STATE GEOLOGICAL SURVEY OF KANSAS

RAYMOND C. MOORE, Ph.D., Sc.D.
State Geologist and Director
(Absent on leave for military service, Quartermaster Corps, U. S. Army)

JOHN C. FRYE, Ph.D.
Assistant State Geologist and Assistant Director, in charge

Division of Ground Water

STANLEY W. LOHMAN
Geologist in Charge

BULLETIN 49

GEOLOGY AND GROUND-WATER RESOURCES OF HAMILTON AND KEARNY COUNTIES, KANSAS

By THAD G. MCLAUGHLIN
with analyses by
E. O. HOLMES

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

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GEOLOGY AND GROUND-WATER RESOURCES OF HAMILTON AND KEARNY COUNTIES, KANSAS

By Thad G. McLaughlin

ABSTRACT

This report describes the geography, geology, and ground-water resources of Hamilton and Kearny counties in southwestern Kansas. The area embraces a total of 51.5 townships, or 1,856 square miles, and had a population of 5,170 in 1940. It is relatively flat and is drained by Arkansas river and its tributaries. The climate is semiarid, the average annual precipitation being about 17 inches. Wheat farming, some cattle raising, and general farming are the principal occupations in the area.

The report contains a map of the area showing by means of shading the depth to water level. The water table ranges in depth from less than 10 feet in parts of the Arkansas valley to more than 200 feet in parts of the upland north of Arkansas river. The report also contains a map of the area showing by means of contours the shape and slope of the water table. The water table slopes east-southeastward. The steepest slopes of the water table are in the upland north of Arkansas river and the most gentle slopes are in the sand hills in southern Kearny county. Arkansas river has cut its valley below the general level of the water table in adjacent upland areas with the result that some ground water moves toward the stream along a part of its course.

Flowing wells are obtained in a small area in the Arkansas valley near Coolidge. The flows range from less than one gallon to more than 25 gallons a minute. The artesian heads were found to range from less than 1 foot to about 10 feet above land surface.

The ground-water reservoir is recharged principally by precipitation that falls within the area, by the addition of water from Arkansas river in the eastern part of the area, and by underflow from adjacent areas. Water is discharged from the ground-water reservoir mainly by underflow eastward and southward into adjacent areas, by transpiration and evaporation in areas of shallow water table, and by wells. All of the domestic, stock, and public water supplies and a part of the irrigation water supplies are obtained from wells.

Most of the wells in the area are drilled, but some are dug, driven, or bored. The water is used principally for irrigation, but much is used for domestic, stock, public, and railroad supplies. Of the 96 irrigation plants visited, 85 were in use in 1939. They supplied about 23,600 acre-feet of water to irrigate approximately 12,650 acres (including 2,000 acres in Finney county; includes also land irrigated by surface water and by a supplementary supply of ground water). Most of these wells are in the Arkansas valley, but a few are in the upland north of Deerfield. It is believed that additional irrigation supplies could be developed in the shallow-water area north of Deerfield, in parts of the Arkansas valley, and in southwestern Hamilton county.

The report includes a discussion of the fluctuations of water levels in wells as determined by periodic measurement of water levels in representative wells. Water levels in this area were relatively low in 1939, but the water levels in most wells rose in 1940, 1941, and 1942 as a result of above-normal precipitation.

The ground water in this area is hard but it is suitable for most ordinary uses. The waters from the Cheyenne sandstone, the Dakota formation, and the undifferentiated Pliocene and Pleistocene deposits are similar in composition and hardness. Waters from the alluvium generally are very hard.

The report also contains a map showing the rock formations that crop out in this area. The rocks discussed in this report range in age from Permian to Recent, but rocks older than the Dakota formation do not crop out in this area. The principal water-bearing formations are the alluvium, the undifferentiated Pliocene (Ogallala formation) and Pleistocene deposits, the Dakota formation, and the Cheyenne sandstone.

The field data upon which most of this report is based are given in tables, and include records of 361 wells and chemical analyses of the water from 50 representative wells. Logs of 70 test holes, water wells, and oil and gas wells in the area are given, including 27 test holes put down by the State and Federal Geological Surveys.

INTRODUCTION

Purpose and Scope of the Investigation

An investigation of the geology and ground-water resources of Hamilton and Kearny counties was begun in September, 1939, by the United States Geological Survey and the State Geological Survey of Kansas, with the coöperation of the Division of Sanitation of the Kansas State Board of Health and the Division of Water Resources of the Kansas State Board of Agriculture. The work was done under the general administration of R. C. Moore and K. K. Landes, state geologists, J. C. Frye, acting state geologist, and O. E. Meinzer, geologist in charge of the Division of Ground Water of the Federal Geological Survey, and under the direct supervision of S. W. Lohman, federal geologist in charge of ground-water investigations in Kansas.

Ground water is one of the principal natural resources of Kansas. In Hamilton and Kearny counties, almost the entire population obtains its water supply from wells. In addition, wells supply water for livestock and for the irrigation of more than 10,000 acres of land (includes also land irrigated by surface water and by a supplementary supply of ground water). Ground water acquires its great value as a natural resource because it is replenished continuously or at frequent intervals by precipitation, by streams, or by both.

If withdrawals of ground water are kept within safe limits, the supply should last indefinitely.

There were repeated crop failures in western Kansas between 1931 and 1939 as a result of an extended drought accompanied by severe dust storms. The precipitation was far below normal, resulting in a cumulative deficiency in rainfall of more than 30 inches for the 9-year period. These conditions have caused a lower farm income and an increased interest in irrigation.

The investigation in Hamilton and Kearny counties was made to determine the quantity, quality, movement, and availability of ground water, the quantity of water that can be withdrawn without permanently diminishing the ground-water storage, and the feasibility of further development of irrigation from wells. It is hoped that the data given herein will facilitate the safe development of the ground-water resources of these counties.

Location and Extent of the Area

Hamilton and Kearny are adjacent counties in southwestern Kansas (fig. 1). They are bordered on the north by Greeley and Wichita counties, on the east by Finney county, on the south by Stanton and Grant counties, and on the west by Prowers county, Colorado. Most of the area lies between parallels 37° 45′ and 38° 15′ north latitude and meridians 101° 7′ and 102° 2′ west longitude. It comprises about 51.5 townships and has an area of 1,856 square miles.

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

Previous Investigations

Geologic and hydrologic studies in western Kansas were first made in 1895 by Haworth (1897), who discussed the regional geology and the occurrence of ground water in the Dakota and younger formations. Johnson (1901; 1902), in his reports on the utilization of the southern High Plains, made special reference to the source, availability, and use of ground water in western Kansas. A few years later, Darton (1905) made a study of the geology and ground-water resources of the central Great Plains including the western part of Hamilton county, and the following year he published a report (Darton, 1906) on the geology and underground-water resources of the Arkansas river valley in eastern Colorado. This report includes a discussion of the artesian wells in the vicinity of Coolidge in western Hamilton county. A survey of the Arkansas valley in Kearny and Finney counties was made by Slichter (1906) in 1904 to determine the source of the ground water, its chemical character, its rate and direction of movement, and the effect of rainfall and floods on the recharge of the ground-water reservoir. Parker (1911) briefly described the geology and ground-water resources of Hamilton and Kearny counties in his report on the chemical character of the water supplies of Kansas. Haworth (1913) briefly described the ground water of this area in 1913.

The first detailed study of this area was made by Darton (1920) in his description of the geology and ground-water resources of the Syracuse-Lakin quadrangles, which include most of the southern half of Hamilton and Kearny counties. His report includes maps showing geology, topography, and depths to water level. A few years later, Bass (1926) described the geology of Hamilton county with special reference to Cretaceous stratigraphy. More recently the Hamilton and Kearny area was briefly described by Theis, Burleigh and Waite (1935), who made a reconnaissance of the ground-water resources of the southern High Plains; and by Smith (1940), who made a reconnaissance of the Tertiary and Quaternary geology of southwestern Kansas.

In 1939 Latta (1941) made a detailed study of the geology and ground-water resources of Stanton county, which borders Hamilton county on the south. The report includes maps showing the geology, depths to water level, and configuration of the water table. Other detailed county reports describing the geology and ground-water resources of southwestern counties include Morton county (Mc-

Laughlin, 1942), Ford county (Waite, 1942), and Meade county (Frye, 1942).

Methods of Investigation

Preliminary investigations were made in Hamilton and Kearny counties during parts of September and October, 1939. During this time about 40 representative wells were selected for periodic depth-to-water-level measurements. Most of these wells have been measured monthly since that time in order to obtain information concerning the fluctuations of the ground-water table and their relation to precipitation and to floods.

Field work was resumed in August, 1940, and continued until December, 1940. During this period, data were obtained on about 320 wells. About 175 of these wells were measured with a steel tape to determine the depth of the well and the depth of the water level below some fixed measuring point (generally the top of the casing). Additional data were obtained from well owners concerning the yield and draw-down of wells and the character of water-bearing materials. Only reported data were obtained for an additional 145 wells. This included the depth of the well, the depth to water level, the yield and draw-down of the well, and the character of the water-bearing materials. Forty-eight samples of water were collected from representative wells, and were analyzed by E. O. Holmes, chemist in the Water and Sewage Laboratory of the Kansas State Board of Health.

Twenty-four test holes were drilled at strategic points in the county by the portable hydraulic-rotary drilling machine of the State and Federal Surveys, operated by Ellis D. Gordon, Perry McNally, and Laurence P. Buck. The locations of the test holes are shown in figure 2.

The drill cuttings were collected and studied in the field by Perry McNally and examined later with a microscope in the office. The altitudes of the measuring points of most of the measured wells and of the test-hole locations were determined with a plane table and alidade. Those in Kearny county were determined by a level party headed by John B. LaDuex. The level work in Hamilton county was done as a part of the regular coöperative topographic mapping program of the Federal and State Geological Surveys. F. S. Bradshaw and Fay Mann directed the level parties. A Federal and State Survey level party headed by H. S. Hall determined a few altitudes of measuring points on wells in northeastern Kearny county as a part of their level work on the Leoti quadrangle.

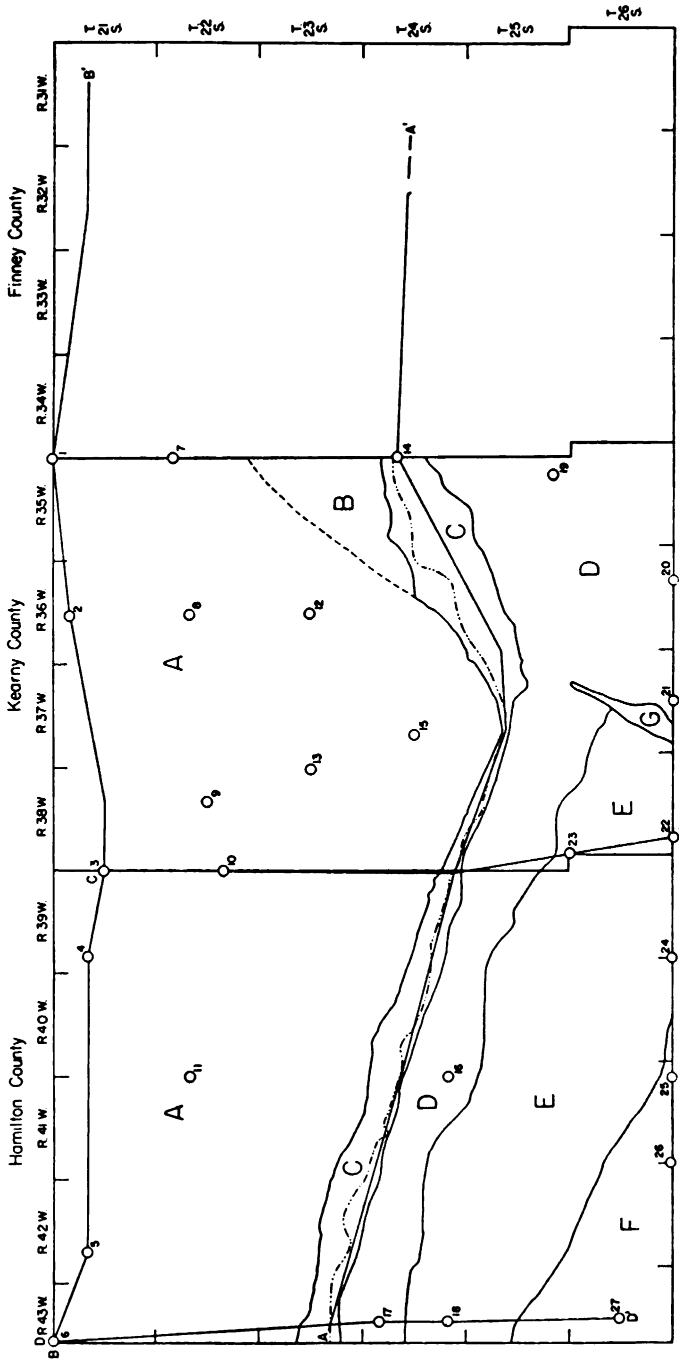

Fig. 2. Map of Hamilton and Kearny counties showing location of test holes, lines along which cross sections are drawn (figs. 7 and 8), and physiographic divisions. A represents the Kearny upland; B, the Scott-Finney basin; C, the Arkansas river valley; D, the sand-hills area; E, the Syracuse upland; F, the Stanton area; and G, the Bear Creek depression.

The field data were recorded on maps prepared for the Kansas Highway planning board by the Kansas Highway Department (pls. 1 and 2). The roads and drainage were corrected by field observations and from aerial photographs obtained from the United States Department of Agriculture. Inasmuch as the geology of most of the area had been previously described by Darton (1920) and Bass (1926), much time in searching for outcrops in the field was saved by reference to their maps. The areal extents of the Cretaceous outcrops were more accurately defined by the use of the aerial photographs. Most of the outcrops of Cretaceous rocks were examined, but no attempt was made to study them in detail. A more detailed study was made of the Tertiary and Quaternary deposits, which are the principal sources of ground water.

The wells shown on plate 2 were located within the sections by use of the speedometer, and the locations are believed accurate to within about 0.1 mile. The wells in each county are numbered by townships from north to south and by ranges from east to west, and within a township the wells are numbered in the same order as the sections. The Hamilton county wells are numbered from 1 to 164; the Kearny county wells are numbered from 165 to 359. For each well shown on plate 2 the number above the line corresponds to the number of the well in the well tables and the number below the line is the depth to the ground-water table below a fixed measuring point.

Acknowledgments

Residents of the area were very coöperative in supplying information about their wells, in permitting test drilling on their land, and in allowing pumping tests to be made on their wells. G. L. Howell supplied information on the wells south of Deerfield that supply water for the Great Eastern irrigation canal. M. T. Barnes furnished data on the municipal-water supply at Lakin, and David Millsap gave similar data on the Syracuse municipal supply.

The manuscript for this report has been reviewed critically by S. W. Lohman, O. E. Meinzer, and W. D. Collins, of the Federal Geological Survey; J. C. Frye, assistant state geologist; Edith H. Lewis of the State Geological Survey; Paul D. Haney, director, and Ogden S. Jones, geologist, of the Division of Sanitation of the Kansas State Board of Health; and George S. Knapp, chief engineer of the Division of Water Resources of the Kansas State Board of Agriculture. The maps and cross sections were prepared under the supervision of Dorothea Weingartner, chief draftswoman of the State Survey.

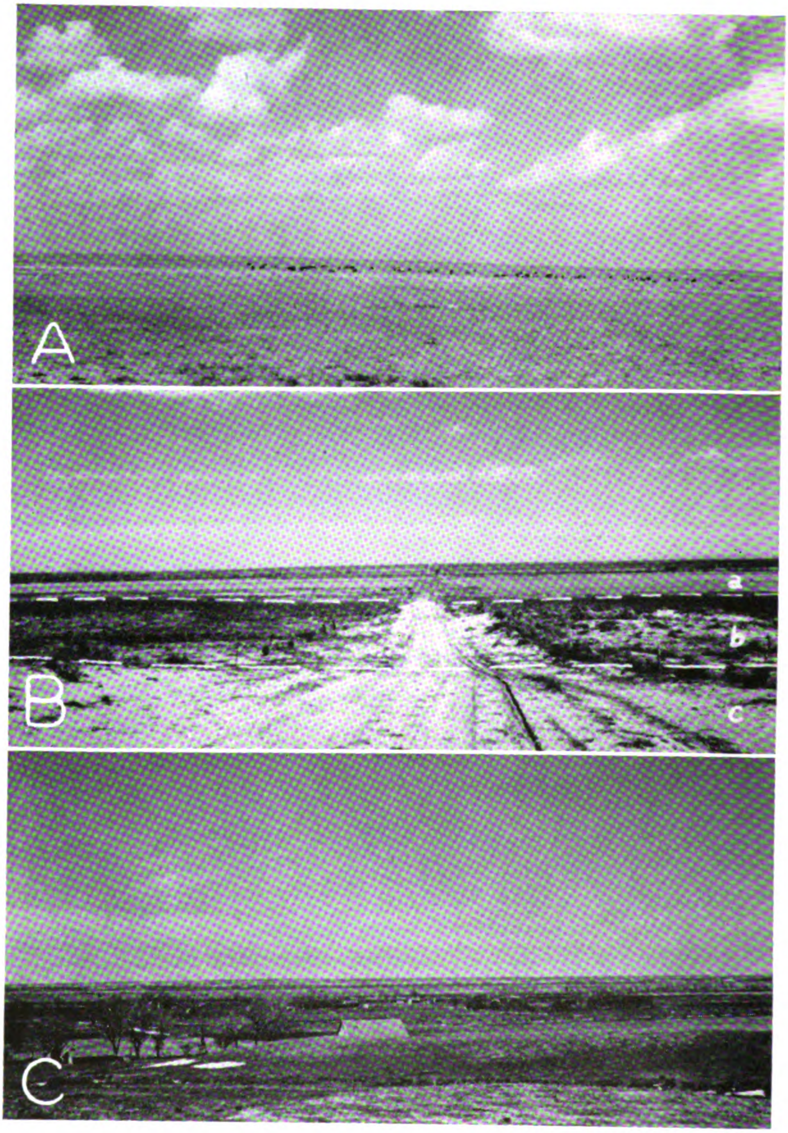

PLATE 4. A, View of the upland in northern Kearny county; B, Arkansas valley south of Mayline showing (a) the valley floor, (b) the river terrace, and (c) the edge of the sand dunes; C, Arkansas river valley near Kendall, sand hills in the distance.

GEOGRAPHY

Topography and Drainage

Hamilton and Kearny counties are in the High Plains section of the Great Plains physiographic province. The area comprises seven physiographic divisions (fig. 2), most of which were defined by Smith (1940, pp. 140-146). These areas are described in the following pages.

Kearny upland.—Most of the northern half of the area is a relatively flat featureless plain that slopes toward and merges with the Scott-Finney depression on the east and slopes toward Arkansas river on the south. Several small intermittent streams in the western part of this area flow southward into Arkansas river. In the eastern part of the area are several long intermittent streams that flow east-southeastward and terminate in broad shallow depressions near the western edge of the Scott-Finney basin. The altitude of the area ranges from about 3,850 feet in northwestern Hamilton county to about 3,100 feet in northeastern Kearny county. The average eastward slope is about 14.5 feet to the mile.

Scott-Finney basin.—A small part of the Scott-Finney basin extends into Kearny county (fig. 2). This basin merges gradually into the upland area, and no sharp dividing line can be drawn between them. The basin slopes gently toward the Arkansas valley and is separated from it by a low bluff.

Arkansas river valley.—Arkansas river rises in the mountains of west central Colorado and, upon leaving the mountains near Canon City, flows eastward across the high plains of eastern Colorado, entering Hamilton county at a point near Coolidge. From that point it flows east-southeastward to Hartland in Kearny county where it swings abruptly toward the northeast and leaves the area at a point near Deerfield. The valley ranges in width from 2 to 3 miles in Hamilton county but is less than 1 mile wide at its narrowest point near Hartland. East of Hartland the valley broadens and attains a maximum width of nearly 4 miles in the eastern part of Kearny county. Bordering the valley on the north is an almost continuous line of bluffs which have a maximum height of nearly 150 feet near Hartland. East of Lakin the bluffs diminish in height and near Deerfield they are hardly discernible. On the south, the river valley is bordered by sand hills which rise only a few feet above the river terrace.

Sand-dune area.—The sand-dune area is adjacent to the Arkansas

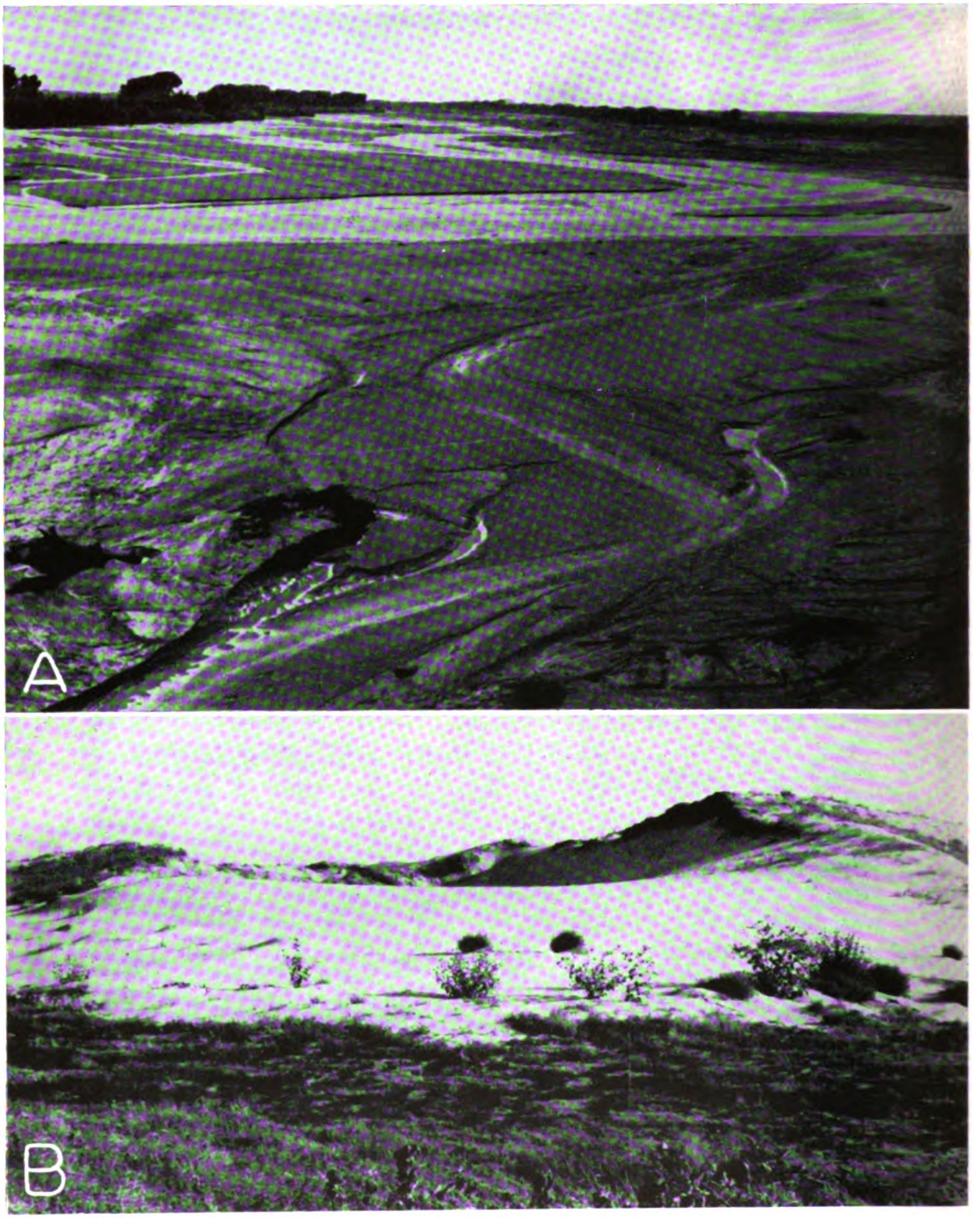

PLATE 5. Channel of Arkansas river at Kendall; B, Blowout in the sand dunes south of Syracuse, view looking south (photographs by H. T. U. Smith).

valley and comprises a narrow belt that is 3 to 5 miles wide in Hamilton county but broadens greatly in eastern Kearny county where its maximum width is more than 16 miles. In several places, particularly west of Syracuse, the dunes have encroached upon Arkansas river until they are only a few yards from the river channel.

The dune area comprises irregular, grass-covered, undrained basins. In eastern Kearny county and in some parts of Hamilton county the dune-sand area is a relatively flat grass-covered plain with broad low mounds and wide shallow depressions, and is bordered on the north and on the south by an east-west band of higher, more rugged, and generally more barren dunes. The altitude of the sand-dune area is only a few tens of feet higher than the Arkansas valley and is more than 150 feet lower than the upland area that lies north of the valley. The maximum relief in the sand-hills area is about 70 feet and is near the river west of Syracuse. The area of minimum relief is in southeastern Kearny county.

Syracuse upland.—This is the name given by Smith (1940) to the long tableland that extends from western Hamilton county to southwestern Kearny county. It is bordered on all sides by steep slopes, but the central part of the area is relatively flat. The Syracuse upland attains a maximum altitude of 3,680 feet in western Hamilton county, which is higher than any other point in the area except the northwestern part of the Kearny upland. The surface of the upland slopes east-southeastward at the rate of 10 to 30 feet to the mile.

Stanton area.—The southwestern corner of Hamilton county is a part of the Stanton area as defined by Smith (1940). It is a relatively flat plain that slopes eastward at the rate of about 18 feet to the mile. It is bordered on the north by the bluffs that form the southern edge of the Syracuse upland. The area is drained by Little Bear creek, an intermittent stream that flows southeastward adjacent to the bluffs of the Syracuse upland.

Bear Creek depression.—Bear creek originates in westernmost Baca county, Colorado, at a point nearly 60 miles west of the state line. From the point in southwestern Stanton county where it enters Kansas, Bear creek flows northeastward to the northeastern part of Stanton county where, at its point of confluence with Little Bear creek, it flows eastward into Grant county. The stream then turns north and terminates in the sand hills southwest of Lakin. Its valley in Kearny county is a long narrow depression that trends north-northeast.

Climate

The climate in Hamilton and Kearny counties, as in other parts of the High Plains section, is characterized by low precipitation, rapid evaporation, and a wide range of temperature variations. The summer days generally are hot, but the wind movement and the usually low humidity cause the nights to be relatively cool. The winters are moderately cold, but generally are free from excessive snowfall and damp cloudy days.

The precipitation in the Hamilton-Kearny area usually is local and sporadic and the amount of rainfall in one storm may vary

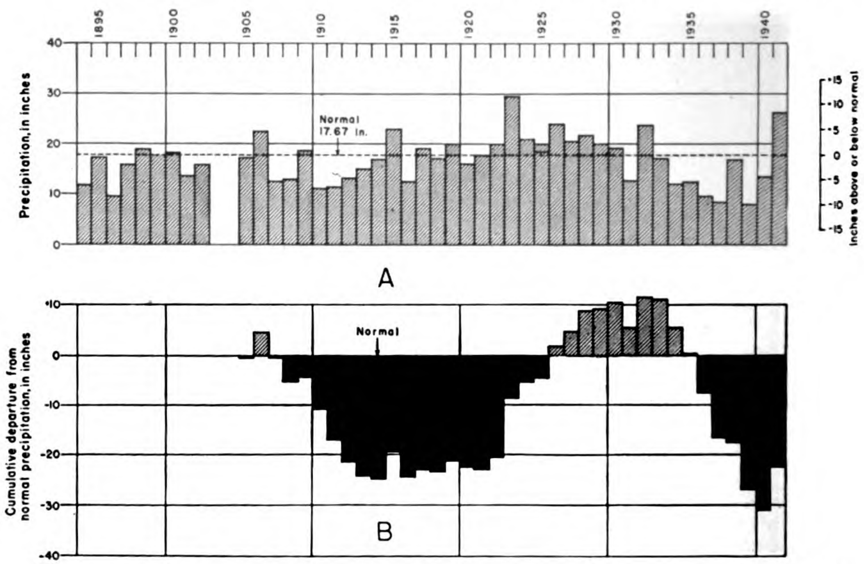

FIG. 3. Graphs showing (A) the annual precipitation at Syracuse, Kansas, and (B) the cumulative departure from normal precipitation at Syracuse (from records of the U. S. Weather Bureau).

greatly from one part of the area to another. The greatest annual precipitation on record in this area was 29.50 inches at Syracuse in 1923. (All climatic data, unless otherwise stated, are based on the records of the U. S. Weather Bureau's stations at Syracuse and Lakin.) The second greatest precipitation was 27.99 inches recorded at Lakin in 1941. The mean annual precipitation at Syracuse is 17.67 inches (fig. 3) and at Lakin it is 15.85 inches (fig. 4). The greatest precipitation is during the summer months, particularly in July, and the least precipitation is during December and January (fig. 5).

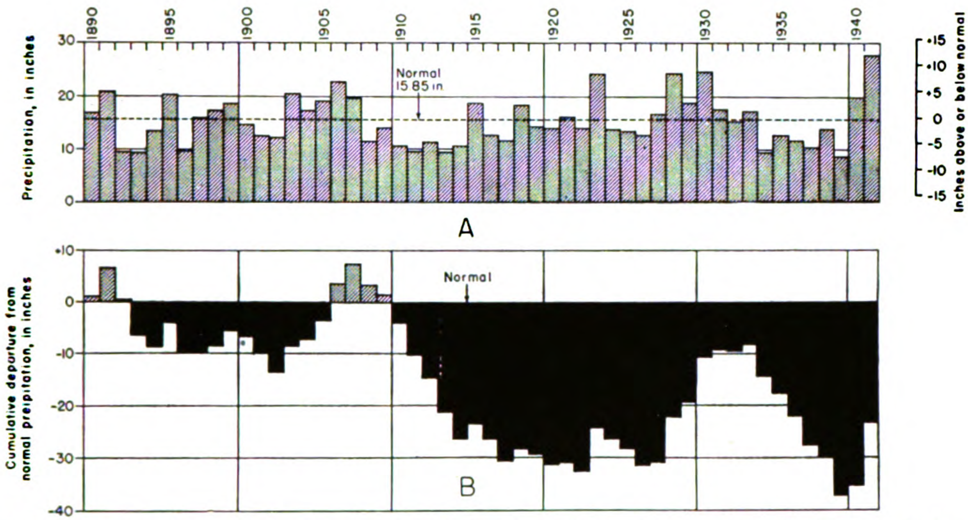

FIG. 4. Graphs showing (A) the annual precipitation at Lakin, Kansas, and (B) the cumulative departure from normal precipitation at Lakin (from records of the U. S. Weather Bureau).

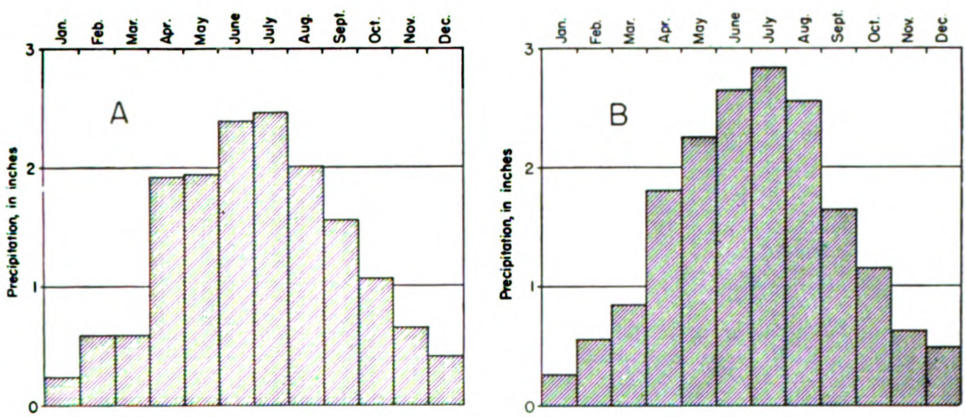

FIG. 5. Graphs showing (A) the average monthly distribution of precipitation at Lakin, and (B) the average monthly distribution of precipitation at Syracuse (from records of the U. S. Weather Bureau).

The mean annual temperature in this area is 53.9° F. The highest temperature ever recorded was 115° F., in July, and the lowest was —26° F., in January. The average date of the last killing frost in the spring is April 27, but there have been killing frosts as late as May 27. The first killing frost in the fall has occurred as early as September 17, but its average date is October 14. The average length of the growing season is 169 days at Syracuse and 171 days

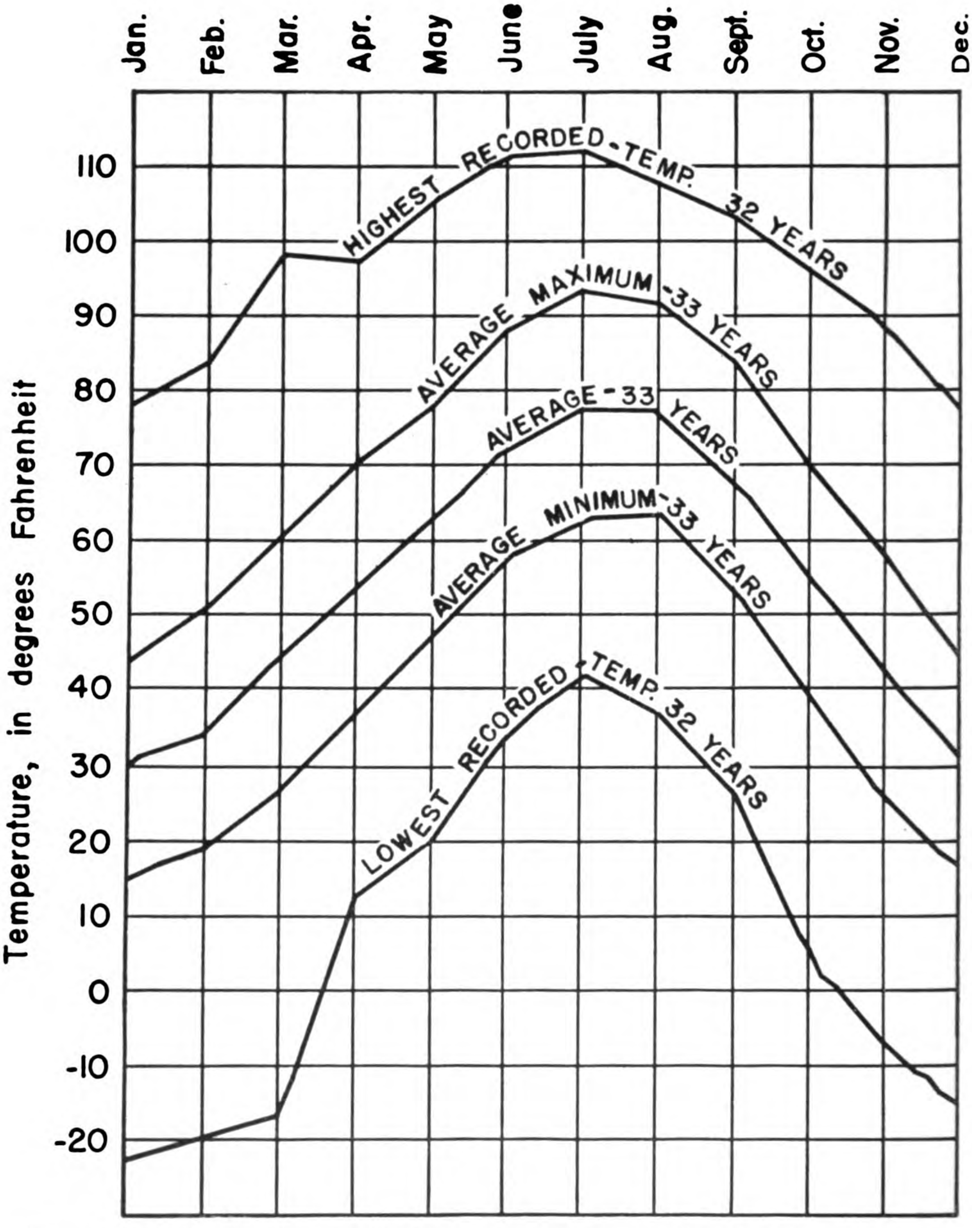

FIG. 6. Graph showing the monthly temperature ranges at Lakin. Modified from Smith (1940, p. 27).

at Lakin. The monthly temperature ranges at Lakin are shown in figure 6.

The winds are strong throughout the year, especially in late winter and early summer, the prevailing winds being from the south and southwest. Generally more than 300 days of each year are clear or only partly cloudy; this high proportion of clear days, together with the high summer temperatures, low relative humidity, and high wind velocity, results in a total yearly evaporation of about 60 to 70 inches from a free water surface.

Mineral Resources

Ten gas wells having open flows of 9,690,000 to 21,600,000 cubic feet a day have been drilled in the sand-hills area in southeastern Kearny county in recent years. These wells, and a few gas wells in southwestern Finney county, once constituted the Holcomb gas field but they are now considered a part of the Hugoton gas field. They obtain gas from the Wreford limestone or the Florence limestone of the Wolfcampian group of the Permian series at depths ranging from 2,670 to 2,850 feet. The gas is carried by pipe line to Lakin, Deerfield, Holcomb, Scott City, and cities in southern Nebraska.

Several unsuccessful oil-test wells were drilled in the Hamilton-Kearny area before oil was finally discovered in 1941. In 1925 the Wood Oil Company No. 1 Ranson well, NW¼ sec. 5, T. 26 S., R. 41 W., southwestern Hamilton county, was drilled to the limestones of Mississippian age at a depth of 5,488 feet but failed to find either oil or gas. The well at that time was the deepest in Kansas. A few years later a test well on the Porter farm, in the NE¼ sec. 30, T. 25 S., R. 41 W., was drilled to a depth of 6,453 feet but failed to find oil or gas. A detailed seismographic survey of the Syracuse anticline in southwestern Hamilton county was begun by Stanolind Oil and Gas Company in the spring of 1942, so the possibilities for commercial production of oil and gas in this area probably will be tested by drilling in the near future.

On May 12, 1940, Stanolind Oil and Gas Company began a deep test on the J. M. Judd farm, SE cor. sec. 15, T. 21 S., R. 38 W., in northwestern Kearny county. This well was drilled into pre-Cambrian rocks to a total depth of 6,071 feet. Shows of oil were found in the Kansas City-Lansing limestones and in the Mississippian limestones but none was adequate for commercial production. After drilling another unsuccessful test near the Judd well, Stanolind Oil and Gas Company, in August, 1941, completed the No. 1 G. O.

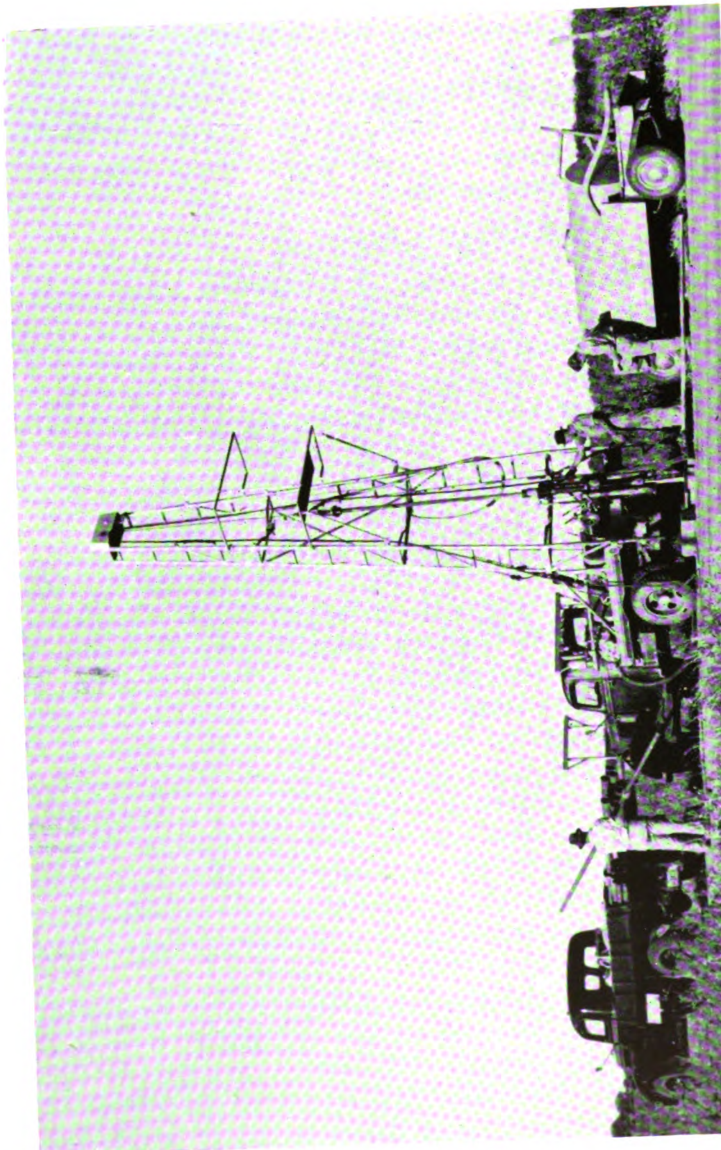

PLATE 6. Portable drilling machine owned by State and Federal Geological Surveys, used in drilling test holes in Hamilton and Kearny counties.

Patterson well in the SE¼ sec. 23, T. 22 S., R. 38 W., at a total depth of 5,690 feet. The well had an initial production of 3,964 barrels a day from a sand zone encountered at 4,740 feet in the Cherokee shale of Pennsylvanian age. Subsequently the Stanolind Oil and Gas Company No. 1 Gropp, an offset to the Patterson well, was drilled to the same producing horizon and obtained an initial production of more than 3,500 barrels a day.

Sand and gravel and building stone are other natural resources of this area. Sand and gravel are used for road material in both Hamilton and Kearny counties, and are taken from the alluvium of the Arkansas valley, from Arkansas river terraces, and from the Pleistocene deposits on the upland near Syracuse and near Kendall.

Building stone has been quarried from the sandstones of the Dakota formation in secs. 22 and 27, T. 26 S., R. 41 W. and sec. 27, T. 26 S., R. 40 W. Many buildings in Coolidge, Syracuse, and Kendall were built with stone from the Bridge Creek limestone member of the Greenhorn limestone. Most of these quarries are along Bridge creek in the southwestern part of T. 22 S., R. 42 W. A few farm buildings have been constructed of stone quarried from the Fort Hays limestone member of the Niobrara formation in sec. 3, T. 22 S., R. 43 W.

Agriculture

The soils of Hamilton and Kearny counties are predominantly of three types (soil types 1, 2, and 6 of Joel, 1937, pp. 8-14). Soil type 1 is a heavy, compact, dark soil consisting of clay loams and silty clay loams and is especially suited for growing wheat and other small grains. This type of soil is derived from the loess that covers much of the northern half of the Hamilton-Kearny area. Although soil type 1 is rather susceptible to wind erosion, it is very thick and is not easily depleted. Soil type 2 is a moderately friable, brown and light-colored soil consisting of silt loams and clay loams overlying a calcareous subsoil. This type of soil is derived from the Pleistocene silts, sands, and gravels and is found in part of the upland north of Arkansas river, in southern Hamilton county, and in southwestern Kearny county. Soil type 6 consists principally of fine sand and is derived from the Quaternary dune sand that is found south of Arkansas river. This type of soil supports only slight plant growth and is very susceptible to wind erosion.

There was a total of 810,692 acres of land under cultivation in Hamilton and Kearny counties in 1940 (all agricultural data, unless otherwise stated, are from records of the U. S. Census Bureau).

There were nearly 1,050 farms and the average farm comprised about 970 acres. There were 17,266 acres of land under irrigation, mostly in the Arkansas valley and in the Kearny county part of the Scott-Finney basin. More than 10,000 acres of this land were irrigated by water from wells or by surface water supplemented by supplies of ground water. The following list of crops grown in Hamilton and Kearny counties was compiled by the 1940 census.

TABLE 1.—*Acreage of principal crops grown in Hamilton and Kearny counties in 1940*

Wheat	73,977
Sorghums	25,320
Hay (other than alfalfa)	8,946
Alfalfa	6,098
Barley	2,649
Root and grain crops (other than corn and annual legumes),	1,957
Broom corn	965
Sugar beets	963
Corn	331
Rye	147

POPULATION

During the period of above-normal precipitation between 1920 and 1930 the population of this area increased more than 25 percent to a total of 6,524 inhabitants. The extended drouth in the next decade resulted in a decrease of 20 percent in population leaving about 5,170 people in 1940, or less than three persons to the square mile. Since the area was first settled, its population has fluctuated in accordance with climatic conditions. Syracuse, the county seat and principal city of Hamilton county, had a population of 1,226 in 1940. Other important cities are Lakin (population 709), county seat of Kearny county, and Deerfield (population 356), also in Kearny county.

TRANSPORTATION

The main line of the Atchison, Topeka, and Santa Fe Railway crosses the area along the Arkansas valley and serves the communities of Deerfield, Lakin, Hartland, Kendall, Syracuse, and Coolidge. The principal hard-surfaced road in this area is U. S. highway 50 which is nearly parallel to the river. Kansas highway 27 is an oiled road that crosses Hamilton county in a north-south direction through Syracuse. From Syracuse to the Stanton county line this road is also a part of U. S. highway 270. Kansas highway 25 crosses Kearny county from north to south through Lakin and is oiled from Lakin to the Grant county line.

In addition, there are several graveled county and township roads in the area. Most of the roads, however, are not surfaced; but because of slight precipitation and rapid evaporation, the earth roads are passable during most of the year. Drifting sand is a hazard to driving in parts of the sand-dune area south of the river.

GENERAL GEOLOGY

Summary of Stratigraphy

The rocks that crop out in Hamilton and Kearny counties are of sedimentary origin and their areal extent is shown on plate 1. The rocks that supply water to wells in this area range in age from Cretaceous to Recent, the principal water-bearing formations being the Dakota formation, the Ogallala formation, the undifferentiated Pleistocene gravels, and the alluvium of the Arkansas river valley (figs. 7 and 8). The character and ground-water supply of the geologic formations in this area are described briefly in the accompanied generalized section (table 2) and in more detail in the section on geologic formations and their water-bearing properties.

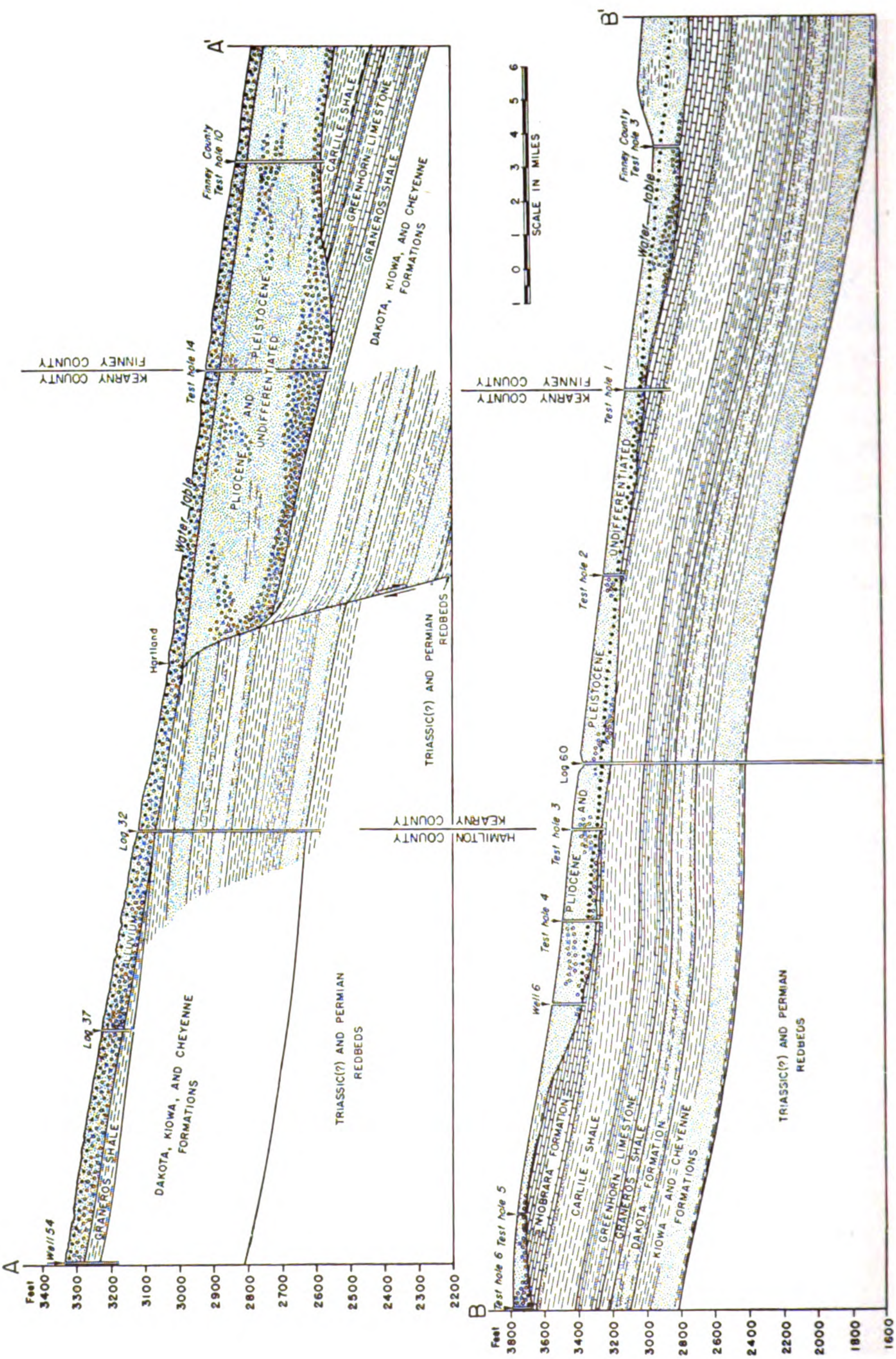

FIG. 7. A, East-west geologic profile along Arkansas river between Coolidge and Garden City; B, East-west geologic profile across the northern part of Hamilton and Kearny counties.

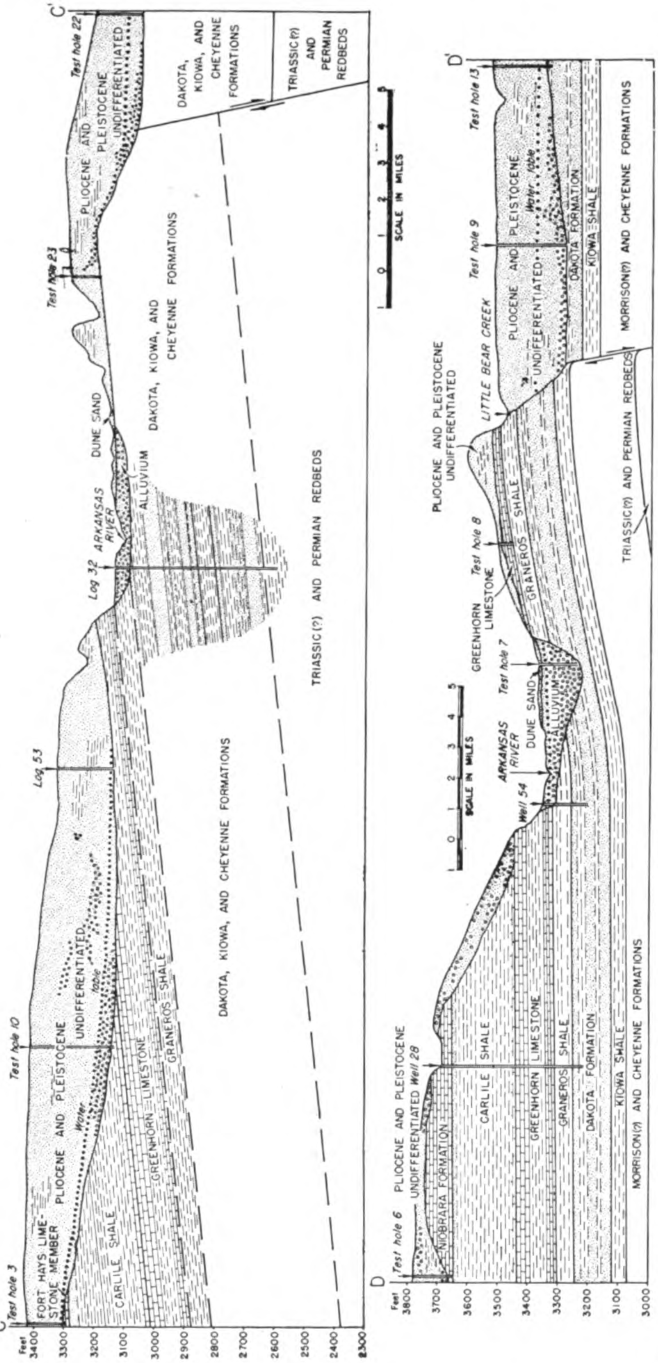

FIG. 8. C, North-south geologic profile across western Kearny county; D, North-south geologic profile across western Hamilton county.

TABLE 2.—*Generalized section of the geologic formations in Hamilton and Kearny counties*

System	Series	Formation	Member	Thickness (feet)	Physical character	Water supply
Quaternary	Pleistocene and Recent	Alluvium *unconformable on older formations*		0–100	Coarse sand and gravel containing silt and clay.	Yields very large supplies of relatively hard water to wells in the Arkansas valley. Supplies more water to wells than any other water-bearing formation in Hamilton and Kearny counties.
		Dune sand *unconformable on older formations*		0–75	Medium-grained, rounded quartz sand.	Lies above the water table and hence does not yield water to wells in this area but serves as a catchment area for rainfall.
		Loess *unconformable on older formations*		0–15	Silt containing fine sand and some clay.	Does not yield water to wells in Hamilton and Kearny counties.
	Pleistocene	Undifferentiated deposits *unconformity*		0–300 (?)	Consolidated and unconsolidated sands and gravels containing much silt and some clay. Locally contains volcanic ash.	Yields moderate to large supplies of moderately hard water to domestic, stock, and irrigation wells in most of Hamilton and Kearny counties.
Tertiary	Pliocene	Ogallala formation *unconformable on older formations*		0–210 (?)	Predominantly silt, but also sand, gravel, caliche, and clay. Lower part locally contains tan, brown, and green bentonitic clay.	Yields moderate to large supplies of moderately hard water to domestic, stock, and irrigation wells in parts of Hamilton and Kearny counties.
Cretaceous	Gulfian *	Niobrara formation	Smoky Hill chalk	0–125 (?)	Soft shaly chalk. Only lower part exposed.	Do
			Fort Hays limestone	61	Cream-colored chalky limestone containing dark-gray calcareous platy shale.	The lower part may yield very small quantities of water to a few wells in northwestern Hamilton county.
		Carlile shale	Codell sandstone	25	Fine- to medium-grained sandstone and sandy shale.	Yields small quantities of water to a few wells in northwestern Hamilton county.
			Blue Hill shale	75	Blue-black fissile shale containing calcareous concretions near the top.	Yields little or no water to wells in Hamilton and Kearny counties.
			Fairport chalky shale	147	Calcareous shale in upper part. Basal part is thin-bedded chalky limestone containing gray shale partings.	Do

Table 2.—Generalized section of the geologic formations in Hamilton and Kearny counties—*Concluded*

System	Series	Formation	Member	Thickness (feet)	Physical character	Water supply
Cretaceous	Gulfian *	Greenhorn limestone	Bridge Creek limestone	74	Thin-bedded chalky limestone and gray limy shale.	Yields very small quantities of water to a few wells in northern Hamilton county.
			Hartland shale	23	Gray limy shale.	Yields little or no water to wells in Hamilton and Kearny counties.
			Lincoln limestone	35	Limy shale containing thin-bedded limestone.	Yields small quantities of water to a few wells in southern Hamilton county.
		Graneros shale		61	Dark-gray fissile shale containing thin-bedded limestone in lower half.	Yields little or no water to wells in Hamilton and Kearny counties.
		Dakota formation		175±	Buff, brown, and tan irregularly-bedded fine-grained sandstone containing sandy shale, shale, and clay.	Yields moderate supplies of moderately hard water to domestic and stock wells in southern and northwestern Hamilton county. Near Coolidge the water is under sufficient pressure to cause it to flow.
	?? Comanchean*	Kiowa shale		125±	Dark-gray to black shale containing lenses of sandstone.	Yields little or no water to wells in Hamilton and Kearny counties.
		—*local disconformity*— Cheyenne sandstone		100±	Gray and light-tan medium-grained sandstone.	Yields moderate quantities of moderately hard water to a few wells in the Arkansas valley near Coolidge. The water is under sufficient pressure to cause some of the wells to flow.
Jurassic (?)		Morrison (?) formation		0–100 (?)	Bluish-green marl containing thin beds of gray and buff sandstones.	Yields little or no water to wells in Hamilton and Kearny counties.
Triassic (?)		—*unconformity*— Undifferentiated redbeds		0–50 (?)	Buff and red fine-grained sandstone and red siltstone.	Do
Permian	Leonardian and Guadalupian*	—*unconformity (?)*— Undifferentiated redbeds		1,550±	Red sandstone and siltstone containing beds of gypsum, anhydrite, and dolomite.	Do

* The classification is that in use by the State Geological Survey of Kansas.

Geologic History

The geologic history of the Hamilton-Kearny area is similar to that of much of the southern High Plains. The area is underlain by thick deposits (6,005 feet in the Stanolind Oil and Gas Company No. 1 Judd in northwestern Kearny county) of limestone, sandstone, shale, clay, sand, and gravel and smaller amounts of salt and gypsum. The character, appearance, and relationships of these rocks as studied in well cuttings and at outcrops reveal much of the geologic history of the region.

PALEOZOIC ERA

Comparatively little is known of the early Paleozoic sediments in this area because only a few test holes have penetrated these beds. The Stanolind Oil and Gas Company No. 1 J. M. Judd well in northwestern Kearny county and the No. 1 Porter well in southwestern Hamilton county penetrated marine limestones and shales of Cambrian, Ordovician, Mississippian, Pennsylvanian, and Permian ages. This indicates that the area was covered by seas during much of the Paleozoic era. The apparent absence of deposits of Silurian and Devonian age probably indicates that this was a land area during that time. If any sediments were laid down at that time, they were removed by subsequent erosion, possibly during early Mississippian time. After Devonian time the area was again submerged and probably remained so during much of the Mississippian, the Pennsylvanian, and the early part of the Permian periods. During this time there were many invasions of the sea interrupted by relatively short periods of emergence. In late Permian time there probably was general emergence that produced shallow basins and broad mud flats in which the redbeds were deposited. The presence of thick deposits of gypsum and salt implies an arid climate in late Permian time.

