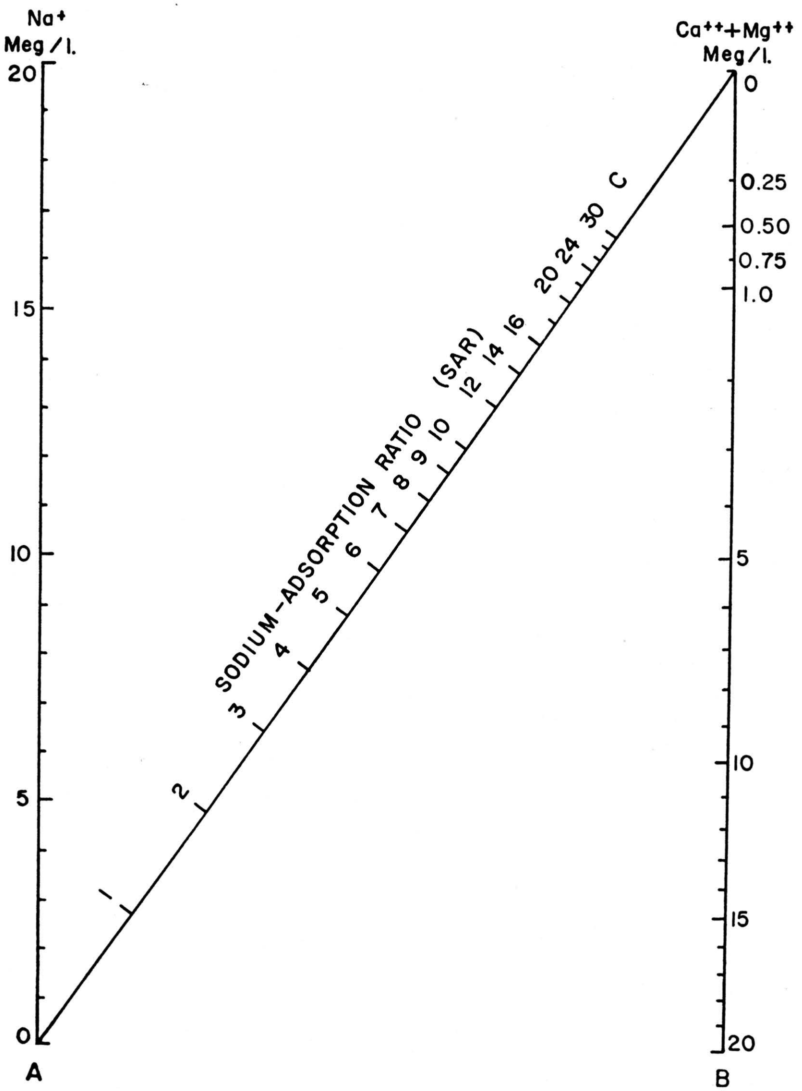

FIG. 11.—Nomogram for determining value of sodium-adsorption ratio of irrigation water.

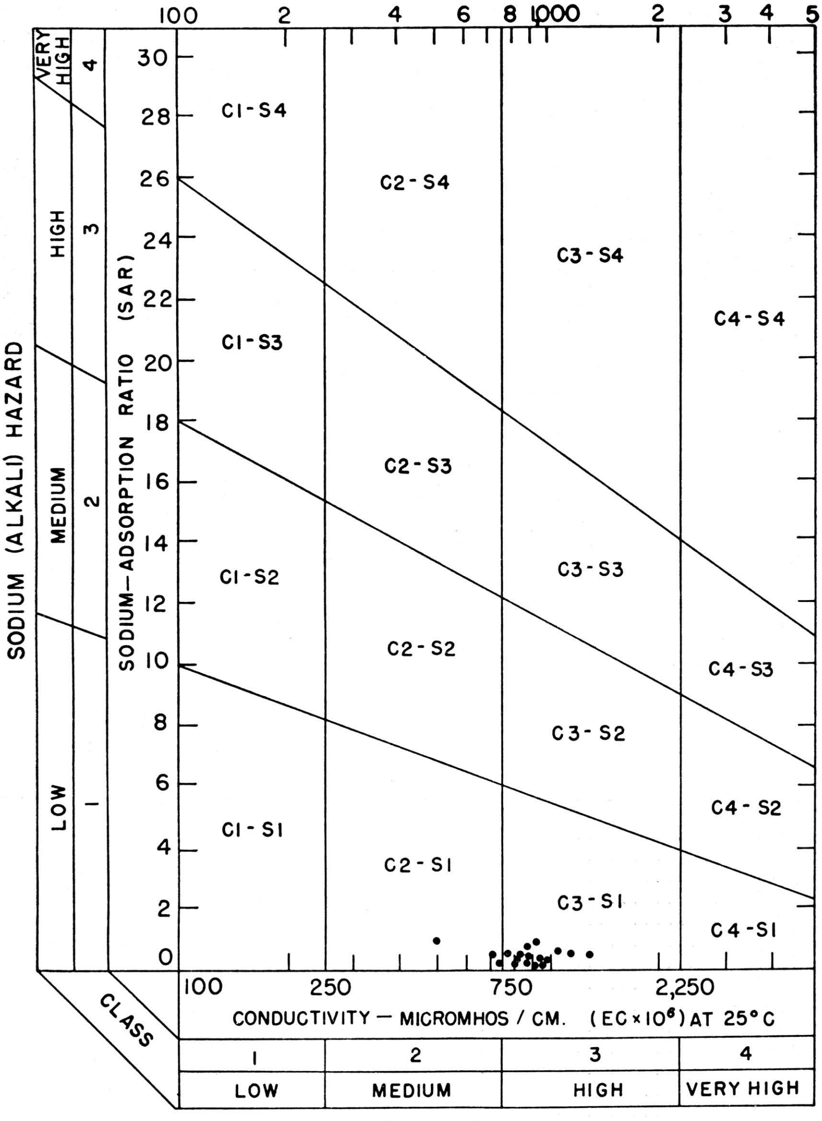

FIG. 12.—Diagram showing classification of water for irrigation.

water (S3) may produce harmful levels of exchangeable sodium in most soils and will require special soil management, such as good drainage, high leaching, and additions of organic matter. Very high sodium water (S4) is generally unsatisfactory for irrigation unless special action is taken, such as addition of gypsum to the soil.

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

Boron is essential to normal plant growth, but the quantity required is very small. Crops differ greatly in their boron tolerances, but in general, the ordinary field crops common to Kansas are not adversely affected by boron concentrations of less than 1 ppm.

TABLE 6.—*The sodium-adsorption ratio (SAR), conductivity, and class of water samples shown on Figure 12. (Chemical analyses of water samples are given in Table 4).*

Well number	SAR	Electrical conductivity, micromhos	Class
9-10-26db	0.40	970	C3-S1
9-11-33ca	0.50	830	C3-S1
10-10-3cd	0.76	500	C2-S1
10-10-11dc	0.46	880	C3-S1
10-10-16ac	0.64	770	C3-S1
10-11-2aa	0.32	880	C3-S1
10-11-5dd	0.30	950	C3-S1
10-11-15ac	1.20	920	C3-S1
10-12-7aa	0.60	1,330	C3-S1
10-12-16db	0.80	860	C3-S1
10-12-28cc	0.75	1,030	C3-S1
10-13-20cb	0.32	960	C3-S1
10-13-31bb	0.40	820	C3-S1
11-13-5da	0.52	800	C3-S1
11-13-12db	0.24	740	C2-S1
11-14-20db	0.12	930	C3-S1
11-14-21ab	0.60	1,470	C3-S1
11-14-23ab	0.52	710	C2-S1

The boron content of water samples from Kansas River valley was not determined, but other investigations in the general area have not found excessive concentration of boron in the water.

