GROUND-WATER CONDITIONS IN ARKANSAS RIVER VALLEY IN THE VICINITY OF HUTCHINSON, KANSAS

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UNIVERSITY OF KANSAS PUBLICATIONS
STATE GEOLOGICAL SURVEY OF KANSAS, BULLETIN 64, PART 5
LAWRENCE, KANSAS

State Geological Survey of Kansas, Bulletin 64
1946 Reports of Studies, Part 5, Pages 145-216, Plates 1-6, Figures 1-11
December, 1946

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with analyses of ground waters by
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Prepared by the State Geological Survey of Kansas, the United States Geological Survey, the Division of Sanitation of the Kansas State Board of Health, and the Division of Water Resources of the Kansas State Board of Agriculture. Publication costs were paid by the Kansas State Board of Health.

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ABSTRACT

This report presents the results of an investigation of the geology and ground-water conditions near Hutchinson, Kansas. The investigation was made with special reference to the possibility of developing ground water of good chemical quality for municipal supply.

The report contains a map showing the areal geology and water-table contours, logs of 40 test holes and wells, and results of mechanical analyses and determinations of permeability of samples of the water-bearing materials penetrated by the test drill. The coefficient of permeability for most of the samples tested ranged from 1,000 to 15,000 (Meinzer's units). The chemical character of the ground waters in this area, as shown by analyses of 63 samples of water collected from test holes and wells, varies widely. In places the ground water is contaminated by intrusion of salt water from streams and industrial wastes. Several maps and graphs illustrating the quality of the ground water are included.

Estimates of the quantity of water available for pumping in the several parts of the area are based on studies of recharge from precipitation, yield of wells, and physical properties of the water-bearing materials. Large quantities of water are available in most parts of the area, and the quantity and quality of the water in each of several sub-areas is discussed. The area along the border of the sand dunes at the edge of Arkansas River Valley north and east of Hutchinson appears most promising for the development of a supply of water of chemical quality suitable for municipal use.

INTRODUCTION

The area described in this report includes about 100 square miles in and near Arkansas River Valley in the vicinity of Hutchinson (Fig. 1). The valley is broad and flat in this area. It is bordered on the northeast by an extensive belt of sand dunes. Many municipal, industrial, and private wells including those of the City of Hutchinson derive ground water from the unconsolidated deposits of sand and gravel which underlie the valley floor. This report is concerned with the quantity and quality of ground water available for municipal water supply and other industrial and private uses in and near Hutchinson.

The report of a cooperative investigation of the general geology and hydrology of a large area in central Kansas, which is in preparation and is now nearly completed, includes part of the area here described. Although the report on this larger area contains some data pertinent to the area near Hutchinson, the nature of the present problems indicated the desirability of a more detailed study of local ground-water conditions.

Study of Arkansas River Valley and bordering areas near Hutchinson was undertaken at the request of Mr. W. C. Hutchin-

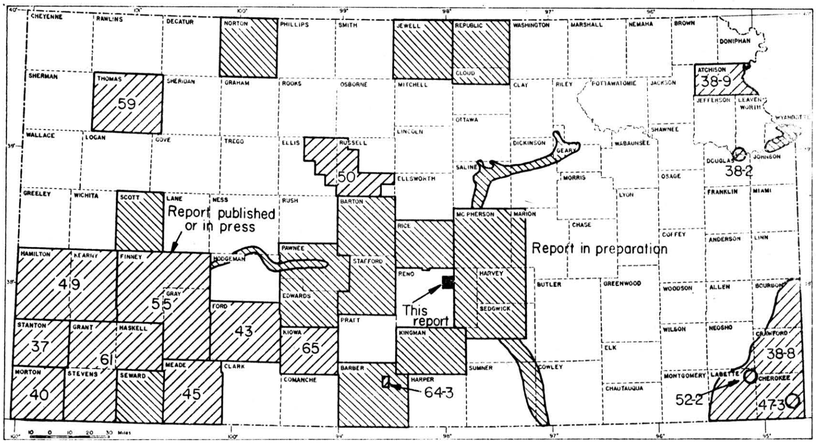

FIG. 1. Area covered by this report and other areas in Kansas for which co-operative ground-water reports have been published or are in preparation.

son, commissioner of utilities acting for the city commission, and Mr. John P. Harris, editor of the Hutchinson News-Herald. Requests for assistance in the study of local ground-water conditions in relation to problems of municipal water supply were made to R. C. Moore, director, State Geological Survey of Kansas, Paul D. Haney, director, Division of Sanitation of the Kansas State Board of Health, and to George S. Knapp, chief engineer of the Division of Water Resources of the Kansas State Board of Agriculture. The work was begun in October 1945 by the U.S. Geological Survey and the State Geological Survey of Kansas in accordance with co-operative agreements in effect between these organizations, the Division of Sanitation of the Kansas State Board of Health, and the Division of Water Resources of the Kansas State Board of Agriculture for studying the occurrence, availability, and chemical quality of ground water in Kansas. The firm of Wilson and Company, consulting engineers retained by the City of Hutchinson, materially assisted in the investigation.

The field work in this area was done mainly during October and November of 1945. Using a portable hydraulic-rotary drilling machine of early design, Mr. Claude Price, driller, and Orin Davenport, helper, drilled 32 test holes in Arkansas River Valley and the sand hills bordering the valley. The cost of test drilling was paid by the City of Hutchinson and, in part, by the Hutchinson Water Company. The author, assisted by C. K. Bayne, supervised the

drilling and collection of water samples from the test holes and collected samples of the earth materials penetrated by the drill. In addition, 7 test holes were drilled by the State Geological Survey. Samples of the material penetrated by the drill were studied and are described in the logs at the end of this report. The locations of the test holes are shown on Plate 1. Analyses of water samples were made in the Water and Sewage Laboratory of the Kansas State Board of Health by H. A. Stoltenberg, chemist.

Levels to the test holes and wells in the area were run by Wilson and Company; Mr. L. F. Shepherd of that company offered helpful advice concerning the location of test holes and other phases of the field work and supervised the leveling. Milton Sears of the Geological Survey assisted in making the well inventory and in the collection of water samples. Mr. W. C. Hutchinson made available water-level measurements which were made in this area in the summer of 1936. These data were collected as a part of a W.P.A. project, and have proved helpful to this study. Mr. A. B. Truman of the Atchison, Topeka and Santa Fe Railway Company furnished logs of the railway wells, and the Layne-Western Company supplied logs of other industrial wells. Mr. D. G. McCamant, manager of the Hutchinson Water Company, was exceedingly helpful and furnished many data relative to the present city water supply.

The manuscript for this report has been reviewed critically by members of the Federal Geological Survey; R. C. Moore, director of research, and J. C. Frye, executive director of the State Geological Survey of Kansas; Paul D. Haney, director, and Ogden S. Jones, geologist, of the Division of Sanitation, Kansas State Board of Health; and George S. Knapp, chief engineer of the Division of Water Resources, Kansas State Board of Agriculture. The base map was compiled from an uncontrolled mosaic of large scale aerial photographs prepared for this purpose (U.S. Department of Agriculture photographs), from existing highway and soil maps, and from field observation.

GEOGRAPHY AND PHYSIOGRAPHY

Hutchinson (population about 30,000) is the second largest city in central Kansas and is situated on the north side of Arkansas River in northeastern Reno County, a short distance southeast of the center of the state. Hutchinson and vicinity are served by the

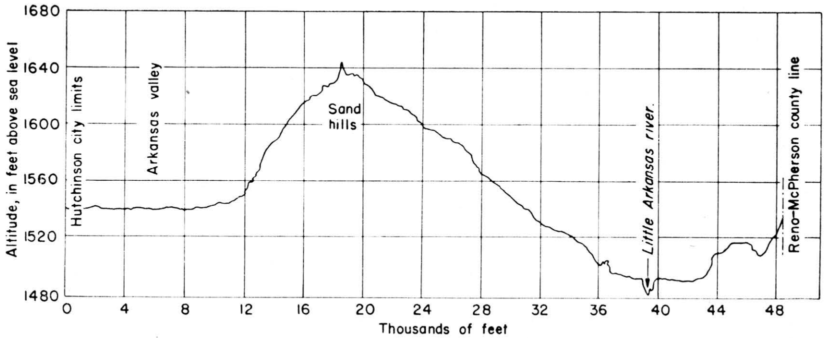

FIG. 2. Profile of the surface of the sand dunes along Chicago, Rock Island, and Pacific Railway from Hutchinson city limits to the Reno-McPherson County line.

Atchison, Topeka and Santa Fe, Missouri Pacific, and Chicago, Rock Island, and Pacific Railways. The principal land use outside the city is agriculture, and a wide variety of crops is grown in the river valley. Industries in this area include the mining and processing of salt; milling, storage, and shipment of grain; meat packing; and fiber-board manufacture.

This area is included in the Great Bend Prairie physiographic province of Moore (1930) and is characterized by the extreme flatness of large areas and low topographic relief in parts of the area. The belt of sand dunes trending northwest-southeast along the northeast side of Arkansas River Valley in the northeast part of this area provide the only prominent relief to the otherwise nearly featureless plain (Fig. 2).

The sand dunes occupy a belt about 5 miles wide which extends northwestward into Rice County and southeastward into Harvey County. The southwest side of the dunes is steeper than the northeast side (Fig. 2) and, although much of the rain that falls on the dunes seeps downward into the sand, some water runs off southwestward in ravines and small creeks which are cut into the easily eroded sand. These ravines lose identity at the southwest edge of the dunes and water flowing in them deploys on the valley plain. Several such small intermittent streams are shown on Plates 1 and 2. Small ponds are common in the interdune areas during rainy seasons. The sand dunes are subject to shifting by wind owing to the scant cover of vegetation (Pl. 3).

The wide, flat, poorly drained valley plain of Arkansas River comprises much of the area here discussed. The valley plain is

PLATE 2. Deployment of drainageways from the sand hills on the surface of Arkansas Valley shown by aerial photograph. Arrow points north and is about 0.5 mile long. (U.S. Department of Agriculture photograph.)

covered with a sandy soil and numerous ponds and wandering small streams are located on it (Pl. 4). The edge of a low terrace marks the edge of the flood plain of Arkansas River about 1 mile north of the river and is traceable for considerable distances northwestward and southeastward. A comparable terrace occurs on the south side of the river southeast of this area and is traceable nearly to the south border of Kansas. Remnants of the latter terrace are found in this area (see geologic profile, Pl. 1) but are not shown on the geologic map.

The edge of a higher terrace marks the edge of the flood plain on the south side of Arkansas River and is shown on Plate 1. The surface of this terrace in the southwestern part of the area is higher than the valley plain and has been traced southeastward to Clearwater in southern Sedgwick County. This higher surface is drained by small creeks and tributaries, but is relatively flat and undissected. The soil is sandy and occasional small areas of subdued sand dunes occur on the terrace surface.

The flood plain of Arkansas River is the belt shown as alluvium on Plate 1 between the two terrace boundaries. This area is low and is traversed by Cow Creek, Salt Creek, and other small streams tributary to the river. Arkansas River, except under extreme flood conditions, remains within the boundaries of its flood plain. The river is at present aggrading its valley in this area, as is indicated by the braided pattern of the sand bars in the channel and by other evidence of recent deposition shown on Plate 5. Cow Creek flows in a shallow, narrow channel on the flood plain of Arkansas River throughout most of its course in this area. In the northwestern part of the area, however, the creek flows in its own flood plain. Cow Creek is a meandering stream and has many small oxbow lakes, meander scars, and cutoffs (Pl. 6).

CLIMATE

The climate of this part of central Kansas is characterized by moderate precipitation, a wide temperature range, moderately high average wind velocity, and comparatively rapid evaporation. The summer days and many of the nights, especially during July and August, are generally hot. The winters are moderately cold, but generally are free from excessive snowfall. All climatic data presented below are based on records of the U.S. Weather Bureau's stations in this area.

The mean annual temperature is 54.3° F. at Hutchinson. The highest temperatures occur during the three summer months, the monthly mean being 74.7° F. in June, 80.2° F. in July, and 79.3° F. in August. The lowest temperatures occur in winter, the monthly

PLATE 3. Features of the sand dunes north of Hutchinson shown by aerial photograph. Center of photograph is sec. 11, T. 22 S., R. 6 W. Arrow points north and is about 0.5 mile long. (U.S. Department of Agriculture photograph.)

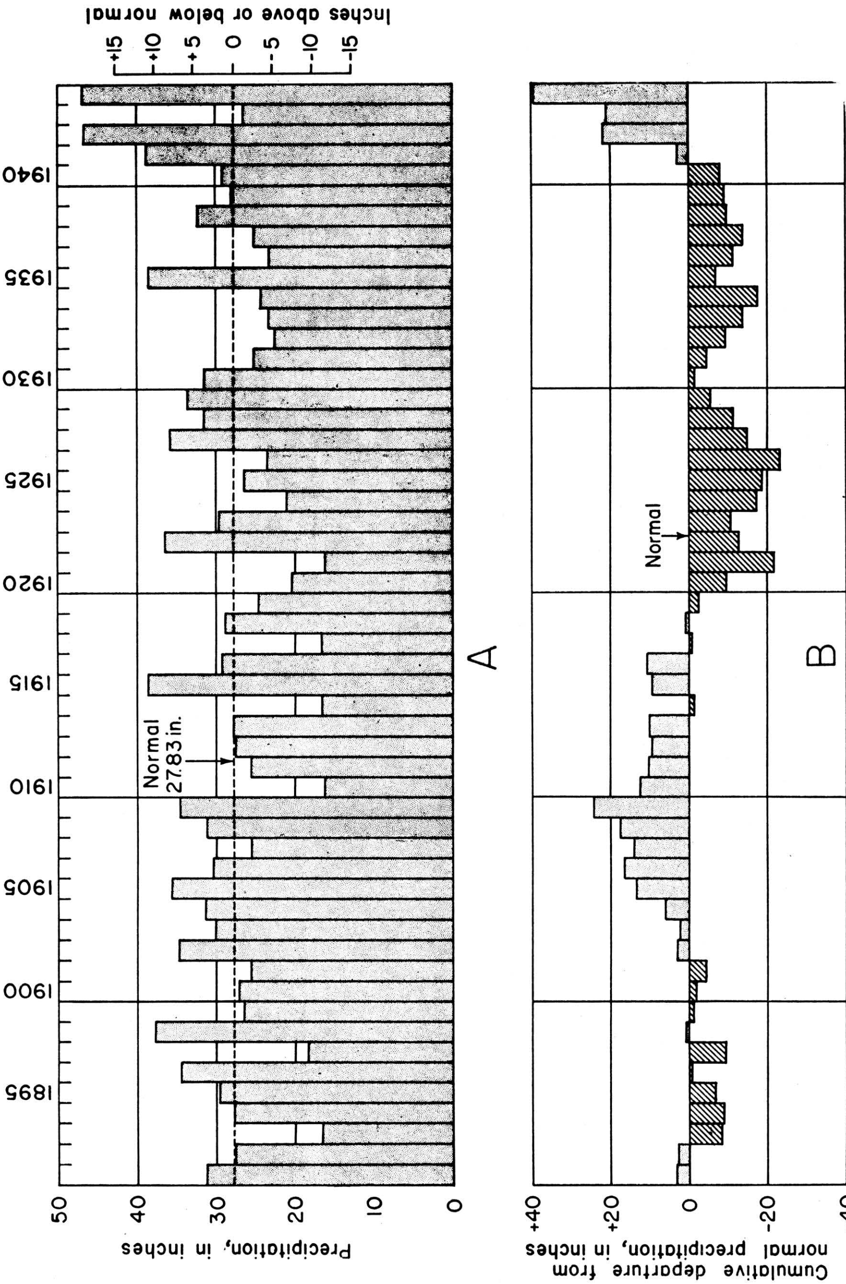

FIG. 3. Annual precipitation (A) and cumulative departure from normal precipitation (B) at Hutchinson. (From records of the U.S. Weather Bureau.)

mean at Hutchinson being 33.6° F. in December, 31.0° F. in January, and 34.6° F. in February. The highest recorded temperature at this station is 116° F., and the lowest recorded temperature is —27° F. The year 1936 was one of the unusual extremes, the highest and lowest temepratures having been 115° and —10° F. at Hutchinson. The average date of the last killing frost in the spring is April 19, but there have been killing frosts as late as May 15. The first killing frost in the fall has occurred as early as September 20 in this area, but the average date is October 18. The average length of the growing season is 182 days.

The normal annual precipitation is 27.83 inches; the lowest recorded annual precipitation at Hutchinson was 16.15 inches in 1910, and the highest recorded annual precipitation was 46.97 inches in 1944. Annual precipitation at Hutchinson is shown graphically in Figure 3A. Deviations from the normal precipitation are frequent, as is shown in Figure 3. Precipitation in the area seems to follow more or less irregular cycles in which periods of excessive moisture alternate with periods of deficient moisture or drought. Much of the precipitation falls as torrential rains followed by periods of scanty rainfall. About 70 per cent of the total annual precipitation falls during the crop-growing season from April through September (Fig. 4). The normal precipitation during May and June, the wettest months, is about 4.4 inches; during January, the dryest month, it is only about 0.7 inch.

The prevailing wind direction over this area is from the south, except in February, when north winds prevail. The greatest wind movement is in March and April, after which it decreases until August, which is the least windy month of the year. The annual evaporation demand in central Kansas greatly exceeds the quantity of moisture available for evaporation from precipitation.

GEOLOGY IN RELATION TO GROUND WATER

Permian Rocks

The Permian rocks which underlie this area are exposed in very few places, being covered by later deposits of sand, gravel, and clay. Where they are exposed it is seen that they dip gently westward. The bedrock underlying this part of Arkansas Valley is the Ninnescah shale. The Stone Corral dolomite overlies the Ninnescah west of the area and crops out just west of well 20, but extends only a very short distance into this area.

