GROUND-WATER SUPPLIES AT HAYS, VICTORIA, WALKER, GORHAM, AND RUSSELL, KANSAS

with special reference to future needs

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BRUCE F. LATTA

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Prepared by the State Geological Survey of Kansas and the United States Geological Survey, with the co-operation of the United States Bureau of Reclamation, 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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ABSTRACT

This report was prepared at the request of the United States Bureau of Reclamation to determine whether provisions should be made to supply water to the cities and towns of Hays, Victoria, Walker, Gorham, and Russell, Kansas, from the proposed Cedar Bluff reservoir or whether ground water adequate to supply the present and future needs of these cities and towns can be developed.

The cities and towns with which the report is concerned are in an area about 25 miles long in Ellis and Russell Counties in north-central Kansas, and lie about midway between Saline and Smoky Hill Rivers. The proposed Cedar Bluff reservoir is on Smoky Hill River in southeastern Trego County about 22 miles southwest of Hays, the western-most city considered.

Ellis and Russell Counties are underlain by sedimentary rocks that range in age from Cretaceous to Quaternary. The Niobrara formation, Carlile shale, Greenhorn limestone, Graneros shale, and Dakota formation, all of Cretaceous age, are exposed on the uplands and along the sides of the valleys. Thin deposits of silt, sand, and gravel of Tertiary age locally overlie the Cretaceous rocks in the upland areas. Adequate supplies of potable water for public supply are not available from Cretaceous or Tertiary rocks in this area.

Quaternary alluvium and terrace deposits composed of unconsolidated gravel, sand, and silt are present in and along the larger valleys. All existing public wells in the area considered obtain water from these deposits. Additional public-supply wells can be developed in alluvium and terrace deposits in certain areas.

The City of Hays is supplied with water from 15 wells in or near the city that tap alluvium and terrace deposits in and along the valley of Big Creek, a tributary of Smoky Hill River. The yields of the wells range from about 30 to 200 gallons a minute. Test drilling indicates that additional wells having comparable yields can be developed in parts of Big Creek Valley northwest and southeast of Hays and in parts of the terrace areas that border the valley. By locating wells over a wide area an additional amount of water equal to the present public supply can be obtained.

The City of Victoria obtains its water from five wells that tap Quaternary deposits along Victoria Creek south, west, and northwest of town. These wells have relatively small yields and are subject to marked declines in yield during prolonged dry periods. Additional water for the future needs of Victoria can be obtained by supplementing the present supply with water pumped from wells tapping the alluvium in Victoria Creek Valley several miles below town, or from wells tapping the alluvium in Big Creek Valley southeast of Victoria.

Neither Walker nor Gorham has a public water supply, and it seems probable that an adequate supply of ground water of satisfactory quality is not available in the immediate vicinity of either town. The nearest underground source of water supply for Walker and Gorham probably would be the alluvial deposits in Victoria Creek Valley or Big Creek Valley.

The municipal water supply for the City of Russell is pumped in part from Smoky Hill River and in part from Big Creek. This supply is unsatisfactory because of the high chloride content of the water during low stages of the streams.

In 1944 the State and Federal Geological Surveys made an investigation to determine the availability of a ground-water supply for the City of Russell. A summary of the unpublished report giving the results of this investigation is published in the present report.

The investigation did not reveal any place near Russell where an adequate supply of potable water to furnish the entire needs of the city could be obtained from wells. However, it was concluded that a supplemental supply could be obtained from the alluvium in the Smoky Hill Valley in the vicinity of Pfeifer, about 20 miles southwest of Russell. It was recommended that the city obtain most of its supply from the Smoky Hill River except during low river stages, at which time ground water could be used.

Logs of 88 test holes, two city supply wells at Hays, and four observation wells are given, including 42 test holes drilled by the State and Federal Geological Surveys.

INTRODUCTION

Included in the plans of the Missouri Basin Program for the development and utilization of all available water supply is the construction of the Cedar Bluff dam and the irrigation of about 13,000 acres of land lying on the north side of Smoky Hill River in southeastern Trego County and southwestern Ellis County in north-central Kansas. Figure 1 shows the location of the proposed dam and the locations of the cities and towns whose water supplies are described in the present report.

Plans for the Cedar Bluff irrigation project will take into consideration the question of whether provision must be made to supply water to the cities and towns of Hays, Victoria, Walker, Gorham, and Russell, Kansas, from the proposed reservoir; or whether adequate ground water is available to supply the present and future needs of those cities and towns.

For planning purposes it is assumed by the United States Bureau of Reclamation that the population of the several cities and towns will double within the next 40 to 50 years. In 1940, according to the Federal Census, the population of Hays was 6,385, that of Russell was 4,819, and that of Victoria was 884. Walker and Gorham are small unincorporated towns whose populations probably do not exceed 400.

In 1944 the State and Federal Geological Surveys, at the request of and in cooperation with the officials of Russell, made an investigation of the ground-water conditions in the Russell area to determine whether a supply of water of good quality adequate for the city's needs could be obtained from wells. The results of this investigation are given in an unpublished report by Thad G. McLaughlin (1944), who was in charge of the field investigation.

I spent 5 days in the Russell area during April 1946, conferred with city officials, mapped the geology in the vicinity of Hays, and selected sites for further test drilling in the vicinity.

In the Hays area 27 test holes were drilled by the United States Geological Survey in cooperation with the State Geological Survey of Kansas during April 1946, four of the holes being cased as observation wells. A portable hydraulic-rotary machine owned by the State Geological Survey was used to drill the test holes.

The following report is based upon the data thus collected, upon previously obtained data relating to the public water supply of Hays, upon data made available by the Kansas State Board of Health, and upon data from other sources. The section of the report dealing with the City of Russell is a summary of the report by McLaughlin.

ACKNOWLEDGMENTS

The investigation made by the writer was under the supervision of V. C. Fishel, who is in charge of ground-water studies of the United States Geological Survey in Kansas. Acknowledgments are also made to V. A. Basgall, city manager of Hays, for furnishing data relating to the city wells and assisting me in other ways; to the Layne-Western Company, who furnished logs of wells and test holes drilled in the Hays area; to Lawrence Wellbrook, city manager of Victoria, who furnished data regarding the public water supply of that city; to Mr. Hamersmith, mayor of the town of Gorham, who furnished data regarding a proposed public water supply for that town; and to many other residents of the area who were most cooperative in supplying information and in giving permission to gather data on their properties.

CLIMATE

The climate of the area considered is of subhumid to semiarid type, involving slight to moderate precipitation, moderately high

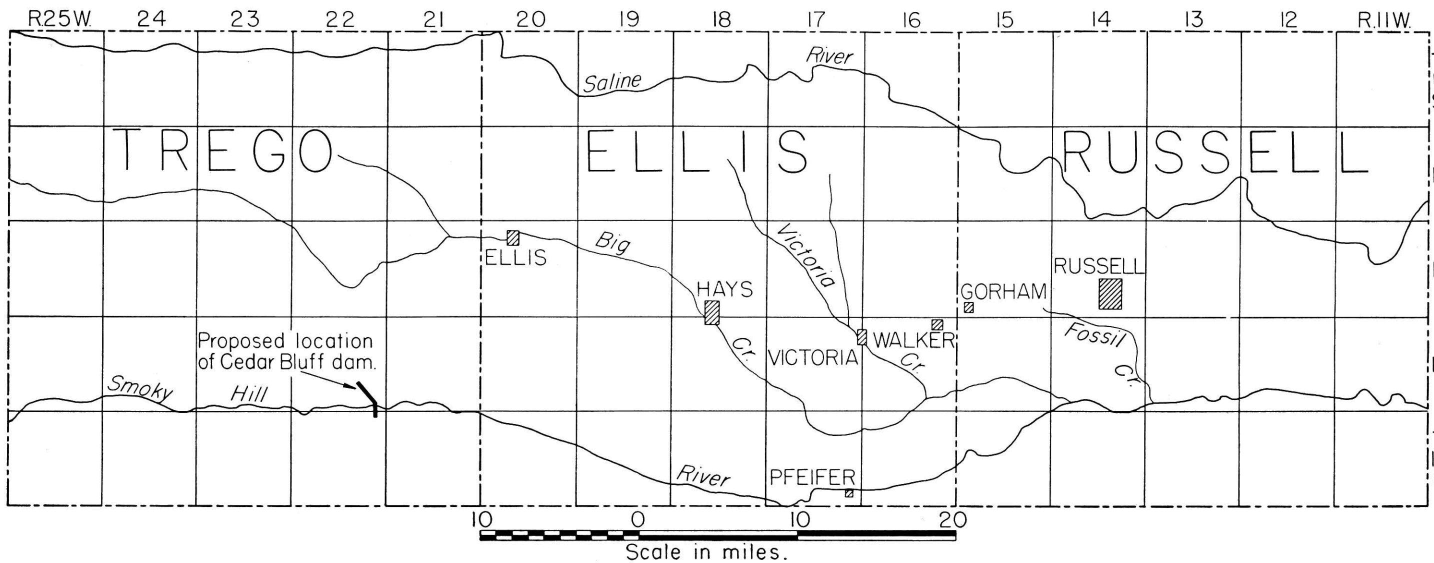

FIG. 1.—Index map of Trego, Ellis, and Russell Counties, Kansas, showing the location of the proposed Cedar Bluff dam and near-by cities and towns.

average wind velocity, and rapid evaporation. The normal annual mean temperature at Hays is 54.1° F. In general the hottest month is July, with a normal mean temperature of 79.4° F., and the coldest month is January with a normal mean of 29.4° F.

The normal annual precipitation at Hays, determined by the U. S. Weather Bureau, is 23.05 inches, but the actual annual precipitation varies widely. The smallest precipitation of any year since the record was begun in 1868 was in 1894, when only 11.80 inches was recorded; and the greatest was in 1878, when 35.40 inches was recorded. Most of the precipitation occurs during the period April through September.

The annual precipitation for the period of record, and the cumulative departure from normal precipitation at Hays are shown in Figure 2. The curve of cumulative departure from normal has a roughly cyclic pattern of recurrent wet and dry periods. This area has experienced several prolonged dry periods in the past, the most recent being the drought of the 1930's, when the precipitation was below normal each year from 1933 through 1940. Other long periods of deficient rainfall were from 1892 through 1895, 1879 through 1884, and 1868 through 1873. In addition many shorter periods of deficient rainfall are recorded. Figure 2 shows the periods of drought and the alternating wet periods.

Although the cumulative rainfall for 1941-45 amounts to 8.72 inches above normal, the record indicates that prolonged dry periods are to be expected in the future. Rainfall studies are important in any ground-water investigation, for in general the amount of water demanded during any period varies inversely with the amount of precipitation and the amount of ground-water recharge in most areas varies with the precipitation received.

TOPOGRAPHY

The cities and towns considered in this report lie about midway between Smoky Hill and Saline Rivers in Ellis and Russell Counties, Kansas. Saline River flows from west to east across northern Ellis County and a little north of the center of Russell County. Smoky Hill River crosses the southern parts of the same counties from west to east.

The largest tributary stream in this area is Big Creek, which flows in a southeasterly direction across central Ellis County and

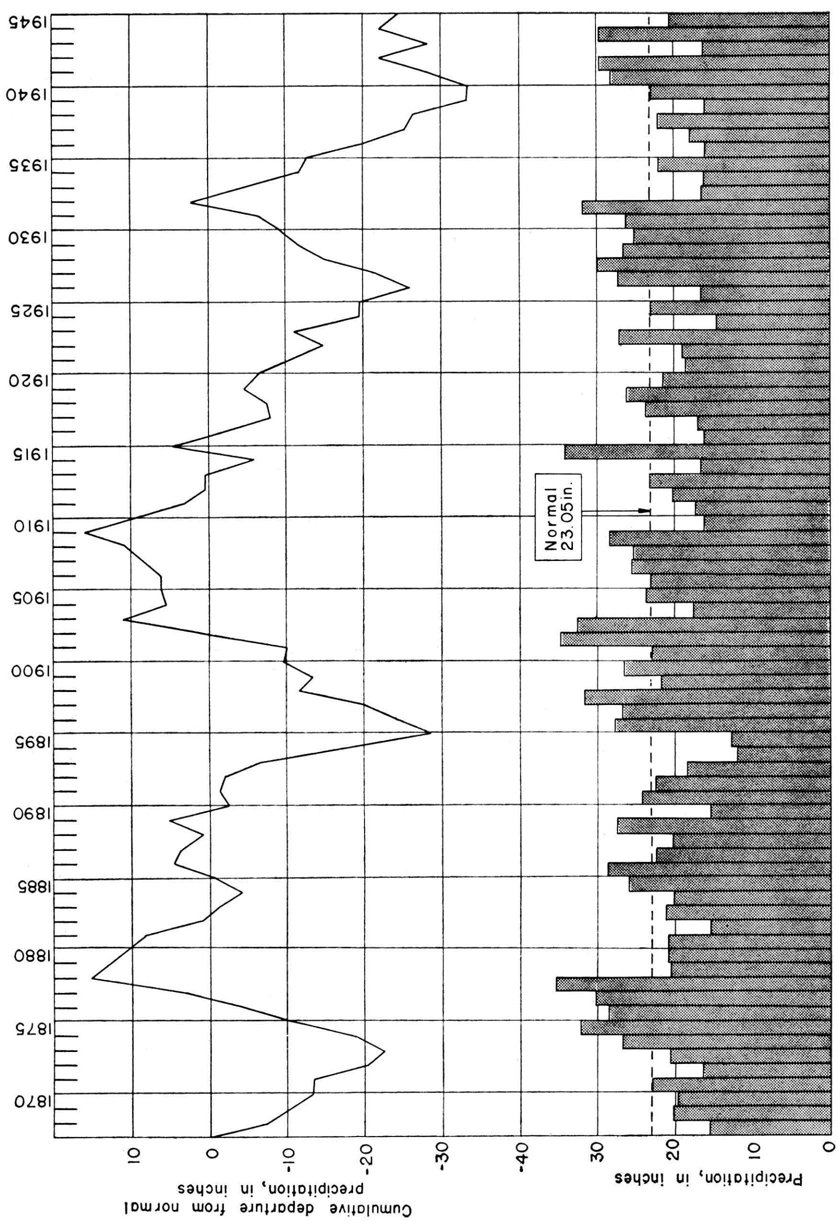

FIG. 2.—Annual precipitation and cumulative departure from normal precipitation at Hays, Kansas. (From records of the United States Weather Bureau)

joins Smoky Hill River in southwestern Russell County. Victoria Creek, a tributary of Big Creek, drains a relatively small area in east-central Ellis County and joins Big Creek south of Walker.

The valleys of the larger streams are relatively flat and less than a mile to several miles in width. They are bordered in some places by terraces, the surfaces of which slope toward the valleys and are dissected by short tributary streams. Gentle to steep slopes separate the valleys and terraces from the upland surface.

The uplands over most of the area are formed by the Carlile shale, which has produced a relatively flat surface having an eastward slope. The gentle slope of the surface of the Carlile shale is broken north and west of Hays by a prominent escarpment produced by resistant chalk beds in the Niobrara formation.

The greater part of the City of Hays is located in the valley of Big Creek. The valley above Hays is about 1 to 1.5 miles wide, but a short distance below Hays it narrows abruptly to 0.5 to 0.8 mile in width. Big Creek is a meandering stream that occupies the northeast side of its valley above Hays, but in the narrow part of the valley southeast of Hays it is cutting against the southwest bluff, most of the valley plain in this area being northeast of the stream. The valley floor in the vicinity of Hays is in most places relatively smooth and has a gradual slope toward Big Creek. The valley floor has been dissected locally by small tributaries that drain into Big Creek.

Big Creek Valley in the Hays area is bordered on both sides by terraces which represent the floor of a large valley that was occupied by Big Creek when it was flowing at a higher level than it is today. The terrace along the north side of the valley ranges from less than 1 mile to about 2 miles in width and has a southward-sloping surface that has been dissected by many southward-flowing tributaries of Big Creek. The divide areas between the tributaries are at approximately the same height, and when viewed from a distance they appear to form a nearly level surface. The southeast edge of this terrace is only about 20 feet above the present floor of Big Creek Valley, whereas the north or outer edge is about 80 feet above the valley floor.

The terrace bordering the southwest side of the valley in the vicinity of Hays is similar to the north terrace except that the southern terrace slopes in a general easterly direction. No major topographic break occurs southwest of this terrace until an escarpment formed by chalk of the Niobrara formation is reached. This area may not be entirely underlain by terrace deposits, for the surface of the terrace deposits that are known to occur near the valley may be topographically continuous with the surface formed by the relatively soft Carlile shale southwest of the area. The escarpment formed by chalk of the Niobrara borders the terrace north and southwest of Hays and rises 80 to 120 feet or more above the terrace surfaces.

The City of Victoria is located on the northeast side of Victoria Creek, about 5 miles above its mouth. Victoria Creek in this area has a poorly defined valley. The land on each side of Victoria Creek slopes uniformly toward the stream and is crossed by many short tributary draws. Walker, Gorham, and Russell are located on relatively flat uplands.

