UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

WATER DEVELOPMENT FOR IRRIGATION IN NORTHWESTERN KANSAS

OPEN-FILE REPORT

4-75

WATER
RESOURCES
DIVISION

KANSAS DISTRICT

LAWRENCE, KANSAS

MARCH 1975

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By

Edward D. Jenkins and Marilyn E. Pabst

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WATER DEVELOPMENT FOR IRRIGATION IN NORTHWESTERN KANSAS

Edward D. Jenkins and Marilyn E. Pabst

ABSTRACT

Northwestern Kansas, an area of 8,050 square miles (21,000 square kilometres), is a flat to gently rolling plain that is dissected by the Smoky Hill and Republican Rivers. Loessial soils underlying the plain are ideal for cultivation.

The climate is semiarid with the mean annual precipitation ranging from 16 to 21 inches (41 to 53 centimetres). Precipitation occurring mainly as thunderstorms during the 6-month growing season is four to five times less than the potential evaporation.

Principal aquifers are the Dakota Formation, which yields a few gallons per minute of water to domestic and stock wells; the Ogallala Formation, which commonly yields 500 to 1,200 gallons per minute (32 to 76 litres per second) to irrigation wells; and the alluvium, which locally yields as much as 1,500 gallons per minute (95 litres per second) to irrigation wells.

Irrigation by ground water from wells has developed principally since the early 1950's. Development has increased from about 100 wells irrigating 10,000 acres (4,000 hectares) in 1950 to about 2,200 wells irrigating 300,000 acres (120,000 hectares) in 1972. The rate of withdrawal by irrigation, municipal, and industrial wells in 1972 was about 500,000 acre-feet (620 x 10^6 cubic metres) of water per year, of which about 99 percent was for irrigation.

A comparison of water levels measured in 1950 and in 1973 indicates that declines greater than 10 feet (3 metres) are common in much of the area. Declines greater than 30 feet (9 metres) have occurred near Goodland and Colby. The areas of greatest irrigation-well density correspond to the areas of greatest water-level decline.

More ground water could be withdrawn annually for irrigation, but additional water-level declines in some areas may make the wells uneconomical to pump. The ground-water reservoir can be managed to prolong the irrigation economy of the area.

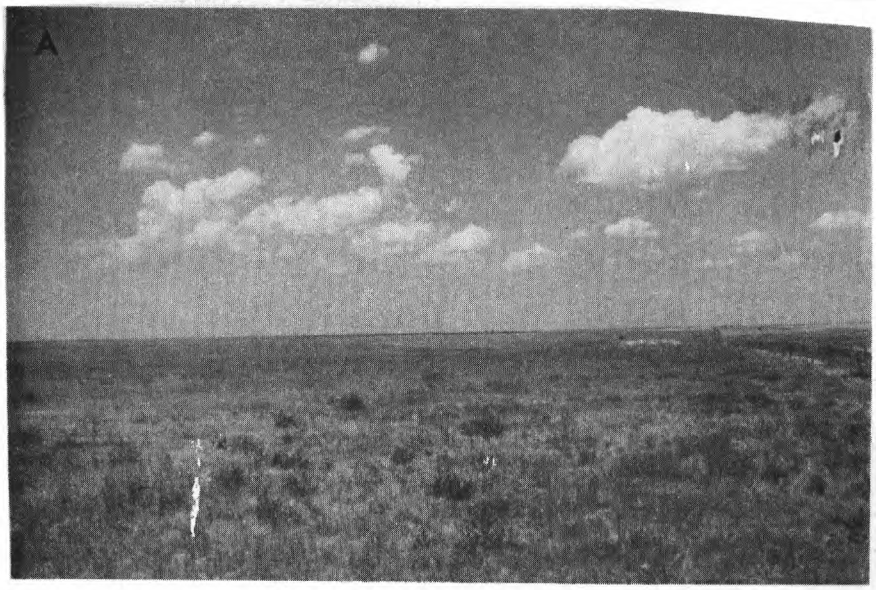


Figure 1.--A, the expanses of prairie that awaited homesteaders and settlers; B, a solitary windmill that gave evidence of habitation.

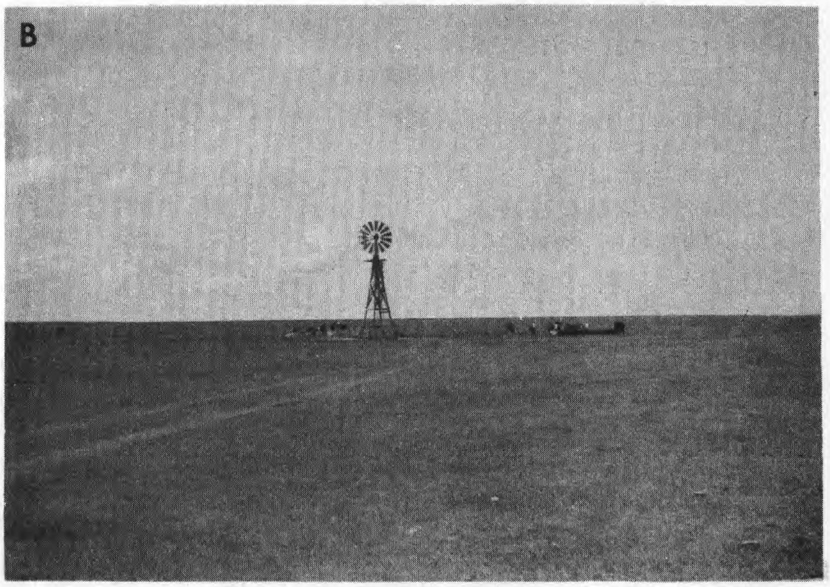


Figure 2.--Harvest time in the "Wheat State."

INTRODUCTION

The development of ground water in northwestern Kansas began when the early settlers on the High Plains constructed wells to supply water for their farms and livestock. During those early years, the vast plains were marked only by an occasional windmill that stood on the horizon as a welcome sign of habitation to the oncoming homesteaders and settlers (fig. 1). The lack of dependable precipitation in summer generally discouraged raising of crops with the exception of wheat. Kansas soon became known as the "Wheat State," and Colby boasted the title of "The Golden Buckle on the Wheat Belt" (fig. 2). With the advent of irrigation, the tremendous production capabilities of the fertile soil are being realized.

This report summarizes water information that has been collected for many years in northwestern Kansas. A cooperative program between the Kansas Geological Survey and the U.S. Geological Survey with data and support from the Kansas Water Resources Board, the Division of Water Resources of the Kansas State Board of Agriculture, and the Division of Environmental Health of the Kansas State Department of Health has been in progress, at least in part, since 1937. Many reports have been prepared as a result of this cooperative effort, and many of these reports are listed in the section entitled, "Where more information can be found."

An intensive study and inventory of ground water in northwestern Kansas began in 1965 with the establishment of an office in Colby staffed by personnel of the Kansas Geological Survey and the U.S. Geological Survey. Information collected in earlier studies has been updated and both technical and basic-data reports have been prepared. Principal among these are Geological Survey Hydrologic Investigations Atlases HA-429 and HA-521, Water resources of northwestern Kansas (Pearl and others, 1972), Water resources in Gove, Logan, and Wallace Counties, west-central Kansas (McClain and others, in press) and Kansas Ground Water Basic Data Releases 1 and 2. This comprehensive report, which contains the principal conclusions from these studies, also provides information on the potential for additional ground-water development in northwestern Kansas.

For those readers who are familiar with or are interested in the metric system of measurement, English units in this report are given in equivalent metric units (in parentheses) using the following abbreviations and conversion factors:

English units	Multiply by	Metric units
inches (in)	2.54	centimetres (cm)
feet (ft)	.3048	metres (m)
miles (mi)	1.609	kilometres (km)
acres	4047	square metres (m^2)
	.4047	hectares (ha)
square miles (mi^2)	2.590	square kilometres (km^2)
acre-feet (acre-ft)	1233	cubic metres (m^3)
gallons (gal)	3.785×10^{-3}	cubic metres (m^3)
gallons per minute (gpm)	6.309×10^{-5}	litres per second (l/s) cubic metres per second (m^3/s)

Acknowledgments

The authors are grateful for the advice, suggestions, and information given by our associates in the State and Federal Geological Surveys, by personnel from other State and Federal agencies related to agriculture and water resources, and by county and city officials, oil- and power-company personnel, water well drillers, and well owners and operators. The authors especially are grateful for the many contributions to the project for which individual credit is not given and for the numerous benefits derived from conversations with our colleagues.

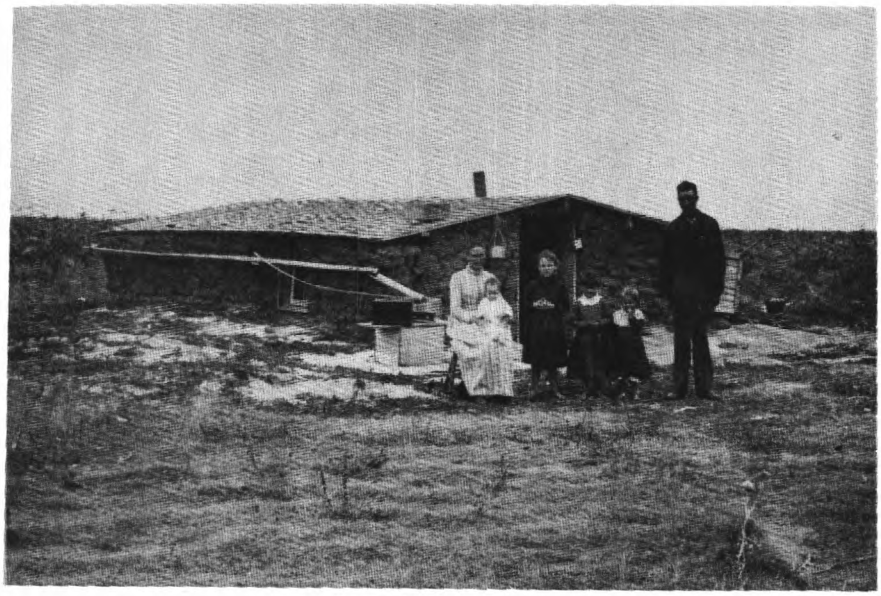
This report is dedicated to the hardy pioneers who settled northwestern Kansas in the period between the Civil War and the turn of the century. These forefathers came from every class, condition, and station, lured to the west by the prospect of land and homes of their own (fig. 3). Not all the settlers were able to withstand the hardships of working the land in their new environment, but those who managed to stay through the hard times generally prospered and expanded their operations. Today, the descendants of those early pioneers commonly operate large farm units (fig. 4) with large investments in machines and irrigation equipment.

Description of Area

This report concerns an area of 8,050 square miles (21,000 km^2) in northwestern Kansas located north of the Smoky Hill River and west of the eastern boundary of Decatur, Sheridan, and Gove Counties (fig. 5). The area is part of the High Plains physiographic province, and is generally a grassy prairie with few trees. The flat to gently rolling land surface slopes eastward at about 10 to 14 feet per mile (2 to 3 m/km). The high point in the area, as well as in Kansas, is 4,039 feet (1,231 m) above sea level on Mt. Sunflower, which is near the State line about 22 miles (35 km) south of Kanorado. The low point is about 2,300 feet (700 m) above sea level in the Smoky Hill River valley in the southeast part of the area. All of northwestern Kansas is drained by the Smoky Hill and Republican Rivers and their tributaries.

The High Plains are underlain mostly by silt and fine sand that was deposited by the wind. These deposits, known as loess, form deep fertile soils that are ideal for cultivation because of the gentle slope, moisture-retention properties, and absence of rocks. Large expanses of the loess-covered plains are used for raising wheat by "dry-land" farming. Many areas of previously dry land are presently utilizing ground water from wells to irrigate crops that have high cash value or crops to support the cattle industry.

When the loessial soils are dry, areas with no cover of vegetation are subject to wind erosion. Shallow undrained depressions, which may have been scooped out by the wind, are common features of the nearly flat High Plains. These depressions, which range in diameter from a few tens of feet to about half a mile, become temporary ponds after heavy rains.



Courtesy of Kansas State Historical Society

Figure 3.--The typical dwelling of early settlers was the sod house.

Courtesy of Sherman County Soil Conservation Service

Figure 4.--Large farm units with massive equipment now dominate the scene in western Kansas.

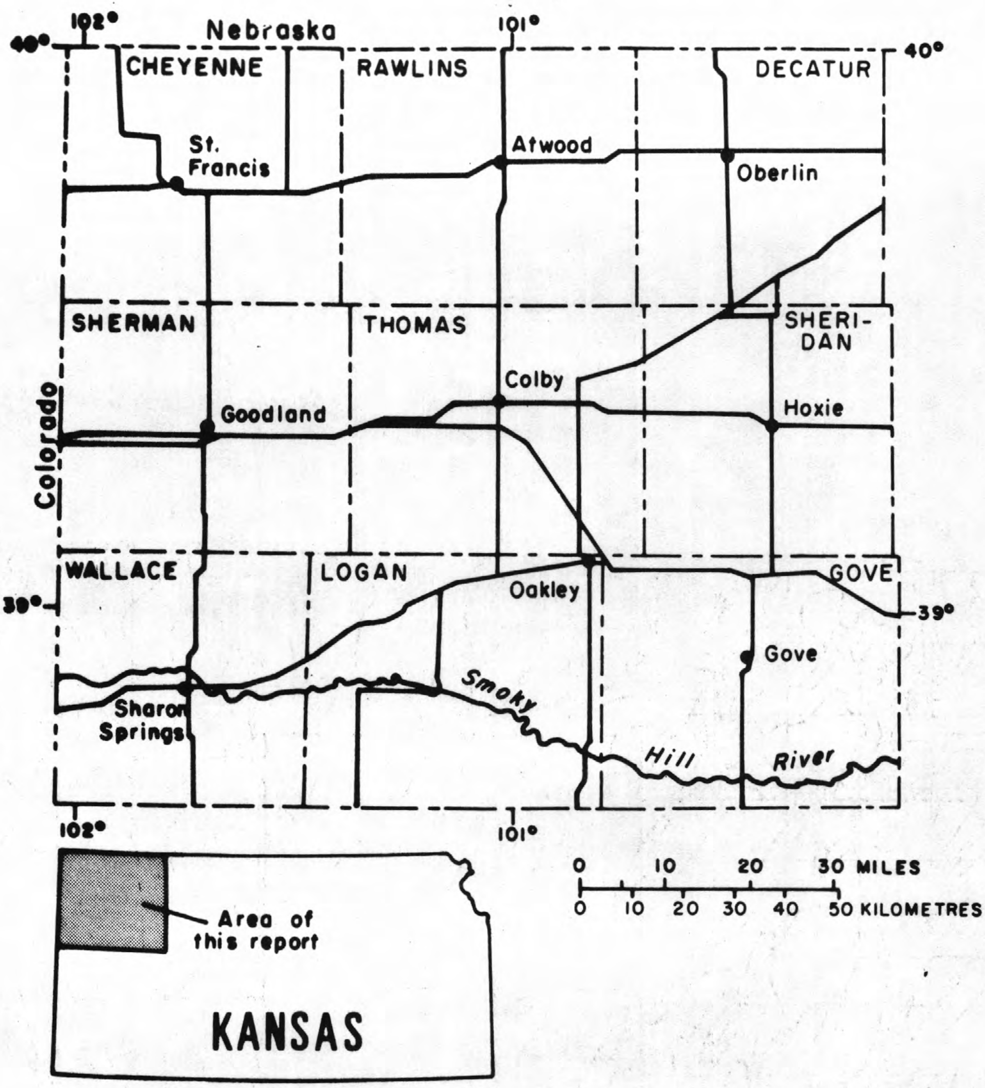


Figure 5.--Location of area discussed in this report.