Of the waters sampled in Kansas River valley, none was unsuitable for irrigation (Fig. 12). None of the samples had a sodium-adsorption ratio greater than 1.2, and for most of the samples it was below 0.75 (Table 6). The electrical conductivity ranged from 500 to 1,470 micromhos and for most samples was between 750 and 1,000. Most soils in Kansas River valley drain adequately, hence waters having conductivities of this magnitude are not detrimental.

RECORDS OF WELLS AND TEST HOLES

Information pertaining to 155 wells and test holes in Kansas River valley between Wamego and the vicinity of Topeka is tabulated in the following pages (Table 7). The well-numbering system used in this report is described on page 11.

TABLE 7.—*Records of wells and test holes in Kansas River valley between Topeka and Wamego*

Well number (1)	Location	Owner or tenant	Type of well (2)	Depth of well, feet (3)	Diameter of well, inches	Type of casing (4)	Principal water-bearing bed		Method of lift (5)	Use of water (6)	Measuring point			Depth to water level below land surface, feet (7)	Date of measurement	REMARKS (Yield given in gallons a minute; drawdown in feet)
							Character of material	Geologic source			Description	Distance above land surface, feet	Height above mean sea level, feet			
	T. 9 S., R. 10 E.															
9-10-26ad	SE NE sec. 26		B	68	3	N	Sand and gravel	Newman Terrace deposits	N	O	Land surface	0.0	975	27.0	10-16-56	
*9-10-26db	NW SE sec. 26	Leland Eichem	Du	50.0	30	R	do.	do.	Cy, H	D, S	Rock platform	1.5	981	33.5	5-22-53	
9-10-27ca	NE SW sec. 27	Lester Jennings	Du	....	30	R	do.	do.	Cy, W	D, S	do.	1.3	992	26.8	7-18-55	Unsatisfactory, abandoned.
9-10-27da	NE SE sec. 27		B	68	3	N	do.	do.	N	O	do.	0.0	981	32.4	1-21-57	
9-10-34ad	SE NE sec. 34		B	67	3	N	do.	do.	N	O	do.	0.0	981	28.8	1-21-57	
9-10-35aa	NE NE sec. 35	School District	Du	38.0	36	R	do.	do.	Cy, H	D	Top of platform	0.5	978	31.3	1-21-57	
9-10-35ab	NW NE sec. 35		B	70	3	N	do.	do.	N	O	Land surface	0.0	973	30.4	1-21-57	
9-10-36ba	NE NW sec. 36		B	56	3	N	do.	do.	N	O	do.	0.0	975	30.0	10-16-56	
9-10-36ca	NE SW sec. 36		B	59	3	N	do.	do.	N	O	do.	0.0	977	27.0	10-24-55	
	T. 9 S., R. 11 E.															
9-11-19cd	SE SW sec. 19		Dr	96.5	4	N	Sand	Buck Creek Terrace deposits	N	O	Land surface	0.0	987	....	....	Test hole log.
9-11-28cc	SW SW sec. 28	R. R. Peddicord	Dr	74.0	6	GI	Sand and gravel	Newman Terrace deposits	Cy, E	D	Top of concrete pit	0.0	967	23.3	8-17-54	
9-11-29cb	NW SW sec. 29	R. P. Peddicord	Dr	73	18	GI	do.	do.	T, G	I	Top of casing	1.2	970	24.1	8-17-54	
9-11-30aa	NE NE sec. 30	R. P. Peddicord	Dr	82	18	GI	do.	do.	T, G	I	do.	0.5	973	30.0	8- 3-56	Estimated specific capacity 100 g/ft. dd.
9-11-30cd	SE SW sec. 30		Dr	83.0	4	N	Sand	do.	N	O	Land surface	0.0	963	....	....	Test hole log.
9-11-30dc	SW SE sec. 30	R. B. Peddicord	Dr	60	6	GI	Sand and gravel	do.	N	D	Top of concrete pit	0.0	969	27.6	8-17-54	Abandoned.
9-11-30dd	SE SE sec. 30	T. Peddicord	Dr	74	18	GI	do.	do.	T, G	I	Land surface	0.0	968	26.0	8- 3-56	Estimated specific capacity 100 g/ft. dd.
9-11-31ca	NE SW sec. 31	H. Rain	Dn	26	1.5	GP	do.	do.	Cy, E	D, S	do.	0.0	964	22.0	8-17-54	
9-11-31da	NE SE sec. 31	R. Peddicord	B	18	3	N	do.	Alluvium	N	D	do.	0.0	960	15.2	6-11-52	