MESOZOIC ERA

Triassic (?) period

The oil-test holes in southwestern Hamilton county penetrated about 320 feet of redbeds, buff and tan sandstones, and gypsum that Norton (1939) believes to be of Triassic age. Similar deposits crop out in northwestern Oklahoma, in Morton county, Kansas, and at Two Buttes in southeastern Colorado. These deposits are very similar to the upper Permian sediments and probably were deposited under conditions not much changed from those that existed during late Permian time.

Jurassic (?) period

Test hole 24 in southern Hamilton county penetrated a few feet of blue-green marl and gray to buff sandstone which probably is correlative with the Morrison formation of Jurassic age that crops out at Two Buttes, Baca county, Colorado. Similar beds were recognized by Norton (1939) in cuttings from the oil-test wells in southwestern Hamilton county. The character of these deposits, together with the nature of the fossils that have been taken from Morrison beds in other localities, indicates that during Jurassic time this area was part of a large land mass upon which the fluviatile Morrison beds were laid down. Subsequent erosion removed much of these beds.

Cretaceous period

Sandstones of the Cheyenne formation were deposited over the entire area in early Cretaceous time. These deposits were laid down either by shallow-water marine deposition or by streams (Twenhofel, 1924, p. 19). Then followed an invasion of the sea and the deposition of a dark fossiliferous clay that formed the Kiowa shale. At the beginning of late Cretaceous time, sandstones and clays were laid down under both fluviatile and near-shore marine conditions. In some areas the sandstones contain salt water and marine fossils and are well stratified, but fossil plants found in the Dakota formation in other areas suggest a fresh-water origin. Moore (1933, p. 443) suggests that the Dakota formation is a stream-laid and sea-worked deposit.

Marine deposits of limestone, chalk, and shale were laid down in this area in late Cretaceous time. These deposits thicken toward the south, but are absent in the southernmost part of Hamilton and Kearny counties. The late Cretaceous sea probably covered this entire area, but the rocks deposited in them were in part removed by subsequent erosion. At the close of the Cretaceous period there were great orogenic movements that produced the Rocky Mountains and affected at least part of the High Plains section. During this time the Cretaceous and older beds probably were tilted to produce their present northward regional dip.

CENOZOIC ERA

Tertiary period

After the tilting of the Cretaceous and older beds at the close of the Mesozoic era, there was a long period of erosion that truncated these Upper Cretaceous sediments, probably during very early

Tertiary time. Some time later, but still in early Tertiary time, there was moderate folding which produced the Scott-Finney structural basin. At this time the Syracuse anticline, which is genetically related to the Scott-Finney basin, probably was beginning to form. The folding was followed by a period of erosion in which the trough of the Scott-Finney basin was deepened. Toward the close of Tertiary time, during the middle of the Pliocene epoch, aggrading and laterally shifting streams deposited the silts, sands, and gravels comprising the Ogallala formation. Subsequent erosion removed much of this material, however, in the Hamilton-Kearny area, particularly in the southern part.

Quaternary period

Pleistocene epoch.—Near the close of the Tertiary period or during early Pleistocene time there was renewed downwarping of the Scott-Finney basin as well as renewed folding of the Syracuse anticline accompanied by faulting. This period of deformation probably was the same as that which produced the major faulting in the Meade basin in Meade county, Kansas (Frye and Hibbard, 1941). Following the folding and faulting, there was a long period of deposition by aggrading and laterally shifting streams that produced thick deposits of silts, sands, and gravels resembling those of the Ogallala formation. These sediments probably were laid down by eastward-flowing streams carrying material from the Rocky Mountain region. The accompanying map (pl. 3) shows a deep valley in the bedrock trending east-southeastward along which much of this material probably was transported.

After these sediments were deposited, there were continued crustal movements resulting in subsidence of the area south of the river including further displacement in the fault along the Syracuse anticline. Much of the present topography owes its origin to this period of movement. At that time the scarp along Little Bear creek probably was formed, the sand-hills area subsided nearly to its present low level, and Arkansas river swung northeastward at a point near Hartland.

The structural movements in late Pleistocene time were accompanied by the formation of at least two and possibly more terraces along Arkansas river. One is 5 to 8 feet above the floodplain level and is locally called "second bottoms." It is well displayed south of Syracuse, northwest of Kendall, and north of Lakin. This terrace is underlain by coarse sand and gravel having a maximum known thickness of 125 feet in western Hamilton county. A second terrace, which is about 15 to 25 feet above the level of the flood plain, is exposed at the north edge of the sand hills area at many places in Hamilton and Kearny counties. It extends many miles southward under the sand hills in eastern Kearny county and in western Finney county. Test hole 19 in the southeastern part of T. 25 S., R. 35 W. (fig. 2) encountered more than 300 feet of very coarse sand and gravel, part of which probably represents this terrace deposit. At test hole 19, the terrace is covered by only a few feet of dune sand and the topography is relatively flat. The altitude of the top of the gravel deposit is approximately the same as that of the exposed part of the terrace nearly 6 miles to the north. Other test holes (20 and 21) farther south encountered similar deposits, the tops of which were at approximately the same altitude as that of the terrace. Remnants of a higher terrace are to be found north of Arkansas river in secs. 25 and 27, T. 23 S., R. 42 W. in western Hamilton county. These remnants are relatively thin and rest on Cretaceous bedrock. Remnants of this terrace have not been found east of Hamilton county, but some of the higher terraces in eastern Colorado may be of the same age.

In late Pleistocene time several events were begun that were continued, at least intermittently, into Recent time. Great dust storms deposited a blanket of loess over much of this area at that time. This activity probably was resumed several times, the last time being the period of dust storms in the last decade. Contemporaneous with or soon after the loess deposition, the said dunes were developed on the flat terrace plain south of Arkansas river. The shifting of these dunes has continued to the present time. The encroachment of the dunes probably caused Bear creek to cease flowing into Arkansas river and may have been in part responsible for the shifting of the channel of Arkansas river in late Pleistocene or Recent time.

Recent epoch.—Since Pleistocene time the area has undergone erosion that has formed much of the present topography. Many of the small intermittent streams have cut into or through Pleistocene sands and gravels and, therefore, probably are of late Pleistocene or of Recent age. Many of these streams, particularly those in northern Kearny county, terminate in broad, rounded, shallow depressions or sink holes. Such depressions are from a few yards to half a mile in diameter and may or may not contain water. Most of them hold water for long periods after heavy rainfall until the water has evaporated or moved downward to the water table. A few such depressions in the Scott-Finney basin are near enough to the water table to support a marshy type of vegetation. There are also many sinks or depressions in southwestern Hamilton county along the southern margin of the Syracuse anticline.

The origin of sinks is problematical. It has been suggested by Smith (1940, p. 171) that—

These depressions are probably a result of subsidence due to solution of salt or gypsum beds in Permian or early Mesozoic formations, or possibly, in the case of the Scott-Finney depression, of calcareous beds in the Cretaceous.

It was suggested by Johnson (1901, p. 711) that—

the innumerable upland basins, especially where the floor is Cretaceous to great depths, are clearly to be ascribed to grain-by-grain processes of readjustment and compacting, at work within the Tertiary only.

The depressions in the Kearny upland are underlain by relatively thick deposits of Tertiary and Quaternary age and probably were formed by solution, readjustment, and compacting within Tertiary and Quaternary sediments. Most of those in the southwestern part of Hamilton county are near the fault on the southern side of the Syracuse anticline. Their linear trend is shown clearly on aerial photographs. The most recent of these depressions is the one that began to sink on December 18, 1929 (Bass, 1931), at the NE cor. sec. 22, T. 25 S., R. 43 W., in western Hamilton county. Originally it had a diameter of about 60 feet, was 40 to 50 feet deep, and contained a shallow pool at the bottom. In 1941 the diameter had increased by caving until it was 150 to 200 feet. At this time it was filled with water to a level about 15 feet below the western rim. Soon after a new cave-in in 1931, Landes (1931, p. 708) found about 10 feet of Graneros shale exposed in the eastern wall and concluded that the sink probably was caused by solution of salt or gypsum in pre-Dakota sediments, possibly those of Triassic (?) age. All of the sinks along the fault probably were formed in the same manner The movement along the fault may have brought water-bearing beds into contact with beds of salt or gypsum, or at least it may have developed channelways along which water could move to gain contact with the soluble gypsum or salt. The age of the soluble beds probably is upper Permian, because oil tests in this area encountered only a small amount of soluble material in the Triassic (?) beds.

Ground Water

Principles of Occurrence

This discussion of the principles governing the occurrence of ground water takes account of conditions in Hamilton and Kearny counties. Preparation of the discussion has been based chiefly on the authoritative and detailed treatment of the occurrence of ground water by Meinzer (1923), to which the reader is referred for more extended consideration. A general discussion of the principles of ground-water occurrence, with special reference to Kansas, has been published by Moore (1940).

The rocks that make up the outer crust of the earth generally are not entirely solid, but have numerous openings, called voids or interstices, which may contain air, natural gas, oil, or water. The number, size, shape, and arrangement of the interstices in rocks depend upon the character of the rocks. The occurrence of water in any region is therefore determined by the geology.

The interstices or voids in rocks range in size from microscopic openings to the huge caverns found in some limestones. The open spaces generally are connected so that water may percolate from one to another, but in some rocks these open spaces are isolated and the water has little chance to percolate. In Hamilton and Kearny counties, the rocks from which most of the ground water is obtained are sandstones and poorly consolidated sands and gravels. Generally the sands and gravels of the Tertiary and Quaternary deposits contain many interstices through which water percolates freely; locally these interstices may be filled with calcium carbonate, clay, or other materials that make the rock relatively impermeable. Much of the silt, sand, and gravel of the Ogallala formation and of the undifferentiated Pleistocene deposits is poorly sorted and the finer particles fill much of the space between the larger particles, thereby decreasing the amount of space available to ground water. The sandstones of the Cheyenne and Dakota formations are cemented with iron oxide, calcium carbonate, or silicon dioxide. The cement occupies a part of the spaces between sand grains, but enough voids are left to contain some water.

The porosity of a rock is the percentage of the total volume of the rock that is occupied by interstices. A rock is said to be saturated when all its interstices are filled with water or other liquid, and the porosity is then practically the percentage of the total volume of rock that is occupied by water. The porosity of a rock determines only the amount of water a given rock can hold, not the amount it may yield to wells. Some rocks may be highly porous but will not yield an appreciable amount of water to a well. The specific yield of a water-bearing formation is defined as the ratio of (1) the volume of water which, after being saturated, it will yield by gravity to (2) its own volume. It is a measure of the yield when it is drained by a lowering of the water table. The permeability of a water-bearing material is defined as its capacity for transmitting water under hydraulic head, and is measured by the rate at which it will transmit water through a given cross section under a given difference of head per unit of distance. A rock containing very small interstices may be very porous, but it would be difficult to force water through it, whereas a coarser-grained rock, although it may have less porosity, generally is much more permeable. Some water is held in rocks by the force of molecular attraction, which, in fine-grained rocks, is sufficiently great to make the rock relatively impermeable.

Below a certain level in the earth's crust, the permeable rocks generally are saturated with water and are said to be in the zone of saturation. The upper surface of the zone of saturation is called the ground-water table, or simply the water table. All the rocks above the water table are in the zone of aeration, which ordinarily consists of three parts: The belt of soil water; the intermediate, or vadose zone; and the capillary fringe.

The belt of soil water lies just below the land surface and contains water held by molecular attraction. In this belt the amount of water must exceed that which will be held by gravity before any water can percolate downward to the water table. The thickness of the zone is dependent upon the character and thickness of the soil and upon the precipitation and vegetation.

The intermediate belt lies between the belt of soil water and the capillary fringe. In this belt the interstices in the rocks contain some water held by molecular attraction, but also may contain appreciable quantities of water while it is moving downward from the belt of soil moisture to the ground-water table. The intermediate belt may be absent in places, such as in some river valleys where the water table is near the surface, or it may be more than 200 feet thick, as it is in parts of Hamilton and Kearny counties.

The capillary fringe lies directly above the water table and is formed by water rising from the zone of saturation by capillary action. The water in the capillary fringe is not available to wells, which must be deepened to the zone of saturation before water will enter them. The capillary fringe may be absent or very thin in coarse-grained sediments, in which the capillary action is negligible, or it may be several feet thick in fine-grained sediments.

WATER IN SAND AND GRAVEL

In Hamilton and Kearny counties, water is found in unconsolidated deposits of sand and gravel in the alluvium of the Arkansas river valley, in the Ogallala formation, and in the undifferentiated Pleistocene sediments. The history of deposition of these deposits is given under Geologic history; their character, distribution and thickness, origin, age and correlation, and water supply are described under Geologic formations and their water-bearing properties.

The sorting action of the streams on these sediments resulted in the deposition of many distinct beds of gravel, sand, silt, and clay. Deposits of such uniform texture may have a relatively high porosity. Coarse, well-sorted gravel of this type has a relatively high specific yield and permeability, and properly-constructed wells in this material yield large quantities of water. Some of the stream-laid material is poorly sorted and finer materials occupy much of the pore space between the larger grains, reducing the porosity and specific yield.

The deposits of sand and gravel in the alluvium of Arkanses river are among the most important sources of ground water in the Hamilton-Kearny area. Most of the irrigation and public-supply wells in this area obtain water from these deposits. The yields of wells ending in alluvium range from a few gallons to more than 4,000 gallons a minute.

The Ogallala formation and the undifferentiated Pleistocene deposits also supply water for irrigation wells; in addition they are the source of water for many domestic and stock supplies, particularly in Kearny county.

WATER IN SANDSTONE

The particles comprising a sandstone generally are more even-grained and better sorted than those found in unconsolidated sand and gravel. These particles are held together by cementing material that in some places fills the interstices and prevents water from percolating through them. Near Hartland, in Kearny county, the sandstones of the Dakota formation are tightly cemented with silicon dioxide and are relatively impermeable. In most of the area where wells obtain water from the sandstones in the Dakota formation, the water-bearing beds are moderately permeable and yield supplies of water adequate for most domestic and stock needs.

Some water may be found also in the Codell sandstone member in the upper part of the Carlile shale.

WATER IN SHALE

Shale is formed by the induration of clay or of clayey mixtures; it generally has a relatively low specific yield and yields little or no water to wells. In some areas the shale may have many open joints and bedding planes and consequently a higher permeability; in other areas it may contain sand grains in sufficient quantity to make it somewhat permeable. In parts of northwestern Hamilton county, the Codell sandstone member of the Carlile shale is a sandy shale and yields small quantities of water to a few stock wells. Little or no water is obtained from other parts of the Carlile shale, however.

WATER IN LIMESTONE AND CHALK

Limestones range greatly in their ability to yield water to wells. Large interconnecting cavities or caverns may be formed in limestones by the solvent action of percolating waters, and wells that penetrate such openings in the rocks below the water table generally obtain large supplies of water. In places where the limestone contains only small cracks and crevices, however, little or no water may be secured from wells. Some wells in Hamilton county obtain small amounts of water from the Greenhorn and Fort Hays limestones. These formations have a relatively small number of open spaces, principally joints and bedding planes.

Chalk is a soft friable limestone and may yield moderate quantities of water to wells. Shaly limestones and calcareous shale are intermediate in composition between limestone and shale and may also yield moderate quantities of water to wells. The Smoky Hill chalk member of the Niobrara formation, which underlies the northern part of the Hamilton-Kearny area, is made up of compact shaly chalk and yields little or no water to wells in this area because of its low permeability and because, in much of the area, it lies above the water table.

PERMEABILITY OF WATER-BEARING MATERIALS

The rate of movement of ground water is determined by the size, shape, quantity, and degree of interconnection of the interstices and by the hydraulic gradient from one point to another. The capacity of a water-bearing material for transmitting water under hydraulic head is its permeability. The coefficient of permeability may be expressed 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. (Meinzer's coefficient; see Stearns, 1927, p. 148.) The coefficient of transmissibility is a similar measure and may be defined as the number of gallons of water a day transmitted through each one-foot strip extending the height of the aquifer under a unit-gradient (Theis, 1935, p. 520). The coefficient of transmissibility may also be expressed as the number of gallons of water a day transmitted through each section 1 mile wide extending the height of the aquifer, under a hydraulic gradient of 1 foot to the mile.

The coefficient of transmissibility is equivalent to the coefficient to permeability (corrected for temperature) multiplied by the thickness of the aquifer.

The coefficient of permeability of water-bearing materials can be determined in the laboratory (methods summarized by V. C. Fishel in Wenzel, 1942, pp. 56-58) or in the field. Five pumping tests were made in Hamilton and Kearny counties between December 1, 1941, and March 27, 1942, by Melvin S. Scanlan of the Division of Water Resources of the Kansas State Board of Agriculture and Woodrow W. Wilson of the Federal Geological Survey. Discharge measurements were made using a Collins flow meter, and draw-down and recovery measurements were made using a steel tape and/or an electrical measuring device.

C. V. Theis (1935) has shown that to the extent that Darcy's law governs the motion of ground water under natural conditions and under the artificial conditions set up by pumping, an analogy exists between the hydrologic conditions in an aquifer and thermal conditions in a similar thermal system. Darcy's law is analogous to the law of the flow of heat by conduction, hydraulic pressure being analogous to temperature, hydraulic gradient to thermal gradient, permeability to thermal conductivity, and specific yield to specific heat. From his final equation expressing the relation between the draw-down and the rate and duration of discharge of a well, Theis developed the following recovery formula for determining the transmissibility of an aquifer (as defined above):

$$T = \frac{264q}{s} \log_{10} \frac{t}{t_1}$$

in which T = coefficient of transmissibility
q = pumping rate, in gallons a minute
t = time since pumping began, in minutes
t_1 = time since pumping stopped, in minutes
s = residual draw-down at the pumped well, in feet, at time t_1.

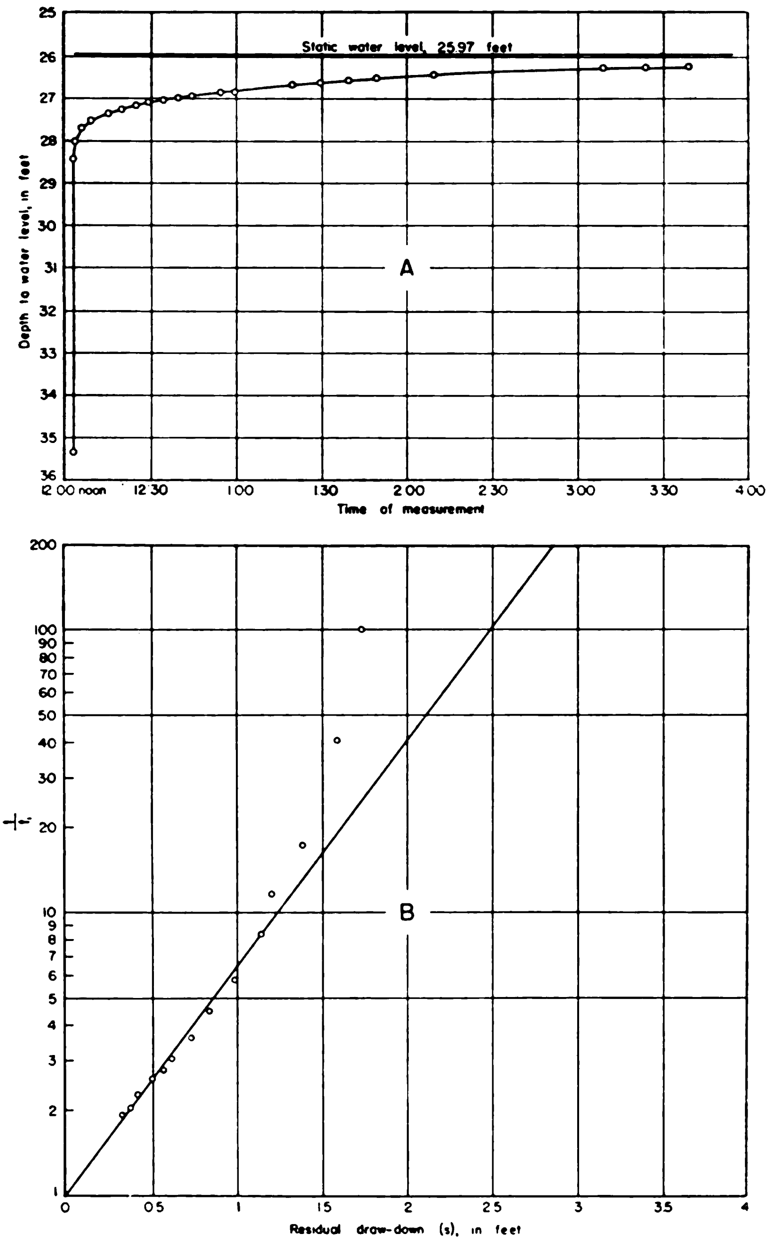

FIG. 9. A, Recovery curve for well 91; B, Curve for pumping test on well 91 obtained by plotting s against t/t_1.

The residual draw-down (s) is computed by substracting the static water-level measurement (table 3) from depth-to water-level measurements made after pumping stops (fig. 9). The proper ratio $\frac{\log_{10} t/t_1}{s}$ is determined graphically by plotting $\log_{10} t/t_1$ against corresponding values of s (fig. 9). This procedure is simplified by plotting t/t_1 on the logarithmic coördinate of semi-logarithmic paper. For any convenient value for $\log_{10} t/t_1$, the corresponding value for s may be found by inspection, provided the curve passes through the origin. If the curve does not pass through the origin, it can be made to do so approximately by applying an empirical correction to the formula as follows: $T = \frac{264_q}{s} \log_{10} \frac{t \pm c}{t_1}$ in which c is a correction factor (Wenzel, 1942, p. 127). The curves for two tests in Hamilton and Kearny counties (wells 92 and 238) did not

TABLE 3.—*Data on pumping test of well 91, Hamilton county, made on March 13, 1942*

Time since pumping started (minutes) t	Time since pumping stopped (minutes) t_1	t/t_1	Yield (gallons a minute)	Depth to water level (feet)	Draw-down (feet)	Remarks
....	....	....	....	25.97	....	Static water level
....	....	....	....	....	....	Pump started
9	....	....	532	30.0	4.0	
34	....	....	528	....	....	
64	....	....	520	34.4	8.0	
94	....	....	534	34.55	8.58	
124	....	....	531	34.55	8.58	
154	....	....	525	34.56	8.59	
184	....	....	524	35.34	9.37	
202	....	....	....	....	....	Pump stopped
204	2	102	....	27.70	1.73	
207	5	41.4	....	27.56	1.59	
214	12	17.67	....	27.37	1.40	
224	22	11.82	....	27.19	1.22	
229	27	8.48	....	27.12	1.15	
244	42	5.81	....	26.96	.99	
259	57	4.54	....	26.82	.85	
279	77	3.62	....	26.71	.74	
299	97	3.08	....	26.60	.63	
314	112	2.80	....	26.55	.58	
329	127	2.59	....	26.49	.52	
359	157	2.28	....	26.40	.43	
389	187	2.04	....	26.36	.39	
419	217	1.93	....	26.31	.34	

pass through the origin. The correction factors needed to make these curves pass through the origin were + 525 and + 105, respectively.

The weighted average discharge (q) of well 91 was 527.2 gallons a minute (table 3). When values for s, t/t_1, and q are substituted in the Theis recovery formula, the coefficient of transmissibility of the water-bearing material at the pumped well is found to be 111,300. Dividing the coefficient of transmissibility by the average thickness of the saturated water-bearing material in the vicinity of the well, 60 feet, the coefficient of permeability is found to be about 1,855 (The temperature of the water was 60° F., hence no temperature correction is needed).

Data on the five pumping tests in Hamilton and Kearny counties are listed in table 4.

As indicated in table 4, the coefficient of permeability of the alluvium of the Arkansas valley is much greater than that of the other water-bearing formations penetrated by irrigation wells in the Hamilton-Kearny area. The undifferentiated Pliocene and Pleistocene deposits generally are comprised of silt and sand containing some gravel, whereas the alluvium generally is predominantly sand and gravel.

Artesian Conditions

The head of water has been defined as the height that a column of water will rise in a tightly cased well that has no discharge. Ground water that rises in wells above the level at which it is first encountered is said to be artesian or "piestic" water (Meinzer and Wenzel, 1942, p. 451).

In some of the rock formations in Hamilton and Kearny counties, strata of relatively permeable rock, principally sandstone, alternate with relatively impermeable beds, such as shale or clay. In this area, the strata dip generally northeastward so that water falling on the outcrop area of a permeable bed moves northeastward down the dip between the confining layers of relatively impermeable material and saturates the permeable strata. Under such conditions, wells drilled to the water-bearing beds in this area, encounter water under artesian head, and in the vicinity of Coolidge in western Hamilton county this head is sufficient to cause them to flow.

Artesian water has been encountered in wells in most of the Syracuse upland area in southern Hamilton county and southwestern Kearny county, in the Arkansas valley in western Hamilton county, and in a part of the Kearny upland area in northwestern

TABLE 4.—*Results of pumping tests in Hamilton and Kearny counties*

Well No	Water-bearing formation	Discharge (gallons a minute)	Draw-down (feet)	Duration of pumping (minutes)	Specific capacity (a)	Coefficient of transmissibility	Approximate thickness of water-bearing material (feet)	Coefficient of permeability (b)
91	Alluvium	527	11.51	202	45.8	11,300	60	1,855
92	do	708	10.86	180	65.2	546,800	60	9,113
213	Undifferentiated Pliocene and Pleistocene deposits	812	32.55	184	24.9	79,000	320	247
238	do	637	61.13	251	10.4	98,100	350	280
268	Alluvium and undifferentiated Pliocene and Pleistocene deposits	1,080	19.38	216	55.6	187,500	340	552

a. The specific capacity of a well is its rate of yield per unit of draw-down and is determined by dividing the tested capacity in gallons a minute by the draw-down in feet.

b. Coefficient of transmissibility divided by thickness of saturated water-bearing material; water temperature 60° F., hence no correction for temperature is needed.

Hamilton county. In the vicinity of Coolidge the water in about nine wells is under sufficient pressure to flow at the surface, but the yields of individual wells do not exceed 30 gallons a minute.

In southern Hamilton county, water under artesian pressure is encountered in the sandstones of the Dakota formation. The height above the water table to which water from the Dakota formation will rise is extremely variable. Some wells penetrated sandstone so tightly cemented that it yields very little water. In other wells in this area, the water will rise as much as 125 feet above the top of the formation, or to within 75 feet of the surface.

Only a few wells in the Syracuse upland area have penetrated the Cheyenne sandstone. Water from this formation generally will rise in wells to a level a few feet higher than the water level in wells that penetrate the Dakota formation. A well in the center of T. 26 S., R. 39 W., however, is reported to have penetrated both the Dakota formation and the Cheyenne sandstone, and encountered water at a depth of nearly 500 feet. The water did not rise in the well.

At least three wells in northwestern Hamilton county have encountered water that is under artesian pressure. The wells penetrated sandstones of the Dakota formation. A well (11) of Dan Huser encountered the Dakota formation at a depth of 800 feet and the water rose to about 450 feet below the land surface. When the well was pumped, however, the water level was drawn down to about 750 feet below land surface. The Jacob Behrendt well (29), in the SE¼ sec. 4, T. 22 S., R. 43 W., encountered the Dakota formation at 480 feet and water rose to about 355 feet below land surface. The Fred Behrendt well (28) in the same section encountered a sandstone in the Dakota formation at 495 feet and the water rose to about 370 feet below land surface. Artesian water probably could be obtained from both the Cheyenne sandstone and the Dakota formation in much of the Kearny upland area, but these beds lie at such great depths in this area that it is unprofitable to obtain water from them.

In the vicinity of Coolidge, in the Arkansas valley in western Hamilton county, many wells have encountered water that is under sufficient artesian pressure to cause them to flow. The first artesian well was reported by Mr. J. W. Egger* to have been drilled in 1885, but most of the wells were drilled during the period from 1907 to 1910. Many of the wells were reported to have yielded initially as much as 75 gallons a minute (Haworth, 1913) and the water was

* Personal communication.

under sufficient head to cause it to rise nearly 20 feet above the land surface. At present the wells yield from less than 1 to more than 25 gallons a minute and the water will rise in some wells to more than 10 feet above the land surface. The decrease in flow and the apparent decrease in head are probably due to faulty well construction rather than to the depletion of the water supply.

Water under artesian head is obtained from both the Cheyenne sandstone and the Dakota formation in this area. The first artesian water is encountered in a sandstone at the top of the Dakota formation. The water rises to a level between 25 feet below and 5 feet above the static level of the water in the alluvium. No flow is obtained from wells that end in this bed, which is encountered at depths of 80 to 110 feet. Some wells encounter artesian water in a second sandstone bed near the base of the Dakota formation. The water from this bed will rise higher than that from the upper zone. One well (61) that penetrates this bed has a flow of nearly 30 gallons a minute; its initial flow was more than 60 gallons a minute. All but one of the flowing wells obtain water from the Cheyenne sandstone—the third zone, which is encountered at depths of 250 to 300 feet.

The area in which artesian flow probably could be obtained is limited to the Arkansas valley in R. 43 W. and the west half of R. 42 W. Many more wells probably could be drilled in this area without seriously depleting the supply, but they should be properly constructed and should not be permitted to flow except when the water is needed. The source of the water in these beds is discussed under the section on ground-water recharge.

The Water Table

The upper surface of the zone of saturation in ordinary permeable soil or rock has been defined as the ground-water table, or simply the water table. Where the upper surface is formed by impermeable material, as it is in parts of Hamilton county, the water table is absent. The water table is not a plane surface in all parts of the area, but in some places has irregularities comparable with and related to those of the land surface, although it is less rugged. It does not remain in a stationary position but fluctuates up and down. The irregularities are due chiefly to local differences in grain and loss of water, and the fluctuations are due to variations from time to time in gain or loss.

SHAPE AND SLOPE

The shape and slope of the water table in Hamilton and Kearny counties is shown on the map (pl. 1) by contour lines drawn on the water table. Each point on the water table on a given contour line has the same altitude. These water-table contours show the configuration of the water surface just as topographic contour lines show the shape of the land surface. The direction of movement of the ground water is at right angles to the contour lines in the direction of the downward slope.

In the Kearny upland in northern Hamilton county and in the Syracuse upland in southern Hamilton county and southwestern Kearny counties the water-table contours are not shown. Northwestern Hamilton county is underlain in part by relatively impermeable beds; therefore, there is no water table in much of this area. In northeastern Hamilton county, water is encountered at several places at greatly varying depths. The bodies of water are not continuous but are probably "perched" on the shales and chalks of the Carlile and Niobrara formations. These "perched" water tables cannot be shown accurately on the water-table contour map.

In the Syracuse upland, wells obtain water from sandstones of the Dakota formation. The water is under artesian head and may rise from less than 1 foot to more than 100 feet above the point at which it is encountered. This difference in the levels to which the water will rise, together with the fact that the Dakota formation has been faulted and uplifted so that it is in some places at an altitude greater than that of the static water level in adjacent areas, makes it impracticable to draw water-table contour lines for this area.

The map (pl. 1) shows that the general direction of movement of the ground water in Hamilton and Kearny counties is east-southeastward, but that the slope and the direction of movement range considerably from one part of the area to another. The maximum slope is in the northeastern part of Kearny county and is nearly 40 feet to the mile. The minimum slope is in the sand-hills area in the vicinity of Bear creek in south central Kearny county and is about 4 feet to the mile. The average slope in the northern part of the area is about 12 feet to the mile; along the Arkansas valley it is 9.5 feet to the mile; and along the southern border of the area it is about 10 feet to the mile.

The shape and slope of the water table, which determine the rate and direction of movement of ground water, are controlled by several factors. Irregularities in the shape and slope of the water table in the Hamilton-Kearny area may be caused by: (1) the configuration of the underlying Cretaceous floor; (2) discharge of ground water into streams; (3) recharge of the ground-water reservoir by ephemeral streams; (4) unequal additions of water to the ground-water reservoir at different places; (5) local differences in the permeability of the deposits; and (6) local depressions on the water table caused by the pumping of water from wells.

The shape of the bedrock floor formed by the underlying Cretaceous rocks controls to some degree the direction of movement of the ground water in this area. The water table in northern Kearny county slopes eastward and southeastward as does the surface of the Cretaceous bedrock (pl. 3). The unusually steep slope of the water table in northeastern and northwestern Kearny county is probably not entirely due to the slope of the Cretaceous floor. A lower permeability or thinner section of the Ogallala formation in this area would tend to increase the slope of the water table.

South of Arkansas river in Kearny county the water table has a more gentle slope, particularly in the southeastern part of the county. The Cretaceous bedrock surface (pl. 3) has a similar slope; however, the relatively high permeability of the gravels in this area probably is the most important factor affecting the slope of the water table. In the Arkansas valley, particularly between Coolidge and Hartland, the slope of the water table is approximately the same as that of the bedrock floor—about 8 feet to the mile, whereas east of Hartland there is no apparent relation between them.

The shape and slope of the water table and the direction of movement of the ground water are also influenced in this area by the discharge of ground water into Arkansas river. In the Arkansas valley in Hamilton county there is a slight upstream flexure of the contour lines indicating that the water is moving toward the river as well as down the valley. In eastern Kearny county the upstream flexure is very pronounced; this is due in part to heavy pumpage of water for irrigation in the valley between Lakin and the Finney county line. Before irrigation was begun in this area, Arkansas river probably had water in it throughout its course through Hamilton and Kearny counties. At that time the water level in eastern Kearny county probably was at about the same altitude as the water level in the northern part of the sand-hills area to the south, but was not as high as the water level in the area north of the river.

Streams that flow only after rains are termed ephemeral or intermittent streams. Their channels lie above the water table and are dry much of the time. During periods of stream flow, part of the water in an ephemeral stream may seep into the stream bed and move downward to the ground-water reservoir. A stream of this type is said to be influent. Bear creek is an excellent example of this type of stream because the dune sand has choked its channelway and prevents the water from emptying into Arkansas river. After each flood, therefore, much of the water must stand in the channelway until it evaporates and/or percolates downward to the water table. Because of its permeable nature, the sand and gravel that underlie the channel permit relatively free passage of the water downward to the ground-water reservoir. The elongated mound on the water table in the southern part of T. 26 S., R. 37 W. (pl. 1) is the result of this type of recharge. In the northern part of T. 26 S., R. 37 W. the channel receives much less flood water; as a result there is no water-table mound but merely a local flattening of an otherwise uniform slope. In southwestern Hamilton county Little Bear creek contributes some water to the ground-water reservoir, but sufficient data are not available to determine the quantity. The addition of water to the ground-water reservoir by Arkansas river is discussed on pages 70 and 71.

Unequal additions of water to the ground-water reservoir have caused some of the irregularities in the shape of the water table in the Hamilton-Kearny area. In some places, where surface conditions are favorable for ground-water recharge, the water that percolates downward tends to build up the water table to form slight mounds or locally to lessen the slope of the water table. In material of low permeability these mounds or ridges may be relatively high, but in more permeable material the slopes generally are gentle. In the eastern part of T. 22 S., R. 35 W. the slope of the water table changes abruptly from about 20 feet to the mile to about 5 feet to the mile. Farther east in Finney county the slope increases to nearly 10 feet to the mile. This local flattening of the water table is probably due to the recharge of the ground-water reservoir by water from shallow depressions or sink holes. The southeastward flowing intermittent streams in the Kearny upland area terminate in these depressions. After heavy rains the water stands in the depressions until it evaporates and/or percolates downward to the water table. Similar depressions in other parts of the Kearny upland also contribute some water to the ground-water reservoir.

Similar and more favorable conditions for the addition of water to the ground-water reservoir are to be found in the sand-hills area where there are many undrained basins underlain by relatively permeable rocks. There are probably many small mounds on the water table in the sand hills, but there are so few wells that data are lacking for showing such mounds on the water-table contour map.

Local differences in the permeability of the water-bearing beds may also affect the shape and slope of the water table. Other things being equal, the slope of the water table in any area, in general, varies inversely with the permeability of the water-bearing material. If the material has a low permeability, the slope of the water table is relatively steep because of the frictional resistance offered by the small interstices through which the water must move. The relatively steep slope in the northern part of Kearny county is due, at least in part, to the relatively low permeability (locally) of the Ogallala formation through which the water must pass. The gentle

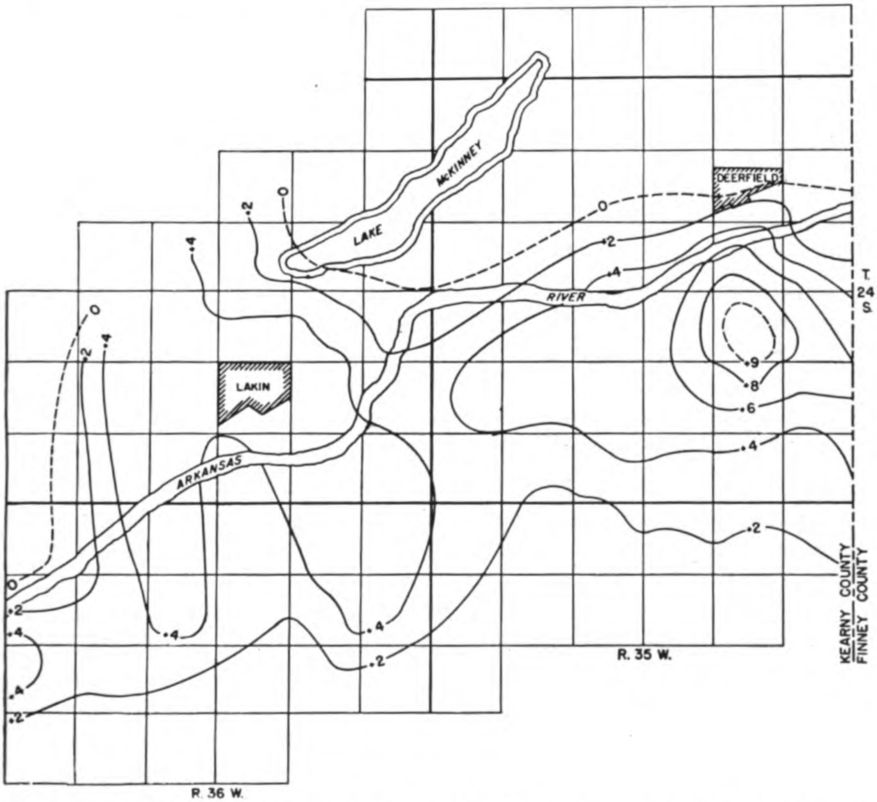

Fig. 10. Map of the Arkansas valley in eastern Kearny county showing the changes in water level between August, 1940, and December, 1941.

slope of the water table in the sand-hills area in Kearny county is caused by the relatively high permeability of the water-bearing material in that area. The sand hills are underlain by thick deposits of coarse sand and gravel.

The very sharp upstream flexures of the contour lines in the Arkansas valley in eastern Kearny county are due primarily to heavy pumpage by the irrigation wells. The water level is lowered during the pumping season but rises after pumping has ceased. The map (pl. 1) is based on water-level measurements made during the summer of 1940 when there was much pumpage. As shown in figure 10, the water level was greatly lowered in this area in the summer of 1940, but in December, 1941, after pumping had ceased and following many months of above normal precipitation, the water level in the most heavily pumped area had risen as much as 9 feet above the 1940 level.

RELATION TO TOPOGRAPHY

The depth to water level below land surface in the Hamilton-Kearny area is controlled largely by the configuration of the land surface. A map (pl. 2) has been prepared showing by isobath lines the depths to water level in wells in Hamilton and Kearny counties. Isobath lines are lines that connect points of equal depth to water level. No attempt was made to draw isobath lines in the western part of the Kearny upland or in the Syracuse upland. In the western part of the Kearny upland it is difficult to find water. It may be encountered in the alluvium of the small intermittent streams, in the sand and gravel just above the Cretaceous bedrock floor, in the Fort Hays limestone member of the Niobrara formation, in the Codell sandstone member of the Carlile shale, or in the sandstones of the Dakota formation. When water is encountered in the Dakota formation it may rise several feet in the well or it may rise several hundred feet. It is, therefore, impracticable to draw isobath lines showing depth to water in this area, for it is difficult to predict at what horizon a supply of water will be found and to what height the water will rise if it is under artesian head. A similar problem exists in the Syracuse upland; however, there it is not so difficult to obtain water because the Dakota formation lies at a much shallower depth. The height to which the water will rise in the well, however, is unpredictable, as it is in the western part of the Kearny upland.

As shown on the map (pl. 2), the depths to water level in the Hamilton-Kearny area range from about 5 feet in the Arkansas river valley to 450 feet on the Kearny upland in northern Hamilton county. The water table is shallowest in the alluvium of the Arkansas river valley and deepest in sandstones of the Dakota formation. For the purpose of detailed description, Hamilton and Kearny counties may be divided into seven areas based upon the depths to water level: (1) Arkansas valley area, (2) Scott-Finney depression area, (3) sand-hills area, (4) Bear Creek depression area, (5) Kearny upland area, (6) Syracuse upland area, and (7) Stanton area. These areas are the same as the topographic divisions, and their locations and areal extents are described in the section on Topography and drainage.

The depths to water level in many of the wells shown on plate 2 are not in complete agreement with the depths to water level in 1913 as reported by Darton (1920, Underground-water maps). This is particularly evident in the Stanton area in southwestern Hamilton county where the average depth to water in 19 wells (as reported by Darton) was 35 feet in 1913. The average depth to water in nine wells in the same area was 102 feet in 1940. Well 158 (plate 2) is 109 feet deep and the static water level in 1940 was about 88 feet. Darton reported that in 1913 a well at the same location was 61 feet deep and had a static water level of 16 feet. Similarly, the water level in well 160 was 64.5 feet below land surface in 1940, whereas in a well at the same site it was reported to be 22 feet in 1913. The depth of well 160 was 78 feet, whereas the depth of the well reported by Darton was 93 feet.

These discrepancies do not necessarily indicate that the water levels have declined greatly since 1913. In fact, the depths to water level in many of the wells reported by Darton were about the same or even greater than in wells measured in 1940. The water level in a well near the middle of the city of Johnson was reported by Darton to be 240 feet below land surface. The water level in a well at Johnson in 1939 was about 165 feet and the water levels in wells near Johnson ranged from 146 to 183 feet below land surface (Latta, 1941, pl. 2). In addition, Darton reported that the water level in a well 200 feet deep in the northern part of Johnson was 10 feet below land surface. This indicates that the water level in one or both of the wells did not represent the main water table. It also indicates that although some water may have been encountered at a depth of 10 feet in the north well the quantity was probably inadequate for domestic and/or stock needs; otherwise the well would not have been drilled or dug to a depth of 200 feet. The average depth of wells reported by Darton is about the same as the average depth of the wells measured in 1940, which probably means that the upper water was "perched" water and hence may not have been adequate for most needs. A few wells, however, probably were able to obtain a moderate supply from bodies of "perched" water, for it is believed that these wells were not deep enough to reach the main zone of saturation. Most of the early wells in this area were dug, and because of the slow process of construction the relatively poor water-bearing materials were noticed. The newer wells, however, generally are drilled so rapidly that poor water-bearing beds probably are overlooked. Furthermore, the dug wells were able to utilize these zones of poor water-bearing material because their large diameter provided a large infiltration area and allowed ample storage of water. These wells, however, were more liable to fail in dry weather and for that reason most of them probably were deepened to the main zone of saturation. In the modern drilled wells the zones of poor water-bearing material generally are cased off and the water is taken only from the main zone of saturation.

Arkansas valley area.—The Arkansas valley is a shallow-water area in which water can be obtained in wells at depths ranging from about 5 to nearly 20 feet; the depths of the wells range from about 10 to nearly 275 feet. The alluvium is the principal water-bearing material, but some of the deeper wells also draw water from the underlying undifferentiated Pleistocene deposits. At Kendall, Syracuse, and in the vicinity of Coolidge some wells penetrate the Dakota formation and the Cheyenne sandstone. The water in wells that penetrate these formations in the Arkansas valley rises nearly to or above the land surface.

An unusual feature of the Arkansas valley is Clear lake, in the NE¼ sec. 13, T. 25 S., R. 37 W., south central Kearny county. The lake, when measured by Slichter (1906, p. 18) in 1904, was 320 feet in length, 280 feet wide at its narrowest point, and about 16 feet deep. Clear lake prabably occupies one of the many depressions or sink holes found in the High Plains area. The surface of the lake represents the level of the water table.

Scott-Finney depression area.—As stated in the section on topography and drainage, it is difficult to distinguish the western limit of the Scott-Finney depression because it gradually merges into the Kearny upland. In this discussion the limits shown in figure 2 will be used. The wells in this area range in depth from about 25 feet to nearly 400 feet and the water levels are 20 to 70 feet below the land surface. The shallow wells obtain water from the unconsolidated gravels of Pleistocene age, and the deeper wells obtain water from both Tertiary and Quaternary deposits.

Sand-hills area.—The water table in the sand-hills area south of Arkansas river is 25 to almost 125 feet below the land surface. The water level in most of the sand-hills area is less than 50 feet below land surface but in southeastern Kearny county the depth to water level exceeds 100 feet. The wells in this area range in depth from about 30 feet to more than 150 feet. The 50-foot isobath line is a dashed line in most of this area (pl. 2) because of the lack of sufficient control points.

Bear Creek depression area.—The Bear Creek depression comprises a relatively small, elongated area in south central Kearny county. Only a few wells were measured in this area and they range in depth from 30 to 60 feet. The depths to water level in the wells that were measured range from 26 to 34 feet below land surface. The principal water-bearing beds are the sands and gravels of Pleistocene age, at least part of which are terrace deposits of Arkansas river.

An unusual feature of the Bear Creek depression area in pioneer days was a "natural well" in the SE¼ sec. 16, T. 26 S., R. 37 W. At this place there was a small pond, similar to Clear lake, that was fed by ground water. The surface of the pond represented the surface of the water table. In recent years the pond has been filled by migrating dune sand.

Kearny upland area.—The largest deep-water area is the Kearny upland in northern Hamilton and Kearny counties. Water is obtained principally from the unconsolidated sands and gravels of Tertiary and Quaternary age. In that part of the area where isobath lines are drawn (pl. 2) the water levels range in depth below land surface from about 50 feet at a point near the Scott-Finney depression to more than 225 feet in west central Kearny county. In the western part of the Kearny upland most of the wells encounter water either in the Ogallala formation, the Codell sandstone member of the Carlile shale, or the Dakota formation. The depths of the wells range from about 60 feet to more than 800 feet.

Syracuse upland area.—Most of the wells in the Syracuse upland obtain water from sandstones in the Dakota formation; however, a few wells get small supplies of water from the Greenhorn limestone and from the Cheyenne sandstone. Wells that end in the Dakota formation range in depth from about 110 feet to more than 250 feet,

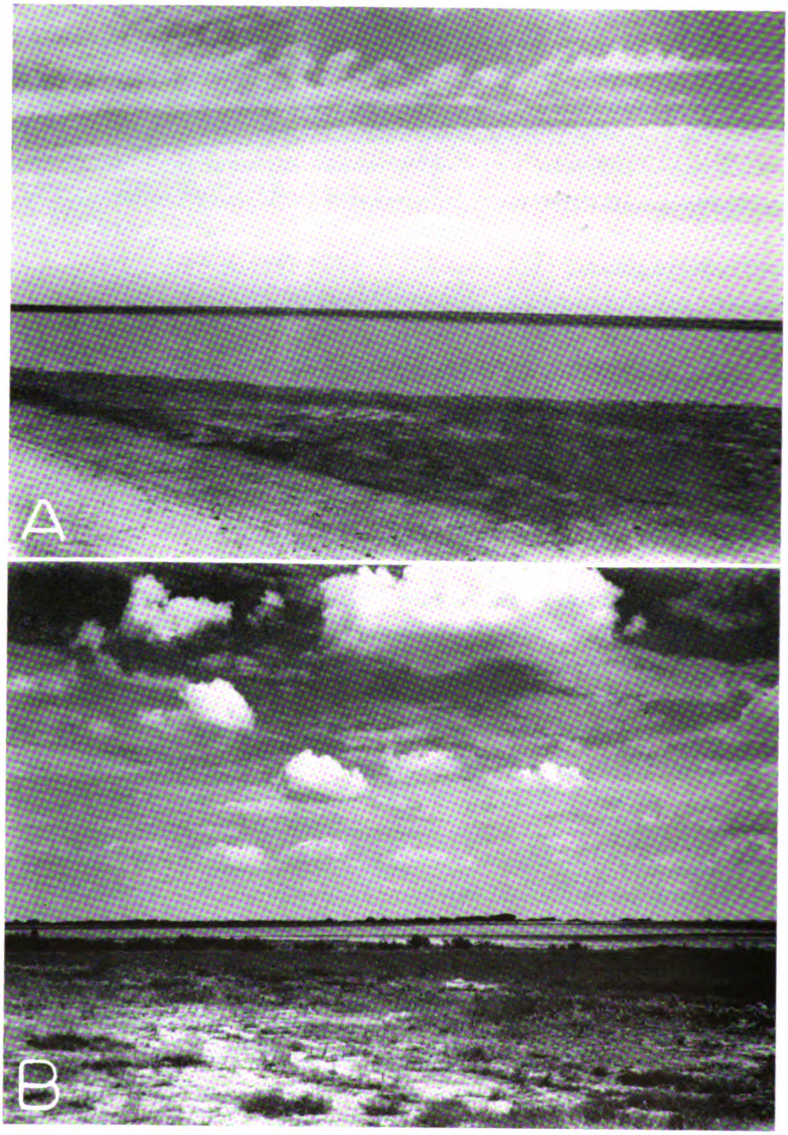

PLATE 7. A, Water-filled depression on the Kearny upland in sec. 26, T. 22 S., R. 38 W.; B, Lake McKinney reservoir used for the storage of water for irrigation.

and the water levels in these wells range from 100 to nearly 250 feet below land surface. Wells that obtain water from the Greenhorn limestone are less than 100 feet deep. The water in the sink hole south of Coolidge probably is derived from the Lincoln limestone member of the Greenhorn limestone. Wells that enter the Cheyenne sandstone are more than 300 feet deep.

Stanton area.—This is an area of intermediate depth to water, the water level in most of the area being between 50 and 150 feet below land surface. In a few wells the water level is as little as 10 feet and in some it is as much as 184 feet below land surface. This area is on the south side of the fault, and the wells obtain most of their water from Tertiary and Quaternary sands and gravels.

FLUCTUATIONS OF THE WATER TABLE

The water table does not remain static but fluctuates much like the water surface of any surface reservoir. Whether the water table rises or declines depends upon the amount of recharge into the ground-water reservoir and the amount of discharge. If the inflow exceeds the draft, the water table will rise; conversely, if the draft exceeds the inflow into the ground-water reservoir the water table will decline. The water table fluctuates more by the addition or depletion of a given quantity of water than does the water surface of a reservoir. If the sand and gravel of a water-bearing formation has an average specific yield of about 25 percent, the addition of 1 foot of water to the sand and gravel will raise the water table in that material about 4 feet. Changes of water levels record the fluctuations of the water table and hence the recharge and discharge of the ground-water reservoir. The safe yield of the ground-water reservoir, therefore, can be estimated by observing the fluctuations of the water levels in wells.

The principal factors that control the rise of the water table (ground-water recharge) in the Hamilton-Kearny area are: (1) the amount of rainfall that penetrates the soil and descends to the zone of saturation, (2) the seepage from streams, depressions and irrigation canals, and (3) the quantity of water added to the ground-water reservoir by underflow from the north and west. The factors that cause a decline in the water table in this area (ground-water discharge) are: (1) underflow into areas to the east and to the south, (2) evaporation and transpiration, (3) seeps and springs, and (4) pumpage from wells. If the quantity of ground water discharged from a ground-water reservoir during a certain year is greater than the recharge during that year the water table will decline. During a period of dry years the water table may decline, but in a subsequent period of wet years the water table may rise. The decline of the water table during a dry year, therefore, does not necessarily mean that there has been an excessive withdrawal of water from the ground-water reservoir, for during dry years there is less recharge of the ground-water reservoir because of the decreased precipitation. At the same time the discharge of ground water is increased by greater evaporation and transpiration and by increased pumpage for irrigation. Conversely, during wet years the recharge from precipitation is increased and the loss of water by evaporation, transpiration, and pumpage is reduced.

The fluctuations of the water table in Hamilton and Kearny counties were determined by observing the water levels in wells. In September, 1939, periodic water-level measurements were begun on 39 wells located at strategic points within the area. The depth to water level in each well has been measured once a month in order to determine the fluctuations of the ground-water table. The meas-

TABLE 5.—*Observation wells in Hamilton and Kearny counties*

Hamilton county		Kearny county	
Well number in this report	Well number in Water-Supply Papers 886, 908, and 938	Well number in this report	Well number in Water-Supply Papers 886, 908, and 938
9	9	167	17
13	13	177	4
20	28	183	21
24	8	189	15
25	12	196	28
37	7	202	22
44	1	205	14
52	2	209	16
68	5	219	3
70	6	232	9
80	3	240	10
82	4	252	12
105	20	286	2
108	22	300	1
109	17	308	6
112	16	313	18
122	27	335	11
140	19	340	7
148	11	343	13
155	24	351	23
160	23	353	26

urements were made by Richard B. Christy and Woodrow W. Wilson. Since 1934, annual water-level measurements have been made in wells 252 and 278 by the Division of Water Resources of the Kansas State Board of Agriculture.

Water-level measurements made in 1939, 1940, and 1941 have been published in annual water-level reports of the U. S. Geological Survey (Water-Supply Papers 886, 908, and 938), and future measurements will be published in ensuing reports of this series. The well numbers used in this report and in Water-Supply Papers 886, 908, and 938 are given in table 5.

The water table in the Hamilton-Kearny area generally reaches its highest stage in the spring and its lowest stage in the fall. When the winters are severe and the ground is frozen, water is unable to reach the zone of saturation and the water table may decline during the winter and early spring. During the summer the great increase in evaporation, transpiration, and pumpage causes the water table to decline. The fluctuations of the water level in 15 wells in Hamilton and Kearny counties are shown in figures 11, 12, 13, and 14.

Fluctuations caused by precipitation.—Part of the precipitation in any area may percolate downward through the interstices of the soil and be added to the zone of saturation. The amount and frequency of the recharge depend in part upon the depth to the water table below the land surface and upon the condition of the soil moisture. In areas of relatively shallow water, the recharge generally is greater than in areas where the water table is relatively far below land surface. The fluctuations of the water level in well 177 (water level is about 107 feet below land surface) are slight as compared to those in well 209 in the Kearny county part of the Scott-Finney depression and to those in wells 286 and 340 in the Arkansas river valley (fig. 13). The rise in water levels in the eastern part of the Arkansas valley between 1940 and 1941 (fig. 10) was caused, at least in part, by the above-normal precipitation during that year. The water levels in some deep upland wells may fluctuate greatly, particularly those that obtain water from materials having low specific yield, such as shale. Well 108 in the western part of the Syracuse upland obtains water from such a bed in the Dakota formation. The difference between the highest and lowest recorded water levels in this well is nearly 16 feet.

The condition of the soil moisture has an important influence upon the recharge of the ground-water reservoir, and hence upon the fluctuations of the water levels in wells. After long dry periods the soil

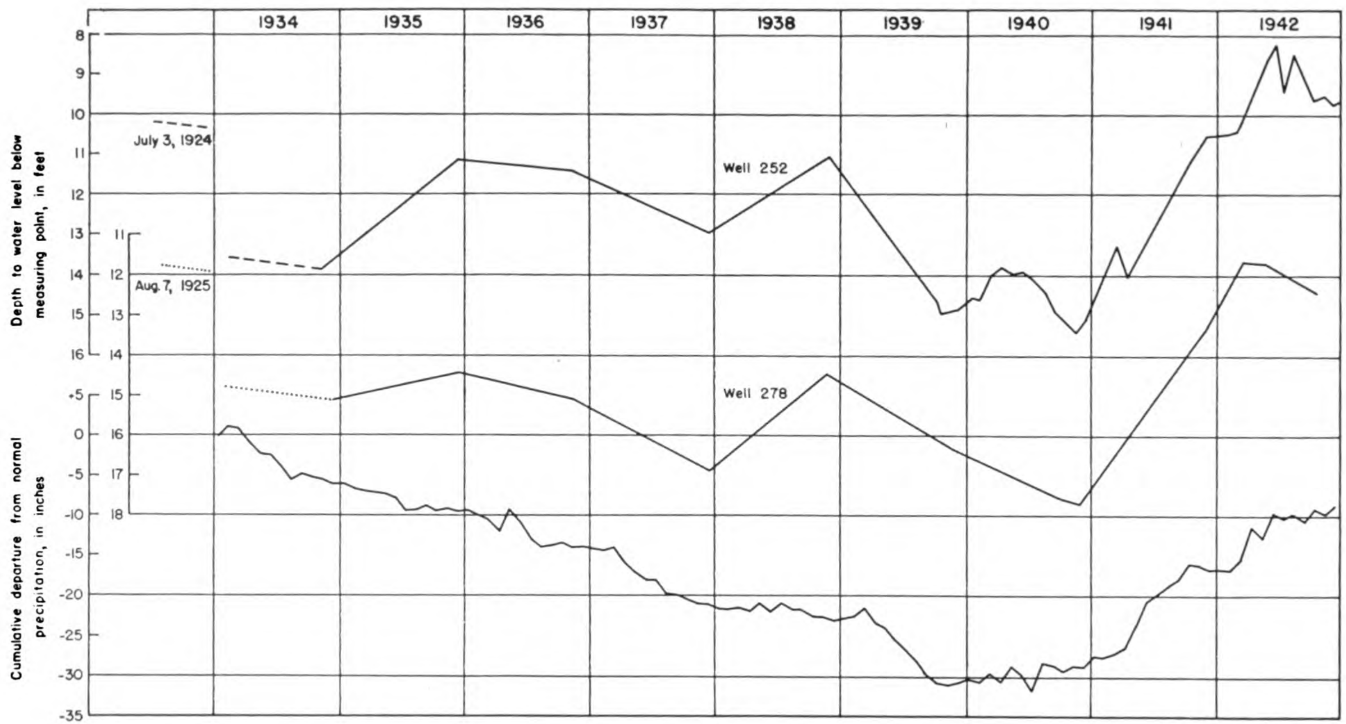

FIG. 11. Hydrographs showing the fluctuations of the water levels in two wells in the Arkansas valley in eastern Kearny county and the cumulative departure from the normal monthly precipitation at Lakin. (Precipitation data in figures 11-14 from U. S. Weather Bureau.)