The plains surface has been dissected by many streams, and deposits of sand, gravel, and caliche of the Ogallala Formation are exposed along the valleys (fig. 6). The break at the edge of the plains may be abrupt, but the slope between the break and the floodplain of the streams commonly is gentle. The broad, gently sloping areas generally are used for grazing cattle on native grass.

Badland topography has been formed along the Smoky Hill Valley by erosion of chalk beds of Cretaceous age. Several prominent exposures of chalk were trail markers on the old B.O.D. (Butterfield Overland Despatch) route that passed near the Chalk Pyramids and Castle Rock in Gove County (fig. 7).

The floodplains of the principal streams, which are underlain by deposits of clay, silt, sand, and gravel, comprise good farmland. Alfalfa commonly is raised on the floodplains because the water table generally is at shallow depths and occasionally water for irrigation is available from the streams.

Photograph by T. J. McClain

Figure 6.--Cemented beds of the Ogallala Formation exposed along valleys in Gove County.

Photograph by T. J. McClain

Figure 7.--The Chalk Pyramids near the "Badlands" in Gove County.

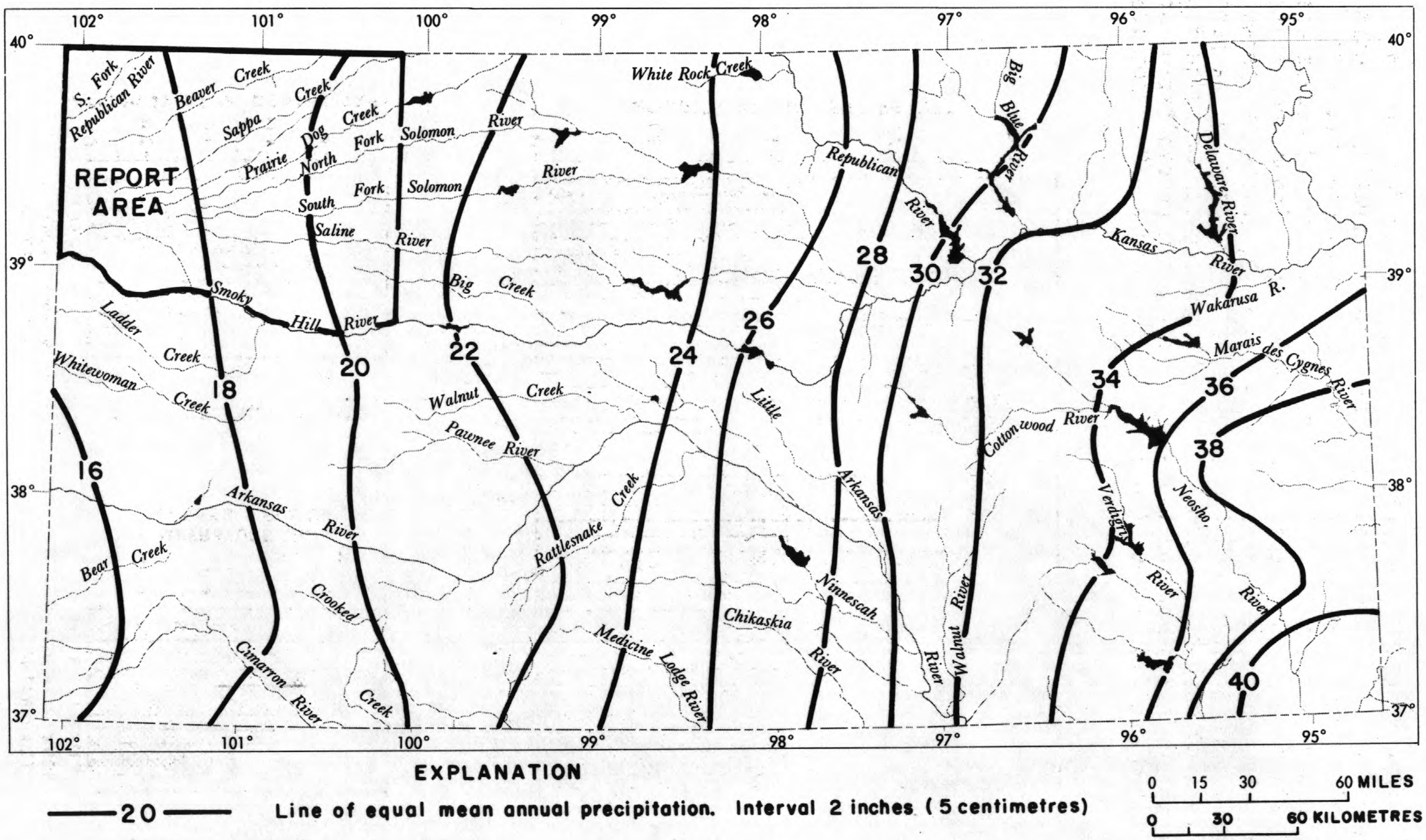


Figure 8.--Mean annual precipitation in Kansas, 1931-60.
(Data from National Weather Service.)

Northwestern Kansas is semiarid and windy. Summer days are hot. Winters are moderate, although cold periods of short duration are common and occasionally there are blizzards. The mean annual precipitation (fig. 8) ranges from about 16 to 21 inches (41 to 53 cm) and occurs mostly as short-duration thunderstorms in spring and summer. Annual precipitation at Colby for the period 1931-71 is shown on figure 9, which also shows the normal monthly precipitation and temperature at Colby based on the period 1931-60. Years of much-below-normal precipitation are common; significant droughts occurred in 1934-37 and 1954-56. Extremes in precipitation at Colby since 1888 are 6.62 inches (16.8 cm) in 1910 and 30.70 inches (78.0 cm) in 1941.

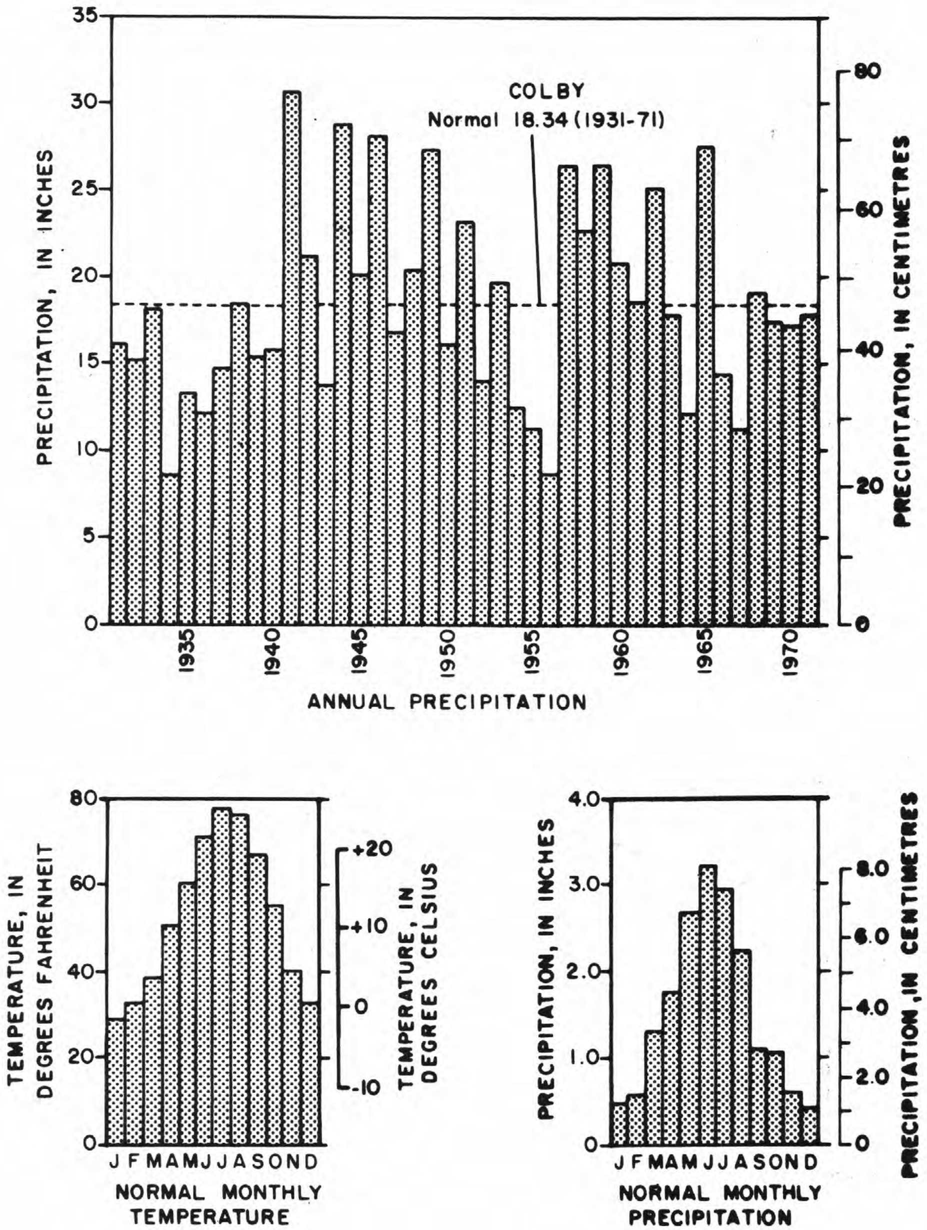


Figure 9.--Annual precipitation (1931-71), and normal monthly precipitation and temperature (1931-60) at Colby.

Temperatures during the growing season are favorable for luxuriant plant growth when sufficient water is available. Normal monthly temperatures from April to October range from 51°F to 78°F (fig. 16), but daytime temperatures often reach the 90's and 100's. Transpiration and plant growth are greatest when temperatures are high because more plant food becomes available as the growing plant uses more water.

Soil temperature at a 4-inch (10-cm) depth under fallow ground at the Goodland Weather Station varied from 24°F in January 1971 to 90°F in July and August 1971. Average monthly soil temperature is shown on figure 10. Optimum plant growth occurs between 70°F and 90°F and practically ceases when temperatures go below 50°F. The average length of the growing season is 162 days.

Most of the precipitation in northwestern Kansas evaporates or is transpired through plants. Droplets of water on plants commonly evaporate quickly. Water at the surface of the soil and at the surface of ponds and streams also is evaporated. Evaporation is increased by the wind, low humidity, and high temperatures that are common to the area.

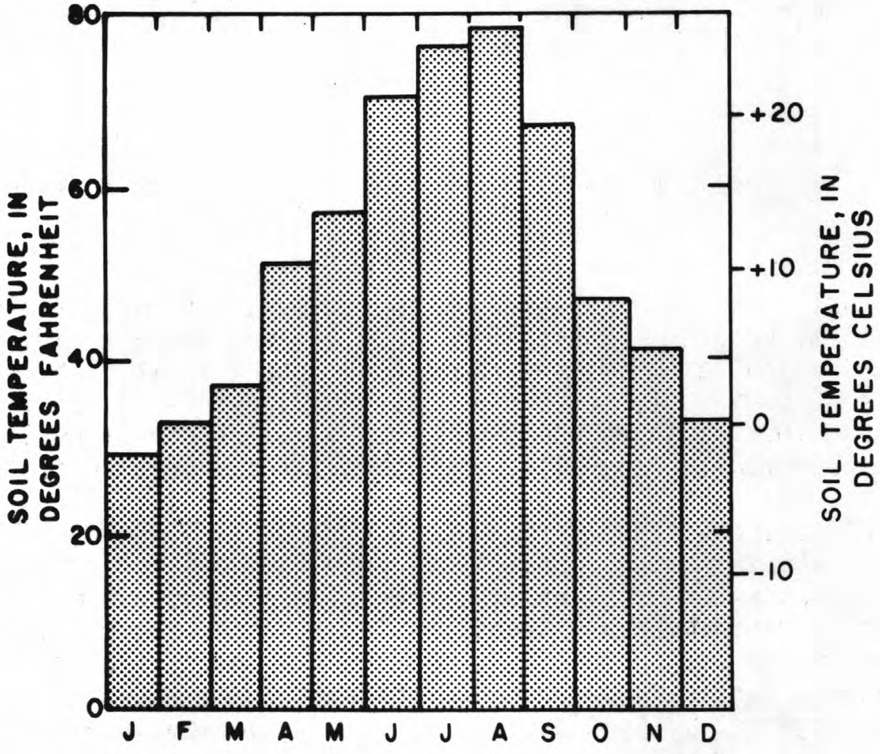


Figure 10.--Average 11:00 A.M. monthly temperature at a 4-inch depth under fallow ground at Goodland, Kansas during 1971 (National Weather Service).

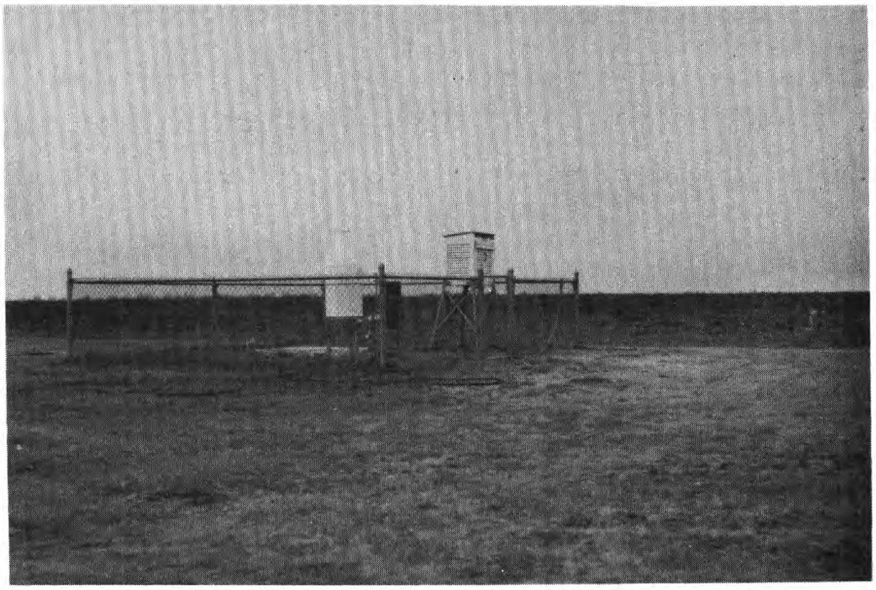


Figure 11.--Meteorological Equipment at Colby Experiment Station is used in measuring evaporation.

Evaporation has been measured at the Colby Experiment Station (fig. 11) from April 1 to October 1 since 1914. The 50-year average (1914-63) for the 6-month period, as measured from a sunken tank level with the land surface, is 42.67 inches (108.4 cm). Evaporation measured in 1966-73 from a tank 1 foot (0.3 m) above the ground is about 1.5 times greater than from the sunken tank. Generally, the potential evaporation is from 4 to 5 times greater than the normal precipitation of 13.93 inches (35.4 cm) during the 6-month growing season.

Plants take in water and nutrients from the soil for use in the growth process. Excess water is given off (transpired) through the leaves as water vapor. Evaporation and transpiration together are called evapotranspiration, which is the process by which about 90 percent of the precipitation in northwestern Kansas is returned to the air.

The average net irrigation requirement for various crops is shown in table 1.

