Geology and Ground-Water Resources of Ford County, Kansas

By
HERBERT A. WAITE
With analyses by
ROBERT H. HESS

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BULLETIN 43

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

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GEOLOGY AND GROUND-WATER RESOURCES OF FORD COUNTY, KANSAS

By Herbert A. Waite

ABSTRACT

This report describes the geography, geology, and the source, occurrence, availability, and chemical character of the ground water in Ford county, in southwestern Kansas. Much of Ford county is situated in the Plains Border section of the Great Plains province, about 75 percent of the county consisting of upland plains and the remainder of stream flood plains and intermediate slopes. Ford county embraces a total of 30 townships, or 1,082 square miles, and is drained by the Arkansas river and its tributaries. The county had a total population of 17,183 in 1940. Dodge City, the county seat, had a population of 8,487 in 1940. The climate is semiarid; the normal annual precipitation at Dodge City is about 20½ inches. Wheat farming, some cattle raising, and general farming are the chief occupations in the county. Sand, gravel and some building stone are quarried in parts of the county.

The exposed rocks are of sedimentary origin, ranging in age from Cretaceous to Quaternary. The Ogallala formation (Pliocene) lies at or near the surface over much of the county north of the Arkansas river. The Kingsdown silt forms a thick surface mantle over most of the county south of the river. Dune sand occurs in a belt of varying width on the south side of Arkansas river and in two other isolated patches in the county. Late Quaternary alluvium floors the Arkansas valley and the valleys of some of the smaller streams. The Greenhorn limestone and Graneros shale (Upper Cretaceous) are exposed in the northern part of the county. The Dakota formation is the oldest formation exposed. Unexposed rocks below the Dakota formation include the Kiowa shale and Cheyenne sandstone and the Permian redbeds.

The Bazine anticline of Hodgeman county continues southeastward through Ford county, crossing the Arkansas river near Ford. Along this structure the Cretaceous rocks lie at or near the surface.

The Fowler fault in the vicinity of Fowler, northeastern Meade county, was encountered in southwestern Ford county by test drilling.

The report contains a map of the county showing the depth to water level by means of shading. The water table ranges in depth from less than 10 feet in areas of shallow water table along the Arkansas valley to about 200 feet in parts of the uplands. The report also contains a map of the county showing the shape and slope of the water table by means of contours. South of the Arkansas valley, where the Ogallala is the principal water-bearing formation, the water table conforms in general to the eastward-sloping bedrock floor and slopes about 7 feet to the mile. In the northeastern part of the county the slope of the water table is greater and is altered in direction by the shallow position of the underlying Dakota formation. Arkansas river and several

smaller streams in the county have cut their valleys beneath the water table with the result that some ground water moves in toward the streams from both sides. Locally in the northern part of the county, down-cutting streams have either drained the Ogallala or have removed the formation entirely. Wells in this part of the county have been drilled into the underlying bedrock for water supplies.

Flowing wells are obtained in a narrow belt bordering Crooked creek in the southwestern part of the county. The flows range from a scant trickle to about 3 gallons a minute. The artesian head was found to be only 1 foot above land surface in two wells whose heads were measured.

The ground-water reservoir is recharged by infiltration of part of the precipitation that falls within the county, by water that is moving into the county through the Ogallala formation, by water entering the Dakota formation in outcrop areas southwest of the county, and in part by water that is moving as underflow down the Arkansas valley and the valleys of several smaller perennial streams. Water is discharged from the underground reservoir mainly by lateral migration eastward out of the county as underflow, in part by transpiration and evaporation in areas of shallow water table, in part by movement toward Arkansas river and several smaller perennial streams, in part through small springs in the northern part of the county, and in small part by wells. Most of the domestic, stock, public, industrial, and irrigation water supplies are obtained from wells. Some water is recovered from gravity springs in the northern part of the county for domestic and stock use, but the flows generally are small.

Ground water is recovered principally from drilled wells, but there are a few dug wells, several dug and drilled wells, and a few driven wells. Most of the drilled domestic and stock wells have a separate cylinder and pump pipe within the outer casing, but a few in the southeastern part of the county are tubular wells in which the casing acts also as the pump pipe and has the cylinder attached directly to the bottom of the casing. Ground water is used by several industries in Ford county, principally for cooling and condensing—by a power plant, two railroads, several laundries, a creamery, a flour mill, a warehouse, and for air conditioning several buildings. The total pumpage from wells for industrial purposes in Ford county in 1938 amounted to about 3,830 acre-feet. Dodge City, Bucklin and Spearville, and the Kansas Soldiers' Home at Fort Dodge each have public water supplies derived from wells. In 1938, approximately 1,845 acre-feet of water was pumped from wells for public supplies. In the Arkansas valley a total of 187 irrigation wells was in operation in 1938. About 2,814 acres were irrigated, and about 4,760 acre-feet of water was pumped from these wells in 1938. There are also 10 irrigation wells on the uplands south of the Arkansas valley. Most of the irrigation wells in the Arkansas valley are equipped with horizontal centrifugal pumps, but those on the uplands are equipped with deep-well turbine pumps. There are several plants that pump irrigation water from streams, most of which are in the Arkansas valley. About 730 acre-feet of water was pumped or diverted from the Arkansas river in 1938 for irrigation. The possibility of developing additional ground water for irrigation in several parts of the county are discussed in the report.

The ground water is hard, but in general is of satisfactory quality for most purposes. The waters in the alluvium are in general considerably harder than the waters from the Ogallala formation or the Dakota formation.

The Ogallala is the principal water-bearing formation in the county. It is composed of structureless silt and fine sand together with some coarse sand and gravel and ranges in thickness from a few feet to 250 feet. In many places the deposits are consolidated by calcium carbonate, forming beds of caliche. Most of the water is obtained from the sands and gravels in the lower part of the formation. The Dakota formation furnishes water to many wells in the northeastern part of the county and to several irrigation wells in the southwestern part of the county. The Dakota comprises beds of lenticular sandstone, variegated shale, clay, and siltstone, and is about 235 feet thick, but only the upper part is exposed in Ford county. It is known to be much thinner in the southern part of the county, and is absent locally in the southeastern part of the county. No wells in the county are known to obtain water from the Cheyenne sandstone. Large supplies of water are obtained from wells in the alluvium of the Arkansas valley.

The basic field data upon which most of this report is based are given in tables, and include records of 531 wells and chemical analyses of the water from 69 representative wells and one spring. Logs of 80 test holes and water wells in the county are given, including 21 test holes put down during the investigation.

INTRODUCTION

Purpose and scope of the investigation.—The investigation upon which this report is based is part of an extended program of ground-water investigations in Kansas begun in July, 1937, by the United States Geological Survey and the State Geological Survey of Kansas in coöperation with the Division of Sanitation of the Kansas State Board of Health and the Division of Water Resources of the Kansas State Board of Agriculture. Similar investigations are being conducted in several other counties in southwestern Kansas. It is expected that additional areas will be selected for study in order to determine ground-water conditions in critical parts of the state.

As a result of several years of recurrent drought, numerous inquiries were received by the state geologist in regard to the possibilities of utilizing ground water for irrigation in parts of southwestern Kansas. As a result of these inquiries S. W. Lohman made a brief investigation in Ford county in November, 1937, in order to determine the nature and extent of recent developments of water supplies from wells available for irrigation in the uplands of that county, and to determine what additional studies should be made in the future. The recommendations made at that time (Lohman, 1938, p. 9) are in part as follows:

A general investigation of ground-water conditions should be made that will cover not only Ford county, but also as much of the territory adjoining as is necessary to make an adequate interpretation of the geologic and hydrologic conditions in each locality as to occurrence, depth, and yield of the water-bearing beds and the depth to the static water level, and to determine so far as possible the safe yield of the water-bearing formation.

A program of water-level measurements should be begun immediately to obtain observations before there is any significant change from natural conditions undisturbed by pumping for irrigation. The measurements should be continued in subsequent years and records should be obtained of the quantities of ground water that are pumped each month or year, in order to determine the trends in movement of water level resulting from irrigation and to check preliminary conclusions as to the safe yield of the water-bearing formations. There is at present so little use of ground water for irrigation in Ford county and the adjacent territory that an unusual opportunity is offered to determine hydrologic conditions as unaffected by artificial withdrawal.

A study should also be made of the chemical character of the water in regard to its suitability for irrigation.

Studies should be made to determine the most economical type of well construction for a given locality or given type of material—especially to determine whether in certain areas irrigation wells can be constructed without artificial gravel packing.

In accordance with the above recommendations, I was assigned to the area in October, 1938. Shortly after the work began, an interagency conference was held in Dodge City in order to coördinate the efforts of federal and state agencies that are concerned with problems relating to the water resources of western Kansas. The scope of the Ford county investigation was temporarily altered to include only a comprehensive inventory of pumpage from wells in the Arkansas valley part of the county. The results of this preliminary survey were included in a brief report and released to the public in a memorandum for the press (Waite, 1939, pp. 1-2). A detailed survey of the entire county was completed in 1939.

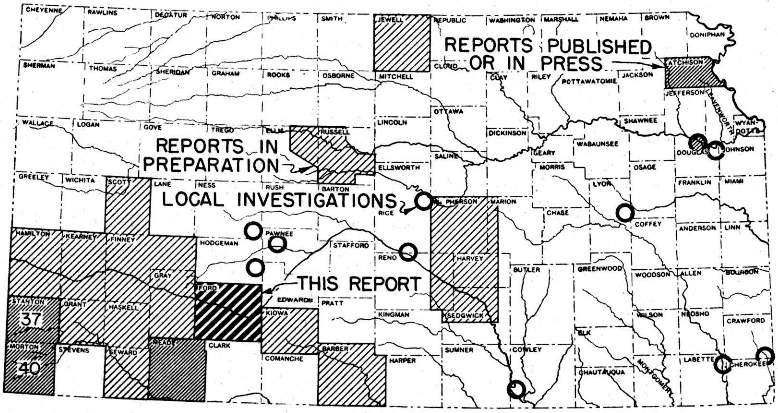


FIG. 1. Index map of Kansas, showing the area covered by this report and other areas for which coöperative ground-water reports have been published or are in preparation.

The investigation was made under the general administration of R. C. Moore and K. K. Landes, state geologists, and O. E. Meinzer, geologist in charge of the Division of Ground Water of the Federal Geological Survey, and under the immediate supervision of S. W. Lohman, federal geologist in charge of ground-water investigations in Kansas.

Location and extent of the area.—Ford county lies in southwestern Kansas and embraces a total of 30 townships, or 1,082 square miles. Its location with respect to adjoining counties is shown by figure 1.

Previous Investigations.—The more important studies dealing with the geology and ground-water resources of southwestern Kansas that have a bearing on Ford county are cited below. Specific references are cited at appropriate places in the text by author and date of issue and are listed in the bibliography at the end of the report.

In 1892, Colonel Nettleton (1892, pp. 27-32, appendix No. 11) reported on the results of some underflow surveys along the Platte and Arkansas river valleys including a discussion and plat of a north-south profile of the water table extending across Ford county and passing through Dodge City. In 1897, Sutton (1897, pp. 40-41) published the log of a well drilled for experimental use at a pumping station in Ford county. In this same report, Haworth (1897a, 49-114) reported on the geology of underground water in western Kansas. Three other papers were contributed by Haworth in 1897, one (1897b) on underground waters of southwestern Kansas, another (1897c) on the physiography of western Kansas, and a third (1897d) on the physical properties of the Tertiary rocks in Kansas. Johnson's scholarly paper on the "Utilization of the High Plains" (1901) dealt with the physiography, underground waters and the land economy of the High Plains. A second paper (Johnson, 1902) containing conclusions and a summary of the first paper appeared in 1902. In 1905, Darton (1905, p. 298) published a preliminary report on the geology and ground-water resources of the central Great Plains, in which he made brief reference to Ford county. In 1906 a report by Slichter (1906) was published on the results of some underflow experiments and related studies on underground water along the Arkansas valley, and although the locale of this work was considerably west of Ford county, his findings have a direct bearing on conditions in parts of the county. In 1911 a very brief description of the availability of ground water in Ford county was given by Parker (1911, pp. 91-94, 269-273) along with the analyses of some typical well waters collected near Dodge City. In 1912 a report by Coffey and Rice (1912) was published that contained the results of a reconnaissance soil survey of the western half of Kansas, including Ford county. In 1913, Haworth (1913) contributed a report on well waters in southwestern Kansas. In 1916 Darton (1916, pp. 35-41, sheets 5 and 6) described the geology along the route of the Atchison, Topeka and Santa Fe Railway. In 1918, Darton (1918, pp. 5-8) described briefly the structure of parts of the central Great Plains, taken in part from several of his earlier reports. In 1931 the Division of Water Resources of the Kansas State Board of Agriculture published a report (1931) that contained a description of some of the most common types of pumping plants in Kansas with approximate costs of construction. In 1935, Theis, Burleigh, and Waite (1935) described briefly the water-bearing formations and the availability of ground water in the southern High Plains. In 1937, Lohman (1937) contributed a short paper on water supplies from wells available for irrigation in the uplands of Ford county, and included the conclusions and recommendations that led to the present investigation. In 1937, Smith (1937, pp. 283-291) contributed some preliminary notes on Pleistocene gravels in southwestern Kansas with particular emphasis on their distribution along the Arkansas valley. In 1937, a report by Throckmorton and others (1937, pp. 69-71) was published on the agricultural resources of Kansas which included important statistical data for Ford county. In 1938 the Division of Water Resources of the Kansas State Board of Agriculture published a report (1938) containing the results of tests of deep-well pumping plants with special attention to fuel consumption. Two of the plants that were tested are located in Ford county. In 1939 Davison (1939) contributed a report on the construction and costs of irrigation pumping plants in Kansas, containing a description of different types of pumping plants, the conditions for which each is best adapted, construction methods, and a discussion of construction costs. Also in 1939, McCall and Davison (1939) contributed a report, on the cost of pumping for irrigation, that includes data on several tests of irrigation pumping plants in Ford county. In 1939, a report was published (Meinzer and Wenzel, 1939, pp. 93-100) on water levels and artesian pressures in the United States in 1938; it contains a chapter on the observation-well program in Ford county. In 1939, I (Waite, 1939) prepared a brief preliminary report on the ground-water resources of the Arkansas valley in Ford county. In 1940, Moore (1940) prepared a generalized report on the ground-water resources of Kansas which includes a section on Ford county. A report by Smith (1940) entitled "Geologic Studies in Southwestern Kansas," includes many references to the geology of Ford county.

Methods of investigation.—The field work upon which this report is based occupied about 2½ months in the fall of 1938 and about 5 months in the summer of 1939. Approximately 530 wells in the county were visited and the total depth and depth to water level below land surface in most of them were measured with a steel tape. Well owners and drillers were interviewed regarding the nature and thickness of the water-bearing formations penetrated by the wells, and all available logs were collected. Records were collected of wells that furnish public, industrial, domestic, and irrigation supplies. Information was obtained regarding the yield, draw-down, temperature of water, chemical character of the water, and the use of ground water.

Samples of water were collected from 65 representative wells and 1 spring and were analyzed by Robert H. Hess, chemist, in the Water and Sewage Laboratory of the Kansas State Board of Health at Lawrence. In addition analyses of water from the 3 public supplies in the county, together with an analysis of water from a well

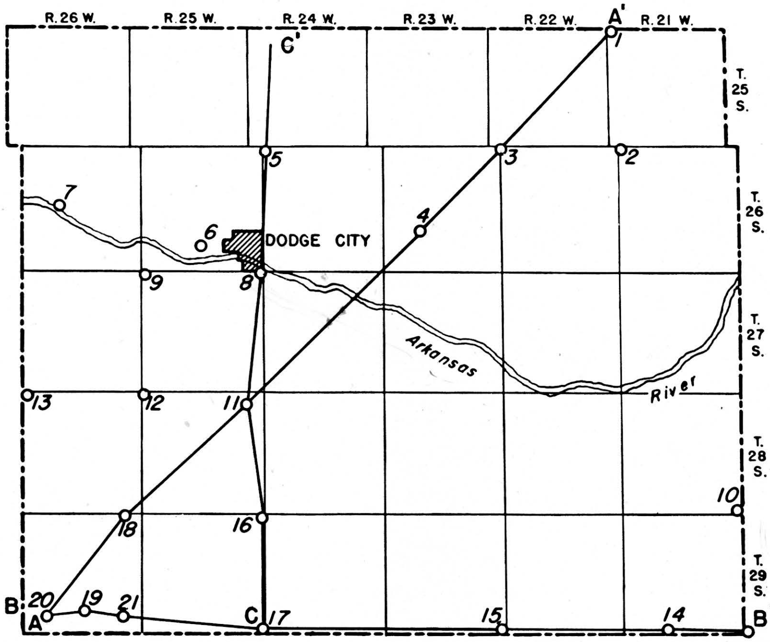


FIG. 2. Map of Ford county showing locations of test holes and locations of cross sections shown on plate 5.

of the Kansas Power Company in Dodge City, were furnished by the Kansas State Board of Health, making a total of 70 analyses for Ford county.

During the investigation 21 test holes (fig. 2) were put down at strategic points in Ford county by Ellis Gordon, Perry McNally, and Fred Holden with a portable hydraulic-rotary rig owned by the State and Federal Geological Surveys. Laurence Buck replaced Fred Holden near the end of the drilling program. Samples of drill cuttings were collected and studied in the field by Perry McNally and were examined later in the office under binocular microscope.

Additional logs and drill cuttings were made available by W. R. Stanley and Lewis H. Bacon, of the Soil Conservation Service at Dodge City, and materially aided in the interpretation of subsurface conditions. A rather comprehensive test-drilling program was conducted by this organization in parts of the Arkansas valley, including Ford county.

Altitudes of the measuring points were established with plane table and telescopic alidade at 368 wells and at the portals of each of the test holes put down by the drilling rig. The levels were run from benchmarks of the United States Coast and Geodetic Survey by Delmar O. Branson, assisted by Everett Johnson and in part by Charles C. Williams. The water-table contour map (pl. 1) is based upon these altitudes together with the measured depths to water level in wells.

Field data were compiled on topographic maps of the U. S. Geological Survey and on an ownership map of Ford county. The base map for plates 1 and 2 was prepared from a county map compiled by the State Highway Department. The locations of the roads were corrected from observations in the field and the drainage was corrected from aerial photographs obtained from the United States Department of Agriculture, Agricultural Adjustment Administration.

The areal geology shown in plate 1 was compiled from field studies supplemented by liberal use of the aerial photographs and by available geologic reports. Many of the boundaries of the areas of alluvium and dune-sand were taken from aerial photographs supplemented by observations in the field.

The locations of all wells for which descriptions are given in the tables of well records are shown in plate 2, with the exception of an area several square miles in extent in and adjacent to Dodge City. On account of the concentration of irrigation wells in this local area, a larger-scale map has been prepared (plate 3) showing the locations of each of the wells that were visited. Two numbers are shown opposite each well symbol, the upper one corresponding with that used in the well tables in the text, and the lower one corresponding with the depth to water level below the land surface.

The wells are numbered consecutively by townships from north to south and by ranges from east to west. Within each township the wells are numbered in the same order as the sections. Within each section the wells are numbered in the sequence of the sixteen 40-acre tracts into which sections are divided by the General Land Office, as shown in the explanation of plate 2.

Acknowledgments.—I am indebted to the many residents of the county who readily gave permission to measure their wells, and who supplied helpful information regarding them. Special acknowledgment should be given to the fine coöperation of all the well drillers in the county for making available to the writer well logs and in some cases samples of water-bearing materials. George S. Knapp, chief engineer of the Division of Water Resources, Kansas State Board of Agriculture, made available unpublished data relating to wells, and assigned Kenneth D. McCall and Milburn H. Davison to conduct pumping tests on several typical irrigation wells in Ford county. I spent several days in the field with McCall and Davison, assisting them with the pumping tests. Thanks are due to Harold T. U. Smith, of the Department of Geology, University of Kansas, for unpublished data and for helpful suggestions in the preparation of this report. Thanks are due also to Claude W. Hibbard, assistant curator of vertebrate paleontology of the Dyche Museum of Natural History, University of Kansas, for close coöperation in the field and for helpful identification of vertebrate and invertebrate material collected in Ford county. Several days were spent in the field with Smith and Hibbard studying stratigraphic relations in Ford county and adjacent areas. Special acknowledgment is due to Fred Moon, irrigation specialist of the Kansas Power Company, Dodge City, for valuable assistance during the entire investigation.

Acknowledgment for helpful information is due also to the following persons: J. C. Denious and Jay Baugh, Dodge City *Daily Globe;* Frank Dunkley, secretary of the Dodge City Chamber of Commerce, and C. C. Isely, chairman of the Special Irrigation Committee of that organization; P. H. Browne, Johnston Pump Company, Dodge City; Fred Kirkpatrick, city engineer; Glenn Faulkner, county engineer; Rex Reynolds, city water commissioner; A. M. Truman, division engineer, and Dave Kriegh, draftsman, both of the Atchison, Topeka and Santa Fe Railway, Dodge City; H. I. Christensen, Norvall White, Frank White, and Frank Westerman, of the Kansas Power Company's plant near Fort Dodge; E. E. Vance, engineer in charge of the power plant at the Kansas Soldiers' Home at Fort Dodge; U. G. Balderston, Dodge City; Tom Stauth, Dodge City; J. E. Homan, Kansas Power Company, Dodge City; John Dortch, water superintendent of Spearville, Kan.; and J. E. Devore, city clerk of Bucklin.

Logs of test wells put down by the Layne-Western Company at Dodge City and at Minneola Booster Station No. 3 of the Natural

Gas Pipe Line Company of America were kindly furnished by R. O. Joslyn, president of that company.

The manuscript for this report has been critically reviewed by S. W. Lohman, O. E. Meinzer, and W. D. Collins of the Federal Geological Survey; R. C. Moore and J. C. Frye of the State Geological Survey; George S. Knapp, chief engineer of the Division of Water Resources of the Kansas State Board of Agriculture; and Lewis Young, acting director of the Division of Sanitation of the Kansas State Board of Health. The illustrations were drafted by G. W. Reimer, Alice Bruce, Dorothea Weingartner, Joan Justice, and Eva Baysinger, of the Kansas Geological Survey.

GEOGRAPHY

Topography and Drainage.—Ford county is situated in the Great Plains physiographic province, much of the county falling within the subdivision known as the Plains Border section (Fenneman, 1930). About 75 percent of the county consists of upland plains and the remainder of stream flood plains and intermediate slopes. South of the Arkansas river the upland plain slopes southeastward from altitudes of about 2,720 feet along the western boundary at a point about 10 miles north of the southwestern corner of the county to about 2,390 feet along the eastern boundary on the upland plains about 4 miles east of Bucklin. North of Arkansas river the upland plain descends from an altitude of about 2,660 feet along the western boundary at a point about 2 miles north of Arkansas river to about 2,280 feet along the eastern boundary at a point about 2 miles south of the northeastern corner of the county. The undissected surfaces of the uplands in general are comparatively flat and featureless, but locally the surface is undulating and is characterized by broad gentle swells and shallow depressions.

The Arkansas river valley ranges in width from about 2 miles along the western border to about 4 miles along the eastern border, and is 50 to 160 feet deep. The valley is bordered by moderately steep slopes or bluffs on the north side of the river and by a wide zone of sand hills on the south side (pl. 1).

The county is drained by Arkansas river which enters the county along the western boundary at a point about 2 miles northeast of Howell and flows in a southeasterly direction to a point east of Ford, where it turns and flows northeastward, leaving the county near the middle of the eastern boundary. The change in course near Ford is part of a large and unusual bend that the river makes in passing from eastern Ford county northeastward to Great Bend, where it again changes direction and swings southeastward. During the summer months Arkansas river often dwindles to an insignificant stream or disappears almost entirely in its sandy bed with little or no visible flow. At such times the sandy stream bed is threaded by shallow channels, as shown in plate 4B. During periods of flood the stream flow is increased in volume, which results in a general overflow of the stream banks and the inundation of the adjacent flood-plain. The average gradient of Arkansas river in Ford county is about 7 feet to the mile. Of the several tributary streams to Arkansas river, only Mulberry creek on the south joins the main stream within the county.

North of the river, where the surface slopes to the northeast, the northeastern drainage heads within a mile and a half of Arkansas river in some places (pl. 1). The largest tributary stream north of the river in Ford county is Sawlog creek, which rises in the northwestern corner of the county, flows eastward along the northern edge of the county, and leaves the county at a point about 3½ miles east of U. S. Highway 283. Sawlog creek joins Buckner creek at Hanston in eastern Hodgeman county. Duck creek, which heads about a mile north of Dodge Ctiy, flows northeast and enters Sawlog creek at a point about 2½ miles west of U. S. Highway 283. Five-mile creek heads about 2 miles west of Wright and flows northeast to join Sawlog creek at a point about a mile east of U. S. Highway 283. Spring creek heads about 2½ miles northeast of Wright, flows northward and joins Sawlog creek about 2 miles east of U. S. Highway 283. A large area southeast of Spearville is drained by Coon creek and its chief tributary, Cow creek. Coon creek heads about 3 miles southwest of Spearville and roughly parallels Arkansas river, leaving the county at a point about 7 miles south of the northeastern corner. With the exception of Duck creek, which is largely spring fed, most of the tributaries are usually dry.

South of Arkansas river Mulberry creek is the principal tributary. An area in the southeastern corner of the county in the vicinity of Bucklin is drained by Rattlesnake creek, which flows northeastward and joins Arkansas river southwest of Alden in Rice county. It is an intermittent stream and is dry most of the year. Crooked creek enters the southwestern corner of the county at a point about 1½ miles east of the southwestern corner, makes a broad loop, and swings out of the county at a point on the south county line about 1¾ miles east of its point of entry. Throughout its course in Ford county Crooked creek has eroded a channel of sufficient depth to intercept ground water from springs and seeps, with the result that the creek bed seldom is entirely dry, although actual flow may at times be supplanted by scattered pools along the stream bed. The anomalous features of the reversal in the direction of flow of this stream are discussed under a later section.

Mulberry creek heads just to the west in Gray county and enters Ford county at a point about 11½ miles north of the southwest corner, flows southeastward to a point about 5 miles northeast of Bloom, after which it swings northeastward to join Arkansas river about 1 mile east of Ford. This stream is usually dry in its upper reaches and throughout much of its course, but carries a small amount of water the year round in a short stretch above its mouth.

The tributary streams north of the Arkansas river, with the exception of Coon creek, have cut their channels from 100 to 150 feet below the level of the uplands and in general have narrow flood plains bordered in some places by rather precipitous bluffs. The northern part of the county comprises a deeply dissected area in which encroaching streams such as Sawlog, Duck, and Five-mile creeks are gradually destroying the original plains surface and have cut through the Ogallala formation into the underlying Cretaceous rocks. South of the river the amount of dissection is not as great and tributary streams have not cut their channels into bedrock. Resistant caliche beds, so characteristic of the plains surface north of the river, generally are absent south of the river, and the tributary streams have eroded valleys lacking in precipitous bluffs but with numerous closely-spaced gullies entering from both sides. Mulberry creek has cut below the plains surface to depths of 80 to 120 feet, but, unlike the streams north of the river, the intermediate slopes on both sides of the valley are gentle. The gullies tributary to Rattlesnake creek in the southeastern part of the county give rise to a semibadland type of topography. Near the southwestern corner of the county the plains surface slopes toward the Crooked creek valley and comprises the northern part of the Meade artesian basin. Within Ford county the channel of Crooked creek has been incised only to a depth of about 10 feet below its floodplain and has not yet reached base-level.

Population.—According to the census of 1940, Ford county had a population of 17,254 and an average density of population of 15.9 inhabitants to the square mile, as compared with 21.9 for the entire state. The population in 1930 was 20,647, indicating a reduction of 3,393 during the decade. Dodge City, the county seat, had a popu-

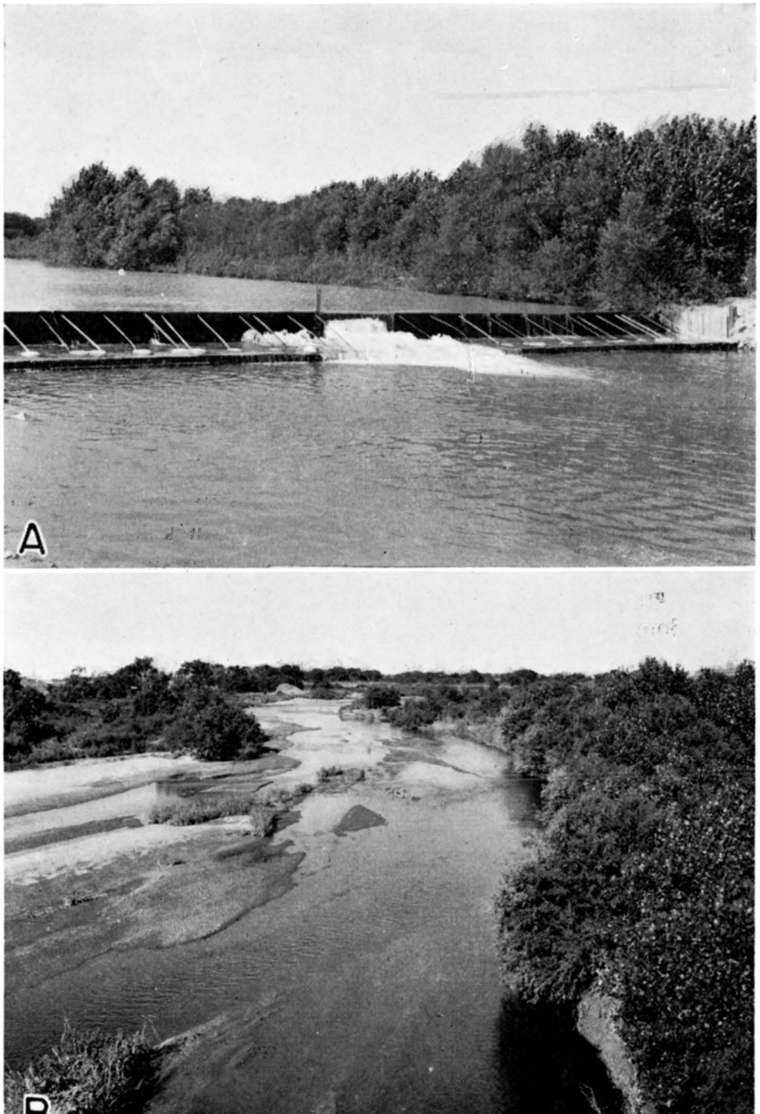


PLATE 4. A, Dam across Arkansas river. Diverts water for the Wilroads Gardens rehabilitation project. Located about 3½ miles below Dodge City in the SW¼ SE¼ sec. 4, T. 27 S., R. 24 W. B, Typical view of Arkansas river. Looking downstream from the Bucklin bridge about 7 miles north of Bucklin.

lation of 8,487 in 1940, having decreased from a population of 10,059 in 1930. Bucklin had a population of 832 in 1940, Spearville, 603, and Ford, 296. Population figures are not available for Fort Dodge (location of the Kansas Soldiers' Home), Wright, Bellefont, Bloom, or Kingsdown.

Transportation.—Ford county is served by the main lines of two railroads as well as a branch line of each. The main line of the Atchison, Topeka and Santa Fe Railway traverses the county from east to west, following the north side of the Arkansas river from Dodge City westward. The main line of the Chicago, Rock Island, and Pacific Railroad from Chicago to Tucumcari, New Mexico, crosses the southeastern part of the county. A branch line of the Santa Fe crosses the river at Dodge City and goes southwestward to Boise City, Oklahoma. A branch line of the Rock Island crosses the river at Dodge City and joins the main line at Bucklin, paralleling the river as far east as Ford.

U. S. Highway 50 South (paved) parallels the Santa Fe Railway for most of its route across the county, a slight deviation being made at Wright, where the highway continues straight west for 6 miles and thence south into Dodge City. U. S. Highway 154 (paved) enters the county 8 miles north of the southeast corner and continues west for 7 miles, turns northwest to Ford, whence it follows the north side of the river to Dodge City. U. S. Highway 54 parallels the main line of the Rock Island, passing through Bucklin, Kingsdown, and Bloom. State Highway 34 (oil-surfaced) enters the county 5 miles south of Bucklin, continues north through Bucklin, and joins U. S. Highway 154 two and one-half miles northwest of Bucklin. State Highway 45 (oil-surfaced) starts at Dodge City and parallels the Elkhart branch of the Santa Fe, leaving the county about 13 miles north of the southwest corner. U. S. Highway 283 (oil-surfaced) traverses the county from north to south through Dodge City.

Ford county has a well-planned and coördinated system of improved farm-to-market roads. Many of the county roads are graveled and are kept in good condition throughout the year, and many of the section roads have been graded. In general, little or no difficulty is encountered in traveling anywhere within the county.

Agriculture.—Agriculture is the chief occupation in Ford county. Dodge City serves as a distributing center and trading point for much of southwestern Kansas. Wheat farming, some cattle raising, and general farming are the principal types of agriculture prevailing in the county. In the Arkansas valley the principal crops consist of wheat and other grains, grain sorghums, several kinds of stock feed, corn, alfalfa, sugar beets, potatoes, and garden truck of all kinds. Irrigation is practiced in the Arkansas valley and in some of the smaller stream valleys, and there are a few irrigation wells on the uplands. In 1938, 3,200 acres were under irrigation in Ford county (see section on Irrigation supplies).

Cattle raising was the principal industry in Ford county when settlement began. With the penetration of railroads into western Kansas after 1860, Dodge City became a famous frontier town—the center of important lines of freighting and the headquarters of the cattle business. This industry attained its maximum development in 1884 when herds aggregating 800,000 cattle tended by 3,000 men passed through Dodge City from Texas on the way north. Overgrazing became a problem during the eighties, the seriousness of which increased as the carrying capacity of the range decreased. Cattlemen suffered great losses as a result of the unusually severe winter of 1886-'87 when great numbers of cattle perished. The prolonged drought that followed (1886-'95) brought further losses and homestead settlement contributed to the difficulties. Thus large-scale cattle ranching was gradually replaced by smaller operations under individual ownership. Years of relatively abundant rainfall from 1910 to 1917, together with high wheat prices brought about by European demand following the outbreak of the World War, gave impetus to the raising of wheat and offered the wheat farmer tangible inducements to produce it in great quantities. Other factors stimulated the process of plowing up the prairies almost to the present time, chief among which were progress in methods of dry farming, and, finally, the introduction of power machinery. With the coming of the tractor and the combine more acres could be seeded because more could be harvested. The common practice was to plow and seed as much land as possible, and then hope for adequate rain, a big crop, and a satisfactory price. Wheat acreages expanded until in 1929 approximately 334,000 acres were harvested. With the coming of several consecutive years of low rainfall associated with the drought of 1931-'39, grain yields were greatly reduced and farm incomes were lessened accordingly. The average harvested acreage of wheat from 1930 to 1934 was reduced to 236,000 acres a year. Many of the wheat growers who had formerly maintained small herds of cattle were forced to sell all or a part of them because of lack of pasturage and forage. For a more detailed historic discussion of the settlement and land use of the High plains the reader is referred to a report entitled "The Future of the Great Plains" (Great Plains Committee, 1936).

Ford county has a total area of 693,120 acres. According to the census of 1940, about 51 percent of the land in use in 1939 was devoted to crops and about 49 percent to grazing. In 1940 one percent of the farms were less than 100 acres in size, 6 percent of the farms ranged in size from 100 to 259 acres, 26 percent ranged from 260 to 499 acres, 43 percent ranged from 500 to 999 acres, 24 percent were 1,000 acres or larger. On April 1, 1940, Ford county had 1,485 farms with an average area of 479.4 acres each. The pastures of Ford county are of the short-grass type and consist chiefly of buffalo grass. In 1939, of the total farm land, 28 percent produced no crop, 24 percent was classified as idle or fallow land, 20 percent was devoted to winter wheat, 16 percent was classified as wasteland and included woodland, house yards, barn yards, feed lots, lanes and roads, 8 percent was classified as plowable pasture, 3 percent as sorghums, including sorghums cut for hay and pasture, and less than 1 percent was devoted to barley, oats, hay, sugar beets and miscellaneous crops.

With the exception of relatively small areas in the extreme northern and northeastern parts of the county, where the soils have been formed from the weathering of the Greenhorn limestone, the soils of Ford county have been formed from the weathering of the underlying plains surface. Throckmorton and others (1937, pp. 69-71) describe these soils as follows:

> These soils are dark gray to brown in color, friable, deep, and relatively easily cultivated. The subsoils are deep and consist of yellowish-brown to grayish-brown silty clay loams and clay loams. The subsoils are sufficiently friable to permit deep penetration of moisture and plant roots. Sheet erosion has taken place on the more sloping soils and in some localities has practically removed the surface layer of soil. Practically all of the soils in the county under cultivation are subject to erosion by wind, but in most cases this can be prevented relatively easily by the adoption of good methods of soil management.

With sufficient moisture the soils are capable of producing large yields. The soils on the upland are suitable for the raising of wheat and grain sorghums. The bottom-land soils are capable of producing these crops and also alfalfa, sugar beets, potatoes, and various garden truck.

Natural resources and industries.—Sand and gravel deposits are the chief mineral resource in Ford county. These deposits are abundant along Arkansas river, both in the present stream bed and in low terraces near the margin of the present flood plain, and they are excavated extensively by shovels or by centrifugal pumps at many different points. Sand and gravel deposits are also worked in the northern part of the county in terrace deposits along Sawlog creek and several of its tributaries, notably in sections 7 and 17, T. 25 S., R. 23 W. The locations of the more important gravel pits are shown in plate 1. The chief use of sand and gravel is for road surfacing, but smaller amounts are used in concrete aggregate for paving, buildings, road culverts, and bridges.

Building stone is quarried at several places in the northern part of the county. The Greenhorn limestone is the most commonly used stone in the county, although the Dakota formation has been quarried rather extensively in the past. The limestone is used for buildings and other structural work and for road metal. Some of the harder calcareous beds in the Ogallala formation have been quarried for road metal in the SW¼ sec. 28, T. 27 S., R. 22 W.

There is no commercial production of oil or gas in Ford county, although several tests have been drilled. Gas was reported in one test drilled in the SW¼ NE¼ sec. 34, T. 27 S., R. 21 W.

In 1936 samples of rock were collected from exposures of the Ogallala formation and Greenhorn limestone along Duck and Sawlog creeks northeast of Dodge City, and tests were made to determine their suitability for making rock wool (Plummer, 1937, pp. 59-64). Extremely fine white rock wool was made from the samples of "mortar beds" of the Ogallala.

Samples of Cretaceous clays in the Dakota formation in the northern part of Ford county were collected in 1940 by Plummer and Romary in connection with an extensive study of the ceramic possibilities of Kansas clays. The results of the tests on the samples from Ford county are to be published as a bulletin of the Kansas Geological Survey.

Climate.—Ford county is characterized by a rather dry climate, abundant sunshine, warm summer days that are alleviated by a good wind movement and low relative humidity. . . . Hot winds occasionally blow during a dry, heated period and are the cause of great crop damage and much discomfort while they are occurring.

Winter months, as a rule, are slightly colder and windier than in eastern Kansas, but are drier. Snowfall, however, is usually light, seldom totaling more than 20 inches in the course of a winter season, and it is rare that the ground is covered for more than a week at a time. It usually falls with a high wind and lies very unevenly on the ground.

The moisture that falls as rain and snow from season to season is the chief limiting factor of crop growth. The distribution of precipitation through the year is peculiarly favorable for crop growth. Approximately 77 percent of the annual amount falls in the six months, April to September, inclusive, when the growing season is at its height and moisture is most needed. The driest month is generally January, after which there is a steady increase in the average monthly totals that mounts rapidly in April and continues until July. A sharp decrease in the average rainfall begins the latter part of October or the first part of November and continues into the winter. Precipitation in this part of the state is inclined to be irregular in occurrence. (Anonymous, 1930.)

According to the U. S. Weather Bureau the normal annual precipitation at Dodge City is 20.51 inches, and at Bucklin it is 20.85 inches.

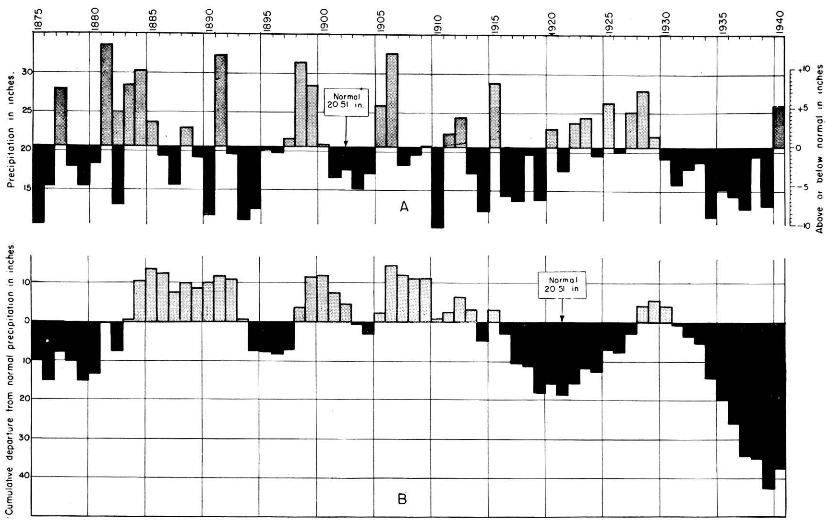


FIG. 3. Graphs showing (A) the annual precipitation at Dodge City, Kansas, and (B) the cumulative departure from normal precipitation at Dodge City.

The annual precipitation and the cumulative departures from normal precipitation for each of these stations are shown in figures 3 and 4. The precipitation at Dodge City has averaged 4.85 inches below normal for the last 10 years, 1930-1939, inclusive. This is by far the longest consecutive period of subnormal precipitation in the 65-year record of the station. The longest periods of subnormal precipitation previously were only of 4 years duration and began with the years 1901 and 1916. The deficiency in annual precipitation of 9.51 inches in 1934 was exceeded previously three times; in 1875 the deficiency was 9.83 inches and in 1893 and 1910 it was 10.39 inches. By the end of 1939 the cumulative departure from normal precipitation amounted to about 42½ inches—an amount equal to more than twice the normal annual precipitation.

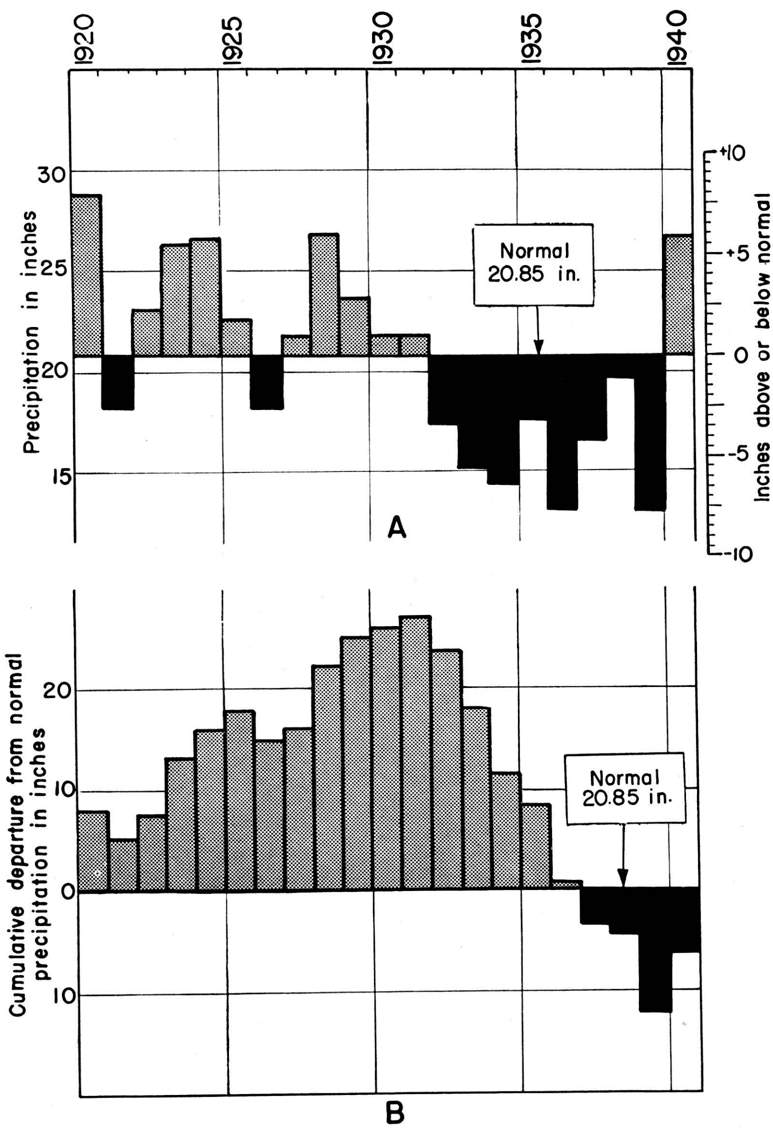


Fig. 4. Graphs showing (A) the annual precipitation at Bucklin, Kansas, and (B) the cumulative departure from normal precipitation at Bucklin.

The driest years since the beginning of record at Dodge City were 1893 and 1910. The wettest year was 1881 when a total of 33.55 inches was recorded. Other unusually wet years were: 1891, with a total of 32.34 inches; 1898, 31.46 inches; 1906, 32.54 inches; and 1915, 28.75 inches.

The period of record at Bucklin is much shorter than that at Dodge City. As shown in figure 3, the precipitation at Bucklin was above normal during the period 1920-1931, but subnormal precipitation prevailed during the period 1932-1939.

The average annual mean temperature as recorded at Dodge City is 54.3° F. The highest temperature recorded was 109° F. on July 31, 1934, and July 18, 1936, and the lowest was —26° F. in February, 1899. July is usually the warmest month of the year. The coldest month in the year is usually January, although the lowest temperature of record occurred in February. The length of the growing season averages about 189 days, but ranges from 148 to 238 days. (Throckmorton and others, 1937, pp. 69-71.) The first killing frost in the fall occurs generally in September or October, and the last killing frost in the spring occurs generally about the middle of April. Killing frosts have occurred as early as September 23 and as late as May 27.

The prevailing wind direction is from the northwest in January, February, and March; from the southeast during the period April through August; from the south in September; from the southeast in October; and from the northwest in November and December. Generally the windiest months are March, April, and May, and the month of least wind is August. Wind movement is considerably higher in the afternoon than at night. High winds in the early spring often cause much damage by blowing off the loose top soil, especially if it happens to be dry. In such cases soil may be blown from the roots of wheat or the plant may suffer mechanical damage by rapidly moving particles of sand carried by the wind. During several of the severe dust storms in the spring of 1935 all forms of travel, including trains and buses, were stopped in the vicinity of Dodge City and highways were closed.

TABLE 1.—*Generalized section of the geologic formations of Ford county, Kansas*

System	Series	Subdivision	Thickness (feet)	Character	Water supply
Quaternary	Pleistocene and Recent	Alluvium and Terrace deposits.	0-60	Sand, gravel, and silt, comprising stream deposits in the Arkansas valley and in the valleys of many smaller streams. Coarse gravels occur as terrace deposits bordering the present flood plain of Arkansas river at levels 15 to 25 feet above the flood plain.	The alluvium yields large supplies of water to wells in the Arkansas valley and lesser amounts in the smaller stream valleys; supplies many irrigation wells in the Arkansas valley. Some waters from the alluvium are very hard, containing from 238 to 1,413 parts per million of hardness. Terrace deposits are dry, except locally where they may occur below the water table.
		unconformable on older formations			
		Dune sand.	0–70	Fine eolian sand. Except where reopened by recent blowouts, the dunes are well stabilized by vegetation.	Probably does not supply water directly to wells, but constitutes favorable catchment area for ground-water recharge to adjacent and underlying formations.
		unconformable on older formations			
		Kingsdown silt.	0–135	Predominantly light buff, even-bedded soft silt and clay containing small, scattered lime nodules; contains unstratified loess in its upper part which grades gradually upward into loess of Pleistocene and Recent age. Contains light-colored sand and gravel at the base that may be correlative with the Meade formation in Meade county. Greatest development of this formation occurs south of Arkansas river.	Yields little or no water in its upper part, but sand and gravel deposits near the base may furnish some water to wells where the water table lies above them. Most of the Kingsdown silt is dry and relatively impermeable.
		disconformity			
Tertiary	Middle and upper Pliocene	Ogallala formation: Rexroad member.	20–250	Alternating beds of gray to greenish clay, buff-colored sandy silt, and rusty sand and gravel. Gravel contains many large-sized pebbles and water-worn fragments of caliche. Has not been recognized north of Arkansas river. (May contain some beds in upper part that are equivalent to the Meade formation.)	Yields good supplies of water to most of the wells located on the uplands south of Arkansas river, including most of the irrigation wells.
		disconformity			
		Ogallala formation		Gravel, sands, silts, "caliche" and structureless silt and silty sand with hard and soft layers of sandstone and conglomerate, much of which is cross-bedded and cemented with lime. Gravel and coarse sand more abundant in the basal part, and lime-cemented beds common in the upper part.	The principal source of water supply in many parts of the county. Yields adequate supplies of water of good quality to domestic, stock, municipal, and industrial wells. Supplies water to many irrigation wells, particularly to deep wells in the Arkansas valley, that tap the so-called "second water."
		unconformable on older formations			

System	Series	Subdivision		Thickness (feet)	Character	Water supply
Cretaceous		Greenhorn limestone	Pfeifer shale member.	20±	Chalky shale with beds of thin chalky limestone, discoidal concretions, and thin beds of bentonite. "Fencepost" limestone at top.	Very few wells obtain water supplies from the Greenhorn limestone in the county. Only very limited supplies of comparatively hard water may be expected from wells penetrating this formation. In general, the water is hard, ranging in hardness from about 350 to 600 parts per million.
			Jetmore chalk member.	20±	Alternating beds of chalky shale and chalky limestone, "Shell" limestone at top.	
			Hartland shale member.	80	Chalky shale with a few thin beds of chalky limestone and bentonite.	
			Lincoln limestone member.		Yellowish chalky shale with hard, thin-bedded, finely-laminated, crystalline limestone at top and bottom, and a few thin beds of chalky limestone.	
		Graneros shale.		43–45	Dark bluish-black, fissile, noncalcareous clay shale with numerous thin lenses of sandy shale, sandstone, and interbedded ironstone concretions. Outcrops are strewn with selenite crystals.	Practically barren of water; no wells are known to derive water supplies from this formation in the county. Any water that might be encountered probably would be highly mineralized and very bitter to the taste.
		Dakota formation.		56–235	Fine-grained, gray to white to yellow-brown sandstone, irregularly-bedded, and varicolored clay and sandy shale. Only the top of the formation is exposed in the county.	Yields moderate supplies of water of good quality to wells in the northeastern part of the county. Several irrigation wells in the extreme southwestern corner of the county tap the Dakota, but obtain most of their water from the overlying Ogallala formation.
		Kiowa shale.		44+	Black to bluish-black to gray to yellowish-gray argillaceous shales with a few thin beds of yellowish or pinkish limestone. Not exposed in county.	Not known to yield water to wells in Ford county.
		Cheyenne sandstone.		70+	Light gray to yellow, fine to coarse-grained, quartz sandstone with interbedded bluish-gray, silty and sandy shale.	Not known to yield water to wells in Ford county.
		unconformity				

GEOLOGY

SUMMARY OF STRATIGRAPHY

The rocks exposed in Ford county are of Quaternary, Tertiary, and Cretaceous age. The areal distribution of the formations is shown in plate 1. The oldest formation cropping out in the county is the Dakota formation. It is best exposed along Sawlog creek in the northern part of the county and on the north side of Arkansas river in the vicinity of Ford. The overlying Cretaceous formations, represented in this area by the Graneros shale and the Greenhorn limestone, are best exposed in the northern part of the county where tributary streams have cut beneath the overlying Tertiary deposits. The uppermost beds of the Cretaceous are absent in Ford county. The Ogallala formation of Tertiary age, which rests unconformably on the Cretaceous rocks, mantles a large part of the county, but south of the river it is largely covered by younger deposits. The Pleistocene water-laid deposits of the Kingsdown formation constitute the surface material of a broad area south of the Arkansas valley. The plains surface is mantled both north and south of the river by deposits of loess of variable thickness, ranging in age from Pleistocene to Recent, which form the upper part of the Kingsdown silt. Dune sand occupies a belt of varying width bordering the south side of Arkansas river and also mantles other isolated tracts. The soils, alluvium, drifting dune sand, and terrace deposits are the most recent deposits in the area.

The character and ground-water supply of the geologic formations in Ford county are described briefly in the following generalized section (table 1) and in more detail under "Water-bearing formations."

GEOLOGIC HISTORY[1]

Although the oldest formation exposed at the surface in Ford county is the Dakota formation, it is known from the records of several deep tests for oil and gas in the county that the exposed rocks are underlain by older sedimentary rocks of Paleozoic age, which in turn rest upon crystalline rocks of pre-Cambrian age.[2]

1. Parts of the following discussion are taken from: Darton, N. H., Geology and underground waters of the Arkansas valley in eastern Colorado: U. S. Geol. Survey, Prof. Paper 52, pp. 45, 46, 1906.

2. Logs and information regarding the several deep test wells for oil and gas in Ford county were furnished by Raymond Keroher of the Kansas Geological Survey.

Paleozoic Era

Cambrian and Ordovician periods.—During early Cambrian time Ford county was a land surface along with a large part of west-central United States. In middle Cambrian time there began the development of an interior sea with a resultant change to marine conditions. Submergence of the land continued with similar shore lines through part of Ordovician time with extensive deposition of lime sediments that were later indurated to form limestones and dolomites. During this interval was deposited the sandy cherty dolomite that forms the Arbuckle limestone or "Siliceous lime." Several of the deep tests in Ford county were drilled into this formation, the top being encountered at depths ranging from about 5,600 to 6,000 feet, although its exact thickness is not known.

Limestones and dolomites that have been correlated with the Viola and Simpson formations of Ordovician age are also known to be present, the top of the Viola being encountered at a depth of about 5,400 feet.

Silurian and Devonian periods.—There is little or no evidence that rocks of Silurian and Devonian age are present under Ford county, either they were never deposited in this area or they were removed by erosion prior to the deposition of the overlying Mississippian strata.

Carboniferous period.—During early Mississippian time there was extensive deposition of marine dolomitic limestone and some shale. According to the logs of several deep tests, Mississippian strata are present under Ford county between the depths of about 4,900 and 5,400 feet. In later Mississippian time there was an uplift, during which time the surface of the early Mississippian strata was subjected to erosion. Following this there was a return to marine conditions at which time the so-called Chester "lime" of late Mississippian age was deposited on the weathered surface of older Mississippian strata.

A long period of erosion intervened between the deposition of the youngest Mississippian rocks and the oldest Pennsylvanian rocks next above. Alternate subsidence below and emergence above sea level were repeated many times during the Pennsylvanian, giving rise to both marine and continental deposits consisting of sandstone, shale, coal, and limestone. This sequence of deposition was interrupted at times when the land surface was elevated and subjected to erosion. Based on the logs of the several deep tests in Ford county, the thickness of the underlying Pennsylvanian strata averages about 1,500 feet, the top being encountered at a depth of about 3,400 feet.

Permian period.—The transition from rocks that are regarded as Pennsylvanian to those that have been classed as Permian is apparently unbroken. Marine conditions during early Permian time were somewhat similar to those existing during late Pennsylvanian time, and alternate successions of limestones, dolomites, and shales were deposited. Following this there was an interval when beds of continental origin were deposited alternately with beds of marine origin. Gradually continental deposition became the dominant mode of origin for late Permian sediments. Most of the deposition took place in shallow water, so that there must have been subsidence that kept pace with deposition during this interval. Presumably an arid climate prevailed and evaporation took place in shallow basins giving rise to extensive deposits of salt and anhydrite interbedded with deposits of gypsum correlated with the Guadalupe series. According to the logs of the several deep tests in Ford county approximately 3,000 feet of Permian sediments are known to underlie the area, including both lower and upper Permian rocks. Permian redbeds have been reported as shallow as 400 feet in one test.

Mesozoic Era

Deposition evidently was terminated by an uplift that brought the region above water at the close of the Paleozoic. Probably this condition extended through the latter part, if not all, of Triassic time and through Jurassic time, during which there was no deposition and probably considerable erosion. Rocks representing the Triassic and Jurassic are not known to occur in Ford county.

Following an early Cretaceous uplift there was at first a land surface followed by a shallow-water body in Comanche time during which were deposited the sandstone and shale of the Cheyenne sandstone. The deposits were laid down either by streams or in a shallow sea or perhaps they were deposited in part on a beach, suggesting that the place of deposition was not far above or far from a shore-line (Twenhofel, 1924, pp. 19-21).

Following this there was a change from continental to marine conditions as a result of submergence of the land surface during which time the Kiowa shale was deposited. The Cheyenne sandstone and the Kiowa shale both have been encountered in test drilling in Ford county and are known to underlie at least part of the county.

In Late Cretaceous time there was a return to conditions similar to those under which the Cheyenne sandstone and sands and clays of the Dakota formation were laid down. The Dakota formation is a fresh-water deposit that was laid down on beaches and near the shore during an uplift in which the sea retreated far to the south. The Dakota formation crops out at several places in the northern and northeastern parts of the county, and is present at varying depths elsewhere in the county.

Following the deposition of the Dakota formation there was a rapid change in the conditions of sedimentation to those under which several thousand feet of clay, lime, and chalk were deposited, beginning with the Graneros shale and including the Greenhorn limestone, the Carlile shale, the Niobrara formation, and the Pierre shale. This marks the beginning of very extensive later Cretaceous submergence, in which marine conditions prevailed over a large area for a long time. Sedimentation was interrupted from time to time by emergence of the land to a point at or near sea level.

Cenozoic Era

TERTIARY PERIOD

At the beginning of Tertiary time an extensive land surface existed. While streams were laying down widespread sheets of sands in the plains area to the north the land surface in western Kansas was being subjected to erosion largely effected by through-flowing streams. As a result great thicknesses of Upper Cretaceous sediments were removed, so that in Ford county all of the strata above the Greenhorn limestone are missing. In parts of Ford county the Greenhorn and Graneros have been removed entirely by erosion, and in the southeastern part of the county the Dakota formation is absent and the Tertiary formations rest upon the Kiowa shale. The surface of the Dakota formation was also subjected to erosion in the areas in which the overlying Cretaceous rocks were completely removed. The bedrock surface thus had a topography of considerable diversity and relief prior to the deposition of the Ogallala formation.

Factors other than erosion also contributed to the configuration of the bedrock floor during Tertiary time. Crustal deformation is believed to have taken place either before or during the deposition of the Ogallala formation. In late Tertiary time erosion was followed by an epoch of deposition during which heavily-laden streams from the Rocky Mountains traversed western Kansas and deposited the sediments of the Ogallala formation in a broad alluvial plain.

Through-flowing streams occupied the main valleys, and deposition continued after the valleys were filled until the interstream divides were covered with a nearly continuous mantle of sediments.

Several causes have been postulated by various authors for the change in behavior of the traversing streams. Interruptions in the gradation cycle from a period of erosion to one of deposition and reversal again finally to erosion have been attributed by Haworth (1897, p. 14) to the instability of the structural slope. Haworth correlated deposition with different periods of rapid elevation intervening between long periods of low upraising with repeated increases in stream gradients. Johnson (1901, p. 628) suggested that the effect of climatic oscillation rather than earth movement was responsible for the conditions whereby streams in Tertiary time were alternately degrading and aggrading. Darton (1920, p. 8) emphasized the effect of differential uplift upon Tertiary streams, but admitted climatic conditions as a contributing factor.

Near the close of middle Pliocene time there may have been some upwarping of the surface to the west of this area (Smith, 1940, p. 94) resulting in the rejuvenation of the master streams and in bringing to a close a period of widespread deposition of the Ogallala. The upper Pliocene part of the Ogallala, the Rexroad member, represents deposits that were trapped in local areas of downwarping and downfaulting. The principal area in which deposits were trapped during this time was the downfaulted area in Meade county, which probably extended into Ford and Clark counties. Smith (1940) suggests that:

> The Rexroad was laid down on the deformed surface of the Ogallala, in a structural and topographic expression progressively modified by marginal erosion concurrent with deposition.

On the basis of test holes in southern Ford county, it is known that deposits of gravel and interbedded limy clay assigned to the Rexroad member rest unconformably on the Cretaceous, the middle Pliocene being absent locally. The Rexroad seems to contain more or less reworked material from the Ogallala, but a large part of it may have been derived from the same source area as the Ogallala.

Crustal deformation is believed to have taken place after the deposition of the Ogallala. In the southwestern part of the county the anomalous reversal in the trend of Crooked creek was brought about by the combined factors of faulting, downwarping, stream erosion and deposition, and solution collapse in the underlying Permian beds. Haworth (1897, pp. 22, 23) emphasized the importance of tectonic movement in explaining this change in the direction of Crooked creek in the vicinity of Wilburn, a former post office in the SW¼ sec. 35, T. 29 S., R. 26 W. He writes as follows:

> The sharp angle at Wilburn and the southwestern direction for nearly 20 miles across a plain sloping to the southeast are certainly very remarkable, and probably have a cause different from that which ordinarily determines the location and direction of streams. But if in post-Tertiary times a triangular area, equaling in size and position the present artesian area, could have dropped 100 feet or more, with a single fault line extending southward to beyond the limits of Kansas, thereby changing the direction of Crooked creek into the present channel below Wilburn, the general physiographic conditions could easily be accounted for.

A geologic section across the southern border of Ford county, based on test holes (pl. 5, section C-C.), shows the position of the inferred fault in the vicinity of Crooked creek as well as the stratigraphy of that part of the county.

A diversified topography comprising a series of basins along the structural trough was developed in late Pliocene time by the interaction of faulting and solution. In these basins were trapped the thick deposits of upper Pliocene sediments comprising the Rexroad member of the Ogallala formation (Frye and Hibbard, 1941, pp. 394, 395).

QUATERNARY PERIOD

Pleistocene epoch.—A disconformity exists between the Rexroad member of the Ogallala and the overlying Pleistocene and Recent Kingsdown silt in Ford county. During this interval deposits comprising the Pleistocene sands and gravels of the Meade formation were being laid down in Meade and Clark counties to the south and may have been deposited locally in Ford county.

Frye and Hibbard (1941, p. 397) suggest that the deposits of fine sand and silt that constitute the lower part of the Kingsdown were laid down during late Pleistocene time by streams that must have shifted laterally at frequent intervals. They also point out that stream deposition probably was accompanied and followed by eolian activity, because the fluvial deposits grade upward into loess, and that the deposition of the stream-laid deposits of the Kingsdown marked the close of the Pleistocene. They add that the upper eolian part of the Kingsdown may have been deposited in the Recent epoch.

According to Smith (1940, p. 115), a part of the Kingsdown was derived from the Ogallala formation. This would indicate that there was an interval of erosion in adjacent areas concurrent with the deposition of the Kingsdown silt in Ford county. He points out that—

> The abundant silt characterizing the greater part of the formation, however, seems adequately explained only by derivation from eolian loess. The even bedding and fine lamination indicate subaqueous deposition, either by flood waters or under lacustrine conditions. . . . The thickness of the formation, however, is too great to be explained wholly on this basis, and fits better with the postulate of material supplied by erosion of loess deposits, either contemporaneous and, or, older, to the west.

He further suggests that deposition must have been due to flattening or actual reversal of stream gradients as a result of crustal warping, with climatic changes as a minor contributing factor.

The transition from the deposition of the water-laid sediments of the Kingsdown to the deposition of the overlying loess mantle which forms the upper part of the Kingsdown is indistinguishable. The loess is possibly contemporaneous with and in part grades laterally into the water-laid deposits. This seems to indicate that during the latter part of the Pleistocene there was a change in climate from humid to relatively arid conditions with considerable wind movement. Loess deposition has continued intermittently until recent time. The erosional development of the area at the time of loess deposition did not differ greatly from that of the present only in that the valleys were not yet quite so deep.

Recent epoch.—At the beginning of the Recent epoch the major streams began the down-cutting that has produced the present topography. In Ford county there are two recognizable terraces along the Arkansas valley. The terrace deposits are best displayed on the south side of the river, the lower terrace lying at about 5 to 8 feet above flood-plain level and the higher terrace occurring at from 15 to 25 feet above the flood plain. Smith (1940, p. 150) suggests that the terraces are of cut-and-fill origin and of late-glacial or post-glacial age. The terrace deposits are younger than the Kingsdown silt, as evidenced by their lower topographic position. It is probable that much of the material in the terrace gravels was derived from source areas to the west and was deposited during late Pleistocene or Recent time when the river was at a higher elevation. Dune sand is widely distributed along the south side of the Arkansas valley in Ford county. Smaller areas of dune sand occur also in other parts of the county, notably north of the river in the vicinity of Ford and in the southwestern part of the county (pl. 1). The age of the dune sand is not definitely known, but it is probable that accumulation of some of the sand started in late Pleistocene time and continued at different times and in different places up until recent times. Darton (1920, p. 3) believed that the present river flood plains constituted the source of the material. Smith (1940, pp. 165-167) disagrees with this mode of origin and suggests that the sand was derived from the terrace deposits, and that toward the southern part of the dune belt the sand originated possibly from sands of the Rexroad member of the Ogallala formation, or the Kingsdown silt, or both, or simply from the denuded slopes cut in the Ogallala. He also suggests that the presence of a continental ice sheet during one or more of the Pleistocene glacial stages could have been responsible for the northerly dune-building winds of the past.

Since the close of the Pleistocene epoch the general aspect of the area has not changed materially. Adjustments in the courses and gradients of streams undoubtedly took place. Some of the streams have deepened their channels, whereas other streams have built up their flood plains. When a stream has its volume diminished or has its efficiency lowered by a decrease in its velocity, it may become overburdened with sediment, in which case it will deposit part of its load. This process is known as aggradation or alluviation. Flood plains are alluvial flats that may be covered by water at times of flood. During floods new layers of sediment are added to the flood plain.

The Arkansas river has no large tributaries in Kansas above the mouth of Pawnee river, which joins the Arkansas at Larned. Ac-

Flood peaks on the Arkansas river in 1923

Date.	Maximum flow at Syracuse (second feet).	Date.	Maximum flow at Larned (second feet).
May 22	11,200	May 25	2,990
June 9	7,370	June 11	2,390
June 18	14,300	June 19	8,770
July 19	5,760	July 21	3,780
July 27	7,600	July 30	2,250
Aug. 13	5,530	Aug. 16	3,810
Aug. 18	9,000	Aug. 19	5,270
Aug. 23	18,000	Aug. 24	14,300

cording to George S. Knapp (personal communication, April 30, 1942), who kindly supplied the figures given in the preceding table, large floods that originate in Colorado proceed down the valley with constantly diminishing volume.

As indicated in the same table, during the flood of May, 1923, the maximum discharge of 11,200 cubic feet per second at Syracuse gradually diminished downstream until at Larned, three days later, the maximum discharge was only 2,990 cubic feet per second, a reduction in volume of 8,210 cubic feet per second. A large part of the water thus "lost" from the flooded stream must have percolated into the porous alluvium, thus recharging the ground water reservoir; and a large part of the load of sediment carried by the floodwaters must have been deposited on the flood plain of the river. Thus, Arkansas river is an aggrading stream, *at least* in the part of its course between Syracuse and Larned.

Several changes in stream courses took place during Pleistocene time. Streams were rejuvenated and cut deeply into the plains surface following uplift to the west, and the original courses of these streams were later altered by piracy to form the present drainage pattern. Arkansas river throughout most of its course in Ford county has not cut its channel as deeply as have the smaller streams in the northern part of the county. At a point due north of Dodge City the stream bed of Sawlog creek is approximately 50 feet lower than the stream bed of Arkansas river at Dodge City. South of the river, however, Mulberry creek has not cut its channel as deeply into the plains surface as have the streams north of the river, the creek bed at a point due south of Dodge City being about 55 feet higher than that of Arkansas river at Dodge City. The "perched" position of Arkansas river has been discussed by Smith (1940, pp. 146-149), who points out that crustal warping within the Kansas area probably played an important part in raising, or in preventing the lowering of, the stream's gradient along this part of its course, and that this condition was closely related to the events responsible for the great bend of the river just to the east.

Haworth (1897*b*, p. 30) postulated an altogether different cause for the great and unusual bend that the river makes in passing from eastern Ford county to the vicinity of Great Bend. He pointed out that the river encountered the easily-eroded Dakota formation where it rises above the surface in eastern Ford county and attacked it with great vigor, following it as far north as Great Bend. As the general inclination of the Dakota formation is to the northeast, the river throughout this interval would follow the path of least resistance, and would therefore migrate northward, downdip with the strata. This hypothesis hardly seems tenable in the light of present knowledge.

It is quite significant that west of the great bend in Ford county no tributaries enter Arkansas river from the north or the south, the river appearing to flow along a ridge trending east and west. Mulberry creek joins Arkansas river at Ford, within the bend area. Below the bend the drainage becomes more natural; tributaries enter the Arkansas from both sides, and the river no longer flows along a ridge. The absence of bluffs north of the river near the eastern edge of Ford county is also a noteworthy feature.

GROUND WATER

GENERAL GROUND-WATER CONDITIONS

Source

Ground water, or underground water, is the water that supplies springs and wells. In Ford county, ground water is derived almost entirely from precipitation in the form of rain or snow. Part of the water that falls as rain or snow is carried away by surface runoff and is lost to streams, part of it may evaporate or be absorbed by vegetation and transpired into the atmosphere. The part that escapes runoff, evaporation, and transpiration percolates slowly downward through the soil and underlying strata until it reaches the water table where it joins the body of ground water known as the zone of saturation. In the southern High Plains, several lines of evidence indicate that on an average only about half an inch of water a year escapes evaporation and transpiration to join the ground-water reservoir (Theis, Burleigh and Waite, 1935, pp. 1-4). In parts of Ford county where the surface is mantled by deposits of loess or silt of the Kingsdown, the amount of recharge may be less than the average given for the entire High Plains, but in parts of the sand hills the amount of recharge probably is considerably greater.