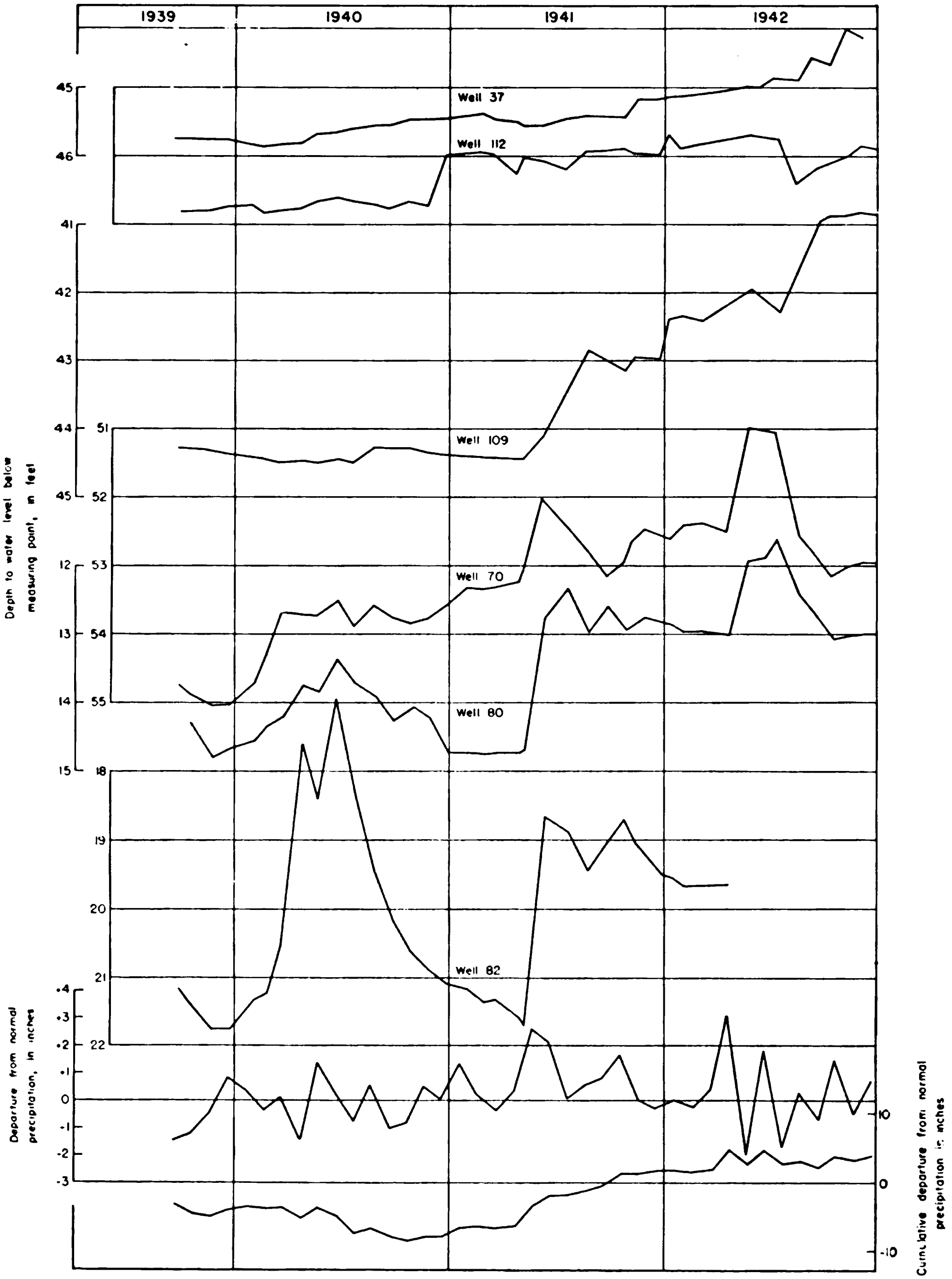

FIG. 12. Hydrographs showing the fluctuations of the water levels in six wells in Hamilton county, the departure from normal monthly precipitation at Syracuse, and the cumulative departure from normal monthly precipitation at Syracuse.

moisture may be depleted and therefore must be replenished before any appreciable amount of water can percolate downward to the water table. In areas such as the Kearny and Syracuse uplands, where the belt of soil moisture is relatively thick, several moderate rains may be necessary to replenish the soil moisture. Such rains, therefore, would have little or no effect on the water table. Pre-

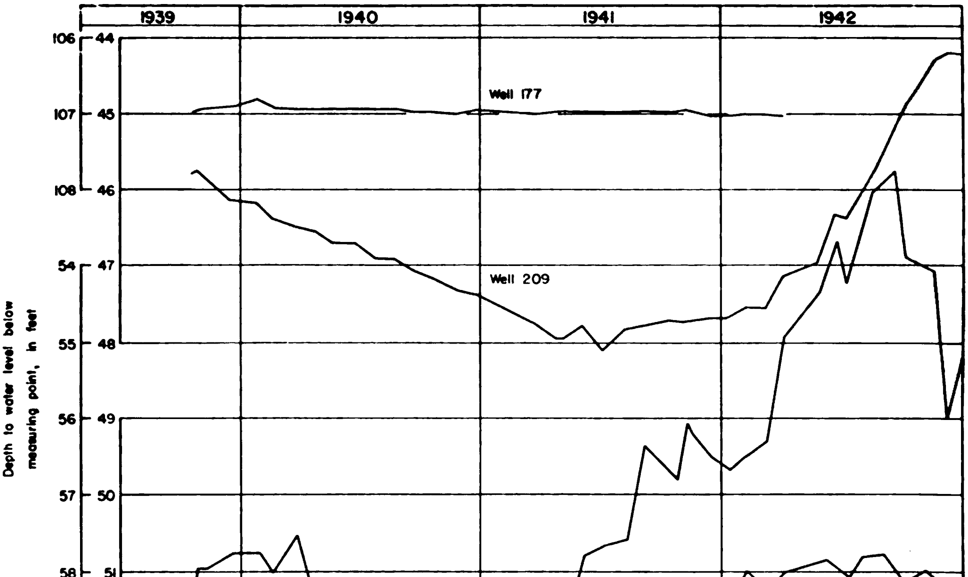

FIG. 13. Hydrographs showing the fluctuations of the water levels in four wells in Kearny county, the departure from normal monthly precipitation at Lakin, and the cumulative departure from normal monthly precipitation at Lakin.

cipitation that falls in the shallow-water areas, where the soil generally is thinner and more porous, has a greater effect on the fluctuations of the water table. In both deep-water and shallow-water areas, plants use much soil moisture and therefore diminish the effect of the precipitation on the water table.

In Hamilton and Kearny counties, the water levels declined during the years of relatively low precipitation from 1931 to 1939. The decline amounted to several feet in much of the Arkansas valley but was relatively slight in the upland areas. During 1940 and 1941, the precipitation was greatly increased and the pumpage for irrigation decreased accordingly, with the result that the water levels in the Arkansas valley rose to higher levels than any recorded since periodic

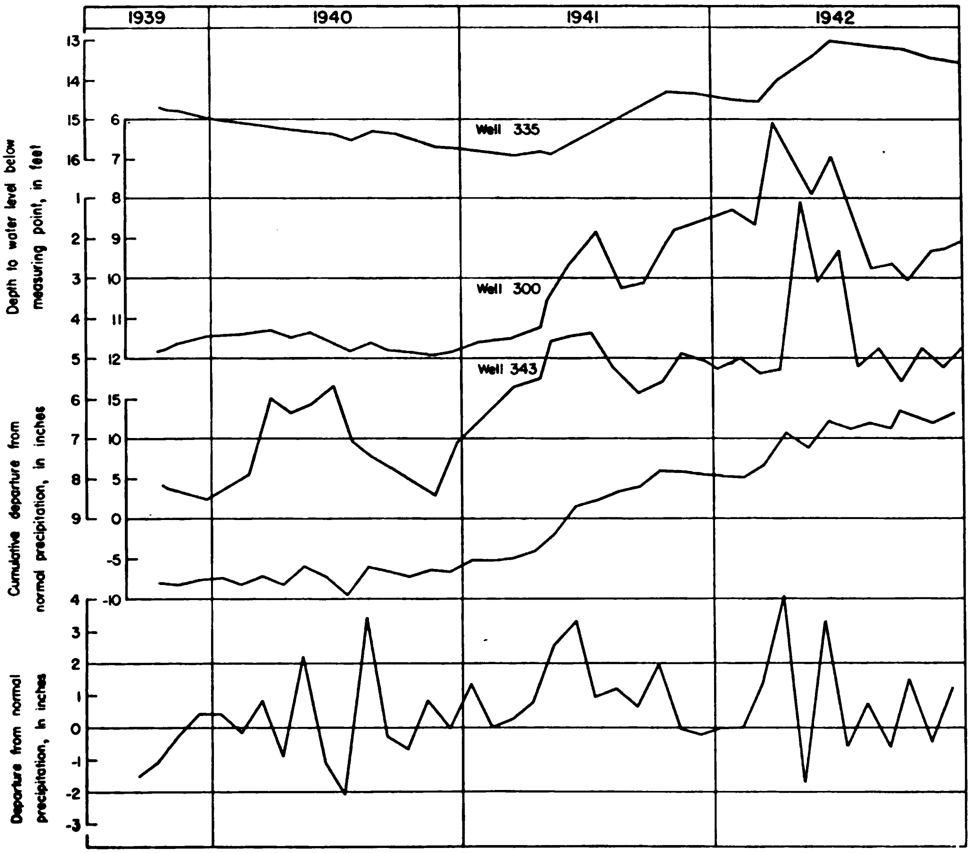

FIG. 14. Hydrographs showing the fluctuations of the water levels in three wells in the Arkansas valley in Kearny county, the departure from normal monthly precipitation at Lakin, and the cumulative departure from normal monthly precipitation at Lakin.

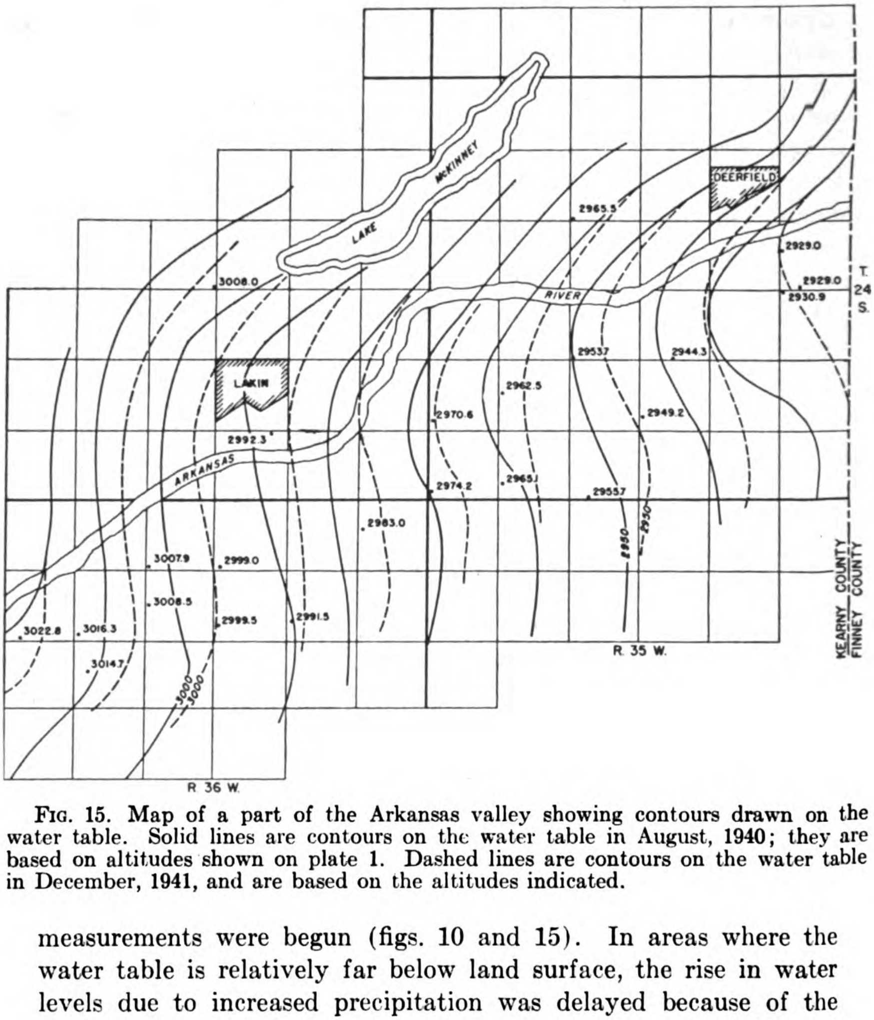

FIG. 15. Map of a part of the Arkansas valley showing contours drawn on the water table. Solid lines are contours on the water table in August, 1940; they are based on altitudes shown on plate 1. Dashed lines are contours on the water table in December, 1941, and are based on the altitudes indicated.

measurements were begun (figs. 10 and 15). In areas where the water table is relatively far below land surface, the rise in water levels due to increased precipitation was delayed because of the greater time required for the moisture to reach the water table and because of the greater thickness and lower permeability of the soil. The water level in well 209 (fig. 13) declined steadily until the summer of 1941; since that time it has risen steadily.

Fluctuations caused by transpiration.—Ground water may be discharged from the ground-water reservoir by vegetation. The water may be taken into the roots of plants from the capillary fringe, which is supplied with moisture from the zone of saturation, or directly from the zone of saturation. It is then discharged from plants by the process of transpiration. In shallow-water areas, such as the

Arkansas valley, many plants extend their roots to the zone of saturation or to the capillary fringe and, therefore, have a direct effect upon the level of the water table. The water table will rise slightly during the night but will decline during the day when the process of transpiration is most active. The plants in upland areas do not extend their roots to the ground-water reservoir, but they may absorb much of the soil moisture which must be replaced before moisture can move downward to the water table. In this manner the plants retard the recharge of the ground-water reservoir and indirectly affect the level of the water table.

Fluctuations caused by pumping.—When a well is pumped the water table in the vicinity of the well declines and takes the form of an inverted cone (called the cone of depression). When the pumping ceases the cone of depression is gradually filled by water withdrawn from adjacent areas. As a result, the regional ground-water level declines somewhat until the surface of the water table again becomes relatively smooth. Most of the wells in the Arkansas valley are pumped intermittently so that cones of depression are being formed in different parts of the valley at different times. Similarly, these cones are being filled in different parts of the valley at different times by inflow from adjacent areas. After the pumping season has ended, the regional water table tends to assume a form similar to the form it had before the pumping began. The level of the water table, however, generally is lower than it would have been had there been no pumping.

The pumping of water for irrigation in the Arkansas valley has an important effect upon the fluctuations of the water table. Generally, the water table declines during the summer even though that is the season of greatest precipitation in this area. This is due to transpiration and to pumping. As illustrated in figure 10, the water table rose in all of the heavily pumped areas in the Arkansas valley in eastern Kearny county between August, 1940, and December, 1941. The greatest rise (about 9 feet) was in the most heavily pumped area south of Deerfield. The water-level measurements of 1940 were made during the pumping season when there were many cones of depression, particularly in the vicinity of the Garden City Company's irrigation project south of Deerfield, where as much as 15,000 gallons of water a minute was withdrawn from the ground-water reservoir. The measurements of 1941 were made in December after pumping for irrigation had ceased and after the water table had risen and become relatively smooth. The sharp upstream flexure of the water table contour lines (pl. 1) in this same area indicate the magnitude of the depression of the water table caused by pumping.

Fluctuations caused by stream flow and by irrigation.—When the discharge of Arkansas river increases sufficiently, the surface of the water in the stream rises to a level above the surface of the ground-water reservoir in the area adjacent to the stream. As a result, water from the stream percolates downward and laterally into the underground reservoir until the level of the water table and the level of the water in the stream are about the same altitude. Thus when the stream flow is increased sufficiently, Arkansas river becomes a losing stream (a stream that contributes water to the zone of saturation). Conversely, when the discharge of the river decreases sufficiently, the water surface declines to a point below the level of the water table in adjacent areas and the river becomes a gaining stream (a stream that receives water from the zone of saturation). Arkansas river is unusual in that it may be a gaining stream in one part of the area and at the same time be a losing stream in another part of the area. When ground-water studies were first made in this area by Slichter in 1904 Arkansas river probably alternated frequently from a losing to a gaining stream, but in recent years the increased pumpage for irrigation has caused the river to be a losing stream most of the time in eastern Kearny county. In Hamilton county, however, where irrigation has not been developed so extensively, Arkansas river continues to fluctuate from a losing to a gaining stream. These fluctuations in the stage of the river probably affect the ground-water levels at a considerable distance south of the river where the water table is at essentially the same altitude as the water table near the river. A small rise or fall in the stage of the river, if maintained for a long time, probably would affect the water table in the northern part of the sand-hills area as well as in the valley. The longer the river maintains a high stage the farther southward will the effect upon the water table be noticeable.

The water table may also fluctuate in response to the addition of water from intermittent streams whose beds lie far above the water table at all times. Such streams are losing streams at all times because ground water cannot percolate into them. Bear creek lies above the water table and is an example of this type of stream. Water in Bear creek is prevented by dune sand from reaching Arkansas river, and it must percolate downward or be dissipated by evaporation, or both. As a result, the water table has been built up in the shape of a large mound beneath the stream bed in south central Kearny county. Latta (1941, p. 40) described a similar mound on the water table beneath Bear creek in Stanton county.

The irrigation of land by surface water diverted from Arkansas river and by ground water pumped from wells may also affect the level of the water table. Because of the relatively high porosity of the sandy soil in the Arkansas valley, part of the water that is spread over the land probably percolates relatively rapidly to the zone of saturation. This is especially important in the Arkansas valley in Hamilton county where the soil is very sandy and where the water table is near the ground surface. The ditches that carry this water may also contribute water to the zone of saturation in a manner similar to Bear creek.

Ground-water Recharge

Recharge is the addition of water to the ground-water reservoir and may be derived by precipitation in the area, by seepage of water from streams, by seepage of irrigation water, and by underflow.

RECHARGE FROM UNDERFLOW

As shown by the water-table contour map (pl. 1), ground water in the Hamilton-Kearny area moves east-southeastward. As a result, water percolates into some of the Tertiary and Quaternary deposits of this area from Prowers county, Colorado, and from Greeley and Wichita counties, Kansas. Most of the water in these formations moves from Prowers county, Colorado, into Hamilton county and thence eastward and northward.

Within the Hamilton-Kearny area, some of the water-bearing formations are recharged by leakage of water from the Dakota formation. Water rises from the Dakota formation into the overlying alluvium in the vicinity of Hartland. Along the southern margin of the Syracuse upland, faulting has brought the Dakota formation into contact with the sands and gravels of Pleistocene age and water can move from the Dakota formation into Pleistocene beds. Generally, water is encountered at the top of the Dakota formation, but near the fault most wells encounter water between 20 and 30 feet below the top of the Dakota. This indicates that much of the water has been drained out of the formation into the Pleistocene beds.

In the vicinity of Kendall, however, a different condition may exist. Well 70 (fig. 12), which obtains its water from the Dakota formation, appears to fluctuate in response to the precipitation, thus suggesting that water from the alluvium may move into the Dakota formation in this locality. Otherwise, the water level in this well probably would not fluctuate so closely with the precipitation.

RECHARGE FROM STREAMS AND IRRIGATION WATER

At one time Arkansas river probably was a gaining stream throughout all of Hamilton and Kearny counties. This is indicated by the fact that many of the early irrigation plants in this area pumped water directly from the river. In recent years, however, Arkansas river often is dry in eastern Kearny county and during the summer it occasionally becomes dry in Hamilton county. Arkansas river often is dry between Hartland and Garden City, particularly during the summer. This has probably been caused by the heavy pumping of water for irrigation, which has lowered the water table and has caused the river to become a losing stream. In Hamilton county, where the water table usually is above the stream bed, ground water discharges into the stream channel. When this flow of water reaches a dry section of the stream it returns to the ground-water reservoir.

Table 6 shows the magnitude of the loss in stream flow between Syracuse and Garden City. Between October 1, 1922, and September 30, 1942, the average yearly net loss of water between Syracuse and Garden City was about 31,600 acre-feet. Most of this water was lost between Hartland and Garden City where the Arkansas usually is a losing stream. If the loss were uniformly distributed between Hartland and Garden City, about 19,000 acre-feet was lost in eastern Kearny county. Some of the loss was caused by evaporation and transpiration, but much of the water probably reached the zone of saturation.

Another contributor of water to the zone of saturation in the Hamilton-Kearny area is the lower part of Bear creek. The channel of Bear creek has been choked by the encroachment of dune sand and water cannot flow northward into Arkansas river.

The addition of water from Bear creek to the ground-water reservoir in south central Kearny county has caused the formation of a prominent mound on the water table (pl. 1). The altitude of the water level in well 354 is about 15 feet greater than the altitude of the water level in well 352, which is 2.7 miles north of well 354, and it is about 24 feet greater than the altitude of the water level in well 353, which is 2 miles northeast of well 354. Farther north, beyond the reach of most of the flood waters of Bear creek, the recharge has

TABLE 6.—*Annual discharge of Arkansas river at Syracuse and Garden City, diversion of water by canals, and loss or gain of stream flow between Syracuse and Garden City, for the 20-year period from Oct. 1, 1922, to Sept. 30, 1942*[1]

Water year (October 1 through September 30)	Annual discharge at Syracuse (acre-feet)	Annual discharge at Garden City (acre-feet)	Loss (—) or gain (+) between Syracuse and Garden City			
			Total (acre-feet)	Diversion into canals[2] (acre-feet)	Net loss or gain exclusive of diversion	
					Acre-feet	Percentage of discharge at Syracuse
1922–1923....	594,000	484,000	—110,000	— 88,761	— 21,329	3.6
1923–1924....	533,000	562,581	+ 29,581	— 48,537	+ 78,118	14.7
1924–1925....	252,000	113,000	—139,000	— 65,327	— 73,673	29.2
1925–1926....	106,000	15,600	— 90,400	— 58,867	— 31,533	29.7
1926–1927....	356,000	204,000	—152,000	— 88,040	— 63,960	18.0
1927–1928....	310,000	236,000	— 74,000	— 50,280	— 23,720	7.7
1928–1929....	232,000	133,000	— 99,000	—105,830	+ 6,830	2.9
1929–1930....	152,000	42,600	—109,400	— 84,670	— 24,730	16.3
1930–1931....	219,000	120,000	— 99,000	— 60,650	— 38,350	17.5
1931–1932....	64,100	11,700	— 52,400	— 42,190	— 10,210	15.9
1932–1933....	161,000	50,000	—111,000	— 86,360	— 24,640	15.3
1933–1934....	68,900	11,960	— 56,940	— 42,140	— 14,800	21.5
1934–1935....	221,600	81,720	—139,880	— 79,840	— 60,040	27.1
1935–1936....	323,800	199,400	—124,400	— 93,370	— 31,030	9.6
1936–1937....	117,500	37,290	— 80,210	— 67,180	— 13,030	11.1
1937–1938....	199,200	32,940	—166,260	—124,060	— 42,200	21.1
1938–1939....	80,800	21,550	— 59,250	— 58,590	— 660	0.8
1939–1940....	24,880	1,340	— 23,540	— 14,622	— 8,918	36.3
1940–1941....	234,500	93,925	—140,575	—109,990	— 30,585	13.0
1941–1942....	1,411,610	1,223,380	—188,240	—110,321	— 77,909	5.5

1. From records of the Division of Water Resources, Kansas State Board of Agriculture.
2. Includes Amazon, South Side, Great Eastern, Farmer's, and Garden City canals.

had less apparent effect upon the shape of the water table. The recharge here has produced a broad flattening of an otherwise uniform dip (pl. 1).

When water is diverted from Arkansas river into irrigation canals, a part of the water is lost by downward percolation. This is not a complete loss, however, because much of the water reaches the zone of saturation and increases the quantity of water available to wells. Similarly, water from irrigation wells may be lost when it is being transported in ditches and after it has been spread over the fields, but part of this water returns to the ground-water reservoir.

RECHARGE FROM PRECIPITATION

Although the average annual precipitation in this area is about 17 inches, only a small part reaches the zone of saturation. Of the total precipitation, part is lost by evaporation and transpiration, part leaves the area as runoff, and the remainder may percolate downward to the zone of saturation.

The quantity lost by evaporation depends upon precipitation, temperature, humidity, amount of vegetative covering, depth to the water table below the land surface, and length of time the processes of evaporation have access to the moisture.

In Hamilton and Kearny counties much of the precipitation occurs from May through August when the climate is characterized by high temperatures and low humidity and plant growth is relatively abundant. Much of the precipitation in this area, therefore, is lost by evaporation. In a large part of the Kearny and Syracuse upland areas where sink holes and other depressions are fairly abundant, rain and snow water may stand for many days, during which much evaporation takes place.

Some of the precipitation is also lost by runoff, but the amount generally is small except after very heavy rains. According to records of the Division of Water Resources of the Kansas State Board of Agriculture, the average annual net runoff in Arkansas river drainage area above Garden City for the period October 1, 1928, to September 30, 1939, was only 0.09 inch (excluding water diverted by irrigation canals west of Garden City). The maximum annual runoff during that period occurred between October 1, 1928, and September 30, 1929, and was 0.56 inch. The average annual runoff is less than one percent of the average annual precipitation. In the sand-hills area and on the upland, the runoff is reduced materially because of many undrained basins which catch and retain water after each rain. The water stands in the basins until it evaporates or moves downward toward the water table. Vegetation also retards the runoff, particularly during the growing season. During other seasons, however, the vegetation has little effect upon the runoff. Modern methods of terracing and contouring of farm land tend to reduce the runoff and, therefore, may increase the rate of recharge to the soil and to the ground-water reservoir.

The water that is not lost by evaporation and runoff percolates downward into the soil zone. The soil will absorb moisture until the amount of water it contains is greater than can be held against the pull of gravity, and not until that time will water move downward to the zone of saturation. This downward movement may be prevented by plant transpiration which, during the growing season, may deplete the soil moisture as rapidly as it can be replenished by precipitation. At the end of the growing season the moisture in the soil may be depleted. Water that enters the soil zone during the fall and winter tends to replenish the soil moisture because there is less transpiration and evaporation during these seasons. From this time until transpiration and evaporation again become important factors, much of the precipitation moves downward through the soil and to the water table. Because of the high rate of transpiration and evaporation, there is probably little recharge during the summer except where the water table is relatively close to the land surface.

Sand-hills area.—Recharge of the ground-water reservoir in the sand-hills area south of Arkansas river is derived largely from precipitation. Because of the high porosity of the dune sand and the presence of many undrained basins that serve as catchment areas for the rainfall, much water percolates downward to the zone of saturation. Most of the precipitation in this area is held in the basins until it percolates downward and/or evaporates. Very little water is lost by runoff. The Arkansas valley probably derives part of its ground water by lateral movement from adjacent areas. Much of this probably is derived from the sand-hills area to the south. The huge area of sand hills that extend from Prowers county, Colorado, to Ford county, Kansas, serves as the principal recharge area for the ground-water reservoir in much of southwestern Kansas.

Upland areas.—The recharge of the ground-water reservoir in the upland areas probably is relatively small as compared to the recharge in the Arkansas valley and in the sand-hills area. Much of the upland in Hamilton and Kearny counties is covered by fairly thick deposits of wind-blown loess. Soils that develop from loess are heavy and dark and consist of topsoils of loams, clay loams, and silty clay loams and heavy clay subsoils that in places are very calcareous. The loess soils have a moderately high porosity and hold moisture well, but because of their low permeability they absorb moisture very slowly.

One of the most important factors affecting the recharge of the upland areas by precipitation is the sink-hole topography. These broad, shallow depressions are abundant in the Hamilton-Kearny area, particularly in the Kearny upland and along the fault at the southern margin of the Syracuse upland (pl. 16A). After heavy rains the depressions are filled with water which may remain for several weeks until it evaporates and/or percolates downward. Although the soil has a fairly low permeability, the water has access to the soil for such a long period of time that a considerable amount of water probably reaches the zone of saturation.

As shown on plate 1, an intermittent stream extends southeastward from northeastern Hamilton county across northern Kearny county and terminates in a broad shallow depression. In the vicinity of the depression there is an abrupt flattening of an otherwise relatively steep slope of the water table. This may be due in part to the slope of the underlying Cretaceous bedrock floor, but it probably is caused mainly by recharge of water from the depression. More convincing evidence of this type of recharge was described by Latta (1943). In eastern Gray county, about 2 miles north of Arkansas river, a small mound has been formed on the water table by recharge from water in a broad depression. The depth to the water table at this point is more than 100 feet. In north central Box Butte county,

TABLE 7.—*Cumulative rise in water level in upland wells in Hamilton and Kearny counties*

Well No.	Cumulative rise in water level, in feet		
	October, 1939 to October, 1940	October, 1940 to October, 1941	October, 1941 to October, 1942
9	0.69	0.19[1]	0.33[1]
13	.34	.82[1]	....
20	.80	....	....
24	.93	1.17	.47
25	.34[1]	....	....
37	.38	.24	.89
167	1.04	.03	....
177	.20	....	....
189	1.06	.65[1]	....
196	.18	2.56[1]	.13
202	.27	.77[1]	....
205	.87	.72	....
209	.03	.55[1]	3.05
219	3.10	.73	2.86
232	.03	....	....
286	2.45	2.86	5.22
308	.91	.94	.88
313	.38	....	....
351	.43	1.04[1]	.97
353	.01	.69[1]	.66
357	.54	1.51	1.45

1. Record incomplete for the year.

Nebraska, Cady (1940, p. 573) found that the recharge ranged in amount from 0.75 inch to slightly more than an inch in an area where the water table is 100 to 250 feet below the surface.

Further evidence of recharge of the ground-water reservoir in upland areas is indicated by the fluctuations of the water table. The fact that the water level in some deep wells fluctuates only slightly does not necessarily mean that there is no recharge, for the water level will rise only when the rate of recharge exceeds the rate of ground-water discharge. It is more probable that the recharge in such areas is more or less continuous and is about equal to the natural discharge. Although the annual net rise in water levels in the deep wells in the upland area of Hamilton and Kearny counties is fairly small, the cumulative rise is relatively large. In table 7 are listed the cumulative rises of water levels in wells on upland areas in Hamilton and Kearny counties determined by adding the rises of water levels based on monthly water-level measurements. The average annual cumulative rise in water level in these wells is about 1 foot, but the amount of cumulative rise varies from year to year, depending primarily upon the precipitation.

Most of the water in the ground-water reservoir in the eastern half of the Kearny upland probably is derived from precipitation on the Kearny upland. Because the relatively impermeable Cretaceous beds lie above the water table in the western half of the Kearny upland area (fig. 7), it would seem that very little water moves eastward into northern Kearny county. Some water may move through this Cretaceous bedrock barrier, but the amount probably is negligible.

A few wells in northern Hamilton county encounter water just above the Cretaceous bedrock, whereas other wells in that area generally fail to find water at that horizon. This may imply that some water moves eastward down the slope of the bedrock surface along pre-Tertiary and Quaternary drainage channels. This water probably is derived from precipitation on the western half of the Kearny upland.

Arkansas valley area.—Recharge from precipitation in the Arkansas valley is relatively large because the water table is near the surface and because the soil is fairly pervious. During successive years of below-normal precipitation, the water table in the Arkansas valley in Hamilton and Kearny counties usually declines. This is caused not only by the decreased precipitation but also by increased pumping for irrigation. The water table returns to or nearly to its previous high level, however, after a few years of above-normal precipitation. The relations of the water-level fluctuations to the precipitation are shown in figures 11, 12, 13 and 14.

Although some valley wells show a net decline in water level during some years, the cumulative rise in water level generally is large. The cumulative rises in water level in a few wells in the Arkansas valley are listed in table 8. The average annual cumulative rise in water levels in these wells is more than 2 feet, but the average rise varies considerably with the precipitation.

Another indication that there must be considerable recharge of the ground-water reservoir in the Arkansas valley as a result of precipitation is the small underflow in the narrow part of the valley about 2 miles west of Hartland. Here the river has cut its valley

TABLE 8.—*Cumulative rise in water level in wells in the Arkansas valley and adjacent shallow-water areas in Hamilton and Kearny counties*

Well No	Cumulative rise in water level, in feet.		
	October, 1939 to October, 1940	October, 1940 to October, 1941	October, 1941 to October, 1942
44	1.27[1]	1.68[1]	0.88[1]
52	.51[1]	1.46[1]	1.76[1]
68	3.17	....	....
70	1.90	1.95	2.18
80	1.71	2.76	1.57
82	5.59	3.80	....
105	.96	....	....
109	.25	1.58	2.68
240	1.62[1]	....	....
252	1.28[1]	4.83[1]	3.65
300	.70	4.12	4.40
335	.20	1.62[1]	1.48
340	.99	3.09	2.35
343	3.19	4.37	6.35[2]

1. Record incomplete for the year.
2. Water level affected by flood in Arkansas river in April and May, 1942.

into relatively impermeable Cretaceous rocks, including the Graneros shale and a dense quartzitic sandstone in the Dakota formation. The alluvium at this point is only 2,250 feet wide and has an average thickness of about 33 feet. Slichter (1906, p. 24) calculated the underflow at this point by the ground-water velocity method and found it to be about 2,100 acre-feet a year. He stated that the above figure "represents the maximum that can be claimed in a high estimate." The results of pumping tests made on three wells in the Arkansas valley in Hamilton and Kearny counties (table 4, wells 91, 92, and 268) indicate that the underflow is considerably less than 2,100 acre-feet a year, and probably is only about 1,000 acre-feet a year. An underflow of 1,000 acre-feet of water a year would be equivalent to less than 700 gallons a minute and would be inadequate to supply either the nearly 20,000 acre-feet of water that is withdrawn annually for irrigation in the Arkansas valley in eastern Kearny county or the large quantity of water that is transpired by plants. If it is assumed that most of the loss in the flow of Arkansas river between Syracuse and Garden City takes place east of Hartland, then Arkansas river would contribute about 19,000 acre-feet of water a year to the ground-water reservoir in eastern Kearny county. If this assumption is incorrect, then the river probably would contribute less than 19,000 acre-feet of water a year to the ground-water reservoir. The remainder of the water pumped for irrigation (about 1,000 acre-feet a year) and transpired by plants probably is derived chiefly from precipitation.

Precipitation upon the upland areas near the Arkansas valley may also contribute water to the ground-water reservoir in the Arkansas valley. After excessively heavy rains on the upland some water may run off into the valley and then percolate downward to the zone of saturation. This is particularly true in Hamilton county where there are many intermittent streams on the Kearny upland that flow southward to the Arkansas valley.

RECHARGE OF THE ARTESIAN AQUIFERS

As discussed in the section on recharge from underflow, the water in the Cheyenne and Dakota formations moves into Hamilton county from the west. The water enters the formations from precipitation on the areas where they crop out and moves eastward and northeastward into Kansas. These formations are exposed in a large part of southeastern Colorado, particularly in Prowers, Bent, Otero, Baca, and Las Animas counties.

DISCHARGE OF SUBSURFACE WATER

The discharge of subsurface water has been divided by Meinzer (1923a, pp. 48-56) into vadose-water discharge (discharge of soil water not derived from the zone of saturation) and ground-water discharge (discharge of water from the zone of saturation).

VADOSE-WATER DISCHARGE

The discharge of soil water not derived from the zone of saturation is called vadose-water discharge and includes the discharge of water directly from the soil by evaporation and through growing plants and crops by transpiration. The consumption of soil water by crops is large and is of vital importance to agriculture. This consumption of soil water generally reduces the recharge, for the deficiency of soil moisture must first be replenished before recharge can take place.

GROUND-WATER DISCHARGE

Ground-water discharge is the discharge of water directly from the zone of saturation or from the capillary fringe, and may take place through evaporation and transpiration or as hydraulic discharge through springs, seeps, wells, or infiltration galleries.

Discharge by transpiration and evaporation.—Water may be taken into the roots of plants directly from the zone of saturation or from the capillary fringe, and discharged from the plants by the process known as transpiration. The depth from which plants will lift the ground water varies with different plant species and different types of soil. The limit of lift by ordinary grasses and field crops is not more than a few feet; however, alfalfa and certain types of desert plants have been known to send their roots to depths of 60 feet or more to reach the water table (Meinzer, 1923, p. 82).

In Hamilton and Kearny counties, any significant discharge of water by evaporation and transpiration is limited to the shallow-water areas in the Arkansas valley, the Scott-Finney basin, and the Bear Creek depression. Although the water level is less than 50 feet below land surface in part of the sand-hills area, very little ground water is lost by transpiration because the sandy soil supports a type of vegetation that cannot send its roots downward more than a few feet. A very large quantity of water is lost by transpiration in the Arkansas valley shallow-water area because trees, alfalfa, and many other plants extend their roots to the water table and take water directly from the zone of saturation. In some parts of the valley, particularly in old abandoned channels of Arkansas river, the water table is sufficiently close to the land surface to support a marshy vegetation. Evaporation of water directly from the zone of saturation is confined primarily to the channel of Arkansas river and the adjacent lowlands or "first bottom," to some abandoned channels of the river, and to Clear lake.

The water table is somewhat deeper in the Scott-Finney shallow-water area where alfalfa and trees probably are the only plants that extend their roots to the water table. In the northern part of this area the water table is too deep to be reached by plants, and little or no ground water is lost by direct evaporation; only the soil moisture is lost.

Some ground water is lost by transpiration in the Bear Creek depression, but because of the small size of the area and the scarcity of plants that have long roots, the quantity is probably small. Some water was lost by evaporation from the "natural well" but the present loss by evaporation is neglible.

Discharge by springs and seeps.—Some ground water in this area is discharged through seeps and springs, although the amount is small. There are a few springs and seeps along Bridge creek and other tributaries to Arkansas river in western Hamilton county. Arkansas river is in part a gaining stream (a stream that stands lower than the water table) and receives much of its base flow by the seepage of ground water into the river channel. Before heavy pumpage for irrigation was begun, there was enough inflow of ground water to keep the river flowing most of the year in its entire course through Hamilton and Kearny counties. At the present time, however, the pumpage is sufficient to lower the water table so that in eastern Kearny county it lies below the bed of the river. South of Arkansas river between Hartland and Kendall the Dakota formation is at or near the surface, and the overlying Graneros shale has been removed so that water from a sandstone in the Dakota formation rises upward into the alluvium. The artesian pressure of the water from the Dakota formation causes water to rise to the surface through an artesian spring in sec. 11, T. 25 S., R. 38 W. Some of the water that rises from the Dakota formation into the alluvium moves laterally into the river channel and some may rise directly from the Dakota formation into the channel.

Discharge by wells.—Another method of discharge of water from the ground-water reservoir is the discharge of water from wells. In 1939, approximately 24,000 acre-feet of water was pumped from irrigation, railroad, and public-supply wells in Hamilton and Kearny counties and, in addition, nearly 150 acre-feet of water was discharged by flowing artesian wells in the vicinity of Coolidge. Most of the rural residents of the area derive their domestic and stock supplies of water from wells, but the amount of water discharged for this purpose is relatively small. The recovery of ground water from wells is discussed in the next section.

Recovery

PRINCIPLES OF RECOVERY

The discharge from a well is produced by a pump or some other lifting device or by artesian head (for a more detailed discussion of principles of recovery see Meinzer, 1923a, pp. 60-68). When water is standing in a well, there is equilibrium between the head of the water inside the well and the head of the water outside the well. Whenever the head inside a well is reduced, a resultant differential head is established and water moves into the well. The head of the water inside a well may be reduced in two ways: (1) by lowering the water level by a pump or other lifting device, and (2) by reducing the head at the mouth of a well that discharges by artesian pressure. Whenever water is removed from a well there is a resulting draw-down or lowering of the water level, or, in a flowing artesian well, an equivalent reduction in artesian head.

When water is being discharged from a well, the water table is lowered in an area around the well to form a depression somewhat resembling an inverted cone. This depression of the water table is known as the cone of depression, and the distance that the water level is lowered is called the draw-down. In any well, the greater the pumping rate the greater will be the draw-down.

The capacity of a well is the rate at which it will yield water after the water stored in the well has been removed. The capacity depends upon the quantity of water available, the thickness and permeability of the water-bearing bed, and the construction and condition of the well. The capacity of a well is generally expressed in gallons a minute. The known or tested capacity of a strong well is generally less than its total capacity, but some weak wells are pumped at their total capacity.

The specific capacity of a well is its rate of yield per unit of draw-down and is determined by dividing the tested capacity in gallons a minute by the draw-down in feet. Well 91 in the Arkansas valley west of Syracuse yields 528 gallons a minute with a draw-down of 11.5 feet. The specific capacity of that well, therefore, is 47.6 gallons a minute per foot of draw-down, or simply 47.6.

When water is withdrawn from a well, the water level drops rapidly at first and then more slowly until it finally becomes nearly stationary. Conversely, when the withdrawal ceases, the water level rises rapidly at first and then more slowly until it eventually resumes its original position, or approximately its original position (fig. 9).

DUG WELLS

Dug wells are excavated with picks, shovels, spades, or by power machinery. They generally are between 2 and 10 feet in diameter and are quite shallow. Many of the earlier wells in the Hamilton-Kearny area were dug by hand, but most of these have since been replaced by drilled wells. At present there are still a few dug wells in the alluvium of the Arkansas valley and of some of its tributary streams, in the Kearny-county part of the Scott-Finney basin, and in the Upper Cretaceous rocks in western Hamilton county. They range in depth from about 15 to 100 feet. Many of the irrigation wells in the Arkansas valley are dug to the water table and then drilled the rest of the way.

The dug wells in Hamilton and Kearny counties are curbed with stone, timber, or barrels. They generally are poorly sealed and may be contaminated by the entrance of surface waters. Because of the difficulties of digging by hand below the water table, dug wells generally are excavated only a few feet below the water table and are, therefore, more likely to fail during a drought than are drilled wells, which generally extend many feet below the water table.

BORED WELLS

Bored wells are made by augers or post-hole diggers in unconsolidated sediments. Many wells in the alluvium in the Arkansas valley and in the northern part of the sand-hills area were made in this way.

DRIVEN WELLS

Some wells in the Arkansas valley are made by driving a 1¼- to 1½-inch pipe (equipped at the bottom with a screened drive point) down below the water table. Such wells can be put down only where the water-bearing material is sufficiently permeable to permit water to flow freely into the pipe, where the material is unconsolidated enough to permit a pipe being driven, and where the depth to water level is not more than about 20 feet below land surface. Most of these wells are equipped with pitcher pumps and are used for domestic and stock purposes. Driven wells also are likely to fail during dry seasons because they generally do not extend far below the water table.

DRILLED WELLS

A drilled well is one that is excavated by means of a percussion or rotary drill. Most of the domestic, stock, irrigation, and public-supply wells in Hamilton and Kearny counties are drilled wells.

Most of them were drilled by means of portable cable-tool drilling rigs and were cased with galvanized-iron or wrought-iron casing. The drilled domestic and stock wells generally are 4 to 6 inches in diameter and those used for irrigation and public-supply purposes generally are 15 to 20 inches in diameter.

Drilled wells in consolidated deposits.—Most of the wells in northwestern Hamilton county, in the Syracuse upland area, and along the north side of Arkansas river valley between Coolidge and Hartland, as well as the artesian wells near Coolidge, are drilled into consolidated deposits, generally after passing through unconsolidated deposits of Tertiary and Quaternary age. North of Arkansas river the wells penetrate chalk, limestone, and shale of Upper Cretaceous age and end in the Dakota formation or the Codell sandstone member of the Carlile shale. In the vicinity of Coolidge the flowing wells end in the Cheyenne sandstone or the Dakota formation after passing through the alluvium and the Graneros shale. Wells in the Syracuse upland area end in a sandstone in the Dakota formation after penetrating younger unconsolidated material.

Wells that obtain water from the consolidated rocks generally are cased through the overlying unconsolidated material and several feet into the bedrock. The water may enter the well along the entire uncased part of the hole whereever the rock is water bearing. In the vicinity of Coolidge, the sandstones of the Dakota formation are cased off in some wells so that water from the Cheyenne sandstone, which is of somewhat better quality, will rise to the surface. If the well is cased its entire depth, several reductions in the diameter of the casing may be necessary.

Drilled wells in unconsolidated deposits.—Almost all of the wells in Kearny county and many wells in Hamilton county obtain water from unconsolidated deposits. The principal unconsolidated water-bearing deposits are the Tertiary Ogallala formation, the undifferentiated Pleistocene sands and gravels, and the alluvium of the Arkansas valley. Wells in these deposits generally are cased nearly to the bottom of the hole with galvanized-iron or wrought-iron casing. In some wells the water may enter only through the open end of the casing, but in many wells—particularly those used for irrigation—the casing is perforated below the water table to provide greater intake facilities. The size of the perforations is an important factor in the construction of a well and the capacity or even the life of the well may be determined by it. If the perforations are too large the fine material may filter through and fill in the well, and if the perforations are too small they may become clogged so that water is prevented from entering the well freely.

Some wells in unconsolidated sediments are equipped with well screens or strainers. It is common practice to select a slot size that will pass 30 to 60 percent of the water-bearing material, depending upon the texture and degree of assortment. Retention of the coarser particles around the screen forms a natural gravel packing that greatly increases the effective diameter of the well, and hence increases its capacity.

Gravel-wall wells generally are effective for obtaining large supplies of water from relatively fine-grained unconsolidated deposits, and are widely used for irrigation. In constructing a well of this type, a hole of large diameter, 30 to 60 inches, is first drilled by the rotary method or by means of an orange-peel bucket and is temporarily cased with unperforated pipe. A well screen or perforated casing of smaller diameter than the hole is then lowered into place and centered in the larger pipe opposite the water-bearing beds. Unperforated casing extends from the screen to the surface. The annular space between the inner and outer casings is then filled with sorted gravel, preferably of a grain size just a little larger than the openings in the screen or perforated casing, and also slightly larger than that of the water-bearing material. In most wells of this type a medium- or coarse-grained gravel is used, but in very fine-grained deposits a fine-grained gravel or coarse-grained sand should be used. The outer casing is then withdrawn part way to uncover the screen and allow the gravel packing to come in contact with the water-bearing material.

In deciding whether or not to use gravel-wall construction it is important to know the character of the water-bearing material. If the material is a coarse gravel (as it is in parts of Hamilton and Kearny counties), it generally is unnecessary to construct a gravel-wall well. Some wells have been walled with a gravel packing that is finer and less permeable than the water-bearing material it replaced, thus reducing the yield.

According to McCall and Davison (1939, p. 29) draw-down can be kept to a minimum in several ways:

First, the well should be put down through all valuable water-bearing material. Secondly, the casing should be properly perforated so as to admit water to the well as rapidly as the surrounding gravel will yield the water. Third, the well should be completely developed so that the water will flow freely into the well. . . . Increasing the depth of a well will have a greater effect on reducing the draw-down than will increasing the diameter, so long as additional water-bearing formations are encountered.

A report (Davison, 1939) containing descriptions of different types of pumping plants, the conditions for which each is best suited, construction methods, and a discussion of construction costs is available from the Division of Water Resources, Kansas State Board of Agriculture, Topeka, Kansas, and the reader is referred to this publication for additional details of well construction.

METHODS OF LIFT AND TYPES OF PUMPS

Most wells in Hamilton and Kearny counties, particularly those used for domestic and stock supplies, are equipped with lift or force pumps. The cylinders or working barrels in lift pumps and force pumps are similar and are placed at a level below that of the water table; a lift pump generally discharges water only at the pump head, whereas a force pump can force water above this point—for example, to an elevated tank. Most of the pumps are operated by windmills, but a few are hand operated. A few wells in the vicinity of Coolidge flow at the surface (p. 46) and therefore do not have to be pumped.

The discharge pipe in drilled wells (1.5 inches to 3 inches in diameter) generally is clamped between two 4- by 4-inch wooden blocks that rest on the top of the casing. On some wells a circular piece of galvanized iron or steel is placed between the clamp and the casing to prevent small objects from falling into the well. In wells equipped with galvanized-iron casing, the clamp may be supported by railroad ties in order to avoid crushing the casing. Many of the irrigation wells in the the Arkansas valley are equipped with centrifugal pumps that are installed in a pit, and can be used only where the depth to water level when pumping does not exceed the working suction limit. A few of the deeper irrigation wells in the valley and all of the irrigation wells in the Kearny county part of the Scott-Finney basin are equipped with deep-well turbine pumps. A turbine pump consists of a series of connected turbines, called bowls or stages, that are placed near or just below the water level and are connected by a vertical shaft to an electric motor or a pulley at the top. If there is a pulley at the top it is connected, usually by a belt, to an electric motor or a gasoline or natural-gas engine. Some turbine pumps have gear heads for direct connection to the source of power.

Utilization of Water

About 80 percent of the wells in Hamilton and Kearny counties supply or have supplied water for domestic and stock use. Most of the water pumped from wells in this area is used for irrigation, although less than 20 percent of the wells are used for this purpose. A few wells are used for public-water supplies and for railroads.

DOMESTIC AND STOCK SUPPLIES

Domestic wells supply water in homes for drinking, cooking, and washing, and in schools other than those supplied by municipal wells. Stock wells supply water for livestock, principally cattle. Supplies of water for domestic and stock use are obtained almost entirely from drilled wells. The water is moderately hard, but generally is satisfactory for domestic and stock use. Much of the water from wells in the Arkansas valley contains a large amount of sulphate, but most of it can be used for domestic and stock purposes. Much of the ground water in the Syracuse upland area contains sufficient fluoride to be injurious to children's teeth during the period of their formation (see Quality of water).

PUBLIC WATER SUPPLIES

Syracuse and Lakin are the only cities in the two counties that have public water supplies and they are supplied from wells.

The water supply for Syracuse is obtained from a well (100) belonging to the Atchison, Topeka and Santa Fe Railway Company. It is located at the north edge of the sand-hills area in the north half of sec. 7, T. 24 S., R. 40 W. The early supplies of water for the city were obtained from wells that penetrated the Dakota formation, but the water was relatively hard and was high in fluoride content. The present supply from the sand-hills area is much softer and has a low fluoride content. The well is 83 feet deep, and the water level is about 15 feet below the land surface. The well has a 22-inch galvanized-iron casing and is equipped with a 5-inch horizontal centrifugal pump operated by a 25-horsepower electric motor. The yield is reported to be about 500 gallons a minute. The well penetrated a few feet of dune sand and then entered the terrace gravels (log 37). The Graneros shale was encountered at a depth of 63 feet, and the casing was perforated from 21.8 feet to 62.3 feet. The well pump delivers the water directly into the mains; the excess water is stored in a standpipe and elevated steel tank holding an aggregate of 315,000 gallons. The total capacity of the well is about 720,000 gallons a day, but the maximum daily consumption for public supply has not exceeded 250,000 gallons. An analysis of the water (table 13) indicates a total hardness of 176 parts per million and a fluoride content of 0.3 part per million. The fluoride content is within the safe limit discussed under Quality of water.

Lakin is supplied by two city-owned wells that are equipped with electrically-driven turbine pumps. The older well (294), drilled in 1910, is 231 feet deep and is cased with 15-inch wrought-iron casing. The static water level was about 15 feet below land surface in 1940. The relatively hard water in the alluvium has been cased off to prevent its mixing with the softer water from the underlying beds. The well is reported to yield about 240 gallons a minute with a draw-down of 40 feet. The newer well (293), drilled in 1934, is 273 feet deep and is cased with 18-inch wrought-iron casing. The water level was about 18 feet below land surface in 1940. The well is reported to yield 560 gallons a minute with a draw-down of 40 feet after 20 hours of pumping. The water is pumped directly into the mains, which are 4 to 8 inches in diameter, and the excess water is stored in an elevated steel tank of 50,000 gallons capacity. A pressure of 48 to 60 pounds to the square inch is maintained in the mains, but a maximum pressure of 125 pounds to the square inch can be produced in case of fire. As indicated by analysis 293, the water from these wells has a total hardness of 608 parts per million and a fluoride content of 0.8 part per million. The fluoride content is within the safe limit discussed under Quality of water.

RAILROAD SUPPLIES

About 10 wells have been drilled in this area to supply water for the Atchison, Topeka and Santa Fe Railway, but only a few of these are now in use. Beginning in 1900, five wells, ranging in depths from 83 to 465 feet, were drilled at Syracuse for the railroad company (logs 33 to 37). Well No. 4 (100) of the company is described in detail under Public water supplies. Each of the wells encountered the Graneros shale below the Quaternary gravels and all but one were drilled into the underlying Cretaceous sandstones.

Four wells that were drilled at Lakin (logs 28 to 31) for railroad use range in depth from 184 to 231 feet. The water was taken from sands and gravels underlying the alluvium of the Arkansas valley. Well No. 4 of the company (log 31) is reported to have encountered "rock" at a depth of 220 feet which may have been a sandstone of the Dakota formation, although no water was reported to have been found at that depth.

Wells also were drilled at Kendall and at Coolidge (logs 32 and 38). The Kendall well (drilled in 1903) encountered redbeds at a depth of 496 feet and the total depth of the well was 537 feet. The well at Coolidge was drilled in 1903 to a depth of 312 feet and encountered four important water-bearing beds. The first water was encountered in the alluvium of Arkansas river at a depth of 25 feet. A water-bearing sandstone was encountered at the top of the Dakota formation from which the water rose to a point 46 feet below land surface. Additional artesian water was encountered in a sandstone of the Dakota formation at a depth of 202 feet, from which the water rose to within 12 feet of the land surface, and in the Cheyenne sandstone at a depth of 300 feet, from which the water rose to within a foot of the land surface.

IRRIGATION SUPPLIES

Many large wells in this area supply water to irrigate crops—principally row crops, alfalfa, and sugar beets. Much land in the Arkansas valley between the Colorado line and Kendall and between Hartland and Deerfield and in the Kearny county part of the Scott-Finney basin is irrigated by water from wells. According to Sutton (1897, p. 250), the second irrigation project in western Kansas was begun by L. A. Martin in the vicinity of Lakin in 1878. By 1895 there were 64 irrigation plants in Hamilton and Kearny counties, of which 44 pumped water from streams, 18 from wells, and 2 from storage reservoirs. They supplied water for irrigating about 2,840 acres of land.

During the summer and fall of 1940 an inventory was made of the irrigation wells in Hamilton and Kearny counties, and estimates were obtained of the total pumpage and the number of acres irrigated during 1939. The records of all the irrigation wells visited are given in tables 20 and 21 and the locations of the wells are shown on plate 2. Records were obtained of about 96 irrigation plants of which 13 are on the upland north of Deerfield. Seven of these plants had been abandoned. The total reported area in Hamilton and Kearny counties that was irrigated from 73 of these wells in 1939 was 10,650 acres. Twelve of the wells supplied water for the irrigation of about 2,000 acres in Finney county.* The estimated total quantity of water pumped for irrigation during 1939 was 23,600 acre-feet, of which about 3,445 acre-feet was pumped from wells on the upland.

The total annual pumpage for irrigation in this area varies con-

* G. L. Howell, personal communication.

siderably with the climate, particularly with the amount of precipitation during the growing season. During the dry years the pumpage increased greatly and many new plants were put into operation. This allows a more regular moistening of the soil and prevents its cracking as it may do in nonirrigated land between periods of precipitation.

An unique irrigation project in this area is that of the Garden City Company in the vicinity of Deerfield which includes 13 plants that were constructed in 1905-'08 by the Bureau of Reclamation.* The plants are situated along a northeast-southwest line from the NW¼ sec. 26 to the NW¼ sec. 13, T. 24 S., R. 35 W. Recently 12 of the plants have been operated by the Garden City Company. Each plant comprises five wells ranging in depth from 30 to 60 feet and cased with 16-inch galvanized-iron casing. The plants are equipped with 12-inch centrifugal pumps powered by 25-horsepower electric motors. The water is pumped into a concrete ditch, is siphoned under Arkansas river, and is carried to a booster station about 1 mile east of Deerfield, where the water is pumped into the Great Eastern canal on the upland in Finney county. The booster station is equipped with a 24-inch pump operated by a 500-horsepower electric motor. The plants are reported to yield an aggregate of about 15,000 gallons a minute when pumping begins, but the yield decreases by about 50 percent after many days of continuous pumping. In 1939, approximately 3,500 acre-feet of water was withdrawn from the ground-water reservoir by these wells. The pumpage was considerably less in 1940.

Yields of irrigation wells.—The yields of the irrigation wells in Hamilton and Kearny counties range widely. Some small wells produce less than 100 gallons a minute and the large wells yield as much as 1,700 gallons a minute. Irrigation plants that draw water from a battery of five or six wells may yield as much as 4,000 gallons a minute. Most of the yields of irrigation wells given in tables 20 and 21 were reported by the owners, but a few were measured. The results of pumping tests, including the discharge, draw-down, and discharge per foot of draw-down (specific capacity), are given in table 9.

Half of the wells tested were in the Arkansas valley and half were in the shallow-water area north of the Arkansas valley. Most of the plants tested consisted of single wells equipped with turbine pumps; however, two plants in the Arkansas valley south of Deer-

* Data supplied by G. L. Howell, superintendent.

TABLE 9.—*Pumping tests of irrigation plants in Hamilton and Kearny counties*[1]

Well No.	Draw-down (feet)	Discharge (gallons a minute)		Well No.	Draw-down (feet)	Discharge (gallons a minute)	
		Total	Per foot of draw-down			Total	Per foot of draw-down
91....	30.0	532	17.7	215....	41.0	915	22.3
	34.4	520	15.1				
	34.55	534	15.5	217....	56.2	480	8.5
	34.55	531	15.4				
	34.56	525	15.2	238....	38.31	697	18.2
	35.34	524	14.8		41.78	679	16.3
					39.66	653	16.5
92....	12.55	700	55.2		41.56	671	16.2
	13.05	693	53.0		49.17	630	12.8
	13.25	708	53.4		49.94	617	12.4
	13.40	712	53.1		50.66	598	11.8
	13.40	719	53.6		51.13	574	11.2
	13.65	712	52.2				
	13.35	712	53.4	252....	8.9[2]	1,810	203.6
	13.15	707	53.6				
	13.13	701	53.4	254....	9.8[3]	1,625	165.9
213....	77.28	791	10.3	268....	29.1[4]	1,103	37.9
	78.86	813	10.3		32.2	1,101	34.2
	79.45	812	10.2		32.6	1,103	33.9
	80.32	812	10.1		32.6	1,087	33.3
	80.10	812	10.1		32.7	1,065	32.6
	80.32	812	10.1		32.5	1,069	32.9
	80.51	807	10.0		32.7	1,073	32.8
	80.64	810	10.0		32.9	1,065	32.4
	81.42	813	10.0		32.9	1,071	32.6
				287....	90.0	1,280	14.2

1. Pumping tests made by the Division of Water Resources of the Kansas State Board of Agriculture in coöperation with the State and Federal Geological Surveys. Wells 91, 92, 213, 238, and 268 were tested by Melvin Scanlan and W. W. Wilson; wells 215, 217, 252, 254, and 287 were tested by K. D. McCall and M. H. Davison.
2. Battery of five wells. Measurement in one well.
3. Battery of six wells. Measurement in one well.
4. Well draws water from the alluvium and the underlying Tertiary and/or Quaternary sediments.

field each comprised batteries of wells connected to one centrifugal pump, as noted in the table. All the pumps were operated by electric motors. Measurements of the discharge were made using a Collins flow gage. An electrical contact device was used for measuring the draw-downs in the wells while pumping, and a steel tape was used for measuring the water levels when the pumps were not running. The yields of individual wells ranged from 480 to 1,103 gallons a minute, the draw-downs ranged from 12.5 feet to more than 90 feet, and the specific capacities ranged from 8.5 to 55.2. The two batteries of wells yielded 1,810 and 1,625 gallons a minute with draw-downs of 8.9 and 9.8 feet, respectively.