11-31dc...	SW SE sec. 31....	....	Dr	53.5	4	N	Sand.....	do..............	N	O	do...........	0.0	962	....	....	Test hole log.
11-32cc...	SW SW sec. 32....	R. Fulmer........	Dr	46.0	18	GI	Sand and gravel	do..............	T, G	I	Top of casing	1.5	960	21.9	8- 8-55	Estimated specific capacity 100 g/ft dd.
9-11-32dc...	SW SE sec. 32....	C. Banks.........	Dr	67	18	GI	do.......	do..............	T, G	I	Land surface..	0.0	963	26.6	5-18-54	
9-11-33bc...	SW NW sec. 33...	....	Dr	55	18	S	do.......	Newman Terrace deposits	T, G	I	Top of casing	1.0	969	25.2	4-26-53	
*9-11-33ca...	NE SW sec. 33....	L. Banks.........	Dn	27	1.25	GP	do.......	do..............	Cy, E	D, S	Land surface..	0.0	966	22.0	8-12-52	
9-11-33cc...	SW SW sec. 33....	Peddicord and Banks	Dr	72	18	GI	do.......	do..............	T, G	I	do...........	0.0	966	27	7-12-55	
9-11-35dd..	SE SE sec. 35.....	....	B	20	3	N	do.......	do..............	N	O	do...........	0.0	954	17.0	4-26-53	
	T. 10 S., R. 10 E.															
10-10-1bd...	SE NW sec. 1.....	....	B	62	3	N	do.......	do..............	N	O	do...........	0.0	976	26.0	10-16-56	
10-10-1ca....	NE SW sec. 1.....	T. E. Macquin....	Dr	63	18	GI	do.......	do..............	T, G	I	Hole in pump base	1.2	972	30.1	8- 8-56	
10-10-2ad...	SE NE sec. 2.....	J. C. Pitney......	Dr	63	14	GI	do.......	do..............	T, G	I	Top of casing	1.4	975	25.7	5-29-53	
10-10-3aa...	NE NE sec. 3.....	....	B	67	3	N	do.......	do..............	N	O	Land surface..	0.0	976	28.0	10-24-55	
10-10-3ad...	SE NE sec. 3.....	....	B	68	3	N	do.......	do..............	N	O	do...........	0.0	976	26.0	10-24-55	
10-10-3bb...	NW NW sec. 3...	....	B	68	3	N	do.......	do..............	N	O	do...........	0.0	984	29.0	10-24-55	
*10-10-3cd...	SE SW sec. 3.....	....	Dn	30	2	GP	do.......	do..............	Cy, H	D	do...........	0.0	984	27	4- 8-52	
10-10-3db...	NW SE sec. 3.....	N. T. Larson.....	Dr	92	18	GI	do.......	do..............	T, G	I	Base of pump	0.7	982	31.8	1-21-57	
10-10-9ba...	NE NW sec. 9....	City of Wamego ..	Dr	59	13	C	do.......	do..............	T, E	P	Top of concrete curb	1.0	991	32.0	6- 5-53	Three wells within 500 ft., all same depth. Average pumpage in 1955, 291,600 gpd.
10-10-9dc...	SW SE sec. 9.....	....	B	46	3	N	do.......	Alluvium.........	N	O	Land surface..	0.0	975	17.6	10-24-55	
10-10-10ac...	SW NE sec. 10....	....	B	58	3	N	do.......	Newman Terrace deposits	N	O	do...........	0.0	980	26.0	10-24-55	
*10-10-11dc...	SW SE sec. 11....	L. Miller.........	Dn	31	1.5	GP	do.......	Alluvium.........	J, E	D, S	do...........	0.0	....	15.0	5-22-53	
10-10-11dd..	SE SE sec. 11.....	L. Miller.........	Dr	43.5	18	GI	do.......	do..............	T, G	I	Hole in pump base	1.0	966	17.0	7-13-56	
10-10-12bb..	NW NW sec. 12 ..	....	Dn	35	2	GP	do.......	do..............	N	D	Top of pipe...	1.0	964	16.5	4- 8-52	
10-10-14bc...	SW NW sec. 14...	L. Reed..........	Dn	25	2	GP	do.......	do..............	Cy, H	D	do...........	-2.0	963	16.0	4- 8-52	
10-10-14bd..	SE NW sec. 14....	J. R. Reed.......	Dr	46.0	18	GI	do.......	do..............	T, G	I	Top of casing	1.3	964	18.7	8- 5-55	Estimated specific capacity 150 g/ft. dd.
10-10-15cc...	SW SW sec. 15....	....	B	42	3	N	do.......	do..............	N	O	Land surface..	0.0	973	16.0	10-24-55	
	T. 10 S., R. 10 E.															
10-10-16aa...	NE NE sec. 16....	C. Banks.........	Dr	63.0	18	GI	do.......	do..............	T, G	I	Hole in pump base	1.0	974	16.0	8- 3-56	
*10-10-16ac...	SW NE sec. 16....	A. Soelter........	Dn	30	2	GP	do.......	do..............	J, E	D	Basement floor	-5.0	969	18.0	4- 8-52	
10-10-16cd...	SE SW sec. 16....	....	B	67	3	N	do.......	do..............	N	O	Land surface..	0.0	977	20.0	10-24-55	
10-10-17da..	NE SE sec. 17....	L. H. Weixelman..	Dr	65	18	GI	do.......	do..............	T, G	I	Hole in pump base	1.3	978	19.9	8- 3-56	
10-10-18ad..	SE NE sec. 18....	W. Pine..........	B	44	3	N	do.......	do..............	N	D	Land surface..	0.0	976	16.0	10-24-55	

Table 7.—*Records of wells and test holes in Kansas River valley between Topeka and Wamego*—Continued

Well number (1)	Location	Owner or tenant	Type of well (2)	Depth of well, feet (3)	Diameter of well, inches	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Distance above land surface, feet	Measuring point: Height above mean sea level, feet	Depth to water level below land surface, feet (7)	Date of measurement	REMARKS (Yield given in gallons a minute; drawdown in feet)
	T. 10 S., R. 10 E.															
10-10-18bd	SE NW sec. 18		Dn	30	2	GP	Sand and gravel	Alluvium	Cy, H	D	Top of pipe	2.0	982	17.0	4- 8-52	
10-10-19ac	SW NE sec. 19		B	65	3	N	do	do	N	O	Land surface	0.0	979	16.0	10-24-55	
10-10-19cd	SE SW sec. 19	C. Erickson	Dr	43	18	GI	do	do	T, G	I	do	0.0	979	16.0	5- 9-56	
10-10-20ca	NE SW sec. 20	A. F. Garansson	Dr	54.0	18	GI	do	do	T, E	I	Top of casing	1.5	981	20.5	8- 3-56	
10-10-20cd	SE SW sec. 20	B. L. Gregg	Dr		6	GI	do	do	J, E	D, S	do	-7.0	976	22.3	6-11-52	
10-10-21ba	NE NW sec. 21	D. Soelter	Dr	54	18	GI	do	Newman Terrace deposits	T, G	I	Land surface	0.0	978	20.0	8- 2-56	
10-10-28ba	NE NW sec. 28	R. Morton	Dr		6	GI	do	Buck Creek Terrace deposits	Cy, E	D, S	Top of platform	0.6	1,014	37.4	6-11-53	
10-10-28bc	SW NW sec. 28	do	Dr	48	18	GI	do	do	T, G	I	Land surface	0.0	998	22.0	8- 3-56	
10-10-30ac	SW NE sec. 30	A. B. Garansson	Dr		6	GI	do	do	Cy, E	D, S	Top of platform	1.3	1,008	39.2	6-11-56	
10-10-30db	NW SE sec. 30	do	Dr	59.0	18	GI	do	do	T, E	I	Top of casing	0.3	1,013	44.9	8- 3-56	
	T. 10 S., R. 11 E.															
*10-11-2aa	NE NE sec. 2	L. Smith	Dn	29	1.25	GP	do	Newman Terrace deposits	Cy, E	D, S	Land surface	0.0	960	22.0	8-10-53	
10-11-2bb	NW NW sec. 2	do	Dr	45	6	GI	do	do	Cy, H	D	Top of pit	1.0	961	21.7	4-26-53	
10-11-2ca	NE SW sec. 2	do	Dr	70.4	18	GI	do	do	T, G	I	Hole in pump base	0.6	961	27.5	7- 9-56	Measured specific capacity 156 g/ft. dd. Used in aquifer test.
10-11-3ba	NE NW sec. 3	F. Pitney	Dr	75.0	6	GI	do	do	Cy, E	D	Top of concrete pit	0.0	958	21.6	5-25-53	
*10-11-5dd	SE SE sec. 5	R. Boyce	Dn	24	1.5	GP	do	Alluvium	Cy, H	D, S	Land surface	0.0	955	16.0	4-22-53	
10-11-7ad	SE NE sec. 7		Dr	38.0	4	N	do	Buck Creek Terrace deposits	N	O	do	0.0	980			Test hole log.
10-11-7dc	SW SE sec. 7		Dr	20.0	4	N	Clay	Kansas Till	N	O	do	0.0	1,040			do
10-11-8aa	NE NE sec. 8		B	20	3	N	Sand and gravel	Alluvium	N	O	do	0.0	959	18.5	6-11-52	
10-11-11bd	SE NW sec. 11	Pessemer Est.	Dr	83	15	GI	do	Newman Terrace deposits	T, G	I	Hole in pump base	0.0	960	29.0	8-17-54	