The ground water percolates slowly through the rocks in directions determined by the topography and geologic structure, until it is discharged eventually through springs or wells, through seepage into streams, or by evaporation and transpiration in bottom lands adjacent to the streams. Most of the water obtained from shallow wells and springs in Ford county is obtained largely from precipitation in the general vicinity, that is, in Ford county and adjacent areas. The water in the Dakota formation under Ford county, however, is derived from precipitation and small streams in the areas of outcrop, which are mainly in southwestern Kansas and southeastern Colorado at higher altitudes.

Some of the deeper rocks under Ford county contain highly mineralized water. Waters of this type have become brackish or salty by circulation through subterranean salt and gypsum deposits.

Occurrence[3]

The rocks that form the crust of the earth are, in general, not solid throughout, but contain numerous open spaces, called voids or interstices, and it is in these spaces that water is found below the surface of the land and from which it is recovered in part through springs and wells. There are many kinds of rocks and they differ greatly in the number, size, shape, and arrangement of their interstices and hence in their water-holding capacities. The occurrence of ground water in any region, therefore, is determined by the geology of the region.

The interstices of rocks range in size from minute pores of microscopic dimensions to openings several inches in width and can be divided into two classes—primary and secondary. The primary or original interstices were formed contemporaneously with the formation of the rock; the secondary interstices were developed by processes that affected the rock after it had been formed. In Ford county the water-bearing rocks are all of sedimentary origin, and the openings that hold the water are: (1) the open spaces between the grains of the rocks; and (2) the joints, crevices, and open bedding planes which have resulted from fracturing of the rocks.

The amount of water that can be stored in any rock depends upon the porosity of the rock. Porosity is expressed quantitatively as the percentage of the total volume of rock that is occupied by interstices. When all its interstices are filled with water a rock is said to be saturated. In a saturated rock the porosity is practically the percentage of the total volume of the rock that is occupied by water. Several types of rock interstices and the relation of rock texture to porosity are shown in figure 5.

The amount of water a given rock can hold is determined by its porosity, but the amount of water that it may yield to wells is de-

3. For a detailed treatment of the occurrence of ground water, see Meinzer, O. E., The occurence of ground water in the United States with a discussion of principles: U. S. Geol. Survey Water-Supply Paper 489, pp. 1-321, 110 figs., 31 pls., 1923. For a general discussion of the occurrence of ground water in Kansas, see Moore, R. C., Ground-water resources of Kansas: Kansas Geol. Survey Bull. 27, pp. 1-112, figs. 1-28, pls. 1-34.

termined by its permeability. The permeability of a rock is its capacity for transmitting water under pressure, and is measured by the rate at which it will transmit water through a given cross section under a given difference of pressure per unit of distance. Certain dense clays and shales may have higher porosities than beds of coarse sand; but, because of the small size of their interstices, they may transmit no water under ordinary pressure; and, hence, under the incompetent force of gravity, they may be impermeable. Rocks differ greatly in their degree of permeability, according to

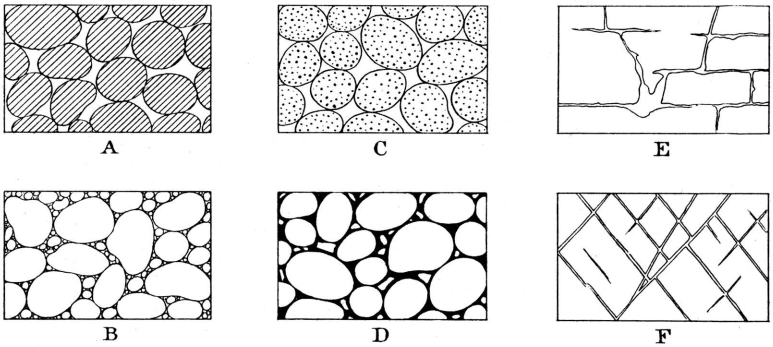


FIG. 5. Diagram showing several types of rock interstices and the relation of rock texture to porosity: A, well-sorted sedimentary deposit having a high porosity; B, poorly-sorted sedimentary deposit having low porosity; C, well-sorted sedimentary deposit consisting of pebbles that are themselves porous, so that the deposit as a whole has a very high porosity; D, well-sorted sedimentary deposit whose porosity has been diminished by the deposition of mineral matter in the interstices; E, rock rendered porous by solution; F, rock rendered porous by fracturing. (After O. E. Meinzer.)

the number and size of their interstices and the extent to which these interstices open into one another. In fine-grained rocks the movement of water under the force of gravity is retarded by the molecular attraction of individual grains; whereas, in a coarse, clean gravel with large openings that communicate freely with one another, the molecular attraction is not as great and more water becomes available to wells.

Water in Sand and Gravel

In Ford county unconsolidated deposits of sand and gravel are found in the alluvium in several of the stream valleys and in the Ogallala formation. The history of their deposition is given under Geologic History; their distribution, character, thickness, and water-yielding capacity are described under Water-bearing formations.

These stream deposits were subjected to the sorting action of water with the result that distinct beds of gravel, sand, silt, or clay were deposited. The source of material and degree of sorting determined the texture of this material, whether coarse or fine, some deposits being composed of clean well-sorted gravel, while in others finer materials predominate. In some poorly-sorted deposits, finer materials occupy the pore spaces between the larger grains reducing the effective porosity. Coarse, clean, well-sorted gravel or sand has a high porosity and high permeability. Properly constructed wells in material of this type yield large quantities of water.

Sand and gravel deposits in the alluvium of the Arkansas valley constitute one of the most important sources of ground water in Ford county. The sand and gravel deposits of the Ogallala formation are equally important and constitute the principal source of water in the upland parts of the county and of many of the deeper wells in the valley. The alluvium and the Ogallala both furnish water to a great many domestic and stock wells and to many irrigation, municipal, and industrial wells. More than 200 irrigation wells in the valley are supplied with water from these deposits. The deposits of sand and gravel in the alluvium along smaller streams are not as thick as along Arkansas river, but, where present, yield small supplies of water to domestic and stock wells.

The yields of wells ending in the alluvium of the Arkansas valley range from less than 5 to about 1,000 gallons a minute. The maximum yields obtainable from the alluvium are largely dependent upon the local character and thickness of the material and upon the construction of the well. Where the thickness of the alluvium is limited, some well owners have resorted to using a battery of wells interconnected to one pump in order to obtain larger yields (p. 104). The Ogallala supplies fewer wells in the valley than the alluvium, but yields as much as 1,700 gallons a minute to some industrial wells.

Water in Sandstone

The Dakota formation contains the only water-bearing sandstones tapped by wells in Ford county and ranks about third in importance, being surpassed only by the alluvium and the Ogallala formation.

The principal factors that determine the water-bearing properties of a sandstone are the size and uniformity of the grains, the degree of sorting, and the amount and character of cementation. The character of the Dakota formation underlying Ford county is variable. Some parts of the formation appear to be rather firmly cemented with iron oxide and other cementing material, and other parts consist of soft, friable, saccharroidal sandstone that readily disintegrates into very fine sand during ordinary drilling operations. Although there may be some water in joints and bedding planes in the sandstones of the Dakota formation, it is believed that the water is derived mainly from the pore spaces of the rock.

Beds of water-bearing sandstone are also present in the Cheyenne sandstone, which is known to underlie the Dakota formation in Ford county. This sandstone resembles the sandstones of the Dakota formation in composition and texture. Although the Cheyenne is not known to yield water to wells in Ford county it seems likely that it contains water and would doubtless yield water to any deep well that might be drilled to it. It is also probable that the water would be under some artesian head.

Most of the wells ending in the Dakota formation in Ford county are used only for domestic and stock purposes; consequently, the maximum water-yielding capacity of the formation is not definitely known. The unused well of the Atchison, Topeka and Santa Fe Railway at Spearville (No. 34) was drilled into the Dakota formation, however; and, according to a test made by the owners, the well yielded about 80 gallons a minute with a draw-down of 8 feet. It is probable that this well would yield as much as 250 gallons a minute with greater draw-down. Many factors control the water-yielding capacity of the Dakota, chief among which are the thickness of the saturated rock penetrated, the physical properties of the sandstone, and the type of well construction. The sandstones of the Dakota formation in Ford county are fine-grained and do not yield water as freely as the Ogallala, but wells drilled to depths of about 200 feet in the northeastern part of the county might yield from 50 to 250 gallons a minute.

Volumetric core samples of the Dakota formation obtained from test holes in Ford county were analyzed in the hydrologic laboratory of the Federal Geological Survey. Mechanical analyses were made to determine the size and assortment of the grains; the porosity and moisture equivalent were determined so that specific yield could be computed; and the permeability was determined so that the rate of flow of water through the material could be approximated. The physical properties of the four cores of the Dakota formation are given in table 2.

The 4 samples tested have very low permeabilities compared to the water-bearing sands in the alluvium and Ogallala formation, but appear to be representative of the sandstones of the Dakota formation in Ford county.

TABLE 2.—*Physical properties of cored volumetric samples of the Dakota formation collected from test holes in Ford county, Kansas*
(By V. C. Fishel, U. S. Geological Survey)

Test-hole No. on fig. 2	Lab. No.	Depth of core sample below land surface (ft.).	Mechanical analysis (percent by weight).					Apparent specific gravity.	Porosity (percent).	Moisture equivalent (percent by vol.) (1).	Coefficient of permeability (2).
			Medium sand (larger than 0.25 mm.).	Fine sand (0.25-0.125 mm.).	Very fine sand (0.125-0.062 mm.).	Silt (0.062-0.005 mm.).	Clay (less than 0.005 mm.).				
8.........	2466	275–277	4.0	45.4	33.5	12.8	3.8	1.96	29.9	6.1	28
8.........	2467	291–292	.7	72.3	19.4	4.2	2.7	1.87	30.8	7.5	4
4.........	2468	70–71	.3	34.4	38.7	18.8	7.1	2.15	18.7	12.0	.02
2.........	2469	134–136	.2	34.9	43.5	15.7	5.3	2.16	22.5	13.9	.007

1. The ratio of (1) the weight of water which the soil, after saturation, will retain against a centrifugal force 1,000 times the force of gravity, to (2) the weight of the soil when dry.

2. 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.

WATER IN SHALE

It is probable that few wells in Ford county obtain supplies of water from shale. The areas in which wells might derive water supplies from shale are limited, and generally are confined to localities in the north-central part of the county where the Ogallala is thin or entirely absent and the sandstones of the Dakota formation are not available to shallow wells. Shales are present in practically all of the bedrock formations in Ford county. The Greenhorn limestone is dominantly chalky shale, the Pfeifer and Hartland members being made up largely of chalky shale with thin beds of limestone. The underlying Graneros shale contains thin-bedded lenticular sandstones and concretionary layers. The thin sandstone lenses might furnish small amounts of water locally to a well, but it is believed that the formation as a whole is rather barren of water. Any water obtained in the Graneros is apt to be of poor quality owing to the presence of considerable gypsum in the form of selenite that is scattered through the black shales of the formation. The shales of the Dakota formation are largely clay shales and siltstones and furnish practically no water to wells. No wells are known to derive water supplies from the Kiowa shale in Ford county, and it is probable that this shale would yield little or no water.

Shale generally has considerable porosity, but much of the water is held in the small interstices by molecular attraction; consequently very little of the water that it does contain is available to wells. Most of the shales in Ford county are relatively soft, and about the only openings along which water might move are the bedding planes of the interbedded limestones and sandstones.

Information concerning the yields of wells in shale in Ford county is not available, but it is believed that they would be limited, and might not be adequate for domestic and stock purposes.

WATER IN LIMESTONE

Limestone is not an important source of water in Ford county, although a few wells in the north-central part of the county are believed to end in limestone. The Greenhorn limestone, only limestone that has been penetrated by water wells in Ford county, is made up of chalky limestone and shale in its upper part, and chalky shale with a few thin beds of chalky limestone in the lower part, with chalky shale and hard thin-bedded crystalline limestone at the base. As pointed out under the discussion of water in shale, it is likely that little if any water could be derived from the shale beds of the Greenhorn. The success of a well in limestone depends upon the number, size, and water-bearing capacity of the joints and fissures that it contains. The limestone beds of the Greenhorn generally are very dense, particularly in the basal part of the formation, and do not appear to contain visible openings other than minute spaces along bedding planes and joints. So far as is known, the water-yielding capacity of the Greenhorn limestone in Ford county is very small, and it is believed that only very small supplies of water may be expected from wells penetrating this formation.

Artesian Conditions

Where a water-bearing formation that slopes downward from its intake area is overlain by a relatively impermeable bed, the water contained may be under sufficient pressure to cause it to rise in tightly-cased wells. Wells of this type in which the water rises to a point above the local water table are known as artesian wells. If the water rises high enough to flow at the surface the well is termed a flowing artesian well. Artesian water is ground water that has artesian pressure head.

Small flowing artesian wells are obtainable from at least two different water-bearing formations in Ford county. The small flowing wells near the southwestern corner of the county obtain artesian water from the Rexroad member of the Ogallala formation and possibly also from overlying Pleistocene beds. The Ogallala formation is the source of one small flowing well (324) in the Arkansas valley about 3 miles east of the western boundary of the county. Although there are no known flowing wells that obtain water from the Dakota formation in Ford county, small flows have been obtained from the Dakota in test holes put down by the Soil Conservation Service in the Arkansas valley near the east county line (logs 33 and 35, p. 226). Moss (1932, pp. 45, 46) reports that there are several flowing wells from the Dakota formation in Sawlog creek valley in secs. 13, 14, 23, and 24, T. 24 S., R. 23 W., in Hodgeman county, only a short distance north of the Ford county line.

The small flowing wells along Crooked creek and some of its tributaries in the southwestern corner of Ford county lie in a northward extension of the Meade county artesian basin. According to Frye (1940, p. 5), the Meade artesian basin is—

> . . . underlain by unconsolidated gravel, sand, silt, and clay, of Pliocene, Pleistocene, and Recent age, which lie unconformably on Cretaceous and Permian rocks. Most of the artesian water is obtained from the Pliocene deposits, but some of it comes from the Pleistocene beds at shallow depths.

The flowing wells in southwestern Ford county are supplied from water that enters the unconsolidated sand and gravel deposits northwest of the Crooked creek area at an elevation higher than the floor of the valley. This water moves down the dip between the confining layers of impervious material and is under sufficient hydrostatic head in the lowest parts of Crooked creek valley to flow feebly at or just above the land surface.

The eight small flowing wells (512, 513, 516, 517, 518, 519, 520 and 521) in southwestern Ford county are situated in a narrow belt averaging half a mile wide along Crooked creek and its tributaries in sections 26, 27, 32, 34 and 35, T. 29 S., R. 26 W. The flows in these wells ranged from a scant trickle to 3 gallons a minute. The artesian heads of two wells (519 and 521) were measured and found to be about 1 foot above the land surface. The wells are situated in the bottom of a small dammed tributary to Crooked creek and discharge beneath the surface of a small pond. The flowing wells range in diameter from 1½ to 3½ inches and in depth from 145 to 275 feet. Some of the deeper wells (Nos. 519, 520 and 521) may tap the Dakota formation, but it is believed that most of the water comes from the Rexroad member of the Ogallala.

A flowing well (324) that taps the Ogallala formation is situated near the north bank of Arkansas river in the SW¼ SW¼ sec. 22, T. 26 S., R. 26 W. According to Jim Johnson, local driller, the well originally flowed naturally into a stock tank, and the flow was reported to have been sufficient to water about 600 head of cattle. When visited in 1939, the well was still flowing a scant trickle—enough to maintain a moist bog about 15 feet in diameter. The well had been tapped at a point 1.7 feet below the land surface in order to maintain a constant flow. There are several possible causes for the diminished flow in this well. The flow may have been reduced by fine sand moving into the well or the hydrostatic pressure may have decreased as a result of a regional lowering of head. The static head of the water in well 324 is approximately 7 feet higher than the static water level in a shallow well in the overlying alluvium (well 323), situated about 100 yards west of well 324. Well 324 is 131 feet deep, whereas well 323 is only 8.5 feet deep. Although a log of the deeper well is not available, it is believed that relatively impermeable beds of clay in the upper part of the Ogallala formation separate the shallow water-bearing alluvium that supplies well 323 from the water-bearing beds near the base of the Ogallala formation that supply well 324, and constitute rather effective confining beds for water moving in from the northwest toward the valley (see pl. 1).

Possibly additional flowing wells could be obtained in low places near well 324, but the flows doubtless would be small.

The water in the Dakota formation is confined beneath the overlying Graneros shale except in places where the shale has been removed by erosion; hence, locally, it is under artesian head. There are relatively few places in Ford county, however, where the head is sufficiently great and the land surface is low enough to give rise to flowing artesian wells from the Dakota. Small flowing wells are doubtless obtainable in a small area on the north side of the Arkansas river near the eastern boundary of the county. To judge from the results of the test drilling (logs 33 and 35), however, the flows from wells drilled into the Dakota formation in this vicinity are apt to be rather small, and the artesian head is likely to be rather low.

The Water Table and Movement of Ground Water

The permeable rocks that lie below a certain level in Ford county and elsewhere generally are saturated with water under hydrostatic pressure. These saturated rocks are said to be in the zone of saturation, the upper surface of which is called the water table. The permeable rocks that lie above the water table may be said to be in the zone of aeration. The relation of the zone of saturation to the zone of aeration is shown in figure 6. The water that enters from the surface into the soil is slowly drawn down by gravity through the zone of aeration to the zone of saturation, except that which is retained by molecular attraction. In fine-grained material the earth is always moist several feet above the water table due to capillarity, and this moist belt is called the capillary fringe. Water in the capillary fringe or in transit in the zone of aeration is not available to wells, hence wells must be sunk to the water table before water enters them.

Where permeable rock is homogeneous down to a considerable depth there is only one zone of saturation, but in certain localities the water may be hindered in its downward course by an impermeable or nearly impermeable bed to such an extent that it forms an upper zone of saturation, or perched water body, that is not associated with the lower zone of saturation. The water table is said to be absent in places where impermeable material immediately overlies the zone of saturation. Small bodies of perched water have been recognized in Ford county, notably along several dry stream courses tributary to Cow creek in the northeastern part of the county and in certain local areas mantled by dune sand north of Arkansas river northwest of Ford.

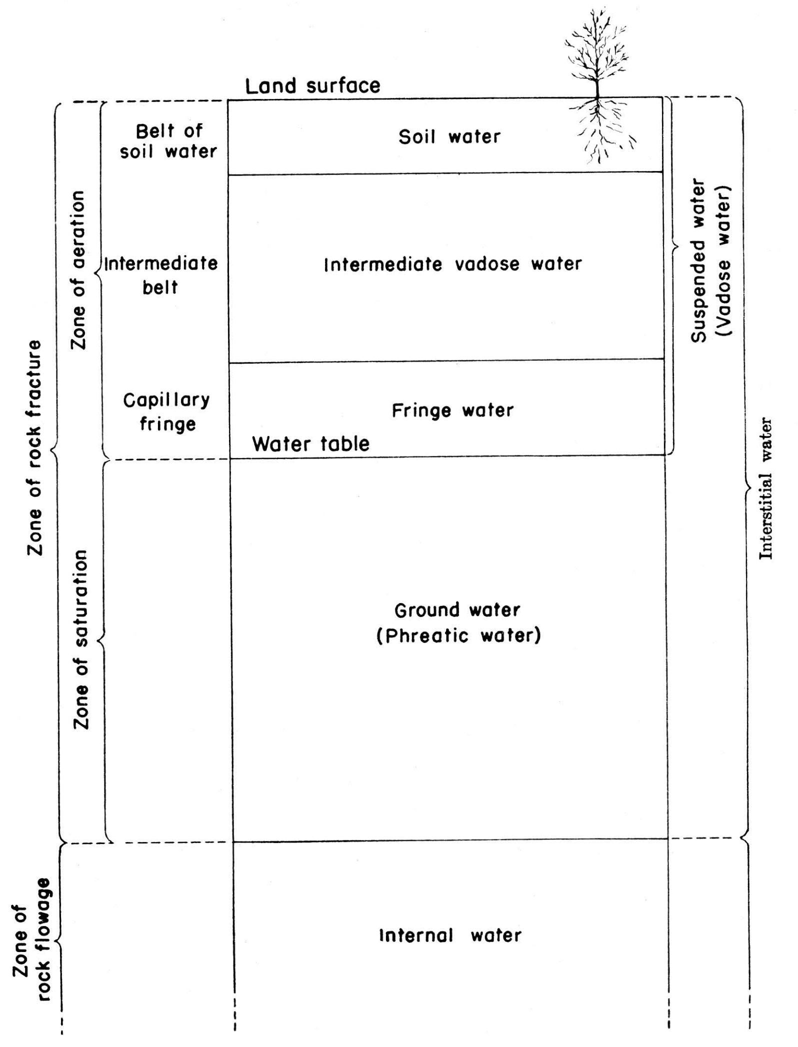


FIG. 6. Diagram showing divisions of subsurface water (after O. E. Meinzer).

SHAPE AND SLOPE

The shape and slope of the water table in Ford county are shown on the map (pl. 1) by means of contours drawn on the water table. Each contour line has been drawn through points on the water table having approximately the same altitude. Collectively they show the configuration of the upper surface of the ground-water body in much the same manner as contours on topographic maps show the general shape of the land surface. The altitudes of the water surfaces in each of the wells that were used in compiling the map have been referred to sea-level datum. Ground water moves in the direction of maximum slope, which is at right angles to the contours. The position of the contours indicates that the water table in general slopes eastward, but that the amount of slope varies considerably because of irregularities of the water table.

The shape of the water table, which in turn determines the rate and direction of movement of ground water, is controlled by several factors. Irregularities in the shape of the water table under Ford county may be caused by: (1) the configuration of the underlying Cretaceous floor; (2) discharge of ground water into perennial streams; (3) recharge of the ground-water body by ephemeral streams; (4) differences in the altitude of the water table in wells that tap different water-bearing formations; (5) unequal addition of water to the ground-water reservoir at different places; (6) local differences in the permeability of the deposits, and (7) local depressions on the water table caused by the pumping of water from wells.

The slope of the bedrock floor formed by the underlying Cretaceous rocks controls to a large degree the direction of movement of the water in Ford county. Thus, south of the Arkansas valley the water table conforms in general to the eastward-sloping bedrock floor, the average slope being about 7.2 feet to the mile. The water-table contours in this part of the county are roughly parallel and are spaced more uniformly than they are north of the river. The contours show that the water table slopes slightly southeastward in the vicinity of Kingsdown and Bucklin.

The upfold or anticline in the Cretaceous rocks, which extends from the city of Ford northwestward into Hodgeman county (p. 11), has a pronounced effect on the position of the contours in the northeastern part of the county, where the slope of the water table is controlled largely by the position of the underlying Dakota formation, which dips toward the northeast. The Dakota formation has been encountered in numerous water wells in this part of the county at depths ranging from about 50 feet to 100 feet or more. In the vicinity of Bellefont and Windhorst, where the Dakota is known to lie at relatively shallow depth, the contours appear to be more closely-spaced than in areas where the Dakota lies at greater depth.

The slope of the water table and the direction of movement of the ground water are also influenced by the discharge of ground water into perennial streams. Along valleys that have been cut below the water table, the water table slopes toward the areas of discharge along the streams. Streams of this type that commonly gain water from the zone of saturation are said to be effluent streams (figure 7). Arkansas river and Sawlog, Duck and Crooked creeks are good examples of effluent streams in Ford county.

The contours show that in the vicinity of the Arkansas valley the water table slopes rather uniformly toward the river from both sides and also slopes downstream toward the vicinity of Ford, indicating that water flows into the valley from both sides and thence down the valley. The contours also indicate that slight ground-water divides exist both north and south of the Arkansas valley throughout most of its course. The divide north of the river is more pronounced than that south of the river and extends farther back from the river, the

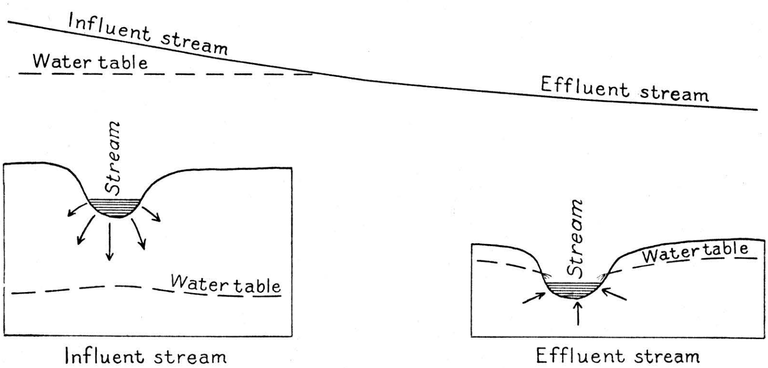


FIG. 7. Diagrammatic sections showing influent and effluent streams. (After O. E. Meinzer.)

distance ranging from about 2 to 5 miles and increasing from east to west; whereas, the divide south of the river nearly everywhere is within 2 miles of the river. East of Ford the river changes direction and flows northeastward. According to the contours in this section of the valley, the water table is sloping in a northeastward direction and the river appears to be in approximate equilibrium with the water table. Arkansas river has an average gradient of 7 feet to the mile in its course through Ford county.

In the northern part of the county, where Sawlog creek and some of its tributaries have cut their valleys below the water table, the slope is principally northward and the contours indicate movement of water into the stream channels.

Streams that flow only after rains are classed as ephemeral or intermittent streams. Their channels are above the water table and are dry much of the time. During periods of stream flow part of the water in an ephemeral stream may seep into the stream bed and descend to the water table. Streams of this type are called influent (figure 7). The lower part of Mulberry creek is influent and the water table on both sides of the creek for several miles above its mouth may be affected by occasional periods of stream flow. Coon and Rattlesnake creeks may be influent also, but, if so, they do not seem to affect the water table appreciably. Artificial lakes or other bodies of impounded water may also be influent and contribute water to the zone of saturation. The water-table contours in the vicinity of Ford county lake and Hain lake (pl. 1) do not indicate that there is any appreciable recharge from these lakes. The water levels in these lakes were low at the time of the field investigation as a result of subnormal precipitation, however, and it is possible that there may be recharge during periods when the lake levels are higher.

An important factor that is responsible for at least some of the irregularities in the water table under Ford county is the presence in some parts of the county of more than one water-bearing formation, each of which may contain water under different hydrostatic pressure. Under such conditions the water levels in adjacent wells that penetrate different formations may stand at different altitudes. Thus, in an area in the northern part of the county (pl. 1) the water levels in some of the deeper wells that obtain water from the Greenhorn limestone and the Dakota formation stand lower than the water levels in nearby wells that draw from the Ogallala formation. There are appreciable differences in the static water levels of some adjacent wells that penetrate different water-bearing formations. Thus, wells 63 and 64 are only half a mile apart, yet the water level in the latter is 109.6 feet lower than in the former. Well 63 penetrates the Ogallala formation whereas well 64, which is much deeper, penetrates the Greenhorn limestone and possibly also the Dakota formation. In this part of the county it is difficult to obtain satisfactory water supplies because the Ogallala formation is thin and in places is absent entirely, so that it has been necessary to depend upon rather meager supplies in the underlying bedrock formations.

Unequal additions of water to the ground-water reservoir are responsible for some of the irreguarities in the shape of the water table in Ford county. In areas where conditions at the surface are especially favorable for ground-water recharge the water that percolates downward tends to build up the water table to form slight mounds or high areas. The water-table contours in plate 1 show a rather pronounced mound along the belt of sand hills bordering the river northwest of Ford, that may be attributed to the more favorable conditions for recharge in this sandy area.

Local differences in the permeability of the water-bearing beds affect the shape of the water table. Other things being equal the slope of the water table in any area in general varies inversely with the permeability of the water-bearing material. Thus, the flow of ground water varies from place to place according to thickness and permeability of the water-bearing material. The permeability of the Ogallala formation is extremely variable as a result of changes in the character of the deposits from one locality to another. In certain areas in the northeastern part of the county the gradient of the water table is steeper because of the fact that the permeability of the fine-grained sandstones of the Dakota formation is lower than that of the overlying Ogallala formation.

RELATION TO TOPOGRAPHY

In Ford county the depth to water level below the land surface is controlled largely by the configuration of the land surface. A map (pl. 2) has been prepared showing the depths to water level in wells in Ford county by means of isobath lines—lines of equal depths to water level. These lines delimit areas in which the depth to water level lies within specified ranges. As shown on this map, the depth to water level ranges from less than 10 feet to about 200 feet. In general the depth to water level is less than 25 feet in the Arkansas valley and in most of the other principal stream valleys and is more than 100 feet beneath the uplands of the county. The water table lies deepest in the southern part of the county in the vicinity of Kingsdown. The relation between the water table and the land surface is shown in the three geologic sections across Ford county in plate 5.

Ford county may be divided into several areas based upon the depth to water level as follows: (1) shallow-water areas, (2) deep-water areas, and (3) areas of intermediate depth to water level. The shallow-water areas may be subdivided into the valley shallow-water areas, the northeastern shallow-water area, and the southwestern shallow-water area. The deep-water areas are in general the upland areas and may be subdivided into the northern deep-water area, the Bloom-Kingsdown deep-water area, and the west-central deep-water area.

Valley shallow-water areas.—The Arkansas valley is the largest and most important shallow-water area in the county. The water table stands less than 25 feet below the land surface in the Arkansas valley, which ranges in width from 2 or 3 miles in the western part of the county to 7 or 8 miles in the extreme eastern part. There are narrow belts along both sides of the valley in which the depth to water level ranges from 25 to 50 feet (pl. 2). Smaller shallow-water areas occur in the narrow valleys of many of the smaller streams, the more important of which are Sawlog and Duck creeks and their tributaries in the northern part of the county, Coon creek and its tributaries in the northeastern part, Crooked creek in the southwestern part, and Mulberry creek. Most of the wells in the stream valleys obtain water from alluvium, but some of the wells in the Arkansas valley have been drilled through the alluvium into the Ogallala formation.

Northeastern shallow-water area.—The northeastern shallow-water area covers most of the northeastern quarter of the county. The depth to water level is less than 100 feet and in much of the area is less than 50 feet (pl. 2). The shallow depth to water level in this part of the county is due in part to the shallow depth of the Dakota formation which supplies water to many of the wells, and in part to the relatively low altitude of the land surface in this area. In some parts of the area the Ogallala formation appears to be thin or absent, but where present may supply some water to wells. In the vicinity of Arkansas river near the eastern line of the county the depth to water level is less than 25 feet in an area covering more than 20 square miles. Most of the wells in this part of the county are supplied from the alluvium.

Southwestern shallow-water area.—The southwestern shallow-water area covers about 22 square miles in the southern part of T. 29 S., R. 26 W., in the southwestern corner of Ford county (pl. 2). The depth to water level in this area is less than 50 feet, and in part of the area it is less than 25 feet. The shallow-water area occurs along Crooked creek and is the northern extension of the Meade county artesian basin. Most of the wells in this area are supplied from Pleistocene sands and gravels or from the Ogallala formation, but a few may obtain water from the Dakota formation. There are several flowing artesian wells in the vicinity of Crooked creek (p. 51). Several successful irrigation wells have been drilled and the possibilities of developing additional supplies for irrigation in this area are discussed on page 121.

Northern deep-water area.—The northern deep-water area is about 7 miles north of Dodge City and includes parts of sections 7, 8, 9, 10, 13, 14, 15, 16, 17, 18, 23 and 24, T. 25 S., R. 25 W. (pl. 2).

The depth to water level in most of the area is more than 100 feet and locally is more than 150 feet. The Ogallala formation is thin or entirely absent in this part of the county and many of the wells have been drilled into the underlying Cretaceous rocks to obtain water supplies. Some of the wells may obtain scanty supplies from the Greenhorn limestone, but the deeper wells doubtless derive water from the Dakota formation.

Bloom-Kingsdown deep-water area. — The Bloom-Kingsdown deep-water area in southern Ford county comprises about 20 square miles in the vicinity of Bloom and Kingsdown in which the depth to water level ranges from 150 feet to a maximum known depth of 197 feet in well 476, 4 miles southwest of Kingsdown—the deepest water level observed in the county (pl. 2). The wells in this area derive water from the Ogallala formation.

West-central deep-water areas.—The west-central deep-water areas comprise two long narrow belts in western Ford county in which the depth to water level is more than 150 feet (pl. 2). The smaller of these parallels the north side of Mulberry creek and coincides with the divide between that creek and Arkansas river. The other belt parallels the south side of Mulberry creek and coincides with the divide between Mulberry and Crooked creeks. The wells in this area derive their water supplies from the Ogallala formation.

FLUCTUATIONS IN WATER LEVEL

General considerations.—The water table in Ford county is not a stationary surface, but a surface that fluctuates up and down much like the water level in a lake or reservoir. A condition of approximate equilibrium exists between the amount of water that is added annually to ground-water storage and the amount that is discharged annually by both artificial and natural means. In general, the water table rises when the amount of recharge exceeds the amount of discharge and declines when the discharge is greater than the recharge. Thus, changes in the water levels in wells indicate to what extent the ground-water reservoir is being depleted or replenished.

The principal factors controlling the rise of the water table in Ford county are the amount of rainfall penetration, the amount of water added to the underground reservoir by seepage from Arkansas river during periods of flood flow, and the amount of water entering the county beneath the surface from areas to the west. The principal factors controlling the decline of the water table are the amount of water lost by underflow to Arkansas river and to several smaller streams, including Duck and Sawlog creeks, the amount of water pumped from wells, the amount of water lost through transpiration and evaporation in stream valleys, and the amount of water leaving the county beneath the surface toward the east. In the Arkansas valley the water table fluctuates in response to the heavy draft made upon the ground-water reservoir by pumping from irrigation wells and to changes in the amount of water flowing in Arkansas river.

In the fall of 1938, 37 wells were selected at strategic points in Ford county, and periodic measurements of water level in them were begun in order to obtain information concerning the fluctuations in storage of the underground reservoir. The descriptions of wells and the 1938 water-level measurements are given in the 1938 annual water-level report of the Federal Geological Survey (Meinzer and Wenzel, 1939, pp. 93-100) and subsequent water-level measurements have been published in ensuing water-level reports (Meinzer and Wenzel, 1940, pp. 146-157). The following table correlates the observation-well numbers used in this report with those given in Water-Supply Papers 845 and 886. The location and description of each well appears in the table of well records at the end of this report.

Fluctuations caused by precipitation.—Fluctuations in ground-water levels in Ford county are related primarily to the amount of recharge received from precipitation. Under favorable conditions

TABLE 3.—*Observation well numbers used in this report and corresponding numbers given in Water-Supply Papers 845 and 886*

Well No. in this report.	Well No. in Water-Supply Papers 845 and 886.	Well No. in this report.	Well No. in Water-Supply Papers 845 and 886.	Well No. in this report.	Well No. in Water-Supply Papers 845 and 886.	Well No. in this report.	Well No. in Water-Supply Papers 845 and 886.
11......	41	176......	76	319......	59	403......	4
14......	47	179......	24	320......	60	406......	100
34......	237	184......	79B	322......	57	411......	26
50......	10	184A.....	79C	339......	101	417......	2
84......	32	228......	52	358......	48	421......	89
98......	96	243......	53	361......	86	423......	13
101......	11	248......	65	364......	25	485......	17
123......	35	256......	8	393......	43	507......	6
128......	38	311......	343	398......	68	510......	15
129......	36	313......	359	399......	68A	522......	7
171......	72	316......	9	401......	5		

part of the precipitation seeps down through the soil zone and is added to the zone of saturation. The amount and frequency of this recharge depend in part upon the depth of the water table below the surface. In the upland areas where the water table lies at considerable depth below the land surface there is less fluctuation in response to precipitation than in areas like the Arkansas valley in which the water table lies close to the surface. There is generally a lag between the time of precipitation and the time the water levels in wells begin to rise, and, other things being equal, the deeper the water level the greater the lag. The amount of precipitation necessary to produce recharge depends also upon the season of the year, and the character of the material in the soil zone and in the zones of aeration and saturation. After a prolonged period of drought, the soil moisture becomes depleted, so that when rain occurs, this deficiency must be satisfied before any of the water can percolate downward to join the water table. Temperature is also an important factor, for during hot summer months part of the water that falls is evaporated directly into the air from the soil zone, and during the winter months any moisture that falls on frozen ground is greatly hindered from reaching the water table. The water table generally declines somewhat during the summer owing to the withdrawal of water by plant transpiration and evaporation even though the rainfall may be greater than in the winter.

The fluctuations of the water level in six observation wells in Ford county and the monthly precipitation at Dodge City are shown in figure 8. Of the six wells, four are in the Arkansas valley, one is on the upland north of Arkansas river, and one is on the upland south of the river.

The water table in the Arkansas valley in Ford county usually reaches its highest stage of the year in the spring, often during March, and its lowest stage in the fall, generally about the first of October. The water table declines from about April 1 until October 1 partly as a result of the heavy draft created by the vegetative cover during the growing season and partly as a result of the withdrawal of large quantities of water from many irrigation wells in the valley. From October to April 1 there is usually a gradual rise of the water table. The water-level records of some of the wells in the valley indicate that there are some deviations from this routine behavior of the water table. During winter months there may be alternate periods of freezing and thawing with the result that recharge may occur intermittently. The effect upon the fluctuations

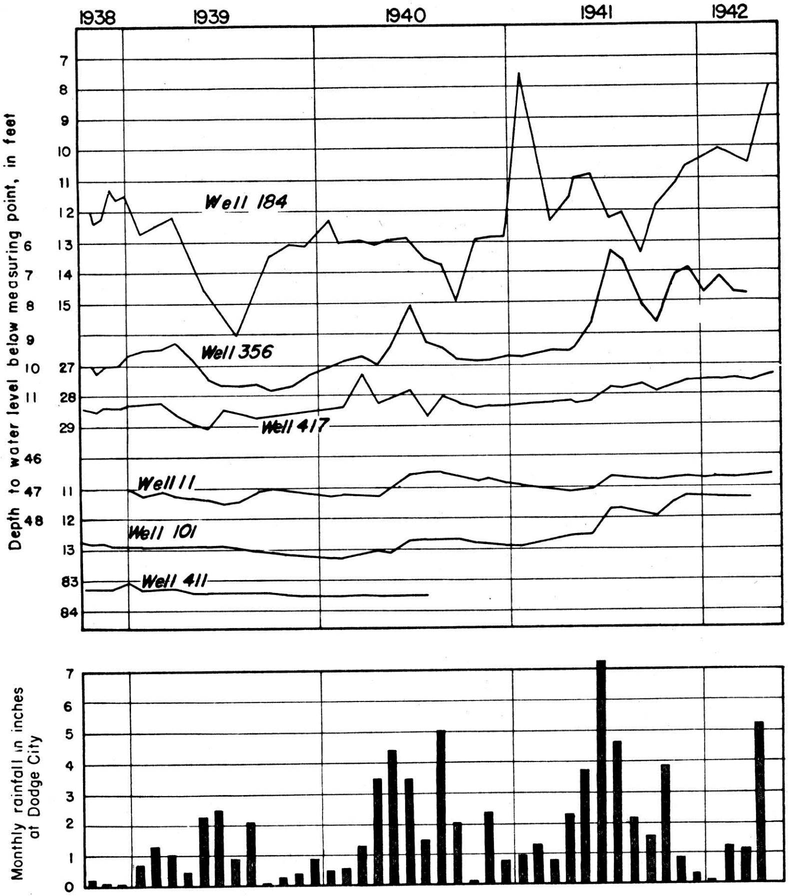
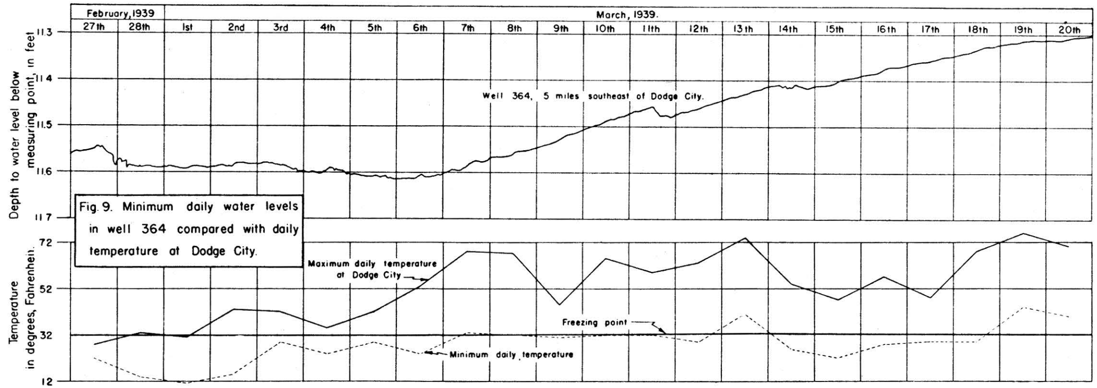


FIG. 8. Hydrographs showing the fluctuations of the water levels in six wells in Ford county and the precipitation at Dodge City. Precipitation data from U. S. Weather Bureau.

of the water level in well 364 of a period of thaw following a period of freezing temperatures, as measured by an automatic water-stage recorder, is shown by the graph in figure 9. Rising temperatures with resultant thawing conditions were responsible for an abrupt rise in water level during the period from March 7 to 20.

During the growing season in 1939 the relation between the precipitation and the water levels in wells in the valley was obscured by heavy pumping from irrigation wells and by transpiration losses. Consequently the wells in the valley were declining even though more than four inches of rainfall was recorded during May and June.



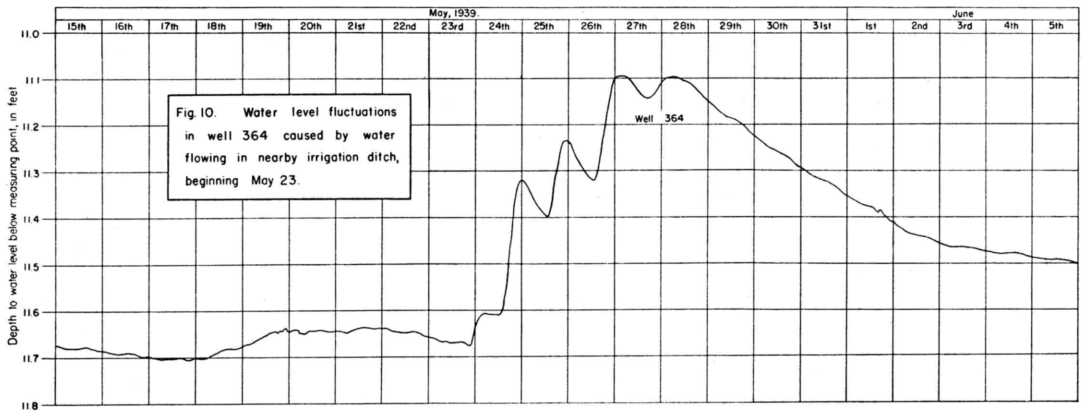


FIG. 9. Minimum daily water levels in well 364 compared with daily temperature at Dodge City.
FIG. 10. Water level fluctuations in well 364 caused by water flowing in near-by irrigation ditch, beginning May 23.

The greatest rises in water level in several of the wells in the valley during the period of record occurred in 1940 during the latter part of April and continued through May and June, following rainfall amounting to 3.54 inches in April, 4.41 inches in May, and 3.53 inches in June.

The effect of precipitation on the water level in well 11 on the upland north of the Arkansas valley is shown by the hydrograph of well 11, figure 8. The depth to water level in this well is about 46 feet. In general, the water level in this well declined from October, 1938, until about July, 1940. Apparently the rather scant precipitation that fell during this period was insufficient to produce recharge to the zone of saturation. As a result of heavy rain during May, June, and August, 1939, the water level in well 11 rose during August and September. Heavy rainfall in April, May and June, 1940, caused rather abrupt rises in water level in May and June. Well 411 is situated on the upland south of the Arkansas river in an area where the water table is at considerable depth. According to the hydrograph shown in figure 8, the water level in this well appears to be unaffected by precipitation, but a much longer period of record would be necessary before any comparison could be made between the water levels in deep wells and the precipitation.

The minimum daily water levels in three observation wells equipped with automatic water-stage recorders in Ford county, and the precipitation at Dodge City for the period from October, 1938, to September, 1939, are shown in figure 11. Well 364 (pl. 1) is a shallow well in the alluvium of the Arkansas valley; well 50, in the valley of Sawlog creek, was originally drilled into the Dakota formation to a depth of 240 feet, but when measured in October, 1938, the total depth was only 90.5 feet, the casing apparently being collapsed below that point; and well 319, in the Arkansas valley near Howell, was drilled to a depth of 186 feet and taps basal sands and gravels of the Ogallala formation, the upper shallow water being cased out. All three wells formerly were used for irrigation.

The period of record is entirely too short to make any definite correlation between water-level fluctuations and the precipitation, particularly for the two deep wells (wells 50 and 319) where there is undoubtedly a considerable lag between the time that precipitation occurs and the time that recharge takes place. The hydrograph of well 364 shows a slight rise in March as a result of recharge following a period of thawing temperatures. The high water levels that occurred in May, July, and August were caused by seepage from

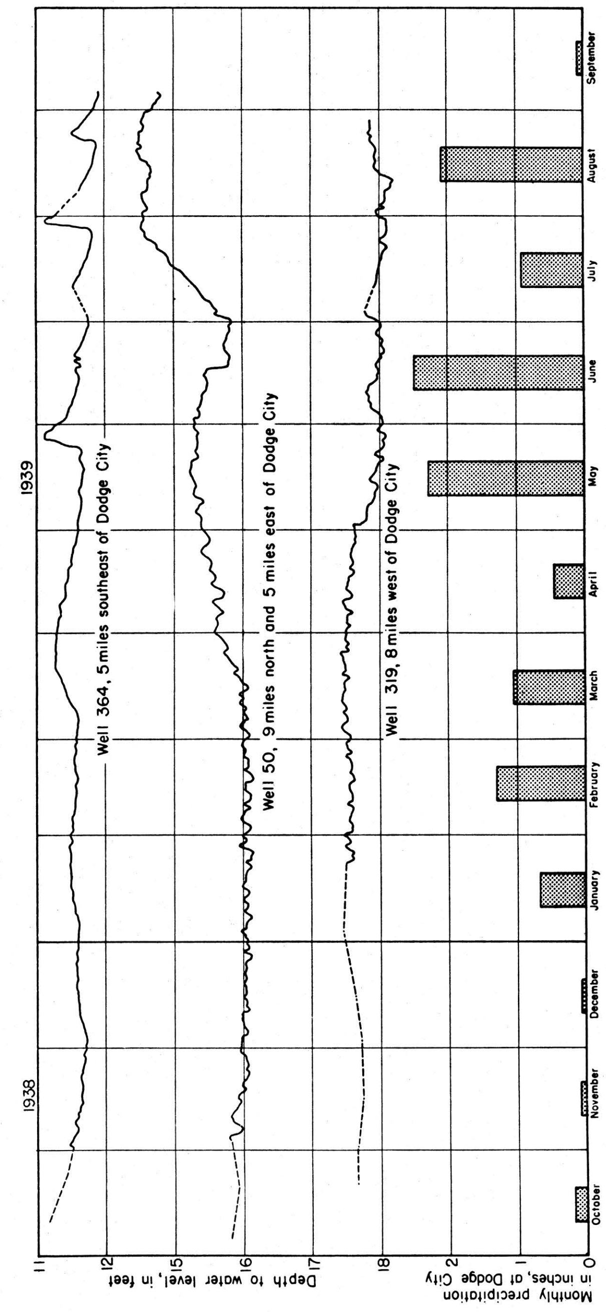


FIG. 11. Graphs showing the minimum daily water levels in 3 observation wells equipped with automatic water-stage recorders in Ford county, Kansas, and the precipitation at Dodge City. Precipitation data from U. S. Weather Bureau.

surface-water irrigation ditches in the vicinity of the well rather than by precipitation, as might first be implied. A more detailed graph of this phenomenon is shown in figure 10. Two irrigation ditches leading from a river pumping plant pass within 10 feet of well 364, with the result that the water level in the well is affected during the times when the ditches are carrying surface water.

The hydrographs for wells 50 and 319 are widely divergent and do not appear to be affected by precipitation. The water level in well 50 started rising about the middle of March and, aside from a rather prominent decline during June, it continued rising until August, after which it remained nearly stationary during the month. The reasons for this rather unusual rise are not definitely known. Since the well is known to tap the Dakota formation, it appears unlikely that fluctuations in water level would be controlled by precipitation falling locally, but rather that the water level would fluctuate in response to changes in the amount of water in storage in the Dakota formation. There appears to be no correlation between the hydrograph of well 319 and precipitation; however, a longer period of record might show conditions of delayed recharge.

Fluctuations caused by transpiration.—Ground water may be taken into the roots of plants directly from the zone of saturation or from the capillary fringe, which in turn is supplied from the zone of saturation, and is discharged from the plants by the process of transpiration (Meinzer, 1923, p. 48). The water table fluctuates in response to plant transpiration, generally, only in areas where the water table lies but a few feet below the land surface. In Ford county, therefore, the only areas in which the water table is directly affected by transpiration are the floodplains of Arkansas river and several smaller streams where the roots of plants draw water directly from the capillary fringe or from the zone of saturation.

Fluctuations caused by changes in atmospheric pressure.—The water levels in wells that penetrate water-bearing formations having a relatively impervious confining bed above the zone of saturation may fluctuate in response to changes in atmospheric pressure. The pressure on the water surface in a well increases with an increase of atmospheric pressure. If this increase in pressure is not transmitted uniformly to the entire ground-water body but acts only on the exposed water surface in the well, the water level in the well fluctuates according to the changes in pressure. If the pressure is transmitted freely through the pore spaces of the soil above the

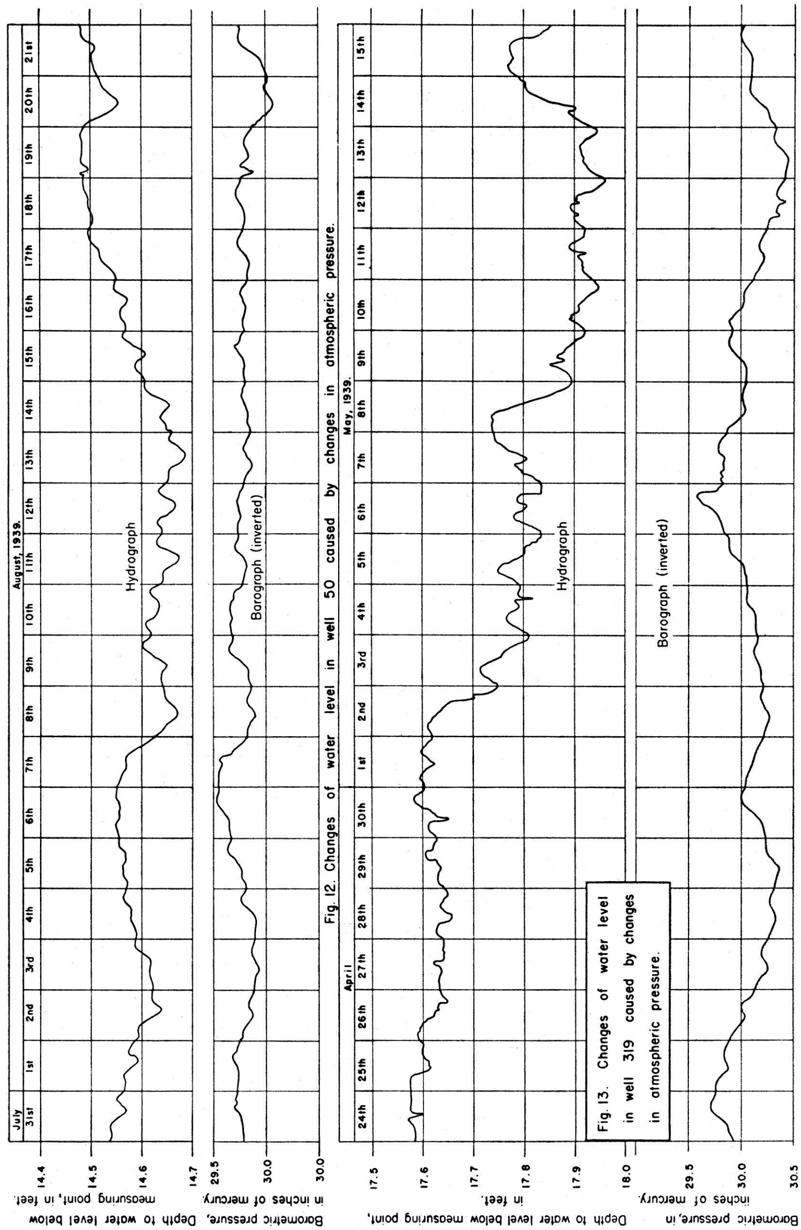


FIG. 12. Changes of water level in well 50 caused by changes in atmospheric pressure.
FIG. 13. Changes of water level in well 319 caused by changes in atmospheric pressure.

zone of saturation to the ground water, however, there is no barometric fluctuation of the water level.

Hydrographs of wells 50 and 319, obtained from automatic water stage recorders and inverted barographs obtained from a recording micro-barograph located in the same shelter, are shown in figures 12 and 13. The barographs are inverted because an increase in atmospheric pressure causes the water levels in wells to decline.

Fluctuations caused by pumping.—When a well is pumped, the water table in its vicinity declines and takes a form similar to an inverted cone, the apex of which is at the well (fig. 14). The cone of depression thus established represents a loss of storage by the un-

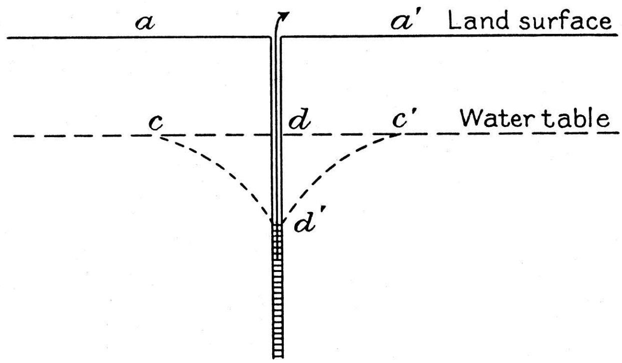


FIG. 14. Diagrammatic section of a well that is being pumped, showing its draw-down (dd'), cone of influence (cc'd'), and area of influence (aa') (after Meinzer).

watering of a portion of the previously saturated material surrounding the well. When pumping stops, the movement of water from surrounding areas continues until the cone of depression fills up, with a resultant slight decline of the regional water table in the vicinity of the well. Most wells are pumped intermittently; hence, a discharging well may be creating a cone of depression in one part of the area while another cone is being refilled following a period of pumping elsewhere. In an area such as the Arkansas valley in Ford county, where a great many wells are being pumped, the fluctuations of water level in any one well are complicated and may represent the sum of the effects of pumping or recovery from many nearby wells. At the end of the pumping season there is a gradual readjustment of the regional water table until it approaches the level that existed before pumping began, but there may be a net decline in water level.

The pumping season in Ford county may start early in the spring and continue until late in the fall. In a few instances winter wheat has been irrigated from wells during December. The length of the season varies from year to year, depending upon the amount and distribution of precipitation and upon the initiative of the well owners.

The hydrographs of several of the wells in the Arkansas valley (fig. 8) show that declines in water level occurred as a result of a general regional lowering of the water table during the pumping season. Well 184 is a deep well in the Arkansas valley that penetrates the Ogallala formation. It is part of a battery of three shallow and two deep wells interconnected to one pump and used for irrigation. The hydrograph of well 184 shows that pronounced declines in water level have occurred during the summer months in 1939 and during July, August and September, 1940, partly as a result of increased withdrawals of water from several near-by irrigation, industrial, and public-supply wells.

Ground-Water Recharge

The addition of water to the zone of saturation is known as ground-water recharge. Ground-water recharge in Ford county is derived from precipitation within the county, from influent streams and irrigation ditches, and from subsurface inflow from areas to the west of the county.

RECHARGE FROM LOCAL PRECIPITATION

Most of the ground-water recharge in Ford county is derived from precipitation. Of the total annual precipitation of 20.5 inches in Ford county, part runs off through surface channels and is drained from the area by Arkansas river, part is evaporated, part is transpired by plants, and part seeps downward to the zone of saturation and recharges the ground-water reservoir. When the amount of water absorbed in the soil zone is greater than can be held against the pull of gravity, the balance will move downward to the zone of saturation. Usually the belt of soil moisture is largely depleted by the end of the growing season, owing to the removal of much of the available water in this belt by evaporation and transpiration. Consequently, this deficiency must first be satisfied before recharge takes place.

Theis (1937, pp. 564-568) presented evidence to show that the average annual ground-water recharge from rainfall in the southern High Plains is somewhat less than half an inch. The surficial materials in the upland parts of Ford county are comparable to those of the southern High Plains, although the total annual precipitation is somewhat greater. That the recharge by rainfall penetration in Ford county probably averages somewhat less than half an inch a year is suggested by the following considerations: (1) Most of the rainfall occurs during the growing season when the amount of water lost by transpiration and evaporation is the greatest; (2) the downward movement of water is impeded in upland areas north of Arkansas river by cemented beds of caliche in the Ogallala formation and in upland areas south of the river by the relatively impervious Kingsdown silt; and (3) some of the water remains in depressions for long periods after heavy rains, showing that very little water percolates downward at these points. No figures are available regarding the annual amount of evaporation in Ford county, but at Hays (about 70 miles northeast of Dodge City) the annual evaporation from a free water surface amounted to about 101 inches for the period April through October, 1939, as recorded by the U. S. Weather Bureau. It seems likely, therefore, that a rather large proportion of the annual precipitation in Ford county is lost through evaporation.

A part of the precipitation that falls is lost through runoff in streams, the amount being determined largely by the intensity of the rainfall, the slope of the land, the porosity of the soil, and the type and amount of vegetative cover. Conditions generally are much more favorable for rainfall penetration during a gentle rain of long duration than during a torrential downpour when the rate of runoff is high.

The slope of the land is an important factor in determining the amount of runoff, and, in general, the steeper the slope the greater the runoff. The slope of the land surface in most parts of Ford county is relatively gentle, but steep slopes occur along some of the major streams.

The type of soil also determines in part the proportion of the precipitation that will be lost as runoff and the part that will percolate into the underground reservoir. In general, runoff is greater in places where the soils are tightly compacted and fine-grained than in places where the soils are sandy and loosely compacted.

A vegetative cover decreases the velocity of the runoff thereby offering a better opportunity for part of the water to seep into the ground.

The most favorable areas in Ford county for ground-water recharge seem to be the areas of sand dunes and the shallow-water areas along stream courses (pl. 1). A large percentage of the precipitation that falls on the sand dunes percolates downward rapidly with little loss by evaporation. There is little or no runoff in the areas of sand dunes, as indicated by the almost total lack of drainage channels.

RECHARGE FROM PRECIPITATION OUTSIDE THE AREA

The general slope of the land surface, the dip of the Ogallala formation, the slope of the water table (pl. 1), and the direction of movement of the ground water are all in an easterly to southeasterly direction; hence, recharge from precipitation that occurs in areas to the west and northwest of Ford county eventually moves into the county and contributes to the available supply of ground water.

Although the Dakota formation is exposed at several different places in Ford county, much of the water that it contains undoubtedly enters the formation from areas of outcrop outside the county. As the regional dip of the Dakota is northeastward, the most logical intake area would be confined to localities southwest of Ford county where the Dakota formation crops out. The Dakota is exposed over wide areas in southeastern Colorado, notably in Las Animas county. Water derived from precipitation falling on the outcrops and from streams flowing across the outcrops is absorbed and flows eastward through the formation into Kansas. Opportunity is afforded for water from the Dakota formation to migrate upward into the Ogallala formation at places where the two formations are in contact and where the Dakota water is under greater head than the Ogallala water. The Dakota is known to be directly overlain by the Ogallala in parts of this area (see log of test hole 4 on p. 208), but in parts of northeastern Ford county where relatively impermeable shale separates the Dakota formation from the Ogallala formation there is no opportunity for movement of water from the Dakota into the Ogallala. In the southern part of the county where the Rexroad member of the Ogallala formation rests directly on the Dakota formation (see logs of test holes 10, 14, 16, 17, 19, 20 and 21, pp. 212-222) the possibilities are very good for movement of water from the Dakota into the overlying Ogallala.

RECHARGE FROM STREAMS AND LAKES

Two factors determine whether or not a stream is capable of supplying water to the underground reservoir: (1) the water surface of the stream must be above the water table; and (2) the material above the water table must be sufficiently permeable to permit downward percolation of the water. Streams that satisfy these conditions are called influent streams (fig. 7). Arkansas river is effluent most of the time, as shown by the water-table contours (pl. 1), but as pointed out on page 42, it becomes influent during occasional periods of flood flow.

With the exception of Sawlog creek and its tributaries, most of the smaller streams in Ford county lose water to the underground reservoir during certain periods of the year when they are carrying runoff. The stream channels in several of the streams south of the river are cut in the Kingsdown silt which is relatively impermeable, so that very little water percolates downward to the zone of saturation. The amount of recharge resulting from occasional stream flow in Mulberry creek is not definitely known but is believed to be rather small.

Evidence of recharge from a small ephemeral stream is furnished by the record of water-level fluctuation in well 123, situated about 200 yards east of a small dry tributary to Coon creek (pl. 2). The depth to water level in the well ranges from about 37 to 40 feet. The water level in well 123 rose abruptly starting about the middle of May, 1940, and reached its highest stage of the year in the latter part of June, 1940, the rise amounting to 3.5 feet. This unusual rise seems to be the result of recharge following rather heavy rainfall in April and May. Water was still standing in the bottom of the tributary drainage at the time that the well was measured on June 19, indicating that part of the rise in water level might have occurred as a result of recharge from the stream.

The possibility of recharge from impounded bodies of surface water is provided whenever the level of such water bodies is above the water table. Ford county lake and Hain lake (pl. 1) have been created by damming tributary drainages that have cut into the Ogallala formation. When the lakes are full, therefore, there may be some opportunity for percolation of water through the Ogallala to the underlying water table. The magnitude and rate of recharge from such sources is not definitely known, but the controlling factors include the height of the lake surface above the water table, the amount of water in storage, and the permeability of the reservoir basin.

REGHARGE FROM IRRIGATION DITCHES AND IRRIGATED LANDS

In the Arkansas valley rather large quantities of water are pumped from wells or diverted from the river for irrigation. Some of this water seeps into the ground and is added to the zone of saturation.

Thus, ground-water recharge may take place in the vicinity of irrigation ditches, and irrigated fields. The effect of seepage from two irrigation ditches upon the water level in a nearby observation well (364) in the Arkansas valley is shown in figure 10 and is discussed on p. 66.

SUMMARY OF RECHARGE

Much of the annual recharge to the ground-water reservoir in Ford county is derived from precipitation that falls on the county and in part from precipitation on outcrop areas outside the county, and from seepage from the Arkansas river at times when it is influent. A part of the local precipitation enters the ground through areas of sand dunes and sandy soil, and small amounts through channels of normally dry streams during periods of flood flow. Some of the water that enters the Dakota formation from precipitation on its outcrops ultimately may recharge the Ogallala formation at places where the two formations are in contact. The amount of average annual recharge cannot be determined on the basis of existing data, but it is probable that only a small percentage of the average annual rainfall of 20.5 inches reaches the zone of saturation.

Ground-Water Discharge

Ground water is discharged in Ford county by transpiration and evaporation, seepage into effluent streams, springs, underflow that leaves the county, and by wells. The rate at which it is discharged varies with many factors, but especially with the stage of the water table and with the season of the year. Local differences in conditions cause more ground water to be discharged in some parts of the county than in others. More ground water is pumped from irrigation wells in the Arkansas valley than in the upland parts of the county. More water is withdrawn from the zone of saturation by plants by evaporation in areas adjacent to Arkansas river and other perennial streams than in areas where the water table lies at great depth. Natural discharge of ground water also takes place in the form of water moving slowly out of the county toward the east, as indicated by the water-table contours on the map, plate 1. The water moving out of the county as underflow along the Arkansas valley represents one phase of this type of ground-water discharge. The amount of water that moves out of the county is approximately the amount that enters from the west plus whatever additions to or subtractions from the ground-water reservoir have been made within the county.

It is probable that before any water was pumped from wells in Ford county, the annual discharge of ground water by natural processes was approximately equal to the annual recharge. Artificial discharge by pumping represents an additional amount of water taken from the underground reservoir without any increase in the amount of replenishment. The development of the ground-water resources of Ford county necessarily will cause some lowering of the water table until the natural discharge through springs and seeps into perennial streams and underground movement of water out of the county is decreased by an amount equal to the withdrawal by pumping. Such adjustments, however, will proceed slowly over a period of many years with only a gradual regional lowering of the water table, as the amount of water in storage is very large. Although quantitative estimates are available for the amount of water discharged from wells in Ford county, the amount of natural discharge is not definitely known.

TRANSPIRATION AND EVAPORATION

The roots of plants may draw water directly from the zone of saturation and discharge the water into the atmosphere by the process of transpiration. The rate at which water is withdrawn from the zone of saturation varies with the type of plants, the depth to the water table, the climate and the season of year, the character of the soil, and possibly other factors. The limit of lift by ordinary grasses and field crops is not more than a few feet, but some types of desert plants have been known to send their roots 60 feet or more below the surface to reach the water table (Meinzer, 1923, p. 82). In parts of the county along the valley margins and on the uplands, where the water table is considerably below the reach of the roots of most plants, water is withdrawn from the belt of soil moisture, thereby depleting the supply of soil moisture, but in the Arkansas valley and some of the other stream valleys many of the plants draw water directly from the zone of saturation. Evaporation of water directly from the zone of saturation is confined almost exclusively to the dry bed of Arkansas river and to the land immediately adjoining the stream, where the water table is very shallow. Most of this water is drawn from the zone of saturation and is evaporated at the top of the capillary fringe. In areas where the water table lies at considerable depth no water from the zone of saturation is lost by direct evaporation; in such places only the soil moisture is evaporated. The amount of water discharged by plant transpiration in the Arkansas valley and other parts of Ford county is not definitely known. Wenzel (Lugn and Wenzel, 1938, p. 151) estimated that in the Platte river valley between Chapman and Gothenburg, Nebraska:

> If an average of 12 inches of supplemental water is used annually by the plants whose roots extend to the zone of saturation, the resulting quantity of water discharged by transpiration . . . would amount to about 390,000 acre-feet a year, or about 12 times the quantity of water pumped annually from wells.

It is believed that the total quantity of water withdrawn by plant transpiration in the Arkansas valley in Ford county is rather large, but probably is less than in the central Platte valley in Nebraska. The areas bordering Arkansas river in which the water table lies within 10 feet of the surface are much smaller in extent than in the Platte valley.

SEEPAGE INTO STREAMS

A stream that stands lower than the water table may receive water from the zone of saturation, and is known as an effluent stream. The principal streams that receive ground-water discharge in Ford county are Arkansas river, during periods of low flow, and Sawlog and Crooked creeks.

As pointed out under the discussion of shape and slope of the water table, ground water moves in toward the Arkansas valley from both sides as shown by the water-table contours on plate 1. Thus, except at flood stage, the Arkansas river is a gaining stream throughout its course in Ford county; that is, it is effluent with respect to the water table. Where tributary streams have cut their channels below the general water table, their flows are also augmented by ground water during most of the year. Seepage of ground water occurs along the banks of these streams and in some instances ground water is discharged through springs along the valley sides. Although water has been observed in the channel of Crooked creek in that part of its course in Ford county, the stream bed is known to be dry for long periods at points downstream, near Fowler, Meade county. At the county line the creek is entrenched about 15 feet below the general land surface and its channel may or may not be below the water table. Ground water may be discharged into Crooked creek during part of the year, but it is probable that stretches of the creek in Ford county would go dry during a part of the year if it were not for several small dams that have been constructed to impound water for stock and for irrigation.

DISCHARGE BY SPRINGS

In Ford county some water is discharged through springs. Most of the springs observed are in the northern part of the county along Sawlog creek and its tributaries, and no springs were observed south of the Arkansas valley. The water table under the south uplands lies at considerable depth, and in general the channels of tributary streams lie above the water table; hence, few, if any, opportunities for springs exist. The total quantity of water discharged by springs in Ford county is not definitely known, but it is thought to be small as compared to discharge by other means. The known springs are described below under Recovery.

DISCHARGE FROM WELLS

Discharge of ground water from wells in Ford county constitutes the principal discharge from the ground-water reservoir. In 1938, approximately 10,435 acre-feet of water was pumped from irrigation wells in the Arkansas valley and from industrial and public supply wells in the county. Most of the rural residents of the county derive their domestic and livestock supplies from wells, but the total volume of water pumped from these wells is comparatively small.

RECOVERY OF GROUND WATER

Springs

In Ford county some water is recovered from springs for domestic and stock use, but the supplies thus obtained are generally small. Small springs are found in the northern part of the county along tributary streams, notably along Duck and Sawlog creeks.

Most of the springs in this area are gravity springs; the water does not issue under artesian pressure but is due to an outcrop of the water table. The water in this type of spring percolates from permeable material or flows from openings in the rock, under the action of gravity, as a surface stream flows down its channel. Gravity springs may be further classified as seepage springs, in which the water percolates from numerous small openings in permeable material; as contact springs, in which water flows to the surface from permeable material over the outcrop of less permeable or impermeable material that retards or prevents the downward percolation of the ground water and thus deflects it to the surface; and as depression springs, in which water flows to the surface from permeable material simply because the surface extends down to the water table (Meinzer, 1923 b, pp. 50-55). The distinctions between these types of springs are somewhat arbitrary and all may grade into one another.