GEOLOGY

General

Ellis and Russell Counties are underlain by rocks of Cretaceous age. In addition, patches of Tertiary deposits overlying the Cretaceous rocks remain on parts of the upland, and materials of Quaternary age have been deposited in the stream valleys.

The following brief discussion of the geology and water-bearing properties of the Cretaceous and younger rocks has been taken chiefly from reports by Rubey and Bass (1925), Frye and Brazil (1943), and McLaughlin (1944).

The oldest Cretaceous rocks that crop out in this area comprise the Dakota formation, which consists of variegated clay, sandy shale, and sandstone. About 160 feet of this formation is exposed along the valleys of Smoky Hill and Saline Rivers in Russell County.

The sandstone beds of the Dakota formation yield small to moderate supplies of water to domestic and stock wells in parts of the area, but in many places the water has a high chloride content and is not suitable for ordinary use.

The Dakota formation is overlain by about 40 feet of dark-gray clay shale and sandy shale classified as Graneros shale, a formation that yields little or no water to wells in the area under consideration.

Overlying the Graneros shale is the Greenhorn limestone, which consists of about 100 feet of chalky shale, chalk, and thin-bedded limestone. The limestone and chalk in this formation yield very small quantities of potable water to a few stock and domestic wells in Russell and Ellis Counties.

The next higher formation in the Cretaceous sequence, the Carlile shale, underlies much of the upland surface in Ellis and Russell Counties. The lower part of this formation consists chiefly of chalky shale and chalk, whereas the upper part is mainly clay shale containing sandy shale and sandstone (Codell sandstone member) at the top. Very little water can be obtained from the Carlile shale, except in a few places where the sandstone member at the top yields small quantities of water for domestic and stock uses.

The uppermost Cretaceous rocks that crop out in Russell and Ellis Counties comprise the Niobrara formation. This formation consists of chalk, chalky limestone, and chalky shale and yields little or no water to wells.

Silt, sand, and gravel of Tertiary age were laid down over most of Ellis and Russell Counties, but much of this material has been removed by erosion, leaving only thin deposits on the higher parts of the upland areas. The down-cutting of the streams has resulted in the draining of so much of the water from these beds that they yield only small quantities of water to a few wells.

Deposits of Quaternary age have been laid down in this area by the major streams. These beds comprise the Pleistocene terrace deposits, which were laid down when the stream flowed at a higher level than at present and are found only along the sides of the valley; and the alluvium that was laid down more recently and is found in the bottom lands.

Silt comprises the upper part of the Quaternary deposits in most places, and unconsolidated sand and gravel comprise the lower part. These deposits in some places are adequately thick and permeable to yield relatively large quantities of water to wells. In most of Russell County, however, the water in the Quaternary deposits has been contaminated by brackish or salt water from the sandstone of the Dakota formation, or from oil-field brines, or from both sources.

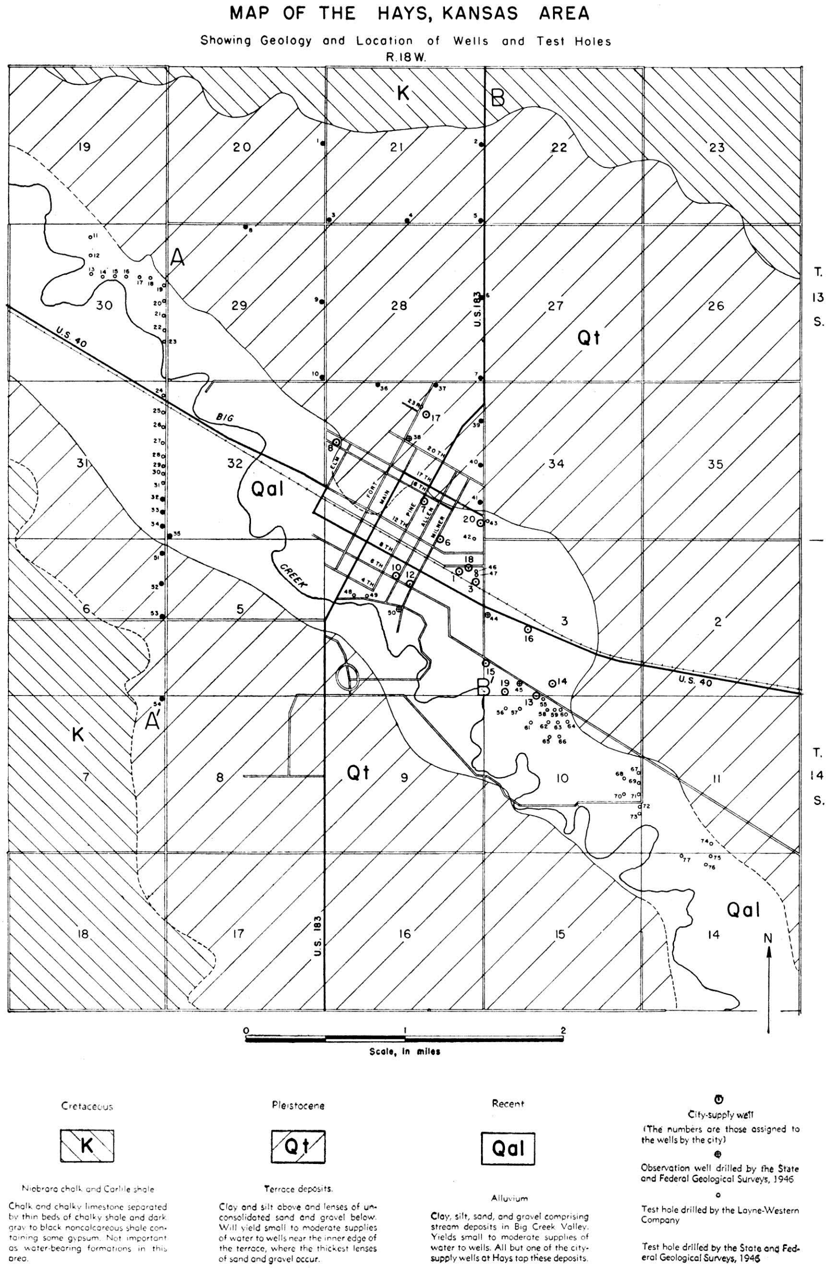

FIG. 3.—Map of the Hays, Kansas, area showing geology and location of wells and test holes.

Vicinity of Hays

The rocks that crop out in the Hays area include the Carlile shale and overlying Niobrara formation, both Cretaceous in age, terrace deposits of Pleistocene age, and Recent alluvium. Their areal distribution is shown on the map of the Hays area (Fig. 3).

The high areas north and southwest of Hays are underlain by the Niobrara formation. The Carlile shale forms the slopes below the Niobrara hills, and makes up the bedrock beneath the terrace deposits and alluvium throughout this area.

The most important sources of ground water in the Hays area are the terrace deposits that underlie the surface northeast and southwest of Big Creek Valley, and the alluvium in Big Creek Valley.

Exploratory test drilling in Big Creek Valley by the Layne-Western Company preceded the drilling of many of the city wells. The logs of most of these test holes are included in the present report. The logs of 27 test holes drilled in the Hays area by the State and Federal Geological Surveys in April 1946 are also included. Altitudes of the land surface at all test holes, city wells, and observation wells were determined by plane table and alidade.

The locations of the test holes in the Hays area are shown on Figure 3 and the logs are given at the end of this report.

North of Hays 16 test holes (nos. 1 to 10 and 36 to 41) were drilled, and four (nos. 51 to 54) were drilled southwest of Hays to determine the character and thickness of the terrace deposits. The test drilling indicates that the terrace deposits attain thicknesses of 55 to 81 feet along the edge of the terraces (Fig. 4) and become very thin near the bluffs formed by Cretaceous rocks, as shown in profile B-B′ of Figure 4.

The maximum thickness encountered, 81 feet, was in test hole 9 about 1½ miles northwest of Hays. In the area west of Hays the maximum thickness of terrace deposits penetrated was 63 feet, in test hole 52, as shown in profile A-A′ of Figure 4.

The terrace deposits consist predominantly of silt but contain some sand and gravel. The silt is mainly in the upper part and is generally tan to brown; but beds of gray, blue-gray, and dark gray silt were encountered in some test holes. Calcium carbonate nodules and stringers are common in the silt and locally there are lenses or zones containing fine to coarse sand. Beds of sand and gravel, ranging in thickness from a few feet to about 35 feet, underlie the silt in most places.

The beds of sand and gravel are comprised of poorly sorted fine sand to coarse gravel that locally contains silt in varying proportions. Pebbles of limestone are common in the gravels. The thickest beds of sand and gravel are near the edge of the terrace bordering the northeast side of Big Creek Valley. A short distance back from the edge of the terrace the beds of sand and gravel are much thinner; and near the Cretaceous bluffs the terrace deposits contain little or no sand and gravel, but consist almost entirely of silt. The greatest thickness of sand and gravel encountered in the terrace deposits southwest of Hays was 15 feet, in test hole 51.

Many stock wells and domestic wells in the Hays area obtain water from sand and gravel in the terrace deposits. Most of these are wells of small diameter having small yields. City well 17, in the northern part of Hays, also derives its supply from these deposits. It is a drilled, gravel-packed well 68 feet deep and 12 inches in diameter. On May 22, 1943, the measured depth to water level in the well was 48.95 feet below the land surface. The yield of this well when it was constructed in 1941 was 260 gallons a minute, but the yield has declined since that time, and in April 1946 was 180 gallons a minute. Comparable yields may be expected from other properly constructed wells in a narrow belt along the terrace bordering Big Creek Valley north and northwest of Hays.

The alluvium in Big Creek Valley consists of stream-laid deposits that range in texture from clay and silt to sand and coarse gravel. The upper 10 to 50 feet of the alluvium consists of silt and sand that has been deposited over the flood plain in time of flood, or under normal conditions in the channel of the stream. Beneath the finer deposits are lenses of coarse sand and gravel that are lithologically similar to the terrace gravels described above.

The sand and gravel in the alluvium varies greatly in thickness, as shown in Figure 3 and as indicated in the logs given at the end of this report. The test holes encountered from a few inches to 23 feet of sand and gravel in the alluvium in the Hays area.

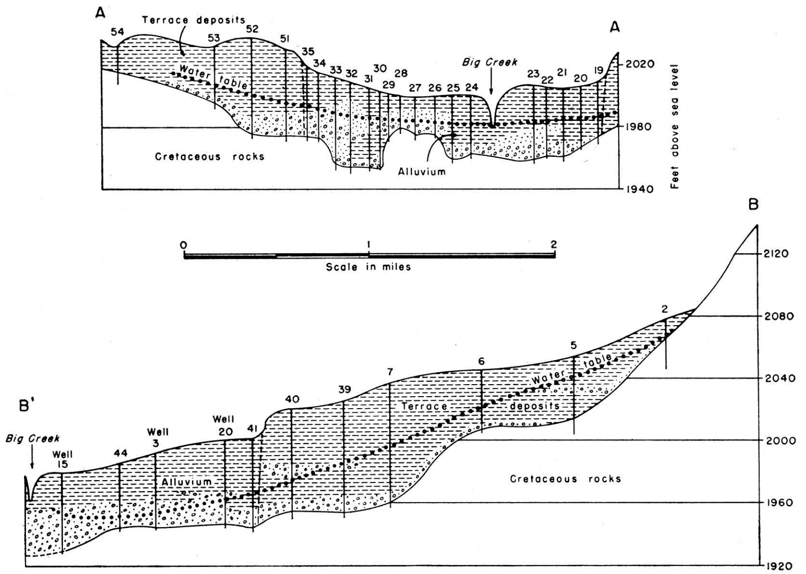

FIG. 4.—Geologic profiles across Big Creek Valley near Hays, Kansas. Locations of the profiles are shown on Figure 3.

Locally the alluvium contains no sand and gravel (logs 19 and 70). The alluvium grades into the terrace deposits, so in some places the lower part of the valley fill is probably of Pleistocene age and represents the basal part of a cut-and-fill terrace deposit. The thickness of the alluvium in Big Creek Valley as revealed by test drilling ranges from about 20 to 56 feet. The thickness differs greatly, however, even in short distances, both along and across the valley (Fig. 4).

The alluvial sand and gravel in Big Creek Valley is the source of supply for all the Hays city-supply wells except number 17 and for many stock and domestic wells. The yields of the city-supply wells tapping the alluvium range from 30 to 200 gallons a minute.

VICINITY OF VICTORIA

The uplands in the vicinity of Victoria are underlain by silt, sand, and a small amount of gravel of Tertiary age. According to the records of stock wells and domestic wells in this area, these deposits are relatively thin and consist chiefly of fine sediments, only the lower few feet being saturated. Available data indicate that the Tertiary deposits in this area furnish only meager supplies of water to wells.

The Tertiary deposits are underlain, in descending order, by the Carlile shale, Greenhorn limestone, Graneros shale, and Dakota formation, all Cretaceous in age. Moderate supplies of water are obtainable from deep sandstone beds of the Dakota formation, but the water is highly mineralized and is not suitable for domestic use.

Unconsolidated deposits of Pleistocene and Recent age occur in a narrow belt along Victoria Creek. The total thickness of these deposits ranges from less than 10 feet to about 50 feet. They consist chiefly of silt, sandy silt, and sand, but contain small lenses of poorly sorted sand and gravel in the lower part. The thickness of the saturated part of the terrace deposits and alluvium ranges from less than 5 feet to about 30 feet.

Small supplies of water are obtained by wells tapping the terrace deposits and alluvium in the valley of Victoria Creek. All the Victoria city-supply wells and a few stock and domestic wells in this area derive water from these deposits.

VICINITY OF WALKER

In 1942 the writer was called upon to assist in locating a water supply for the Walker Army Air Base, situated about 1¼ miles north of Walker. During the course of this investigation the Layne-Western Company drilled a total of 16 test holes, six being on or near the site of the air base, seven in Victoria Creek Valley south of Walker, and three in Big Creek Valley south of Walker. The following discussion is based in part on the results of this test drilling.

The surface in the vicinity of Walker is underlain by 20 to 35 feet of Tertiary deposits that consist chiefly of silt and clay but contain some sand and a very little gravel. Although these deposits furnish small supplies of water to stock and domestic wells in this area, they are not sufficiently permeable or thick enough to serve as a source for city-supply wells. The Tertiary deposits are underlain by the Carlile shale.

Test holes drilled in Victoria Creek Valley southwest of Walker, in the S½ NE¼ sec. 21, T. 14 S., R. 16 W., indicate that the thickness of alluvium in this area ranges from about 30 feet to 38 feet. The upper part of the alluvium consists of silt and clay and the lower 10 to 20 feet consists of water-bearing sand and gravel. A test well tapping alluvium in this area yielded 35 gallons a minute with a drawdown of 5.6 feet.

In the valley of Big Creek south of Walker three test holes were drilled in the NE¼ NE¼ sec. 34, T. 14 S., R. 16 W. The alluvium in this small area was 18 to 21 feet thick, and a maximum of 14 feet of sand and gravel was encountered. It is believed that a more extensive test-drilling program would reveal greater thicknesses of alluvium in other places in this area.

Vicinity of Gorham

Clay, silt, sand, and gravel of Tertiary age overlie the Carlile shale and comprise the surface deposits in the Gorham area. These deposits are less than 30 feet thick in most places, and only the lower few feet, which generally consists of sand or gravel, is water bearing. Stock and domestic wells in this area obtain small supplies of water from these sediments.

A narrow belt of Recent alluvium consisting chiefly of clay, silt, and sand occupies the valley of a small unnamed ephemeral stream that flows from north to south along the west edge of Gorham. The alluvium in this small valley is very thin and only the lower part is water bearing. A few shallow stock and domestic wells and the Gorham school well obtain water from the alluvium.

Vicinity of Russell

The upland area in the vicinity of Russell is underlain by the Carlile shale. Thin deposits of silt, sand, and gravel of Tertiary age locally mantle these Cretaceous rocks. Saline River north of Russell and Smoky Hill River south of Russell have cut relatively wide and deep valleys, exposing along the sides the Greenhorn limestone, Graneros shale, and Dakota formation. Alluvial deposits of Pleistocene and Recent age have been deposited in those valleys.

GROUND WATER

Vicinity of Hays

PUBLIC WATER SUPPLY

The City of Hays has had a public water supply since 1903, when three dug wells of large diameter were constructed and curbed with brick. These early wells, two of which were not in use in 1946, range from 45 to 65 feet in depth and are supplied with water from the alluvium in Big Creek Valley.

Increasing demands for water caused by the growth of the city necessitated the construction of additional wells, and the city had 12 wells in operation during 1941. The city furnished water to the Walker Army Air Base, located about 11 miles east of Hays, during World War II. This requirement, plus an increased demand due to a wartime increase in population, overtaxed the existing wells. Therefore, two new wells were constructed during 1944 and one during 1945, which made a total of 15 wells in the city's public water system in 1946.