Large cracks sometimes form when the loessial soils are dry. When moisture again is available from precipitation or from irrigation wells, these cracks provide a means for water to accumulate below the root zone. Some of this water may eventually reach the water table.

Small cracks in the loessial soils are common following dry periods and during the winter freeze-thaw cycle. These small cracks generally disappear as the soil absorbs moisture and expands.

DEVELOPMENT OF IRRIGATION

Early Attempts

Irrigation has been practiced on a small scale in northwest Kansas since the earliest settlers diverted water from streams in the late 1800's. However, because many of the streams were dry most of the time, the quantity of water available for diversion was enough to irrigate only limited acreages of bottom land adjacent to the streams. The limited availability of surface water in the area is caused by two factors. Most streams in the western part of the area lose flow by infiltration to the water table and, consequently, flow only during and for a short time after periods of heavy precipitation. Furthermore, runoff amounts to only 1 to 2 percent of the average annual precipitation because of the nearly flat land surface and the ability of the soils to absorb and hold moisture.

Table 1.--Average net irrigation requirements for crops grown in the area. [Data from Hanson and Meyer, 1953; Israelson and Hansen, 1967; and National Weather Service.]

Crop	Total moisture requirement, in inches1/	Normal precipitation at Colby during growing season, in inches1/	Average net irrigation requirements, in inches1/
Alfalfa	30	14	16
Beans	22	10	12
Corn	24	11	13
Milo	22	10	12
Sugar beets	30	12	18

1/ Inches times 2.54 equals centimeters.

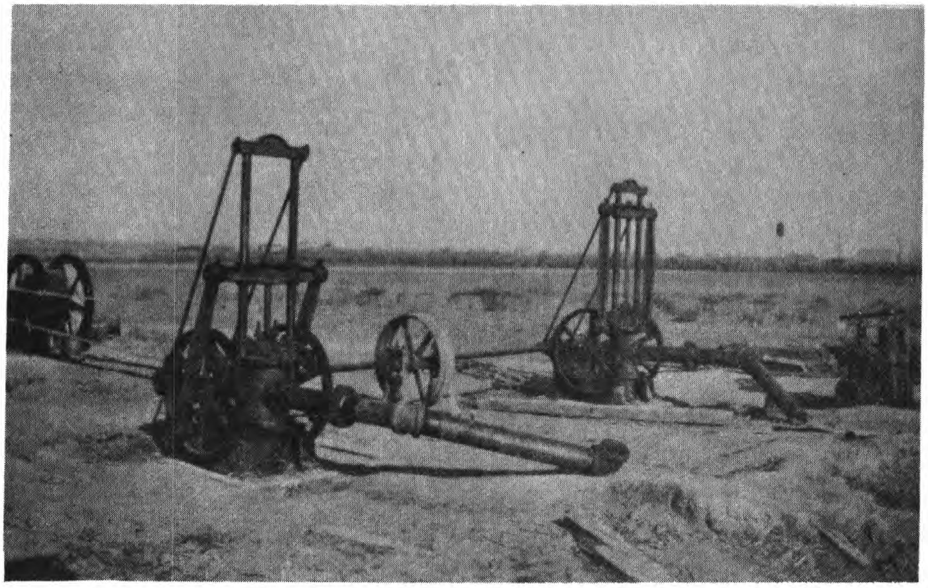


Figure 12.--Engine and pump head of the first irrigation plant at Colby Experiment Station. (Photograph from Kansas State University Bulletin 468.)

Windmills were used in northwestern Kansas as early as 1875 to pump water for the irrigation of small areas of crops and gardens. Windmills with wheels 12 to 16 feet (4 to 5 m) in diameter commonly would pump 1,000 gallons (4 m^3) of water per hour when the depth to water was 15 to 20 feet (5 to 6 m) and the wind velocity was 12 miles (19 km) per hour or more (Frost, et. al., 1897, p. 155). Windmills on the uplands, where the depth to water was 50 to 150 feet (15 to 46 m), commonly were used to irrigate gardens of 1 acre (0.4 ha) or less. An irrigation well dug in 1910 by Henry Tagtmeyer in Sherman County was used to irrigate potatoes, watermelons and other truck-garden crops for sale to the residents of Goodland and to the railroad.

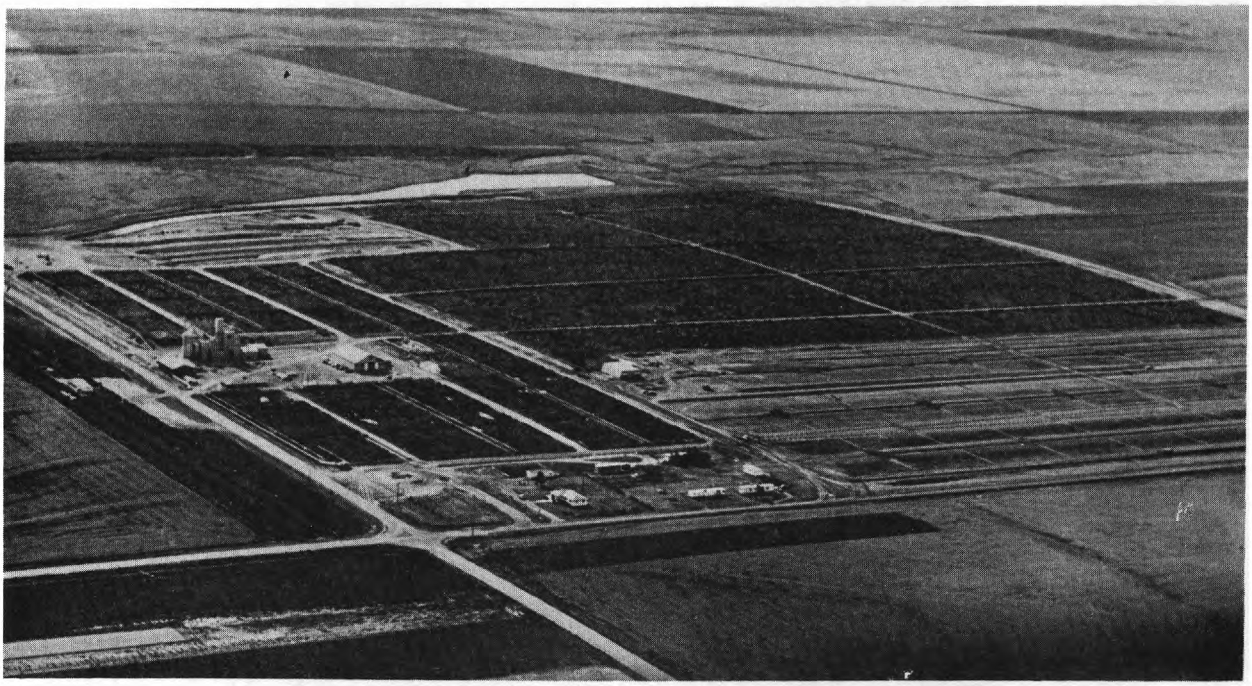
In 1914 an irrigation plant was installed at the Colby Experiment Station (Call, 1964) at the southwest corner of Colby (NW¼ sec. 1, T. 8S., R. 34 W.) to irrigate small areas of alfalfa, corn and sorghum silage, potatoes, pinto beans, and a fruit orchard. The plant consisted of two wells, 12 feet (4 m) apart, equipped with 5 3/4-inch (14.6 cm) cylinder pumps powered by an eight-horsepower engine, as shown in figure 12. The capacity of the plant was tested to 200 gpm (gallons per minute), which is equivalent to 12.6 l/s (liters per second). The depth to water was reported to be 112 feet (34 m) below the land surface at that time. During 1919, the pumping plant was operated for 318 hours at a rate of 98 gpm (6.2 l/s). The cost of diesel fuel and oil was reported to be $5.62 per acre-foot (1.2 x 10^3 m^3) of water pumped. Irrigation at the Experiment Station was abandoned in about 1920 because of mechanical difficulties and the shortage of labor after World War I, but was resumed in 1957 with the drilling of a new well and the installation of a turbine pump. One of the original wells is now equipped with a continuous recorder to monitor the changes in water level as ground water is withdrawn for irrigation.

The Major Development

Irrigation in northwestern Kansas has developed primarily since the early 1950's when power and efficient pumping plants became available and when there was a rising demand for agricultural crops. The laying of distribution lines for natural gas greatly spurred interest in irrigation. Further encouragement came from the successful introduction to the area of irrigated crops of high cash value such as sugar beets, corn, and pinto beans. With the removal of acreage restrictions on sugar beets in 1960, a new industry developed in the area. Another new industry is developing rapidly as many farmers are irrigating corn and milo for use as feed for cattle in feedlots (fig. 13).

Growth Rate

Many irrigation wells have been drilled in northwestern Kansas; the location of the wells as of 1972 is shown on plate 1. Development of ground water has progressed from about 100 wells irrigating 10,000 acres (4,000 ha) in 1950 to about 2,200 wells irrigating 300,000 acres (120,000 ha) in 1972. The greatest increase in the number of wells began in about 1966 and is continuing, as shown on figure 14. The amount of ground water withdrawn for irrigation has increased also as the number of wells and irrigated acres have increased. About 500,000 acre-feet (620 x 10^6 m^3) of ground water was pumped for irrigation, municipal, and industrial uses in 1972 in northwestern Kansas. About 99 percent of the total pumpage was for irrigation.



Courtesy of Pioneer Feed Yards, Inc.

Figure 13.--Cattle in feedlots provide a new market for farmers growing corn and milo.

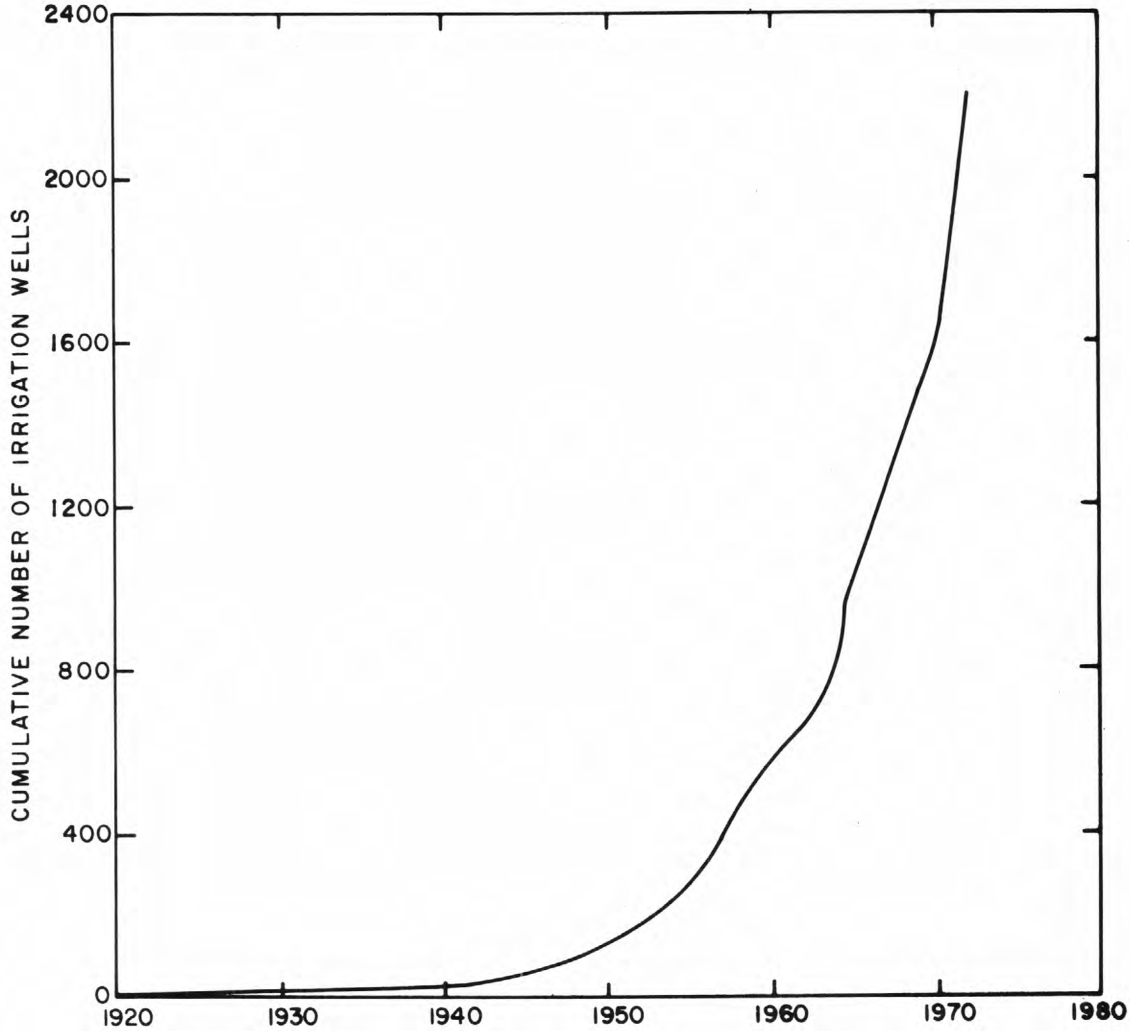


Figure 14.--Cumulative number of irrigation wells constructed during 1920-72.

Source of the Water

The origin of all the water in northwestern Kansas is precipitation on the area or on adjacent areas in Colorado. The movement of water into and out of the area is shown by the diagrammatic sketch on figure 15. Recharge to the ground-water reservoir is by percolation to the water table of a small part of the precipitation that infiltrates the land surface, by ground-water inflow across the State line, and by seepage losses from streams during periods of short duration following major storms. Discharge from the ground-water reservoir is by evapotranspiration, by ground-water outflow to adjacent areas to the east, by streams, and by wells. The total amount of recharge to and discharge from the ground-water reservoir in northwestern Kansas is unknown. Annual recharge from precipitation is estimated to be about 0.25 inch (0.6 cm), or about 100,000 acre-feet (120×10^6 m^3) of water.

