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GEOLOGY AND GROUND WATER RESOURCES OF GRADY AND NORTHERN STEPHENS COUNTIES, OKLAHOMA

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GEOLOGY AND GROUND WATER RESOURCES OF GRADY AND NORTHERN STEPHENS COUNTIES

By Leon V. Davis

ABSTRACT

This report describes the areal geology and ground-water resources of Grady County and northern Stephens County in south-central Oklahoma. The area includes all or parts of 45 congressional townships and covers about 1,236 square miles. The largest city is Chickasha, which is the county seat of Grady County and is an industrial and farming community. The other towns are primarily agricultural centers. The average annual temperature at Chickasha is about 61.6° F., and the average annual precipitation is about 30.81 inches.

The area is characterized by rolling plains, cut in places by deeply eroded valleys. About 85 percent of the area is drained by the Washita River, about 10 percent by the Canadian River, and about 5 percent by tributaries of the Red River.

Rocks cropping out in the area of the middle and upper parts of the Permian system are divided into the El Reno and Whitehorse groups, overlain by the Cloud Chief formation.

Rocks of the El Reno group crop out at the surface in the eastern and extreme southern parts of the area. They include (ascending) the Duncan sandstone, Chickasha formation, and the Blaine formation and Dog Creek shale, undifferentiated. The Duncan sandstone consists of interbedded sandstone and shale, and it yields hard water to domestic and stock wells in the outcrop area. Down dip to the west, the Duncan contains water under artesian pressure, and a few wells tapping this water flow at the surface. The water is generally hard in the south and highly mineralized in the north; locally it is too highly mineralized even for stock use. The Chickasha formation is composed of irregularly bedded conglomeratic siltstone with erratic sandy lenses occuring sparingly throughout the formation. It yields little water to wells except where sandstone lenses are penetrated. The water is very hard and in places is salty. The Dog Creek shale and Blaine formation, undifferentiated, are composed of dark red even-bedded shales and a few lenses of siltstone conglomerate. These beds yield almost no water to wells in Grady County.

Rocks of the Whitehorse group crop out at the surface in the southwestern third of the area and also in the northwestern part. They include, in ascending order, the Marlow formation and the Rush Springs sandstone. The Marlow formation is composed of even-bedded sandy or silty shale, with a few bands of sandy gypsum. The Verden sandstone member occurs near the middle of the Marlow and the Relay Creek dolomite beds are at the top

of the formation. The ground water in the Marlow formation is highly mineralized and the yields to wells are only a few gallons per minute. The Rush Springs sandstone is a fine-grained, cross-bedded sandstone, containing irregular silty lenses. Wells yield moderate supplies of water in most of the area of outcrop. The water is suitable for most industrial, municipal, and irrigation uses. The towns of Rush Springs and Marlow get their municipal water supplies from this formation.

The Cloud Chief formation occurs only as scattered thin outliers. The formation is mostly gypsum, which locally is dolomitic, but at many places it contains inter-bedded red clay shale. It is not water bearing in Grady County.

Terrace deposits composed of alluvial gravel, sand, silt, and clay, laid down when the streams flowed at higher elevations, occur along the major streams. These deposits yield moderate amounts of hard water to small municipal, domestic, and stock wells. The towns of Tuttle, Verden, and Alex get their municipal water supplies from terrace deposits.

Alluvium along both the major and minor valleys is composed of gravel, sand, silt, and clay. It yields hard water to domestic and stock wells. Alluvium is the source of the municipal water supply at Minco, Oklahoma.

The ground-water recharge comes mostly from precipitation within the area and in part by underflow from outside the area. Discharge is by transpiration and evaporation, by effluent seepage, and by springs and wells. The ground water in alluvium along the Washita and Canadian Rivers is recharged during most of the year from precipitation and at times of high water it is recharged by seepage from the rivers.

Records of 94 water wells and test holes are given in table 15, and the chemical analyses of 73 samples of ground water are listed in table 13. The water wells in alluvial sediments range in depth from 20 to 105 feet. Water-table wells in bedrock range from 15 to 200 feet in depth, and some artesian wells are as much as 400 feet deep. Yields range from a few gallons per minute to several hundred gallons per minute. The ground water is generally suitable for most domestic, industrial, and irrigation uses, but in some areas it is too highly mineralized for any of these purposes. The total discharge of ground water from wells is estimated at several hundred million gallons per year.

Four controlled pumping tests on wells in Grady County gave the following values for the coefficients of transmissibility and storage: in terrace deposits, transmissibility 18,500 gallons per day per foot, storage 1.95×10^{-3}; in the Rush Springs sandstone, transmissibility 12,650 gallons per day per foot in the Duncan sandstone, transmissibility 900 gallons per day per foot, storage 2.8×10^{-4}.

INTRODUCTION

SCOPE AND PURPOSE OF THE REPORT

Ground water is one of the most abundant and most valuable natural resources. However, it should not be assumed that ground water is available in unlimited quantities in all places. The demands of cities or of industries using ground water may, in given localities, increase the use of water far beyond the local rate of replenishment. If more water is taken out of a ground-water reservoir than can be replenished by precipitation, the excess must come from ground-water storage. The water table will be lowered and contamination may occur by encroachment of mineralized ground water. Such damage to ground-water supplies is not easily reparable. A ground-water reservoir is an invisible pool from which all users draw their supply. If the ground-water reservoir becomes contaminated by one user it may be spoiled for all; and if it is overdrawn by one user, the supply for all will be reduced. In Grady and Stephens Counties, as elsewhere, an understanding of the occurrence and movement of ground water and of the quantity and quality of water available is necessary for efficient development of available supplies to fill the expanding needs of municipal, industrial, and agricultural activities.

Accurate information about the chemical character of the water in the local aquifers is essential to aid in the selection of the most satisfactory water-bearing stratum, to permit advance estimation of the cost of treatment of the waters that may be available, and to prevent useless drilling in areas where prospects for suitable water are poor.

Ground water for municipal and industrial use in Grady and northern Stephens Counties, Oklahoma is obtained principally from alluvium along the major streams, at depths ranging from 20 to 105 feet, and from beds of water-bearing sandstone of Permian age at depths ranging from 15 to 200 feet. The water tapped by such wells is under water-table or semi-artesian conditions and some wells have relatively high yields. Other deeper wells penetrate aquifers in which the water is under artesian pressure. Increased

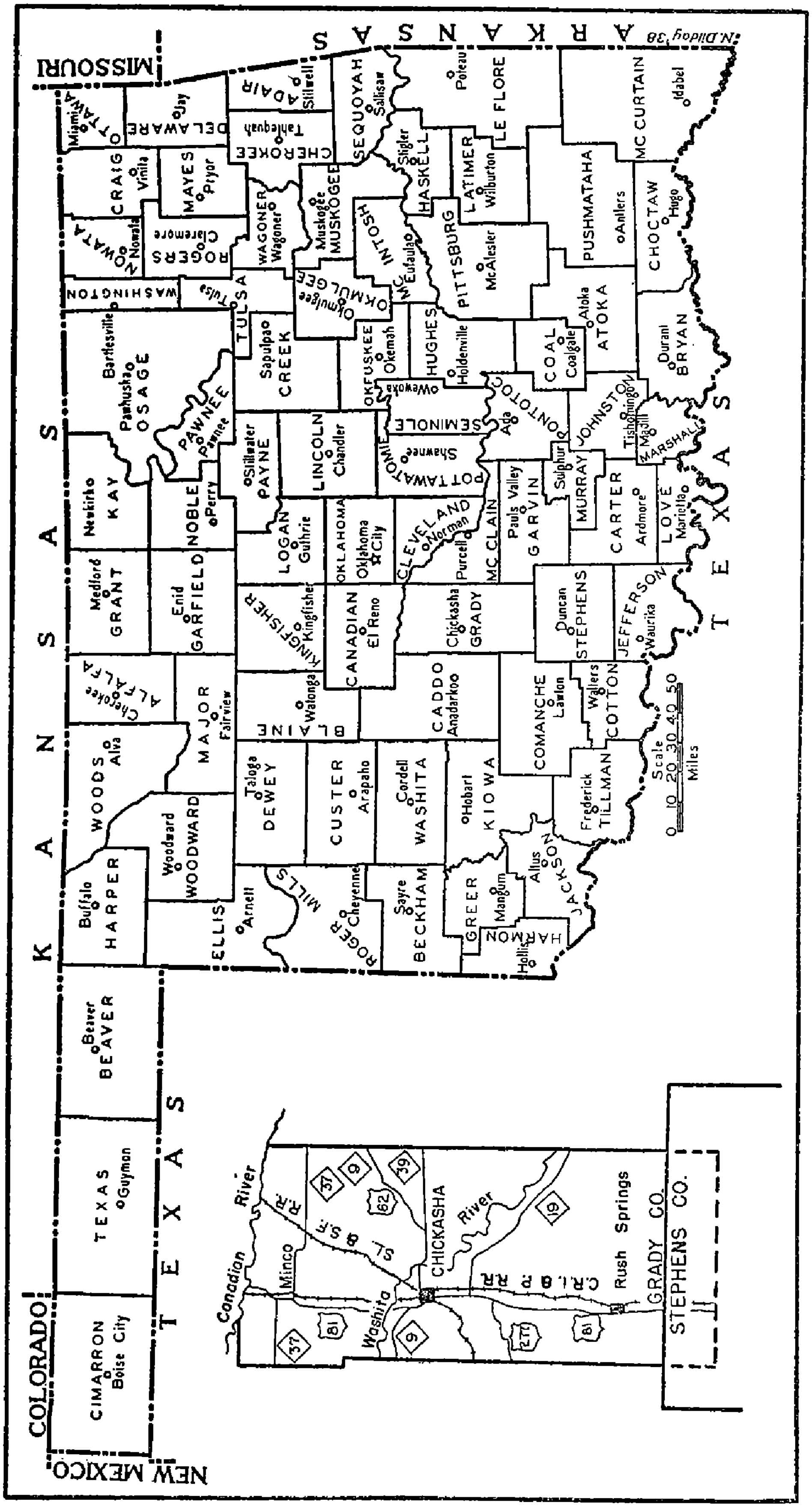


FIG. 1. Index map of Oklahoma, showing location of the area investigated in this report.

use of water has resulted in a demand for more ground water; but the occurrence, quantity, and quality of the available ground water in Grady County have been but imperfectly understood.