Most of the springs in Ford county are either contact springs or seepage springs, and issue from permeable beds at or near the base of the Ogallala formation near its contact with the underlying Cretaceous bedrock. In some localities, the bedrock is Graneros shale, and in other areas, notably along Duck creek and along the upper reaches of Sawlog creek, the Ogallala rests directly on the basal

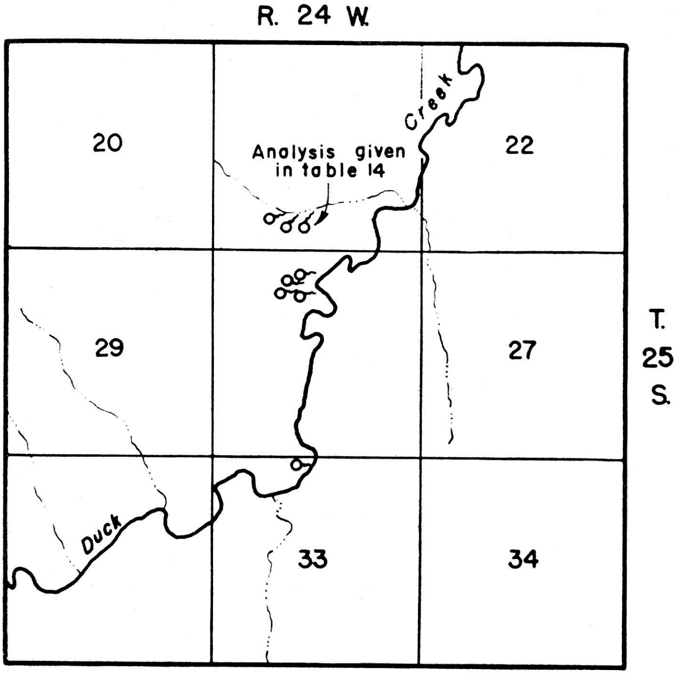


FIG. 15. Map showing location of springs along Duck creek in T. 25 S., R. 24 W., Ford county.

members of the Greenhorn limestone. Water is discharged from many springs of this type on both sides of Duck creek near the Ogallala-Greenhorn contact. At some of the seeps there is no visible discharge of water, but the vegetation near the contact is much greener and more luxuriant, indicating that the plants are transpiring ground water as fast as it is being discharged. Depression springs are found in some parts of the area, particularly at the heads of perennial streams in upland areas, and along the major stream channels.

Several small seepage springs are found on sloping hillsides adjacent to some of the streams in the northern part of the county. Some of these springs in the vicinity of Duck creek have been developed and equipped with discharge pipes by the Works Progress Administration. The locations of several of these springs are shown in figure 15. The flow of a typical spring in this area was measured on July 17, 1939, and found to be about one gallon a minute, and an analysis of water from this spring is given in table 14. Some of the springs shown on the map in figure 15 were not visited in the field, but according to reports from local residents, their rates of discharge ranged from less than one gallon a minute to 3 or 4 gallons a minute.

Wells

PRINCIPLES OF RECOVERY FROM WELLS

In Ford county, ground water is recovered principally from wells, but some water is recovered also from dug wells and driven wells.

When a well is pumped, there is a difference in head between the water inside the well and the water in the material outside the well. The water table in the vicinity of a pumped well declines and assumes a form comparable to an inverted cone, the apex of which is at the well, as illustrated in figure 14. When a well is discharged under artesian conditions, there is a comparable lowering of the "piezometric surface"—the imaginary surface to which artesian water will rise under its full head. Under artesian conditions the cone of depression exists only as an imaginary cone whose apex is the point of discharge of the well. In any given well the greater the pumping rate the greater will be the draw-down and the greater will be the extent of the cone of depression. Thus, the effects of the discharge will be felt at greater distances from the pumped well; and, if heavy pumping continues, the water levels in wells several hundred feet or even a mile or more distant may be lowered somewhat.

The specific capacity of a well is its rate of yield per unit of draw-down, and is usually stated in gallons a minute, per foot of draw-down. For example, well 37, one of the city wells at Spearville, is reported to yield 50 gallons a minute with a draw-down of about 9 feet. Its specific capacity, therefore, is about 5.5 gallons a minute, per foot of draw-down. Wells in some of the unconsolidated rocks, such as the alluvium of the Arkansas valley, have specific capacities ranging up to 100 gallons a minute per foot of draw-down; whereas, wells in some of the consolidated rocks may yield less than one gallon a minute, per foot of draw-down.

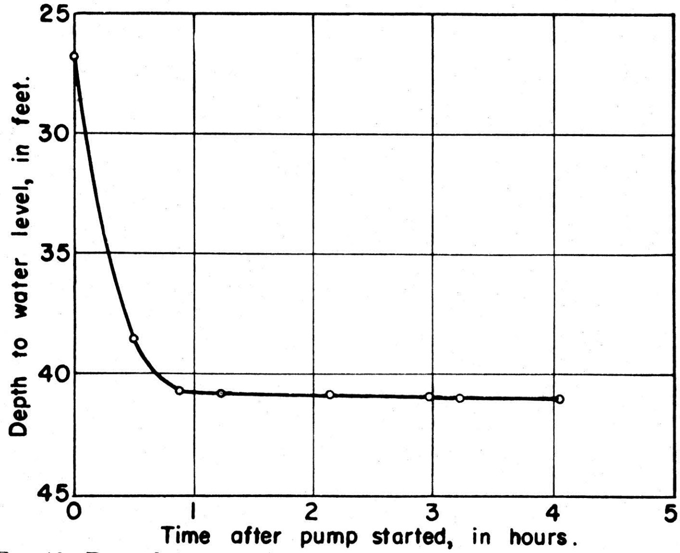


FIG. 16. Draw-down curve of well 421, southeast of Ford, Kansas. Well was pumped at rate of 860 to 980 gallons a minute.

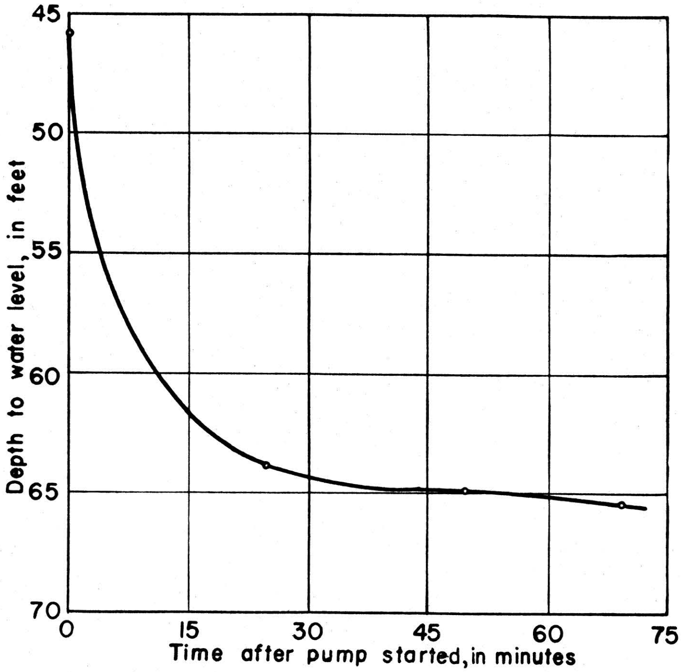


FIG. 17. Draw-down curve of well 507, in southwestern Ford county. Well was pumped at a rate of 930 to 950 gallons a minute.

When a well is pumped, the water level drops rapidly at first and then more slowly until conditions of approximate equilibrium are approached, and, in some wells, the water level may continue to decline for several hours or days before approximate equilibrium is established. Draw-down curves of wells 421 and 507 are shown in figures 16 and 17. In determining the specific capacity of a well, therefore, it is important to continue pumping until the water level remains approximately stationary. When pumping stops, the water level rises rapidly at first, but the rate of recovery becomes progressively slower and may continue long after pumping has ceased.

Increasing the specific capacity of a well reduces the cost of pumping, as the cost of pumping water increases with the draw-down. The specific capacity of wells sometimes can be increased by modern methods of well construction, some of which are described below under "Drilled Wells."

METHODS OF LIFT

Most of the rural residents in Ford county derive their domestic and stock supplies from wells equipped with hand-operated lift or force pumps, or with pumps operated by windmills, engines, or electric motors. Some of the farms have been equipped with small pneumatic pressure systems in which the water is forced against air pressure into an air-tight tank from which it flows under pressure to any part of the home or farm.

Many of the irrigation wells in the Arkansas valley are equipped with centrifugal pumps. This type of pump is usually mounted in a pit, or sometimes at the land surface, and can be used only where the depth to water level plus the draw-down does not exceed the working suction limit. A few of the deeper wells in the valley and all of the irrigation wells on the south uplands are equipped with deep-well turbine pumps. A series of connected turbines called stages or bowls are submerged below the water table (or just above, in some wells) and are connected by a vertical shaft to a pulley or vertical motor at the top. The number of such units varies, depending on the height the water must be forced, but the average installation in irrigation wells in Ford county comprises 3 stages. Most of the pumps used for irrigation are driven by stationary gasoline engines, but a few are electrically driven. Tractors are used to operate some of the pumps.

Many types of power-driven pumps or lifting devices are in use on the industrial and municipal wells of the area. Some of the older installations consist of single- or double-action plunger-type pumps installed in the well, and driven by electricity, steam or internal-combustion engines. Some of the older wells, including well 196, are pumped by air lift. In this method compressed air is forced through a nozzle submerged some distance below the water level, and the resulting mixture of water and air is carried to the surface where it is discharged. Where draw-downs are excessive or where the water level is at considerable depth, air-lifts of two or three stages are sometimes used. One well (482) is pumped by natural gas, using the same principle as air lift. Most of the industrial and municipal wells in the area are equipped with deep-well turbines driven by electric motors.

A few wells in the county flow at the surface (p. 50) and therefore do not have to be pumped unless larger supplies are needed.

DUG WELLS

Of a total of about 530 wells visited in Ford county, 20 were dug wells and 8 were combination dug and drilled wells. Of these 28 wells, 6 were used for irrigation and 10 were out of use. Most dug wells tap rather poor water-bearing material, but because of their large diameter they have a large infiltration area and ample storage capacity. Dug wells generally are more apt to fail during dry seasons and are more subject to contamination than the deeper drilled wells. Dug wells generally are curbed with native rock, brick, or wood, but some are curbed with concrete blocks and a few with tile. Most of the dug wells for domestic use are about 4 feet in diameter, but some dug wells used for public supply range from 4 feet to 10 feet, such as wells 36 and 37 which are used for the public supply at Spearville. Two of the three city wells at Bucklin (467 and 468) are dug wells 7 feet in diameter, one being curbed with brick, the other with rock.

A few dug wells have been listed in the tables of well records as dug and drilled wells, and well 36 at Spearville, well 467 at Bucklin, and five of the wells used for irrigation on the uplands south of the Arkansas valley (393, 402, 425, 435, 485) are examples of this type of well. Well 467 was dug 7 feet in diameter to a depth of 111 feet, or 8½ feet below the water table, and between the depths of 111 and 125 feet. Most of these irrigation wells were dug and uncased down to about the water level—below which a 15- or 20-inch hole was drilled and cased down into the water-bearing gravel.

DRIVEN WELLS

Driven wells can be put down only where the materials are sufficiently permeable and soft enough to permit a pipe being driven and where the depth to water level is within 10 or 15 feet of the surface. Driven wells are used for domestic and stock supplies in some of the valleys containing water-bearing alluvium. They range in diameter from 1¼ to 1½ inches and are equipped with a screened drivepoint at the bottom. Most of them are equipped with hand-operated pitcher pumps. Driven wells are likely to fail during dry seasons, but where the thickness of the water-bearing formation is not limited, additional pipe can be added and the screened point can be driven deeper into the formation.

DRILLED WELLS

Most of the domestic and public supplies and all of the industrial ground-water supplies in Ford county are obtained from drilled wells. Many of the drilled wells used for domestic and stock purposes on the uplands were drilled by portable cable-tool (or solid-tool) rigs. These wells are cased with galvanized-iron or wrought-iron casing, generally 5⅝ inches in diameter. Those drilled for industrial or municipal use range from 6 to 24 inches in diameter.

Wells in consolidated rocks.—A few drilled wells in Ford county obtain water from the consolidated rock formations and are cased through the overlying unconsolidated deposits and several feet into the bedrock. In most of those wells the water enters only at the lower open end of the casing and these are called open-end wells. In some wells, however, the casing extends to the bottom of the hole and the water enters the well through a section of screen or slotted casing placed opposite the water-bearing material. This type of well is usually cased only a short distance into the rock, the lower part of the hole being left uncased. The yields of drilled wells in the several consolidated deposits in Ford county are discussed on page 120, and the records of all wells visited are given in table 15.

Wells in unconsolidated deposits.—Many of the drilled wells, in the upland areas, that obtain water from unconsolidated material (sand or gravel) are cased to the bottom, and receive water only through the open end of the casings.

The efficiency of wells drilled in unconsolidated deposits may be increased in several ways. The intake area may be increased by perforating those portions of the casing opposite the water-bearing beds or by using commercial well screens. In order to know where to perforate the casing and in order to select the openings of the proper size, it is important to know the depth and thickness of the water-bearing beds. While the well is being drilled it is advisable to take samples of the material every few feet. The grain-size of the water-bearing material determines the size of openings to be used in the screen. Where the water-bearing material is fine-grained, a layer of carefully-screened gravel may be placed in the annular space between the well screen and the outside wall of the well. In wells of this type, which are called gravel-packed wells, the effective diameter and intake area of the well is increased and the velocity of the incoming water may be reduced sufficiently to prevent fine material from moving into the well. There are two methods for making gravel-packed wells. In one method the gravel is placed around the casing after the hole is completed; in the other, the gravel is put in at the same time the well is being drilled. In constructing a gravel-wall well by the first method, which is most commonly used in Kansas, a hole of large diameter (48-60 inches) is first drilled and temporarily cased. A well screen or perforated casing of a smaller diameter than the hole (12-25 inches) is then lowered into place and centered opposite the water-bearing beds. Blank casing extends from the screen to the surface. The annular space between the inner and outer casings then is filled with carefully sorted gravel —preferably of a grain-size just slightly larger than the openings in the screen or perforated casing, and also just slightly larger than that of the water-bearing material. The outer casing is then withdrawn in order to uncover the screen and allow the water to flow through the gravel packing from the water-bearing material.

The logs of some of the test holes drilled during the investigation show that in some places the water-bearing materials are sufficiently coarse and well sorted that gravel-packed wells are not required in order to obtain large yields. In such places less expensive wells employing well screens or slotted casings but without gravel packing may be used satisfactorily. In places where the water-bearing materials are fine-grained, however, the gravel-packed wells have several advantages that offset the greater initial cost. The envelope of selected gravel that surrounds the screen increases considerably the effective diameter of the well and, hence, decreases the velocity of the water entering the well. This reduction in velocity prevents the movement of fine sand into the well and increases the production of sand-free water. Owing to the increased effective area offered by this type of construction, the entrance friction of the water is reduced and, hence, the draw-down may be reduced materially. As stated above, a reduction in draw-down, at a given yield, means an increased specific capacity and reduces the cost of pumping.

Assuming that a well of the best possible construction is employed, then the maximum amount of water that can be withdrawn from the well is fixed by nature and nothing more can be done to make the well yield more than the water-bearing material will provide. The problem for the driller, then, is to construct each individual well in such a manner as to obtain the greatest yield with the smallest amount of draw-down that is possible under the existing conditions. For further discussion of gravel-packed wells the reader is referred to a report by Rohwer (1940, p. 62) and another by McCall and Davison (1939, p. 29).

Cased drilled wells containing a separate pipe and cylinder for conducting the water to the surface are the dominant type of domestic and livestock well over much of the county; however, tubular wells predominate in a large area in the southeastern quarter of the county. Tubular wells are drilled wells with no separate pump pipe —the casing being used to conduct the water to the surface. Tubular wells range in diameter from 2 to 4 inches and generally are cased with galvanized-iron pipe, at the bottom of which is attached a screened point and a brass-lined cylinder of the same diameter as the pipe. The submerged cylinder is connected with a pump at the surface by rods within the casing. This type of well is less expensive than a drilled well of the regular type. The piston and valve leathers can be repaired by pulling out the pump rods, but the pump cylinder can be repaired only by pulling the well casing. Cased wells have the advantage that the entire pumping equipment can be removed for inspection and repair without danger of caving the well.

Accurate measurements of water level in tubular wells are difficult if not impossible, as the water level in the well generally is held somewhat above the water table by the check valve in the cylinder. In most abandoned tubular wells the bottom check valve remains intact so that the water level in the well does not represent the true water table. Some tubular wells have been abandoned because the screens at the bottom have become sealed off with incrusting materials. The predominance of tubular wells in the southeastern part of the county made it difficult to obtain enough water-level measurements for the preparation of the water-table contour map, plate 1.

It is probable that larger supplies of water generally could be obtained from unconsolidated material if proper methods of well construction were used. There are surprisingly many examples of poor well construction in Ford county, particularly in the Arkansas valley where many of the small irrigation wells have been constructed by the individual owners with improvised equipment and, as a result, are not very efficient. In several of these wells, homemade screens have been used, ranging from improperly-slotted oil drums to rims of tractor-wheels piled one above the other. After a few years use, some of these screens gradually become clogged, resulting in increased draw-downs and reductions in yield. The cost of pumping water from wells increases with an increase in draw-down; hence, any improvement in the efficiency of a well represents a material saving in operating costs. Some of the factors that influence the cost of pumping water have been summarized by McCall and Davison (1939, p. 29):

> First, the well should be put down through all valuable water-bearing material. Second, the casing used should be properly perforated so as to admit water to the well as rapidly as the surrounding gravel will yield the water. Third, the well should be completely developed so that the water will flow freely into the well. . . . Increasing the diameter of the well will decrease the draw-down but little, all else remaining equal. The small saving in lift due to use of a large casing usually will not offset the extra cost of the larger well. It is much better to put a 16-inch casing down through all valuable water-bearing material than to start a 24-inch casing and have to stop short of the desired depth. Increasing the depth of the well will have a greater effect on reducing the draw-down than will increasing the diameter, so long as additional water-bearing formations are encountered.

For a description of different types of pumping plants, the conditions for which each is best adapted, construction methods, and a discussion of construction costs, the reader is referred to a report by Davison (1939).

UTILIZATION OF GROUND WATER

The development and utilization of ground-water supplies in Ford county are more highly concentrated in the Arkansas valley than in any other part of the county. Domestic and livestock supplies and a few irrigation supplies have been developed on the upland areas of the county, but the greater depth to water level in most of the upland areas limits the development of large ground-water supplies. The uses of ground water in Ford county are many. In table 15 the uses of ground water are divided, principally, as follows: domestic, livestock, public supply, irrigation, industrial, and cooling or condensing. The principal uses are described below.

Domestic and Municipal Uses

DOMESTIC SUPPLIES

Practically all of the domestic supplies in the rural areas and in small towns that have no public water supplies are obtained from wells. In the early days springs and dug wells were used, but in later years drilled wells became more predominant. Springs are the source of supply on a few farms at the present time. Some of the dug wells have been abandoned and replaced by drilled wells. Dug wells have gradually fallen into disfavor because they are subject to pollution and are apt to fail in dry weather. Practically all new wells put down in the area are drilled.

The domestic use of water generally includes drinking, cooking, washing, and the cooling of milk and other perishables. Water from some wells or springs may be polluted and care should be taken to avoid the use of such water or to remove the source of the pollution. In this area the ground waters generally are satisfactory for all domestic purposes, although some contain objectionable concentrations of fluoride, a few have rather high content of iron, and some are hard enough to be unsuitable for laundry purposes (see "Quality of water").

LIVESTOCK SUPPLIES

On many of the farms drilled wells supply water for livestock, and on most upland farms the same well supplies water both for domestic use and for watering livestock. Some wells have been put down in pastures for the sole purpose of watering livestock. Most of the stock wells are equipped with windmills capable of pumping a few gallons of water a minute, and some are provided also with auxiliary pump jacks operated by small gasoline engines.

INDUSTRIAL SUPPLIES

Ground-water is used by several industries in Ford county for many different purposes. For some industrial purposes water must be of a certain chemical character and for others its temperature is the most important factor.

The principal industrial use of ground water in this area is for cooling and condensing. The largest single industrial use of ground-water in Ford county is for cooling and condensing at the power plant of the Kansas Power Company near Fort Dodge. Ground water is used also for cooling condensers at the booster station of the Natural Gas Pipeline Company of America, about 17 miles southeast of Dodge City. Ground water is used by several industries at

Dodge City, including the Fairmont Creamery, the Dodge City Flour Mills, Dodge City Steam Laundry, and the Dodge City Warehouse. The Atchison, Topeka and Santa Fe Railway Company at Dodge City is the second largest industrial user of ground water in the county. Most of the water is used at the roundhouse at Dodge City for washing and filling locomotive boilers, and smaller amounts are used for depot facilities, stockyards, and miscellaneous purposes. The Chicago, Rock Island and Pacific Railway Company uses ground water obtained from two wells at Bucklin for filling locomotive boilers and miscellaneous railroad uses.

Relatively little ground water is used in the county for air-conditioning except in Dodge City, where most of the water thus used is purchased from the city. Several firms have installed small wells for air-conditioning, however, including the office building of the Kansas Power Company, Duckwall Stores, Inc., a department store, and the J. S. Dillon Grocery company in South Dodge City. As given in table 4, the total volume of ground water developed for air-conditioning in Dodge City in 1938 was about 44 acre-feet, and it is probable that the amount of ground water used for this purpose will increase in the future. There are several smaller air-conditioning plants installed in private homes and in smaller business houses and restaurants, but well records and pumpage estimates were not obtained for them. According to Mr. Kirkpatrick, city engineer at Dodge City (personal communication), during several periods of extremely warm weather, in the summers of 1936, 1937, and 1938, the sewage-disposal plant at Dodge City was taxed to capacity, owing to the large amount of waste water from air-conditioning plants.

The great advantage of ground water for cooling is not only its relatively low temperature, but its uniform temperature throughout the year, which approximates the mean annual temperature of the air. The temperature of the ground water in Ford county ranges from about 57° to 63° F. The temperature of water in any one well, moreover, probably does not vary more than 2° or 3° F. during the year. In general, the chemical character of water used for cooling is unimportant as long as it is not corrosive and does not contain iron or other constituents that might clog condenser pipes. The ground water used in Ford county for cooling purposes is not corrosive and does not contain any harmful constituents that would interfere with such use.

Some ground water is used in this area for boilers. Water for this purpose should be relatively free from foam- and scale-forming constituents. Most of the ground water used for this purpose in Ford county requires treatment for reduction of hardness. Two separate treating plants are maintained by the Atchison, Topeka and Santa Fe Railway Company at Dodge City for the purpose of softening ground water for boiler use. The Dodge City laundry also maintains a treatment plant for softening its water supply.

The power plant of the Kansas Power Company is situated on the north side of the Arkansas river about 4 miles east of Dodge City. The water supply is pumped from three wells (369, 370, and 371) 152 feet in depth from water-bearing sands and gravels near the base of the Ogallala formation (pl. 2). A fourth well was drilled, but in 1939 it had not been equipped with a pump. The wells are 30 inches in diameter, equipped with 24-inch Armco iron casing, and back-filled with selected gravel. The three wells are equipped with vertical deep-well turbine pumps direct-connected to electric motors. When the wells were put down in 1931, each well yielded between 2,050 and 2,150 gallons a minute with a 50-foot drawdown. In October, 1932, a pumping test indicated that the three wells, when pumped at the same time, yielded a total of 5,590 gallons a minute with draw-downs ranging from 55.5 to 56.5 feet. A similar test in July, 1937, indicated that the total discharge of the three wells amounted to 4,550 gallons a minute with draw-downs ranging from 58.5 to 68.75 feet. In 1939 the yields of the three wells had diminished still further and the average draw-down was about 70 feet. In 1939, generally, only one well was pumped at a time, at the rate of 1,800 gallons a minute, but during peak loads two wells were pumped about 8 hours a day at an aggregate rate of about 3,400 gallons a minute. In the summer the peak load at the plant comes about noon, whereas in winter it comes about 6:00 p. m. The water is moderately hard, as shown by analysis 370 in table 14. The water is used for cooling condensers at the plant, and some of it, after treatment, is used for boiler supply. The initial temperature of the water is about 57°, but after the water has passed through the condensers its temperature is raised about 18°. The warm water is discharged through a ditch into the Arkansas river.

The Atchison, Topeka and Santa Fe Railway Company obtains its water supply from five wells situated near the roundhouse at Dodge City. Of this number only two (wells 195 and 196) were in use in 1939 (see fig. 18, pl. 3). A columnar section of one of these wells (195) is shown in figure 18. Well 195 is equipped with a deep-well turbine pump, whereas well 196 is pumped by air lift. Both wells are 148 feet deep and penetrate the Ogallala formation. The water is pumped to two separate steel standpipes 24 feet in diameter, and to two separate water-treating plants. One standpipe is at the

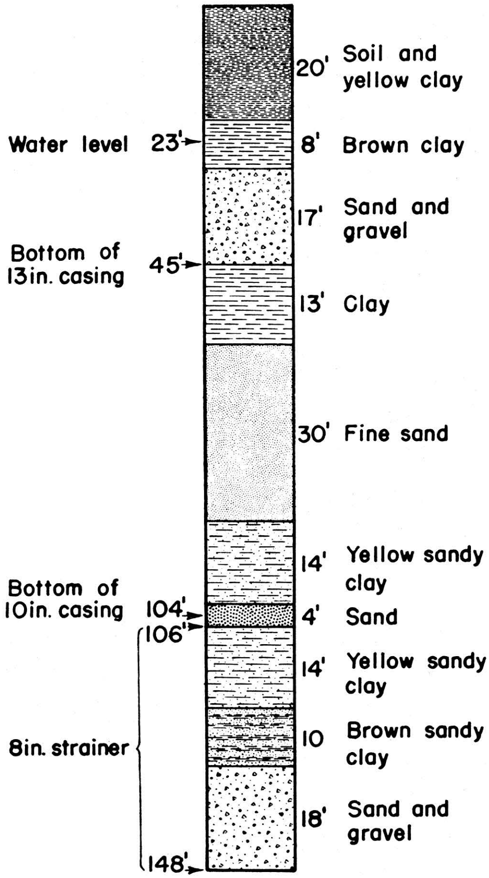


FIG. 18. Diagrammatic section of well 195 at the Atchison, Topeka, and Santa Fe Railway Company's roundhouse at Dodge City, Kansas.

roundhouse, the other is at the passenger yard. The total consumption by the roundhouse and depot facilities during the period from November 1, 1937, to November 1, 1938, was 108,655,194 gallons. The balance of the total annual pumpage of 118,366,694 gallons, or 9,711,500 gallons, was used for washing and filling locomotive and stationary boilers, for passenger trains, stockyards, and shops.

The Fairmont Creamery obtains its entire water supply from one drilled well situated at its plant in Dodge City. The well is 140 feet deep and is equipped with a 4-inch turbine pump. The pump is operated about 16 hours daily and delivers about 250 gallons a minute. The estimated total quantity of water pumped from this well in 1938 is given in table 4.

The J. S. Dillon Grocery Store in South Dodge City uses a deep well (274) for air-conditioning purposes, and the waste water is discharged into a shallow disposal well. The deep well (274) taps the Ogallala formation and is used about 6 hours daily during the period from April to October.

The Kansas Power Company uses a small well (197) that taps the Ogallala formation for air-conditioning its office building in Dodge City. The pump is operated intermittently at a rate of about 50 gallons a minute. The estimated total annual pumpage from this well is given in table 4.

Well 205, 100 feet in depth, furnishes water for air-conditioning at Duckwalls Stores, Inc., in Dodge City. About 40 gallons a minute are pumped during 6 months of each year. An estimate of the total annual pumpage for this well is given in table 4.

The Dodge City Steam Laundry develops its own water supply from one deep well (204). The well is equipped with a 2-cylinder plunger-type pump, and the estimated total annual pumpage in 1938 for this well is shown in table 4. Well 204 is situated close to city well 202, as shown in plate 3. It was reported by Mr. Balderston, owner of the laundry, that for four days during the summer of 1938 the water level in the well 204 at the laundry was lowered below the bottom of the pump intake by the continuous pumping of city well 202. Both wells are drawing from the Ogallala formation. All of the water used by the laundry is softened before being used.

The Dodge City Warehouse installed a drilled well in their plant in September, 1938. It is a shallow well equipped with a small pressure pump capable of delivering about 500 gallons an hour. The well was to be used continuously for about four months of the year and for about three hours daily during the remainder of the year. The estimated pumpage from this well from October to December 31, 1938, is given in table 4.

The only industrial use of ground water in Ford county outside of the Arkansas valley is that which is used for locomotive boiler supplies by the Chicago, Rock Island and Pacific Railway at Bucklin, and that which is used for cooling condensers and for boilers at the Booster Station No. 3 of the Natural Gas Pipeline Company of

America, on the uplands about five miles northeast of Minneola. At the Booster Station four wells (481, 482, 483, and 484) supply all the water used. Three of the wells are equipped with electrically-driven deep-well turbines, and one well is pumped by gas lift (p. 81). The average daily pumpage is about 150,000 gallons; the maximum daily pumpage occurred on August 24, 1938, and amounted to 279,600 gallons. The total pumpage for the year from November 1, 1937, to October 31, 1938, amounted to 39,959,000 gallons. The water that is used in the boilers is treated.

Two wells (12 inches in diameter) are used by the Chicago, Rock Island and Pacific Railway Company at Bucklin to supply water for locomotive boiler use. The wells are 145 feet in depth and are equipped with reciprocating, plunger-type pumps each having a capacity of 100 gallons a minute and operated by steam. The quantity of water pumped is not known. These wells have not been included in table 15.

An estimate of the pumpage of ground water from industrial wells in Ford county in 1938 is given in table 4. According to these estimates, the total annual pumpage from industrial wells in Ford county in 1938 was about 3,830 acre-feet.

PUBLIC SUPPLIES

Dodge City, Bucklin, and Spearville are the only cities in Ford county that have public water systems, and each of them is supplied by ground water pumped from wells. Several of the smaller communities have no public water systems and depend entirely upon private wells. The Kansas Soldiers Home at Fort Dodge is supplied from one deep well (367). Information on the public and institutional ground-water supplies is given in the following paragraphs.

Dodge City.—Dodge City (population 8,487) is supplied by four drilled wells. Three of the wells (202, 262 and 273) range in depth from 140 to 147 feet. As a result of a survey to determine the availability of a softer water supply for Dodge City, a fourth well was drilled in 1940, after the completion of the investigation upon which this report is based. A description of this well, therefore, is not given in table 15. The new well was put down on the south side of Kansas Highway 45, south of Dodge City, at a site previously determined by test drilling. It is 165 feet deep and is equipped with an electrically-driven turbine pump. Nine drilled wells with an average depth of 135 feet were put down in 1910 for municipal supply, but have since been abandoned. The locations of the present city wells and the nine abandoned wells are shown in plate 3.

TABLE 4.—*Estimated pumpage from industrial wells in Ford county, Kansas, in 1938*

OWNER AND LOCATION.	Use of water.	Period.	Number of wells.	Total pumpage in acre-feet(1).
Kansas Power Co. (new plant) .... 4 miles east of Dodge City.	Cooling condensers....	1 year	3	2,769
A. T. & S. F. Railway Co............. Dodge City.	Roundhouse, locomotive, and depot facilities, etc.	11- 1-37 to 11- 1-38	2	363
Fairmont Creamery.................. Dodge City.	Creamery facilities.....	1 year	1	269
Dodge City Flour Mills............... Dodge City.	Cooling condensers, and boiler supplies.	6- 1-37 to 6- 1-38	4	253
J. S. Dillon, Gro. Stores, Inc........... Dodge City.	Air-conditioning.......	1 year	1	17.4
Kansas Power Co. Office Building...... Dodge City.	Air-conditioning.......	1 year	1	14.6
Duckwalls, Inc., Dept. Store........... Dodge City.	Air-conditioning.......	1 year	1	12.2
Dodge City Steam Laundry........... Dodge City.	Laundry facilities......	1 year	1	8.9
Dodge City Warehouse............... Dodge City.	Washing fruit, produce, etc.	10- 1-38 to 12-31-38	1	.4
Booster Sta. No. 3, Nat. Gas Pipe Line Co. of America.................. Near Mineola.	Cooling condensers and boiler supply.	11- 1-37 to 10-31-38	4	122.6
Totals.........................	....	....	19	3,830.1

1. One acre-foot is the quantity of water required to cover one acre to a depth of one foot, or 325,851 gallons.

Wells (202, 262 and 273) are equipped with turbine pumps having a combined capacity of 2,800 gallons a minute. The water is pumped directly into the mains, and the excess is conducted by two centrifugal booster pumps into a steel standpipe, with a capacity of 500,000 gallons, that is situated on high ground near the margin of the valley at the north end of Dodge City. The domestic pressure ranges from 50 to 90 pounds to the square inch, and the fire pressure ranges from 90 to 125 pounds. Although each of the three turbines is equipped with a master flow meter, mechanical difficulties in two of the meters made it impossible to get accurate pumpage figures for 1938. The total consumption of water in 1936 was 459,473,000 gallons, or an average of about 1,259,000 gallons a day. There are 238 fire hydrants in the system and 40.86 miles of mains, not including mains that have since been laid to the sewage disposal plant east of the city and to the cemetery west of the city. An analysis (202) of a composite sample of water from all three wells is given in table 14. The water is hard and is not treated.

Bucklin.—Bucklin (population 832) is supplied by three wells (466, 467, 468), ranging in depth from 113 to 125 feet. Well 466, near the city hall, is used only in emergencies. Well 467 is in the city hall building, and well 468, put down in 1935, is in the city park (pl. 2). Well 467 is a dug well 7 feet in diameter and is curbed with rock. Well 466 is equipped with a reciprocating plunger-type pump capable of delivering about 70 gallons a minute, well 467 is equipped with a 5-stage turbine and has a capacity of about 200 gallons a minute, and well 468 is equipped with a turbine capable of delivering 400 gallons a minute. The water is pumped directly into the mains, and the excess is conducted into an elevated steel tank, with a capacity of 50,000 gallons, situated behind the city hall. The water system is equipped with a master flow meter but it was not in operation in 1939. J. E. Devore, city clerk, estimates the total annual consumption to be 30,000,000 gallons; the maximum monthly consumption, 3,000,000 gallons (occurring in June); and the maximum daily consumption, 100,000 gallons. An analysis (467) of a composite sample of water from wells 467 and 468 is given in table 14. The water is hard and is not treated.

Spearville.—Spearville (population 603) is supplied by three wells (35, 36, 37), ranging in depth from 86.5 to 104 feet. Wells 36 and 37 have been used only intermittently. Well 35 was drilled in 1931 and reconditioned in the summer of 1939. When the waterworks system was originally installed at Spearville in about 1914, the supply was derived from three 8-inch wells equipped with three reciprocating plunger-type pumps. The three original wells have since been abandoned. The present city wells are equipped with deep-well turbine pumps having capacities ranging from 47 to 50 gallons a minute. Well 35 is a drilled well 12 inches in diameter; well 36 is a combination dug and drilled well; and well 37 is a dug well, 10 feet in diameter, curbed with concrete blocks. This latter well was put down in 1935 as a project of the Public Works Administration. According to reports, red clay was encountered at the bottom of the well, and the well was gravel-packed from the bottom to a point above the static water level. Well 35 is situated about 2½ blocks east of the Santa Fe depot on the north side of the tracks, well 36 is under the elevated tank, and well 37 is in the southern part of town (pl. 2). Two of the pumps discharge directly into the mains; the third well pumps into the elevated tank. Storage is provided by an elevated steel tank having a capacity of 60,000 gallons. The average domestic pressure is about 45 pounds to the square inch and the maximum fire pressure is about 55 pounds to the square inch. There are 26 fire hydrants. Figures on the consumption of water are not available. From records of the number of kilowatt hours of electricity consumed in pumping the wells during the year from September, 1938, through August, 1939, however, it is estimated that the total quantity of water pumped during that year amounted to about 16,467,800 gallons—an average daily consumption of about 45,120 gallons. An analysis (36) of a composite sample of water is given in table 14. The water is moderately hard and is not treated.

Kansas Soldiers' Home.—The Kansas Soldiers' Home at Fort Dodge obtains its water supply from a single deep well (367) situated in the power plant. Although there are three deep wells on the premises, two of them are used entirely for irrigation. Well 367 is the oldest of the three and furnishes the water supply for the institution and for the houses in Fort Dodge and for cooling condensers at the power plant and the ice plant. This well is 12 inches in diameter and 150 feet deep and is equipped with an electrically-driven turbine pump capable of yielding about 300 gallons a minute. It is used about 12 hours a day during half of each year, and as much as 18 hours a day during the remainder of the year. The total quantity of water pumped from this well during 1938 is estimated to be 95,310,000 gallons, or about 292 acre-feet.

The following table gives the approximate annual pumpage from wells for public supplies in Ford county. According to the records given in this table, about 1,845 acre-feet of ground water is pumped each year for municipal and institutional use.

TABLE 5.—*Pumpage from wells for public water supplies in Ford county, Kansas, in 1938*

PUBLIC WATER SUPPLY.	Total annual pumpage (acre-feet).
Dodge City	1,410
Bucklin	92
Spearville	51
Kansas Soldiers' Home at Fort Dodge	292
Total	1,845

USE IN AGRICULTURE

IRRIGATION SUPPLIES

Many farmers in the Arkansas valley in Ford county pump water from one or more large wells to irrigate crops—principally feed crops, consisting of sorghums, cane, kafir and sudan. Other crops irrigated from wells included wheat and other small grains, sugar beets, alfalfa, garden truck and miscellaneous crops. In the fall of 1938 an inventory was made of the irrigation wells in Ford county, and estimates were obtained of the total pumpage and number of acres irrigated during 1938. The detailed records of all irrigation wells in the Arkansas valley are given in table 15 and the locations of the wells are shown in plates 2 and 3. Most of the irrigation wells are situated in the Arkansas valley, but 10 of them are on the upland south of the valley.

Records were obtained of 187 irrigation wells in the Arkansas valley. The total reported area irrigated from these wells in 1938 was 2,814 acres (table 6), an average of about 17½ acres to the well. Most of the small irrigation wells in the vicinity of Dodge City supply tracts of only 1 to 10 acres and many of the wells are used to irrigate gardens, trees and lawns. Some of the larger wells, of which there are approximately 60, each irrigate more than 100 acres. The water from most of the larger wells is used for irrigating feed crops, and also small grains, alfalfa and sugar beets.

TABLE 6.—*Acreage irrigated with water from wells in the Arkansas valley, Ford county, Kansas, in 1938, by townships*

TOWNSHIP.	Number of wells visited.	Number of wells not used in 1938.	Number of wells not reported.	Acres irrigated.
T. 26 S., R. 26 W	12	2	0	490
T. 27 S., R. 26 W	1	0	0	10
T. 26 S., R. 25 W	95	12	4	859
T. 27 S., R. 25 W	13	1	0	178
T. 25 S., R. 24 W	43	6	0	475
T. 27 S., R. 24 W	4	1	0	175
T. 27 S., R. 23 W	4	0	0	191
T. 28 S., R. 22 W	8	0	0	319
T. 26 S., R. 21 W	5	0	1	95
T. 27 S., R. 21 W	1	0	0	8
T. 26 S., R. 20 W	1	0	0	14
Totals	187	22	5	2,814

An estimate of the quantity of water pumped annually from irrigation wells in the Arkansas valley in Ford county, based upon reported estimates of pumpage obtained from well owners, is given by townships in table 7. For wells that are pumped by electricity, pumpage estimates were computed from power records that showed the total number of kilowatt-hours of electricity consumed in 1938.

Mr. Fred Moon, irrigation specialist of the Kansas Power Company, assisted in working out the pumpage estimates based on power consumption. The estimated total quantity of water pumped for irrigation in 1938 was about 4,760 acre-feet.

The total annual pumpage for irrigation in the Arkansas valley varies considerably from year to year, and during any one year varies with the amount of precipitation and with the water requirements of the crops being irrigated. Some wells are not used each year, some standing idle because of the owner's lack of time or facilities, others being out of use because the type of crop did not require irrigation.

TABLE 7.—*Pumpage from irrigation wells in the Arkansas valley, Ford county, Kansas, in 1938, by townships*

TOWNSHIP.	Number of wells visited.	Number of wells for which pumpage estimates were not available.	Number of wells not used in 1938.	Pumpage, in acre-feet.
T. 26 S., R. 26 W.	12	0	2	956
T. 27 S., R. 26 W.	1	0	0	14
T. 26 S., R. 25 W.	95	6	13	1,614
T. 27 S., R. 25 W.	13	0	0	196
T. 26 S., R. 24 W.	43	4	6	1,107
T. 27 S., R. 24 W.	4	0	1	277
T. 27 S., R. 23 W.	4	0	0	233
T. 28 S., R. 22 W.	8	1	0	233
T. 26 S., R. 21 W.	5	0	0	87
T. 27 S., R. 21 W.	1	0	0	15
T. 26 S., R. 20 W.	1	0	0	29
Totals	187	11	22	4,761

Yields of irrigation wells.—The yields of irrigation wells in the Arkansas valley in Ford county range from less than 100 gallons a minute up to about 1,200 gallons. Most of the yields of irrigation wells given in table 15 were reported by the owners, but the yields of many irrigation wells in southwestern Kansas, including 15 wells in Ford county, were made in 1938 and 1939 by M. H. Davison and K. D. McCall of the Division of Water Resources, Kansas State Board of Agriculture. Two of the wells in Ford county (522 and 393) were tested in 1938 (Anon., 1938, p. 20) and the others were tested in 1939 (McCall and Davison, 1939, pp. 50-54). The results of these pumping tests are given in table 8.

TABLE 8.—*Pumping tests of irrigation wells in Ford county*

By M. H. Davison and K. D. McCall of the Division of Water Resources, Kansas State Board of Agriculture, assisted in part by H. A. Waite

Well No. in plates 2 and 3, and table 15.	Discharge (gallons a minute).	Draw-down (feet).	Specific capacity (gallons a minute per foot of draw-down).
180(a)	1,040	5.1	204
181(b)	690	45.1	15.3
183(c)	340	18.27	18.6
320(d)	1,200	6.25	192
393	765	15	51
402	320	(e)22.9±	14
403	360	22±	16.4
417	1,184	15.16	78.1
421	983	14	70.2
423	270	20.6	13.1
435	765	14.3	53.5
485	320	6.7	47.8
507	950	19.6	48.5
510	690	47.8	14.4
522	570	(f)41.5	13.7

a. Ten shallow and two deep wells connected to same pump; one deep well shut off during test; draw-down given represents average for the 10 shallow wells only—draw-down in two deep wells not known.

b. Well taps both the shallow water in the alluvium and the deeper water in the underlying Ogallala formation.

c. One shallow well and one deep well connected to same pump.

d. Five shallow wells connected to one pump. Draw-down given is average for all five wells.

e. Actual draw-down greater than the figure given, because water levels below certain point could not be measured.

f. Estimated.

Of the 15 wells that were tested in Ford county, 8 are in the Arkansas valley, 4 are on the uplands south of the Arkansas valley, and 3 are in Crooked creek valley in the southwestern part of the county. Most of the wells in the valley and all of the wells south of the Arkansas valley that were tested are single wells equipped with deep-well turbine pumps. Some, however, comprise a battery of wells connected to one pump, as noted in the table. Some of the pumps were operated by gasoline or distillate engines, and some were powered by electric motors. Measurements of the discharge were made in part by means of a Cipolletti weir (pls. 6B and 7B) and in part

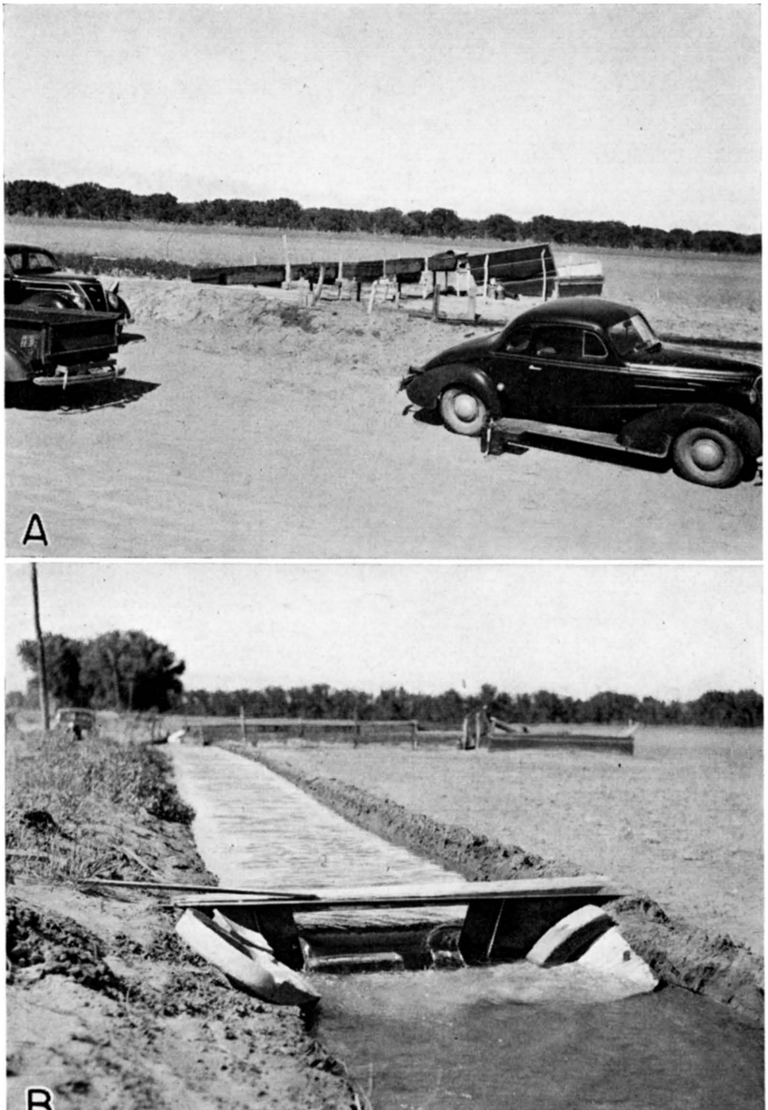


PLATE 6. A, Irrigation well 320 in the Arkansas valley south of Howell. B, Discharge of well 320 being measured by Cipolletti weir during pumping test.

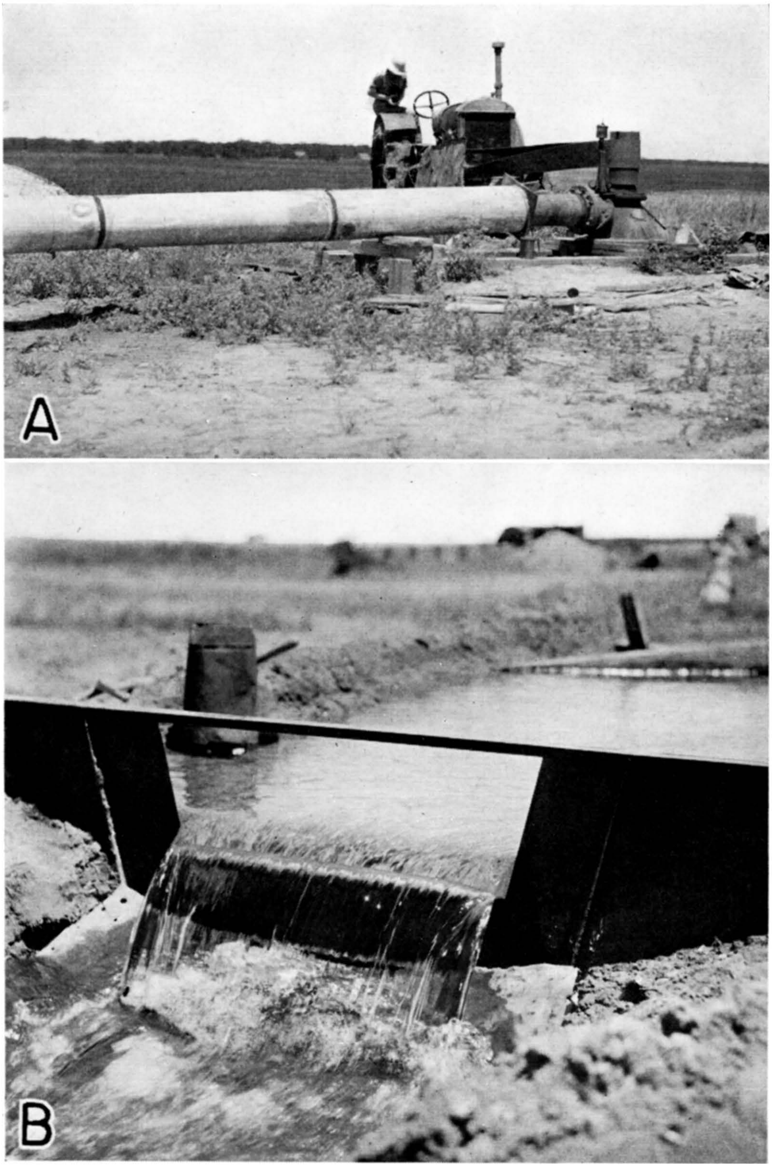


PLATE 7. A, Typical deep-well turbine pump on well 417 in the Arkansas valley southeast of Ford. B, Discharge of 1,184 gallons a minute from well 417 flowing through Cipolletti weir during pumping test.

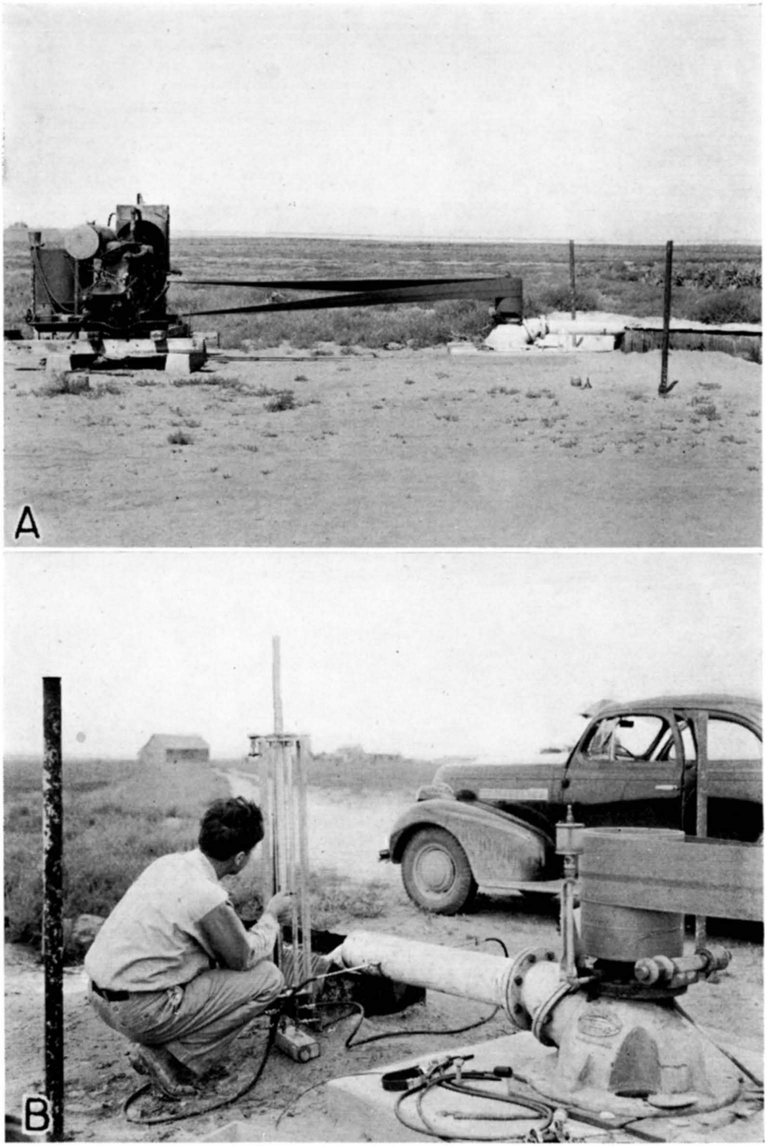


PLATE 8. A, Typical upland irrigation well (403) equipped with a turbine pump driven by a combine engine. B, Measuring discharge of well 403 using a Collins flow gauge.

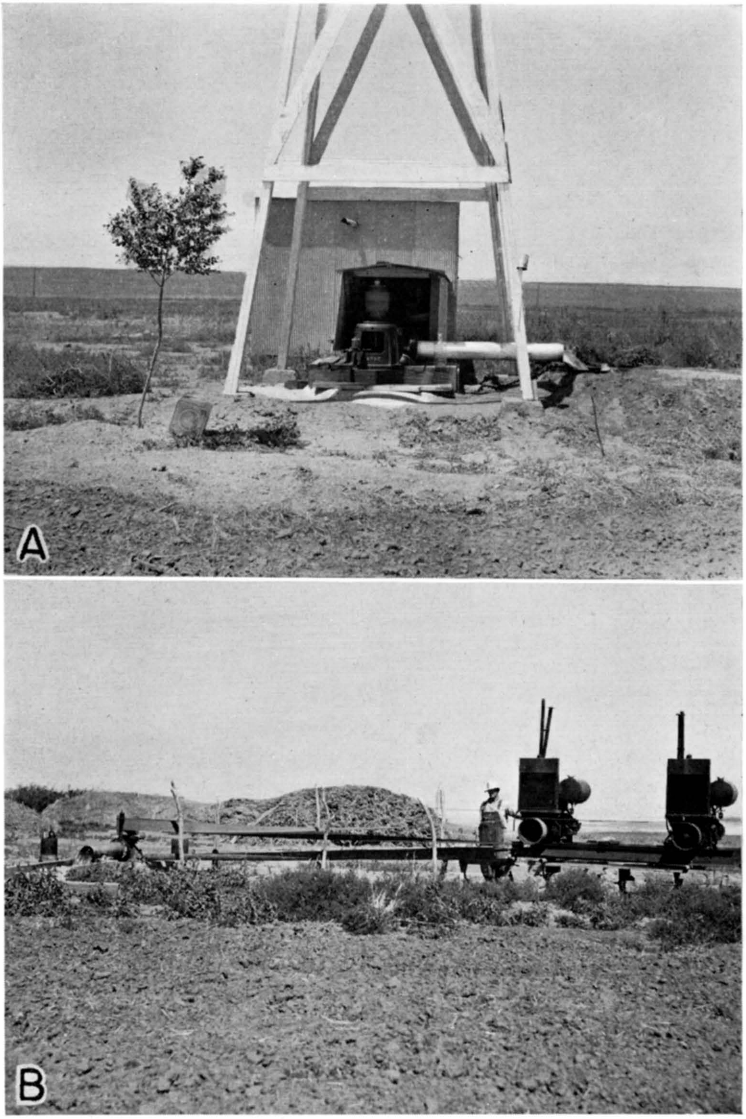


PLATE 9. A, Typical upland irrigation well (485) equipped with turbine pump. B, Turbine pump on well 435, driven by two combine engines.

with a Collins flow gage (pl. 8B), which measures the velocity of the water in the discharge pipe of the pump. An electrical contact device was used for measuring the draw-downs in the wells while pumping and a steel tape was used for measuring the water levels when the pumps were not running.

The pumping tests emphasized the fact that the irrigation wells in Ford county range widely in yield and over-all efficiency. The yields of the 15 wells ranged from 320 to 1,200 gallons a minute and the specific capacities ranged from 13.1 to 204 gallons a minute per foot of draw-down. The draw-downs ranged from about 3.5 feet to more than 47 feet. There are many factors that determine the yield of wells, including the methods of construction, the character and thickness of the water-bearing formation, the diameter of the casing, the material used for casing, the quality of the water—whether harmless or corrosive or whether likely to form incrusting material readily, the type and placing of the screen, the development of the well, the finishing of the well—whether gravel-packed or not, the age of the well, and, for battery wells, the spacing of the wells. There are doubtless other factors, but the most important ones are listed. The relative importance of the different factors vary for different wells and under different conditions.

Construction of irrigation wells.—Several methods have been used in constructing irrigation wells in Ford county. Some irrigation wells have been put down by professional drillers; others have been drilled by the owners. Almost all of the professional drilling has been done with cable-tool rigs, although one portable hydraulic rotary rig has been used extensively in the county for test drilling. Most of the small irrigation wells in the vicinity of Dodge City have been put down by the owners using homemade equipment.

The typical installation in the Arkansas valley, where the water table stands only a few feet below the land surface, consists of one or more drilled wells pumped by one centrifugal pump installed at the surface or, more generally, in a pit. The type of casing used ranges from the ordinary commercial type of galvanized-iron, to home-made types consisting of almost anything at hand. The casing in most of the irrigation wells in Ford county ranges in diameter from 16 to 24 inches and is most commonly made of galvanized-iron. Perhaps the most common type of improvised casing used in shallow irrigation wells is made from ordinary 55-gallon oil barrels. The barrels are converted into casing by first knocking out the heads and then lapping the cylinders together end to end. Used hot-water tanks have been used similarly as a substitute for galvanzed-iron casing. The rims of tractor wheels stacked one above the other have been used for casing one or two wells. Homemade casing that has been perforated haphazardly obviously is not as satisfactory as a manufactured casing perforated uniformly. The number and size of perforations is extremely important because the yield and the life of the well are dependent largely on them.

Many irrigation wells are curbed with concrete rings manufactured locally. These rings range in diameter from 12 to 24 inches and are about 4 inches thick. They are assembled, a few rings at a time, as the well is being drilled. Each ring rests flatly on the ring next below, the alignment being maintained by vertical iron rods that pass through holes in the rings and act as guides. Water enters the well through spaces between the rings. There appears to be less danger of the openings in concrete screens becoming sealed off by incrusting materials than with common galvanized-iron casing with punched perforations. Some farmers in the eastern part of the county have constructed their own concrete rings and have devised a rather ingenious method of sinking them. A metal shoe shaped like an inverted funnel is first placed in the hole, and concrete rings are placed around the shoe, one above the other, on iron rods serving as guides. The bottom end of the funnel is larger in diameter than the outside of the concrete rings, and serves as a reamer in keeping the hole larger than the casing. As material is removed from the hole by a sand bucket the casing and funnel-shaped shoe follow down by gravity. Sometimes additional weight in the form of sand bags is applied at the surface to facilitate downward movement of the casing. Sand buckets and sand pumps of various types are used in the valley for sinking wells.

Where the water table is comparatively deep some wells are partly dug and partly drilled. Generally, a pit is first dug to the water table and a hole is then drilled in the bottom of the pit. The sides of the pit are cribbed with wood or surfaced with concrete. The pump is generally installed over the casing on the floor of the pit. Two types of wells are used for irrigation, depending upon the character of the water-bearing material—wells that are gravel-packed and wells that are not. The methods of construction are slightly different, although the same type of drilling equipment is used in both methods. In constructing a gravel-packed well, the hole is made somewhat larger than the casing and an outer "dummy" casing is generally used. The annular space between the outer blank casing and the inner screened or perforated casing is filled with screened gravel, and the outer casing is pulled up slowly as gravel-filling progresses. The functions and advantages of the gravel-packed well are described on pages 82, 83. The more common type of irrigation well in Ford county, however, is not gravel-packed, and is constructed by sinking a screened or perforated casing as the well is being drilled. The casing generally is weighted with sandbags and forced downward as the sand bucket removes the material. Individuals drilling their own wells generally erect tripods and use small gas engines for power. Well drillers use portable rigs, generally mounted on trucks. For a more detailed discussion of methods of constructing and developing wells, types of equipment used, gravel-walled wells, etc., the reader is referred to Davison (1939, pp. 10-23) and Rohwer (1940, pp. 18-40).

Some of the irrigation plants in the valley comprise two or more large wells connected to one pump and commonly called "battery wells." A battery of wells is used where the water table is comparatively shallow and where the thickness of the water-bearing formation is limited so that a single well of the same depth will not give the desired quantity of water. If the wells are spaced properly the yield from a battery of wells may be considerably greater than the yield from a single well, but the yield of each well is less than if the other wells were not being pumped. The typical installation consists of two or more wells, 40 to 50 feet apart, connected to one pump by a suction pipe laid in the ground just above the water table. The wells generally are put down in a straight line at right angles to the direction of movement of the ground water. This type of plant has the advantage of having a flexible capacity—more wells can be added if production is less than desired. The yield does not increase proportionately with the addition of more wells, however, because of mutual interference between wells. For a more thorough discussion of battery wells and their construction and cost the reader is referred to Davison (1939, pp. 25-34) and Rohwer (1940, pp. 16-18).

Some irrigation wells in the valley are so constructed that they draw water from two distinct water-bearing beds—from the shallow alluvium and also from sands and gravels of the underlying Ogallala formation, at depths ranging from 100 to 150 feet. The presence of two separate water-bearing beds in the Arkansas valley has long been recognized, and the original city wells at Dodge City, drilled in 1906, tapped the so-called "second water" in order to obtain softer water. When wells were first drilled to the "second water" there was a popular belief that the efficiency of the wells would be increased if the upper water were cased off completely and only the "second water" were used. A well drawing water from the Ogallala formation alone yields softer water than a well that is supplied from both the alluvium and the Ogallala formation, but larger yields are obtainable from wells that tap both sources.

In 1939, there were 10 irrigation wells south of the Arkansas valley in Ford county. Three of these wells (507, 510, and 522) are situated in the valley of Crooked creek—the others are on the uplands. The depth to water level in the upland wells ranges from about 86 to 135 feet, and the depths of all 10 wells ranges from 116 to 211.5 feet (table 15).

The wells on the south uplands were constructed by digging an open hole down to the water level and sinking a 16 to 20-inch casing down into the water-bearing formation. Well 485, a typical upland well (pl. 9A), is an open hole, 4 feet in diameter and about 130 feet deep, uncurbed except for a concrete wall to a depth of about 30 feet below the land surface. A 20-inch galvanized-iron casing has been sunk at the bottom of the 4-foot hole to a depth of 154 feet below land surface. The depth to water level is about 135 feet. Wells 402, 423, 425, and 435 were constructed in a similar manner. In constructing most of these wells, a hole was dug down to a depth where a sand bucket could be operated in the saturated water-bearing material, below which a 20-inch casing was sunk using a sand bucket.

The three wells (507, 510, and 522) in the valley of Crooked creek were drilled by a commercial driller and range in depth from 149 to 211.5 feet (see logs 78, 79, and 80). The depth to water level in these three wells range from 23 to 45 feet below land surface. The wells were drilled to a diameter of 30 inches, and equipped with perforated, oil-well casing 16 inches in diameter, surrounded by an envelope of screened gravel. Perforations one-fourth inch wide were cut in the blank casing with a torch and the sections of casing were welded together. Wells 507 and 510 are equipped with 60 feet of perforated casing and well 522 has 82 feet of perforated casing.

It is probable that irrigation wells of greater capacity and efficiency could be obtained in Ford county if better methods of well construction were employed. Some of the wells do not penetrate completely the water-bearing formation and would doubtless yield more water if deepened.

In some parts of the county the sediments comprising the water-bearing formation are so fine-textured that well screens should be gravel-packed in order to obtain satisfactory yields. In all but the eastern part of the Arkansas valley in Ford county, however, the materials comprising the alluvium generally are coarse enough that gravel-packing is not necessary, and very few wells have been constructed with gravel envelopes. Gravel packing should be recommended only after thorough test drilling has shown that the water-bearing material is so fine-textured that the water surrounding the screen cannot move readily into the well. The grade size of the material to be used in the gravel screen should be determined following an examination of the samples of material obtained from test drilling and after the dimensions of the perforations of the well screen have been decided upon. Because of the added construction costs involved, gravel-packing should be recommended only in cases where it is absolutely essential in order to obtain satisfactory yields.

In some of the wells the water level in the casing when the pump is running is several feet below the water level on the outside of the casing, so that the water spurts into the well through the open perforations, indicating that the material immediately surrounding the screen is too fine or has become clogged with fine sand preventing the water from moving in toward the well, or that the perforations are too small to admit water freely. By remedying one or both of these conditions the draw-down can be lessened and the yield of the well increased.

Depth and diameter of irrigation wells.—The depth and diameter of irrigation wells are given in tables 9 and 10.

Most of the irrigation wells in the Arkansas valley in Ford county are 20 to 30 feet deep, many are only 10 to 20 feet deep, and only a few exceed 100 feet in depth. The depth of the 10 irrigation wells south of the Arkansas valley range from 116 to 211.5 feet.

The diameters of the irrigation wells range from 1¼ inches for the driven wells to 48 inches for the wells curbed with the rims of tractor wheels. Of the 187 irrigation wells visited in the Arkansas valley 124 are between 16 and 24 inches in diameter of which the greatest number are 16 or 20 inches in diameter.

Types of pumps on irrigation wells.—Most irrigation wells in the Arkansas valley in Ford county are equipped with centrifugal pumps, largely of the horizontal type, that range in size from 1¼ to 10 inches (table 11). Only 9 of the 187 wells visited were equipped with vertical centrifugal pumps. Eleven irrigation wells

TABLE 9.—*Irrigation wells in Ford county classified according to depth*

DEPTH (in feet).	Number of wells in the Arkansas valley.	Number of wells south of the Arkansas valley.
Less than 10	2	....
10–20	39	....
20–30	68	....
30–40	17	....
40–50	7	....
50–100	8	....
100–150	5	5
150–200	7	4
200–211.5	0	1
Totals	187	10

TABLE 10.—*Irrigation wells in Ford county classified according to diameter*

DIAMETER (in inches).	Number of wells in the Arkansas valley.	Number of wells south of the Arkansas valley.	DIAMETER (in inches)(a).	Number of wells in the Arkansas valley.	Number of wells south of the Arkansas valley.
1¼	1	....	20	(b)44	2
2	1	....	22	12	....
8	2	....	24	10	....
10	9	....	34	1	....
12	14	....	36	2	....
14	12	....	42	1	....
15	10	....	48	3	....
16	51	6	Unknown	7	....
18	3	....	Totals	187	10
19	4	2			

a. For dug and drilled wells, diameter of drilled part is given.
b. Includes one well in Edwards county.

in the valley are equipped with turbine pumps. Two cylinder-type pumps were observed, but doubtless there are many other pumps of this type (most of which are probably powered by wind) used for small-scale irrigation on farmsteads.

The 10 irrigation wells south of the Arkansas valley are equipped with turbine pumps. The number of stages, or bowls, in each well range from 2 to 5 and the diameter of the bowls generally is about 14 inches.

The turbine is best adapted for pumping water from deep irrigation wells. The advantages of this type of pump are several—they are constructed so as to operate in relatively small diameter wells, no priming is necessary because the pump bowls are submerged, and the power unit is at the surface, thereby eliminating the need for a pump pit.

TABLE 11.—*Types and sizes of pumps on irrigation wells in the Arkansas valley in Ford county*

TYPE OF PUMP.	Size.	Number.
	(inches)	
Horizontal centrifugal	1¼	1
	1½	2
	1¾	1
	2	19
	2½	11
	3	48
	4	26
	5	14
	6	(a)29
	8	3
	10	3
Total		157
Vertical centrifugal	4	1
	5	7
	6	1
Total		9
	(inches)	
Turbine	8	2
	12	1
	14	4
	unknown	4
Total		11
Cylinder	2	2
None		4
Removed		4
Total		10
Total number of pumps		187

a. Includes one irrigation well in Edwards county.

Type of power used for pumping irrigation wells.—The type of power used to pump irrigation wells in Ford county is given in table 12. Gasoline engines are most commonly used for pumping from wells for irrigation in Ford county (pl. 10A). Most of the gasoline engines in use were removed from old combines. Many of these are belted to the pump pulley, and some are direct-connected to the pump shaft. Some pumps are powered by old car engines, some by stationary gasoline engines, several by tractor, and two by diesel engines. Fifty-five of the wells are operated by electric motors.

TABLE 12.—*Type of power used for pumping irrigation wells in Ford county*

TYPE OF POWER.	Number of wells in the Arkansas valley.	Number of wells south of the Arkansas valley.
Gasoline engine	(a)107	9
Diesel engine	2	....
Electric motor	55	....
Tractor	12	1
None	11	....
Totals	187	10

a. Includes one well in Edwards county.

Irrigation water pumped from streams.—Pumping water from streams for irrigation is practiced to a considerable extent in Ford county, principally along Arkansas river but to some extent along some of the smaller streams (pl. 11 B). In the Arkansas valley there are 10 river pumping plants, the locations of which are shown in figure 19. All of these pump from Arkansas river, with the exception of plant 6, northwest of Ford, which pumps out of a small lake created by a dam across Mulberry creek near its mouth. Plant 9 pumps out of an abandoned sand pit on the north bank of Arkansas river southeast of Sears siding. Plant 8 is situated just above the diversion dam across Arkansas river maintained by the Wilroads Rehabilitation Project (pl. 4). The water from this plant is used for irrigating some of the small tracts that cannot be reached

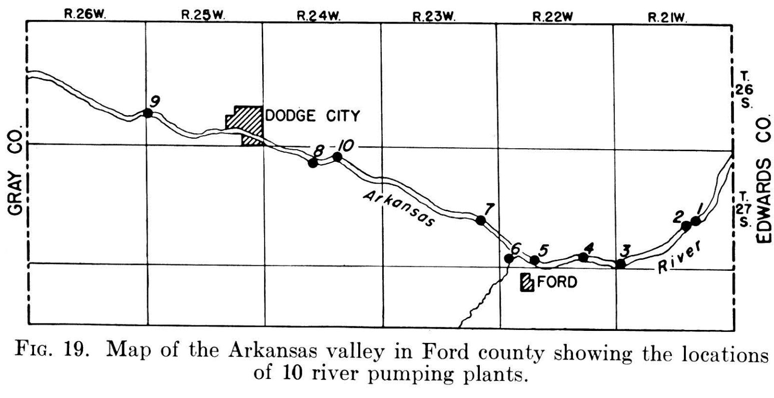


FIG. 19. Map of the Arkansas valley in Ford county showing the locations of 10 river pumping plants.