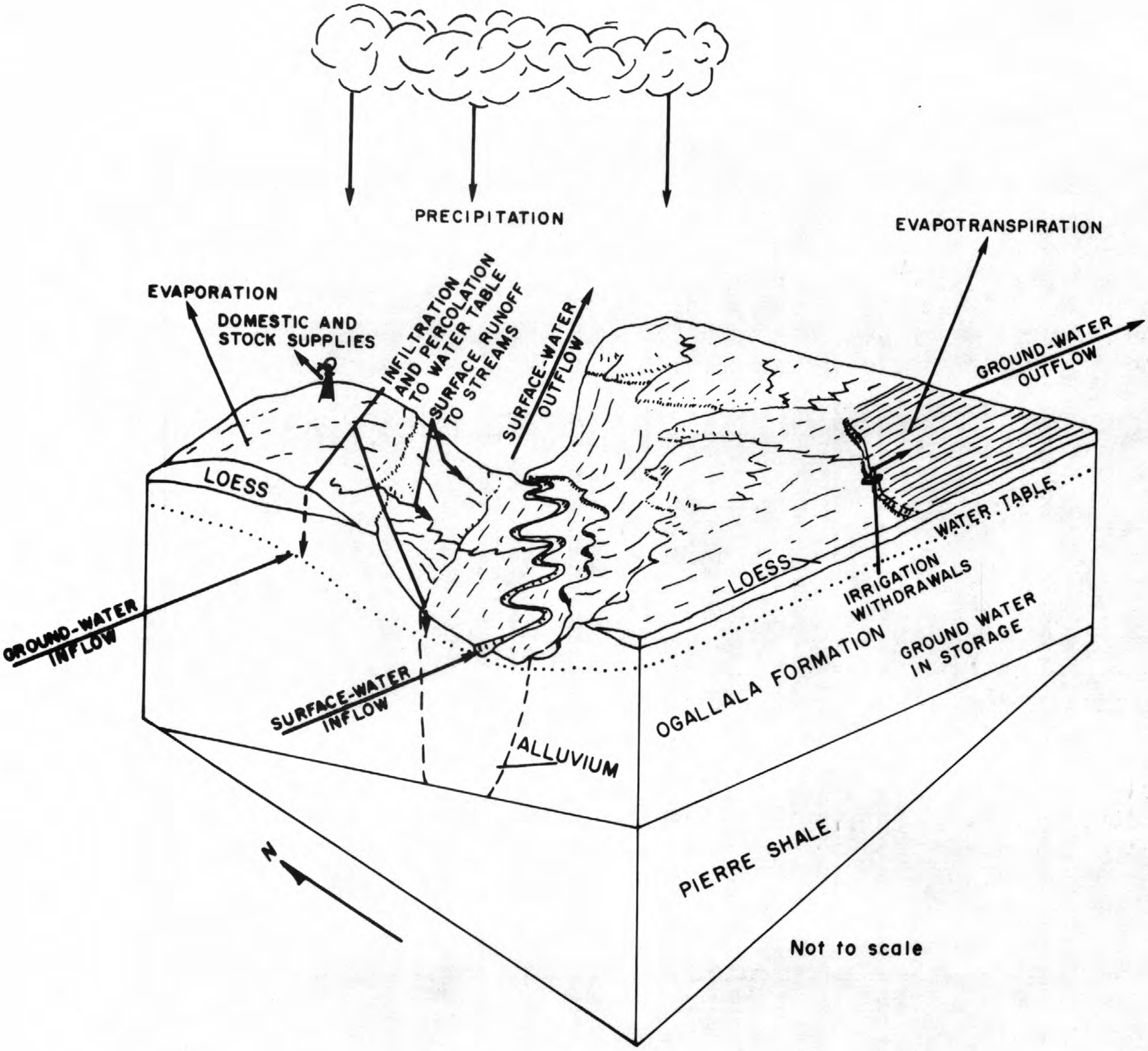


Figure 15.--Diagrammatic sketch of the movement of water in northwestern Kansas.

The common belief that an amount of water equal to the annual recharge can be withdrawn without upsetting the hydrologic balance often is misinterpreted. Before the ground-water reservoir is developed by wells, recharge to and discharge from the reservoir are virtually in balance over a long period of time. This "dynamic equilibrium" is upset by discharge from wells, which removes water from storage in the reservoir. Equilibrium cannot be restored until the loss from storage is compensated by an increase in natural or artificial recharge, a decrease in natural discharge, or both. Although there has been some readjustment of the hydrologic system in northwestern Kansas to withdrawals of ground water by wells, most of the water pumped at present (1973) comes from storage in the ground-water reservoir.

Aquifers

Ground water is contained in cracks and pore spaces between rock particles. A geologic unit or formation that will yield significant quantities of water to wells is called an aquifer. Three aquifers are significant in northwestern Kansas; the Dakota Formation of Cretaceous age, the Ogallala Formation of Tertiary age, and the alluvium of Quaternary age. The physical character and the water-supply characteristics of these aquifers and of other geologic units that underlie the area are described in table 2.

Dakota Formation

The Dakota Formation of Cretaceous age is widely distributed; it is recognized from Montana to Oklahoma and from northwestern Iowa to Utah. The formation was named in 1882 by Meek and Hayden and was described from exposures along the Missouri River in Dakota County, Nebraska. The formation is not exposed in northwestern Kansas; it lies below the land surface at depths ranging from about 600 feet (180 m) in southeastern Gove County to about 2,600 feet (790 m) in Sherman County (pl. 2). The Dakota ranges in thickness from about 200 to 300 feet (61 to 91 m) (Elias, 1931, p. 28) and consists primarily of shale, siltstone, and sandstone. No irrigation wells have been drilled to the Dakota in northwestern Kansas because of the depth, relatively small yields, and the chemical quality of the water. Water from the Dakota generally is unsuitable for irrigation, but is used for domestic supplies locally along the Smoky Hill River valley.

Ogallala Formation

The Ogallala Formation either underlies the surface of the High Plains or is covered by relatively thin deposits of wind-blown silt and fine sand (loess). The formation extending from South Dakota to Texas and from eastern Colorado to central Kansas; it was named by Darton in 1898 for exposures near Ogallala, Nebraska. The Ogallala consists primarily of clay, silt, sand, and gravel that were deposited millions of years ago by streams flowing eastward from the Rocky Mountains. Subsequent erosion has completely cut off any connection of these deposits with the mountains except for the "gangplank" area of southern Wyoming. There is no recharge to the Ogallala in northwest Kansas by ground-water inflow from the mountains or by seepage losses from streams that originate in the mountains.

The Ogallala Formation was deposited on an eroded surface that had been dissected by streams. Consequently, the Ogallala deposits are thickest and the saturated thickness is greatest in places where the deposits fill ancient stream valleys. The saturated thickness of unconsolidated deposits in northwestern Kansas is shown on plate 3. The location of a buried valley is indicated on the figure by a broad band of saturated deposits that generally are 100 to 250 feet (30 to 76 m) thick in the area from Hoxie to Goodland. This same buried channel also extends westward into Colorado where many irrigation wells have been drilled along the channel trend. The saturated thickness of the Ogallala ranges from 0 to about 270 feet (82 m) in northwestern Kansas.

Table 2.--Generalized section of geologic units. [1]

System	Series	Geologic unit		Thickness (feet)	Rock symbol	Physical character	Water supply [2]
Quaternary	Holocene	Alluvium		0-105		Stream-laid deposits ranging from clayey silt to coarse sand and gravel that occur along principal stream valleys.	Yields moderate to large quantities of water to wells in the principal valleys, and small quantities in the tributary valleys. Yields commonly range from 300 to 800 gpm (gallons per minute) with many yields as much as 1500 gpm. Chemical quality of water may be objectionable for some uses in localities where alluvium overlies Cretaceous rocks.
	Pleistocene	Undifferentiated deposits		0-135±		Silt and fine sand, mostly eolian (loess), mantle most of the upland and mask much of the valley walls.	Most of the deposits are above the water table, but locally yield small quantities of water to wells.
		Terrace deposits		0-90		Stream-laid deposits ranging from clayey silt to sand and gravel occur chiefly along principal valleys.	Yields moderate quantities of water to wells. Yields commonly range from 100 to 400 gpm.
Tertiary	Pliocene	Ogallala Formation		0-400		Sand, gravel, silt, clay, and caliche, largely unconsolidated but cemented locally by calcium carbonate or silica.	Principal aquifer in the report area. Yields moderate to large quantities of water to wells across the central part of the area and small to moderate quantities of water along the northern and southern borders. Yields commonly range from 500 to 1200 gpm with many yields as much as 1600 gpm.
		Pierre Shale		0-1,600±		Dark-gray fissile shale. In the subsurface, the upper few feet locally is a yellow weathered zone called "ochre".	Yields little or no water to wells. Most significant as a restricting layer for the movement of water.
		Niobrara Formation	Smoky Hill Chalk Member	0-750±		Gray and light-gray chalk and thin-bedded and platy chalky shale. Locally the upper few feet weathers orange.	Yields little or no water to wells. Forms a restricting layer for the movement of water.
			Fort Hays Limestone Member	40-85		Gray to light-gray chalk and massive microfossiliferous chalky limestone with thin light- to dark-gray chalky shale beds separating the massive limestone beds.	Not known to yield significant amounts of water to wells.

Cretaceous	Upper Cretaceous	Carlile Shale	Codell Sandstone Member	10-45	Brown to gray fine-grained silty sandstone. Locally contains thin shale stringers.	Yields small quantities of water to domestic and stock wells in the southern part of Gove County.
			Blue Hill Shale Member	85-115	Dark-gray blocky to fissile clayey shale.	Not known to yield significant amounts of water to wells.
			Fairport Chalky Shale Member	60-85	Bluish-gray to gray chalky shale containing thin beds of chalk.	Not known to yield significant amounts of water to wells.
		Greenhorn Limestone		50-100	Alternating light- to dark-gray thin-bedded chalky limestone and calcareous shale that weathers yellowish gray or yellowish tan.	Not known to yield significant amounts of water to wells.
		Graneros Shale		35-100	Medium- to dark-gray fissile shale that weathers gray or yellowish brown.	Not known to yield significant amounts of water to wells.
	Lower Cretaceous	Dakota Sandstone		200-500	Fine- to medium-grained sandstone with interbedded shale and siltstone.	Yields small quantities of water to domestic and stock wells in southern Gove and Logan Counties. Only the top 100 feet tapped by water wells. Chemical quality of water may be objectionable for some uses.

[1] The classification and nomenclature of the stratigraphic units used in this release are those of the U.S. Geological Survey and differ somewhat from those of the Kansas Geological Survey.

[2] For this report, small quantities of water means less than 10 gpm, moderate quantities mean 10 to 100 gpm, and large quantities means more than 100 gpm.

EXPLANATION OF ROCK SYMBOLS

Sand   Gravel   Silt   Loess   Clay   Shale   Calcareous   Limestone   Fossiliferous   Concretions

The yield to wells in the Ogallala in northwestern Kansas commonly ranges from 500 to 1,200 gpm (32 to 76 l/s) and many wells yield as much as 1,600 gpm (100 l/s). The potential yield to wells in the area is shown on plate 4. Wells can be completed in the Ogallala almost everywhere in northwestern Kansas except in a few places along stream valleys in the eastern and southern parts of the area. In these areas, the Ogallala either has been removed by erosion or has been drained. Graphs showing the area underlain by various saturated thicknesses of unconsolidated deposits and estimates of the amount of water in storage are shown on figures 16, 17, and 18.

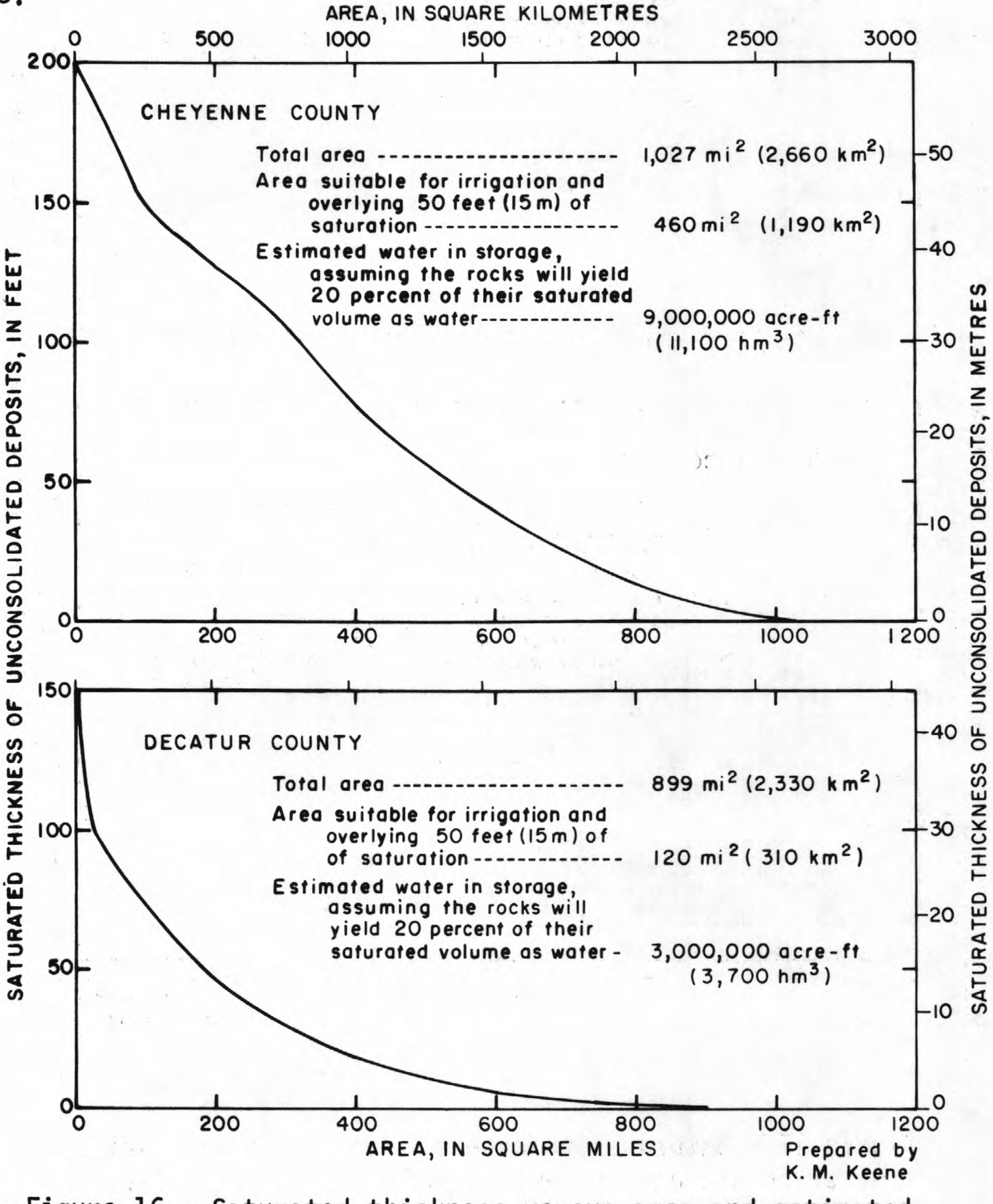


Figure 16.--Saturated thickness versus area and estimated water in storage in Cheyenne and Decatur Counties.