10-11-14dc	SW SE sec. 14		Dr	48.5	4	N	do	Buck Creek Terrace deposits	N	O	Land surface	0.0	990			Test hole log.
*10-11-15ac	SW NE sec. 15	F. Lytle	Dr	44	6	GI	do	do	Cy, E	D, S	do	0.0	984	40.0	5- 9-53	
10-11-16dc	SW SE sec. 16	J. Steinmeyer	Du	65.0	30	R	do	do	Cy, W	D	Top of rock pit	0.5	1,030	33.2	7- 1-52	Abandoned.
10-11-17aa	NE NE sec. 17		Dr	50.0	4	N	do	do	N	O	Land surface	0.0	1,007			Test hole log.
	T. 10 S, R. 12 E.															
10-12-5cd	SE SW sec. 5	J. C. Ronnau	Dr	45.0	18	GI	do	Newman Terrace deposits	T, G	I	Top of casing	0.7	957	23.6	3-31-56	
*10-12-7aa	NE NE sec. 7	Pessemer Est.	Dn	25	1.5	GP	do	Alluvium	Cy, E	D, S	Land surface	0.0	948	15.0	4-22-53	
10-12-7bd	SE NW sec. 7	do	Dr	74	18	GI	do	do	T,G	I	Hole in pump base	1.0	950	19.5	3-31-56	
10-12-9bc	SW NW sec. 9	P. Kramer	Dn	28.5	1.5	GP	do	do	Cy, E	D, S	Top of concrete pit	0.5	944	15.0	5-28-53	
10-12-9da	NE SE sec. 9	City of St. Marys	Dr	68	8	S	do	Newman Terrace deposits	T, E	P	Land surface	0.0	960	32.0	6-11-52	
10-12-10cc	SW SW sec. 10	do	Dr	44	8	S	do	Alluvium	T, E	P	do	0.0	947	21.0	8-13-56	Estimated specific capacity 40 g/ft. dd.
10-12-10dc	SW SE sec. 10	St. Marys College	Dr	47	6	GI	do	Newman Terrace deposits	T, E	D, S	Top of casing	-26.5	928	31.0	6-27-52	Battery of 6 wells.
10-12-16cb	NW SW sec. 16	G.W.Hammarlund	Dr	60	18	GI	do	do	T, G	I	do	0.5	943	21.0	8- 8-56	
*10-12-16db	NW SE sec. 16	G. L. Schoemann	Dn	25	1.5	GP	do	do	Cy, E	D, S	Land surface	0.0	943	19.0	4-22-53	
10-12-20ca	NE SW sec. 20		Dr	45	6	GI	do	do	J, E	D	do	0.0	950	28.0	9-26-53	
10-12-21ba	NE NW sec. 21	A. T. Rezac	Dr	38	6	GI	do	do	J, E	D, S	Top of platform	0.0	939	19.0	5-28-53	
10-12-22bb	NW NW sec. 22	G.W.Hammarlund	Dn	25	1.25	GP	do	do	C, E	D, S	Pump joint	-7.0	929	15.0	6-20-52	
10-12-23dc	SW SE sec. 23	A. A. Ronsee	Dr	31	6	GI	do	do	C, E	D, S	Top of casing	-11.2	934	22.5	6-19-52	3 wells within diameter of 5 ft.
10-12-24ab	NW NE sec. 24	State Highway Commission	Dr	70	6	GI	do	do	J, E	D	do	-3.4	951	27.9	6-20-52	
10-12-24dc	SW SE sec. 24	R. B. Hoferer	Dr	69	15	GI	do	do	T, G	I	Land surface	0.0	933	13.0	5-28-53	
10-12-25dc	SW SE sec. 25	T. B. Pearl	Dn	28	1.25	GP	do	Alluvium	J, E	D, S	do	0.0	930	14.0	6-16-52	
10-12-26ac	SW NE sec. 26	Lenherr Bros.	Dr	55	18	GI	do	Newman Terrace deposits	T, G	I	do	0.0	939	17.0	8-17-54	
*10-12-28cc	SW SW sec. 28	M. Holvorson	Dr	55.7	6	GI	do	do	J, E	D, S	Top of pit	0.0	954	31.5	5- 9-53	
10-12-29dc	SW SE sec. 29		Dr	59.5	4	N	do	Buck Creek Terrace deposits	N	O	Land surface	0.0	985			Test hole log.
	T. 10 S., R. 13 E.															
10-13-18da	NE SE sec. 18		Dr	16.0	4	N	do	Kansas Till	N	O	do	0.0	1,066			do
10-13-19aa	NE NE sec. 19		Dr	59.0	4	N	do	Buck Creek Terrace deposits	N	O	do	0.0	977			do
10-13-19da	NE SE sec. 19		Dr	70.0	1.25	S	do	Newman Terrace deposits	N	O	do	0.0	937	19.0	6- 3-52	Log; observation well.
10-13-19db	NW SE sec. 19	F. Hailand	Dr	75	18	GI	do	do	T, G	I	Top of casing	1.3	939	22.8	8-17-54	

TABLE 7.—*Records of wells and test holes in Kansas River valley between Topeka and Wamego—Continued*

Well number (1)	Location	Owner or tenant	Type of well (2)	Depth of well, feet (3)	Diameter of well, inches	Type of casing (4)	Principal water-bearing bed		Method of lift (5)	Use of water (6)	Measuring point			Depth to water level below land surface, feet (7)	Date of measurement	REMARKS (Yield given in gallons a minute; drawdown in feet)
							Character of material	Geologic source			Description	Distance above land surface, feet	Height above mean sea level, feet			
	T. 10 S., R. 13 E.															
10-13-20bc	SW NW sec. 20	F. McCollough	Dr	82	15	C	Sand and gravel	Newman Terrace deposits	T, G	I	Hole in pump base	1.2	945	27.0	7-22-55	
*10-13-20cb	NW SW sec. 20	R. Cantillon	Dn	30	2	GP	do	do	J, E	D	Land surface	0.0	937	21.0	4-26-53	
10-13-20dc	SW SE sec. 20	J. C. Campbell	Dr	75	18	GI	do	do	T, G	I	Top of casing	0.0	935	23.2	8- 9-56	
10-13-28cb	NW SW sec. 28	do	Dr	72	18	GI	do	do	T, G	I	Hole in pump base	0.0	931	23.6	8- 8-56	
10-13-30ab	NW NE sec. 30	do	Dr	46	18	GI	do	do	T, G	I	do	0.0	935	19.9	4-15-56	
10-13-30ba	NE NW sec. 30	do	Dr	58	18	GI	do	do	T, G	I	do	0.5	939	22.4	8-13-56	
10-13-30cc	SW SW sec. 30	Scott Kelsey	Dr	37	18	GI	do	do	T, E	I	do	1.2	930	16.0	8- 8-56	
10-13-30dc	SW SE sec. 30	R. Kelsey	Dr	39	18	GI	do	do	T, G	I	Top of platform	0.0	930	17.0	4-15-55	
10-13-31ba	NE NW sec. 31		Dr	60.0	1.25	S	Sand	Alluvium	N	O	Land surface	0.0	929	16.1	4- 8-52	Log; observation well.
*10-13-31bb	NW NW sec. 31	Scott Kelsey	Dr	41	8	GI	Sand and gravel	do	J, E	D, S	Top of casing	-5.5	933	19.1	4-26-53	
10-13-31cd	SE SW sec. 31		Dr	70.0	4	N	do	do	N	O	do	0.0	924			Test hole log.
10-13-32bd	SE NW sec. 32	Scott Hughes	Dr	24.0	6	GI	do	Newman Terrace deposits	J, E	D, S	Concrete platform	0.0	926	15.8	6- 2-53	
10-13-34ab	NW NE sec. 34	W. Hess	Dr	82	18	GI	do	do	T, G	I	Land surface	0.0	929	23.0	7-11-55	
10-13-34bd	SE NW sec. 34	City of Rossville	Dr	90	10	S	do	do	T, E	P	do	0.0	929	22.0	6-16-52	
10-13-34cb	NW SW sec. 34	J. Parr	Dr	60.0	18	GI	do	do	T, G	I	Top of casing	1.2	930	24.4	3-30-56	
10-13-34dc	SW SE sec. 34	K. C. Rasch	Dr	80	18	GI	do	do	T, G	I	Hole in pump base	1.3	931	25.1	8-22-56	
10-13-35bc	SW NW sec. 35	W. Hess	Dr	83	18	GI	do	do	T, G	I	do	1.4	934	24.5	8- 9-56	
10-13-35dc	SW SE sec. 35	H. Reid	Dr	60	18	GI	do	do	T, E	I	do	1.1	932	24.8	8-13-56	
	T. 10 S, R. 14 E.															
10-14-32bb	NW NW sec. 32		Dr	80.0	4	N	do	Kansas Till	N	O	Land surface	0.0	1,032			Test hole log.
10-14-32cc	SW SW sec. 32		Dr	84.5	4	N	do	do	N	O	do	0.0	1,035			do