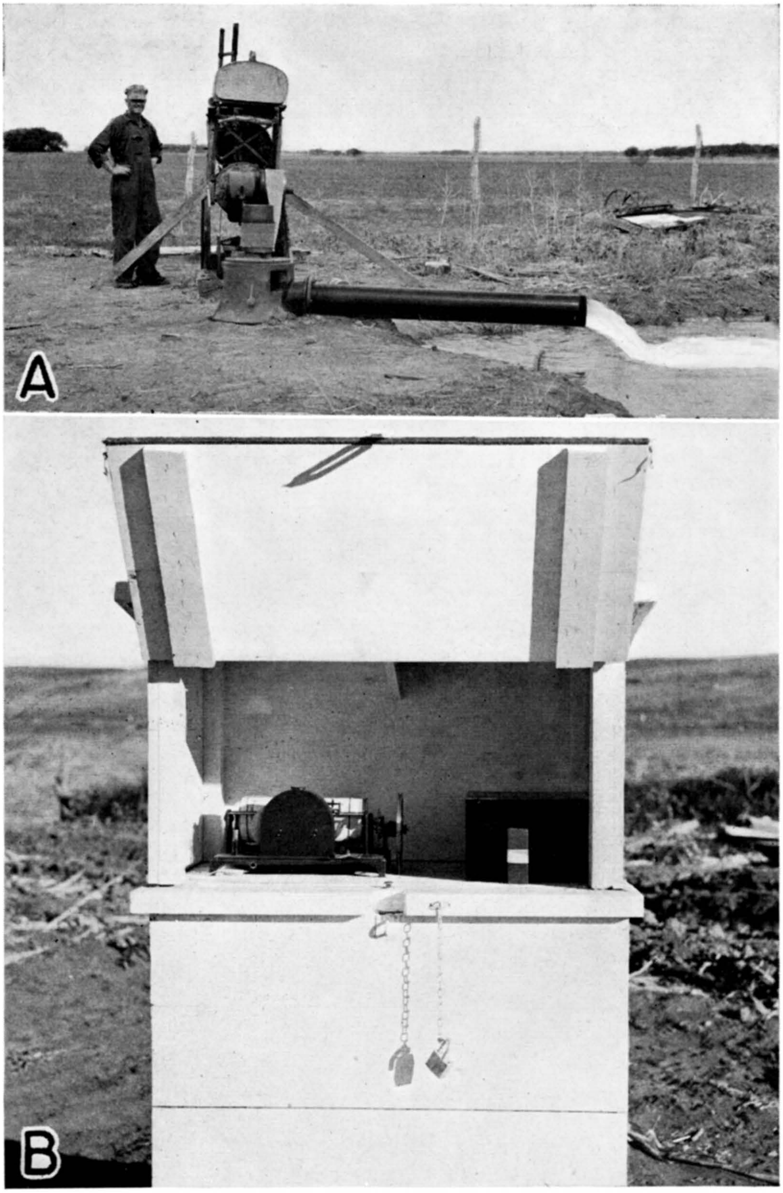


PLATE 10. A, Irrigation well 248 equipped with turbine pump driven by combine engine. In the Arkansas valley 2 miles southwest of Dodge City. B, Automatic water-stage recorder on well 364 in the Arkansas valley about 1 mile southeast of Fort Dodge.

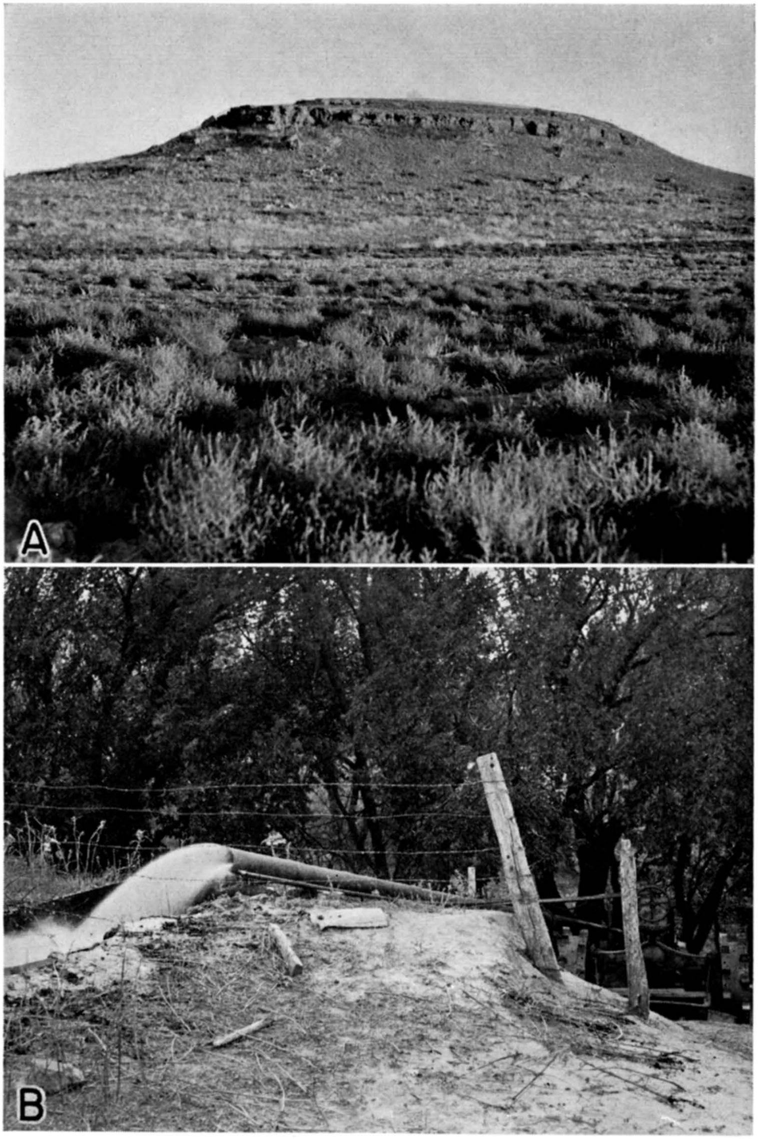


PLATE 11. A, "Turtle back," a prominent feature on the south side of Sawlog creek in northern Ford county. The Dakota formation in the lower slope is overlain by the Graneros shale which in turn is capped by Tertiary Ogallala formation. B, Typical plant for pumping irrigation water from Sawlog creek, in northern Ford county. Situated about 200 yards above a dam across the creek in the SW cor. SE¼ sec. 2, T. 25 S., R. 24 W.

by the gravity ditch. The total amount of irrigation water pumped from streams in the Arkansas valley is estimated to be about 734 acre-feet (table 13). Approximately 600 acres were irrigated in 1938 from these plants.

TABLE 13.—*Acreage irrigated with water pumped from streams, and estimated pumpage in the Arkansas valley in Ford county in 1938*

Pumping plant No., Fig. 19.	OWNER.	Acres irrigated.	Total pumpage (acre-feet).
1	Ray L. Shellheimer	52	44
2	M. E. Neal	65	55(a)
3	J. L. Riegel	40	40(a)
4	Wm. C. Fowler	42	40
5	G. R. Hensley	42	20
6	J. C. Lovette	20	29
7	J. E. Burke	95	112
8	Wilroads Gardens (Rehabilitation Project)	100(a)	180
9	Chas. Staples	60(b)	66
10	Judge Karl Miller	75	148
	Totals	591	734

a. Approximately 300 acres are covered by water that flows by gravity from a diversion dam on the river and from a river pumping plant. The number of acres covered by the pump is indeterminate, therefore the figure given in the table is an estimate.

b. Estimated.

There are several other pumping plants that draw water from Sawlog and Duck creeks in the northern part of the county for which acreage and pumpage figures are not available. In several places dams have been constructed across these streams and the water thus impounded is pumped to higher ground for irrigating feed crops. One such plant is situated on the bank of Sawlog creek about 200 yards upstream from the dam in the SW corner SE¼ sec. 2, T. 25 S., R. 24 W.

POSSIBILITIES OF FURTHER DEVELOPMENT OF IRRIGATION SUPPLIES FROM WELLS

The ability of an underground reservoir to yield water over a long period of years is just as definitely limited as that of a surface-water reservoir. If water is withdrawn from an underground reservoir by pumping faster than water enters it, the supply will be depleted and water levels in wells will decline. The amount of water that can be withdrawn annually over a long period of years, without depletion of the available supply which may be termed the safe yield, is largely dependent upon the capacity of the underground reservoir and upon the amount of water that is added annually to the reservoir by infiltration in favorable recharge areas.

The feasibility of developing additional water supplies from wells for irrigation in Ford county is dependent not only upon the safe yield of the underground reservoir, but also upon other complex geologic, hydrologic, and economic factors. The depth to water level determines, in part, the depth of wells and the costs of drilling, of pumping equipment, and of operation. In general, the greater the pumping lift the greater the cost of lifting water to the surface. The permeability and thickness of materials also has a bearing on the depth and construction of wells. On the uplands, for example, a well at one locality may encounter thick beds of permeable gravel and yield an adequate supply of water for irrigation, whereas a well a short distance away at the same depth may encounter little or no gravel and yield but little water. The character of the water-bearing formation also determines the type of well screen and the size and type of perforations to be used.

For purposes of description, the areas in which are possibilities for additional water supplies from wells for irrigation have been classified as follows: the Arkansas valley, the uplands south of the Arkansas valley, the area in the northeastern part of the county that is underlain by the Dakota formation, and the shallow-water area in the vicinity of Crooked creek in the southwestern part of the county.

Arkansas Valley.—The capacity of the alluvium and the underlying Ogallala formation in the Arkansas valley in Ford county appears to be large enough to withstand much more pumping for irrigation, particularly in parts of the valley in which there is now little if any pumping. The water table in the valley generally is near the surface (pl. 2) so that pumping lifts are low. In all but the eastern part of the valley, water from two separate water-bearing formations is available to irrigation wells. Conditions for recharge, moreover, are more favorable in the Arkansas valley than in any other part of the county (pp. 70-72).

If the ground-water supply in an area such as the Arkansas valley in Ford county is extensively developed by drilling many wells and drawing heavily from them, the water levels in the wells may inevitably decline. The mere fact that there is a decline in the water levels during a period of development when the rate of withdrawal is increasing is not necessarily an indication of over-development as long as the decline is not so great as to indicate the approach of pumping lifts beyond the economic limit. In evaluating the prospects for the possible additional development of ground water supplies in the Arkansas valley, the following question arises: What is the safe limit of pumping; that is, what quantity may be pumped perennially without overdraft?

A study of the relations of water levels in observation wells in the Arkansas valley to the amount of pumpage should furnish reliable information as to the safe yield of the underground reservoir. If the water levels in the wells remain virtually stationary during a considerable period of pumping it may be concluded that the rate of recharge has been about equal to the rate of discharge, including both natural discharge and withdrawals from wells. Regardless of the manner in which the water levels fluctuate from day to day, if at the end of any period they return approximately to the position they had at the beginning of the period, the record of pumpage furnishes a measure of the recharge during the same period minus the natural loss.

Thus, the water levels in 10 wells (98, 101, 184, 184A, 248, 256, 319, 322, 358, and 417) situated in the Arkansas valley showed net declines, during 1939, ranging from 0.2 foot to 1.70 feet and averaging 0.70 foot. In 1940, however, the water levels in 7 of the 10 wells rose by amounts ranging from 0.02 to 0.72 foot whereas the water levels in 3 wells (256, 248, 184A) declined by amounts ranging from 0.11 to 0.65 foot. The 3 wells in which the water levels declined during 1940 were pumped during the irrigation season and are situated in the most heavily pumped parts of the valley. Thus, the water levels in the 10 wells showed an average net rise of 0.06 foot during 1940.

The hydrographs shown in figure 8 indicate that there has been no persistent downward trend in the water levels in wells 11, 101, 184, 358, and 417 in the Arkansas valley during the period from

October, 1938, to July, 1941. In general, the hydrographs show that during this period the fluctuations of the water table in the Arkansas valley are of a seasonal type, and that the major trend of the water levels has been about stationary or slightly upward. In response to the above-normal precipitation the water levels in most of the wells rose appreciably during the part of 1941 for which records were available at the time of publication.

Water-level observations in the Arkansas valley in Ford county were begun in October, 1938, at a time when the water table presumably was somewhat lower than normal as a result of several years of subnormal precipitation and increased pumpage from irrigation wells. As pointed out under the discussion of climate (p. 29), the precipitation at Dodge City has averaged 4.85 inches below normal for the 10-year period from 1930 through 1939—the longest consecutive period of subnormal precipitation in the 65-year record of the station. Precipitation at Dodge City in 1939 was 7.53 inches below normal—the ninth driest year of record. Thus during the 10-year period the water levels in the Arkansas valley declined partly as a result of subnormal precipitation and partly as a result of increased pumpage. In 1940, the precipitation at Dodge City was 25.84 inches, or 5.30 inches above normal—almost twice the annual precipitation in 1939—and the water levels in most of the wells in the Arkansas valley showed a net rise during the year. The trends in water levels during the period of record indicates, therefore, that the pumpage has not exceeded the safe yield, but a longer record of water levels will be needed in order to evaluate the safe yield.

In 1938 about 10,170 acre-feet of water was pumped from wells in the Arkansas valley, of which about 4,760 acre-feet was used to irrigate about 2,800 acres of crops (tables 4, 5, 6 and 7). The water-level fluctuations during the period of record seem to indicate that this rate of pumping is not depleting the underground reservoir and that some additional pumping can be undertaken without exceeding the safe yield. If additional development takes place, however, care should be exercised in the spacing of the wells in order to prevent local overdevelopment.

Conditions appear to be especially favorable for additional pumping from wells in several different parts of the Arkansas valley in Ford county. One such area is situated on the south side of the river between Dodge City and Ford. There is some pumping from wells for irrigation on the south side of the river, just east of Dodge City, and there is opportunity for additional development farther east. Although the valley is limited south of the river by the belt of sandhills, there are many acres of flat bottom land that doubtless could be irrigated by pumping from wells, if care were exercised in selecting areas with the most favorable soils. In this part of the valley, yields up to 500 gallons a minute may be expected from shallow wells in the alluvium; and larger yields might be expected from deeper wells or from a battery of wells. Deep test drilling on this side of the river indicates that the basal part of the Ogallala formation contains a considerable thickness of coarse, unconsolidated gravel capable of transmitting water freely to wells (see log of test hole 8, p. 211). A single deep well of the proper construction should be capable of yielding up to 1,500 gallons a minute. In this part of the valley the water-bearing material in the Ogallala is coarse enough that the additional expense of installing a gravel pack probably is not warranted, but in other parts of the valley the gravels in the Ogallala may not be as favorable, and the use of a gravel pack might improve the yield of wells drilled into the Ogallala.

There are several areas on the south side of the river, west of Dodge City, where additional pumping from wells might prove successful, provided that the land is selected where the soils are not too sandy. Well 320, on the south side of the river south of Howell, is a good example of a successful battery of shallow wells in this part of the valley. At this plant the 5 wells have a combined yield of 1,200 gallons a minute (pl. 6A). Well 248 is a good example of a single deep well equipped with a turbine pump that taps the Ogallala formation in the valley southwest of Dodge City (pl. 10A). Preliminary test holes should provide the necessary information to determine whether a deep or shallow well should be constructed and whether the well should be gravel-packed or not.

On the north side of the river between Fort Dodge and Ford is another irrigable part of the valley that has not yet been developed to any great extent. This area is just east of the heavily-pumped district between Dodge City and Fort Dodge. In 1939, this part of the valley contained only a few scattered battery wells. The logs of two deep test holes drilled in the valley just east of Fort Dodge by the Soil Conservation Service (logs 53 and 57, pp. 232, 234) indicate that a single deep well equipped with a turbine should prove to be successful for irrigating from as much as 60 to 80 acres of land in this area.

Some additional pumping from wells for irrigation might prove successful in the valley on the north side of the river, extending from a point northeast of Ford to Edwards county. In this part of the valley, however, the Cretaceous bedrock underlies the valley at shallow depth, the Ogallala formation is entirely absent in most places, and the alluvium is very thin in many places near the river. The alluvium in this part of the valley is much finer-textured and is not as productive as in other parts of the valley. For this reason many test holes have had to be drilled before suitable localities for irrigation wells could be selected. Thus, it was necessary to drill 13 test holes before the location for well 95 was chosen, and more than 13 test holes were necessary before some of the other wells in the area were located. In 1939 there were six small irrigation wells (89, 93, 95, 96, 98, 99, 101, and 339), that ranged in depth from 26 to 45 feet, in this part of the valley. Six of the wells are equipped with vertical centrifugal pumps, manufactured locally by the Wetzel Brothers, and two of the wells are equipped with horizontal centrifugal pumps. The wells are capable of yields up to about 500 gallons a minute. There are undoubtedly possibilities for some additional development in this part of the valley, but the yields of individual wells are apt to be rather small owing to the limited thickness and the low permeability of the alluvium. The yields of irrigation wells doubtless could be improved by the use of suitable gravel packs. No battery wells are known in this area, but it is possible that, with careful location and construction, this type of well might prove successful. It is doubtful whether the Dakota formation, known to underlie this part of the valley at shallow depth, would yield sufficient quantities of water for irrigation.

Uplands south of Arkansas river.—Water in quantity sufficient for irrigation has been obtained in several places on the uplands south of Arkansas river in Ford county, and it seems likely that irrigation wells can be drilled at several other places in this part of the county. The practicability of irrigation in this part of the county depends upon the quantity of water available and upon whether the water can be pumped from a considerable depth at a low enough cost.

In many parts of the uplands south of the valley the depth to water level is more than 100 feet, and in some places it ranges in depth from 150 to 200 feet (pl. 2). The depth to water level in seven irrigation wells on the uplands (402, 403, 417, 423, 425, 435, and 485) ranges from about 81 to 135 feet and in four of them is more than 100 feet. The yields of these seven wells range from about 240 to about 765 gallons a minute. Four of the wells were tested in 1939 and found to yield less than 360 gallons a minute.

Owing to the conditions under which the Ogallala formation was deposited, individual beds of sand and gravel beneath the uplands are discontinuous and may grade laterally into finer materials such as silt or clay. Thus, a well at one locality may encounter thick beds of permeable gravel, whereas a well not far away may encounter little or no gravel. These differences in the character of the water-bearing formation beneath the uplands, together with differences in well construction and in operating lifts, are responsible for differences in yield.

In general, pumping from wells for irrigation on the uplands south of the Arkansas valley has not proven to be entirely successful. With the exception of the three wells in the Crooked creek valley in the southwestern part of the county, which are described under a separate heading, only one well is producing water in sufficient quantity to make operation of the pumping plant practical, and two engines are necessary to insure a satisfactory yield from this well. Most of the well owners reported that pumping water from wells for irrigation in upland areas has not proved profitable in places where the total lifts are more than 100 feet and where the yields are relatively small. Several were of the opinion that the cost of pumping water under such conditions was in excess of any increase in production that resulted from the application of the water to the crops. In 1939 some of the well owners discontinued pumping operations after a short period of irrigation at the start of the growing season.

It is possible that with improved methods of constructing the wells the yields of wells on the uplands might be increased. Preliminary test holes should provide the necessary information in order to determine whether or not the well should be gravel-packed, and what type of screen to use. In some wells a natural gravel-pack can be produced by careful development of the well by controlled pumping rates, immediately after completion of the well. In at least two of the upland plants upon which pumping tests were run the water levels immediately outside of the well screen during pumping were several feet higher than the water level inside the casing, indicating that the movement of water into the well was being impeded either by fine material surrounding the casing or by improper screen openings, or possibly both. This condition in one well was serious enough to cause the pump to lose suction and take air, with a resultant lowering of the yield when pumped beyond a certain rate. Proper construction doubtless would eliminate this trouble, reduce the amount of draw-down and consequently the total lift, and increase the yield. The depth to water level at any given locality will undoubtedly be the most important factor in determining whether irrigation on the uplands can be economically successful.

Ground water is pumped for irrigation at several other places on the uplands of the High Plains where conditions are somewhat comparable to those on the uplands of Ford county. In Scott county, Kansas, for example, approximately 17,160 acres were irrigated from wells in the Scott county shallow-water basin in 1940, according to a survey conducted by K. D. McCall of the Division of Water Resources, Kansas State Board of Agriculture, and the writer. Depths to water level in this area range from about 20 to 90 feet. At the end of 1940, there were approximately 90 irrigation wells in operation in Scott county. There are also several deep irrigation wells on the uplands in northern Finney and Kearny counties, Kansas, north and west of Garden City. The depths of the wells range from 200 to 300 feet and the depths to water level range from 40 to 70 feet.

Well 410 (table 15) on the uplands about half a mile north of Ensign, Gray county, is 200 feet deep, and the depth to water level in October, 1938, was about 165.3 feet. This well is reported to yield about 800 gallons a minute with an estimated draw-down of about 30 feet.

Schoff (1939, pp. 109-118) reported that there had been increasing interest on the part of farmers in Texas county, Oklahoma, in regard to the possibilities of irrigating from deep wells, and described four wells on the upland plains in Texas county. The wells range in depth from 238 to 298 feet, and the depths to water level range from 104 to 135 feet. The yields of these four wells range from about 425 to 960 gallons a minute with draw-downs ranging from 30 to 38 feet. All of them derive water from the Ogallala formation.

According to White, Broadhurst and Lang (1940, pp. 15-31), about 1,700 irrigation wells in the High Plains of Texas were pumped in 1939 and about 230,000 acres were irrigated from them. On the basis of a partly completed inventory it was estimated that about 400 wells were to be put down and equipped for irrigation in the Texas High Plains in 1940, representing a greater development than has taken place in any year except 1937. The development has reached proportions of considerable magnitude in more than 14 counties. The annual pumpage increased greatly during the period

1937-1939. In 1937 it amounted to about 130,000 acre-feet; in 1938, about 145,000 acre-feet; and in 1939, about 165,000 acre-feet. The depths of the wells range from 150 to 300 feet, and the depth to water level in the irrigated areas average about 60 or 65 feet. Most of the wells are equipped with turbine pumps capable of yielding from 500 to about 2,000 gallons a minute.

Northeastern shallow-water area.—There is a large area covering almost the entire northeastern quarter of the county in which the depth to water level is less than 100 feet and in large parts of the area is less than 50 feet (pl. 2). Many of the wells in this part of the county obtain water from the Dakota formation, which underlies the area at shallow depth. The Ogallala formation rests on Cretaceous rocks ranging from the Greenhorn limestone to the Dakota formation and appears to be thin over much of the area. The sand and gravel deposits, so characteristic of the basal part of the Ogallala formation in other parts of the county, appear to be thin or absent over much of this area. In this area the Ogallala formation is composed largely of beds of caliche with a conspicuous absence of unconsolidated sand and gravel. Most of the beds are hard and cemented and consist largely of silty sand impregnated with calcium carbonate. The permeability of this material probably is low.

The sandstones of the Dakota formation underlying Ford county are fine-grained and do not yield water as freely as the Ogallala (p. 145), but under favorable conditions a well in the Dakota might yield as much as 250 gallons a minute. The possibilities of developing additional water supplies from wells for irrigation in the northeastern shallow-water area in Ford county are dependent largely on the water-yielding capacity of the Dakota formation. In parts of the area the Ogallala formation may furnish some water to wells, but it is probable that the yield would be too small for irrigation. The yields of wells in this area might be increased by drawing water from both sources. In order to furnish yields as high as 250 gallons a minute, wells in this area would have to be drilled to considerable depth into the Dakota formation. The depths of wells probably would average about 200 feet over much of this area. Although the depth to water level over much of the area is comparatively shallow, the specific capacities of wells penetrating the Dakota formation will be less than those of irrigation wells in other parts of the county, consequently the draw-downs will be greater.

If many irrigation wells are drilled into the Dakota formation in this area the wells should be spaced as far apart as possible because the effect of pumping is communicated more quickly and to greater distances in an artesian water-bearing formation, such as the Dakota formation, than it is under water-table conditions.

Southwestern shallow-water area.—The shallow-water area along Crooked creek in the southwestern part of the county is the northern extension of the Meade county artesian basin (p. 24). In an area covering approximately 22 square miles the depth to water level is less than 50 feet, and in much of the area in the vicinity of Crooked creek the depth to water level ranges from about 4 to 25 feet (pl. 2).

Wells in this part of the county may encounter more than one water-bearing formation, and some of the wells penetrate as many as 3, including recent deposits of sand and gravel, the Ogallala formation and the Dakota formation. Most of the artesian water that supplies the flowing wells in the vicinity of Crooked creek is derived from Pleistocene sands and gravels and from the Ogallala formation.

In 1939 there were three successful irrigation wells (507, 510 and 522) in this part of Ford county, and several others in adjacent areas in Meade county. The three wells in Ford county are of similar construction and range in depth from 149 to 211.5 feet. Sites for the wells were selected by drilling test holes by the hydraulic rotary method, and the most successful test hole was reamed out to a diameter of 30 inches by the same method. The wells have 16-inch perforated casings and are gravel-packed. The depths to water level range from about 23 to 45 feet. The saturated water-bearing material ranges in thickness from 52 feet in well 510 to 124 feet in well 507 (see logs of test holes 19, 20, and 21). The yields of these wells range from 570 to 950 gallons a minute.

Although relatively small in size, the southwestern shallow-water area has excellent possibilities for the development of additional irrigation water from wells. Water in sufficient quantity for irrigation can be obtained in any part of this area, and the pumping lifts are low.

QUALITY OF WATER

The general chemical character of the ground waters in Ford county is shown by the analyses of water from 69 representative wells and one spring, distributed as uniformly as practicable within the county and among the principal water-bearing formations (table 14). The samples of water were analyzed by Robert H. Hess, chemist, in the water and sewage laboratory of the Kansas State Board of Health. The constituents given were determined by the methods used by the U. S. Geological Survey.

TABLE 14.—*Analyses of water from wells in Ford county, Kansas*

(Analyzed by Robert H. Hess. Dissolved constituents given in parts per million, reacting values [in italics] given in equivalents per million)

No. on plates 2 or 3.	Location, depth, and geologic horizon.	Date of collection, 1939	Temperature (°F)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)(2)	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Total dissolved solids (2)	Hardness (calculated as $CaCO_3$). Total	Carbonate	Noncarbonate
	T. 25 S., R. 21 W.															
9	NE corner SE¼ sec. 4, 46.4 feet, Ogallala	Aug. 2	58	0.03	70 *3.49*	16 *1.32*	12 *.54*	277 *4.54*	13 *.27*	15 *.42*	0.9 *.05*	4.4 *.07*	270	242	227	15
17	NW¼ NE¼ sec. 24, 58.7 feet, Ogallala	Aug. 2	59	.03	68 *3.39*	14 *1.15*	31 *1.33*	288 *4.72*	23 *.48*	20 *.56*	.9 *.05*	4 *.06*	305	227	227	0
22	NW¼ NE¼ sec. 35, 155 feet, Dakota	July 18	65	.19	44 *2.2*	24 *1.97*	35 *1.54*	283 *4.64*	22 *.46*	15 *.42*	2 *.11*	4.9 *.08*	289	209	209 (3)	0
	T. 25 S., R. 22 W.															
28	SE¼ SW¼ sec. 10, 50.2 feet, Ogallala	July 24	59	(4)	66 *3.29*	15 *1.23*	22 *.97*	229 *3.76*	44 *.92*	23 *.65*	1 *.05*	6.6 *.11*	292	226	188	38
32	NW¼ NE¼ sec. 24, 156 feet, Dakota; sample contained flocculent material in suspension	July 18	60	......	30 *1.5*	23 *1.89*	114 *4.97*	312 *5.12*	103 *2.14*	33 *.93*	2.7 *.14*	1.8 *.03*	464	170	170 (5)	0
36	SE¼ NE¼ sec. 29, composite sample from wells 35, 36, and 37, 86.5-104 feet, Ogallala	Nov. 22	......	0.0	60 *2.99*	16 *1.32*	10 *.45*	246 *4.03*	10 *.21*	15 *.42*	1.5	4.9 *.08*	293	216	202	14
38	NW¼ NW¼ sec. 32, 80 feet, Ogallala	July 25	58	(4)	62 *3.09*	16 *1.32*	39 *1.7*	252 *4.13*	7.4 *1.54*	9.5 *.27*	1.0 *.05*	7.5 *.12*	268	221	207	14
	T. 25 S., R. 23 W.															
43	NE corner sec. 18, 43.6 feet, Dakota	July 18	59	4.8	46 *2.3*	28 *2.3*	25 *1.07*	260 *4.26*	38 *.79*	16 *.45*	2.6 *.14*	1.8 *.03*	292	239	213	26
46	SE corner SW¼ sec. 24, 89.7 feet, Dakota	July 18	59	.45	65 *3.24*	14 *1.15*	5.8 *.25*	208 *3.41*	21 *.44*	21 *.59*	2 *.11*	5.3 *.09*	239	221	171	......
	T. 25 S., R. 24 W.															
51	NE¼ NE¼ sec. 11, 37.1 feet, alluvium	July 17	59	.12	144 *7.19*	25 *2.06*	42 *1.81*	427 *7.0*	102 *2.12*	37 *1.04*	1.0 *.85*	53 *.05*	618	463	350	113
55	SW corner sec. 21, 39.8 feet, Ogallala and/or Greenhorn; sample cloudy when collected	July 17	59	......	157 *7.83*	22 *1.81*	64 *2.77*	403 *6.61*	32 *.67*	42 *1.18*	.7 *.04*	243 *3.91*	762	482	330	152
......	SW¼ SE¼ sec. 21, spring, Ogallala and/or Greenhorn	July 17	64	0	61 *3.04*	18 *1.48*	16 *.46*	249 *4.08*	23 *.48*	7 *.2*	1.5 *.08*	8.4 *.14*	260	226	204	22
58	NE corner NW¼ sec. 26, 58 feet, Ogallala	July 24	59	2.2	45 *2.25*	20 *1.64*	12 *.54*	225 *3.69*	14 *.29*	7 *.2*	3.6 *.19*	4 *.06*	221	199	184	15

	T. 25 S., R. 25 W.															
65	SW corner sec. 10, 173.1 feet, Greenhorn and/or Dakota,	July 19	60	4.2	51 *2.54*	35 *2.88*	73 *3.19*	292(6) *4.79*	123 *2.56*	31 *.87*	2.2 *.12*	1.8 *.03*	474	279	251	28
	T. 25 S., R. 26 W.															
79	SW¼ SE¼ sec. 8, 123.1 feet, Ogallala	July 19	59	1.2	45 *2.25*	29 *2.38*	5 *.22*	256 *4.2*	13 *.27*	5 *.14*	2.9 *.15*	5.3 *.09*	234	234	210	24
85	SW corner sec. 25, 76.1 feet, Ogallala	July 24	60	(4)	54 *2.69*	23 *1.89*	14 *.59*	240 *3.94*	28 *.58*	11 *.31*	1.6 *.08*	16 *.26*	268	229	197	32
88	NE¼ SE¼ sec. 32, 109.1 feet, Ogallala	July 19	59	.08	66 *3.29*	27 *2.22*	15 *.64*	217 *3.56*	73 *1.52*	23 *.65*	1.9 *.1*	20 *.32*	335	276	178	98
	T. 26 S., R. 21 W.															
98	SE¼ NE¼ sec. 23, 29.3 feet, alluvium	July 18	59	.08	80 *3.99*	24 *1.97*	64 *2.80*	265 *4.35*	122 *2.54*	50 *1.41*	1.0 *.05*	25 *.41*	499	298	217	81
	T. 26 S., R. 23 W.															
113	SE¼ NW¼ sec. 5, 47.1 feet, Ogallala	July 24	59	.33	48 *2.4*	26 *2.14*	10 *.44*	256 *4.20*	15 *.31*	7 *.2*	2.8 *.15*	7.5 *.12*	245	228	210	18
115	SW corner SE¼ sec. 10, 65.5 feet, Ogallala	Aug. 2	59	(4)	59 *2.94*	19 *1.56*	13 *.55*	232(7) *3.8*	9.5 *.2*	15 *.42*	1.3 *.07*	9.7 *.16*	255	225	210	15
	T. 26 S., R. 24 W.															
129	NE¼ SE¼ sec. 2, 95.7 feet, Ogallala and/or Dakota	July 24	59	(4)	53 *2.64*	23 *1.89*	.7 *.03*	239 *3.92*	4.1 *.09*	13 *.37*	2.0 *.11*	4.4 *.07*	220	227	196	31
131	NW¼ NW¼ sec. 8, 84.2 feet, Ogallala	July 18	59	1.0	72 *3.59*	26 *2.14*	1.6 *.07*	272 *4.46*	12 *.25*	26 *.73*	2.2 *.12*	15 *.24*	292	289	223	66
176	NE¼ SE¼ sec. 32, 41.3 feet, alluvium	July 18	59	.1	217 *10.83*	76 *6.25*	132 *5.76*	317 *5.2*	606 *12.6*	115 *3.24*	1.8 *.09*	106 *1.71*	1413	854	260	594
	T. 26 S., R. 25 W.															
185	NE corner sec. 3, 63.4 feet, Ogallala	July 18	59	1.1	62 *3.09*	21 *1.73*	4 *.17*	261 *4.28*	14 *.29*	5 *.14*	1.8 *.09*	12 *.19*	252	243	214	29
201	SE¼ SE¼ sec. 26, ——, Ogallala	......	......	0	349 *17.42*	98 *8.06*	343 *14.92*	322 *5.28*	1442 *29.99*	109 *3.07*	1.7	128 *2.06*	2828	1274	264	1010
202	SW¼ SE¼ sec. 26, composite sample from wells 202, 262, and 273	......	......	.06	122 *6.09*	24 *1.97*	52 *2.28*	193 *3.16*	295 *6.14*	30 *.85*	.4	12 *.19*	702	403	158	245
229	SE¼ SW¼ sec. 29, 32.4 feet, alluvium	July 18	57	0	183 *9.13*	55 *4.52*	173 *7.51*	251 *4.12*	737 *15.33*	56 *1.58*	.9 *.05*	4.9 *.08*	1336	683	206	477
248	SW corner sec. 33, 166 feet, Ogallala	July 18	58	0	58 *2.89*	10 *.82*	22 *.96*	220 *3.61*	30 *.62*	7 *.20*	.1 *.23*	14 *.01*	251	186	180	6
	T. 26 S., R. 26 W.															
316	SW¼ SW¼ sec. 16, 23.1 feet, alluvium	July 17	58	0	124 *6.19*	41 *3.37*	184 *5.19*	243 *3.99*	449 *9.34*	40 *1.13*	.9 *.05*	15 *.24*	976	478	199	279
320	NW¼ SW¼ sec. 21, 22.7 feet, alluvium	July 26	60	(4)	66 *3.29*	11 *.9*	23 *1.01*	193 *3.16*	73 *1.52*	6 *.17*	.5 *.03*	20 *.32*	296	210	158	52
322	NW¼ SE¼ sec. 22, 26.7 feet, alluvium	July 24	58	(4)	133 *6.64*	40 *3.29*	63 *2.75*	266 *4.36*	310 *6.44*	40 *1.13*	1.3 *.07*	42 *.68*	762	497	218	279
324	SW¼ SW¼ sec. 22, 130.9 feet, Ogallala	Aug. 4	60	1.8	58 *2.89*	9.8 *.81*	21 *.91*	208 *3.41*	35 *.73*	7 *.20*	.1 *.01*	16 *.26*	253	188	171	17
326	SE¼ SE¼ sec. 23, 165 feet, Ogallala	July 17	59	0	57 *2.84*	11 *.9*	23 *.63*	199 *3.26*	34 *.71*	6 *.17*	0.3 *.02*	13 *.21*	244	187	163	24
334	SE¼ NE¼ sec. 36, 48 feet, alluvium	Aug. 3	59	(4)	62 *3.09*	11 *9*	24 *1.03*	220 *3.61*	37 *.77*	7.5 *.21*	.1 *.01*	26 *.42*	278	200	180	20

TABLE No. 14.—Analyses of water from wells in Ford county, Kansas (*Continued*)

No. on plates 2 or 3.	Location, depth, and geologic horizon.	Date of collection, 1939	Temperature (°F)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)(2)	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Total dissolved solids (2)	Hardness (calculated as $CaCO_3$). Total	Carbonate	Noncarbonate
	T. 27 S., R. 22 W.															
344	NE¼ NE¼ sec. 5, 37.1 feet, Ogallala and/or Dakota	Aug. 2	59	(4)	64 *3.19*	9 *.74*	47 *2.05*	295 *4.84*	23 *.48*	13 *.37*	.4 *.02*	17 *.27*	321	197	197(8)	0
350	NE¼ SE¼ sec. 27, 78.9 feet, Dakota	Aug. 2	60	.66	74 *3.69*	9.8 *.81*	34 *1.49*	265 *4.35*	9 *.19*	18 *.51*	.1 *.01*	58 *.93*	336	226	217	9
	T. 27 S., R. 23 W.															
352	NE¼ NE¼ sec. 3, 114.9 feet, Greenhorn; sample cloudy when collected	Aug. 1	60	4.8	26 *1.3*	13 *1.07*	157 *6.84*	289 *4.74*	162 *3.37*	32 *.9*	2.2 *.12*	4.9 *.08*	546	127	127(9)	0
353	SW corner sec. 5, 88.4 feet, Greenhorn; sample slightly cloudy when collected	July 18	60	.47	87 *4.34*	20 *1.64*	15 *.64*	287 *4.71*	9.1 *.19*	30 *.85*	.3 *.02*	53 *.85*	358	300	235	65
357	SE¼ NE¼ sec. 16, 23 feet, alluvium	July 17	59	26 *.93*	442 *22.06*	104 *8.55*	266 *11.56*	234 *3.84*	1740 *36.19*	94 *2.65*	1.9 *.1*	20 *.32*	2811	1577	192	1385
360	SW corner sec. 20, 57 feet, Ogallala	Aug. 2	60	.33	61 *3.04*	10 *.82*	17 *.72*	227 *3.72*	16 *.33*	8 *.23*	.1 *.01*	18 *.29*	244	194	186	8
	T. 27 S., R. 24 W.															
370	NW¼ NE¼ sec. 4, 152 feet, Ogallala	July 18	57	0	74 *3.69*	27 *2.22*	22 *.97*	231 *3.79*	109 *2.27*	16 *.45*	1.6 *.08*	18 *.29*	383	296	189	107
	T. 27 S., R 25 W															
390	SW¼ NW¼ sec. 4, 57 feet, alluvium	July 18	59	0	60 *2.99*	9 *.74*	17 *.74*	220 *3.61*	22 *.46*	6.5 *.18*	.1 *.01*	13 *.21*	238	187	180	7
	T. 27 S., R. 26 W.															
398	NE¼ NE¼ sec. 1, 86.1 feet, alluvium and/or Ogallala	Aug. 1	60	(4)	61 *3.04*	9.2 *.76*	22 *.96*	222 *3.64*	26 *.54*	9 *.25*	.1 *.01*	20 *.32*	258	190	182	8
402	SW¼ SE¼ sec. 6, 123 feet, Ogallala	July 26	59	.33	65 *3.24*	9.2 *.76*	12 *.5*	232 *3.8*	14 *.29*	4.5 *.13*	.1 *.01*	17 *.27*	238	201	190	11
403	SE¼ NE¼ sec. 7, 126.9 feet, Ogallala	July 26	59	(4)	58 *2.89*	9.2 *.76*	8.5 *.37*	220 *3.61*	3.7 *.08*	4.5 *.13*	.1 *.01*	12 *.19*	206	183	180	3
	T. 28 S., R. 21 W.															
412	SW corner NW¼ sec. 36, 83.2 feet, Rexroad	Aug. 1	60	(4)	70 *3.49*	11 *.9*	16 *.69*	249 *4.08*	19 *.4*	10 *.28*	.1 *.01*	19 *.31*	270	220	204	16
	T. 28 S., R. 22 W.															
417	SW¼ SW¼ sec. 4, 77.1 feet, alluvium	July 22	60	(4)	57 *2.84*	13 *1.07*	21 *.89*	212 *3.48*	34 *.71*	13 *.37*	.5 *.03*	13 *.21*	258	196	174	22

420	SW¼ NE¼ sec. 10, 69 feet, alluvium	July 18	59	.04	58 *2.89*	14 *1.15*	18 *.76*	216 *3.54*	33 *.69*	12 *.34*	.3 *.02*	13 *.21*	256	202	177	25
422	NE¼ NE¼ sec. 20, 169 feet, Rexroad	Aug. 1	60	(4)	66 *3.29*	11 *.9*	18 *.76*	235 *3.85*	27 *.56*	12 *.34*	.1 *.01*	12 *.19*	264	210	193	17
	T. 28 S., R. 23 W.															
423	SW corner NW¼ sec. 9, 116 feet, Rexroad	July 22	60	(4)	55 *2.74*	11 *.9*	12 *.54*	209 *3.43*	26 *.54*	6 *.17*	.2 *.01*	1.6 *.03*	216	182	171	11
	T. 28 S., R. 24 W.															
435	SW¼ NW¼ sec. 11, 160 feet, Rexroad	July 25	59	(4)	54 *2.69*	9.9 *.81*	18 *.8*	205 *3.36*	26 *.54*	5.5 *.16*	.2 *.01*	14 *.23*	230	175	168	7
441	SE¼ SE¼ sec. 35, 132.6 feet, Rexroad	July 25	60	1.3	58 *2.89*	19 *1.56*	7.6 *.33*	215 *3.53*	5.8 *.12*	36 *1.02*	.5 *.03*	4.9 *.08*	241	225	176	49
	T. 28 S., R. 25 W.															
443	NW¼ NW¼ sec. 2, 151.6 feet, Rexroad	July 22	60	.28	52 *2.59*	9.8 *.81*	19 *.82*	203 *3.33*	26 *.54*	5 *.14*	.3 *.02*	12 *.19*	226	171	166	5
445	NE corner NW¼ sec. 6, 148.4 feet, Rexroad	Aug. 3	59	4.7	52 *2.59*	10 *.82*	21 *.89*	212 *3.48*	25 *.52*	4.5 *.13*	.1 *.01*	9.7 *.16*	233	179	174	5
	T. 28 S., R. 26 W.															
461	SW corner NW¼ sec. 9, 163 feet, Rexroad	July 26	60	.28	54 *2.69*	14 *1.15*	14 *.61*	203 *3.33*	26 *.54*	11 *.31*	.2 *.01*	16 *.26*	237	193	166	27
464	SE corner NE¼ sec. 27, 162.9 feet, Rexroad	Aug. 1	60	1.3	53 *2.64*	19 *1.56*	7.1 *.31*	244 *4.00*	10 *.21*	5 *.14*	.3 *.02*	8.8 *.14*	227	213	200	13
	T. 29 S., R. 21 W.															
467	SW¼ NE¼ sec. 5, composite sample from wells 467 and 468, 111.8–125 feet, Rexroad	......	......	.05	70 *3.49*	14 *1.15*	12 *.5*	264 *4.33*	14 *.29*	10 *.28*	.1	15 *.24*	288	232	214	18
	T. 29 S., R. 22 W.															
471	SE¼ SW¼ sec. 18, 171.1 feet, Rexroad	July 22	60	.76	74 *3.69*	10 *.82*	7.1 *.31*	271 *4.44*	5.8 *.12*	4 *.11*	.1 *.01*	8.9 *.14*	246	227	222	5
473	SW corner SE¼ sec. 28, 108.1 feet, Rexroad	July 22	60	.39	51 *2.54*	18 *1.48*	13 *.55*	246 *4.03*	12 *.25*	6 *.17*	.5 *.03*	5.8 *.09*	230	202	202	0
	T. 29 S., R. 23 W.															
476	NE¼ NE¼ sec. 21, 206.2 feet, Rexroad	July 25	61	(4)	52 *2.59*	16 *1.32*	17 *.72*	249 *4.08*	14 *.29*	5 *.14*	.5 *.03*	5.8 *.09*	235	196	196	0
	T. 29 S., R. 24 W.															
480	SW¼ SW¼ sec. 13, 134.9 feet, Rexroad	Aug. 3	60	1.1	46 *2.3*	16 *1.32*	22 *.97*	242 *3.97*	15 *.31*	6 *.17*	.5 *.03*	7.1 *.11*	235	183	183	0
485	NW¼ SW¼ sec. 17, 152.6 feet, Rexroad	July 25	59	(4)	48 *2.4*	16 *1.32*	16 *.68*	232 *3.8*	14 *.29*	6 *.17*	.5 *.03*	6.6 *.11*	223	186	186	0
	T. 29 S., R. 25 W.															
489	SW¼ SW¼ sec. 1, 158.5 feet, Rexroad	Aug. 3	60	1.3	52 *2.59*	18 *1.48*	8.5 *.37*	245 *4.02*	6.6 *.14*	5.5 *.16*	.3 *.02*	6.2 *.1*	221	206	201	5
497	NE corner sec. 29, 100.3 feet, Rexroad	Aug. 3	60	(4)	73 *3.64*	12 *.99*	8.3 *.36*	282 *4.62*	5.3 *.11*	4 *.11*	.1 *.01*	8.4 *.14*	252	232	231	1

TABLE No. 14.—Analyses of water from wells in Ford county, Kansas (*Concluded*)

No. on plates 2 or 3.	Location, depth and geologic horizon.	Date of collection, 1939	Temperature (°F)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)(2)	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Total dissolved solids (2)	Hardness (calculated as $CaCO_3$). Total	Carbonate	Noncarbonate
	T. 29 S., R. 26 W.															
505	SW corner NW¼ sec. 6, 96.2 feet, Rexroad	Aug. 3	60	.12	56 *2.79*	18 *1.48*	4.4 *.19*	255 *4.18*	4.9 *1*	4 *.11*	.3 *.02*	3.1 *.05*	218	214	209	5
507	NE¼ SW¼ sec. 15, 149 feet, Rexroad and/or Dakota	July 26	59	(4)	48 *2.4*	14 *1.15*	15 *.65*	221 *3.62*	14 *.29*	5 *.14*	.7 *.04*	6.6 *.11*	214	178	178	0
510	SW¼ NW¼ sec. 24, 211.5 feet, Rexroad and/or Dakota	July 26	60	(4)	51 *2.54*	16 *1.32*	14 *.6*	243 *3.99*	11 *.23*	4.5 *.13*	.5 *.03*	4.9 *.08*	223	193	193	0
518	SE¼ NE¼ sec. 34, depth not known, flowing well, Rexroad and/or Dakota	Aug. 1	61	.1	56 *2.79*	20 *1.64*	21 *.89*	284 *4.66*	17 *.35*	6 *.17*	.7 *.04*	6.2 *.1*	269	222	222(11)	0
521	SW¼ NW¼ sec. 35, 175 feet, flowing well, Rexroad and/or Dakota	July 18	60	.08	54 *2.69*	17 *1.40*	20 *.85*	260 *4.26*	23 *.48*	5 *.14*	.5 *.03*	1.8 *.03*	251	205	205	0
	T. 30 S., R. 22 W.															
526(12)	SW corner NW¼ sec. 5, 93.3 feet, Rexroad	July 22	60	(4)	50 *2.5*	17 *1.4*	17 *.75*	246 *4.03*	14 *.29*	7 *.2*	.5 *.03*	6.2 *.1*	235	195	195	0

1. One part per million is equivalent to 1 pound of substance per million pounds of water and is equivalent to 8.33 pounds per million gallons.
2. Calculated.
3. Total alkalinity, 232 parts per million; excess alkalinity, 9 parts per million.
4. Less than 0.15 part per million.
5. Total alkalinity, 256 parts per million; excess alkalinity, 86 parts per million.
6. Sample also contains 7.2 parts per million carbonate (*0.24* equivalents per million).
7. Sample also contains 12 parts per million carbonate (*0.4* equivalents per million).
8. Total alkalinity, 242 parts per million; excess alkalinity, 45 parts per million.
9. Total alkalinity, 237 parts per million; excess alkalinity, 110 parts per million.
10. Total alkalinity, 198 parts per million; excess alkalinity, 15 parts per million.
11. Total alkalinity, 233 parts per million; excess alkalinity, 11 parts per million.
12. Located in Clark county.

Chemical Constituents in Relation to Use

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

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

The ground waters from most of the Ford county wells that were analyzed contain less than 400 parts per million of dissolved mineral matter, and are entirely satisfactory for most ordinary purposes. The waters from three of the wells (32, 65, and 98) contained between 400 and 500 parts per million of dissolved solids, the waters from five other wells (51, 55, 202, 322, and 352) contained between 500 and 800 parts, the waters from three wells (176, 229, and 316) contained between 900 and 1,500 parts, and the waters from two wells (201, 357) contained 2,828 and 2,811 parts, respectively.

Hardness.—Hardness of a water is commonly recognized by the increased amount of soap needed to produce a lather, and by the curdy precipitate that forms before a permanent lather is obtained. Calcium and magnesium are constituents that cause practically all the hardness of ordinary waters and they are also the active agents in the formation of the greater part of all the scale formed in steam boilers and in other vessels in which water is heated or evaporated.

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

Water having a hardness of less than 50 parts per million is generally rated as soft, and its treatment for the removal of hardness is rarely justified. 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 profitable for laundries or other industries that use large quantities of soap. Treatment for the prevention of scale is necessary for the successful operation of steam boilers using water in the upper part of this range of hardness. Hardness of more than 150 parts per million is noticed by anyone, and where the hardness is 200 or 300 parts per million it is common practice to soften water for household use or to install cisterns to collect soft rain water. Where public supplies are softened, an attempt is generally made to reduce the hardness to from 60 to 80 parts per million. The additional improvement from further softening of a whole public supply is not deemed worth the additional cost.

The ground waters of Ford county are all hard, most of the samples ranging in hardness from 170 to 300 parts per million. Seven samples contained between 403 and 854 parts per million of hardness (analyses 51, 55, 176, 202, 229, 316, and 322), and the samples from wells 201 and 357 contained 1,274 and 1,577 parts, respectively.

There are two processes in general use for softening water, the lime and soda process and the exchange silicate or so-called "zeolite" process. Both of these methods also effectively remove undesirable amounts of iron. None of the public water supplies in the county are softened or otherwise treated; but the water is treated, principally to soften it, for the railroads, several industrial plants, and a laundry.

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

Iron is found in objectionable amounts in some of the ground waters of Ford county, as indicated in table 14. All but 14 of the 70 samples of water from Ford county contained less than 1 part per million of iron. The samples from 4 (43, 65, 352, and 445) contained between 4 and 5 parts per million of iron. The sample of water from well 357, an irrigation well in the alluvium in the Arkansas valley, contained 26 parts per million of iron—an amount sufficient to give the water a disagreeable taste. The irrigation ditches leading from the well and much of the irrigated land was coated with a reddish sediment that had settled out after exposure to the air because of the large amount of iron in the water. The samples from 9 wells (58, 79, 131, 185, 324, 441, 464, 480, and 489) contained between 1.0 and 2.2 parts per million of iron.

Fluoride.—Although determinable quantities of fluoride are not so common as fairly large quantities of the other constituents of natural waters it is desirable to know the amount of fluoride present in waters that are likely to be used by children. Fluoride in water has been shown to be associated with the dental effect known as mottled enamel which may appear on the teeth of children who drink water containing fluoride during the period of formation of the permanent teeth. It has been stated that waters containing 1 part per million or more of fluoride are likely to produce mottled enamel, although the effect of 1 part per million is not usually very serious (Dean, 1935, pp. 1269-1272). If the water contains as much as 4 parts per million of fluoride, 90 percent of the children exposed are likely to have mottled enamel and 35 percent or more of the cases will be classified as moderate or worse.

Of the 70 samples of water collected in Ford county, 26 contained 1.0 part per million or more of fluoride. Fifteen of these contained from 1.0 part to 2.0 parts; 10 contained between 2 and 3 parts; and one well (58), at a school, contained 3.6 parts. The following other school wells yielded waters having more than 1 part per million of fluoride: well 43, 2.6 parts per million; well 65, 2.2 parts; well 79, 2.9 parts; and well 185, 1.8 parts. A composite sample of water from the city wells of Spearville (36) contained 1.5 parts per million of fluoride. 44 samples contained less than 1 part per million of fluoride.

Water for irrigation.—The suitability of water for use in irrigation is commonly held to depend on the quantity and chemical character of the dissolved salts and on the rainfall, the nature of the land, the crops, the manner of use, and the drainage. In a discussion of the interpretation of analyses with reference to irrigation in southern California, Scofield (1933, pp. 23-24) gives some limits for different factors as they have been found to hold in southern California.

All of the samples of water collected in Ford county would be classed as safe for use in irrigation according to the principles discussed by Scofield.

Sanitary Considerations

The analyses of water given in the tables show only the amounts of dissolved mineral matter in the water and do not indicate the sanitary quality of the water.

Dug wells and springs are more likely to become contaminated than are properly-constructed drilled wells, but great care should be taken to protect from pollution every well and spring used for domestic or public supply. It is important that the top of the casing be sealed in such a manner as to prevent surface water from entering the wells, and, where pump pits are used, the top of the casing should extend above the floor of the pit so that surface water cannot drain into the well. In constructing wells equipped with ordinary lift or force pumps, it is a good plan to allow the casing to extend several inches above the platform so that the pump base will fit down over the top of the casing, thus effecting a tight seal. If the casing is left flush with the top of the platform opportunity is afforded for drainage into the well and for possible contamination. Wells should not be located where there are possible sources of contamination such as drainage from the vicinity of buildings, privies, or cesspools. The type and condition of casing used for domestic wells also warrants careful consideration. During the course of the present investigation, several wells were visited in which the casings had become obstructed on the inside by the roots of trees and vines, whose presence indicated that there were openings in the casing, probably near joints.

Quality in Relation to Water-bearing Formations

The Ogallala formation, by far the most important source of ground water in Ford county, yields calcium bicarbonate waters of moderate mineral content. The forty Ogallala waters that were analyzed were remarkably uniform in total mineral content and in their content of the different major mineral constituents. For example, 38 of the 40 waters analyzed had between 190 and 335 parts per million of total dissolved mineral matter, between 200 and 290 parts per million of bicarbonate, and between 170 and 280 parts per

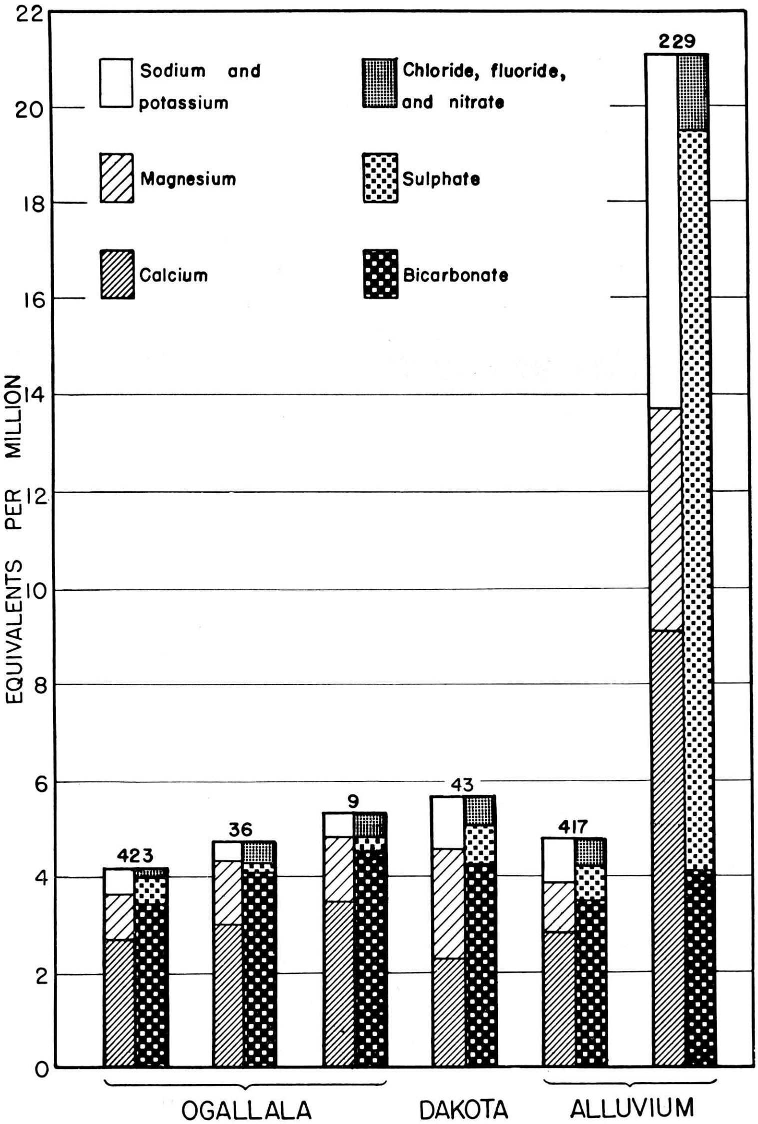


FIG. 20. Analyses of typical waters from the Ogallala formation, the Dakota formation, and the alluvium in Ford county.

million of hardness. The waters generally had less than 35 parts per million of sulfate and of chloride. Analyses of typical Ogallala waters are shown graphically in figure 20. Number 36 is an Ogallala water of average mineral content; number 423 is one of the softer, less mineralized waters; and number 9 is one of the harder, more highly mineralized waters.

One water, presumably from the Ogallala, had 1,442 parts per million of sulfate. The very high nitrate content of this water (128 parts per million) suggests that the water has been contaminated by surface drainage and that it is not a true Ogallala water.

About half of the Ogallala waters that were analyzed had more than 10 parts of nitrate, suggesting that these waters, too, have been contaminated to some extent.

Generally the Ogallala waters appear to be low in iron. Only five of those analyzed had more than 0.5 part per million of iron and the highest of these was 2.2 parts.

Ogallala waters north of Arkansas river were higher in fluoride content than were those south of the river. The areal distribution of fluoride in Ogallala waters is shown in figure 21. With but one

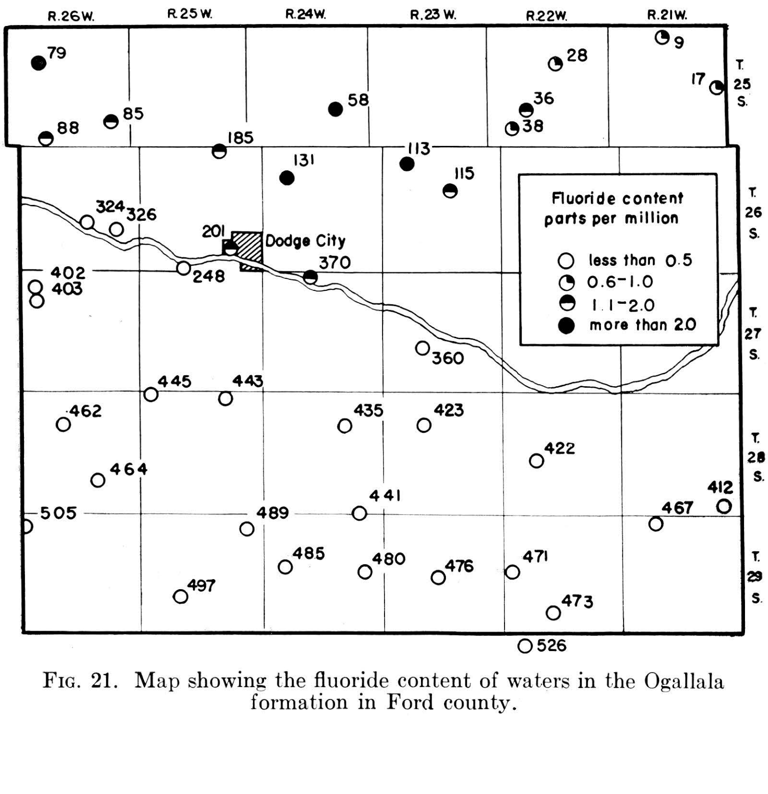


FIG. 21. Map showing the fluoride content of waters in the Ogallala formation in Ford county.

exception all the analyses of Ogallala waters north of the river showed more than 0.5 part per million of fluoride and more than half of these analyses showed more than 1 part, whereas all the analyses of Ogallala waters south of the river showed less than 0.5 part of fluoride.

Only five of the samples that were analyzed are definitely correlated as having come from the Dakota formation. These waters had from 239 to 464 parts per million of total dissolved mineral matter, 208 to 312 parts of bicarbonate and 170 to 239 parts of hardness. Only one water had more than 40 parts of sulfate and all had less than 35 parts of chloride. The analysis of a typical Dakota water (No. 43) is shown graphically in figure 20. Although this water is slightly less mineralized than the average water from the Dakota formation it is fairly typical of 31 samples of water collected for analysis from wells in the Dakota formation in Morton, Stanton, Hamilton, Gray, and Ford counties. The analyses of water from Morton and Stanton counties have been published (McLaughlin, 1942, pp. 59-62; Latta, 1941, pp. 57-59), and those from Hamilton and Gray counties will be published in forthcoming bulletins of the State Geological Survey of Kansas.

The information available indicates that waters in the Dakota formation are similar in mineral content and in chemical character to waters in the Ogallala formation. Fluoride was relatively high in the Dakota waters analyzed—four of the waters having more than 2 parts per million. The fifth water had 0.1 part per million of fluoride. One Dakota water (No. 350) had 58 parts per million of nitrate, suggesting contamination by surface drainage.

The Greenhorn limestone is relatively unimportant as a source of ground water in Ford county and only two analyses were made of water from the formation. The two waters analyzed differed considerably in total mineral content, in sulfate content, and in hardness (Nos. 352 and 353, table 14). One was moderately high in sulfate, iron and fluoride and only moderately hard (No. 352), the other was low in sulfate, iron, and fluoride, and very hard (No. 353). These scanty data permit no generalizations as to the kind of water likely to be obtained from the Greenhorn limestone.

Eleven analyses indicate that two distinct types of waters may be obtained from the alluvium of Arkansas river. These two types are represented graphically in figure 20. The waters from alluvium on the south side of the river were typical calcium bicarbonate waters of moderate mineral content. They were very similar in chemical character and in mineral content to waters from the Ogallala formation. All these waters had less than 75 parts per million of sulfate. On the other hand waters from allivium on the north side of the river had, with only one exception (No. 98), more than 300 parts per million of sulfate. One water (No. 357) had 1,740 parts of sulfate. These relations are shown in figure 22. The sulfate waters from the alluvium are the hardest waters found in the county. The waters in the alluvium north of the river also differed from those south of the river in fluoride content. Those north of the river had from 0.9 to 1.9 parts per million of fluoride, whereas those south of the river had 0.5 part or less. This relationship with respect to fluoride content is analogous to that found in the Ogallala waters. With but one exception the waters in the alluvium had no more than 0.1 part per million of iron. The exception, No. 357, which had 26 parts of iron, also has the highest sulfate content and is by far the hardest water found in the county.

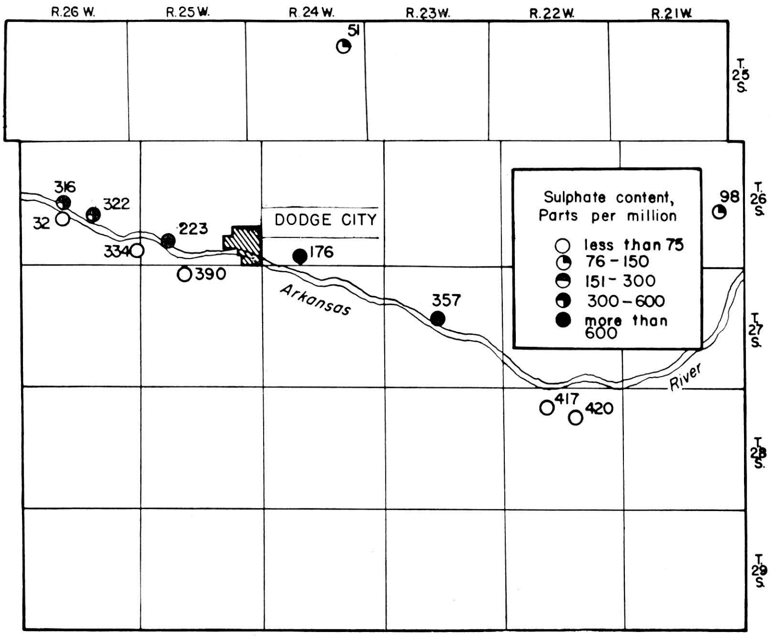


FIG. 22. Map showing the sulphate content of waters in the alluvium in Ford county.

WATER-BEARING FORMATIONS

PALEOZOIC ROCKS

The oldest rocks encountered by deep tests for oil and gas in the county belong to the Cambrian and Ordovician systems. No wells are known to obtain water supplies from these rocks in Ford county, but scanty data indicate that any water encountered would be apt to be salty and highly mineralized.

From the records of several deep tests for oil and gas, it is known that approximately 3,000 feet of Permian sediments underlie the county, representing most of the Permian rocks exposed in areas to the east and south. Permian redbeds were reported as shallow as 400 feet in one test in the center of the NE¼ sec. 22, T. 29 S., R. 21 W. (see log 71, p. 239). The top of the Permian redbeds was encountered at a depth of 500 feet in a test for oil and gas on the Young farm in the center of the south line of the NE¼ sec. 34, T. 27 S., R. 21 W.

Darton (1919, p. 8) reported on a boring 800 feet deep put down just east of the old plant of the Kansas Power Company at Dodge City, but according to Oscar Johnson, a well driller of Ford county (personal communication, December, 1938), the total depth of the boring that Darton referred to was about 980 feet. Johnson also reported that, in this boring, black shale (Graneros?) was encountered at a depth of 180 feet, and that a strong flow of salt water encountered at a depth of 650 feet was under sufficient pressure to lift the tools off the bottom of the hole. The log (42) of the upper 325 feet of this test hole is given on page 229. The Permian rocks contain beds of salt, gypsum, and anhydrite, and it is likely that any water contained in them is salty and highly mineralized.

CRETACEOUS SYSTEM

Historical Summary

The succession of sandstones and shales lying beneath the Graneros shale and above the Permian redbeds in Kansas and adjacent areas have been described under various classifications in earlier reports.

Cragin (1886, 1889, 1895) subdivided the rocks of Cretaceous age in southern Kansas into the Cheyenne sandstone, the Kiowa shale, and the Dakota sandstone named in ascending order. Gould (1898) used this same classification, but called the beds between the Dakota sandstone and the Kiowa shale the "Medicine" beds. Darton (1920, p. 2) subdivided the Cretaceous strata below the Graneros in western Kansas into the Cheyenne sandstone, the Kiowa shale, and the Dakota sandstone. Twenhofel (1924, pp. 12-30) proposed the following classification of Cretaceous strata in southern Kansas: Cheyenne sandstone, Belvidere formation and "Dakota" formation. Bass (1926, pp. 59, 73-76) used the name Dakota sandstone for strata between the Graneros shale and the Permian in Hamilton county, but stated that possibly it included representatives of the Purgatoire formation of eastern Colorado.

Lee (1927, p. 17) correlated the Dakota and Purgatoire formations in southern Colorado with rocks designated by him as the Dakota group at the Bellvue section in northern Colorado. Tester (1931, pp. 234-283) assigned the name "Dakota stage" to the succession of sandstone and shale beneath the Graneros shale and overlying the Pennsylvanian rocks at the type locality in eastern Nebraska, and stated that the Dakota stage belongs to the same general sequence as the Washita-Kiowa-Mentor series of Kansas. Elias (1931, p. 28, 1937, p. 10) and later Landes and Keroher (1939, p. 24) classified the strata between the Graneros shale and the Permian in western Kansas as the Dakota group.

In 1937 the Kansas Geological Survey (Moore and Landes, 1937) used the term Dakota group to include all Cretaceous strata below the Graneros. At a conference of survey geologists in Lawrence in January, 1941, a decision was reached by the state geologists to continue the use of the term Dakota group as interpreted by Tester (1931) and subsequently adopted in Kansas reports (Moore and Landes, 1937; Moore, 1940, p. 40). The Dakota group as thus defined included all the strata from the base of the Cheyenne sandstone to the base of the Graneros shale. The term Dakota group also is used by the Nebraska Geological Survey and many oil geologists (Kansas Geol. Society Guidebook 1940, pp. 14, 55), but the name Dakota also is used in some states to designate the upper sandstone division and such usage might result in some confusion. In a report on Stanton county, Latta (1941, p. 70) states:

> Accordingly, under conditions of present knowledge it seems best to recognize the Dakota group as including the somewhat variable, partly undifferentiated succession of clastic deposits of Cretaceous age below the Graneros shale and to use local names for the subdivisions of the group in those areas where it is possible to subdivide the Dakota group.
>
> All Cretaceous strata in Stanton county belong to the Dakota group. They comprise the Cheyenne sandstone, Kiowa shale, and an upper sandstone (formerly called Dakota) that is here named the Cockrum sandstone.

The inclusion in the Dakota group of the Cheyenne sandstone, Kiowa shale, and Cockrum sandstone, as adopted by Latta, has been followed in Morton county by McLaughlin (1941, p. 74).

In February, 1942, several conferences were held by Survey geologists in Lawrence on the nomenclature and classification of the pre-Greenhorn Cretaceous deposits of Kansas. As a result, the term Dakota group, which formerly included the Cheyenne sandstone, the Kiowa shale, and overlying beds to the base of the Graneros shale, was abandoned by the Kansas Geological Survey because: The group as previously defined, transgressed the Upper Cretaceous-Lower Cretaceous boundary line; a multiplicity of names has existed for the various units involved, many of them having been applied to such nonpersistent units as channel sandstone that cannot be correlated with certainty beyond the confines of their type localities; many of the stratigraphic units were never adequately described. Moreover, the Dakota group, as used previously in Kansas, could not be correlated with the Dakota sandstone at the type locality; it was not acceptable to the Committee on Geologic Names of the U. S. Geological Survey; it did not constitute a satisfactory genetic grouping of strata; and the term Dakota group was confused with other usages of Dakota and almost universally implied a sandstone.

It was proposed to use the term Dakota formation for the non-marine beds classed as Upper Cretaceous that lie between the base of the Graneros shale and the top of the Kiowa shale. The term Dakota formation was formally adopted for use in all counties in the main area of outcrop in central Kansas, including Ford county, but it was decided to retain use of the name Cockrum sandstone in southwesternmost Kansas, as used by Latta and by McLaughlin. The Cockrum sandstone of southwesternmost Kansas is equivalent only to a part of the Dakota formation of central Kansas. Plummer and Romary, who have worked in nearly the entire outcrop area of the Cheyenne, Kiowa, and Dakota beds in central Kansas, have redefined and subdivided the Dakota formation according to the present usage of the State Geological Survey of Kansas (1942, p. 319). Usage of the term Dakota formation is followed in the present report on Ford county.