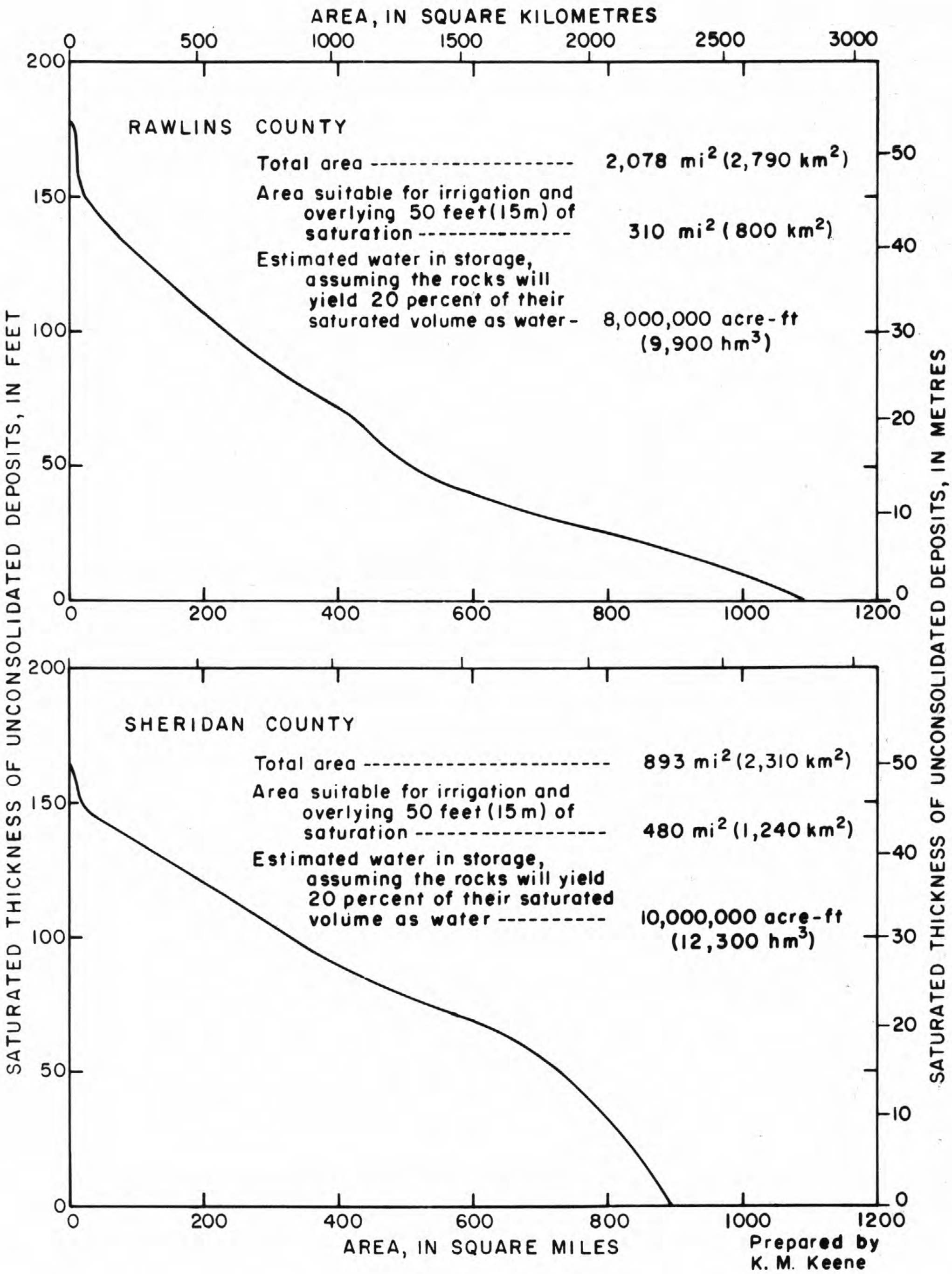


Figure 17.--Saturated thickness versus area and estimated water in storage in Rawlins and Sheridan Counties.

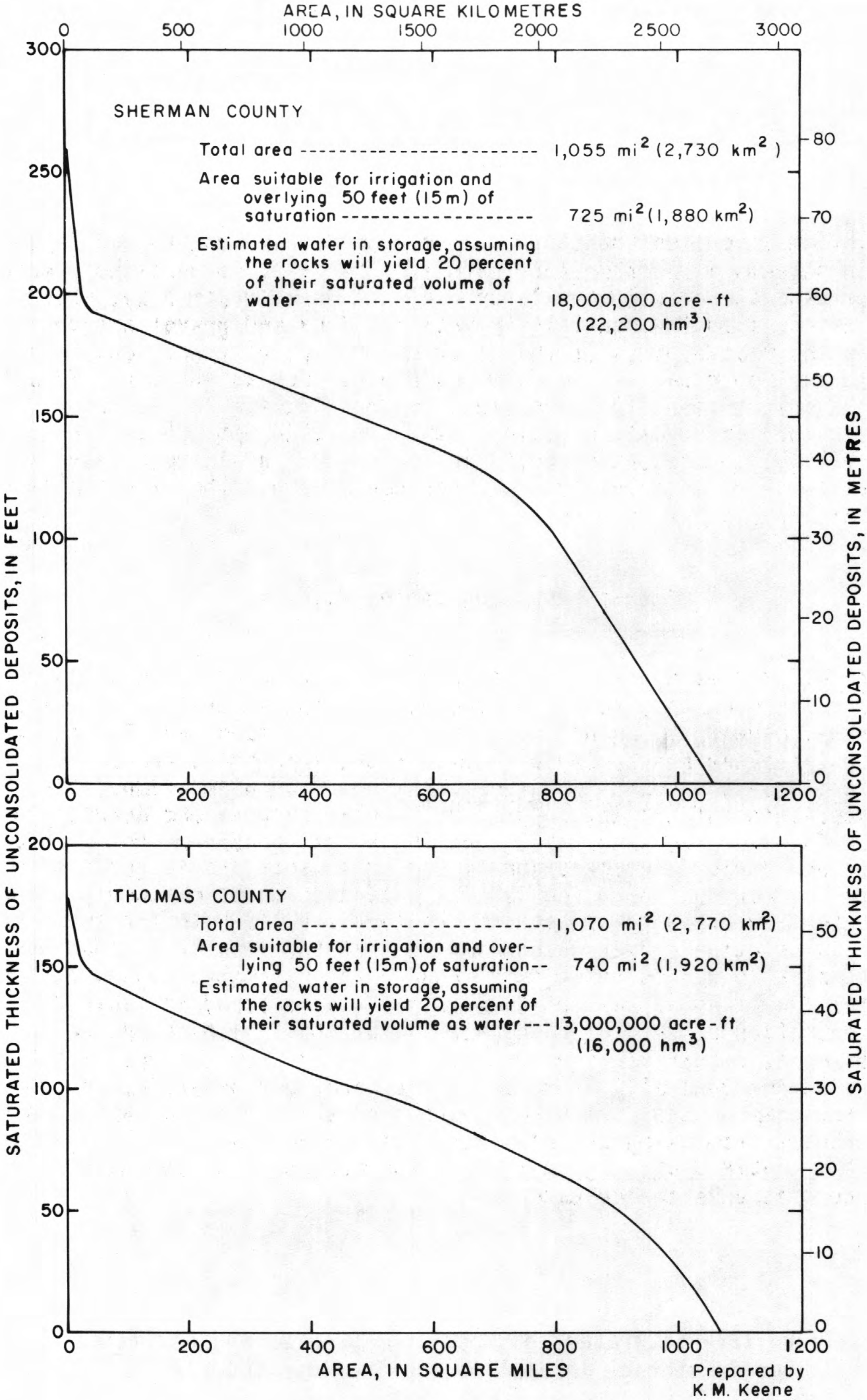


Figure 18.--Saturated thickness versus area and estimated water in storage in Sherman and Thomas Counties.

Alluvium

Alluvium underlies the flood plains and occurs along the valleys of the major streams in northwestern Kansas. The alluvium consists predominantly of sand and gravel with lesser amounts of silt and clay, which were derived mainly from the Ogallala Formation. Sand and gravel are common in the lower and middle parts of the alluvium whereas silt and sandy silt are common in the upper part. The deposits are as much as 105 feet (32 m) thick, but only 65 feet (20 m) or less of the alluvium is saturated. Wells located in the major valleys yield as much as 1,500 gpm (95 l/s). In the smaller valleys, where the deposits are thin and contain much fine sand and silt, wells may yield only a few gallons per minute. The alluvium is dry in some of the small stream valleys.

Chemical Quality of the Water

Pure water does not exist in nature. Even rain and snow contain some dust and gases when they reach the ground. Common impurities in water include gases, minerals, organic matter, silt, clay, sand, and living organisms such as algae and bacteria. Some of the impurities are of no major consequence unless present in large quantities. Sometimes impurities add to the usefulness of the water for a particular purpose and detract for another. For example, water that contains a low concentration of calcium carbonate and a high concentration of sodium is soft and is good for washing, but it may be harmful when used for irrigation of crops on poorly drained soil. Water for drinking or cooking should be tested both for impurities that are in solution and in suspension so that the impurities that make the water undesirable can be removed or reduced to acceptable concentrations.

Water from the Dakota Formation is soft, as classed in table 3, because the concentration of calcium carbonate is low, but the high concentration of sodium makes it unsuitable for irrigation. Water from the Ogallala Formation and the alluvium generally is hard to very hard, but otherwise is suitable for all the common uses. No harm to crops or soils has been noted in northwestern Kansas from using ground water from the Ogallala or alluvium for irrigation. Table 3 and figure 19 show the magnitude of the principal mineral constituents in the waters.

Table 3.--Typical chemical analyses of water from the Dakota Formation, Ogallala Formation, and alluvium.

[Dissolved constituents and hardness given in mg/l (milligrams per liter). Analyses by Kansas Department of Health and Environment.]

Constituent	Geologic Source			
	Dakota Formation	Ogallala Formation	Alluvium	Recommended limits 1/
Temperature (°C)	20	16	14	
(°F)	68	60	58	
Dissolved solids	1,180	295	643	500
Silica (SiO_2)	9.5	43	38	
Iron (Fe)	.26	.4	.2	.3
Manganese (Mn)	.03	.0	.4	.05
Calcium (Ca)	4.4	43	116	
Magnesium (Mg)	.8	15	32	
Sodium (Na)	435	27	71	
Potassium (K)	5.6	7	18	
Bicarbonate (HCO_3)	675	222	417	
Sulfate (SO_4)	40	38	164	250
Chloride (Cl)	240	14	53	250
Fluoride (F)	5.5	1.4	1.0	
Nitrate (NO_3)	1.4	13	8	45
Hardness as $CaCO_3$ 2/	14	163	407	
Specific conductance (Micromhos at 25°C)	1,830	442	1,020	
PH	8.3	7.7	7.5	

1/ Recommended limits in drinking water, Kansas State Board of Health (1973).

2/ Hardness of water is classed in this report as follows: 60 mg/l or less, soft; 61-120 mg/l, moderate; 121-180 mg/l, hard; and 181 mg/l or more, very hard.

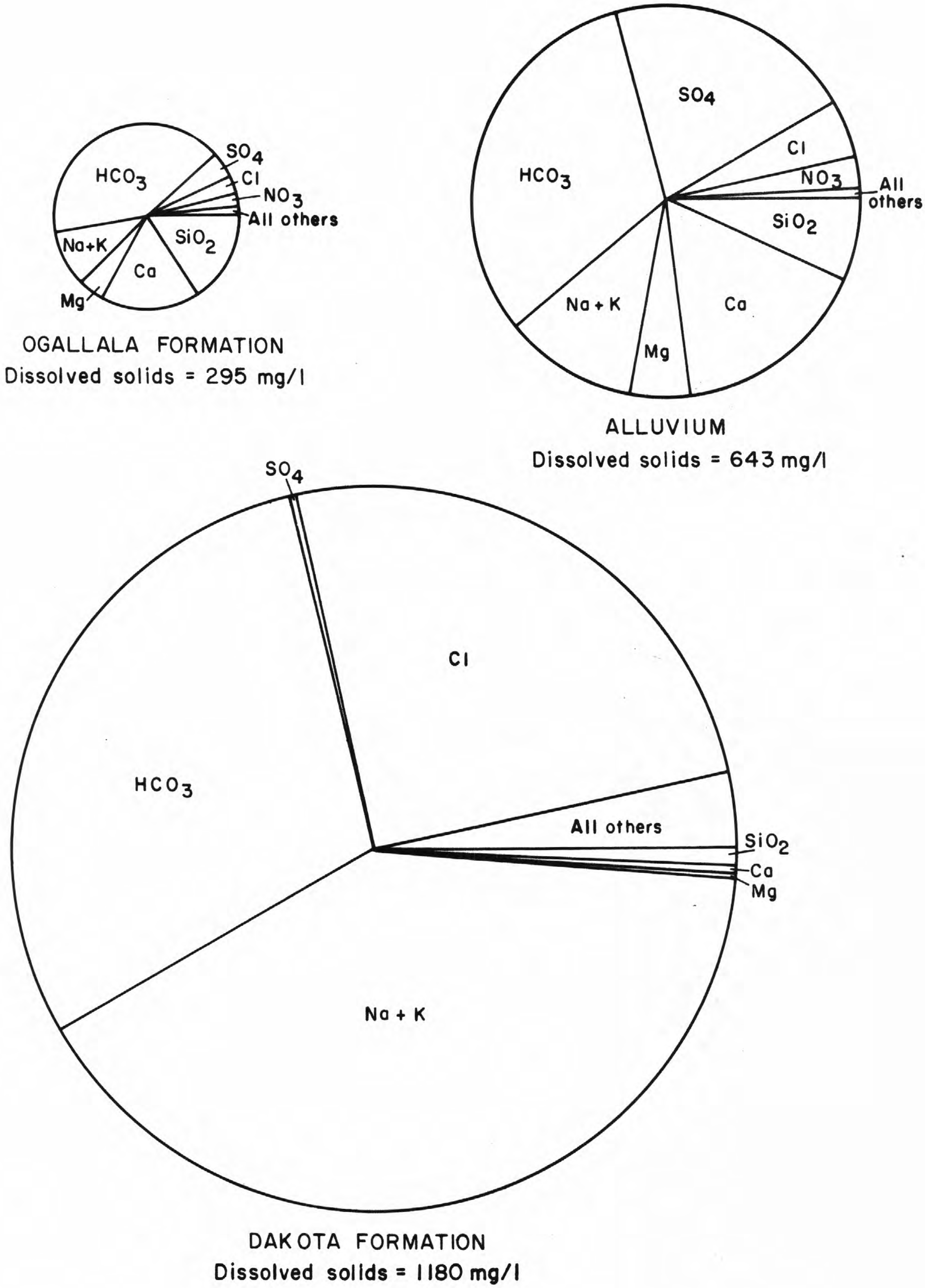


Figure 19.--Pie diagrams showing concentrations of mineral constituents as a percent of dissolved solids, in milligrams per liter. Size of circle shows relative concentration of dissolved solids.

THE WATER TABLE

The water table marks the top of the saturated aquifer material; it is defined by the levels at which water stands in wells that penetrate the water body far enough to hold standing water (Lohman et al, 1972, p. 14). With time, the water table rises and falls as the rate of recharge to and discharge from the aquifer varies. Stories of a declining water table are common in northwestern Kansas and, as with most stories, they are partly true and partly false.

Measurements of the depth to water below land surface have been made in a number of wells in northwestern Kansas since the 1940's. Maps showing the configuration of the water table have been published in reports of the Kansas Geological Survey and U.S. Geological Survey. Data from the earlier reports have been compiled into the water-table map shown on plate 5. This composite map shows the configuration of the water table in about 1950, before significant ground-water withdrawals by irrigation wells began and under essentially natural conditions of recharge and discharge.

Plate 6 shows the configuration of the water table in January 1973 (from Pabst and Jenkins, 1973). Comparison of the 1950 and 1973 water-table maps indicates that significant changes in water level have occurred in some places. These water-level changes also are shown on plate 6. Declines greater than 10 feet (3 m) are common in the area, and declines greater than 30 feet (9 m) have occurred near Goodland and about 12 miles (19 km) south of Colby. As can be seen from the water-level-change map, stories about a declining water table and about mining of ground water are true in parts of northwestern Kansas. However, the map also shows large areas in which there has been little or no change in water level since 1950. There are, in fact, places in the area where the water table was higher in 1973 than it was in 1950.

The water-level declines in northwestern Kansas have been caused primarily by ground-water withdrawals for irrigation. A comparison of figure 17 showing the location of irrigation wells and figure 27 indicates the cause-effect relationship between well density and water-level changes. The areas with the greatest density of wells correspond to the areas of greatest withdrawals and water-level declines.

Hydrographs of two wells (fig. 20) show the effects of ground-water development on water levels in the areas of Goodland and Colby. Records for the well at Goodland reflect the water-level decline in the area where ground-water mining began to take place in the mid 1950's, whereas, at Colby, the decline does not become evident until the early 1960's. Nevertheless, ground-water mining is taking place and water levels are dropping where ground water is being pumped in significant quantities for irrigation, industrial, and municipal use.