	T. 11 S, R. 12 E.															
11-12-12ad	SE NE sec. 12	....	Dr	57.0	4	N	do	Buck Creek Terrace deposits	N	O	do	0.0	965	....	....	do
11-12-24da	NE SE sec. 24	....	Dr	55.0	1.25	S	Silt and gravel	Newman Terrace deposits	N	O	do	0.0	947	40.0	8- 4-54	Log; observation well.
	T. 11 S, R. 13 E.															
11-13-1bb	NW NW sec. 1	F. Parker	Dr	80	18	GI	Sand and gravel	do	T, E	I	Hole in pump base	0.0	931	25.8	8-13-56	
11-13-1bd	SE NW sec. 1	L. D. Hartzell	Dr	80	18	GI	do	Alluvium	T, G	I	do	0.0	926	21.5	8-13-56	
11-13-1dc	SW SE sec. 1	Zoeller Turkey Farm	Dr	....	18	GI	do	Newman Terrace deposits	T, G	I	Top of casing	0.0	915	17.9	5- 9-53	
*11-13-1dd	SE SE sec. 1	do	Dn	30	2	GP	do	do	J, E	D	Land surface	0.0	915	18.0	4-26-53	
11-13-3bb	NW NW sec. 3	K. C. Rasch	Dr	53.0	18	GI	do	do	T, G	I	Hole in pump base	1.3	927	24.0	3-30-56	
11-13-3db	NW SE sec. 3	Clyde Rogers	Dr	57.0	18	GI	do	do	T, E	I	do	1.0	....	30.7	7-26-56	Used in aquifer test.
11-13-5aa	NE NE sec. 5	J. Parr	Dr	51	18	GI	do	do	T, G	I	do	0.5	927	20.0	8- 8-56	
*11-13-5da	NE SE sec. 5	G. Stadler	Dr	34.3	1.5	GP	do	Alluvium	J, E	D, S	Top of pipe	-2.0	922	17.9	4-26-53	
11-13-10aa	NE NE sec. 10	W. McCleery	Dr	38.0	6	GI	do	do	J, E	D, S	Top of casing	0.0	922	17.0	5-29-53	
11-13-10bd	SE NW sec. 10	C. Erickson	Dr	43	18	GI	do	do	T, G	I	Land surface	0.0	914	16.0	8- 2-56	
11-13-11ad	SE NE sec. 11	C. Berkey	Dr	28.8	6	GI	do	do	J, E	D, S	Top of pit	0.0	920	21.7	5-29-53	
11-13-11bc	SW NW sec. 11	K. C. Rasch	Dr	45.0	18	GI	do	do	T, G	I	Top of concrete pit	0.3	924	22.0	3-30-56	
11-13-11bd	SE NW sec. 11	H. French	Dr	45.0	18	GI	do	do	T, G	I	Hole in pump base	1.3	922	21.6	5- 9-56	
11-13-11cc	SW SW sec. 11	C. Erickson	Dr	32	18	GI	do	do	C, G	I	Land surface	0.0	906	9.0	8- 2-56	
11-13-18bc	SW NW sec. 18	....	Dr	41.5	4	N	do	Buck Creek Terrace deposits	N	O	do	0.0	967	....	....	Test hole log.
11-13-30bc	SW NW sec. 30	....	Dr	38.5	4	N	do	Alluvium	N	O	do	0.0	930	....	....	do
	T. 11 S, R. 14 E.															
11-14-5bc	SW NW sec. 5	....	Dr	65.0	4	N	Sand	Kansas Till	N	O	do	0.0	1,000	....	....	do
11-14-5cc	SW SW sec. 5	....	Dr	54.0	4	N	Sand and gravel	Newman Terrace deposits	N	O	do	0.0	918	....	....	do
11-14-7dd	SE SE sec. 7	....	Dr	98.0	4	N	do	Alluvium	N	O	do	0.0	906	....	....	do
11-14-8bc	SW NW sec. 8	....	Dr	80.0	4	N	do	Newman Terrace deposits	N	O	do	0.0	917	....	....	do
11-14-8db	NW SE sec. 8	S. Kelsey	Dr	60.0	18	GI	do	do	T, E	I	Top of casing	1.0	920	24.5	3-31-56	
11-14-9ca	NE SW sec. 9	City of Silver Lake	Dr	47.0	6	S	do	do	T, E	P	Base of pump	0.0	911	23	6-16-52	
11-14-10ad	SE NE sec. 10	E. Blush	Dr	60	6	GI	do	do	J, E	D, S	Top of concrete pit	0.0	916	29.5	6- 4-53	
11-14-13bc	SW NW sec. 13	Clark and Renier	Dr	....	15	C	do	do	T, G	I	Land surface	0.0	913	28.0	3-30-56	
11-14-14cb	NW SW sec. 14	C. A. Neuber	Dr	96	18	GI	do	do	T, G	I	do	0.0	910	27.0	8-13-56	
11-14-15db	NW SE sec. 15	S. G. Kelsey	Dr	75	18	GI	do	do	T, E	I	Top of pit	0.0	909	26.0	6- 2-53	
11-14-17ab	NW NE sec. 17	W. J. Anderson	Dr	40	4	GI	do	do	J, E	D	Land surface	0.0	916	22.0	6-16-52	
11-14-17ca	NE SW sec. 17	L. O. Johnson	Dn	25	1.25	GP	do	Alluvium	J, E	D, S	Top of pipe	0.0	913	18.0	6-16-52	
11-14-17dd	SE SE sec. 17	H. French	Dn	22.4	2	GP	do	do	N	D	Top of pit	0.0	906	18.0	6- 2-53	Abandoned.