CHEYENNE SANDSTONE

Character.—The Cheyenne sandstone does not crop out in Ford county, but sandstone believed to be equivalent to the Cheyenne was encountered in a test hole (log 19, p. 219) near the southwestern corner of the county. In this test, beds of sandstone and shale tentatively assigned to the Cheyenne sandstone were encountered at a depth of 310 feet below beds of bluish-gray shale believed to be the Kiowa. The drill cuttings indicate that the Cheyenne sandstone at this locality consists of beds of lenticular sandstone containing interbedded layers of bluish-gray silty and sandy shale and variegated clay shale. A few thin layers of sandstone were encountered that seemed to be harder than the rest. The sandstone is composed of well-rounded grains of quartz and is light gray to yellow in color.

According to Twenhofel (1924, pp. 12-20), the Cheyenne sandstone generally consists of beds of light gray to yellow quartz sandstone and a few beds of shale. The bedding is extremely irregular and discontinuous and most beds are merely lenses of limited extent. Cross-lamination is common throughout, the inclinations tending to be steep and in large part appear to have a southerly direction. Although most of the beds are gray to yellow in color, and probably were originally so, many of the beds are stained with iron derived probably from the oxidation of pyrite or marcasite. Where the staining has taken place along bedding and lamination planes, the rock has been striped with almost every shade of color. The rock ranges in texture from fine-grained sandstone to fine-grained conglomerate. Interbedded with the sandstone are lenses of sand— and clay-shale. Some beds are characterized by rather well-assorted small pebbles of chert, quartz, and clay. Pyrite is abundant in some beds; selenite crystals are extremely common and selenite needles occur throughout; limonite concretions are common and are believed to have resulted from weathering. As a rule the sandstones are poorly cemented, but locally they are firmly cemented with silica.

Distribution and thickness.—The nearest known outcrop of the Cheyenne sandstone is at Osage Rock, three quarters of a mile west of Belvidere, Kiowa county. In a measured section of the Kiowa shale in Bluff creek canyon in Clark county, which borders Ford county on the south, Twenhofel (1924, p. 26) describes a friable, fine-grained white sandstone 12 feet thick as the number 1 bed at the base of the section, and suggests that it may be the equivalent of the Cheyenne, but that it is conformable on the Permian redbeds and is probably Permian. Moss (1932, pp. 33, 34) reported that a sandstone encountered below a shale, tentatively correlated with the Kiowa shale, and above the Permian redbeds, in the Phillips-Hausman oil test in sec. 30, T. 22 S., R. 22 W., Hodgeman county, may be equivalent to the Cheyenne sandstone but that it is more probably of Kiowa age, as are similar sandstones in McPherson county.

The Cheyenne sandstone, where present under Ford county, lies unconformably on Permian redbeds. It is possible that it is absent under the northern part of the county. The exact thickness of the Cheyenne sandstone under Ford county is not known, but it is believed to be at least 70 feet thick in test hole 19 (see log 19, p. 219).

Measured sections of the Cheyenne sandstone in its area of outcrop indicate that it ranges widely in thickness. According to Twenhofel (1924, pp. 12-20) the Cheyenne ranges in thickness from about 42 feet at Osage Rock to about 98 feet in a section measured in Champion Draw, 1½ miles south of Belvidere.

Age and correlation.—Correlation of the sandstone and shale encountered in test hole 19 in southwestern Ford county with the Cheyenne sandstone at its type locality near Belvidere, Kiowa county, is known only from drill cuttings from which no fossils were recovered. These beds are tentatively assigned to the Cheyenne sandstone, however, on the basis of their lithology and stratigraphic position. A hard bed of limestone about six inches thick was encountered at a depth of about 303 feet near the base of the Kiowa shale. It is probable that this bed is correlative with the "Champion shell bed" at the base of the Kiowa shale, described by Twenhofel (1924, pp. 20-28) and that the lenticular sandstone and interbedded sandy shale encountered below the Kiowa, between the depths of 310 and 380 feet, is correlative with the Cheyenne sandstone.

Water supply.—Sufficient quantities of water for most purposes generally are obtained from formations above the Cheyenne sandstone in Ford county so that no wells are known to have penetrated the Cheyenne sandstone in order to obtain a water supply.

KIOWA SHALE

Character.—The Kiowa shale rests conformably on the Cheyenne sandstone and underlies the Dakota formation. Although it does not crop out in Ford county, it has been encountered in two test holes (see logs 15 and 19, pp. 216, 219). In test hole 19 the Kiowa was represented by a soft bluish-gray clay-shale with occasional fragments of maroon to red silty clay-shale, and in test hole 15 it was represented predominantly by bluish-gray clay-shale.

According to Twenhofel (1924, pp. 22-28), the Kiowa consists of shales and interbedded thin limestones. The shales in the lower half are black, thinly laminated, and contain few identifiable fossils which are generally small. A few layers contain pebbles of quartz and brown chert. The shales in the upper part of the Kiowa are dark blue to gray, and are weathered yellow in some exposures. They are considerably more limey than the shales in the lower part and contain large *Gryphaea*. Thin beds of limestone, mostly coquina, occur throughout the formation, but are more common in the upper half. Gypsum, mostly in the form of selenite, is common throughout the Kiowa.

Distribution and thickness.—The Kiowa shale underlies the southern part of Ford county, but it is not definitely known whether or not it is present under the northern part of the county. The nearest outcrops of the Kiowa shale are those in Bluff creek canyon and near St. Jacobs well in Clark county. Probably the best exposed section of the Kiowa near Ford county is that in Champion draw, about one-half mile south of Belvidere, Kiowa county. A bluish-gray shale containing fragments of fossils encountered in the Phillips-Hausman well, in sec. 30, T. 22 S., R. 22 W., Hodgeman county, was referred by Moss (1932, pp. 33-34) to the Kiowa shale. Although no fossils could be identified, he suggested that the lithology and position of the shale, together with the occurrence of fossils, justified its correlation with the Kiowa shale of southern Kansas.

The Kiowa shale was found to be 44 feet thick in test hole 19 in southwestern Ford county. Its thickness in test hole 15, on the Clark county line south of Kingsdown, is not known, as only about 10 feet of the formation was penetrated. According to Twenhofel (1924, pp. 23-26) the thickness of the Kiowa shale ranges from about 28 feet in the section near St. Jacobs well, in western Clark county, to 160 feet in the section at Avilla Hill, in southern Comanche county. The Kiowa shale is about 122 feet thick in the section exposed in Champion Draw, near Belvidere. Thus, there is a reduction in the thickness of the Kiowa westward from Champion Draw to St. Jacobs well.

Age and correlation.—The soft bluish-gray clay-shale encountered in test hole 19 between the depths of about 266 and 310 feet and in test hole 15 at a depth of 220 feet is correlated with the Kiowa shale of southern Kansas largely on the basis of its lithology and stratigraphic position, as no identifiable fossils were recovered from the drill cuttings. The shale is stratigraphically below the Dakota formation and above beds that have been assigned to the Cheyenne sandstone. In test hole 15 the Dakota formation was absent and the Ogallala formation rested directly on the Kiowa shale.

Water supply.—The materials making up the Kiowa shale are relatively impermeable and supply little or no water to wells. No wells are known to derive water supplies from this formation in Ford county.

DAKOTA FORMATION

Character.—The strata of the Dakota formation consist of lenticular beds of quartz sandstone, and beds of variegated shale, clay, and siltstone. The beds of sandstone are fine- to medium-grained, range in color through gray, yellow, buff, brown, and reddish-brown, and generally are cross-bedded. The beds may be cemented with iron oxide or calcium carbonate, and those cemented by iron oxide generally are harder than the rest. Because the sandstone beds of the Dakota are exposed prominently in many places, the formation is generally thought to be composed almost entirely of sandstone. Moss (1932, p. 32) points out, however, that Dakota in Ness and Hodgeman counties is only about one-fourth sandstone. In some outcrops only the hardest beds are exposed, but in others beds of sandstone ranging in thickness from less than 1 foot to several feet alternate with layers of shale and clay. The softer beds consist of yellow and light silty clay, white plastic clay, light gray to buff siltstone, and varicolored sandy shale.

The sections that follow were measured by Norman Plummer and John Romary of the Kansas Geological Survey in connection with the study of clay deposits in the outcrop areas of the Cheyenne, Kiowa, and Dakota beds in Kansas, and show the character of the upper part of the Dakota formation throughout the extent of the exposures in Ford county. A report entitled "Stratigraphy of the pre-Greenhorn Cretaceous beds of North-central Kansas" is in preparation (Plummer and Romary, 1942).

Section of a part of the Dakota formation near the large Cottonwood tree along Five-mile creek, in the SE corner NW¼ NW¼ sec. 30, T. 25 S., R. 23 W.

(Section measured by Norman Plummer and John Romary)

	Thickness, feet
Ogallala formation	
Dakota formation	
13. Silt and fine-grained sandstone, yellow to light gray, horizontally-bedded, containing streaks of hematite, limonite, and some siderite	1.5
12. Clay, silty, light gray, brownish sandstone at bottom	1.0
11. Clay, plastic, nearly white, containing scattered carbonized root molds and some root molds filled with limonite	5.0
10. Clay, plastic, dark gray	0.4
9. Clay, slightly silty, light gray, stained light yellow	1.3
8. Sandstone, yellow and gray	0.6
7. Siltstone, light gray, hard	5.0
6. Clay, light gray, stained light yellow	1.3
5. Silt, light gray and yellow	1.2
4. Sandstone, fine-grained, buff to yellow to light gray, horizontally bedded	2.1
3. Silt, clayey, very light gray	1.6
2. Sandstone, fine-grained, yellow	0.8
1. Silt, clayey, in alternating beds gray buff and yellow in color	4.0
Total thickness of Dakota formation exposed	25.8

Section of a part of the Dakota formation on the west side of Spring creek, on the farm of Mrs. E. G. Hain, in the NE¼ NE¼ sec. 20, T. 25 S., R. 23 W.

(Section measured by Norman Plummer and John Romary)

	Thickness, feet
Graneros shale	
Kaolin, white	0.2
Shale, black	5.3
Dakota formation	
10. Sandstone, buff	0.2
9. Clay, slightly silty, light gray; containing root channel filled with limonite	1.0
8. Silt and very fine-grained sandstone, yellow to buff, containing numerous root channels filled with brown limonite	2.3
7. Clay, platy, very dark gray, stained light yellow	0.7
6. Silt, gray	0.3
5. Clay, plastic, very light gray	0.8
4. Clay, plastic, gray, containing clusters of hematite and limonite grains about the size of buckshot	1.3
3. Clay, plastic, gray, containing limonite and some hematite in the form of yellow powdery dust near the base	4.3
2. Siltstone, hard, light gray to buff (has been quarried)	8.5
1. Clay, light gray, with clusters of purplish hematite and limonite grains about the size of buckshot	1.5
Total thickness of Dakota formation exposed	20.9

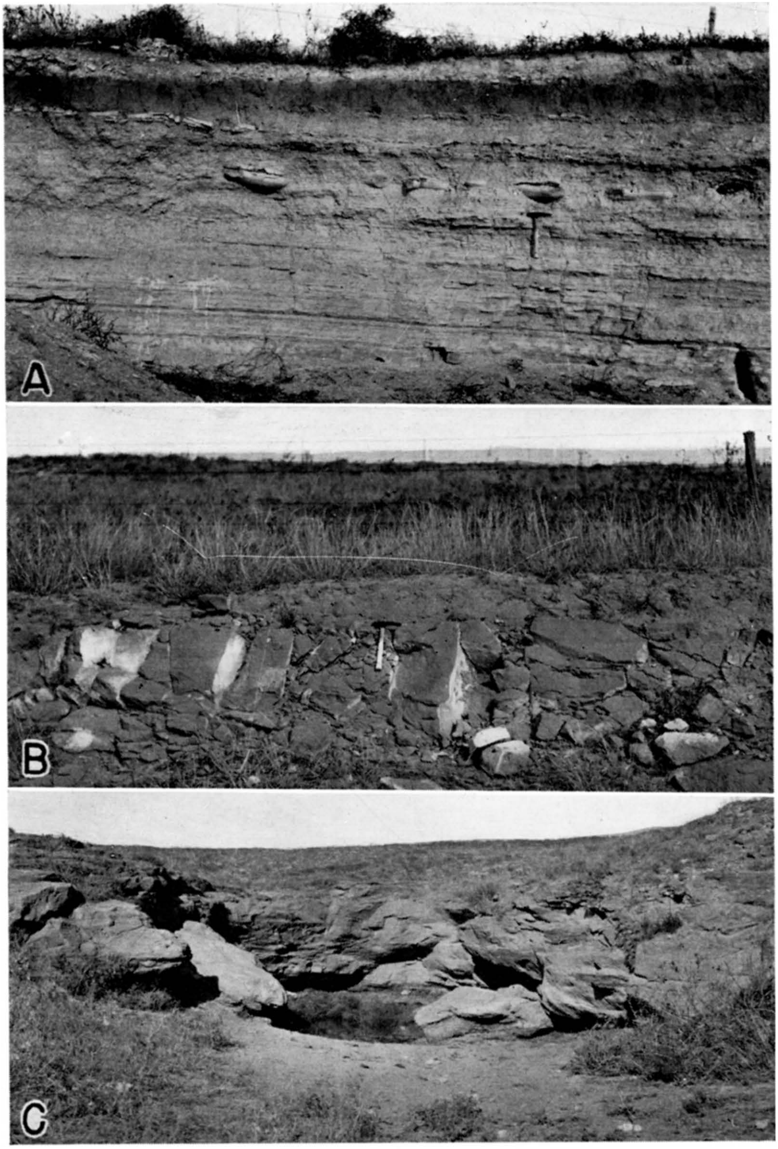


PLATE 12. A, Jetmore chalk member of the Greenhorn limestone. Exposed in quarry north of Highway 154 about 5 miles northwest of Ford in the SW¼ SW¼ sec. 14, T. 27 S., R. 23 W. B, Exposure of the Dakota formation. Along north side of Highway 154 about 2½ miles northwest of Ford in the NW¼ sec. 30, T. 27 S., R. 22 W. C, Dakota formation exposed in the "Black Pool." Along the north side of Arkansas river about 4 miles northeast of Ford in the SE¼ NE¼ sec. 35, T. 27 S., R. 22 W.

Distribution and thickness.—The Dakota formation, which is the oldest formation exposed in the county, crops out along Sawlog creek from a point about 1½ miles above the bridge on U. S. Highway 283 to the Ford-Hodgeman county line, and along several of its tributaries including Five-mile creek and Spring creek. Small exposures occur on the south side of Cow creek at the Hain quarry in the SW¼ sec. 10, T. 26 S., R. 22 W., and in sections 14 and 15 adjoining. It is also exposed on the north side of U. S. Highway 154 about 2½ miles northwest of Ford in the NE¼ NW¼ sec. 30, T. 27 S., R. 22 W. (pl. 12B). East of Ford, Arkansas river has cut into the Dakota giving rise to exposures in a narrow belt on the north side of the river extending from about the center of sec. 34, T. 27 S., R. 22 W., to the east line of sec. 30, T. 27 S., R. 21 W. (pl. 1, 120). The Dakota was encountered in 11 of the 21 test holes put down during the investigation (fig. 2), in 4 irrigation wells southeast of Ford (417, 419, 420 and 421), in 3 irrigation wells in the southwestern part of the county (507, 510 and 522), and in many wells in the northeastern quarter of the county (log 25). The Dakota appears to be absent in some parts of southeastern Ford county, perhaps as a result of post-Dakota erosion, or possibly uneven deposition (see log 15 and cross section B-B^1, pl. 5). It is present at or below the surface nearly everywhere else in the county.

The base of the Dakota is not exposed at any of the outcrops in the county so that the maximum thickness of the formation is not definitely known. A complete section of the Dakota, penetrated in test hole 19, in the southwestern part of the county, was found to be only 56 feet thick, and the Dakota is known to be even thinner in some places in the southern part of the county. In the northeastern part of the county the Dakota formation attains greater thickness, and appears to be about 235 feet thick in a well (34) at Spearville (log 25).

Age and correlation.—The age and correlation of the Dakota formation are discussed under the heading Historical summary.

Water supply.—The Dakota formation, known elsewhere generally as the Dakota sandstone, is an important water-bearing formation in several other states and is a notable source of artesian water. In Ford county the Dakota formation is the most important water-bearing formation below the Ogallala formation. In places where the Ogallala formation is thin and fails to produce water, as in parts of northern Ford county, the wells generally are drilled into the Dakota formation.

The Dakota formation furnishes water to flowing artesian wells in Sawlog valley in sections 13, 14, 23, and 24, T. 24 S., R. 23 W., in Hodgeman county, just north of Ford county (Moss, 1932, pp. 45-46). The wells start near the top of the Dakota and obtain the artesian water at a depth of about 200 feet. In Ford county the water in the Dakota formation generally is under some artesian head, but in most places the head is not sufficient to produce flowing wells. The Dakota is believed to supply, in part, one flowing well (520) in the southwestern part of the county. The source of several other flowing wells in this part of the county is not definitely known, but is believed to be the overlying sands and gravels of Tertiary and Pleistocene age (p. 51). The possibility of obtaining flowing wells in the Dakota in the Arkansas valley near the Edwards county line is discussed under Artesian conditions.

Many of the domestic and stock wells in the northeastern part of the county obtain water from the Dakota formation. Most of the wells range in depth from about 50 to 250 feet, but well 34, formerly used as a source of supply for the Atchison, Topeka and Santa Fe Railway at Spearville, was drilled to a depth of 389 feet (see log 25). The wells that obtain water from the Dakota formation in the southwestern part of the county range in depth from about 175 to about 275 feet. The sandstone in the Dakota is fine-grained and does not yield water as freely as either the Ogallala or the alluvium. Under favorable conditions, however, a well in the Dakota might yield as much as 250 gallons a minute (p. 120).

Five waters from the Dakota formation that were analyzed had from 239 to 464 parts per million of total dissolved solids, except for one sample, which had 4.8 parts of iron. Four of the five waters had two or more parts of fluoride.

GRANEROS SHALE

Character.—The Graneros shale, which overlies conformably the Dakota formation, consists of bluish-gray, noncalcareous clay-shale with a few thin beds of sandstone and sandy shale. It is less calcareous than the overlying Lincoln limestone member of the Greenhorn limestone. The contact at the base of the formation, however, is less distinct because generally there is a transitional zone between the Graneros and the underlying Dakota formation. In places where the sandstones in the upper part of the Dakota are massive, the contact is placed at the top of the sandstone, but in places where the upper part of the Dakota is thin-bedded and shaly the contact is recognized by a change from dark-colored argillaceous shale containing selenite crystals above to a blue sandy shale below.

The Graneros shale is generally dark bluish-gray to black in color, but it contains numerous flakes of yellow sandstone and an abundance of selenite crystals. Outcrops of the shale generally are strewn with these transparent crystals, some of which are six inches or more in length. Many thin lenses of sandy shale, sandstone, sandy limestone, and ironstone concretions are interbedded in the shale. The base of the Graneros shale commonly is marked by ferruginous concretions or thin-bedded layers of ironstone. The following section was measured on the west side of a tributary drainage to Sawlog creek in the northern part of the county (pl. 13A).

Section of the Graneros shale near the middle of section 10, T. 25 S., R. 23 W.

	Thickness, feet
Lincoln limestone member of the Greenhorn limestone	
Graneros shale	
11. Shale, clayey, fissile, bluish-gray, containing yellow to olive-green streaks and scattered chips of limonite	3.0
10. Shale, sandy gray, containing interlaminated stringers of olive-green fine-grained sandstone and shale	4.5
9. Shale, clayey, bluish-gray, similar to bed 11, but containing also thin beds of gray platy sandstone	5.5
8. Shale, fissile, gray to black, containing a lentil of rusty brown sandstone at the top and thin interstratified stringers of olive-green to gray to brown shaly sandstone	7.5
7. Shale, papery fissile, gray to black, containing considerable gypsum, some interlaminated shaly sandstone, and near the top, limonitic shaly sandstone	5.5
6. Shale, similar to bed 8, but containing a few thin seams of selenite near the base	2.0
5. Sandstone, hard, reddish-brown, limonitic, thin-bedded. Forms slight ledge in face of exposure	0.5
4. Shale, fissile, gray to black, containing interlaminated stringers of sandstone and scattered thin seams of selenite crystals	2.5
3. Shale, fissile, gray-black, containing selenite crystals	5.7
2. Shale, sandy, gray to black, containing large angular clusters of selenite crystals, some 5 to 6 inches in length, and, near the base, stringers of grayish-brown shaly sandstone	2.0
1. Shale, sandy, dark gray, containing 3 or 4 beds of ironstone concretions averaging 3 inches thick at base	4.0
Total thickness of Graneros shale exposed	42.7

Distribution and thickness.—The Graneros shale is exposed along Sawlog creek and several of its tributaries in the northern part of Ford county, notably in the northeastern part of T. 25 S., R. 24 W.,

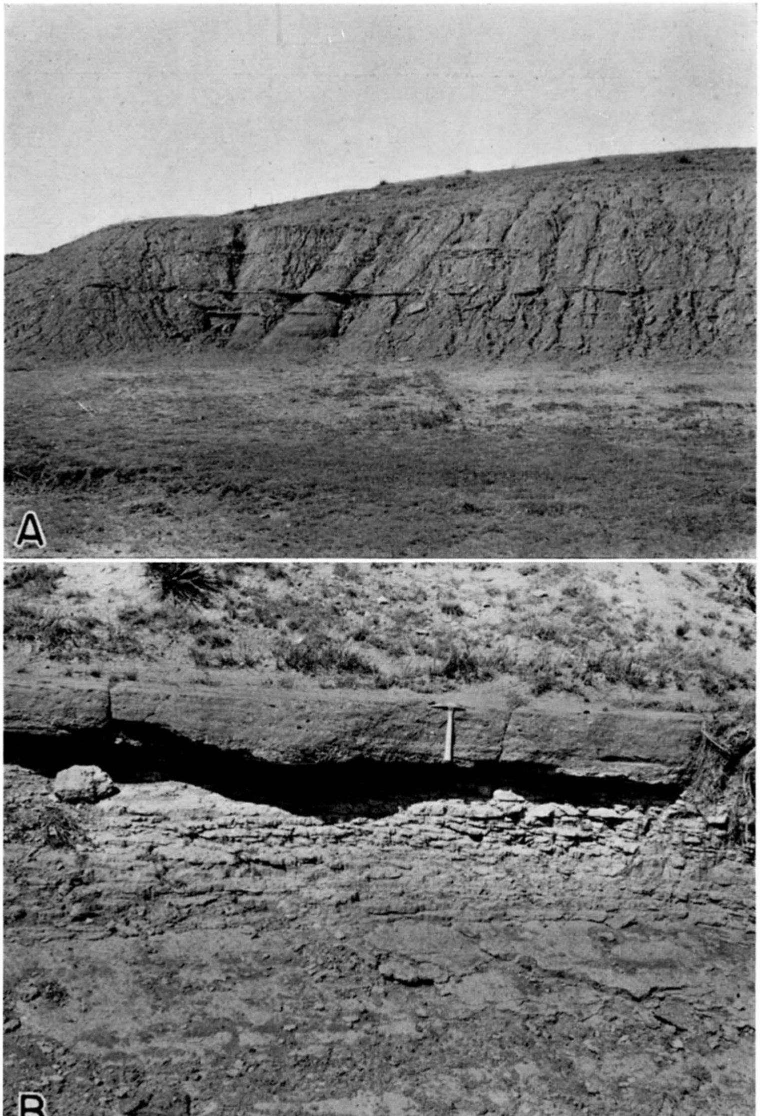


PLATE 13. A, Exposure of Graneros shale. West side of tributary drainage near the middle of sec. 10, T. 25 S., R. 23 W. About 14 feet of the overlying Lincoln limestone member of the Greenhorn limestone is exposed in the grass-covered slope above the cut bank. B, Upper part of Dakota formation. Exposure is about 100 yards north of Plate 13 A, farther down the same drainage. Top ledge is cross-bedded conglomeratic sandstone and is underlain by rusty-yellow, very fine-grained sandstone.

and in the northwestern part of T. 25 S., R. 23 W. It generally forms a slope between ledges of the Greenhorn limestone and the Dakota formation. Approximately 17 feet of the Graneros is exposed on the south side of Sawlog creek in the NE¼ sec. 9, T. 25 S., R. 24 W., but west of this point it passes under cover and only the basal members of the Greenhorn limestone are exposed. In some parts of the county the Graneros is very thin, and it is absent entirely in the Hain quarry, in the SW¼ sec. 10, T. 26 S., R. 22 W., where the Ogallala formation rests directly on the Dakota formation, and in exposures about 2½ miles northwest of Ford and on the north side of the Arkansas river east of Ford. A thin remnant of the Graneros is exposed in the slope between the Dakota formation and the overlying Ogallala formation on the east side of Fivemile creek in the NW¼ NW¼ sec. 30, T. 25 S., R. 23 W. The Graneros shale was encountered in test holes 1, 2, 5, and 8 (fig. 2) and in many wells in the northern and central parts of the county.

The thickness of the Graneros in Ford county ranges from a few feet to about 43 feet, and was 21 to 39 feet thick in four of the test holes (1, 2, 5, and 8). According to Moss (1932, p. 31), the Graneros in Ness and Hodgeman counties ranges in thickness from about 21 to 36 feet. He suggests that the variable thickness of the Graneros probably is due to its having been deposited on the slightly irregular surface of the underlying Dakota formation, and that this irregular surface may have resulted from uneven deposition, erosion of the top of the sandstone, or from compaction within the Dakota formation. According to Bass (1926, p. 36), the Graneros is about 32 feet thick in Ellis county, 40 feet in Russell county, and 61 feet in western Kearny and Hamilton counties.

Age and correlation.—Although no fossils were noted in the drill cuttings the Graneros shale was readily identified in test holes by the argillaceous, noncalcareous character of the black shales that comprise the formation, and by the stratigraphic position of these shales above the Dakota formation. The cuttings from the Graneros comprise rubbery chips of soft, sticky, black clay-shale containing a few chips of gypsum and bentonite. The cuttings differ from those obtained from the overlying slabby limestones and chalky shales of the Greenhorn limestone and are less sandy and darker-colored than those from the underlying blue shales of the Dakota formation.

Water supply.—No wells are known to derive water supplies from the Graneros shale in Ford county. Because of the relatively low permeability of most of the formation, the quantity of water contained in the shale and interbedded stringers of sandstone doubtless would be small, and movement of water through the formation would be confined largely to bedding planes and fissures. Because of the abundance of gypsum throughout the formation, any water contained in it is likely to be highly mineralized and very bitter to the taste.

GREENHORN LIMESTONE

Character.—The Greenhorn limestone consists of a lower series of thin chalky and crystalline limestone and bentonitic clay and an upper series of interbedded chalky shales and chalky limestones capped by the "Fence-post" limestone. The shales in the upper part of the formation contain several zones of limestone concretions (pl. 12A). On fresh exposure the limestones and shales are dull gray in color and the bentonitic clays are light pearly gray. Upon weathering, however, the color of the limestones changes to tan, buff, or orange-tan, and the shales weather tan or light gray in the upper part and tan or orange-tan in the lower part. The basal part of the Greenhorn weathers to a distinctive rusty-brown or orange color.

Previous workers in western Kansas (Rubey and Bass, 1925, p. 45) have subdivided the Greenhorn into four members which from top to bottom are the Pfeifer shale, Jetmore chalk, Hartland shale, and Lincoln limestone. In Ford county the upper two members are easily recognized, but it is difficult to distinguish between the lower two members.

The Pfeifer shale member consists of beds of cream-colored to yellow chalky shale, some beds of thin chalky limestone, and some concretions of limestone (pl. 14C). The "Fencepost" limestone at the top of the member is resistant to erosion and generally forms a ledge.

The Jetmore chalk member, which underlies the Pfeifer shale member, consists of about 23 feet of interbedded chalky shale and chalky limestone. The beds of chalky limestone in this member are harder than those of the overlying Pfeifer member and form the most resistant part of the Greenhorn. The Jetmore member is capped by a hard, fossiliferous, chalky bed of limestone approximately one foot thick, and because it is very resistant and contains an abundance of the Pelecypod *Inoceramus labiatus* it has been called "shell rock." The shell rock breaks into large slabs which cover the slopes below.

The Hartland shale member consists of beds of calcareous shale, thin beds of chalky limestone, and generally weathers light tan or

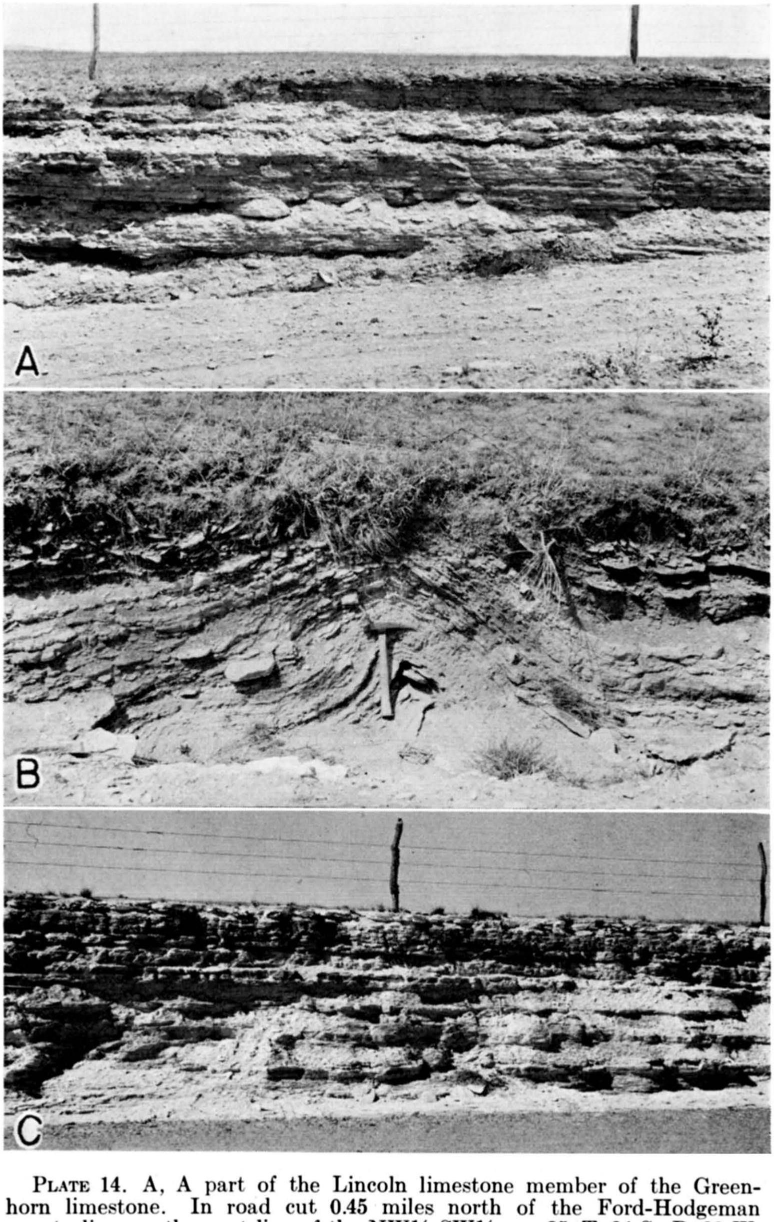


PLATE 14. A, A part of the Lincoln limestone member of the Greenhorn limestone. In road cut 0.45 miles north of the Ford-Hodgeman county line, on the west line of the NW¼ SW¼ sec. 35, T. 24 S., R. 23 W. B, Small fold in the Lincoln limestone member of the Greenhorn limestone. In road ditch on the east line of the SE¼ NE¼ sec. 3, T. 25 S., R. 23 W. C, A part of the Pfeifer shale member of the Greenhorn limestone. In road cut on the south side of section road in the NW¼ NE¼ sec. 17, T. 25 S., R. 25 W.

gray. The Lincoln limestone member, which underlies the Hartland member, consists of beds of chalky shale alternating with thin beds of chalky limestone, and, near the base, beds of hard, thin-bedded, finely-banded, dark-colored limestone (pl. 14). When freshly broken, the beds of dark-colored limestone near the base of the Lincoln member have an odor resembling petroleum.

The four members of the Greenhorn are not all exposed at any one place in Ford county, therefore sections measured at several different places were correlated in order to obtain the total thickness of the formation. The following section, at a point about eight miles northwest of Dodge City, gives the character of the lower part of the Pfeifer shale member and the complete Jetmore chalk member.

Section of the Pfeifer shale and Jetmore chalk members of the Greenhorn limestone, in a quarry in the SE¼ SW¼ sec. 11, T. 25 S., R. 25 W.

	Thickness, feet
Ogallala formation	
Greenhorn limestone	
Pfeifer shale member	
29. Limestone, chalky, containing a ferruginous band near the middle, resembling casts of inoceramus replaced by limonite, very fossiliferous, weathers yellow to brown	0.5
28. Shale, limy, white to cream-colored, very fossiliferous	1.7
27. Limestone, chalky, hard, tan to white, contains abundant fossils; similar to No. 25	.7
26. Shale, chalky, white to cream-colored	.4
25. Limestone, chalky, tan to cream-colored, fossiliferous—contains abundant *Inoceramus labiatus* (represents the upper or main quarry level)	6.0
24. Shale, chalky, white	.5
Total thickness of Pfeifer shale member exposed	9.8
Jetmore chalk member	
23. Limestone, hard, chalky, white to cream-colored, has tendency to break off in flat blocks	1.1
22. Shale, chalky, white	.9
21. Limestone, relatively hard, chalky, tan to cream-colored, and interbedded chalk shale	2.6
20. Shale, chalky, gray, very fossiliferous, grades laterally into slabby thin-bedded limestone, weathers light yellow to tan	1.0
19. Limestone, chalky, white to cream-colored, fossiliferous	.5
18. Shale, chalky, white to gray, grades into bed 19	1.3
17. Limestone, chalky, white to gray, stained with limonite	.7
16. Limestone, chalky, dark bluish-gray on fresh exposure, platy in upper part, breaks off in large flat-sided slabs	1.8
15. Shale, chalky, bluish-gray on fresh exposure	1.5
14. Limestone, chalky, white, weathers into platy slabs	.9
13. Shale, chalky, bluish-gray on fresh exposure	.7

		Thickness, feet
12.	Limestone, chalky, white	.3
11.	Shale, chalky, bluish gray on fresh exposure, somewhat fissile; similar to bed 13	.6
10.	Limestone, chalky, white, has tendency to weather into platy slabs	.9
9.	Shale, chalky, yellow to tan	.5
8.	Shale, chalky, bluish-gray on fresh exposure, fossiliferous—containing abundant *Inoceramus labiatus,* breaks off in plates resembling slate	2.7
7.	Shale, chalky, yellow to buff, fossiliferous	.4
6.	Limestone, hard, yellow to white, streaked with brown stains of limonite	.5
5.	Shale, chalky, yellow to buff, fossiliferous, banded with seams of limonite, weathers tan to flesh-colored, similar to beds 7 and 9	1.1
4.	Limestone, chalky, white, weathers yellow to buff	.2
3.	Shale, chalky, yellow, weathers buff to flesh-colored	1.0
2.	Limestone, chalky, gray to white, weathers yellow to tan	.6
1.	Shale, chalky, buff to tan, weathers flesh-colored, contains *Inoceramus labiatus*	1.0
	Total thickness of Jetmore chalk member	22.8

In the above section the base of the Jetmore member is not sharply defined, the chalky limestone beds in the lower part of the Jetmore becoming thinner and less numerous and grading into the calcareous shale of the underlying Hartland shale member.

Some of the beds of limestone in the Greenhorn have been quarried extensively and used for fence posts, flagging, and building stone. The "Fencepost" limestone is used chiefly for fence posts but has also been used for building road culverts, bridges and other works. It is remarkably persistent and very uniform in thickness—which ranges from about 7 to 9 inches. It is usually soft when quarried but case-hardens on exposure.

The Jetmore chalk member is quarried in the SW¼ SW¼ sec. 14, T. 27 S., R. 23 W. (pl. 12 A), and a 5-inch bed of chalky limestone about 20 feet below the base of the Jetmore member has been quarried for building stone.

Distribution and thickness.—The Greenhorn limestone is exposed along Sawlog creek and several of its tributaries in northern Ford county. Outcrops of the upper part of the formation extend west along Sawlog creek to within about 7 miles of the northwest corner of the county where it is overlapped by the Ogallala formation. The lower part of the formation is well exposed along Duck creek, the outcrop area extending southwest along the creek to a point about 5 miles north of Dodge City, and along Sawlog creek and its tributaries from a point about due north of Dodge City to the point where Sawlog creek leaves the county, 3 miles east of U. S. Highway 283. Exposures of the upper part of the formation occur in the heads of tributaries to Coon creek, about 2½ miles northeast of Wright in sections 2, 10, and 11, T. 26 S., R. 23 W., and in the bluffs on the north side of the Arkansas valley in sections 14, 15, 23 and 24. A part of the Lincoln member is well exposed in a road cut about one-half mile north of the Ford-Hodgeman county line, on the west line of the NW¼ SW¼ sec. 35, T. 24 S., R. 23 W. (pl. 14A).

It is known from test drilling that the Greenhorn limestone underlies much of the northern part of the county and a large area in the southern part of the county on the uplands between Mulberry creek and the Arkansas valley. Thin remnants of the Greenhorn were encountered above the Graneros shale in some of the test holes in the Arkansas valley, but the Greenhorn is believed to be entirely absent in the Arkansas valley east of Ford. The Greenhorn was encountered in 10 of the 21 test holes put down in the county (fig. 2) but was not encountered in test holes 4 and 5 in the northern part of the county, 8 in the Arkansas valley, 19, 20, and 21 in the southwestern corner of the county, and in test holes 10, 14, 15, 16 and 17 in the southern and southeastern part of the county. Thus, the Greenhorn appears to have been removed by erosion in a large area south of Mulberry creek and east of U. S. Highway 283, including the entire area south of Arkansas river and east of Ford.

The thickness of the Greenhorn limestone in Ford county is about 123 feet, but the entire thickness is not exposed at any one place. The total thickness of the Pfeifer shale member is not definitely known, but is believed to be about 20 feet, as it is in western Hodgeman county (Moss, 1932, p. 28). The Jetmore chalk member is about 23 feet thick, and the Hartland and Lincoln members have an aggregate thickness of 80 feet in sec. 5, T. 25 S., R. 24 W.

Age and correlation.—Where the Greenhorn limestone is exposed at the surface in Ford county, the identification of the individual members on the basis of their lithology and stratigraphic position is relatively simple. At the base of the formation there is a sharp lithologic break between the thin beds of hard crystalline limestone at the base of the Lincoln member and the underlying beds of soft, noncalcareous clay shale of the Graneros shale. The top of the formation is marked by the top of the "Fencepost" limestone.

Practically all of the beds of the Greenhorn limestone contain Upper Cretaceous fossils, the most abundant and characteristic fossil being *Inoceramus labiatus*. The overlying Fairport chalky shale member of the Carlile shale (not present in Ford county) contains a few specimens of this pelecypod, but none are found below the Greenhorn.

Exposures of the Greenhorn in Ford county are correlative with similar exposures in Ness and Hodgeman counties, described by Moss (1932, pp. 26-31). Along the Arkansas valley in Kearny and Hamilton counties, beds equivalent to the Pfeifer and Jetmore members in Ford and Hodgeman counties have been included in the Bridge creek limestone member of the Greenhorn (Bass, 1924, pp. 34, 35). There the Bridge creek member is 74 feet thick and is underlain by the Hartland and Lincoln members.

In areas where the Greenhorn is buried it is possible to segregate the upper part of the Greenhorn from the lower part by a study of the drill cuttings from test holes, but it is difficult to differentiate between the 4 separate members. In Ford county the Greenhorn is the youngest Cretaceous formation; hence, there is no confusion with the overlying Fairport chalky shale member of the Carlile shale which is similar in character. The base of the Greenhorn limestone is readily identified from drill cuttings by a change from the chips of calcareous shale and limestone of the basal part of the Greenhorn to the chips of noncalcareous, softer and darker clay-shale of the Graneros shale.

Water supply.—Very few wells have been drilled into the Greenhorn limestone for water supply in Ford county. It is likely that the water-yielding capacity of the formation is low, and very small supplies of comparatively hard water may be expected from wells penetrating this formation. The hardness of the three samples of water (wells 55, 352, and 353, in table 14) from the Greenhorn ranged from 358 to 546 parts per million.

Tertiary System

PLIOCENE SERIES

Ogallala Formation

Character.—The Ogallala formation is composed of structureless silt and fine sand, together with some coarse sand and gravel, and ranges in color from buff to gray to white. The coarser sediments are present at all horizons but are most prominent in the lower part of the formation, the part that yields water most freely to wells.

Sand constitutes the principal material of the Ogallala formation and ranges in texture from fine- to coarse-grained, some of the coarser material containing scattered pebbles and thin beds of pebbles. The pebbles and grains are composed chiefly of granite, but there are a few pebbles of chert, limestone, and basic igneous rock. Quartz and feldspar generally make up about 95 percent of the mineral content of the sediments.

The finer materials of the Ogallala are composed chiefly of silt and generally contain only minor amounts of clay. Lenses or beds of sandy silt occur in all parts of the formation but principally in the upper part. The color of the silt ranges from gray to buff to light tan.

The gravels of the Ogallala comprise mainly pebbles of limestone, sandstone, and ironstone, but also contain pebbles of quartz and quartzite. The coarse gravel near the base of the Ogallala in the Arkansas valley in Ford county comprises mainly water-worn pellets of Greenhorn limestone but contains some pebbles of sandstone and ironstone that probably were derived from the Dakota formation. The occurrence of pebbles of this type indicates that locally at least some of the Ogallala sediments were derived from the erosion of Cretaceous bedrock in nearby areas. Smith (1940, pp. 42, 43) described two distinct facies of gravel in the Ogallala formation, one composed principally of sandstone, ironstone and quartzite, and the other made up mainly of crystalline igneous and metamorphic rocks. The former facies occurs at the base of the formation and the latter is widespread along the Arkansas valley in outcrops above the base of the formation. The sandstone-ironstone-quartzite facies is composed of material similar to that found in the Dakota formation and other Cretaceous formations; whereas, the granite facies that occurs above the base of the formation is composed of granite, feldspar, quartzite, quartz, felsite and other crystalline igneous and metamorphic rocks.

The Ogallala formation is characterized by lenticular bedding; thus, individual beds of sand or gravel are not continuous over wide areas, but generally are discontinuous lenses that may grade laterally into finer materials such as silt or clay, in some places within relatively short distances. The deposits range from those that exhibit definite bedding to those that show no bedding whatever. The structureless layers are commonly found in the upper part of the formation, are rather fine-grained, and contain some silt and small amounts of clay and lime. Irregular limy concretions are abundant in these layers, typical exposures of which occur in the bluffs on the north side of U. S. Highway 154, about one-half mile east of Fort Dodge. The color of this structureless part of the Ogallala ranges from gray to buff to light tan.

In many places the deposits are consolidated by calcium carbonate, forming beds of caliche. In some places the cemented beds resemble true limestone; elsewhere they may consist of sand and pebbles imbedded in a lime matrix. The cemented beds of the Ogallala have long been called "mortar beds," and in many places the "mortar beds" are highly cross-bedded (pl. 15). Cemented beds occur in the Ogallala at many places, but are most common in the upper part of the formation.

The character of the Ogallala formation as revealed by drilling is illustrated by the logs of wells and test holes, pages 206 to 243. Although some of the individual beds have been described in the logs as clay, only minor amounts of clay are known to occur in the Ogallala formation. Some of the beds of silt are described by drillers as sand or clay or as combinations of both, and some beds of different texture are described simply as sand. The finer sands, sandy silts, and limy clays have been lumped together and called "magnesium and clay" by some drillers. The term "magnesia rock" appears frequently in drillers' logs and generally implies a hard, dense, lime-cemented bed. The terms "gyp," "gyp and sand," and "gyp rock" also have been used by some drillers in describing the more resistant lime-cemented beds encountered in the Ogallala. The upper unsaturated part of the formation consisting of fine sand, sandy silt, and some clay is described by some drillers as "dry sand" or as "fine packed sand." When coarser grains are imbedded in the matrix the material has been described by some as "coarse packed sand." The terms "sand rock" and "cemented sand" given in some of the drillers' logs refer to beds of sand and gravel that have been more or less cemented with calcium carbonate.

Subdivisions.—In much of western Kansas the top of the Ogallala formation is formed by the top of the "Algal limestone," which marks the top of the middle Pliocene (Elias, 1931, pp. 136-143; Smith, 1940, pp. 44-46; and Frye and Hibbard, 1941, pp. 404, 405). In the Meade basin adjoining the southwestern corner of Ford county, however, beds that have yielded upper Pliocene fossils (Hibbard. 1938, p. 241) occur above the middle Pliocene beds. Smith (1940, p. 95) named these beds the Rexroad formation, from exposures on Rexroad ranch in south-central Meade county from which Hibbard collected the Rexroad fauna. Frye and Hibbard (1941, p. 407), however, have pointed out that in the central part of the

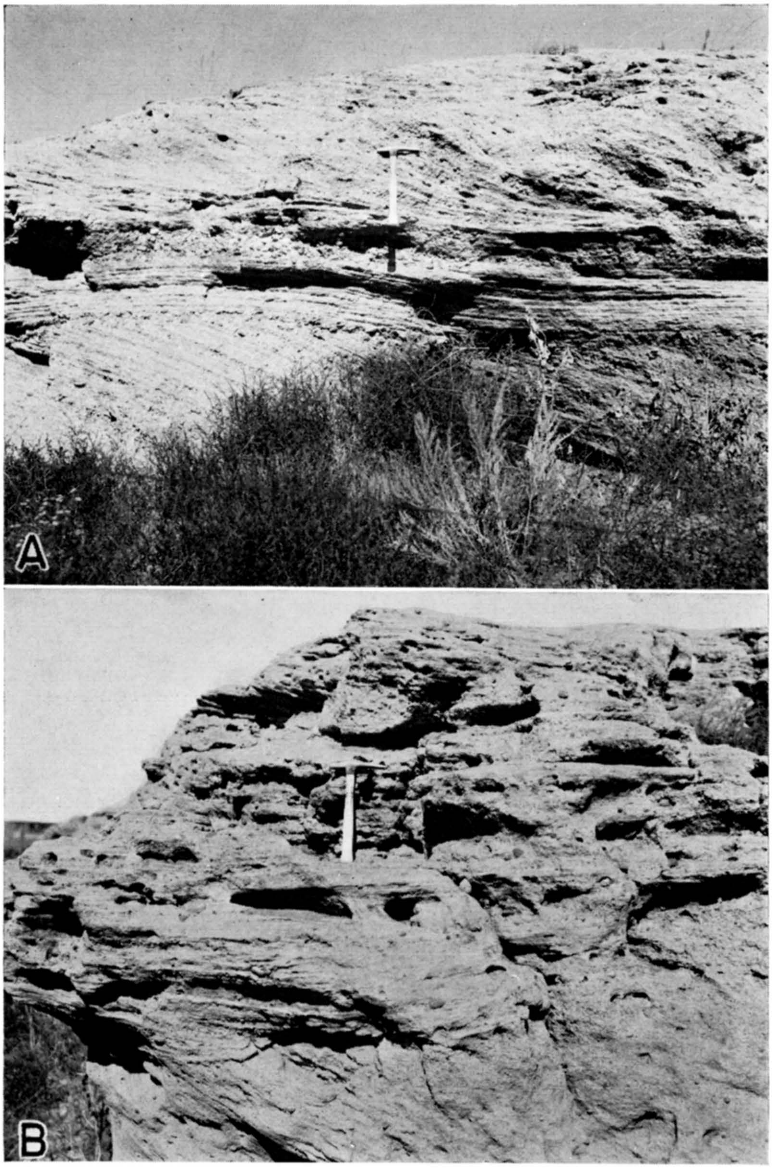


PLATE 15. A, Typical "mortar bed" of the Ogallala formation showing the cross-bedded structure. On the north side of Arkansas river about 5 miles west of Dodge City in the NW corner sec. 25, T. 26 S., R. 25 W. B, Closer view of the same exposure showing the pitted character of the weathered surface.

Meade basin these beds conformably overlie middle Pliocene deposits with no apparent break, and generally are indistinguishable lithologically from the middle Pliocene deposits of that area. For these reasons they have classified the deposits as the Rexroad member of the Ogallala formation. Deposits of sand and gravel and interbedded silt and clay, encountered in test drilling in southern Ford county, at the northern end of the Meade basin, occur at the same stratigraphic position as the Rexroad member of Meade county and may be equivalent in age. Fresh-water mollusks from some of these beds (described below) indicate, however, that some of the beds may be of Pleistocene age.

Distribution and thickness.—The Ogallala formation is exposed at or near the surface over most of the county north of Arkansas river in Ford county, the top of the formation being essentially the surface of the High plains (pl. 1). No exposures have been noted south of Arkansas river where the Ogallala formation is mantled by the Kingsdown silt. In certain areas deposits of dune sand overlie both the Kingsdown and the Ogallala. In much of the Arkansas valley west of the city of Ford, the Ogallala formation is covered with alluvium. East of Ford the Ogallala has been largely removed in the Arkansas valley, and the alluvium rests unconformably on the Dakota formation. The Ogallala is thin or entirely absent in the north-central part of the county in places where dissecting streams such as Sawlog creek and its tributaries have cut beneath the plains surface into the underlying Cretaceous bedrock.

The Ogallala formation ranges in thickness from a few feet to about 250 feet, and its maximum thickness is probably attained under the uplands north and west of Dodge City. The maximum thickness of the formation was not encountered in any of the test holes but is inferred from the geologic cross-sections (pl. 15). The thickness of the Ogallala in the 21 test holes drilled during the investigation ranged from about 22 feet in test hole 1 in the northeastern part of the county to 150 feet in test hole 6 in the Arkansas valley 1 mile west of Dodge City. The test drilling indicated that the Ogallala becomes progressively thinner toward the east and northeast.

Origin.—As pointed out under Geologic history the sediments comprising the Ogallala formation were deposited by heavily-laden streams that flowed from the Rocky Mountain region. The pebbles of igneous and metamorphic rocks in the gravels and abundance of quartz and feldspar in the sands are believed to have been derived from the Rocky Mountains. Locally, the basal gravels also contain some reworked material from less distant sources, including water-worn fragments of Greenhorn limestone and pebbles of sandstone and ironstone from the Dakota formation. Much of this material probably was derived from Cretaceous rocks in or just west of the county.

The origin of the abundant calcium carbonate in the Ogallala has been discussed by Smith (1940, p. 79) who concluded that—

> the transported calcareous matter in the Ogallala originated mainly, if not only, in the Rocky Mountain area from weathering of Paleozoic limestone and calcic minerals in the crystalline rocks. . . . Additional lime may have been provided also by weathering *in situ* after deposition.

Smith also suggested that the silt and clay of the Ogallala probably were derived from soils and weathering products in the mountain area and to a lesser extent from the wearing down of coarser materials in transit. The coarser beds of sand and gravel represent channel deposits and the finer materials represent floodwater deposits formed by the overflow of shallow channels that perhaps approached the character of sheet-floods locally.

The sandstone and conglomerate in the Ogallala represent beds of sand and gravel that have been cemented by underground waters. Deposits of sandy silt, cemented with calcium carbonate, and often referred to as caliche, probably are a product of surficial calichification formed during a relatively long pause in deposition, at a time when streams had shifted to some other part of the region. The concentration of calcium carbonate, in the soil zone, by surficial processes was accomplished during such periods, and was halted by recurring periods of deposition to give rise to caliche zones at varying intervals throughout the formation.

There are at least 3 different hypotheses to account for the origin of the capping limestone at the top of the Ogallala. Elias (1931, p. 41) suggested a lacustrine origin and stated that the limestone was deposited on the nearly flat bottom of a very large and very shallow lake at the close of Ogallala time.

Gould and Lonsdale (1926, pp. 29-33) advanced the caliche hypothesis for the capping limestone in the Oklahoma area. Smith (1940, pp. 91, 92) suggested that:

> Possibly both hypotheses are partly right, and both caliche and lacustrine limestone are present in different parts of the region, possibly gradational into one another.

Theis (1936) suggested that the capping limestone was deposited, either by inorganic or by organic agencies, in unconnected pools that resulted from the flooding of shallow depressions by a rising water table under conditions of a cooling climate and probably increasing precipitation associated with the approach of Pleistocene time. For a much more detailed discussion of the origin of the Ogallala formation the reader is referred to the report by Smith (1940, pp. 77-94).

Age and correlation. — The Ogallala formation originally was named and described by Darton (1899, pp. 732, 734) and its age was given as late Tertiary, or Pliocene(?). Darton later (1920, p. 6) designated the type locality near Ogallala station in western Nebraska. The conclusions of later workers regarding the age and correlation of the Ogallala formation in western Kansas have been summarized by Smith (1940, pp. 73-74).

The Ogallala formation is classified as Pliocene by the United States Geological Survey. Smith (1940, pp. 75, 76) concluded that the Ogallala of southwestern Kansas, insofar as it is represented by exposures at the surface, may be assigned to middle Pliocene age. According to this definition, the top of the Ogallala formation is marked by the top of the capping limestone. Smith considered the overlying beds that have yielded upper Pliocene fossils as a separate formation which he called the Rexroad formation (see p. 95). For reasons stated earlier all of the deposits below the Kingsdown silt and above the Cretaceous bedrock are included in the Ogallala formation, the upper (late Pliocene) part of the formation being segregated as the Rexroad member.

Few vertebrate fossils have been collected from the Ogallala formation in Ford county. A horse tooth that had been recovered from the Ogallala at a depth of 113 feet during the drilling of an irrigation well (402, see log 61) in the SW¼ sec. 6, T. 27 S., R. 26 W., was given by me to C. W. Hibbard who identified it as a right molar of *Pliohippus* cf. *interpolatus*. Schoff (1939, pp. 61, 62) reported that large collections of vertebrate remains taken from excavations in the vicinity of Optima and Guymon, Texas county, Oklahoma, were considered by Stovall to be middle Pliocene in age. According to Schoff, the fossils were found in the upper 100 feet of the formation.

Elias (1932, pp. 333-340) described fossil grass and hackberry seeds that were collected mostly from typical "mortar beds" of the Ogallala formation. In a later paper (Chaney and Elias, 1936) it was shown that certain of the fossil seeds are of widespread occurrence and have a short vertical range, making them useful as guide fossils. Fossil grass and hackberry seeds were collected by me from the Ogallala formation in Ford county, notably on the east side of Five-mile creek in the NW¼ NW¼ sec. 30, T. 25 S., R. 23 W., and on the east side of Spring creek in the SW¼ sec. 28, T. 25 S., R. 23 W. In both localities the seeds were collected from hard massive layers of cemented grit and coarse sand from 8 to 10 feet in thickness that formed abrupt benches along the sides of the valleys. At the first locality mentioned, the seeds were collected from beds about 15 feet above the top of the Dakota formation. From comparisons with forms described by Elias, the grass seeds are believed to be *Biorbia rugosa* and the hackberry seeds are believed to be *Celtis willistoni.*

The following fresh-water mollusks recovered from a test hole in the Rexroad member of the Ogallala formation were identified by Dr. Calvin Goodrich of the University of Michigan.

Fresh-water mollusks from test hole 21, in the NW corner sec. 36, T. 29 S., R. 26 W.

Depth below land surface, in feet	
132-135	*Gyraulus parvus* (Say)
135-138	*Gyraulus parvus* (Say)
138-151	*Gyraulus parvus* (Say)
151-157	*Gyraulus parvus* (Say), 1 specimen; 1 fragment apparently of a gastropod; 1 fragment apparently of bone; and 1 unidentified fragment.
157-164	*Gyraulus parvus* (Say), 1 specimen, and fragments possibly of a more mature specimen than this, or of a very young specimen of *Helisoma.*
167-170	Fragments of a small gastropod, possibly of the genus *Lymnaea,* certainly not of a shell with flattened spire such as *Gyraulus* or *Helisoma.*

These forms have been described from the Meade formation of Pleistocene age which overlies the Rexroad member in Meade county (Frye and Hibbard, 1941, pp. 413-415) so it is possible that some of the beds below the Kingsdown silt encountered in test holes in southwestern Ford county are of Pleistocene age. Due to the fact that beds believed to be equivalent to the Rexroad member of the Ogallala formation and of the Meade formation are nowhere exposed in Ford county; however, it is impossible to make any definite correlation on the basis of the data available.

Water supply.—In Ford county, as in many other parts of the High Plains, the Ogallala formation is the most important water-bearing formation. Most of the domestic and stock wells on the uplands, many of the irrigation wells, and all of the large industrial and public-supply wells derive water from the Ogallala formation. Even in the Arkansas valley, where water is available at shallow depth in the alluvium, many well owners have drilled their wells deeper to tap the Ogallala formation. All of the irrigation wells south of the Arkansas valley in Ford county obtain water from this formation.

The yields of wells tapping the Ogallala range from several gallons a minute from small domestic and stock wells to about 1,700 gallons a minute for some of the large industrial wells (369, 370 and 371). The largest yields from the Ogallala are obtained from the coarser materials, generally in the lower part of the formation.

The beds of the Ogallala formation once extended from the Rocky Mountains eastward to perhaps as far as the eastern third of Kansas, but they have been removed by erosion from much of the territory they once occupied. A much greater thickness of the formation may have been saturated at one time, but dissection by streams such as Arkansas river and Sawlog creek have cut below the zone of saturation and are draining part of the water from the formation.

In recent years there has been an increase in the number of wells tapping the Ogallala formation in the Arkansas valley in Ford county, largely as a result of increased demands for irrigation and industrial supplies.

The water from the Ogallala is hard. The analyses of typical waters from the Ogallala formation are shown in figure 20. Analyses of 45 samples of water collected from the Ogallala formation indicate that the hardness ranged from 171 to 276 parts per million and averages about 228 parts. The analyses also indicate that the amount of iron contained in these samples of water from the Ogallala ranges from 0.0 to 4.7 parts per million, but about half had less than .1 part per million. The fluoride content of these 45 samples ranged from 0.1 to 3.6 parts per million—28 samples of water from this group contained 0.5 parts per million or less of fluoride and 13 contained more than 1 part. The analyses indicate that the water from the Ogallala is well within the suggested safe limits for use in irrigation. The water in the Ogallala is generally softer than the water in the overlying alluvium.

Quaternary System

KINGSDOWN SILT

Character.—The Kingsdown silt consists mainly of light buff to brownish silt, clay, and fine sand, but contains some light-colored sand and gravel at the bottom, and at the top it grades upward into loess. Some of the beds contain small calcareous nodules. Probably a part of the silt is reworked loess. Most of the beds are even-bedded—some of the beds being finely and evenly laminated.

In most places the contact between the lower water-laid silt of the Kingsdown and the overlying loess is indistinguishable, making it difficult to differentiate between them. For this reason the Kingsdown silt, as redefined by Frye and Hibbard (1941, pp. 419, 420), locally includes loess at the top.

In Ford county the character of the Kingsdown silt is best revealed from the cuttings obtained from test drilling (see logs of test holes 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, and 21). The base of the formation is not exposed in Ford county, but the upper part of the formation is exposed along Mulberry and Rattlesnake creeks and their tributaries. On the basis of samples from test holes, the Kingsdown silt may be described as being made up predominantly of soft light brown to reddish-brown to light gray limy silt, but it also contains a few nodules and streaks of lime and, locally at the base, a few beds of sand and gravel. The Kingsdown silt drills rather easily as there are no hard cemented beds to impede the progress of the drill.

Distribution and thickness.—The areal extent of the Kingsdown silt in Ford county is shown in plate 1. The Kingsdown is widely exposed south of the Arkansas valley, the best exposures occurring along Mulberry creek and especially along the headwaters of Rattlesnake creek and its tributaries in the vicinity of Bucklin. Because the Kingsdown silt is relatively soft, it is commonly eroded to form a semibadland type of topography, with numerous branching, closely spaced gullies (pl. 16 A). Few exposures of the Kingsdown were found north of the Arkansas valley, and it is believed to occur only in isolated patches on the upland in this part of the county.

The reasons for the thinness of the Kingsdown north of the Arkansas valley are puzzling, but it is believed that this anomalous condition may be traceable to related tectonic causes. Smith (1940, p. 115) pointed out that drainage conditions at the time of deposition were undoubtedly different from those of the present and that, ultimately, deposition must have been due to a flattening or actual reversal of stream gradients as a result of crustal warping. He added that it was significant that the Kingsdown occurs in an area where:

(1) The general land surface is higher south of the Arkansas valley than on the north; (2) Arkansas river begins its swing northeastward into the very anomalous Great bend; (3) the Arkansas is perched as much as 180 feet higher

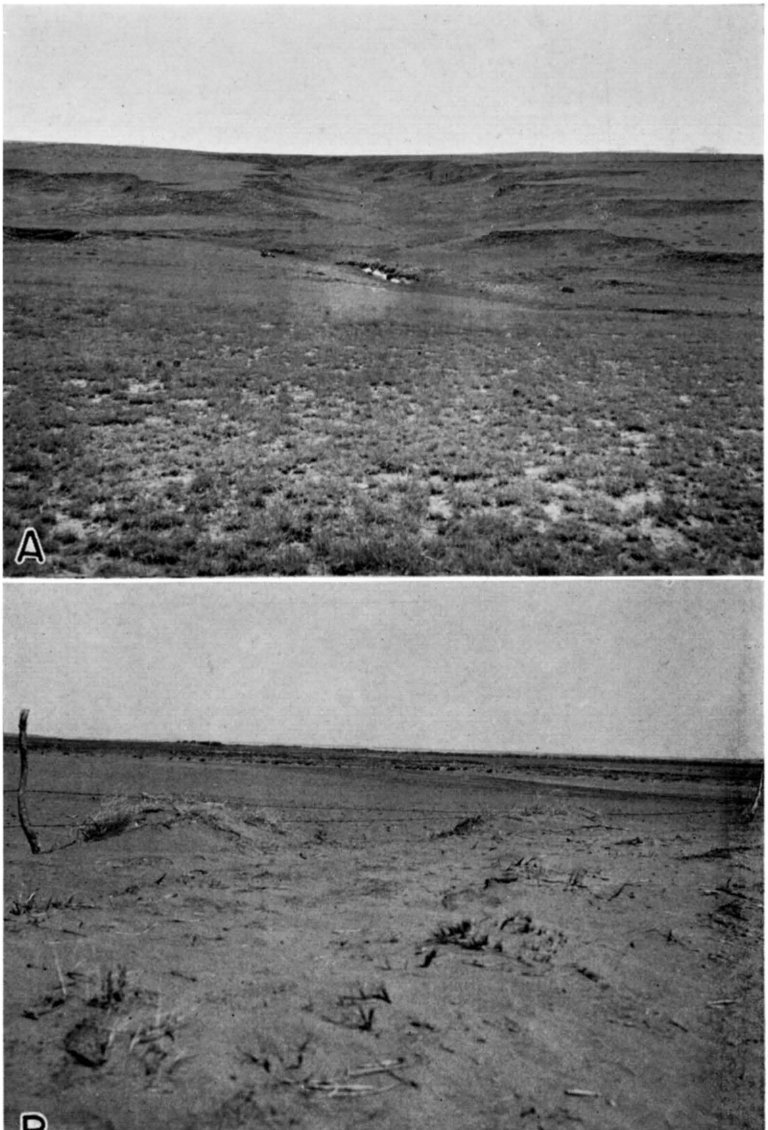


PLATE 16. A, Typical view of gulley erosion in the Kingsdown silt. Southwest of Ford in the SW¼ SE¼ sec. 34, T. 28 S., R. 23 W. B, Drifting sand in the sand hills bordering the south side of the Arkansas valley. South of Howell, along east side of sec. 31, T. 26 S., R. 26 W.

than its tributary valleys, Buckner creek, Pawnee river and Walnut creek, on the north; and (4) the outer Arkansas valley and the sand-hill belt to the west are abnormally wide.

He further suggested that the inferred differential warping began possibly before the deposition of the Kingsdown, and continued during and after that event. As evidence of post-Kingsdown movement, Smith referred to the broad arching of the depositional surface along an east-west axis as shown by an examination of the topographic maps.

The localization of the Kingsdown silt in southern Ford county doubtless is related to the abnormal breadth of the outer valley of Arkansas river in southeastern Kearny county, southern Finney county, and central Gray county as shown by the width of the sand-hill belt. Smith (1940, p. 138) suggested that this broad belt was formed probably by areal subsidence, continuous with but less regular in outline than that north of the river, and that this subsidence may have been a factor in leading to the deposition of the Rexroad or Kingsdown or both. It seems plausible that this subsidence and the deposition of the Kingsdown may be related to similar tectonic causes. Just prior to the deposition of the Kingsdown there was renewed downward movement of the structural trough in which the Rexroad and early Pleistocene sediments had been deposited. The effect of such downward movement was to trap the sediment of any through-flowing streams and to increase the quantity of material carried in from surrounding areas toward the middle of the trough.

According to Smith (1940, p. 112), the best exposures of the Kingsdown "formation" are found along Bluff creek and its tributaries in Clark county, Kansas. A 5-foot bed of clean, even-bedded volcanic ash is also described as occurring near the base of the Kingsdown in the vicinity of an exposure in sec. 13, T. 30 S., R. 23 W.

Only the upper part of the formation is exposed in Ford county, but the entire formation was penetrated in 12 test holes (see logs 10-21) and in most of the wells south of the Arkansas valley. The thickness of the Kingsdown ranges from about 55 feet in test hole 12 to 123 feet in test hole 11, and appears to be the greatest beneath the divides north and south of Mulberry creek. In the southwestern corner of the county the Kingsdown ranges in thickness from about 90 to 118 feet, (logs 19, 20 and 21) and was found to be 108 feet thick in test hole 15, four miles south and one mile west of Kingsdown. It was found to be 107.5 feet thick in the city well (467) at Bucklin (log 70) and 110 feet thick in an oil test southeast of Bucklin (log 71) in the NE¼ sec. 22, T. 29 S., R. 21 W.

Origin.—The origin of the Kingsdown silt has been discussed under Geologic history, page 39. Probably a part of the material comprising these deposits is reworked eolian loess, and a part of the basal sand and gravel was undoubtedly derived from erosion of the Ogallala. Lacustrine deposition is suggested by the finely and evenly-bedded lamination. The cause of deposition probably is related to differential downwarping with a resultant flattening or actual reversal of stream gradients.

Age and correlation.—Smith (1940, p. 111-112) suggested the name "Kingsdown formation" as a revival of Cragin's loosely-defined "Kingsdown marl" (1896), of supposed late Pliocene age, and redefined the term to include beds of Pleistocene age only. He also points out that it was included in the "Tertiary marl" as mapped by Hay. Because it is composed largely of silt it was called the Kingsdown silt by Frye and Hibbard (1941, p. 419), who included the loess overlying the water-laid deposits as the upper part of the formation; this usage is followed in the present report. The loess may have been deposited during the Recent epoch.

The Kingsdown silt has yielded very few fossils, and so far as known, none have been collected from these deposits in Ford county. Hay (1917, p. 42) reported that Cragin found *Elephas columbi* along the upper part of Bluff creek, in Clark county; and Williston (1897, p. 303) reported teeth of *Equus occidentalis* from Bluff creek, but no details of the location are given. Smith (1940, p. 114) reported that Hibbard found one vertebra of *Bison* in the Stephenson ranch section in sec. 13, T. 30 S., R. 23 W in Clark county. Hibbard states (Frye and Hibbard, 1941, p. 420):

> The only fossils recovered from the formation, *Taxidea taxus* (Schreber), *Cynomus ludovicianus* Ord, and *Bison bison* Linneaus, are identical with forms living . . . during the Recent epoch.

Water supply.—The Kingsdown silt is composed mainly of relatively impervious material that yields little or no water; moreover, most of the formation lies above the water table. The sand and gravel near the base of the formation might contain water in places where they lie below the water table. It is more likely, however, that the saturated deposits of the underlying Rexroad member of the Ogallala constitute the principal source of water to wells in the southern part of Ford county. As the formation consists mainly of silt overlain by loess, probably little or none of the rain falling upon its surface percolates downward to the water table.

DUNE SAND

Dune sand occurs mainly in a belt of varying width along the south side of the Arkansas river in Ford county, but is found also in an area of several square miles on the north side of the river, north of Ford, and in another area several square miles in extent in the southwestern part of the county (pl. 1). The thickness of the dune sand ranges from a few feet to a maximum of 70 feet. The dunes, except where reopened by recent blowouts, are old and well stabilized, and may date back well into the Pleistocene. The dunes on the south side of the river were derived at least in part from the terrace deposits. In places the soil zone is thin and attempts at cultivation have stripped the protective cover allowing the upper surface to be subjected to renewed wind action. (pl. 16 B). Smith (1940, pp. 165-168) pointed out that the present river floodplains along the Arkansas valley could not have been a source for the dune sand, contrary to the assumptions of previous writers (Darton, 1916, p. 42; 1920, p. 3), because no movement of sand from the channel toward the dune belt is to be observed. He contends further that few if any dunes of any consequence are to be found either on the floodplain or the lowest terrace, and that the dune belt is far too wide to have been supplied from the present valley unless there was extensive movement of migratory dunes.

He suggests that older and higher terraces, as yet unrecognized, or the sands of older formations, including the Kingsdown and the Ogallala, may have been the source or sources of dune-building sand.

The dunes on the north side of Arkansas river, north of Ford, may have been derived from the underlying Ogallala, although any contribution from this formation would necessarily be limited to source areas where the cemented beds at the top were eroded away, so as to uncover the softer beds of sand below.

The dunes in southwestern Ford county are the northern extension of a much larger expanse of sand dunes in northeastern Meade county. Smith (1940, p. 167) suggested that the sand was derived, either wholly or in part, from the strand flats of a lake that may once have occupied a part of the Meade basin and that the sand probably came from the west. In connection with a discussion of the existence of a temporary lake that may have occupied an area northeast of Meade and west of Fowler after the close of Pleistocene time, Frye (1940, p. 14) pointed out that the sand dunes north of Fowler have the aspect of beach dunes.