This investigation has been conducted as a cooperative project of the United States Geological Survey and the Oklahoma Geological Survey in order to make available to the public information on the occurrence, quantity, and quality of the ground water in Grady and northern Stephens Counties.

It was carried out under the general supervision of O. E. Meinzer and A. N. Sayre, successively Chiefs of the Ground Water Branch, U. S. Geological Survey, and R. H. Dott, Director (field work and most of the manuscript), W. E. Ham, Acting Director (completion of manuscript), and C. C. Branson, Director (editing and publication), Oklahoma Geological Survey, and immediately under the direction of S. L. Schoff, District Geologist, U. S. Geological Survey.

LOCATION OF THE AREA

Grady County lies just southwest of the middle part of Oklahoma, north of the Oklahoma Base Line and west of the Indian Meridian. It is approximately rectangular in shape and is bounded by Canadian County on the north; Cleveland, McClain, and Garvin Counties on the east; Stephens County on the south; and Comanche and Caddo Counties on the west. Grady County comprises all or part of Tps. 3 to 10 N., and Rs. 5 to 8 W., and totals about 1,092 square miles. Also included are T. 2 N., Rs. 5, 6, 7 and 8 W., about 144 square miles in area, comprising a part of the northernmost tier of townships in Stephens County and lying immediately adjacent to and south of Grady County.

Grady County was included in the land given to the Choctaws by the treaty of Doak's Stand in 1820. It remained a part of the Choctaw country until the treaty of 1839 between the Choctaws and Chickasaws that allowed the latter tribe to settle in the Choctaw country and to form a separate district there. In 1855 the Chickasaws made a bilateral treaty with the Choctaws and the United States, and the Chickasaw District became the Chickasaw Nation. In the treaty of 1866 between the Choctaws and Chickasaws and the United States, the Leased District which included the westernmost tier of townships in what is now Grady County, was ceded to the United States for the use of friendly Indians. Later, in 1890, this western land became part of the Oklahoma Territory but was not opened to settlement until 1901. The present boundaries of the county were established when Oklahoma and Indian Territories were combined to form the State of Oklahoma in 1907.

The largest town and county seat is Chickasha, with a population of about 15,842. In the northern part are Minco, Tuttle, Amber, and Middleberg; and in the southern part are Rush Springs, Marlow, Ninnekah, Alex, and Bradley.

Grady County is transversed by U. S. Highways 62, 81, and 277; by Oklahoma State Highways 1, 17, 19, 29, 37, 39, 41, and 92; and by the St. Louis and San Francisco Railway, and the Chicago, Rock Island and Pacific Railroad.

PREVIOUS INVESTIGATION

Prior to this investigation the geological reports on Grady County have been more concerned with the geology and nomenclature of the sedimentary rocks rather than with the ground-water possibilities. The earliest noteworthy report including Grady County is that by Gould (1905) which was made in connection with his study of the geology and water resources of Oklahoma. Many other geologists have contributed to the knowledge of the geology of Grady County. The principal reports relating to the geology or ground water of Grady County are as follows:

1902

Gould, C. N., General geology of Oklahoma: Oklahoma Dept. of Geol. and Nat. History: Bienn. Rept. 2, p. 17-74.

1905

Gould, C. N., Geology and water resources of Oklahoma: U. S. Geol. Survey, Water-Supply Paper 148.

1915

Wegemann, C. H., The Duncan gas field: U. S. Geol. Survey, Bull. 621-D.

1918

Ohern, D. W., A contribution to the stratigraphy of the red beds: Amer. Assoc. Petroleum Geologists, Bull., vol. 2, p. 114.

1921

Clapp, F. G., Geology of Cement oil field: Amer. Inst. Min. Met. Eng., Trans., vol. 65, p. 156-164.

1921

Reeves, Frank, Geology of the Cement oil field, Caddo County, Oklahoma: U. S. Geol. Survey, Bull. 726, p. 41-85.

1924

Sawyer, R. W., Areal geology of a part of southwestern Oklahoma: Amer. Assoc. Petroleum Geologists, Bull., vol. 8, p. 312-321.

1924

Gould, C. N., A new classification of the Permian red beds of southwestern Oklahoma: Amer. Assoc. Petroleum Geologists, Bull., vol. 8, p. 322-341.

1926

Gould, C. N., The correlation of the Permian of Kansas, Oklahoma and northern Texas: Amer. Assoc. Petroleum Geologists, Bull., vol. 10, p. 144-153.

1926

Aurin, F. L., Officer, H. G., and Gould, C. N., The subdivision of the Enid formation: Amer. Assoc. Petroleum Geologists, Bull., vol. 10, p. 786-799.

1926

Gould, C. N., and Lewis, F. E., The Permian of western Oklahoma and the panhandle of Texas: Oklahoma Geol. Survey, Circular 13.

1927

Gould, C. N., and Willis, Robin, Tentative correlation of the Permian formations of the southern Great Plains: Geol. Soc. Amer., Bull., vol. 38, p. 431-442.

1927

Becker, C. M., Geology of Caddo and Grady Counties, Oklahoma: Oklahoma Geol. Survey, Bull. 40-I.

1930

Sawyer, R. W., Oil and gas in Oklahoma, Kiowa and Washita Counties: Oklahoma Geol. Survey, Bull. 40, vol. 2, p. 311-321.

1930

Becker, C. M., Structure and stratigraphy of southwestern Oklahoma: Amer. Assoc. Petroleum Geologists, Bull., vol. 14, p. 37-56.

1931

Evans, Noel, Stratigraphy of Permian beds of northwestern Oklahoma: Amer. Assoc. Petroleum Geologists, Bull., vol. 15, p. 405-439.

1936

Green, D. A., Permian and Pennsylvanian sediments exposed in central and west-central Oklahoma: Amer. Assoc. Petroleum Geologists, Bull., vol. 20, p. 1454-1475.

1937

Brown, O. E., Unconformity at base of Whitehorse formation, Oklahoma: Amer. Assoc. Petroleum Geologists, Bull., vol. 21, p. 1535-1556.

1937

Green, D. A., Major divisions of Permian in Oklahoma and southern Kansas: Amer. Assoc. Petroleum Geologists, Bull., vol. 21, p. 1515-1533.

PRESENT INVESTIGATION

This is the first investigation having as its primary objective an evaluation of the ground-water resources of Grady County, Oklahoma. Initially, it was intended to study only the Rush Springs sandstone in southwestern Grady County, but later the program was expanded to cover the entire county, and still later, to include four townships at the north end of Stephens County. In the spring of 1946 surface mapping of the exposed rock formations was begun and the mapping was continued with interruptions until the spring of 1950. Meanwhile, several pumping tests were made, municipal supplies were investigated, and records of pumpage obtained where available. Samples of water collected from wells and springs were analyzed, and in addition several unpublished analyses representing ground water from Grady County were made available by oil companies.

A well inventory was made of representative wells throughout the county with special emphasis on wells in the Rush Springs sandstone. Test holes were drilled in areas where information from farm wells was meager or lacking. Altitudes of wells selected as observation wells were determined by alidade or level.

As the published geologic maps of Grady County are on a small scale the area was remapped in the field, using aerial photographs on a scale of approximately 3.2 inches to the mile as a base. Descriptions of the rocks and the geology of the area are based on the author's observations and on published reports.

WELL-NUMBERING SYSTEM

The well-numbering system used in this report is based on the township system of the General Land Office. The first part of the well number is the township number, the second is the range number, and the third is the section. Thus 5N8W-14 designates a well in sec. 14, T. 5 N., R. 8 W. Where several wells are recorded in the same section, serial numbers are added to distinguish one from another. For example, well 5N8W-14-2 is the second well recorded in sec. 14.

In table 15 the wells are grouped by townships set off by a center heading. The well numbers are given in the first, or left-hand, column. The part of the well number derived from the township and range is given once, at the left in bold-face type, with only the section and serial elements of the number showing on the line describing the well, thus:

5N8W
-14-1
-14-2

Locations within the sections are given in the second column of the well tables, following the usual pattern of land descriptions: NW¼NW¼NW¼. In this example, the smallest fractional unit is given first, and the location is the northwesternmost 10 acres of the section, and is read the NW¼ of the NW¼ of the NW¼. This part of the location is not repeated in other tables, and in most cases is not mentioned in the text.

ACKNOWLEDGMENTS

Without the cooperation of many individuals who supplied information or aided in the collection of field data, this report would not be possible. Well drillers supplied information concerning the materials penetrated while drilling water wells, and furnished data on the quality of water in completed wells. Individual well owners and tenants were free with information and data pertaining to farm wells.

Special thanks are due the Sawyer Drilling Co., Chickasha, Oklahoma, for time, freely given, in arranging pumping tests, and for data on water wells throughout the area, and to the Oklahoma Municipal Engineering Co., the Oklahoma Natural Gas Co., the Magnolia Petroleum Co., and the Consolidated Gas Utilities Co. for assistance in conducting pumping tests. The officials of the towns willingly furnished information about their respective water supplies.

Chemical analyses of water samples were made by the Quality of Water Branch of the U. S. Geological Survey at Stillwater, Oklahoma. Messrs. Ross Phillips, Stanley Grayson, Bill Beach, Wayne Wick, Peter Hanf, and Miss Tuva Vaughn drafted the illustrations and the geologic map.

Advice and encouragement were given by members of the U. S. Geological Survey and of the Oklahoma Geological Survey.

GEOGRAPHY

TOPOGRAPHY

The area covered in this report is in the Osage Plains of the Central Lowland Province (Fenneman, 1930, p. 455, p. 605-630). Rolling plains developed by erosion of shales and siltstones characterized the eastern part. The western part is cut by deep drainage channels eroded in sandy shales and sandstones. Local relief in most places does not exceed 200 feet and generally is much less. The Washita River crosses about midway of Grady County flowing southeast. The Canadian River also flowing southeast forms the north boundary of the County.