TABLE 7.—*Records of wells and test holes in Kansas River valley between Topeka and Wamego—Concluded*

Well number (1)	Location	Owner or tenant	Type of well (2)	Depth of well, feet (3)	Diameter of well, inches	Type of casing (4)	Principal water-bearing bed		Method of lift (5)	Use of water (6)	Measuring point			Depth to water level below land surface, feet (7)	Date of measurement	REMARKS (Yield given in gallons a minute; drawdown in feet)
							Character of material	Geologic source			Description	Distance above land surface, feet	Height above mean sea level, feet			
11-14-18db..	NW SE sec. 18....	....	Dn	26.7	1.5	GP	Sand and gravel	Alluvium.........	N	D	Top of pit....	0.0	911	19.6	6- 2-53	do
11-14-18dd..	SE SE sec. 18.....	....	Dr	80.0	4	N	do.......	do...............	N	O	Land surface..	0.0	908	....	....	Test hole log.
11-14-20bc...	SW NW sec. 20...	....	Dr	30.0	4	N	Sand.....	do...............	N	O	do...........	0.0	910	....	....	do
*11-14-20db..	NW SE sec. 20....	L. Davis.........	Dn	27	2	GP	Sand and gravel	do...............	Cy, H	D	do...........	0.0	905	18.0	4-26-53	
*11-14-21ab..	NW NE sec. 21...	G. C McCoid.....	Dn	26	1.5	GP	do.......	do...............	J, E	D, S	do...........	0.0	910	17.0	4-26-53	
11-14-22dd..	SE SE sec. 22.....	H. L Reamer.....	Dn	23	1.5	GP	do.......	do...............	N	D	Top of pipe...	0.0	899	18.0	6- 2-53	Abandoned.
*11-14-23ab..	NW NE sec. 23...	C. Arvidson......	Dn	28	1.25	GP	do.......	Newman Terrace deposits	J, E	D, S	do...........	-6.0	900	21.0	6-16-52	
11-14-23ba..	NE NW sec. 23...	R. Neiswonder....	Dr	92	18	GI	do.......	do...............	T, G	I	Land surface..	0.0	910	27.0	8-13-56	
11-14-23cb...	NW SW sec. 23...	Coaling-Thompson	Dr	80	18	GI	do.......	Alluvium.........	T, G	I	Hole in pump base	0.7	895	14.1	8- 9-56	
11-14-24ac...	SW NE sec. 24....	H. Renyer.......	Dr	49	15	C	do.......	do...............	T, G	I	Land surface..	0.0	899	16.9	8-20-56	
11-14-30ab..	NW NE sec. 30...	....	Dr	31.5	4	N	Clay and sand	Kansas Till.......	N	O	do...........	0.0	1,072	....	....	Test hole log.

1. Well-numbering system described on page 11.
2. B, bored; Dn, driven; Dr, drilled; Du, dug.
3. Reported depths are given in feet below land surface; measured depths are given in feet and tenths below land surface.
4. C, concrete; GI, galvanized sheet iron; GP, galvanized iron pipe; N, none; R, rock; S, steel pipe.
5. Method of lift: C, centrifugal; Cy, cylinder; J, jet; N, none; T, turbine.
Type of power: E, electric; G, gas engine: H, hand; W, windmill.
6. D, domestic; I, irrigation; O, observation; P, public; S, stock.

* Chemical analysis given in Table 4.

LOGS OF TEST HOLES

On the following pages are the logs of 26 test holes drilled in Kansas River valley between Topeka and Wamego by the Federal and State Geological Surveys.

9-11-19cd.—*Sample log of test hole in the SE¼ SW¼ sec. 19, T. 9 S., R. 11 E., Pottawatomie County, drilled 1952. Surface altitude, 987 feet.*

	Thickness, feet	Depth, feet
Quaternary—Pleistocene, Illinoian		
Buck Creek Terrace deposits		
Clay, silty, calcareous, dark gray to black; topsoil	2	2
Clay, silty, slightly calcareous, gray tan	7	9
Clay, silty, slightly calcareous, tan; contains some very fine quartz sand	10	19
Sand, very fine, silty; contains calcareous fragments	18	37
Sand, coarse, clayey, calcareous, chiefly limestone, some granite fragments	4	41
Clay, silty, calcareous, tan	16	57
Clay, sandy, tan; contains quartz sand lenses	4	61
Sand, fine to coarse; contains some fragments of granite, limestone, and sandstone	35	96
Pennsylvanian—Virgilian, Wabaunsee		
Limestone, hard, gray	0.5	96.5

9-11-30cd.—*Sample log of test hole in the SE¼ SW¼ sec. 30, T. 9 S., R. 11 E., Pottawatomie County, drilled 1952. Surface altitude, 963 feet.*

	Thickness, feet	Depth, feet
Quaternary—Pleistocene, Wisconsinan		
Newman Terrace deposits		
Silt, clayey, leached, dark gray; topsoil	8	8
Clay, silty, slightly calcareous, friable, tan gray	10	18
Clay, sandy, calcareous, gray tan	5	23
Sand, fine to medium, mostly quartz	11	34
Sand, coarse, and subrounded granite gravel	25	59
Sand, fine to medium, subrounded; contains granite fragments	17	76
Sand, medium to coarse, subrounded; contains granite fragments	2	78
Pennsylvanian—Virgilian, Wabaunsee		
Shale, limy, dense, blue gray	5	83

9-11-31dc.—*Sample log of test hole in the SW¼ SE¼ sec. 31, T. 9 S., R. 11 E., Pottawatomie County, drilled 1952. Surface altitude, 962 feet.*

	Thickness, feet	Depth, feet
Quaternary—Pleistocene, Wisconsinan and Recent		
Alluvium		
Silt, clay, and sand, dark gray; road fill	10.5	10.5
Sand, fine to medium, silty, calcareous, mostly quartz,	7.5	18
Sand, fine to coarse, light gray; contains some subrounded quartz and feldspar gravel	17	35
Sand, fine to coarse, gray; contains some fragments of granite and shale	14.5	49.5
Pennsylvanian—Virgilian, Wabaunsee		
Shale, silty, clayey, calcareous, light gray	4	53.5

10-11-7ad.—*Sample log of test hole in the SE¼ NE¼ sec. 7, T. 10 S., R. 11 E., Wabaunsee County, drilled 1952. Surface altitude, 980 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene, Illinoian		
Buck Creek Terrace deposits		
Silt, clayey, leached, light tan; topsoil	1	1
Clay, compact, tan brown to yellow brown	3	4
Silt, clayey, leached, red to red brown; contains some very fine quartz sand	5	9
Clay, silty, leached, red to tan brown; contains granules of granite and quartz	10	19
Clay, silty, slightly calcareous, tan gray; contains some quartz sand	8	27
Sand, coarse, to coarse gravel of quartz, granite, and limonite	8.5	35.5
PENNSYLVANIAN—Virgilian, Wabaunsee		
Limestone, medium crystalline, fragmental, weathered, tan yellow	0.5	36
Shale, clayey, compact, blue black	2	38

10-11-7dc.—*Sample log of test hole in the SW¼ SE¼ sec. 7, T. 10 S., R. 11 E., Wabaunsee County, drilled 1952. Surface altitude, 1,040 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene, Kansan		
Kansas Till		
Silt and clay, dark gray; topsoil	3	3
Clay, silty, calcareous, mottled tan gray; contains some fine sand	6.5	9.5
Clay, silty, calcareous, friable; contains some quartz sand and shale fragments	7	16.5
PENNSYLVANIAN—Virgilian, Wabaunsee		
Shale, clayey, thin bedded, dark gray	3.5	20

10-11-14dc.—*Sample log of test hole in the SW¼ SE¼ sec. 14, T. 10 S., R. 11 E., Wabaunsee County, drilled 1954. Surface altitude, 990 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene, Illinoian		
Buck Creek Terrace deposits		
Clay and gravel; road fill	3	3
Clay, silty, slightly calcareous, granular, olive drab	2	5
Clay, silty, tan brown	2	7
Clay, silty, gravelly, blocky, red brown	4	11
Clay, brown gray; contains some gravel	6	17
Clay, sandy, olive drab; contains some gravel	16	33
Sand, fine to coarse, and rounded granite gravel	10	43
PENNSYLVANIAN—Virgilian, Wabaunsee		
Shale, clayey, thin bedded, blue gray	4	47
Limestone, hard, blue gray	1.5	48.5