According to L. F. Roderick (personal communication), well 275, in sec. 31, T. 24 S., R. 35 W., in the Arkansas river valley about 2.5 miles southeast of Lakin, had a measured yield in 1938 of 4,480 gallons a minute. This is the largest known yield of any irrigation plant in the Hamilton-Kearny area; it was reported that at one time this plant had the largest yield of any irrigation plant in Kansas. It comprises a battery of six wells ranging in depth from 40.5 to 43 feet, each of which is equipped with an 18-inch perforated galvanized-iron casing. The water level in one well on August 6, 1940, was 13.6 feet below land surface. Water is drawn from the wells by a 12-inch centrifugal pump powered by an electric motor.

Construction of irrigation wells.—Most of the irrigation wells in Hamilton and Kearny counties were constructed by professional well drillers; however, a few were drilled by farmers in areas where the water table is relatively shallow and the drilling of a well is comparatively easy. Several methods of well construction have been used in the Hamilton-Kearny area.

In the Arkansas valley, where the water table stands only a few feet below land surface, most of the irrigation wells are constructed by digging a pit nearly to the water table and then drilling a well through the bottom of the pit. The sides of the pit are walled with wood or concrete. The pump may be placed at or near ground level, but in most wells having pits it is placed at the bottom of the pit. Almost all the wells in the Arkansas valley are constructed with galvanized-iron casing but a few are constructed with concrete pipe or oil barrels. The casings generally are perforated to facilitate the entry of water into the well but these perforations may become closed by encrustation after several years of use.

Two types of wells are used for irrigation in the Arkansas valley; although the methods of construction are slightly different the same type of drilling equipment is used in both methods. One type is the gravel-wall well, the construction and advantages of which are described on page 83. The more common type of well in the Arkansas valley is not gravel packed and is constructed by sinking a screened or perforated casing as the well is being drilled. The material is removed by a sand bucket or sand pump and the casing is forced downward by weighting with sandbags.

Most of the irrigation plants in the Arkansas valley comprise two or more wells connected to one pump and commonly called a battery of wells. Such plants are used where the water table is relatively shallow and where the thickness of the water-bearing formation is limited. In the Arkansas valley in Hamilton county the alluvium is underlain by relatively impermeable shale so that it is necessary in most places to construct a battery of wells to obtain a large yield. In eastern Kearny county, however, the alluvium is underlain by additional water-bearing sands and gravels so that a single deep well will yield a large quantity of water. The so-called "second water" that is obtained from the Pliocene and/or Pleistocene deposits is softer than that in the overlying alluvium and is the water used by the city of Lakin for municipal supply. Only a few irrigation wells in the Arkansas valley in eastern Kearny county penetrate the sands and gravels below the alluvium. Additional wells in this area should penetrate all water-bearing formations in order to prevent excessive withdrawal from the alluvium. At present, most of the irrigation plants in this area comprise a battery of about five wells spaced 40 to 50 feet apart. The yield from a battery of wells is greater than the yield from a single well, but the yield from each well is less than if the other wells were not being pumped.

There are several irrigation wells on the upland north of Arkansas river in eastern Kearny county. This area is the southwestern part of the Scott-Finney shallow-water basin, where the water level ranges in depth from 25 to about 70 feet below land surface. Several deep wells (275 to 384 feet) that were drilled there many years ago proved unsuccessful, but modern improvements in pumping equipment have made irrigation in this area feasible so that about 10 new wells have been drilled since 1935. Most of the new wells are between 200 and 350 feet in depth, are cased with galvanized-iron casing, and are equipped with electrically-driven turbine pumps.

Wells of greater capacity and efficiency could be obtained in the Hamilton-Kearny area if better methods of well construction were used. Those plants comprising only one well probably would have a greater capacity and greater efficiency if the wells were deepened to penetrate all the water-bearing formations. Many of the plants comprising two or more wells are poorly constructed and most battery wells are not spaced widely enough to prevent excessive mutual interference. In several plants the wells are not aligned in a direction at right angles to the direction of movement of the ground water, causing an increase in the mutual interference of the wells.

Some of the wells in the Arkansas valley and in the Scott-Finney basin penetrate water-bearing formations that are so fine-grained that the wells should be gravel-packed in order to keep out the sand and obtain larger yields. Conversely, a few wells have been gravel-packed with gravel that is less satisfactory than the water-bearing material it replaced. Gravel-packing adds to the construction cost and should be used only where water in satisfactory quantities can be obtained in no other way and then only after a thorough study of the water-bearing material to determine the proper size of gravel to be used and, therefore, the proper slot size of the screen. For detailed descriptions of gravel-packing, the reader is referred to Rohwer (1940), Bennison (1943), and Davison (1939).

Depth and diameter of irrigation wells.—Most of the irrigation wells in the Hamilton-Kearny area are 30 to 50 feet deep (table 10), a few are less than 30 feet deep, and 19 are more than 100 feet deep. Thirteen of the 19 deep wells are on the upland north of the Arkansas river valley.

TABLE 10.—*Irrigation wells in Hamilton and Kearny counties classified according to depth*

Depth (in feet)	Number of wells
Less than 30	7
30– 40	26
41– 50	37
51–100	7
101–200	8
201–300	5
Greater than 300	6
Total	96

The diameters of the irrigation wells range from 8 to 24 inches (table 11). Most of the wells are cased with 15-, 16-, or 18-inch casing.

Types of irrigation pumps.—Most irrigation wells in the Arkansas valley are equipped with horizontal or vertical centrifugal pumps, ranging in diameter of discharge pipe from 3 to 12 inches. All irrigation wells in the upland that are now in use and several irrigation

TABLE 11.—*Irrigation wells in Hamilton and Kearny counties classified according to diameter*

Diameter (in inches)[a]	Number of wells	Diameter (in inches)[a]	Number of wells
8	2	18	28
12	8	19	2
14	2	20	2
15	11	24	1
16	29	Unknown	11
Total			96

a. For dug and drilled wells, diameter of drilled part is given.

wells in the valley are equipped with turbine pumps. There were 22 turbine pumps in use in the Hamilton-Kearny area in 1940.

Irrigation pump power.—Electric motors are used to operate most of the pumps on irrigation wells in Hamilton and Kearny counties. A few pumps, however, are driven by tractors, gasoline engines, or natural-gas engines (table 12). The power units generally are belted to the pump pulleys, but some are direct-connected to the

TABLE 12.—*Type of power used for pumping irrigation wells in Hamilton and Kearny counties*

Type of power	Number of wells
Electric motor	76
Gasoline engine	13
Natural-gas engine	5
Tractor	2
Total	96

shafts. After the discovery of natural gas in southeastern Kearny county, a few farmers adopted natural-gas engines for power. This economical type of power probably will be more extensively used in the future. For a discussion of energy consumption of irrigation plants using electricity, gasoline, and natural gas, the reader is referred to McCall and Davison (1939).

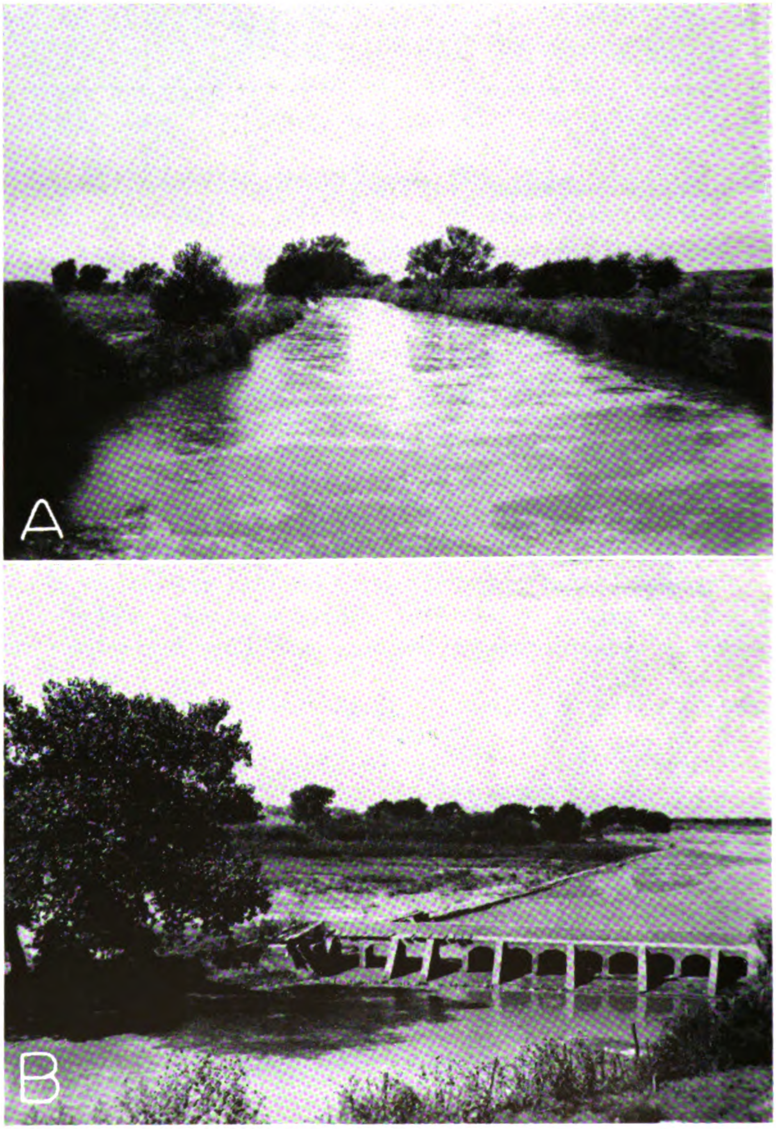

PLATE 8. Amazon irrigation canal near Hartland; B, Headgate of Amazon irrigation canal.

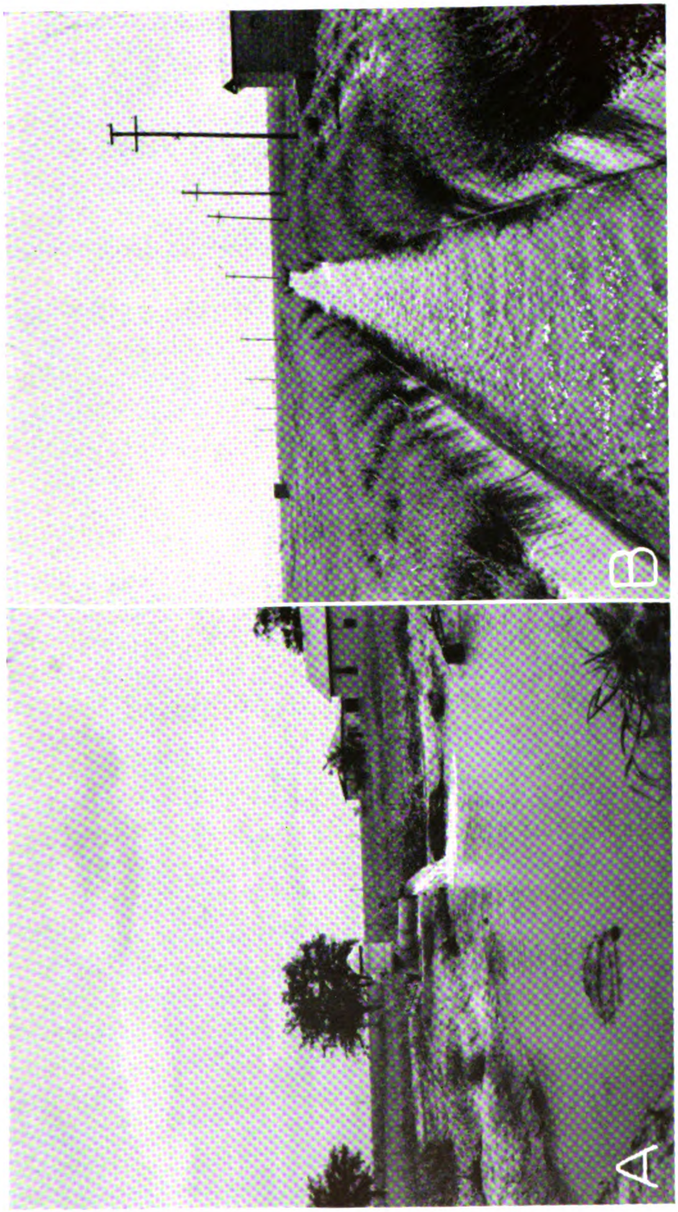

PLATE 9. A, Electrically-driven turbine pump in the Arkansas valley 1 mile east of Deerfield; B, Irrigation plants and canal of the Garden City Company in the Arkansas valley.

POSSIBILITIES OF FURTHER DEVELOPMENT OF IRRIGATION SUPPLIES FROM WELLS

The feasibility of further development of irrigation supplies from wells is dependent upon the safe yield of the ground-water reservoir (the amount of water that can be withdrawn annually over a long period of years without depletion), the cost of drilling and pumping, the types of soil, and perhaps other factors. The ability of an underground reservoir to yield water over a long period of years is limited, as is that of a surface reservoir. If water is withdrawn from an underground reservoir by pumping and by other means (seeps, springs, evaporation, and transpiration) faster than water enters it, the supply will be depleted and the water levels in wells will decline. The amount of water that can be withdrawn annually over a long period of years without depletion of the ground-water reservoir is dependent upon the capacity of the underground reservoir and upon the amount of water that is added annually to the reservoir by recharge.

The cost of drilling and pumping is determined in part by the depth to water level. In areas where the water level is relatively deep the wells must be deeper and the pumping lift is greater. The cost of a well is also determined in part by the permeability and the thickness of the materials. Some wells may encounter relatively fine-grained materials that cause the yield of the well to be relatively small. Gravel-packing may increase the yield somewhat, but it also adds to the cost.

The character of the soil is also an important factor. The soil may be too sandy in parts of the Arkansas valley and, in other parts of the valley where irrigation by surface water has been extensively practiced, the soil may have many "alkali" spots that support only slight plant growth.

For the purpose of more detailed description, Hamilton and Kearny counties may be divided into three areas based upon the possibilities of further development of irrigation supplies from wells: (1) Arkansas valley area, (2) Scott-Finney depression area, and (3) Stanton area.

Arkansas valley area.—The capacity of the alluvium in the Arkansas valley appears to be large enough to withstand more pumping for irrigation, particularly in parts of the valley where there is little or no pumping at the present time. The water table in the valley is near the land surface so that pumping lifts are low. In the eastern part of the valley, water from more than 300 feet of water-bearing formations is available to irrigation wells. Also, conditions for recharge are more favorable in the Arkansas valley than in any other part of Hamilton and Kearny counties, with the possible exception of the sand-hills area.

The development of irrigation with water from wells usually results in a decline in the level of the water table. The fact that there is a decline in water levels during a period of development when the rate of withdrawal is increasing is not necessarily an indication of overdevelopment as long as the decline is not so great as to indicate the approach of pumping lifts beyond the economic limit. A study of the relations of water levels in observation wells to the amount of pumpage should furnish reliable information as to the safe yield of the underground reservoir. If the pumpage during a given period does not cause an appreciable permanent lowering of the water table, it may be concluded that the recharge has been about equal to the rate of discharge, including both natural discharge and the withdrawal from wells. Regardless of the diurnal fluctuations of water levels, if, at the end of any period, they return to approximately their original position, the record of withdrawal furnishes a measure of the recharge during the same period minus the natural discharge.

The water levels in the observation wells in the Arkansas valley showed a marked decline from the time observations were begun in September, 1939, until 1941 (figs. 11, 12, and 14). As a result of the above-normal precipitation in 1941 and in the spring of 1942, the water levels in these wells rose rapidly, however, so that in May, 1942, they were higher than they have been at any time since periodic water-level measurements were begun. The water levels in wells 252 and 278 (fig. 11) were first measured in 1924 and 1925, respectively, and since 1934 they have been measured once each year. In October, 1939, monthly measurements were begun on well 252. The measurements from 1934 to 1940 were made during one of the worst periods of drought since the area was first settled and, as a result, the water levels were much lower than they were at the time when the first measurements were made during the years of above-normal precipitation in 1924 and 1925. As a result of the unusually large precipitation in 1941 and in the spring of 1942, the water levels in these wells were higher than they were when measurements were first made. These wells are in the most heavily pumped area in Hamilton and Kearny counties.

More than 23,000 acre-feet of water was pumped from wells for irrigation in the Arkansas valley in Hamilton and Kearny counties in 1939. More than 3,500 acre-feet of this was used for irrigation in Finney county; the rest was used in Hamilton and Kearny counties. The water-level fluctuations during the period of record indicate that this rate of pumping is not depleting the ground-water reservoir and that some additional pumping can be undertaken without exceeding the safe yield. Much care, however, should be exercised in spacing the wells, in choosing the well sites, and in construction of the wells.

Further irrigation development could be made in several parts of the Arkansas valley in this area. North of Arkansas river between Lakin and Deerfield much of the land is not irrigated by water from wells, and many new wells probably could be drilled in this area without endangering the safe yield of the ground-water reservoir. The wells should be properly spaced and should penetrate both the alluvium and the underlying Tertiary and Quaternary deposits, which include nearly 300 feet of saturated sediments. South of the river between Lakin and Deerfield more water could be pumped for irrigation, but no additional wells should be drilled in the vicinity of the Garden City Company's project south of Deerfield because this locality probably is already overdeveloped. In 1939, about 20 percent of all the water withdrawn from wells in Hamilton and Kearny counties was pumped by the Garden City Company's 12 plants. Other areas between the river and the sand hills, however, could supply additional water for irrigation without permanently lowering the ground-water levels. Wells in this area should penetrate both the alluvium and the underlying Tertiary and Quaternary deposits. Single deep wells of this type probably would yield 750 to 1,500 gallons of water a minute.

There are only about 20 irrigation plants in the Arkansas valley in Hamilton county and much more water could be pumped for irrigation in that area, particularly north of Arkansas river. Throughout its course in Hamilton county, Arkansas river usually is a gaining stream. Flood waters that move down the channel probably contribute very little water to the ground-water reservoir before reaching the dry section of the stream in eastern Kearny county. If pumping for irrigation were sufficiently increased in the Arkansas valley in Hamilton county, the water level would decline until it would be lower than the level of the stream and Arkansas river would then become a losing stream in that part of its course. As a result, a large quantity of water would be contributed to the groundwater reservoir by the river whenever water moves down its channel.

For this reason, it is believed that much more water could be pumped for irrigation in the Arkansas valley in Hamilton county.

The alluvium in most of the Arkansas valley in Hamilton county is underlain by the relatively impermeable Graneros shale; wells, therefore, should not be drilled below the base of the alluvium. Irrigation plants in this part of the valley commonly consist of a battery of shallow wells connected to one pump in order to obtain greater efficiency. Such plants may be expected to yield 500 to 2,000 gallons of water a minute.

Scott-Finney depression area.—Most of the recent development of irrigation with ground water in the Hamilton-Kearny area has been in the southwestern part of the Scott-Finney depression in eastern Kearny county. Considerable irrigation was done here many years ago by the Garden City Company, but this did not prove successful and many of the plants were abandoned. Modern improvements in well construction and in pump efficiency have resulted in the drilling of many new wells in this area since 1935. The water levels in these wells range in depth from about 25 to 100 feet. Because of the greater depth to water, more time is required for precipitation to percolate downward to the water table. Although there was heavy precipitation in 1941 and 1942, the water level in well 209 did not start to rise until the last half of 1941. The water level in well 286, which is at the edge of the valley, began to rise in the fall of 1940. The water level in well 286 was higher in May, 1942, than at any time since periodic water-level measurements were begun in 1939. The water level in well 209 responded more slowly to the precipitation but exceeded its previous high level by the end of 1942. The records of the water-level fluctuations indicate that more water could be safely withdrawn from the ground-water reservoir in this area, much of which is undeveloped as far as irrigation using water from wells is concerned.

Irrigation from wells could be developed in most of T. 23 S., R. 39 W., in the south half of T. 24 S., R. 40 W., and in upland part of T. 24 S., R. 39 W. The northernmost irrigation well in the upland north of Deerfield is well 187 in sec. 33, T. 22 S., R. 39 W. West of the areas mentioned above, the pumping lift is too great to permit economical pumping of water for irrigation. The thickness of the saturated sediments decreases rapidly northward so that north of T. 23 S. careful test drilling is necessary before drilling irrigation wells. Irrigation wells in the Kearny county part of the Scott-Finney shallow-water area should penetrate most or all of the water-bearing sediments, which in much of the area exceed 300 feet in thickness. Single irrigation wells here could be expected to yield 500 to 1,500 gallons a minute.

Stanton area.—A small amount of irrigation probably could be developed in the Stanton area in southwestern Hamilton county, particularly between Little Bear creek and the 100-foot isobath line (pl. 2). Irrigation wells would have to penetrate all of the saturated material, which probably would not exceed 150 feet. A few plants have been successfully operated in northern Stanton county a few miles southeast of this area. The yields of these wells range from 450 to 800 gallons a minute (Latta, 1941, pp. 51-54).

The above discussion on possibilities of further development of irrigation with water from wells is based entirely upon geologic and hydrologic observations. Many other factors will play an important part in determining the location and extent of irrigation; among these are such factors as character of the soil, type of crops to be grown, and shape and slope of the land to be irrigated.

Quality of Water

The chemical character of the ground waters in Hamilton and Kearny counties is shown by the analyses given in tables 13 and 14. The analyses were made by E. O. Holmes in the Water and Sewage Laboratory of the Kansas State Board of Health. Fifty samples of water were collected from representative wells distributed as uniformly as possible within the area and among the water-bearing formations. The analysis of the water supply at Lakin (listed as well 293) is an analysis of a composite sample from two wells. The constituents listed were determined by methods used by the U. S. Geological Survey.

TABLE 13.—*Analyses of waters from typical wells in Hamilton county, Kansas*

Analyzed by E. O. Holmes. Parts per million[a] and equivalents per million[b] (in italics)

No. on plate 2	LOCATION	Depth (feet)	Geologic subdivision	Date of collection, 1940	Temperature (°F)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K) (c)	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Total dissolved solids	Hardness (calculated as $CaCO_3$)		
																Total	Carbonate	Noncarbonate
6	*T. 21 S., R. 40 W.* SE SE sec. 8	204	Pliocene and Pleistocene	Nov. 26	56	3.7	46 *2.30*	16 *1.32*	41 *1.79*	182 *2.98*	77 *1.60*	20 *.56*	1.5 *.08*	12 *.19*	308	188	149	39
16	*T. 21 S., R. 42 W.* NW SW sec. 36	135	do	do	59	.35	52 *2.59*	22 *1.81*	22 *.94*	199 *3.26*	63 *1.31*	23 *.65*	.7 *.03*	5.8 *.09*	288	221	163	58
27	*T. 22 S., R. 43 W.* SE SE sec. 2	53	do	do	57	.76	54 *2.69*	23 *1.89*	46 *1.99*	193 *3.16*	127 *2.64*	23 *.65*	.6 *.03*	5.3 *.09*	376	231	158	73
28	SE SE sec. 4	516	Dakota	do	63	.44	20 *1.00*	9.7 *0.80*	161 *6.98*	243 *3.99*	186 *3.87*	29 *.87*	1.3 *.07*	1.6 *.03*	531	91	91d	0
38	*T. 23 S., R. 40 W.* SW SW sec. 32	260	do	do	60	.14	52 *2.59*	37 *3.04*	187 *8.13*	238 *3.90*	382 *7.95*	63 *1.78*	1.8 *.09*	2.2 *.04*	844	282	195	87
39	SW SW sec. 35	65	Pliocene and Pleistocene	do	58	.9	40 *2.00*	14 *1.15*	12 *.53*	183e *3.00*	18 *.37*	5.5 *.16*	.4 *.02*	8 *.13*	190	159	150	9
52	*T. 23 S., R. 43 W.* NW NW sec. 22	33	Alluvium	do	57	.18	520 *25.95*	154 *12.66*	375 *16.32*	226 *3.71*	2,247 *46.74*	144 *4.06*	1.2 *.06*	22 *.36*	3,576	1,931	185	1,746
54	NE NW sec. 23	156	Dakota	do	57	.9	52 *2.59*	18 *1.48*	64 *2.77*	206 *3.38*	137 *2.85*	19 *.54*	.9 *.05*	1.3 *.02*	396	205	169	36
57	SW NE sec. 24	287	Cheyenne	do	58	.5	62 *3.09*	23 *1.89*	51 *2.23*	204 *3.35*	167 *3.47*	12 *.34*	.8 *.04*	.7 *.01*	419	250	167	83
65	*T. 24 S., R. 39 W.* SE SE sec. 1	150	Pliocene and Pleistocene	do	59	7	42 *2.10*	9.3 *.77*	6.9 *.30*	150 *2.46*	19 *.40*	5 *.14*	.5 *.03*	8.9 *.14*	174	156	123	33

TABLE 13.—Analyses of waters from typical wells in Hamilton county, Kansas—*Concluded*

No. on plate 2	LOCATION	Depth (feet)	Geologic subdivision	Date of collection, 1940	Temperature (°F)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K) (c)	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Total dissolved solids	Hardness (calculated as $CaCO_3$)		
																Total	Carbonate	Noncarbonate
68	*T. 24 S., R. 39 W.* SE NE sec. 20	21	Alluvium	Nov. 25	57	.13	506 *25.25*	208 *17.10*	681 *29.62*	326 *5.35*	2,794 *58.12*	270 *7.90*	1.5 *.08*	32 *.52*	4,666	2,118	267	1,851
71	NW SE sec. 35	65	Dakota	do	57	2.1	60 *2.99*	15 *1.23*	34 *1.47*	161 *2.64*	124 *2.58*	15 *.42*	.7 *.04*	.4 *.01*	332	215	132	83
94	*T. 24 S., R. 41 W.* SE SE sec. 6	10	Alluvium	Nov. 26	61	.03	59 *2.94*	14 *1.15*	22 *.95*	204 *3.35*	68 *1.41*	6 *.17*	.6 *.03*	4.9 *.08*	277	205	167	38
100	NE NE sec. 24	82	Pleistocene			.04	54 *2.69*	10 *.82*	34 *1.48*	159 *2.61*	79 *1.64*	4 *.11*	.3 *.02*	7.1 *.11*	303	176	130	46
104	*T. 24 S., R. 42 W.* SE SE sec. 34	225	Dakota	Nov. 25	61	4.6	42 *2.10*	19 *1.56*	58 *2.52*	203 *3.33*	122 *2.54*	9 *.25*	1.1 *.06*	.2 *.0*	357	192	166	26
106	*T. 24 S., R. 43 W.* SE SE sec. 10	60	Pliocene and Pleistocene	Nov. 26	58	.7	167 *8.33*	48 *3.95*	37 *1.62*	320 *5.25*	215 *4.47*	56 *1.58*	.7 *.04*	159 *2.56*	843	616	262	354
113	*T. 25 S., R. 39 W.* SE SW sec. 22	100	Dakota	Nov. 25	59	.27	40 *2.00*	26 *2.14*	74 *3.23*	305 *5.00*	94 *1.96*	9.3 *.26*	2.6 *.14*	.8 *.01*	400	208	208f	0
117	*T. 25 S., R. 40 W.* NW NW sec. 7	200	do	do	58	2.8	54 *2.69*	25 *2.06*	150 *6.51*	329 *5.40*	228 *4.74*	34 *.96*	2.9 *.15*	.5 *.01*	662	243	243g	0
121	SW SE sec. 22	276	do	do	59	.9	41 *2.05*	31 *2.55*	60 *2.62*	290 *4.76*	95 *1.98*	11 *.31*	3.3 *.17*	.2 *.0*	387	232	232h	0
126	*T. 25 S., R. 41 W.* NE NE sec. 5	250	do	do	60	7	59 *2.94*	29 *2.38*	162 *7.02*	337 *5.53*	276 *5.74*	32 *.90*	2.6 *.14*	1.6 *.03*	738	279	276	3

132	*T. 25 S., R. 42 W.* NW NW sec. 6	165	do	do	59	1.6	44 *2.20*	20 *1.64*	66 *2.86*	255 *4.18*	97 *2.02*	12 *.34*	2.2 *.12*	2 *.04*	372	195	195i	0
139	*T. 26 S., R. 39 W.* SE SW sec. 22	254	do	do	58	3.4	44 *2.20*	24 *1.97*	94 *4.07*	288 *4.72*	145 *3.02*	12 *.34*	2.8 *.15*	.7 *.01*	470	215	215j	0
143	*T. 26 S., R. 40 W.* NW NW sec. 1	210	do	do	56	2.4	40 *2.00*	41 *3.37*	48 *2.10*	322 *5.28*	80 *1.66*	12 *.34*	3.2 *.17*	1.1 *.02*	389	273	264	9
151	*T. 26 S., R. 41 W.* NE SE sec. 2	145	do	do	58	2.1	85 *9.24*	34 *2.79*	29 *1.27*	312 *5.12*	90 *1.87*	31 *.87*	.6 *.03*	26 *.41*	454	356	256	100
156	*T. 26 S., R. 42 W.* NW SW sec. 7	100	Pliocene and Pleistocene	do	59	.63	66 *3.29*	19 *1.56*	20 *.88*	153 *2.51*	130 *2.70*	12 *.34*	.7 *.04*	8.4 *.14*	333	244	125	119

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 (e.p.m.) is a unit chemical equivalent weight of solute per million unit weights of solution. Concentration in equivalents per million is calculated by dividing concentration in parts per million by the chemical combining weight of the substance or ion.

c. Calculated.

d. Total alkalinity, 199 parts per million; excess alkalinity, 108 parts per million.

e. Includes equivalent of 2.4 parts per million of carbonate (CO_3).

f. Total alkalinity, 250 parts per million; excess alkalinity, 42 parts per million.

g. Total alkalinity, 270 parts per million; excess alkalinity, 27 parts per million.

h. Total alkalinity, 238 parts per million; excess alkalinity, 6 parts per million.

i. Total alkalinity, 209 parts per million; excess alkalinity, 14 parts per million.

j. Total alkalinity, 236 parts per million; excess alkalinity, 21 parts per million.

TABLE 14.—*Analyses of waters from typical wells in Kearny county, Kansas*

Analyzed by E. O. Holmes. Parts per million[a] and equivalents per million[b] (in italics)

No. on plate 3	LOCATION	Depth (feet)	Geologic subdivision	Date of collection, 1940	Temperature (°F)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K) (c)	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Total dissolved solids	Hardness (calculated as $CaCO_3$)		
																Total	Carbonate	Noncarbonate
166	*T. 21 S., R. 35 W.* NE SW sec. 6	120	Pliocene and Pleistocene	Nov. 8	59	0.47	55 *2.74*	30 *2.47*	44 *1.91*	225 *3.69*	96 *2.00*	39 *1.10*	1.7 *.09*	15 *.24*	394	262	184	78
171	NE NW sec. 35	80	do	do	58	.76	46 *2.30*	22 *1.81*	28 *1.22*	220 *3.61*	52 *1.08*	16 *.45*	1.3 *.07*	7.5 *.12*	284	207	180	27
3	*T. 21 S., R. 36 W.* SW NW sec. 27	100	do	do	58	.62	47 *2.35*	27 *2.22*	48 *2.08*	210 *3.44*	99 *2.06*	30 *.85*	1.9 *.10*	12 *.20*	371	230	172	58
176	*T. 21 S., R. 37 W.* SW NW sec. 4	112	do	do	59	.57	45 *2.25*	33 *2.71*	36 *1.57*	209 *3.43*	83 *1.73*	32 *.90*	2 *.11*	22 *.36*	358	249	171	78
183	*T. 21 S., R. 38 W.* NE SE sec. 19	162	do	Nov. 7	59	.43	51 *2.54*	31 *2.55*	46 *2.01*	173 *2.84*	161 *3.35*	25 *.71*	1.3 *.07*	8 *.13*	410	256	142	114
193	*T. 22 S., R. 36 W.* NW NW sec. 22	180	do	Nov. 8	59	.39	41 *2.05*	18 *1.48*	19 *.82*	190 *3.12*	38 *.79*	10 *.28*	1.1 *.06*	6.2 *.10*	229	176	156	20
199	*T. 22 S., R. 37 W.* SE SE sec. 34	154	do	Nov. 7	59	2.4	64 *3.19*	22 *1.81*	43 *1.85*	185 *3.03*	144 *3.00*	20 *.56*	.9 *.05*	13 *.21*	402	255	152	103
203	*T. 22 S., R. 38 W.* NW NW sec. 14	180	do	do	60	7.8	54 *2.69*	25 *2.06*	37 *1.59*	185 *3.03*	122 *2.54*	22 *.62*	1.1 *.06*	5.8 *.09*	367	252	152	100

	T. 23 S., R. 35 W.																
207	SW NW sec 12	75	do	Nov. 8	58	.71	56 *2.79*	23 *1.89*	21 *.89*	216 *3.54*	68 *1.41*	16 *.45*	.9 *.05*	7.5 *.12*	301	236	177	59
214	NW NW sec. 29	65	do	do	59	.71	56 *2.79*	22 *1.81*	17 *.74*	212 *3.48*	61 *1.27*	17 *.48*	.5 *.03*	4.9 *.08*	285	232	174	58
	T. 23 S., R. 38 W.																
228	SE NE sec. 5	250	do	Nov. 7	60	4.2	51 *2.54*	29 *2.38*	60 *2.60*	106d *3.05*	170 *3.54*	27 *.76*	1.5 *.08*	5.8 *.09*	441	254	152	102
230	SW SE sec. 25	223	do	do	61	.22	33 *1.65*	19 *1.56*	14 *.61*	162e *2.66*	40 *.83*	6 *.17*	.8 *.05*	7.1 *.11*	201	161	133	28
	T. 24 S., R. 35 W.																
234	SE NE sec. 3	36	Pleistocene	Nov. 8	57	.51	276 *13.77*	66 *5.43*	196 *8.52*	229 *3.76*	966 *20.09*	128 *3.61*	.6 *.03*	14 *.23*	1,762	961	188	773
270	NW NW sec. 29	25	Alluvium	Nov. 9	58	.21	253 *12.63*	132 *10.85*	297 *12.92*	237 *3.89*	1,420 *29.54*	100 *2.82*	1.6 *.08*	4.4 *.07*	2,327	1,175	194	981
	T. 24 S., R. 36 W.																
288	SW SE sec. 22	25	do	Nov. 9	62	.18	222 *11.08*	105 *8.63*	225 *9.77*	361 *5.92*	944 *19.64*	133 *3.75*	1.6 *.08*	5.3 *.09*	1,817	986	296	690
293	NW NW sec. 27	273	Pliocene and Pleistocene			.08	163 *8.13*	49 *4.03*	42 *1.81*	174 *2.85*	457 *9.51*	52 *1.47*	.8 *.04*	8.8 *.14*	964	608	143	465
	T. 24 S., R. 37 W.																
306	SE SE sec. 20	200	do	Nov. 8	60	.90	33 *1.65*	14 *1.15*	10 *.45*	168 *2.76*	16 *.33*	1.8 *.05*	.7 *.04*	4.4 *.07*	165	141	38	3
	T. 24 S., R. 38 W.																
310	NE NE sec. 6	174	do	Nov. 7	59	1.3	41 *2.05*	13 *1.07*	9.2 *.40*	136d *2.23*	40 *.83*	6 *.17*	.5 *.03*	6.2 *.10*	190	159	119	40
311	SW SW sec. 22	145	do	Nov. 8	60	.84	54 *2.69*	18 *1.48*	25 *1.09*	189 *3.10*	86 *1.79*	9.5 *.27*	1.2 *.06*	2.2 *.04*	291	210	155	55
	T. 25 S., R. 35 W.																
315	SE NE sec. 2	50	Pleistocene	Nov. 9	59	.25	59 *2.94*	11 *.90*	18 *.78*	183 *3.00*	62 *1.29*	9 *.25*	.7 *.04*	2.7 *.04*	254	193	50	43
	T. 25 S., R. 37 W.																
341	SW SE sec. 10	16	Alluvium	Nov. 8	60	.64	323 *16.12*	114 *9.37*	349 *15.16*	215 *3.53*	1,620 *33.70*	115 *3.24*	1.3 *.07*	6.6 *.11*	2,637	1,276	176	1,100
	T. 25 S., R. 38 W.																
348	NW NW sec. 11	15	do	do	59	.28	45 *2.25*	19 *1.56*	19 *.81*	185 *3.03*	62 *1.29*	8 *.23*	.9 *.05*	1.2 *.02*	248	191	152	39

TABLE 14.—Analyses of waters from typical wells in Kearny county, Kansas—*Concluded*

No. on plate 3	LOCATION	Depth (feet)	Geologic subdivision	Date of collection, 1940	Temperature (°F)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K) (c)	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Total dissolved solids	Hardness (calculated as $CaCO_3$)		
																Total	Carbonate	Noncarbonate
355	*T. 26 S., R. 37 W.* SW SW sec. 35	160	Pliocene and Pleistocene	Nov. 9	63	2.7	58 *2.89*	32 *2.63*	109 *4.74*	227 *3.72*	272 *5.66*	25 *.71*	2.5 *.13*	2.2 *.04*	617	281	186	95
356	*T. 26 S., R. 38 W.* SW SW sec. 3	160	do	do	60	.33	44 *2.20*	26 *2.14*	16 *.68*	243 *3.99*	28 *.58*	11 *.31*	1.6 *.08*	4 *.06*	252	218	199	19
359	SW SW sec. 34	135	do	do	61	.71	57 *2.84*	40 *3.29*	38 *1.65*	215 *3.53*	159 *3.3*	25 *.71*	1.7 *.09*	8.4 *.14*	437	306	176	130

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 (e.p.m.) is a unit chemical equivalent weight of solute per million unit weights of solution. Concentration in equivalents per million is calculated by dividing concentration in parts per million by the chemical combining weight of the substance or ion.
c. Calculated.
d. Includes equivalent of 4.8 parts per million of carbonate (CO_3).
e. Includes equivalent of 3.6 parts per million of carbonate (CO_3).

CHEMICAL CONSTITUENTS IN RELATION TO USE

The following discussion of the chemical constituents of ground water in relation to use has been adapted from publications of the United States Geological Survey.

Total dissolved solids.—When water is evaporated the residue that is left consists mainly of the mineral constituents listed above and generally includes a small quantity of organic material and a little water of crystallization. Waters containing less than 500 parts per million of dissolved solids generally are entirely satisfactory for domestic use, except for difficulties resulting from their hardness or occasional excessive content of iron. Waters containing more than 1,000 parts per million are likely to include enough of certain constituents to produce a noticeable taste or to make the water unsuitable in some other respects.

The total dissolved solids in samples of water collected in Hamilton and Kearny counties ranged from 165 to 4,666 parts per million. The samples from more than half of the wells contained between 200 and 400 parts per million of dissolved solids (table 15). Two-thirds of the samples of water contained less than 500 parts per million and are, therefore, suitable for most ordinary purposes.

TABLE 15.—*Total dissolved solids in water samples from wells in Hamilton and Kearny counties*

Total dissolved solids (parts per million)	Number of samples	Total dissolved solids (parts per million)	Number of samples
101–200	4	1,001–2,000	2
201–300	10	2,001–3,000	2
301–400	16	3,001–4,000	1
401–500	7	4,001–5,000	1
501–1,000	7		
		Total	50

Hardness.—The hardness of water, which is the property that receives the most attention as a general rule, is most commonly recognized by its effects when soap is used with the water in washing. Calcium and magnesium cause almost all the hardness of ordinary water. These constituents are also the active agents in the formation of the greater part of all the scale formed in steam boilers and in other vessels in which water is heated or evaporated.

In addition to the total hardness, the tables of analyses show the carbonate hardness and the noncarbonate hardness. The carbonate hardness is that due to the presence of calcium and magnesium bicarbonates and can be almost entirely removed by boiling. In some reports this type of hardness is called temporary hardness. The noncarbonate hardness is due to the presence of sulphates or chlorides of calcium and magnesium; it cannot be removed by boiling and has sometimes been called permanent hardness. With reference to use with soaps, there is no difference between the carbonate and noncarbonate hardness. In general, the noncarbonate hardness forms harder scale in steam boilers.

Water having a hardness of less than 50 parts per million generally is rated as soft, and its treatment for the removal of hardness under ordinary circumstances is not necessary. Hardness between 50 and 150 parts per million does not seriously interfere with the use of water for most purposes; however, it does slightly increase the consumption of soap, and its removal by a softening process is profitable for laundries or other industries using large quantities of soap. Waters in the upper part of this range of hardness will cause considerable scale on steam boilers. Hardness above 150 parts per million can be noticed by anyone, and if the hardness is 200 or 300 parts per million it is common practice to soften water for household use or to install cisterns to collect soft rain water. Where municipal water supplies are softened, an attempt is generally made to reduce the hardness to 60 or 80 parts per million. The additional improvement from further softening of a whole public supply is not deemed worth the increase in cost.

Water samples collected in Hamilton and Kearny counties ranged in hardness from 91 to 2,118 parts per million. Thirty-nine of the samples of water had a hardness between 100 and 300 parts per

TABLE 16.—*Hardness of water samples from wells in Hamilton and Kearny counties*

Hardness (parts per million)	Number of samples	Hardness (parts per million)	Number of samples
Less than 100	1	301–400	2
101–200	12	401–1,000	4
201–300	27	More than 1,000	4
		Total	50

million (table 16). The hardness of eight samples exceeded 400 parts per million.

Iron.—Next to hardness, iron is the constituent of natural waters that in general receives the most attention. The quantity of iron in ground waters may differ greatly from place to place, even though the waters are derived from the same formation. If a water contains much more than 0.1 part per million of iron, the excess may precipitate and settle as a reddish sediment. Iron, which may be present in sufficient quantity to give a disagreeable taste and to stain cooking utensils, may be removed from most waters by simple aeration and filtration, but a few waters require the addition of lime or some other substance.

All but three of the samples of water collected in the Hamilton-Kearny area contained more than 0.1 part per million of iron (table 17). More than 60 percent of the samples contained less than one part per million and five samples contained more than four parts per million of iron.

TABLE 17.—*Iron content of water samples from wells in Hamilton and Kearny counties*

Iron (parts per million)	Number of samples	Iron (parts per million)	Number of samples
Less than 0.1	3	2.1–3.0	6
0.1–1.0	32	3.1–4.0	2
1.1–2.0	2	More than 4.0	5
		Total	50

Fluoride.—Although determinable quantities of fluoride are not so common as fairly large quantities of the other constituents of natural water, it is desirable to know the amount of fluoride present in water that is likely to be used by children. Fluoride in water has been shown to be associated with the dental defect known as mottled enamel, which may appear on the teeth of children who, during the period of formation of the permanent teeth, drink water containing fluoride. It has been stated that waters containing one part per million or more of fluoride are likely to produce mottled enamel, although the effect of one part per million is not usually very serious (Dean, 1936). If the water contains as much as four parts per million of fluoride, 90 percent of the children drinking the water are likely to have mottled enamel, and 35 percent or more of the cases will be classified as moderate or worse.

More than half of the water samples that were collected in this area contained fluoride in excess of one part per million (table 18). The amount of fluoride in the water samples ranged from 0.3 part to 3.3 parts per million.

TABLE 18.—*Fluoride content of water samples from wells in Hamilton and Kearny counties*

Fluoride (parts per million)	Number of samples	Fluoride (parts per million)	Number of samples
Less than 1	22	2.1–3	6
1.0–2.0	20	More than 3	2
		Total	50

Water for irrigation.—The suitability of water for use in irrigation is commonly believed to depend mainly on the total quantity of soluble salts and on the ratio of the quantity of sodium to the total quantity of sodium, calcium, and magesium. The quantity of chloride may be large enough to affect the use of the water and in some areas other constituents, such as boron, may be present in sufficient quantity to cause difficulty. In a discussion of the interpretation of analyses with reference to irrigation in southern California, Scofield (1933) states that if the total concentration of dissolved salts is less than 700 parts per million there is not much probability of harmful effects in irrigation use. If it exceeds 2,100 parts per million, there is a strong probability of damage to either the crops or the land, or both. Water containing less than 50 percent sodium (the percentage being calculated as 100 times the ratio of the sodium to the total bases, in equivalents) is not likely to be injurious, but if it contains more than 60 percent its use is inadvisable. Similarly, a chloride content less than 142 parts per million is not objectionable, but more than 355 parts per million is undesirable. It is recognized that the harmfulness of irrigation water is so dependent on the nature of the land and the crops, on the manner of use and the drainage that no hard and fast limits can be adopted.

The amount of dissolved solids in nine of the 50 water samples collected in Hamilton and Kearny counties exceeded 700 parts per million. Four of these samples contained more than 2,100 parts per million of dissolved solids and (according to Scofield) probably are unsuitable for irrigation use. The chloride content of only two samples exceeded 142 parts per million and none exceeded the upper limit of 355 parts per million as set by Scofield. The water from four wells contained more than 50 percent sodium, the percentage ranging from 51.9 to 79.5. All of these samples, however, were obtained from wells that draw water from the Dakota formation in areas where irrigation is not feasible.

SANITARY CONSIDERATIONS

The analyses of water given in tables 13 and 14 show only the amounts of dissolved mineral matter in the water and do not indicate the sanitary quality of the water. An abnormal amount of certain mineral matter, such as nitrate, however, may indicate pollution of the water.

About half of the population of Hamilton and Kearny counties is dependent upon private water supplies from wells, and every precaution should be taken to protect these supplies from pollution. A well should not be located where there are possible sources of pollution, such as barnyards, privies, and cesspools, and every well should be tightly sealed down to a level somewhat below that of the water table. As a general rule, dug wells are more subject to contamination from surface water than are drilled wells, chiefly because they generally are not effectively cased or sealed at the surface. Drilled wells generally are well protected by the casing, although many are poorly sealed at the top.

QUALITY IN RELATION TO WATER-BEARING FORMATIONS

The quality of water from the four principal water-bearing formations in Hamilton and Kearny counties is shown in figure 16 and is discussed below.

Cheyenne sandstone.—The Cheyenne sandstone yields water to flowing wells in the vicinity of Coolidge in western Hamilton county. One sample of water from this formation was analyzed. The sample contained 419 parts per million of dissolved solids and had a hardness of 250 parts per million. It also contained 204 parts per million of bicarbonate and 167 parts per million of sulphate. A few analyses were made by Parker (1911, pp. 104, 105) of water from the Cheyenne sandstone in 1908. One sample contained 483 parts per million of dissolved solids. The sulphate content of four samples

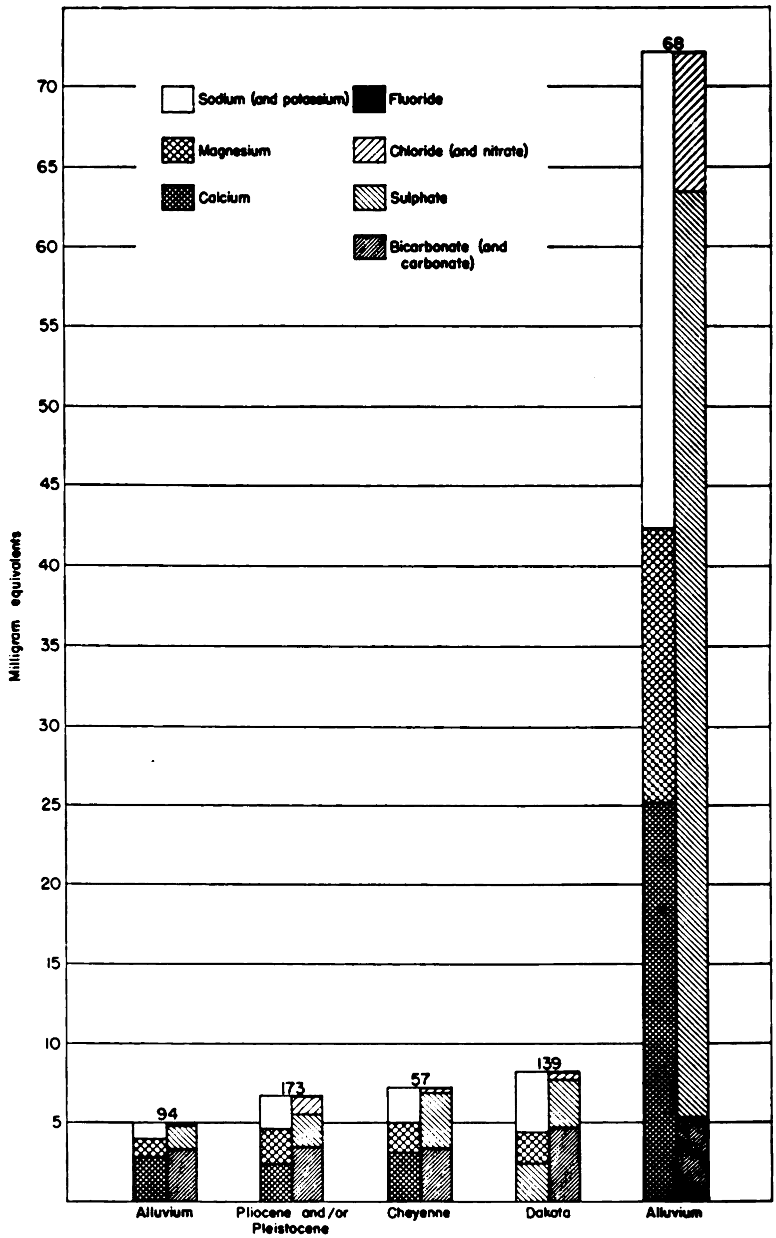

FIG. 16. Analyses of waters from the principal water-bearing formations in Hamilton and Kearny counties.

ranged from 171 to 222 parts per million and two samples contained 191 and 200 parts per million of bicarbonate.

Dakota formation.—Some wells in the western part of Kearny upland and most of the wells in the Syracuse upland obtain water from sandstones of the Dakota formation. Samples of water collected from 13 of these wells ranged in hardness from 91 to 356 parts per million, and averaged about 230 parts per million. The amount of dissolved solids ranged from 332 to 844 parts per million. All but three of the samples contained sufficient fluoride to be harmful to children's teeth. The average fluoride content of the 13 samples was two parts per million. The water from the Dakota formation is comparable in chemical character to the sample of water from the Cheyenne sandstone except that the fluoride content of the Dakota water is higher than the fluoride content of the single sample from the Cheyenne.

Water from the Dakota formation differs from water in the other water-bearing formations in that the ratio of sodium to the total bases is relatively high. This ratio exceeded 50 percent in four of the water samples taken from wells in the Dakota formation. The highest ratio was 79.5 percent in water from well 28. Water from well 28 contained 531 parts per million of dissolved solids, but its hardness was only 91 parts per million. This relatively soft sodium bicarbonate water may represent calcium bicarbonate water that has exchanged its calcium and magnesium for sodium by reaction with base-exchange silicates in the rock as it percolated through the formation. The base-exchange silicates probably are the clay-forming minerals in the Dakota formation. The degree of softening depends upon the amount and softening capacity of base-exchange silicates in the clay and upon the length of time the hard water remains in contact with these silicates. Water in deep wells probably is softer than water in shallow wells because a greater time probably would be required for the water to percolate from the surface down the dip of the bed and possibly because of exhaustion of the softening capacity of the materials nearer the surface. Water in well 28, referred to above, was encountered at a depth of 495 feet.

Undifferentiated Pliocene and Pleistocene deposits.—The Pliocene deposits, comprising the Ogallala formation, and the sands and gravels of Pleistocene age yield water to many wells in this area, particularly in Kearny county. Because of the similarity of these deposits and because a large number of the wells probably obtain water from both groups of sediments, the quality of the water from both formations will be discussed in one section.

Samples of water from these deposits range in hardness from 141 to 961 parts per million; the average hardness is about 270 parts per million. The hardest water collected was from well 234 which derives its water entirely from Pleistocene deposits and the softest water collected was from well 306 which probably obtains most of its water from Pliocene deposits. The total dissolved solids in waters from the Pliocene and Pleistocene sediments averaged 410 parts per million. The amount ranged from 165 parts per million in water from well 306 to 1,762 parts per million in water from well 234. The fluoride content of these waters averaged about 1.06 parts per million, and ranged from 0.3 to 2.5 parts. Thirteen of the 29 water samples collected from wells in these deposits contained more than one part per million of fluoride and may be harmful to children's teeth.

Alluvium.—Water from wells in the alluvium of the Arkansas river valley is relatively hard. The waters from seven of these wells ranged in hardness from 191 to 2,118 parts per million and averaged about 1,126 parts per million. The amount of total dissolved solids ranged from 248 to 4,666 parts per million. The fluoride content of water from these wells is also relatively high. The average fluoride content of seven samples was 1.2 parts per million. Water from wells in the alluvium near the north edge of the sand hills between Hartland and Coolidge is relatively soft. This is caused by the northward movement of the softer water from the sand-hills area.

Analyses of water from Arkansas river were made in 1906 and 1907 at the chemical laboratories of the University of Kansas (Parker, 1911, pp. 283, 284). The total dissolved solids in 26 samples that were analyzed ranged from 410 to 2,179 parts per million. The average amount of dissolved solids was 1,571 parts per million. The bicarbonate content averaged 231 parts per million and the sulphate content averaged 826 parts per million.

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

Permian System

UNDIFFERENTIATED REDBEDS

Character.—The Permian redbeds are not exposed in Hamilton and Kearny counties and no detailed lithologic description can be given because the only available data concerning these beds are the logs of oil and gas tests drilled in this area. The redbeds encountered in oil and gas tests in Hamilton and Kearny counties consist principally of red siltstone and sandstone with interbedded salt, gypsum, anhydrite, and dolomite.

Distribution and thickness.—The Permian redbeds underlie all of Hamilton and Kearny counties, but the nearest outcrops of these beds are in Texas county, Oklahoma, and in Meade and Clark counties, Kansas. The only data concerning the thickness of the beds in the Hamilton-Kearny area are the logs of oil and gas tests. The Wood Oil Company No. 1 Ranson well, in sec. 5, T. 26 S., R. 41 W., encountered more than 1,500 feet of red siltstone, sandstone, salt, and gypsum. Most of these beds are of Permian age but the uppermost beds may be of Triassic age. Norton (1939, p. 1,764) stated that about 1,550 feet of redbeds was encountered by the No. 1 Porter well in sec. 30, T. 25 S., R. 41 W. The oil-test wells of the Stanolind Oil and Gas Company in northwestern Kearny county encountered 1,050 to 1,130 feet of Permian redbeds.

Age and correlation.—On a basis of the study of well logs, it has been determined that the Permian redbeds underlying Hamilton and Kearny counties include representatives of all the formations recognized by the State Geological Survey of Kansas from the lower Ninnescah shale to the Taloga formation.

Water supply.—Little or no water is obtained from these beds by wells in Hamilton and Kearny counties. Farther south, in Morton county, water under artesian pressure is obtained from Permian redbeds, but the relatively high mineral content makes it unsuitable for most uses.

Triassic (?) System

UNDIFFERENTIATED REDBEDS

Redbeds of Triassic age crop out in Morton county, Kansas, Texas and Cimarron counties, Oklahoma, and at Two Buttes near the Prowers-Baca county line in southeastern Colorado. The outcrop at Two Buttes, which is about 40 miles southwest of the southwestern corner of Hamilton county, consists of about 240 feet of massive, cross-bedded, medium-grained, friable sandstone (Saunders, 1934, p. 865). It is probable that at least a part of this formation extends into western Hamilton county. A part of the redbeds encountered in the oil-test wells in southwestern Hamilton county may be of Triassic age. These beds yield no water to wells in Hamilton and Kearny counties.

JURASSIC (?) SYSTEM

MORRISON (?) FORMATION

Deposits of Morrison age probably underlie most of Hamilton county and at least a part of Kearny county. The No. 1 Porter well in southwestern Hamilton county penetrated more than 200 feet of sediments which are probably equivalent to the Morrison beds that crop out at Two Buttes in southeastern Colorado. Test hole 24, in the SE corner sec. 36, T. 26 S., R. 40 W., encountered nearly 100 feet of similar deposits (log 24). The deposits consist primarily of blue-green, rusty-brown, and maroon clay shales and marls containing beds of buff sandstone. These beds thin toward the east and are absent in eastern Finney county. They extend northward for many miles and have been encountered in wells in Norton county, Kansas, near the Kansas-Nebraska line. These deposits yield little or no water to wells in Hamilton and Kearny counties. Water probably could be obtained from the sandstones in this formation, but adequate quantities generally can be obtained from the overlying Cretaceous sandstones.

CRETACEOUS SYSTEM

Cragin (1886, 1889, 1895) classified the Cretaceous sediments of southern Kansas into the Cheyenne sandstone, the Kiowa shale, and the Dakota sandstone, named in ascending order. A little later, Gould (1898) redefined the Kiowa and Dakota of this area and described the Medicine beds between the Kiowa shale and the Dakota sandstone. Stose (1912) classified equivalent rocks in eastern Colorado into the Purgatoire formation, containing a lower sandstone member and an upper shale member, and the Dakota sandstone. In 1920, Darton (p. 2) subdivided the Cretaceous rocks that lie below the Graneros shale in western Kansas into the Cheyenne sandstone, the Kiowa shale, and the Dakota sandstone. Twenhofel (1924, pp. 12-30) used the terms Cheyenne sandstone, Belvidere formation, and "Dakota" formation for the Cretaceous sediments of southern Kansas, and retained the term Kiowa for the lower shale member of the Belvidere formation. In describing similar beds in Hamilton county, Bass (1926, pp. 59, 73-76) used the term Dakota sandstone for all sediments between the Permian redbeds and the Graneros shale. He recognized, however, that part of these sediments probably were equivalent to the Purgatoire formation of eastern Colorado. Lee (1927, p. 17) correlated the Purgatoire formation and the Dakota sandstone of southeastern Colorado with sediments designated by him as the Dakota group at the Bellvue section in northern Colorado. Elias (1931, p. 28; 1937, p. 10) classified equivalent sediments in western Kansas as the Dakota group. In 1931, Tester (1934, pp. 234-283) applied the name Dakota stage to the succession of strata lying between the Graneros shale and Pennsylvanian sediments at the type locality of the Dakota in eastern Nebraska. Saunders (1934, pp. 862-865) divided similar sediments of the Two Buttes area of southeastern Colorado into the Purgatoire formation and the Dakota sandstone. Schoff (1939, pp. 54-57) classified the Cretaceous sediments of western Oklahoma into the Purgatoire formation, including the Cheyenne sandstone and the Kiowa shale members, and the Dakota sandstone.