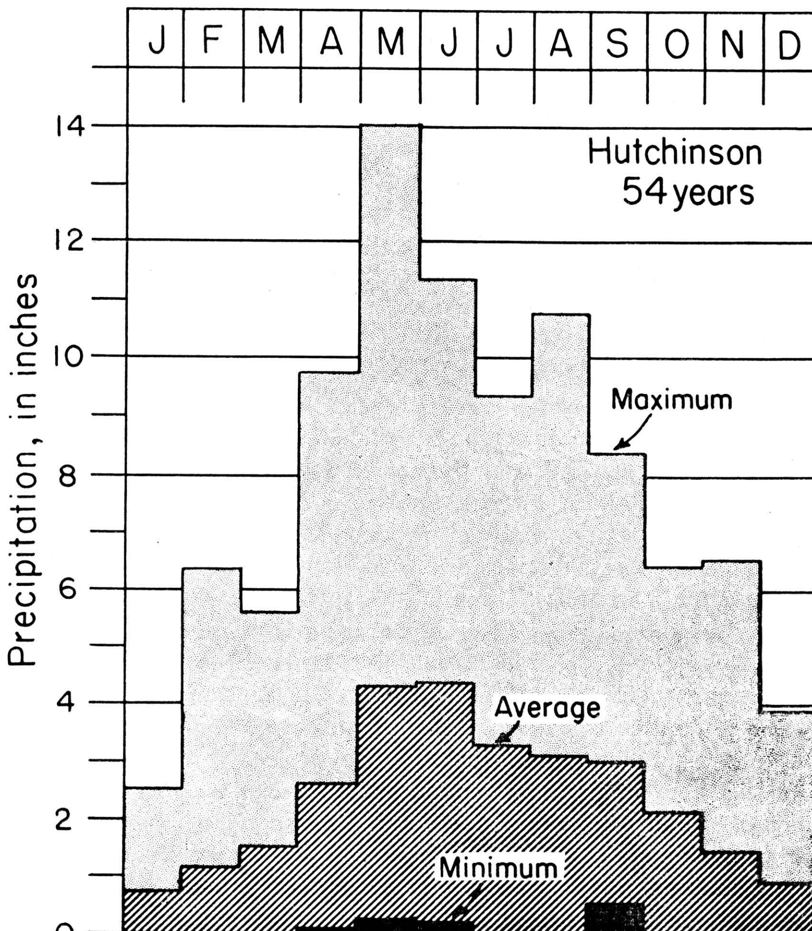

FIG. 4. Normal monthly distribution of precipitation at Hutchinson.

The Ninnescah shale, as the name implies, is predominantly a shale unit throughout its occurrence in Kansas. It conformably overlies the Wellington formation, also of Permian age, and is conformably overlain by the Stone Corral dolomite. It is composed mostly of brick-red shale but contains some beds of green shale, thin beds of argillaceous limestone near the base, and a rather persistent calcareous zone about 5 feet thick near the middle of the formation. Thin beds of light-gray and red sandstone composed of very fine to medium grains occur in the upper part of the Ninnes-

PLATE 4. Features of Arkansas Valley plain shown by aerial photograph. The meander scars mark the wandering beginning of Kisiwa Creek. Photograph includes sec. 9, T. 23 S., R. 5 W. Arrow points north and is about 0.5 mile long. (U.S. Department of Agriculture photograph.)

PLATE 5. Aerial photograph of Arkansas River and vicinity southeast of Hutchinson. The junction of Cow Creek with the river is shown, right center. The arrow points north and is about 0.5 mile long. (U.S. Department of Agriculture photograph.)

cah. Gypsum occurs in thin crosscutting and intersecting veins, having been deposited secondarily in the red and green shale.

The Ninnescah shale attains a maximum thickness of about 275 feet in near-by areas where it crops out. Excellent exposures occur on both forks of the Ninnescah River in south-central Reno and north-central Kingman Counties.

As described by Norton (1939, pp. 1767-1774) the Ninnescah shale is the basal formation of the Salt Fork division, Cimarron series. Present classification of the State Geological Survey of Kansas places the Ninnescah as the middle formation of the Sumner group, Leonardian series.

Few, if any, wells derive water from the Ninnescah shale in this area. In the area of outcrop to the south some farms are supplied with very hard water from wells penetrating the weathered zone at the top of the shale, the thin sandstones at depth, or from wells intersecting thin limestones and crevices in the shale. However, the formation does not provide large quantities of water.

Quaternary Deposits

McPherson Formation

The McPherson formation of Pleistocene age comprises most of the unconsolidated deposits above the bedrock floor in McPherson and Harvey Counties (Moore and Landes, 1937). These deposits were formerly known as the McPherson *Equus* beds (Haworth and Beede, 1897). This formation has been studied in the type area by the present author and others (Lohman and Frye, 1940), and test drilling has shown that the material underlying much of this area is coextensive with the McPherson formation in McPherson County. A terrace has been formed on the surface of the McPherson formation on the north side of Arkansas River in this area by an ancestral river flowing at a level higher than the present stream. The surface of the terrace records a stage of flood plain development which occurred before the river occupied its present channel and flood plain or inner valley. Some of the material underlying the surface of the terrace has been washed down from the sand hills and deposited recently on the valley plain.

Study of the geologic profile shown on Plate 1, together with numerous other geologic profiles and data pertaining to the area just east of this area, leads to the conclusion that a large stream flowed southeastward south of the present Arkansas River and

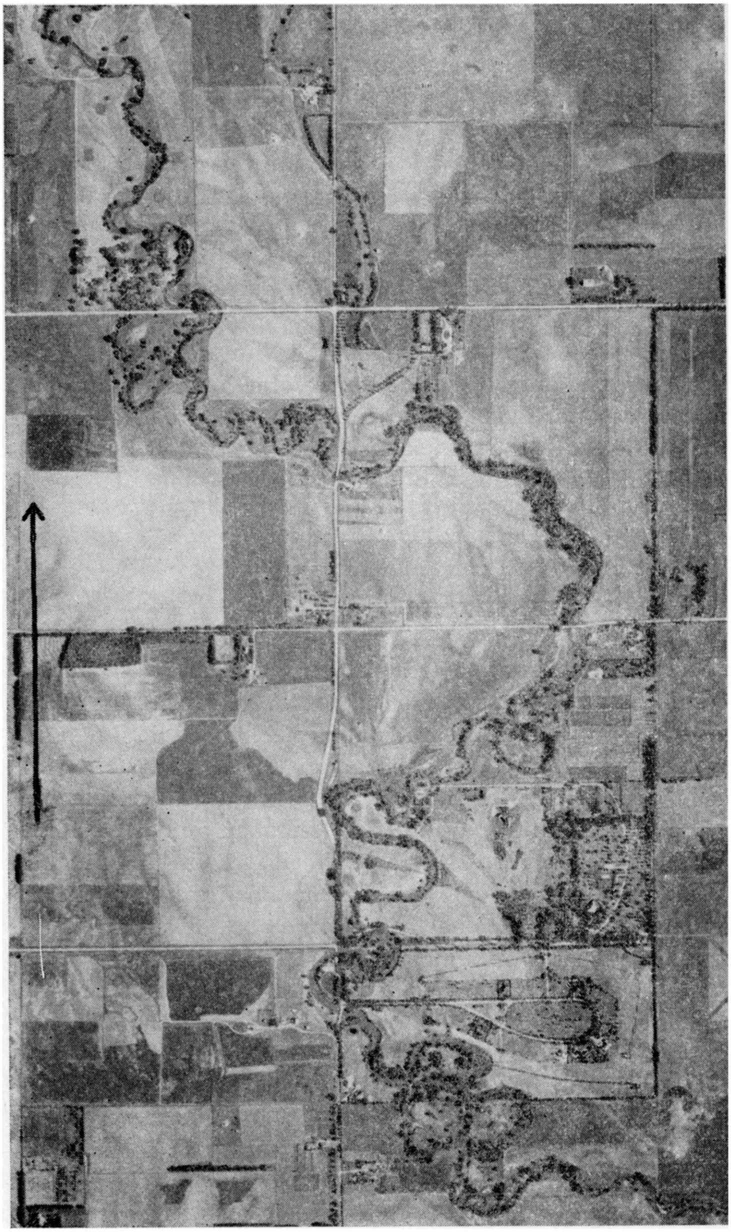

PLATE 6. The meandering channel of Cow Creek northeast of Hutchinson shown by aerial photograph. The arrow points north, is about 0.5 mile long, and is located in sec. 29, T. 22 S., R. 6 W. (U.S. Department of Agriculture photograph.)

joined the stream flowing southward through McPherson Valley at a point east of Mt. Hope. This southeastward-flowing stream cut a valley considerably deeper than the present Arkansas Valley and subsequently was filled with stream deposits of sand, gravel, and silt. The time of downcutting and filling appears to have coincided with the cutting and filling of the McPherson channel in McPherson and Harvey Counties. Vertebrate and invertebrate fossils collected from the McPherson formation in the type area indicate that it was deposited during several stages of the Pleistocene epoch.

The material comprising the McPherson formation in this area consists of sand, sandy silt, silt, and clay in varying proportions in the upper part and sand and gravel with thin layers of silt and clay intercalated in the lower part. The formation ranges in thickness from a featheredge to 160 feet. Logs given at the end of this report and mechanical analyses given in Table 1 show that, in general, the McPherson formation is coarser north of Arkansas River than it is south of the river in the deeper parts of the channel.

The McPherson formation yields large quantities of moderately hard to hard water to wells in this area. North of Arkansas River many wells of proper construction yield as much as 1,000 gallons a minute with relatively small drawdown, and some wells yield as much as 2,000 gallons a minute with small drawdown. The present Hutchinson municipal supply and several industrial water supplies are derived from the McPherson formation north of the river, and additional large quantities of ground water probably can be developed by wells. However, the chemical quality of the water is quite variable. Study of the materials recovered from test drilling south of Arkansas River indicates that comparatively large quantities of water may be obtained from the McPherson formation. The wells which supply the Naval Air Station southeast of this area derive water from the McPherson formation. When tested at the time of construction these wells yielded 340 gallons a minute with 16 feet drawdown, and after 12 hours pumping, 600 gallons a minute with 28 feet drawdown. The water samples collected from the McPherson formation south of Arkansas River, although few in number, indicate that the chemical quality of the water from this formation is comparatively good (Table 4).

DUNE SAND

On the northeast side of Arkansas River Valley is a wide belt of sand dunes which trends northwestward from Little Arkansas

River northeast of Burrton in Harvey County to a point east of Saxman in Rice County. These sand dunes occupy the northeast part of the area included in this report (Pl. 1), and form the only prominent topographic relief in this area (Fig. 2). The higher dunes (Pl. 3) near the center of the dune area are subject to shifting by wind owing to the scanty cover of vegetation. Small ponds are common in the interdune areas during rainy seasons. Near the edge of the dune area (Pl. 1) the dunes are lower, more rounded, have a soil zone, and, in many places, have a cover of vegetation. The subdued dunes are subject to blowout in times of prolonged drought, but are relatively more stable than the higher dunes.

The material comprising the sand dunes consists mainly of fine- to medium-grained, well-rounded quartz sand. Locally silt, clay, and organic matter are admixed and intercalated, probably representing soil zones developed on the dunes in quiescent periods and interdune pond areas which later became covered with drifting sand. The sand is believed to have been derived from the deposits in Arkansas Valley and from older Pleistocene stream deposits southwest of this area. North of Hutchinson, Smith (1938, p. 115) has found evidence, consisting primarily of buried soil zones and variations of bedding, that indicates at least three periods of rapid growth alternated with periods of quiescence. The longitudinal dunes shown in Plate 3 indicate the south-southwesterly direction of recent dune-forming winds.

No large supplies of ground water have been developed in the parts of the area underlain by sand dunes. The sand-hills area is range land for the most part and contains many stock wells yielding quantities of water sufficient for the needs of the cattle. Farms and orchards located along the edge of the dune area are supplied with water for domestic, stock, and spraying purposes. The material comprising the dunes is relatively fine and probably will not yield large quantities of water to wells. The water from wells in the dunes is relatively very soft, but contains up to 44 parts per million of iron. The presence of large quantities of iron is manifested by a slimey deposit of precipitated iron oxide which borders many of the small springs flowing from the dunes. The sand-dune area affords an excellent catchment area for rainfall and much of the rain falling on the porous dunes moves southwestward toward the deposits of the McPherson formation (Pl. 1), recharging the ground-water reservoir there.

ALLUVIUM

Alluvium of Recent age underlies the flood plain or inner valley of Arkansas River and the flood plains of Little Arkansas River and Cow Creek (Pl. 1). In Arkansas River Valley the alluvium is similar in character to the deposits of the McPherson formation and is derived largely from the McPherson. There is physical evidence of Recent deposition in the inner valley of the river, noted above, and fossils of Recent age have been collected from the alluvium. However, in subsurface study no division can be made between the alluvium and the McPherson formation by differences in lithology. It is convenient to treat the entire thickness of material underlying the flood plain of Arkansas River as a unit, not only because of the similarity of the unconsolidated deposits, but also because of the similarity of the chemical quality of the ground water contained in these beds.

The deposits comprising the alluvium are composed of unconsolidated gravel, sand, and silt (see log 76). Some of the gravel is very coarse and large yields may be expected from properly constructed wells penetrating the coarse deposits.

The chemical quality of the ground water in the alluvium is very poor compared to that contained in the McPherson formation and sand dunes. The water is very hard and very high in chloride content, being noticeably salty to the taste. Although large quantities of water are available from the alluvium, it is unfit for municipal and most industrial uses.

PHYSICAL AND HYDROLOGIC PROPERTIES OF WATER-BEARING MATERIALS

The quantity of water that an aquifer will yield to wells depends upon the physical and hydrologic properties of the material of which it is composed. Detailed geologic descriptions of materials encountered in drilling, such as those included in the logs at the end of this report, are useful in making estimates of the quantity of water available in a given area, but more exact quantitative estimates of water supplies necessarily are based on more precise analyses of these earth materials in laboratory or field tests.

Samples of water-bearing materials penetrated by the test drill were collected and quantitative analyses of them were made in the hydrologic laboratory of the Geological Survey in Lawrence. These studies included mechanical analyses and determinations of permeability. The results of the laboratory studies are summarized in Table 1.

Mechanical Analyses

A mechanical analysis of granular material consists of separating into groups the grains of different sizes and determining the percentage, by weight, of each constituent size group.

In preparation for making the laboratory analyses, samples collected from the test holes were dried, placed in a large mortar, and adhering lumps of material were gently separated. Representative samples of the desired volume were obtained by repeated quartering through a sample splitter. Mechanical analyses of carefully weighed samples averaging about 100 grams each were made. The samples were placed in a set of standard 8-inch screens and were shaken vigorously for 15 minutes in a Ro-Tap shaker. The fractions of the sample remaining on each screen were weighed on a precision balance.

The mechanical analyses were made in order to determine the percentage of each grade of material present in the samples so that comparison with materials from wells of known yield and performance could be made. The results of the mechanical analyses given in Table 1 illustrate the differences in the grain size of the constituent rock particles and the degree of homogeneity in the water-bearing materials in this area.

Permeability Determinations

The permeability of a formation is usually expressed as a coefficient of permeability which may be defined as the number of gallons of water a day, at 60° F., that is conducted laterally through each mile of the water-bearing bed under investigation (measured at right angles to the direction of flow), for each foot of thickness of the bed, and for each foot per mile of hydraulic gradient (Meinzer's coefficient; see Stearns, 1927, p. 148). The quantity of water that will percolate through a given cross section of water-bearing material under a known hydraulic gradient is directly proportional to the permeability of the material. It is necessary to determine this important hydrologic property in order to compute the quantity of ground water that percolates into or out of a ground-water basin, reservoir, a specific well, or well field.

TABLE 1. *Physical properties of water-bearing materials from test holes near Hutchinson, Kansas* (Analyzed by Theodore Hickok and Elliott Mosley.)

Number on Plate 1	Depth of sample, feet	Mechanical analyses, percent by weight: Coarse gravel (larger than 4.0 mm.)	Medium gravel (4.0-2.0 mm.)	Fine gravel (2.0-1.0 mm.)	Coarse sand (1.0-0.50 mm.)	Medium sand (0.50-0.25 mm.)	Fine sand (0.25-0.125 mm.)	Very fine sand (0.125-0.062)	Silt and clay (less than 0.062 mm.)	Coefficient of permeability[a]
2	0-2					31.3	49.0	11.7	8.0	
	2-14				0.4	34.6	51.4	7.6	6.0	
	14-16				.9	23.9	37.8	10.0	27.4	
	16-28				.4	36.8	50.0	6.4	6.4	
	28-38				.9	27.1	35.8	11.8	24.5	
	66-92				7.1	58.0	27.5	2.9	4.5	110
9	0-29				2.3	48.1	43.0	4.7	1.9	
	29-34				1.0	40.4	42.0	8.3	8.3	
	34-65				2.4	25.7	28.5	15.3	28.1	
	65-85				3.4	28.8	34.2	10.3	23.3	50
	85-116				4.8	54.8	32.7	3.8	3.9	110
11	0-3				.9	28.8	33.1	12.4	24.8	
	11-20	45.5	26.5	14.3	6.3	4.2	1.6	.5	1.1	24,600
	20-28	30.5	37.8	22.7	5.2	2.1	.9	.4	.4	11,300
	28-32	16.4	31.5	35.7	10.5	3.4	1.3	.8	.4	3,900
	32-34	25.7	36.9	26.2	6.8	2.4	1.0	.5	.5	18,500
12	0-3				3.9	35.3	39.8	10.5	10.5	
	12-18	20.3	26.4	30.0	15.9	4.8	1.3	.4	.9	5,300
	18-25	3.2	11.2	27.1	28.2	21.1	6.4	1.2	1.6	1,400
	25-31	7.9	22.2	27.5	19.9	13.9	6.4	1.1	1.1	2,800
	31-34	5.0	14.9	29.0	25.6	16.0	7.3	1.1	1.1	750
13	0-3		.6	2.2	5.6	36.1	39.4	11.1	5.0	
	11-14	10.5	6.8	5.3	8.4	35.3	22.6	5.3	5.8	20
	14-20	7.7	17.6	23.2	17.6	15.8	13.6	2.7	1.8	1,300
	20-34	35.0	32.5	11.5	8.6	8.1	3.3	.5	.5	8,700
15	0-4	.4	.4	3.5	8.8	26.4	34.8	10.2	15.5	
	16-31	6.7	24.2	36.4	21.1	8.5	1.8	.4	.9	3,200
23	0-5			.7	4.6	31.8	44.5	10.0	8.4	
	5-12	3.0	12.4	21.4	22.4	24.9	11.4	1.5	2.0	30
	12-48	39.7	34.4	14.0	5.7	3.5	1.7	.5	.5	16,200
24	0-8				2.1	26.9	47.3	16.3	7.4	
	12-20		.8	7.1	38.9	40.9	9.5	1.2	1.6	
	20-44	5.6	36.4	38.4	13.2	4.0	1.6	.4	.4	14,700
27	0-4			.4	3.8	13.1	11.2	16.5	55.0	
	7-12	31.5	37.6	18.8	6.7	2.4	1.2	.6	1.2	13,800
	18-38	30.9	37.1	18.5	7.3	3.4	1.1	.6	1.1	3,000
	38-56	17.6	40.4	27.8	7.8	3.4	1.5	.5	1.0	41,300
	56-66	.4	13.2	48.5	23.4	9.8	3.0	.4	1.3	3,200
	66-67	.8	10.8	48.7	26.1	9.2	2.4	.4	1.6	
31	0-4				7.1	22.3	32.6	17.0	21.0	
	8-12	6.1	18.4	36.0	24.5	9.9	2.8	.9	1.4	2,000
	12-18	7.4	24.5	29.8	26.1	8.5	2.1	.5	1.1	3,600

TABLE 1. *Physical properties of water-bearing materials from test holes near Hutchinson, Kansas* (Analyzed by Theodore Hickok and Elliott Mosley.) *(continued)*