Water supply.—The dune sand lies above the water table nearly everywhere, and for this reason probably does not supply water directly to wells. The areas that are mantled with dune sand provide the opportunity for effective recharge to the underlying groundwater reservoir, because of the high porosity of the sand deposits as indicated by the relative absence of surface drainage in such areas. Probably a rather large percentage of the rain that falls on such areas moves downward to join the water table.

TERRACE GRAVEL

At many places along the south side of Arkansas river, deposits of fairly coarse gravel are found in a terrace about 15 to 25 feet above the level of the river, and averaging about 20 feet above. They were deposited by Arkansas river at some time during the Pleistocene when it was flowing at a higher level than at present. These Quaternary terrace deposits have been described by Smith (1938, 1940, p. 125, 126). The deposits range in thickness from a few feet to about 20 feet, and the material consists of beds of clean, unconsolidated, cross-bedded sand and lenticular beds of gravel. The terrace gravels are well exposed in several commercial pits on the south side of Arkansas river in the vicinity of Dodge City, the locations of which are shown on the geologic map (pl. 1). The terrace deposits were mapped with the alluvium in plate 1. According to Smith (1940, pp. 125, 126), the deposits are probably late Pleistocene in age on the basis of a few vertebrate fossils that have been recovered; and, because the terrace deposits are situated lower topographically than the Kingsdown, he suggests that they are younger than that formation.

The terrace deposits are not a source of water in Ford county because any water that they may have contained before the river became intrenched to its present level has since drained out.

ALLUVIUM

Alluvium of late Quaternary age is found principally in the Arkansas valley and in the valleys of some of the other streams in Ford county, (pl. 1). Some of the streams are still in the process of downcutting so that there is little or no alluvium along the greater part of their courses in Ford county. Streams with little or no alluvium include Mulberry, Crooked and Rattlesnake creeks south of the Arkansas valley, and Coon and Cow creeks in the northeastern part of the county.

The character of the alluvium is typical of stream-laid deposits and ranges in texture from silt to sand and coarse gravel. The youngest deposits consist largely of sand and silt deposited over the flood plain in time of flood or under normal conditions in the channel of the stream. Beneath the finer surface deposits are layers of sand and gravel slightly older but of similar origin. Possibly a part of the valley fill in some places is of late Pleistocene age, and represents the basal part of a cut and fill terrace deposit. The sand and gravel deposits are best developed in the alluvium of the Arkansas valley. The smaller valleys are partly filled with alluvium consisting mainly of silt and fine sand.

The thickness of the alluvium in the Arkansas valley in Ford county, as revealed by test drilling, ranges from about 15 feet in the eastern part of the county (logs 48 and 49) to about 40 feet in the central and western part of the county (logs 6, 7, 8, and 9). The alluvium is 33 to 42 feet thick along the south side of Arkansas river, just east of Ford (logs 63, 64, 65). It is possible that in some places the alluvium in the Arkansas valley attains a thickness of 50 feet or more.

The alluvium is underlain by the Ogallala formation in most parts of the Arkansas valley, but near and east of Ford the alluvium rests unconformably on the Dakota formation.

Scanty data indicate that the thickness of the alluvium along Sawlog valley and some of its tributaries ranges from a few feet up to an estimated maximum of 25 or 30 feet.

The alluvial sand and gravel deposits are very permeable and yield large quantities of water to wells tapping them. In the Arkansas valley the alluvium is the source of supply for many irrigation, domestic, and stock wells. The yields of wells tapping the alluvium in the Arkansas valley range from a few gallons a minute to about 1,000 gallons a minute. The yields of wells in the smaller stream valleys generally are adequate for domestic and livestock purposes.

The hardness of 13 samples of ground water obtained from the alluvium ranges from 187 to 1,577 parts per million (fig. 20). The waters from alluvium were of two distinct types—differentiated by content of sulfate. Those low in sulfate, about half of those analyzed had less than 15 parts per million—are very similar in chemical character and mineral content to Ogallala waters. The others usually contain more than 300 parts of sulfate but have about the same bicarbonate content as the waters with low sulfate. Twelve of the 13 samples from the alluvium contained less than 0.15 parts per million of iron, but one sample contained 26 parts. The fluoride content of the samples of water from the alluvium ranged from 0.1 to 1.9 parts per million, and five of the samples contained more than 1.0 part.

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RECORDS OF TYPICAL WELLS

On the following pages are tabulated the information obtained in regard to water wells in Ford county (table 15). The numbers in the first column correspond to the well numbers on the maps (plates 2 and 3) and in the table of analyses (table 14). The wells are listed in order by townships from north to south and by ranges from east to west. Within a township the wells are listed in the order of the sections. Depths of wells and water levels that were reported rather than measured are given only to the nearest foot. Depths of wells not classed as "reported" are given to the nearest 0.1 foot below the measuring point described in the table, and measured water levels are given to the nearest 0.01 foot. Records are included of a few wells in adjoining counties.

TABLE 15.—*Records of typical wells in Ford county, Kansas*

No. on plate 2 and plate 3	Location	Owner or tenant	Type of well(1)	Depth of well(2) (feet)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic horizon	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Height above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (feet)	Date of measurement	Remarks—(Yield given in gallons a minute; draw-down in feet)
	T. 24 S., R. 21 W.(6)															
1	SE¼ SE¼ sec. 35	John Kisner	Dr	20.1	5½	GI	Sand and gravel	Ogallala	Cy,W	N	Top of casing, west side	+1.0	2,259.8	13.02	4-19-39	Unused stock well
	T. 24 S., R. 22 W.(6)															
2	SW corner SE¼ sec. 32	Mard Cole	Dr	90.1	5½	GI	Sand and gravel and/or sandstone	Ogallala and/or Dakota	Cy,H	N	Top of casing, south side	+ .2	2,422.7	82.98	4- 8-39	Unused domestic well
3	SW¼ SW¼ sec. 34	Isabel Heberlee	Dr	88.7	5½	GI	do	do	Cy,H	N	Top of casing, east side,	+ .5	2,383.4	39.49	4- 8-39	Do
	T. 24 S., R. 23 W.(6)															
4	SW¼ SE¼ sec. 31	O. S. Basye	Dr	109.9	6	GI	do	do	Cy,W,H	N	Top of casing, north side	+ .7	2,390.3	70.26	12-12-38	Do
5	SE corner NE¼ sec. 36	C. S. Sturtevant	Dr	215.8	4	I	Sandstone	Dakota	Cy,W,H	N	Top of casing, west side	+ .7	2,398.9	83.76	4-20-39	Unused domestic and stock well
	T. 24 S., R. 24 W.(6)															
6	SE¼ SW¼ sec. 34	Wright Coöp. Exch.	Du	24.2	40	N	Sand and gravel	Ogallala	N	N	Top of pump-pipe hole in railroad tie.	.0	2,429.4	22.30	4-27-39	Unused stock well; bottom of well in Greenhorn limestone?
	T. 24 S., R. 26 W.(6)															
7	NW¼ SW¼ sec. 35	A. C. James	Dr	90.0	5½	GI	do	do	Cy,H	N	Top of casing, north side	+ .5	2,609.3	69.65	5-17-39	Unused domestic and stock well
	T. 25 S., R. 21 W.															
8	SE corner sec. 1	W. O. Sand	Dr	53.2	5½	GI	do	do	Cy,H	S	Top of casing, west side	+ .8	2,281.5	43.81	4-19-39	Used occasionally
9	NE corner SE¼ sec. 4	Everett Decker	Dr	46.4	5½	GI	do	do	Cy,W,H	S	Top of plank under pump base.	+1.1	2,302.1	38.20	4-19-39	
10	NW corner sec. 11	G. Stegman	Dr	45.8	6	GI	do	do	Cy,H	N	Top of casing, east side	+ .2	2,295.0	34.20	10-13-38	Unused well at old church site
11	NW¼ SW¼ sec. 11	J. J. Burghardt	Dr	88.05	6	GI	Sand and gravel and/or sandstone.	Ogallala and/or Dakota	Cy,W	N	Top of casing, west side	+1.0	2,312.3	47.05	10-13-38	Unused stock well; reported depth, 116 feet; observation well
12	NE corner NW¼ sec. 15	do	Dr	55.8	5½	GI	Sand and gravel	Ogallala	Cy,W	N	Top of casing, south side	+1.0	2,309.9	42.78	4-13-39	Unused domestic well
13	NW¼ NW¼ sec. 16	Chas. E. Way	Dr	30.1	5½	GI	do	do	Cy,H	N	Top of casing, west side	+ .7	2,322.3	28.84	4-13-39	Unused domestic well; total depth not known, casing obstructed by cylinder at depth given.

14	NW¼ NE¼ sec. 18	R. C. Sturgeon	Dr	101.2	6	GI	Sand and gravel and/or sandstone.	Ogallala and/or Dakota	Cy,W	N	Top of casing, east side,	+1.0	2,354.3	49.80	10-20-38	Unused stock well; observation well
15	SW¼ NW¼ sec. 21	Lulu Winter	Dr	120	5½	GI	Sandstone	Dakota	Cy,W,G	S	Top of 5½-inch hole in concrete platform.	+ .6	2,349.9	65.01	4-19-39	
16	SE¼ NE¼ sec. 23	John Stegman	Dr	42.3	5½	GI	do	do	N	N	Top of casing, east side,	+ .3	2,294.5	41.50	4- 6-39	Unused domestic well
17	NW¼ NE¼ sec. 24	F. W. Weiss	Dr	58.7	5½	GI	Sand and gravel	Ogallala	Cy,W	S	Top of casing, south side	+ .7	2,287.6	44.08	4-13-39	
18	SW¼ SW¼ sec. 25	Wm. Herrman	Dr	107.9	5½	GI	Sandstone	Dakota	Cy,W	S	Top of casing, north side	+ .9	2,277.1	34.49	4- 6-39	Reported depth, 130 feet
19	SE¼ SW¼ sec. 27	W. C. Kasselmann	Dr	113.5	6	GI	do	do	Cy,N	N	Top of casing, east side,	+1.0	2,317.5	48.91	4- 6-39	Unused stock well
20	SW¼ NW¼ sec. 32	Wm. C. Schmehr	Du	14.6	48	R	Sand and gravel	Ogallala	Cy,W	S	Top of wooden platform	+ .6	2,361.8	13.10	4-13-39	
21	NE¼ SE¼ sec. 32	Wm. Kasselmann	Dr	41.6	5½	GI	do	do	Cy,N	N	Top of casing, west side	+1.2	2,337.0	34.87	4-13-39	Do
22	NW¼ NE¼ sec. 35	Leo R. Krumrey	Dr	155	5½	GI	Sandstone	Dakota	Cy,W	D,S	Top of casing in pit	—4.7	2,294.8	45.45	4- 6-39	
23	NW¼ NE¼ sec. 35	do	Dr	69.8	5½	GI	Sand and gravel	Ogallala	Cy,W,H	S	Top of casing	.0	2,297.7	48.37	4- 7-39	Reported depth, 85 feet
	T. 25 S., R. 22 W.															
24	SE¼ SW¼ sec. 1	Rosa Demuth	Du	46.4	36	R	do	do	Cy,N	N	Top of small square hole in platform.	+ .5	2,386.6	44.70	4- 5-39	Unused domestic and stock well
25	NW¼ NW¼ sec. 2	C. K. Thomas	Dr	91.1	6	N	Sandstone	Dakota	N	N	Land surface, edge of 6-inch hole.	.0	2,388.0	41.26	4-14-39	Irrigation test; originally drilled to depth of 153 feet
26	SW¼ SW¼ sec. 7	G. Klein	Dr	80.9	5½	GI	Sand and gravel and/or sandstone.	Ogallala and/or Dakota	Cy, H	N	Top of casing, north side	+ .5	2,437.9	60.06	4-20-39	Unused domestic well
27	SW corner NW¼ sec. 10	J. A. Herron	Dr	....	6	GI	Sand and gravel	Ogallala	Cy,H	N	Top of casing, west side	+ .7	2,417.5	59.56	10-12-38	Unused domestic and stock well
28	SE¼ SW¼ sec. 10	Andrew Hornung	Dr	50.2	4	GI	do	do	Cy,W	S	Top of casing, west side	+ .3	2,398.6	39.91	4- 8-39	
29	NE¼NE¼ sec. 13	R. C. Sturgeon	Dr	87.7	5½	GI	do	do	Cy,N	N	Top of casing, west side	+1.0	2,376.9	44.91	4-13-39	Do
30	SE¼ SE¼ sec. 14	I. Strecker	Du	66.6	24	R	do	do	N	N	Top of 2-inch hole in platform.	+1.0	2,410.6	55.75	4-13-39	Unused domestic well
31	NE corner sec. 20	Mary Arends	Dr	86.4	5½	GI	do	do	Cy,H	D	Top of casing, southeast side	+ .3	2,438.2	66.26	4-20-39	Cemetery well
32	NW¼ NE¼ sec. 24	M. T. Keith	Dr	156	5½-4½	GI	Sandstone	Dakota	Cy,W	D,S	Top of casing, east side	+ .7	2,398.3	77.92	4-25-39	Water contains considerable fluoride, see analysis
33	SW¼ SE¼ sec. 24	Theo. Buxe	Du	50.1	48	GI	Sand and gravel	Ogallala	B,H	D	Top of wooden box above platform	+2.6	2,397.6	47.04	4-19-39	
34	NE¼ NE¼ sec. 29	A. T. & S. F. Ry.	Dr	166.5	10	I	Sandstone	Dakota	N	N	Top of concrete floor	+ .5	2,459.6	86.49	4- 5-39	Unused railroad well; originally drilled to depth of 389 ft. and later plugged to present depth; observation well
35	NE¼ NE¼ sec. 29	City of Spearville	Dr	104	12	BS	Gravel	Ogallala	T,E	P	....	......	....	85±	....	Located just north of railroad tracks; reported yield 50, draw-down 18; bottom of well is in blue shale

TABLE NO. 15.—Records of typical wells in Ford county, Kansas (*Continued*)

No. on plate 2 and plate 3	Location	Owner or tenant	Type of well (1)	Depth of well (2) (feet)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic horizon	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Height above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (feet)	Date of measurement	Remarks—(Yield given in gallons a minute; draw-down in feet)
36	SE¼ NE¼ sec. 29	City of Spearville	DD	97.6	48–24	R,GI	Gravel	Ogallala	T,E	P	....	....	....	90±	....	Located under the elevated tank; reported yield 47, draw-down 6±; bottom of well is in blue shale
37	NE¼ SE¼ sec. 29	do	Du	86.5	120	C	do	do	T,E	P	....	....	....	75±	....	Put down in 1935 by PWA; curbed with concrete blocks, gravel walled between depths of 75 and 86.5 ft, reported yield 50, draw-down 9±
38	NW¼ NW¼ sec. 32	Will Bosman	Dr	80	5½	GI	Sand and gravel	Ogallala	Cy,W	S	Top of casing, west side	+1.8	2,451.2	67.12	4–21–39	Seldom used
	T. 25 S., R. 23 W.															
39	SE¼ SW¼ sec. 2	Conrad J. Fox	Dr	124.8	5½	GI	Sand and gravel and/or sandstone.	Ogallala and/or Dakota	N	N	Top of casing, south side	+1.3	2,418.2	37.93	4–20–39	Unused stock well
40	SW¼ NW¼ sec. 7	C. W. Cobb	Dr	37.7	6	GI	Sand and gravel	Alluvium	Cy,W	N	Top of casing, west side	+ .95	2,347.0	30.96	12–12–38	Do
41	SE¼ SE¼ sec. 10	Willis B. Warner	Dr	56.3	4	GI	do	Ogallala	N	N	Top of casing, east side	+ .5	2,419.7	54.28	4–20–39	Unused domestic well
42	SE¼ NE¼ sec. 16	do	Du	47.9	48	N	do	do	N	N	Top of 2-ft. square hole in platform.	+1.0	2,429.5	44.51	10–12–38	Unused domestic and stock well
43	NE corner sec. 18	School Dist. No. 5	Dr	43.6	5½	GI	Sandstone	Dakota	Cy,H	D	Top of triangular wooden curb.	+0.3	2,423.4	39.47	4–29–39	School well; water contains considerable fluoride, see analysis
44	SE¼ SE¼ sec. 19	Phoenix Bank	Dr	70.6	4½	I	Sand and gravel and/or sandstone.	Ogallala and/or Dakota	Cy,N	N	Top of casing, west side	+1.3	2,458.2	57.37	4–29–39	Unused domestic well
45	SE corner sec. 20	E. G. Hain	Du	61.0	48	R	Sand and gravel	Ogallala	Cy,H	D	Top of 18-inch square hole in concrete platform.	+1.5	2,445.6	56.68	4–25–39	
46	SE corner SW¼ sec. 24	Albert Burghart	Dr	89.7	5½	GI	Sandstone	Dakota	Cy,W	D,S	Top of casing, east side	+1.0	2,460.2	71.85	4–25–39	Reported depth 97 ft. casing obstructed by cylinder at depth given
47	NE corner sec. 34	School District	Dr	76.2	4	GI	Sand and gravel	Ogallala	Cy,H	D	Top of casing, north side	.0	2,469.4	68.78	4–25–39	School well; total depth not known, casing obstructed by cylinder at depth given

	T. 25 S., R. 24 W.														
48	NW¼ NE¼ sec. 7	Robt. M. Roth	Dr	135.8	4½	I	Sandstone	Dakota	N	N	Top of casing, west side	+2.6	2,478.0	80.39	4-27-39	Unused stock well
49	NE corner sec. 9	J. H. Hessman	Dr	25.8	5½	GI	Sand and gravel and/or limestone.	Ogallala and/or Greenhorn.	Cy,W	S	Top of 2 by 2 wooden clamp.	+ .1	2,385.7	22.86	4-29-39	Total depth not known, casing obstructed by cylinder at depth given
50	NE¼ NE¼ sec. 11	Ed. Sayre	Dr	90.5	16	GI	Sandstone	Dakota	N	N	Top of casing, south side	+ .5	2,363.0	15.82	10- 5-38	Formerly used for irrigation; originally drilled to depth of 240 feet; casing now collapsed at depth of 90.5 feet; observation well
51	NE¼ NE¼ sec. 11	J. E. Sayre	Dr	37.1	5½	GI	Sand and gravel	Alluvium	Cy,W	D,S	Top of casing, northeast side.	+ .1	....	24.34	6- 5-39	
52	SE¼ SE¼ sec. 13	W. J. Holliday et al.	Dr	41.3	4	I	Sand and gravel and/or sandstone.	Ogallala and/or Dakota	Cy,W	N	Top of casing, south side	+3.0	2,388.7	24.25	11- 8-38	Unused stock well
53	SW corner sec. 14	A. Schauf	Dr	71.9	5½	GI	do	do	N	N	Top of 5½-inch hole in concrete platform.	+1.0	2,474.0	69.55	4-29-39	Unused domestic and stock well
54	SW¼ SE¼ sec. 16	Mrs. Geo. Preston.	Dr	50.1	5½	GI	Sand and gravel and/or limestone.	Ogallala and/or Greenhorn.	Cy,W	S	Top of casing, south side	+1.0	2,481.3	35.82	4-29-39	Total depth not known; casing obstructed by cylinder at depth given
55	SW corner sec. 21	Bell Center School District.	Dr	39.8	5½	GI	do	do	Cy,H	D	Top of casing, south side	+ .2	2,483.6	24.51	4-29-39	School well, water is harder than average, see analysis
56	SW corner SE¼ sec. 21	Mrs. Geo. Preston.	Dr	13.3	5½	GI	Sand and gravel	Ogallala	Cy,H	N	Top of casing, west side	+ .9	2,445.8	3.15	4-29-39	Unused domestic well
57	SE¼ SE¼ sec. 25	A. Winters	Dr	55.9	4	I	do	do	Cy,W	N	Top of casing, south side	+1.6	2,465.3	48.46	11- 8-38	Do
58	NE corner NW¼ sec. 26	School District	Dr	58.0	4½	GI	do	do	Cy,H	D	Top of casing, north side	+ .9	2,487.8	51.29	4-29-39	School well, not in use in 1939; water contains fluoride, see analysis
59	SW¼ SW¼ sec. 28	L. W. Devoe	Du	23.3	5½	GI	Sand and white shale.	Alluvium and/or Greenhorn.	Cy,H	S	Top of casing, west side	+1.3	2,462.4	18.54	4-27-39	
60	SW¼ NW¼ sec. 31	Mrs. Mary Taylor	Dr	30.8	5½	GI	Sand and gravel.	Ogallala	Cy,W	S	Top of 3 by 3 pipe clamp, north side	+ .4	2,502.1	13.33	4-27-39	Used some for irrigation
	T. 25 S., R. 25 W.															
61	SW¼ SE¼ sec. 4	H. B. Wood	Dr	41.6	5½	GI	Limestone	Greenhorn	Cy,W	N	Top of 3 by 3 pipe clamp, south side.	+1.2	2,510.5	33.07	5-13-39	Unused stock well; total depth not known, casing obstructed by cylinder at depth given
62	NW¼ NE¼ sec. 5	Chas. Ravenkamp.	Dr	52.6	5½	GI	do	do	Cy,W	D,S	Top of casing, north side	+ .4	2,541.3	26.08	5-13-39	Reported depth 58 feet
63	SE¼ SW¼ sec. 7	A. F. Cook	Dr	81.9	5½	GI	Sand and gravel	Ogallala	Cy,H	N	Top of 7-inch iron form in platform.	+ .5	2,599.8	63.49	5-13-39	Unused domestic and stock well
64	SW¼ SW¼ sec. 8	Jeff Anders	Dr	175.8	4½	I	Limestone and/or sandstone.	Greenhorn and/or Dakota	Cy,W	N	Top of casing in pit, west side.	—3.0	2,577.3	150.58	5-13-38	Unused domestic and stock well

TABLE NO. 15.—Records of typical wells in Ford county, Kansas (*Continued*)

No. on plate 2 and plate 3	Location	Owner or tenant	Type of well (1)	Depth of well (2) (feet)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic horizon	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Height above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (feet)	Date of measurement	Remarks—(Yield given in gallons a minute; draw-down in feet)
65	SW corner sec. 10	School Dist. No. 36	Dr	173.1	4½	I	Limestone and/or sandstone.	Greenhorn and/or Dakota.	Cy,H	D	Top of casing, north side	+ .4	2,545.3	104.91	5- 9-39	School well; water contains considerable fluoride, see analysis
66	SW corner SE¼ sec. 13	Federal Land Bank	Dr	233.2	4½	I	Sandstone	Dakota	Cy,N	N	Top of casing, east side	+1.0	2,570.2	153.21	4-27-39	Unused domestic and stock well
67	SW¼ SE¼ sec. 14	M.A. Rummel et al.	Dr	161.1	6	GI	Limestone and/or sandstone.	Greenhorn and/or Dakota	N	N	Top of casing, southwest side.	+ .5	2,540.2	104.25	4-27-39	Unused stock well
68	NE corner NW¼ sec. 20	E. R. Snyder	Dr	65.4	4½	I	Sand and gravel and/or limestone.	Ogallala and/or Greenhorn.	Cy,W	S	Top of casing, west side	+2.9	2,582.7	54.42	5-13-39	
69	SW corner sec. 21	Chas. C. Dirks	Dr	55.8	5½	GI	Sand and gravel	Ogallala	Cy,W	N	Top of 18-inch farm-disc cover plate.	+ .8	2,568.1	41.06	5-13-39	Unused domestic and stock well
70	NE¼ NW¼ sec. 25	M. R. Zimmer	Dr	63.7	7	GI	do	do	Cy,W	N	Top of casing, north side	+ .2	2,551.8	60.11	4-27-39	Do
71	NW¼ SW¼ sec. 26	Wm. Meng	Dr	61.8	5½	GI	Sand and gravel and/or limestone.	Ogallala and/or Greenhorn	N	N	Land surface	.0	2,559.0	55.09	5-11-39	Unused stock well; top of casing 3 feet below land surface
72	SW¼ SW¼ sec. 29	D. W. Snyder	Dr	77.3	5	I	Sand and gravel	Ogallala	Cy,W	S,I	Top of triangular casting.	+ .6	2,604.8	71.22	5-13-39	Total depth not known, casing obstructed by cylinder at depth given
73	SW¼ NE¼ sec. 30	John Drewes	Dr	48.1	15,12	GI	do	do	N	N	Top of round 15-inch form in concrete curb.	+1.0	2,561.4	21.95	10-11-38	Not yet equipped with irrigation pump
74	SE¼ SE¼ sec. 31	M. R. Zimmer	Dr	130.3	5½	GI	do	do	Cy,W	N	Top of casing, north side	+1.7	2,616.7	85.32	5-13-39	Unused stock well
75	SE corner sec. 32	V. Ousley	Dr	93.4	4	I	do	do	Cy,W	D,S	Top of casing, east side	+ .9	2,603.5	77.35	5-11-39	
	T. 25 S., R. 26 W.															
76	SW¼ SW¼ sec. 4	Henry J. Katz	Dr	100.2	5½	GI	do	do	Cy,H	D,S	Top of casing, south side	+ .5	2,638.9	68.58	5-17-39	Occasionally used
77	SE¼ SW¼ sec. 5	C. L. Deford	Dr	100.1	5½	GI	do	do	Cy,W	D,S	Top of casing, west side	+ .3	2,652.2	72.70	5-18-39	
78	SW¼ NW¼ sec. 6	Gray Co. State Bk.	Du	24.3	6	W	do	do	N	N	Top of brass M.P. plate in curb.	.0	2,609.8	19.30	10-11-38	Unused domestic and stock well; hole is square

79	SW¼ SE¼ sec. 8	School Dist. No. 18	Dr	123.1	5½	I	do	do	Cy,W,H	D	Top of casing, west side	+ .2	2,665.5	92.27	5-19-39	School well; water contains considerable fluoride, see analysis
80	SE¼ NE¼ sec. 11	B. Webb	Dr	80.1	5½	GI	do	do	N	N	Top of casing, south side	+ .2	2,607.9	64.69	5-16-39	Unused domestic well
81	SE¼ SE¼ sec. 15	J. Feist	Dr	101.9	4½	I	do	do	Cy,W	N	Top of 6-inch hole in concrete base.	+ .8	2,621.9	72.46	5-16-39	Unused domestic and stock well
82	SE corner NE¼ sec. 21	Jos. Schuette	Dr	103.8	4½	GI	do	do	Cy,H	N	Top of casing, south side	+ .3	2,639.1	78.45	5-17-39	Unused stock well
83	SE¼ NE¼ sec. 24	J. Weiss	Dr	94.6	5½	GI	do	do	Cy,W	N	Top of 5½-inch hole in concrete platform.	+ .3	2,621.6	78.24	5-17-39	Unused domestic and stock well
84	NW corner SW¼ sec. 24	John Drewes	DD	74.3	5½	I	do	do	Cy,W	I	Top of casing, east side	+ .5	2,614.3	68.28	10-11-38	Occasionally used; reported depth 80 feet; observation well
85	SW corner sec. 25	Ray Stein	Dr	76.1	5½	GI	do	do	Cy,W	D,S	Top of casing, west side	+ .8	2,613.1	66.77	5-17-39	
86	NW¼ SE¼ sec. 27	W. A. Layton	Dr	62.4	6	GI	do	do	Cy,W	N	Top of casing, south side	+1.2	2,610.5	55.11	5-16-39	Unused domestic and stock well
87	NW¼ NW¼ sec. 31	H. J. Hessman	Dr	110.2	5½	GI	do	do	Cy,W	D,S	Top of casing, south side	+ .7	2,679.5	108.03	5-19-39	
88	NE¼ SE¼ sec. 32	C. M. H. Johnson	Dr	109.1	4	GI	do	do	Cy,W,H	D	Top of casing, east side	+ .5	2,656.1	96.97	10-11-38	
	T. 26 S., R. 20 W. (7)															
89	SE¼ SW¼ sec. 19	R. Speck	Dr	20	20	GI	do	Alluvium	C,G	I	Top of casing in pit, east side.	−4.0	2,261.5	8.38	10-28-38	Reported yield 500
	T. 26 S., R. 21 W.															
90	SW corner sec. 3	E. B. Frolich	Dr	42.3	5½	GI	do	Ogallala	Cy,H	D	Top of casing, north side	+ .4	2,291.7	34.68	4- 7-39	Used for milkhouse supply; reported depth 45 feet
91	SW corner sec. 3	do	Dr	92.4	5½	GI	do	do	N	N	Top of casing, south side	+ .5	2,294.3	35.85	4- 7-39	Core test drilled by an oil company; reported depth 900± feet; cased top part of the open test hole
92	NW¼ SW¼ sec. 9	Frank Ackermann	Dr	110.6	5½	GI	Sandstone	Dakota	N	N	Top of casing, east side	+ .6	2,317.6	48.35	4- 7-39	Unused domestic well
93	NW¼ SW¼ sec. 11	Harry Wetzel	Dr	45.4	36	GI	Sand and gravel	Alluvium	C,T	I	Top of 2 by 8 plank across curb.	+ .7	2,280.5	27.82	10-27-38	Reported yield 400
94	NE¼ NE¼ sec. 13	Henry Quasebarth	Dr	13.7	5½	GI	do	do	Cy,H	N	Top of casing, south side	+ .3	2,252.8	9.71	4- 8-39	Unused domestic well
95	SE¼ NW¼ sec. 13	Herman Wetzel	Dr	26.0	24	CR	do	do	VC,G	I	Top of casing, north side	+1.5	2,255.7	9.94	10-27-38	Reported yield 500
96	NE¼ SE¼ sec. 14	A. C. Kurth	Dr	16.9	5½	GI	do	do	N	N	Top of casing, south side	+ .1	2,264.6	14.42	4- 8-39	Formerly used for irrigation
97	NW¼ NW¼ sec. 20	K. G. Nau	Du	33.6	72	N	do	Ogallala	Cy,G	I	Top of railroad tie across curb.	+ .5	2,321.9	26.20	4-27-39	
98	SE¼ NE¼ sec. 23	Henry Hattrup	Dr	29.3	34	S	do	Alluvium	VC,G	I	Top of casing, east side	+ .8	2,263.2	10.46	10-28-38	Reported yield 400; observation well
99	SE¼ SE¼ sec. 25	W. A. Wetzel	Dr	36.2	22	OB	do	do	VC,G	I	Top of casing, south side	+ .5	2,268.7	9.78	10-28-38	Reported yield 500, drawdown 10-12
100	SW¼ SW¼ sec. 31	Leonard Dinkela	Dr	51.5	8	N	Sand and gravel and/or shale.	Ogallala and/or Dakota	N	N	Top of 8-inch dirt hole	− .5	....	41.54	7-29-39	Irrigation test hole

TABLE No. 15.—Records of typical wells in Ford county, Kansas (*Continued*)

No. on plate 2 and plate 3	Location	Owner or tenant	Type of well(1)	Depth of well(2) (feet)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic horizon	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Height above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (feet)	Date of measurement	Remarks— (Yield given in gallons a minute; draw-down in feet)
101	SW corner NW¼ sec. 36	Geo. W. Molitor	Dr	29.8	24	GI	Sand and gravel	Alluvium	VC,G	I	Top of casing, south side	+1.0	2,279.7	12.78	10- 5-38	Reported yield 500; observation well
	T. 26 S., R. 22 W.															
102	SE¼ NW¼ sec. 2	J. H. Torline	Dr	41.8	4½	I	do	Ogallala	Cy,W	N	Top of casing, north side	+ .5	2,384.6	21.42	8-10-39	Unused stock well
103	NW¼ NW¼ sec. 4	John A. Imel	Dr	89.2	5½	GI	Sand and gravel and/or sandstone.	Ogallala and/or Dakota	N	N	Top of casing, south side	+1.3	2,409.4	33.49	4- 8-39	Unused domestic well
104	SW¼ SW¼ sec. 6	Flo. D. Lancaster	Du	47.8	40	B	Sand and gravel	Ogallala	Cy,W	N	Top of wooden plank in platform.	+1.0	2,412.5	23.58	4-22-39	Unused domestic and stock well
105	NE corner SE¼ sec. 7	Emma E. Imel	Dr	....	4	I	do	do	Cy,W,H	N	Top of 5-inch hole in concrete platform.	+ .5	2,425.6	36.50	4-22-39	Do
106	SE¼ SE¼ sec. 11	School District	Dr	25.0	4½	GI	do	do	Cy,H	D	Top of casing, west side	+0.1	2,347.4	19.66	8-10-39	School well
107	NW¼ NW¼ sec. 15	Anna Heskamp	Dr	90.6	5½	GI	Sandstone	Dakota	Cy,H	N	Top of casing, south side	+ .4	2,391.7	53.35	4- 7-39	Unused domestic and stock well
108	NW corner SW¼ sec. 15	School Dist. No. 11	Dr	81.5	5½	GI	do	do	Cy,H	D	Top of casing, west side	+ .2	2,404.7	52.64	4- 7-39	Unused school well
109	SW¼ SE¼ sec. 22	Jos. J. Duesing	Dr	39.8	6	GI	Sand and gravel	Ogallala	Cy,W,H	D,I	Top of square wooden platform.	+ .3	2,358.3	27.67	4- 4-39	Used occasionally to water garden and trees
110	NW¼ NW¼ sec. 24	John Thesing	Du	25.6	40	R	do	Alluvium	N	N	Top of concrete platform, south side.	+ .5	2,334.7	23.80	4- 7-39	Unused domestic well
111	SE corner sec. 29	H. F. Tassett	Dr	43.5	5½	GI	do	Ogallala	Cy,W	D	Top of casing, south side	+ .5	2,372.4	17.23	8-11-39	
	T. 26 S., R. 23 W.															
112	SW corner sec. 4	Ed. Brown	Dr	82.5	5½	GI	do	do	Cy,H	N	Top of casing, south side	+ .1	2,483.2	62.66	4-14-39	Unused domestic well
113	SE¼ NW¼ sec. 5	Lee Collingwood	Dr	47.1	5½	GI	do	do	Cy,W	D,S	Top of casing, south side	+1.0	2,453.5	36.17	5- 5-39	Seldom used; water contains considerable fluoride, see analysis
114	NW corner sec. 7	F. Lorimor	Dr	44.3	4½	GI	do	do	N	N	Top of casing, west side	+1.9	2,481.9	41.03	5- 4-39	Unused domestic well
115	SW corner SE¼ sec. 10	John F. Ingles	Dr	65.5	4	GI	do	do	Cy,W,H	N	Top of casing, northeast side.	+ .4	2,474.2	57.15	4-21-39	Unused domestic well; measured depth may not be true depth

116	NE¼ NE¼ sec. 11	Jos. Duesing	Dr	100+	5½	GI	Sand and gravel and/or sandstone.	Ogallala and/or Dakota	Cy,W,H	N	Top of casing, west side	+ .2	2,447.6	76.91	4-21-39	Unused domestic and stock well
117	SE¼ SW¼ sec. 12	G. H. Perkins	Dr	68.8	4	GI	Sand and gravel	Ogallala	Cy,W	S	Top of casing, northeast side.	+1.0	2,407.1	40.10	4-22-39	Total depth not known; casing obstructed by cylinder at depth given
118	NE corner sec. 13	Wm. Dorsett	Dr	50.2	4	GI	do	do	N	N	Top of casing, west side	+ .2	2,405.9	27.70	4-22-39	Unused stock well
119	SE¼ SE¼ sec. 13	John and Rose Kirmer.	Dr	68.9	4	GI	do	do	N	N	Top of casing, south side	+ .1	2,410.8	41.20	4-22-39	Unused domestic well
120	NE¼ SE¼ sec. 14	G. Bleumer	Dr	13.9	8	GI	do	do	N	N	Top of casing, west side	.0	....	11.55	10-12-38	Unused stock well
121	SE¼ NE¼ sec. 18	Frank Vogel	Dr	81.1	4	I	do	do	Cy,W	N	Top of casing, west side	+1.0	2,514.1	75.20	4-22-39	Unused domestic well
122	SW¼ SW¼ sec. 21	Henry Kleissen	Dr	36.3	5½	GI	do	do	Cy,W	N	Top of casing, north side	+ .7	2,462.6	26.57	4-21-39	Unused stock well; total depth not known; casing obstructed by cylinder at depth given
123	NW¼ SE¼ sec. 22	Jos. N. Shean	Dr	....	6	GI	do	do	Cy,H	N	Top of casing, north side	+ .5	2,451.0	38.32	10-12-38	Unused domestic and stock well; observation well
124	NE corner SE¼ sec. 31	Eugene Stein	Dr	76.1	5½	GI	do	do	Cy,W	N	Top of casing, south side	+1.0	2,489.1	54.13	5- 8-39	Unused stock well
125	NE¼ NW¼ sec. 32	A. J. Mann	Dr	63.1	6	I	do	do	Cy,W,H	N	Top of wooden platform	+1.0	2,487.8	50.78	5- 6-39	Unused domestic and stock well
126	NE¼ NE¼ sec. 34	J. A. Fiest	Du	18.4	36	B	do	do	N	N	Top of square concrete slab resting on curb.	+ .3	2,427.7	17.01	10-14-38	Unused stock well
127	SW¼ SE¼ sec. 35	J. E. Debrusk	Dr	49.4	......	......	do	do	Cy,W,H	N	Top of plank in platform	+ .6	2,447.2	37.52	5- 6-39	Unused domestic and stock well
	T. 26 S., R. 24 W.															
128	SE¼ NE¼ sec. 1	F. Burns	Dr	46.9	4	GI	do	do	N	N	Top of casing, east side	0.0	2,474.6	41.43	10-12-38	Unused stock well; observation well
129	NE¼ SE¼ sec. 2	R. D. Buell	Dr	95.7	5½	GI	Sand and gravel and/or sandstone.	Ogallala and/or Dakota	Cy,W	I	Top of casing, north side	+ .3	2,507.0	62.90	10-12-38	Reported depth 124 feet; well caved in at bottom
130	SW¼ SE¼ sec. 4	First Nat. Bank	Dr	91.5	5½	GI	Sand and gravel	Ogallala	Cy,W	D,S	Top of casing, west side	+ .1	2,536.6	77.03	4-26-39	
131	NW¼ NW¼ sec. 8	T. A. O'Keefe	Dr	84.2	5½	GI	do	do	Cy,W	D,S	Top of 5½-inch hole in concrete platform.	+ .7	2,549.2	77.59	5-10-39	Water contains considerable fluoride, see analysis
132	SE¼ SW¼ sec. 9	J. C. Umbach	Dr	100.9	5½	GI	do	do	Cy,W	N	Top of casing	+ .5	2,540.1	82.60	4-26-39	Unused domestic well
133	NE¼ NE¼ sec. 10	J. B. Wrighten	Du	44.8	48	R	do	do	Cy,H	D	Top of wooden platform	+ .6	2,497.2	43.88	4-26-39	
134	NW corner sec. 15	H. R. Brown est	Du	57.8	40	......	do	do	N	N	Top of 4-inch square hole in platform.	+ .3	2,510.6	56.23	4-26-39	Unused domestic well
135	SW corner sec. 17	Mary Fox	Dr	149.2	4	I	do	do	Cy,W	N	Top of casing, west side	+1.0	2,587.4	122.50	4-26-39	Unused domestic and stock well; measured depth may not be true depth
136	NW¼ NW¼ sec. 18	E. H. Williams	Dr	95.9	5½	GI	do	do	Cy,W	D,S	Top of 6-inch hole in concrete platform.	.0	2,543.5	70.85	5-10-39	Reported depth 120 feet
137	SW¼ SW¼ sec. 18	Geo. A. Eckles	Dr	120.1	4½	I	do	do	Cy,W	N	Top of casing, south side	+0.3	2,579.7	108.02	4-26-39	Unused stock well
138	NE corner SE¼ sec. 20	J. M. Plazzek	Dr	134.6	6	GI	do	do	Cy,W	N	Top of casing, west side	+ .5	2,573.1	115.75	4-26-39	Do

TABLE No. 15.—Records of typical wells in Ford county, Kansas (*Continued*)

No. on plate 2 and plate 3	Location	Owner or tenant	Type of well (1)	Depth of well (2) (feet)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed		Method of lift (4)	Use of water (5)	Measuring point			Depth to water level below measuring point (feet)	Date of measurement	Remarks— (Yield given in gallons a minute; draw-down in feet)
							Character of material	Geologic horizon			Description	Height above (+) or below (—) land surface (feet)	Height above sea level (feet)			
139	NE corner NW¼ sec. 23	Geo. R. Crane	Dr	101.4	4	GI	Sand and gravel	Ogallala	Cy,H	N	Top of casing, west side	+ .3	2,528.8	80.86	11- 8-38	Unused domestic well; measured depth may not be true depth
140	NW¼ SE¼ sec. 30	Mrs. Clara Perkins	Dr	87.7	4½	GI	do.	do.	N	N	Top of casing, southeast side	+ .6	.....	73.53	8- 4-39	Unused domestic well
141	NE¼ NW¼ sec. 31	Norby Pippitt	Dr	.....	16	GI	do.	Alluvium	C,G	I	.....	.....	.....	.....	.....	Reported yield 250
142	NE¼ NW¼ sec. 31	Arthur Sahm	Dr	31.1	10	GI	do.	do.	C,G	I	Top of casing in pit	—10.4	.....	7.86	11-12-38	Reported yield 300
143	NE¼ NW¼ sec. 31	Boyce	Dr	.....	16	GI	do.	do.	C,G	I	.....	.....	.....	.....	.....	Unused irrigation well
144	NE¼ NW¼ sec. 31	Virgil Hanna	Dr	27.9	12	GI	do.	do.	C,G	I	Top of concrete block curb, east side.	+ .6	.....	19.88	11-12-38	Reported yield 250
145	NE¼ NW¼ sec. 31	Frank Kennedy	Dr	.....	.....	.....	do.	do.	C,E	I	.....	.....	.....	.....	.....	Pump connected directly to casing; reported yield 250
146	NE¼ NW¼ sec. 31	Tom Barrett	Dr	37.4	16	GI	do.	do.	C,E	I	Top of square concrete curb, west side.	+ .5	.....	25.17	11-12-38	Reported yield 250
147	NE¼ NW¼ sec. 31	W. A. Pippitt	Dr	34.4	16	GI	do.	do.	C,G	I	Top of rectangular concrete curb, west side.	.0	2,484.2	24.68	11-12-38	Reported yield 200
148	NW¼ NW¼ sec. 31	(?)	Dr	.....	16	GI	do.	do.	C,N	I	.....	.....	.....	.....	.....	Pump dismantled; well not used for several years
149	NW¼ NW¼ sec. 31	C. D. Freeman	Dr	26.1	16	GI	do.	do.	C,E	I	Top of 2 by 6 sill resting on concrete curb, north side.	+ .2	.....	16.54	12- 1-38	Reported yield 250
150	NW¼ NW¼ sec. 31	J. L. Jones	Dr	30.0	8	GI	do.	do.	C,G	I	.....	.....	.....	.....	.....	Reported yield 150
151	NW¼ NW¼ sec. 31	Geo. Brosius	Dr	31.4	15	GI	do.	do.	C,G	I	Top of wooden platform	+ .3	.....	18.45	11-16-38	Reported yield 350
152	NW¼ NW¼ sec. 31	C. A. Reinert	Dr	30.0	15	GI	do.	do.	C,G	I	.....	.....	.....	.....	.....	Reported yield 150
153	NW¼ NW¼ sec. 31	C. W. Cross	Dr	47.0	15	GI	do.	do.	C,E	I	Top of 2 by 6 at head of stairway to pit.	+1.5	.....	17.29	11-16-38	Reported yield 300, draw-down 6
154	SE¼ NW¼ sec. 31	Virgil Hanna	Dr	17.0	24	GI	do.	do.	C,G	I	Top of casing, east side	—2.0	.....	5.21	11-10-38	Reported yield 500

155	SE¼ NW¼ sec. 31	Oscar E. Smith	Dr	....	20	OB	do.	do.	C,E	I	....	....	....	....	....	Reported yield 150
156	SE¼ NW¼ sec. 31	Harry Burns	Dr	22.8	22	OB	do.	do.	C,E	I	Top of channel iron sill across curb.	+ .1	....	15.26	11-10-38	Reported yield 250
157	SE¼ NW¼ sec. 31	do.	Dr	117.6	4	I	do.	Ogallala	P,E	D	Top of round concrete cover 3 ft. in diameter.	+ .5	....	16.42	11-10-38	Supplies 2 homes
158	SE¼ SW¼ sec. 31	Will Ricken	Dr	25.2	16	GI	do.	Alluvium	C,E	I	Top of 4 by 12 beam seated in curb.	.0	....	15.59	11-10-38	Reported yield 300
159	SE¼ NW¼ sec. 31	Henry Bestegan	Dr	21.8	14	GI	do.	do.	C,E	I	Top of 2 by 4 sill on west side of curb.	+ .5	....	15.52	11-10-38	Reported yield 200
160	SE¼ NW¼ sec. 31	(?)	Dr	....	12	GI	do.	do.	C,G	I	....	....	....	....	....	
161	SW¼ NE¼ sec. 31	Albert Kline	Dr	25	16	GI	do.	do.	C,E	I	Top of casing in pit, west side.	—6.1	....	6.43	11-10-38	Reported yield 300
162	SW¼ NE¼ sec. 31	J. C. May	Dr	28	16	GI	do.	do.	C,E	I	Top of culvert casing, northeast side.	—7.0	....	8.04	11-10-38	Reported yield 500
163	SW¼ NE¼ sec. 31	E. P. Cyphers	Dr	27	16	GI	do.	do.	C,E	I	Top of wooden 4 by 10 platform in curb.	—2.0	....	14.41	11-10-38	Reported yield 300
164	SE¼ NE¼ sec. 31	Herman Freeman	Dr	27.9	16	GI	do.	do.	C,E	I	Top of 2 by 6 sill resting on curb, west side.	+ .2	....	16.61	11-10-38	Reported yield 300
165	SE¼ NE¼ sec. 31	Mike Pedilla	Dr	27.6	20	CR	do.	do.	C,E	I	Top of 2 by 4 sill resting flat on curb, north side.	+ .9	....	15.73	11-10-38	Reported yield 400
166	SE¼ NE¼ sec. 31	Mrs. M. A. Owens	Dr	26.1	20	CR	do.	do.	C,G	I	Top of opening in floor for discharge pipe.	.0	2,470.4	15.55	11-10-38	Reported yield 300
167	SE¼ NE¼ sec. 31	C. E. Boyer	Dr	27	16	GI	do.	do.	C,E	I	Top of casing in pit, south side.	—5.5	....	5.20	11-10-38	Reported yield 400
168	NW¼ SE¼ sec. 31	Brundage	Dr	21.8	20	GI	do.	do.	C,G	I	Top of 4 by 6 sill across curb.	+0.5	....	10.19	11-10-38	Reported yield 350
169	NW¼ SE¼ sec. 31	G. E. Eagan	Dr	20.6	16	OB	do.	do.	C,G	I	Top of casing, north side	+ .8	2,467.8	10.52	11-10-38	Reported yield 300
170	NW¼ NW¼ sec. 32	John Godfrey	Dr	43.9	48-15	GI	do.	do.	C,E	I	Top of plank resting on north end of curb.	+ .5	....	36.41	10-25-38	Reported yield 350
171	SW¼ NW¼ sec. 32	H. Wilkinson	Dr	43.4	48	TW	do.	do.	C,E	I	Top of rectangular concrete pit.	+1.5	2,487.8	34.53	10-25-38	Reported yield 400; observation well
172	SW¼ NW¼ sec. 32	Mrs. Alice Brown	Dr	34.3	16	GI	do.	do.	C,T	I	Top of rectangular concrete curb, west side.	+1.0	....	24.33	10-26-38	Reported yield 400
173	SE¼ NW¼ sec. 32	Walker estate	Dr	29.3	16	GI	do.	do.	R,—	I	Top of square concrete curb, north side.	+ .5	....	24.85	11- 9-38	Not used
174	SW¼ NE¼ sec. 32	E. G. Moody	Dr	33.7	20	CR	do.	do.	C,E	I	Top of 4 by 6 across south edge of curb.	+ .3	....	25.80	10-25-38	Reported yield 400; temperature 59° F
175	SW¼ NE¼ sec. 32	J. Ed. Homan	Dr	30.8	20	CR	do.	do.	C,E	I	Top of round concrete curb, 12 feet in diameter, south side.	+ .6	....	22.90	11- 9-38	Reported yield 300
176	NE¼ SE¼ sec. 32	Wm. R. Cook	Dr	41.3	20	CR	do.	do.	C,G	I	Top of window sill, east side of pumphouse.	+ .8	2,471.9	28.75	10-25-38	Reported yield 800; observation well; water very hard and contains considerable fluoride, see analysis

TABLE No. 15.—Records of typical wells in Ford county, Kansas (*Continued*)

No. on plate 2 and plate 3	Location	Owner or tenant	Type of well(1)	Depth of well (2) (feet)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic horizon	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Height above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (feet)	Date of measurement	Remarks— (Yield giver in gallons a minute; draw-down in teet)
177	NW¼ SE¼ sec. 32	Wm. Akers	Dr	27	20	CR	Sand and gravel	Alluvium	C,G	I	Top of casing in pit, south side.	-11.0	....	5.95	11-9-38	Reported yield 400.
178	NE corner SW¼ sec. 32	Fred Bonnerling	Dr	29.3	12	CR	do	do	C,G	I	Top of flat wooden roof over pump pit.	+1.0	....	20.79	11-9-38	Middle well of a battery of 3 similar wells; reported yield 500
179	NE¼ SW¼ sec. 32	Jess Staggs	Dr	33.1	12	CR	do	do	C,E	I	Top of 2 by 12 plank across curb.	.0	2,475.0	23.18	10-10-38	Reported yield 500; observation well
180	NW corner SW¼ sec. 32	Vic Carson	Dr	24.4	20	CR	do	Alluvium and Ogallala	C,E	I	Top of round concrete block curb, north side.	+ .8	....	14.61	10-26-38	Second well north of the pumphouse in a battery of 10 shallow and 2 deep wells; temperature 59°F. Measured yield 1,010 to 1,040, draw-down 4 to 6(8)
181	NE¼ SW¼ sec. 33	J. M. Hulpieu	Dr	129	16	BS	Gravel	do	T,E	I	Land surface; plant not completed	.0	2,470.7	31.26	10-25-38	Single casing taps both shallow and deep sources; measured yield 700; draw-down 46 in deep well, 4 in shallow well(8)
182	NW¼ SW¼ sec. 33	do	Dr	27.4	16	GI	Sand and gravel	Alluvium	R	N	Top of round concrete curb, north side.	.0	2,468.3	24.60	10-25-38	Southernmost well of a battery of 6 similar wells; pump removed and plant abandoned
183	NW¼ SW¼ sec. 33	R. L. Dilley	2 Dr	39.6 and 138	16, 6	GI, I	do	Alluvium and Ogallala	C,E	I	Top of round concrete curb 8 ft. in diameter, southeast side.	+ .7	2,478.1	33.73	6-5-39	Shallow well of battery of 2 wells; temperature 58° F.; measured yield 275 to 340; draw-down 18.3 in deep well, 3.5 in shallow well(8)
184	SW¼ SW¼ sec. 33	O. N. Nevins	Dr	125	8	I	do	Ogallala	C,E	I	Top of northernmost casing in pump pit.	-9.3	2,453.9	12.09	10-25-38	Wells 184 and 184A are in same pump pit; deep well of battery of 3 shallow wells and 2 deep wells; observation well

184a	SW¼ SW¼ sec. 33	do	Dr	28	12	CR	do	Alluvium	C,E	I	Top of southernmost casing in pump pit.	—9.0	2,454.2	9.52	10-25-38	Shallow well of battery of 3 shallow and 2 deep wells; observation well
	T. 26 S., R. 25 W.															
185	NE corner sec 3	School Dist. No. 20	Dr	63.4	4½	GI	do	Ogallala	Cy,H	D	Top of casing, north side	+ .6	2,544.1	44.99	5- 9-39	Schoolwell; watercontains considerable fluoride, see analysis
186	SE¼ NW¼ sec. 4	M. R. Zimmer	Dr	69.6	6	GI	do	do	Cy,H	N	Top of casing, south side	+ .6	2,567.5	50.38	5- 9-39	Unused domestic and stock well
187	SE¼ SE¼ sec. 4	B. Nieto	Dr	56.7	5½	GI	do	do	Cy,W	N	Top of casing, south side	+1.6	2,567.1	56.16	5- 9-39	Do
188	SW¼ SE¼ sec. 6	J. Peterson	Dr	95.8	4	GI	do	do	N	N	Top of casing, south side	.0	2,607.8	81.93	5-11-39	Do
189	SE corner NE¼ sec. 8	Johnson & Trester	Dr	72.1	4½	GI	do	do	N	N	Top of casing, south side	+ .5	2,581.4	71.05	5- 9-39	Unused stock well
190	SE corner SW¼ sec. 10	Vic Carson	Dr	111.2	4½	GI	do	do	Cy,W	N	Top of casing, south side	+0.3	2,601.1	104.53	5- 9-39	Do
191	SE¼ SW¼ sec. 11	P. H. Young est	Dr	126.1	6	GI	do	do	Cy,W	D,S	Top of casing, south side	+1.5	2,589.4	102.41	5- 9-39	
192	SW¼ NW¼ sec. 12	Albert Rumsey	Dr	74.2	5	GI	do	do	Cy,W	D,S	Top of square wooden platform.	+1.8	2,543.6	55.41	5-25-39	Reported depth 180 feet
193	NE¼ NE¼ sec. 22	L. L. Taylor	Dr	165.2	4, 3	I	do	do	Cy,W	N	Top of 3-inch casing, northwest side.	+1.1	2,619.1	135.38	10-11-38	Unused domestic well
194	SW¼ NW¼ sec. 24	W. F. McCoy	Dr	231.1	5½	GI	do	do	Cy,W	D,S	Top of casing, east side	+ .2	2,612.4	139.98	5-10-39	
195	SW¼ SE¼ sec. 25	A. T. & S. F. Ry.	Dr	148	13, 8	I	do	do	T,E	In						Railroad well at Dodge City roundhouse
196	SE¼ SW¼ sec. 25	do	Dr	148	13, 8	I	do	do	AL	In						do
197	NW¼ SE¼ sec. 26	Kansas Power Co.	Dr	159	6	I	do	do	T,E	A						Used for air-conditioning office building
198	SW¼ SW¼ sec. 26	Mrs. Albert Warren	Dr	20.4	22	OB	do	Alluvium	C,G	I	Top of concrete curb	+ .7	2,486.6	11.35	11-29-38	Reported yield 150
199	SW¼ SW¼ sec. 26	J. J. Houser	Dr	24	16	GI	do	do	C,G	I	Top of 3 by 5 on top of casing.	—5.3		3.50	11-29-38	Reported yield 150
200	SW¼ SW¼ sec. 26	O. H. Thompson	Dr	27.8	16	GI	do	do	C,G	I	Top of concrete curb	.0		12.40	11-29-38	Reported yield 400
201	SE¼ SE¼ sec. 26	Kansas Power Co.	Dr				do	Ogallala	T,E	In						Standby equipment; seldom used
202	SW¼ SE¼ sec. 26	City of Dodge City	Dr	145	38	S	do	do	T,E	P			2,477.0	16±		Reported yield 1,300, drawdown 23
203	SW¼ SE¼ sec. 26	Dodge City Warehouse.	Dr	34	6	I	do	Alluvium	Pr,E	In						Reported yield 8
204	SW¼ SE¼ sec. 26	Dodge City Steam Laundry.	Dr	143	5	I	do	Ogallala	P,G	In						Laundry supply
205	SE¼ SE¼ sec. 26	Duckwall's Stores Co., Inc.	Dr	100	6	I	do	do	C,E	A						Reported yield 40

TABLE NO. 15.—Records of typical wells in Ford county, Kansas (*Continued*)

No. on plate 2 and plate 3	Location	Owner or tenant	Type of well(1)	Depth of well (2) (feet)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic horizon	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Height above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (feet)	Date of measurement	Remarks— (Yield given in gallons a minute; draw-down in feet)
206	SE¼ SE¼ sec. 26	Dodge City Flour Mills.	Dr	150	5	I	Sand and gravel	Ogallala	P,E	In	....	....	....	....	....	Used to supply mill and for cooling condensers; reported yield 100, draw-down 15 to 20
207	do	do	Dr	150	5	I	do	do	C,E	In	....	....	....	....	....	Wells 207–209 connected to same pump, supplies mill and cooling condensers
208	do	do	Dr	30	24	GI	do	Alluvium	C,E	In	....	....	....	....	....	
209	do	do	Dr	30	16	GI	do	do	C,E	In	....	....	....	....	....	
210	SW¼ SW¼ sec. 27	H. G. Wright	Dr	22	16	GI	do	do	C,G	I	Top of casing in pit, west side.	—4.5	....	4.83	11–28–38	Reported yield 500
211	SW¼ SW¼ sec. 27	J. H. Crouch	Dr	24.4	12	GI	do	do	C,G	I	Top of wooden 4 by 4 pipe clamp.	+ .3	....	12.42	11–28–38	Reported yield 200
212	SE¼ SW¼ sec. 27	A. C. Sever	Dr	32	22	OB	do	do	C,G	I	....	....	....	....	....	Reported yield 300
213	SE¼ SW¼ sec. 27	Madge Vickers	Dr	33	16	GI	do	do	C,E	N	Top of 2 by 6 cross piece ladder support.	—12.4	....	5.84	11–29–38	Middle well of a battery of 3 similar unused irrigation wells
214	SE¼ SW¼ sec. 27	Grover Hunter	Dr	33.7	20	OB	do	do	C,E	I	Top of 2 by 4 sill on top of concrete curb.	+ .4	....	21.32	11–29–38	Reported yield 300
215	SW¼ SE¼ sec. 27	Norman Elliott	Dr	....	16	GI	do	do	C,E	I	....	....	....	....	....	Reported yield 300
216	SW¼ SE¼ sec. 27	T. W. Doane	Dr	29	14	GI	do	do	N	N	Top of casing in pit	—11.4	....	3.15	11–29–38	Unused irrigation well
217	SW¼ SE¼ sec. 27	H. C. Wright	Dr	21	16	GI	do	do	C,E	I	Top of casing in pit	—8.4	....	5.26	11–29–38	Reported yield 350
218	SE¼ SE¼ sec. 27	R. G. Gorman	Dr	22.8	10	GI	do	do	C,E	I	Top of casing	+ .6	....	10.28	11–29–38	Reported yield 100
219	SE¼ SE¼ sec. 27	W. C. Babcock	Dr	24	....	....	do	do	C,G	I	....	....	....	....	....	Reported yield 300

220	SE¼ SE¼ sec. 27	Godfrey Smith	Dr	18	......	......	do.	do.	C,G	I	......	......	......	......	......	Reported yield 300
221	SE corner sec. 27	(?)	Dr	20	14	GI	do.	do.	C,G	I	Top of casing, west side	—5.0	......	4.39	11-29-38	Reported yield 300
222	SW¼ SE¼ sec. 28	Chet Wright	Dr	23	20	CR	do.	do.	C,G	I	Top of casing in pit, north side.	—8.5	2,490.5	4.21	12- 1-38	Reported yield 300
223	SW¼ SE¼ sec. 28	J. H. Burnett	Dr	140	16	GI	do.	Ogallala	C,E	I	......	......	......	......	......	Reported yield 800
224	SE¼ SE¼ sec. 28	J. T. Rakes	Dr	24	40	TW	do.	Alluvium	C,G	I	Top of tractor—wheel casing in pit.	—9.9	2,487.4	1.80	11-23-38	Reported yield 600
225	SE¼ SE¼ sec. 28	Hal Shumway	Dr	......	16	GI	do.	do.	R	N	......	......	......	......	......	Unused irrigation well; pump removed
226	NE corner, sec. 29	T. F. and J. L. Garner.	Dr	64.1	5½	GI	do.	Ogallala	Cy,W	N	Top of casing, south side	+1.6	2,543.8	52.35	5-11-39	Unused stock well
227	NE¼ SW¼ sec. 29	J. P. McCollon	Dr	30	20	CR	do.	Alluvium	C,G	I	Top of casing in pit, southwest side.	—7.7	2,499.2	2.48	10-21-38	Reported yield 450
228	SW¼ SW¼ sec. 29	John Matthews	Dr	27	36	GI	do.	do.	C,E	I	Top of casing in pit, east side.	—7.4	2,504.0	3.34	10-21-38	Reported yield1,000, draw-down 7; battery of 2 similar wells; observation well
229	SE¼ SW¼ sec. 29	J. P. McCollon	Dr	32.4	20	CR	do.	do.	C,I	I	Top of 1 by 12 plank across curb.	+1.0	2,505.5	9.39	11- 4-38	Reported yield 1,000; water hard, see analysis
230	SW¼ SE¼ sec. 29	Paul Strain	Dr	24.0	18	GI	do.	do.	C,G	I	......	......	......	......	......	Reported yield 300
231	SW¼ SE¼ sec. 29	Harry Finkle	Dr	......	18	GI	do.	do.	C,G	I	......	......	......	......	......	Reported yield 250
232	SW¼ SE¼ sec. 29	M. L. Shaw	Dr	22.9	20	GI	do.	do.	C,G	I	Top of square brick curb	+1.0	......	13.42	11-22-38	Reported yield 150
233	SW¼ SE¼ sec. 29	J. A. Daniel	Dr	......	24	GI	do.	do.	C,G	I	......	......	......	......	......	Reported yield 150
234	SW¼ SE¼ sec. 29	H. H. Haken	Dr	......	10	GI	do.	do.	C,G	I	......	......	......	......	......	Reported yield 300
235	SW¼ SE¼ sec. 29	Jim McDowell	Dr	25	14	GI	do.	do.	C,E	I	......	......	......	......	......	Reported yield 300
236	SW¼ SE¼ sec. 29	C. A. Mullerdore	Dr	20	15	GI	do.	do.	C,E	I	Top of casing in pit, south side.	—7.2	2,497.3	2.49	11-21-38	Reported yield 300
237	SE¼ SE¼ sec. 29	M. H. Lappin	Dr	25.5	18	GI	do.	do.	C,G	I	......	......	......	......	......	Reported yield 400
238	SE¼ SE¼ sec. 29	W. H. Coleman	Dr	......	12	GI	do.	do.	C,G	I	Top of casing in pit	—14.0	2,499.1	6.83	11-22-38	Reported yield 300
239	SE¼ SE¼ sec. 29	R. S. Glaze	Dr	......	10	GI	do.	do.	C,E	I	......	......	......	......	......	Reported yield 125
240	SE¼ SE¼ sec. 29	M. H. Lappin	Dr	26.5	10	GI	do.	do.	C,G	I	......	......	......	......	......	Reported yield 150; for irrigating garden and trees
241	SE¼ SE¼ sec. 29	W. H. Coleman	Dr	28.3	12	GI	do.	do.	N	N	Top of 1½-inch hole in wooden platform.	+ .5	......	15.06	11-22-38	Formerly used for irrigation
242	SE¼ SE¼ sec. 29	Dayle Gonder	Dr	27.2	16	GI	do.	do.	C,G	I	Top of rectangular hole in floor.	+1.5	......	14.92	11-21-38	Reported yield 400

TABLE No. 15.—Records of typical wells in Ford county, Kansas (*Continued*)

No. on plate 2 and plate 3	Location	Owner or tenant	Type of well (1)	Depth of well (2) (feet)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic horizon	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Height above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (feet)	Date of measurement	Remarks— (Yield given in gallons a minute; draw-down in feet)
243	SE¼ NE¼ sec. 30	Chas. Staples	2 Dr	40 and 165	16 and 5	GI and I	Sand and gravel	Alluvium and Ogallala	C,E	I	Top of 16-inch casing in pit, west side.	—13.0	2,507.3	5.34	10-21-38	Shallow well of a battery of one deep and one shallow well; reported yield 500, draw-down 18-20; observation well
244	SE¼ NE¼ sec. 30	Jim Akin	Dr	46.3	10	GI	do	do	Cy,E	I	Top of 2 by 8 sill in floor, above well.	.0	2,536.3	32.64	5-11-39	
245	SW¼ SW¼ sec. 32	C. L. Bullock	Dr	32	19	GI	do	Alluvium	C,T	I	Top of casing in pit, north side.	—8.0	2,504.3	4.03	10-24-38	Reported yield 500, draw-down 4
246	NE¼ NW¼ sec. 33	R. E. Riney	Dr	27.1	20	CR	do	do	C,G	I	Top of rectangular concrete pit, east side.	+1.0	2,497.3	9.57	10-21-38	Reported yield 1,000
247	NW¼ SW¼ sec. 33	John Clark	Dr	31	20	CR	do	do	C,G	I	Top of casing in pit, south side.	—2.7	2,496.0	2.85	10-24-38	Reported yield 400 not used in 1938
248	SW corner sec. 33	do	Dr	166	16, 8	I	do	Ogaliala	T,G	I	Top of rectangular break in pumphead.	+1.0	2,511.0	17.99	10-24-38	Upper shallow water cased off; reported yield 550, draw-down 34.5; observation well
249	NE¼ NE¼ sec. 34	H. A. Hart	Dr	9	22	OB	do	Alluvium	P,G	I	Top of casing in pit, north side.	—3.5	....	2.20	11-29-38	Reported yield 75
250	NE¼ NE¼ sec. 34	C. O. Woodside	Dr	18.0	24	GI	do	do	Cy,G	I	....	....	....	....	....	Reported yield 150
251	NE¼ NW¼ sec. 34	Bill Bader	Dr	38	20	CR	do	do	C,E	I	Top of casing in pit, southeast side.	—8.0	2,483.0	3.33	11-29-38	Reported yield 750
252	NW¼ NW¼ sec. 34	C. W. Wilkerson	Dr	24	16	GI	do	do	C,E	I	Top of casing in pit, northeast side.	—10.0	....	3.68	11-29-38	Middle well of a battery of 3 similar wells; reported yield 650
253	NW¼ NW¼ sec. 34	F. H. Diehl	Dr	....	....	....	do	do	C,G	I	....	....	....	....	....	Reported yield 300
254	NW¼ NW¼ sec. 34	Albert Schraeder	Dr	....	19	GI	do	do	C,E	I	....	....	....	....	....	Reported yield 300
255	NW¼ NW¼ sec. 34	Roy Wells	Dr	21.3	20	GI	do	do	C,G	I	Top of 4 by 8 sill across curb.	+ .3	....	7.34	11-22-38	Reported yield 400
256	NW¼ NW¼ sec. 34	F. H. Diehl	Dr	22.2	20	CR	do	do	VC,G	I	Top of casing	+0.8	2,491.0	7.19	10- 5-38	Reported yield 800; observation well

257	SW¼ NW¼ sec. 34	Roy Wells	Dr	19.5	48	WI	do.	do.	N	N	Top of casing, east side	—1.0	2,489.3	5.17	11-29-38	Unused irrigation well; pump removed
258	SW¼ NW¼ sec. 34	Harry Hart	Dr	11	16	GI	do.	do.	C,T	I	Top of wooden pipe clamp.	—2.5		3.38	11-29-38	Not used in 1938; reported yield 600
259	SE¼ NE¼ sec. 34	do.	Dr	14.9	24	OB	do.	do.	N	N	Top of oil-barrel casing, east side.	—1.0		4.98	11-29-38	Unused irrigation well; pump removed
260	SW¼ SE¼ sec. 34	C. M. States	2 Dr	35 and 150.0	24, 8	BS	do.	Alluvium and Ogallala	C,E	I	Top of round concrete-block curb, east side.	.0	2,494.7	15.81	10-24-38	Shallow well of a battery of one deep and one shallow well; reported yield 800
261	NE¼ NE¼ sec. 35	Fairmont Cream'y	Dr	140.0	15	S	Gravel	Ogallala	T,E	In						Creamery well; reported yield 250
262	NE¼ NE¼ sec. 35	City of Dodge City	Dr	140.0	38	S	do.	do.	T,E	P			2,472.0	7±		Reported yield 500, draw-down 21
263	NE¼ NW¼ sec. 35	Kansas Power Co.	Dr				do.	do.	T,E	In						Standby equipment; seldom used
264	NW¼ NW¼ sec. 35	L. R. Doonon	Dr		15	GI	Sand and gravel	Alluvium	C,G	I						Not used in 1938; reported yield 300
265	NW¼ NW¼ sec. 35	Alex Mullendorf	Dr	22.5	14	GI	do.	do.	C,E	I	Top of casing, northeast side.	+ .5		7.46	11-29-38	Reported yield 200
266	NW¼ NW¼ sec. 35	R. E. Bisbee	Dr	20.6	14	GI	do.	do.	C,G	I	Top of casing, west side	+1.5	2,483.6	9.07	11-29-38	Reported yield 250
267	NW¼ NW¼ sec. 35	C. L. Ralston	Dr				do.	do.	C,G	I						Reported yield 300
268	NW¼ NW¼ sec. 35	E. E. Agalson	Dr	12.8	12	GI	do.	do.	C,G	I	Top edge of barrel over casing, north side.	.0		5.63	11-29-38	Not used in 1938; reported yield 125
269	NW¼ NW¼ sec. 35	E. S. Phillips	Dr		14	GI	do.	do.	C,G	I						Reported yield 300
270	NW¼ NW¼ sec. 35	E. E. Innes	Dr		10	GI	do.	do.	C,G	I						Not used in 1938; reported yield 100
271	SE¼ NW¼ sec. 35	Kansas Power Co.	Dr				Gravel	Ogallala	N	N						Unused industrial well; pump removed
272	SE¼ NW¼ sec. 35	O. T. Curry	Dr	24	20	CR	Sand and Gravel	Alluvium	C,G	I	Top of angle-iron sill on pump base.	—3.9	2,477.8	4.38	12- 1-38	Reported yield 250, draw-down 4
273	SW¼ NE¼ sec. 35	City of Dodge City	Dr	147	38	S	Gravel	Ogallala	T,E	P			2,477	7±		Reported yield 1,000, draw-down 20
274	SW¼ NE¼ sec. 35	J. S. Dillon Groc. Stores, Inc.	Dr	128	6	I	do.	do.	C,E	A						Reported yield 75; temperature 58° F
275	SE¼ NE¼ sec. 35	Joe Hulpieu	Dr	22	20	CR	Sand and gravel	Alluvium	C,E	I	Top of casing, south-east side.	—5.2		2.01	11-30-38	Reported yield 820
276	NE¼ SE¼ sec. 35	Mrs. Lena Brown	Dr	25.0	20	CR	do.	do.	T,E	I						Reported yield 600
277	NE¼ SE¼ sec. 35	Chas. Wilkerson	Dr	26	20	CR	do.	do.	C,E	I	Top of casing	—7.3		3.27	11-29-38	Reported yield 600, draw-down 10
278	NE¼ SW¼ sec. 35	John Shumard	Dr	22.4	16	GI	do.	do.	C,G	I	Top of concrete curb, south side.	.0	2,481.0	7.90	12- 1-38	Reported yield 300
279	NE¼ SW¼ sec. 35	A. J. Fullerton	Dr		14	BS	do.	do.	C,G	I						Reported yield 200
280	NW¼ SW¼ sec. 35	W. F. McCoy	Dr	138.0	16, 8	I	do.	Alluvium and Ogallala	C,G	I	Top of cleated 6 by 6 resting on curb.	+1.0	2,485.1	11.16	11-30-38	Combination of first and second waters; reported yield 800