Three distinct alluvial terraces, 2 to 5 miles wide, flank the Washita River forming broad flat plains across the area. Correlative terraces are found along most of the major tributary streams and also along the Canadian River at the north edge of Grady County.

DRAINAGE

The area lies within the Washita River drainage basin, with the exception of two townships adjacent to the southwest corner, which are drained southward into the Red River by Buckhorn Creek, and a strip about 5 miles wide along the north side of the county, which is drained by the Canadian River. The Washita River is a perennial stream with steep mud banks, very little sand in the stream bed and heavy timber on the bottom lands. The Washita flows generally eastward from Verden to Chickasha, thence southeastward to Alex and Bradley, and leaves the area near the northeast corner of T. 4 N., R. 5 W. The other perennial streams are Little Washita River and Rush Creek, both tributary to the Washita, and Boggy Creek, which flows into the Canadian River. These streams head in the outcrop area of the Rush Springs sandstone and are spring fed. Other major tributaries of the Washita River include High, Salt, Otter, West Fork Bitter, East Fork Bitter, Winter, Loflin, and Colbert Creeks. Rush Creek, in the southeastern part of Grady County, flows eastward and enters the Washita River near Pauls Valley in adjacent Garvin County.

North of the principal drainage divide, which is near the north edge of Grady County, the drainage is northward into the Canadian River, which flows eastward and forms the north boundary of the county. Its tributaries are Store, Worley, and Cool Creeks (intermittent) and Boggy Creek (perennial).

ECONOMIC DEVELOPMENT

Prior to the opening of the area to settlement, the economy of the region of which this area is a part was confined to hunting and fishing, and later, after the bison disappeared, to ranching, but as the white population increased, farming became more and more important. Farming increased income, and towns and cities grew up as service centers for the rural population. Corn was the major farm crop until about 1910, when it was displaced by cotton, which reached peak production about 1929. Since 1929 farming in this area has become highly diversified. Although corn and cotton are still the principal crops, the area is now widely known for the broomcorn raised in the east-central part of Grady County, and watermelons and produce raised in the vicinity of Rush Springs. Alfalfa is an important crop on the alluvial soils of the Washita Valley, and peanuts are a major crop on the sandy soils in the southwestern part of the area. In the change to diversification, cattle have not been neglected. In the areas not suited to the plow, both beef and dairy cattle are raised, including pure-bred stock, which are highly valued for breeding purposes.

Mineral resources other than oil are little used. Gypsum, in the form of gypsite, formerly was processed into wallboard at a plant near Acme. The plant has been abandoned for many years. Calcareous sandstone suitable for the manufacture of rock wool is found at several localities in Grady County, but none of these deposits has been developed. Analyses of this rock and results of laboratory experiments by the Oklahoma Geologcial Survey are summarized in Table 1 (Wood, 1939, p. 30, 31, 32). Sand and gravel in large quantities are available from terrace deposits, but only one large gravel quarry is operated continuously although many small pits have been opened and operated for short periods to meet local needs for road gravel. Building stone has been quarried from the Verden sandstone member of the Marlow formation, but the rock is difficult to quarry and waste is high. Little or none has been quarried since 1937.

TABLE I

ANALYSES OF ROCK SUITABLE FOR THE PRODUCTION OF ROCK WOOL

Laboratory No. 4981
Location: SW¼ NE¼ SE¼ sec. 9 T. 5 N., R. 7 W.

Chemical Components (percent)

Silica (SiO_2)	34.32	Calcium oxide (CaO)	21.14
Alumina (Al_2O_3)	0.76	Magnesium oxide (MgO)	13.12
Iron oxide (Fe_2O_3)	1.22	Carbon dioxide (CO_2)	28.86
Manganese dioxide (MnO_2)	trace	Combined water (H_2O)	none
		Total	99.42

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing Temperature
Maximum	Minimum	Aver.			
15.0	1.0	5.4	White	Long fibered and flexible. Very good grade of wool.	1410° C.

Laboratory No. 4982
Location: SE¼ NW¼ NW¼ sec. 1, T. 4 N., R. 7 W.

Chemical Components (percent)

Silica (SiO_2)	42.26	Calcium oxide (CaO)	16.26
Alumina (Al_2O_3)	0.99	Magnesium oxide (MgO)	11.74
Iron oxide (Fe_2O_3)	1.13	Carbon dioxide (CO_2)	25.57
Manganese dioxide (MnO_2)	0.09	Combined water (H_2O)	0.22
		Total	99.06

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing Temperature
Maximum	Minimum	Aver.			
15.0	1.5	5.1	Very White	Soft and flexible. Good grade of wool.	1527° C.

Laboratory No. 4983
Location: SE¼ SE¼ NE¼ sec. 12, T. 4 N., R. 7 W.

Chemical Components (percent)

Silica (SiO_2)	36.88	Calcium oxide (CaO)	19.61
Alumina (Al_2O_3)	1.17	Magesium oxide (MgO)	12.18
Iron oxide (Fe_2O_3)	1.79	Carbon dioxide (CO_2)	27.54
Manganese dioxide (MnO_2)	none		
		Total	99.17

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing Temperature
Maximum	Minimum	Aver.			
15.0	1.3	5.0	White	Soft and flexible. Good grade of wool.	1532° C.

Laboratory No. 4985
Location: SE¼ SW¼ SE¼ sec. 1, T. 4 N., R. 7 W.

Chemical Components (percent)

Silica (SiO_2)	36.30	Calcium oxide (CaO)	20.24
Alumina (Al_2O_3)	1.05	Magnesium oxide (MgO)	12.98
Iron oxide (Fe_2O_3)	2.29	Carbon dioxide (CO_2)	26.75
Manganese dioxide (MnO_2)	none		
		Total	99.61

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing Temperature
Maximum	Minimum	Aver.			
7.0	1.5	2.4	White	Fine and soft. Good grade of wool.	1527° C.

Grady and northern Stephens Counties are becoming increasingly important in oil production in Oklahoma. The Chickasha gas field, discovered in 1922, is the major gas field; and the Carter-Knox oil field, discovered in 1919, is the major oil field. Drilling and production have continued in these two fields since their discovery. Within the past several years oil has been found in older and deeper rocks, and several new fields have been developed. At the same time, deeper drilling has proved new reserves in the older fields. Exploration for and discovery of additional oil and gas may be expected to continue for many years.

CLIMATE

Grady County has a moist-subhumid climate (Thornthwaite, 1941, p. 3, pl. 3). In winter the temperatures generally are moderate with occasional short periods of severe cold and relatively little snow. In summer temperatures often are uncomfortably hot during the day, but usually the nights are cool. The distribution of precipitation is generally such that it exceeds the losses by evaporation and plant needs, resulting in a moist subsoil and accretion to ground water. Farming without irrigation is practical in most years, but several years of average or above-average rain may be followed by several dry years during which irrigation would be necessary for optimum crop growth.

Records of precipitation and temperature have been kept by the U. S. Weather Bureau at Chickasha and Marlow (Stephens County) from 1901 to date (tables 2-9, and fig. 2). Intense precipitation over small areas is common, as well as storms of regional extent. Storms of the latter type are most frequent in the spring and fall, and may cause extensive flooding in the valleys. The average annual precipitation for the period of record is 30.81 inches at Chickasha, about 7 percent below State average, and 32.93 inches at Marlow, about 1 percent below State average. The annual precipitation has ranged from 16.33 inches to 47.45 inches at Chickasha, and from 17.51 inches to 58.32 inches at Marlow.

Thus, the highest annual precipitation has been about three times the lowest at Chickasha and four times the lowest at Marlow. About 63 percent of the total annual precipitation occurs in the spring and summer (table 2).

The air temperatures recorded at Chickasha have ranged from —11° F. on January 4, 1947, to 116° F., recorded on August 11, 1936 (table 6). January has the lowest average temperature and July has the highest (table 3). The average annual air temperature at Chickasha is 61.6° F., just 1 degree above the average for the State.

The average number of days between the last killing frost in the spring and the first killing frost in the fall, for the period of record, is 213 days at Chickasha and 223 days at Marlow. The last killing frost in spring occurs late in March, but has varied from February 22 to May 1. The first frost in the fall usually occurs late in October or the first part of November, but has ranged from October 8 to December 1 (tables 6-7).

TABLE 2.

AVERAGE MONTHLY PRECIPITATION, IN INCHES, AT CHICKASHA, OKLAHOMA, 1901 to 1953 INCLUSIVE.

Winter		Spring		Summer		Autumn	
December	1.51	March	2.13	June	3.95	September	[d]3.24
January	1.31	April	[b]3.45	July	2.28	October	2.98
February	[a]1.31	May	5.19	August	[c]2.48	November	[e]1.86
Seasonal total	4.13		10.77		8.71		8.08

a. 1947 not included.
b. 1936 not included.
c. 1936 and 1947 not included.
d. 1939 not included.
e. 1932 and 1949 not included.

TABLE 3.

AVERAGE MONTHLY TEMPERATURE, IN DEGREES FAHRENHEIT, AT CHICKASHA, OKLAHOMA, 1901 to 1953 INCLUSIVE.

January	39.1	April	[a]61.2	July	82.6	October	63.4
February	43.2	May	69.0	August	82.7	November	50.9
March	52.3	June	78.5	September	74.8	December	41.3

a. April 1933 not included.

TABLE 4.