Number on Plate 1	Depth of sample, feet	Mechanical analyses, percent by weight								Coefficient of permeability[a]
		Coarse gravel (larger than 4.0 mm.)	Medium gravel (4.0-2.0 mm.)	Fine gravel (2.0-1.0 mm.)	Coarse sand (1.0-0.50 mm.)	Medium sand (0.50-0.25 mm.)	Fine sand (0.25-0.125 mm.)	Very fine sand (0.125-0.062)	Silt and clay (less than 0.062 mm.)	
	18-44	16.6	33.8	26.9	14.6	6.0	1.3	.4	.4	5,800
	52-69	31.2	33.0	19.3	10.2	4.0	1.1	.6	.6	16,100
32	0-4				6.0	36.4	36.4	13.0	8.2	
	7-12	13.3	15.6	11.8	11.8	21.2	17.1	5.8	3.4	
	12-49	13.8	33.7	35.7	11.2	3.1	1.5	.5	.5	14,200
	49-62		1.6	18.5	43.1	30.3	4.9	.8	.8	1,300
33	0-3				3.8	34.5	38.3	11.7	11.7	
	12-35	15.0	32.2	28.0	17.0	5.6	2.0	.1	.1	12,100
34	0-3				.8	11.1	10.3	16.1	61.7	
	10-20	3.6	17.0	28.9	26.8	11.6	4.9	2.7	4.5	120
	20-25	6.6	17.1	32.3	23.2	12.3	3.8	1.9	2.8	810
	25-68	19.2	27.4	33.6	13.5	3.8	1.0	.5	1.0	2,400
39	0-2			1.5	8.1	22.7	23.7	13.6	30.4	
	15-71	34.2	33.5	17.7	8.0	4.0	1.3	.3	1.0	8,300
43	0-6			1.3	11.5	54.1	27.4	3.8	1.9	
	10-43	15.7	34.2	29.9	12.8	5.5	1.1	.4	.4	1,500
45	32-58									50
47	0-5				1.0	44.7	43.6	7.1	3.6	
	5-16			.4	5.9	55.4	26.6	4.7	7.0	40
	16-28				1.5	49.3	42.6	5.1	1.5	190
	28-31			.4	8.4	59.3	21.3	4.4	6.2	
	31-41				3.6	56.2	33.7	4.1	2.4	140
	41-47				4.2	58.3	30.9	4.2	2.4	210
	47-57			1.1	15.4	49.2	17.7	6.3	10.3	30
	57-98				5.9	47.4	23.0	7.9	15.8	10
	98-107				6.4	44.6	36.2	6.4	6.4	
	107-109				13.8	55.2	20.0	3.8	7.2	80
	109-123				2.3	33.7	32.7	10.6	20.7	
52	0-4			.6	4.0	13.5	24.8	18.1	39.0	
	11-40	27.0	31.6	27.0	10.7	2.5	.4	.4	.4	16,500
	40-48	28.9	43.5	18.5	6.0	1.6	.5	.5	.5	33,100
	48-66	13.8	46.8	29.5	7.5	1.2	.4	.4	.4	20,600
53	0-3				1.6	10.6	15.7	13.3	28.8	
	3-5					1.8	7.8	12.1	78.3	
	5-23	3.6	9.1	14.6	18.7	33.4	17.4	2.3	.9	
	23-30	20.9	25.4	28.8	15.2	6.2	2.3	.6	.6	4,400
	30-42	8.8	13.6	25.3	26.6	16.3	8.2	.7	.7	1,090
	42-57	33.2	20.1	21.6	15.1	6.5	2.0	1.0	.5	7,000
	57-62	13.8	13.8	19.6	25.0	21.3	5.5	.5	.5	1,200

TABLE 1. *Physical properties of water-bearing materials from test holes near Hutchinson, Kansas* (Analyzed by Theodore Hickok and Elliott Mosley.) *(continued)*

54	0-3				4.7	35.6	32.7	11.8	15.2	
	3-10		.9	4.7	15.5	43.5	23.3	6.9	5.2	120
	10-26	50.4	25.0	13.7	5.7	2.8	1.4	.5	.5	18,800
	26-36	41.3	36.8	12.0	5.4	2.5	1.2	.4	.4	13,000
55	0-6			1.3	10.7	52.8	25.8	5.0	4.4	
	10-28	22.9	39.6	26.9	6.2	2.2	.9	.4	.9	8,500
	28-41	22.6	30.5	31.2	10.6	3.5	.8	.4	.4	7,800
	53-101	3.2	18.4	39.4	22.9	10.6	3.7	.9	.9	950
	101-137	7.4	30.7	32.8	20.1	6.9	1.1	.5	.5	1,700
57	0-4			.9	8.2	56.4	28.9	3.9	1.7	
	4-7	.7	2.9	5.8	16.1	33.6	22.6	6.6	11.7	
	7-42	21.5	25.2	29.0	19.4	4.1	.8			2,200
	42-47	10.2	19.6	34.5	28.0	5.8	1.1	.4	.4	950
59	0-3			1.3	9.0	20.0	15.5	12.3	41.9	
	8-14	23.6	29.9	24.1	13.2	6.3	1.7	.6	.6	
	14-18	50.9	25.2	12.2	6.1	3.5	1.3	.4	.4	14,300
	18-45	26.9	25.1	26.0	13.0	6.5	1.7	.4	.4	14,300
	46-59	13.6	32.0	26.8	15.4	9.2	2.2	.4	.4	4,900
60	0-3				5.5	27.0	14.7	19.9	32.9	
	10-18	45.7	24.6	17.7	7.3	2.3	1.2	.4	.8	16,500
	18-35	43.0	27.1	16.7	7.5	3.3	1.4	.5	.5	16,500
	35-46	23.7	41.1	20.2	8.1	4.0	1.6	.4	.8	13,000
	48-63	29.2	38.9	21.0	6.6	2.6	.9	.4	.4	41,300
67	0-2	3.0	4.5	7.1	7.6	24.3	29.8	12.6	11.1	
	11-35	64.0	18.0	12.0	3.6	1.2	.4	.4	.4	14,100
	35-60	39.5	30.1	21.1	6.7	1.3	.5	.4	.4	18,800
69	0-2		.5	3.8	7.5	19.8	30.4	18.2	19.8	
	4-46	24.5	31.1	25.2	11.9	4.6	1.3	.7	.7	2,300
	46-50	5.2	19.1	36.4	26.0	9.8	2.3	.6	.6	650
	50-97	42.6	35.9	14.8	3.6	1.4	.9	.4	.4	6,300
70	9-69									1,900
72	0-2			4.6	16.9	18.0	13.7	10.9	35.9	
	11-35	21.7	34.8	28.6	10.3	3.4	.6	.6		13,600
	35-47	27.0	37.6	22.7	9.0	3.2	.5			16,300
76	0-2			3.1	11.8	21.0	37.4	13.9	12.8	
	2-33	34.2	38.0	18.6	6.2	1.2	.6	.6	.6	20,600
	33-58	36.7	35.6	18.6	6.5	1.1	.5	.5	.5	20,600
78	0-3				3.8	18.1	33.1	16.7	28.3	
	11-70	26.6	34.9	22.3	9.7	4.0	1.4	.4	.7	2,120
93	0-3				2.8	23.5	16.6	13.9	43.2	
	20-64	24.3	28.8	19.2	13.5	7.4	3.4	1.1	2.3	3,400
	74-79	1.6	4.0	19.8	37.1	23.8	8.1	2.4	3.2	50
	89-124	8.5	34.8	24.2	20.3	7.6	2.5	.8	1.3	3,800
	124-136	3.1	30.7	32.5	14.2	9.3	5.3	1.8	3.1	2,400
95	0-3			1.6	16.8	39.8	16.7	7.3	17.8	
	20-29		1.3	9.4	37.1	34.6	8.2	3.1	6.3	380
	29-40	.6	8.1	19.1	45.0	22.0	3.5	.6	1.1	140
	46-72	2.2	27.7	35.4	19.7	7.7	2.9	1.5	2.9	540
	80-152	6.2	19.0	24.4	23.4	14.2	5.7	2.7	4.4	90

[a]Number of gallons of water a day, at 60° F., that is conducted laterally through each mile of water-bearing bed under investigation (measured at right angles to the direction of flow), for each foot of thickness of the bed and for each foot per mile of hydraulic gradient.

Coefficients of permeability vary widely. Fine sand is, in general, less permeable than coarse sand and therefore transmits less water through equal cross-sectional areas under the same hydraulic gradient. Clay and other fine-grained materials may, and often do, contain more water per unit volume than sand or gravel, but the permeability is generally low and therefore the quantity of water transmitted through silt and clay is much less than is transmitted through sand and gravel. Coefficients of permeability of less than 100 are said to be low, coefficients between 100 and 1,000 are medium, and coefficients above 1,000 are considered as high.

The coefficient of permeability for most of the samples listed in Table 1 was determined in the hydrologic laboratory at Lawrence by Elliott Mosley under the supervision of the author. Laboratory methods employed in determining permeability have been described by Fishel (in Wenzel, 1942). The coefficients of permeability determined for individual samples are given in Table 1; they ranged from 10 for poorly sorted fine and medium sand mixed with silt to 41,300 for coarse and medium gravel. The coefficient of permeability for most of the samples tested ranged from 1,000 to 15,000. The permeability of samples of silt and clay was not determined, but this value usually is very low.

SHAPE OF THE WATER TABLE AND MOVEMENT OF WATER

The approximate shape of the water table north of Arkansas River in this area is shown by water-table contours on Plate 1. A 5-foot contour interval has been used in the valley plain, and a 10-foot interval employed in the sand-hills area where the gradient is much steeper. As a basis for constructing this map the altitude of the water table was determined instrumentally by Wilson and Company at most of the 96 test holes, wells, and stream-measurement stations shown on Plate 1. The locations, altitudes, and other data pertaining to the test holes, wells, and stream stations are given in Table 2.

The water table is a short distance below land surface in most of this area and intersects the land surface at a few places, as is indicated by the occurrence of the ponds shown on Plate 1. The water table ranges in depth from about 4 to 22 feet, and is less than 10 feet below land surface in most parts of the valley plain (Table 2).

A ground-water divide occurs a little southwest of the center of the belt of dunes and roughly coincides with the topographic divide. From this divide ground water moves northeastward toward Little Arkansas River, southwestward from the divide to the edge of the sand dunes, thence southeastward in a direction roughly parallel to Arkansas River, and does not reach the river in this area.

Ground water beneath the valley plain moves southeastward in the direction of the flow of Arkansas River. The gradient of Arkansas River is nearly the same and is in the same direction as the slope of the ground-water surface. The river is nearly in equilibrium with the ground-water body at normal stages, neither receiving water from nor contributing to it. This condition does not hold when the stage of the river is above normal, nor where tributary streams enter the river. The river appears to have been contributing water to the alluvium near well 87 at the time of this investigation. The inflow of water from the stream at this place may be due to the addition of water from Salt Creek. At very low stages Arkansas River probably receives water from the alluvium and McPherson formation. In the northwestern part of the area the water-table contours cross Cow Creek nearly at right angles and curve gently southward toward the river. At low stages Cow Creek is also nearly in equilibrium with the ground-water body in this area.

Data collected were insufficient for extending the water-table contours south of Arkansas River in the southwestern part of the area. Studies made just southeast of this area indicate that the

TABLE 2. *Records of test holes and wells in the vicinity of Hutchinson, Kansas*

No. on Plate 1[a]	Location	Source of data[b]	Depth of test hole or well (feet)	Depth to water level below land surface[c] (feet)	Date of measurement (1945)	Altitude of land surface[d] (feet)
	T. 22 S., R. 5 W.					
1	NW¼ NW¼ sec. 18	W	9	4.6	Nov. 2	1635.1
[2]	NW cor. NE¼ sec. 19	T	117	10.5	Nov. 6	1643.8
(3)	SW¼ SE¼ sec. 19	W	19	5.6	Oct. 31	1607.4
4	NE¼ NE¼ sec. 20	W	11	4.5	Oct. 27	1605.2

TABLE 2. *Records of test holes and wells in the vicinity of Hutchinson, Kansas (continued)*

No. on Plate 1[a]	Location	Source of data[b]	Depth of test hole or well (feet)	Depth to water level below land surface[c] (feet)	Date of measurement (1945)	Altitude of land surface[d] (feet)
(5)	SW¼ SW¼ sec. 20	W	46	16.8	Oct. 31	1634.1
6	NW¼ NW¼ sec. 22	W	30	7.6	Nov. 5	1551.9
(7)	SW¼ SE¼ sec. 27	W	36	16.1	Nov. 1	1519.9
(8)	NW¼ NW¼ sec. 28	W	35	19.1	Oct. 31	1630.0
9	NE¼ SE¼ sec. 28	T	120	13.0	Nov. 5	1616.4
10	SE¼ NE¼ sec. 29	W	29	10.9	Oct. 31	1624.8
[11]	NW cor. SW¼ sec. 30	T	35	6.8	Oct. 12	1544.9
[12]	SW cor. SE¼ sec. 30	T	35	6.0	Oct. 11	1540.5
[13]	NE cor. SE¼ sec. 31	T	35	8.2	Oct. 11	1536.7
14	NW¼ SW¼ sec. 31	W	30	8.9	Oct. 30	1540.6
[15]	SE cor. sec. 32	T	33	11.2	Oct. 10	1533.7
(16)	NW¼ SW¼ sec. 33	W	17	3.7	Nov. 1	1576.9
(17)	SW¼ SW¼ sec. 34	W	26	5.1	Nov. 1	1588.2
18	SE¼ SE¼ sec. 34	W	36	21.9	Nov. 1	1627.0
(19)	NW¼ SW¼ sec. 36	W	10	5.2	Nov. 7	1582.1
	T. 22 S., R. 6 W.					
(20)	SW¼ SE¼ sec. 9	W	29	18.9	Nov. 2	1588.4
21	SE¼ NE¼ sec. 14	W	34	17.4	Oct. 20	1627.3
(22)	SE¼ SW¼ sec. 14	W	86	17.7	Nov. 6	1597.6
[23]	NW cor. SW¼ SW¼ sec. 15	T	50	9.5	Oct. 15	1566.1
[24]	SE cor. SW¼ sec. 15	T	45	10.4	Oct. 15	1564.0
(25)	SW¼ SE¼ sec. 16	W	19	8.6	Oct. 20	1565.5
26	NE cor. NE¼ sec. 17	S		10.3	Nov. 2	1573.8
[27]	SE¼ NE¼ sec. 17	T	67	7.4	Oct. 16	1569.1
28	NE¼ NW¼ sec. 20	W	24	6.7	Nov. 2	1569.1
29	NE¼ SE¼ sec. 20	W	19	8.2	Nov. 2	1563.1
30	SE¼ SE¼ sec. 21	W	18	10.7	Nov. 2	1560.1
[31]	SE cor. sec. 21	T	70	7.8	Oct. 17	1558.9
[32]	SE cor NE¼ sec. 22	T	64	5.3	Oct. 15	1555.0
[33]	SE¼ SW¼ SW¼ sec. 24	T	36	9.4	Oct. 12	1552.5
[34]	NW cor. SW¼ sec. 26	T	73	8.0	Oct. 17	1553.2
35	NE¼ NE¼ sec. 29	S		8.4	Oct. 20	1562.0
36	NE cor. SE¼ sec. 33	S		8.0	Oct. 19	1551.0
37	SE¼ NE¼ sec. 34	W	29	9.7	Nov. 2	1549.2
(38)	NW¼ SW¼ sec. 35	W	22	9.5	Nov. 2	1548.2
[39]	NW cor. sec. 36	T	72	6.7	Oct. 18	1546.4
	T. 23 S. R. 4 W.					
(40)	SW¼ SW¼ sec. 6	W	26	10.5	Nov. 7	1587.8
(41)	SW¼ SW¼ sec. 7	W	21	6.9	Oct. 26	1553.8
42	NW cor. sec. 18	TS	57			1546.8
[43]	NW cor. SW¼ SW¼ sec. 18	T	47	7.3	Oct. 26	1500.8
(44)	SW¼ SW¼ sec. 19	W	12	5.6	Nov. 7	1494.5
	T. 23 S., R. 5 W.					
[45]	NE cor. SE¼ SE¼ sec. 2	TS	90	12.9	Dec. 8	1601.4
(46)	SE¼ SE¼ sec. 2	W	21	5.1	Nov. 3	1589.1
47	NE cor. sec. 3	T	124	9.9	Nov. 7	1624.5
48	SE¼ NE¼ sec. 3	W	35	9.4	Nov. 1	1604.2
49	NW¼ NW¼ sec. 4	W	27	12.8	Oct. 19	1530.1

TABLE 2. *Records of test holes and wells in the vicinity of Hutchinson, Kansas (concluded)*

[50]	NW¼ NW¼ SE¼ sec. 4	IW	40	19	July 1944	1528.3
(51)	NE¼ NE¼ sec. 6	W	17	10.8	Oct. 31	1533.5
[52]	SE cor. sec. 6	T	68	10.3	Oct. 20	1528.8
[53]	NE cor. sec. 8	IW	63	22.8	July 1943	1528.1
[54]	NW¼ SW¼ sec. 11	T	37	7.3	Oct. 22	1515.2
[55]	SE cor. sec. 13	T	139	4	Oct. 25	1499.4
56	NE cor. sec. 14	TS	36			1520.5
[57]	NE cor. SE¼ sec. 14	T	49	5.4	Oct. 27	1503.8
58	NE cor. sec. 15	TS	57			1511.4
[59]	SE cor. sec. 15	T	60	3.9	Oct. 23	1507.1
[60]	NE cor. sec. 16	T	64	8.6	Oct. 22	1517.5
[61]	NE cor. NW¼ sec. 17	CW	69	13.4	Oct. 23	1522.8
[62]	SW¼ NW¼ NW¼ sec. 17	CW	50	18.6	Oct. 23	1523.7
[63]	NE cor. NW¼ SW¼ sec. 18	CW	80	18.1	Oct. 23	1531.0
64	SW¼ SW¼ sec. 18	W	21	12.8	Oct. 26	1526.7
(65)	NE¼ NE¼ sec. 20	W	20	12.1	Oct. 30	1519.0
66	NW¼ NW¼ sec. 20	W	29	12.3	Oct. 30	1520.7
[67]	NE cor. sec. 21	T	62	9.0	Oct. 30	1514.4
68	SW¼ SE¼ sec. 23	W	15	7.2	Oct. 29	1500.8
[69]	SE cor. sec. 23	T	100	3.9	Oct. 29	1498.1
[70]	SE cor. NE¼ sec. 24	TS	71	4.4	Dec. 8	1495.0
(71)	NW¼ NW¼ sec. 27	W	24	12.3	Oct. 29	1515.1
[72]	NE cor. sec. 29	T	50	9.9	Oct. 30	1515.5
73	NE cor. NW¼ sec. 29	S		6.3	Oct. 30	1515.2
74	NE¼ NE¼ sec. 30	W	16	5.6	Oct. 30	1515.6
(75)	NW¼ NE¼ sec. 30	W	15	6.1	Oct. 30	1518.3
[76]	NW cor. sec. 32	T	60	5.4	Oct. 31	1512.1
77	NE¼ NE¼ sec. 33	S		6.4	Oct. 30	1501.8
	T. 23 S., R. 6 W.					
[78]	NE cor. sec. 1	T	72	9.2	Oct. 19	1539.0
[79]	SW¼ SE¼ NW¼ sec. 1	CW	65			
(80)	SW cor. sec. 2	W	10	7.7	Oct. 19	1537.7
81	NW¼ NE¼ sec. 9	W	18	7.5	Oct. 19	1548.4
[82]	Cen. NW¼ NW¼ sec. 12	CW	60	12.6	Oct. 23	1537.8
[83]	NE cor. SE¼ sec. 12	CW	58	11.3	Oct. 23	1530.5
[84]	SW cor. SE¼ SW¼ sec. 12	CW	65			
[85]	SW¼ SW¼ SE¼ sec. 12	CW	73			
86	SW¼ SE¼ SE¼ sec. 12	W		14.4	Oct. 23	1531.7
87	SW¼ SW¼ sec. 13	W	28	10.7	Oct. 26	1529.0
(88)	SE¼ NW¼ sec. 14	W	21	11.7	Oct. 26	1536.1
89	NE¼ NE¼ sec. 15	W	29	7.1	Oct. 22	1538.3
90	NW¼ NW¼ sec. 15	W	21	6.4	Oct. 22	1540.3
91	SE¼ NE¼ sec. 24	W	17	11.2	Oct. 26	1524.7
92	SE¼ NW¼ sec. 24	S		12.0	Oct. 26	1531.3
[93]	SE cor. sec. 36	T	138	8.2	Nov. 1	1523.0
	T. 24 S., R. 6 W.					
[94]	SW cor. sec. 11	TS	106	14.4	Dec. 6	1547.5
[95]	NW cor. sec. 12	T	153	19	Nov. 2	1545.7
[96]	NW cor. sec. 22	TS	62	7.5	Dec. 7	1558.9

[a]Brackets around numbers indicate analyses in Table 4; parentheses indicate partial analyses.