The locations of the city wells are shown on Figure 3, and information concerning them is given in Table 1. The well numbers given in the first column of this table are the numbers that have been assigned to the wells by the city. The water-level measurements were made by employees of the city.

Of the 15 city wells, 14 tap the alluvium in Big Creek Valley and one (well 17) taps the terrace deposits north of the valley. All but two (wells 10 and 13) are drilled wells ranging from 34 to 68 feet in depth cased with steel or concrete. Wells 10 and 13 are dug wells of large diameter that are 35 and 38 feet deep, respectively, and are curbed with brick. The depth to water level in the wells ranges from about 24 feet to nearly 50 feet below the surface. The drilled wells, with the exception of wells 3 and 12, are gravel packed.

The yield of each city well as reported for December 1945 is given in Table 1. Some of the wells are not capable of being pumped continuously, but can be pumped only a few hours each day, then must be shut off to allow the well to recover. Well 13, for example, is capable of supplying only 30 gallons a minute for 8 hours a day. Wells 3 and 8 yield 90 gallons a minute for 12 and 10 hours a day, respectively. The other wells are reported to yield

65 to 200 gallons a minute continuously, and average about 115 gallons a minute.

It is important to note from Table 1 that the yields of all the wells have declined since they were drilled. The amount of decline in yield has been relatively small for some wells, but for others it has been more than 100 gallons a minute. Wells 18 and 19, drilled in June 1944, and well 20, drilled in August 1945, already show declines in yield of about 35, 40, and 20 percent, respectively. In an area such as this, where the water-bearing material is relatively thin and the amount of possible drawdown is limited, decrease in yield is a necessary result of the development of a cone of depression to intercept recharge or reduce natural discharge.

Records of the amount of water used by the city and by the Walker Army Air Base during each month from July 1942 to March 1946 were obtained. These data are shown graphically in Figure 5. The consumption of water at Hays has streadily increased in the past and will continue to increase as the population grows. The consumption of water is least during the winter months December through March, and is greatest during the summer months of June through September.

Table 2 shows the amount of water used by the city and by the air base for January, when the demand for water is generally the least; and for August, when the demand is generally the greatest, during the period 1942-1946.

The minimum monthly consumption of water at Hays proper during this period was 14,500,000 gallons in January 1943; and the maximum monthly consumption was 37,700,000 gallons in August 1945. The total consumption of water at Hays and the air base for August 1945 was 51,500,000 gallons, which was the maximum amount of water that could be supplied from the wells. Warnings were issued in the local paper during this month informing the townspeople of a shortage of water and asking them to economize as much as possible in its use. It is believed that had there been an adequate supply of water the total consumption would have reached 60,000,000 gallons, and of this amount the city would have used about 46,000,000 gallons.

The trend of population at Hays indicates that within the next 40 or 50 years it may become twice as large as it was in 1946. This will at least double the demand for water, and an increased

TABLE 1.—*Records of city wells at Hays, Kansas*

Well no. on Fig. 3	Year drilled	Type of Well	Depth, feet	Dia-meter, inches	Type of casing	Depth to water level below land surface, feet	Date of measure-ment	Altitude of land surface, feet	Reported yield, Dec. 1945, gallons a minute [a]	Remarks (Reported yield given in gallons a minute; draw down in feet)
1		Drilled	49	24	Steel	39.80	Jan. 19, 1946	1991.1	75 (24) 100 (8)	Yield when new 160, drawdown 4.
3	1903	do.	49	6	do.	40.50	do.	1992.7	90 (12)	Battery of two wells, one horizontal centrifugal pump. Measured east well. Yield when new 125, drawdown 7.
6	1926	do.	48	24	Concrete	38.90	do.	1991.1	80 (24)	Yield when new 100, drawdown 8.
7	1927	do.	48	14	Steel	36.21	do.	1996.3	75 (24)	Yield when new 80, drawdown 14.
8	1927	do.	64	14	do.	48.00	do.	2014.0	90 (10)	Yield when new 80, drawdown 14.
10	1935	Dug	35	120	Brick	28.00	Jan. 18, 1946	1988.7	75 (24)	Yield when new 110, drawdown 4.
12	1937	Drilled	34	10	Steel	26.40	do.	1986.5	65 (24)	Battery of two wells and one pump. Yield when new 75, drawdown 10.
13	1937	Dug	38	240	Brick	29.10	Jan. 19, 1946	1978.8	30 (8)	Yield when new 180, drawdown 7.
14	1938	Drilled	51.5	19	Concrete	26.85	Jan. 19, 1946	1976.9	100 (24) 140 (10)	

15	1938	do.	51	19	do.	26.61	May 22, 1943	1979.6	180 (24) 225 (10)	Yield when new 300, drawdown 14.
16	1941	Drilled	54	12	Steel	24.84	Oct. 22, 1942	1980.9	90 (24)	Yield when new 100, drawdown 10.
17	1941	do.	68	12	do.	48.95	May 22, 1943	2012.1	180 (24)	Yield 260 when new.
18	1944	do.	52.7	12	do.	[b] 40	June 1944	1991.4	80 (24) 100 (10)	Yield 125 when new.
19	1944	do.	44.5	12	do.	[b] 24.8	June 1944	1979.1	180 (24) 200 (8)	Yield 295, drawdown 14 when new.
20	1945	do.	53.7	12	do.	[b] 34	August 1945	200.5	200 (24)	Yield 250 when new.

[a]Number in parentheses indicates number of hours a day that well can be pumped at the rate shown.
[b]Reported by driller.

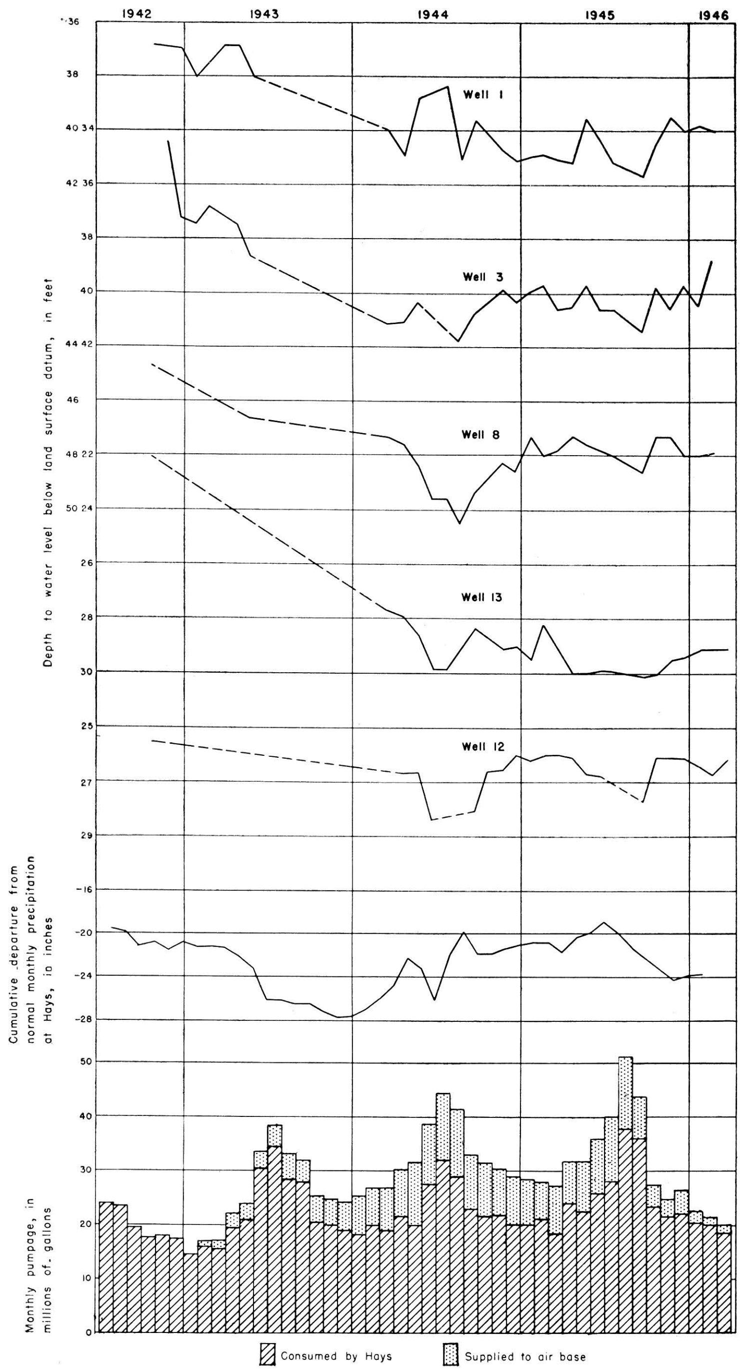

FIG. 5.—Hydrographs of five city wells, cumulative departure from normal monthly precipitation, and monthly pumpage from city wells at Hays from 1942 to 1946.

TABLE 2.—*Monthly consumption of water by the City of Hays and the Walker Army Air Base for January and August during the period 1942-1946 (in millions of gallons)*

Year	January Hays	January Air base	January Total	August Hays	August Air base	August Total
1942				23.5	0	23.5
1943	14.5	0	14.5	28.5	4.6	33.1
1944	18.3	7.1	25.4	29	12.3	41.3
1945	20	8.5	28.5	37.7	13.8	51.5
1946	20.2	2.3	22.5			

number of industries and the increased use of water for air conditioning during the summer months may more than double the water consumption.

SHAPE OF THE WATER TABLE AND MOVEMENT OF GROUND WATER

The approximate shape of the water table in part of the Hays area is shown by the contours in Figure 6. As a basis for constructing this map the altitude of the land surface at most of the test holes, observation wells, and city wells was determined by instruments. Data for the four observation wells drilled by the State and Federal Geological Surveys and for all the test holes are given in Table 3 and the data for the city-supply wells are given in Table 1. The altitude of the water surface in Big Creek at nine points in the Hays area was determined instrumentally.

The water-table contours in the terrace area north of Hays are nearly parallel to the valley, indicating that the movement of the ground water in the terrace deposits is toward the valley. The gradient of the water table in this area is very steep, being about 60 feet to the mile. The slope of the water table in the valley is in general downstream, indicating that the ground water after entering the alluvium moves down the valley. The upstream flexure of the 1,985-foot contour above Hays shows that the ground water in this area is moving toward Big Creek (see also section A-A′ in Fig. 3); thus Big Creek upstream from Hays may receive some water from the zone of saturation.

Before there were any heavy withdrawals of ground water in the vicinity of Hays, seepage to Big Creek probably took place throughout the valley in the Hays area. Heavy pumping of the city wells in and southeast of Hays, however, has caused a local trough in the water table to be formed northeast of the creek.

TABLE 3.—*Records of observation wells and test holes in the vicinity of Hays, Kansas*

No. on Fig. 3	Location	Driller [a]	Depth of test hole or well, feet	Depth to water level below land surface, feet [b]	Date of measurement	Altitude of land surface, feet [c]
	T. 13 S., R. 18 W.					
1	NE cor. SE sec. 20	S	60			2,065.8
2	NE cor. SE sec. 21	S	30	9.1	4/19/46	2,076.4
3	SW cor. sec. 21	S	35	23.9	4/17/46	2,045.0
4	SW cor. SE sec. 21	S	40			2,0489.
5	SE cor. sec. 21	S	50	13.5	4/13/46	2,053.7
6	SE cor. NE sec. 28	S	40	23.4	4/19/46	2,045.6
7	SE cor. sec. 28	S	80	41.6	4/13/46	2,037.8
8	NE cor. NW sec. 29	S	76	49.9	4/19/46	2,050.4
9	SE cor. NE sec. 29	S	85	54.3	4/17/46	2,043.2
10	SE cor. sec. 29	S	80			2,027.8
11	NW NW NE sec. 30	L	48	22.2	11/44	2,011
12	SW NW NE sec. 30	L	48	23.5	do.	2,012
13	NW SW NE sec. 30	L	48	23.4	do.	2,011
14	NW SW NE sec. 30	L	43	24.0	do.	2,010
15	NE SW NE sec. 30	L	49	22.0	do.	2,009
16	NE SW NE sec. 30	L	40	22.0	do.	2,008
17	NW SE NE sec. 30	L	35	22.5	do.	2,007
18	NE SE NE sec. 30	L	49	21.8	do.	2,007
19	SE SE NE sec. 30	L	40	26.1	do.	2,009
20	SE SE NE sec. 30	L	40	22.8	do.	2,007
21	NE NE SE sec. 30	L	48	21.2	do.	2,005
22	SE NE SE sec. 30	L	44	21.3	do.	2,005
23	NE SE SE sec. 30	L	47	22.6	do.	2,006
24	NE NE NE sec. 31	L	40	18.1	do.	2,000
25	SE NE NE sec. 31	L	45	19.0	do.	2,001
26	NE SE NE sec. 31	L	28	17.0	do.	2,000
27	SE SE NE sec. 31	L	28	15.0	do.	1,999
28	SE SE NE sec. 31	L	25	15.0	do.	2,000
29	NE NE SE sec. 31	L	28			2,001
30	NE NE SE sec. 31	L	50	21.0	do.	2,003
31	SE NE SE sec. 31	L	53			2,005
32	NE cor. SE SE sec. 31	S	60	21.0	4/20/46	2,009.0
33	NE SE SE sec. 31	S	60	31.8	do.	2,011.1
34	SE SE SE sec. 31	S	45	33.5	4/22/46	2,014.5
35	SW cor. sec. 32	S	50	40.5	do.	2,020.4
36	NW NE NW sec. 33	S	70	49.5	4/16/46	2,024.2
37	NE NW NE sec. 33	S	80	53.4	4/15/46	2,027.8
38	SE NW sec. 33	S	70	55.4	4/27/46	2,020
39	SE SE NE sec. 33	S	75			2,025.1

40	NE NE SE sec. 33	S	70			2,020.1
41	NE cor. SE SE sec. 33	S	60	35.8	4/12/46	2,001.4
42	SE SE SE sec. 33	L	50			
43	SW SW sec. 34	L	55			
	T. 14 S., R. 18W.					
44[d]	SW SW NW sec. 3	S	43	34.1	4/27/46	1,985.7
45[d]	SW SW sec. 3	S	39	27.1	4/25/46	1,980.1
46	SE NE NE sec. 4	L	50			1,994
47	SE NE NE sec. 4	L	47	40.0	11/43	1,993
48	NE SW NW sec. 4	L	31			1,989
49	NW SE NW sec. 4	L	33			1,988
50[d]	SE SE NW sec. 4	S	36	26.1	4/27/46	1,986.0
51	NE NE NE sec. 6	S	60			2,030.3
52	NE cor. SE NE sec. 6	S	66			2,037.9
53	SE cor. NE sec. 6	S	40	24.0	4/23/46	2,031.2
54	NE cor. sec. 7	S	25			2,031.7
55	SE SW sec. 3	L	45	24.5	11/43	1,977
56	NE NW NW sec. 10	L	40	23.1	do.	1,979
57	NE NW NW sec. 10	L	40	22.1	do.	1,977
58	NE NE NW sec. 10	L	33	16.8	do.	1,976
59	NE NE NW sec. 10	L	33	23.3	do.	1,976
60	NE NE NW sec. 10	L	33	18.4	do.	1,975
61	SW NE NW sec. 10	L	38	18.3	do.	1,976
62	SW NE NW sec. 10	L	42	19.0	do.	1,975
63	SW NE NW sec. 10	L	38	19.0	do.	1,975
64	SW NW NE sec. 10	L	40	18.0	do.	1,975
65	NE SE NW sec. 10	L	36	18.0	do.	1,975
66	NE SE NW sec. 10	L	36	18.1	do.	1,975
67	SE SE NE sec. 10	L	50	20.0	11/44	1,974
68	NE NE SE sec. 10	L	35	18.4	do.	
69	NE NE SE sec. 10	L	50	19.0	do.	1,973
70	Center NE SE sec. 10	L	29	18.0	do.	
71	NE NE SE sec. 10	L	51	18.0	do.	1,972
72	SE NE SE sec. 10	L	48	17.7	do.	1,972
73	SE NE SE sec. 10	L	48	19.7	do.	1,971
74	SE SE SW sec. 11	L	33	14.8	do.	
75	NE NE NW sec. 14	L	38	14.0	do.	
76	NE NE NW sec. 14	L	36	14.8	do.	
77	NE NW NW sec. 14	L	40			

[a]S, State and Federal Geological Surveys: L, Layne-Western Company.
[b]Water levels in the wells and test holes drilled by the State and Federal Geological Surveys were measured by James B. Cooper; all other measurements were furnished by the Layne-Western Company.
[c]The altitudes for the test holes drilled by the Layne-Western Company are approximate only.
[d]Observation well.