TABLE No. 15.—Records of typical wells in Ford county, Kansas (*Continued*)

No. on plate 2 and plate 3	Location	Owner or tenant	Type of well(1)	Depth of well (2) (feet)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic horizon	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Height above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (feet)	Date of measurement	Remarks— (Yield given in gallons a minute; draw-down in feet)
281	SE¼ SW¼ sec. 35	Clyde Burk	Dr	17.9	15	GI	Sand and gravel	Alluvium	C,G	I	Top of channel-iron sill across curb.	.0	2,484.8	10.24	11-30-38	Reported yield 200
282	SE¼ SW¼ sec. 35	E. B. Steele	Dr	17.8	12	GI	do	do	C,G	I	Top of range-boiler casing.	+ .3	....	10.58	11-30-38	Reported yield 150
283	SE¼ SW¼ sec. 35	A. N. Thomas	Dr	....	1¼	GP	do	do	C,G	I	....	....	....	....	....	Reported yield 60
284	SE¼ SW¼ sec. 35	Frank Goff	Dr	18.4	22	OB	do	do	C,G	I	Top of tin cover plate across casing.	+ .2	....	9.99	11-30-38	Reported yield 150
285	SE¼ SW¼ sec. 35	F. R. Wyatt	Dr	....	14	GI	do	do	C,E	I	....	....	....	....	....	Reported yield 150
286	SE¼ SW¼ sec. 35	J. H. Wyatt	Dr	16	12	GI	do	do	C,G	I	Top of flange below elbow on suction pipe.	—4.8	....	4.12	11-30-38	Reported yield 200
287	SE¼ SW¼ sec. 35	Geo. W. Sutton	Dr	....	2	GP	do	do	C,G	I	....	....	....	....	....	Not used in 1938; reported yield 200
288	SE¼ SW¼ sec. 35	J. W. Holbrook	Dr	18	16	GI	do	do	C,E	I	Top of casing, north side	—3.9	....	3.90	11-30-38	Reported yield 300
289	SE¼ SW¼ sec. 35	P. O. Riley	Dr	18.5	12	GI	do	do	C,G	I	Top of range—boiler casing.	+1.1	....	10.83	11-30-38	Reported yield 100
290	SE¼ SW¼ sec. 35	Ray Partridge	Dr	....	16	GI	do	do	C,E	I	....	....	....	....	....	Do
291	SW¼ SE¼ sec. 35	F. H. Shelor	Dr	....	20	CR	do	do	C,E	I	....	....	....	....	....	Reported yield 480
292	SW¼ SE¼ sec. 35	Clyde Burk	Dr	25.5	15	GI	do	do	C,G	I	Top of square concrete-block curb, south side.	.0	....	10.31	11-30-38	Reported yield 200
293	SE¼ SE¼ sec. 35	Lighter and Pierce	Dr	26.8	14	GI	do	do	C,G	I	Top of 3-inch "I" beam on concrete curb.	+1.1	....	10.10	11-30-38	Do
294	SE¼ SE¼ sec. 35	O. M. Barton	Dr	30	20	CR	do	do	C,G	I	Top of 22-in. steel form in concrete floor.	—6.3	....	2.92	11-29-38	Reported yield 900
295	NE¼ NE¼ sec. 36	Dr. Simpson est.	Dr	28.3	16	GI	do	do	C,G	I	Top of 2 by 12 plank across curb, west side.	+ .5	2,479.2	16.16	11-16-38	Reported yield 250
296	NW¼ NE¼ sec. 36	C. L. Miller	Dr	33.4	12	BS	do	do	C,G	I	Top of rectangular concrete curb, northeast corner.	.0	....	19.55	11-16-38	Reported yield 450
297	NE¼ NW¼ sec. 36	C. H. Wilcoxen	Dr	29.1	16	GI	do	do	C,G	I	Top of 2 by 6 that braces 4-inch discharge pipe.	+1.0	....	18.32	11-16-38	Reported yield 600

298	NE¼ NW¼ sec. 36	....	Dr	28.8	16	GI	do	do	C,G	I	Top of vertical 2 by 6 sill resting on north side of concrete curb.	+1.0	....	15.21	11-16-38	Not used in 1938; reported yield 150
299	NE¼ NW¼ sec. 36	Paul Bays	Dr	....	16	GI	do	do	C,G	I	....	....	....	....	....	Reported yield 300
300	NE¼ NW¼ sec. 36	Geo. Lochmann	Dr	27	16	I	do	do	C,G	I	Top of casing in pit, south side.	—8.7	....	6.68	12- 1-38	One of a battery of 2 similar wells; reported yield 300
301	NW¼ NW¼ sec. 36	Geo. Beall	Dr	17	22	OB	do	do	C,G	I	Top of railroad-tie pump base.	—3.6	2,478.0	6.50	12- 1-38	Reported yield 200
302	SE¼ NE¼ sec. 36	Rollie Kiner	Dr	21	20	CR	do	do	C,G	I	Top of casing, southeast side.	—6.7	2,473.2	2.64	11-16-38	Reported yield 500, drawdown 12
303	NW¼ SE¼ sec. 36	Mrs. Thompson	Dr	....	....	....	do	do	C,G	I	....	....	....	....	....	Neighbor reported yield of 300
304	SW¼ SW¼ sec. 36	W. P. Jones	Dr	38.3	20	CR	do	do	C,G	I	Top of wooden cleat connecting railroad ties resting on curb.	+1.0	2,481.0	13.19	11-29-38	Reported yield 800
305	SE¼ SW¼ sec. 36	U. L. Hood	Dr	....	10	GI	do	do	C,G	I	....	....	....	....	....	Reported yield 60
306	SW¼ SE¼ sec. 36	W. F. McCoy	Dr	23.0	24	GI	do	do	C,G	I	....	....	....	....	....	Battery of 2 shallow wells; reported yield 400
307	SW¼ SE¼ sec. 36	Guy McConnell	Dr	21.9	16	GI	do	do	C,G	I	Top of round concrete-block curb, north side.	+ .2	....	8.92	11-29-38	North well of a battery of 3 similar wells; reported yield 600
308	SW¼ SE¼ sec. 36	Fred Pitman	Dr	23.4	16	GI	do	do	C,G	I	Top of 2 by 4 form inside well curb, west side.	+1.5	2,473.1	9.53	11-29-38	Battery of 2 similar wells; measured well situated in pump pit; reported yield 500
309	SE¼ SE¼ sec. 36	John G. Donovan	Dr	....	22	OB	do	do	C,G	I	....	....	....	....	....	Reported yield 400
310	SE¼ SE¼ sec. 36	M. E. O'Connor	Dr	23.3	12	GI	do	do	C,G	I	Top edge of old car chassis across curb, north side.	+ .5	2,477.8	14.98	11-29-38	Reported yield 300
	T. 26 S., R. 26 W.															
311	NE corner sec. 1	B. A. Schuette	Dr	132.2	4½	I	Gravel	Ogallala	N	N	Top of casing, east side	+ .6	2,608.7	76.68	5-15-39	Unused stock well; observation well
312	SE¼ NE¼ sec. 4	W. F. Berish	Dr	225.9	6	I	do	do	Cy,W	N	Top of casing, south side	— .2	2,638.4	92.41	5-16-39	Unused stock well
313	NW¼ NE¼ sec. 6	W. C. Gould	Dr	123.4	5½	GI	do	do	N	N	Top of casing, north side	+ .4	2,671.7	109.15	5-19-39	Unused stock well; observation well
314	SW corner SE¼ sec. 9	W. J. Strooker	Dr	110.1	4	I	do	do	Cy,W	N	Top of casing, west side	.0	2,641.5	101.30	10-11-38	Unused domestic well
315	NE corner sec. 13	E. R. Reynolds	Dr	129.2	10	I	do	do	Cy,W,G	D	Top of lower edge of long slot cut in casing in pit.	—4.6	2,629.8	110.05	5-15-39	Temperature 59° F.
316	SW¼ SW¼ sec. 16	Albert Miller	Dr	23.1	16	GI	Sand and gravel	Alluvium	C,E	I	Top of concrete curb of well pit, east side.	.0	2,544.9	7.35	10- 5-38	North well of battery of 6 similar wells; reported yield 1,200; observation well; see analysis
317	SW¼ SE¼ sec. 16	Albert Miller	Dr	....	16	GI	do	do	C,G	I	....	....	....	....	....	Reported yield 450, drawdown 5

Table No. 15.—Records of typical wells in Ford county, Kansas (*Continued*)

No. on plate 2 and plate 3	Location	Owner or tenant	Type of well(1)	Depth of well (2) (feet)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic horizon	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Height above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (feet)	Date of measurement	Remarks— (Yield given in gallons a minute; draw-down in feet)
318	NW¼ NE¼ sec. 20	C. T. Morrow	Dr	20	16	BS	Sand and gravel	Alluvium	C,G	I	Top of casing in pit, east side.	—3.0	2,541.8	1.50	1- 3-39	Reported yield 700, draw-down 14 after 4 hours
319	NE¼ NE¼ sec. 21	Bud Webb	Dr	186.7	16	OW	Gravel	Ogallala	C,D	N	Top of round concrete cover over pit.	+1.0	2,551.5	17.66	10-21-38	Unused irrigation well; middle well of a battery of 5 similar wells; reported yield 1,500; observation well
320	NW¼ SW¼ sec. 21	Maurice Thompson	Dr	22.7	20	CR	Sand and gravel	Alluvium	C,G	I	Top of round concrete-block curb, west side.	+ .4	2,542.8	7.37	10-22-38	Battery of 5 shallow wells, first well south of pump-house measured; measured yield 1,200, average draw-down 6.25(8); observation well
321	SW¼ NE¼ sec. 22	Fred Hessman	Dr	18.7	24	CR	do	do	C,G	I	Top of square concrete curb, west side.	.0	2,535.7	8.40	10-21-38	Battery of 5 shallow wells; first well north of pump-house measured; reported yield 600
322	NW¼ SE¼ sec. 22	Andrew Bogner	Dr	26.7	20	CR	do	do	C,G	I	Top of 1-inch hole in wooden platform resting on curb.	+1.0	2,534.6	8.76	10-21-38	North well of a battery of 3 similar wells; reported yield 1,000, draw-down 12; observation well; see analysis
323	SW¼ SW¼ sec. 22	Bud Webb	Dr	8.5	6	GI	do	do	N	N	Top of casing	+1.3	2,534.4	7.91	8- 8-39	Unused stock well
324	SW¼ SW¼ sec. 22	do	Dr	130.9	3	I	Gravel	Ogallala	N	E	Top of tee on 3-in. pipe	—1.7	2,533.1	0.04	8- 4-39	Formerly flowed at land surface, now tapped at a point 1.7 feet below land surface and flows only a trickle
325	SE¼ SW¼ sec. 23	R. R. Kiner	Dr	30.6	16	GI	Sand and gravel	Alluvium	C,D	I	Top of round concrete-block curb, north side.	+ .3	2,533.4	13.91	10-21-38	Battery of 6 shallow wells, first well south of pump-house measured; reported yield 1,800, draw-down 9

326	SE¼ SE¼ sec. 23	W. F. Rhinehart	Dr	165	8	I	do.	Ogallala	C,G	I	....	....	2,530.2	....	....	Pump connected directly to casing; depth to water could not be measured; reported yield 600
327	SW¼ NW¼ sec. 24	J. F. Foley	Dr	37.5	4½	GI	do.	do.	Cy,W	N	Top of casing, northeast side.	+ .6	2,552.0	35.42	5-16-39	Unused stock well
328	SE¼ SE¼ sec. 24	do.	Dr	30.9	5½	GI	do.	do.	Cy,W	S	Top of casing, southwest side.	+ .6	2,538.4	29.17	5-16-39	
329	NE¼ SE¼ sec. 25	Roger Shumard	Dr	29.7	20	CR	do.	Alluvium	VC,T	I	Top of casing, south side	+ .6	2,515.9	8.34	10-22-38	Reported yield 600
330	SE¼ SW¼ sec. 25	Erwin Strieff	Dr	30	20	CR	do.	do.	C,G	I	Top of 1½-inch brass plate on wooden pipe clamp.	—8.1	2,513.3	1.75	10-22-38	Reported yield 800
331	NE¼ NE¼ sec. 26	Homer C. Rumsey	Dr	30	20	CR	do.	do.	C,G	I	Top of casing in pit, northeast side.	—5.1	2,518.5	1.71	10-21-38	Reported yield 900, draw-down 22
332	NW¼ SW¼ sec. 33	Mrs. Elizabeth Everett	Dr	95.9	4½	I	Gravel	Ogallala	Cy,W	D,S	Top of old pumphead in top of 4½-inch casing, south side.	+ .8	2,613.1	71.39	5-22-39	
333	SE¼ SW¼ sec. 34	Erwin Strieff	Dr	39.1	5½, 4	GI	Sand and gravel	Alluvium	Cy,W	S	Top of casing, northwest side.	+1.4	2,565.0	33.95	5-23-39	
334	SE¼ NE¼ sec. 36	John Shumard	Dr	48	22	OB	do.	do.	C,G	I	....	....	2,523.1	....	....	Reported yield 700
	T. 26 S., R. 27 W.(9)															
335	SE¼ NE¼ sec. 2	Arthur Adams	Dr	134.7	3	I	Gravel	Ogallala	N	N	Top of casing, north side	+2.6	2,694.3	113.36	10-11-38	Unused domestic well
336	NW¼ NW¼ sec. 13	C. E. Butcher	Dr	28	16	GI	Sand and gravel	Alluvium	C,G	I	Top of casing in pump pit, east side.	—5.0	2,564.3	4.77	5-20-39	Battery of 4 similar wells; measured well situated in pump pit; reported yield 800
337	SW¼ SE¼ sec. 14	J. C. Keech	Dr	29.5	20	CR	do.	do.	T,G	I	Top of casing, east side	+1.5	....	10.35	6- 6-39	Reported draw-down 10.5
338	NE corner NW¼ sec. 25	I. J. Gilleland	Dr	40.3	5½	GI	Gravel	Ogallala	Cy,W	D,S	Top of casing, west side	+ .7	....	31.48	5-20-39	—
	T. 27 S., R. 21 W.															
339	NE¼ SE¼ sec. 2	Warner Jochems	Dr	28.8	22	OB	Sand and gravel	Alluvium	VC,T	I	Top of casing, north side	+ .9	2,283.1	9.59	11- 3-38	Reported yield 600; observation well
340	NE corner sec. 7	School District	Dr	62.2	4½	GI	Gravel	Ogallala	Cy,H	D	Top of casing, southeast side.	+ .4	2,356.2	50.96	8-11-39	School well
341	NE corner sec. 10	A. P. Hyer	Dr	15.3	22	OB	Sand and gravel	Alluvium	C,G	I	Top of wooden cover 0.4 foot above top of casing.	.0	2,285.8	7.51	8-12-39	Water supply not sufficient for operating pump at full capacity
342	NW¼ SW¼ sec. 20	T. L. Miller	Dr	57.6	6, 4	GI	Gravel	Ogallala	Cy,W	D,S	Top of wooden platform resting on oil-barrel curb.	+ .7	2,362.6	35.54	8-11-39	
343	SE¼ SE¼ sec. 30	J. L. Burgan	Dr	22.1	6	T	Sand and gravel	Alluvium	Cy,W	S	Top edge of round pump base, east side.	+ .7	2,338.2	17.04	8-12-39	
	T. 27 S., R. 22 W.															
344	NE¼ NE¼ sec. 5	O. G. Bartlett	Dr	37.1	5½	GI	Gravel and/or sandstone.	Ogallala and/or Dakota	Cy,W	D,S	Top of casing, west side	+ .2	2,391.9	23.92	7-29-39	
345	NE corner SE¼ sec. 10	Mrs. G. W. Avery	Dr	39.9	5½	GI	Gravel	Ogallala	N	N	Top of casing, east side	+1.0	2,412.5	38.68	10-15-38	Unused domestic well

TABLE No. 15.—Records of typical wells in Ford county, Kansas (*Continued*)

No. on plate 2 and plate 3	Location	Owner or tenant	Type of well(1)	Depth of well (2) (feet)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic horizon	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Height above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (feet)	Date of measurement	Remarks— (Yield given in gallons a minute; draw-down in feet)
346	SW corner sec. 10	Mrs. I. M. Dawson	Dr	38.9	2	GP	Gravel	Ogallala	N	N	Top of 2-inch pipe	+ .1	2,414.2	20.57	10-15-38	Unused domestic tubular well; depth to water level is questionable
347	NE¼ NE¼ sec. 14	E. Konda	Dr	56.3	4½	GI	Gravel and/or sandstone.	Ogallala and/or Dakota	Cy,H	N	Top of casing, west side	+1.0	2,404.4	39.16	7-29-39	Unused stock well
348	NE corner NW¼ sec. 16	Lincoln School Dist. No. 67.	Dr	59.3	4½	I	do.	do.	Cy,H	D	Top of casing, west side	+ .5	2,417.5	43.16	7-29-39	School well
349	SW¼ SW¼ sec. 24	I. L. Plattner	Dr	88.2	4½	GI	Sandstone	Dakota	Cy,W	D,S	Top of casing, south side	+ .3	2,414.6	51.49	7-29-39	Reported depth 180 feet
350	NE¼ SE¼ sec. 27	W. H. Cook	Dr	78.9	5½	GI	do.	do.	Cy,H	D	Top of casing, northwest side.	+1.1	2,417.3	46.96	7-29-39	
351	NW¼ NW¼ sec. 33	Geo. Molitor	Du	14.4	22	OB	Sand and gravel	Alluvium	Cy,W	D	Top of casing, east side	+1.2	2,368.4	13.97	10- 8-39	
	T. 27 S., R. 23 W.															
352	NE¼ NE¼ sec. 3	H. Gum et al.	Dr	114.9	5½	GI	Gravel	Ogallala	Cy,W	N	Top of wooden board under pump base.	.0	2,454.1	70.11	5- 6-39	Unused domestic and stock well; water contains considerable fluoride, see analysis
353	SW corner sec. 5	H. J. Vogel	Du	88.4	40	N	do.	do.	Cy,W	D,S	Top of wooden plank under pump base.	+1.0	2,514.8	83.83	4-15-39	
354	NW¼ SE¼ sec. 8	A. B. Fisher	Dr	19.2	16	GI	Sand and gravel	Alluvium	C,G	I	Top of round concrete-block curb, west side.	.0	2,415.9	9.68	4-15-39	Battery of 5 shallow wells, first well south of pump-house measured
355	NW¼ NE¼ sec. 10	J. H. English	Dr	59.8	5	T	Gravel	Ogallala	Cy,W	N	Top of casing, south side	+ .2	2,465.2	56.43	8-11-39	Unused domestic well
356	SW corner NW¼ sec. 12	Geo. Molitor	Dr	16.0	4½	GI	do.	do.	Cy,W	D,S	Top of casing, north side	— .8	2,448.4	9.87	8-11-39	
357	SE¼ NE¼ sec. 16	C. Van Riper	Dr	23	20	CR	Sand and gravel	Alluvium	C,E	I	Top of casing in pump pit, south side.	—4.9	2,399.7	5.57	11- 3-38	Middle well of a battery of 3 similar wells; reported yield 900; water hard and contains considerable iron, see analysis

358	NE¼ SE¼ sec. 16	G. D. Cochran	Dr	20.5	20	CR	do	do	C,G	I	Top of round concrete cover resting on curb.	+ .5	2,404.0	10.16	10-20-38	North well of a battery of 3 similar wells; reported yield 900, draw-down 5; observation well
359	NE¼ SE¼ sec. 18	P. H. Young	Dr	25.4	20	GI	do	do	C,G	I	Top of round concrete-block curb, north side.	.0	2,424.1	10.44	8- 3-39	Reported yield 300
360	SW corner sec. 20	School Dist. No. 37	Dr	57.0	4	I	Gravel	Ogallala	Cy,H	D	Top of casing, west side	+ .8	2,477.7	56.26	10- 8-38	School well.
361	SE¼ NE¼ sec. 23	G. D. Cochran	Dr	19.1	20	CR	Sand and gravel	Alluvium	C,G	I	Top of square concrete curb, south side.	.0	2,392.3	7.85	10-26-38	Battery of 6 shallow wells; first well south of pump-house measured; reported yield 800; temperature 62° F.; observation well
362	SW¼ SW¼ sec. 33	Dorothy Thomas	Dr	96.7	5½	GI	Gravel	Ogallala	Cy,W	N	Top of casing, east side	+ .3	2,489.2	78.22	7-20-39	Unused domestic well
	T. 27 S., R. 24 W.															
363	SW¼ SW¼ sec. 1	E. R. and L. E. Robertson.	Dr	33.7	12	GI	do	do	Cy,W	N	Top of casing, west side	+1.5	2,455.8	29.85	11- 8-38	Unused stock well
364	NW¼ SW¼ sec. 2	Karl Miller	Dr	21.6	16	GI	Sand and gravel	Alluvium	N	N	Brass plate at edge of square hole in 4-foot wooden platform.	+ .4	2,448.7	11.17	10-10-38	Unused battery of 8 shallow irrigation wells; pump removed; third well north of pumphouse measured; observation well
365	SW¼ NW¼ sec. 3	Kansas Soldiers' Home, Ft. Dodge.	Dr	150	12	I	Gravel	Ogallala	T,E	I						Reported yield 800
366	SW¼ NE¼ sec. 3	do	Dr	153	24, 12	I	do	do	T,E	I						Reported yield 400; gravel packed
367	NW corner SE¼ sec. 3	do	Dr	150	12	I	do	do	T,E	P						Supplies Ft. Dodge homes, power plant, and ice plant; reported yield 300
368	NW¼ NE¼ sec. 4	Kansas Power Co.	Dr	152	24	I	do	do	N	N						Unused industrial well
369	do	do	Dr	152	24	I	do	do	T,E	In						Measured yield 1,475, draw-down 68; used for cooling condensers; temperature 57°F.
370	do	do	Dr	152	24	I	do	do	T,E	In						Measured yield 1,740, draw-down 62; used for cooling condensers
371	do	do	Dr	152	24	I	do	do	T,E	In						Measured yield 1,730, draw-down 57; used for cooling condensers.
372	SW corner NW¼ sec. 5	T. F. Garner	Dr	11.7	4½	GI	Sand and gravel	Alluvium	Cy,W	N	Top of casing, south side	+ .4	2,461.3	8.24	6- 9-39	Unused stock well
373	NW corner sec. 9	Ernest C. Martin	Dr	38.5	5½	GI	do	do	C,G	S	Top of casing, north side	+ .7	2,464.0	11.45	6- 9-39	Used for filling silo
374	NW¼ SE¼ sec. 10	do	Dr	26.5	5½	GI	do	Alluvium and/or Ogallala.	Cy,W	S	Top of 2 by 2 nailed to wooden pipe clamp.	+ .5	2,462.9	21.77	6- 9-39	

TABLE No. 15.—Records of typical wells in Ford county, Kansas (*Continued*)

No. on plate 2 and plate 3	Location	Owner or tenant	Type of well(1)	Depth of well (2) (feet)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic horizon	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Height above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (feet)	Date of measurement	Remarks— (Yield given in gallons a minute; draw-down in feet)
375	SW¼ NE¼ sec. 12	Vic Carson	Dr	15.5	16	GI	Sand and gravel	Alluvium	C,G	I	Top of oil-barrel curb, east side.	— .5	2,424.7	4.75	10-26-38	North well of a battery of 2 similar wells; reported yield 500
376	NW corner sec. 17	Hiram Burr	Dr	51.7	5½	GI	do	Alluvium and/or Ogallala	Cy,W	S	Top of casing, south side	+2.3	2,503.3	42.30	6-10-39	
377	NW corner sec. 19	L. E. Pendleton	Dr	90.4	5½	GI	Gravel	Ogallala	Cy,W	N	Top of casing, south side	+ .6	2,548.4	82.36	6-10-39	Unused domestic and stock well
378	NE¼ SE¼ sec. 30	T. Hartman	Dr	110.8	5½	GI	do	do	Cy,W	N	Top of 3-inch hole in disc base plate.	+ .2	2,551.4	93.31	6-10-39	Do
379	NE corner SE¼ sec. 35	Mrs. Stella Barngrover.	Dr	97.8	4½	I	do	Rexroad	N	N	Top of casing, west side	—3.0	2,505.6	74.38	5- 4-39	Well abandoned and pit filled with earth
	T. 27 S., R. 25 W.															
380	NW corner sec. 2	Otis Beeson	Dr	24.8	15	GI	Sand and gravel	Alluvium	C,G	I	Top of square concrete curb, south side.	+ .3	2,492.8	16.10	10-24-38	South well of a battery of 3 similar wells; installed in 1908; reported yield 300
381	NW¼ NE¼ sec. 3	W. S. Tackley	Dr	23.3	14	GI	do	do	C,E	I	Top of board cover, north side.	+1.0	....	13.07	11-30-38	Reported yield 375
382	NW¼ NE¼ sec. 3	Chas. Beall	Dr	25.0	12	GI	do	do	C,G	I	....	....	....	....	....	Reported yield 250
383	SW¼ NE¼ sec. 3	Silas Potter	Dr	....	....	....	do	do	C,G	I	....	....	....	....	....	Do
384	NW¼ NE¼ sec. 3	Chas. Beall	Dr	29.4	42	TW	do	do	C,G	I	Top of iron brace on auto frame, north side.	+1.6	2,497.7	17.37	12- 1-38	Reported yield 300
385	NE¼ NE¼ sec. 3	S. G. Joy	Dr	25	22	OB	do	do	C,G	I	Top of oil-barrel casing, east side.	—5.5	....	8.92	11-30-38	Reported yield 250
386	NE¼ NE¼ sec. 3	H. Kruger	Dr	....	20	CR	do	do	C,G	I	....	....	....	....	....	Reported yield 200
387	NE¼ NE¼ sec. 3	Carl Williams	Dr	....	14	....	do	do	C,G	I	....	....	....	....	....	Reported yield 250
388	NE¼ NW¼ sec. 3	Dr. C. L. Williams	Dr	28	15	GI	do	do	C,E	I	Top of casing, east side	—9.5	....	3.05	11-30-38	Reported yield 300
389	SE¼ NW¼ sec. 3	Clyde Burk	Dr	47.3	19	GI	do	do	C,G	I	Top of round concrete curb, northwest side.	—1.0	2,509.2	24.69	11- 4-38	Reported yield 700, draw-down 12 after 40 hours

390	SW¼ NW¼ sec. 4	Clarence Aten	Dr	57.0	48	TW	do	do	C,G	I	....	....	2,512.3	20±	....	Reported yield 950, drawdown 13½
391	NE¼ SW¼ sec. 4	Hanson Widup	Dr	65.0	20	BS	do	do	VC,T	I	....	....	....	37±	....	Water level could not be measured; reported yield 800
392	NE¼ NE¼ sec. 8	S. W. Aten	Dr	35.3	5½	GI	do	do	Cy,W	S	Top of casing, north side	+ .6	2,513.9	25.07	5-25-39	
393	NW¼ NE¼ sec. 10	Ralph Williams	Dr	94.1	40, 16	OW	do	Alluvium and Ogallala	T,T	I	Top of channel-iron sill under pump, east side.	+ .7	2,540.1	62.22	10-14-38	Measured yield 765, drawdown 15(8)
394	NE corner sec. 15	F. S. Lorimor	Dr	93.6	5½	GI	do	Ogallala	Cy,W	S	Top of casing, east side	+ .3	2,560.8	82.29	6- 3-39	
395	SW¼ NW¼ sec. 21	Floyd Massey	Dr	110.7	5½	GI	do	do	Cy,W	D,S	Top of small brass plate on wooden pipe-clamp.	+ .8	....	107.15	6- 3-39	Seldom used
396	NE corner sec. 27	A. Gerdes	Dr	91.8	5½	GI	do	do	Cy,W	S	Top of casing, north side	+ .4	2,567.2	90.99	6- 3-39	
397	SW corner sec. 30	Roth and Wagner	Dr	170.0	4	I	do	do	Cy,W,G	N	Top of casing, northeast side.	+1.6	2,670.1	158.57	5-25-39	Unused domestic and stock well
	T. 27 S., R. 26 W.															
398	NE¼ NE¼ sec. 1	Mrs. R. E. Pennington.	Dr	86.1	20	OW	do	Alluvium and/or Ogallala.	T,T	I	Top of casing, south side	+1.5	2,567.4	56.13	10-24-38	Reported yield 750; observation well until February, 1939
399	NE¼ NE¼ sec. 1	do	Dr	66.8	6	GI	do	do	N	N	Top of casing, north side	+ .3	....	55.92	10-24-38	Unused stock well 28 feet south of well 398; observation well beginning in May, 1939
400	NW¼ NW¼ sec. 2	Erwin Streiff	Dr	72	5½	GI	do	do	Cy,W	D,S	Top of square opening to concrete pit.	+1.0	2,589.8	63.85	5-23-39	
401	SW¼ SE¼ sec. 6	W. S. Johnson	Dr	118.9	6, 5	I	do	Ogallala	N	N	Top of 5-inch reducer in 6-inch casing.	+ .5	2,650.1	96.01	10- 4-38	Unused irrigation well formerly pumped with windmill; observation well
402	SW¼ SE¼ sec. 6	do	DD	123	32, 15	C and GI	do	do	T,G	I	Top of channel-iron sill under pumphead.	+1.0	2,649.5	95.50	10-22-38	Measured yield 240, drawdown 22.9(8)
403	SE¼ NE¼ sec. 7	John E. Wagner	Dr	126.9	16	BS	do	do	T,G	I	Top of casing, southwest side.	+ .4	2,655.6	103.68	10-14-38	Measured yield 360, drawdown 22(8); observation well
404	NE¼ NW¼ sec. 10	Otto Streiff	Dr	107	4	I	do	do	Cy,W,G	D,S	Top of square opening to pump pit.	+1.0	2,619.6	88.76	5-23-39	
405	NW corner sec. 17	A. C. Diers	Dr	130.9	4½	GI	do	do	Cy,W	D,S	Top of casing, southwest side.	+ .8	2,672.1	121.91	5-22-39	
406	SE¼ NW¼ sec. 21	F. and E. Blume	Dr	147.5	3½	I	do	do	N	N	Top of casing, west side	+1.0	2,672.4	131.05	11- 1-38	Unused domestic well; observation well until May 2, 1939
407	NE corner NW¼ sec. 23	M. Kiler, et al	Dr	146.9	4½	I	do	do	Cy,W	N	Top of tin-can cover on casing.	+ .5	2,667.2	145.28	5-23-39	Unused domestic and stock well
408	NE¼ NW¼ sec. 29	E. E. Groves	Dr	153.7	4½	I	do	do	Cy,W	D,S	Top of casing, north side	+ .2	2,700.0	146.66	5-27-39	
409	NW corner sec. 34	Eli Shrock	Dr	164.6	5½	GI	do	do	Cy,W	S	Top of casing, south side	+ .6	2,679.4	150.12	5-27-39	

TABLE No. 15.—Records of typical wells in Ford county, Kansas (*Continued*)

No. on plate 2 and plate 3	Location	Owner or tenant	Type of well(1)	Depth of well (2) (feet)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic horizon	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Height above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (feet)	Date of measurement	Remarks—(Yield given in gallons a minute; draw-down in feet)
	T. 27 S., R. 27 W.(9)															
410	SW¼ SW¼ sec. 25........	Arthur Slocum....	Dr	200	16	I	Sand and gravel...	Ogallala....	T,G	I	Top of projection on pumphead holding air pipe line.	+1.4	2,727.2	166.76	10- 4-38	Reported yield 800, draw-down 20
	T. 28 S., R. 21 W.															
411	NE¼ NW¼ sec. 25.......	M. L. Gilliom.....	Dr	108.9	4	I	do..............	Rexroad....	Cy,W,H	N	Top of casing, north side	+1.6	2,375.8	83.32	10-10-38	Unused stock well; observation well
412	SW corner NW¼ sec. 36...	J. L. Ramsey.....	Dr	83.2	5½	I	do..............	do.........	Cy,W	S	Top of casing, north side	+ .9	2,354.9	68.10	7-26-39	
	T. 28 S., R. 22 W.															
413	SW¼ NW¼ sec. 2........	Mrs. Cora M. Rickard.	Dr	19	20	CR	do..............	Alluvium...	C,G	I	Top of casing in pump pit west side.	—5.0	....	6.00	10-27-38	Battery of 7 shallow wells measured well in pump pit; reported yield 500
414	NW¼ NE¼ sec. 4........	Russell Riegel.....	Dr	29	20	CR	do..............	do.........	C,G	I	Top of oil-barrel curb above casing in pump pit.	—8.7	2,355.8	3.60	10-27-38	Battery of 4 shallow wells; measured well in pump pit; reported yield 500
415	NE¼ NW¼ sec. 4........	E. P. Hoover.....	Dr	26	19	GI	do..............	do.........	C,T	I	Top of casing, north side	—10.0	2,355.9	5.42	10-27-38	Reported yield 250
416	NE¼ NW¼ sec. 4........	do..............	Dr	31.0	14	GI	do..............	do.........	C,G	I	....	......	2,366.0	....	....	Reported yield 125; temperature 59°F.
417	SW¼ SW¼ sec. 4.........	L. A. Lamb.......	Dr	77.1	20	CR	do..............	do.........	T,T	I	Top of casing, east side	+1.0	2,386.2	28.49	10-10-38	Measured yield 1,165, draw-down 14.5 feet(8); 50 feet of gravel reported; observation well
418	NE¼ NE¼ sec. 6.........	G. C. Pinkney....	Dr	48	5½	GI	do..............	do.........	Cy,W	D	Top of sill under floor..	.0	2,387.4	22.38	10- 8-39	
419	NE¼ NE¼ sec. 9.........	T. P. Russell......	Dr	78.0	20	BS	do..............	do.........	T,T	I	Top of casing, west side	+1.0	2,383.2	27.68	10-26-38	Reported yield 900
420	SW¼ NE¼ sec. 10........	J. J. Maas........	Dr	69.0	16	BS	do..............	do.........	T,G,T	I	Bottom edge of round pumphead base.	.0	2,372.0	24.49	11-15-38	Reported yield 900; Dakota sandstone encountered at a depth of 69 feet
421	SE¼ NW¼ sec. 11........	E. V. Melia.......	Dr	71.0	20	CR	do..............	do.........	T,G	I	Top of casing, west side	.0	2,375.7	25.85	10-27-38	Measured yield 975, draw-down 13.85 (8); observation well

422	NE¼ NE¼ sec. 20	E. H. Patterson	Dr	169	19	GI	do	Rexroad	T,T	I	Top of hole in base of pumphead.	+1.0	2,495.9	134.83	10-15-38	Reported yield 700, drawdown 18
	T. 28 S., R. 25 W.															
423	SW corner NW¼ sec. 9	Ira Paulin	DD	116	48, 16	GI	do	do	T,T,G	I	do	+ .4	2,496.2	85.57	10-20-38	Measured yield 270, drawdown 20.6(8); observation well since May 4, 1939
424	NE¼ NW¼ sec. 10	H. L. Hartshorn	Dr	86.1	4½	GI	do	do	Cy,W	D,S	Top of casing, east side	+1.1	2,480.9	81.00	7-21-39	Total depth not known, casing obstructed by cylinder at depth given,
425	NW¼ NW¼ sec. 15	Mrs. Milton Patterson	DD	120	48, 19	GI	do	do	T,T	I	Top edge of plank platform across curb.	+ .3	2,484.5	81.53	12- 7-38	Reported yield 400; fine sand moves into well
426	SE¼ NE¼ sec. 19	J. H. Rirk	Dr	99.2	2	GP	do	do	N	N	Top of 2-inch pipe	+1.8	2,506.0	88.61	6-29-39	Unused tubular stock well; accuracy of water-level measurement questionable
427	SE corner NE¼ sec. 20	J. I. Wilcoxen	Dr	83.0	4½	I	do	do	N	N	Top of casing	+ .8	....	62.92	10- 8-39	Unused domestic well
428	SW corner sec. 27	C. E. Miller	Dr	113.1	......	N	do	do	N	N	Top edge of 2-inch hole in barrel-head cover.	— .3	2,504.7	81.00	10- 8-38	Unused domestic well; upper sections of casing removed
	T. 28 S., R. 24 W.															
429	SE corner sec. 2	Enterprise School	Dr	102.7	5	GI	do	Ogallala	Cy,H	D	Top of casing, northwest side.	+ .4	2,518.5	88.36	10- 8-38	School well; reported depth 112 ft., casing obstructed by cylinder at depth given
430	NE¼ NE¼ sec. 3	Martha D. Abell	Dr	....	2	GP	do	do	Cy,W	N	Top of 2-inch tee on pipe.	+2.5	2,537.2	93.46	10- 8-38	Unused tubular stock well accuracy of water-level measurement questionable
431	SW corner sec. 3	A. Yeager est	Dr	143.2	6	GI	do	do	Cy,W	N	Top of casing, north side	+ .8	2,568.2	127.17	6- 7-39	Unused domestic well
432	NE¼ NE¼ sec. 6	C. H. Roesener	Dr	136.9	5½	GI	do	Rexroad	Cy,W	N	Top of casing, south side	+1.3	2,581.6	132.00	7- 1-39	Unused domestic and stock well
433	SE¼ NE¼ sec. 8	Fred G. Bell	Dr	148.9	5½	GI	do	do	Cy,W	N	Top of 5½-inch hole in concrete platform.	+ .5	2,575.5	127.45	6- 7-39	Do
434	NW¼ SW¼ sec. 10	R. and C. F. Royse	Dr	128.2	5½	GI	do	do	Cy,W	N	Top of casing, north side	+ .4	2,559.4	117.15	6- 7-39	Unused stock well
435	SW¼ NW¼ sec. 11	Robert Lehman	DD	160.0	48, 20	C, OW	do	do	T,G	I	Top of 48-inch concrete curb.	.0	2,553.8	126.82	10- 6-38	Measured yield 765, drawdown 14.3(8); powered by 2 combine engines in tandem
436	NW¼ NE¼ sec. 12	Mrs. R. E. Bisbee	Dr	127.0	4	I	do	do	Cy,W	D,S	Top of casing, northwest side.	+ .5	2,529.6	101.04	10- 8-38	
437	NE¼ NW¼ sec. 16	C. E. Kincaid	Dr	124.8	4½	I	do	do	Cy,W	N	Top of casing, southeast side.	+ .5	2,565.7	118.50	6- 7-39	Unused domestic and stock well
438	NE corner sec. 18	T. F. Anderson	Dr	155.4	5½	GI	do	do	Cy,W	N	Top of casing, northeast side.	+1.4	2,594.4	139.82	6- 7-39	Do
439	NW¼ NW¼ sec. 22	Mrs. H. H. Kimbell	Dr	105.5	5½	GI	do	do	Cy,W	D,S	Top of tin cover plate on casing.	+ .7	2,543.4	102.66	6-29-39	Reported depth, 117 feet; casing obstructed by cylinder at depth given

Table No. 15.—Records of typical wells in Ford county, Kansas (*Continued*)

No. on plate 2 and plate 3	Location	Owner or tenant	Type of well(1)	Depth of well (2) (feet)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic horizon	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Height above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (feet)	Date of measurement	Remarks—(Yield given in gallons a minute; draw-down in feet)
440	NW¼ NW¼ sec. 27	Fidelity Trust Co.	Dr	48.1	5½	GI	Sand and gravel	Alluvium and/or Rexroad.	N	N	Top of casing, north side	+1.2	2,494.5	44.21	6-29-39	Unused stock well
441	SE¼ SE¼ sec. 35	Geo. B. Rooney	Dr	132.6	5½	GI	do	Rexroad	Cy,W	N	Top of casing, north side	+ .8	2,525.1	98.04	7-12-39	Unused domestic well
	T. 28 S., R. 25 W.															
442	SW¼ SE¼ sec. 1	J. C. Kliesen	Dr	131.4	4	OW	do	do	Cy,W	S	Top of casing, north side	+ .4	2,593.2	129.61	6- 7-39	
443	NW¼ NW¼ sec. 2	H. N. Bell	Dr	151.6	5½	GI	do	do	Cy,W	D,S	Top of casing, east side	+ .7	2,623.3	149.44	6-21-39	Reported depth, 160 feet; casing obstructed by cylinder at depth given
444	NE¼ NE¼ sec. 5	C. W. Leighty	Dr	157.2	4	I	do	do	Cy,W	D,S	Top of casing, east side	+3.3	2,637.7	144.19	6- 5-39	
445	NE corner NW¼ sec. 6	Albert Byer	Dr	148.4	5½	GI	do	do	Cy,W	N	Top of 5½-inch iron curb	+2.3	2,641.7	137.01	5-25-39	Unused domestic and stock well
446	NW corner NE¼ sec. 7	W. F. Sandifer	Dr	139.4	5½	GI	do	do	Cy,H	N	Top of casing, north side	+ .9	2,619.9	119.04	5-25-39	Unused stock well
447	SE¼ SW¼ sec. 8	G. W. Railing	Dr	54.7	5½	GI	do	do	N	N	Top of casing, north side	— .2	2,572.6	53.79	6- 3-39	Do
448	SE¼ NE¼ sec. 9	M. L. Adams	Dr	109.2	5½	GI	do	do	Cy,W	N	Top of 2-inch pipe, south side.	+2.4	2,606.7	102.12	6- 3-39	Unused domestic and stock well
449	NW¼ NW¼ sec. 11	G. M. Bell	Dr	131.2	5½	GI	do	do	Cy,W	S	Top of iron pipe clamp, north side.	+1.3	2,590.6	119.02	6-17-39	
450	SE¼ SW¼ sec. 11	W. J. Scofield	Dr	142.9	4½	GI	do	do	Cy,W	D,S	Top of casing, northeast side.	+ .3	2,596.3	129.29	6- 7-39	
451	NE¼ NE¼ sec. 13	John G. Gerdes	Dr	124.3	5½	GI	do	do	Cy,W	D,S	Top of casing, north side	+ .5	2,576.2	112.62	6- 7-39	
452	NE¼ NE¼ sec. 16	M. L. Adams	Dr	121.2	5½	GI	do	do	Cy,W	D,S	Top of casing, south side	+ .3	2,598.7	119.20	6-21-39	Casing obstructed by cylinder at measured depth of 121.2 feet
453	SW corner sec. 22	J. R. Burnett	Dr	123	5½	GI	do	do	Cy,W	D,S	Top of casing, south side	+ .5	2,595.6	113.74	6-16-39	Measured depth, 117.9 ft.
454	SW¼ NE¼ sec. 23	C. F. and T. Bragg	Dr	76.9	5½	GI	do	do	Cy,W	S	Top of casing, south side	+1.6	2,531.3	61.77	6-16-39	
455	SE¼ SE¼ sec. 25	do	Dr	131.7	5½	GI	do	do	Cy,W	N	Top of casing, east side	+ .2	....	108.67	6-28-39	Unused stock well

456	NW¼ NE¼ sec. 29	C. G. Austin	Dr	112.3	4½	GI	do	do	N	N	Inside edge of iron collar in casing.	− .3	2,598.1	107.63	6–5–39	Do
457	NW¼ SW¼ sec. 33	Jos. Reinert	Dr	159.2	5½	GI	do	do	Cy,W,H	N	Top of casing, north side	+ .2	2,638.8	148.71	6–17–39	Unused domestic and stock well
	T. 28 S., R. 26 W.															
458	SW¼ NW¼ sec. 5	S. B. Thompson	Dr	134.6	4	I	do	do	Cy,W	S	Top of casing, south side	+2.6	2,672.9	123.88	6–21–39	
459	NE corner NW¼ sec. 7	M. J. Wood	Dr	155.2	4½	I	do	do	Cy,W	N	Top of wooden 3 by 3 pipe clamp.	+ .3	2,703.4	152.02	5–27–39	Unused domestic and stock well; total depth not known; casing obstructed by cylinder at depth given
460	SE¼ SW¼ sec. 8	W. H. Zirkle	Dr	177.7	4	I	do	do	Cy,W	D,S	Top of casing, west side	+ .8	2,705.8	163.34	6–14–39	
461	SW corner NW¼ sec. 9	S. B. and E. Thompson.	Dr	163	4	I	do	do	Cy,W	D,S	Top of casing, east side	+ .8	2,690.2	149.07	6–14–39	
462	SW¼ NW¼ sec. 11	L. and B. Reinert	Dr	137.8	5½	GI	do	do	Cy,W	N	Top of casing, southwest side.	+ .6	2,645.4	127.07	6–21–39	Unused domestic and stock well
463	NE corner sec. 15	Lewis Reinert	Dr	171.7	4	GI	do	do	Cy,W	D,S	Top of casing, east side	+ .5	2,667.0	145.66	5–27–39	
464	SE corner NE¼ sec. 27	C. J. Heyen	Dr	162.9	5½	GI	do	do	Cy,W	D,S	Top of casing, north side	+ .2	2,674.8	155.70	6–22–39	
	T. 28 S., R. 27 W. (9)															
465	NE corner sec. 25	F. L. Crabb	Dr	178.6	4	I	do	do	Cy,W	D,S	Top of casing, north side	+ .7	2,716.6	170.55	6–15–39	Located near basement house
	T. 29 S., R. 21 W.															
466	SW¼ NE¼ sec. 5	City of Bucklin	Dr	125.0	12½	OW	do	do	P,E	P	....	....	....	102.5±	....	Stand-by well; seldom used; reported yield 85
467	SW¼ NE¼ sec. 5	do	DD	125.0	84, 15	B and GI	do	do	T,E	P	....	....	....	102.5±	....	Located in city hall building; reported yield 200
468	SE¼ SE¼ sec. 5	City of Bucklin	Du	111.8	84, 42	R and GI	do	do	T,E	P	Top edge of 2-foot square opening in pump pit.	−2.6	....	87.20	7–28–39	Reported yield 400, draw-down 10
469	SW¼ NE¼ sec. 22	Mrs. Lulu Edwards	Dr	169.2	8	OW	do	do	N	N	Top of casing, north side	+ .4	2,418.5	133.58	7–28–39	Unused; originally supplied water for near-by oil test
	T. 29 S., R. 22 W.															
470	SW corner NW¼ sec. 10	Lois Black	Dr	150.1	2	GP	do	do	Cy,W	N	Top of 2-inch pipe	+3.5	2,490.9	138.96	7–26–39	Unused tubular domestic well, accuracy of water-level measurement questionable
471	SE¼ SW¼ sec. 18	Mrs. Paul Mason	Dr	171.1	5½	GI	do	do	Cy,W	D,S	Top of casing, south side	+ .8	2,487.7	119.86	7–22–39	Reported depth 180 feet
472	SW¼ SE¼ sec. 27	G. H. Caustland	Dr	124.2	2	GP	do	do	N	N	Top of 2-inch tee on pipe.	+1.0	2,428.7	84.79	7–21–39	Unused tubular domestic well, accuracy of water-level measurement questionable
473	SW corner SE¼ sec. 28	Harold Astell	Dr	108.1	5½	I	do	do	Cy,W	D	Top of casing, north side	+3.3	2,438.0	93.58	7–21–39	
474	SW¼ NW¼ sec. 6	C. A. Smith	Dr	175.2	5½	GI	do	do	Cy,W	N	Top of casing, south side	+ .3	2,542.0	129.33	7–14–39	Unused stock well

TABLE No. 15.—Records of typical wells in Ford county, Kansas (*Continued*)

No. on plate 2 and plate 3	Location	Owner or tenant	Type of well (1)	Depth of well (2) (feet)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic horizon	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Height above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (feet)	Date of measurement	Remarks— (Yield given in gallons a minute; draw-down in feet)
475	NE corner NW¼ sec. 14	Jacob Hitz	Dr	197.3	4	GI	Sand and gravel	Rexroad	Cy,W	D,S	Top of 4-inch hole in concrete base.	+ .5	2,549.6	167.28	7-25-39	
476	NE¼ NE¼ sec. 21	Chas. Hill	Dr	206.2	5½	GI	do	do	Cy,W	D,S	Top of 15-inch circular floor flange.	+ .2	2,595.3	197.4	7-25-39	
	T. 29 S., R. 24 W.															
477	NW¼ SW¼ sec. 9	Wm. Buckhannon	Dr	155.8	5½	GI	do	do	Cy,W	N	Top of casing, northwest side.	+1.1	2,552.5	104.72	7-14-39	Do
478	SE¼ SE¼ sec. 11	E. S. Villines	Dr	162.1	5½	GI	do	do	Cy,W	N	Top of casing, northeast side.	+ .5	2,571.0	145.11	8- 3-39	Unused domestic and stock well
479	SE corner sec. 12	S. O. Albright	Dr	104.3	5½	GI	do	do	N	N	Top of casing, south side	.0	2,514.7	98.09	7-12-39	Do
480	SW¼ SW¼ sec. 13	do	Dr	134.9	5½	GI	Gravel	do	Cy,W	S	Top of casing, northeast side.	+1.5	2,544.6	121.51	7-12-39	
481	NE¼ SE¼ sec. 17	Nat. Gas Pipeline Co. of America.	Dr	138.5	30, 12	I	do	do	T,E	In	....	....	....	120.5±	....	Reported yield 100, draw-down 3
482	do	do	Dr	270	30, 8	I	do	do	GL	In	....	....	....	....	....	Reported yield 100
483	do	do	Dr	133	30, 12	I	do	do	T,E	In	....	....	....	117.5±	....	Reported yield 100, draw-down 7
484	do	do	Dr	149	30, 12	I	do	do	T,E	In	....	....	....	116.3±	....	Reported yield 110
485	NW¼ SW¼ sec. 17	E. B. Spahr	DD	152.6	48,20	C and GI	do	do	T,G	I	Top of 1-inch hole in base of pumphead.	+1.6	2,590.2	135.48	3- 6-39	Measured yield 320, draw-down 6.7(8); observation well
486	SW¼ SW¼ sec. 20	W. McInteer	Dr	135.5	5½	GI	do	do	Cy,W	N	Top of casing, north side	+ .2	2,586.2	129.24	6-28-39	Unused stock well
487	NE¼ SE¼ sec. 31	G. E. Lembrook	Dr	106.5	5½	GI	do	do	Cy,W	S	Top of casing, west side	+1.8	2,560.2	98.43	6-28-39	
488	NW¼ NE¼ sec. 36	Gerald Bradley	Dr	160.2	4	GI	do	do	Cy,H	N	Top of casing, east side	.0	2,579.9	158.23	10- 7-38	Unused domestic and stock well
	T. 29 S., R. 25 W.															
489	SW¼ SW¼ sec. 1	E. W. Reed	Dr	158.5	5½	GI	do	do	Cy,W	D,S	Top of casing, west side	+ .2	2,621.3	149.60	6-27-39	Reported depth 185 feet
490	SE corner NE¼ sec. 5	L. E. Wait	Dr	134.9	5½	GI	do	do	Cy,W,H	N	Top of casing, west side	+ .7	2,616.9	126.16	6-17-39	Unused domestic and stock well

491	SE corner SW¼ sec. 10	Paul J. Harshberger	Dr	155.3	6	GI	do	do	Cy,W	N	Top of casing, west side	+ .4	2,613.8	129.89	6-17-39	Unused stock well
492	NE¼ NW¼ sec. 14	Anna Mary Beck	Dr	157.2	5½	GI	do	do	N	N	Top of tin-can form in concrete curb.	+ .8	2,623.6	146.95	6-17-39	do
493	NW¼ NE¼ sec. 17	R. G. and J. Hall	Dr	91.6	5½	GI	do	do	Cy,W	S	Top of casing, west side	+2.0	2,582.3	87.18	6-17-39	
494	NE¼ SE¼ sec. 19	C. H. Knoy	Dr	119.5	5½	GI	do	do	Cy,W	S	Top of casing, south side	+1.0	2,592.1	92.83	6-27-39	
495	NW¼ NE¼ sec. 21	H. R. Brown	Dr	124.3	5	GI	do	do	N	N	Top of casing, north side	+1.4	2,609.0	121.63	10- 7-38	Unused domestic and stock well
496	SE corner sec. 23	W. B. Stevens	Dr	163.4	5½	GI	do	do	Cy,H	S	Top of casing, west side	+ .4	2,604.5	133.21	6-27-39	Used occasionally
497	NE corner sec. 29	G. R. Shaffer	Dr	100.3	5½	GI	do	do	Cy,W	D,S	Top of casing in pit, north side.	—5.0	2,574.6	83.62	6-27-39	
498	NW¼ NW¼ sec. 32	C. W. Faris	Dr	115.4	5½	GI	do	do	Cy,W	S	Top of casing, west side	+0.3	2,566.7	65.85	6-27-39	
499	SE¼ SW¼ sec. 32	C. H. Wilcoxen	Dr	55.5	5½	GI	do	do	N	N	Top of casing, north side	+ .5	2,582.3	54.28	8- 3-39	Unused domestic and stock well
500	SW¼ SE¼ sec. 33	R. H. Tice	Dr	94.6	5½	GI	do	do	Cy,W	N	Top of casing, northwest side.	+ .3	2,584.5	88.71	6-27-39	Do
501	NW¼ NW¼ sec. 34	J. G. McConnell	Dr	117.3	5½	GI	do	do	Cy,W	N	Top of casing, north side	+ .5	2,583.9	94.67	6-27-39	Do
502	NE¼ NE¼ sec. 36	Lucille Cannon	Dr	185.2	5½	GI	Sand and gravel	do	Cy,W	N	Top of casing, west side	+1.0	2,584.9	120.13	6-28-39	Unused stock well
	T. 29 S., R. 26 W.															
503	SW¼ SW¼ sec. 3	A. Reinert	Dr	74.7	5½	GI	do	do	Cy,W	N	Top of casing, east side	+1.4	2,589.5	60.57	6-15-39	Unused domestic and stock well
504	NW¼ NW¼ sec. 4	Mrs. Katie Stohr	Dr	113.7	5½	GI	do	do	Cy,W	D,S	Top of casing, southwest side.	+ .3	2,625.5	84.50	6-22-39	
505	SW corner NW¼ sec. 6	S. E. and L. Holten	Dr	96.2	4	I	do	do	Cy,W	S	Top of casing, west side	+ .8	2,647.3	81.92	6-15-39	
506	SE corner NE¼ sec. 10	August Reinert	Dr	96.3	4	I	do	do	Cy,W	D,S	Top of casing, east side	+4.4	2,590.4	80.96	6-21-39	
507	NE¼ SW¼ sec. 15	Joseph Lutz	Dr	149	16	OW	Sand and gravel and/or sandstone.	Rexroad and/or Dakota	T,G	I	Top of lower edge of rectangular break in base of pumphead.	+1.3	2,556.2	45.45	10- 4-38	Measured yield 950, drawdown 19.5 after 1½ hrs. pumping(8); observation well
508	SW corner sec. 20	E. W. Flinn	Dr	55.5	6, 4	OW	Sand and gravel	Rexroad	Cy,W	D,S	Top of casing, west side	.0	2,571.9	47,58	6-22-39	Reported depth 120 feet, casing obstructed by cylinder at depth given
509	SE corner sec. 20	O. J. Deaver	Dr	33.5	4	I	do	do	Cy,W	D,S	Top of casing, north side	+ .3	2,550.7	30.04	6-22-39	Casing obstructed by cylinder at measured depth of 33.5 feet
510	SW¼ NW¼ sec. 24	George Lutz	Dr	211.5	16	OW	Sand and gravel and/or sandstone.	Rexroad and/or Dakota	T,G	I	Top of lower edge of rectangular break in base of pumphead.	+1.8	2,540.4	35.47	10- 7-38	Measured yield 690, drawdown 48+(8); observation well
511	NW¼ SW¼ sec. 26	William Long	Dr	43.4	5½	GI	Sand and gravel	Alluvium and/or Rexroad.	Cy,H	N	Top of casing, east side	+1.3	2,515.8	13.96	6-22-39	Unused stock well
512	SW¼ SW¼ sec. 26	do	Dr	....	1½	I	Sand and gravel and/or sandstone.	Rexroad and/or Dakota	F	S	....	....	....	....	....	

Table No. 15.—Records of typical wells in Ford county, Kansas (*Concluded*)

No. on plate 2 and plate 3	Location	Owner or tenant	Type of well (1)	Depth of well (2) (feet)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic horizon	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Height above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (feet)	Date of measurement	Remarks—(Yield given in gallons a minute; draw-down in feet)
513	SE¼ NW¼ sec. 27	B. C. Waters	Dr	......	......	......	Sand and gravel and/or sandstone.	Rexroad and/or Dakota	F	S	......	......	......	......	......	Well not visited
514	SE¼ SE¼ sec. 28	Hamar Bros	Dr	30.1	5½	GI	Sand and gravel	Alluvium	Cy,H	S	Top of casing, west side	+ .5	2,517.9	4.80	6–22–39	
515	NW¼ NW¼ sec. 29	A. C. Veatch	Dr	62.1	5½	GI	do	Alluvium and/or Rexroad	N	N	Top of casing, east side	+ .6	2,562.9	39.38	6–22–39	Unused stock well
516	NE¼ NE¼ sec. 32	J. E. Long	Dr	......	......	......	Sand and gravel and/or sandstone.	Rexroad and/or Dakota	F	S	......	......	......	......	......	Well not visited
517	NW¼ NE¼ sec. 34	William Long	Dr	145	3½	I	do	do	F	S	......	......	2,512.1	......	......	Estimated flow 1 gallon in 3 minutes
518	SE¼ NE¼ sec. 34	do	Dr	......	1½	GP	do	do	F	S	......	......	......	......	......	Measured flow, 1 gallon in 8 minutes
519	NW¼ NW¼ sec. 35	do	Dr	175	2	I	do	Rexroad and/or Dakota	F	S	Top of 2-inch pipe in ponded creek.	—3.0±	......	+4.16(9)	7-15-39	Measured flow 3 gallons a minute; top of 2-inch pipe is 0.4 foot below surface of pond
520	NW¼ NW¼ sec. 35	do	Dr	275	3	I	Sandstone	Dakota	F	S	......	......	......	......	......	Flows a scant trickle
521	SW¼ NW¼ sec. 35	do	Dr	175	2	I	Sand and gravel and/or sandstone.	Rexroad and/or Dakota	F	S	Top of 2-inch pipe in ponded creek.	—3.0±	......	+4.18(9)	7-15-39	Measured flow 3 gallons a minute; top of 2-inch pipe is 0.55 foot below surface of pond
522	SE¼ NE¼ sec. 35	do	Dr	188	16	OW	do	do	T,G	I	Top of ¾-inch hole in base of pumphead, east side.	.0	2,530.3	23.13	10– 4–38	Measured yield 570, estimated draw-down 41.5 (8); observation well
523	SW corner SE¼ sec. 35	do	Dr	32.9	3	I	do	Alluvium	Cy,W	N	Top of casing, north side	.0	2,518.4	12.02	6–22–39	Unused stock well; measured depth may not be true depth
	T. 29 S., R. 27 W.(10)															
524	SW¼ SE¼ sec. 25	Mrs. Sarah Marney	Dr	51.9	3	I	Sand and gravel	Rexroad	Cy,H	N	Top of casing, west side	+ .4	2,576.7	46.16	6–21–39	Unused stock well; total depth not known; casing obstructed by cylinder at depth given

525	SW¼ SE¼ sec. 36	W. R. Reese	Du	23.9	40±		do	Alluvium	Cy,W	N	Top of 2 by 6 plank in platform.	+1.0	2,545.1	22.91	6-21-39	Unused domestic and stock well
	T. 30 S., R. 22 W.(11)															
526	SW corner NW¼ sec. 5	M. J. Tipton	Dr	93.3	5½	GI	do	Rexroad	Cy,W	D,S	Top of casing, north side	+ .4	2,440.2	89.86	7-22-39	
	T. 30 S., R. 23 W.(11)															
527	NE¼ NE¼ sec. 6	E. F. Houff	Dr	156.1	5½	GI	do	do	Cy,W	D,S	Top of casing, south side	+ .7	2,557.4	142.78	6-28-39	
	T. 30 S., R. 24 W.(11)															
528	NE¼ NE¼ sec. 2	T. E. Scott	Dr	152.1	5½	GI	do	do	Cy,W	N	Top of casing, east side	+ .4	2,562.3	137.66	6-18-39	Unused domestic and stock well
529	NE¼ NW¼ sec. 4	W. O. Rogers	Dr	140.3	5½	GI	do	do	Cy,W	N	Top of casing, north side	+ .7	2,568.2	114.33	6-28-39	Do
	T. 30 S., R. 25 W.(11)															
530	NW corner SW¼ sec. 2	Phoenix Jt. Stock Land Bank.	Dr	103.9	5	GI	do	do	Cy,W	N	Top of casing, north side	+1.3	2,572.0	88.75	6-27-39	Unused stock well
	T. 30 S., R. 26 W.(12)															
531	NW¼ SW¼ sec. 5	W. A. Ellson	Dr	210	16	OW	do	Rexroad and/or Dakota	T,G	I	Top of 22-inch oil-barrel form in round concrete base.	+ .5	2,538.4	21.40	6-21-39	Measured yield, 1938, 900, draw-down 30.6 (8)

1. DD, dug and drilled; Dr, drilled; Du, dug.
2. Reported depths below the land surface are given in feet; measured depths are given in feet and tenths below measuring points.
3. B, brick; BS, boiler steel; C, concrete; CR, concrete rings; GI, galvanized iron; GP, galvanized pipe; I, iron; OB, oil barrels; OW, oil well; R, rock; T, tile; TW, tractor wheels; W, wood; WI, wrought iron.
4. Method of lift: A, air lift; C, horizontal centrifugal; Cy, cylinder; F, natural flow; GL, gas lift; N, none; P, plunger type; Pr, pressure; R, removed; T, turbine; VC, vertical centrifugal.
   Type of power: D, diesel; E, electric; G, gasoline engine; H, hand; T, tractor; W, wind.
5. A, air-conditioning; D, domestic; I, irrigation; In., industrial (other than cooling of air-conditioning); N, none; P, public supply; S, stock.
6. Situated in Hodgeman county.
7. Situated in Edwards county.
8. Pumping test conducted and results furnished by the Division of Water Resources, Kansas State Board of Agriculture
9. Water level in feet above measuring point.
10. Situated in Gray county.
11. Situated in Clark county.
12. Situated in Meade county.

LOGS

On the following pages are listed the logs of 80 wells and test holes in Ford county. Logs 1-21 are of test holes drilled by the State and Federal Geological Surveys (fig. 2). Logs 22-80 include logs of test holes drilled by other agencies, logs of water wells (pl. 2), and partial logs of oil tests.

Most of the logs of water wells were obtained from drillers' written records but a few were supplied from memory by well owners. Lithologic terms used in the drillers' logs have been retained. The terms "gyp," "gyp rock," "magnesia," or "magnesia rock" have been used by some drillers in describing the harder cemented beds in the Ogallala formation. Many of the softer unconsolidated beds of the Ogallala have been logged as clay, but in those wells from which cuttings are available for study most of the so-called clay was found to be silt.

1. Log of test hole 1, 75 feet south of NW corner sec. 6, T. 25 S., R. 21 W., drilled by the State and Federal Geological Surveys, 1940. Surface altitude, 2,351.4 feet. (Authority, samples studied by Perry McNally and H. A. Waite.)

	Thickness, feet	Depth, feet
Ogallala formation		
Road fill	5	5
Silt, light brown	6	11
Silt, fine, sandy, limy, brown to light gray; contains caliche	9	20
Silt, limy, light gray; contains fragments of caliche	2	22
Greenhorn limestone		
Shale, fine, sandy, calcareous, brown	9	31
Shale, fine, sandy, calcareous, gray-green to olive-green	3	34
Shale and silty clay, soft, calcareous, light gray to brown; contains bentonite; drilled easily	5	39
Shale, calcareous, dark gray to black; drilled hard; hard bed about 3 inches thick at depth of 39 feet	12	51
Graneros shale		
Shale, argillaceous, black; contains fragments of gypsum; drilled hard	9	60
Shale, argillaceous, black; contains gypsum and some bentonite; drilled hard	22	82
Dakota formation		
Shale, hard, light gray; drilled fairly hard	8	90
Shale, hard, light gray; contains fragments of lignite	7	97
Shale, sandy, hard, gray; drilled hard, drill stem chattered,	4	101
Shale, fine, sandy, variegated, brown-gray, green, and yellow	2	103
Shale, silty, gray, fairly soft	1	104
Shale, fine, sandy, yellow brown	6	110

2. Log of test hole 2, 100 feet south of NW corner sec. 6, T. 26 S., R. 21 W., drilled by the State and Federal Geological Surveys, 1940. Surface altitude, 2,385.1 feet. (Authority, samples studied by Perry McNally and H. A. Waite.)

	Thickness, feet	Depth, feet
Ogallala formation		
Road fill	3	3
Silt, brown	3	6
Silt, fine, sandy, brown with a slight reddish cast	2	8
Silt, gritty, light gray, and caliche	3	11
Silt, gray-green, fairly soft	3	14
Silt, fine, sandy, limy, soft, gray and cream colored	17	31
Greenhorn limestone		
Shale, calcareous, white, some yellow-brown in color	5	36
Shale, fine, sandy, calcareous, yellow to gray; hard limestone bed 0.5 foot thick at top	4	40
Shale, fine sandy, calcareous, brown	5	45
Shale, calcareous, blue gray to dark gray; drilled fairly hard	7	52
Shale, calcareous bluish-gray	2	54
Shale, calcareous, sandy, gray-black, hard; alternating with thin beds of black shale	6	60
Shale, calcareous, bluish-gray; drilled fairly hard	10	70
Graneros shale		
Shale, argillaceous, bluish gray to black; drilled fairly hard	15	85
Shale, argillaceous, soft, blue-gray to light gray	1	86
Shale, soft, black; drilled easily	2	88
Shale, gritty, light gray; drilled harder than bed above	4	92
Shale, black; contains fragments of bentonite	17	109
Dakota formation		
Shale, clayey, gray to white	7	116
Sandstone, fine-grained, gray	1	117
Shale, sandy, gray to white, soft and sticky	7	124
Shale, clayey, variegated, brown, gray, and maroon	1	125
Shale, clayey, variegated, mostly brown	2	127
Shale, sandy, gray to white	3	130
Shale, clayey, variegated	4	134
Sandstone, fine-grained, saccharoidal, light-gray	6	140

3. Log of test hole 3, 100 feet south of the NW corner sec. 6, T. 26 S., R. 22 W., drilled by the State and Federal Geological Surveys, 1940. Surface altitude, 2,434.0 feet. (Authority, samples studied by Perry McNally and H. A. Waite.)

	Thickness, feet	Depth, feet
Ogallala formation		
Road fill	2	2
Silt, soft, light brown	6	8
Silt, fine, sandy, light brown; contains a small amount of lime	4	12

Silt, limy, soft, light gray to white; contains caliche and gravel intermixed	8	20
Silt, limy, gray to buff; contains coarse sand and gravel, and a few fragments of limestone (Greenhorn)	2	22
Silt, fine, sandy, limy, light brown; cuttings contained well-preserved specimen of *Biorbia rugosa*	2	24
Greenhorn limestone		
Shale, fine, sandy, calcareous, yellow	9	33
Shale, hard, calcareous, gray, variegated in part; contains a few limonitic streaks	15	48
Shale, clayey, dark bluish-gray; contains rusty-brown sandy streaks; gummy, drilled fairly hard	2	50

4. Log of test hole 4, 50 feet NW of SE corner sec. 20, T. 26 S., R. 23 W., drilled by the State and Federal Geological Surveys, 1940. Surface altitude, 2,481.6 feet. (Authority, samples studied by Perry McNally and H. A. Waite.)

	Thickness, feet	Depth, feet
Ogallala formation		
Top soil, silty loam, brown	7	7
Silt, fine, sandy, limy, light brown, contains caliche; drilled harder from 11 to 18 feet	11	18
Silt, limy, light gray to almost white; contains some caliche	12	30
Silt, limy, white; contains some caliche	5	35
Sand, fine, soft, orange-brown to yellow	2	37
Sand, cemented, brown, fairly hard	9	46
Sand, fine, to coarse gravel, dirty; contains admixture of silt	10	56
Sand, fine, to fine gravel, contains some fine sandy silt	2	58
Silt, fine, sandy, brown; to fine, gray, limy silt; contains sand and gravel	9	67
Dakota formation		
Shale, clayey, fine, sandy, yellowish-green, contains interbedded yellow, green, and gray, soft sandstone	3	70
Sandstone, fine-grained, soft, light gray	1	71
Shale and sandy clay, variegated, gray to orange-yellow	4	75

5. Log of test hole 5, 125 feet east of NW corner sec. 6, T. 26 S., R. 24 W., drilled by the State and Federal Geological Surveys, 1940. Surface altitude, 2,513.0 feet. (Authority, samples studied by Perry McNally and H. A. Waite.)