CLIMATIC DATA FOR CHICKASHA, GRADY COUNTY, OKLA.: MONTHLY AND ANNUAL PRECIPITATION, IN INCHES.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual	Departure from average[1]
1901	0.51	0.55	0.25	1.22	8.33	0.78	0.28	0.77	0.35	0.88	1.00	1.41	16.33	—14.48
1902	0.10	0.08	2.85	3.48	12.56	0.51	2.11	2.51	6.00	2.14	7.62	1.74	41.70	+10.89
1903	0.35	2.44	2.97	0.06	4.27	1.39	1.90	4.74	2.36	1.93	0.00	0.52	22.93	— 7.88
1904	1.67	T	0.37	1.44	5.42	8.05	1.18	3.76	3.97	....	T	0.20	29.51	
1905	1.50	1.42	3.50	7.58	10.34	1.05	4.25	0.89	....	0.30	....	....	38.81	
1906	....	....	....	....	....	....	....	....	....	....	....	....	40.81	
1907	1.70	0.40	1.38	3.30	5.12	5.04	1.64	1.89	0.85	5.17	2.03	1.80	30.32	— 0.49
1908	1.35	2.95	0.92	5.30	10.78	11.19	2.35	1.11	2.32	4.98	3.31	T	46.56	+15.75
1909	0.33	0.80	2.31	2.72	0.62	2.94	3.38	0.77	0.40	1.28	4.56	0.26	20.37	—10.44
1910	1.00	0.77	0.62	3.61	3.33	0.99	2.62	1.17	1.53	1.50	T	0.13	17.27	—13.54
1911	0.37	2.26	T	3.39	....	0.36	6.22	1.52	2.28	0.75	0.54	4.94	27.81	
1912	T	1.27	5.52	1.86	1.11	4.54	1.86	....	....	2.11	0.15	0.82	30.30	
1913	....	....	3.16	1.78	2.70	4.90	1.37	0.04	7.10	2.84	3.38	4.12	31.20	
1914	T	0.70	1.94	3.59	5.50	T	2.71	5.67	0.82	1.73	0.71	2.73	26.10	— 4.71
1915	0.62	2.61	1.30	6.75	6.67	10.28	1.81	4.86	4.28	1.56	0.17	0.20	41.11	+10.30
1916	3.35	T	1.44	3.75	2.83	6.29	1.47	0.18	5.11	1.89	1.71	0.32	28.34	— 2.47
1917	0.22	0.34	2.02	3.57	2.74	1.49	2.32	4.12	2.60	0.45	1.04	T	20.91	— 9.90
1918	0.90	0.16	1.84	2.03	1.23	4.99	0.43	1.65	3.26	6.22	0.98	1.85	25.54	— 5.27
1919	0.43	....	....	....	....	....	....	2.76	1.00	9.71	2.50	....	40.81	
1920	....	....	....	3.65	4.56	1.57	1.60	3.48	2.20	7.09	1.19	0.98	31.81	
1921	2.04	1.60	2.82	1.79	1.90	6.88	5.80	0.80	2.78	0.12	0.36	0.29	27.18	— 3.63
1922	1.00	0.84	2.79	5.68	8.19	0.29	2.16	0.03	1.19	2.73	2.12	0.47	27.49	— 3.32
1923	3.03	0.39	3.06	5.53	6.62	3.08	0.61	2.57	6.37	12.08	1.72	2.21	47.27	+16.46
1924	0.11	0.25	2.95	5.23	3.69	1.57	2.73	0.88	1.64	0.82	1.11	2.13	23.11	— 7.70
1925	0.21	0.67	0.08	6.09	8.41	0.27	1.66	0.90	9.48	1.79	1.92	0.15	31.63	+ 0.82
1926	2.10	0.00	2.44	2.57	2.26	2.08	2.65	5.23	5.79	4.65	0.48	4.53	34.78	+ 3.97
1927	1.77	0.99	1.70	8.27	6.81	4.67	3.25	6.72	4.20	5.71	0.92	1.27	46.28	+15.47
1928	0.74	1.97	1.76	2.32	3.48	5.06	4.79	2.58	0.74	2.57	2.76	1.84	30.61	— 0.20
1929	1.49	1.20	6.72	2.81	7.59	2.91	2.00	0.36	6.29	1.93	1.55	0.19	35.04	+ 4.23

TABLE 4. (Continued)

CLIMATIC DATA FOR CHICKASHA, GRADY COUNTY, OKLA.: MONTHLY AND ANNUAL PRECIPITATION, IN INCHES.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual	Departure from Average[1]
1930	2.30	0.31	0.35	3.05	8.16	3.17	0.82	1.44	1.47	6.25	2.36	1.97	31.65	+ 0.84
1931	0.79	1.21	2.26	2.49	2.67	0.58	1.24	2.91	1.63	4.64	8.99	1.51	30.92	+ 0.11
1932	3.97	1.25	0.59	2.22	2.18	12.64	1.18	4.07	2.28	1.95	T	5.01	37.34	+ 6.53
1933	0.33	1.30	3.15	3.37	4.18	0.53	1.69	8.73	5.04	3.96	0.73	3.08	36.09	+ 5.28
1934	1.99	0.91	1.62	2.25	2.19	1.41	0.53	2.40	8.24	1.71	3.57	0.49	27.31	— 3.50
1935	0.42	0.81	2.39	2.70	8.03	4.50	0.55	4.58	3.95	1.87	2.51	1.83	34.14	+ 3.33
1936	0.08	0.30	0.26	T	4.68	1.33	0.18	T	11.49	1.19	0.08	0.92	20.51	—10.30
1937	1.39	0.40	2.45	2.74	1.52	4.13	0.69	2.95	3.13	1.94	1.41	1.29	24.04	— 6.77
1938	1.17	5.41	5.22	2.58	8.61	3.88	1.39	0.27	1.35	0.13	1.84	0.44	32.29	+ 1.48
1939	3.33	0.30	1.46	0.62	2.89	6.60	1.66	4.10	T	1.66	0.50	0.65	23.77	— 7.04
1940	0.33	2.55	0.10	3.50	3.86	3.21	3.07	1.74	1.06	1.82	5.28	1.53	28.05	— 2.76
1941	1.00	2.96	0.35	4.80	7.86	8.69	1.75	2.02	3.57	11.43	1.30	1.72	47.45	+16.64
1942	0.39	0.99	0.87	7.73	1.67	3.74	1.66	5.74	5.50	3.23	0.55	2.58	34.65	+ 3.84
1943	0.15	0.88	1.45	5.68	7.07	4.23	0.03	0.41	1.79	1.24	0.35	2.88	26.16	— 4.65
1944	1.99	2.66	2.38	3.04	2.53	3.64	2.35	1.87	2.09	3.62	2.75	2.22	31.14	+ 0.33
1945	1.43	2.32	5.99	5.55	1.01	8.56	6.81	1.93	9.77	0.51	0.27	0.03	44.18	+13.37
1946	3.47	1.71	1.70	1.91	6.97	4.50	2.03	4.98	1.47	1.05	3.87	2.57	36.23	+ 5.42
1947	0.48	T	0.18	7.50	7.54	3.32	0.33	0.00	1.81	4.63	1.98	1.06	28.83	— 1.98
1948	1.28	2.72	4.88	1.82	4.89	6.86	1.00	1.02	0.03	0.82	1.11	0.21	26.64	— 4.17
1949	5.43	0.92	1.52	1.40	6.69	4.89	0.62	1.47	2.77	4.21	0.00	1.55	31.47	+ 0.66
1950	0.96	2.19	0.05	1.34	8.26	3.46	11.00	3.92	1.87	0.87	0.17	0.02	34.11	+ 3.30
1951	1.91	1.50	0.89	1.18	11.73	4.88	2.95	1.63	2.30	1.95	2.12	T	33.04	+ 2.23
1952	1.32	1.63	2.26	2.69	5.38	3.05	2.35	1.13	0.02	0.00	2.46	1.25	23.54	— 7.27
1953	0.28	1.65	3.25	2.77	1.91	2.28	5.41	2.86	1.34	6.22	1.38	1.01	30.36	— 0.45
Normal[2]	1.11	1.13	1.98	3.49	5.06	3.71	1.99	2.52	3.39	3.12	1.79	1.52	30.81	

1. Computed from average for period of available data through 1943.
2. Normal as computed from available data through 1943.

T - Trace

.... No Record.

TABLE 5.

CLIMATIC DATA FOR MARLOW, STEPHENS COUNTY, OKLA.: MONTHLY AND ANNUAL PRECIPITATION, IN INCHES.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual	Departure from Average[1]
1900	....	....	....	....	....	....	....	....	....	3.07	1.07	0.06	....	
1901	0.36	0.74	0.19	3.30	6.93	1.50	1.06	0.57	1.05	1.31	1.54	1.42	19.97	—12.96
1902	0.05	0.06	3.34	4.91	12.25	0.40	0.76	0.95	7.45	3.16	10.87	1.39	45.59	+12.66
1903	0.84	4.38	1.42	0.59	3.34	1.81	0.79	1.50	3.11	0.20	T	0.39	18.37	—14.56
1904	1.83	0.15	T	1.79	4.43	14.36	1.28	2.06	4.37	T	T	0.30	30.57	— 2.36
1905	1.63	2.05	4.53	6.04	10.90	3.42	3.66	0.96	2.14	1.56	3.42	2.54	42.85	+ 9.92
1906	0.87	0.20	4.08	6.12	2.46	5.37	4.86	8.62	6.24	2.79	1.79	1.34	44.74	+11.81
1907	2.20	T	1.93	1.73	7.30	5.70	3.36	1.74	1.45	6.75	1.96	2.12	36.24	+ 3.31
1908	1.30	2.50	0.50	6.35	12.93	16.39	4.33	0.67	5.93	4.03	3.32	0.07	58.32	+25.39
1909	0.32	0.95	2.34	2.15	1.32	5.89	0.31	1.29	0.14	0.88	4.20	0.45	20.24	—12.69
1910	0.28	0.74	0.47	4.10	3.78	1.38	2.56	3.70	2.78	3.42	0.53	0.23	23.97	— 8.96
1911	0.41	1.95	0.15	1.91	4.27	0.72	5.66	3.19	3.28	0.95	0.23	5.20	27.92	— 5.01
1912	T	0.81	6.09	4.34	2.69	3.08	2.04	7.07	2.17	3.04	0.45	0.76	32.54	— 0.39
1913	1.75	0.53	3.10	1.06	3.90	5.10	0.83	0.00	5.22	3.64	3.01	5.55	33.69	+ 0.76
1914	T	0.98	3.62	4.00	8.43	0.20	T	5.78	0.88	3.45	1.46	2.99	31.79	— 1.14
1915	1.20	4.60	1.67	7.94	6.57	7.60	1.25	8.53	4.62	4.16	0.10	1.24	49.48	+16.55
1916	6.59	T	1.03	5.62	2.61	3.57	0.57	0.33	2.94	1.35	1.72	1.06	27.39	— 5.54
1917	0.60	1.43	1.38	0.19	4.77	2.13	2.64	4.12	1.64	T	2.27	T	21.17	—11.76
1918	0.40	0.10	1.77	3.48	2.55	4.82	1.05	2.68	3.49	6.29	1.64	4.47	32.74	— 0.19
1919	1.76	2.41	2.78	4.03	4.14	4.36	4.78	2.30	1.42	13.30	5.03	0.44	46.75	+13.82
1920	1.94	1.19	1.26	4.14	5.31	2.01	0.87	4.50	3.10	7.08	2.41	0.90	34.71	+ 1.78
1921	2.74	2.04	1.35	3.92	4.21	7.13	6.19	0.21	0.93	0.06	1.12	0.13	29.13	— 3.80
1922	1.02	0.95	2.85	10.92	6.29	1.25	4.24	1.02	2.30	2.78	2.12	0.25	35.99	+ 3.06
1923	3.38	1.03	1.44	5.39	7.36	3.46	1.37	2.63	2.77	9.18	3.25	2.28	43.54	+10.61
1924	0.17	0.46	3.88	4.96	3.11	2.13	0.66	0.87	0.83	1.06	1.03	0.42	19.08	—13.85
1925	0.58	0.76	0.52	7.04	1.93	0.03	2.60	2.24	8.47	1.41	1.64	T	27.22	— 5.71
1926	1.79	0.00	2.49	2.31	2.48	1.98	2.38	4.23	5.37	4.65	0.67	4.23	32.58	— 0.35
1927	1.89	2.10	1.93	5.93	1.94	3.54	5.10	2.73	5.09	2.35	1.16	1.49	35.25	+ 2.32
1928	1.54	1.89	1.06	5.25	2.58	6.96	3.76	1.01	1.97	3.10	2.79	6.45	38.26	+ 5.33