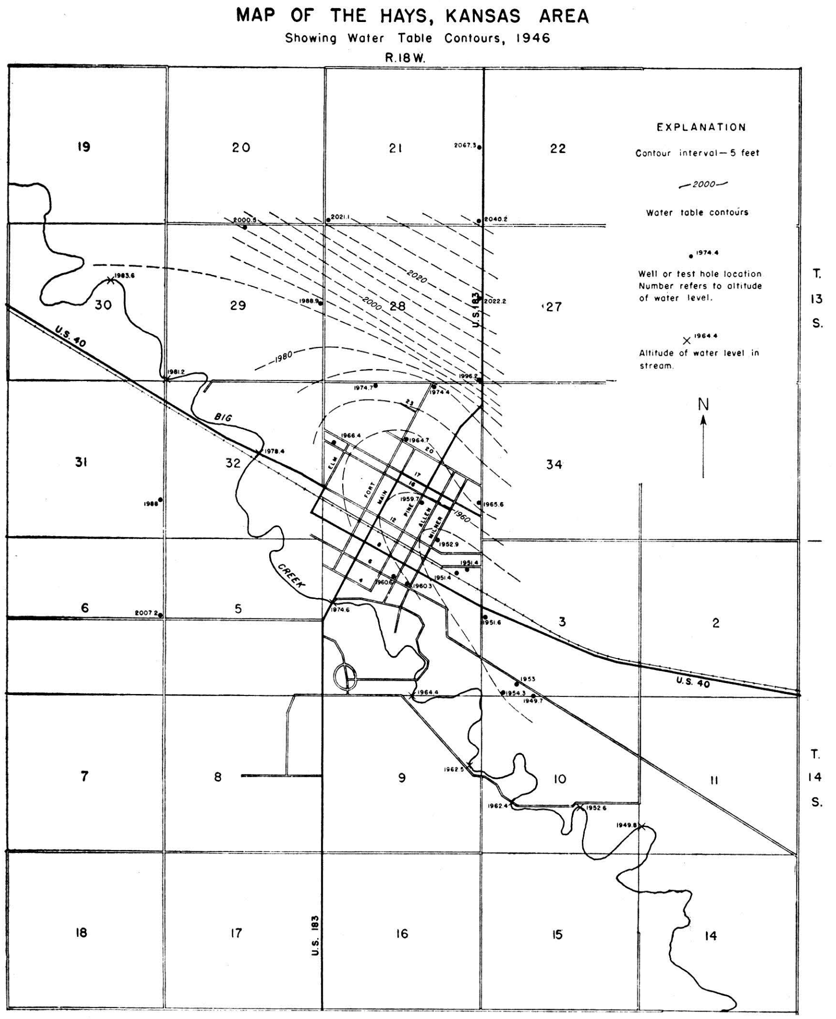

FIG. 6.—Map of the Hays, Kansas, area showing water-table contours, 1946.

The form of this trough is shown in profile by section B-B′ in Figure 4. At Hays and for a short distance downstream, the water table on the northeast side of Big Creek is below its channel. Big Creek in this part of the area may contribute some water to the underground reservoir, but because of the low stream flow during most of the year the amount of water contributed in this way probably is small. Furthermore, the test-hole data indicate that the channel of Big Creek is underlain by several feet of silt and clay (Fig. 4). This material is relatively impermeable and would retard or prevent the movement of water from the stream to the water table.

The depth of water beneath the terrace north of Hays differs roughly according to the topography of the land surface. In general it ranges from less than 10 feet near the bluffs of Cretaceous rocks to about 55 feet along the edge of the terrace. In 1945-46 the measured depths to water in the valley ranged from 15 to 47 feet. The greatest depths to water in the valley are at Hays, where the water table has been lowered by the heavy withdrawals from the city wells.

FLUCTUATIONS OF THE WATER TABLE

The City of Hays began keeping records of the water levels in the city wells in October 1942. These records are complete for most wells except for the period from June 1943 to March 1944, when no records were kept. Periodic measurements have been made in wells 1, 3, 6, 7, 8, 10, 12, and 13; and monthly gage readings have been taken at the other wells. The measurement or gage reading has been made at each well after it has been idle for several hours to several days.

Figure 5 shows hydrographs of wells 1, 3, 8, 12, and 13, the cumulative departure from normal monthly precipitation at Hays from July 1942 to January 1946, and the total monthly pumpage from the Hays wells from July 1942 to March 1946. The wells for which hydrographs are given were selected as representative of the city wells and are believed to show the general trend of water-level fluctuations in all the wells.

Of the eight wells in which tape measurements were made, all but well 10 showed net declines in water level from the beginning of record, in October 1942, to October 1945. The declines in water level in these wells ranged from 0.53 to 7.97 feet and averaged 3.21 feet. As shown by the hydrographs the greatest decline in water levels for this period occurred during 1943, partly as the result of the relatively heavy pumping and partly as the result of a deficiency in normal precipitation, which amounted to 6.86 inches.

Both the precipitation and the pumpage were greater in 1944 and 1945 than they were in 1943. The precipitation in 1944 was 6.65 inches above normal and in 1945 it was 2.71 inches below normal. During this 2-year period part of the wells showed net rises in water levels and part showed net declines. Of the eight wells for which tape measurements of the water levels are available, five wells (nos. 1, 3, 7, 10, and 12) showed net rises in water level of .09 to 1.95 feet for the period from March 1944 to March 1946, and three wells (nos. 6, 8, and 13) showed net declines of 0.90 foot, 0.29 foot, and 1.4 feet, respectively.

The fluctuations of the water levels in the Hays wells depend in part on the amount of water pumped and in part upon the amount of precipitation received. Although the pumpage during 1944 and 1945 was greater than it had been in previous years, the amount of recharge to the ground-water reservoir from precipitation was sufficient to prevent any great lowering of the water table. Pumpage from the city wells plus a deficiency in precipitation in 1943 caused the water levels to decline several feet in most of the wells, even though the amount of water withdrawn from the ground-water reservoir was less than in 1944 and 1945. Although the precipitation in 1944 and 1945 was greater than in 1943, the greater amount of withdrawal prevented the water levels from returning to the position they had at the beginning of 1943.

From the standpoint of precipitation the period for which water-level measurements are available, from 1942 to 1946, was in general a favorable period for ground-water recharge. Although earlier water-level measurements are not available for comparison, the shape of the water table in April 1946 (Fig. 6) indicates that since pumping began there has been a general lowering of the water levels in the vicinity of Hays as the result of heavy withdrawals of water from the city wells. During future periods when the precipitation is below normal for several consecutive years, and withdrawals continue heavy, the water levels in this area may decline even more.

PROSPECT FOR ADDITIONAL SUPPLIES

Big Creek Valley.—The amount of water that can be pumped from an underground reservoir without causing excessive permanent lowering of the water table depends on the capacity of the reservoir and on the amount of annual recharge to the reservoir. If water is withdrawn from an underground reservoir by pumping faster than water enters it, the water levels in wells will decline and if this condition persists the supply eventually will be depleted. The hydrographs in Figure 5 indicate that the total amount of water withdrawn by wells in Big Creek Valley in the immediate vicinity of Hays from 1942 to 1945 exceeded the amount of water added by recharge.

During 1944 and 1945, when the precipitation was high, the amount of water withdrawn by wells was nearly equal to the amount added by recharge; but during 1943, when the precipitation was below normal, the amount of water withdrawn by wells exceeded the amount added by recharge. It should be noted that the amount of pumpage in 1943 was less than in 1944 and in 1945.

Additional wells could be constructed in certain areas in the valley northwest and southeast of Hays. Each well, if properly constructed, probably would yield 75 to 150 gallons a minute; but nowhere in the valley in the Hays area are the conditions favorable for developing very large supplies of water from wells. The character and thickness of the alluvium northwest of Hays is indicated by the logs of test holes 11 to 35, and by profile A-A′ on Figure 4.

The valley in this area is about 1.2 miles wide and the total thickness of the alluvium ranges from about 20 to 55 feet. The thickness of the saturated part of the alluvium ranges from about 6 feet over a bedrock ridge south of Big Creek to 34 feet in the deepest part of the old bedrock channel. The thickest and coarsest water-bearing materials in this area were encountered in test holes 11, 12, and 13 north of Big Creek, and in test holes 34 and 35 near the southwest bluff of the valley.

Southeast of Hays the valley is less than three-quarters of a mile wide in most places. The alluvium in this part of the valley ranges from about 25 to 50 feet in thickness and generally contains less productive water-bearing materials than it does at Hays. The thickest and coarsest water-bearing materials in this area were encountered by test holes 72 and 73.

Terrace areas.—City well 17 is located on the terrace that borders the northeast side of Big Creek Valley. This well has a reported yield of 180 gallons a minute. Available data indicate that additional wells having comparable yields can be developed in this area in a narrow belt about three-quarters of a mile wide along the edge of the terrace. The terrace deposits in this narrow belt have a total thickness ranging from about 60 to 81 feet (test holes 7 to 10 and 36 to 40). The depth to water in this part of the terrace ranges from about 40 to 55 feet below the surface. The amount of water-bearing sand and gravel, however, varies widely. Test holes 7 and 9, for example, encountered less than 5 feet of water-bearing sand and gravel, whereas test holes 8 and 37 encountered 21 feet and 25 feet of water-bearing sand and gravel, respectively.

The materials making up the terrace deposits in the area northeast of this narrow belt are relatively thin and consist predominantly of fine sediments, as indicated by the logs of test holes 1 to 6. For this reason, successful public-supply wells could not be developed in the northern part of the terrace area.

Test holes 53 and 54, drilled on the terrace southwest of Hays, failed to encounter sand and gravel. Test holes 51 and 52, near the edge of the terrace, encountered 15 feet and 9 feet of water-bearing sand and gravel, respectively. Although sufficient data for this area are lacking, it seems that wells having small yields probably could be developed along the edge of the terrace.

Certain procedures should be followed in locating and constructing future wells, whether in the valley or on the terraces, to take the fullest advantage of the local conditions. The wells should be spaced as far apart as practicable, preferably a quarter of a mile or more, to prevent local overdevelopment; and the rate of pumping from individual wells should be less than the potential yields indicated by pumping tests. The drilling of each well should be preceded by the drilling of a test hole, to determine the thickness and character of the water-bearing material, the proper length and slot size of the screen to employ, and the proper type of well construction for the final well.

Summary.—The test drilling did not indicate any place in the Hays area where large supplies of water could be obtained from wells. Additional wells having yields comparable to the existing city wells could be developed in parts of the valley northwest and southeast of Hays and in parts of the terrace areas. The test drilling indicated that the number of localities in the valley and in the terrace areas having a sufficient thickness of coarse water-bearing material to supply a city well are limited. Because of the narrowness of the valley and small amount of coarse water-bearing material in the alluvium southeast of Hays, only a relatively small supply of water could be developed in the valley in this part of the area.

By locating wells over a wide area an additional amount of water could be obtained, probably equal to the present public supply. If the ground water in the outlying localities is not developed for public supply, it will be available in moderate amounts for industries or other establishments in these localities.

Vicinity of Victoria

PUBLIC WATER SUPPLY

The public water-supply system at Victoria was constructed in 1921 and consists of five wells situated south, west, and northwest of the town as shown in Figure 7. Records of the five wells are given in Table 4. Some of the data given in this table were obtained from Mr. Lawrence Wellbrock, city water superintendent, and some were obtained from annual engineering reports on file in the office of the Division of Sanitation, Kansas State Board of Health, at Lawrence, Kansas.

According to the engineering reports of the Kansas State Board of Health, Victoria has experienced difficulties in the past in obtaining adequate water, especially during summers when the rainfall is least and the consumption is the greatest. During the summer of 1930 the supply, which was obtained from wells 1 and 2, was insufficient to meet the demand, and it was necessary to place restrictions on the use of water. It is reported that had the summer rate of consumption continued very much longer in 1934 the supply from wells 1, 2, and 3 would have failed. Well 2 failed entirely during the summer of 1934. In August 1937 well 2 could be pumped only 35 minutes a day.

In 1944 the supply from five wells was inadequate to meet the summer demand. In 1946 wells 1, 2, and 3 could be pumped dry in a few hours.

Because of the thinness and low permeability of the water-bearing materials in the terrace deposits and alluvium in Victoria Creek Valley, wells that tap these deposits are limited to relatively small yields; and, as the source of recharge is the small

TABLE 4.—*Records of city wells at Victoria, Kansas*

Well no. on Fig. 7	Location	Type of well	Depth, feet	Diameter, inches	Type of casing	Reported depth to water level below land surface, feet	Reported yield, gallons a minute	Remarks
	T. 14 S., R. 16 W.							
1	NE SW NW sec. 18	Dug	34	180	Brick	25	70	Reported to pump dry in in 3 hours.
	T. 14 S., R. 17 W.							
2	NE SE sec. 12	do.	34	360	Tile	28	Small	Reported to pump dry in a very short time.
3	NW cor. sec. 12	do.	50	144	Stone	26	25	Reported to pump dry in 3 hours.
4	NW SE SE sec. 2	do.	40	180	do			
5	SE NE NW sec. 2	Drilled	34	12	Steel		28	Gravel packed.

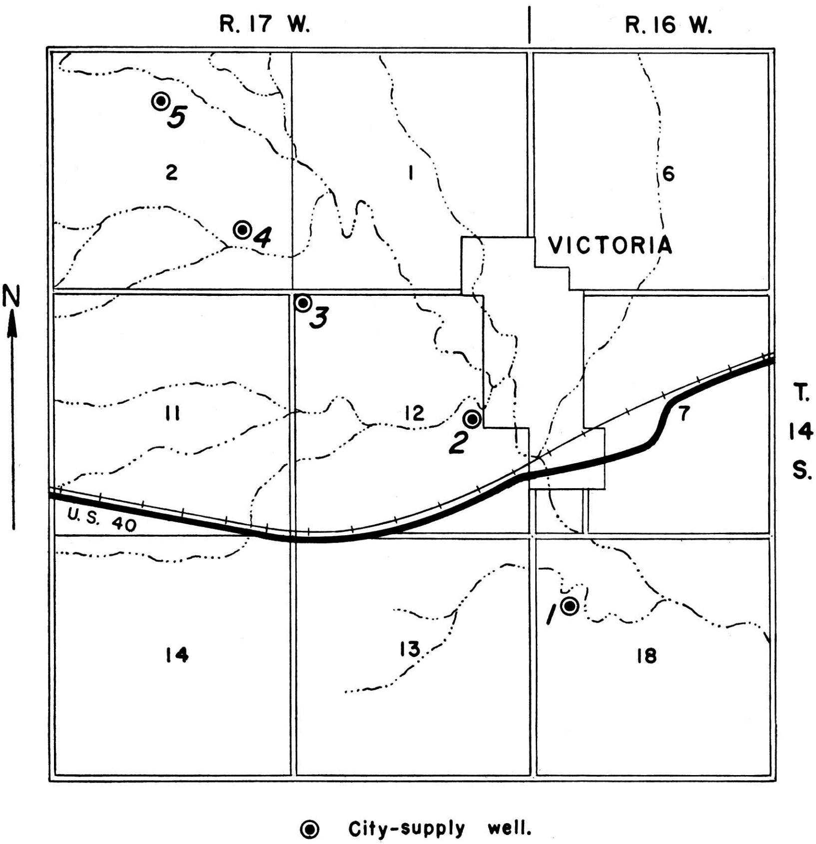

FIG. 7.—Map showing the locations of the city wells at Victoria, Kansas.

amount of precipitation that falls on this area, the wells are subject to marked declines in yield or to complete failure during prolonged dry periods.

The city does not have a public sewerage system, but one may be installed in the future. Records of the consumption of water at Victoria are not available. According to records of the Kansas State Board of Health (1945), cities in Kansas of the size of Victoria which have sewerage systems generally require 50,000 to 150,000 gallons of water a day.

PROSPECT FOR ADDITIONAL SUPPLIES

Although additional wells having small yields can be developed in some places in the terrace and alluvial deposits along Victoria Creek, the data indicate that the amount of water available from these deposits near Victoria would be insufficient during prolonged dry periods to supply the anticipated future demand of the city. Adequate water probably could be obtained by supplementing this supply with water pumped from wells tapping the alluvium in Victoria Creek Valley several miles below Victoria or from wells tapping the alluvium in Big Creek Valley southeast of Victoria.

VICINITY OF WALKER

Walker does not have a public water-supply system, as an adequate supply of ground water of satisfactory quality for public use is not available in the vicinity of the town. Probably the nearest source of a ground-water supply is in the alluvial deposits in Victoria Creek Valley about 3½ miles southwest of the town. Test holes drilled in that area, in the S½ NE¼ sec. 21, T. 14 S., R. 16 W., encountered 10 to 20 feet of water-bearing sand and gravel at the base of the alluvium.

A test well was constructed near Walker in September 1942, by the Layne-Western Company for the United States Army Air Base. It was a gravel-packed well, 36 feet deep and 8 inches in diameter. The depth to water level in the well was 17.26 feet below the land surface on September 24, 1942. During a 7-hour pumping test the well discharged an average of 35 gallons a minute, with a maximum drawdown of 5.6 feet.

VICINITY OF GORHAM

Gorham does not have a public water supply. In 1941 the town, with the aid of the Works Progress Administration, started construction of a public water-supply system; but this project was stopped because of the war.