[b]T, Test hole drilled by contractor for City of Hutchinson; TS, test hole drilled by State and Federal Geological Surveys; W, domestic and stock well; CW, city-supply well; IW, industrial well; S, stream measurement station.

[c]Depth to water measured from bridge surfaces at stream measurement stations.

[d]Altitudes of measuring points on bridge surfaces at stream measurement stations.

water-table contours bend southeastward and roughly parallel Arkansas River southwest of the border of the alluvium. The graphic representation of the water table on the geologic profile (Pl. 1) also indicates this contour direction. Ground water in the comparable area southeastward in Reno County moves northwestward to the south border of the alluvium and thence southeastward parallel to the river.

GROUND-WATER RECHARGE

Recharge is the term used to denote the addition of water to the ground-water reservoir and may be accomplished in several ways. The ultimate source of all ground water of quality suitable for ordinary uses is precipitation in the area or in near-by areas. Once the water becomes a part of the ground-water body it moves in the direction of the slope of the water table, later to be discharged at some point down gradient. The underground reservoir beneath this area is recharged principally by precipitation and by subsurface flow into the area from the northwest. Water is added by seepage from Arkansas River and Cow Creek during periods of high stage, although the quantity of water derived in this manner probably is small compared to that received from rainfall.

Water added to the ground-water reservoir in the sand-dune area is derived largely from precipitation. Because of the relatively high porosity and permeability of the dune sand and the presence of many undrained basins which serve as catchment areas for rainfall, a large percentage of the water percolates downward to the zone of saturation. Contours representing the shape of the ground-water surface (Pl. 1) indicate that the underground reservoir beneath the sand-hills area receives more recharge from precipitation than neighboring areas. Computations based on laboratory permeability tests, the water-table gradient as shown by the contours, and thicknesses shown by well logs and test holes show that about 500 acre-feet of water moves southwestward across each mile of the sand-dunes border each year toward the area underlain by deposits of the McPherson formation. This quantity of water represents about one-third of the annual precipitation (27.83 inches) which falls on the dune area southwest of the drainage divide. The gross recharge in the dune area probably is more than one-half and may be as much as three-fourths of the annual precipitation.

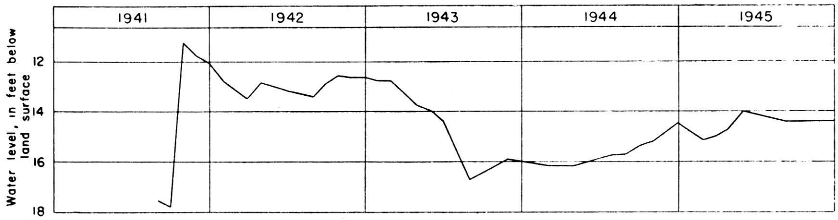

FIG. 5. Fluctuations of water level at well 86. Measurements made by Mr. Phillips, Hutchinson Water Company.

The sandy soil, topography, depth to water level, and other factors are favorable for recharge from precipitation in the Arkansas River Valley plain. The hydrograph of well 86 (Fig. 5) shows fluctuations of the water table as revealed by periodic measurements. The fluctuations were caused by recharge and discharge in the vicinity of the well between times of measurement. Most significant is the rise in water level which occurred in October 1944 in response to heavy precipitation. Well 86 is affected by pumping at well 85.

Southeast of this area in Harvey and Sedgwick Counties several wells drilled in similar deposits near Arkansas River and equipped with automatic water-stage recorders have been observed since 1938. Study of the records of the water-table fluctuations in these wells has revealed that about 20 per cent of the annual precipitation reaches the water table. The deposits penetrated by the recorder wells are coextensive with the McPherson formation in this area, and it is believed that an average of about 20 per cent of the annual precipitation reaches the water table beneath the valley plain near Hutchinson. This quantity of water is about 300 acre-feet a year on each square mile in the valley. The small ravines and creeks which issue from the sand hills and deploy on the edge of the McPherson formation probably greatly increase the recharge in the sand-dune border area of the valley plain.

Field data collected by the Works Progress Administration in 1936, made available to the writer by Commissioner W. C. Hutchinson, indicate a significant change in water level in this area since 1936. In the summer of 1936 water levels ranged from 1 foot lower at well 50 to 9 feet lower at test hole 15. The W.P.A. data show lower water levels in 1936 at the following wells and test holes: No.

24, 4 feet lower; No. 33, 5 feet lower; Nos. 11 and 12, 6 feet lower; and No. 17, 8 feet lower. The present higher water table signifies an addition in ground-water storage which is the result of an excess of recharge over discharge since 1936.

Although detailed measurements have not been made, calculations based on data at hand indicate that a quantity of water of the order of 20,000 acre-feet enters the area each year by subsurface inflow from the unconsolidated deposits of Arkansas Valley upstream. Probably about the same quantity of water percolates southeastward from the east side of the segment of the valley here considered. The gradient of the ground-water surface in the valley plain is not nearly as great as that in the sand-dunes area, but the coarse sand and gravel comprising the deposits beneath the valley are very permeable.

As is noted above, only scanty data were collected southwest of Arkansas River in this area, and little is known of ground-water conditions there. The soil is not as sandy as in the valley-plain area and other features are not as favorable for recharge; therefore the quantity of recharge probably is somewhat less than in the valley plain.

GROUND-WATER DISCHARGE

When water derived from precipitation or other sources reaches the zone of saturation in the ways described above, it moves in the direction of the slope of the water table according to the conditions existing at the point of recharge; in any case, the water remains a part of the ground-water body until removed or discharged by some natural or artificial means. Discharge of ground water may be accomplished in several ways. Water may be removed from the aquifer by evaporation, by transpiration, by seepage into streams, by discharge from springs, or by pumping from wells. These methods of discharge are operative singly or in combination in all parts of this area. Over a period of years the quantity of ground-water discharge is approximately equal to the quantity of recharge.

Water may be taken into the roots of plants directly from the zone of saturation or from the capillary fringe above it, and discharged from the plants by the process known as transpiration. The depth from which plants will lift ground water varies with different plant species and different types of soil. The limit of lift by ordinary grasses and cultivated plants is not more than a few feet; however, alfalfa and certain types of desert plants have been known to extend their roots to depths of 60 feet or more to reach the water table (Meinzer, 1923, p. 82). It is believed that the quantity of ground water discharged from this area by evaporation and transpiration is greater than that discharged by all other means.

Superimposed upon natural discharge is the discharge occasioned by pumping from wells in and near the City of Hutchinson. No attempt was made to make a complete inventory of industrial and other wells, and an estimate of the total quantity of water pumped is not included. The quantity of water pumped monthly and annually by the City of Hutchinson is given in Table 3. The average annual pumpage for municipal use has been about 1,000 million gallons a year, or about 3,000 acre-feet a year. This quantity could be produced by continuous pumping at the rate of about 1,900 gallons a minute if consumption were distributed evenly throughout the year. Data furnished by the Hutchinson Water Company show that the greatest pumpage in one month occurred in August 1943 when 114,300,000 gallons was pumped; an average of 2,565 gallons a minute for the month. The greatest daily pumpage since 1940 occurred on August 2, 1943, when 5,081,000 gallons was pumped. This quantity could be produced at an average pumping rate of 3,530 gallons a minute.

Information furnished by the Central Fibre Products Company indicates that about 2,000 gallons a minute is pumped continuously from a group of wells (No. 53) to supply this factory. This quantity is approximately equivalent to the quantity pumped for municipal use.

The Atchison, Topeka, and Santa Fe Railway Company pumps about 54 million gallons a year, or about 160 acre-feet a year, from two wells (No. 50). About two-fifths of this quantity is pumped during the 3 summer months.

Reference to the water-table contour map (Pl. 1) shows that the gradient of the water table has become flattened southeast of wells 53, 62, and 50, and steepened northwestward. This change in gradient is not great, however, considering the quantity of water withdrawn annually.

A considerable but unknown quantity of water is pumped by other industrial and private wells in this area, especially during

TABLE 3. *Monthly and annual pumpage of water for the City of Hutchinson, in millions of gallons*

(Data furnished by the Hutchinson Water Company.)

Month	1941	1942	1943	1944	1945
Jan.	82.0	68.0	74.8	81.7	71.0
Feb.	75.5	61.7	67.8	72.5	64.3
Mar.	68.1	68.9	77.8	73.2	73.2
Apr.	59.5	65.4	82.4	66.3	69.5
May	68.6	77.5	81.3	74.6	80.8
June	78.2	70.4	91.4	95.8	81.2
July	106.6	93.6	103.4	91.3	100.2
Aug.	89.7	78.0	114.3	90.6	100.4
Sept.	78.0	71.9	83.1	76.2	95.1
Oct.	68.9	71.5	81.6	64.2	80.0
Nov.	65.3	63.1	79.1	68.8	76.7
Dec.	64.7	68.2	84.8	71.3	82.1
Year	905.1	858.2	1,021.8	926.5	974.5

summer months when much ground water is used for air-conditioning purposes.

QUANTITY OF GROUND WATER AVAILABLE FOR PUMPING

YIELD OF WELLS

According to information furnished by the Hutchinson Water Company, well No. 61 yielded 2,000 gallons a minute at the time of testing with a drawdown of 15 feet after 7.5 hours pumping; well 79, when tested, yielded 2,000 gallons a minute with 14.7 feet drawn-down after 12 hours pumping; and well 62 yielded 1,000 gallons a minute with a draw-down of 17 feet. Other wells operated by the company yield quantities of water ranging from 1,000 to 2,000 gallons a minute with comparable drawdown.

Wells owned and operated by the Central Fibre Products Company (No. 53) yield from 750 to 800 gallons a minute, but results of pumping tests at this installation are not available. According to engineers of the company, three of the four wells are pumped continuously with an aggregate yield of about 2,000 gallons a minute. On August 8, 1943, shortly after the fourth well of the group had been drilled but before the pump had been installed, the depth to water at the newest well was 22.8 feet below land surface. This well is located about 300 feet from the pumped wells and the water level in 1943 was affected by pumping. The normal depth to water in this area is about 10 feet and a lowering of the water table of about 13 feet by near-by pumping is indicated.

Results of a pumping test conducted at the time of construction of the wells owned and operated by the Atchison, Topeka, and Santa Fe Railway Company (No. 50) have been made available by Mr. A. B. Truman, division engineer. This plant consists of two similar wells located 150 feet apart. The wells are about 40 feet deep and are equipped with turbine pumps. A pumping test was made at each well in July 1944. Each well yielded 215 gallons a minute with a drawdown of 1.5 feet after several hours pumping.

In 1937 a pumping test was made under the direction of S. W. Lohman, U.S. Geological Survey, at a well owned and operated by the Kansas Gas and Electric Company. The well is located about 3 miles north of Wichita near Little Arkansas River. This pumping test has been described (Wenzel, 1942, pp. 142-146), and a summary of the test made at this well is included here because the thickness, character, permeability of the water-bearing material, and the location within the Arkansas River Valley are comparable to this section of the valley, especially the sand-dunes border area. The well is 20 inches in diameter, 45.3 feet deep, and the thickness of the saturated water-bearing material is 27 feet. The well was pumped continuously at a rate of 1,000 gallons a minute for 18 days. Eighteen observation wells were constructed on 4 radial lines and ranged from 3 to 900 feet from the pumped well. At the end of the pumping period, the drawdown was 15 feet at the pumped well, 5½ feet at a well 50 feet away, 4 feet at a well 100 feet away, and 2 feet and 1 foot at observation wells 500 and 900 feet distant, respectively, from the pumped well. The average permeability was computed to be about 5,500. Attention is called to the comparable thickness of sand and gravel and permeability in several of the test holes drilled near the northeast edge of the valley in the sand-dunes border area.

No pumping tests were made southwest of Arkansas River in this area. However, wells supplying the Hutchinson Naval Air Station just southeast of this area were tested when they were drilled in 1942[1]. The wells are located in the NW¼ NE¼ sec. 16, T. 24 S., R. 5 W. and penetrate deposits coextensive with those encountered in test hole 93. These wells are about 125 feet deep. One

[1]Data collected by Bruce F. Latta, U.S. Geological Survey.

of the wells was pumped for 21½ hours at the rate of 365 gallons a minute, and the drawdown in the pumped well was 15 feet. The drawdown in two observation wells, 100 and 300 feet respectively from the pumped well, was 5.1 feet and 3.4 feet. The average coefficient of permeability was computed to be 750 (see definition above).

Although several additional pumping tests, at which more detailed data had been collected, would be desirable, some conclusions may be drawn from the information at hand. It appears that properly constructed wells located in the central part of the valley plain will yield very large quantities of water with comparatively small drawdown. The water-table contour map (Pl. 1) indicates that the pumping in and near Hutchinson has affected the shape of the water table, but the effect has been comparatively slight and it appears reasonable that a considerably larger quantity of water could be developed in that area. Near the edge of the valley plain, at the edge of the sand dunes, the evidence concerning the quantity of water available is meager, but the very small draw-down at well 50 indicates that wells yielding at least 500 gallons a minute could be developed if properly spaced. There is little data available from wells located southwest of Arkansas River in this area, but tests at wells supplying the Hutchinson Naval Air Station indicate that other wells properly constructed and properly spaced may yield from 300 to 500 gallons a minute.

Estimates Based on Laboratory Tests

Laboratory permeability tests were made on samples of sand and gravel collected from the test holes drilled in this area; the results of these tests are given in Table 1. These values form the basis for the estimates of recharge made above and, together with the logs of test holes and mechanical analyses of drill samples, may be used in estimating the quantities of water available for pumping in parts of this area.

The deposits of sand and gravel underlying the central part of the Arkansas valley plain contain some very coarse material, but are rather poorly sorted. The coefficients of permeability (see definition above) of samples of material collected from test holes in this part of the area ranged from about 2,000 at test holes 34 and 78 to about 14,000 at test hole 59. At test hole 60, however, permeability of the samples ranged from about 13,000 to about 40,000.

Samples tested from one of the battery of wells at No. 53 ranged in permeability from 1,000 to 7,000. As is pointed out above, four similar wells at this place yield about 2,000 gallons a minute continuously. It is believed that wells in this part of the valley plain will yield up to 2,000 gallons a minute if spaced and constructed properly. Very coarse gravel, in which wells yielding large quantities of water can be developed, was encountered in test hole 27 near the northwest corner of the area, and in test hole 76 near Arkansas River. It is shown below that ground water from these parts of the area is of poor chemical quality and that the large quantities available have limited utility.

The water-bearing material underlying the edge of the valley near the border of the sand dunes is coarse and very permeable, although not as thick as the material nearer the river. The coefficients of permeability ranged from 1,000 to 14,000 at test hole 32, from 4,000 to 24,000 at test hole 11, from 1,000 to 5,000 at test hole 12, and from 1,000 to 8,000 at test hole 55. Comparison of the thickness, character, and permeability of these deposits with those penetrated by wells of known performance elsewhere indicates that wells yielding from 500 to 1,000 gallons a minute can be developed in the sand-dune border area. As is noted above, inflow from the sand hills together with recharge from precipitation is at least 800 acre-feet per square mile per year along the edge of the valley. This quantity probably is greater than 800 acre-feet owing to additional recharge from surface runoff from the sand hills during periods of heavy precipitation. Furthermore, the water-table contour map shows that under present conditions ground water percolating southwestward from the sand hills follows a course which becomes deflected southeastward within the first mile from the edge of the dunes, so that a well located along the edge of the valley (such as well No. 50) receives sand-hills water indirectly from the northwest as well as directly from the northeast. Large quantities of water could be produced from small areas along the sand-hills border, but if the quantity produced exceeded recharge from precipitation and inflow from the northeast and northwest, the deficiency would be drawn from the southwest, and, as is pointed out below, ground water of less desirable quality would enter the wells. The water-table contours (Pl. 1) indicate that such a condition has developed at the Central Fibre Products Company wells (No. 53).

TABLE 4. *Analyses of water from test holes and wells in the vicinity of Hutchinson, Kansas*

Analyzed by H. A. Stoltenberg. Dissolved constituents given in parts per million *a*, reacting values (in italics) given in equivalents per million *b*.