10-11-17aa.—*Sample log of test hole in the NE¼ NE¼ sec. 17, T. 10 S., R. 11 E., Wabaunsee County, drilled 1954. Surface altitude, 1,007 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene, Illinoian		
Buck Creek Terrace deposits		
Clay, silty, leached, compact, gray to tan	7	7
Clay, silty, limonite-stained, calcareous, red brown	3	10
Clay, silty, calcareous, tan	5	15
Clay, calcareous, gray	5	20
Clay, silty, calcareous, granular, gray tan	13	33
Sand, medium to coarse, and fine clayey granite gravel, green tan	3	36
PENNSYLVANIAN—Virgilian, Wabaunsee		
Shale, limy, gray	9	45
Shale, clayey, green gray	5	50

10-12-29dc.—*Sample log of test hole in the SW¼ SE¼ sec. 29, T. 10 S., R. 12 E., Wabaunsee County, drilled 1954. Surface altitude, 985 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene, Illinoian		
Buck Creek Terrace deposits		
Road fill and soil	3	3
Clay, silty, calcareous, red brown	4	7
Clay, silty, calcareous, red tan; contains some gravel	8	15
Clay, silty, lightly compacted, gray tan; contains a 2-foot sand lens at 25 feet	17	32
Clay, silty, gray; contains some quartz sand	15	47
Sand, medium to coarse, arkosic	3	50
Gravel, fine to medium, arkosic	6	56
PENNSYLVANIAN—Virgilian, Wabaunsee		
Shale, clayey, fissile, blue gray	2.5	58.5
Limestone, hard; no sample	1	59.5

10-13-18da.—*Sample log of test hole in the NE¼ SE¼ sec. 18, T. 10 S., R. 13 E., Shawnee County, drilled 1952. Surface altitude, 1,066 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene, Kansan		
Kansas Till		
Clay, yellow; contains some gravel	4.5	4.5
Clay, silty, sandy, granular, green brown	1.5	6
Clay, yellow; contains some fragments of quartz and basic igneous rock	3	9
Sand and gravel, clayey; contains large fragments of limestone and chert and smaller fragments of quartz	6.5	15.5
PENNSYLVANIAN—Virgilian, Wabaunsee		
Limestone, finely crystalline, light tan	0.5	16

10-13-19aa. *Sample log of test hole in the NE¼ NE¼ sec. 19, T. 10 S., R. 13 E., Shawnee County, drilled 1952. Surface altitude, 977 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene, Illinoian		
Buck Creek Terrace deposits		
Silt and clay, black; topsoil	4	4
Silt, slightly sandy, calcareous; contains a few subangular pebbles	2	6
Clay, silty, calcareous, light brown	12	18
Clay; contains pebbles of quartz, quartzite, and limestone	2	20
Sand and gravel, clayey, pebbles of quartz, limestone, and quartzite; contains a few igneous rock fragments	14	34
Clay, silty, friable, yellow	15	49
PENNSYLVANIAN—Virgilian, Wabaunsee		
Shale, clayey, blue gray	10	59

10-13-19da.—*Sample log of test hole in the NE¼ SE¼ sec. 19, T. 10 S., R. 13 E., Shawnee County, drilled 1952. Surface altitude, 937 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene, Wisconsinan		
Newman Terrace deposits		
Silt, clayey, friable, leached, dark gray	5	5
Silt, clayey, slightly calcareous, gray tan	12	17
Sand, very fine, silty	2	19
Clay, silty, tan	7	26
Sand, fine to medium; contains subrounded pebbles of quartz, granite, and feldspar	20	46
Sand, coarse, arkosic, subrounded; contains some gravel	4	50
Sand, coarse, and medium subrounded granite gravel,	15	65
PENNSYLVANIAN—Virgilian, Wabaunsee		
Shale, silty, clayey, blue	5	70

10-13-31ba.—*Sample log of test hole in the NE¼ NW¼ sec. 31, T. 10 S., R. 13 E., Shawnee County, drilled 1952. Surface altitude, 929 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene, Wisconsinan and Recent		
Alluvium		
Silt, clayey, dark gray; topsoil	2	2
Clay, silty, slightly calcareous, light gray	6	8
Sand, very fine, silty, gray	4	12
Sand, coarse, rounded, green; contains some granite gravel	25	37
PENNSYLVANIAN—Virgilian, Wabaunsee		
Shale, clayey, gray blue	10	47
Limestone, shaly, gray blue	1	48
Shale, clayey, blue gray	11	59
Limestone, shaly, blue gray	1	60

10-13-31cd.—*Sample log of test hole in the SE¼ SW¼ sec. 31, T. 10 S., R. 13 E., Shawnee County, drilled 1952. Surface altitude, 924 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene, Wisconsinan and Recent		
Alluvium		
Silt, dark gray; topsoil	2	2
Sand, very fine, quartz, rounded	13	15
Sand, coarse, quartz; contains rounded grains of feldspar and granite	20	35
Sand, fine, and medium gravel, granite	6	41
PENNSYLVANIAN—Virgilian, Wabaunsee		
Shale, clayey, blue gray	29	70

10-14-32bb.—*Sample log of test hole in the NW¼ NW¼ sec. 32, T. 10 S., R. 14 E., Shawnee County, drilled 1952. Surface altitude, 1,032 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene, Kansan		
Kansas Till		
Clay, sandy, red brown	7	7
Sand, clayey, yellow	12	19
Gravel, yellow; contains fragments of chert, quartzite, dark igneous rock; interbedded with clay	7	26
Clay and gravel, sandy, gray yellow	18	44
Sand, fine to medium, predominantly quartz	3	47
Clay, slightly sandy, yellow	20	67
Sand, very fine to fine, predominantly quartz	4.5	71.5
PENNSYLVANIAN—Virgilian, Wabaunsee		
Shale, clayey, blue gray	8.5	80

10-14-32cc.—*Sample log of test hole in the SW¼ SW¼ sec. 32, T. 10 S., R. 14 E., Shawnee County, drilled 1952. Surface altitude, 1,035 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene, Kansan		
Kansas Till		
Clay, sandy, reddish brown	6	6
Sand, clayey; contains granules of quartzite	10	16
Sand, fine to medium, clayey, yellow	3	19
Clay, gray yellow; contains some sand lenses	5	24
Clay, sandy, blue gray; contains granules of limestone, quartzite, and dark igneous rock	34	58
Sand, medium to coarse, clayey; contains some fine gravel composed chiefly of quartz and some limestone granules	26	84
PENNSYLVANIAN—Virgilian, Wabaunsee		
Limestone, dense, gray	.5	84.5