Neither the Cretaceous nor the Tertiary rocks in the vicinity of Gorham would be capable of furnishing adequate water of good quality for a public supply.

Records of two dug wells near Gorham that tap Tertiary deposits are available. One of these is at the SE cor. sec. 29, T. 13

S., R. 15 W., about 1 mile east of Gorham, and is 23.7 feet deep and 36 inches in diameter. On August 29, 1941, this well contained only 1.7 feet of water. The other well is in the SE¼ NW¼ sec. 30, T. 13 S., R. 15 W., about three-quarters of a mile northwest of Gorham. This well is 25.6 feet deep, 48 inches in diameter, and on August 29, 1941, contained only 2 feet of water.

In 1941 the city drilled two test wells in Tertiary deposits north of town in the search for a public water supply. Specific information on these test wells is not available; but, according to Mr. Hamersmith, the first well, in the SW¼ sec. 29, T. 13 S., R. 15 W., was a complete failure; and the second well, in the SE¼ sec. 30, T. 13 S., R. 15 W., encountered a little water-bearing sand and gravel, but the amount of water available was inadequate for a public-supply well.

The Gorham school well is supplied with water from thin alluvial deposits in a small valley at the west edge of town. It is a dug well of large diameter about 15 feet deep, in the SW¼ NE¼ sec. 31, T. 13 S., R. 15 W. The supply available from this well is reported to be adequate to meet the needs of the school, but this fact does not indicate that the alluvium at the locality would be a reliable source for a public supply. The amount of water pumped from the school well is relatively small compared to the amount that would be pumped from public-supply wells. Furthermore, the school well is not pumped during the summer months, when the demands of the town are the greatest and recharge to the underground reservoir is the least. A number of small wells tapping the alluvium probably would furnish adequate water for future needs during periods of normal rainfall, but because of the thinness of the saturated material such wells would be subject to failure during periods of drought.

Vicinity of Russell

PUBLIC WATER SUPPLY

The municipal water supply for Russell is pumped in part from Smoky Hill River and in part from Big Creek. The water is pumped to an impounding reservoir on Fossil Creek, just south of the city, whence it is pumped to a filtration plant having a rated capacity of 1,050,000 gallons a day. In wet years the drainage basin of Fossil Creek also supplies some water directly to the impounding reservoir. This supply is adequate, but the water is of poor quality.

The intake on Smoky Hill River is situated downstream from oil fields from which oil-field brine escapes to the stream, mainly by underground percolation. It might be pointed out that this condition existed for many years prior to the establishment of the Oil Field Section of the State Board of Health. In addition, some natural salt water seeps into the stream from sandstone of the Dakota formation. At some periods during the last several years when the stream was at low stage, the chloride content at the intake has been as high as several thousand parts per million for short periods; and for periods of many days water in the city mains has averaged 1,100 parts per million of chloride. The supply from Big Creek, although of better quality, is not adequate to furnish the total needs of the city.

SUMMARY OF PREVIOUS INVESTIGATION

Purpose of investigation.—An investigation of ground-water conditions in the Russell area was made by Thad G. McLaughlin in 1944 as a cooperative study by the State and Federal Geological Surveys. The purpose of the investigation was to determine if an adequate supply of water of good quality for public supply could be obtained from wells in the Russell area. Sufficient data to indicate that a suitable supply of water could not be obtained from the Cretaceous rocks in the vicinity of Russell were already available; therefore, the field investigation was confined to a study of the material overlying the Cretaceous bedrock.

The alluvium of Smoky Hill and Saline Rivers is the only formation in the area that might yield a large supply of potable ground water. In order to obtain a supply of potable water in the Smoky Hill or Saline Valleys, however, it would be necessary to go upstream to a point where the water in the alluvium is not contaminated by salt water from the Dakota formation or from oil-field brine.

Both the Saline and Smoky Hill Rivers have cut their valleys into the Dakota formation, but because Saline River has cut deep into the Dakota formation it would be necessary to go farther west in its valley to obtain a supply of potable water than in the Smoky Hill Valley. For this reason, together with the fact that the intakes for the present city water supply are on Smoky Hill

River and on Big Creek, test drilling of the alluvium was confined to the Smoky Hill Valley.

Test holes.—Fifteen test holes were drilled in 1944, using a portable hydraulic-rotary drilling machine owned by the State Geological Survey, to determine the thickness and character of the material overlying the Cretaceous bedrock and to collect samples of ground water for chloride analysis.

The 12 principal tests were drilled in the Smoky Hill Valley, two were drilled near the city reservoir on Fossil Creek, and one was drilled in Big Creek Valley south of Gorham. Records of the test drilling are given in Table 5 and are discussed below; and the logs (nos. 78 to 92) are given among the logs in the present report.

Smoky Hill Valley near Landon Creek.—Test holes 78 to 85 were drilled in the Smoky Hill Valley near its confluence with Landon Creek, as shown on Figure 8. Each test hole was drilled into bedrock, and samples of water from test holes 78, 79, 80, and 82 were collected for chloride analysis. As indicated by the test-hole data in Table 5 and by the logs of the test holes, this area probably would not yield an adequate supply of potable ground water for a public supply.

In the area south of test hole 80 there is very little saturated material. Part of the water that falls on this area as precipitation moves downward to or nearly to bedrock and then moves in the direction of the slope of the bedrock surface. The relatively steep slope of the bedrock causes the ground water to move away toward the north about as fast as additional water is received from precipitation or as seepage from the Cretaceous rocks. For this reason, the water table does not rise appreciably following rains, and the thickness of the saturated material remains small. The alluvium in this area, therefore, would yield only small quantities of water to a few domestic and stock wells.

Because of the northward movement of the water and the continued replenishment by precipitation, the water in the alluvium in the southern part of this area has a relatively low chloride content.

An example of the poor water-bearing properties of the alluvium in the southern part of the area is afforded by a well 200 feet southwest of test hole 83. This well was drilled through the alluvium and into the Graneros shale. About 15 minutes after

TABLE 5.—*Records of test holes drilled in Russell and Ellis Counties, Kansas, in 1944*

No.	Location	Depth of test hole, feet	Depth to bedrock, feet	Depth to water level, feet	Altitude of water level, feet	Thickness of saturated material, feet	Chloride content of water in alluvium, parts per million
	Russell County						
78	SW¼SW¼ sec. 28, T. 14 S., R. 14 W.	84	73	27.8	1,704.3	45.2	200
79	SE¼NE¼ sec. 32, T. 14 S., R. 14 W.	40	18	5.6	1,708.9	12.4	550
80	NE cor. sec. 5, T. 15 S., R. 14 W.	65	44.5	22.9	1,712.1	21.6	245
81	SE cor. SW¼ sec. 33, T. 14 S., R. 14 W.	30	20			0	
82	SE cor. sec. 33, T. 14 S., R. 14 W.	30	18	15.4	1,741.0	2.6	840
83	SW cor. NW¼ sec. 4, T. 15 S., R. 14 W.	35	19.5	17.5	1,750.2	2.0	10 [a]
84	SE cor. NW¼ sec. 4, T. 15 S., R. 14 W.	30	22	20.0	1,743.3	2.0	
85	SE cor. NW¼ sec. 3, T. 15 S., R. 14 W.	2	2			0	
86	NW cor .sec. 20, T. 15 S., R. 15 W.	50	35	14.0	1,761.5	21.0	1,290
	Ellis County						
87	SE¼NE¼ sec. 28, T. 15 S., R. 16 W.	55	48	14.7	1,796.8	33.3	1,200
88	SW¼SW¼ sec. 30, T. 15 S., R. 16 W.	50	32	15.3	1,827.9	16.7	90
89	NW cor. sec. 31, T. 15 S., R. 16 W.	60	54	22.3	1,838.3	31.7	44
	Russell County						
90	NE¼SE¼ sec. 30, T. 14 S., R. 15 W.	20	19	15.1	1,793.8	3.9	550
91	SW¼NE¼ sec. 3, T. 14 S., R. 14 W.	35	33			0	
92	SE¼NE¼ sec. 3, T. 14 S., R. 14 W.	50	17			0	

[a]Sample taken from well 200 feet from test hole.

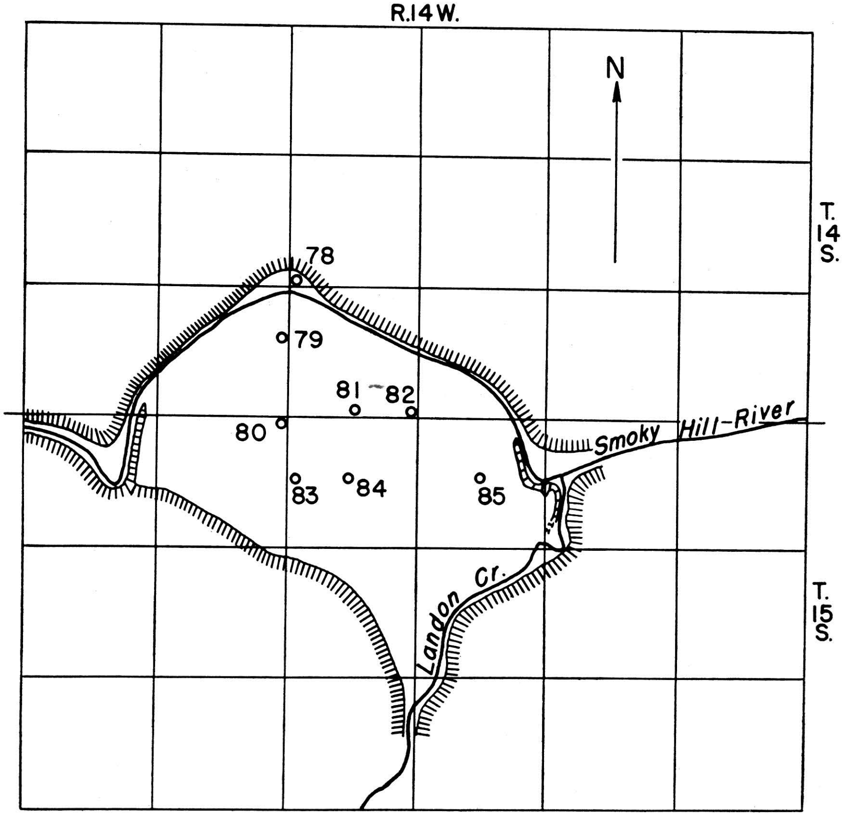

FIG. 8.—Locations of test holes 78 to 85 near the confluence of Landon Creek and Smoky Hill River, Russell County. Hachures indicate outcrops of Cretaceous rocks.

a few gallons of water had been pumped from the well, the water level was about 6 feet below its level just before pumping began, and was about 3 feet below the base of the alluvium. Thus, in 15 minutes not enough water had moved from the surrounding alluvium into the well to replace the water that had been pumped out. Further evidence as to the poor ground-water conditions in the southern part of the area is the fact that test holes 81 and 85 failed to encounter water.

The alluvium in the southern part of the area lies on Graneros shale. The contact between these formations is exposed at both the east and west ends of this area, as shown by hachures on Figure 8. At the west end the base of the gravel is 38 feet above the water level in Smoky Hill River and at the east end it is 40 feet above the river level. This indicates that the alluvium in the eastern and western parts of this area contains little or no water.

The alluvium between test hole 80 and the bluffs of Cretaceous rocks at the north is thicker than it is in the southern part of the area. In the north, however, the alluvium has been deposited on sandstone of the Dakota formation and the water in the lower part of the alluvium is being contaminated by salt water from those beds. The saturated upper part of the alluvium between test hole 80 and the river is not of sufficient thickness to yield even a supplementary supply of ground water for the City of Russell. In addition, the water has a relatively high chloride content, and heavy pumping would accelerate the movement of salt water from the Dakota formation upward into the alluvium.

The old channel of Smoky Hill River was cut adjacent to the bluffs in the northernmost part of the area, where test hole 78 encountered 45.2 feet of saturated sand, gravel, and silt. The area in which such a thickness of saturated material occurs is relatively small. Wells in this part of the area probably would not supply all the water needed by the City of Russell, but could supply adequate water for supplementary use. However, the chloride content of the ground water here is 200 parts per million, and heavy pumping would cause salt water to move in from the Dakota formation and from the Smoky Hill River.

The water table in this area slopes toward Smoky Hill River; hence, ground water in this area is discharging into the river. Heavy pumping in the vicinity of test hole 78, however, would cause a lowering of the water table around the well. This lowering would create a water-table slope from the river toward the well, and the river then would contribute part of its salt water to the ground-water reservoir and thus to the wells.

Smoky Hill Valley south of Gorham.—Test hole 86 was drilled in the Smoky Hill Valley near the Gorham bridge, in the NW cor. sec. 20, T. 15 S., R. 15 W. The drill penetrated sand containing gravel and silt and encountered the Dakota formation at a depth of 35 feet. The chloride content of the water from the Dakota formation was 1,305 parts per million and the chloride content of water from the alluvium was 1,290 parts per million. The alluvium in this locality has been deposited in a channel that has been cut into the Dakota formation, and salt water from the Dakota formation has contaminated the water in the alluvium.

The river valley at the Gorham bridge is about 0.3 mile wide. The saturated material, which is 21 feet thick at test hole 86, is composed mostly of sand containing gravel and silt. Therefore, properly spaced and properly constructed wells in this area probably would yield enough water for a supplementary supply for the City of Russell. The valley becomes very narrow a short distance above the bridge, and the river meanders from one bluff to the other. The pumping of wells in this area would lower the ground-water level considerably, causing the water table to slope from the river toward the well. The river would then contribute water to the ground-water reservoir.

Smoky Hill Valley south of Walker.—Test hole 87 was drilled in the NE¼ sec. 28, T. 15 S., R. 16 W., in Ellis County. The drill encountered chiefly sand and gravel before entering the Graneros shale at a depth of 48 feet. Water from the lower part of the alluvium had a chloride content of 1,200 parts per million.

Altitudes determined on the top of the Jetmore chalk member of the Greenhorn limestone and on the land surface at the test hole indicate that the drill entered the Graneros shale 15 or 20 feet above the top of the Dakota formation. The high chloride content of the water in the alluvium in this area probably has been caused either by percolation of salt water from the Dakota formation (the lower part of the Graneros shale may be sandy at this point) or by pollution from near-by improperly cased oil-test wells.

The saturated part of the alluvium at test hole 87 is 33 feet thick and consists mostly of gravel and sand, and the valley in this area is about a quarter of a mile wide. If surface water were used whenever possible, properly constructed wells in the alluvium probably would yield enough water to supply the city's needs during low stages of the river; but the quality of the water would not be satisfactory.

Smoky Hill Valley at Pfeifer.—Test holes 88 and 89 were drilled near the Pfeifer bridge in T. 15 S., R. 16 W., Ellis County. The drill encountered 17 feet of saturated sand and gravel in test hole 88, and 32 feet of saturated sand and gravel in test hole 89. The chloride content of water from these two holes was 90 parts per million and 44 parts per million, respectively. In this area the alluvium of Smoky Hill River is underlain by the entire thickness of Graneros shale, which serves as an effective seal and prevents pollution of water in the alluvium by salt water from the underlying Dakota formation. An analysis of water from test hole 89 is given in Table 6.

The Smoky Hill Valley at Pfeifer is about a quarter of a mile wide. The ground-water reservoir is recharged mainly by precipitation in the valley near Pfeifer. Part of this water moves downward through the sandy soil to the water table and tends to increase the thickness of saturated material. As the water table rises there is a resultant slope toward Smoky Hill River, causing the ground water to move toward and into the river. The amount of ground water discharged into the river annually probably is about equal to the amount of water added to the ground-water reservoir by precipitation.

If properly constructed wells were put down in this area they probably could obtain a relatively large quantity of water from the alluvium. As a result the water level would decline and the water table would slope toward the south away from the river. The water that is added to the ground-water reservoir would no longer be discharged into the river but would be utilized by the wells. Smoky Hill River would then become a losing stream, as it would contribute water to the ground-water reservoir, and it would thus help to supply the wells. The river probably would contribute much more water to the ground-water reservoir than would be added by recharge from precipitation.

TABLE 6.—*Analysis of water from test hole 89, Ellis County, Kansas*
Analyzed by Howard A. Stoltenberg, Kansas State Board of Health

Constituent	Parts per million
Calcium (Ca)	174
Magnesium (Mg)	28
Sodium (Na)	52
Bicarbonate (HCO_3)	292
Sulfate (SO_4)	345
Chloride (Cl)	44
Fluoride (F)	0.5
Nitrate (NO_3)	1.3
Total dissolved solids	791
Total hardness as $CaCO_3$	549
Carbonate hardness as $CaCO_3$	240
Noncarbonate hardness as $CaCO_3$	309

A group of properly spaced and properly constructed wells in this area probably would supply sufficient water of acceptable quality to supply the city during periods when surface-water supplies are not usable, but probably would not supply the entire needs continuously. Before a definite decision is made regarding this area, however, it would be desirable to construct a test well and conduct a pumping test in order to determine the permeability of the water-bearing material, the proper spacing of proposed wells, and the optimum yield of each well.