No. on Plate 1	Location	Depth, feet	Date of Collection	Temperature (°F)	Dissolved solids	Silica	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Fluoride (F)	Total Alkalinity (as $CaCO_3$)	Hardness (as $CaCO_3$) Total	Carbonate	Non carbonate
	T. 22 S., R. 5 W.																		
2	NW cor. NE sec. 19	52-55	11-6-45	59	172	28	24	36 *1.79*	4.2 *.34*	11 *.48*	122 *2.01*	2.9 *.06*	6.5 *.18*	22 *.35*	0.2 *.01*	100	107	100	7
3	SW SE sec. 19	19	10-31-45	60			.30					8.2	64			64			
5	SW SW sec. 20	46	10-31-45	60			.54					22	47			40			
7	SW SE sec. 27	36	11-1-45	58			17					14	29			32			
8	NW NW sec. 28	35	10-31-45	58			.34					8.2	16			26			
11	NW cor. SW sec. 30	30-34	11-29-45	60	234	22	3.0	34 *1.70*	9.2 *.76*	32 *1.40*	149 *2.43*	48 *1.00*	14 *.39*	1.1 *.02*	.3 *.02*	122	123	122	1
12	SW cor. SE sec. 30	29-33	11-28-45	60	212	31	6.1	24 *1.20*	7.8 *.64*	32 *1.39*	110 *1.80*	38 *.79*	18 *.51*	7.1 *.11*	.3 *.02*	90	92	90	2
13	NE cor. SE sec. 31	30-34	11-28-45	60	254	18	4.3	38 *1.90*	10 *.82*	37 *1.60*	171 *2.80*	51 *1.06*	15 *.42*	.97 *.02*	.4 *.02*	140	136	136	0
15	SE cor. sec. 32	27-31	11-28-45	60	335	18	12	69 *3.44*	10 *.82*	34 *1.47*	215 *3.53*	62 *1.29*	26 *.73*	10 *.16*	.3 *.02*	176	213	176	37
16	NW SW sec. 33	17	11-1-45	60			.32					1.6	5			46			
17	SW SW sec. 34	26	11-1-45	59			3.3					44	35			50			
19	NW SW sec. 36	10	11-7-45	60			.10					4.2	7			46			
	T. 22 S., R. 6 W.																		
20	SW SE sec. 9	29	11-2-45	58			2.3					14	19			418			
22	SE SW sec. 14	86	11-6-45	58			.86					6.6	13			130			

23	NW cor. SW SW sec. 15	44-48	11-30-45	60	294	23	1.0	56 *2.79*	12 *.99*	29 *1.28*	222 *3.64*	37 *.77*	15 *.42*	13 *.21*	.3 *.02*	182	189	182	7
24	SE cor. SW sec. 15	33-37	11-30-45	59	289	16	1.9	64 *3.19*	11 *.90*	22 *.96*	232 *3.80*	25 *.52*	10 *.28*	27 *.43*	.3 *.02*	190	204	190	14
25	SW SE sec. 16	19	10-20-45	60			.05					188	216			300			
27	SE NE sec. 17	61-65	11-30-45	59	692	14	.60	92 *4.59*	22 *1.81*	131 *5.69*	337 *5.53*	120 *2.50*	137 *3.86*	9.7 *.16*	.8 *.04*	276	320	276	44
31	SE cor. sec. 21	65-69	12-1-45	60	779	15	.34	104 *5.19*	23 *1.89*	149 *6.48*	303 *4.97*	124 *2.58*	209 *5.89*	5.3 *.08*	.7 *.04*	248	354	248	106
32	SE cor. NE sec. 22	52-56	11-29-45	59	296	20	.84	59 *2.94*	12 *.99*	29 *1.27*	229 *3.76*	36 *.75*	19 *.54*	8 *.13*	.3 *.02*	188	196	188	8
33	SE SW SW sec. 24	33-35	10-24-45	61	258	20	1.5	43 *2.16*	8.8 *.72*	28 *1.22*	149 *2.43*	30 *.62*	15 *.42*	38 *.61*	0.4 *.02*	122	144	122	22
34	NW cor. SW sec. 26	66-68	12-1-45	61	726	14	1.9	94 *4.69*	22 *1.81*	142 *6.19*	317 *5.20*	117 *2.43*	174 *4.91*	6.6 *.11*	.7 *.04*	260	325	260	65
38	NW SW sec. 35	22	11-2-45	59			.49					126	179			258			
39	NW cor. sec. 36	48-52	12-3-45	60	669	18	.40	100 *4.99*	23 *1.89*	110 *4.77*	322 *5.28*	118 *2.45*	134 *3.78*	6.2 *.10*	.7 *.04*	264	344	264	80
	T. 23 S., R. 4 W.																		
40	SW SW sec. 6	26	11-7-45	59			44					2.4	17			27			
41	SW SW sec. 7	21	10-26-45	58			.40					3.2	4			64			
43	NW cor. SW SW sec. 18	33-36	10-26-45	58	213	18	4.1	22 *1.10*	6.4 *.53*	40 *1.75*	127 *2.07*	40 *.83*	9 *.25*	14 *.22*	.2 *.01*	104	82	82	0
44	SW SW sec. 19	12	11-7-45	61			.08					44	39			241			
	T. 23 S., R. 5 W.																		
45	NE cor. SE SE sec. 2	69-73	12-8-45	57	152*c*	63*c*	8.6	14 *.70*	5 *.41*	9.7 *.42*	60 *.98*	2.1 *.04*	4.5 *.13*	23 *.37*	.2 *.01*	49	56	49	7
46	SE SE sec. 2	21	11-3-45	58			1.3					5.8	10			32			
50	NW NW SE sec. 4	40	8-3-45	59	344	21	.06	62 *3.09*	10 *.82*	25 *1.09*	161 *2.64*	84 *1.75*	14 *.39*	12 *.19*	.3 *.02*	132	196	132	64
51	NE NE sec. 6	17	10-31-45	62			11					268	33			214			
52	SE cor. sec. 6	62-66	11-27-45	59	352	16	15	57 *2.84*	15 *1.23*	52 *2.24*	260 *4.26*	44 *.92*	38 *1.07*	1.5 *.02*	.7 *.04*	213	204	204	0

TABLE 4. *Analyses of water from test holes and wells in the vicinity of Hutchinson, Kansas (concluded)*

No. on Plate 1	Location	Depth, feet	Date of Collection	Temperature (°F)	Dissolved solids	Silica	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Fluoride (F)	Total Alkalinity (as $CaCO_3$)	Hardness (as $CaCO_3$) Total	Carbonate	Non carbonate
53	NE cor. sec. 8	68	3-1-38	—	396	18	2.5	80 *3.99*	15 *1.23*	26 *1.13*	198 *3.25*	123 *2.56*	19 *.54*	0		162	261	162	99
54	NW SW sec. 11	31-33	10-24-45	59	240	16	4.3	34 *1.70*	7.8 *.64*	37 *1.61*	137 *2.26*	63 *1.31*	12 *.34*	1.4 *.02*	.3 *.02*	112	117	112	5
55	SE cor. sec. 13	33-36	10-25-45	58	194	16	5.9	24 *1.20*	6.6 *.54*	31 *1.36*	102 *1.67*	53 *1.10*	10 *.28*	2 *.03*	.3 *.02*	84	87	84	3
55	SE cor. sec. 13	130-133	10-25-45	57	193	17	2.7	29 *1.45*	7 *.57*	26 *1.13*	120 *1.96*	40 *.83*	11 *.31*	2.2 *.03*	.3 *.02*	98	102	98	4
57	NE cor. SE sec. 14	42-45	10-27-45	58	241	28	2.1	21 *1.05*	6.2 *.51*	49 *2.13*	127 *2.08*	61 *1.27*	11 *.31*	.66 *.01*	.4 *.02*	104	78	78	0
59	SE cor. sec. 15	52-54	10-23-45	59	14457	43	25	3270 *163.16*	445 *36.58*	1419 *61.73*	152 *2.49*	79 *1.64*	9125 *257.34*	0	0	125	9988	125	9863
60	NE cor. sec. 16	50-54	11-27-45	59	944	20	7.2	139 *6.94*	27 *2.22*	162 *7.06*	243 *3.98*	158 *3.29*	316 *8.91*	1.3 *.02*	.3 *.02*	199	458	199	259
61	NE cor. NW sec. 17	69	6-6-38	—	843	17	0	38 *1.90*	9.4 *.77*	270 *11.73*	342 *5.61*	115 *2.39*	222 *6.26*	8.8 *.14*	1.7 *.09*	280	134	134	0
62	SW NW NW sec. 17	50	6-6-38	—	770	15	.1	102 *5.09*	20 *1.64*	141 *6.15*	317 *5.20*	139 *2.89*	152 *4.29*	31 *.50*	0.7 *.04*	260	337	260	77
63	NE cor. NW SW sec. 18	80	6-6-38	—	1826	16	0	185 *9.23*	32 *2.63*	383 *16.64*	271 *4.44*	192 *3.99*	694 *19.57*	31 *.50*	.6 *.03*	222	593	222	371
65	NE NE sec. 20	20	10-30-45	60			.09					222	840			214			
67	NE cor. sec. 21	55-58	10-30-45	59	13704	23	14	1880 *93.80*	274 *22.51*	2896 *125.95*	283 *4.64*	230 *4.78*	8250 *232.67*	9.3 *.15*	.4 *.02*	232	5816	232	5584
69	SE cor. sec. 23	94-97	10-29-45	59	2957	19	2.4	417 *20.80*	104 *8.55*	539 *23.45*	273 *4.48*	102 *2.12*	1635 *46.11*	4.4 *.07*	.4 *.02*	224	1468	224	1244

70	SE cor. NE sec. 24	57-60	12-8-45	58	236	17	3.6	42 *2.10*	9 *.74*	29 *1.26*	183 *3.00*	39 *.81*	9 *.25*	.66 *.01*	.5 *.03*	150	142	142	0
71	NW NW sec. 27	24	10-29-45	60			.42					90	490			216			
72	NE cor. sec. 29	35-38	10-30-45	59	1244	14	6.3	87 *4.34*	19 *1.56*	353 *15.34*	260 *4.26*	137 *2.85*	495 *13.97*	8 *.13*	.6 *.03*	213	295	213	82
75	NW NE sec. 30	15	10-30-45	62			1.8					214	355			319			
76	NW cor. sec. 32	53-56	10-31-45	58	3935	16	6.7	285 *14.22*	67 *5.51*	1103 *47.96*	222 *3.64*	307 *6.39*	2040 *57.55*	5.8 *.09*	.4 *.02*	182	986	182	804
	T. 23 S., R. 6 W.																		
78	NE cor. sec. 1	64-68	12-4-45	60	458	17	.58	86 *4.29*	20 *1.64*	52 *2.25*	283 *4.64*	67 *1.39*	74 *2.09*	2 *.03*	.6 *.03*	232	296	232	64
79	SW SE NW sec. 1	65	6-6-38	—	662	16	.08	87 *4.34*	19 *1.56*	123 *5.34*	290 *4.76*	97 *2.02*	148 *4.17*	18 *.29*	.7 *.04*	238	295	238	57
80	SW cor. sec. 2	10	10-19-45	62			.27					46	37			215			
32	Cen. NW NW sec. 12	60	3-27-44	—	576	15	0	88 *4.39*	17 *1.40*	87 *3.78*	242 *3.97*	96 *2.0*	119 *3.36*	13 *.21*	.6 *.03*	198	290	198	92
83	NE cor. SE sec. 12	58	6-6-38	—	726	15	.05	102 *5.09*	19 *1.56*	137 *5.95*	310 *5.09*	129 *2.68*	161 *4.54*	18 *.29*	.9 *.05*	254	333	254	79
84	SW cor. SE SW sec. 12	65	6-6-38	—	1198	15	0	148 *7.39*	25 *2.06*	220 *9.56*	237 *3.89*	135 *2.81*	429 *12.10*	13 *.21*	.3 *.02*	194	473	194	279
85	SW SW SE sec. 12	73	6-6-38	—	662	16	0	101 *5.04*	18 *1.48*	98 *4.26*	256 *4.20*	119 *2.48*	134 *3.78*	20 *.32*	.8 *.04*	210	326	210	116
88	SE NW sec. 14	21	10-26-45	60			.86					428	320			203			
93	SE cor. sec. 36	133-136	11-1-45	59	426	20	3.5	52 *2.59*	8.8 *.72*	93 *4.03*	311 *5.11*	32 *.66*	43 *1.21*	21 *.34*	.3 *.02*	255	166	166	0
	T. 24 S., R. 6 W.																		
94	SW cor. sec. 11	22-25	12-5-45	57	386	15	3.3	65 *3.24*	11 *.90*	65 *2.81*	333 *5.46*	21 *.44*	25 *.70*	19 *.31*	.7 *.04*	273	207	207	0
95	NW cor. sec. 12	145-148	11-2-45	59	268	19	9.7	46 *2.29*	5.2 *.43*	42 *1.83*	212 *3.47*	19 *.39*	16 *.45*	14 *.22*	0.3 *.02*	174	136	136	0
96	NW cor. sec. 22	24-27	12-7-45	59	361	17	4.0	80 *3.99*	13 *1.07*	38 *1.67*	334 *5.48*	10 *.21*	32 *.90*	6.2 *.10*	.7 *.04*	274	253	253	0

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

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

c. Influenced by the presence of material which passed through filter paper.

The unconsolidated material penetrated by the drill in the test holes southwest of Arkansas River is considerably thicker in the deepest part of the filled channel than that underlying most of the valley plain (Pl. 1). Logs of test holes 93, 94, and 95 indicate that this material is poorly sorted and has low permeability. The coefficient of permeability was found to be about 3,000 at test hole 93 and ranged from 100 to 500 at test hole 95. Although the thickness of the water-bearing material is greater in these test holes than elsewhere in the area, the lower permeability indicates that drawdown would be greater in wells having comparable yields.

Laboratory tests show that the material comprising the sand hills is composed principally of medium to fine sand containing thin beds of silt and clay locally. The permeability of this material is very low in comparison to that of the coarse gravel underlying the valley plain, but is high in comparison to the permeability of the sandy soil developed on the surface of the valley. Thus, the sand hills comprise an area comparatively favorable for infiltration of rainfall, but will yield comparatively small quantities of water to individual wells.

QUALITY OF WATER

The chemical character of the ground waters in this area is shown by analyses of 63 samples of water collected from test holes and wells. The results of the analyses are given in Table 4. Only partial analyses were made of samples collected from shallow private wells. The analyses, which were made by Howard A. Stoltenberg in the Water and Sewage Laboratory of the Kansas State Board of Health, show only the dissolved mineral content of the waters and do not, in general, indicate the sanitary condition of the waters.

Chemical Constituents in Relation to Use

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

Dissolved Solids.—The residue left after a natural water has evaporated consists of rock materials, with which may be included some organic material and some water of crystallization. Waters containing less than 500 parts per million of dissolved

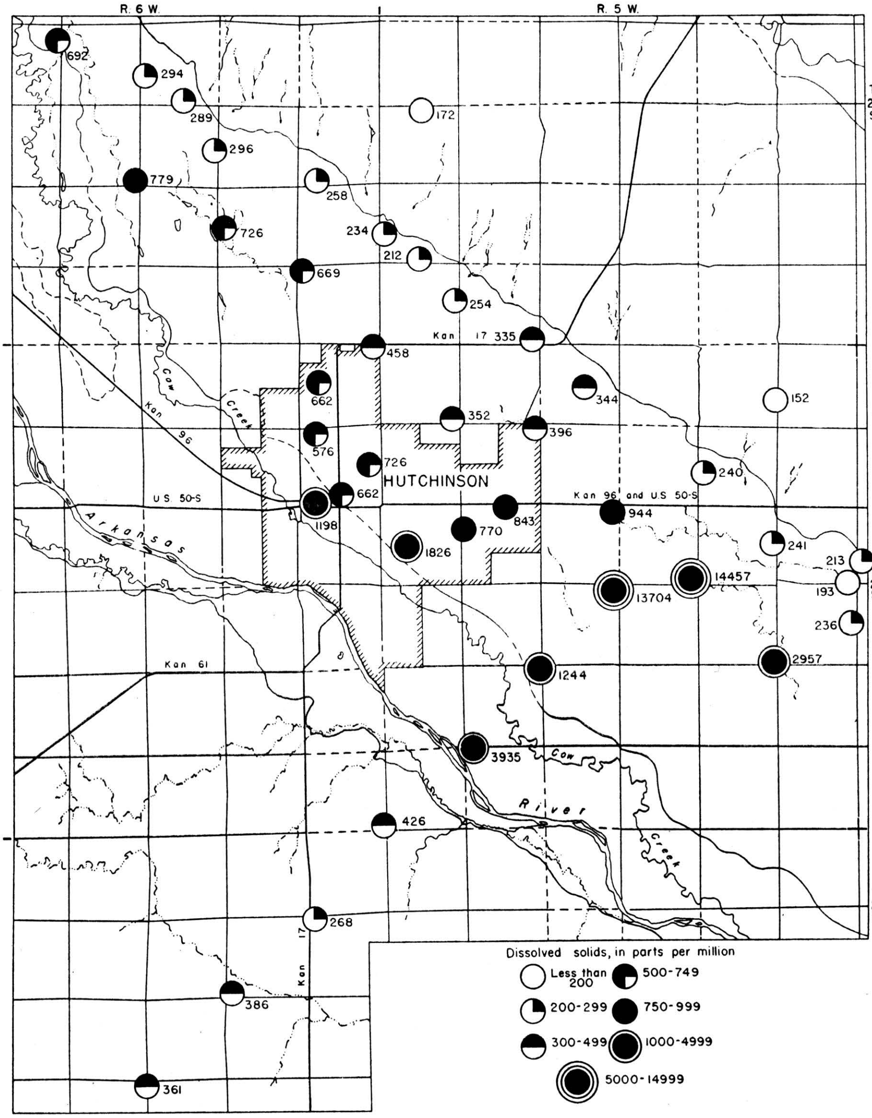

Fig. 6. Dissolved solids in ground water in Arkansas River Valley.

solids are generally entirely satisfactory for domestic use, except for the difficulties resulting from their hardness and, in some areas, excessive iron or corrosiveness. Waters having more than 1,000 parts per million are generally not satisfactory, for they are likely to contain enough of certain constituents to produce a noticeable taste or to make the water unsuitable in some other respects.

The analyses given in Table 4 indicate that the dissolved solids contained in ground water in this area range from 152 parts per million at test hole 45 to 14,457 parts per million at test hole 59. The quantity of dissolved solids contained in the samples collected is shown graphically on Figure 6. It may be noted that ground water in the sand hills contains less than 200 parts per million dissolved solids; water in the sand-dunes border area contains dissolved solids ranging from 190 to 350 parts per million; water in the valley plain ranges from 352 parts per million at test hole 52 to 3,935 parts per million at test hole 76. The four samples collected southwest of Arkansas River contain dissolved solids ranging from 268 to 426 parts per million. Contamination is apparent at test holes 59 and 67 where the ground water is very highly mineralized.