The term Dakota group has formerly been used by the State Geological Survey of Kansas (Moore and Landes, 1937; Moore, 1940, p. 40) to include all Cretaceous strata that lie below the Graneros shale. The name Cockrum sandstone was applied by Latta (1941, p. 70) to the upper sandstone member of the Dakota group in Stanton county, and was also used in Morton county by McLaughlin (1942, p. 70). The beds formerly included in the Dakota group were studied in detail over their outcrop area in central and north central Kansas by Plummer and Romary (1942), and the terms Cheyenne sandstone, Kiowa shale, and Dakota formation (named in ascending order) were adopted to include all Cretaceous strata that lie below the Graneros shale. The term Dakota formation is used in preference to Dakota sandstone because in most of the outcrop area of these beds in Kansas the dominant rock constituents are clay, shale, and siltstone rather than sandstone. In central and north central Kansas the Dakota formation is subdivided into the Terra Cotta (lower) and Janssen (upper) members. These members cannot be clearly recognized in Hamilton and Kearny counties, however.

In collecting the data for this report, most of the field studies and observations were of the principal water-bearing formations. Therefore, the geology of the Cretaceous deposits that overlie the Dakota formation has been largely drawn from Darton (1920) and from Bass (1926). Bass made a detailed study of the Cretaceous formations in Hamilton county in 1926.

CHEYENNE SANDSTONE

Character.—The Cheyenne sandstone is not exposed at the surface in Hamilton and Kearny counties. Where it crops out in adjacent areas in southeastern Colorado and southern Kansas it is composed principally of white to yellow quartz sandstone of medium to coarse grain but contains subordinate amounts of shale. In some areas the sandstone is conglomeratic near the base. The character of the materials that comprise this formation in Hamilton and Kearny counties is known only from records of wells that penetrate these beds. The logs indicate that in this area the Cheyenne is composed principally of a fine- to medium-grained sandstone which ranges in color from white to buff.

Distribution and thickness.—The Cheyenne sandstone underlies all of Hamilton and Kearny counties. In this area it is overlain by the Kiowa shale and it unconformably overlies older formations, principally the undifferentiated Permian redbeds and locally the Morrison (?) formation or the Triassic (?) redbeds. The thickness of the Cheyenne sandstone is somewhat variable. Test hole 25 (log 25) penetrated 54 feet of Cheyenne and in test hole 24 (log 24) it was 33 feet thick. Sixty-six feet of the formation was encountered in the old railroad well at Kendall (log 32). Some drillers have reported as much as 100 feet of Cheyenne sandstone encountered by wells in this area. This thickness, however, probably includes the Morrison (?) formation. The thickness of the Cheyenne sandstone is 15 to 50 feet in Cimarron county, Oklahoma; 50 feet at Two Buttes, in southeastern Colorado; and 10 to 55 feet in the vicinity of the type locality in Kiowa and Comanche counties, Kansas.

Age and correlation.—No fossils were obtained from the Cheyenne sandstone in Hamilton and Kearny counties, so its age must be determined by correlation with sandstones that crop out in adjacent areas. These beds are lithologically very similar to the lower part of the Purgatoire formation of southeastern Colorado, northeastern New Mexico, and western Oklahoma. They also closely resemble the Cheyenne sandstone of Kiowa and Comanche counties, Kansas. Its stratigraphic position below a dark shale that is believed

KIOWA SHALE

Character.—The Kiowa shale does not crop out in Hamilton and Kearny counties, so its character in this area can be determined only by the study of cuttings from test holes. As a result of such studies, the Kiowa shale in this area was found to consist principally of dark-gray to black fissile shale containing lenses of fine sand. The beds are in part calcareous. The Kiowa shale is, in most places, conformable on the Cheyenne sandstone but there are some apparent local disconformities.

Distribution and thickness.—The Kiowa shale probably underlies the entire Hamilton-Kearny area. It has been encountered by every test hole that has been drilled to Triassic (?) or Permian redbeds.

The thickness of the Kiowa shale in this area is quite variable. Wells have penetrated as little as 49 feet of these beds (well 57 near Coolidge) whereas as much as 131 feet of Kiowa shale was encountered in test hole 24 (log 24). The thickness of these beds is 122 feet at Syracuse and 58 feet at Kendall. The maximum reported thickness of the Kiowa shale is 150 feet at the type locality in Kiowa county, Kansas.

Age and correlation.—No fossils were obtained from the shale in the Hamilton-Kearny area, so it must be correlated on a basis of lithology and stratigraphic position. These beds appear to correlate with the Kiowa shale of Kiowa and Comanche counties, Kansas.

Water supply.—The Kiowa shale yields little or no water to wells in Hamilton and Kearny counties.

DAKOTA FORMATION

Character.—The character of the Dakota formation in this area was determined by a study of the outcrops and of cuttings from test holes. The uppermost 25 or 30 feet of the formation crops out in this area and is composed principally of gray to buff, fine-grained, irregularly-bedded sandstone and varicolored clay. The sandstone beds near the top of the formation grade into the overlying Graneros shale. They are ferruginous and very fine-grained and in places are strongly ripple-marked and cross-bedded. The top sandstone bed is a light-tan massive bed about 3 feet thick that weathers into large blocks. It is this bed that is commonly quarried for building stone in southern Hamilton county. Some of the sandstone layers are rusty brown and contain many small ironstone concretions and lignitic zones. In the vicinity of Hartland, the uppermost sandstone of the Dakota formation has been cemented by silica to form a very hard quartzitic rock that weathers into smooth rounded boulders. The rock weathers to tan or brown, but it is white to gray on unweathered surfaces.

The sandstones of the Dakota formation are interbedded with and interfinger with clay and silty clay. Data obtained from well cuttings indicate that most of the sandstone beds are near the top and near the base of the Dakota formation. About 40 to 45 percent of the formation is made up of clay. The clay is varicolored, the most common colors being buff and tan. A section of the Dakota formation measured in southern Hamilton county follows:

Section of the Dakota formation in sec. 24, T. 26 S., R. 41 W.

	Feet
9. Clay, buff to rusty	1.0
8. Clay, gray to buff, with concretionary nodules near the base	0.8
7. Sandstone, fine, thinly bedded, gray	1.1
6. Sandstone, fine, irregularly bedded, gray, and some clay	2.0
5. Sandstone, fine, hard, thinly bedded, gray	0.9
4. Clay, compact, gray to purple, containing ironstone concretions	1.2
3. Clay, fractured, light gray	1.2
2. Clay, nodular, yellowish to buff	1.4
1. Sandstone, fine, soft, buff to yellow	3.0
Base not exposed	...
Total	12.6

Upon microscopic examination, it was found that specimens of sandstone from the Dakota formation are composed principally of fine-grained quartz sand containing very fine-grained sand and some silt. The clay beds are composed of clay with some silt and very fine sand. The cementing material is principally iron oxide, but the sandstone from the outcrop near Hartland is cemented with silica.

Distribution and thickness.—Beds belonging to the Dakota formation underlie all of Hamilton and Kearny counties. The upper 25 or 30 feet of this formation crop out in a few small areas in southern Hamilton county and in the vicinity of Hartland in Kearny county (pl. 1).

The thicknesses of the Dakota formation encountered by wells in this area range from 130 feet in test hole 24 (log 24) in southern Hamilton county to 314 feet at Kendall. Other thicknesses encountered were 142 feet near Coolidge (well 57) and 165 feet at Syracuse (log 33).

Age and correlation.—For a discussion of the age and correlation of the Dakota formation, see pages 116 and 117.

Structure.—The structure of the Dakota formation in this area was studied by Bass (1926), who made a contour map showing the structure of the Dakota in Hamilton county and one showing the structure of the Dakota in most of western Kansas. The map showing the structure in Hamilton county was based on outcrops of the Cretaceous rocks and on records of water wells. The altitudes were in part determined with an aneroid barometer and in part taken from the topographic maps of the Syracuse and Lakin quadrangles. The map shows two elongated domes in southern Hamilton county.

Smith (1940) recognized the possibility of a fault on the southern margin of the structure. His conclusions were based primarily on physiographic evidence. He stated (pp. 136, 137) that:

It may be observed that the general level of the plains declines slightly from north to south across the Arkansas valley, from the Kearny area to the Syracuse upland, then drops abruptly to the Stanton area in southern Hamilton county, thereafter to rise regularly and very gradually toward the Oklahoma line, but without regaining its full northerly height. The topographic maps show the contours in the Stanton area to trend slightly west of north up to the base of the Syracuse upland, where they bend abruptly east, thus marking a pronounced topographic break. Conceivably, this break may represent a product either of erosion or of deformation. A study of the size and spacing of streams in the Stanton area, however, soon leads to the conclusion that post-Ogallala erosion has been very moderate in amount. The streams are few and far apart, and feeble in comparison with the Arkansas, which has carved out a valley that is small in comparison with the lower part of the Stanton area. Furthermore, the westward indentation of the contours in the Stanton area varies inversely with the strength of the traversing streams. The lowest part of the area lies not along Bear creek, a moderately vigorous stream, but along its northern branch, a much shorter and feebler water course. These relations are incompatible with any hypothesis attempting to explain the present topography as a result of dissection and removal of a once thicker Ogallala fill aligned with the top of the Syracuse upland. It is therefore concluded that the observed topographic anomalies represent the result of an abrupt and asymmetrical downwarp of the original Ogallala surface, the trough of the flexure being close against the base of the Syracuse upland.

The rectilinear trend of the north branch of Bear creek (Syracuse topographic sheet) suggests that the flexure was broken by a fault. Northwest of the junction of this branch with the main stream for about 15 miles the course of the tributary is conspicuously linear in comparison with the winding course of Bear creek itself. The trend veers from about N 70° W at the southeast to about N 50° W toward the northwest. On aerial mosaics the linear character of the valley is even more conspicuous and the valley is seen to be marked by a series of depressions, presumably of solutional origin, and localized by the fault. A short *en echelon* fault at the northwest is suggested by a linear tributary valley, also marked by depressions, one of which was formed in historic times.

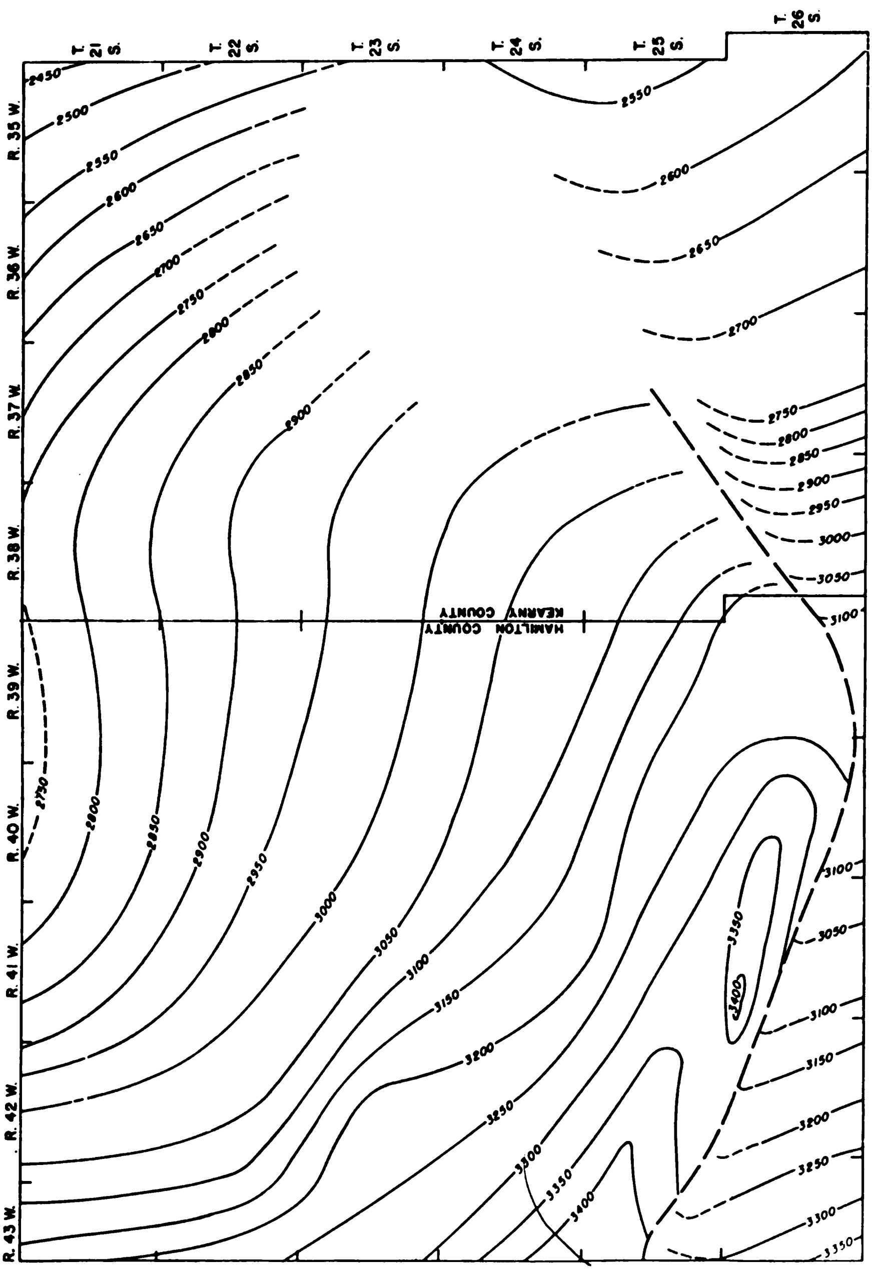

FIG. 17. Map of Hamilton and Kearny counties showing the structure of the Dakota formation. Heavy dashed line indicates the probable extent of the fault.

The presence of a fault was proved conclusively by Latta (1941). A test hole (log 25) was drilled on the Hamilton-Stanton county line at a point about 1.2 miles southeast of an outcrop of the Dakota formation. In this test hole the Dakota formation was encountered at a depth of 230 feet. The altitude of the top of the Dakota formation is more than 300 feet higher at the outcrop than in the nearby test hole.

The accompanying map (fig. 17) shows the structure of the Dakota formation in Hamilton and Kearny counties. The data are based principally on outcrops of Cretaceous rocks, records of test holes drilled by the State and Federal Geological Surveys, records of a few water wells, and records of oil and gas test wells. Altitudes of the test holes were determined with an alidade. The altitudes of the top of the Dakota formation in the area south of the fault may be incorrect because a part of the Dakota formation may have been removed by post-Cretaceous erosion. If this error could be corrected, however, the map would be only slightly changed. The trend of the fault was determined in several ways. In southwestern Hamilton county the linear nature of Little Bear creek and of the sink holes suggested its location. Along the southern margin of the Syracuse upland there are outcrops of Cretaceous formations, and in spite of the fact that the regional dip of the Dakota formation is toward the north and east the Cretaceous beds do not crop out a few miles south of the Syracuse upland where the altitude is 50 to 100 feet lower. Also, assuming a uniform northeastward regional dip, the Dakota formation should crop out in the sand-hills area in western Kearny county. Instead, it is encountered in wells in this area at depths of 100 to 400 feet.

The fault (fig. 17 and pl. 3) probably trends northeastward from southwestern Kearny county and merges into the structure that forms the west side of the Scott-Finney depression. This would account for the fact that a test hole (log 48) 5 miles east of the outcrop of the Dakota formation near Hartland failed to encounter these beds even though it was drilled to a depth of 297 feet. The altitude of the test hole was about 30 feet lower than the top of the Dakota formation at the outcrop.

A smaller flexure is also present in northwestern Kearny county. It is along this structure that oil was recently discovered.

Water supply.—Sandstones of the Dakota formation are important water-bearing beds in this area. They yield water to most of the wells in the Syracuse upland area (fig. 18), in the Arkansas

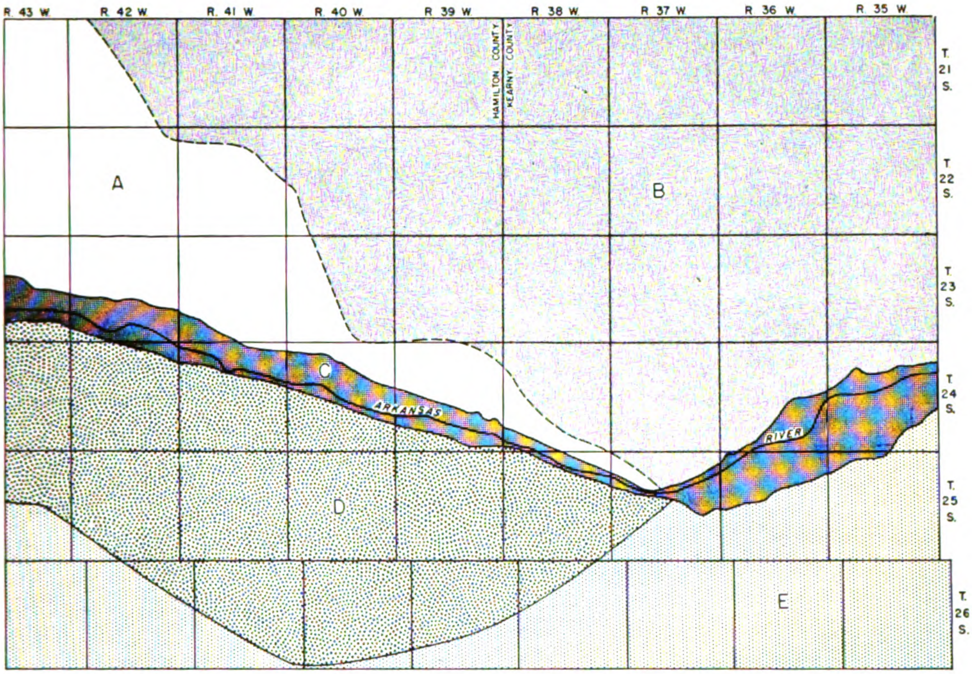

FIG. 18. Map of Hamilton and Kearny counties showing areas in which the principal water-bearing formations supply water to wells. A, little or no water available to wells (except at great depths); B, most wells obtain water from the Ogallala formation; C, most wells obtain water from the alluvium; D, most wells obtain water from the Dakota formation; E, most wells obtain water from undifferentiated Pleistocene deposits.

valley in Hamilton county, and in the western part of the Kearny upland.

In the Syracuse upland, wells encounter the Dakota formation at depths of 50 to 300 feet. The water in these wells generally rises under artesian pressure to a level about 100 to 200 feet below land surface. In some parts of this upland area the sandstones of the Dakota formation are relatively impermeable and yield little or no water to wells; however, an adequate supply generally can be obtained for domestic and stock use.

In the Arkansas valley in Hamilton county many deep wells have been drilled to the Dakota formation to obtain water that is softer than the water in the alluvium. The formation is encountered at depths of 50 to 125 feet and the water rises under artesian pressure to a level near the land surface. In the vicinity of Coolidge, two sandstone horizons are encountered in the Dakota formation. Water from the first zone, which is 50 to 105 feet below land surface, rises

PLATE 10. A, Graneros shale capped by basal beds of the Lincoln limestone member of the Greenhorn limestone in cut near Amazon headgate in Kearny county; B, Massive sandstone bed at top of the Dakota formation in sec. 27, T. 26 S., R. 41 W.; C, Cross-bedding in the upper part of the Dakota formation in sec. 17, T. 26 S., R. 41 W. (Photographs by N. W. Bass.)

the base of the formation are thin-bedded fossiliferous limestones that weather a rusty brown. The formation is sharply separated at the top from the limestones of the Greenhorn formation (pl. 10), but it grades into the underlying Dakota formation.

Distribution and thickness.—The Graneros shale underlies all but the southern part of the Hamilton-Kearny area (pl. 3). It crops out in small areas along the sides of the Syracuse upland and on the northern side of Arkansas river between Hartland and Syracuse.

The thickness of the Graneros shale increases toward the west. It generally is less than 40 feet thick in Russell county, 50 feet thick in Hodgeman county, 61 feet thick in Hamilton county, and 200 feet thick in Otero county, Colorado (Dane, Pierce, and Reeside, 1937). The overlying Greenhorn limestone thins toward the west, indicating that the Graneros shale thickens at the expense of the Greenhorn limestone.

Water supply.—The Graneros shale is relatively impermeable and yields little or no water to wells in Hamilton and Kearny counties.

GREENHORN LIMESTONE

The Greenhorn limestone was differentiated as a formation by Gilbert (1896, pp. 564, 570), who named it from Greenhorn station south of Pueblo, Colorado, and from Greenhorn creek. At the type locality the formation consists of 25 to 40 feet of alternating beds of fine-grained, compact, pale bluish-gray limestone and light-gray, laminated, calcareous shale. In Hamilton and Kearny counties the formation consists of about 132 feet of calcareous shale interbedded with thin layers of chalky and crystalline limestone and bentonitic clay. The formation merges into the overlying Fairport chalky shale member of the Carlile shale and is sharply defined from the Graneros shale which it conformably overlies. The thickness of the formation decreases from about 130 feet in Hamilton county to about 40 feet at the type locality. In this area, the Greenhorn limestone is commonly divisible into three members: the Lincoln limestone member, the Hartland shale member, and the Bridge Creek limestone member (named in ascending order).

Lincoln limestone member.—The basal 35 feet of the Greenhorn limestone in this area is called the Lincoln limestone member. The Lincoln limestone was named by Logan (1897, p. 216) from the city of Lincoln in Lincoln county, north central Kansas. It was adopted as the basal member of the Greenhorn limestone by Rubey and Bass (1925). The member consists predominantly of calcareous shale with thin beds (1 to 4 inches thick) of hard, finely-banded limestone that emit a petroliferous odor on fresh fracture. The limestone beds are gray but weather to brown. They are most abundant at the top and near the base of the member. The uppermost beds form the cap rock of a bench along the north side of Arkansas river between Hartland and Kendall (pl. 11). The Lincoln limestone member underlies all of the Hamilton-Kearny area north of Arkansas river as well as much of the Syracuse upland. These beds yield small quantities of water to a few wells in southern Hamilton county and they probably are the source of part or all of the water in the sink hole south of Coolidge.

Hartland shale member.—The type locality of the Hartland shale member is in western Kearny county between Hartland and Kendall (Bass, 1926, p. 69). The beds are exposed in the bluffs along the north side of Arkansas river (pl. 11). In this area the shale forms the gentle slopes between the lowermost beds of the Bridge Creek limestone member and the uppermost beds of the Lincoln limestone member. The Hartland member consists of 23 feet of gray calcareous shales containing many thin beds of bentonitic clay which range in thickness from one-fourth inch to 2 inches. There are also a few very thin lenses of dark-gray fossiliferous limestone, none of which exceeds one inch in thickness. The Hartland shale underlies all of the Hamilton-Kearny area that is north of Arkansas river. The shale is relatively impermeable and yields little or no water to wells in that area.

Bridge Creek limestone member.—The Bridge Creek limestone member was named by Bass (1926) after Bridge creek which enters the Arkansas valley about 2 miles west of Medway in western Hamilton county. It consists of 74 feet of interbedded calcareous shale and chalky limestone. The member is about four-fifths shale. The limestone beds range in thickness from 1 inch to 10 inches and are somewhat equally spaced (pl. 12). Interbedded with the limestone and shale are several beds of bentonitic clay ranging in thickness from one-fourth inch to 5 inches. Fossils are abundant in the upper two-thirds of the member. The limestone beds that lie between 40 and 50 feet above the base of the member are composed almost entirely of fossil shells of *Inoceramus labiatus*, a characteristic species of the Greenhorn limestone.

At the base of the Bridge Creek limestone member is a bed (1 foot thick) of limestone that is split near the middle by a thin shale

PLATE 11. A, View of bluffs north of Arkansas river west of Hartland showing the Hartland shale member overlain by the lowermost beds of the Bridge Creek limestone member of the Greenhorn limestone; B, Lowermost beds of the Smoky Hill chalk member of the Niobrara formation in sec. 3, T. 22 S., R. 43 W.

parting. This double limestone bed, which is much more resistant to erosion than the underlying Hartland shale, forms the prominent scarp along the north side of Arkansas river west of Hartland, and minor terraces are formed by several of the overlying beds. A section measured along Bridge creek northwest of Medway in Hamilton county follows:

Section of Bridge Creek limestone member of the Greenhorn limestone in sec. 7, T. 23 S., R. 42 W.

	Feet	Inches
32. Shale, fissile, calcareous, dark gray	1	4
31. Limestone, chalky, white	..	3
30. Shale, chalky, fissile, gray	1	3
29. Limestone, compact, cream-colored	..	3
28. Shale, fissile, gray	1	3
27. Limestone, hard, platy, gray	..	2
26. Shale, fissile, gray	1	2
25. Limestone, platy, gray	..	2
24. Shale, calcareous, fissile, gray	5	2
23. Limestone, massive, white	..	8
22. Shale, fissile, dark gray	2	6
21. Limestone, hard, compact	..	5
20. Shale, fissile, gray	1	3
19. Limestone, compact, fossiliferous, gray	..	7
18. Shale, fissile, gray	1	2
17. Limestone, platy, fossiliferous, gray	..	6
16. Shale, fissile, dark gray; contains bentonitic clay at the top and base	1	4
15. Limestone, platy, hard, fossiliferous	..	6
14. Shale, fissile, gray; contains bentonitic clay at the base	1	3
13. Limestone, platy, gray	..	4
12. Shale, fissile, buff to gray	1	6
11. Limestone, thin-bedded, gray	..	6
10. Shale, fissile, gray, containing limy zones	1	8
9. Limestone, chalky, compact, white	..	10
8. Shale, fissile, gray	3	2
7. Limestone, chalky, white	..	6
6. Shale, fissile, dark gray	1	6
5. Limestone, compact, white	..	5
4. Shale, fissile, dark gray	1	2
3. Limestone, compact, white	..	6
2. Shale, thinly bedded, gray	1	6
1. Limestone, compact, cream-colored	..	6
Base not exposed	..	..
Total	35	3

The above section represents the upper part of the Bridge Creek limestone member. Bed 32 lies about 13 feet below the base of the Fairport chalky shale member of the Carlile shale.

According to Bass (1926, p. 69), the uppermost 25 feet of the Bridge Creek member is equivalent to the Pfeifer shale member of the Greenhorn limestone in Ellis county, Kansas. The lowermost beds are equivalent to the Jetmore chalk member of the Greenhorn limestone in Hodgeman county, Kansas. Bass believes that the thick limestone bed that lies 49 feet above the base of the Bridge Creek member (bed 23 in the above section) is equivalent to the topmost limestone bed of the Jetmore chalk member.

The Bridge Creek limestone member underlies all of northern Hamilton and Kearny counties and crops out on the northern side of the Arkansas valley between Hartland and Coolidge and along several of the tributaries of Arkansas river in the western part of the Kearny upland. These beds yield very little water to wells in the Hamilton-Kearny area.

CARLILE SHALE

The Carlile shale was named by Gilbert (1896, p. 565) from Carlile station and Carlile spring, about 21 miles west of Pueblo. At the type locality it consists of gray argillaceous shale 175 to 200 feet thick. The upper one-fourth contains sand, and the topmost part is a yellow friable sandstone. In the Hamilton-Kearny area it consists of shale that is noncalcareous, blue-black, and fissile in the upper 100 feet, becoming limy and light-colored in the lower part. The thickness of the formation in this area is about 250 feet. It underlies the northern half of the Hamilton-Kearny area. In this area the Carlile shale is commonly divisible into three members —the Fairport chalky shale member, the Blue Hill shale member, and the Codell sandstone member (named in ascending order).

Fairport chalky shale member.—This member is poorly exposed in the Hamilton-Kearny area and only the lowermost beds have been carefully studied. The member was named from the city of Fairport in Russell county, Kansas, by Rubey and Bass (1925, p. 16). The Fairport member comprises about 150 feet of calcareous blue-black shale in the upper part which becomes lighter colored and more calcareous downward. Interbedded thin chalky limestones and limy shales make up the basal 35 feet. The upper three-fourths of the member is poorly exposed but its topographic expression indicates that it is principally shale containing a few thin shaly limestone beds. The lower one-fourth of the member consists of alternating calcareous shale and thin-bedded limestone. The limestones generally are light gray, chalky, and fossiliferous and are nowhere more than 6 inches in thickness. The member contains many thin layers of bentonitic clay which generally are from one-fourth inch to 1 inch in thickness. One bentonite bed 32 feet above the base of the member is 8 inches thick.

The Fairport chalky shale member crops out in several small areas along the tributaries to Arkansas river between Medway and Coolidge and north of Syracuse. These beds probably yield little or no water to wells in the Hamilton-Kearny area.

Blue Hill shale member.—The Blue Hill shale member of the Carlile shale is made up predominantly of blue-black noncalcareous fissile clay shale and has a thickness of about 75 feet. Near the top of the member is a zone of calcareous concretions that range in diameter from a few inches to about 15 feet (pl. 12). The Blue Hill member grades downward into the Fairport chalky shale member. It can be differentiated from the Fairport, however, because the shale in the Blue Hill member is noncalcareous. The Blue Hill shale member and the overlying Codell sandstone member were mapped as a unit (pl. 1).

The shale of the Blue Hill member is relatively impermeable and yields little or no water to wells in this area.

Codell sandstone member.—The Codell sandstone was named by Bass (1926, p. 28) from exposures near Codell in Ellis county, Kansas. The name was applied to the sandy zone forming the topmost 20 to 25 feet of the Blue Hill shale member. In 1933, Dane and Pierce (1933) elevated the Codell sandstone to the rank of member and restricted Blue Hill shale member to the underlying part of the Blue Hill shale of previous reports. In the Hamilton-Kearny area the Codell sandstone member comprises about 2 feet of very fine-grained sandstone underlain by about 20 feet of sandy shale. Northeast of this area, in Ellis county, the sandstone bed is 20 feet thick. The Codell sandstone member crops out along Bridge creek and other tributaries of Arkansas river in northwestern Hamilton county (pl. 1). It has been encountered in many wells in the Hamilton-Kearny area and it probably underlies the northern one-third of these counties.

The sandstone bed in the Codell sandstone member yields small quantities of water to a few wells in northwestern Hamilton county. In much of the area the sandstone is very fine-grained and contains silt and clay in sufficient quantities to make it relatively impermeable. Generally, wells drilled to this bed cannot obtain supplies of water adequate for most domestic and stock uses.

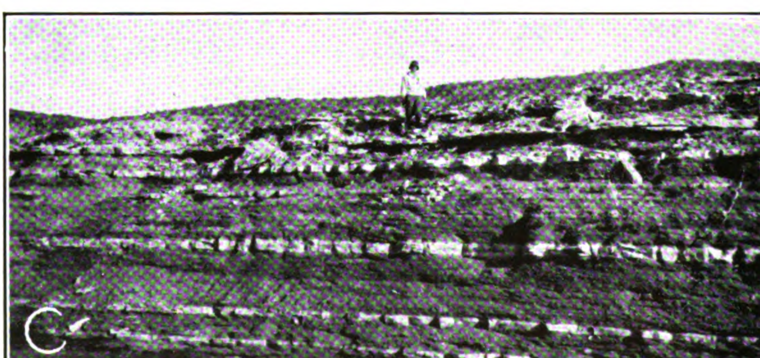

PLATE 12. A, Fault in sec. 29, T. 22 S., R. 42 W., Hamilton county. Fort Hays limestone member of the Niobrara formation on the right and Codell sandstone member on the left. B, Calcareous concretions in the Blue Hill shale member of the Carlile shale in sec. 36, T. 22 S., R. 42 W. C, A part of the Bridge Creek limestone member of the Greenhorn limestone in the east bank of Bridge creek in sec. 14, T. 23 S., R. 42 W. (Photographs by N. W. Bass.)

NIOBRARA FORMATION

The uppermost Cretaceous beds in the Hamilton-Kearny area belong to the Niobrara formation. They consist of chalk, chalky shale, and chalky limestone and crop out in several stream valleys in northwestern Hamilton county. In this area the Niobrara formation consists of the Fort Hays limestone member and the Smoky Hill chalk member.

Fort Hays limestone member.—The Fort Hays limestone member was named by Williston (1893, pp. 108, 109) from the old Fort Hays in Ellis county, Kansas. The member is comprised of thick beds of cream-colored, chalky limestone separated by thin beds of gray calcareous fissile shale (pls. 12 and 13). The limestone beds are as much as 3.5 feet in thickness and contain many specimens of *Inoceramus deformis* and *Ostrea congesta*. The Fort Hays limestone member grades upward into the Smoky Hill chalk member, but beds in the Smoky Hill member are darker, softer, and contain limonitic concretions and abundant specimens of *Inoceramus grandis*. The base of the Fort Hays member can easily be distingished from the underlying Codell sandstone member of the Carlile shale. A measured section of the Fort Hays limestone member follows:

Section of Fort Hays limestone member of Niobrara formation in sec. 3, T. 22 S., R. 43 W.

	Feet	Inches
14. Limestone, platy, and shale, interbedded	3	6
13. Limestone, platy, gray	3	..
12. Limestone, chalky, cream-colored	1	2
11. Shale, fissile, calcareous, gray	..	1
10. Limestone, chalky, cream-colored	..	4
9. Shale, fissile, limy, dark gray	..	2
8. Limestone, chalky, white	..	4
7. Limestone, platy, and shale, interbedded	..	10
6. Limestone, chalky, cream-colored	1	..
5. Limestone, platy, chalky	2	..
4. Limestone, chalky; shale parting near middle	4	2
3. Limestone, platy, hard	..	5
2. Limestone, chalky, cream-colored	1	..
1. Limestone, shaly, gray	..	8
Base not exposed	..	..
Total	18	8

The above section represents the uppermost part of the Fort Hays limestone member. The total thickness of this member in the Hamilton-Kearny area is about 61 feet. Beds of the Fort Hays member underlie most of the northern one-fourth of Hamilton and

Kearny counties (pl. 3) and crop out in northwestern Hamilton county along Bridge creek and other small tributaries of Arkansas river. These beds probably yield very little water to wells in Hamilton and Kearny counties.

Smoky Hill chalk member.—The Smoky Hill chalk member was named by Cragin (1896, p. 51) from Smoky Hill river in northwestern Kansas. The thickness of the Smoky Hill chalk member in the Hamilton-Kearny area is not known for it is exposed in only two localities (sec. 3, T. 22 S., R. 43 W. and sec. 14, T. 22 S., R. 42 W.). The beds are comprised principally of chalk and chalky shale with many limonitic concretions and numerous shells of *Inoceramus grandis* and *Ostrea congesta*. Although some of the beds appear to be massive, they can be broken easily into thin plates (pl. 11). The lateral gradation prevents the correlation of single beds from one locality to another. A section of the Smoky Hill chalk member measured in sec. 3, T. 22 S., R. 43 W. follows:

Section of Smoky Hill chalk member of the Niobrara formation in sec. 3, T. 22 S., R. 43 W.

	Feet	Inches
9. Chalk, compact, cream-colored; weathers to buff, irregular, pitted surfaces	3	1
8. Chalk, fissile, soft, buff	2	8
7. Chalk, buff	..	2
6. Chalk, fissile, gray	..	3
5. Chalk, hard, cream-colored	..	10
4. Shale, chalky, fissile, gray	..	8
3. Chalk, hard, fossiliferous; contains flat circular limonitic concretions	..	5
2. Chalk, platy	..	5
1. Shale, chalky, fissile, gray	3	1
Base not exposed	..	..
Total	11	7

The chalk beds of the Smoky Hill member probably underlie the northernmost part of the Hamilton-Kearny area. They are relatively impermeable and yield little or no water to wells in this area.

Tertiary System

PLIOCENE SERIES

The silts, sands, and gravels that overlie the Cretaceous bedrock and that underlie the loess, dune sand, and alluvium are of Tertiary and Quaternary age. Because of the lithologic similarity of the Ogallala formation and the undifferentiated Pleistocene deposits in this area it was necessary to map them as a single unit in Hamilton and Kearny counties (pl. 1). Although the contact of the two deposits could not be accurately traced in the field, there is sufficient lithologic and fossil evidence to indicate the general distribution and thickness of each of these deposits. For that reason they are discussed separately in the text.

Several test holes (7, 8, 9, 13, and 15) in the northern part of Kearny county encountered relatively thin deposits of bentonitic clay above the Cretaceous bedrock floor. The clay generally is blocky and is tan, brown, or green. The thickness of these beds encountered in test holes ranges from 2.5 feet to 28.5 feet. The deposits display a marked contrast in lithology to the overlying part of the Ogallala formation in that they are made up almost entirely of clay. Other than the Woodhouse zone the Ogallala formation in this area contains very little clay, and that generally is silty or sandy.

Similar deposits were observed by Elias (1931, pp. 155-158) in Wallace county, Kansas, where they were described as a local phase of the basal Ogallala and named the "Woodhouse clays." In Wallace county they consist of pale-green, reddish-brown, and chocolate-brown bentonitic clays. Because they are relatively impermeable, they yield little or no water to wells in the Hamilton-Kearny area.

Ogallala Formation

Character.—The Ogallala formation consists principally of silt, sand, gravel, and some clay. It may be loosely consolidated or tightly cemented by calcium carbonate to form a very compact "mortar bed" that resembles concrete. The material comprising the Ogallala formation is poorly sorted. Individual beds generally are discontinuous and within very short distances may grade laterally or vertically into material of different composition. For this reason it is often necessary to drill several test holes in these beds in order to determine the most suitable location for an irrigation well. Wells that are only a short distance apart may encounter almost totally unlike sequences of sediments above the Cretaceous bedrock floor.

The predominant material in the Ogallala is silt, which constitutes as much as 80 percent of the formation in some localities. The silt is composed almost entirely of irregular and subangular grains of quartz and generally is admixed with fine sand. The sand in the Ogallala is predominantly fine-grained, but in most places where it is associated with gravel it is medium to coarse. Gravel constitutes a relatively small part of the Ogallala formation and generally is found near the base. It is composed principally of feldspar, quartz, and other material derived from igneous rocks but also contains reworked Cretaceous rocks such as sandstone from the Dakota formation. Clay is not abundant in the Ogallala in Hamilton and Kearny counties and where present generally is found near the top of the formation.

Distribution and thickness.—Most of the Hamilton-Kearny area is underlain by the Ogallala formation and the undifferentiated Pleistocene deposits (pl. 1). In much of this area, however, these deposits are covered by a thin mantle of loess and dune sand. The Ogallala formation probably crops out in much of the Syracuse upland area and possibly at a few other places where the Cretaceous rocks are exposed. In southern Hamilton county there are several exposures of volcanic ash that Landes (1928, pp. 23-25) and Bass (1926, p. 60) believed to be of Pleistocene age. The ash lies a few feet above the Dakota formation, indicating that the Ogallala is probably very thin or absent in at least a part of the Syracuse upland. In northwestern Hamilton county, the gravels that overlie the Cretaceous beds appear to be of Pleistocene age although no fossils were found that could be used to definitely determine their age. Ogallala deposits probably underlie undifferentiated Pleistocene deposits in most of the Hamilton-Kearny area.

The thickness of the Pliocene and Pleistocene silts, sands, and gravels that overlie the Cretaceous bedrock is extremely variable. Test hole 18 (log 18) encountered only 18.5 feet of such material in the Syracuse upland. In the Stanton area the thickness encountered by test holes ranged from 226 to 254 feet (logs 25 and 26); in the Kearny upland the combined thickness ranges from 56 feet in test hole 5 (log 5) in northwestern Hamilton county to 288 feet in test hole 13 (log 13) in west central Kearny county. In the Kearny county part of the Scott-Finney basin these deposits are more than 380 feet thick (log 43). The greatest thickness of these deposits is in the sand-hills area in southeastern Kearny county where it exceeds 400 feet (logs 19 and 20).

The thickness of the Ogallala formation alone is also quite variable. It is probably absent or very thin in southern and northwestern Hamilton county. In the Syracuse upland the Ogallala formation ranges in thickness from a few feet in western Hamilton county to about 75 feet in southeastern Hamilton county. Much of the unconsolidated silts, sands, and gravels overlying the Cretaceous bedrock in northeastern Hamilton county and northern Kearny county belong to the Ogallala formation. The thickness of Ogallala deposits encountered by test holes in that area ranged from about 10 to about 180 feet. In the Stanton area in southwestern Hamilton county and in the sand-hills area in southeastern Kearny county, only a small part of the post-Cretaceous deposits are of Ogallala age. The formation is very thin or absent in the Stanton area and is about 60 feet thick in southeastern Kearny county.

Origin.—The silt, sand, and gravel of the Ogallala formation and of the undifferentiated Pleistocene deposits were carried in from the Rocky Mountains by shifting streams. This would explain the rapid gradations in lithology both vertically and laterally. Smith (1940, pp. 85, 86), in his discussion of the origin of the Ogallala formation, states that:

> The deposition of the Ogallala formation began with the change from stream degradation to aggradation. Just where this reversal first took place along the stream courses is uncertain, but it may plausibly be inferred that the locus of initial deposition corresponds approximately with the zone of maximum thickness in the formation, and thus falls within western Kansas. During the early stages of deposition, there was a topography of moderate relief. The main valleys were occupied by through-going streams from the Rocky Mountains, and the valley bottoms were mantled by normal flood-plain deposits. Some local material was probably carried in by side streams, and locally, as in Clark county, there was creep of sizable blocks of rock down the valley sides. In the southern part of the area, there may have been streams heading in the Sierra Grande arch. Deposition probably began with the filling of stream channels, leading to more frequent overflow and thus to the upbuilding of the floodplains. This soon led to shifting of the channels themselves, and probably to the development of anastomosing patterns. As filling progressed, the valley flat overlapped farther and farther on the slopes of the bordering hills, and the zone of deposition encroached farther and farther east and west. Relief was lowered, the valley plains grew broader, and finally the divides were overtopped, and there followed overlapping and coalescing of the depositional zones of individual streams. As depositional areas grew broader the rate of upbuilding must have declined, allowing greater time for the work of soil processes on the successive accretions of sediment. Undoubtedly the trunk streams deployed into branching distributaries, and these shifted sluggishly across broad and overlapping triangular areas. The bedrock divides were buried deeper and deeper, and one vast, continuous alluvial plain came to extend from the slopes of the Rockies perhaps as far as the Flint Hills in Kansas. Probably the waters of the depositing streams were gradually dissipated as they neared the border of this plain, so that none escaped beyond. Eastward and westward the margins of the alluvial mantle thinned out against the older rocks, and at the south the Sierra Grande highland probably rose gradually above the depositional surface. Over a great area, only one monadnock rose sharply above the alluvial plain—"Two Buttes," in southeastern Colorado, held up by an igneous intrusion and surrounding altered sediments.

Age and correlation.—The Ogallala formation is probably equivalent in age to the Ogallala in other parts of Kansas and Oklahoma. Fossils taken from these beds in other areas indicate that they are of middle Pliocene age. Schoff (1939, p. 61) reports that more than 10,000 middle Pliocene horse teeth have been taken from excavations in these beds at a point near Optima in Texas county, Oklahoma.

Water supply.—Most of the wells in northeastern Hamilton county and in northern Kearny county obtain their water from the Ogallala formation. In the Kearny-county part of the Scott-Finney basin deep irrigation wells obtain water from both the Ogallala formation and the overlying Pleistocene deposits. In other parts of the Hamilton-Kearny area the Ogallala formation yields little or no water to wells. In the Syracuse upland these beds lie above the water table so that wells must be drilled to the Dakota formation in order to obtain water. In the Arkansas valley, in the sandhills area, and in the Stanton area wells can obtain supplies of water adequate for most uses from the Quaternary deposits so that only a few wells in those areas penetrate the underlying Ogallala beds. The yields of wells in the Ogallala formation range from a few gallons a minute from many domestic and stock wells to more than 1,000 gallons a minute from some irrigation wells in the Kearny county part of the Scott-Finney basin. The largest yields from the Ogallala can be obtained from the coarse sands and gravels that are most abundant in the lower part of the formation.

Water from the Ogallala formation is relatively hard, but it is suitable for most ordinary uses. Because of its relatively high fluoride content it may be harmful to children's teeth.

Quaternary System

PLEISTOCENE SERIES

Undifferentiated Deposits

Character.—The undifferentiated Pleistocene deposits consist principally of unconsolidated sand, gravel, and silt, containing local deposits of volcanic ash. Sand generally is the most abundant material and gravel and silt occur in lesser amounts but locally may be the predominant constituents. Test hole 20 (log 20), for example, penetrated 315 feet of these deposits of which about 50 percent was gravel and 40 percent was sand. The silt is made up almost entirely of angular to subangular quartz grains as is the fine and medium sand. The coarse sand and the gravel are composed of quartz, feldspar, and other material derived from igneous rocks.

The Pleistocene deposits are poorly sorted. Individual beds generally are discontinuous and within very short distances may grade vertically or laterally into material of different composition. For that reason, most beds along the outcrops of these deposits can be traced for only short distances. Beds of gravel generally contain many lenses of silt and sand as well as clay in the form of rounded "clay balls" that range in diameter from a few inches to nearly 2 feet. These deposits generally are unconsoliated. Some beds, however, are cemented by calcium carbonate to form hard "mortar beds" resembling concrete.

The undifferentiated Pleistocene deposits include the terrace deposits of the Arkansas river valley (pl. 17), which are composed mainly of gravel containing intermixed silt, sand, and clay. The sand and gravel is made up principally of material derived from igneous rocks. The gravels in the 30-foot terrace northwest of Medway, however, contain many flat tabular platy and subangular fragments of limestone that probably were derived from near-by outcrops of Cretaceous rocks. Terrace deposits extend many miles south of the Arkansas valley, but their southern limit was not mapped because of their similarity to other Pleistocene deposits and because of the mantle of dune sand that covers much of that area.

Thin beds of volcanic ash crop out in southern Hamilton county along Little Bear creek and its tributaries (Bass, 1926, p. 60; Landes, 1928, p. 25). The largest of these is along a small stream bed in the northern half of sec. 13, T. 26 S., R. 41 W., where it is 2.5 feet thick (pl. 13). It is a compact white ash underlain by several feet of buff to tan clay and overlain by several feet of unconsolidated sand and gravel. Samples collected from this outcrop were analyzed by Landes (1928, p. 25) who found that 39 percent of the ash passed through a 20-mesh screen and was retained on a 100-mesh screen. This was the coarsest of 37 samples of Kansas ash analyzed by Landes.

Because of its color and associations, the ash was believed by Landes to be of Pleistocene age. It differs from most Pleistocene ash deposits, however, in that it is more compact and breaks off into slabby layers. The presence of a bed of clay beneath the ash also implies that it is equivalent in age to the Pleistocene ash of Grant, Haskell, and Meade counties.

As suggested by Landes (1928, p. 19), the original source of the ash must have been volcanic vents in the southwest—perhaps the

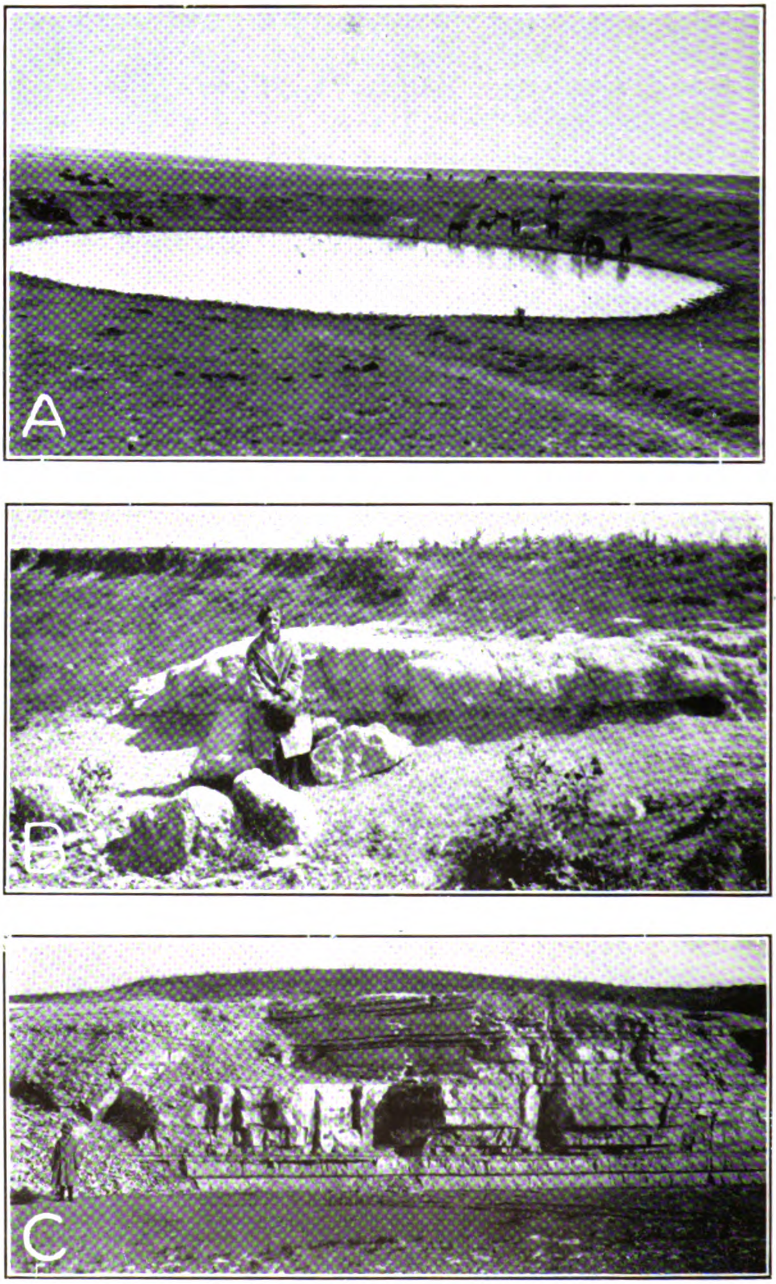

PLATE 13. A, Old sink hole in sec. 25, T. 25 S., R. 43 W., Hamilton county; B, Outcrop of volcanic ash in sec. 13, T. 26 S., R. 41 W., Hamilton county; C. Upper beds of the Fort Hays limestone member of the Niobrara formation in sec. 3, T. 22 S., R. 43 W. (Photographs by N. W. Bass.)

Capulin group of volcanoes in northeastern New Mexico. The ash was showered over a large area, but subsequent erosion carried part of it away and part was concentrated in small areas.

Distribution and thickness.—The undifferentiated Pleistocene deposits crop out in a large part of Hamilton and Kearny counties (pl. 1). They crop out in all of the Kearny county part of the Scott-Finney basin and they underlie almost all of the Kearny upland and the Stanton area, where they are in most places covered by a thin mantle of loess. They also underlie most of the sand-hills area, where they are covered by a relatively thin deposit of dune sand.

The undifferentiated Pleistocene deposits range in thickness from a few feet in northwestern Hamilton county to more than 300 feet in southeastern Kearny county. In the Stanton area they generally are about 200 feet thick, and in the Kearny upland they are 25 to about 250 feet thick. The greatest thickness of these beds is in the sand-hills area in southeastern Kearny county where they average more than 200 feet.

Origin.—The undifferentiated Pleistocene deposits probably were laid down in a manner similar to that in which the beds of the Ogallala formation were deposited (p. 139).

Age and correlation.—Fossils collected from these beds in this and adjacent areas indicate that they are of Pleistocene age. A fossil tooth taken from a gravel pit a few miles south of the Kearny-Grant county line was identified by Claude W. Hibbard of the University of Kansas Museum of Vertebrate Paleontology as *Equus niobrarensis* Hay, indicating that those beds probably are equivalent in age to the Meade formation in Meade county, Kansas (Frye and Hibbard, 1941, p. 411). The undifferentiated Pleistocene beds in Hamilton and Kearny counties probably are in part equivalent in age to the Pleistocene gravels in Scott, Finney, Gray, Grant, Haskell, and Seward counties, Kansas. Some of these deposits may be in part equivalent to the lower part of the Kingsdown silt of Ford, Meade, and Clark counties.

Water supply.—Almost all of the wells in the sand-hills area, in the Stanton area, and in the Kearny county part of the Scott-Finney basin obtain part or all of their water from the undifferentiated Pleistocene deposits at depths ranging from 20 feet to more than 100 feet. The yields of the wells range from a few gallons a minute from most domestic and stock wells to more than 1,000 gallons a minute from some irrigation wells in the Scott-Finney basin north of Lakin and Deerfield. Large yields are also obtained from a few wells in the Arkansas valley that penetrate both the alluvium and the underlying Pleistocene deposits.

The undifferentiated Pleistocene deposits, together with the beds of the Ogallala formation, serve as a huge underground reservoir. The reservoir may at one time have been nearly full, but streams such as Arkansas river have cut down into the reservoir and have drained part of the water from it. Drillers speak of the water in these beds as occurring in "sheets" separated by zones that yield little or no water. Some drillers have reported as many as eight such "sheets" within these deposits. It is probable that these are not separate zones of saturated material, but simply one saturated zone containing alternating beds of fine and coarse material. The fine material, although saturated, probably does not yield enough water for domestic or stock use so the drillers regard it as dry. The coarse material yields water freely and is logged as "water sand."

Water from the undifferentiated Pleistocene beds is relatively hard, particularly in the Scott-Finney basin north of Deerfield. The softest water obtained from these beds is found in the sand-hills area south of the Arkansas river. The fluoride content is relatively high in the Scott-Finney basin and is relatively low in the sand-hills area.

PLEISTOCENE AND RECENT SERIES

Loess

General features.—A thin deposit of loess overlies the Ogallala formation and undifferentiated Pleistocene deposits in much of Hamilton and Kearny counties. It occurs principally on the Kearny upland in northeastern Hamilton county and northern Kearny county and on the Syracuse upland in southern Hamilton county. The loess generally is buff to brown but may be dark brown to black in the soil zone. The material is structureless and may contain scattered limy concretionary nodules. It is composed principally of silt but contains some very fine sand. Mechanical analyses (table 19) made by Smith (1940, p. 122) indicate maxima in the 0.062-0.031 mm. division for most of the samples studied. Fractions larger than 0.062 mm. were separated by screening; those smaller than 0.062 were separated by the pipette method.

The soils formed from the loess are dark compact heavy silt loams, clay loams, and silty clay loams underlain by a lighter-colored calcareous clay subsoil. Because of the incoherent character of the loess, natural exposures are few and the complete thick-

TABLE 19.—*Mechanical analyses of loess and associated materials*[1]
The maxima are shown in italics

No. of sample	Location	Mechanical composition					
		0.5 mm.	0.5–0.25	0.25–0.125	0.125–0.062	0.062–0.031	0.032
1	SW¼ sec. 26, T. 21 S., R. 41 W.	0.03	1.0	6.5	*49.4*	34.5	8.7
2	SW¼ sec. 31, T. 22 S., R. 40 W.	1.8	0.9	6.8	27.9	*47.0*	15.7
3	W½ sec. 19, T. 23 S., R. 40 W.	0.0	0.03	2.2	32.6	*49.5*	15.6
4	SW¼ sec. 18, T. 25 S., R. 40 W.	0.8	1.4	3.2	3.7	*45.7*	*45.7*
5	NW¼ sec. 33, T. 25 S., R. 42 W.	0.02	0.2	2.0	20.2	*41.5*	36.1
10	SW¼ sec. 3, T. 22 S., R. 36 W.	0.03	0.1	9.0	13.6	57.1	20.1

1. Modified from Smith (1940, p. 122).

ness of the deposits cannot readily be determined. Thicknesses in excess of 10 feet were observed north of Arkansas river between Lakin and Hartland and along the north side of the Syracuse upland southwest of Syracuse. Most of the test holes in the Hamilton-Kearny area encountered deposits of loess that ranged in thickness from 1 to 8 feet. These deposits probably are equivalent to the Kingsdown silt of southwestern Kansas.

Water supply.—No water is obtained from the loess because it lies above the zone of saturation. Because the loess has low permeability, it retards the downward movement of rain water and thus hinders the recharge of the ground-water reservoir.

Dune Sand

Character.—A thin mantle of dune sand covers a large area south of Arkansas river in Hamilton and Kearny counties (pl. 1). The material consists of uniform medium-grained well-rounded quartz sand. Where soil zones have developed on the dune sand, it contains small amounts of clay and organic material.

Distribution and thickness.—The dune sand covers a large area on the south side of Arkansas river from western Hamilton county to eastern Kearny county. Between Coolidge and Hartland the sand-hills area ranges in width from 3 to 7 miles. All of southeastern Kearny county that lies south of Arkansas river and east

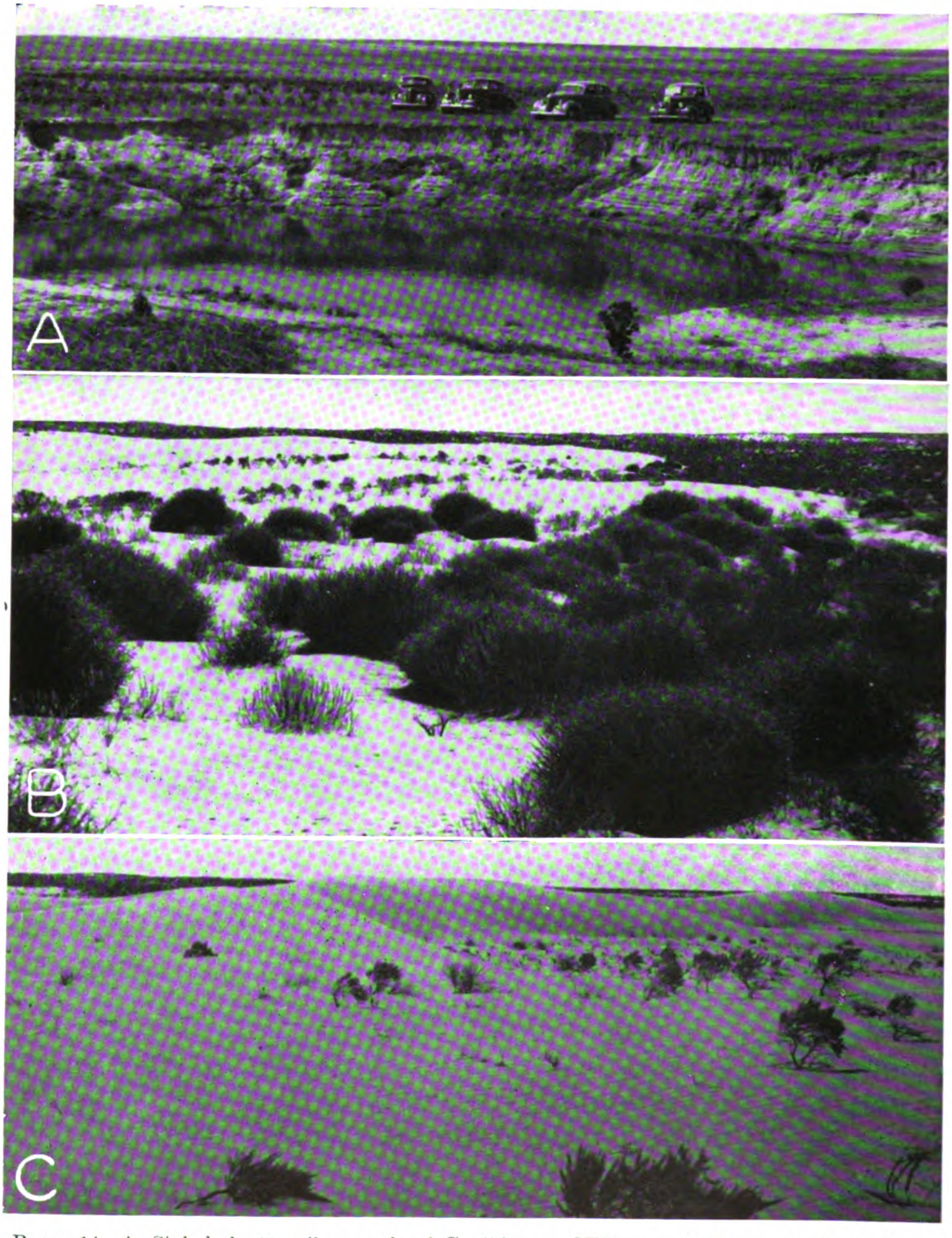

PLATE 14. A, Sink hole 11 miles south of Coolidge at SE¼ sec. 15, T. 25 S., R. 42 W.; B. Sand drifts invading field in sec. 22, T. 25 S., R. 38 W., Kearny county; C, Dune ridge of recent origin in blowout 9 miles southeast of Kendall, Kearny county. (Photographs by H. T. U. Smith.)

of Bear creek is covered by dune sand. This belt of sand dunes extends westward into Prowers county, Colorado, and eastward to Reno county.