TABLE 5. (Continued)
CLIMATIC DATA FOR MARLOW, STEPHENS COUNTY, OKLA.: MONTHLY AND ANNUAL PRECIPITATION, IN INCHES.

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual	Departure from Average[1]
1929	1.50	1.28	3.90	0.41	7.67	4.13	4.46	0.32	5.47	3.08	1.09	0.31	33.62	+ 0.69
1930	2.40	1.02	0.62	3.80	10.05	2.34	0.17	0.68	3.20	7.85	2.30	2.70	37.13	+ 4.20
1931	0.67	2.62	4.32	4.09	0.67	0.70	2.07	1.96	0.16	8.85	5.92	1.04	33.07	+ 0.14
1932	4.33	2.46	0.41	2.17	1.34	9.00	1.94	1.59	2.07	2.56	0.00	5.67	33.54	+ 0.61
1933	0.92	1.21	4.88	3.36	3.73	0.12	3.78	6.02	3.26	2.01	0.79	2.15	32.23	— 0.70
1934	1.32	1.54	2.25	1.15	1.60	1.32	T	2.17	5.10	1.17	3.49	0.21	21.32	—11.61
1935	0.48	1.00	1.38	1.88	10.31	7.39	0.49	2.65	2.45	2.01	4.00	1.89	35.93	+ 3.00
1936	0.10	T	0.51	0.30	6.56	1.60	0.05	0.00	8.73	0.93	0.00	0.74	19.52	—13.41
1937	0.93	T	3.49	3.27	2.34	3.16	0.93	2.34	0.78	2.27	1.16	2.00	22.67	—10.26
1938	2.02	7.29	6.32	2.73	6.89	3.22	1.36	0.40	2.84	0.26	1.71	0.52	35.56	+ 2.63
1939	2.74	0.31	2.12	0.50	1.29	4.55	0.55	1.98	0.06	1.74	0.97	0.70	17.51	—15.42
1940	0.51	2.16	0.00	4.59	5.75	4.91	4.44	2.71	1.18	2.02	5.32	2.43	36.02	+ 3.09
1941	2.22	2.93	0.59	5.93	7.73	8.31	1.22	3.99	3.51	14.54	1.13	1.44	53.54	+20.61
1942	0.49	1.05	1.32	10.09	2.30	8.18	1.47	6.61	5.43	4.52	1.52	2.04	45.02	+12.09
1943	T	0.24	2.02	3.15	11.21	5.25	0.19	0.05	1.91	0.57	0.36	3.64	28.59	— 4.34
1944	2.40	2.07	1.33	3.61	3.38	6.17	4.79	1.92	2.94	4.46	3.09	1.57	37.73	+ 4.80
1945	1.66	3.47	3.81	4.23	2.41	12.14	5.87	1.04	11.67	1.18	0.58	T	48.06	+15.13
1946	4.15	1.95	1.83	2.07	6.00	4.85	0.78	3.70	1.53	2.23	3.06	3.68	35.83	+ 2.90
1947	0.48	T	0.13	8.12	8.61	3.23	0.24	0.00	3.02	5.31	2.52	1.48	33.14	+ 0.21
1948	0.07	2.41	3.40	0.59	2.68	3.90	2.55	0.71	2.22	....	0.76	0.73	....	
1949	....	2.30	2.19	1.98	8.65	4.83	0.77	1.54	4.70	3.17	0.00	0.83	....	
1950	1.29	3.52	T	1.55	11.11	3.79	7.37	4.84	3.50	0.60	0.11	T	37.68	+ 4.75
1951	0.65	3.09	1.54	1.70	10.91	5.70	3.58	1.45	1.87	4.87	1.38	0.00	36.74	+ 3.81
1952	1.05	1.14	2.24	2.37	9.30	0.85	5.97	1.30	0.10	0.00	2.57	2.57	28.99	— 3.94
1953	T	1.10	3.98	1.50	3.87	4.71	5.71	2.77	1.18	10.00	2.75	0.95	38.52	+ 5.59
Normal[2]	1.34	1.40	2.11	3.88	5.12	4.15	2.14	2.53	3.19	3.40	2.06	1.61	32.93	

1. Normal as computed from available data through 1943 by W. E. Maughan.
2. Computed from average for period of available data through 1943.
T - Trace
.... No Record.

TABLE 6.

CLIMATIC DATA FOR CHICKASHA, GRADY COUNTY, OKLA: TEMPERATURE EXTREMES AND DATES OF KILLING FROSTS.

Year	Highest degrees F.	Date	Lowest degrees F.	Date	Last spring frost Date	First autumn frost Date	Growing season (Days)
1901					4/18	11/4	200
1902					3/31	11/17	231
1903					5/1	10/24	176
1904					4/17	10/28	194
1905					2/22	10/20	240
1906	....	....	......	....	....	....	......
1907					3/14	10/12	212
1908					3/10	10/24	228
1909					4/9	11/17	223
1910					3/12	10/28	230
1911					3/27	11/2	220
1912					3/25	11/2	222
1913					3/27	10/27	214
1914					4/12	10/27	198
1915					4/3	11/15	226
1916					4/9	10/20	194
1917					3/27	10/9	196
1918					3/17	11/19	247
1919					....	11/1	......
1920					4/5	11/3	212
1921					4/17	10/8	174
1922					3/11	11/14	248
1923					3/23	11/6	228
1924					4/1	10/23	205
1925					3/19	10/25	220
1926					4/15	11/9	208
1927					3/24	11/16	237
1928					3/30	11/3	218
1929					3/17	10/24	221
1930	[a]116°	July	[a]-11°	Jan.	3/30	10/29	213
1931	106°	7/3	15°	1/14	4/22	11/30	222
1932	101°	7/29[1]	2°	12/17	3/31	10/11	225
1933	105°	7/11	- 5°	2/8	3/21	11/8	232
1934	110°	7/30[1]	13°	2/26	3/31	12/1	245
1935	107°	8/11	1°	1/21	4/13	11/5	206
1936	116°	8/11	2°	2/8	4/7	10/27	203
1937	108°	8/10	8°	1/8	4/5	10/23	201
1938	105°	8/21	11°	1/31	4/9	10/24	198
1939	109°	7/21	11°	2/21	4/19	10/31	195
1940	105°	7/20	- 3°	1/8	4/12	11/11	182
1941	104°	7/30	21°	1/18[1]	3/29	11/12	193
1942	102°	8/5	- 2°	1/5	3/31	10/26	209
1943	108°	8/3	0°	1/19	3/22	10/27	219
1944	106°	8/2[1]	- 1°	1/9	4/3	11/21	201
1945	100°	8/18	7°	2/28	4/5	11/14	192
1946	107°	7/27[1]	9°	12/30	3/10	11/11	215
1947	109°	7/17[1]	-11°	1/4	3/16	11/11	209
1948	104°	8/20	- 8°	3/12	3/29[2]	10/18[2]	203
1949	104°	7/19	3°	1/30[1]	4/3[2]	10/31[2]	211
1950	97°	6/26[1]	5°	12/7	4/6[2]	11/4[2]	212
1951	111°	8/6	- 3°	2/2	4/12[2]	11/1[2]	203
1952	108°	8/15[1]	14°	12/15	4/10[2]	10/7[2]	180
1953	110°	6/14	9°	1/17	4/20[2]	10/27[2]	190
Average							211

1. On other dates also.
2. A temperature of 32° or below.

.... No data

a. Highest and lowest during period 1901 through 1930.

TABLE 7.

CLIMATIC DATA FOR MARLOW, STEPHENS COUNTY, OKLA.: TEMPERATURE EXTREMES AND DATES OF KILLING FROSTS.