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

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

Water having a hardness of less than 50 parts per million is generally rated as soft, and its treatment for the removal of hardness under ordinary circumstances is not necessary. Hardness between 50 and 150 parts per million does not seriously interfere with the use of water for most purposes, but it does slightly increase the consumption of soap, and its removal by a softening process is

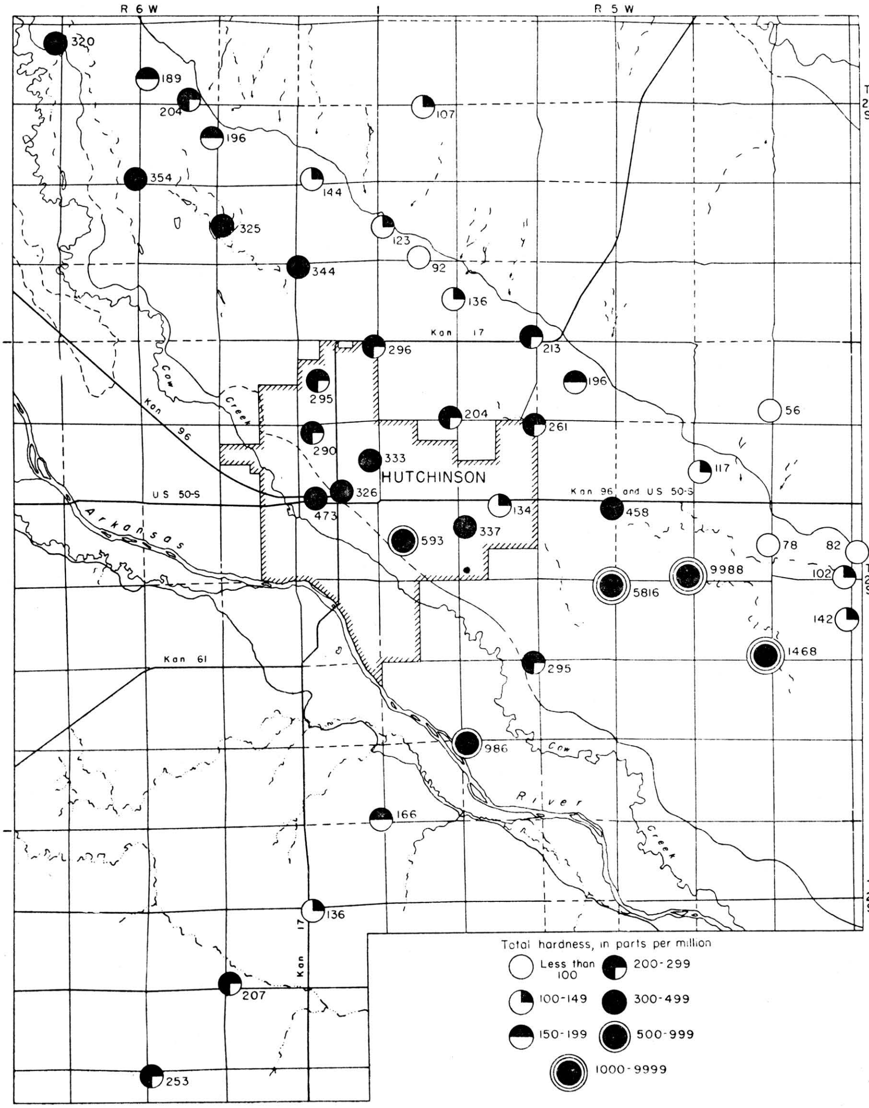

FIG. 7. Total hardness of ground water in Arkansas River Valley.

profitable for laundries or other industries using large quantities of soap. Waters in the upper part of this range of hardness will cause considerable scale on steam boilers. Hardness above 150 parts per million can be noticed by anyone and if the hardness is 200 or 300 parts per million, it is a common practice to provide a municipal water softening plant. Where municipal water supplies are softened, an attempt is generally made to reduce the hardness to about 60 or 80 parts per million. The additional improvement resulting from further softening of a whole public supply usually is not deemed worth the increase in cost.

As is shown by the analyses given in Table 4 and on Figure 7, the hardness of the ground water in this area varies greatly. Four of the samples collected had less than 100 parts per million hardness; the least hardness was 56 parts per million at test hole 45 in the sand hills, and the greatest hardness was 9,988 parts per million at test hole 59. The analyses shown graphically on Figure 7 indicate that in this area water having the least hardness may be found in the sand hills, that water low to moderately low in hardness occurs along the border of the sand dunes, and that hard to very hard water occurs beneath the valley plain. In general the hardness increases from the sand hills toward Arkansas River. The calcium chloride contained in samples collected from test holes 59 and 67 causes much of the hardness in ground water there and indicates contamination. Relatively soft water was found to occur along the border of the sand hills, especially at test holes 12, 57, and 43.

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

The analyses given in Table 4 show that the quantity of iron contained in the ground water in many parts of the area is great enough to be troublesome. Figure 8 shows graphically the iron content at the several test holes and wells sampled. It may be noted that the highest concentration of iron occurs in ground water in the sand hills, and that water in most parts of the area contains iron in sufficient quantities to require removal for municipal and most industrial uses. The least iron contained in the wells and test holes

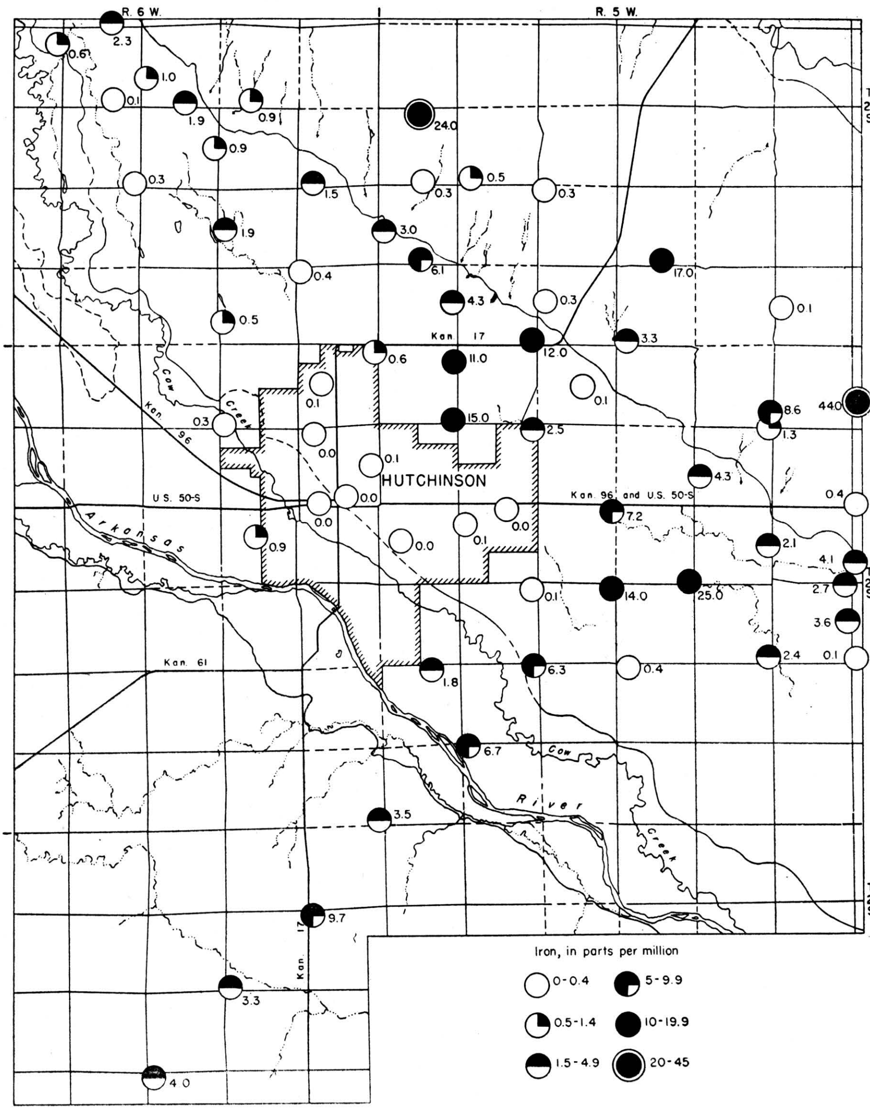

FIG. 8. Iron in ground water in Arkansas River Valley.

sampled occurs in the City of Hutchinson at the present city-supply wells.

Sulfate.—Sulfate in ground water is derived in large quantities from gypsum and from deposits of sodium sulfate. It is also formed by the oxidation of sulfides of iron and is therefore present in considerable quantities in waters from mines and from many beds of shale. Sulfate in waters that contain much calcium and magnesium causes the formation of hard scale in steam boilers and may increase the cost of softening the water.

The analyses given in Table 4 show that the sulfate in the samples collected ranged from 1.6 parts per million at well 16 to 488 parts per million at well 88. In general, the sulfate content is very low in water in the sand hills, low in the sand-dune border area, and becomes increasingly higher nearer Arkansas River. Water collected from test hole 76 contained 307 parts per million of sulfate, and the sulfate contained in samples collected from the present city wells ranged from 96 to 192 parts per million.

Chloride.—Chlorine combined as chlorides is widely distributed in nature; it is an abundant constituent of sea water and oil-field brines and is dissolved in small quantities from many rock materials. Chloride has little effect on the suitability of water for ordinary use, unless there is enough present to impart a salty taste and render the water unpalatable. Waters high in chloride may be corrosive if used in steam boilers. Chlorides of calcium and magnesium contribute to the hardness of a water in a manner similar to the sulfates and carbonates of these elements. The removal of chloride from water supplies is difficult and expensive.

The chloride content of ground water in this area is given in Table 4 and is shown on Figure 9. Samples collected contained chloride ranging from 4 parts per million at well 41 to 9,125 parts per million at test hole 59. The chloride content is low in water in the sand dunes and in the sand-dune border area, and becomes increasingly higher toward Arkansas River. Water at test hole 76, near the river, contained 2,040 parts per million of chloride; water at test holes 59 and 67 contained 9,125 and 8,250 parts per million, respectively, and contamination is indicated. Water collected from test holes drilled south of Arkansas River contained small quantities of chloride. Samples collected from the Hutchinson city-supply wells contained chloride ranging from 119 parts per million at the Northwest well (No. 82) to 694 parts per million at the Cleveland Street well (No. 63).

Fluoride.—Although determinable quantities of fluoride are not so common as fairly large quantities of the other constituents of natural water, it is desirable to know the amount of fluoride pres-

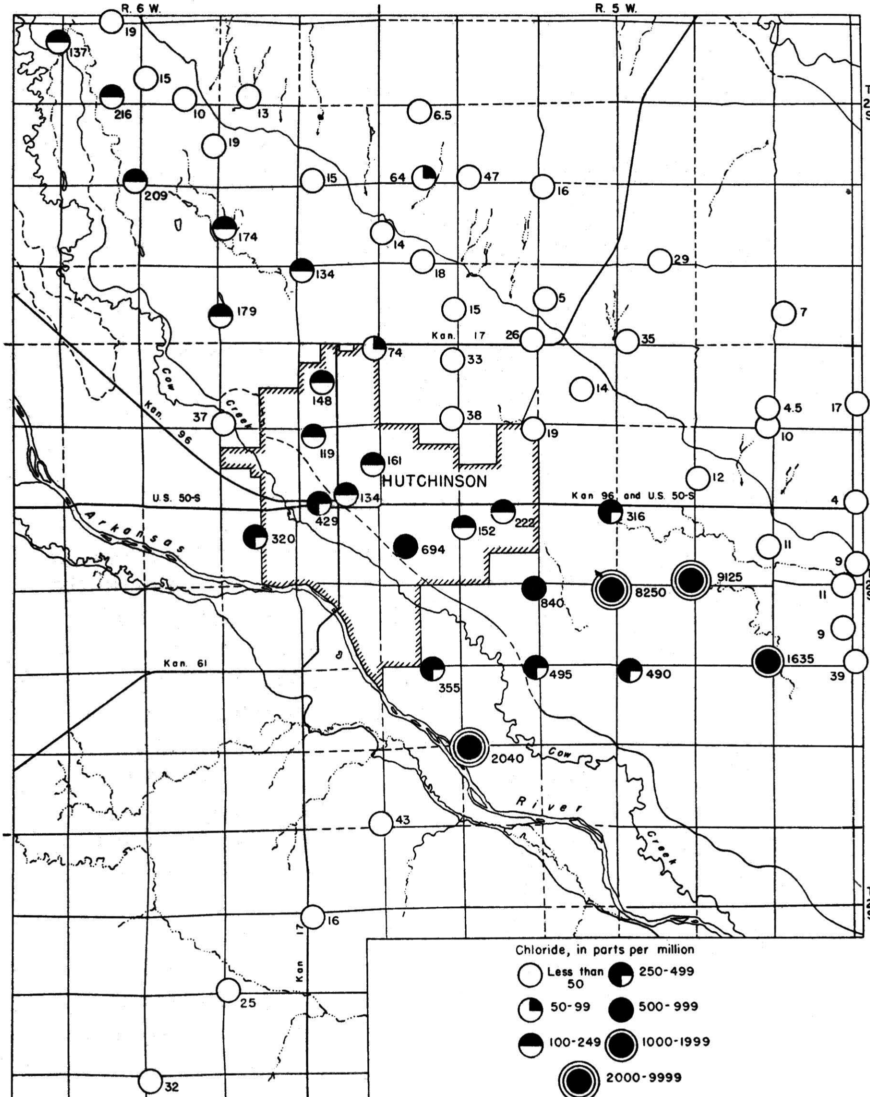

FIG. 9. Chloride in ground water in Arkansas River Valley.

ent in water that is likely to be used by children. Flouride in water has been shown to be associated with the dental defect known as mottled enamel, which may appear on the teeth of children who, during the period of formation of the permanent teeth, drink water containing fluoride. It has been stated that waters containing more than 1.5 parts per million of fluoride are likely to produce mottled enamel. If the water contains as much as four parts per million of fluoride, 90 percent of the children drinking the water are likely to have mottled enamel, and 35 percent or more of the cases will be classified as moderate or worse. Recent investigations indicate that small amounts of fluoride in drinking water, up to one part per million, may have a beneficial effect in the way of inhibiting decay of teeth.

The analyses given in Table 4 indicate that ground water in this section contains only very small quantities of fluoride. The analyses show that all samples collected from this area contained less than 1 part per million of fluoride except the sample from well 61 which contained 1.7 parts per million.

Salt Water Intrusion

Intrusion from Streams.—In general, the ground water in Arkansas River Valley becomes increasingly highly mineralized from Great Bend to the Kansas-Oklahoma boundary, and the greatest mineral content is found nearest the river and the least at the valley's edge. Above Great Bend the Arkansas River carries fresh water having a relatively low chloride content. Below Sterling, however, the river water generally contains sufficient chloride to be classed as brackish or salty. A large part of this salt is believed to come from salt marshes along Rattlesnake Creek in Stafford and Reno Counties and from salt-water disposal into Cow Creek in Barton and Rice Counties. The areas embraced by these marshes are underlain principally by unconsolidated Pleistocene sediments which in turn are underlain by Cretaceous sandstones and shales and by Permian rocks. Thick salt beds in the Permian strata underlie Reno County and the area westward and at one time extended somewhat farther eastward. These salt beds are mined commercially at Hutchinson and Lyons, and have been mined at Sterling and Nickerson, and together with the oil-field waste waters disposed of in this drainage area, seem to be the most likely original source of the salt water. The Cretaceous sandstones, however, are known to contain salt water farther west and may supply some of the salt marshes.

In this area the brackish water carried by Arkansas River and Cow Creek at high stages enters the sand and gravel near the streams and contaminates the ground water there. Figure 9 shows the very high concentration of chloride near the river (as at test hole 76) and the much lower chloride content near the sand hills at the valley's edge.

From data in the files of the Geological Survey it has been noted that during the fall of 1937, the chloride content of Arkansas River water between Hutchinson and Wichita was as high as 1,400 parts per million and generally was more than 1,000 parts. The chloride content of the ground water in this part of Arkansas River Valley ranges from a few hundred to as much as 1,200 parts per million in wells within about a mile of the river, but excepting the high concentrations encountered in some of the oil fields, the chloride content is progressively lower in wells situated farther from the river.

Intrusion from Industrial Wastes.—Although it was not the purpose of this investigation to search for areas in which ground water was contaminated nor to seek the source of contamination, it appears probable that contamination of ground water by industrial waste is occurring in parts of this area. The extremely high concentration of dissolved solids in the samples collected from test holes 59 and 67 indicate a source of contamination near by. Test hole 67 was drilled near a salt mine, and test hole 59 was drilled not far from a railway service plant.

Ground water of good chemical quality was found at test hole 55, and the thick deposits of permeable material at that place probably would yield large quantities of water to wells located there. However, the apparent contamination near test hole 59 should be proved and the effect of contamination on water pumped from wells drilled near test hole 55 should be determined before this area is extensively developed.

Quality of Water in Relation to Stratigraphy

As is noted above, very few wells, if any, derive water from the Ninnescah shale in this area, and no samples of water were collected from wells drawing from the Ninnescah. However, data in the files of the Geological Survey show that water contained in this formation in near-by areas is very hard and of limited usefulness; hence wells should not, and most wells do not, extend below the base of the unconsolidated deposits overlying the shale.

Few data were collected in the area southwest of Arkansas River. However, analyses of water collected from test holes 93, 94,

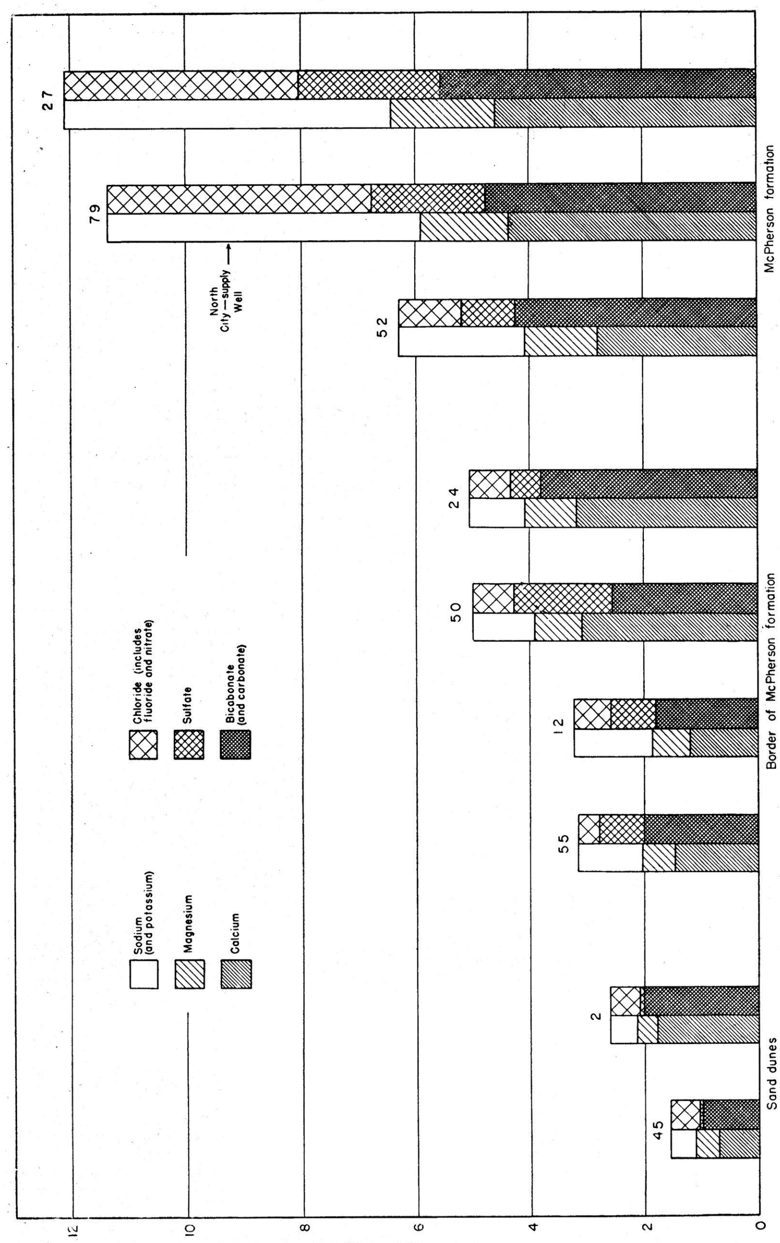

Fig. 10. Analyses of ground water from the sand dunes and McPherson formation.