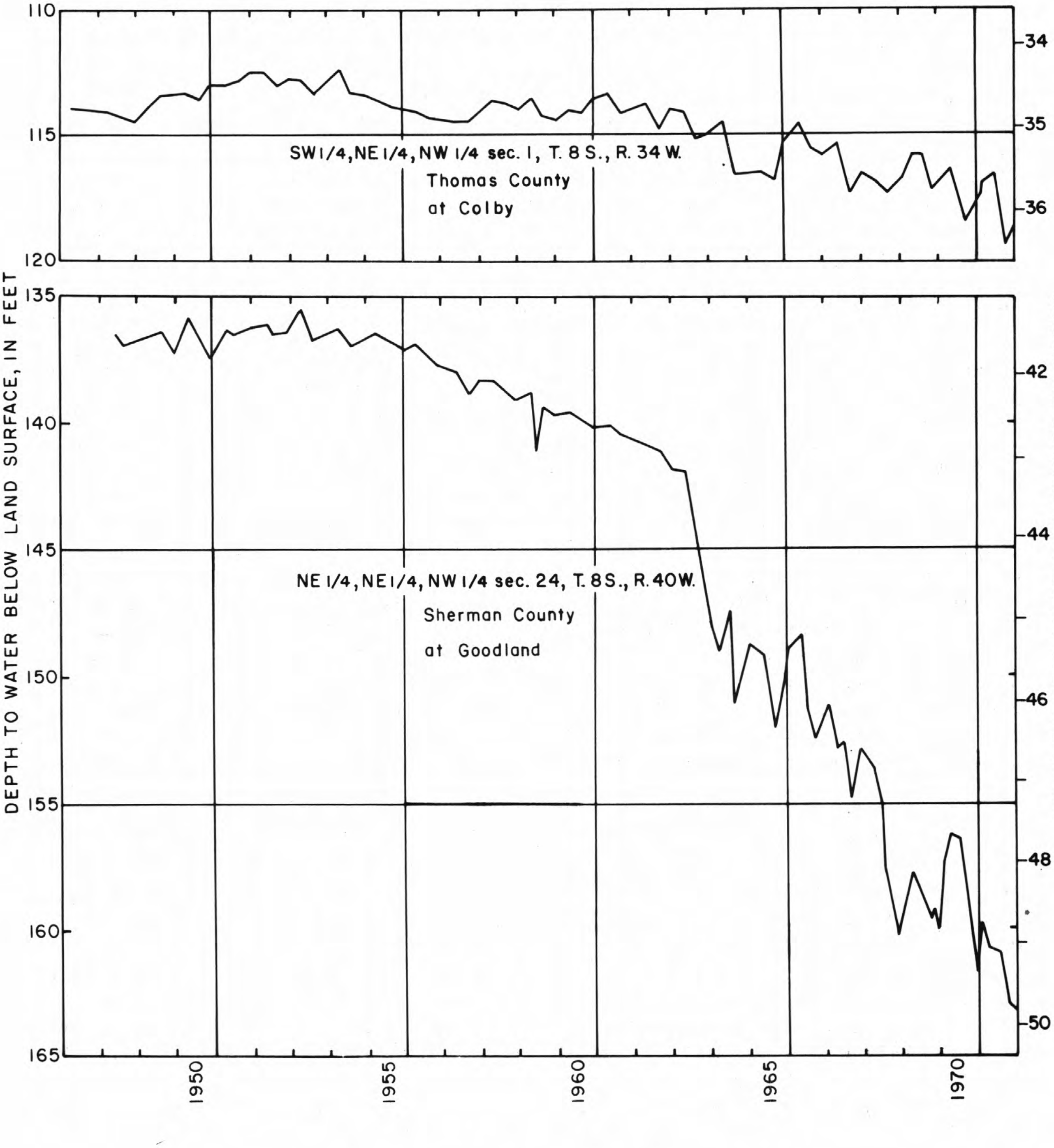


Figure 20.--Hydrographs for selected wells.

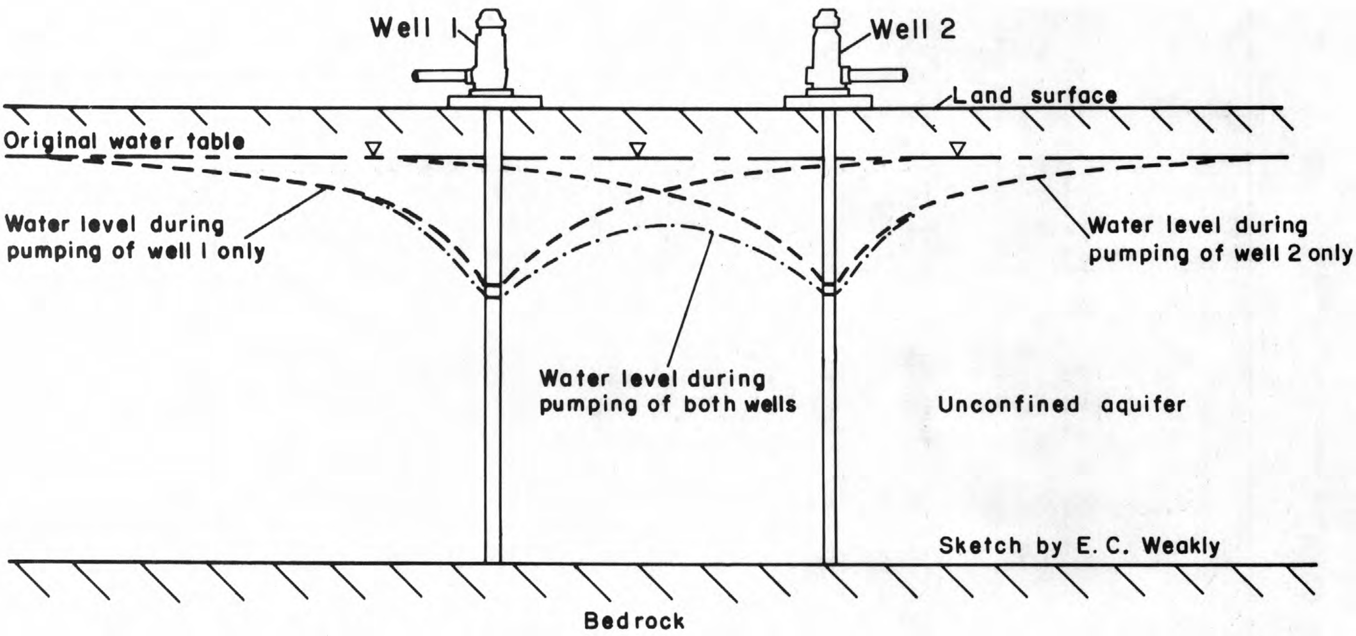


Figure 21.--Sketch showing profile of water table near two closely spaced discharging wells.

The water-level surface around a discharging well assumes the shape of an inverted cone centered on the well. This so-called drawdown cone deepens and expands in area until an amount of water equal to that being pumped is induced to flow toward the well. In areas where there are many wells, the drawdown cones may overlap as shown on figures 21 and 22. Such interference between wells results in larger drawdowns and (or) reduced well yields. Continued pumping of mutually interfering wells can lower water levels to the point that one well, or both, becomes uneconomical to pump or fails because of insufficient water above the pump intake. Failure of older domestic and stock wells is common in parts of northwestern Kansas where these wells are located near irrigation wells. Many of the older wells, which were drilled to only a few feet below the water table, go dry when the water table drops as a result of irrigation pumpage. The effect of water-level declines on the pumping rate is shown on figure 23. Declines caused by interference between wells should not be significant if wells in the alluvium are spaced at least 500 feet (150 m) apart and if wells in the Ogallala are spaced 1,000 feet (300 m) apart. Even if interference between individual wells is prevented, however, water levels will continue to decline in areas where total withdrawals exceed the recharge.

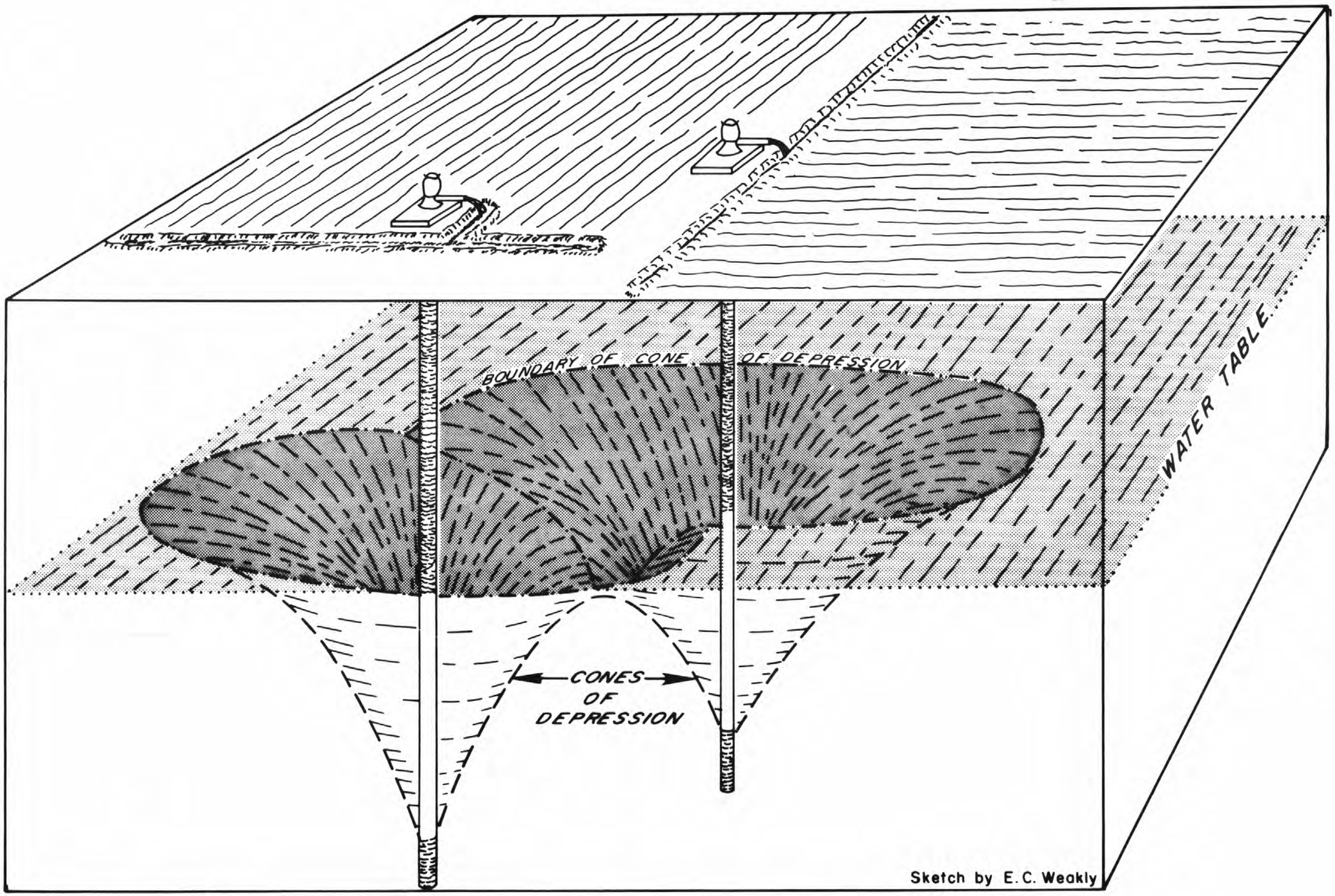


Figure 22.--Sketch showing interference between drawdown cones of two closely spaced discharging wells.

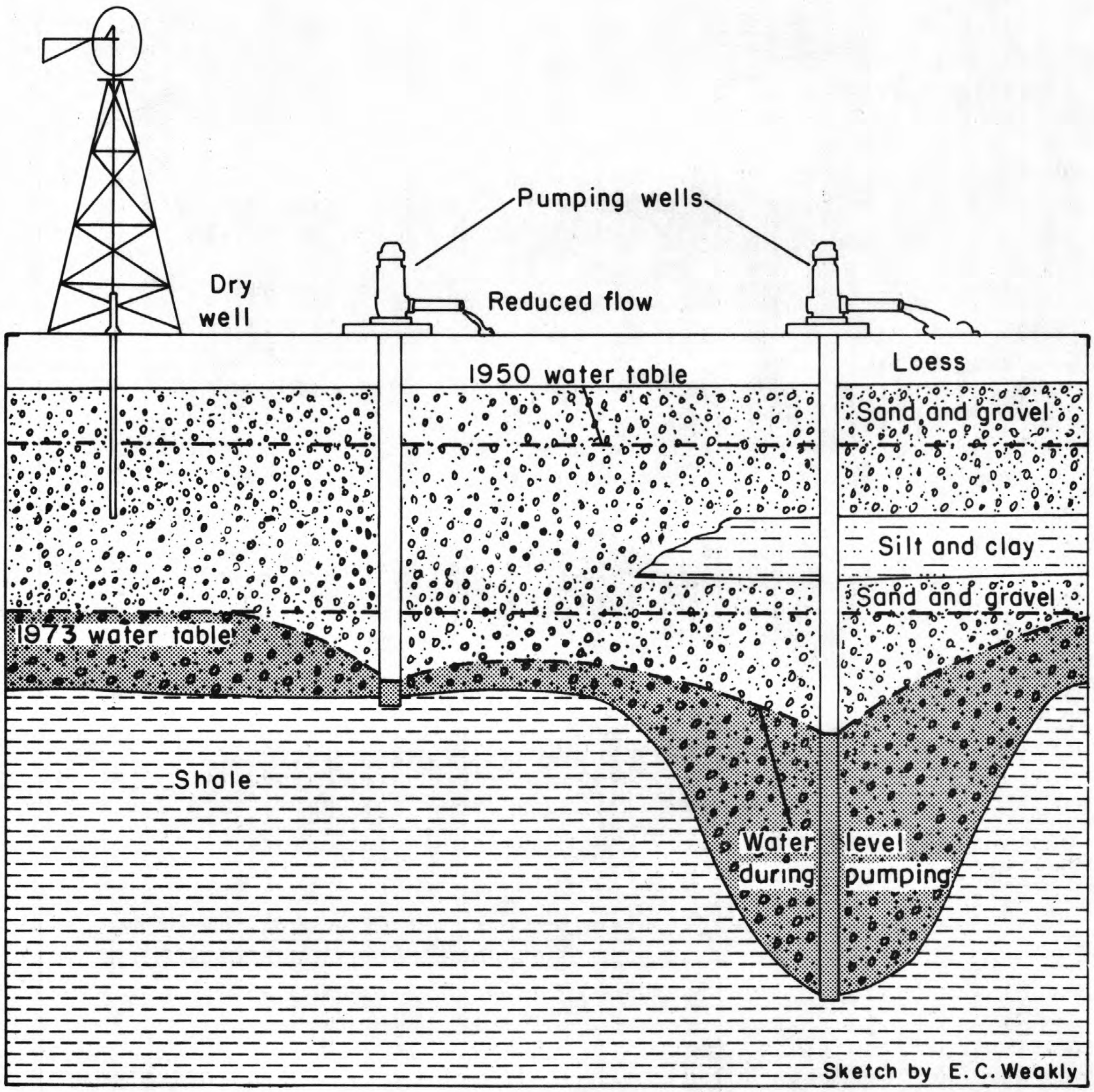


Figure 23.--Sketch showing effect of water-level decline on the yield of wells.