Year	Highest degrees F.	Date	Lowest degrees F.	Date	Last spring frost Date	First autumn frost Date	Growing season (Days)
1901—1930	....	....	....	....	3/26*	11/5*	224*
1931	104°	7/3[1]	14°	1/14	3/29	11/30	246
1932	104°	7/29	5°	12/12	3/22	11/11	234
1933	110°	7/11	- 7°	2/8	3/21	11/7	231
1934	109°	7/30[1]	12°	2/25	3/31	12/1	244
1935	107°	8/11	- 1°	1/21	....	11/5	......
1936	114°	8/11	1°	2/8	4/7	11/3	210
1937	110°	8/10	10°	1/9	3/31	10/23	206
1938	104°	8/25	10°	1/31	4/9	11/7	212
1939	109°	7/21[1]	8°	2/21	4/8	11/3	109
1940	103°	8/3	- 2°	1/8	4/12	11/11	213
1941	102°	7/30	21°	1/18	3/19	11/6	232
1942	100°	8/2	0°	1/5	3/31	10/26	209
1943	109°	8/3[1]	- 1°	1/19	3/22	10/27	219
1944	104°	8/11[1]	3°	1/9	3/30	11/2	217
1945	101°	8/18[1]	9°	12/19	4/5	11/22	231
1946	109°	7/28	10°	12/30	3/8	11/11	248
1947	108°	9/1	-10°	1/4	....	....	......
1948	105°	8/20	0°	3/11	3/28	10/18	204
1949	102°	7/8[1]	7°	1/30	3/19	10/31	226
1950	96°	8/11	5°	12/6[1]	4/5[2]	10/27[2]	205
1951	110°	8/6	1°	2/1	4/12[2]	11/2[2]	204
1952	108°	8/3	18°	12/15	4/10[2]	10/7[2]	180
1953	108°	6/14	11°	12/24	4/20[2]	11/9[2]	203
Normal							220

1. On other dates also.
2. A temperature of 32° or below.
* Average during period 1901-30.
.... No data.

TABLE 8.

CLIMATIC DATA FOR CHICKASHA, GRADY COUNTY, OKLA.: AVERAGE MONTHLY AND ANNUAL TEMPERATURES, DEGREES F.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual	Departure from Normal[1]
1901 to 1930 incl.	38.8	42.8	53.1	61.4	68.9	78.1	82.5	82.5	74.9	62.9	51.9	41.1	61.8	....
1931	43.8	49.3	47.0	57.1	64.6	80.6	84.0	80.2	81.7	68.4	55.1	45.4	63.1	+1.5
1932	41.2	51.0	46.6	62.9	69.2	77.0	82.8	81.4	73.5	61.3	45.2	37.6	60.8	—0.8
1933	47.2	39.8	53.3	....	70.5	79.5	83.8	79.0	78.5	64.2	53.0	45.5	....	
1934	41.8	43.4	49.4	62.2	69.6	83.0	88.0	87.6	71.6	65.6	53.1	41.0	63.0	+1.4
1935	43.9	45.4	58.8	59.2	65.0	74.8	82.6	84.4	69.5	63.8	45.7	39.8	61.1	—0.5
1936	35.6	34.6	56.6	61.1	71.4	80.5	86.6	88.2	77.0	59.0	48.4	44.3	61.9	+0.3
1937	31.9	41.7	46.8	61.4	71.6	79.2	84.9	85.0	75.4	61.2	47.0	39.0	60.4	—1.2
1938	42.4	47.4	58.8	59.6	69.7	77.3	82.8	86.2	76.3	68.6	49.2	42.0	63.4	+1.8
1939	45.0	40.0	55.2	60.7	72.0	79.6	85.3	83.2	80.5	67.2	48.8	45.4	63.6	+2.0
1940	26.4	41.8	54.0	60.8	69.0	75.4	81.4	79.8	73.7	67.6	47.4	42.8	60.0	—1.6
1941	42.8	41.2	47.4	61.2	71.0	74.6	81.5	81.9	75.2	65.1	50.0	44.8	61.4	—0.2
1942	37.6	42.0	51.4	63.1	68.5	77.8	82.0	80.3	71.4	61.2	53.0	40.9	60.8	—0.8
1943	38.2	47.8	47.2	65.3	66.7	79.7	84.0	88.2	74.2	61.0	49.4	38.0	61.6	0.0
1944	40.6	45.6	50.1	59.9	69.8	79.4	82.6	84.0	73.8	64.2	52.4	37.6	61.7	+0.1
1945	39.8	42.0	54.9	58.2	68.2	75.6	78.6	79.4	74.2	61.8	53.1	36.7	60.2	—1.4
1946	39.6	48.7	57.4	64.8	66.2	76.2	83.0	83.4	71.9	65.8	51.4	46.0	62.9	+1.3
1947	38.0	38.3	46.2	59.8	67.0	77.8	81.2	85.3	78.2	69.3	46.0	41.4	60.7	—0.9
1948	31.4	37.6	43.9	66.5	68.7	77.9	81.3	80.5	74.3	60.6	47.9	42.3	59.4	—2.2
1949	29.9	39.5	48.6	58.5	70.6	78.2	83.4	78.7	69.2	61.6	53.6	41.9	59.5	—2.1
1950	40.1	47.8	50.3	61.2	70.1	77.9	77.5	77.5	71.4	67.4	49.1	40.0	60.9	—0.7
1951	40.7	44.5	51.6	60.5	69.2	76.3	82.9	86.7	75.8	65.3	45.2	43.4	61.9	+0.3
1952	47.2	48.3	49.6	57.6	68.8	82.6	82.5	86.7	74.5	59.9	49.3	40.1	62.3	+0.7
1953	44.1	45.7	56.3	58.5	70.0	86.0	80.1	78.4	75.7	62.3	49.5	40.2	62.2	+0.6
Normal[2]	38.8	43.0	51.3	61.2	68.9	78.1	83.1	83.0	74.8	64.0	50.1	41.7		

1. Computed from average for period of available data through 1943.
2. Normal as computed from available data through 1943.
.... No record.

TABLE 9.

CLIMATIC DATA FOR MARLOW, STEPHENS COUNTY, OKLA.: AVERAGE MONTHLY AND ANNUAL TEMPERATURES, DEGREES F.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual	Departure from Normal[1]
1900 to 1930 incl.	39.7	42.7	53.1	61.4	68.9	77.4	81.8	81.9	74.6	63.3	52.1	41.0	61.5	
1931	43.5	49.3	47.3	57.2	65.1	79.6	82.5	79.6	81.0	67.4	54.6	45.6	62.7	+1.2
1932	40.2	51.0	47.6	63.0	68.8	75.9	81.8	81.2	72.7	61.2	47.4	36.6	60.6	—0.9
1933	47.4	41.0	52.6[a]	62.0	70.5	79.8	83.8	79.0	78.7	65.3	53.7	48.8	63.6	+2.1
1934	43.2	44.7	50.6	64.7	72.0	84.0	88.8	87.0	72.6	67.3	55.2	42.3	64.4	+2.9
1935	44.4	46.4	....	60.4	65.4	75.6	83.3	84.2	70.2	63.4	46.7	40.6	....	
1936	37.6[b]	36.5	59.1	63.3	71.5	80.4	86.0	87.6[b]	76.2	59.8	48.8	45.5	62.7	+1.2
1937	33.0	43.4	47.6	62.2	72.2	79.0	85.1	85.6	77.0	63.7	47.9	38.8	61.3	—0.2
1938	44.3	48.5	58.7	59.6	69.8	77.4	82.6	85.1	77.2	69.6	49.5	43.4	63.8	+2.3
1939	44.7	40.2	55.9	61.5	72.8	79.4	85.8	83.2	80.4	67.2	50.6	46.3	64.0	+2.5
1940	27.2	42.6	54.9	60.8	68.3	74.0	79.1	....	73.4	69.2	48.8	45.0	....	
1941	44.4	43.0	48.8	62.5	72.4	74.9	81.7	81.8	74.6	65.8	51.8	45.6	62.3	+0.8
1942	39.0	43.4	52.6	63.1	68.8	77.7	81.0	80.2[b]	71.9	62.6	54.8	42.8	61.5	0.0
1943	41.4	49.0	48.2	66.0	67.8	79.4	83.6	87.5	74.3	62.6	51.4	38.8	62.5	+1.0
1944	41.2	46.0	50.4	60.0	69.5	78.2	82.0	83.0	74.4	65.7	54.3	38.8	62.0	+0.5
1945	41.3	43.6	56.2	59.6	68.2	75.2	78.5	80.2	74.4	63.0	55.6	38.4	61.2	—0.3
1946	40.0	46.2	58.1	66.0	67.1	75.7	83.2	82.5	72.0	65.8	53.0	47.0	63.3	+1.8
1947	40.3	39.8	47.1	60.0	67.6	77.5	81.0	84.6	77.9	69.6	47.0	44.0	61.4	—0.1
1948	34.4	39.2	46.5	67.6	67.6	77.5	80.9	82.0	75.6	64.2[m]	51.5[m]	44.9[m]	61.0	—0.5
1949	32.1	40.9	50.7	58.9	70.7	77.7	83.4	79.1	70.3	62.6	54.2	42.4	60.2	—1.3
1950	40.3	49.0[m]	51.7	63.0[m]	70.0	76.9	77.8	77.2	71.7	68.8	50.8	41.4	61.5	—0.3
1951	40.7	45.9	51.9[m]	61.5	69.7	76.5	82.8[m]	86.0	76.3[m]	64.9	46.9	45.1	62.3	+0.5
1952	48.2	49.3	51.0[m]	59.2	69.4[m]	81.5	82.1	87.1	76.1	61.6	51.4	41.8	63.2	+1.4
1953	46.3	46.7	58.1	60.5	70.9	85.6	81.0	80.5	77.4	65.5	51.4	42.8	63.9	—2.1
Normal	40.0	43.9	51.9	62.0	69.3	77.8	82.3	82.9	75.0	65.0	51.4	42.8		

1. Computed from average for period of available data through 1943.
a. One day's record missing.
b. Two day's record missing.
m. Three to ten day's record missing.