	Thickness, feet	Depth, feet
Ogallala formation		
Road fill	3	3
Silt, light brown, limy, and caliche	7	10
Silt, fine sandy, brown	2	12
Silt, light gray, limy, and caliche	3	15
Silt, sandy, limy, brown, and caliche	5	20
Silt, sandy, brown	1	21
Sand, brown, and limy conglomerate; drilled fairly hard	4	25

	Thickness, feet	Depth, feet
Sand, medium to gravel, coarse; contains a few pebbles,	4	29
Silt, fine, sandy, brown	2	31
Silt, light gray, limy, and caliche	2	33
Silt, fine, sandy, brown, contains some lime	3	36
Silt, limy, light gray to white, and caliche	5	41
Sand, silty, limy, gray to white, and caliche	1.5	42.5
Caliche, light gray, and silt, limy	2.5	45
Silt, fine, sandy, limy, greenish-gray	9	54
Sand, silty, fine, limy, light gray to white	12	66
Sand, silty, limy, gray to buff; contains some caliche	10	76
Sand, medium; contains some lime	11	87
Silt, greenish-gray, and clay, hard; drilled fairly hard	6	93
Clay, gray to red to yellow-brown	3	96
Graneros shale		
Shale, argillaceous, bluish-gray to black, sticky	14	110

6. Log of test hole 6, in the SE¼ NE¼ sec. 28, T. 26 S., R. 25 W., drilled by the State and Federal Geological Surveys, 1939. Surface altitude, 2,502.6 feet. (Authority, samples studied by Fred T. Holden and H. A. Waite.)

	Thickness, feet	Depth, feet
Alluvium		
Soil, brown, sandy	3	3
Silt, tan-brown, sandy; contains some lime	6	9
Silt, tan, and fine sand to coarse gravel	2	11
Silt, brown, limy	7	18
Silt, gray and brown, limy	2	20
Sand and gravel, tan, coarse; mainly quartz and feldspar,	8	28
Ogallala formation		
Silt, sandy, limy, reddish-brown	2	30
Gravel, tan; mainly quartz and feldspar	1	31
Clay and silt, tan, limy	4	35
Clay, light tan and tan-brown; silt, and caliche	16	51
Clay, light tan and tan-brown, sandy; silt, and caliche	5	56
Clay, dark tan; and silt	2	58
Clay, light tan, limy; and silt; contains thin layers of caliche	6	64
Sand and gravel, tan; interbedded with thin layers of limy clay, silt and caliche	3	67
Clay and silt, tan-brown and cream colored; contains caliche	10	77
Clay and silt, tan, very sandy; interbedded with thin layers of tan sand	25	102
Sand, fine, tan, to coarse gravel; contains water-worn chips of limestone	5	107
Clay, sandy, drab tan; silt, and caliche	3	110
Sand, fine, quartz, tan, to coarse gravel; contains some balls of clay	6	116

Clay and silt, sandy, tan; contains water-worn chips of limestone	10	126
Sand and gravel, quartz, tan; contains water-worn chips of limestone	32	158
Sand and gravel, quartz, tan; contains fragments of caliche and rounded water-worn chips of limestone	3	161
Same as bed above; contains balls of tan silt	12	173
Clay, whitish-gray	5	178
Greenhorn limestone (lower part)		
Shale, calcareous, brownish-black	2	180
Shale, calcareous, light gray and pink-gray	10	190

7. Log of test hole 7, at the SE corner sec. 17, T. 26 S., R. 26 W., drilled by the State and Federal Geological Surveys, 1939. Surface altitude, 2,544.0 feet. (Authority, samples studied by Fred T. Holden and H. A. Waite.)

	Thickness, feet	Depth, feet
Alluvium		
Soil, brown	3	3
Sand and gravel, tan; mainly quartz and feldspar	24	27
Ogallala formation		
Clay and silt, tan	15	42
Silt, tan, and sand, quartz	11	53
Silt, tan, and sand, quartz; contains balls of white limy clay	6	59
Clay and silt, pink-brown to yellow-brown; contains lumps of white, limy clay and nodules of lime	9	68
Lime nodules, white, tan-brown; silt, and tan sand (typical "mortar bed")	5	73
Clay and silt, brown and tan	4	77
Clay and silt, brown and tan; and sand, fine to medium, quartz, tan	1	78
Clay, sandy and silt; yellow-tan	7	85
Clay and silt, yellow-tan, soft; and sand, fine, tan	8	93
Clay and silt, limy, tan	3	96
Sand and gravel, quartz, tan; contains balls of tan silt	21	117
Clay, sandy and silt; light tan	4	121
Clay, sandy and silt; light tan, tan and brown	14	135
Clay, sandy and silt; light tan, tan and brown; and some tan and white quartz gravel and scattered water-worn chips of limestone	5	140
Sand, quartz, tan and white; contains water-worn chips of limestone	6	146
Gravel, quartz, tan; contains water-worn chips of limestone	24	170
Sand, quartz, tan; contains water-worn chips of limestone,	4	174
Greenhorn limestone (lower part)		
Shale, calcareous, gray black	16	190

8. Log of test hole 8, at the NE corner sec. 1, T. 27 S., R. 25 W., drilled by the State and Federal Geological Surveys, 1939. Surface altitude, 2,469.8 feet. (Authority, samples studied by Fred T. Holden and H. A. Waite.)

	Thickness, feet	Depth, feet
Alluvium		
Soil, sandy, brown	2	2
Sand, fine to medium, tan	2	4
Sand and gravel, tan; predominantly medium and coarse sand	2	6
Sand and gravel, gray to tan; predominantly medium sand,	1	7
Sand, fine and medium, tan	2	9
Sand, fine to coarse, tan; and medium gravel	1	10
Gravel, coarse, tan	10	20
Ogallala formation		
Clay and silt, sandy, limy; tan-brown with lime nodules and very coarse gravel	27	47
Sand, tan, and very coarse gravel; contains some pebbles,	3	50
Gravel, very coarse, angular	10	60
Clay, limy, yellow-brown; interbedded with coarse gravel,	20	80
Sand and silty sand; interbedded with gravel and angular fragments of lime and chert	31	111
Sand and gravel, tan; and flat, water-worn fragments of limestone; poorly sorted	49	160
Graneros shale		
Shale, argillaceous, black	14	174
Shale, gray	6	180
Shale, gray with partings of black shale	5	185
Shale, tan-brown and gray-black	6	191
Dakota formation		
Shale, tan and gray-black; hard layer encountered from 191 to 191.5 feet	2	193
Shale, sandy, light gray	4	197
Shale, gray to tan to ochre-colored	2	199
Shale, light gray and gray black; hard concretionary layer from 206 to 207 feet	8	207
Shale, black and light gray	3	210
Shale, light gray and black; very hard layer encountered from 214 to 215 feet	20	230
Shale, slightly sandy; light gray; 4 feet of core obtained in this interval	10	240
Shale, gray, mottled with red, brown, and yellow streaks; 6.5 feet of core obtained in this interval	10	250
Shale, similar to bed above; 4 feet of core obtained	10	260
Shale, sandy, gray; 2.75 feet of core obtained; drilled hard from 266 to 267 feet (sandstone?)	10	270
Sandstone, very fine-grained, gray contains streaks of yellow-brown and brown-black fine sand; 1.5 feet of core obtained	10	280

	Thickness, feet	Depth, feet
No returns; drilled medium hard; some light gray, dark gray and yellow-brown clay and silt recovered from drilling mud	10	290
Shale, variegated, ranging in color from yellow to brown to gray to red and to black	0.5	290.5
Sandstone, very fine-grained, yellow-brown	1.5	292
Shale, gray	3	295
Shale, red and gray	1	296
No samples	4	300
Shale, variegated, ranging in color from gray to red to yellow to black	10	310

9. Log of test hole 9, in the NW corner sec. 6, T. 27 S., R. 25 W., drilled by the State and Federal Geological Surveys, 1939. Surface altitude, 2,549.7 feet. (Authority, samples studied by Fred T. Holden and H. A. Waite.)

	Thickness, feet	Depth, feet
Alluvium		
Silt and fine sand, brown	5	5
Sand, fine and medium, brown and tan	7	12
Sand and gravel, tan-brown; mainly quartz and feldspar	13	25
Sand and gravel, poorly sorted; contains some tan and gray balls or clay	7	32
Gravel, tan; mainly quartz and feldspar	10	42
Ogallala formation		
Gravel, medium and coarse, tan; mainly quartz and feldspar; contains few beds of sand near top	74	116
Clay and silt, gray-tan and tan-brown	20	136
Sand and gravel, tan; predominantly quartz and feldspar; contains some tan clay balls, tan chips of limestone and white nodules of limestone	4	140
Clay, silt, and sand; tan; contains some nodules of lime	13	153
Clay and silt, limy, light tan; contains some nodules lime,	22	175
Greenhorn limestone (lower part)		
Shale, calcareous, black-gray to brown	5	180

10. Log of test hole 10, in the SE corner sec. 36, T. 28 S., R. 21 W., drilled by the State and Federal Geological Surveys, 1940. Surface altitude 2,372.2 feet. (Authority, samples studied by Perry McNally and H. A. Waite.)

	Thickness, feet	Depth, feet
Kingsdown silt		
Top soil, silty, brown	2	2
Clay, soft, silty, limy, brown	3	5
Silt, soft, limy, light brown; contains some nodules of lime,	65	70
Sand, fine, brown	3	73
Silt, fine, sandy, brown; contains a few reddish-brown streaks	7	80
Silt, fine, sandy, brown, contains a few pebbles	9	89

Ogallala formation		
Sand, fine, to fine gravel	6	95
Gravel, very coarse; comprises pebbles of quartz, granite, feldspar, basalt, and Greenhorn limestone; some pebbles ½ inch in diameter	23	118
Silt, limy, gritty, light gray	12	130
Silt, limy, light gray; contains fragments of lime	18	148
Silt, limy, and caliche; contains lenses of fine sand	2	150
Silt, fine, sandy, brown	1	151
Gravel, fine to coarse, poorly sorted; contains fragments of brown sandstone and limestone (Greenhorn)	2	153
Dakota formation		
Shale, clayey, fine sandy, limonitic, yellow; drilled easily,	3	156
Shale, clayey, light gray and green, somewhat sticky; drilled fairly hard	4	160

11. Log of test hole 11, 100 feet south of the NW corner SW¼ sec. 1. T. 28 S., R. 25 W., drilled by the State and Federal Geological Surveys, 1940. Surface altitude, 2604.9 feet. (Authority, samples studied by Perry McNally and H. A. Waite.)

	Thickness, feet	Depth, feet
Kingsdown silt		
Top soil, silty loam, brown	4	4
Silt, limy, light brown	4	8
Silt, limy, light brown; contains nodules of lime	43	51
Silt, maroon brown; contains pebbles and nodules of lime,	19	70
Silt, fine, sandy, maroon-brown	10	80
Silt, fine, sandy, maroon-brown; contains pebbles and nodules of lime	43	123
Ogallala formation		
Sand, coarse, to very coarse gravel, poorly sorted; contains pebbles of quartz, granite, and feldspar	10	133
Silt, limy, light brown	4	137
Sand, coarse, to very coarse gravel; poorly sorted	23	160
Sand, coarse, to very coarse gravel	5	165
Sand, and medium to fine gravel	5	170
Sand, fine, to fine gravel; contains some broken pebbles	13	183
Silt, limy, light gray; caliche; and some coarse gravel	13	196
Greenhorn limestone		
Limestone, light gray; drilled very hard	8	204
Shale, calcareous, soft, yellowish-brown; drilled easily	2	206
Limestone, hard, light gray; drilled very hard	0.5	206.5
Shale, clay, black, soft, calcareous; harder drilling near bottom	3.5	210

12. Log of test hole 12, in the NW corner sec. 6, T. 28 S., R. 25 W., drilled by the State and Federal Geological Surveys, 1939. Surface altitude, 2,643.0 feet. (Authority, samples studied by Perry McNally and H. A. Waite.)

	Thickness, feet	Depth, feet
Kingsdown silt		
Top soil, sandy, brown	8	8
Silt, soft, light brown; contains nodules of lime	32	40
Silt, light brown; contains nodules of gray lime; drilled fairly hard	15	55
Ogallala formation		
Sand, fine to medium, uniform, gray-brown	5	60
Sand, medium to coarse, uniform, brown	10	70
Sand, coarse to medium gravel, brown	14	84
Sand, fine to medium, brown	14	98
Silt, limy, light gray	4	102
Sand, fine to medium, brown	6	108
Silt, limy, light gray	8	116
Silt, limy, light gray; drilled alternately hard and soft	11	127
Sand, coarse, brown to coarse gravel	8	135
Gravel, medium to very coarse; mainly quartz and granite,	10	145
Gravel, medium to very coarse; contains water-worn fragments of brown limestone and pebbles up to 3/8 inch in diameter	25	170
Gravel, medium to coarse; contains many water-worn chips of yellow-brown limestone	19	189
Greenhorn limestone		
Shale, clay, soft, white to cream-colored; drilled easily	2	191
Shale, calcareous, gray to black; drilled very hard from 192 to 192½ feet	9	200

13. Log of test hole 13, in the NW corner sec. 6, T. 28 S., R. 26 W., drilled by the State and Federal Geological Surveys, 1939. Surface altitude, 2,710.7 feet. (Authority, samples studied by Perry McNally and H. A. Waite.)

	Thickness, feet	Depth, feet
Kingsdown silt		
Top soil, silty loam, brown	7	7
Soil, silty clay, brown to light brown	4	11
Silt, limy, brown; contains nodules of lime	6	17
Silt, brown; contains little or no lime	3	20
Silt, light brown; contains small amount of lime from 29 to 40 feet	27	47
Silt, hard, brown; contains pebbles of quartz; contains some fine sand from 60-69 feet	22	69
Silt, sandy, limy, soft, brown; contains some pebbles	21	90
Ogallala formation		
Sand, fine, brown; and silt, limy; contains fragments of lime	20	110
Sand, fine, soft, brown, less limy silt	20	130

Sand, fine, brown; increase in limy silt	9	139
Silt, sandy, soft, limy, gray and brown	8	147
Sand, fine, brown, intermixed with silt; contains some fine gravel; drilled alternately hard and soft	6	153
Sand, coarse to coarse gravel; contains well rounded pebbles of quartz and granite; poorly sorted; drilled hard,	7	160
Silt, sandy, brown	1	161
Sand, coarse, to coarse gravel; contains pebbles of quartz, granite and feldspar	9	170
Silt, sandy, brown	3	173
Sand, medium, to coarse gravel; poorly sorted	17	190
Sand, medium, to coarse gravel; predominantly medium gravel	17	207
Greenhorn limestone		
Shale, clayey, light gray to cream-colored, calcareous; upper part drilled hard	2	209
Shale, clayey, soft, calcareous, black	3	212
Shale, sandy, hard, gray	.5	212.5

14. Log of test hole 14, 125 feet E. of SW corner sec. 33, T. 29 S., R. 21 W., drilled by the State and Federal Geological Surveys, 1940. Surface altitude, 2,400.5 feet. (Authority, samples studied by Perry McNally and H. A. Waite.)

	Thickness, feet	Depth, feet
Kingsdown silt		
Top soil, silty, brown	2	2
Soil, clayey, silty, sticky, brown	9	11
Silt, brown	5	16
Silt, limy, yellowish-brown; contains nodules of lime	7	23
Silt, limy, yellowish-brown	5	28
Silt, fine, sandy, light brown; fairly hard drilling	4	32
Silt, fine, sandy, limy, light brown	7	39
Silt, limy, light gray; contains streaks of lime	9	48
Silt, fine, sandy, red-brown; drilled fairly hard	2	50
Silt, fine, sandy, limy, gray and brown, contains nodules of lime; drilled easily	17	67
Silt, fine, sandy, red-brown	8	75
Ogallala formation		
Sand, fine, to fine gravel; brown; contains some gravel and fragments of lime	3	78
Silt, fine, sandy, red-brown; contains fragments of lime	2	80
Silt, fine, sandy; limy silt; and caliche	5	85
Silt, limy, red-brown; contains fragments of lime	15	100
Sand, fine to coarse; contains soft white fragments of lime,	4	104
Silt, limy, gray; contains fragments of lime and coarse sand	4	108
Sand, fine to fine gravel, brown	4	112
Sand, gravel and caliche in alternating beds; drilled easily except for a few hard layers	19	131

	Thickness, feet	Depth, feet
Gravel, fine to coarse; hard drilling from 135-136 feet....	5	136
Silt, fine, sandy, limy, light brown to gray; contains some fine sand and pebbles.	10	146
Sand, fine, brown, uniform; contains some silt.	3	149
Silt, fine, sandy, limy, light brown to gray; drilled alternately hard and soft.	11	160
Silt, fine, sandy, soft, yellow brown to white to olive-green to gray; contains limy streaks.	3	163
Dakota formation		
Shale, clayey, soft, variegated, red to yellow to green to gray; drilled fairly hard.	17	180

15. Log of test hole 15, in the NE corner sec. 1, T. 30 S., R. 23 W., drilled by the State and Federal Geological Surveys, 1940. Surface altitude, 2,473.5 feet. (Authority, samples studied by Perry McNally and H. A. Waite.)

	Thickness, feet	Depth, feet
Kingsdown silt		
Top soil, silty loam, dark brown.	2	2
Silt, brown	6	8
Silt, fine, sandy, brown; contains nodules of lime.	12	20
Silt, fine, sandy, limy, light brown to gray; contains a few nodules of lime.	70	90
Silt, fine, sandy, limy; contains limonitic streaks, fragments of lime, sand, and gravel.	12	102
Silt, fine, sandy, gray to brown.	6	108
Ogallala formation		
Gravel, fine to coarse; contains pebbles of quartz, granite feldspar, and caliche.	19	127
Silt, fine, sandy; and fine sand, orange-brown and gray...	2	129
Sand, fine, gray; contains some coarse gravel, and a soft layer of white sand from 132 to 132.5 feet.	12	141
Sand, fine, brown; and silt, greenish-gray.	6	147
Sand, fine, reddish-brown; and greenish-gray silty fine sand and limy silt.	9	156
Silt, fine, sandy, reddish-brown to green; contains fragments of lime.	17	173
Sand, fine to fine gravel; contains small amount of caliche,	7	180
Sand, fine to coarse gravel, brown; contains water-worn fragments of caliche; poorly sorted.	30	210
Silt, gritty, soft, yellow, contains sand and gravel; contains a hard bed of caliche from 212 to 212.5 feet.	10	220
Kiowa shale		
Shale, clayey, bluish-gray; contains reworked brown to gray to black to yellow shale-like material and considerable amounts of sand, gravel, and broken fragments of Cretaceous rocks; drilled fairly hard.	10	230

16. Log of test hole 16, in the NE corner sec. 1, T. 29 S., R. 25 W., drilled by the State and Federal Geological Surveys, 1940. Surface altitude, 2,578.8 feet. (Authority, samples studied by Perry McNally and H. A. Waite.)

	Thickness, feet	Depth, feet
Kingsdown silt		
Top soil, silty, brown	5	5
Silt, light brown; contains nodules of lime	35	40
Silt, fine, sandy, brown	6	46
Silt, limy, light brown	18	64
Silt, limy, gritty, gray to brown	6	70
Silt, fine, sandy, brown	6	76
Silt, limy, light brown to gray; contains nodules of lime	6	82
Silt, limy, light brown; contains nodules of lime; hard drilling from 103 to 104 feet	22	104
Silt, fine, sandy, olive green to brown; contains some soft white lime; streaked with yellow fine sand and some gravel	10	114
Ogallala formation		
Gravel, medium to coarse; composed mainly of quartz, granite, and feldspar; contains some sand and a few pebbles	8	122
Sand, medium to coarse, light gray; contains some pebbles and some white fragments of lime	6	128
Silt, fine, sandy, brown; contains fragments of lime	12	140
Silt, fine, sandy, brown; contains some limy silt	6	146
Gravel, fine to coarse; contains some silt and fragments of caliche	1	147
Silt, fine, sandy, limy, brown and gray	11	158
Gravel, medium to coarse; and brown; silt, poorly sorted,	4	162
Sand, fine, brown; and silt	4	166
Gravel, medium to coarse, dirty; and some silt	5	171
Silt, fine, sandy, reddish-brown; contains sand and gravel and some fragments of caliche	19	190
Sand, fine, brown; and silt, limy, gray	10	200
Silt, fine sandy, gray to reddish-brown, limy; contains a hard cemented bed of caliche from 211 to 211.5 feet	20	220
Silt, fine, sandy, gray to yellowish-brown; fairly hard	8	228
Silt, fine, sandy, limy, greenish-gray to buff	3	231
Silt, fine, sandy, brown; and caliche	19	250
Dakota formation		
Shale, clayey, yellowish-brown to red; contains many fragments of hard, maroon-red sandstone; drilled very hard	5	255
Shale, soft, variegated; gray to green to red to brown to yellow; drilled hard	5	260

17. Log of test hole 17, in the SE corner sec. 36, T. 29 S., R. 25 W., drilled by the State and Federal Geological Surveys, 1939. Surface altitude, 2,566.3 feet. (Authority, samples studied by Perry McNally and H. A. Waite.)

	Thickness, feet	Depth, feet
Kingsdown silt		
Top soil, sandy clay, brown	7	7
Silt, soft, light brown; contains nodules of lime	12	19
Silt, cream to light brown; contains a few nodules of lime,	7	26
Silt, brown to gray	9	35
Silt, fine, sandy, brown; contains gravel and some nodules of lime	3	38
Silt, fine, sandy, reddish-brown; contains a few pebbles and fragments of lime near the base	35	73
Ogallala formation		
Gravel, poorly sorted; contains quartz, granite and feldspar; some pebbles ½ inch in diameter	12	85
Silt, brown; contains some fine to coarse sand	2	87
Silt, limy, gray, reddish-brown; and silt	13	100
Silt, fine, sandy, brown; contains a few grains of sand	7	107
Sand, hard, lime-cemented; silty sand; limy silt; and a few fragments of chert; drilled fairly hard	4	111
Silt, limy, soft, light gray	14	125
Silt, limy, light gray; contains beds of cemented caliche,	8	133
Dakota formation		
Shale, sandy, varicolored—ranging from yellow to gray to brick-red and blue-gray; contains some scattered fragments of Greenhorn limestone; drilled hard	7	140
Shale, clayey, hard, yellow and gray	10	150

18. Log of test hole 18, in the NW corner sec. 1, T. 29 S., R. 26 W., drilled by the State and Federal Geological Surveys, 1939. Surface altitude, 2,635.3 feet. (Authority, samples studied by Perry McNally and H. A. Waite.)

	Thickness, feet	Depth, feet
Kingsdown silt		
Top soil, sandy, light brown	1.5	1.5
Silt, dark tan, soft; contains fragments of lime	31.5	33
Silt, light tan; contains nodules of lime	32	65
Sand, fine, and sandy silt, reddish-brown; contains fragments of lime that increase in number with depth	15	80
Silt, sandy, light grayish-brown; contains a little coarse sand and gravel	10	90
Silt, sandy, gray to brown; contains a little sand and gravel	14	104
Ogallala formation		
Gravel, medium to coarse, brown; fairly well sorted; predominantly quartz but contains some granite	15	119
Sand, fine, and limy silt; yellowish-brown; contains a few pebbles	6	125

	Thickness, feet	Depth, feet
Gravel, coarse, brown; contains considerable sand and a few dark pebbles	15	140
Silt, sandy, light brown, lime-cemented	11	151
Silt, limy, cream to light gray; drilled hard	9	160
Sand, silty, white, lime-cemented; contains some fine gravel	14	174
Silt, sandy, soft, yellowish; and limy silt; contains some sand, fine to medium brown	12	186
Greenhorn limestone (lower part)		
Shale, clay, dark gray to black, soft calcareous; drilled alternately hard and soft	4	190
Shale, clay, dark gray; contains fragments of limestone, drilled very hard	1	191

19. Log of test hole 19, in the SW corner sec. 27, T. 29 S., R. 26 W., drilled by the State and Federal Geological Surveys, 1939. Surface altitude, 2,514.0 feet. (Authority, samples studied by Perry McNally and H. A. Waite.)

	Thickness, feet	Depth, feet
Kingsdown silt		
Top soil, sandy	2	2
Silt and clay, brown	12	14
Clay balls, silty, gray; containing yellow streaks	14	28
Clay balls, silty, very light gray; containing yellow streaks	7	35
Clay, silty, brown to greenish-gray; contains grains of sand and lime	4	39
Gravel, fine; and sand, coarse, brown	2	41
Gravel, fine to coarse, brown; predominantly coarse	4	45
Gravel, coarse; contains balls of gray clay	4	49
Clay balls silty, gray and brown	8	57
Clay balls, silty, blue-gray	61	118
Ogallala formation		
Silt, limy, hard, light gray; contains fragments of caliche,	3	121
Sand, fine; and caliche, reddish-brown	4	125
Silt, limy, and fine sand, cemented; gray to brown; contains fragments of lime	7	132
Sand, coarse and gravel, fine; brown; contains red sand	13	145
Gravel, fine to medium, poorly sorted; contains fragments of granite and feldspar	5	150
Gravel, medium, brown; some fine gravel contains pebbles of quartz and red granite	5	155
Gravel, coarse, brown; contains pebbles of quartz and pink granite	9	164
Sand, fine, silty, limy, light gray	3	167
Caliche and limy silt	3	170
Sand, silty, lime-cemented, light gray to tan	20	190
Sand, silty, cemented, medium to coarse	7	197
Sand, fine to medium quartz, cemented	9	206
Silt, soft, limy; and cemented fine sand	4	210

Dakota formation		
Clay, soft, silty, yellow; having white streaks; contains dark gray partings of shale	6	216
Sandstone, fine-grained, soft, brown to purple; drilled easily	7	223
Sandstone, hard, maroon to purple; sample return very poor in this interval—no recovery on an attempted coring	7	230
Shale, soft, clay, red to brown to gray, mottled; upper 4 feet drilled easier than lower part	9	239
Gravel, coarse, fairly uniform	11	250
Shale, soft, clayey, variegated red to maroon to yellow to gray	8	258
Shale, sandy, soft, variegated, mostly gray	8	266
Kiowa shale		
Shale, sandy, soft, blue-gray	7	273
Shale, soft, blue-gray, somewhat platy, contains some partings of maroon to red shale	17	290
Shale, soft, blue-gray; somewhat harder than bed above; contains some fragments of red silty clay, and thin bed of limestone ½-foot thick at base	13.5	303.5
Shale, silty and sandy, blue-gray; interbedded with variegated clay shale and coarse sand	6.5	310
Cheyenne sandstone (?)		
Shale, silty, blue-gray; contains some lenses of sandstone throughout, some fragments of reddish-yellow soft clay-shale in the lower 10 feet of this interval, and thin layers of hard sandstone from 348 to 350 feet	40	350
Shale, silty, blue-gray, interbedded with thin layers of sandstone	30	380

20. Log of test hole 20, in the NW corner sec. 32, T. 29 S., R. 26 W., drilled by the State and Federal Geological Surveys, 1939. Surface altitude, 2,545.5 feet. (Authority, samples studied by Perry McNally and H. A. Waite.)

	Thickness, feet	Depth, feet
Kingsdown silt		
Top soil, sandy, clay, brown	4	4
Silt, limy, light-brown	17	21
Silt, limy, gray; contains nodules of lime	10	31
Silt, sandy, brown to olive-green	15	46
Sand, fine to medium, brown; interbedded with olive-green limy silt and small fragments of lime	4	50
Silt, fine, sandy, brown to gray	15	65
Silt, limy, light gray to brown	11	76
Silt, limy, brown and gray; contains some coarse sand	8	84
Silt, sandy, brown; contains some fine to coarse gravel	6	90

	Thickness, feet	Depth, feet
Ogallala formation		
Gravel, medium to coarse; very poorly sorted; contains some water-worn fragments of limestone; gravel contains pebbles of quartz and granite	18	108
Sand, medium to fine gravel, and sandy silt, brown; contains considerable lime throughout; drilled alternately hard and soft	12	120
Sand, fine, uniform, brown	10	130
Gravel, medium to coarse; contains some sand	30	160
Sand, medium, brown, to coarse gravel	13	173
Silt, limy, brown; contains some medium sand and a few pebbles	3	176
Sand, medium, brown, to coarse gravel	6	182
Silt, sandy, limy, brown; contains some medium to coarse sand	8	190
Silt, fine; sandy, brown; contains some pebbles	15	205
Dakota formation		
Shale, silty, clayey, soft, bluish-gray, contains a few yellow streaks; somewhat harder drilling from 220 to 260 feet,	55	260

21. Log of test hole 21, in the NW corner sec. 36, T. 29 S., R. 26 W., drilled by the State and Federal Geological Surveys, 1939. Surface altitude, 2,535.0 feet. (Authority, samples studied by Perry McNally and H. A. Waite.)

	Thickness, feet	Depth, feet
Kingsdown silt		
Top soil, sandy, light brown	2.5	2.5
Silt, sandy, light brown	3.5	6
Silt, soft, light brown; a few coarse grains of sand; somewhat sandier from 20 to 59 feet	53	59
Sand, fine to medium, brown	7	66
Silt, gray	9	75
Silt and fine sand, blue-gray to brown	5	80
Silt, fine sandy, light gray to brown	9	89
Ogallala formation		
Sand, coarse, gray-tan; contains a few nodules of lime	6	95
Silt, sandy, gray-tan; contains lime nodules	5	100
Sand, fine to coarse, gray-tan	8	108
Silt, fine sandy, dark gray to buff	24	132
Sand, coarse, and fine gravel, dark gray; contains balls of clay, and a few broken pebbles and fragments of limestone	3	135
Sand, coarse, and fine gravel, dark gray; contains many balls of clay	3	138
Silt and fine sand, gray-brown; contains pebbles of caliche,	13	151
Sand, coarse, and gravel, fine; gray; intermixed with gray to brown silt	6	157
Silt, sandy, and fine sand, light gray	7	164
Sand, coarse to medium gravel, brownish-gray	6	170

	Thickness, feet	Depth, feet
Sand, coarse to coarse gravel, tan; intermixed with sandy silt	5	175
Gravel, fine to coarse; contains some well-rounded pebbles intermixed with silt	5	180
Gravel, fine to coarse, brown, poorly sorted, contains water-worn fragments of lime	12	192
Dakota formation		
Sandstone, fine to medium-grained, reddish-purple	3	195
Sandstone, limonitic, yellow to gray; interbedded with clay shale	5	200

22. Log of well (18) of Chas. Herrman, in the SW corner sec. 25, T. 25 S. R. 21 W. (Authority, owner, from memory.)

	Thickness, feet	Depth, feet
Ogallala formation		
Soil	3	3
Clay, reddish; encountered small amount of water in dark brown to gray sandy material at 90 feet	87	90
Graneros shale		
Shale, soft, rubbery, black	15	105
Dakota formation		
Sandrock, soft, white, water-bearing	25	130

23. Log of well (22) of Leo R. Krumrey, in the NW ¼ NE ¼ sec. 35, T. 25 S., R. 21 W. (Authority, owner.)

	Thickness, feet	Depth, feet
Ogallala formation		
Soil	3	3
Clay, brown; contains white limy pebbles; trace of water at 40 feet	37	40
Rock, gray to brown, in layers	25	65
Dakota formation		
Shale, bluish-gray changing to red and to yellow	20	85
Sandstone, soft, reddish-brown; some water at 87 feet	2	87
Shale, bluish-gray and yellow to black	63	150
Sandstone, reddish-brown; considerable water	5	155

24. Log of well (25) of C. K. Thomas, in the NW¼ NW¼ sec. 2, T. 25 S., R. 22 W. (Authority, owner, from memory.)

	Thickness, feet	Depth, feet
Ogallala formation		
Soil	5	5
Clay, brown, contains white limy pebbles	35	40
Graneros shale (?)		
Shale, blue	6	46
Dakota formation (?)		
Sandrock and gravel; (first water at 46 feet)	17	63
Shale, bluish-black, yellow, varicolored	22	85
Sandrock, bluish-gray	1	86
Shale, bluish-black	13	99

Sandrock	1	100
Shale, bluish-black	27	127
Sandrock, fairly hard, grayish-white; some water	6	133
Shale, bluish-black	20	153
Sandrock	—	153

25. Log of well (34) of the Atchison, Topeka and Santa Fe Railway at Spearville, in the NE¼ NE¼ sec. 29, T. 25 S., R. 22 W. Surface altitude, 2,459 feet. (Authority, A. M. Truman, division engineer, Dodge City.)

	Thickness, feet	Depth, feet
Ogallala formation		
Soil, black	8	8
Clay, brown	14	22
Rock, "gyp," white (normal water level, 86 feet)	72	94
Sand, water, coarse (water)	9	103
Clay, sandy, yellow	5	108
Cheyenne, Kiowa, and Dakota formations, undifferentiated		
Shale, sticky, black	6	114
Shale, sticky, light blue	30	144
Clay, light blue	22	166
Sand, fine, gray (little water)	3	169
Gravel, coarse, (little water; water raised to 103 feet; tested 5 gallons a minute)	4	173
Clay, dark blue	13	186
Not described	35	221
Clay, light blue	10	231
Shale, sticky, black	10	241
Clay, sandy, light gray	21	262
Sandrock, soft, gray (little water, salty)	5	267
Clay, dark blue	23	290
Clay, variegated	5	295
Clay, dark blue	13	308
Clay, sticky, red	7	315
Clay, variegated	26	341
Sandrock, light gray (no water)	8	349
Shale, dark blue	40	389

26. Log of city well (35) at Spearville, in the NE¼ NE¼ sec. 29, T. 25 S., R. 22 W. (Authority, John Dortch, city water superintendent.)

	Thickness, feet	Depth, feet
Ogallala formation		
Soil	4	4
Clay	9	13
"Magnesia"	52	65
Rock	3	68
"Magnesia"	10	78
"Magnesia" and sand (water level at 85.5 feet)	7	85
Rock	3	88
Sand, coarse	6	94

Rock	1	95
Clay	1	96
Graneros shale (?)		
"Soapstone" and shale	8	104

27. Partial log of oil test on the H. Henthorn farm, in the middle of the NW¼ sec. 21, T. 25 S., R. 24 W. Surface altitude, 2,502 feet. (Authority, driller's log.)

	Thickness, feet	Depth, feet
Ogallala formation		
Surface	12	12
Gyp rock	38	50
Shale	13	63
Sand, water (water)	3	66
Shale	19	85
Sand and gravel, water (water)	5	90
Shale	10	100
Sand, water (water)	2	102
Pre-Tertiary beds		
Shale, black	18	120
Shale, blue	33	153
Shale, brown	26	179
Shale, blue	6	185
Shale, white	30	215
Shale, brown	12	227

28. Log of test hole drilled for the Soil Conservation Service on the Harry Froetschner farm, in the SW¼ NE¼ sec. 1, T. 26 S., R. 21 W. (Authority, Lewis H. Bacon, Soil Conservation Service.)

	Thickness, feet	Depth, feet
Ogallala formation		
Top soil and clay	14	14
Sand, fine	3	17
Gravel, fine, dry	5	22
Gravel, medium to coarse	4	26
Clay, sandy, yellow; and coarse gravel	19	45
Dakota formation		
Sandstone, soft	25	70
Shale, jointed, blue	15	85
Sandstone; very hard drilling	—	—
Shale, blue	15	100
Sandstone, hard, yellow; very hard drilling	26	126

29. Log of test hole drilled by the Soil Conservation Service on the Anna Quasebarth farm, in the NE¼ SE¼ sec. 12, T. 26 S., R. 21 W. (Authority, Lewis H. Bacon, Soil Conservation Service.)

	Thickness, feet	Depth, feet
Alluvium		
Top soil	6	6
Sand, fine	5.5	11.5
Gravel, fine to medium to coarse; contains balls of clay	6	17.5
Clay, contains some gravel	34.5	52

Dakota formation		
Sandstone, soft	9	61
Gravel, fine to medium (water-bearing)	10	71
Sandstone, soft, bluish gray	21	92
Gravel, fine to medium	10	102
Clay, yellow; contains some gravel, hard brown sandstone, and blue clay	18	120
Sandstone, brown	6	126

30. Log of test hole drilled by the Soil Conservation Service on the Herman Wetzel farm, near the NW corner SW¼ NW¼ sec. 13, T. 26 S., R. 21 W. (Authority, Lewis H. Bacon, Soil Conservation Service.)

	Thickness, feet	Depth, feet
Alluvium		
Top soil	6	6
Sand and gravel (static water level, 11.5 feet)	12	18
Clay and some gravel	9	27
Clay balls and gravel, tight	11	38
Dakota formation (?)		
Clay, gray and light blue (shale)	7	45

31. Log of test hole drilled for the Soil Conservation Service on the Grover Fields farm, in the NW corner SW¼ SE¼ sec. 13, T. 26 S., R. 21 W. (Authority, Lewis H. Bacon, Soil Conservation Service.)

	Thickness, feet	Depth, feet
Alluvium		
Top soil	4.5	4.5
Sand	2.5	7
Gravel, fine and clay	4.5	11.5
Gravel medium; and soft silty clay	1.5	13
Clay, contains some gravel (may be Ogallala formation in lower part)	44	57
Dakota formation		
Clay, solid but rather soft, yellow (shale)	3	60
Sandstone, dark brown	5	65

32. Log of well (98) of Henry Hattrup, in the SE¼ NE¼ sec. 23, T. 26 S., R. 21 W. (Authority, owner, from memory.)

	Thickness, feet	Depth, feet
Alluvium		
Top soil	3	3
Sand, fine and dry	2	5
Gravel, dry	5	10
Gravel, medium to coarse; water-bearing	7	17
Clay, sandy, fine	2	19
Gravel	10	29

33. Log of test hole drilled for the Soil Conservation Service on the Leo Hattrup farm, in the NW¼ SE¼ sec. 23, T. 26 S., R. 21 W. (Authority, Lewis H. Bacon, Soil Conservation Service.)

	Thickness, feet	Depth, feet
Alluvium		
Top soil and clay	13	13
Sand, fine	3	16
Gravel, fine	2	18
Gravel, medium	17	35
Dakota formation (?)		
Clay, very sandy, reddish	25	60
Clay, very sandy, bright yellow	13	73
Sandstone, soft; artesian flow in this interval	23	96
Shale, gray and light blue	6	102

34. Log of test hole drilled by the Soil Conservation Service on the Harry Speck farm, in the NE¼ SE¼ sec. 24, T. 26 S., R. 21 W. (Authority, Lewis H. Bacon, Soil Conservation Service.)

	Thickness, feet	Depth, feet
Alluvium		
Top soil and fine sand	3	3
Sand, fine	5	8
Sand and medium to fine gravel	8	16
Gravel, medium to coarse; slight trace of yellow clay	2	18
Clay	9	27
Sand, fine	10	37
Dakota formation		
Clay, yellow	4	41
Shale, blue	8	49
Sandstone, light gray	3	52
Clay, fine, sandy	8	60
Shale, blue, and fine sandy clay	3	63
Sandstone, hard	3	66
Sandstone, soft, and fine sand	8	74
Sandstone, soft, dense; contains sharp fine gravel near the top	52	126
Sandstone; contains some sharp sandy gravel and a little gray shale	4	130
Sandstone and sharp, coarse gravel	1	131
Shale, bluish-gray	3	134

35. Log of test hole drilled for the Soil Conservation Service on the Otto Kurth farm, in the SE¼ SW¼ sec. 24, T. 26 S., R. 21 W. (Authority, Lewis H. Bacon, Soil Conservation Service.)

	Thickness, feet	Depth, feet
Alluvium		
Top soil	4	4
Sand, fine	4	8
Sand, fine to medium	7	15
Gravel, fine	1	16
Sand, fine to medium; and some gray clay	7	23
Gravel, fine; and trace of clay	4	27
Gravel, good water-bearing; and yellow clay	3	30

Dakota formation		
Clay, yellow, changing to bright yellow with depth; contains 2-inch bed of sandstone at base	31	61
Sandstone; water flowed from the top of the hole from a depth of 63 feet	4	65
Sandstone, soft, yellowish-brown; artesian flow increased in magnitude at a depth of 67 feet	20	85
Sandstone, slightly harder than bed above	6	91
Sandstone, hard, in layers; very hard layer at 94 feet; contains some gray shale; flow mudded off at this depth	6	97
Shale, bluish-gray; and yellow sandy clay-shale	18	115
Shale, sandy, clayey, reddish and blue; changes to yellowish sandy clay	9	124
Sandstone, hard; slight artesian flow	1	125

36. Log of well (100) of Leonard Dinkela, in the SW¼ SW¼ sec. 31, T. 26 S., R. 21 W. (Authority, owner, from memory.)

	Thickness, feet	Depth, feet
Ogallala formation		
Soil	5	5
Sand, reddish-brown; contains white limy pebbles (water at 42 feet)	37	42
Rock, lime rock	0.5	42.5
Clay, white	17.5	60
Dakota formation		
Shale, blue to slate-colored	70	130
Clay, "rainbow," red, white, maroon (varicolored)	10	140
Shale, blue	50	190

37. Log of domestic well on the Ben Lampe farm, in the SE corner sec. 14, T. 26 S., R. 22 W. (Authority, owner, from memory.)

	Thickness, feet	Depth, feet
Ogallala formation		
Soil	3	3
Clay, brown; contains white streaks; becomes sandy with depth. (Some water at 18 feet)	67	70
Dakota formation		
Sandrock	6	76
"Soapstone," variegated clay containing red, yellow, and blue streaks	26	102

38. Log of test hole drilled on the Wm. G. Duesing farm, near the center of the SE¼ SW¼ sec. 23, T. 26 S., R. 22 W. (Authority, samples studied by H. A. Waite.)

	Thickness, feet	Depth, feet
Ogallala formation		
Soil	5	5
Clay, brown	5	10
Clay, brown; contains limy nodules	10	20
Clay, silty, reddish-brown	5	25

Clay, limy, brown; contains some sand	5	30
Clay, limy; contains some cemented clay and some sand and gravel (water at 39 feet)	9	39
Dakota formation		
Shale, varicolored, yellow to light gray, streaked	2	41
Shale, bluish-gray	14	55

39. Log of test hole drilled on the east side of Ford County Lake southeast of the Ford County Farm, in the NE¼ NW¼ sec. 2, T. 26 S., R. 24 W. (Authority, Jos. F. Bauer, driller.)

	Thickness, feet	Depth, feet
Ogallala formation		
"Gyp rock," white, sandy	18	18
"Gyp rock" and yellow clay	42	60
Graneros shale (?)		
Shale, black	25	85
Dakota formation (?)		
Sandstone, fine, shelly; bit came up clean	8	93

40. Log of well (129) of R. D. Buell, in the NE¼ SE¼ sec. 2, T. 26 S., R. 24 W. Surface altitude, 2,507 feet. (Authority, owner.)

	Thickness, feet	Depth, feet
Ogallala formation		
Soil and clay	25	25
"Gyp" rock	43	68
Dakota formation		
Sandstone (drilled easily)	16	84
Shale, variegated (soapy and hard drilling at bottom)	40	124

41. Log of well (195) at the roundhouse of the Atchison, Topeka, and Santa Fe Railway Company at Dodge City, drilled in 1900, in the SW corner SW¼ SE¼ sec. 25, T. 26 S., R. 25 W. (Authority, A. M. Truman, division engineer, Dodge City.)

	Thickness, feet	Depth, feet
Alluvium		
Loam and clay. (First water level at 18 feet; second water level at 20 feet)	22	22
Sand and gravel (Arkansas river bed)	17	39
Ogallala formation		
Clay	17	56
Sand, streaked with clay	8	64
Clay	2	66
Sand	5	71
Clay	4	75
Sand	10	85
Clay	7	92
Sand	7	99
Clay	3	102
Sand, streaked with clay (second water)	0.8	122.8
Sand and gravel, coarse (third water)	21	143.8

42. Log of test hole drilled about 1910, in the SE corner SW¼ sec. 26, T. 26 S., R. 25 W., 300 feet east of waterworks and ice plant at Dodge City, Kansas.[a] (Authority, Oscar Johnson, driller.)

	Thickness, feet	Depth, feet
Alluvium		
Soil, sandy loam	3	3
Sand, water	27	30
Ogallala formation		
Clay, yellow, soft, impermeable	10	40
Sand, water-bearing	40	80
Clay, yellow, and sand	10	90
Sand, fine, resembles quicksand (water)	60	150
Gravel, coarse, clean (strong water)	10	160
Graneros shale (?)		
Clay, mucky, sticky, black, impermeable	20	180
Shale, black	40	220
Dakota formation (?)		
Sand and sandrock, yellow; contains 8 to 10 inches of coal at base	20	240
Sandrock, white (water)	15	255
Sandstone, dark	10	265
Clay, mucky, black	10	275
Rock, red	10	285
Rock, red	40	325
Sandrock, gray	10	335
Shale, yellow	20	355
Rock, red	70	425

43. Log of well (248) of John Clark, in the SW corner sec. 33, T. 26 S., R. 25 W. (Authority, owner, from memory.)

	Thickness, feet	Depth, feet
Alluvium		
Top soil	12.5	12.5
Sand (water at 14 feet)	1.5	14
Gravel, medium	7	21
Sand, coarse	7	28
Ogallala formation		
Sand, fine, resembles quicksand	42	70
Clay, yellow	5	75
Sand, and interbedded layers of cement rock	52	127
Rock, hard, cemented, white	0.5	127.5
Gravel, coarse, water	38.5	166

a. It is reported that this test hole was drilled to a depth of 980 feet, and that a flow of salt water was encountered at a depth of 650 feet sufficiently strong to lift the drilling tools.

44. Log of domestic well of A. J. Kline on the south side of the Arkansas river at Dodge City, in the NE¼ SE¼ sec. 34, T. 26 S., R. 25 W. (Authority, Tom Stauth, driller.)

	Thickness, feet	Depth, feet
Alluvium		
Soil	3	3
Sand, dry, mealy	4	7
Gravel	4	11
Clay	2	13
Gravel	4	17
Clay	1	18
Gravel, water-bearing	4	22
Clay, streak	3	25
Sand, water-bearing	4	29
Ogallala formation		
Clay	61	90
Gravel, good	12	102
Quicksand	2	104
Gravel, good water-bearing size	13	117
Rock, hard	1	118

45. Log of abandoned city well (west well) in Wright Park at Dodge City in the NE¼ NW¼ sec. 35, T. 26 S., R. 25 W. (Authority, Rex Reynolds, water superintendent.)

	Thickness, feet	Depth, feet
Alluvium		
Sand	24	24
Clay	8	32
Ogallala formation		
Sand	12	44
Sandy clay	27	71
Clay	19	90
Sand	7	97
Clay	8	105
Gravel	3	108
Hardpan	2	110
Gravel (second water gravel)	25	135

46. Log of city well (273) at Dodge City, in the SW¼ NE¼ sec. 35, T. 26 S., R. 25 W. (Authority, Layne-Western Co., drillers.)

	Thickness, feet	Depth, feet
Alluvium		
Sand, fine	8	8
Sand and gravel	28	36
Ogallala formation		
Rock with streaks of fine sand	7	43
Clay	3	46
Sand	5	51
Clay	7	58
Sand, fine	18	76
Clay	7	83
Sand and gravel	64	147

47. Log of test hole of Arthur Adams, in the SW¼ SW¼ sec. 2, T. 26 S., R. 27 W., Gray County. (Authority, owner.)

	Thickness, feet	Depth, feet
Ogallala formation		
Soil, etc.	85	85
Rock	6	91
Sand, dry	6	97
"Gyp" and sand	15	112
Sand, fine, some gravel	53	165
"Gyp"	5	170
Sand and gyp	30	200
Sand with water	5	205
"Gyp" and sand	25	230
Sand, medium to coarse	19	249
Rock	1	250
Sand, medium to coarse	15	265
"Gyp"	5	270
Clay	5	275
Rock	11	286

48. Log of test hole drilled for the Soil Conservation Service on the Roy Shellheimer farm, in the SW corner SE¼ NE¼ sec. 22, T. 27 S., R. 21 W. (Authority, samples studied by W. R. Stanley and H. A. Waite.)

	Thickness, feet	Depth, feet
Alluvium		
Top soil, sandy loam	8	8
Sand, medium to coarse; contains some gravel	8	16
Dakota formation		
Shale, soft, muddy, bluish-gray; contains streaks of sand stained with limonite	14	30
Shale, soft, muddy, bluish-gray to varicolored; contains yellow limonitic streaks	2	32
Shale, hard, bluish-gray, compact	29	61
Shale, sandy, red; contains some bluish-gray shale	5	66
Shale, sandy, bluish-gray	9	75

49. Log of test hole drilled for the Soil Conservation Service on the Roy Shellheimer farm, in the SW corner NW¼ SW¼ sec. 23, T. 27 S., R. 21 W. (Authority, samples studied by W. R. Stanley and H. A. Waite.)

	Thickness, feet	Depth, feet
Alluvium		
Loam, sandy, brown	5	5
Clay, sandy, gray to white	1	6
Clay, gray; contains some caliche and reworked fragments of Dakota sandstone	3	9
Gravel, medium to coarse	4	13
Dakota formation		
Sandstone, fine-grained, bluish-gray; contains some olive-green sandy shale	3	16
Shale, sandy, bluish-gray	1	17
Shale, sandy, bluish-gray; drilled harder	7	24

50. Partial log of oil test of the Olson et al. Company on the S. Fowler farm, in the middle of the SW¼ sec. 26, T. 27 S., R. 22 W. Surface altitude, 2,419 feet. (Authority, driller's log.)

	Thickness, feet	Depth, feet
Ogallala formation		
Sand and shale	65	65
Pre-Tertiary beds		
Rock, red, and shale	132	197
Sand and shale	28	225
Sand	10	235
Shale and shells	235	470
Rock, red	72	542
Shale and shells	28	570
Shale, red	60	630

51. Log of well (350) of W. H. Cook, in the NE¼ SE¼ sec. 27, T. 27 S., R. 22 W. (Authority, owner, from memory.)

	Thickness, feet	Depth, feet
Ogallala formation		
Soil	30	30
Clay, yellow	23	53
Dakota formation (?)		
Quicksand, fine, gray (probably sandstone)	6	59
Shale, bluish-gray	21	80

52. Log of test hole drilled for the Soil Conservation Service on the Carl Van Riper farm, in the NW¼ SW¼ sec. 15, T. 27 S., R. 23 W. (Authority, Lewis H. Bacon, Soil Conservation Service.)

	Thickness, feet	Depth, feet
Alluvium		
Top soil	4	4
Sand	4	8
(Static water level, 7.5 feet)		
Gravel, medium to coarse	10.5	18.5
Clay	2	20.5
Greenhorn limestone (?)		
Shale, very hard, dark gray	15.5	36

53. Log of test hole drilled for the Soil Conservation Service on the Judge Karl Miller farm, in the NW corner SW¼ SW¼ sec. 2, T. 27 S., R. 24 W. Surface altitude, 2,446.6. (Authority, samples studied by W. R. Stanley and H. A. Waite.)

	Thickness, feet	Depth, feet
Alluvium		
Soil, sandy loam, black	5	5
Clay, sandy, gray	4	9
Sand, medium to coarse, and fine gravel	3	12
Gravel, medium to coarse	10	22
Ogallala formation		
Silt, fine, sandy, gray to white	6	28
Silt, fine, sandy, soft, brown	12	40

Silt, fine, sandy, soft, brownish-buff and olive-green	20	60
Silt, fine, sandy, brown; contains some coarse sand	1	61
Sand, fine, and some silt; harder drilling	7	68
Sand, medium to coarse; contains fragments of caliche and pebbles	12	80
Sand, silty, fine, light buff	6	86
Gravel, medium to coarse; contains some caliche	4	90
Gravel, medium to coarse; contains caliche and some coarse sand; encountered a hard cemented bed at 107 feet	19	109
Gravel, medium to coarse, and coarse sand; cemented layer from 110-111 feet	3	112
Gravel, medium to coarse, and some coarse sand; contains water-worn pebbles of Greenhorn limestone and Dakota sandstone; hard cemented layer from 114 to 114.5 feet,	10	122
Silt, fine, sandy; contains some coarse sand and fine gravel,	16	138
Gravel, medium to coarse, and coarse sand; contains some water-worn fragments of Greenhorn limestone and Dakota sandstone, slow drilling from 150 to 154 feet, cemented?	18	156
Graneros shale		
Shale, tough, sticky, compact, argillaceous, gray to black; cuttings came up in soft rubbery chips	1.5	157.5

54. Log of well (366) at the Kansas Soldiers' Home, Fort Dodge, in the SW¼ NE¼ sec. 3, T. 27 S., R. 24 W. (Authority, Earl Vance, Engineer in charge.)

	Thickness, feet	Depth, feet
Alluvium		
Soil	2	2
Clay	10	12
Sand and gravel	15	27
Ogallala formation		
Clay and "magnesia"	11	38
Sand, fine	19	57
Clay	3	60
Sand, fine	10	70
Clay, sandy	8	78
Sand	8	86
Muck	4	90
Sand and gravel	31	121
Sand, packed	6	127
Sand and gravel	3	130
Clay	5	135
Sand, coarse	19	154

55. Log of test hole drilled for the Kansas Power Co. northeast of the new power plant, in the NW¼ NE¼ sec. 4, T. 27 S., R. 24 W. (Authority, Layne-Western Co., drillers.)

	Thickness, feet	Depth, feet
Alluvium		
Top soil	3	3
Sand, coarse, and a little gravel	21	24
Ogallala formation		
"Magnesia," fine sand, and clay	8	32
Sand, fine, packed	18	50
Clay and "magnesia," hard	8	58
Sand, fine	32	90
Sand, coarse (medium)	25	115
Sand, fine, clay, and "magnesia"	8	123
Sand, coarse	17	140
Sand, fine, and "magnesia"	3	143
Sand, coarse, streaked with "magnesia"	13	156

56. Log of test hole put down for the Kansas Power Co. on the north bank of the Arkansas river, south of the new power plant, in the NW¼ SE¼ sec. 4, T. 27 S., R. 24 W. (Authority, Layne-Western Co., drillers.)

	Thickness, feet	Depth, feet
Alluvium		
Sand, fine	2	2
Sand, coarse, and some gravel	16	18
Ogallala formation		
"Magnesia," fine sand and hard clay	74	92
Sand, coarse, "magnesia" and clay	20	112
Gravel and coarse sand, "magnesia" and clay	6	118
Sand, coarse, "magnesia" and clay	4	122
Sand, coarse, gravel and clay	20	142

57. Log of a test hole drilled for the Soil Conservation Service on the Ernest Martin farm, in the NE¼ NE¼ sec. 9, T. 27 S., R. 24 W. (Authority, Tom Stauth, driller, and H. A. Waite.)

	Thickness, feet	Depth, feet
Alluvium		
Soil, loam, sandy, black	1.5	1.5
Sand, grading from fine to coarse, iron stained	8.5	10
Sand, medium to coarse	5	15
Sand, fine to coarse, and gravel; contains fragments of Ogallala material	26	41
Ogallala formation		
Sand, fine	4	45
Sand, predominantly fine	30	75
Sand, fine; contains a few grains of coarser sand	10	85
Sand, fine; contains a few grains of coarser sand	5	90
Sand, very fine, uniform	5	95
Sand, fine to medium	5	100
Sand, very fine to medium	20	120
Sand, fine to medium to coarse; contains some gravel	10	130

Gravel, fine to medium	5	135
Gravel, medium to coarse	10	145
Gravel, medium to coarse; becomes coarser with depth	5	150
Gravel, predominantly coarse	5	155

58. Log of new city well at Dodge City drilled in 1940, on the south side of the Arkansas river, in the NW¼ NE¼ sec. 2, T. 27 S., R. 25 W. (Authority, Layne-Western Co., drillers.)

	Thickness, feet	Depth, feet
Alluvium		
Clay, sandy	10	10
Clay	6	16
Sand and gravel (water level, 18 feet)	8	24
Ogallala formation		
Clay	21	45
Sand, medium fine	18	63
Clay	2	65
Sand, fine	8	73
Clay	5	78
Sand, medium fine	2	80
Sand, clay, "magnesia"	6	86
Sand, medium fine	9	95
Clay	3	98
Sand and gravel	7	105
Sand, medium fine	5	110
Sand, clay, and "magnesia"	10	120
Sand and gravel; contains a few balls of clay and a few cemented streaks on rock	45	165

59. Log of well (393) of Ralph Williams, in the NW¼ NE¼ sec. 10, T. 27 S., R. 25 W. Surface altitude 2,540.1 feet. (Authority, Tom Stauth, driller.)

	Thickness, feet	Depth, feet
Soil	10	10
Soil, sandy	20	30
Ogallala formation		
Sand, coarse (dry)	30	60
Clay	.5	60.5
Gravel, medium to coarse	35.5	96
Clay, white	1	97

60. Log of test hole drilled for the city of Dodge City in the NW¼ NE¼ sec. 11, T. 27 S., R. 25 W. (Authority, Layne-Western Co., drillers.)

	Thickness, feet	Depth, feet
Ogallala formation		
Sand, fine	13	13
Sand and gravel (water level, 36 feet)	38	51
Clay	19	70
Sand, hard, cemented, and "magnesia"	8	78
Clay	5	83

Sand, medium coarse	18	101
Clay	7	108
Sand, fine	5	113
Clay	5	118
Sand, fine	10	128
Clay, "magnesia" and sand	17	145
Sand, gravel	25	170
Graneros shale (?)		
Shale	3	173

61. Log of well (402) of W. S. Johnson, in the SW¼ SE¼ sec. 6, T. 27 S., R. 26 W. (Authority, owner, from memory; samples from 180-230 feet examined by H. A. Waite.)

	Thickness, feet	Depth, feet
Kingsdown silt		
Top soil (hardpan)	12	12
Sand, fine, brown	48	60
Ogallala formation		
"Magnesia," white	10	70
Rock, "magnesia," white	30	100
Gravel	7	107
Rock, "magnesia," white	3	110
Gravel; a tooth taken from a depth of 113 feet has been identified by C. W. Hibbard as a right molar of *Pliohippus cf interpolatus*	4	114
Hardpan and fine sand	3	117
Sand, fine, (quicksand)	5	122
Clay; contains streaks of sand and interbedded hard cemented layers	58	180
Greenhorn limestone		
Limestone, hard, yellow to white; larger fragments contain impressions of *Inoceramus labiatus;* interbedded with yellow to white chalky shale	30	210
"Shell" rock, hard, white, similar to bed above	20	230
Graneros shale (?)		
Shale, soft, compact, bluish-black	..	230

62. Log of test hole drilled for the Soil Conservation Service on the E. P. Hoover farm, in the SW¼ NW¼ sec. 4, T. 28 S., R. 22 W. (Authority, Lewis H. Bacon.)

	Thickness, feet	Depth, feet
Alluvium		
Top soil	3	3
Clay, sandy, tight, yellowish-gray color	6	9
Clay, sandy	4	13
Sand, fine	3	16
Gravel, fine to medium; contains some fine sand	11	27
Gravel, fine (good water gravel)	12	39
Ogallala formation		
Clay, sandy, yellowish	6	45
Clay, yellow	7	52

Clay; contains some fine gravel	23	75
Clay, sandy	5	80
Dakota formation		
Shale, bluish-gray to gray	20	100
Sandstone, very hard	1	101
Sandstone, and some interbedded yellow clay	9	110
Sandstone, hard	0.5	110.5
Sandstone; contains hard bed from 123 to 123.5 feet	14.5	125

63. Log of well (417) of L. A. Lamb, in the SW¼ SW¼ sec. 4, T. 28 S., R. 22 W. (Authority, J. R. Maas, driller, from memory.)

	Thickness, feet	Depth, feet
Alluvium		
Loam, sandy	6	6
Loam, sandy; contains hard, white, limy pebbles	22	28
Sand; fine; mixture of quicksand cemented with bluish white sticky clay	6	34
Ogallala formation		
Gravel, medium to coarse; contains yellow clay and a few balls of clay	44	78
Dakota formation		
Sandstone	1	79

64. Log of well (420) of J. J. Maas, in the SW¼ NE¼ sec. 10, T. 28 S., R. 22 W. (Authority, J. R. Maas, driller, from memory.)

	Thickness, feet	Depth, feet
Alluvium		
Top soil, sandy loam	7	7
Loam, mixed with "gyp" pebbles and hard clay (water at 24 feet)	17	24
Gravel, medium to coarse	18	42
Ogallala formation		
Clay, yellow	1	43
Gravel, medium to coarse	26	69
Dakota formation		
Sandstone	1	70

65. Log of well (421) of E. V. Mella, in the SE¼ NW¼ sec. 11, T. 28 S., R. 22 W. (Authority, J. R. Maas, driller, from memory.)

	Thickness, feet	Depth, feet
Alluvium		
Top soil, sandy loam	5	5
Loam, soft, clay; contains white limy pebbles	16	21
Clay, yellow (water at 26 feet)	5	26
Quicksand	7	33
Ogallala formation		
Gravel, large-size	36	69
Dakota formation		
Shale, blue, sticky	2	71
Sandstone, fine, brownish-yellow	6	77

66. Log of well (425) of Milton Patterson, in the NW¼ NW¼ sec. 15, T. 28 S., R. 23 W. Surface altitude, 2,484.5 feet. (Authority, owner, from memory.)

	Thickness, feet	Depth, feet
Kingsdown silt		
Top soil	15	15
Clay, brown (water at 83 feet)	68.5	83.5
Sand, fine	7	90.5
Ogallala formation		
Sand and gravel, coarse	29.5	120
Sandstone	.5	120.5
Gravel, coarse, pea-size	11.5	132.0

67. Log of well (435) of Leo Lehman, in the SW¼ NW¼ sec. 11, T. 28 S., R. 24 W. Surface altitude, 2,553.8 feet. (Authority, owner.)

	Thickness, feet	Depth, feet
Kingsdown silt		
Top soil	3	3
Clay, sandy, reddish-yellow	57	60
Sand, cavy	55	115
Ogallala formation		
Sand and rock, hard cemented layer	2	117
Sand, river, some layers of boulder gravel	23	140
Rock, cemented	0.5	140.5
Gravel, good	18.3	158.8

68. Log of test hole drilled for the Natural Gas Pipeline Co. of America, in the NE corner sec. 28, T. 28 S., R. 24 W. (Authority, Layne-Western Co., drillers.)

	Thickness, feet	Depth, feet
Kingsdown silt		
Soil	4	4
Clay, sandy	56	60
Sand, coarse	12	72
Clay, hard	18	90
Ogallala formation		
Sand, coarse, and some gravel	25	115
Clay, red	3	118
Sand, coarse, and gravel	47	165
Clay	3	168
Sand, coarse, and gravel	22	190
Sand and gravel; contains a few cemented streaks	16	206
Clay	1	207
Sand, medium coarse	8	215
Clay, brown sandy	9	224
Dakota formation (?)		
Sand, medium fine	7	231
Sand, medium coarse	23	254
Clay, sandy	7	261
Sand, coarse, and some gravel	29	290
Hard rock	1	291

Sand, coarse, some gravel	29	320
Clay, sand, and "magnesia," cemented	5	325
Sand, coarse, and gravel	5	330
Rock, hard	3	333

69. Log of test hole drilled for the Natural Gas Pipeline Co. of America, in the SE corner sec. 32, T. 28 S., R. 24 W. (Authority, Layne-Western Co., drillers.)

	Thickness, feet	Depth, feet
Kingsdown silt		
Soil	2	2
Clay and "magnesia"	98	100
Ogallala formation		
Clay, sandy, and "magnesia"	70	170
Sand, coarse, and some gravel	33	203
"Magnesia" and clay	21	224
Rock, hard	1	225
Dakota formation (?)		
Clay, blue; contains streaks of fine sand	27	252
Rock, hard	2	254
Clay, sandy, gray	21	275
Sand, coarse, some gravel	21	296
Clay, sandy, gray	12	308
Sand, medium coarse	16	324
Clay, sandy, gray	11	335
Sand, coarse	5	340
"Magnesia," sand	41	381
Rock	3	384

70. Log of city well (467) at Bucklin, in the SW¼ NE¼ sec. 5, T. 29 S., R. 21 W. (Authority, J. E. Devore, city clerk)

	Thickness, feet	Depth, feet
Kingsdown silt		
Clay, brown	87	87
Sand	20.5	107.5
Ogallala formation		
Sand and gravel; contains a layer of clay near the top	17.5	125

71. Partial log of oil test drilled on the Elizabeth Everett farm, in the center of NE¼ sec. 22, T. 29 S., R. 21 W. Altitude, 2,418 feet. (Authority, driller's log.)

	Thickness, feet	Depth, feet
Kingsdown silt		
Surface and clay	46	46
Clay	64	110
Ogallala formation		
Sand and gravel	10	120
Sand, water	81	201
Sand and gravel	59	260
Kiowa shale (?)		
Shale, sticky	80	340

72. Log of test hole drilled for the Natural Gas Pipeline Co. of America, in the NE corner sec. 9, T. 29 S., R. 24 W. (Authority, Layne-Western Co., drillers.)

	Thickness, feet	Depth, feet
Kingsdown silt		
Soil	4	4
Clay and "magnesia"	46	50
Sand, coarse	5	55
Clay, "magnesia," and sand	35	90
Sand, coarse	4	94
Ogallala formation		
Clay, sandy	11	105
Sand, coarse	5	110
"Magnesia," sandy	47	157
Sand, very fine	3	160
Dakota formation (?)		
Shale, hard, blue	103	263

73. Log of test hole drilled for the Natural Gas Pipeline Co. of America, in the NE corner sec. 17, T. 29 S., R. 24 W. (Authority, Layne-Western Co.)

	Thickness, feet	Depth, feet
Kingsdown silt		
Soil	4	4
Clay, sandy, and "magnesia"	101	105
Sand, coarse	5	110
Ogallala formation		
Clay, sandy	18	128
Sand, coarse	4	132
"Magnesia"	8	140

74. Log of well (482) at Booster Station No. 3, of the Natural Gas Pipeline Co. of America, in the NE¼ SE¼ sec. 17, T. 29 S., R. 24 W. (Authority, Layne-Western Co., drillers.)

	Thickness, feet	Depth, feet
Kingsdown silt		
Soil and yellow clay	57	57
Ogallala formation		
"Magnesia" and sandy clay	19	76
Clay and "magnesia" rock	11	87
"Magnesia" rock and cemented sand	3	90
Sand and gravel, cemented	3	93
Sand and gravel	5	98
"Magnesia" and gravel	6	104
Sand rock and gravel	8	112
Sand and gravel, mucky	10	122
Sand rock	2	124
Sand and gravel, cemented	7	131
Sand and gravel	8	139
Dakota formation		
Shale, blue, containing few streaks of sand	131	270

75. Log of well (483) at Booster Station on No. 3, of the Natural Gas Pipeline Co. of America, in the NE¼ SE¼ sec. 17, T. 29 S., R. 24 W. (Authority, Layne-Western Co., drillers.)

	Thickness, feet	Depth, feet
Kingsdown silt		
Soil	2	2
Clay, yellow	51	53
Ogallala formation		
Clay and "magnesia"	21	74
"Magnesia" rock and sandy clay	13	87
"Magnesia" rock	3	90
Sand and gravel, cemented	3	93
Sand and gravel	5	98
Sand rock, hard	6	104
"Magnesia" rock and gravel	8	112
Sand and gravel, mushy	10	122
Sand rock, hard	2	124
Sand and gravel, cemented	7	131
Clay and "magnesia"	2	133

76. Log of test hole drilled for the Natural Gas Pipeline Co. of America, near the SW corner of the NW¼ SE¼ sec. 17, T. 29 S., R. 24 W. (Authority, Layne-Western Co., drillers.)

	Thickness, feet	Depth, feet
Kingsdown silt		
Soil	3	3
Clay, sand and "magnesia"	87	90
Coarse sand	10	100
Ogallala formation		
"Magnesia"	15	115
Sand, coarse, and some gravel	22	137
"Magnesia," sandy	13	150
Dakota formation		
Clay, hard red	15	165
Shale, hard blue	136	301

77. Log of test hole drilled for the Natural Gas Pipeline Co. of America, in the NE corner sec. 21, T. 29 S., R. 24 W. (Authority, Layne-Western Co., drillers.)

	Thickness, feet	Depth, feet
Kingsdown silt		
Soil	5	5
Clay, sand, and "magnesia"	106	111
Ogallala formation		
Sand, coarse, and some gravel	10	121
"Magnesia" rock	7	128
Sand, coarse, and some gravel	12	140
Sand, hard, cemented	3	143
Sand, coarse, and some gravel	12	155
Clay, white	16	171

	Thickness, feet	Depth, feet
Clay, yellow, sandy	12	182
"Magnesia," sandy	37	219
Dakota formation (?)		
Shale, blue	5	224
Shale, hard, blue	43	267

78. Log of well (507) of Joseph Lutz, in the NE¼ SW¼ sec. 15, T. 29 S., R. 26 W. Surface altitude, 2,556.2 feet. (Authority, Lee and McCauley, drillers.)

	Thickness, feet	Depth, feet
Kingsdown silt		
Soil	3	3
Clay	25	28
Sand, medium to coarse, dry	15	43
Ogallala formation (?)		
Sandstone, hard	7	50
Sand, coarse, water-bearing	70	120
Gravel, fine, and coarse sand; becomes coarser with depth to coarse gravel	29	149
Dakota formation (?)		
Sandstone, hard, white	25	174

79. Log of well (510) of George Lutz, in the SW¼ NW¼ sec. 24, T. 29 S., R. 26 W. Surface altitude, 2,540.4 feet. (Authority, Lee and McCauley, drillers.)

	Thickness, feet	Depth, feet
Kingsdown silt		
Clay	108	108
Ogallala formation		
Gravel, fine, water-bearing	15	123
Clay	50	173
Gravel, coarse, water-bearing	37	210
Dakota formation (?)		
Hard layer at	..	210

80. Log of well (522) of William Long, in the SE¼ NE¼ sec. 35, T. 29 S., R. 26 W. Surface altitude, 2,530.3 feet. (Authority, Lee and McCauley, drillers.)

	Thickness, feet	Depth, feet
Kingsdown silt		
Soil	3	3
Clay	42	45
Sand, medium to coarse, clean	10	55
Ogallala formation		
Sand, medium to coarse; contains some clay and caliche,	10	65
Sand, medium to coarse, clean	10	75
Clay, chiefly blue, sand red, some sandy	41	116
Gravel, fine, and coarse sand	116	125
Sand, medium to coarse, reddish, becoming coarser with depth	43	168

Sand, bluish, becoming coarser with depth to fine and medium gravel	7	175
Gravel, fine to coarse; contains a few large pebbles and boulders	13	188
Dakota formation (?)		
Shale or clay, red and blue	1	189

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