Big Creek Valley south of Gorham.—Test hole 90 was drilled in Big Creek Valley south of Gorham, in the NE¼ SE¼ sec. 30, T. 14 S., R. 15 W., on the south side of Big Creek. The drill penetrated 19 feet of surficial material before encountering the Greenhorn limestone. Water from this test hole, taken between depths of 14 and 19 feet, contained 550 parts per million of chloride.

The static water level at the test hole was 15.1 feet below the land surface, indicating that the saturated part of the alluvium was only 3.9 feet thick. The alluvium in this locality would yield very little water to wells. As the width of the valley is about 2,000 feet, further test drilling might reveal a greater thickness of saturated material in some other part. Because of the high chloride content of the water, however, no additional drilling was done in the area in 1944.

Area near Fossil Creek reservoir.—Test holes 91 and 92 were drilled in the NE¼ sec. 3, T. 14 S., R. 14 W., near the city reservoir on Fossil Creek. The holes penetrated surficial silt and sand and encountered the Greenhorn limestone at depths of 17 and 33 feet, respectively. These test holes encountered little or no water above the Cretaceous bedrock.

The surficial deposits that overlie the Cretaceous bedrock in these upland areas are relatively thin and contain little or no water. The material in many places is made up largely of fragments of limestone, chalk, and shale, derived from Cretaceous rocks, and is relatively impermeable. In addition, most of these deposits are present in small areas that are nearly surrounded by streams or draws that have been cut through the surficial deposits into the bedrock, and thus have drained the water from the surficial deposits nearly as fast as they could be recharged by precipitation. The thickness of the saturated material remains small and therefore the deposits are capable of yielding very little water to wells.

Conclusions.—In his report of 1944 McLaughlin gives the following conclusions in regard to the availability of a water supply from wells for the City of Russell.

1. The Cretaceous formations would not yield enough water for the City of Russell, and in many places parts of these formations contain salt water, particularly the Dakota formation.

2. The surficial deposits, such as those on the upland areas near the impounding reservoir on Fossil Creek, are relatively thin and would yield little or no water to wells.

3. The alluvium in that part of Big Creek Valley accessible to the City of Russell probably would not yield enough water for the total needs of the city. The thickness of saturated material is small, the valley is narrow, and the water is somewhat salty. Farther west, in the vicinity of Hays, however, the valley is considerably wider and the chloride content of the water is much lower.

4. In the Smoky Hill Valley below Pfeifer the alluvium at several places probably would yield enough water for at least a supplementary supply for the City of Russell. Below Pfeifer, however, the water in the alluvium has been contaminated by salt water from the Dakota formation and by oil-field brines.

5. In the Smoky Hill Valley in the vicinity of Pfeifer the alluvium probably would yield adequate water for the City of Russell during parts of each year. However, it would be advisable for the city to obtain most of its water supply from Smoky Hill River whenever practicable because water in the river generally is much softer, as indicated by many analyses of the city water, than is the ground water at Pfeifer; and also because continuous heavy pumping might cause excessive lowering of the ground-water level. The city could obtain most of its supply from the river, except during low stages of the river, at which time ground water could be used.

Test drilling should precede the construction of wells, in order to find the best water-bearing materials and in order to determine the proper slot size for well screens and the depths at which the casing should be perforated. Test drilling should also indicate whether or not the well should be gravel-walled, and if so, the proper size of gravel that should be used in order to obtain maximum efficiency.

The wells should be widely spaced in order to prevent local overdevelopment of the ground-water reservoir, and if possible the optimum spacing and yield per well should be determined by conducting a pumping test on a preliminary well.

If a well field is developed in this area, periodic analyses of the river water and of ground water at strategic points above the well field should be made in order to detect at an early date any contaminated water that might be moving toward the well field from present or future oil-field developments.

GENERAL CONCLUSIONS

The investigation made by me did not reveal any place in the area where large supplies of water could be obtained from wells.

The Cretaceous rocks that underlie Russell and Ellis Counties are composed chiefly of materials having low permeability, and which yield only small supplies of water to domestic and stock wells. Sandstone of the Dakota formation is capable of yielding fairly large supplies, but in many places the water is highly mineralized and is unfit for most ordinary uses.

The surficial deposits of Tertiary age that overlie the Cretaceous rocks on the uplands furnish small supplies of water for domestic and stock use, but nowhere in the area studied were they found to be sufficiently permeable or thick to serve as a source for municipal supplies.

Ground water for public-supply, industrial, or other uses is available in moderate amounts from the alluvium and terrace deposits in and along parts of the principal stream valleys, such as the Smoky Hill River, Big Creek, and Victoria Creek Valleys. At many places in Russell County, however, the water contained in these deposits has been contaminated by salt water from the Dakota formation and in some instances by oil-field brines.

In Ellis County water that is obtained from alluvial deposits is generally suitable for public supply, although it contains rather high amounts of calcium and bicarbonate and is therefore quite hard.

LOGS OF WELLS AND TEST HOLES

Logs of 88 test holes, two city-supply wells, and four observation wells are given on the following pages. Logs 1 to 10, 32 to 37, 39 to 41, and 51 to 54 are of test holes; and 38, 44, 45, and 50 are of observation wells drilled in the vicinity of Hays by the State Geological Survey during April 1946. Logs 78 to 92 are of test holes drilled by the State Geological Survey during 1944 as a part of the investigation for the City of Russell.

The logs were prepared by geologists of the State and Federal Geological Surveys after examining samples of the drill cuttings, and are referred to as sample logs. Logs 11 to 31, 42, 43, 46 to 49, and 55 to 77 are of test holes drilled by the Layne-Western Company for the City of Hays in 1938 and 1944. These logs, and also logs 93 and 94 of Hays city wells, are driller's logs furnished by the Layne-Western Company.

1. *Sample log of test hole 1 at the NE cor. SE¼ sec. 20, T. 13 S., R. 18 W., drilled by the State Geological Survey, 1946. Altitude of land surface, 2,065.8 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, tan to brown; contains some sand in lower part	20	20
Silt, sand, and limestone pebbles; poorly sorted	4	24
CRETACEOUS—Gulfian		
Carlile shale		
Shale, light gray and yellow; contains a little gypsum	36	60

2. *Sample log of test hole 2 at the NE cor. SE¼ sec. 21, T. 13 S., R. 18 W., drilled by the State Geological Survey, 1946. Altitude of land surface, 2,076.4 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, sandy, light tan to dark brown	7	7
Sand, very fine to coarse	4	11
CRETACEOUS—Gulfian		
Carlile shale		
Shale, light gray and gray; contains a little gypsum	19	30

3. *Sample log of test hole 3 at the SW cor. sec. 21, T. 13 S., R. 18 W., drilled by the State Geological Survey, 1946. Altitude of land surface, 2,045.0 feet. Depth to water level, 23.88 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, gray, tan, and brown	20	20
Sand, fine to coarse, silty	4	24
Sand, very fine to coarse; a little fine gravel and many limestone pebbles	7	31

	Thickness, feet	Depth, feet
CRETACEOUS—Gulfian		
Carlile shale		
Shale, gray to black	4	35

4. *Sample log of test hole 4 at the SW cor. SE¼ sec. 21, T. 13 S., R. 18 W., drilled by the State Geological Survey, 1946. Altitude of land surface, 2,048.9 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, tan, gray, and dark brown; contains some sand and gravel in lower part	15	15
Sand and gravel; contains a few pebbles of limestone	10	25
CRETACEOUS—Gulfian		
Carlile shale		
Limy shale, very hard, gray	2	27
Shale, light gray, yellow, and brown	13	40

5. *Sample log of test hole 5 at the SE cor. sec. 21, T. 13 S., R. 18 W., drilled by the State Geological Survey, 1946. Altitude of land surface, 2,053.7 feet. Depth to water level, 13.51 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, tan to light gray; contains a little sand in upper part and caliche and gravel in lower part	20	20
Silt, sand, and gravel; poorly sorted	5	25
Clay, compact, light gray and yellow	15	40
CRETACEOUS—Gulfian		
Carlile shale		
Shale, dark gray	10	50

6. *Sample log of test hole 6 at the SE cor. NE¼ sec. 28, T. 13 S., R. 18 W., drilled by the State Geological Survey, 1946. Altitude of land surface, 2,045.6 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, cream and tan to dark brown; contains a little sand in lower part	36	36
Silt and sand, tan; contains a little gravel and limestone pebbles	2	38
CRETACEOUS—Gulfian		
Carlile shale		
Shale, light gray and yellow	2	40

7. *Sample log of test hole 7 at the SE cor. sec. 28, T. 13 S., R. 18 W., drilled by the State Geological Survey, 1946. Altitude of land surface, 2,037.8 feet. Depth to water level, 41.58 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, sandy, tan to gray	9	9
Silt, tan, cream, and gray	65	74
Sand and gravel; contains a few limestone pebbles	4	78
CRETACEOUS—Gulfian		
Carlile shale		
Shale, dark gray to black	2	80

8. *Sample log of test hole 8 at the NE cor. NW¼ sec. 29, T. 13 S., R. 18 W., drilled by the State Geological Survey, 1946. Altitude of land surface, 2,050.4 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, light tan to white; contains some sand and a few limestone pebbles	37	37
Sand, fine to coarse; contains a small amount of gravel	12	49
Sand, gravel, and limestone pebbles	22	71
CRETACEOUS—Gulfian		
Carlile shale		
Shale, gray black	5	76

9. *Sample log of test hole 9 at the SE cor. NE¼ sec. 29, T. 13 S., R. 18 W., drilled by the State Geological Survey, 1946. Altitude of land surface, 2,043.2 feet. Depth to water level, 54.25 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, tan to brown; contains many large limestone pebbles in lower half	39	39
Clay, plastic, gray	6	45
Silt, sandy, gray, blue gray, and dark gray	33	78
Sand, gravel, and limestone pebbles	3	81
CRETACEOUS—Gulfian		
Carlile shale		
Shale, gray black	4	85

10. *Sample log of test hole 10 at the SE cor. sec. 29, T. 13 S., R. 18 W., drilled by the State Geological Survey, 1946. Altitude of land surface 2,027.8 feet. Depth to water level, 25.0 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, tan and gray-tan	37	37
Sand, very fine to coarse; contains some gravel	3	40
Sand, gravel, and limestone pebbles	13.5	53.5
Silt, gray	14.5	68
Sand, fine to medium gravel, contains a few small limestone pebbles	9	77
CRETACEOUS—Gulfian		
Carlile shale		
Shale, gray black	3	80

11. *Driller's log of test hole 11 in the NW¼ NW¼ NE¼ sec. 30, T. 13 S., R. 18 W., drilled by the Layne-Western company for the City of Hays. Approximate altitude of land surface, 2,011 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Soil	1	1
Clay, brown	27	28
Clay, blue	5	33
Sand, medium to coarse; contains clay streaks	4	37
Sand and gravel, loose	7	44

	Thickness, feet	Depth, feet
CRETACEOUS—Gulfian		
Carlile shale		
Shale, dark gray	4	48

12. *Driller's log of test hole 12 in the SW¼ NW¼ NE¼ sec. 30, T. 13 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays. Approximate altitude of land surface, 2,012 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Recent		
Alluvium		
Soil	1	1
Clay, brown	29	30
Clay, blue	3	33
Sand and gravel; contains clay streaks	7	40
Sand and gravel, clean	5	45
CRETACEOUS—Gulfian		
Carlile shale		
Shale, dark gray	3	48

13. *Driller's log of test hole 13 in the NW¼ SW¼ NE¼ sec. 30, T. 13 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays. Approximate altitude of land surface, 2,011 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Recent		
Alluvium		
Soil	1	1
Clay, black	14	15
Clay, brown	13	28
Sand, coarse	2	30
Sand and gravel	5	35
Clay	3	38
Sand and gravel; contains clay streaks	5	43
Sand and gravel	2	45
CRETACEOUS—Gulfian		
Carlile shale		
Shale, dark gray	3	48

14. *Driller's log of test hole 14 in the NW¼ SW¼ NE¼ sec. 30, T. 13 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays. Approximate altitude of land surface, 2,010 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Recent		
Alluvium		
Soil	1	1
Clay, black	7	8
Clay, brown	24	32
Clay, blue	6	38
Sand and gravel	5	43
CRETACEOUS—Gulfian		
Carlile shale		
Shale, dark gray	1	44

15. *Driller's log of test hole 15 in the NE¼ SW¼ NE¼ sec. 30, T. 13 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays. Approximate altitude of land surface, 2,009 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Recent		
Alluvium		
Soil	1	1
Clay	32	33
Sand and clay streaks	5	38
Sand and gravel, loose	3	41
Sand and gravel, tight	6	47
CRETACEOUS—Gulfian		
Carlile shale		
Shale, dark gray	2	49

16. *Driller's log of test hole 16 in the NE¼ SW¼ NE¼ sec. 30, T. 13 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays. Approximate altitude of land surface, 2,008 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Recent		
Alluvium		
Soil	1	1
Clay	9	10
Clay, jointed	3	13
Clay, brown	20	33
Sand, fine	7	40
CRETACEOUS—Gulfian		
Carlile shale		
Shale, dark gray	1	41

17. *Driller's log of test hole 17 in the NW¼ SE¼ NE¼ sec. 30, T. 13 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays. Approximate altitude of land surface, 2,007 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Recent		
Alluvium		
Soil	1	1
Clay, brown	25	26
Sand and gravel; contains clay streaks	9	35
CRETACEOUS—Gulfian		
Carlile shale		
Shale, dark gray	1	36

18. *Driller's log of test hole 18 in the NE¼ SE¼ NE¼ sec. 30, T. 13 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays. Approximate altitude of land surface, 2,007 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Recent		
Alluvium		
Soil	1	1
Clay, brown	32	33
Clay, blue	3	36
Sand, fine; contains clay streaks	3	39
Sand and gravel; contains numerous clay streaks	10	49
CRETACEOUS—Gulfian		
Carlile shale		
Shale, dark gray	1	50

19. *Driller's log of test hole 19 in the SE¼ SE¼ NE¼ sec. 30, T. 13 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays. Approximate altitude of land surface, 2,009 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Clay, black	3	3
Clay, brown	35	38
CRETACEOUS—Gulfian		
Carlile shale		
Shale, dark gray	2	40

20. *Driller's log of test hole 20 in the SE¼ SE¼ NE¼ sec. 30, T. 13 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays. Approximate altitude of land surface, 2,007 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Clay, black	3	3
Clay, brown	25	28
Clay, blue	8	36
Sand, fine to medium coarse	4	40
CRETACEOUS—Gulfian		
Carlile shale		
Shale, dark gray	1	41

21. *Driller's log of test hole 21 in the NE¼ NE¼ SE¼ sec. 30, T. 13 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays. Approximate altitude of land surface, 2,005 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Clay, black	6	6
Clay, brown	22	28
Clay, soft, blue	8	36
Sand, medium coarse; contains clay balls	2	38
Sand and gravel	7	45
CRETACEOUS—Gulfian		
Carlile shale		
Shale, dark gray	3	48

22. *Driller's log of test hole 22 in the SE¼ NE¼ SE¼ sec. 30, T. 13 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays. Approximate altitude of land surface, 2,005 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Clay, black	8	8
Clay, brown	15	23
Sand, medium coarse; contains numerous clay streaks	6	29
Clay	2	31
Sand, fine	3	34
Clay	1	35
Sand and gravel	2	37
Clay, blue	3	40
Sand, fine to medium	4	44

CRETACEOUS—Gulfian		
Carlile shale		
Shale, dark gray	1	45

23. *Driller's log of test hole 23 in the NE¼ SE¼ SE¼ sec. 30, T. 13 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays. Approximate altitude of land surface, 2,006 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Clay	8	8
Clay, brown	7	15
Clay, soft	14	29
Sand, fine, dirty	4	33
Sand, medium coarse	2	35
Sand and gravel	4	39
Clay	1	40
Sand and gravel	7	47
CRETACEOUS—Gulfian		
Carlile shale		
Shale, dark gray	1	48

24. *Driller's log of test hole 24 in the NE¼ NE¼ NE¼ sec. 31, T. 13 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays. Approximate altitude of land surface, 2,000 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Clay, brown	19	19
Clay, soft, sandy	6	25
Clay, blue	3	28
Sand and clay	5	33
Sand and gravel; loose	5	38
CRETACEOUS—Gulfian		
Carlile shale		
Shale, dark gray	2	40

25. *Driller's log of test hole 25 in the SE¼ NE¼ NE¼ sec. 31, T. 13 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays. Approximate altitude of land surface, 2,001 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Clay	25	25
Sand and clay	3	28
Clay, blue	5	33
Sand and gravel; contains clay streaks	10	43
CRETACEOUS—Gulfian		
Carlile shale		
Shale, dark gray	2	45