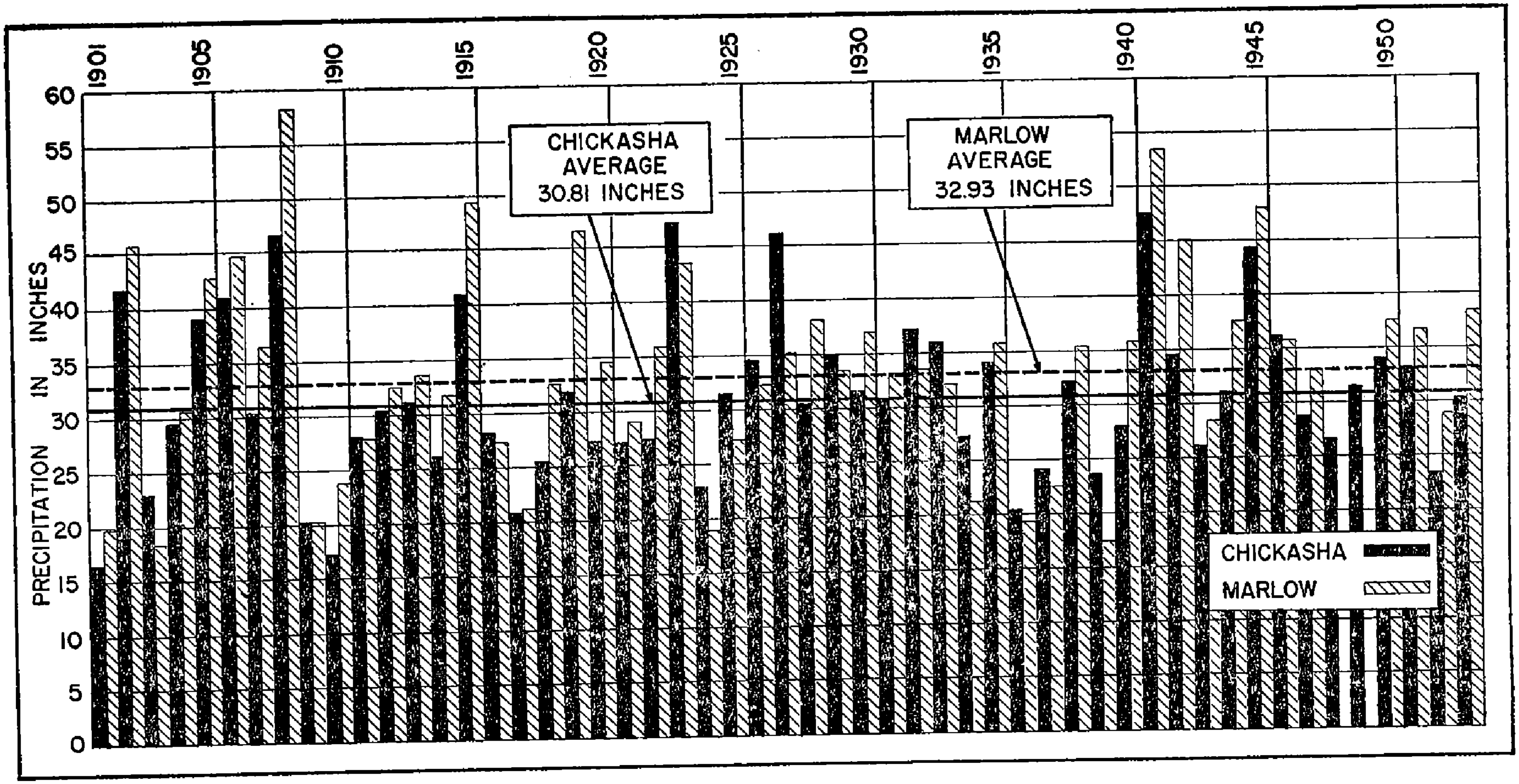


FIG. 2. Precipitation at Chickasha and Marlow, by years, from 1901 to 1953.

POPULATION

Chickasha, located near the center of Grady County, is the largest city in the area of this report. The populations of the incorporated towns for the years 1930, 1940, and 1950, as reported by the United States Census Bureau, are given in table 10. These figures show the towns have just about held steady in population, but the area as a whole has been losing population since 1930. An ever decreasing number of people are living in the rural areas. The losses of the rural population are probably due, in great part, to increasing mechanization of farm operations and the resulting increase in size of individual farm units, and to the greater opportunities for employment in industrial areas elsewhere.

TABLE 10.—POPULATION

GRADY COUNTY

Incorporated city or town	1930	1940	1950
Chickasha	14,099	14,111	15,842
Rush Springs	1,340	1,422	1,402
Minco	962	921	978
Tuttle	766	940	715
Alex	598	544	563
Verden	587	575	508
Bradley	....	282	248
Smaller towns and rural	29,286	22,321	14,616
County total	47,638	41,116	34,872
Northern Stephens County			
Marlow	3,084	2,899	3,399
Smaller towns and rural	6,697	5,840	3,724
Northern county total	9,781	8,739	7,123

GENERAL GEOLOGY

STRATIGRAPHIC SUMMARY

The bedrock exposed in Grady and northern Stephens Counties consists of sedimentary rocks of the Permian system (pl. 1). The oldest is the Duncan sandstone, which is overlain by the Chickasha formation, the Blaine formation, and the Dog Creek shale, all of the El Reno group. These crop out in eastern Grady County, and in northern Stephens County. Above them are, from oldest to youngest, the Marlow formation, Rush Springs sandstone, and Cloud Chief formation, which crop out in northwestern and southwestern Grady County, and in northern Stephens County. Alluvial deposits overlie the bedrock in the valleys.

The bedrock in the southwestern part of Grady County and extending a few miles into Stephens County is mostly sandstone, and the same is true in a small area in the extreme northwestern part of the county. The bedrock in the remainder of the area is predominantly shale, siltstone, and siltstone conglomerate, with only minor amounts of sandstone, some of which occurs as persistent beds traceable for many miles and also some as lenses of limited extent. Gypsum in the form of selenite and satin spar is found in all formations, being most abundant in the shaly and silty rocks and least common in the sandstone. The quantity and quality of ground water differs from formation to formation, and depends largely on the character and composition of the rocks and soils.

Table 11 shows the sequence and character of the bedrock formations at the surface in Grady and northern Stephens Counties. Fig. 5 shows by a diagrammatic sketch the relative positions of the aquifers in Grady and northern Stephens Counties, Oklahoma; Fig. 3 shows cross sections of these aquifers based on electric logs.

TABLE 11.

GENERALIZED SECTION OF ROCKS EXPOSED IN GRADY AND NORTHERN STEPHENS COUNTIES, OKLA.

System	Series	Group	Formation	Thickness (feet)	Lithology and water-bearing properties
Quaternary	Pleistocene and Recent		Alluvium and Terrace deposits	0 - 105	Gravel, sand, silt, and clay on the present and old flood plains of the Canadian and Washita Rivers and their tributaries. Yields hard water to municipal, domestic, and stock wells. Maximum reported yield about 300 gpm.
	Pleistocene		High-level gravels	0 - 10	Unconsolidated gravels occuring as thin, scattered remnants of formerly extensive deposits; on divides and slumped along valley bluffs, contain no appreciable ground water.
Permian			Cloud Chief formation	0 - 15	Mostly gypsum, dolomitic at base in some places; interbedded with red clay shale at many places. Does not yield water to wells in Grady County. Not present in Stephens County.
		Whitehorse	Rush Springs sandstone	0 - 280	Fine-grained, cross-bedded sandstone; includes irregular silty lenses, and in southern Grady County a silty shale wedge that thickens to the southeast. Contains large amounts of potable ground water. Maximum reported yield about 550 gpm (from developed spring), and about 150 gpm (from wells). Probably could supply sufficient water for irrigation in some areas.
			Marlow formation	0 - 120	Mostly even-bedded, brick red, sandy shale generally gypsiferous; Verden sandstone member near the middle, Relay Creek dolomite beds at the top. Yields small quantities of highly mineralized water.

TABLE 11. (Continued)

GENERALIZED SECTION OF ROCKS EXPOSED IN GRADY AND NORTHERN STEPHENS COUNTIES, OKLA.

System	Series	Group	Formation	Thickness (feet)	Lithology and water-bearing properties
Permian		El Reno	Dog Creek shale and Blaine gypsum	0 - 230	Mostly dark red even-bedded shales interbedded with fine-grained gypsiferous sandstones that locally grade into pure gypsum. Yields very little water to wells. The water is very hard and contains large quantities of calcium sulfate.
			Chickasha formation	135 - 260	A heterogeneous mixture of sandstones, shales, siltstones, and siltstone conglomerates. Yields small to moderate quantities of water to wells over much of Grady County and northern Stephens County. Water generally potable although locally too mineralized even for stock use.
			Duncan sandstone	100 - 250	Mostly sandstone, with minor amounts of interbedded shales and intraformational siltstone conglomerates. Yields water to wells throughout Grady County and northern Stephens County. The water is hard and in some localities is too highly mineralized even for stock use.