FUTURE DEVELOPMENT

More ground water can be withdrawn annually for irrigation in northwestern Kansas than is being withdrawn at present (1973). Large parts of the area that are dry-land farmed are underlain by saturated deposits in the Ogallala Formation that are suitable for development by wells. About 25 percent of the irrigable land in Sherman County is being irrigated; less than 20 percent in the other counties. The potential for increased irrigation in northwestern Kansas, therefore, is large. However, if all irrigable land in the area could be irrigated by wells, the rate of ground-water depletion would increase greatly, and the day would soon come when it would be uneconomical to pump all the wells.

If the unconsolidated deposits are capable of yielding 15 to 20 percent of their saturated volume as water, interpretation of figure 21 indicates that about 50 to 70 million acre-feet (62×10^9 m^3 to 86×10^9 m^3) of water is in storage. In general, about half the water stored in the ground-water reservoir can be withdrawn by wells. Based on the current withdrawal rate of 500,000 acre-feet (620×10^6 m^3) per year and the estimated recharge from precipitation of 100,000 acre-feet (120×10^6 m^3) per year, one might assume that ground water will be depleted in about 60 to 90 years. This assumption, however, is not realistic. The ground-water reservoir in northwestern Kansas will never be depleted completely because it is physically impossible to pump out all the water. Also, it may become uneconomical to pump large quantities of water for irrigation in parts of the area; particularly where the saturated deposits are less than 50 feet (15 m) thick and where there is insufficient spacing between large-capacity wells. In other words, all the wells in the area will not "go dry" at once. Irrigation operations that are favorably located over areas of greatest saturated thickness will be able to continue indefinitely, provided that an adequate spacing is maintained between wells. On the other hand, irrigation operations that are marginally feasible because of relatively low well yields and little saturated thickness may have to revert to dry-land operations in only a few years.

The ground-water reservoir can be managed in several ways depending on the intended objective. One management scheme might be to continue development of the resource and let economics be the controlling factor. Under this scheme, irrigation would continue to increase for some time, but eventually, many irrigators would be forced to return to dry-land farming. This scheme follows what has been called the "get it while it's there" philosophy.

Numerous schemes can be devised to prolong the irrigation economy of the area by making the water last longer. All of these schemes depend primarily on controlling withdrawals from the ground-water reservoir by limiting (1) the amount of water that can be pumped per well, (2) the number of wells, or (3) the irrigated acreage. These schemes also depend on the operation of a regulatory group with the authority to enforce controls and to encourage conservation of the resource.

The Kansas Groundwater Management District Act recognizes "that a need exists for the creation of special districts for the proper management of the groundwater resources of the state; for the conservation of groundwater resources; for the prevention of economic deterioration; for associated endeavors within the state of Kansas through the stabilization of agriculture; and to secure for Kansas the benefit of its fertile soils and favorable location with respect to national and world markets." The policy of the act is "to preserve basic water use doctrine and to establish the right of local water users to determine their destiny with respect to the use of the ground water insofar as it does not conflict with the basic laws and policies of the state of Kansas." Therefore, the people of the State have the tools for proper management. Application of the legal tools for management, however, must be compatable with the hydrologic laws of nature if they are to be successfully implemented for maximum long-term benefits.

Proper management leads to the conservation and efficient use of water and is desireable for the orderly development and economic growth of the area. To insure that management is effective, the following are possible actions that could be considered:

1. Inform the public of the need for management and of alternate solutions to problems so that a wise policy can be chosen.
2. Continue water-resources studies in the area so that current information is available to managers for making decisions.
3. Encourage continuous (regular) measurement of pumpage (well discharge) and regular measurement of depth to water so that each well owner will become more aware of how much water is pumped and what the effect has been.
4. Conserve water by (1) more efficient scheduling and application of water, (2) constructing tail-water pits and reusing the excess water pumped, and (3) pooling equipment to pump water collected in potholes and small reservoirs.
5. Prevent pollution of surface and ground water.
6. Continue research studies designed to develop better water appraisal, development, and management techniques and more efficient and accurate instruments for collecting water facts.

Basically the answer to the question "Can the water be managed?" lies within the most valuable of all resources -- the people. If people choose to do so, the water supply can be managed to support a thriving economy for generations.

WHERE MORE INFORMATION CAN BE FOUND

Information on or related to the water resources of northwestern Kansas is available from several agencies. The general types of data and the agencies involved with collecting, interpreting, or using it are listed below.

Ground water

- Kansas Geological Survey
- Kansas State Board of Agriculture, Division of Water Resources
- Kansas Water Resources Board
- Kansas Department of Health and Environment, Division of Environment
- U.S. Geological Survey

Geology and soils

- Kansas Geological Survey
- Kansas State University Cooperative Extension Service
- Kansas State University Experiment Station
- State Highway Commission
- County Extension Council
- Soil Conservation Service
- U.S. Geological Survey

Surface water

- Kansas Water Resources Board
- Kansas Department of Health and Environment, Division of Environment
- U.S. Bureau of Reclamation
- U.S. Army, Corps of Engineers
- Soil Conservation Service
- National Oceanic and Atmospheric Administration
- U.S. Geological Survey

Published reports that contain information related to water resources of northwestern Kansas are listed in the selected references. Most of these reports are in the major libraries in the State. Reports of the U.S. Geological Survey may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D.C. 20402. Reports of the Kansas Geological Survey may be purchased from the Kansas Geological Survey, University of Kansas, Lawrence, Kansas 66045. Reports of the Kansas Water Resources Board may be obtained from the Kansas Water Resources Board, 4th floor, Mills Building, 109 W. 9th Street, Topeka, Kansas 66612.

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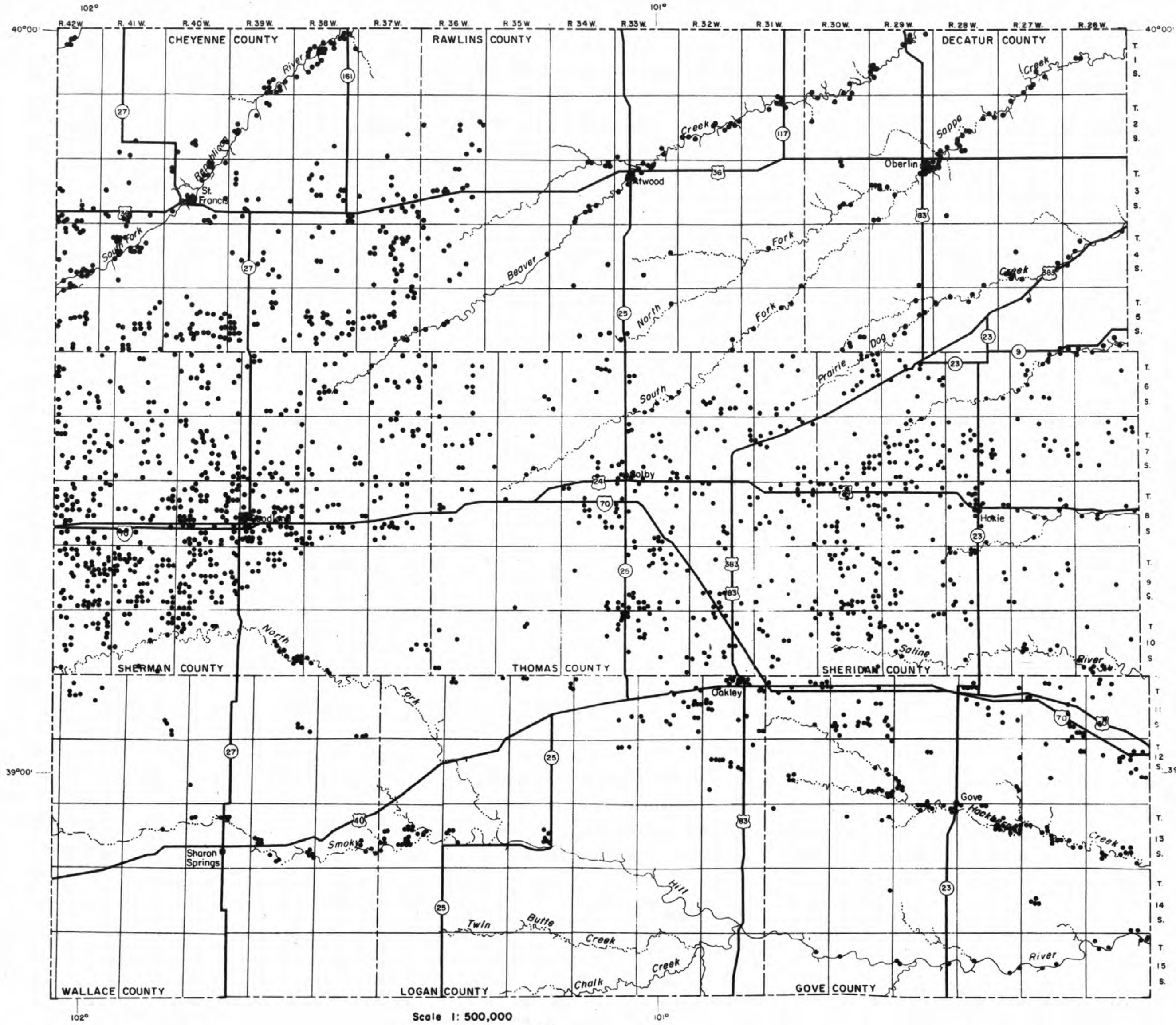


Base from U.S. Geological Survey

Scale 1: 500,000
5 0 5 MILES
5 0 5 10 KILOMETRES

EXPLANATION

• Large-capacity well, 1972
100 to 2,000 gallons per minute (6 to 130 litres per second)

MAP SHOWING LOCATION OF IRRIGATION WELLS, 1972, NORTHWESTERN KANSAS

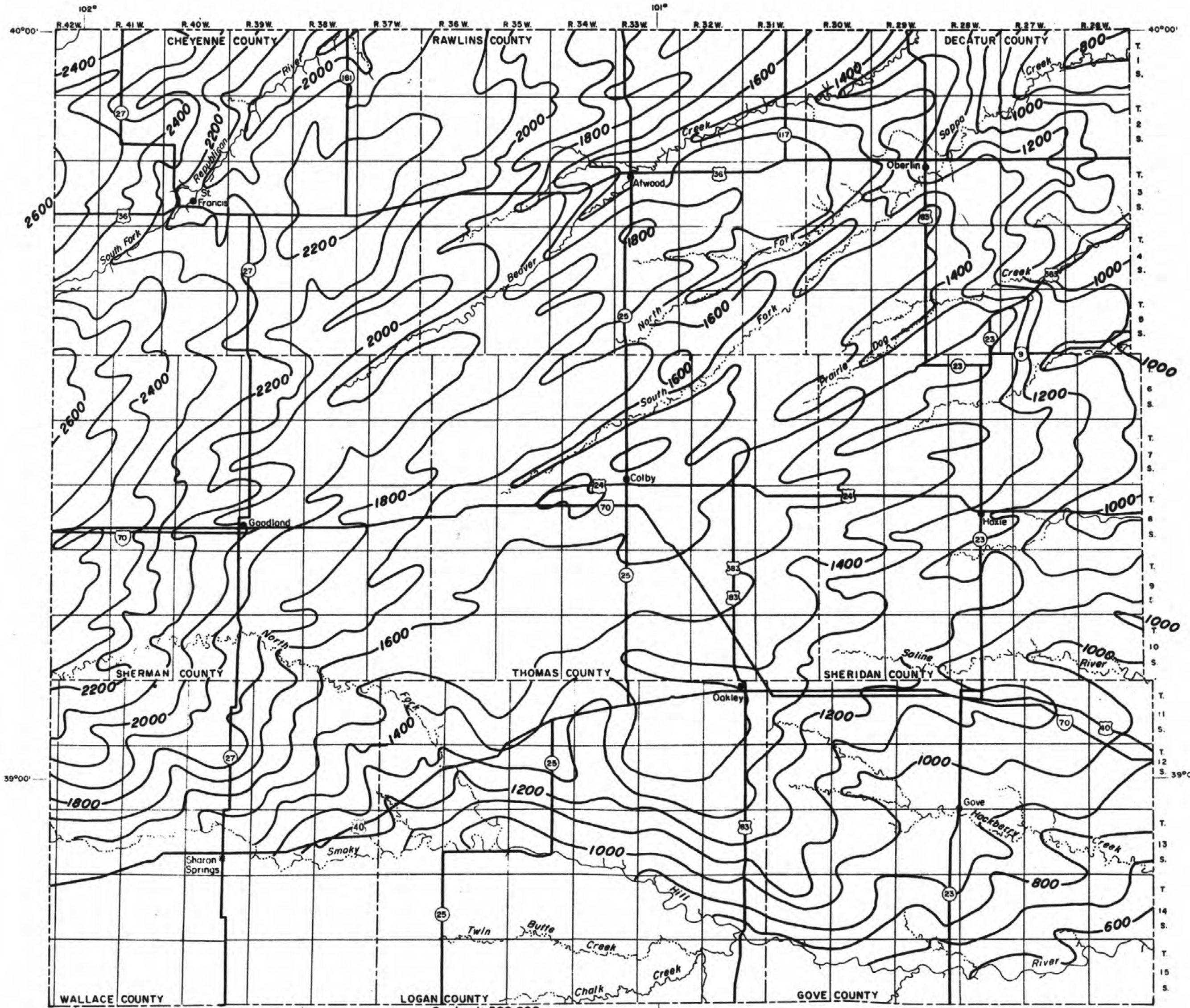
UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH THE
KANSAS GEOLOGICAL SURVEY

OPEN-FILE REPORT 4-75

PLATE 2



Scale 1: 500,000

5 0 5 MILES

5 0 5 10 KILOMETRES

Base from U.S. Geological Survey

Prepared by K. M. Keene

EXPLANATION

——1400——

Line of equal depth to top of Dakota Formation. Interval 100 feet (30 metres)