The thickness of dune sand encountered by test holes ranges from 5 feet (log 16) to about 34 feet (log 19). The test holes, however, were drilled between sand hills and therefore did not penetrate the maximum thickness of dune sand. It is probable that in some of the high dunes the thickness is 75 feet.

Origin.—The dune sand probably was derived from sands of the alluvium of Arkansas river valley and from the terrace deposits that extend many miles south of the valley. The broad flat plain formed by the terrace deposits constitutes an excellent area for dune development.

In his discussion of the origin of sand dunes in western Kansas, Smith (1940, p. 160) describes an ideal dune cycle consisting of two phases: First, an eolian, or active phase, during which the dune is built up; second, an eluvial, or passive phase, during which vegetation prevents further growth and the dune is subdued by weathering and creep. He divides the eluvial phase into stages of youth, maturity, and old age. In the youth stage the soil zone is formed and the slopes are somewhat reduced. The dune becomes mature when its profile is smooth and regular and when its soil becomes thicker and more stable. Old age is reached when the dune form is undistinguishable. He states that the eluvial phase in any stage may be interrupted by rejuvenation.

Both the eluvial and eolian phases are represented in the sand hills in Hamilton and Kearny counties, but most of the dunes are in the eluvial phase at the present time. Most of the dunes are in the youthful stage of the eluvial phase in this area (pl. 16) for their slopes are moderate and a thin soil zone has developed. At several places in this area, however, the dunes are in the eolian phase (pl. 15). Recent droughts accompanied by strong winds have caused the rejuvenation of many sand dunes (pl. 14). Blowouts have formed around water wells where the livestock have trampled the grass and in fields where cultivation has been attempted.

Age.—The dune sand probably was deposited after the formation of the loess. Smith (1940, p. 128) found loess beneath the dune sand in Finney and Meade counties; however, test holes drilled in the sand hills in Hamilton and Kearny counties failed to encounter loess beneath the dune sand. The formation of the dunes probably began in Pleistocene time and continued into Recent time. Fossil snails taken from beds underlying the dune sand in northern Haskell county were identified by A. B. Leonard of the Department of Zoölogy, University of Kansas, who recognized 14 species and stated that the beds were Pleistocene and probably equivalent to the "Jones Ranch beds" of the Meade formation in Meade county, Kansas (Frye and Hibbard, 1941, p. 415).

Water supply.—The dune sand lies above the water table so it does not supply water to wells; however, the porous sand dunes provide excellent recharge facilities for the underlying ground-water reservoir.

Alluvium

Alluvium is found in the valleys of Arkansas river and its tributaries, but only in the Arkansas river valley is it of sufficient importance to discuss in this report. The following discussion, therefore, deals only with the alluvium of Arkansas river.

General features.—The alluvium comprises sand and gravel and lesser amounts of silt and clay. The material is poorly sorted and grades into material of different composition within a few feet both laterally and vertically. The sand and gravel are made up of rounded and subrounded grains of quartz, feldspar, and other material derived from igneous rocks. The sand, gravel, and silt may be found in any part of the formation but the clay generally is found at or near the base.

The alluvium is underlain by the Graneros shale and the Dakota formation between Coolidge and Hartland and by undifferentiated Pliocene and Pleistocene deposits between Hartland and Deerfield. In the area between Hartland and Deerfield the bed of clay that is encountered at depths of 35 to 45 feet represents the base of the alluvium. Below the bed of clay, the character of the material as well as the quality of the water is quite different from that of the alluvium.

The thickness of the alluvium ranges from about 10 feet southwest of Hartland to about 100 feet south of the river near Coolidge. Generally, however, the thickness in Hamilton county is between 50 and 60 feet and in Kearny county it is between 40 and 50 feet.

Most of the material comprising the alluvium was derived from the Rocky Mountains. Part was brought directly from the mountains and part is reworked material from the Tertiary and Pleistocene deposits which in turn were derived principally from the Rocky Mountains. A relatively small amount of the alluvium was derived from near-by Cretaceous rocks.

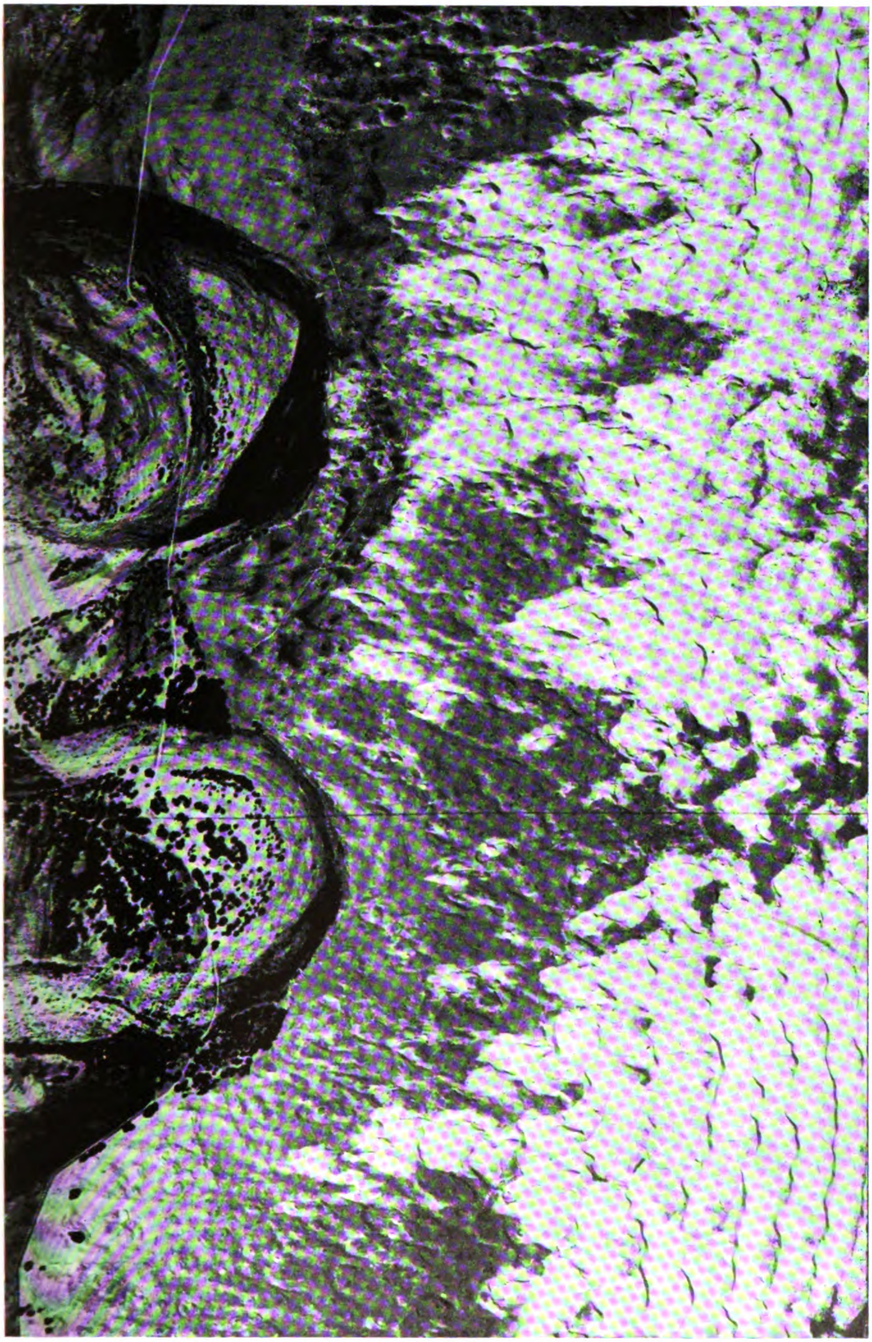

PLATE 15. Aerial photograph of dune ridges southwest of Syracuse. Scale: 3 inches = 1 mile. (Photograph from the U. S. Soil **Conservation Service, August, 1936.)**

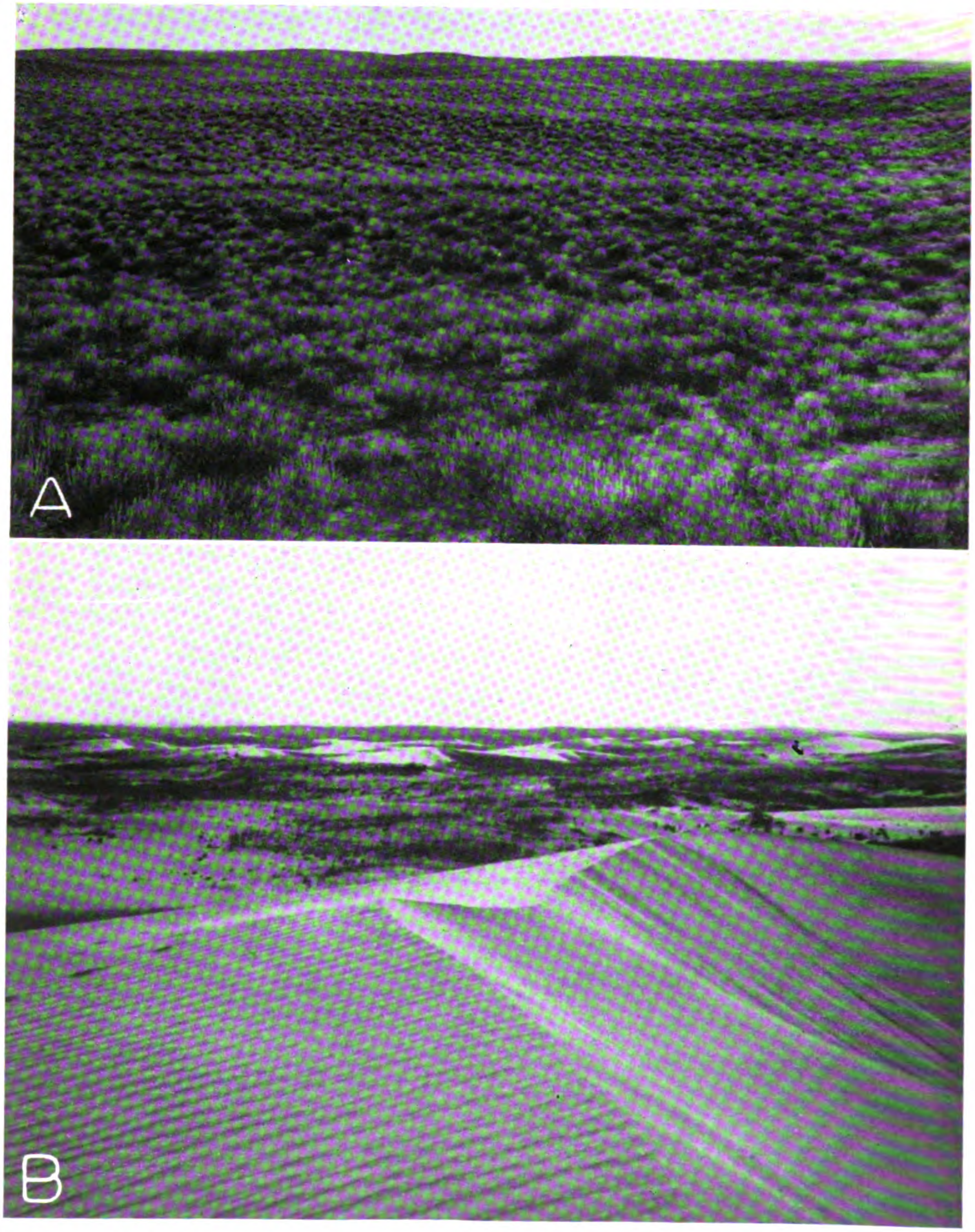

PLATE 16. A, Grass-covered sand hills southeast of Deerfield; B, Active sand dunes about 4 miles southwest of Syracuse. (Photographs by H. T. U. Smith.)

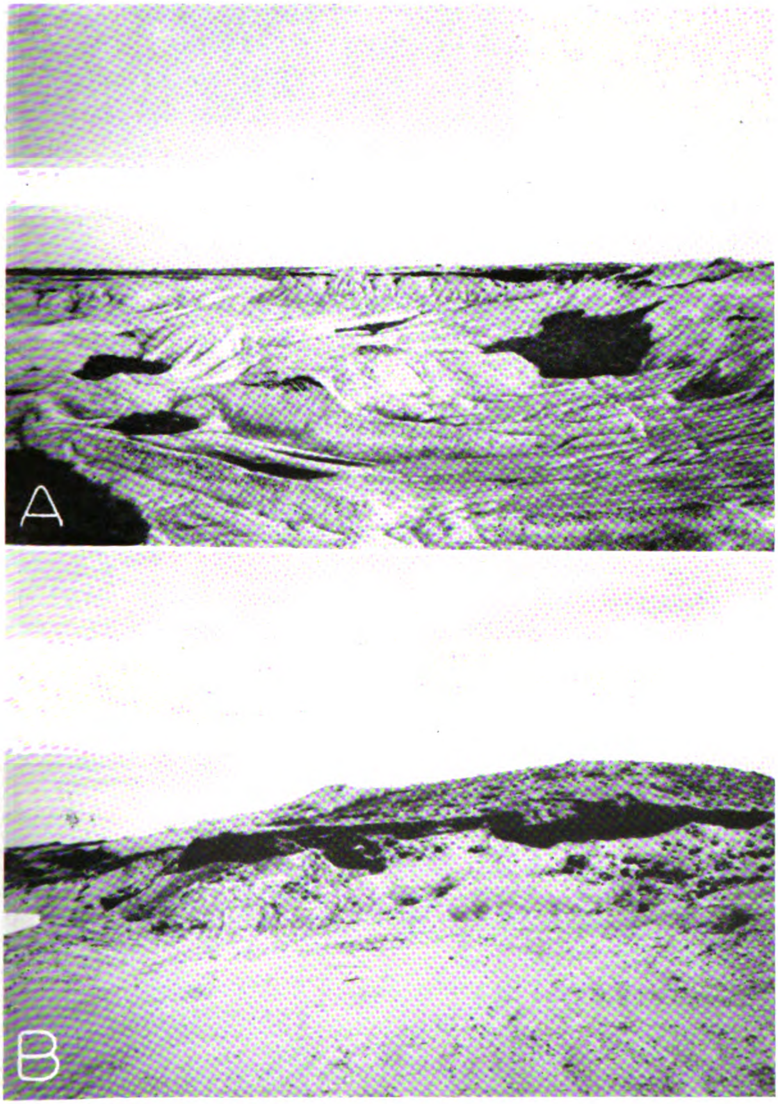

PLATE 17. A, Quarry in terrace gravels in sec. 18, T. 25 S., R. 36 W., Kearny county; B, Terrace gravels in sec. 27, T. 23 S., R. 42 W., Hamilton county.

Water supply.—As indicated by the pumping tests (pp. 88-90), the alluvium is relatively permeable and yields large quantities of water to wells in both Hamilton and Kearny counties. Properly constructed wells may obtain 1,000 gallons of water a minute from the alluvium in almost any part of the Arkansas valley. The depths to water level in the alluvium range from 5 feet to about 20 feet.

The water from the alluvium is hard and has a relatively large content of sulphate and fluoride. The fluoride content is sufficiently great to cause the mottling of some children's teeth. South of the river in western Hamilton county, recharge of the alluvium from rainfall in the near-by sand hills has caused water in the alluvium to be relatively soft.

WELL RECORDS

Information pertaining to water wells in Hamilton and Kearny counties is tabulated on the following pages (tables 20 and 21). The numbers in the first column correspond to the well numbers on the map (pl. 2) and in the tables of analyses (tables 13 and 14). The numbers in the first column that are in parentheses indicate wells from which samples of water were taken for analysis. The wells are listed in order by townships from north to south and by ranges from east to west. Within a township the wells are listed in the order of the sections. The measured depths of water levels are given to the nearest 0.01 foot, whereas reported depths are given only to the nearest foot and are subject to error. Records of two wells in adjoining counties are included (360 and 361).

TABLE 20.—*Records of wells in Hamilton county, Kansas*

Location	Owner or tenant	Type of well (1)	Depth of well (ft.) (2)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Distance above (+) or below (−) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (ft.) (6)	Date of measurement	Remarks
T. 21 S., R. 39 W.															
NE SE sec. 1	B. J. Cory	Dr	146.0	5	GI	(?)	Pliocene and Pleistocene	N	N	Top of casing, east side	+0.3	3,422.6	140±	8-27-40	Abandoned, formerly a stock well.
SW NW sec. 2	E. C. Bell	Dr	185	6	GI	Sand and gravel	do	N	N	Land surface	0	....	175		
SE NE sec. 10	C. Maune	Dr	170	6	GI	do	do	Cy,W	D,S	do	0	....	165		
NW SW sec. 11	E. E. Fanestill	Dr	210	6	GI	do	do	N	N	Top of casing	+ .3	....	200		Do
SE SE sec. 34	First Nat'l Bank	Dr	196.0	5	GI	(?)	do	N	N	Top of casing, east side	+ .5	....	195.06	10-28-40	Abandoned, formerly a domestic and stock well.
T. 21 S., R. 40 W.															
SE SE sec. 8	Albert Finkenbinder	Dr	204	6	GI	Sand	do	Cy,W	D,S	Land surface	0	3,548.3	202		Encountered blue shale at depth of 204 ft. Pumped 30 gallons a minute.
NW NW sec. 12	E. L. Wickiser	Dr	206.0	6	GI	(?)	do	Cy,W	N	Top of casing, north side	0	3,505.6	202.42	10-29-40	Abandoned, formerly a stock well.
NE NE sec. 17	J. Q. Blue	Dr	208	6	GI	Sand	do	Cy,W	D,S	Land surface	0	....	204	....	Encountered blue shale at depth of 207 feet.
SE SE sec. 21	Inez Dikeman	Dr	223.7	5	GI	(?)	do	N	N	Top of casing, south side	+ .3	....	190.32	9-23-39	Abandoned, formerly a domestic well.
NE NW sec. 33	J. J. Brehm	Dr	191.0	6	GI	Sand and gravel	do	Cy,H	N	Top of casing, west side	+ .6	....	187.05	10-28-40	Do
T. 21 S., R. 41 W.															
SE SE sec. 8	Dan Huser	Dr	850	6	I	Sandstone	Dakota	Cy,G	D,S	Land surface	0	3,661.2	450	....	Encountered Dakota formation at depth of 800 feet. Water rose 350 feet. Draw-down of more than 375 feet when pumped continuously.

SW SW sec. 25	Alfred M. Neptune	Dr	163.0	6	GI	(?)	Pliocene and Pleistocene	Cy,W	N	Top of casing, west side	0	3,610.0	142.35	10-31-40	Abandoned, formerly a domestic and stock well.
T. 21 S., R. 42 W. SE SW sec. 13	Carl Lewis	Du	60.4	30	B	(?)	do	N	N	Top of casing, northeast side	+ .4		57.34	9-29-39	Abandoned, formerly a domestic well. Yields meager supply of water.
SE SW sec. 22	O. R. Kendrick	Dr	96	6	GI	Sand	do	Cy,W	D,S	Land surface	0		90		
SE SE sec. 35	E. M. Scott	Dr	109.0	6	GI	(?)	do	Cy,W	N	Top of casing, west side	(?)	3,709.0	98.10	10-25-40	Abandoned, formerly a domestic and stock well.
NW SW sec. 36	Katie Lewis	Dr	135	6	GI	(?)	do	Cy,W	D,S	Land surface	0		105		
T. 21 S., R. 43 W. NE NE sec. 21	S. Davis	Dr	160.0	6	(?)	Sand	do	Cy,W	N	Top of 2-in. board over casing.	+ .2	3,841.9	153.72	10-26-40	Abandoned, formerly a domestic and stock well.
SW NE sec. 34	C. Robinson	Du	9.0	30	C	Sand and gravel	Alluvium	P,H	N	Top of 1-in. board over well	+ .4	3,706.3	6.24	do	Well goes dry in excessively dry seasons.
NE SW sec. 34	E. Plunkett	Du	13.5	48	C	do	do	Cy,W	N	Top of concrete casing, east side	+2.0		11.96	do	Do
T. 22 S., R. 39 W. SE SE sec. 13	F. J. Gilliam	Dr	225.6	6	GI	(?)	Pliocene and Pleistocene	Cy,W	N	Top of iron pipe clamp, north side	+ .2	3,410.5	221.77	10- 9-39	Abandoned, formerly a domestic and stock well.
SE SE sec. 21	H. H. Smalley	Dr	261.0	6	(?)	(?)	do	Cy,W	N	Top of wooden pipe clamp, north side	+ .4	3,468.2	253.62	10-29-40	Do
T. 22 S., R. 40 W. SW SE sec. 16	Fred Dikeman	Dr	218	(?)	(?)	Sand	do	Cy,W	D,S	Land surface	0		215		
SE SW sec. 20	I. E. Martin	Dr	152.0	6	GI	(?)	do	Cy,W	N	Top of casing, east side	+ .5	3,528.7	147.72	10-28-40	Do
SW NW sec. 28	R. D. Woodman	Dr	159.9	5	GI	(?)	do	Cy,W	N	do	+ .4	3,513.8	147.22	9-22-39	Do
T. 22 S., R. 41 W. NE SW sec. 2	I. E. Martin	Dr	149.9	(?)	(?)	(?)	do	Cy,W	N	Top of tee joint in 3-inch pipe	+4.0	3,621.9	144.12	9-29-39	Do
T. 22 S., R. 42 W. NW SW sec. 4	Dan Huser	Dr	105.0	6	GI	(?)	do	Cy,W	D,S	Top of casing, south side	+ .1	3,732.9	98.66	10-25-40	
T. 22 S., R. 43 W. SE SE sec. 2	Harry Plunkett	Dr	53	6	GI	Sand and gravel	do	Cy,W	D,S	Land surface	0		46		
SW SE sec. 4	Fred Behrendt	Dr	512	10	GI	Sandstone	Dakota formation	N	N	do	0	3,689.2	370		Abandoned, formerly a domestic and stock well. Encountered Dakota formation at depth of 495 feet. Water rose 125 feet.

TABLE 20.—*Records of wells in Hamilton county, Kansas*—*Continued*

o. n . 2	LOCATION	Owner or tenant	Type of well (1)	Depth of well (ft.) (2)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Distance above (+) or below (−) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (ft.) (6)	Date of measurement	Remarks
	T. 22 S., R. 43 W.															
29	SE SE sec. 4	Jacob Behrendt	Dr	516	(?)	(?)	Sandstone	Dakota formation	Cy,W	D,S	Land surface	0		355		Encountered Dakota formation at depth of 480 feet (log 51); water rose 125 feet.
	T. 23 S., R. 39 W.															
30	NW NE sec. 22	A. Pults	Dr	165.1	6	I	(?)	Pliocene and Pleistocene	Cy,W	N	Top of casing, west side	+ .7		163.16	9-23-39	Abandoned, formerly a domestic and stock well.
31	SE SE sec. 29	G. J. Downer	Dr	178	6	(?)	(?)	do	Cy,W	S	Land surface	0		170		
32	SE SE sec. 30	Mary R. Worth	Dr	158	6	GI	(?)	do	Cy,W	N	Top of 1½-inch pipe	+4.0	3,372.0	157	10-24-40	Do
33	SW SW sec. 32	Lakin State Bank	Dr	150	6	(?)	Sand and gravel	do	Cy,W	S	Land surface	0		146		
	T. 23 S., R. 40 W.															
34	SW NW sec. 1	H. F. Sanders	Dr	180	6	(?)	(?)	do	Cy,W	D,S	do	0		155		
35	NE SE sec. 2	John Bayer, Jr.	Dr	174.0	6	GI	(?)	do	Cy,G	S	Top of casing, north side	+ .3	3,436.4	136.08	10-28-40	
6	SW SE sec. 4	P. A. Woodburn	Dr	117.0	6	GI	(?)	do	Cy,W	N	Top of casing, east side	+ .1		105.15	do	
7	NW SW sec. 16	I. E. Martin	Dr	61.1	5	GI	Coarse gravel	do	Cy,W	N	Top of casing, south side	0		45.77	9-22-39	Do
8)	SW SW sec. 32	P. M. Singer	Dr	260	6	(?)	Sandstone	Dakota formation	Cy,W	D,S	Land surface	0	3,344.8	170		Water rose 90 feet. Small yield.
9)	SW SW sec. 35	A. L. Eaton	Dr	65	6	GI	Coarse gravel	Pliocene and Pleistocene	Cy,W	D,S	do	0	3,318.4	38		Large yield reported.
	T. 23 S., R. 41 W.															
0	NE NW sec. 6	E. C. Brooks	Du	11.5	36	C	Shale	Blue Hill (?)	Cy,W	S	Top of wooden pipe clamp	+ .3	3,470.2	9.77	10-30-40	Water obtained from concretionary zone in the Blue Hill shale.

41	SE SE sec. 6	P. M. Singer	Du	11.0	45	S	(?)	Codell (?)	N	N	Top of casing, west side	+ .1	3,496.9	7.70	do	Abandoned, formerly a domestic well.
42	SE SW sec. 16	Thomas Read	Dr	41.0	6	GI	Gravel	Pliocene and Pleistocene	Cy,W	N	Top of casing, east side	+ .3		39.87	do	Abandoned, formerly a domestic and stock well.
43	NE SW sec. 24	P. S. Martin	Du	9.0	48	(?)	Sand	Alluvium	Cy,W	N	Top of board wall, west side	+1.5		5.99	11-18-40	Abandoned, formerly a stock well.
44	NE NE sec. 32	R. E. Bray, Jr	Du	26.5	48	(?)	Sand and gravel	do	Cy,W	N	Top of platform over well	+ .3	3,284.9	26.15	9-21-39	Abandoned, formerly a domestic and stock well.
	T. 23 S., R. 42 W.															
45	SW SW sec. 19	J. W. Egger	Dr	74	18	GI	do	do	T,G	I	Land surface	0		24		Reported to yield 1,000 gallons a minute.
46	SW SW sec. 20	Josh Owings	Dr	300	(?)	(?)	Sandstone	Cheyenne	F	(?)	do	0				Reported to have a small yield.
47	NW NE sec. 31	L. G. Hazen	Dr	10.0	(?)	(?)	Gravel	Alluvium	Cy,W	S	Top of wooden pipe clamp.	+ .3	3,323.0	8.04	10-26-40	
	T. 23 S., R. 43 W.															
48	SE NE sec. 14	City of Coolidge	Dr	171.0	6	GI	(?)	Dakota	Cy,W	N	Top of casing, south side	+ .2	3,491.9	163.48	10-16-40	Abandoned, formerly used to irrigate trees in cemetery.
49	NE NE sec. 21	Robert Hazlett	5 Dr	28	18	GI	Sand and gravel	Alluvium	C,E	I	Land surface	0		14		Originally yielded 1,400 gallons a minute. Now yields 700 gallons a minute with a draw-down of 12 feet.
50	NW NE sec. 21	H. C. Merrifield	Dr	300	(?)	(?)	Sandstone	Cheyenne-Dakota	Cy,W	D	do	0		8		
51	SE NE sec. 21	Robert Hazlett	Dr	140	6	GI	do	do	Cy,W	D,S	do	0		63		Encountered Dakota formation and very hard water at depth of 70 feet. Water rose to the surface. Softer water was encountered at depth of 140 feet and rose 125 feet. See log 52.
(52)	NW NW sec. 22	R. Holdren	Du	33.2	70	(?)	Gravel	Alluvium	Cy,W	S	Top of platform over well	+ .2	3,369.2	27.21	9-21-39	Encountered shale at depth of 32 feet.
53	NW SW sec. 22	C. C. Reed	Dr	300	3	(?)	Sandstone	Cheyenne	F	N	Land surface	0				Reported to flow a small amount and to have a pressure head of less than 6 feet.
(54)	NE NW sec. 23	City of Coolidge	Dr	156	6 to 5	I	do	do	Cy,H	C	do	0		15		
55	NE SE sec. 23	Jesse Craig	Dr	290	4	I	do	do	F	D	do	0			10-25-41	Flows 25.5 gallons a minute. Reported to have a pressure head of 10 feet.

TABLE 20.—*Records of wells in Hamilton county, Kansas*—*Continued*

No. on pl. 2	LOCATION	Owner or tenant	Type of well (1)	Depth of well (ft.) (2)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Distance above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (ft.) (6)	Date of measurement	Remarks
	T. 23 S., R. 43 W.															
56	NE SW sec. 23	Mr. Fearno	Dr	298	3	I	Sandstone	Cheyenne	F	D,S	Top of 3-inch discharge pipe	+1.5			10-25-41	Flows 6 gallons a minute Water will rise 3.48 fee above measuring point
(57)	SW NE sec. 24	J. W. Egger	Dr	287	3	I	do	do	F	D,S	Land surface	0				Water in alluvium en countered at depth of 2 feet. Second water en countered in Dakota for mation at depth of 9 feet; water rose 88 feet Third water encountere at depth of 249 feet water rose 254 feet Measured flow on Nov 16, 1940, 5 gallons minute. See log 55.
58	NW SW sec. 24	Dan Huser	Du	18.0	48	C	Sand and gravel	Alluvium	C,T	S	Top of concrete curb, north side	0		8.26	11-15-40	
59	do	do	Dr	280	3	I	Sandstone	Cheyenne-Dakota	F	D,S	Top of concrete water tank	+1.95			11-13-40	Flows 1.5 gallons a minute Water rose 5.75 fee above measuring poin on Oct. 25, 1941.
60	SE SE sec. 24	J. M. Conard	Dr	285	3	I	do	do	F	D,S	do	0				Reported to flow 3 gallon a minute and to have pressure head of 3.5 ft.
61	SW SE sec. 25	Ephriam Taylor	Dr	240	6	I	do	Dakota	F	N	Top of iron casing	+2.0	3,333.7			Reported to have origi nally flowed 60 gallon a minute. Present esti mated flow, 30 gallons minute. Pressure head reported to be 4 feet.

62	NE NW sec. 26	M. B. Herrick	Dr	27.0	6	GI	Sand and gravel	Alluvium	P,H	D	Top of casing, north side	+1.0	3,341.7	8.23	10-26-40	Reported to have a smal yield.
63	SE NE sec. 27	Mr. Traxell	Dr	290	3	I	Sandstone	Cheyenne	F	S	Top of 3-inch discharge pipe	+1.53			10-25-41	Flows 2 gallons a minute Water rose 3.73 feet above measuring point
64	NW NE sec. 36	G. H. Tate	Dr	10.0	6	GI	Gravel	Alluvium	Cy,W	S	Top of casing, east side	+ .4	3,329.6	5.74	10-26-41	
	T. 24 S., R. 39 W.															
(65)	SE SE sec. 1	T. N. Thorpe	Dr	150	6	GI	(?)	Pliocene and Pleistocene	Cy,W	D,S	Land surface	0		143		
66	SW NW sec. 4	Edward Hubbard	Dr	84	6	(?)	(?)	do	Cy,W	S	do	0		78		
67	NW SW sec. 18	N. E. Jaggers	Dr	100.0	6	GI	(?)	do	N	N	Top of casing, south side	+ .2	3,220.1	47.99	11-15-40	Abandoned, formerly a stock well.
(68)	SE NE sec. 20	W. A. Dunn	Dr	20.8	6	GI	Sand and gravel	Alluvium	Cy,W	S	Top of tee joint in pipe	+2.4	3,172.2	17.31	9-21-39	
69	SW SW sec. 22	Paul Johnson	Dr	35	15	GI	Gravel	do	C,G	I	Land surface	0		25		Reported to yield 750 gallons a minute.
70	SW SE sec. 24	Belle Heinlen	Dr	106.4	6	GI	Sandstone	Dakota	Cy,W	N	Top of casing, south side	+1.3	3,181.8	54.74	do	Abandoned, formerly a stock well.
(71)	NW SE sec. 25	(not known)	Dr	65	6	(?)	do	do	Cy,H	C	Land surface	0		10		
72	SE NE sec. 26	Robert Johnson	Dr	40	18	GI	Gravel	Alluvium	C,G	I	do	0		7		Reported to yield 1,800 gallons a minute with a draw-down of 5 feet.
73	SW SW sec. 31	R. W. Beatty	Dr	36.0	6	GI	do	Pleistocene	Cy,W	N	Top of casing, east side	0	3,201.7	35.83	10- 8-40	Abandoned, formerly a stock well.
	T. 24 S., R. 40 W.															
74	NE SE sec. 6	(not known)	Dr	200	6	(?)	Sandstone	Dakota	Cy,W	D	Land surface	0	3,301.8	110		
75	SW SW sec. 6	M. Schroll	Dr	161.0	8	GI	do	do	N	N	Top of casing, north side	0	3,257.1	75.58	11-18-40	Abandoned, formerly a domestic well.
76	NE NW sec. 7	City of Syracuse	Dr	390.0	8	I	do	Cheyenne-Dakota	N	N	Top of casing	+1.0		81.00	— 1939	Abandoned, formerly a public-supply well for the city of Syracuse. Depth to water level measured in summer of 1939 by David Millsap.
77	NW SW sec. 7	do	Dr	300+	12	I	do	do	N	N	do	+1.5		25.97	11-15-40	Abandoned, formerly a public-supply well for the city of Syracuse. Casing is broken so water level is that of the water in the alluvium.
78	do	do	Dr	300+	12	I	do	do	N	N	do	+ .8		45.48	do	Abandoned, formerly a public-supply well for the city of Syracuse.

TABLE 20.—*Records of wells in Hamilton county, Kansas*—*Continued*

No.	Location	Owner or tenant	Type of well (1)	Depth of well (ft.) (2)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed		Method of lift (4)	Use of water (5)	Measuring point			Depth to water level below measuring point (ft.) (6)	Date of measurement	Remarks
							Character of material	Geologic subdivision			Description	Distance above (+) or below (−) land surface (feet)	Height above sea level (feet)			
	T. 24 S., R. 40 W.															
9	SW SE sec. 7	David Millsap	2 Dr	51	18	GI	Sand and gravel	Alluvium	C,NG	I	Land surface	0	....	13	....	Battery of 2 wells reported to yield 1,200 gallons a minute with a draw-down of 11 feet.
0	SW NW sec. 8	B. Rees	Dr	24.7	12	GI	do	do	N	N	Top of bolt in concrete curbing, west side	+ .3	3,223.6	14.42	10-10-39	Abandoned, formerly an irrigation well. Last used in 1938.
1	SW SW sec. 8	Pike Lanquist	Dr	46	18	GI	do	do	C,E	I	Land surface	0	....	12	....	Reported to yield 800 gallons a minute.
2	NW SE sec. 14	Cont'l Life Ins. Co.	Dr	24.1	6	GI	do	do	Cy,W	S	Top of casing, north side	+1.0	3,204.7	21.09	9-21-39	
3	NW SW sec. 14	Joseph Thomeczek	Dr	22	8	GI	do	do	C,G	I	Land surface	0	....	8		
4	SW NE sec. 16	Carl Graves	Dr	38	19	GI	do	do	C,G	I	do	0	....	8	....	Reported to yield 1,000 gallons a minute with a draw-down of 12 feet.
5	NW NW sec. 17	Robert Helm	Dr	50	18	GI	do	do	C,N	N	do	0	....	7	....	Abandoned, formerly an irrigation well. Not used since 1937.
6	NW NE sec. 18	David Millsap	Dr	50	(?)	(?)	do	do	T,N	N	do	0	....	12	....	Abandoned, formerly an irrigation well. To be used again in 1941.
7	NW NW sec. 18	William Marshall	2 Dr	40	18	GI	do	do	C,E	I	do	0	....	10	....	Battery of 2 wells reported to yield 1,000 gallons a minute.
8	NW NW sec 26	Russel Schroll	5 Dr	40	15	GI	do	do	C,G	I	do	0	....	7	....	Battery of 5 wells reported to yield 1,500 gallons a minute with a draw-down of 12.5 feet.
9	SE NW sec. 26	George R. Schroll	Dr	12.1	5	GI	do	do	Cy,W	S	Top of metal plate over casing	+ .3	....	8.46	9-30-39	

T. 24 S., R. 41 W.														
SW SW sec. 2	M. W. Rex	5 Dr	44.0	18	GI	do.	do.	C,E	I	Top of concrete curb of north well	+ .5	3,249.4	13.35	11-14-40	Battery of 5 wells.
NW NW sec. 3	Francis Carter	Dr	45.0	16	GI	do.	do.	T,E	I	Top of pump base	(?)	....	25.97	3-13-42	Yields 527 gallons a minute with a draw-down of 11.51 feet.
NW NW sec. 4	Murray Carter	Dr	38.0	15	GI	do.	do.	C,E	I	Top of casing	—6±	....	2.44	3-17-42	Yields 708 gallons a minute with a draw-down of 10.86 feet.
SE NE sec. 4	Merlin Carter	Dr	52	15	GI	do.	do.	C,E	I	Land surface	0	....	12	....	Reported to yield 1,000 gallons a minute with a draw-down of 14 feet.
) SE SE sec. 6	G. H. Tate	Dr	12.0	(?)	(?)	do.	do.	Cy,W	S	Top of wooden pipe clamp	0	3,269.2	9.40	10-26-40	
NE NW sec. 11	James Brogan	Dr	38	20	GI	do.	do.	C,E	I	Land surface	0	....	11	....	Reported to yield 1,100 gallons a minute with a draw-down of 12 feet.
NW NW sec. 11	do.	2 Dr	40	18	GI	do.	do.	C,T	I	do.	0	....	12	....	Battery of 2 wells reported to yield 2,000 gallons a minute.
SW NE sec. 11	George Starkey	Dr	40	16	GI	do.	do.	C,NG	I	do.	0	....	7	....	Reported to yield 500 gallons a minute with a draw-down of 7 feet.
SW NE sec. 12	Inland Utilities Co.	4 Dr	33	18	GI	do.	do.	C,E	I	do.	0	....	12	....	Battery of 4 wells reported to yield 1,100 gallons a minute. Encountered shale at depth of 33 feet.
NE SW sec. 13	H. E. Coombs	Dr	15.0	5	GI	do.	do.	Cy,W	S	Top of 1-in. board over casing	+1.0	3,234.1	12.24	10-17-40	
0) NE NE sec. 24	A. T. & S. F. Ry. Co.	Dr	82	22	GI	do.	Pleistocene	C,E	P,R	Land surface	0	....	15	....	Reported to yield 500 gallons a minute.
NW NE sec. 25	William Marshall	Du	32.0	(?)	(?)	do.	do.	Cy,W	N	Top of plank over well	0	3,246.4	28.71	10- 7-40	Abandoned, formerly a stock well.
T. 24 S., R. 42 W.														
SW NE sec. 2	G. H. Tate	Du	16.6	60	C	do.	Alluvium	Cy,W	N	Top of tee joint	+2.7	....	12.53	9-30-40	Abandoned, formerly a domestic and stock well.
SE NE sec. 4	do.	Du	11.5	8	GI	do.	do.	Cy,W	N	Top of casing, east side	+1.0	3,304.0	7.52	10-17-40	Abandoned, formerly a stock well.
4) SE SE sec. 34	M. B. Barnett	Dr	225	(?)	(?)	Sandstone	Dakota	Cy,W	D,S	Land surface	0	....	75		
T. 24 S., R. 43 W.														
SW SW sec. 2	Alpha H. Bennett	Dr	35.5	5	GI	Gravel	Pleistocene	N	N	Top of casing, west side	+ .5	3,367.8	33.85	10- 5-39	Abandoned, formerly a domestic and stock well.
6) SE SE sec. 10	do.	Dr	60	6	GI	do.	do.	Cy,W	D,S	Land surface	0	....	43		
NW SW sec. 14	E. H. Brown	Dr	128.6	5	GI	Sand	Pliocene and Pleistocene	Cy,N	N	Top of casing, west side	+ .5	3,453.3	114.83	10- 5-39	Abandoned, formerly a stock well.

TABLE 20.—*Records of wells in Hamilton county, Kansas—Continued*

No. on pl. 2	Location	Owner or tenant	Type of well (1)	Depth of well (ft.) (2)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Distance above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (ft.) (6)	Date of measurement	Remarks
	T. 24 S., R. 43 W.															
08	NW SW sec. 26	T. J. Crist	Dr	132.1	5	GI	(?)	Dakota	N	N	Top of 5-inch hole in concrete, north side	+ .4	3,489.3	116.17	10- 5-39	Abandoned, formerly a domestic and stock well.
	T. 25 S., R. 39 W.															
09	NW NW sec. 11	T. A. Wells	Dr	49.1	5	I	(?)	Pleistocene	Cy,W	N	Top of casing, north side	+1.0	....	44.26	9-30-39	Do
10	SW SW sec. 18	J. H. Lewis	Dr	145.0	6	GI	(?)	Pliocene and Pleistocene	Cy,W	N	do	0	3,321.8	132.56	10- 8-40	Do
11	SW SW sec. 20	Peter Dyke	Dr	165.5	6	(?)	Sandstone	Dakota	Cy,W	N	Top of wooden pipe clamp, east side	+ .5	3,353.6	155.89	10-10-40	Do
12	SE SW sec. 22	C. H. Miller	Dr	100.1	5	GI	(?)	Pliocene and Pleistocene	Cy,W	N	Top of casing, northwest side	+ .1	....	85.82	9-30-39	Abandoned, formerly a stock well.
113	SE SW sec. 26	do	Dr	100	5	GI	(?)	do	Cy,W	D,S	Land surface	0	....	85		
14	NW NE sec. 26	E. I. Hiatt	Dr	114.0	5	GI	(?)	do	Cy,W	N	Top of casing, north side	+ .2	3,307.1	104.46	10-10-40	Abandoned, formerly a domestic and stock well.
15	NW SW sec. 30	K. A. Scott	Dr	220.0	6	GI	Sandstone	Dakota	Cy,W	N	Top of casing, east side	+ .5	3,392.1	178.15	10- 8-40	Do
16	SE SE sec. 36	O. G. Jury	Dr	81.0	6	GI	do	do	Cy,W	N	do	+ .3	3,244.4	68.04	9- 3-40	Do
	T. 25 S., R. 40 W.															
117	NW NW sec. 7	G. R. Holman	Dr	225	(?)	(?)	do	do	Cy,W	D	Land surface	0	....	200		
18	SW SW sec. 10	W. J. Behrendt	Dr	185.0	5	GI	do	do	Cy,W	N	Top of casing, south side	0	....	131.97	10- 8-40	Do
19	NE NW sec. 18	J. V. Brittingham	Dr	241.0	5	GI	do	do	Cy,W	N	Top of wooden pipe clamp, south side	+ .3	3,415.4	236.17	do	Do
20	SE SE sec. 20	W. S. Gilpin	Dr	300+	5	GI	do	Cheyenne-Dakota	Cy,W	N	Top of casing, east side	+ .4	....	247.86	do	Do
121	SW SE sec. 22	J. W. Gayler	Dr	276	4	I	do	Dakota	Cy,W	D,S	Land surface	0	....	236		

SE SE sec. 24	B. M. Rupert	Dr	189.1	6	GI	do	do	Cy,N	N	Top of casing, east side	+1.2	3,361.4	171.30	10- 7-39	Abandoned, formerly a domestic and stock well.
NW NW sec. 26	C. R. Dollings	Dr	255.0	6	GI	do	do	Cy,W	N	Top of casing, west side	+ .3	3,411.1	213.62	10- 8-40	Do
NE NW sec. 27	S. A. Arnold	Dr	276	4	I	do	do	Cy,W	D,S	Land surface	0		240		
SE SW sec. 34	Peter Unruh	Dr	232	(?)	(?)	do	do	Cy,W	D,S	do	0		212		
T. 25 S., R. 41 W. NE NE sec. 5	Charles McCanahay	Dr	250	6	GI	do	do	Cy,W	D,S	do	0		100		Encountered Dakota formation at depth of 240 feet.
NE NE sec. 8	Isaac Forgy	Dr	328	6	GI	do	Cheyenne-Dakota	Cy,W	D,S	do	0		260		Encountered limestone at depth of 35 feet; Dakota formation at depth of 300 feet.
NE NW sec. 14	C. W. Beeler	Du	12.0	48	C	Sand and gravel	Alluvium	Cy,W	S	Top of 2-in. board over well	+1.4		10.56	10-18-40	Well was pumping when measurement was made.
SW NW sec. 14	do	Du	38	(?)	(?)	do	do	Cy,W	S	Land surface	0		30		
NE SW sec. 14	Anne Millsap	Du	69	48	(?)	Sand	Graneros(?)	Cy,W	N	do	0		60		Penetrated 8 feet of sand before entering shale at depth of 69 feet.
T. 25 S., R. 42 W. NW NE sec. 6	I. H Smithson	Dr	162.6	5	GI	Sandstone	Dakota	Cy,W	N	Top of casing, east side	+1.0		158.81	10- 6-39	Abandoned, formerly a domestic and stock well.
NW NW sec. 6	John Helfrick	Dr	165	(?)	(?)	do	do	Cy,W	D,S	Land surface	0		161		
SW NE sec. 12	E. M. Stateler	Dr	273.0	(?)	(?)	do	do	Cy,W	D,S	Top of 2-in. pipe, south side	+4.1	3,519.5	58.33	10-30-40	
T. 25 S., R. 43 W. NE NW sec. 36	J. B. Pratt	Dr	125.0	6	GI	(?)	Pliocene and Pleistocene	Cy,W	N	Top of casing, north side	+ .1	3,504.7	118.06	10-31-40	Do
T. 26 S., R. 39 W. SW NW sec. 2	W. A. Weber	Dr	151.0	6	GI	Sandstone	Dakota	Cy,W	N	Top of casing, south side	+ .2	3,305.5	122.89	10-10-40	Do
NW NW sec. 8	Fred Herrin	Dr	188.0	6	GI	do	do	Cy,W	N	Top of casing, west side	+ .2	3,389.6	164.95	do	Do
NW NW sec. 11	A. Golliart	Dr	140.1	6	GI	do	do	Cy,W	N	Top of casing, northwest side	0	3,289.1	102.69	10- 4-40	Do
NE NE sec. 22	G. D. Miller	Dr	173.0	6	GI	do	do	Cy,H	N	Top of casing, south side	+ .2	3,321.0	136.10	10-10-40	Do
SE SW sec. 22	W. C. S. Bishop	Dr	254	6	GI	do	do	Cy,W	D,S	Land surface	0		133		
NW NE sec. 26	W. E. Bereman	Dr	167.9	(?)	(?)	(?)	Pliocene and Pleistocene	Cy,W	N	Top of outer casing, northeast side	+ .3	3,298.6	129.13	10- 4-39	Abandoned, formerly a stock well.
NE SE sec. 30	J. B. Lampe	Dr	124.0	6	(?)	(?)	do	Cy,W	N	Top of casing, south side	0	3,306.0	104.57	10-10-40	Abandoned, formerly a domestic and stock well.

Table 20.—*Records of wells in Hamilton county, Kansas*—Concluded

No. on pl. 2	Location	Owner or tenant	Type of well (1)	Depth of well (ft.) (2)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed		Method of lift (4)	Use of water (5)	Measuring point			Depth to water level below measuring point (ft.) (6)	Date of measurement	Remarks
							Character of material	Geologic subdivision			Description	Distance above (+) or below (—) land surface (feet)	Height above sea level (feet)			
	T. 26 S., R. 39 W.															
42	SW SW sec. 32	J. F. Gregory	Dr	141.0	6	I	Sandstone	Dakota	Cy,W	N	Top of casing, east side	+ .8	3,262.0	128.79	8-10-39	Abandoned, formerly a domestic well.
	T. 26 S., R. 40 W.															
143	NW NW sec. 1	J. B. Lampe	Dr	210	(?)	(?)	do	do	Cy,W	D,S	Land surface	0	....	175		
44	SE SW sec. 2	C. Miller	Dr	205.0	6	(?)	do	do	Cy,W	N	Top of wooden pipe clamp, south side	+ .5	3,434.0	169.01	10- 9-40	Abandoned, formerly a domestic and stock well.
45	NW SE sec. 6	Anthony Stammen	Dr	132.0	6	GI	do	do	N	N	Top of casing, north side	+ .1	3,462.8	118.77	10-15-40	Abandoned, formerly a stock well.
46	NW NE sec. 9	P. Schmidt	Dr	162.0	4	I	do	do	Cy,H	N	Top of casing, east side	+1.0	3,447.2	156.17	10- 9-40	Abandoned, formerly a domestic well.
47	NE SE sec. 10	E. Levens	Dr	165.0	6	GI	do	do	Cy,H	N	do	0	3,409.4	120.05	10- 9-40	Abandoned, formerly a domestic and stock well.
48	NE NW sec. 18	M. Williamson	Dr	134.4	(?)	(?)	do	do	Cy,W	S	Top of bolt in pipe clamp, north side	+1.0	3,452.2	124.60	9-28-39	
49	NE NE sec. 20	Ben Wedelet	Dr	80.0	6	I	do	do	N	N	Top of casing, north side	+1.0	....	72.60	10- 9-40	Do
50	NE NE sec. 25	Federal Land Bank	Dr	155.0	6	GI	do	do	Cy,N	N	Top of casing, west side	0	3,336.3	126.07	do	Do
	T. 26 S., R. 41 W.															
151	NE SE sec. 2	J. V. Brittingham	Dr	145	5	I	do	do	Cy,W	D,S	Land surface	0	....	131		
52	SE NE sec. 14	G. H. Norton	Dr	134.0	6	I	do	do	N	N	Top of casing, east side	+6.0	3,424.8	132.84	9-19-40	
53	NW SW sec. 21	C. L. Young	Dr	11.5	6	GI	Sand and gravel	Alluvium	Cy,W	S	Top of casing, north side	+1.3	....	9.97	10-15-40	
54	SE SE sec. 36	Dorothy Jackson	Dr	36.2	6	GI	(?)	Pliocene and Pleistocene	Cy,H	N	Top of casing, south side	+ .8	3,261.3	35.80	do	Do
	T. 26 S., R. 42 W.															
55	NE NW sec. 5	Eugene Scherick	Dr	68.4	6	GI	(?)	do	Cy,W	D,S	do	+1.0	3,427.2	59.39	10- 5-39	

NW SW sec. 7	H. Dodson	Dr	100	6	GI	(?)	do	Cy,W	D,S	Land surface	0		82		
SW NW sec. 12	W. I. Crissman	Dr	63.0	6	GI	(?)	Dakota	Cy,W	N	Top of casing, west side	+2.0	3,356.6	26.52	10-15-40	Do
SE SE sec. 16	C. Boroughs	Dr	109.0	6	GI	Sand	Pliocene and Pleistocene	Cy,W	D,S	Top of casing south side	+ .4	3,433.1	88.18	10-16-40	
NE SW sec. 18	S. Loomis	Dr	105.0	5	GI	(?)	do	Cy,W	N	Top of casing, east side	+ .1		98.56	10-17-40	Do
NW NW sec. 23	J. C. Kitch	Dr	76.8	6	GI	(?)	do	Cy,W	S	do	0	3,394.2	64.48	10- 6-39	
T. 26 S., R. 43 W.															
SE NE sec. 12	H. J. Cornwell	Dr	115.6	(?)	(?)	(?)	do	Cy,W	S	Top of concrete block, 4 inches east of well	+ .3	3,471.7	101.90	10- 5-39	
NE NE sec. 14	J. D. Stewart	Dr	162.0	5	GI	Sand and gravel	do	Cy,H	N	Top of casing, east side	+ .3		120.28	10-17-40	Well originally drilled to depth of 200 feet. First water encountered at depth of 150 feet.
NW NE sec. 23	H. M. Hutchinson	Dr	187.0	5	GI	(?)	do	Cy,W	N	do	+ .5	3,501.1	117.16	do	Abandoned, formerly a domestic and stock well.
SW SW sec. 34	F. Law	Dr	197.0	6	(?)	(?)	do	Cy,W	N	Top of iron cover over well	+1.0	3,573.5	187.18	do	Do

1. B, bored; Dn, driven; Dr, drilled; Du, dug.
2. Measured depths given in feet and tenths of feet, reported depths given in feet.
3. B, barrel; C, concrete; GI, galvanized iron; I, iron; N, none; S, stone.
4. Pumps: C, centrifugal (horizontal and vertical); Cy, cylinder; F, natural flow; N, none; P, pitcher; T, turbine. Power: E, electric motor; G, gasoline engine; H, hand; N, none; NG, ural gas engine; T, tractor; W, wind.
5. C, community; D, domestic; I, irrigation; R, railroad; N, none; P, public supply; S, stock.
6. Measured water levels given in feet and in tenths and hundredths of feet, reported water levels given in feet.