95, and 96 indicate that, in general, ground water in the McPherson formation in the southwestern area is of better chemical quality than that contained in the alluvium and McPherson formation near the river. The quality of the water in the McPherson formation in the southwestern area is not as desirable as that in the sand dunes or in the McPherson near the sand-dunes border. The analyses given in Table 4 indicate that water in the McPherson formation south of Arkansas River contains a relatively small quantity of chloride, moderately high quantities of iron, and ranges in hardness from 136 to 263 parts per million. Samples of water were collected from many test holes and wells drilled in the McPherson formation north of Arkansas River and the analyses given in Table 4 show that the chemical quality of the water contained in these deposits varies greatly in this area. Several of the analyses are shown graphically on Figures 10 and 11. The considerable difference in the quality of water in the McPherson formation at the border of the sand dunes and elsewhere in the valley is shown on Figure 10. Analyses of some of the more highly mineralized waters from the McPherson are shown on Figure 11.

Of all the samples collected from this area, water having the least dissolved mineral content was taken from test holes and wells in the sand dunes. Ground water in the sand dunes is comparatively very soft and low in chloride content. A comparison of the quality of the water from the sand dunes and from the McPherson formation is shown graphically on Figure 10. Most of the samples collected from the dunes, however, contained relatively large quantities of iron, as high as 44 parts per million (Fig. 8). Most of the samples collected from this part of the area were red-brown in color a few days after collection owing to the presence of iron oxide.

In general, the ground water in the alluvium of Arkansas River is of very poor quality because, as is noted above, hard water containing sodium chloride enters the alluvium when the river is at high stages. Analyses of water collected from test hole 76 and well 84 are shown graphically on Figure 11. Samples collected from wells 75 and 88 were not as highly mineralized as the sample from test hole 76 because the wells are shallow—15 feet and 21 feet deep, respectively. It has been noted in near-by areas that the mineral content of ground water increases with depth, and that the water of best chemical quality at any given location occurs near the surface.

No samples of ground water were collected from the alluvium of Little Arkansas River in the northeast part of this area.

HUTCHINSON WATER SUPPLY

Hutchinson is supplied by the privately owned Hutchinson Water Company (formerly by the Kansas Power and Light Company) from 8 gravel-walled drilled wells situated in different parts of the city, numbers 61, 62, 63, 79, 82, 83, 84, and 85 on Plate 1 and Table 2, all of which obtain water from sand and gravel in the alluvium and terrace deposits of Arkansas River Valley. The wells range in depth from 50 to 75 feet, are equipped with electrically driven turbine or centrifugal pumps, and each yields from 750 to 2,000 gallons a minute. The wells discharge directly into the distribution mains and there are no storage facilities, the water pressure being maintained by varying the number of wells pumped according to demand. To facilitate this procedure, the pumps on six of the wells are controlled from a central station. Because the water from the several wells differs considerably in chemical composition, particularly in chloride content (see Table 4), wells yielding water of least desirable quality are kept in reserve for peak loads or standby use.

According to officials of the Hutchinson Water Company, wells 79 and 85 furnish most of the water used by the city during fall and winter months, the other city-supply wells being pumped only during hours of greatest demand and in times of emergency. Well 85 supplies about 1.5 million gallons a day and well 79 supplies about 1 million gallons a day. The quantity of water pumped monthly and annually is given above in Table 3. The analyses given in Table 4 show that waters from wells 79 and 85 contain 662 parts per million dissolved solids and that the hardness of the water is 295 parts per million and 326 parts per million, respectively, at wells 79 and 85. The chloride content of water from these wells is 148 and 134 parts per million respectively. Two of the present city wells are used only in emergency because of the very poor chemical quality of the water. These two wells, numbers 63 and 84, are located nearer Arkansas River than are wells 79 and 85, and their waters contain 1,826 and 1,198 parts per million dissolved solids respectively. Wells 61, 62, and 83 appear to furnish water of better chemical quality than the other city wells, although these wells do not contribute greatly to the city supply at present.

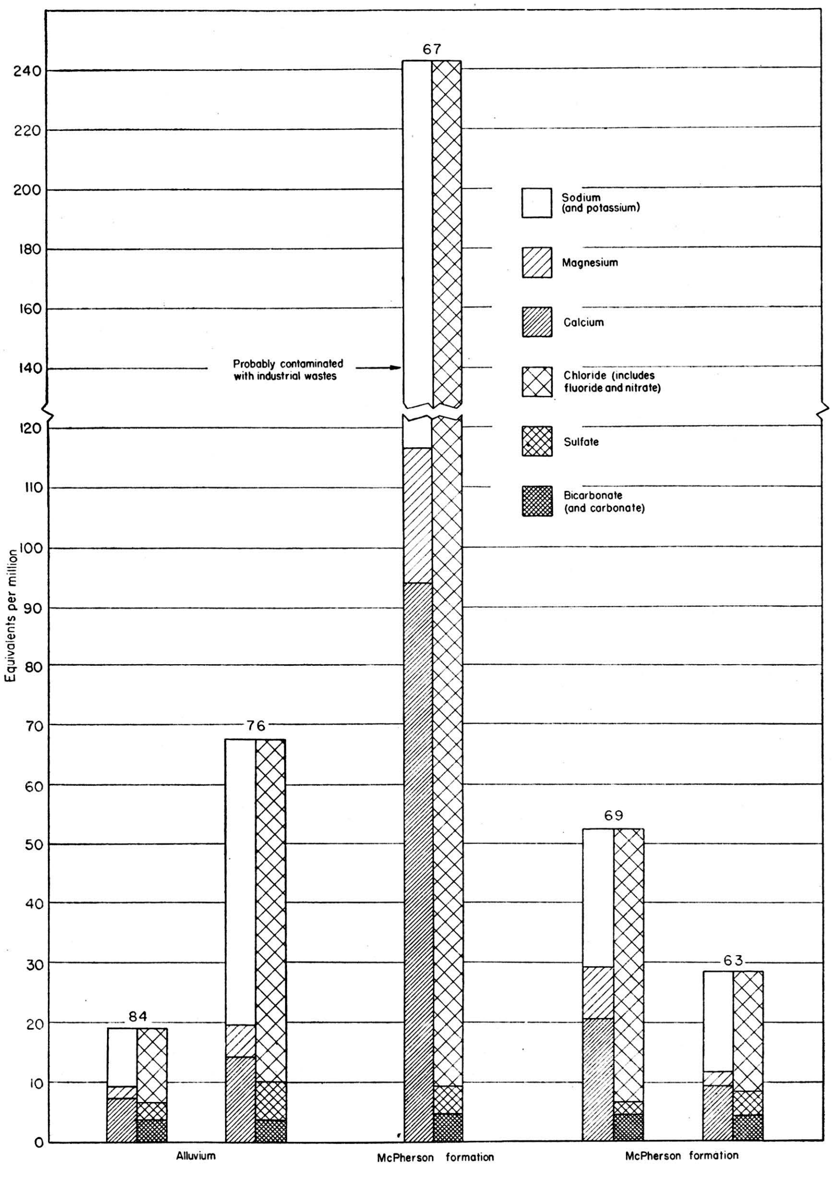

Fig. 11. Analyses of ground water from the alluvium and McPherson formation. Note difference in scales used in Figures 10 and 11.

GROUND-WATER CONDITIONS WITH REFERENCE TO USE

Sand-Dune Area.—The part of this area underlain by dune sand (Pl. 1) comprises an excellent catchment area, and a large part of the precipitation recharges the ground-water reservoir. The water in the dunes is of very good chemical quality except for the iron content which is unusually high. Logs of test holes, mechanical analyses of drill samples, and permeability tests (Table 1) indicate that the fine-grained materials of which the sand dunes are composed will yield only small quantities of water to individual wells. Ground water in the sand dunes is used principally for stock and domestic purposes at farms and in pastures, but some water is pumped seasonably for use in the spraying of orchards. It appears that no large supplies of ground water can be developed from the sand-dune area.

Sand-Dune Border Area.—The sand-dune border area does not comprise a distinct geologic or physiographic unit, but for purposes of this report it is convenient to consider the edge of the valley plain separately. The following remarks pertain to an elongate area about 1 mile wide at the northeast side of Arkansas River Valley bordering the sand dunes.

The quality of the ground water in the McPherson formation in the sand-dune border area is variable, but is good in most places and better than the water elsewhere in the valley. Water of very good quality, except for the content of iron, was encountered at several of the test holes drilled in this area. It is noted above that wells yielding large quantities of water probably can be developed in the sand-dune border area. However, it is pointed out that wells should be properly spaced and that the pumping rate of each well should not be so great that water of less desirable quality will be drawn from the southwest toward the wells. The removal of iron from the water in this area would be necessary for municipal and many industrial uses.

Valley-Plain Area.—The valley-plain area comprises the area underlain by the McPherson formation north of Arkansas River (Pl. 1), exclusive of the sand-dune border area discussed above.

The present Hutchinson city-supply wells are located in this area and yield up to 2,000 gallons a minute with small draw-down. Many other private and industrial wells derive large quantities of water from the McPherson formation beneath this area, and laboratory permeability tests indicate that wells having large yields may be developed in most parts of the valley plain. The quality of the water in this area varies greatly but in general is very hard and brackish in many places. The quality of the water in and near the City of Hutchinson is undesirable for municipal and some industrial uses. Ground water in this area, however, is used extensively for cooling and air conditioning. Contamination is indicated at some places in the valley-plain area.

Flood-Plain Area.—The alluvium of Arkansas River (Pl. 1) underlies the flood plain area. Mechanical analyses and permeability tests made from samples collected from test hole 76 indicate that very large yields may be expected from wells located in the flood plain. Chemical analyses show that the ground water is of very poor quality and that its usefulness is limited. Hard, brackish water may be expected from the flood plains of Arkansas River and Cow Creek throughout their extent in this area.

Southwestern Area.—Few data were collected from the area southwest of Arkansas River; however, it is believed that moderately large quantities of water of comparatively good quality can be developed there. Further investigation of this area seems to be needed and it is likely that parts of the area may prove to be favorable for development.

LOGS OF TEST HOLES AND WELLS

Logs describing the materials encountered in test drilling in Arkansas River Valley and vicinity in Reno County are listed on the following pages. Thirty-two holes were drilled by Claude Price for the City of Hutchinson, 7 test holes were drilled by the State Geological Survey, and logs of wells were furnished by the Layne-Western Company, the Atchison, Topeka, and Santa Fe Railway Company, and the Hutchinson Water Company. The locations of the test holes are shown on Plate 1. Samples from most of the test holes described are on file in the sample library of the State Geological Survey, and were studied by the author with the assistance of C. K. Bayne.

2. *Sample log of test hole at NW cor. NE¼ sec. 19, T. 22 S., R. 5 W.; drilled by Claude Price for the City of Hutchinson, November 1945. Surface altitude, 1,643.8 feet.*

	Thickness, feet	Depth, feet
QUATERNARY		
Dune sand		
Sand, fine to medium; contains very fine sand and brown silt	2	2
Sand, fine to medium	12	14
Sand, fine to medium, and clay, buff; contains some sand; very fine	14	28
Sand, medium to very fine, and clay, buff	10	38
Clay and silt, gray to brown; contains fine sand	28	66
Sand, medium to fine	26	92
Clay, gray to brown; contains some caliche at base of interval	24	116
PERMIAN—Leonardian		
Ninnescah shale		
Shale, red	1	117

9. *Sample log of test hole in NE¼ SE¼ sec. 28, T. 22 S., R. 5 W.; drilled by Claude Price for the City of Hutchinson, November 1945. Surface altitude, 1,616.4 feet.*

	Thickness, feet	Depth, feet
QUATERNARY		
Dune sand		
Sand, medium to fine	29	29
Sand, medium to very fine; contains buff silt and clay	5	34
Sand, medium to fine, and silt and clay, tan; contains very fine sand	31	65
Sand, fine to medium, and clay, gray; contains some very fine sand	20	85
Sand, medium to fine; grains stained red brown	31	116
Clay, gray	2	118
PERMIAN—Leonardian		
Ninnescah shale		
Shale, red	2	120

11. *Sample log of test hole at NW cor. SW¼ sec. 30, T. 22 S., R. 5 W.; drilled by Claude Price for the City of Hutchinson, October 1945. Surface altitude, 1,544.9 feet.*

	Thickness, feet	Depth, feet
Soil, very sandy	3	3
QUATERNARY—Pleistocene		
McPherson formation		
Clay, gray to tan; contains some fine to medium sand	8	11
Gravel, coarse to fine; contains some coarse to medium sand	9	20
Gravel, medium to coarse, and gravel, fine	8	28
Gravel, fine to coarse; contains coarse sand	4	32
Gravel, coarse to fine; contains some coarse sand	2	34
PERMIAN—Leonardian		
Ninnescah shale		
Shale, gray green and brick red	1	35

12. *Sample log of test hole at SW cor. SE¼ sec. 30, T. 22 S., R. 5 W.; drilled by Claude Price for the City of Hutchinson, October 1945. Surface altitude, 1,540.5 feet.*

	Thickness, feet	*Depth, feet*
Soil, very sandy, brown	3	3
QUATERNARY—Pleistocene		
McPherson formation		
Sand, fine to medium, and clay, gray	5	8
Clay, gray	4	12
Gravel, fine to coarse, and sand, coarse	6	18
Sand, coarse to medium, and gravel, fine to medium	7	25
Gravel, fine to medium, and sand, coarse to medium	6	31
Gravel, fine to medium, and sand, coarse to fine; poorly sorted	3	34
PERMIAN—Leonardian		
Ninnescah shale		
Shale, brick red	1	35

13. *Sample log of test hole at NE cor. SE¼ sec. 31, T. 22 S., R. 5 W.; drilled by Claude Price for the City of Hutchinson, October 1945. Surface altitude, 1,536.7 feet.*

	Thickness, feet	*Depth, feet*
Soil, very sandy	3	3
QUATERNARY—Pleistocene		
McPherson formation		
Silt and clay; contains fine to medium sand	8	11
Sand, medium to fine; contains some gravel and silt; very poorly sorted	3	14
Gravel, fine to medium, and sand, coarse to fine	6	20
Gravel, coarse to fine; contains some coarse to medium sand	14	34
PERMIAN—Leonardian		
Ninnescah shale		
Shale, red	1	35

15. *Sample log of test hole at SE cor. sec. 32, T. 22 S., R. 5 W.; drilled by Claude Price for the City of Hutchinson, October 1945. Surface altitude, 1,533.7 feet.*

	Thickness, feet	*Depth, feet*
Soil, very sandy, brown	4	4
QUATERNARY—Pleistocene		
McPherson formation		
Clay and silt, gray to tan; contains fine sand	4	8
Clay and silt, gray to blue gray; interval contains thin layers of fine sand	8	16
Gravel, fine to medium, and sand, coarse	15	31
PERMIAN—Leonardian		
Ninnescah shale		
Shale, gray green and brick red	2	33

23. *Sample log of test hole at NW cor. SW¼ SW¼ sec. 15, T. 22 S., R. 6 W.; drilled by Claude Price for the City of Hutchinson, October 1945. Surface altitude, 1,566.1 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene		
McPherson formation		
Sand, fine to medium	5	5
Sand, coarse to fine, and gravel, fine to medium	7	12
Gravel, coarse to fine; interval contains some very coarse material; very permeable	36	48
PERMIAN—Leonardian		
Ninnescah shale		
Shale, brick red	2	50

24. *Sample log of test hole at SE cor. SW¼ sec. 15, T. 22 S., R. 6 W.; drilled by Claude Price for the City of Hutchinson, October 1945. Surface altitude, 1,564.0 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene		
McPherson formation		
Sand, fine to medium; contains very fine sand and tan silt	8	8
Clay and silt, brown to gray	4	12
Sand, medium to coarse	8	20
Gravel, fine to medium, and sand, coarse	24	44
PERMIAN—Leonardian		
Ninnescah shale		
Shale, green gray	1	45

27. *Sample log of test hole in SE¼ NE¼ sec. 17, T. 22 S., R. 6 W.; drilled by Claude Price for the City of Hutchinson, October 1945. Surface altitude, 1,569.1 feet.*

	Thickness, feet	*Depth, feet*
Soil, dark brown; composed of sandy silt	4	4
QUATERNARY—Pleistocene		
McPherson formation		
Silt and clay, gray to tan; contains some fine sand	3	7
Gravel, coarse to fine; contains coarse sand	5	12
Sand, medium to coarse, and gravel, fine	6	18
Gravel, coarse to fine; contains some coarse sand	20	38
Gravel, medium to fine; contains coarse gravel and coarse sand	18	56
Gravel, fine to medium, and sand, coarse	10	66
PERMIAN—Leonardian		
Ninnescah shale		
Shale, brick red	1	67

31. *Sample log of test hole at SE cor. sec. 21, T. 22 S., R. 6 W.; drilled by Claude Price for the City of Hutchinson, October 1945. Surface altitude, 1,558.9 feet.*

	Thickness, feet	*Depth, feet*
Soil, sandy, dark brown	4	4
QUATERNARY—Pleistocene		
McPherson formation		
Clay and silt, gray	4	8
Gravel, fine to medium, and sand, coarse to medium	4	12
Gravel, fine to coarse, and sand, coarse to medium	6	18
Gravel, coarse to fine; contains coarse sand	26	44
Clay and silt, gray to tan	4	48
Gravel, very coarse	4	52
Gravel, coarse to fine; contains coarse sand	17	69
PERMIAN—Leonardian		
Ninnescah shale		
Shale, red brown	1	70

32. *Sample log of test hole at SE cor. NE¼ sec. 22, T. 22 S., R. 6 W.; drilled by Claude Price for the City of Hutchinson, October 1945. Surface altitude, 1,555.0 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene		
McPherson formation		
Sand, fine to medium; contains very fine sand and brown silt	4	4
Clay and silt, gray to tan	3	7
Sand, medium to fine; contains gravel and silt; very poorly sorted	5	12
Gravel, fine to coarse, and sand, coarse	37	49
Sand, coarse to medium, and gravel, fine	13	62
PERMIAN—Leonardian		
Ninnescah shale		
Shale, gray green and brick red	2	64