26. *Driller's log of test hole 26 in the NE¼ SE¼ NE¼ sec. 31, T. 13 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays. Approximate altitude of land surface, 2,000 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Clay, brown	10	10
Sand, fine	3	13
Sand, coarse; contains clay streaks	5	18
Sand, coarse, and gravel	4	22
Clay	2	24
CRETACEOUS—Gulfian		
Carlile shale		
Shale, dark gray	4	28

27. *Driller's log of test hole 27 in the SE¼ SE¼ NE¼ sec. 31, T. 13 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays. Approximate altitude of land surface, 1,999 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Clay	7	7
Sand, fine	3	10
Sand and clay	6	16
Sand and gravel	8	24
CRETACEOUS—Gulfian		
Carlile shale		
Shale, dark gray	4	28

28. *Driller's log of test hole 28 in the SE¼ SE¼ NE¼ sec. 31, T. 13 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays, 1944. Approximate altitude of land surface, 2,000 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Clay	10	10
Sand, fine; contains clay streaks	5	15
Sand, medium fine, clean	6	21
CRETACEOUS—Gulfian		
Carlile shale		
Shale, dark gray	4	25

29. *Driller's log of test hole 29 in the NE¼ NE¼ SE¼ sec. 31, T. 13 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays, 1944 .Approximate altitude of land surface, 2,001 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Clay	13	13
Sand, fine; contains clay streaks	5	18
Sand and gravel	9	27
CRETACEOUS—Gulfian		
Carlile shale		
Shale, dark gray	1	28

30. *Driller's log of test hole 30 in the NE¼ NE¼ SE¼ sec. 31, T. 13 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays, 1944. Approximate altitude of land surface, 2,003 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Clay, hard	5	5
Clay, brown	9	14
Sand, fine to medium, and clay	6	20
Sand and gravel	5	25
Clay, gray	8	33
Clay, soft, blue	10	43
Sand, gravel, and clay streaks	7	50
CRETACEOUS—Gulfian		
Carlile shale		
Shale, dark gray	1	51

31. *Driller's log of test hole 31 in the SE¼ NE¼ SE¼ sec. 31, T. 13 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays, 1944. Approximate altitude of land surface, 2,005 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Clay	28	28
Sand, coarse, and clay streaks	5	33
Clay, blue	8	41
Clay; contains sand streaks	7	48
Sand and gravel	3	51
CRETACEOUS—Gulfian		
Carlile shale		
Shale, dark gray	2	53

32. *Sample log of test hole 32 at the NE cor. SE¼ SE¼ sec. 31, T. 13 S., R. 18 W., drilled by the State Geological Survey, 1946. Altitude of land surface, 2,009.0 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Silt, dark gray to tan	7	7
Silt, sandy, tan	3	10
Sand, very fine to coarse	6	16
Sand, fine to coarse, and a little fine to coarse gravel	17	33
Sand and gravel, silty; contains a few pebbles of limestone	6	39
Silt, dark gray; contains some sand and gravel	16	55
CRETACEOUS—Gulfian		
Carlile shale		
Shale, black	5	60

33. *Sample log of test hole 33 in the NE¼ SE¼ SE¼ sec. 31, T. 13 S., R. 18 W., drilled by the State Geological Survey, 1946. Altitude of land surface, 2,011.1 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Silt, tan to brown	17	17
Sand, very fine to medium	3	20
Sand, fine, to coarse gravel; contains limestone pebbles	21	41
Sand, fine to coarse, and silt; gray and tan; contains a little gravel, and many limestone pebbles	9	50
Sand, very fine to medium; contains some gravel, limestone pebbles, and silt	6	56
CRETACEOUS—Gulfian		
Carlile shale		
Shale, black	4	60

34. *Sample log of test hole 34 in the SE¼ SE¼ SE¼ sec. 31, T. 13 S., R. 18 W., drilled by the State Geological Survey, 1946. Altitude of land surface, 2,014.5 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Silt, tan, gray, and brown; contains some sand and limestone pebbles in lower part	15	15
Silt, tan gray	10.5	25.5
Sand, gravel, and limestone pebbles	15.5	41
CRETACEOUS—Gulfian		
Carlile shale		
Shale, black	4	45

35. *Sample log of test hole 35 at the SW cor. sec. 32, T. 13 S., R. 18 W., drilled by the State Geological Survey, 1946. Altitude of land surface, 2,020.4 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Silt, tan to brown	3	3
Silt, tan and light gray; contains very little sand, gravel, and limestone pebbles	21	24
Sand and silt, tan; contains a little gravel	8	32
Sand, gravel, and limestone pebbles	15	47
CRETACEOUS—Gulfian		
Carlile shale		
Shale, black	3	50

36. *Sample log of test hole 36 in the NW¼ NE¼ NW¼ sec. 33, T. 13 S., R. 18 W., drilled by the State Geological Survey, 1946. Altitude of land surface, 2,024.2 feet. Depth to water level, 49.45 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, tan, gray tan, and dark gray; contains caliche	33	33
Sand, fine to coarse, and fine gravel	2	35
Silt, gray, dark gray, and brown	12	47
Sand, fine to coarse, contains a few limestone pebbles and some silt	11	58
Sand, gravel, and limestone pebbles	11	69
CRETACEOUS—Gulfian		
Carlile shale		
Shale, dark gray to black	1	70

37. *Sample log of test hole 37 in the NE¼ NW¼ NE¼ sec. 33, T. 13 S., R. 18 W., drilled by the State Geological Survey, 1946. Altitude of land surface, 2,027.8 feet. Depth to water level, 53.38 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, tan to brown; contains a little sand and gravel in lower part	47	47
Sand and gravel, poorly sorted; contains much silt in lower part	23	70
Gravel, fine to very coarse; contains limestone pebbles and some fine to coarse sand	5	75
CRETACEOUS—Gulfian		
Carlile shale		
Shale, dark gray to black	5	80

38. *Sample log of observation well 38 in the SE¼ NW¼ sec. 33, T. 13 S., R. 18 W., at 20th and Fort Streets, Hays, drilled by the State Geological Survey, 1946. Well finished at 66 feet. Altitude at top of 1½-inch pipe, 2,020.1 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, tan and red brown	10	10
Silt, sandy, tan, gray, and brown gray	30	40
Sand, very fine to coarse, tan; contains some silt	20	60
Sand, fine, to coarse gravel	7	67
CRETACEOUS—Gulfian		
Carlile shale		
Shale, black	3	70

39. *Sample log of test hole 39 in the SE¼ SE¼ NE¼ sec. 33, T. 13 S., R. 18 W., drilled by the State Geological Survey, 1946. Altitude of land surface, 2,025.01 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, tan to gray; contains a little sand and fine gravel	40	40
Sand, fine to coarse; contains a few limestone pebbles	9	49

Silt, sandy, dark gray	12	61
Sand, fine to coarse; a little gravel	11	72
CRETACEOUS—Gulfian		
Carlile shale		
Shale, dark gray to black	3	75

40. *Sample log of test hole 40 in the NE¼ NE¼ SE¼ sec. 33, T. 13 S., R. 18 W., drilled by the State Geological Survey, 1946. Altitude of land surface, 2,020.1 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, light tan to brown	28	28
Silt and sand, tan; contains limestone pebbles	7	35
Sand, fine to coarse, and some fine gravel	5	40
Gravel, fine to very coarse, and fine to coarse sand	5	45
Silt, tan; contains some gravel, and limestone pebbles	13	58
Sand, fine to coarse, and a little fine gravel	8	66
CRETACEOUS—Gulfian		
Carlile shale		
Shale, black	4	70

41. *Sample log of test hole 41 at the NE cor. SE¼ SE¼ sec. 33, T. 13 S., R. 18 W., drilled by the State Geological Survey, 1946. Altitude of land surface, 2,001.4 feet. Depth to water level, 35.75 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, light gray, gray, and tan; in part sandy	37	37
Clay, plastic, dark gray	2	39
Silt, sandy, tan and gray	5	44
Sand, fine, and coarse gravel; contains limestone pebbles and a little silt	13	57
CRETACEOUS—Gulfian		
Carlile shale		
Shale, dark gray to black	3	60

42. *Driller's log of test hole 42 in the SE¼ SE¼ SE¼ sec. 33, T. 13 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Soil	1	1
Clay	17	18
Sand, fine to medium fine	7	25
Sand, coarse; and gravel	4	29
Clay	18	47
Sand, coarse, mixed with clay	3	50
CRETACEOUS—Gulfian		
Carlile shale		
Shale, dark gray to black	1	51

43. *Driller's log of test hole 43 in the SW¼ SW¼ sec. 34, T. 13 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays. Approximate altitude of land surface, 2,000 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Clay	33	33
Clay, sandy	2	35
Sand and gravel	4	39
Sand, medium to coarse; contains clay streaks	4	43
Clay, soft	2	45
Sand and gravel; contains a few clay streaks	10	55
CRETACEOUS—Gulfian		
Carlile shale		
Shale, dark gray to black	1	56

44. *Sample log of observation well 44 in the SW¼ SW¼ NW¼ sec. 3, T. 14 S., R. 18 W., drilled by the State Geological Survey, 1946. Well finished at 41.4 feet. Altitude at top of 1½-inch pipe, 1,985.7 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Silt, gray and brown	10	10
Silt, sandy, tan and gray; contains few limestone pebbles	13	23
Sand and gravel; contains limestone pebbles and scattered balls of gray and yellow clay	18	41
CRETACEOUS—Gulfian		
Carlile shale		
Shale, black	2	43

45. *Sample log of observation well 45 in SW¼ SW¼ sec. 3, T. 14 S., R. 18 W., drilled by the State Geological Survey, 1946. Well finished at 35.3 feet. Altitude at top of 1¼-inch pipe, 1,980.1 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Silt, tan, gray brown, and brown	19	19
Silt, sandy, gray black	6	25
Sand, very fine to coarse; and some fine gravel	5	30
Sand, gravel, and limestone pebbles	6	36
CRETACEOUS—Gulfian		
Carlile shale		
Shale, black	3	39

46. *Driller's log of test hole 46 in the SE¼ NE¼ NE¼ sec. 4, T. 14 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays. Approximate altitude of land surface, 1,994 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Soil	1	1
Clay	25	26

Sand and clay	2	28
Sand, coarse; contains clay streaks	7	35
Clay	4	39
Sand and clay	4	43
Sand, coarse, and gravel	3	46
Sand and clay	2	48
Sand, coarse, and gravel	2	50
CRETACEOUS—Gulfian		
Carlile shale		
Shale, black	1	51

47. *Driller's log of test hole 47 in the SE¼ NE¼ NE¼ sec. 4, T. 14 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays. Approximate altitude of land surface, 1,993 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Soil	1	1
Clay	25	26
Clay and sand	4	30
Sand, coarse, and gravel	8	38
Sand and gravel, coarse; contains a few clay streaks	9	47
CRETACEOUS—Gulfian		
Carlile shale		
Shale, black	1	48

48. *Driller's log of test hole 48 in the NE¼ SW¼ NW¼ sec. 4, T. 14 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays. Approximate altitude of land surface, 1,989 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Soil	1	1
Clay	19	20
Sand, fine; contains some clay	5	25
Sand, gravel, and clay	6	31
CRETACEOUS—Gulfian		
Carlile shale		
Shale, black	1	32

49. *Driller's log of test hole 49 in the NW¼ SE¼ NW¼ sec. 4, T. 14 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays. Approximate altitude of land surface, 1,988 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Soil	1	1
Clay	19	20
Clay, sandy	4	24
Sand, fine	6	30
Sand, coarse, and gravel	3	33
CRETACEOUS—Gulfian		
Carlile shale		
Shale, black	1	34

50. *Sample log of observation well 50 in the SE¼ SE¼ NW¼ sec. 4, T. 14 S., R. 18 W., at the south end of Milner Street, Hays, drilled by the State Geological Survey, 1946. Well finished at 34 feet. Altitude at top of 1½-inch pipe, 1,986.0 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Silt, tan, gray, and brown	18	18
Silt, and brown sand	3	21
Sand, very fine to coarse, and fine gravel	7	28
Sand and gravel, fine to very coarse	7	35
CRETACEOUS—Gulfian		
Carlile shale		
Shale, black	1	36

51. *Sample log of test hole 51 in the NE¼ NE¼ NE¼ sec. 6, T. 14 S., R. 18 W., drilled by the State Geological Survey, 1946. Altitude of land surface, 2,030.3 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, tan and brown; contains some fine to coarse sand	13	13
Silt, light tan; contains scattered limestone pebbles	20	33
Silt, tan; contains much sand and gravel	8	41
Sand, very fine to coarse, and fine to coarse gravel	15	56
CRETACEOUS—Gulfian		
Carlile shale		
Shale, black	4	60

52. *Sample log of test hole 52 at the NE cor. SE¼ NE¼ sec. 6, T. 14 S., R. 18 W., drilled by the State Geological Survey, 1946. Altitude of land surface, 2,037.9 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, tan, gray tan, and brown, in part sandy; contains limestone pebbles near base	54	54
Sand, fine to coarse	6	60
Sand, fine, to medium gravel	3	63
CRETACEOUS—Gulfian		
Carlile shale		
Shale, black	3	66

53. *Sample log of test hole 53 at the SE cor. NE¼ sec. 6, T. 14 S., R. 18 W., drilled by the State Geological Survey, 1946. Altitude of land surface, 2,031.2 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, brown and dark gray brown	11	11
Silt, sandy, tan; contains a few limestone pebbles	21	32
Silt and sand, tan and buff; contains some gravel and limestone pebbles	3	35

	Thickness, feet	Depth, feet
CRETACEOUS—Gulfian		
Carlile shale		
Shale, gray black	5	40

54. *Sample log of test hole 54 at the NE cor. sec. 7, T. 14 S., R. 18 W., drilled by the State Geological Survey, 1946. Altitude of land surface, 2,031.7 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, black	5	5
Silt, light to dark gray; contains a few limestone pebbles	11	16
CRETACEOUS—Gulfian		
Carlile shale		
Shale, tan, light gray, and gray black; contains gypsum	9	25

55. *Driller's log of test hole 55 in the SE¼ SW¼ sec. 3, T. 14 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays, 1943. Approximate altitude of land surface, 1,977 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Soil, black	2	2
Clay, brown	8	10
Clay, gray	9	19
Sand, fine to medium fine	4	23
Sand, coarse to medium coarse; contains some gravel	4	27
Clay	1	28
Sand, coarse, and gravel; very loose	3	31
Clay, brown	4	35
Clay, blue	3	38
Sand, coarse to medium coarse	2	40
CRETACEOUS—Gulfian		
Carlile shale		
Shale, soft, dark gray	5	45

56. *Driller's log of test hole 56 in the NE¼ NW¼ NW¼ sec. 10, T. 14 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays. Approximate altitude of land surface, 1,979 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Soil	1	1
Clay, brown	21	22
Clay, soft, sandy	4	26
Sand, fine to medium fine; contains clay streaks	4	30
Sand, coarse, and gravel	8	38
CRETACEOUS—Gulfian		
Carlile shale		
Shale, dark gray	2	40

57. *Driller's log of test hole 57 in the NE¼ NW¼ NW¼ sec. 10, T. 14 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays. Approximate altitude of land surface, 1,977 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Soil	1	1
Clay	22	23
Clay, soft, blue	6	29
Sand, coarse; contains clay streaks	4	33
Sand and gravel, cemented	5	38
CRETACEOUS—Gulfian		
Carlile shale		
Shale, dark gray	2	40

58. *Driller's log of test hole 58 in the NE¼ NE¼ NW¼ sec. 10, T. 14 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays. Approximate altitude of land surface, 1,976 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Soil, black	2	2
Clay, brown	5	7
Sand, fine	6	13
Sand, coarse to medium coarse; contains some gravel	5	18
Sand, coarse, and gravel; some light streaks	13	31
CRETACEOUS—Gulfian		
Carlile shale		
Shale, dark gray	2	33

59. *Driller's log of test hole 59 in the NE¼ NE¼ NW¼ sec. 10, T. 14 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays. Approximate altitude of land surface, 1,976 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Soil, black	2	2
Clay, brown	6	8
Clay, jointed	10	18
Sand, fine to medium fine	4	22
Sand, coarse; contains some gravel	9	31
CRETACEOUS—Gulfian		
Carlile shale		
Shale, dark gray	2	33

60. *Driller's log of test hole 60 in the NE¼ NE¼ NW¼ sec. 10, T. 14 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays. Approximate altitude of land surface, 1,975 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Recent		
Alluvium		
Soil, black	1	1
Clay, brown	16	17
Sand, medium coarse; contains some clay streaks	5	22
Sand, coarse, and gravel (tight drilling)	8	30
CRETACEOUS—Gulfian		
Carlile shale		
Shale, dark gray	3	33

61. *Driller's log of test hole 61 in the SW¼ NE¼ NW¼ sec. 10, T. 14 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays. Approximate altitude of land surface, 1,976 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Recent		
Alluvium		
Soil	1	1
Clay, brown	19	20
Clay, soft blue	4	24
Sand, medium coarse	1	25
Clay, blue	6	31
Sand, coarse, and gravel; contains numerous clay streaks	4	35
Sand, coarse, and gravel	3	38
CRETACEOUS—Gulfian		
Carlile shale		
Shale, dark gray	1	39