TABLE 21.—*Records of wells in Kearny county, Kansas*

No. on pl. 2	Location	Owner or tenant	Type of well (1)	Depth of well (ft.) (2)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed		Method of lift (4)	Use of water (5)	Measuring point			Depth to water level below measuring point (ft.) (6)	Date of measurement	Remarks
							Character of material	Geologic subdivision			Description	Distance above (+) or below (—) land surface (feet)	Height above sea level (feet)			
	T. 21 S., R. 35 W.															
165	NE SW sec. 6	W. F. Wilken	Dr	120	(?)	(?)	Sand	Pliocene and Pleistocene	Cy,W	D,S	Land surface	0	....	100		
(166)	SW SW sec. 6	do	Dr	105.0	5	GI	(?)	do	Cy,W	S	Base of pump, south side	+ .8	3,201.15	99.23	8-29-40	
167	NE NW sec. 15	A. G. Campbell	Dr	122.9	6	GI	(?)	do	Cy,W	N	Top of casing, north side	0	3,129.08	91.48	10-19-39	Abandoned, formerly stock well.
168	NW NW sec. 17	George Riffel	Dr	90.0	6	GI	Sand and gravel	do	Cy,W	D,S	Land surface	0	3,135.65	50		
169	SW NW sec. 17	do	Dr	100	6	GI	do	do	Cy,W	N	do	0	....	40	....	Do
170	NE SW sec. 27	Maude McNellis	Dr	122	6	GI	(?)	do	Cy,W	D,S	do	0	3,092.98	100		
(171)	NE NW sec. 35	J. H. Fredalake	Dr	80	(?)	(?)	(?)	do	Cy,W	D,S	do	0	....	72		
	T. 21 S., R. 36 W.															
172	SW SW sec. 3	H. Kuhlman	Dr	77.0	6	GI	Sand and gravel	do	Cy,W	S	Top of casing, east side	+2.0	3,203.48	67.15	9- 5-40	
(173)	SW NW sec. 27	S. B. Fulmer	Dr	100	(?)	(?)	Sand	do	Cy,W	D,S	Land surface	0	....	94		
174	SW SE sec. 28	C. J. Michel	Dr	122.5	6	GI	(?)	do	Cy,W	N	Top of casing, east side	+ .3	3,231.93	109.37	do	Do
	T. 21 S., R. 37 W.															
175	SW SE sec. 1	A. J. Collingwood	Dr	132.0	5	GI	(?)	do	N	N	Top of casing, north side	+1.0	3,278.73	98.29	12-20-39	Do
(176)	SW NW sec. 4	C. P. Lanier	Dr	112	(?)	(?)	(?)	do	Cy,W	S	Land surface	0	....	104		
177	NW SW sec. 11	C. W. Walker	Dr	112.3	5	GI	(?)	do	N	N	Top of casing, north side	+ .3	3,299.18	106.97	10-16-39	Abandoned, formerly a d mestic and stock well

178	SE SW sec. 22	G. C. Whitacker	Dr	117.0	5	GI	(?)	do	Cy,W	N	Top of casing, south side	+2.0	3,303.28	114.04	9-12-40	Abandoned, formerly a stock well.
179	SE SE sec. 24	P. Marquardt	Dr	144.0	5	GI	(?)	do	Cy,T	S	Top of casing, north side	+ .5	3,270.13	131.93	9-11-40	
180	SE SE sec. 26	Service Oil Co	Dr	115.0	5	GI	(?)	do	N	N	Top of casing, east side	+ .5	3,280.68	107.96	do	Abandoned, formerly a domestic and stock well.
181	SE SE sec. 28	J. C. Anderson	Dr	103.0	6	GI	(?)	do	N	N	do	+1.1	3,303.23	91.08	9-12-40	Abandoned, formerly used to irrigate orchard.
	T. 21 S., R. 38 W.															
182	NE SE sec. 15	S. P. Biehm	Dr	76.0	6	GI	(?)	do	Cy,W	S	Top of casing, west side	+ .5	3,327.69	59.00	11- 6-40	
(183)	SE SE sec. 19	B. P. Aubun	Dr	162.0	6	(?)	(?)	do	Cy,W	S	Top of bolt in pipe clamp, west side	+ .8	3,410.80	156.07	10-23-39	
	T. 22 S., R. 35 W.															
184	NW NE sec. 6	J. P. Pinegar	Dr	102.0	6	GI	(?)	do	Cy,W	S	Top of casing, east side	0	3,167.75	89.30	8-29-40	Encountered shale at a depth of 102 feet.
185	SW SW sec. 19	G. V. Butler	Dr	92.0	6	GI	(?)	do	Cy,W	N	Top of casing, west side	+ .7	3,091.65	84.48	8-28-40	Abandoned, formerly a domestic and stock well.
186	SE SE sec. 22	Orra Dean	Dr	105.0	6	GI	(?)	do	Cy,W	N	do	+1.2	3,034.65	103.49	do	Do
187	SW NW sec. 33	H. E. Scheuerman	Dr	181	(?)	(?)	Sand and gravel	do	T,G	I	Land surface	0	....	110	....	Reported to yield 800 gallons a minute.
188	SE SE sec. 33	do	Dr	100	6	GI	do	do	Cy,W	D,S	do	0	3,044.40	85		
189	SW SW sec. 36	Joseph McNellis	Dr	84.7	5	GI	(?)	do	N	N	Top of casing, north side	0	3,005.48	71.87	9-20-40	Abandoned, formerly a domestic and stock well.
	T. 22 S., R. 36 W.															
190	NE NW sec. 15	G. H. Tate	Dr	79.0	6	GI	Sand and gravel	do	Cy,W	N	Top of 6-inch hole in concrete, west side	+ .6	3,146.39	75.53	8-29-40	Do
191	NE SE sec. 17	do	Dr	182.0	5	GI	(?)	do	Cy,W	D	Top of plate over casing	+ .1	3,236.89	170.36	do	
192	NE SE sec. 19	Federal Land Bank	Dr	176.0	6	GI	(?)	do	Cy,W	N	Top of board over casing, north side	+ .1	3,235.24	159.45	do	Do
(193)	NW NW sec. 22	R. M. Shaw	Dr	180	(?)	(?)	(?)	do	Cy,W	D,S	Land surface	0	....	177		
	T. 22 S., R. 37 W.															
194	SE SW sec. 4	A. A. Gropp Est	Dr	158.0	5	GI	(?)	do	Cy,H	N	Top of casing, south side	+ .5	3,308.51	151.89	9-11-40	Do
195	SE SW sec. 13	L. V. Tate	Dr	184	6	GI	(?)	do	Cy,W	D	Land surface	0	....	178		
196	NW NW sec. 26	Harry Tate	Dr	133.0	6	GI	(?)	do	N	N	Top of casing, east side	+ .5	3,231.00	124.27	12-20-39	
197	SW SW sec. 27	C. A. Loucks	Dr	154	(?)	(?)	(?)	do	Cy,W	D,S	Top of casing	0	....	142		
198	NW NW sec. 30	H. S. Ploeger	Dr	167.0	5	GI	(?)	do	N	N	Top of casing, north side	+1.0	3,301.60	163.73	9- 4-40	Do

TABLE 21.—*Records of wells in Kearny county, Kansas*—*Continued*

No. on pl. 2	LOCATION	Owner or tenant	Type of well (1)	Depth of well (ft.) (2)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Distance above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (ft.) (6)	Date of measurement	Remarks
	T. 22 S., R. 37 W.															
(199)	SE SE sec. 34	E. Campbell	Dr	154	(?)	(?)	(?)	Pliocene and Pleistocene	Cy,W	D,S	Land surface	0	3,219.25	142		
200	SE SE sec. 35	J. N. Davis	Dr	156	(?)	(?)	(?)	do	Cy,W	D,S	do	0	....	150		
	T. 22 S., R. 38 W.															
201	SE NE sec. 3	V. McDaniel	Dr	102.0	6	GI	(?)	do	Cy,W	N	Top of casing, west side	+ .5	3,321.60	91.06	9- 4-40	Abandoned, formerly a domestic and stock well.
202	NE SE sec. 6	J. A. Denslow	Dr	188.0	5	GI	(?)	do	Cy,W	N	Top of casing, southwest side	+ .5	3,391.40	182.80	10-23-39	Do
(203)	NW NW sec. 14	J. W. Slaven	Dr	180	(?)	(?)	Sand and gravel	do	Cy,W	D,S	Land surface	0	....	162		
204	NW NW sec. 28	T. W. Ploeger	Dr	208.0	6	GI	(?)	do	Cy,W	N	Top of metal cover over casing	+ .2	3,371.00	203.34	8-27-40	Abandoned, formerly a stock well.
205	SW SW sec. 32	W. H. Ploeger	Dr	249.9	5	GI	(?)	do	N	N	Top of casing, west side	+ .3	3,390.50	227.12	10-18-39	Do
	T. 23 S., R. 35 W.															
206	SW SE sec. 7	Adam Molz	Dr	99.0	5	GI	Sand	do	Cy,W	N	Top of casing, north side	+ .5	3,077.56	82.48	9- 5-40	Do
(207)	SW NW sec. 12	B. D. Meyer	Dr	75	(?)	(?)	do	do	Cy,W	D,S	Land surface	0	....	67		
208	NW NW sec. 13	Garden City Co.	Dr	384.0	18	N	Sand and gravel	do	N	N	Top of platform, south side	+1.0	3,010.85	64.77	8- 9-40	Abandoned, formerly an irrigation well. See log 43.
209	SE SE sec. 15	C. B. Campbell	Dr	59.8	6	GI	(?)	do	N	N	Top of casing, north side	+ .3	3,017.46	45.78	10-19-39	Abandoned, formerly a domestic and stock well.
210	SW NW sec. 20	J. F. Peiper	Dr	90	6	GI	(?)	do	Cy,W	D,S	Land surface	0	....	74		
211	NW NW sec. 25	C. C. Hamlin	Dr	294	(?)	(?)	Sand and gravel	do	T,E	I	do	0	....	52	....	Reported to yield 1,700 gallons a minute with a draw-down of 38 feet. See log 44.

212	NW NW sec. 26	Henry Mols	Dr	320	14	(?)	do	do	T,E	I	do	0	....	50	....	Reported to yield 900 gallons a minute.
213	NW SW sec. 26	J. W. Gillock	Dr	180	16	(?)	do	do	T,E	I	Base of turbine pump	(?)	3,017.85	47.80	3-26-42	Yields 812 gallons a minute with a draw-down of 32.55 feet.
(214)	NW NW sec. 29	A. C. Maddox	Dr	65	6	GI	(?)	do	Cy,W	S	Land surface	0	....	56		
215	NE SE sec. 29	do	Dr	165	(?)	(?)	Sand and gravel	do	T,E	I	Base of pump	(?)	3,024.55	31.0	....	Yields 855 gallons a minute with a draw-down of 50 feet.
216	NE NE sec. 32	M. Marquardt	Dr	150	(?)	(?)	do	do	T,E	I	Land surface	0	....	25	....	Reported to yield 900 gallons a minute with a draw-down of 42 feet.
217	NW SW sec. 34	O. J. Downing	Dr	180	(?)	(?)	do	do	T,E	I	do	0	3,012.11	39.2	....	Yields 480 gallons a minute with a draw-down of 56.2 feet.
	T. 23 S., R. 36 W.															
218	NW NW sec. 2	Carl Marquardt	Dr	151.0	5	GI	(?)	do	Cy,W	N	Top of casing, west side	0	3,164.78	138.64	8-28-40	Abandoned, formerly a domestic and stock well.
219	SW NW sec. 10	F. G. Worthen	Dr	97.9	5	GI	(?)	do	Cy,W	N	Top of casing, east side	+ .6	3,126.52	94.63	10-16-39	Do
220	SW SE sec. 14	N. B. Siebert	Dr	106.0	5	GI	(?)	do	Cy,W	N	Top of casing, west side	+ .3	3,118.71	97.16	8-28-40	Do
221	SW NW sec. 26	T. N. Thorpe	Dr	179.0	5	GI	(?)	do	Cy,W	N	Top of casing, east side	0	3,172.91	149.77	do	Do
222	NW SW sec. 35	George Finnup	Dr	113.0	6	GI	(?)	do	Cy,W	N	Top of wooden pipe clamp, south side	0	3,127.08	105.13	do	Abandoned, formerly a stock well.
	T. 23 S., R. 37 W.															
223	NE NE sec. 4	W. H. S. Eckhardt	Dr	206	6	GI	Sand and gravel	do	Cy,W	D	Land surface	0	....	188		
224	SW NW sec. 5	M. Smith	Dr	205	(?)	(?)	Sand	do	Cy,W	D,S	do	0	....	196		
225	SE NE sec. 9	J. L. Burnett	Dr	215.0	6	GI	(?)	do	Cy,WH	N	Top of casing, north side	+1.0	3,288.62	200.86	9- 6-40	Abandoned, formerly a domestic and stock well.
226	SE NE sec. 28	Perry Bryan	Dr	215.0	5	GI	(?)	do	N	N	Top of casing, southwest side	+ .7	3,283.84	205.88	do	Do
	T. 23 S., R. 38 W.															
227	NW NW sec. 3	B. Strowbridge	Dr	220.0	5	GI	(?)	do	N	N	Top of casing, west side	+ .3	3,357.4	207.58	8-27-40	Do
(228)	SE NE sec. 5	W. H. Ploeger	Dr	250	(?)	(?)	Sand	do	Cy,W	D,S	Land surface	0	....	228		
229	SW SW sec. 23	H. Gaeddert	Dr	234.0	5	GI	(?)	do	Cy,H	N	Top of casing, west side	+ .6	3,347.6	225.36	9-12-40	Abandoned, formerly a domestic well.
(230)	SW SE sec. 25	G. M. Dittmer	Dr	223	(?)	(?)	Sand and gravel	do	Cy,W	S	Land surface	0	....	218		
231	NE NW sec. 32	W. J. Roth	Dr	183.0	6	GI	(?)	do	Cy,W	N	Top of casing, north side	+ .4	3,312.7	175.66	8-19-40	Abandoned, formerly a domestic and stock well.

TABLE 21.—*Records of wells in Kearny county, Kansas*—Continued

No. on pl. 2	Location	Owner or tenant	Type of well (1)	Depth of well (ft.) (2)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Distance above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (ft.) (6)	Date of measurement	Remarks
	T. 24 S., R. 35 W.															
232	NW NW sec. 2	R. Bentrup	Dr	30.8	8	GI	(?)	Pliocene and Pleistocene	Cy,W	N	Top of casing, west side	+ .2	2,994.98	26.52	10-17-39	Abandoned, formerly a domestic and stock well.
233	NE SE sec. 2	Deerfield Township	Dr	180	(?)	(?)	Sand and gravel	do	Cy,E	I	Land surface	0	2,988.28	25	....	Reported to yield 10 gallons a minute.
(234)	SE NE sec. 3	H. A. Mansfield	Dr	36	(?)	(?)	(?)	Pleistocene	Cy,W	S	do	0	....	26		
235	NW SW sec. 3	Adam Molz	Dr	310	(?)	(?)	Sand and gravel	Pliocene and Pleistocene	T,E	I	do	0	....	24	12-16-39	Yields 1,465 gallons a minute.
236	SW NE sec. 5	Charles Bentrup	Dr	352	16	GI	do	do	T,E	I	do	0	....	48	....	Reported to yield 880 gallons a minute with a draw-down of 20 feet.
237	NW NW sec. 9	Garden City Co.	Dr	(?)	24	I	do	do	N	N	Top of hole in base plate, south side	+1.0	3,001.35	23.55	10-17-39	Abandoned, formerly an irrigation well.
238	SW SW sec. 9	August Kettler	Dr	253.0	16	GI	do	do	T,E	I	Base of pump	(?)	2,998.05	32.55	12- 1-41	Yields 637 gallons a minute with a draw-down of 61.13 feet. See log 41.
239	NW SE sec. 11	Garden City Co.	5 Dr	50	18	GI	do	Alluvium	C,E	I	Land surface	0	....	15	....	Battery of 5 wells. Reported to yield 800 gallons a minute.
240	NE NE sec. 13	Phoenix Joint Stock Land Bank	Dr	13.4	6	GI	do	do	N	N	Top of casing, southeast side	+2.0	2,926.84	6.65	10-17-39	Abandoned, formerly a stock well.
241	SW NW sec. 13	Garden City Co.	5 Dr	50	16	GI	do	do	C,E	I	Land surface	0	....	10	....	Battery of 5 wells reported to yield about 1,250 gallons a minute.
242	do	do	5 Dr	30	16	GI	do	do	C,E	I	Top of concrete curb, north side	+1.2	2,935.54	10.81	8- 8-40	Battery of 5 wells reported to yield 1,250 gallons a minute; measured draw-down of 5.97 feet.

243	NW SW sec. 13	do	5 Dr	50	16	GI	do	do	C,E	I	Land surface	0		12		Battery of 5 wells reported to yield 1,250 gallons a minute.
244	SW SW sec. 13	do	5 Dr	50	16	GI	do	do	C,E	I	do	0		14		Do
245	do	do	5 Dr	50	16	GI	do	do	C,E	I	do	0		16		Do
246	SE SW sec. 13	American Life Ins. Co.	4 Dr	20.0	16	GI	do	do	C,G	N	Top of 2-inch plank over well, east side	+ .4	2,939.24	17.00	8- 6-40	Battery of 4 wells. Formerly used for irrigation.
247	NW NE sec. 14	C. Dale	Dr	40	(?)	(?)	do	do	C,E	I	Land surface	0		10		Reported to yield 1,000 gallons a minute.
248	SE NE sec. 14	Charles Bentrup	Dr	15.0	5	GI	do	do	N	N	Top of casing, east side	+1.0	2,934.94	8.02	8-12-40	Abandoned, formerly a stock well.
249	NW sec. 17	do	Dr	267	16	GI	do	do	T,E	I	Land surface	0		42		Reported to yield 950 gallons a minute with a draw-down of 20 feet.
250	NW SE sec. 20	Raymond Walters	8 Dr	45	18	GI	do	do	C,E	I	do	0		15		Battery of 8 wells reported to yield 1,200 gallons a minute with a draw-down of 13 feet.
251	SW SW sec. 21	L. F. Roderick	4 Dr	27.0	12	GI	do	do	C,E	I	Top of concrete curb, northwest side	+1.7	2,965.69	15.53	8- 6-40	Battery of 4 wells reported to yield 1,680 gallons a minute.
252	SE SW sec. 22	J. E. Beymer	6 Dr	46.7	14	GI	do	do	C,E	I	Top of concrete curb, west side	+ .4	2,954.84	14.62	10-17-39	Battery of six wells; measured aggregate yield on July 17, 1939 was 1,810 gallons a minute with a draw-down of 8.85 feet.
253	NE NE sec. 23	Garden City Co.	5 Dr	50	16	GI	do	do	C,E	I	Land surface	0		15		Battery of 5 wells reported to yield 1,250 gallons a minute.
254	SW NW sec. 23	R. F. Bardwell	6 Dr	45	15	GI	do	do	C,E	I	Top of concrete curb	+1.0		16.44	7-18-39	Battery of 5 wells yields 1,625 gallons a minute with a draw-down of 9.77 feet.
255	SE NE sec. 23	Garden City Co.	5 Dr	50	16	GI	do	do	C,E	I	Land surface	0		15		Battery of 5 wells reported to yield 1,250 gallons a minute.
256	NE SE sec. 23	do	5 Dr	50	16	GI	do	do	C,E	I	do	0		16		Do
257	NW SE sec. 23	do	5 Dr	50	16	GI	do	do	C,E	I	do	0		16		Do
258	SW SW sec. 23	W. A. Taylor Est.	3 Dr	35	16	GI	do	do	C,E	I	do	0		15		Battery of 3 wells reported to yield 900 gallons a minute.

TABLE 21.—*Records of wells in Kearny county, Kansas—Continued*

No. on pl. 2	Location	Owner or tenant	Type of well (1)	Depth of well (ft.) (2)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Distance above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (ft.) (6)	Date of measurement	Remarks
	T. 24 S., R. 35 W.															
59	SE SW sec. 23	Garden City Co.	5 Dr	28.5	16	GI	Sand and gravel	All vium	C,E	I	Top of concrete curb, east side	0	2,948.39	21.36	8- 8-40	Battery of 5 wells reported to yield 1,250 gallons a minute. Pumped the day before water-level measurement.
60	SW SE sec. 23	do.	5 Dr	50	16	GI	do.	do.	C,E	I	Land surface	0	....	17	....	Battery of 5 wells reported to yield 1,250 gallons a minute.
61	NW NW sec. 24	do.	5 Dr	41.7	16	GI	do.	do.	C,E	I	Top of concrete curb, east side	0	2,939.54	16.79	8-12-40	Do
62	SW SE sec. 25	C. C. Hamlin	Dr	45.0	5	GI	do.	Pleistocene	Cy,W	S	Top of casing, east side	+1.1	2,965.09	34.88	9-10-40	
63	NE NE sec. 26	F. Kriete	Dr	45	(?)	(?)	do.	Alluvium	C,NG	I	Land surface	0	....	15	....	Reported to yield 50 gallons a minute.
64	NW NE sec. 26	H. C. Kriete	Dr	53.0	12	GI	do.	do.	C,E	I	Top of casing, west side	—10.0	....	10.55	8- 8-40	Reported to yield 700 gallons a minute. Measured draw-down was 7.13 feet.
65	NE NW sec. 26	Garden City Co.	5 Dr	50	16	GI	do.	do.	C,E	I	Land surface	0	....	19	....	Battery of 5 wells reported to yield 1,250 gallons a minute.
66	SW NW sec. 27	E. R. McCue	5 Dr	42	15	GI	do.	do.	C,E	I	do.	0	....	15	....	Battery of 5 wells reported to yield 2,800 gallons a minute.
67	NW SW sec. 27	G. L. McCue	6 Dr	56.0	18	GI	do.	do.	C,G	I	Top of casing, west side	+1.0	2,960.19	16.52	8-12-40	Battery of 6 wells reported to yield 2,000 gallons a minute.
68	SW SW sec. 28	E. A. Smith	Dr	100	20	GI	do.	Alluvium and Pleistocene	T,E	I	Center of discharge pipe	(?)	....	13.22	3-27-42	Yields 1,080 gallons a minute with a draw-down of 19.4 feet.

NE NE sec. 29	R. B. Ernest	2 Dr	43	24	GI	do	Alluvium	C,NG	I	Land surface	0	....	14	....	Battery of 2 wells reported to yield 1,000 gallons a minute.
NW NW sec. 29	A. D. White	Dr	25	(?)	(?)	do	do	Cy,W	S	do	0	....	15		
SW NW sec. 29	do	Dr	212	18	(?)	do	do	T,E	I	Top of hole in concrete block, west side	+1.6	2,975.69	17.90	8- 7-40	Reported to yield 1,800 gallons a minute with a draw-down of 32 feet. The water-level measurement was made in old well 20 feet to the northeast.
SE NW sec. 30	E. M. Beymer	8 Dr	40	16	GI	do	do	C,E	I	Land surface	0	....	15	....	Battery of 8 wells reported to yield 2,000 gallons a minute.
NW SE sec. 30	G. W. Singleton	12 Dr	40	16	GI	do	do	C,E	I	do	0	....	20	....	Battery of 12 wells reported to yield 2,800 gallons a minute.
SW SW sec. 30	Louis Burg Est	5 Dr	46.0	18	GI	do	do	C,E	I	Top of concrete curb, east side	+1.5	2,986.69	22.12	8- 6-40	Battery of 5 wells reported to yield 2,000 gallons a minute.
SW NW sec. 31	Irene Thorpe Est	6 Dr	40.5	18	GI	do	do	C,E	I	Top of concrete curb, west side	+1.7	....	15.34	do	Battery of 6 wells reported to yield 4,480 gallons a minute.
SW SW sec. 31	T. H. Orr	9 Dr	40.5	18	GI	do	do	C,G	I	Top of 2-inch plank over well, east side	+ .2	2,985.59	16.55	8- 5-40	Battery of 9 wells reported to yield 3,000 gallons a minute.
NW NE sec. 32	R. L. Edson	2 Dr	30	24	GI	do	do	C,E	I	Land surface	0	....	18	....	Battery of 2 wells reported to yield 800 gallons a minute.
SW NW sec. 32	M. E. Lee	4 Dr	45	15	GI	do	do	C,E	I	Top of concrete curb	(?)	....	17.65	12- 6-40	Battery of 4 wells reported to yield 1,500 gallons a minute.
NW SW sec. 32	R. G. Morris	4 Dr	31.5	18	GI	do	do	C,E	I	Top of concrete curb, north side	+1.1	2,978.49	17.03	8- 6-40	Battery of 4 wells reported to yield 1,000 gallons a minute.
SE SW sec. 33	E. L. White	5 Dr	48	15	GI	do	do	C,E	I	Land surface	0	....	16	....	Battery of 5 wells reported to yield 2,200 gallons a minute.
SE SW sec. 33	Claude Harpster	6 Dr	36.7	18	GI	do	do	C,G	I	Top of galvanized-iron rim, east side	+1.4	2,969.49	15.86	8- 5-40	Have not been used for several years.
NW NW sec. 34	E. McKee	6 Dr	45	18	GI	do	do	C,E	I	Land surface	0	....	15	....	Battery of 6 wells reported to yield 2,000 gallons a minute.
T. 24 S., R. 36 W.															
SE SE sec. 10	A. D. Millyard	Dr	57.5	6	GI	(?)	Pleistocene	Cy,W	N	Top of casing, west side	+ .3	3,058.43	50.28	8- 7-40	Abandoned, formerly a stock well.

TABLE 21.—*Records of wells in Kearny county, Kansas—Continued*

Location	Owner or tenant	Type of well (1)	Depth of well (ft.) (2)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Distance above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (ft.) (6)	Date of measurement	Remarks
T. 24 S., R. 36 W.															
NW NE sec. 12	O. A. White	Dr	204	16	GI	(?)	Pliocene and Pleistocene	T,E	I	Land surface	0	....	37.5	....	Reported to yield 700 gallons a minute with a draw-down of 22.5 feet.
SW SE sec. 15	L. V. Tate	Dr	49.0	6	GI	(?)	Pleistocene	Cy,W	N	Top of casing, north side	+ .4	3,044.23	43.91	8-28-40	Abandoned, formerly a stock well.
SE SE sec. 16	C. E. Worthen	Dr	64.2	6	GI	(?)	do	Cy,W	N	Top of casing, south side	+ .2	3,064.49	58.68	10-16-39	Do
NW NE sec. 22	A. D. White	Dr	170	16	GI	Sand and gravel	do	T,E	I	Land surface	0	....	35	12-13-38	Yields 1,280 gallons a minute with a draw-down of 90 feet.
SW SE sec. 22	Frank Stewart	Dr	25.0	6	GI	do	Alluvium	Cy,E	C	Top of concrete wall, north side	+1.3	3,006.63	17.72	11- 9-40	
SW NW sec. 23	Lakin cemetery	Dr	172	8	I	(?)	Pleistocene	Cy,E	I	Top of casing, south side	+ .6	3,034.03	42.18	8- 7-40	Reported to yield 30 gallons a minute.
SW SE sec. 25	H. L. Burg	10 Dr	33	16	GI	Sand and gravel	Alluvium	C,E	I	Land surface	0	....	17.5	....	Battery of 10 wells reported to yield 1,800 gallons a minute with a draw-down of 12.5 feet.
SW SW sec. 26	L. V. Tate	7 Dr	25	19	GI	do	do	C,G	I	do	0	....	11.2	....	Encountered clay at a depth of 25 feet.
NE NW sec. 27	Roy Puyear	Dr	220	4.5	I	(?)	Alluvium, Pliocene and Pleistocene	N	N	Top of casing, east side	0	....	12.84	10-23-39	Abandoned, formerly a domestic well.
NW NW sec. 27	City of Lakin	Dr	273	18	I	Sand and gravel	Pliocene and Pleistocene	T,E	P	Land surface	0	....	18	....	Reported to yield 560 gallons a minute with a draw-down of 40 feet after 20 hours of pumping. See log 40.
SE NW sec. 27	do	Dr	231	15	I	do	do	T,E	P	do	0	....	15	....	Reported to yield 240 gallons a minute with a draw-down of 40 feet.

5	NE SE sec. 27	Fleet Thomas	2 Dr	28	12	GI	do	Alluvium	C,E	I	Land surface	0	....	11	....	Battery of 2 wells reported to yield 600 gallons a minute.
6	SW SE sec. 27	Mae Beatty	3 Dr	35	(?)	(?)	do	do	C,E	I	do	0	....	11	....	Battery of 3 wells reported to yield 500 gallons a minute.
7	SW SE sec. 28	Virginia Hicks	Dr	32.5	6	GI	do	fo	Cy,W	N	Top of casing, west side	0	3,023.95	25.46	8- 7-40	Abandoned, formerly a stock well.
8	NE SW sec. 29	Bert Cooper Est	Dr	42.0	6	GI	(?)	Pliocene and Pleistocene	Cy,N	N	Top of casing, north side	+1.2	3,049.25	39.22	8-28-40	Do
9	SE SE sec. 33	Eva Beatty	Dr	11.3	5	GI	Sand and gravel	Alluvium	N	N	do	+ .6	3,003.89	8.30	8- 3-40	Do
0	NW NE sec. 34	R. T. Beatty	Dr	94.6	16	GI	do	do	N	N	Top of 16-inch hole in concrete block, south side	+ .5	3,000.94	11.83	10-16-39	Abandoned, formerly an irrigation well.
1	do	do	Dr	45	16	GI	do	do	T,NG	I	Land surface	0	....	12	....	Reported to yield 900 gallons a minute.
2	SW SE sec. 34	C. E. Beymer	Dr	14.7	12	GI	do	do	N	N	Top of casing, north side	+1.2	2,999.34	9.54	do	Abandoned, formerly a stock well.
3	NE NW sec. 36	K. E. Roderick	5 Dr	40	18	GI	do	do	C,E	I	Land surface	0	....	13	....	Battery of 5 wells reported to yield 2,000 gallons a minute with a draw-down of 17 feet.
4	SW SE sec. 36	H. L. Gibeaut	Dr	45	12	GI	do	do	C,G	I	do	0	....	15	....	Reported to yield 1,000 gallons a minute with a draw-down of 15 feet.
	T. 24 S., R. 37 W.															
5	SE SW sec. 18	B. P. Graber	Dr	183.5	(?)	(?)	(?)	Pliocene and Pleistocene	Cy,W	N	Top of hole in pump base, southeast side	+1.0	3,286.57	182.27	9-12-40	Abandoned, formerly a domestic and stock well.
06)	SE SE sec. 20	Mary Krehbiel	Dr	200	6	GI	(?)	do	Cy,W	D,S	Land surface	0	....	190		
	NW SE sec. 24	Ralph Ray	Dr	100.0	4.5	I	(?)	do	Cy,W	N	Top of casing, north side	+ .1	3,137.40	96.04	9- 6-40	Do
	NW NW sec. 26	Meta Kettler	Dr	173.5	6	GI	(?)	do	Cy,W	N	Top of casing, east side	+ .5	3,222.35	154.88	10-16-39	Do
	SE SE sec. 28	C. E. Beymer	Dr	198	6	GI	Sand	do	Cy,W	D,S	Land surface	0	....	188		
	T. 24 S., R. 38 W.															
0)	SE NE sec. 6	V. H. Wells	Dr	174	6	GI	(?)	do	Cy,W	D,S	do	0	....	169		
1)	SW SW sec. 22	E. Wiatt	Dr	145	(?)	(?)	Sand	do	Cy,W	D,S	do	0	....	132		
	NW NW sec. 24	Thomas Dodge	Dr	123.0	4.5	I	(?)	do	Cy,W	N	Top of casing, south side	+ .6	3,237.69	118.91	9-12-40	Do
	SW SE sec. 25	G. H. Cook	Dr	92.7	1	GI	(?)	do	Cy,W	N	Top of casing, northeast side	+ .4	3,235.70	72.30	10-20-40	Do

TABLE 21.—*Records of wells in Kearny county, Kansas*—*Continued*

Location	Owner or tenant	Type of well (1)	Depth of well (ft.) (2)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Distance above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (ft.) (6)	Date of measurement	Remarks
T. 24 S., R. 38 W.															
NW SW sec. 30	Thomas Wright	3 Dr	39	18	GI	Sand and gravel	Alluvium	C,G	I	Land surface	0	....	20	....	Battery of 3 wells reported to yield 900 gallons a minute with a draw-down of 15 feet.
T. 25 S., R. 35 W.															
SE NE sec. 2	H. C. Kriete	Dr	50	5	GI	do	Pleistocene	Cy,W	S	Top of casing, south side	+ .2	2,973.14	38.95	9-10-40	
NE SE sec. 14	O. Dean	Dr	56.0	5	GI	do	do	Cy,W	S	Top of casing, east side	+ .5	2,980.94	49.58	do	
SW SW sec. 18	M. E. Thornbrough	Dr	60	5	GI	do	do	Cy,W	N	do	+ .2	3,012.94	48.29	9- 9-40	Abandoned, formerly a stock well.
NW SE sec. 32	Earl Campbell	Dr	70	6	GI	do	do	Cy,W	N	Top of casing, north side	+ .5	3,009.24	57.76	9- 8-40	Do
NE NE sec. 34	A. D. White	Dr	59.0	6	GI	do	do	Cy,W	S	Top of casing, south side	0	2,990.29	51.05	9-10-40	
SW NW sec. 36	L. V. Tate	Dr	72.5	6	GI	do	do	Cy,W	N	Top of casing, north side	+2.2	2,990.39	70.35	do	Do
T. 25 S., R. 36 W.															
SW NW sec. 1	Basil McCue	5 Dr	46.0	18	GI	do	Alluvium	C,E	I	Top of concrete curb, west side	+ .3	2,993.49	14.39	8- 5-40	Battery of 5 wells reported to yield 1,800 gallons a minute.
SE SE sec. 2	M. A. Gilyeat	Dr	19.0	12	GI	do	do	C,T	I	Top of 6-inch plank over well	+ .5	2,990.09	10.42	do	Reported to yield 100 gallons a minute.
SW SW sec. 3	Colorado Title and Trust Company.	5 Dr	36.8	18	GI	do	do	C,E	I	Top of concrete curb, southwest side	+1.0	3,009.49	14.75	8- 3-40	Battery of 5 wells reported to yield 2,000 gallons a minute.
NW SE sec. 4	Charles Tate	Dr	50	16	I	do	do	T,E	I	Top of casing	0	....	13.8	....	Reported to yield 1,070 gallons a minute with a draw-down of 11.5 feet.
SW SW sec. 4	C. O. Spiers	5 Dr	45.0	16	GI	do	do	C,E	I	Top of concrete curb, north side	+ .3	3,018.19	15.40	8- 4-40	Battery of 5 wells reported to yield 2,000 gallons a minute.
SW SW sec. 7	G. E. Gano	5 Dr	41.5	18	GI	do	do	C,E	I	Top of concrete curb, west side	+1.3	3,037.69	18.52	8- 3-40	Do
NW SW sec. 8	Georgia Menn	3 Dr	47.0	18	GI	do	do	C,E	I	Top of concrete curb, northeast side	+ .3	3,027.89	16.25	8- 5-40	Battery of 3 wells reported to yield 1,500 gallons a minute.

328	SW NW sec. 9	G. E. Gano	5 Dr	40	12	GI	do	do	C,E	I	Top of iron rail over well, west side	0	3,018.59	15.57	8- 4-40	Battery of 5 wells reported to yield 1,700 gallons a minute.
329	SW SW sec. 9	do	5 Dr	40	12	GI	do	do	C,E	I	Land surface	0	....	15	....	Battery of 5 wells reported to yield 2,000 gallons a minute.
330	NW NE sec. 10	G. W. Finnup	Dr	15.3	5	GI	do	do	N	N	Top of casing, south side	0	3,003.74	11.78	8- 3-40	Abandoned, formerly a stock well.
331	NW NW sec. 10	R. S. Worthen	5 Dr	39	18	GI	do	do	C,E	I	Land surface	....	....	15	....	Battery of 5 wells reported to yield 2,000 gallons a minute.
332	NW SW sec. 10	E. R. Thorpe	5 Dr	34.5	18	GI	do	do	C,E	I	Top of concrete curb, south side	+2.0	3,010.29	14.98	8- 4-40	Battery of 5 wells reported to yield 2,000 gallons a minute with a draw-down of 7 feet.
333	SW SE sec. 10	G. E. Porter	3 Dr	40	18	GI	do	do	C,E	I	Land surface	0	....	14	....	Battery of 3 wells reported to yield 1,000 gallons a minute.
334	SW NE sec. 11	P. J. Fichter	4 Dr	(?)	15	GI	do	do	C,N	N	Top of concrete curb	+1.0	....	10.28	5-23-34	Abandoned, formerly an irrigation well. Water level measured by H. A. Waite.
335	SW SW sec. 11	do	5 Dr	32.8	16	GI	do	do	C,E	N	Top of bolt in concrete curb, west side	+ .5	3,005.89	14.68	10-17-39	Abandoned, formerly an irrigation well.
336	NW NW sec. 14	Earl Campbell	Dr	47.0	6	I	do	Pleistocene	Cy,W	N	Top of casing, east side	+1.5	3,035.64	45.42	9- 9-40	Abandoned, formerly a stock well.
337	SW NW sec. 17	G. E. Gano	6 Dr	33.0	18	GI	do	Alluvium	C,E	I	Top of curb, south side	+1.1	3,029.29	16.90	8- 5-40	Battery of 6 wells reported to yield 1,800 gallons a minute.
338	NE NE sec. 23	Earl Campbell	Dr	63.0	6	GI	do	Pleistocene	Cy,W	N	Top of casing, north side	+1.0	3,026.64	47.38	9- 8-40	Abandoned, formerly a stock well.
339	SE NE sec. 26	L. F. Roderick	Dr	30.0	6	I	do	do	Cy,W	S	Top of casing, northwest side	+ .8	3,022.34	28.65	do	Do
	T. 25 S., R. 37 W.															
340	NW SW sec. 8	C. H. Browne	Dr	74.2	5	GI	Sandstone	Dakota	C,N	N	Top of casing, east side	+ .5	3,117.11	53.87	10-16-39	Abandoned, formerly a domestic and stock well.
(341)	SW SE sec. 10	Owner unknown	Dn	16	(?)	N	Sand and gravel	Alluvium	P,H	D	Land surface	0	....	9		
342	NE SE sec. 14	Lois Treville	Dr	28.5	6	GI	do	do	Cy,W	N	Top of casing, west side	+ .2	3,045.04	24.30	9- 3-40	Do
343	NW NE sec. 15	D. S. Nicholson	Du	15.7	24	B	do	do	C,E	I	Top of casing, south side	— .4	3,049.47	8.16	10-18-39	Reported to yield 75 gallons a minute.
344	SE NW sec. 16	C. A. Ridge	Dr	36.0	5	GI	do	do	Cy,H	N	Top of casing, west side	+ .9	3,065.12	14.10	9-14-40	Abandoned, formerly a domestic well.
345	SE SW sec. 17	A. M. Fleming	B	12.0	6	GI	do	do	Cy,W	N	Top of casing, north side	+ .2	3,068.25	5.43	9- 6-40	Abandoned, formerly a domestic and stock well.

TABLE 21.—*Records of wells in Kearny county, Kansas—Concluded*

No. on pl. 2	Location	Owner or tenant	Type of well (1)	Depth of well (ft.) (2)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Distance above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (ft.) (6)	Date of measurement	Remarks
	T. 25 S., R. 37 W.															
346	SW SE sec. 24	W. H. Johnson	Dr	27.0	6	GI	Sand and gravel	Pleistocene	Cy,W	N	Top of casing, south side	+1.5	3,040.84	25.95	9- 8-40	Abandoned, formerly stock well.
	T. 25 S., R. 38 W.															
347	NE sec. 5	R. T. Beatty	Du	9.0	24	B	do	Alluvium	Cy,W	N	Top of casing, east side	+1.2	....	6.61	9- 6-40	Do
(348)	NW NW sec. 11	do	Dr	15	6	GI	do	do	Cy,W	S	Land surface	0	....	11		
	T. 26 S., R. 36 W.															
349	SE SE sec. 35	Federal Land Bank	Dr	122.9	5	I	(?)	Pleistocene	N	N	Top of casing, south side	+1.5	3,073.00	121.60	10-24-39	Abandoned, formerly a domestic and stock well.
	T. 26 S., R. 37 W.															
350	NW NW sec. 2	Louis Moore	B	27.5	6	GI	Sand and gravel	do	Cy,W	N	Top of casing, east side	+ .4	3,044.99	25.65	9- 8-40	Abandoned, formerly stock well.
351	NW NW sec. 18	James Coghill	Dr	205.5	6	GI	(?)	do	Cy,W	N	do	+ .7	3,203.55	174.63	10-24-39	Abandoned, formerly a domestic and stock well.
352	NE NE sec. 20	G. H. Tate	Dr	172	5	I	(?)	do	Cy,W	N	Top of casing, south side	+1.0	3,121.25	105.50	9- 3-40	Do
353	SE SE sec. 22	Anna Davidson	Dr	100.1	4.5	I	(?)	do	N	N	do	+ .4	3,092.53	86.30	10-24-40	Do
354	NW SW sec. 33	H. P. Johnson	Dr	53.0	(?)	(?)	Sand and gravel	do	Cy,W	S	Top of metal plate over casing	+ .3	3,064.12	33.67	7-18-41	
(355)	SW SW sec. 35	Anna Davidson	Dr	160	6	GI	do	do	Cy,W	D,S	Land surface	0	3,102.12	95		
	T. 26 S., R. 38 W.															
(356)	SW SW sec. 3	R. T. Beatty	Dr	160	6	GI	Sandstone	Dakota	Cy,W	S	do	0	....	140		
357	NE NW sec. 8	E. M. Beymer	Dr	151.7	(?)	(?)	do	do	Cy,W	N	Top of galvanized iron plate over casing	0	3,247.40	130.87	10-23-39	Do
358	SE SW sec. 31	J. P. Schaeffer	Dr	132.0	6	GI	Sand and gravel	Pleistocene	Cy,T	S	Top of wooden pipe clamp, west side	+ .6	3,213.10	123.85	9- 3-40	

59)	SW SW sec. 34	William Harvey	Dr	135	(?)	(?)	(?)	do	Cy,W	D,S	Land surface	0	3,181.80	115		
0	(7) *T. 20 S., R. 35 W.* NE SE sec. 34	Not known	Dr	125.0	6	GI	(?)	do	Cy,H	N	Top of casing, southeast side	+ .5	3,165.63	118.53	9- 5-40	Do
1	(8) *T. 27 S., R. 36 W.* NW NW sec. 5	do	Dr	163.3	4.5	I	(?)	do	Cy,WG	S	Top of casing, north side	+4.5	3,095.40	123.99	10-24-39	

1. B, bored; Dn, driven; Dr, drilled; Du, dug.
2. Measured depths given in feet and tenths of feet, reported depths given in feet.
3. B, barrel; C, concrete; GI, galvanized iron; N, none; S, stone.
4. Pumps: C, centrifugal (horizontal and vertical); Cy, cylinder; N, none; P, pitcher; T, turbine.
ower: E, electric motor; G, gasoline engine; H, hand; N, none; NG, natural gas engine; T, tractor; W, wind.
5. C, community; D, domestic; I, irrigation; N, none; P, public supply; S, stock.
6. Measured water levels given in feet and in tenths and hundredths of feet, reported water levels given in feet.
7. Well in Wichita county, Kansas.
8. Well in Grant county, Kansas.

WELL LOGS

Listed in the following pages are the logs of 70 wells and test holes in Hamilton and Kearny counties, including 27 test holes drilled by the State and Federal Geological Surveys (1-27), 32 water wells (28-59), and 11 oil- and gas-test wells (60-70). The locations of the test holes are shown in figure 2 and most of the wells are shown on plate 2. About two-thirds of the logs were made by well drillers, and many of the drillers' rock names have been changed to conform with geologic terminology. "Gyp" or "gyp rock" has been interpreted to mean caliche, and "soapstone" has been changed to shale or clay. The term "sandrock" is used by drillers to describe a rock that is so well consolidated that no casing is needed to prevent caving. In the Dakota and Cheyenne formations this has been interpreted to mean sandstone and in the Tertiary and Quaternary deposits it implies a consolidated sand and gravel deposit (often called mortar bed). Much of the Ogallala formation has been logged by well drillers as clay, but in those wells from which cuttings were available for study it was found that much of the so-called clay was silt.

1. Log of test hole 1 in the SE¼ SW¼ sec. 32, T. 20 S., R. 34 W. (Scott county), drilled by State and Federal Geological Surveys, 1940. Surface altitude, 3,089.5 feet. (Authority, samples studied by Perry McNally, H. A. Waite, Bruce F. Latta, and Thad McLaughlin.)

	Thickness, feet	Depth, feet
Soil, sandy, dark	1.5	1.5
Undifferentiated Pleistocene deposits		
Silt and sand, fine; limy; tan; containing gastropods	11	12.5
Silt and sand, fine; pinkish-brown; containing thin limy zones	5.5	18
Caliche, soft, tan to light gray	6	24
Sand, fine to medium, pinkish-brown, containing some silt,	2.5	26.5
Caliche, soft, tan-gray; and clay, limy	6.5	33
Clay, tan-gray	5	38
Sand, medium, to gravel, medium; brown	16.5	54.5
Ogallala formation (?)		
Sand and gravel; lime-cemented, gray	4	58.5
Sand, medium, to gravel, coarse; brown; contains a few lime-cemented zones	37	95.5
Silt, sandy, light gray-yellow	8	103.5
Silt, sandy, lime-cemented, soft, light gray; contains lenses of brown, fine to medium sand and fragments of *Celtis willistoni* (?) and *Biorbia fossilia* (?)	15.5	119

Niobrara formation		
Smoky Hill chalk member		
Chalk, silty, soft, light yellow to light gray	15	134
Shale, chalky, soft, dark blue-gray; contains a few fragments of white bentonite	6	140
Shale, chalky, dark blue-gray; contains interbedded lighter gray hard sandy shale	14	154
Fort Hays limestone member		
Shale, chalky, dark gray to white	10	164
Chalk, light gray to white	3	167
Shale, chalky, light gray to dark gray	5	172
Chalk, light gray to white	12	184
Shale, chalky, dark gray	1	185
Chalk, light gray to white	15	200
Shale, chalky, light gray to white	19	219
Carlile shale		
Codell sandstone and Blue Hill shale members		
Shale, sandy, noncalcareous, dark gray	33	252
Shale, sandy, light to dark gray	1.5	253.5
Shale, clayey, noncalcareous, dark gray to black	16.5	270

2. Log of test hole 2 at NE corner sec. 9, T. 21 S., R. 36 W., drilled by State and Federal Geological Surveys, 1941. Surface altitude, 3,220.6 feet. (Authority, samples studied by Perry McNally and Thad McLaughlin.)

	Thickness, feet	Depth, feet
Soil, sandy, dark	1.5	1.5
Undifferentiated Pleistocene deposits		
Clay, sandy, tan	2.5	4
Clay, sandy, tan, and caliche	8	12
Sand, medium, and gravel, fine	10.5	22.5
Clay, silty and fine sandy, tan	6	28.5
Ogallala formation (?)		
Sand, coarse, and gravel, coarse; brown	59.5	88
Silt, and sand, fine; light gray	10	98
Niobrara formation		
Shale, chalky, yellow	12	110
Shale, chalky, white	20	130

3. Log of test hole 3 at SW corner sec. 18, T. 21 S., R. 38 W., drilled by State and Federal Geological Surveys, 1941. Surface altitude, 3,421.5 feet. (Authority, samples studied by Perry McNally and Thad McLaughlin.)

	Thickness, feet	Depth, feet
Soil, sandy, brown	1.5	1.5
Undifferentiated Pliocene and Pleistocene deposits		
Silt, gray to tan	1.5	3
Clay, sandy, tan	5.5	8.5
Sand, medium, to gravel, fine; dark brown	2.5	11
Caliche, tan to white	3	14
Sand and gravel; consolidated; brown	11	25
Sand and gravel	15	40

Clay, sandy, tan	3	43
Sand, coarse, to gravel, coarse; brown	36	79
Sand, medium, to gravel, coarse; brown	18	97
Clay, sandy, tan	2	99
Caliche, gray to brown	7	106
Clay, sandy, light gray to tan	19	125
Sand and gravel; contains silt and fine sand	18	143
Silt and sand, fine; gray	2	145
Sand and gravel; brown	10	155
Silt and sand, fine; tan	15	170
Sand, medium, to gravel, medium; brown	33	203
Sand, medium, to gravel, fine; brown	14	217
Niobrara formation		
Chalk, white	13	230

4. Log of test hole 4 at NE corner sec. 18, T. 21 S., R. 39 W., drilled by State and Federal Geological Surveys, 1941. Surface altitude, 3,480.4 feet. (Authority, samples studied by Perry McNally and Thad McLaughlin.)

	Thickness, feet	Depth, feet
Soil, dark	3	3
Undifferentiated Pliocene and Pleistocene deposits		
Silt, tan	5	8
Silt, sand, and gravel; gray	10.5	18.5
Gravel, fine to coarse; brown	18.5	37
Silt and sand; tan	6	43
Sand, medium, to gravel, coarse; brown	6	49
Clay, sandy, tan	5.5	54.5
Sand, coarse, to gravel, coarse; brown	20.5	75
Clay, silty, tan	8	83
Silt and sand; limy; gray	5	88
Gravel, fine to coarse, brown	6	94
Silt, limy, and sand; tan	20	114
Gravel, fine to coarse, brown	18.5	132.5
Sand, coarse, to gravel, coarse; brown	9.5	142
Clay, silty, gray to pale green	4	146
Sand, gray to pale green	1	147
Silt and sand; limy; tan	18	165
Sand, coarse, to gravel, coarse; brown	10	175
Silt and sand; limy; gray to tan	3	178
Gravel, fine to coarse, brown	15	193
Clay, silt, and sand, fine; tan	2	195
Gravel, fine to coarse, brown	11.5	206.5
Clay, silty, gray	8	214.5
Gravel, medium to coarse	5.5	220
Clay, silt, and sand; tan	1	221
Gravel, fine to medium	2.5	223.5
Niobrara formation		
Smoky Hill chalk member (?)		
Chalk, white	6.5	230

5. Log of test hole 5 at SE corner sec. 8, T. 21 S., R. 42 W., drilled by State and Federal Geological Surveys, 1941. Surface altitude, 3,757.0 feet. (Authority, samples studied by Perry McNally and Thad McLaughlin.)

	Thickness, feet	Depth, feet
Soil, dark brown	3	3
Undifferentiated Pleistocene deposits		
Silt and clay; tan; contains lime nodules	13	16
Silt and sand; limy; gray	5	21
Sand and gravel; gray	3	24
Ogallala formation (?)		
Silt and sand; tan; some caliche	13	37
Gravel, consolidated, brown	19	56
Niobrara formation		
Smoky Hill chalk member (?)		
Clay, calcareous, pale yellow to white	3	59
Chalk, pale yellow	1	60

6. Log of test hole 6 in NW corner sec. 3, T. 21 S., R. 43 W., drilled by State and Federal Geological Surveys, 1941. Surface altitude, 3,783.9 feet. (Authority, samples studied by Perry McNally and Thad McLaughlin.)

	Thickness, feet	Depth, feet
Soil, silty, brown	3	3
Undifferentiated Pliocene and Pleistocene deposits		
Sand, brown, containing some gravel and caliche	29.5	32.5
Gravel, fine to coarse, brown	17.5	50
Silt and clay; greenish-gray	4	54
Silt and sand; tan	6	60
Sand, coarse, to gravel, coarse; brown	18.5	78.5
Sand, tan to gray	2.5	81
Sand and caliche; gray	5	86
Silt and sand; tan	4	90
Sand and caliche; tan to gray	4	94
Silt, sand, and gravel; tan	15.5	109.5
Gravel, fine to coarse, brown	12.5	122
Niobrara formation		
Smoky Hill chalk member		
Shale, chalky, brown	8	130

7. Log of test hole 7 at NW corner of sec. 7, T. 22 S., R. 34 W. (Finney county), drilled by the State and Federal Geological Surveys, 1941. Surface altitude, 3,009.1 feet. (Authority, samples studied by Perry McNally and Bruce F. Latta.)

	Thickness, feet	Depth, feet
Soil, sandy, dark	1	1
Undifferentiated Pleistocene deposits		
Silt and sand, fine; limy; tan to brown; containing gastropod shells	36	37
Silt and sand, fine; tan; containing thin lenses of sand and gravel	5	42

Ogallala formation (?)		
Silt, clayey, hard, tan and gray, containing fragments of caliche	8	50
Sand, fine, tan and gray	4	54
Silt and sand, fine; tan; containing gravel and coarser sand,	6	60
Sand and gravel; fine to coarse	9.5	69.5
Sand, fine, limy, gray	2.5	72
Sand and gravel; containing some tan limy silt	31	103
Sand and gravel; containing caliche and fragments and pebbles of limestone	7	110
Sand and gravel; cemented; hard; gray	1.5	111.5
Clay-shale, noncalcareous, greenish yellow	28.5	140

8. Log of test hole 8 at SW corner sec. 10, T. 22 S., R. 36 W., drilled by State and Federal Geological Surveys, 1941. Surface altitude, 3,186.6 feet. (Authority, samples studied by Perry McNally and Thad McLaughlin.)

	Thickness, feet	Depth, feet
Soil, sandy, brown	1	1
Undifferentiated Pleistocene deposits		
Silt and sand; fine; brown	6	7
Clay, silt, and sand; tan	9	16
Sand, medium, to gravel, medium; brown	4	20
Silt and sand, fine; tan to gray	2.5	22.5
Sand, medium, to gravel, medium; brown	21.5	44
Sand, medium, to gravel, coarse; brown	19	63
Silt and sand, fine; tan	17	80
Sand, medium, to gravel, medium; brown	41	121
Ogallala formation (?)		
Silt and sand, fine; tan to gray	9	130
Sand, coarse, to gravel, medium; brown	2	132
Clay, bentonitic, varicolored	20.5	152.5
Niobrara formation (?)		
Shale, calcareous, dark gray	7.5	160

9. Log of test hole 9 at SE corner sec. 15, T. 22 S., R. 38 W., drilled by State and Federal Geological Surveys, 1941. Surface altitude, 3,339.6 feet. (Authority, samples studied by Perry McNally and Thad McLaughlin.)

	Thickness, feet	Depth, feet
Soil, sandy, dark brown	1	1
Undifferentiated Pleistocene deposits		
Silt and sand, fine; tan	16	17
Sand and gravel; poorly sorted; brown	82	99
Sand and gravel; containing clay and fragments of caliche,	14	113
Sand, medium, to gravel, coarse; brown to gray	12	125
Sand and gravel; brown	1	126
Ogallala formation (?)		
Silt and caliche; white to gray	8	134
Silt and sand, fine; tan	6	140
Sand, coarse, to gravel, medium; brown	20	160

Sand, medium, to gravel, medium; brown	11.5	171.5
Silt and sand, fine; tan to gray	17.5	189
Sand, medium, to gravel, medium; gray to brown	23.5	212.5
Clay, silty, blocky, brown	2.5	215
Carlile shale (?)		
Shale, black	5	220

10. Log of test hole 10 at SE corner sec. 25, T. 22 S., R. 39 W., drilled by State and Federal Geological Surveys, 1941. Surface altitude, 3,407.9 feet. (Authority, samples studied by Perry McNally and Thad McLaughlin.)

	Thickness, feet	Depth, feet
Soil, silty, dark brown	3.5	3.5
Undifferentiated Pleistocene deposits		
Silt and sand; tan	11.5	15
Silt, tan, containing nodules of caliche	15	30
Sand, fine, to gravel, coarse; brown	13.5	43.5
Clay, silty, gray	1.5	45
Sand, fine, to gravel, coarse; brown	41	86
Silt and sand, fine; tan to gray	14	100
Gravel, fine to coarse, brown	8	108
Silt, limy, and sand; brown	11	119
Sand, fine, to gravel, medium; brown	21	140
Sand, fine, and silt; tan	11	151
Sand, fine, to gravel, medium	8	159
Sand, coarse, to gravel, coarse; brown	26	185
Ogallala formation (?)		
Silt, limy, and sand; gray	31	216
Clay, silt and sand; tan	3	219
Gravel, fine to coarse; brown	46.5	265.5
Niobrara formation (?)		
Smoky Hill chalk member (?)		
Clay, calcareous, blue-gray and tan	4.5	270
Clay, calcareous, orange-yellow to blue-gray	10	280

11. Log of test hole 11 in NW corner sec. 18, T. 22 S., R. 40 W., drilled by State and Federal Geological Surveys, 1941. Surface altitude, 3,594.1 feet. (Authority, samples studied by Perry McNally and Thad McLaughlin.)

	Thickness, feet	Depth, feet
Soil, sandy, tan to brown	3	5
Undifferentiated Pliocene and Pleistocene deposits		
Silt and sand, fine; tan	13	16
Sand, coarse, to gravel, coarse; brown	11	27
Caliche, gray to white	1	28
Sand, coarse, to gravel, coarse; brown	43	71
Silt and sand, fine; tan	2.5	73.5
Sand, fine, to gravel, fine; brown	15.5	89
Silt and caliche; tan	10.5	99.5
Sand, medium, to gravel, medium; brown	26	125.5

Caliche, sand, and gravel	5.5	131
Sand, coarse, to gravel, medium; brown	8	139
Clay, silt, and sand; gray to white	8.5	147.5
Niobrara formation		
Smoky Hill chalk member		
Chalk, white to gray	7.5	155
Chalk, white	3.5	158.5
Chalk, white to tan	2.5	161
Fort Hays limestone member		
Limestone, chalky, white to tan	29	190
Limestone, chalky, white to gray	7	197
Shale, calcareous, blue-gray	9	206
Shale, calcareous, brown to gray	10	216
Shale, calcareous, blue-gray	7.5	223.5
Carlile shale		
Codell sandstone member		
Shale, sandy, noncalcareous, blue-gray	16.5	240

12. Log of test hole 12 at SW corner sec. 15, T. 23 S., R. 36 W., drilled by State and Federal Geological Surveys, 1941. Surface altitude, 3,209.4 feet. (Authority, samples studied by Perry McNally and Thad McLaughlin.)

	Thickness, feet	Depth, feet
Soil, sandy	1	1
Undifferentiated Pliocene and Pleistocene deposits		
Clay, sandy, brown	10	11
Sand, fine to coarse, brown	4	15
Silt and sand, fine; white to tan	6	21
Sand, fine, and gravel; brown	14	35
Silt and sand, fine; gray to tan	4	39
Gravel, fine to coarse, brown	17	56
Sand, fine, tan to brown	8	64
Clay, sandy, containing sand and gravel; gray	3	67
Sand, medium, to gravel, medium; brown	19	86
Silt and sand, fine; tan to gray	17	103
Silt, sand, and gravel; tan	6	109
Sand, medium, to gravel, medium; brown	10	119
Clay, sandy, tan	4	123
Sand, coarse, to gravel, fine; brown	6.5	129.5
Silt and sand, fine; light gray to brown	36.5	166
Clay, silty, yellow to tan	8	174
Sand and gravel; brown	16	190
Silt and sand, fine; tan to brown	10	200
Sand and gravel; brown; contains some clay	10	210
Caliche, light gray	4	214
Greenhorn limestone (?)		
Limestone, dense, light to medium gray	5	219
Shale, clayey, tan	1.5	220.5
Shale, calcareous, black	3.5	224

Limestone, dense, light to medium gray	1	225
Shale, calcareous, black	2	227
Limestone, dense, light to medium gray	.5	227.5
Shale, calcareous, black	.5	228
Limestone, gray	.5	228.5
Shale, black, and limestone, gray	1.5	230

13. Log of test hole 13 at SE corner sec. 13, T. 23 S., R. 38 W., drilled by State and Federal Geological Surveys, 1941. Surface altitude, 3,318.3 feet. (Authority, samples studied by Perry McNally and Thad McLaughlin.)

	Thickness, feet	Depth, feet
Soil, sandy, dark brown	1	1
Undifferentiated Pleistocene deposits		
Clay, sandy, tan	9	10
Silt and sand, fine; tan; contains some caliche	16	26
Sand, coarse, to gravel, coarse; brown	17	43
Silt and sand, fine; tan	6.5	49.5
Sand, medium, to gravel, coarse; brown	16	65.5
Silt and sand, fine; tan to gray; contains some clay	7	72.5
Sand, medium, to gravel, medium; brown	5.5	78
Silt and sand, fine; light gray to tan	4	82
Sand, medium, to gravel, medium; brown	6	88
Silt and sand, fine; light gray to tan	2	90
Sand, medium, to gravel, medium; brown	10	100
Sand, fine, to gravel, medium; brown	5	105
Ogallala formation (?)		
Silt and sand, fine; light gray to tan	15	120
Sand, medium, to gravel, medium; brown	10	130
Silt and sand, fine; light gray to tan; caliche	13	143
Sand and gravel; brown	4	147
Clay, silty, tan	18	165
Silt and sand, fine; tan; containing some gravel	7.5	172.5
Sand, medium, to gravel, medium; brown	11.5	184
Clay, silty, gray to tan, containing sand and gravel	29	213
Sand, medium, to gravel, fine; gray	13.5	266.5
Clay, silty, tan to gray	5.5	232
Sand, fine, to gravel, medium; gray	26.5	258.5
Clay, silty, tan, containing sand and gravel	13.5	272
Sand, coarse, to gravel, medium; brown	7.5	279.5
Silt and sand, fine; light gray	4.5	284
Sand, coarse, to gravel, medium; brown	4	288
Clay, silty, tan	3	291
Carlile shale		
Blue Hill shale member (?)		
Shale, black to gray	11.5	302.5
Shale, clayey, tan to black	27	329.5
Shale, clayey, tan	9	338.5
Shale, clayey, black	9.5	348

Limestone, hard, gray	.5	348.5
Shale, black	2	350.5
Fairport chalky shale member (?)		
Limestone, chalky, white, containing shale and bentonite,	20	370.5
Shale, calcareous, black	26	396.5
Limestone, chalky, gray, containing some shale	6.5	403
Shale, calcareous, black	6	409
Limestone, gray	3	412
Shale, calcareous, gray to black	9	421
Shale, calcareous, black	7	428
Limestone, hard, and shale, calcareous, gray to black	45.5	473.5
Limestone, hard, gray to white	26.5	500
Greenhorn limestone (?)		
Bridge Creek limestone member (?)		
Limestone, hard, gray to white	20	520
Shale, calcareous, gray, and limestone, hard, gray	60	580
Hartland shale member (?)		
Shale, calcareous, gray	30	610
Lincoln limestone member (?)		
Limestone, hard, buff to gray, and interbedded shale	7	617

14. Log of test hole 14 at NE corner sec. 13, T. 24 S., R. 35 W., drilled by State and Federal Geological Surveys, 1941. Surface altitude, 2,925.5 feet. (Authority, samples studied by Laurence P. Buck and Thad McLaughlin.)