33. *Sample log of test hole in SE¼ SW¼ SW¼ sec. 24, T. 22S., R. 6 W.; drilled by Claude Price for the City of Hutchinson, October 1945. Surface altitude, 1,552.5 feet.*

	Thickness, feet	*Depth, feet*
Soil, sandy, brown	3	3
QUATERNARY—Pleistocene		
McPherson formation		
Silt and clay, tan; contains some fine sand	5	8
Clay and silt, tan to gray	4	12
Gravel, medium to fine; contains coarse sand and coarse gravel	23	35
PERMIAN—Leonardian		
Ninnescah shale		
Shale, brick red	1	36

34. *Sample log of test hole at NW cor. SW¼ sec. 26, T. 22 S., R. 6 W.; drilled by Claude Price for the City of Hutchinson, October 1945. Surface altitude, 1,553.2 feet.*

	Thickness, feet	*Depth, feet*
Soil, brown; contains some sand	3	3
QUATERNARY—Pleistocene		
McPherson formation		
Clay and silt, gray to brown	7	10
Gravel, fine to medium, and sand coarse to medium; contains plant material	10	20
Gravel, fine to coarse, and sand coarse to medium	5	25
Gravel, fine to coarse; contains some coarse sand	46	71
PERMIAN—Leonardian		
Ninnescah shale		
Shale, red brown	2	73

39. *Sample log of test hole at NW cor. sec. 36, T. 22 S., R. 6 W.; drilled by Claude Price for the City of Hutchinson, October 1945. Surface altitude, 1,546.4 feet.*

	Thickness, feet	*Depth, feet*
Soil, sandy, brown	2	2
QUATERNARY—Pleistocene		
McPherson formation		
Clay, gray	13	15
Gravel, coarse to fine; contains some coarse sand material uniform throughout interval	56	71
PERMIAN—Leonardian		
Ninnescah shale		
Shale, brick red and gray green	1	72

42. *Sample log of test hole at NW cor. sec. 18, T. 23 S., R. 4 W.; drilled by State Geological Survey, December 1944. Surface altitude, 1,546.8 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY		
Dune sand		
Sand, medium to fine; contains some dark-gray silt	6	6
Sand, coarse to fine; contains nodules of limonite	5	11
Silt, light gray, and sand, medium to fine	5	16
Sand, medium to fine, and silt, light gray	12	28
Sand, medium to fine	3	31
Silt, gray to tan	9	40
Silt, buff; contains nodules of calcium carbonate	11	51
PERMIAN—Leonardian		
Ninnescah shale		
Shale, brick red and green gray	6	57

43. *Sample log of test hole in NW¼ SW¼ SW¼ sec. 18, T. 23 S., R. 4 W.; drilled by Claude Price for the City of Hutchinson, October 1945. Surface altitude, 1,500.8 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene		
McPherson formation		
Sand, medium to fine; contains some coarse sand and brown silt	6	6
Clay, tan to gray	4	10
Gravel, medium to fine; contains coarse gravel and coarse sand	33	43
Clay, blue gray	3	46
PERMIAN—Leonardian		
Ninnescah shale		
Shale, hard, red	1	47

45. *Sample log of test hole at NE cor. SE¼ SE¼ sec. 2, T. 23 S., R. 5 W.; drilled by State Geological Survey, December 1945. Surface altitude, 1,601.4 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY		
Dune sand		
Silt, red brown, and sand, loose, fine	7	7
Silt, light gray; contains fine sand	21	28
Sand, fine to medium	4	32
Silt, brown, and sand, fine to medium	26	58
Sand, fine to very fine	16	74
Silt, light brown to gray	13	87
PERMIAN—Leonardian		
Ninnescah shale		
Shale, red brown, gray, and blue green	3	90

47. *Sample log of test hole at NE cor. sec. 3, T. 23 S., R. 5 W.; drilled by Claude Price for the City of Hutchinson, November 1945. Surface altitude, 1,624.5 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY		
Dune sand		
Sand, fine to medium	5	5
Sand, medium to very fine, and silt and clay, blue gray	11	16
Sand, medium to fine	12	28
Sand, medium to fine, and silt and clay, blue gray	3	31
Sand, medium to fine	10	41
Sand, medium to fine; grains stained red brown	6	47
Sand, medium to fine; contains some coarse sand and tan clay	10	57
Sand, medium to very fine; contains gray silt and clay	41	98

47. *Sample log of test hole at NE cor. sec. 3, T. 23 S., R. 5 W. (continued)*

	Thickness, feet	*Depth, feet*
Sand, medium to fine, and clay, gray	9	107
Sand, medium to fine; contains some coarse sand	2	109
Sand, medium to very fine, and clay, gray to tan	14	123
PERMIAN—Leonardian		
Ninnescah shale		
Shale, blue gray and red	1	124

50. *Driller's log of wells at NW¼ NW¼ SE¼ sec. 4, T. 23S., R. 5 W.; drilled by the Atchison, Topeka, and Santa Fe Railway Company, June 1944. Surface altitude, 1,528.3 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene		
McPherson formation		
Sand, fine	12	12
Sand, medium to coarse	3	15
Gravel, fine, and sand, dirty	4	19
Sand and gravel, clean, sharp	4	23
Sand, coarse	2	25
Gravel, fine	1	26
Gravel and sand, coarse	14	40

52. *Sample log of test hole in SE cor. sec. 6, T. 23 S., R. 5 W.; drilled by Claude Price for the City of Hutchinson, October 1945. Surface altitude, 1,528.8 feet.*

	Thickness, feet	*Depth, feet*
Soil, sandy, dark brown	4	4
QUATERNARY—Pleistocene		
McPherson formation		
Silt and clay, gray to brown; contains fine sand	7	11
Gravel, coarse to fine, and sand, coarse; contains some very coarse gravel	29	40
Gravel, coarse to fine	8	48
Gravel, medium to fine; contains coarse gravel and coarse sand; grains and pebbles stained red brown	18	66
PERMIAN—Leonardian		
Ninnescah shale		
Shale, soft, gray green	2	68

53. *Sample log of well at NE cor. sec. 8, T. 23 S., R. 5 W.; drilled by the Layne-Western Company for the Central Fibre Products Company, June 1943. Surface altitude, 1,528.1 feet.*

	Thickness, feet	*Depth, feet*
Soil, brown	3	3
QUATERNARY—Pleistocene		
McPherson formation		
Silt, brown, and sand, very fine	2	5
Sand, medium to coarse; contains fine gravel and fine sand	18	23
Gravel, fine to coarse, and sand, coarse	7	30
Sand, coarse to medium, and gravel, fine to coarse	12	42
Gravel, coarse to fine; contains coarse sand	15	57
Sand, coarse to medium, and gravel, fine to coarse	5	62
PERMIAN—Leonardian		
Ninnescah shale		
Shale, micaceous, light brown	1	63

54. *Sample log of test hole in NW¼ SW¼ sec. 11, T. 23 S., R. 5 W.; drilled by Claude Price for the City of Hutchinson, October 1945. Surface altitude, 1,515.2 feet.*

	Thickness, feet	*Depth, feet*
Soil, brown, very sandy	3	3
QUATERNARY—Pleistocene		
McPherson formation		
Sand, medium to fine, contains coarse sand	7	10
Gravel, coarse to fine; contains some very coarse gravel	16	26
Gravel, coarse to fine	10	36
PERMIAN—Leonardian		
Ninnescah shale		
Shale, green	1	37

55. *Sample log of test hole at SE cor. sec. 13, T. 23 S., R. 5 W.; drilled by Claude Price for the City of Hutchinson, October 1945. Surface altitude, 1,499.4 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene		
McPherson formation		
Sand, medium to fine	6	6
Clay, gray; contains fine sand	4	10
Gravel, coarse to fine; contains coarse sand; grains and pebbles stained red brown	18	28
Gravel, fine to coarse, and coarse sand	13	41
Silt, tan, soft	12	53
Gravel, fine to medium, and sand, coarse to medium	48	101
Gravel, medium to fine, and coarse sand	36	137
PERMIAN—Leonardian		
Ninnescah shale		
Shale, blue gray	2	139

56. *Sample log of test hole at NE cor. sec. 14, T. 23 S., R. 5 W.; drilled by State Geological Survey, December 1944. Surface altitude, 1,520.5 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene		
McPherson formation		
Sand, medium to fine	3	3
Silt, blue gray, interbedded with sand, medium to fine, limonitic	14	17
Silt, brown; contains much organic material	3	20
Gravel, coarse to fine, and sand, coarse	10	30
Gravel, medium to fine, and sand, coarse	4	34
PERMIAN—Leonardian		
Ninnescah shale		
Shale, brick red	2	36

57. *Sample log of test hole at NE cor. SE¼ sec. 14, T. 23 S., R. 5 W.; drilled by Claude Price for the City of Hutchinson, October 1945. Surface altitude, 1,503.8 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene		
McPherson formation		
Sand, medium to fine; contains some coarse sand	4	4
Sand, medium to fine; contains tan silt and clay, and some coarse sand	3	7
Gravel, fine to coarse, and sand, coarse	35	42
Gravel, fine to medium, and sand, coarse	5	47
PERMIAN—Leonardian		
Ninnescah shale		
Shale, red and blue gray	2	49

58. *Sample log of test hole at NE cor. sec. 15, T. 23 S., R. 5 W., drilled by State Geological Survey, December 1944. Surface altitude, 1,511.4 feet.*

	Thickness, feet	*Depth, feet*
Soil, very sandy, brown	2	2
QUATERNARY—Pleistocene		
McPherson formation		
Silt, yellow gray; contains fine gravel and coarse to fine sand	4	6
Gravel, fine to coarse, and sand, coarse to medium	4	10
Sand, coarse to fine; contains some fine to medium gravel	10	20
Gravel, medium to fine, and sand, coarse; interval includes a few thin beds of green clay	33	53
PERMIAN—Leonardian		
Ninnescah shale		
Shale, thin-bedded, brick red, and some green shale	4	57

59. *Sample log of test hole at SE cor. sec. 15 T. 23 S., R. 5 W.; drilled by Claude Price for the City of Hutchinson, October 1945. Surface altitude, 1,507.1 feet.*

	Thickness, feet	*Depth, feet*
Soil, brown, sandy	3	3
QUATERNARY—Pleistocene		
McPherson formation		
Clay, gray to tan	5	8
Gravel, fine to coarse, and sand, coarse	6	14
Gravel, coarse to fine	4	18
Gravel, coarse to fine, and sand, coarse	27	45
Clay, green to tan	1	46
Gravel, fine to coarse, and sand, coarse	13	59
PERMIAN—Leonardian		
Ninnescah shale		
Shale, red brown	1	60

60. *Sample log of test hole at NE cor. sec. 16, T. 23 S., R. 5 W.; drilled by Claude Price for the City of Hutchinson, October 1945. Surface altitude, 1,517.5 feet.*

	Thickness, feet	*Depth, feet*
Soil, brown, sandy	3	3
QUATERNARY—Pleistocene		
McPherson formation		
Clay, tan to gray	7	10
Gravel, coarse to fine; contains some coarse sand	8	18
Gravel, very coarse to fine	17	35
Gravel, coarse to fine, and sand, coarse	11	46
Clay, tan	2	48
Gravel, coarse to fine	15	63
PERMIAN—Leonardian		
Ninnescah shale		
Shale, brick red and gray green	1	64

63. *Driller's log of city-supply well (Cleveland St. well) at NE cor. NW¼ SW¼ sec. 18, T. 23 S., R. 5 W.; drilled for United Gas, Water, and Electric Company (now owned by Hutchinson Water Company), June 1922. Surface altitude, 1,531.0 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene		
McPherson formation		
Sand and gravel	10	10
Gravel and clay balls	18	28
Clay balls and gravel	20	48
Good clean sand	13	61
Fine sand	17	78

67. *Sample log of test hole at NE cor. sec. 21, T. 23 S., R. 5 W.; drilled by Claude Price for the City of Hutchinson, October 1945. Surface altitude, 1,514.4 feet.*

	Thickness, feet	*Depth, feet*
Soil, brown, very sandy	2	2
QUATERNARY—Pleistocene		
McPherson formation		
Clay, buff to tan	9	11
Gravel, very coarse to fine	24	35
Gravel, coarse to fine; contains thin layers of clay in lower part of interval	25	60
PERMIAN—Leonardian		
Ninnescah shale		
Shale, red	2	62

69. *Sample log of test hole at SE cor. sec. 23, T. 23 S., R. 5 W.; drilled by Claude Price for the City of Hutchinson, October 1945 Surface altitude, 1,498.1 feet.*

	Thickness, feet	*Depth, feet*
Soil, very sandy, brown	2	2
QUATERNARY—Pleistocene		
McPherson formation		
Clay, soft, tan	2	4
Gravel, coarse to fine, and sand, coarse	42	46
Gravel, fine to medium, and sand, coarse to medium; grains stained red brown	4	50
Gravel, coarse to fine	47	97
PERMIAN—Leonardian		
Ninnescah shale		
Shale, blue green	3	100

70. *Sample log of test hole at SE cor. NE¼ sec. 24, T. 23 S., R. 5 W.; drilled by State Geological Survey, December 1945. Surface altitude, 1,495.0 feet.*

	Thickness, feet	*Depth, feet*
Soil, brown	4	4
QUATERNARY—Pleistocene		
McPherson formation		
Silt and clay, plastic, light gray	5	9
Gravel, fine to medium, and sand, coarse to medium; contains some gray silt	59	68
PERMIAN—Leonardian		
Ninnescah shale		
Shale, red and blue green	4	71

72. *Sample log of test hole at NE cor. sec. 29, T. 23 S., R. 5 W.; drilled by Claude Price for the City of Hutchinson, October 1945. Surface altitude, 1,515.5 feet.*

	Thickness, feet	*Depth, feet*
Soil, sandy, brown to gray	2	2
QUATERNARY—Pleistocene		
McPherson formation		
Clay, gray	5	7
Clay and silt, gray to tan; contains fine sand	4	11
Gravel, fine to coarse, and sand, coarse	24	35
Gravel, coarse to fine, and sand, coarse	12	47
PERMIAN—Leonardian		
Ninnescah shale		
Shale, red	3	50

76. *Sample log of test hole at NW cor. sec. 32, T. 23 S., R. 5 W.; drilled by Claude Price for the City of Hutchinson, October 1945. Surface altitude, 1,512.1 feet.*

	Thickness, feet	*Depth, feet*
Soil, sandy, dark gray to brown	2	2
QUARTERNARY		
Alluvium and McPherson formation		
Gravel, coarse to fine; contains clay balls near middle of interval	31	33
Gravel, coarse to fine	25	58
PERMIAN—Leonardian		
Ninnescah shale		
Shale, gray green	2	60

78. *Sample log of test hole at NE cor. sec. 1, T. 23 S., R. 6 W.; drilled by Claude Price for the City of Hutchinson, October 1945. Surface altitude, 1,539.0 feet.*

	Thickness, feet	*Depth, feet*
Soil, sandy, brown	3	3
QUATERNARY—Pleistocene		
McPherson formation		
Clay, tan to gray	8	11
Gravel, coarse to fine; contains coarse sand; material throughout interval	59	70
PERMIAN—Leonardian		
Ninnescah shale		
Shale, brick red	2	72

85. *Driller's log of city-supply well (Main St. well) at SW¼ SW¼ SE¼ sec. 12, T. 23 S., R. 6 W.; drilled for United Gas, Water and Electric Company (now owned by Hutchinson Water Company), July 1922.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene		
McPherson formation		
Sand and gravel	16	16
Good gravel	18	34
Gravel and sand	12	46
Sand, some clay balls	9	55
Fine clean sand	20	75

95. *Sample log of test hole at NW cor. sec. 12, T. 24 S., R. 6 W.; drilled by Claude Price for the City of Hutchinson, November 1945. Surface altitude, 1,545.7 feet.*

	Thickness, feet	*Depth, feet*
Soil, sandy, dark gray	3	3
QUATERNARY—Pleistocene		
McPherson formation		
Clay, buff to tan; contains fine sand	11	14
Clay, blue gray	6	20
Sand, coarse to fine; contains some fine gravel	9	29
Sand, coarse to medium, and fine gravel	11	40
Clay, gray, hard	6	46
Gravel, fine to medium, and sand, coarse to medium	26	72
Clay, gray	8	80
Gravel, fine to medium, and sand, coarse to fine; very poorly sorted	72	152
PERMIAN—Leonardian		
Ninnescah shale		
Shale, gray green	1	153

93. *Sample log of test hole at SE cor. sec. 36, T. 23 S., R. 6 W.; drilled by Claude Price for the City of Hutchinson, October 1945. Surface altitude, 1,523.0 feet.*

	Thickness, feet	*Depth, feet*
Soil, sandy, brown	3	3
QUATERNARY—Pleistocene		
McPherson formation		
Clay, buff; contains fine sand	6	9
Clay, buff, and sand, fine; partly cemented zone at 19 feet	11	20
Gravel, coarse to fine, and sand, coarse to medium	44	64
Gravel, and sand, coarse to fine, and clay, gray to buff	10	74
Sand, coarse to medium, and gravel, fine	5	79
Clay, buff, and sand fine	10	89
Gravel, medium to fine, and sand, coarse to medium	35	124
Gravel, medium to fine, and sand, coarse to medium; contains some buff clay and fragments of shale	12	136
PERMIAN—Leonardian		
Ninnescah shale		
Shale, red and gray	2	138

94. *Sample log of test hole at SW cor. sec. 11, T. 24 S., R. 6 W.; drilled by State Geological Survey, December 1945. Surface altitude, 1,547.5 feet.*

	Thickness, feet	*Depth, feet*
Soil, dark gray	3	3
QUATERNARY—Pleistocene		
McPherson formation		
Silt, light gray	4	7
Silt, light brown, iron-stained; contains some fine sand	8	15
Gravel, fine, and sand, fine to coarse	28	43
Gravel, fine, sand, fine to medium, and silt, buff	6	49
Silt, dark tan	12	61
Silt, brown, and sand, fine to coarse; contains some caliche	9	70
Sand, fine to medium, and gravel, fine; contains some gray to brown silt	11	81
Silt, tan, interbedded with sand, fine	9	90
Silt and clay, gray to red brown; plastic	13	103
PERMIAN—Leonardian		
Ninnescah shale		
Shale, red and light blue	3	106

96. *Sample log of test hole at NW cor. sec. 22, T. 24 S., R. 6 W.; drilled by State Geological Survey, December 1945. Surface altitude, 1,558.9 feet.*

	Thickness, feet	*Depth, feet*
Road material	2	2
QUATERNARY—Pleistocene		
McPherson formation		
Silt, gray	5	7
Silt, light gray; contains nodules of calcium carbonate	5	12
Silt, tan	5	17
Sand, fine to very fine; contains tan silt	10	27
Silt, tan to red brown; contains some fine sand	18	45
Silt, brown; contains nodules of calcium crabonate	4	49
Silt, gray and red brown	10	59
PERMIAN—Leonardian		
Ninnescah shale		
Shale, soft, red and blue green	3	62

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