62. *Driller's log of test hole 62 in the SW¼ NE¼ NW¼ sec. 10, T. 14 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays, Approximate altitude of land surface, 1,975 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Recent		
Alluvium		
Soil, black	1	1
Clay, brown	7	8
Sand, fine to medium	8	16
Sand, medium coarse to coarse	4	20
Clay, tough, gray	9	29
Sand, medium coarse	2	31
Clay, soft	2	33
Sand, coarse, and gravel; contains a few clay streaks	7	40
CRETACEOUS—Gulfian		
Carlile shale		
Shale, dark gray	2	42

63. *Driller's log of test hole 63 in the SW¼ NE¼ NW¼ sec. 10, T. 14 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays, Approximate altitude of land surface, 1,975 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Soil	1	1
Clay	6	7
Sand, fine to medium fine	8	15
Sand, coarse	4	19
Clay	4	23
Sand, coarse	1	24
Clay	7	31
Sand, coarse, and gravel (tight drilling)	4	35
Sand, coarse, and loose gravel	3	38
CRETACEOUS—Gulfian		
Carlile shale		
Shale, dark gray	1	39

64. *Driller's log of test hole 64 in the SW¼ NW¼ NE¼ sec. 10, T. 14 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays. Approximate altitude of land surface, 1,975 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Soil	1	1
Clay	9	10
Sand, very fine	3	13
Sand and clay	2	15
Clay	14	29
Sand, medium coarse; contains clay streaks	2	31
Sand, coarse, and gravel	6	37
CRETACEOUS—Gulfian		
Carlile shale		
Shale, blue	3	40

65. *Driller's log of test hole 65 in the NE¼ SE¼ NW¼ sec. 10, T. 14 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays. Approximate altitude of land surface, 1,975 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Soil	1	1
Clay	6	7
Sand, fine, mucky	6	13
Sand and gravel; contains a few clay streaks	8	21
Clay; contains a few sandy streaks	8	29
Sand, coarse, and gravel	5	34
CRETACEOUS—Gulfian		
Carlile shale		
Shale, blue	2	36

66. *Driller's log of test hole 66 in the NE¼ SE¼ NW¼ sec. 10, T. 14 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays. Approximate altitude of land surface, 1,975 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Soil	1	1
Clay	19	20
Clay, soft, gray	3	23
Clay, sandy	3	26
Sand and gravel	8	34
CRETACEOUS—Gulfian		
Carlile shale		
Shale, gray	2	36

67. *Driller's log of test hole 67 in the SE¼ SE¼ NE¼ sec. 10, T. 14 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays. Approximate altitude of land surface, 1,974 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Soil	1	1
Clay	9	10
Sand, fine; contains clay streaks	9	19
Sand, cemented, coarse	7	26
Sand and gravel	9	35
Clay	3	38
Sand, fine; contains clay streaks	4	42
Sand, medium fine	4	46
Clay and sand	4	50
CRETACEOUS—Gulfian		
Carlile shale		
Shale, gray	1	51

68. *Driller's log of test hole 68 in the NE¼ NE¼ SE¼ sec. 10, T. 14 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays. 1944.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Soil	1	1
Clay, yellow	21	22
Clay, blue	7	29
Sand	2	31
CRETACEOUS—Gulfian		
Carlile shale		
Shale, gray	4	35

69. *Driller's log of test hole 69 in the NE¼ NE¼ SE¼ sec. 10, T. 14 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays, 1944. Approximate altitude of land surface, 1,973 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Soil	1	1
Clay	10	11
Sand, fine	5	16
Sand, coarse	4	20
Sand and gravel (tight)	14	34
Clay	4	38
Sand, fine to medium; contains a few sand streaks	11	49
Sand, coarse	1	50
CRETACEOUS—Gulfian		
Carlile shale		
Shale, gray	1	51

70. *Driller's log of test hole 70 in the cen. NE¼ SE¼ sec. 10, T. 14 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays, 1944.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Soil	1	1
Clay	6	7
Clay, jointed	3	10
Sand, fine, and clay	15	25
Clay, yellow	2	27
CRETACEOUS—Gulfian		
Carlile shale		
Shale, gray	2	29

71. *Driller's log of test hole 71 in the NE¼ NE¼ SE¼ sec. 10, T. 14 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays, 1944. Approximate altitude of land surface, 1,972 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Soil	1	1
Clay	10	11
Sand, fine	5	16
Sand and gravel	14	30
Clay	6	36
Sand, fine, rocks, and clay	4	40
Sand, fine to medium	8	48
Sand, coarse; contains clay streaks	3	51
CRETACEOUS—Gulfian		
Carlile shale		
Shale, gray	1	52

72. *Driller's log of test hole 72 in the SE¼ NE¼ SE¼ sec. 10, T. 14 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays, 1944. Approximate altitude of land surface, 1,972 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Soil	2	2
Clay	17	19
Sand, fine	3	22
Sand, medium to coarse; contains clay streaks	3	25
Clay	5	30
Sand and gravel	16	46
CRETACEOUS—Gulfian		
Carlile shale		
Shale, gray	2	48

73. *Driller's log of test hole 73 in the SE¼ NE¼ SE¼ sec. 10, T. 14 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays, 1944. Approximate altitude of land surface, 1,971 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Soil	2	2
Clay	32	34
Sand and gravel, loose	6	40
Sand, fine to coarse, and gravel	6	46
CRETACEOUS—Gulfian		
Carlile shale		
Shale, gray	2	48

74. *Driller's log of test hole 74 in the SE¼ SE¼ SW¼ sec. 11, T. 14 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays, 1944.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Soil	1	1
Clay	27	28
Sand and gravel	2	30
CRETACEOUS—Gulfian		
Carlile shale		
Shale, gray	3	33

75. *Driller's log of test hole 75 in the NE¼ NE¼ NW¼ sec. 14, T. 14 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays, 1944.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Soil	1	1
Clay, brown	19	20
Clay, blue	9	29
Sand, medium fine	4	33
Sand and gravel	3	36
CRETACEOUS—Gulfian		
Carlile shale		
Shale, gray	2	38

76. *Driller's log of test hole 76 in the NE¼ NE¼ NW¼ sec. 14, T. 14 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays, 1944.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Soil	1	1
Clay	19	20
Clay, blue	8	28
Sand and gravel; contains clay streaks	6	34
CRETACEOUS—Gulfian		
Carlile shale		
Shale, gray	2	36

77. *Driller's log of test hole 77 in the NE¼ NW¼ NW¼ sec. 14, T. 14 S., R. 18 W., drilled by the Layne-Western Company for the City of Hays, 1944.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Soil	1	1
Clay, brown	19	20
Clay, blue	10	30
Sand, fine, and clay	5	35
Sand and gravel	3	38
CRETACEOUS—Gulfian		
Carlile shale		
Shale, gray	2	40

78. *Sample log of test hole 78 in the SW¼ SW¼ sec. 28, T. 14 S., R. 14 W., drilled by the State Geological Survey, 1944. Altitude of land surface, 1,732.1 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Sand, coarse to fine; contains coarse to fine gravel, and buff and dark-gray silt	9	9
Silt, yellow gray; contains medium to fine gravel and sand	25	34
Silt, clayey, soft, dark greenish gray	6	40
Silt, clayey, soft, blue gray; contains medium to fine gravel	10	50
Gravel, medium to fine; contains clayey, soft blue-gray silt	10	60
Gravel, very coarse to fine, and sand	13	73
CRETACEOUS—Gulfian		
Dakota formation		
Sandstone, medium to fine, soft, gray white	2	75
Clay, gray white and pink	5	80
Clay, gray white	4	84

79. *Sample log of test hole 79 in the SE¼ NE¼ sec. 32, T. 14 S., R. 14 W., drilled by the State Geological Survey, 1944. Altitude of land surface, 1,719.5 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Silt, yellow gray, and fine to medium sand	7	7
Gravel, fine, and medium sand	3	10
Gravel, fine to coarse, and sand	6.5	16.5
Sand, medium to fine, loosely cemented, white	1.5	18
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, light blue gray, mottled dull yellow and dull red	22	40

80. *Sample log of test hole 80 in the NE cor. sec. 5, T. 15 S., R. 14 W., drilled by the State Geological Survey, 1944. Altitude of land surface, 1,735.0 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Road fill	2	2
Gravel, fine to coarse; contains light-gray silt	25	27
Silt, clayey, blue gray; contains fine gravel and sand	17.5	44.5
CRETACEOUS—Gulfian		
Dakota formation		
Clay, light blue gray and gray white, mottled yellow	3.5	48
Sandstone, silty, hard, fine-grained, partly carbonaceous, gray white	8	56
Silt, clayey, partly carbonaceous, compact, gray; contains very fine sand	9	65

81. *Sample log of test hole 81 in the SE cor. SW¼ sec. 33, T. 14 S., R. 14 W., drilled by the State Geological Survey, 1944. Altitude of land surface, 1,760.8 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Road fill	2	2
Silt, brown gray to yellow gray	5	7
Gravel, coarse to fine, and sand	13	20
CRETACEOUS—Gulfian		
Graneros shale		
Clay, sandy; contains thin layers of hard gray and white sandstone	10	30

82. *Sample log of test hole 82 in the SE cor. sec. 33, T. 14 S., R. 14 W., drilled by the State Geological Survey, 1944. Altitude of land surface, 1,756.4 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Road fill	2	2
Silt, clayey, yellow gray; contains a few caliche nodules	3	5
Sand, coarse to fine; contains yellow-gray silt and fine gravel	3	8
Gravel, fine to coarse, and sand	10	18
CRETACEOUS—Gulfian		
Graneros shale		
Clay, partly sandy, black; contains silty white sandstone	12	30

83. *Sample log of test hole 83 in the SW cor. NW¼ sec. 4, T. 15 S., R. 14 W., drilled by the State Geological Survey, 1944. Altitude of land surface, 1,767.7 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Soil, dark gray	3	3
Silt, clayey, compact, dark gray	3	6
Silt, clayey, compact, light greenish gray; contains fine to coarse sand	8	14
Gravel, fine to medium, and sand; contains light-gray and light-brown silt	5.5	19.5
CRETACEOUS—Gulfian		
Graneros shale		
Shale, clayey, blue gray; contains a few thin layers of fine to very fine hard gray sandstone	6.5	26
Shale, clayey to sandy, dark gray; contains fine to very fine dark-gray sandstone	9	35

84. *Sample log of test hole 84 in the SE cor. NW¼ sec. 4, T. 15 S., R. 14 W., drilled by the State Geological Survey, 1944. Altitude of land surface, 1,763.3 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene		
Alluvium		
Soil, dark gray	3	3
Silt, clayey, light gray green, mottled yellow brown	6	9
Gravel, fine to coarse, and sand; contains buff silt	13	22
CRETACEOUS—Gulfian		
Graneros shale		
Shale, sandy, dark blue gray	8	30

85. *Sample log of test hole 85 in the SE cor. NW¼ sec. 3, T. 15 S., R. 14 W., drilled by the State Geological Survey, 1944. Altitude of land surface, 1,738.8 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Soil, sandy, black	1.5	1.5
CRETACEOUS—Gulfian		
Graneros shale		
Shale, dark gray	.5	2.0

86. *Sample log of test hole 86 in the NW cor. sec. 20, T. 15 S., R. 15 W., drilled by the State Geological Survey, 1944. Altitude of land surface, 1,775.5 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Sand, coarse to fine; contains buff-gray silt and medium to fine gravel	6	6
Silt, clayey, gray	2	8
Sand, coarse to fine; contains coarse to fine gravel and gray and dark blue-gray silt	27	35
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, gray; contains medium to fine sand and carbonaceous matter	3	38
Sandstone, medium to fine, soft, gray white	2.5	40.5
Clay, gray white; contains carbonaceous matter	9.5	50

87. *Sample log of test hole 87 in the SE¼ NE¼ sec. 28, T. 15 S., R. 16 W., drilled by the State Geological Survey, 1944. Altitude of land surface, 1,811.5 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Sand, coarse to fine; contains fine gravel and gray silt	8	8
Gravel, medium to fine; contains coarse gravel and sand	8	16
Caliche, hard, white	.5	16.5
Gravel, fine, greenish gray; contains medium to coarse gravel and sand	3.5	20
Gravel, fine to medium, and sand	10	30
Gravel, coarse to fine, and sand; contains clayey gray silt	10	40
Gravel, medium to fine	8	48
CRETACEOUS—Gulfian		
Graneros shale		
Shale, dark gray to dark brown; contains fine hard gray-green sandstone	7	55

88. *Sample log of test hole 88 in the SW¼ SW¼ sec. 30, T. 15 S., R. 16 W., drilled by the State Geological Survey, 1944. Altitude of land surface, 1,843.2 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Recent		
Alluvium		
Silt, gray buff; contains medium to fine gravel and sand	7	7
Gravel, coarse to fine, and sand; contains gray silt	13	20
Gravel, very coarse to fine; contains sand	12	32
CRETACEOUS—Gulfian		
Greenhorn limestone and Graneros shale		
Shale, dark gray	8	40
Shale, dark greenish gray; contains fine greenish-gray sandstone	10	50

89. *Sample log of test hole 89 in the NW cor. sec. 31, T. 15 S., R. 16 W., drilled by the State Geological Survey, 1944. Altitude of land surface, 1,860.6 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Recent		
Alluvium		
Road fill	3	3
Sand, coarse to fine, and buff silt; contains coarse to fine gravel	7	10
Silt, slightly clayey, yellow gray; contains medium to fine gravel and sand	15	25
Sand, coarse to fine; contains buff and green silt and medium to fine gravel	5	30
Sand, coarse to fine; contains medium to fine gravel	10	40
Gravel, very coarse to fine, and sand	10	50
Gravel, medium to fine; contains sand	4	54
CRETACEOUS—Gulfian		
Greenhorn limestone or Graneros shale		
Shale, greenish gray; contains very fine silty gray-green sandstone	6	60

90. *Sample log of test hole 90 in the NE¼ SE¼ sec. 30, T. 14 S., R. 15 W., drilled by the State Geological Survey, 1944. Altitude of land surface, 1,808.9 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Recent		
Alluvium		
Silt, dark gray, and medium to fine sand	6	6
Silt, light gray, and coarse to fine sand	4	10
Gravel, medium to fine, and sand; contains coarse gravel	9	19
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, calcareous, laminated, brittle, gray and dark gray	1	20

91. *Sample log of test hole 91 in the SW¼ NE¼ sec. 3, T. 14 S., R. 14 W., drilled by the State Geological Survey, 1944.*

	Thickness, feet	Depth, feet
TERTIARY—Pliocene		
Silt, clayey, compact, light gray brown to light gray green	6	6
Silt, yellow buff, contains medium to fine sand	7	13
Silt, light buff; contains medium sand and caliche	8.5	21.5
Sand, coarse to fine; contains coarse to fine gravel and buff silt	8.5	30
Gravel, coarse to medium, and clayey white silt	3	33
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, white and buff; contains limestone	2	35

92. *Sample log of test hole 92 in the SE¼ NE¼ sec. 3, T. 14 S., R. 14 W., drilled by the State Geological Survey, 1944.*

	Thickness, feet	Depth, feet
TERTIARY—Pliocene		
Silt, blocky, brown	4	4
Silt, yellow buff; contains coarse to fine sand and medium to fine gravel	3	7
Silt, clayey, gray; contains coarse to fine sand and coarse to fine gravel	10	17
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, yellow and white; contains hard gray-white limestone	1.5	13.5
Shale, gray black to dark greenish gray; contains hard gray limestone	21.5	40
Shale, calcareous, gray; contains blue-gray bentonite and light-gray limestone	1	41

93. *Drillers log of city well 19 at Hays, Kansas, SE¼ SW¼ SW¼ sec. 3, T. 14 S., R. 18 W., drilled by the Layne-Western Company. Altitude of land surface, 1,979.1 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Recent		
Alluvium		
Soil	1	1
Clay, brown	22	23
Clay, blue	5	28
Sand, medium coarse; contains a few clay streaks	2	30
Sand, coarse, loose	5	35
Sand, coarse, and gravel	8	43
Sand, coarse, tight	3	46
Sand and gravel	2	48
Sand, coarse, tight	2	50
CRETACEOUS—Gulfian		
Carlile shale		
Shale, gray	1	51

94. *Driller's log of city well 18 at Hays, Kansas in the SE¼ NE¼ NE¼ sec. 4, T. 14 S., R. 18 W., drilled by the Layne-Western Company. Altitude of land surface, 1,991.4 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Alluvium		
Soil	1	1
Clay	22	23
Sand and gravel; tight drilling	7	30
Clay; contains some sand streaks	5	35
Clay	5	40
Sand and gravel	12.7	52.7
CRETACEOUS—Gulfian		
Carlile shale		
Shale, gray	0.3	53

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