11-12-12ad.—*Sample log of test hole in the SE¼ NE¼ sec. 12, T. 11 S., R. 12 E., Wabaunsee County, drilled 1952. Surface altitude, 965 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene, Illinoian		
Buck Creek Terrace deposits		
Clay, silty, noncalcareous, dark gray	2	2
Clay, silty, slightly calcareous, sandy in lower part	3	5
Clay; contains sandy lenses, sand composed mostly of fine to medium slightly calcareous quartz grains	24	29
Clay, calcareous, gray; contains some fine quartz sand,	8	37
Sand, fine, clayey, mostly quartz, gray	6	43
Sand, coarse, and fine gravel; contains subrounded to rounded grains of quartz, granite, and quartzite	10	53
PENNSYLVANIAN—Virgilian, Wabaunsee		
Shale, silty, calcareous, weathered, yellow	2	55
Limestone, shaly, light brown	2	57

11-12-24da.—*Sample log of test hole in the NE¼ SE¼ sec. 24, T. 11 S., R. 12 E., Wabaunsee County, drilled 1952. Surface altitude, 947 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene, Wisconsinan		
Newman Terrace deposits		
Clay, silty, leached, dark gray	3	3
Clay, silty, slightly calcareous, blocky, mottled gray brown	7	10
Clay, silty, calcareous, granular to nodular, yellow to gray	5	15
Silt, clayey, calcareous, light tan	21	36
Silt, clayey, dark gray	6	42
Gravel, fine to medium; contains subangular fragments of limestone, chert, and quartz, and some igneous rock fragments	7	49
PENNSYLVANIAN—Virgilian, Wabaunsee		
Shale, clayey, blue gray	6	55

11-13-18bc.—*Sample log of test hole in the SW¼ NW¼ sec. 18, T. 11 S., R. 13 E., Wabaunsee County, drilled 1952. Surface altitude, 967 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene, Illinoian		
Buck Creek Terrace deposits		
Silt, clayey, and sand, dark gray; road fill	2	2
Clay, silty, very limonite-stained, gray brown	2	4
Silt and clay, gray	2	6
Clay, silty, granular, red brown	7	13
Silt, clayey, sandy, gray to red brown; contains quartz and limestone pebbles	10	23
Clay and fine to medium sand, red and gray; contains gravel lenses	12	35
Gravel; contains rounded fragments of chert and igneous and metamorphic rock	4	39
PENNSYLVANIAN—Virgilian, Wabaunsee		
Shale, silty and clayey, blue gray	2	41
Limestone, hard, light gray	0.5	41.5

11-13-30bc.—*Sample log of test hole in the SW¼ NW¼ sec. 30, T. 11 S., R. 13 E., Wabaunsee County, drilled 1952. Surface altitude, 930 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene, Wisconsinan and Recent		
Alluvium		
Silt and clay, dark gray; topsoil	2	2
Clay, silty, calcareous, gray	6	8
Silt and clay, calcareous, gray; contains gastropod fragments	17	25
Sand, fine, and coarse gravel composed of fragments of quartz, limestone, and chert; contains pelecypod and gastropod fragments	13	38
PENNSYLVANIAN—Virgilian, Wabaunsee		
Limestone, dense, hard, gray brown	0.5	38.5

11-14-5bc.—*Sample log of test hole in the SW¼ NW¼ sec. 5, T. 11 S., R. 14 E., Shawnee County, drilled 1952. Surface altitude, 1,000 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene, Kansan		
Kansas Till		
Clay, sandy; topsoil	2	2
Clay, red; contains a few granules of limestone	1.5	3.5
Clay, granular, yellow; contains some fragments of basic igneous rock	16.5	20
Sand, fine to medium, quartz; contains some angular fragments of limestone and a few fragments of igneous and metamorphic rock	40	60
PENNSYLVANIAN—Virgilian, Wabaunsee		
Shale, clayey, gray to black	5	65

11-14-5cc.—*Sample log of test hole in the SW¼ SW¼ sec. 5, T. 11 S., R. 14 E., Shawnee County, drilled 1952. Surface altitude, 918 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene, Wisconsinan		
Newman Terrace deposits		
Soil and road fill	3	3
Clay, very weathered, black	3	6
Clay, silty, unweathered, gray to yellow	10	16
Clay, sandy, yellow	3	19
Sand, very fine, silty, gray	7	26
Sand, coarse, and fine granite gravel	23	49
PENNSYLVANIAN—Virgilian, Wabaunsee		
Shale, clayey, light blue	5	54

11-14-7dd. *Sample log of test hole in the SE¼ SE¼ sec. 7, T. 11 S., R. 14 E., Shawnee County, drilled 1952. Surface altitude, 906 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene, Wisconsinan and Recent		
Alluvium		
Silt, very fine, sandy, tan	6	6
Sand, fine, silty, tan	8	14
Sand, coarse, and fine granite gravel	51	65
PENNSYLVANIAN—Virgilian, Wabaunsee		
Shale, sandy, blue gray	5	70
Shale, limy, hard, blue gray	2	72
Shale, sandy, blue gray	26	98

11-14-8bc.—*Sample log of test hole in the SW¼ NW¼ sec. 8, T. 11 S., R. 14 E., Shawnee County, drilled 1952. Surface altitude, 917 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene, Wisconsinan		
Newman Terrace deposits		
Silt, clay, and gravel, mixed; road fill	2	2
Clay, sandy, very weathered	2	4
Clay, sandy, unweathered, gray	6	10
Clay, blocky, yellow	3	13
Sand, medium to coarse, arkosic	7	20
Sand, fine to medium, arkosic	5	25
Sand, coarse, and fine granite gravel; contains clay lenses	49.5	74.5
PENNSYLVANIAN—Virgilian, Wabaunsee		
Shale, silty, blue gray	5.5	80

11-14-18dd.—*Sample log of test hole in the SE¼ SE¼ sec. 18, T. 11 S., R. 14 E., Shawnee County, drilled 1952. Surface altitude, 908 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene, Wisconsinan and Recent		
Alluvium		
Silt, slightly calcareous, black	6	6
Sand, medium; contains some coarse fragments of quartz and feldspar	7	13
Sand, fine to coarse; contains shell fragments	10	23
Sand, coarse; contains some granite gravel	7	30
Gravel, fine to medium; contains lenses of blue clay	10	40
Gravel, fine to coarse, arkosic; contains boulder at 63 feet	34	74
PENNSYLVANIAN—Virgilian, Wabaunsee		
Shale, noncalcareous, light gray	6	80

11-14-20bc.—*Sample log of test hole in the SW¼ NW¼ sec. 20, T. 11 S., R. 14 E., Shawnee County, drilled 1952. Surface altitude, 910 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene, Wisconsinan and Recent		
Alluvium		
Clay, silty in lower part	8	8
Clay, silty, gray yellow; contains a few limestone fragments	2	10
Sand, very fine, quartz; contains a few subrounded granules of feldspar and granite	8.5	18.5
PENNSYLVANIAN—Virgilian, Wabaunsee		
Limestone, gray; three layers separated by shale	1.5	20
Shale, silty, gray	10	30

11-14-30ab.—*Sample log of test hole in the NW¼ NE¼ sec. 30, T. 11 S., R. 14 E., Shawnee County, drilled 1952. Surface altitude, 1,072 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene, Kansan		
Kansas Till		
Clay, calcareous, gray	4	4
Clay and very fine sand, pink	2	6
Clay, noncalcareous, pale yellow	2	8
Clay, silty, and fine quartz sand, tan	4	12
Clay, grading downward into very fine quartz and feldspar sand, brown	4	16
Sand, clayey, yellow gray	10	26
Clay, sandy, yellow	3	29
PENNSYLVANIAN—Virgilian, Wabaunsee		
Limestone	2.5	31.5

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INDEX

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