MAP SHOWING GENERALIZED DEPTH TO TOP OF THE DAKOTA FORMATION, NORTHWESTERN KANSAS

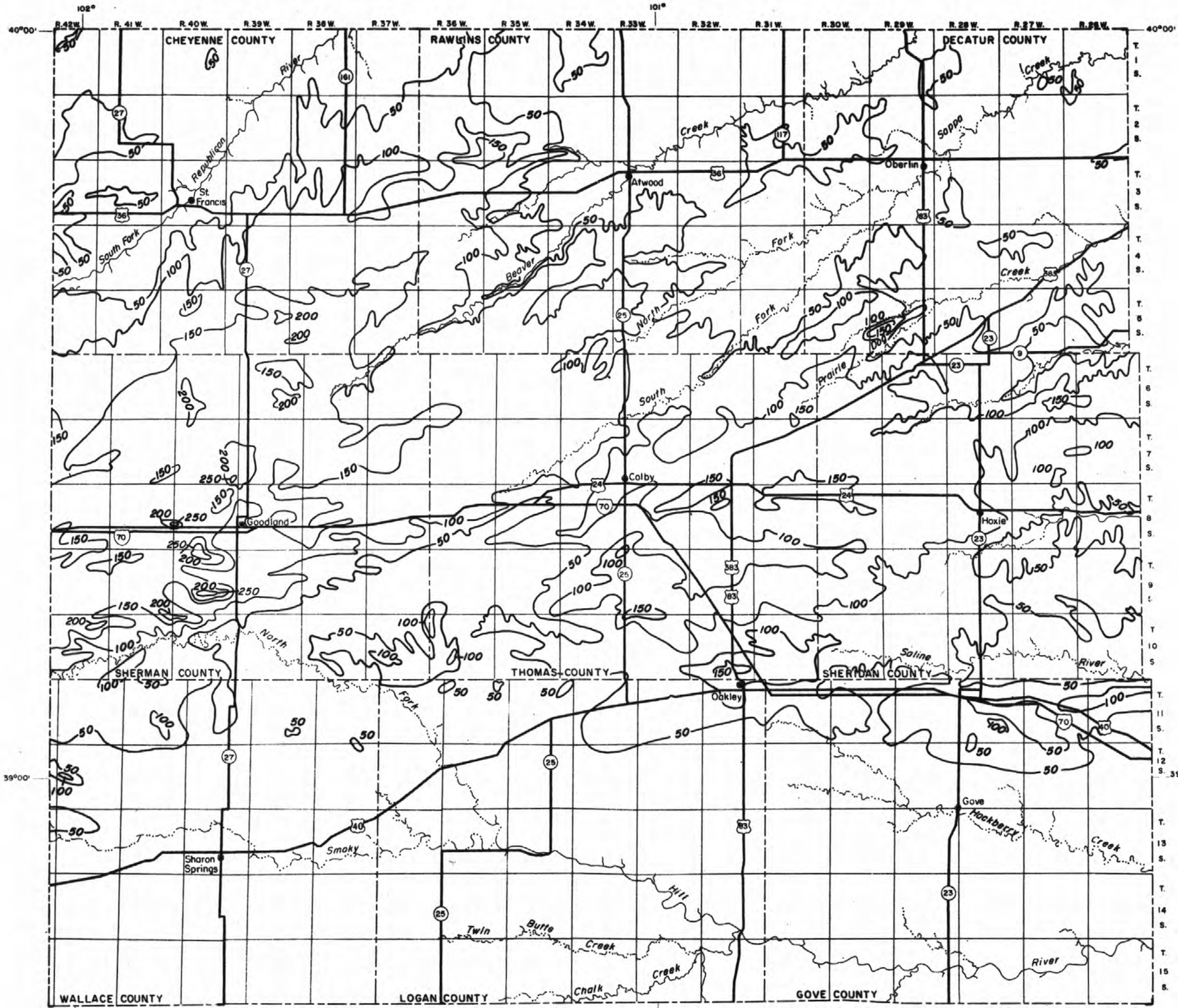
UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH THE KANSAS GEOLOGICAL SURVEY

OPEN-FILE REPORT 4-75

PLATE 3



Base from U.S. Geological Survey

Scale 1: 500,000

5 0 5 MILES

5 0 5 10 KILOMETRES

EXPLANATION

——50——

Line of equal thickness of saturated material. Interval 50 feet (15 metres)

MAP SHOWING GENERALIZED SATURATED THICKNESS OF UNCONSOLIDATED DEPOSITS, JANUARY 1973, NORTHWESTERN KANSAS

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH THE
KANSAS GEOLOGICAL SURVEY

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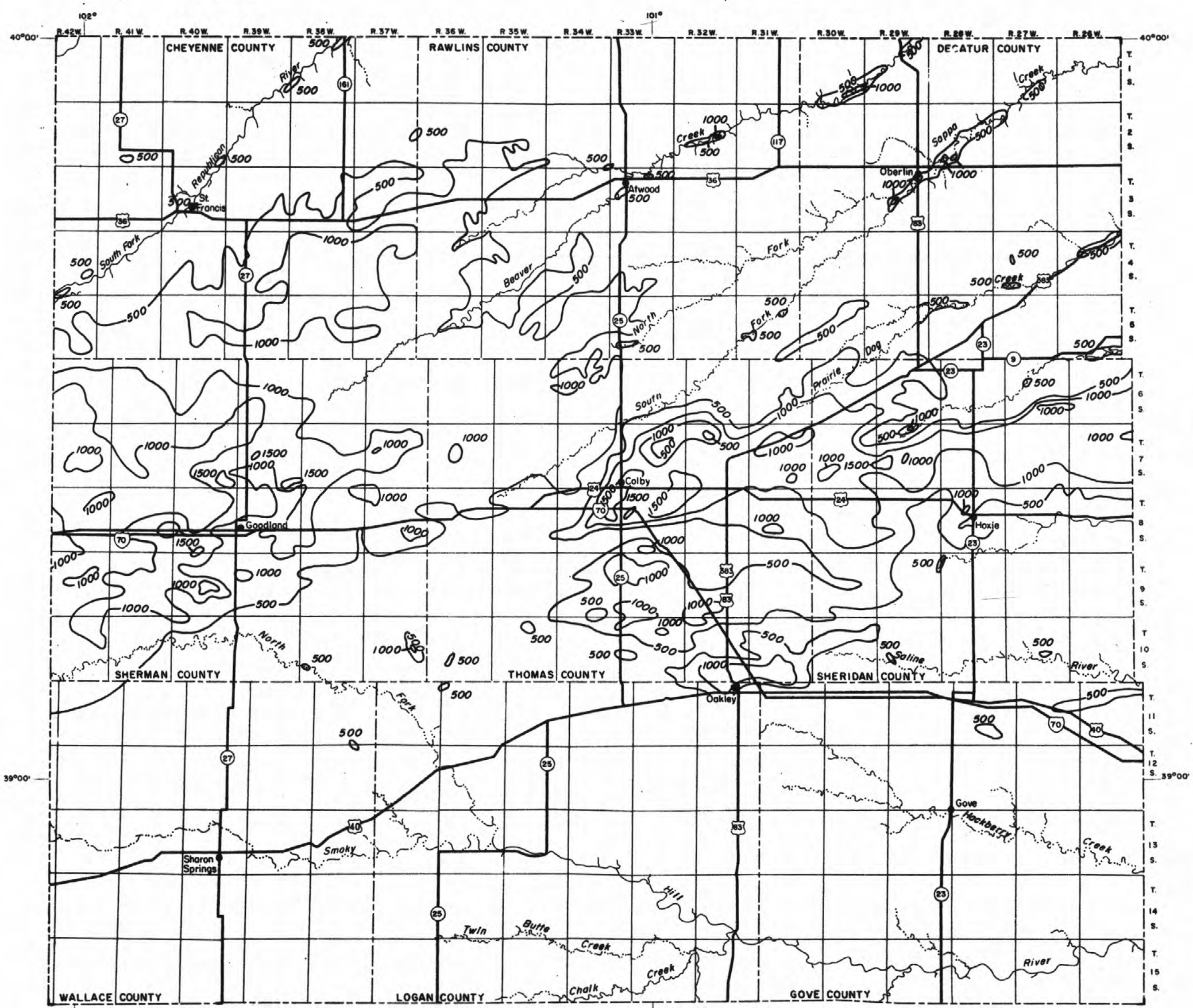
PLATE 4



EXPLANATION

——1000——

Line of equal yield to wells. Interval 500 gallons per minute (32 litres per second)

Base from U.S. Geological Survey

Scale 1: 500,000

5 0 5 MILES

5 0 5 10 KILOMETRES

MAP SHOWING GENERALIZED POTENTIAL YIELD TO WELLS IN UNCONSOLIDATED DEPOSITS, NORTHWESTERN KANSAS

UNITED STATES DEPARTMENT OF THE INTERIOR

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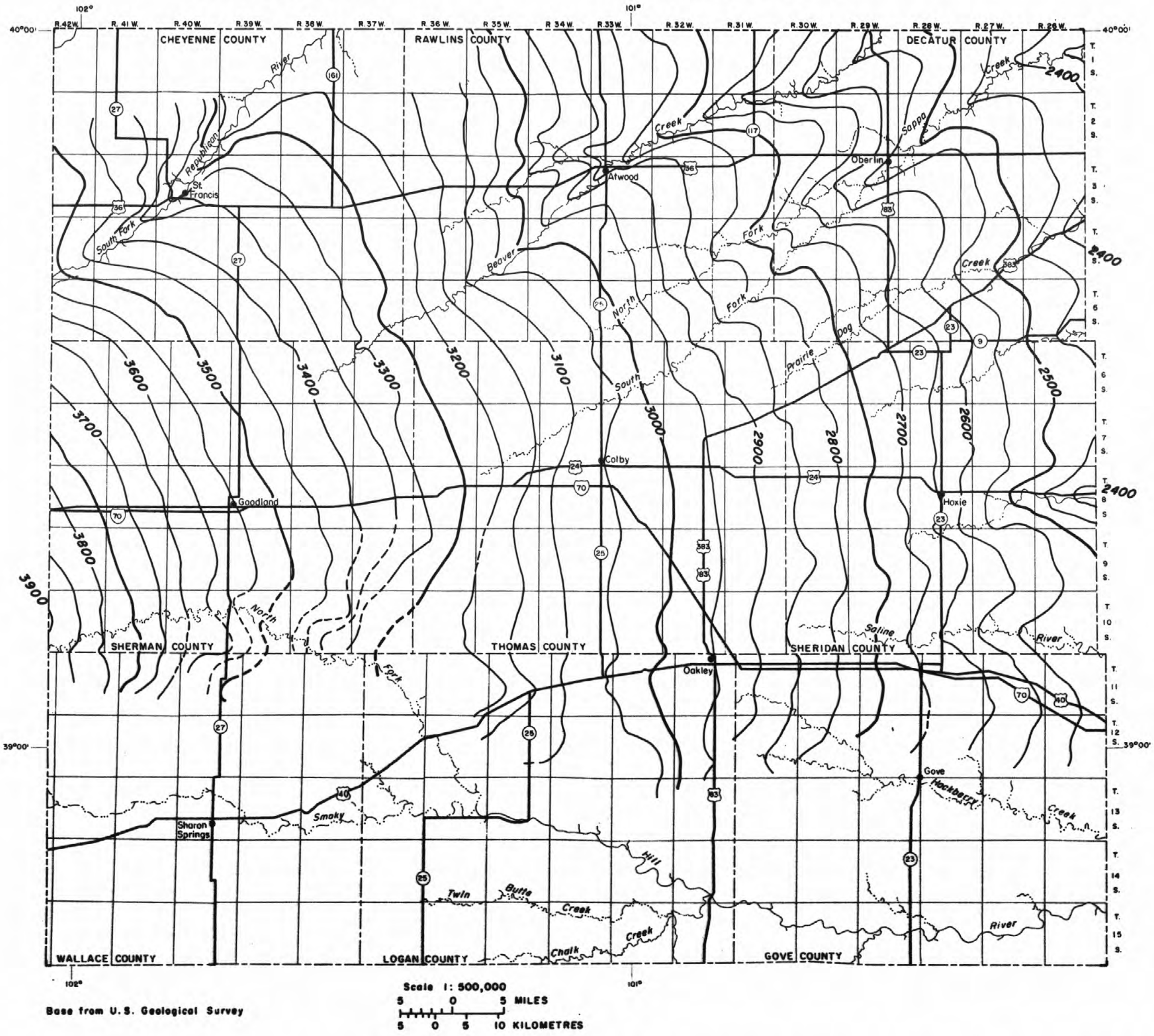
PLATE 5



EXLANATION

——3000---

Water-table contour

Shows altitude of water table, 1950. Dashed where approximately located. Contour interval 50 feet (15 metres). Datum is mean sea level

MAP SHOWING GENERALIZED CONFIGURATION OF THE WATER TABLE, 1950, NORTHWESTERN KANSAS

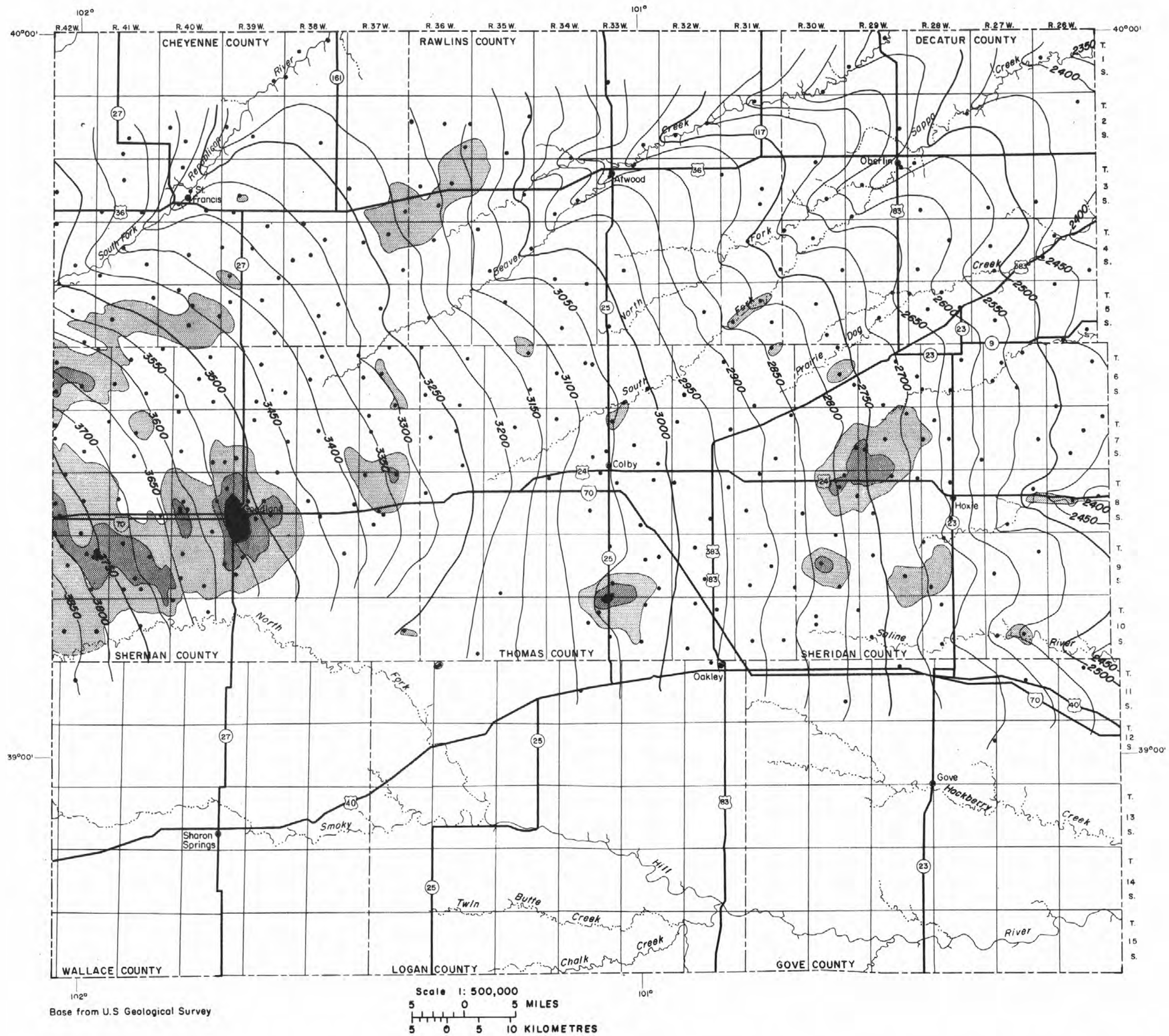
UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH THE
KANSAS GEOLOGICAL SURVEY

OPEN-FILE REPORT 4-75

PLATE 6



EXPLANATION

——3000——

Water-table contour

Shows altitude of water table in January 1973. Contour interval 50 feet (15 metres). Datum is mean sea level

•

Observation well for water-level measurements

Water-level decline 1950-73, in feet

Less than 10

10-20

20-30

30-40

MAP SHOWING GENERALIZED CONFIGURATION OF THE WATER TABLE, JANUARY 1973, AND WATER-LEVEL DECLINE FROM 1950-73 IN NORTHWESTERN KANSAS