	Thickness, feet	Depth, feet
Soil, sandy, light brown	1	1
Alluvium		
Sand, coarse, rusty	3	4
Gravel, fine to coarse	16	20
Sand, coarse, and gravel, coarse	9	29
Silt and sand, fine; brown; contains some gravel	11	40
Undifferentiated Pliocene (?) and Pleistocene deposits		
Silt and sand, fine; tan	34	74
Silt and sand, fine; gray	4	78
Caliche, gray	2	80
Silt and sand, fine; gray	12	92
Sand, coarse, and gravel, coarse	6	98
Sand, fine, gray to tan	19	117
Sand, coarse, and gravel, medium	7	124
Silt and sand, fine; tan to gray	17	141
Sand, coarse, and gravel, coarse; containing fine sand	22.5	163.5
Sand, fine, blue-gray to gray	16.5	180
Silt and sand, fine; blue-gray	20	200
Silt and sand, fine; blue-gray; containing some gravel	20	220
Sand, fine, to gravel, coarse; tan	25	245
Sand, fine, light tan	5	250
Sand, coarse, to gravel, medium	17	267
Sand, fine, to gravel, medium; tan to gray	8	275

Sand, coarse, to gravel, medium; tan	5	280
Sand, coarse, to gravel, medium; tan; contains some sand, fine	10	290
Sand, fine to coarse; tan; contains some gravel	10	300
Sand, coarse, to gravel, medium	10	310
Sand, medium, to gravel, coarse	4	314
Sand, fine, containing some clay and fine gravel	16	330
Sand, coarse, to gravel, coarse	16	346
Sand, fine, and silt; tan	4	350
Sand, coarse, to gravel, coarse; containing rounded fragments of caliche	10.5	360.5
Graneros shale		
Shale, noncalcareous, black to light gray	8.5	369

15. Log of test hole 15 at NW corner sec. 21, T. 24 S., R. 37 W., drilled by State and Federal Geological Surveys, 1941. Surface altitude, 3,275.0 feet. (Authority, samples studied by Laurence P. Buck and Thad McLaughlin.)

	Thickness, feet	Depth, feet
Soil, sandy, light brown	2	2
Undifferentiated Pleistocene deposits		
Silt and sand, fine to coarse; light brown	13	15
Caliche, tan	6	21
Sand, fine, tan to brown	7.5	28.5
Sand, coarse, to gravel, coarse; brown	31.5	60
Sand, fine, brown	4	64
Sand, coarse, to gravel, coarse; brown	32.5	96.5
Sand, fine, and silt; tan	5	101.5
Gravel, fine to coarse	1.5	103
Silt and sand, fine; tan to gray	7	110
Ogallala formation (?)		
Gravel, fine, and sand	6	116
Sand, fine, and silt; tan	20	136
Silt and sand, fine; light brown	14	150
Sand, medium, to gravel, medium	7	157
Silt and sand, fine; gray to brown	15	172
Caliche, light gray	.5	172.5
Silt and sand, fine; tan	10.5	183
Sand, fine, tan	9.5	192.5
Sand, coarse, to gravel, coarse	12	204.5
Silt and sand, fine; tan	7.5	212
Sand, fine, tan, containing some gravel	26.5	238.5
Clay, blocky, tan	11.5	250
Greenhorn limestone		
Shale, calcareous, dark gray	27	277
Shale, black, and limestone, gray	6.5	283.5
Shale, clayey, calcareous, gray	7	290.5

	Thickness, feet	Depth, feet
Graneros shale		
Shale, light gray	1	291.5
Shale, silty, gray	.5	292
Shale, tan to dark gray	24	316
Shale, fissile, gray, and bentonite, tan	2	318
Shale, clayey, dark gray	12	330

16. Log of test hole 16 in SW corner sec. 30, T. 24 S., R. 40 W., drilled by State and Federal Geological Surveys, 1941. Surface altitude, 3,286.4 feet. (Authority, samples studied by Perry McNally and Thad McLaughlin.)

	Thickness, feet	Depth, feet
Undifferentiated Pleistocene deposits		
Sand, fine to medium, brown	3	3
Silt, sand, and gravel; brown	7	10
Sand, coarse, and gravel, coarse; brown	46	56
Silt and sand, fine; tan	4	60
Sand and gravel; brown	6	66
Graneros shale		
Shale, black	29	95
Limestone, hard, gray, and shale, black	5	100
Shale, noncalcareous, black	22.5	122.5
Dakota formation		
Sandstone, gray, and shale, sandy	2.5	125
Shale, blue-gray, and sandstone, hard	5	130
Shale, sandy, and sandstone, gray to tan	20	150

17. Log of test hole 17 in SW corner sec. 2, T. 24 S., R. 43 W., drilled by State and Federal Geological Surveys, 1941. Surface altitude, 3,367.3 feet. (Authority, samples studied by Perry McNally and Thad McLaughlin.)

	Thickness, feet	Depth, feet
Dune sand		
Sand, fine to medium, brown	6	6
Alluvium		
Silt, sandy, brown	10	16
Gravel, coarse, brown	24	40
Gravel, coarse, containing a thin bed of clay	10	50
Gravel, coarse, brown	74	124

18. Log of test hole 18 NE corner sec. 34, T. 24 S., R. 43 W., drilled by State and Federal Geological Surveys, 1941. Surface altitude, 3,503.8 feet (Authority, samples studied by Perry McNally and Thad McLaughlin.)

	Thickness, feet	Depth, feet
Soil, silty, brown (probably loess)	16	16
Undifferentiated Pleistocene (?) deposits		
Clay, silty, gray to tan	2.5	18.5
Greenhorn limestone		
Lincoln limestone member		
Clay, calcareous, tan	10	28.5
Chalk, white, and shale, calcareous, tan	3.5	32

Limestone, chalky, and shale, calcareous	4.5	36.5
Limestone, chalky, hard	4	40.5
Graneros shale		
Shale, fissile, black	7.5	48
Shale, blue, containing some bentonite	1.5	49.5
Shale, fissile, black	20.5	70

19. Log of test hole 19 at the SE corner sec. 26, T. 25 S., R. 35 W., drilled by State and Federal Geological Surveys, 1941. Surface altitude, 2,992.5 feet. (Authority, samples studied by Laurence P. Buck and Thad McLaughlin.)

	Thickness, feet	Depth, feet
Dune sand		
Sand, fine to medium	34	34
Undifferentiated Pleistocene deposits		
Sand, coarse, and gravel, coarse	62	96
Silt and sand, fine	7	103
Sand, fine, and gravel, fine to coarse	7	110
Sand, coarse, and gravel, coarse	10	120
Sand, fine, and gravel, fine	30	150
Sand, fine, and gravel, coarse	7	157
Silt and clay	6	163
Silt, containing some gravel	26	189
Gravel, coarse, to sand, coarse	12	201
Sand and gravel; consolidated	9	210
Gravel, fine to coarse, consolidated	7	217
Gravel, fine to coarse, and sand	31	248
Sand, silt, and gravel; consolidated	52	300
Sand, fine, and caliche	26	326
Sand, fine, to gravel	34	360
Silt and sand, fine; containing gravel	31	391
Sand, fine, to gravel, medium	9	400
Clay, silty	10	410
Clay, containing silt, sand, and gravel	12	422
Clay, silty, containing sand and gravel	14	436
Dakota formation		
Clay and clay shale; silty	10	446
Sandstone	4	450

20. Log of test hole 20 at SE corner sec. 34, T. 26 S., R. 36 W., drilled by State and Federal Geological Surveys, 1941. Surface altitude 3,090.5 feet. (Authority, samples studied by Perry McNally and Thad McLaughlin.)

	Thickness, feet	Depth, feet
Dune sand		
Sand, fine, tan to gray	30	30
Undifferentiated Pleistocene deposits		
Sand, fine to coarse, brown	18	48
Silt and sand, fine; tan to brown	35	83
Sand, fine, brown, containing clay and pebbles of caliche	7	90
Sand, coarse, to gravel, coarse; brown	45	135

	Thickness, feet	Depth, feet
Gravel, fine to coarse, brown	5	140
Sand, coarse, to gravel, coarse; tan to brown	35	175
Sand, medium, to gravel, fine; brown	4	179
Sand, coarse, to gravel, coarse; brown	21	200
Sand, medium, to gravel, medium; brown	16	216
Clay, silty, gray to buff	7	223
Sand, medium, to gravel, fine; brown	101	324
Clay, silty, varicolored	10.5	334.5
Sand, coarse, to gravel, coarse; brown	10.5	345
Ogallala formation (?)		
Silt and sand, fine; tan to gray; and caliche	35	380
Silt and sand, fine; tan to gray; and clay, black	10	390
Sand, fine, to gravel, fine; brown	10	400
Clay, silty, tan to gray	6	406
Dakota formation		
Sandstone, dark brown, and clay, varicolored	1	407
Sandstone, white to gray	3	410

21. Log of test hole 21 at SE corner sec. 33, T. 26 S., R. 37 W., drilled by State and Federal Geological Surveys, 1941. Surface altitude, 3,073.9 feet. (Authority, samples studied by Perry McNally and Thad McLaughlin.)

	Thickness, feet	Depth, feet
Soil, sandy, brown	4	4
Undifferentiated Pliocene and Pleistocene deposits		
Clay, silty, greenish-gray	6	10
Clay, silty to fine sandy; gray	5	15
Clay, silty and fine sandy; tan to gray	21	36
Sand, fine, and silt; tan	4	40
Clay, sandy, and silt; tan	30	70
Silt and sand; fine; tan	10	80
Silt, sand, and gravel	3	83
Silt and sand, fine; brown	19	102
Silt and sand, fine; tan; contains some gravel	48	150
Clay, silty, tan, containing fine sand and gravel	22.5	172.5
Clay, silty and fine sandy; dark gray	47.5	220
Clay, silty, dark gray, containing lenses of sand and gravel,	9	229
Silt, sand, and gravel; brown	11	240
Sand, medium, and gravel, fine	12	252
Silt, and sand, fine; light gray	12	264
Clay, silty and fine sandy; tan	56	320
Dakota formation		
Sandstone, white, containing concretions of iron	20	340

22. Log of test hole 22 at SE corner sec. 31, T. 26 S., R. 38 W., drilled by State and Federal Geological Surveys, 1941. Surface altitude, 3,203.2 feet. (Authority, samples studied by Perry McNally and Thad McLaughlin.)

	Thickness, feet	Depth, feet
Soil, sandy, brown	1	1
Undifferentiated Pleistocene deposits		
Silt and sand, fine; tan to gray	17	18
Sand and gravel; containing some silt	15	33
Silt and sand, fine; tan	11.5	44.5
Sand, medium, to gravel, coarse; brown	30	74.5
Caliche, white	1.5	76
Sand, medium, to gravel, coarse; brown	6	82
Ogallala formation (?)		
Silt and sand, fine; tan to gray	39	121
Caliche, soft, light gray to white	14	135
Caliche, tan, containing fragments of sandstone, brown	7	142
Dakota formation		
Sandstone, brown, and clay, yellow	3	145
Shale and sandstone; varicolored	8.5	153.5
Shale, sandy, blue-gray, and sandstone, fine	1.5	155
Shale and sandstone, fine; varicolored	2.5	157.5
Sandstone, rusty-brown	2.5	160

23. Log of test hole 23 at NE corner sec. 1, T. 26 S., R. 39 W., drilled by State and Federal Geological Surveys, 1941. Surface altitude, 3,281.1 feet. (Authority, samples studied by Perry McNally and Thad McLaughlin.)

	Thickness, feet	Depth, feet
Soil, silty, brown	2.5	2.5
Undifferentiated Pliocene and Pleistocene deposits		
Silt, and sand, fine; tan	7.5	10
Sand, fine, brown	10	20
Silt, limy, and sand, tan	8	28
Gravel, fine to coarse; brown	22	50
Silt and sand; tan	14	64
Clay, sandy, tan, containing caliche	6	70
Silt and clay; tan	10	80
Sand and silt; limy; tan	9	89
Dakota formation		
Sandstone, gray	1	90
Sandstone, fine-grained, gray	5	95
Sandstone, fine-grained, varicolored	5	100

24. Log of test hole 24 in SE corner sec. 36, T. 26 S., R. 40 W., drilled by State and Federal Geological Surveys, 1941. Surface altitude, 3,303.2 feet. (Authority, samples studied by Perry McNally and Thad McLaughlin.)

	Thickness, feet	Depth, feet
Soil, sandy, brown	1	1
Undifferentiated Pliocene and Pleistocene deposits		
Silt and sand, fine; tan	11	12
Silt, tan to gray	8	20
Silt and sand, fine; tan	12	32
Sand and gravel; coarse; brown	17.5	49.5
Clay, silty, tan	7.5	57
Silt and sand; tan	21	78
Sand, coarse, to gravel, coarse	6.5	84.5
Silt and clay; tan	11.5	96
Silt and sand, fine to coarse; tan	6	102
Clay, silt, and sand; calcareous	4.5	106.5
Dakota formation		
Sandstone, tan, and clay, varicolored	7.5	114
Clay, silty, varicolored	10	124
Sandstone, tan to brown, and shale, gray	2	126
Clay, silty, gray to purple	7	133
Sandstone, gray to brown	7	140
Clay, gray to yellow	15	155
Sandstone, varicolored	4.5	159.5
Clay, gray	17.5	177
Sandstone, tan to brown	6	183
Clay, silty, gray	5	188
Sandstone, tan to brown	3	191
Clay, silty, gray	15	206
Sandstone, tan to dark brown, containing concretions of ironstone	12.5	218.5
Sandstone, pale yellow to tan	17.5	236
Kiowa shale		
Shale, sandy, blue-gray	16	252
Shale, gray, containing sandstone	8	260
Shale, black	67.5	327.5
Shale, sandy, dark gray	39.5	367
Cheyenne sandstone		
Clay, silty, white	3	370
Sandstone, fine, white to buff	33	403
Morrison (?) formation		
Clay, silty, blue-green	4	407
Sandstone, buff, and clay, varicolored	5	412
Clay, silty, gray	8	420
Sandstone, buff to red, and clay, blue-green to black	63.5	483.5
Sandstone, white to buff, and shale, varicolored	20	503.5
Permian (?) redbeds		
Siltstone, dark red	6.5	510

25. Log of test hole 25 at the SW corner sec. 36, T. 26 S., R. 41 W., drilled by State and Federal Geological Surveys, 1940. Surface altitude, 3,265 feet. (Authority, samples studied by Perry McNally, Frank Conselman, and Bruce F. Latta.)

	Thickness, feet	Depth, feet
Undifferentiated Pliocene and Pleistocene deposits		
Silt, fine sandy, tan to gray	25	25
Silt, fine sandy and clayey, gray	11	36
Sand and gravel; gray to brown	8	44
Silt, sandy, light brown	26	70
Sand, medium, to gravel, coarse; tan	10	80
Silt, sand, and gravel, tan	10	90
Sand, fine, to gravel, medium; tan	11	101
Silt, light gray to brown, and clay	9	110
Silt and clay; blue-gray	10	120
Silt, fine sandy, brown	4	124
Sand, fine to coarse, tan	16	140
Sand, fine, to gravel, coarse; tan	10	150
Sand, coarse, to gravel, coarse; tan	19	169
Silt, sandy, brown	16	185
Sand, coarse, to gravel, coarse; tan	18	203
Silt and clay; sandy; brown	14	217
Sand, medium, to gravel, medium; tan	9	226
Dakota formation		
Sandstone, yellow-brown and red-brown	4	230
Clay, soft, light gray and blue	2.5	232.5
Sandstone, light brown, yellow, and red-brown	5	237.5
Sandstone, red-brown, and clay, yellow and gray	6.5	244
Clay, yellow, gray, and blue	6	250
Sandstone, soft, yellow to light brown	20	270
Clay, sandy, gray-green to yellow	19	289
Kiowa shale		
Shale, clayey, blue-gray	16	305
Shale, sandy, hard, blue-gray	10	315
Shale, clayey, soft, blue-gray	15	330
Shale, hard, blue-gray	26	356
Cheyenne sandstone		
Sandstone, fine to medium, gray	14	370
Shale, clayey, blue-gray, and sandstone, fine, hard	24	394
Sandstone, soft, light gray	10	404
Sandstone, hard, buff	8	412
Triassic (?) redbeds		
Clay, red and light gray	5	417
Sandstone, buff	2	419
Clay, red, and sandstone, soft, yellow-brown	5	424
Clay, red and light gray	3	427
Sandstone, hard, light brown to buff	14	441
Clay, red, brown, and light gray	22	463
Sandstone, light gray to buff	30	493
Siltstone, hard, red	5	498

Clay, gritty, light gray to white	6.5	504.5
Sandstone, light brown to buff	5.5	510
Clay, silty, red-brown, light gray, and gray-green	13	523
Sandstone, buff to gray-brown	65	588
Sandstone, hard, fine, buff, blue-green, and gray	25	613
Clay, silty, light gray and blue-gray	4	617

26. Log of test hole 26 in SE corner sec. 36, T. 26 S., R. 42 W., drilled by State and Federal Geological Surveys, 1941. Surface altitude, 3,366.2 feet. (Authority, samples studied by Perry McNally and Thad McLaughlin.)

	Thickness, feet	Depth, feet
Undifferentiated Pliocene (?) and Pleistocene deposits		
Sand, fine to medium, brown	13	13
Silt, tan, and sand, fine to coarse	9	22
Clay, silty, tan	9	31
Silt, brown, and sand, fine to coarse	11.5	42.5
Silt, calcareous, tan, and clay	13	55.5
Gravel, fine to coarse, brown	7.5	63
Sand and gravel; brown	7	70
Silt and sand; gray	6	76
Clay, silt, and sand; tan	14	90
Sand and silt; brown	10	100
Sand and gravel; brown	8	108
Silt and sand; tan	27	135
Sand, fine, to gravel, medium	10.5	145.5
Silt and sand, fine; tan	20.5	166
Gravel, fine to coarse, brown	4.5	170.5
Silt and sand; tan to gray	19.5	190
Sand and gravel; brown	20	210
Silt and sand, fine to coarse; tan to gray	15.5	225.5
Sand, coarse, to gravel coarse; brown	10.5	236
Clay, silty, gray	6	242
Sand, fine to medium, brown, containing rounded pebbles of caliche	7	249
Gravel, varicolored (reworked pebbles of sandstone from the Dakota formation)	5	254
Dakota formation		
Sandstone, yellow-brown	6	260

27. Log of test hole 27 in NW corner sec. 23, T. 26 S., R. 43 W., drilled by State and Federal Geological Surveys, 1941. Surface altitude, 3,516.7 feet. (Authority, samples studied by Perry McNally and Thad McLaughlin.)

	Thickness, feet	Depth, feet
Soil, sandy, tan	5	5
Undifferentiated Pliocene and Pleistocene deposits		
Silt, tan	3	8
Sand, fine to medium, tan	3	11
Sand, fine to coarse, tan, containing pebbles of caliche	15	26

Sand, coarse, to gravel, coarse; brown	9	35
Clay, silty, tan	4	39
Gravel, fine to coarse, brown	18	57
Silt and sand, medium to coarse; tan	7.5	64.5
Sand, coarse, to gravel, coarse; brown	1.5	66
Sand, fine to medium, tan	14	80
Clay, silt, and sand; gray to tan	40.5	120.5
Silt and sand, medium; tan	5.5	126
Clay, silt, and sand; tan	15	141
Sand and gravel; brown	13	154
Silt and clay; tan	9	163
Silt and sand; brown	17	180
Silt, sand, and gravel	5	185
Sand, coarse, to gravel, coarse; brown	15	200
Clay, silty, blocky, tan to gray	32	232
Dakota formation		
Clay, varicolored	8	240

28. Log of former railroad well at Lakin in sec. 27, T. 24 S., R. 36 W., drilled in May, 1900. (Authority, Atchison, Topeka, and Santa Fe Railway Company.)

	Thickness, feet	Depth, feet
Undifferentiated Pliocene and Pleistocene deposits		
Loam	12	12
Sand and gravel	28	40
Clay	3	43
Clay, blue	12	55
Sand, fine, blue	11	66
Sand, fine	86	152
Clay, blue	2	154
Clay, yellow	2	156
Sand and gravel	20	176
Conglomerate (probably gravel)	8	184

29. Log of former railroad well at Lakin in sec. 27, T. 24 S., R. 36 W., drilled in August, 1901. (Authority, Atchison, Topeka, and Santa Fe Railway Company.)

	Thickness, feet	Depth, feet
Undifferentiated Pliocene and Pleistocene deposits		
Loam	12	12
Sand and gravel	28	40
Clay	3	43
Clay, blue	12	55
Sand, blue	99	154
Clay, yellow	2	156
Sand and gravel	32	188
Conglomerate (probably gravel)	3	191

30. Log of former railroad well at Lakin in sec. 27, T. 24 S., R. 36 W., drilled in September, 1901. (Authority, Atchison, Topeka, and Santa Fe Railway Company.)

	Thickness, feet	Depth, feet
Undifferentiated Pliocene and Pleistocene deposits		
Loam	12	12
Sand and gravel'	28	40
Clay	15	55
Sand, blue	29	84
Clay, blue	68	152
Sand and gravel	43	195
Conglomerate (probably gravel)	2	197

31. Log of railroad well at Lakin in sec. 27 T. 24 S., R. 36 W., drilled in 1919. (Authority, Atchison, Topeka, and Santa Fe Railway Company.)

	Thickness, feet	Depth, feet
Alluvium		
Loam	7	7
Sand and gravel	24	31
Clay, yellow	3	34
Undifferentiated Pliocene and Pleistocene deposits		
Sand, blue (water at 110 feet)	73	107
Clay, blue	7	114
Sand, coarse (water at 125 feet)	8	122
Sand, blue	5	127
Clay, blue	8	135
Sand, coarse, red (water)	4	139
Sand and gravel; yellow (water)	20	159
Clay, yellow	7	166
Sand and gravel; yellow (water at 177 feet)	21	187
Sand and gravel; red (water)	16	203
Clay, sandy, yellow	3	206
Sand and gravel; coarse (water)	14	220
Rock	1	221

32. Log of railroad well at Kendall in sec. 25, T. 24 S., R. 39 W. (Authority, Atchison, Topeka, and Santa Fe Railway Company.)

	Thickness, feet	Depth, feet
Alluvium		
Soil, gravel, and sand	53	53
Dakota formation		
Sandstone	56	109
Lignite	2	111
Clay	3	114
Sandstone, gray (soft water)	38	152
Clay, very hard	2	154
Sandstone, gray	13	167
Shale, hard	48	215
Sandstone, gray (soft water)	53	268
Shale	23	291
Sandstone	6	297

Shale	35	332
Sandstone, black	3	335
Shale	13	348
Sandstone, gray (soft water)	19	367
Kiowa shale		
Shale, gray	58	425
Cheyenne sandstone		
Sandstone, brown	5	430
Clay, brown	23	453
Clay, sandy	23	476
Sandstone, light gray	17	493
Fire clay	3	496
Permian redbeds		
Redbeds	41	537

33. Log of railroad well at Syracuse in sec. 7, T. 24 S., R. 40 W. (Authority, Atchison, Topeka, and Santa Fe Railway Company.)

	Thickness, feet	Depth, feet
Alluvium		
Soil, sand, and gravel (water level 20 feet)	33	33
Graneros shale		
Shale, black	32	65
Talc (probably shale)	2	67
Shale, black	38	105
Shale, light	5	110
Clay, blue	15	125
Dakota formation		
Sand rock (water rose to a level 65 feet below land surface)	5	130
Shale, black	10	140
Limestone, white (probably shale)	25	165
Clay, white	10	175
Soapstone (probably shale)	10	185
Shale, gray	10	195
Sand rock	15	210
Clay, light gray	10	220
Sand rock, soft	5	225
Clay, white	30	255
Slate, brown (probably shale)	10	265
Clay, white	5	270
Shale, light	10	280
Clay, white	10	290
Kiowa shale		
Shale, black	9	299
Shale, light	16	315
Shale, black	89	404
Rock, hard	2	406
Shale, black	6	412

	Thickness, feet	Depth, feet
Cheyenne sandstone		
Sand rock, white (water rose to a level 135 feet below land surface)	28	440
Shale, light	20	460

34. Log of former railroad well at Syracuse in sec. 7, T. 24 S., R. 40 W. (Authority, Atchison, Topeka, and Santa Fe Railway Company.)

	Thickness, feet	Depth, feet
Alluvium		
Loam	10	10
Sand and gravel	14	24
Clay	9	33
Graneros shale		
Shale, black	117	150
Dakota formation		
Shale, gray	31	181
Sand rock (water rose to a level 70 feet below land surface)	4	185
Shale, gray	17	202
Sand rock (water rose to a level 58 feet below land surface)	5	207
Shale, gray	13	220
Sand rock, white	5	225
Shale, gray	10	235
Sand rock, white	2	237
Clay, white	12	249
Sand rock, white	6	255
Shale, gray	7	262
Sand rock, brown	3	265
Shale, gray	18	283
Sand, white	3	286
Shale, gray	5	291

35. Log of former railroad well at Syracuse in sec. 7, T. 24 S., R. 40 W. (Authority, Atchison, Topeka, and Santa Fe Railway Company.)

	Thickness, feet	Depth, feet
Alluvium		
Sand and gravel	62	62
Graneros shale		
Shale	68	130
Dakota formation		
Clay, white	31	161
Shale, sandy, dark brown	9	170
Sand	12	182
Clay, white	38	220
Sand and shale	4	224
Limestone (probably shale)	4	228
Clay, white	27	255
Sand	12	267
Clay, white	13	280
Sand, dark	26	306

Kiowa shale		
Shale	94	400
Cheyenne sandstone		
Shale, sandy, dark	58	458
Rock, red, and shales, variegated (water rose to a level 75 feet below land surface)	7	465

36. Log of former railroad well at Syracuse in sec. 7, T. 24 S., R. 40 W., drilled in 1900. (Authority, Atchison, Topeka, and Santa Fe Railway Company.)

	Thickness, feet	Depth, feet
Alluvium		
Loam	10	10
Sand, gravel, and silt	51	61
Graneros shale		
Shale	59	120
Dakota formation		
Clay	3.6	123.6
Sandstone (water)	89.4	213
Shale	27	240
Clay, white	10	250
Sandstone	34	284

37. Log of railroad well (100) in NE¼ NE¼ sec. 24, T. 24 S., R. 41 W., drilled in 1923. (Authority, David Millsap.)

	Thickness, feet	Depth, feet
Pleistocene		
Sand and gravel (water level, 14 feet)	15	15
Sand and gravel, coarse	48	63
Graneros shale		
Shale, black	20	83

38. Log of railroad well at Coolidge in sec. 23, T. 23 S., R. 43 W., drilled in January, 1903. (Authority, Atchison, Topeka, and Santa Fe Railway Company.)

	Thickness, feet	Depth, feet
Alluvium		
Loam	18	18
Sand and gravel (water level, 23 feet)	34	52
Clay, sandy	14	66
Graneros shale		
Shale	13	79
Lime and shale	26	105
Dakota-Cheyenne formations		
Sand rock, white (water rose to a level 46 feet below land surface)	25	130
Shale	58	188
Sand rock (water rose to a level 12 feet below land surface)	14	202
Clay, white	10	212
Sand rock (water rose to a level 1 foot below land surface)	88	300
Shale	12	312

39. Partial log of well of the city of Syracuse in sec. 7, T. 24 S., R. 40 W. (Cited by Darton, 1920.)

	Thickness, feet	Depth, feet
Graneros shale		
Shale, black	..	122
Dakota-Cheyenne formations		
Sandstone, hard	8	130
Clay, white	4	134
Shale, sandy, compact	16	150
Clay, white	4	154
Sandstone	24	178
Shale, sandy	36	214
Limestone (probably shale)	10	224
Clay, white	6	230
Shale, sandy	22	252
Sandstone	28	280
Shale, black	12	292
Sandstone, dark	18	310
Soapstone (probably shale)	12	322
Shale, dark	6	328
Soapstone (probably shale)	6	334
Shale, blue	51	385
Shale, sandy	17	402
Sandstone, gray (water)	38	440
Shale, sandy	8	448
Limestone (probably shale)	4	452
Sandstone, gray	12	464
Shale, brown	4	468
Clay, white	4	472
Clay, sandy, white	6	478

40. Log of municipal supply well (293) no. 2 of the city of Lakin in sec. 27, T. 24 S., R. 36 W. (Authority, driller.)

	Thickness, feet	Depth, feet
Undifferentiated Pliocene and Pleistocene deposits		
Soil, clay, and sand	70	70
Clay	23	93
Sand	2	95
Clay, sandy	49	144
Clay, tough	12	156
Clay, sandy	51	207
Sand	5	212
Sandstone, soft	3	215
Rock, soft	8	223
Sand	10	233
Rock, soft	4	237
Clay, sandy	9	246
Sand	27	273

41. Log of well (238) of August Kettler in SW¼ sec. 9, T. 24 S., R. 35 W. (Authority, driller.)

	Thickness, feet	Depth, feet
Undifferentiated Pliocene and Pleistocene deposits		
Soil, clayey	47	47
Sand and gravel; calcareous	9	56
Sand (water)	10	66
Sand, blue, and clay	34	100
Shale, gray (probably clay)	15	115
Sand, calcareous	50	165
Shale, blue (probably clay)	25	190
Sand	30	220
Sand and gravel	23	243
Clay, brown	7	250
Sand, fine	3	253

42. Log of test well of the Garden City Company in sec. 25, T. 22 S., R. 35 W. (Authority, driller.)

	Thickness, feet	Depth, feet
Undifferentiated Pliocene and Pleistocene deposits		
Soil and silt	19	19
Sand, fine	53	72
Sand	58	130
Clay	12	142
Sand	32	174
Clay	10	184
Gravel, coarse	22	206
Clay	21	227
Shale, blue	75	302

43. Log of well (208) of the Garden City Company in NW¼ NW¼ sec. 13, T. 23 S., R. 35 W. (Authority, driller.)

	Thickness, feet	Depth, feet
Undifferentiated Pliocene and Pleistocene deposits		
Soil and clay	20	20
Sand, fine (water level, 65 feet)	45	65
Clay and sand	99	164
Sand	28	192
Clay, soft	44	236
Sand (water rose to a level 76 feet below land surface)	129	365
Gravel, coarse	18	383
Cretaceous		
Shale, blue	1	384

44. Log of well (211) of the Garden City Company in NW¼ sec. 25, T. 23 S., R. 35 W. (Authority, driller.)

	Thickness, feet	Depth, feet
Undifferentiated Pliocene and Pleistocene deposits		
Soil and clay	5	5
Sand, red	10	15
Clay	25	40
Clay, sandy	10	50

Sand, fine (water level, 52 feet)	10	60
Clay	14	74
Sand, fine	8	82
Sand	190	272
Clay	3	275
Sand	6	281

45. Log of well of the Garden City Company in SW¼ sec. 25, T. 23 S., R. 35 W. (Authority, driller.)

	Thickness, feet	Depth, feet
Undifferentiated Pliocene and Pleistocene deposits		
Soil	15	15
Sand, red	10	25
Sand and clay (water level, 52 feet)	28	53
Sand, fine	15	68
Sand and clay	15	83
Sand, red	20	103
Sand and clay	25	128
Sand	135	263
Clay	10	273
Sand, coarse	18	291
Clay	3	294

46. Log of test well of the Garden City Company in sec. 1, T. 24 S., R. 35 W. (Authority, driller.)

	Thickness, feet	Depth, feet
Undifferentiated Pliocene and Pleistocene deposits		
Sand and clay	30	30
Sand	5	35
Clay	15	50
Sand, fine	5	55
Clay	10	65
Sand	4	69
Clay	5	74
Sand	6	80
Clay	35	115
Sand	15	130
Clay	8	138
Sand	16	154
Clay	7	161
Sand	25	186
Clay	8	194
Sand	36	230
Boulders and sand	7	237
Clay	4	241
Boulders and sand	19	260
Rock	2	262
Clay	9	271
Sand	23	294

47. Log of test well of the Garden City Company in sec. 13, T. 24 S., R. 35 W. (Authority, driller.)

	Thickness, feet	Depth, feet
Soil	3	3
Undifferentiated Pliocene and Pleistocene deposits		
Sand, fine	8	11
Gravel (water level, 13 feet)	14	25
Gravel, coarse	19	44
Clay	1	45
Sand, fine	15	60
Clay	105	165
Sand	8	173
Clay	57	230
Sand	28	258
Gravel	9	267
Clay and rock	8	275
Sand	10	285
Clay and caliche	12	297
Rock and clay	7	304
Sand	17	321
Clay	4	325
Sand	45	370
Rock	3	373
Graneros shale (?)		
Clay, blue	5	378

48. Log of well of the Garden City Company in sec. 17, T. 25 S., R. 36 W. Surface altitude, 3,020 feet. (Authority, driller.)

	Thickness, feet	Depth, feet
Undifferentiated Pliocene and Pleistocene deposits		
Soil and sand	20	20
Sand	27	47
Clay	30	77
Sand, fine	10	87
Clay, soft, and sand	44	131
Sand, fine, and clay	15	146
Sand, fine, and shale	23	169
Sand	15	184
Shale, blue	12	196
Sand and shale	12	208
Shale, blue	21	229
Sand	11	240
Clay, hard, blue	6	246
Clay, soft, yellow	24	270
Clay	10	280
Shale and gravel	17	297

49. Log of well (11) of Dan Huser at SE corner sec. 8, T. 21 S., R. 41 W. Surface altitude, 3,661.2 feet. (Authority, Mr. Huser)

	Thickness, feet	Depth, feet
Undifferentiated Pliocene and Pleistocene deposits		
Sand and gravel (water at 165 feet)	175	175
Niobrara formation		
Chalk	185	360
Greenhorn-Graneros formations		
Shale and limestone	440	800
Dakota formation		
Sandstone (water rose to a level 375 feet below land surface)	50	850

50. Log of well (28) of Fred Behrendt in SW¼ SE¼ sec. 4, T. 22 S., R. 43 W. Surface altitude, 3,689.2 feet. (Authority, driller.)

	Thickness, feet	Depth, feet
Pleistocene (?)		
Gravel	5	5
Niobrara formation		
Fort Hays limestone member		
Clay, white (probably limestone)	50	55
Carlile, Greenhorn, and Graneros formations		
Shale, blue to white	440	495
Dakota formation		
Sandstone (water rose to a level 370 feet below land surface)	17	512

51. Log of well (29) of Jacob Behrendt in SE¼ SE¼ sec. 4, T. 22 S., R. 43 W. (Cited by Bass, 1926.)

	Thickness, feet	Depth, feet
Niobrara formation		
Fort Hays limestone member		
Rock (probably limestone)	5	5
Clay, white (probably limestone and shale)	35	40
Carlile, Greenhorn, and Graneros formations		
Shale, black	440	480
Dakota formation		
Sandstone (water rose to a level 355 feet below land surface)	36	516

52. Log of well (51) of Robert Hazlett in SE¼ NE¼ sec. 21, T. 23 S., R. 43 W. (Authority, Robert Hazlett.)

	Thickness, feet	Depth, feet
Alluvium		
Sand and gravel (water level, 20 feet)	50	50
Graneros shale		
Shale, black	20	70
Dakota formation		
Sandstone (water rose to land surface)	40	110
Shale	21	131
Sandstone (water rose to a level 15 feet below land surface)	9	140

53. Log of State well in NE¼ NE¼ sec. 36, T. 23 S., R. 39 W. (Cited by Haworth, 1897.)

	Thickness, feet	Depth, feet
Soil	8	8
Undifferentiated Pliocene and Pleistocene deposits		
"Gypsum" (caliche)	6	14
Sand and gravel	57	71
Rock, solid	28	99
Sand and gravel	6	105
"Gypsum," red (caliche)	5	110
Clay, sandy	20	130
Gravel and boulders	12	142
Sand, fine, yellow	13	155
Gravel	9	164
Clay	6	170
Sand and gravel (water level, 180 feet)	10	180
Gravel	7	187
Sand, fine	5	192
Carlile shale (?)		
Shale, compact, yellow	4	196

54. Log of community well (54) at Coolidge in NE¼ NW¼ sec. 23, T. 23 S., R. 43 W. (Authority, P. A. Bauer, driller.)

	Thickness, feet	Depth, feet
Alluvium		
Soil and sand (water level, 16 feet)	16	16
Gravel	34	50
Graneros shale		
Shale, black	40	90
Shale, sandy, hard	16	106
Dakota formation		
Sandstone (water rose to a level 15 feet below land surface)	45	151
Shale	5	156

55. Log of well (57) of J. W. Egger in SW¼ NE¼ sec. 24, T. 23 S., R. 43 W. Surface altitude, 3,340.91 feet. (Authority, J. W. Egger.)

	Thickness, feet	Depth, feet
Alluvium		
Sand and gravel (water level, 12 feet)	58	58
Graneros shale		
Shale	38	96
Dakota formation		
Sandstone (water rose to a level 8 feet below land surface)	53	149
Shale	26	175
Sandstone	25	200
Kiowa shale		
Shale	49	249
Cheyenne sandstone		
Sandstone (water rose to a level 5 feet above land surface)	38	287

56. Log of well of Mr. Beeler in SE¼ sec. 9, T. 25 S., R. 41 W. (Cited by Darton, 1920.)

	Thickness, feet	Depth, feet
Undifferentiated Pliocene and Pleistocene deposits		
Sand and gravel	210	210
Graneros shale		
Shale, sandy, hard	40	250
Dakota-Cheyenne formations		
Sandstone	20	270
Clay, white	35	305
Lime (probably shale)	13	318
Shale, hard	12	330
Clay, white	40	370
Shale, variegated	20	390
Rock and clay	26	416
Sandstone, gray	14	430
Shale, sandy, hard	24	454
Sandstone, gray	15	469
Clay, brown and white	35	504
Sandstone and clay	20	524
Sandstone, light gray	12	536
Shale, black	3	539

57. Partial log of well in NE¼ sec. 27, T. 25 S., R. 41 W. (Cited by Darton, 1920.)

	Thickness, feet	Depth, feet
Dakota formation		
Shale, sandy, hard	34	170
Sandstone	15	185
Clay, white	15	200
Limestone (probably shale)	10	210
Sandstone	20	230
Clay, white	2	232

58. Partial log of well in NW¼ sec. 33, T. 25 S., R. 41 W. (Cited by Darton, 1920.)

	Thickness, feet	Depth, feet
Graneros shale		
Shale, black	..	140
Dakota-Cheyenne formations		
Sandstone, gray	40	180
Clay, white	30	210
Shale, sandy, hard	50	260
Limestone (probably shale)	22	282
Shale, sandy, hard	23	305
Sandstone, gray	53	358
Clay, white	4	362

59. Log of well in sec. 6, T. 26 S., R 41 W. (Cited by Darton, 1920.)

	Thickness, feet	Depth, feet
Soil	18	18
Undifferentiated Pliocene and Pleistocene deposits		
Sand	7	25
Sand, light	11	36
Graneros shale		
Slate, black (probably shale)	69	105
Dakota-Cheyenne formations		
Shale, brown	43	148
Shale, sandy, light	122	270
Slate, light (probably clay or shale)	10	280
Sand, coarse, gray	10	290
Slate, light (probably clay or shale)	30	320
Slate, gray (probably clay or shale)	15	335
Slate, light to dark (probably clay or shale)	35	370
Lime, chalky, white	30	400
Rock, red, soft	5	405
Lime, pink	20	425
Rock, red, soft	5	430
Sand, soft	25	455
Lime, sandy, containing pyrite	15	470
Lime, sandy, fine	38	508
Sandstone, gray	72	580
Sand, gray	32	612

60. Partial log of Stanolind Oil and Gas Company no. 1 J. M. Judd in SE¼ SE¼ sec. 15, T. 21 S., R. 38 W. Surface altitude, 3,347 feet. (Authority, driller.)

	Thickness, feet	Depth, feet
Undifferentiated Pliocene and Pleistocene deposits		
Sand	165	165
Carlile, Greenhorn, and Graneros formations		
Shale	215	380
Chalk	60	440
Chalk and shale	90	530
Dakota-Cheyenne formations		
Sand	130	660
Shale	10	670
Sand	150	820
Sand and chalk	50	870
Shale	30	900
Sand	30	930
Shale	30	960
Permian redbeds		
Shale, red, and gypsum	150	1,110
Shale, red	40	1,150

61. Partial log of Stanolind Oil and Gas Company no. 1 Patterson in SE¼ SE¼ sec. 23, T. 22 S., R. 38 W. (Authority, driller.)

	Thickness, feet	Depth, feet
Undifferentiated Pliocene and Pleistocene deposits		
Sand	240	240
Carlile shale		
Shale	26	266
Greenhorn-Graneros formations		
Shale and sand	154	420
Dakota-Cheyenne formations		
Sandstone	175	595
Shale	185	780
Sand	20	800
Shale	20	820
Lime	10	830
Shale	16	846
Sand	19	865
Shale	35	900
Permian redbeds		
Redbeds	100	1,000

62. Partial log of Fin-Ker Oil and Gas Company no. 1 Campbell at NW corner SE¼ sec. 32, T. 25 S., R. 35 W. (Authority, driller.)

	Thickness, feet	Depth, feet
Undifferentiated Pliocene and Pleistocene deposits		
Sand, gravel, and silt	390	390
Dakota-Cheyenne formations		
Sandstone and shale	102	492
Shale	128	620
Sandstone and shale	200	820
Permian redbeds		
Redbeds	22	842

63. Partial log of Fin-Ker Oil and Gas Company no. 2 Campbell at NW corner sec. 7, T. 25 S., R. 35 W. (Authority, driller.)

	Thickness, feet	Depth, feet
Undifferentiated Pliocene and Pleistocene deposits		
Sand, gravel, and silt	395	395
Dakota-Cheyenne formations		
Sandstone and shale	405	800
Permian redbeds		
Redbeds	200	1,000

64. Partial log of Fin-Ker Oil and Gas Company no. 3 Campbell in SE¼ NE¼ sec. 19, T. 25 S., R. 35 W. (Authority, driller.)

	Thickness, feet	Depth, feet
Undifferentiated Pliocene and Pleistocene deposits		
Sand and gravel	380	380
Dakota-Cheyenne formations		
Sandstone and shale	185	565
Shale	160	725
Sandstone	55	780
Permian redbeds		
Redbeds	50	830

65. Partial log of Fin-Ker Oil and Gas Company no. 4 Campbell in NE¼ sec. 6, T. 25 S., R. 35 W. (Authority, driller.)

	Thickness, feet	Depth, feet
Undifferentiated Pliocene and Pleistocene deposits		
Sand and gravel	236	236
Sand, hard	44	280
Sand and gravel	100	380
Sand, hard	60	440
Dakota-Cheyenne formations		
Sand (water)	40	480
Shale, blue	15	495
Shale	18	513
Sand	52	565
Shale	120	685

66. Partial log of W. E. Sherry et al. no. 1 Porter at SW corner NE¼ sec. 30, T. 25 S., R. 41 W. (Authority, driller.)

	Thickness, feet	Depth, feet
Dakota-Cheyenne formations		
Shale, dark	140	140
Shale	10	150
Shale, sandy	303	453
Shale	122	575
Shale, green and white	200	775
Triassic (?) -Permian redbeds		
Red rock and salt	500	1,275

67. Partial log of Stanolind Oil and Gas Company no. 1 Bellinger in sec. 15, T. 21 S., R. 38 W. (Authority, driller.)

	Thickness, feet	Depth, feet
Carlile shale		
Shale and clay	320	420
Greenhorn limestone		
Limestone and shale	70	490
Graneros shale		
Shale, black	50	540
Dakota-Cheyenne formations		
Sandstone and shale	390	930
Morrison (?) formation		
Shale and clay, green	50	980
Permian redbeds		
Redbeds	20	1,000

68. Partial log of Fin-Ker Oil and Gas Company no. 2 Masonic Home in SE¼ NE¼ sec. 6, T. 26 S., R. 35 W. (Authority, driller.)

	Thickness, feet	Depth, feet
Undifferentiated Pliocene and Pleistocene deposits		
Sand	80	80
Gravel, coarse	200	280
Shale	19	299
Shale and sand	141	440
Dakota-Cheyenne formations		
Sand, hard	35	475
Shale, blue	7	482
Shale	13	495
Sand and shale	55	550
Shale	275	825
Permian redbeds		
Redbeds	65	890

69. Partial log of Helmerick and Payne Company no. 2 Jones at center of south line of NE¼ sec. 25, T. 26 S., R. 35 W. (Authority, driller.)

	Thickness, feet	Depth, feet
Dune sand		
Sand	60	60
Undifferentiated Pliocene and Pleistocene deposits		
Sand and gravel	240	300
Sand	120	420
Dakota-Cheyenne formations		
Shale, red	14	434
Sandstone and shale	366	800
Permian redbeds		
Redbeds	290	1,090

70. Partial log of Wood Oil Company no. 1 Ranson at NW corner sec. 5, T. 26 S., R. 41 W. (Cited by Bass, 1926.)

	Thickness, feet	Depth, feet
Undifferentiated Pliocene and Pleistocene deposits		
Sand and gravel	37	37
Greenhorn and Graneros formations		
Shale, black	68	105
Dakota-Cheyenne formations		
Shale, sandy, and sandstone	185	290
Shale, dark	110	400
Rock red	30	430
Sandstone, light-colored	182	612
Triassic (?) redbeds		
Redbeds	192	804

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to a level somewhat below the static level of the water in the alluvium. The second zone is encountered at a level about 150 feet below the top of the formation. Water from these beds generally will rise nearly to the land surface. One flowing well (61) in the vicinity of Coolidge obtains its water from these beds.

In the western part of the Kearny upland, a few wells are supplied with water from the Dakota formation. These wells range in depth from 400 to 850 feet and the water rises to a level about 300 to 400 feet below land surface. The great depth at which the Dakota formation lies in this area prevents extensive development of water supplies from these beds.

Generally, the sandstones of the Dakota formation are moderately permeable and yield adequate quantities of water for most domestic and stock uses, but in a few localities little or no water can be obtained from them. Well 11 when pumping at the rate of only a few gallons a minute has a draw-down of more than 375 feet because the sandstone at this point probably is tightly cemented, preventing the water from moving freely through it. Where the sandstones are cemented with silica, probably little or no water can be obtained from them. In such places the underlying Cheyenne sandstone generally will supply adequate water for most uses.

Water from the Dakota formation is relatively hard and generally contains enough fluoride to be harmful to children's teeth. The average water from the Dakota formation, based on 31 analyses from wells in Hamilton, Gray, Ford, Stanton, and Morton counties, contains about 395 parts per million of dissolved solids and has a hardness of about 215 parts per million. The fluoride content of these samples averaged about 2.2 parts per million. Water from the Dakota formation in Hamilton county had an average fluoride content of 2.0 parts per million. The ratio of the sodium content to total amount of calcium, magnesium, and sodium is relatively high in water from the Dakota formation, and sodium constituted 79.5 percent of the total bases in one sample (29).

GRANEROS SHALE

Character.—The Graneros shale was defined by Gilbert (1896) as a laminated argillaceous shale 200 to 210 feet thick. It was named from a creek in the northern part of the Walsenberg quadrangle in south central Colorado. In the Hamilton-Kearny area the Graneros shale comprises about 60 to 65 feet of gray-black fissile argillaceous shale with a 5- to 16-inch bed of bentonitic clay about 10 feet below the top of the formation. At 20 to 22 feet above to be correlative with the Kiowa shale and with the upper shaly part of the Purgatoire formation also aids in its correlation.

Marine fossils collected from the Cheyenne sandstone in Cimarron county, Oklahoma, are believed by Bullard (1928, p. 116) to be of Washita (Lower Cretaceous) age. Marine pelecypods collected by Schoff (1939, p. 55) in the Cheyenne sandstone in the Red Point district in Texas county, Oklahoma, were identified by T. W. Stanton as representing a horizon near the base of the Washita group (Lower Cretaceous).

Origin.—The presence of marine fossils in the Cheyenne sandstone in Texas and Cimarron counties, Oklahoma, implies a marine origin for these beds in that area. In Kiowa and Comanche counties, Kansas, however, discontinuous bedding, cross-lamination, apparent absence of marine fossils, and presence of land plants seem to indicate a nonmarine origin. Twenhofel (1924, pp. 19, 20) states that the vegetable matter appears to have floated in and that the Cheyenne sandstone in this area is also marine.

Water supply.—Moderate quantities of water under artesian pressure are obtained from the Cheyenne sandstone by wells in the vicinity of Coolidge. In wells that penetrate these beds the water rises nearly to or above the land surface. All but one of the flowing artesian wells in the Coolidge area obtain water from the Cheyenne sandstone at depths of 285 to 325 feet. A few wells penetrate these beds at Syracuse and at Kendall. Water from the Cheyenne sandstone rises to about 45 feet below land surface in well 78 at Syracuse, whereas the static water level in a near-by well (77) that obtains water from the alluvium is 25 feet below land surface. Water could be obtained from the Cheyenne sandstone in almost any part of Hamilton and Kearny counties, but the Cheyenne is everywhere overlain by the Dakota formation which would yield adequate quantities of water for most uses. The great depth at which the Cheyenne sandstone lies also prevents much development of its water supply. It ranges in depth below land surface from about 250 feet in the Syracuse upland to about 900 feet in the northern part of the Kearny upland.

Water from the Cheyenne sandstone is moderately hard and is similar to water from the Dakota formation. Generally it is somewhat softer than water from the Dakota formation and from Tertiary and Quaternary sediments.

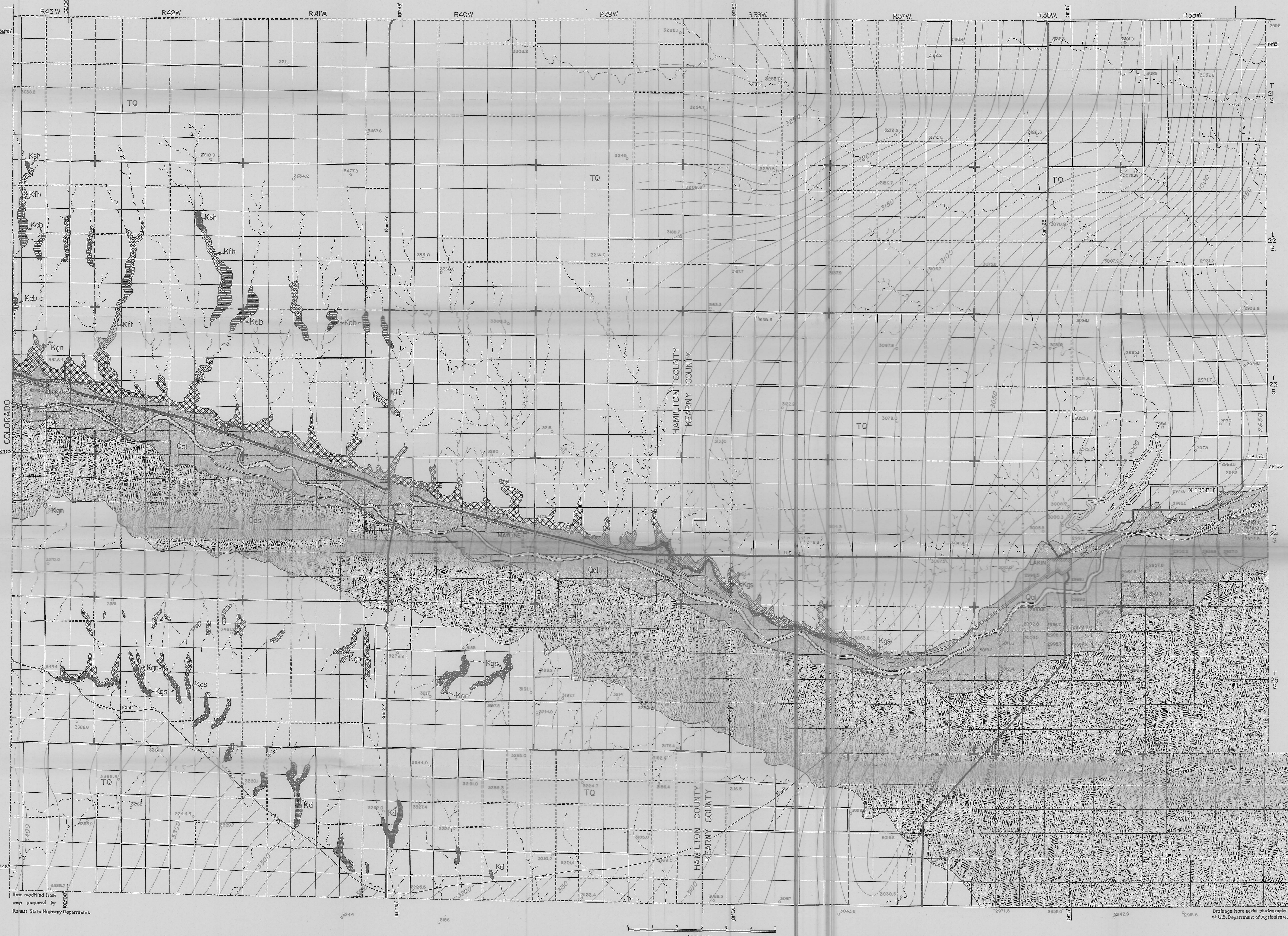
MAP OF HAMILTON AND KEARNY COUNTIES, KANSAS

Showing Geology and Water-Table Contours, 1940

By Thad G. McLaughlin

State Geological Survey
of Kansas

Bulletin 49
Plate 1



EXPLANATION

PLEISTOCENE AND RECENT — QUATERNARY

Qal

Alluvium

Gravel, sand, and silt. Yields large quantities of hard water to domestic, stock, municipal, and irrigation wells.

Qds

Fine eolian sand. Sand dunes are above the water-table and do not yield water to wells. Important catchment areas for recharge of the ground-water reservoir.

PLIOCENE AND PLEISTOCENE — TERTIARY AND QUATERNARY

TQ

Undifferentiated Pliocene and Pleistocene deposits

Sand, silt, gravel, and caliche. Yields moderate to large quantities of moderately hard water to domestic, stock, and irrigation wells.

GULFIAN — CRETACEOUS

Ksh

Niobrara formation
Smoky Hill chalk member

Orange-yellow shaly chalk. Yields little or no water to wells.

Kfh

Niobrara formation
Fort Hays limestone member

Cream-colored chalky limestone. May yield small quantities of water to a few wells.

Kcb

Carlile shale
Codell sandstone and Blue Hill shale members

Codell sandstone member is comprised of fine-grained sandstone and sandy shale. Yields small quantities of water to a few wells. Blue Hill shale member is blue-black fissile shale and yields little or no water to wells.

Kft

Carlile shale
Fairport chalky shale member

Calcareous shale in upper part. Basal part is thin-bedded chalky limestone and gray shale. Yields little or no water to wells.

Kgn

Greenhorn limestone

Thin-bedded chalky limestone and gray limy shale. Yields very small quantities of water to a few wells in northern Hamilton county.

Kgs

Graneros shale

Dark gray fissile shale. Yields little or no water to wells.

Kd

Dakota formation

Buff, brown, and tan fine-grained sandstone containing vari-colored shale and clay. Yields moderate quantities of moderately hard water to domestic and stock wells in Hamilton county and southwestern Kearny county.

Contour interval 10 feet

2950 — Water-table contours based on instrumental levels (dashed where position is inferred)

3063.2 — Well location. Number refers to altitude of water level

Federal or State Highway

Graded road

Ungraded road

Section line (no road)

Township line (no road)

Railroad

MAP OF HAMILTON AND KEARNY COUNTIES, KANSAS

Showing the depths to Water Level and the Location of Wells for which Records are given

By Thad G. McLaughlin

1940

State Geological Survey of Kansas

Bulletin 49

Plate 2

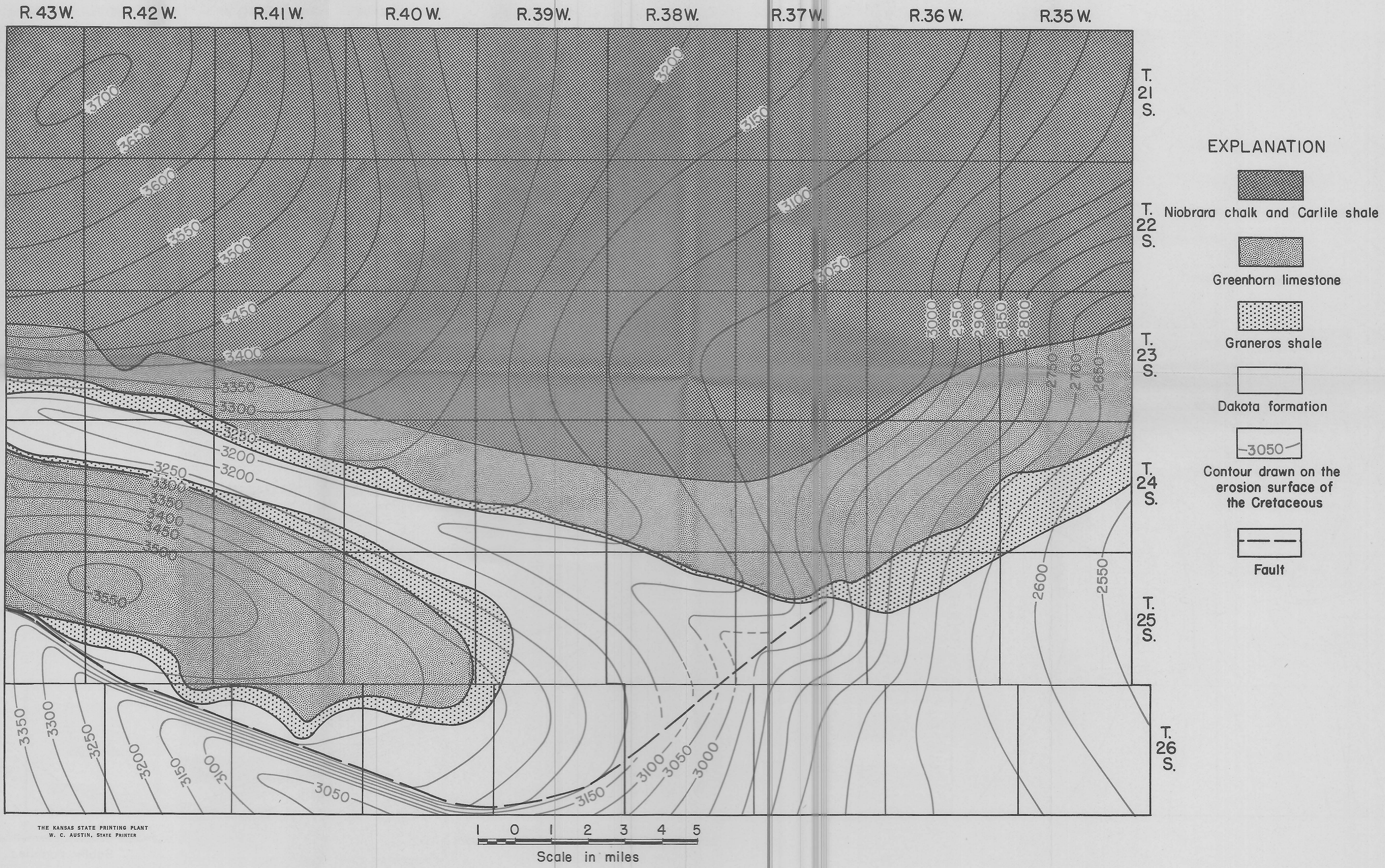
MAP OF HAMILTON AND KEARNY COUNTIES, KANSAS

Showing the Geology and Topography of the Rocks Beneath the Tertiary and Quaternary Deposits

State Geological Survey of Kansas

By Thad G. McLaughlin

Bulletin 49
Plate 3



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