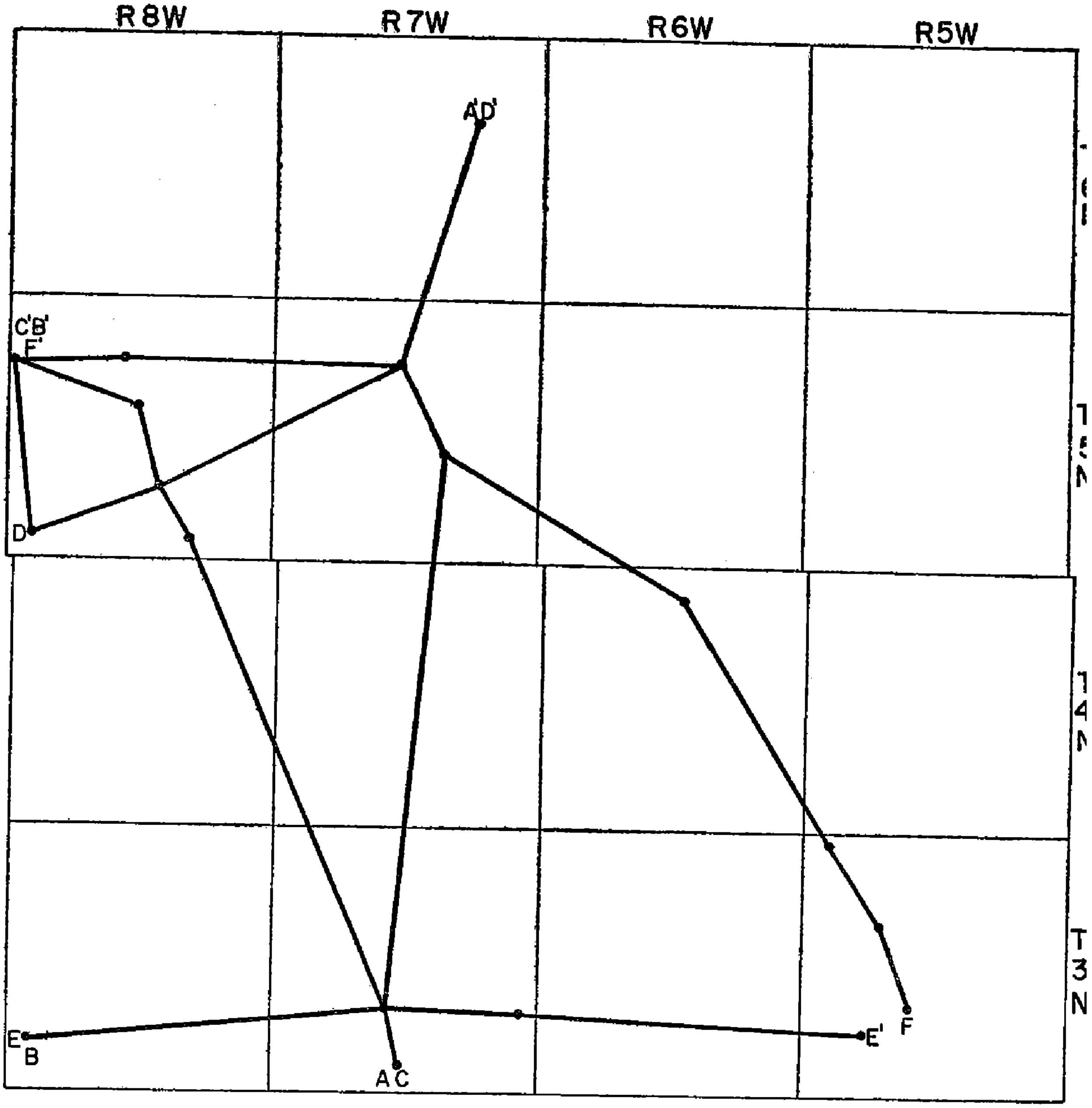
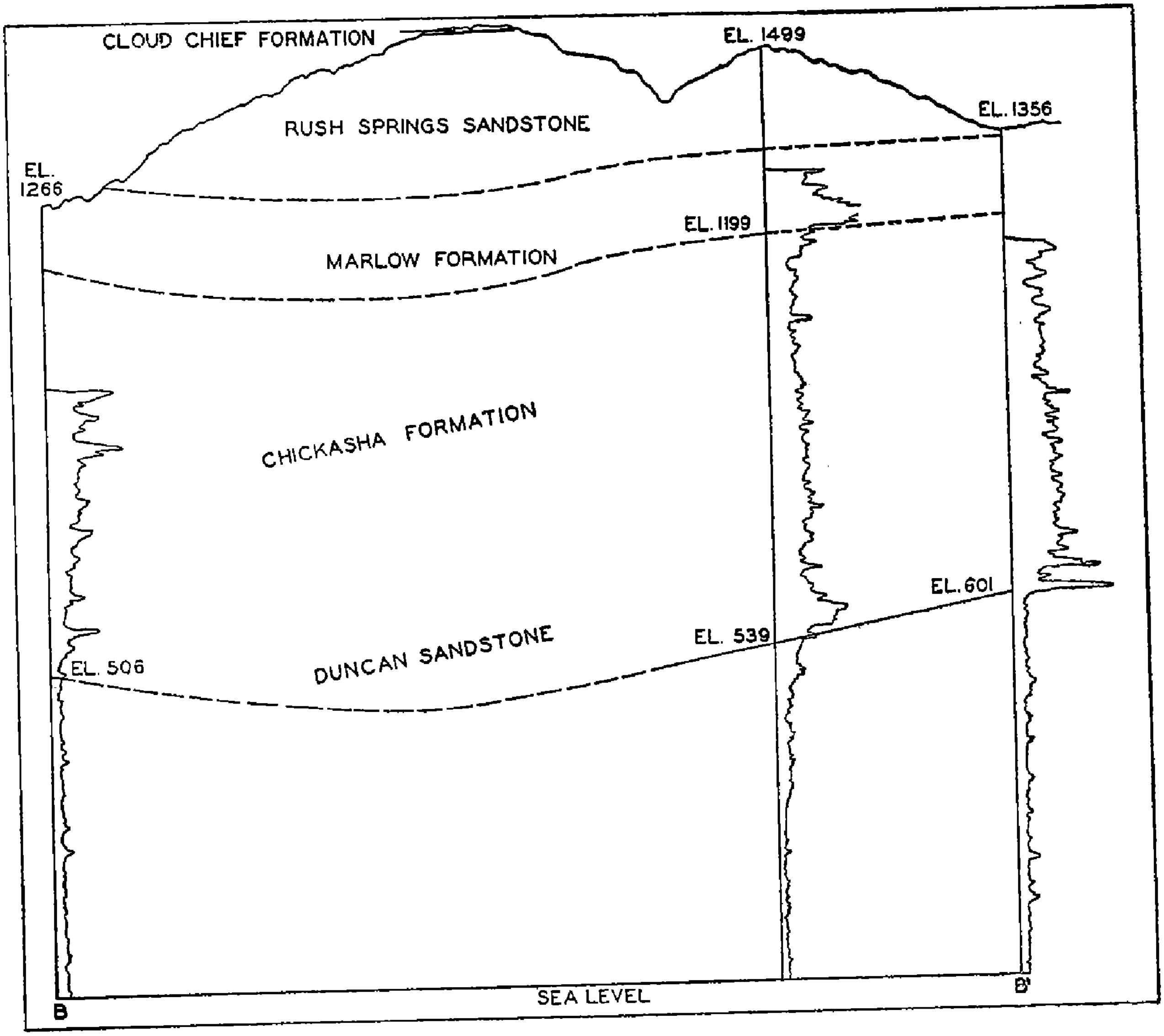


FIG. 3A. Cross sections, Grady and northern Stephens Counties, Oklahoma, based on electric logs.


CLOUD CHIEF FORMATION
EL. 1499
RUSH SPRINGS SANDSTONE
EL. 1356
EL. 1266
EL. 1199
MARLOW FORMATION
CHICKASHA FORMATION
EL. 601
EL. 539
DUNCAN SANDSTONE
EL. 506
SEA LEVEL
B
B'

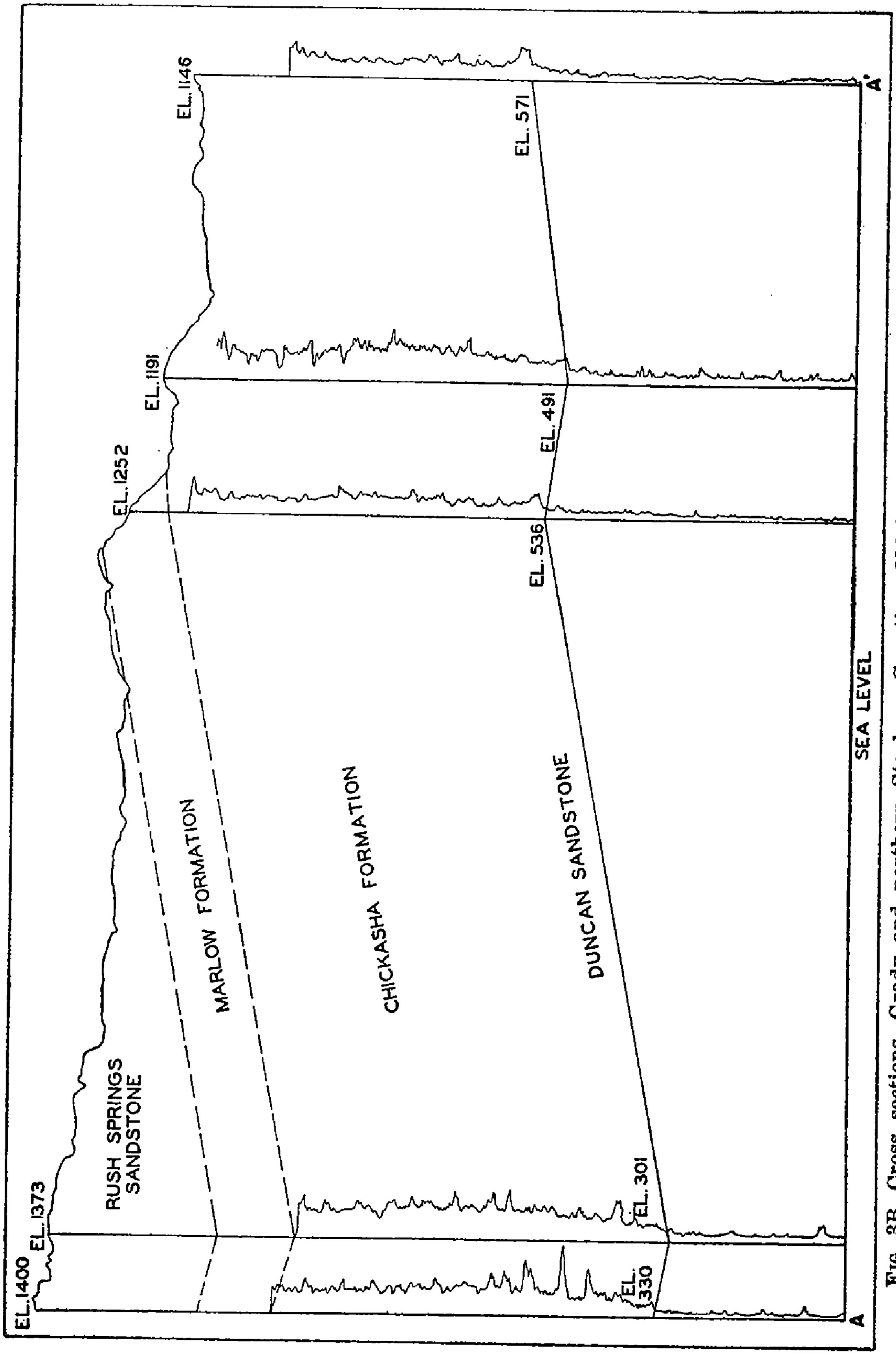
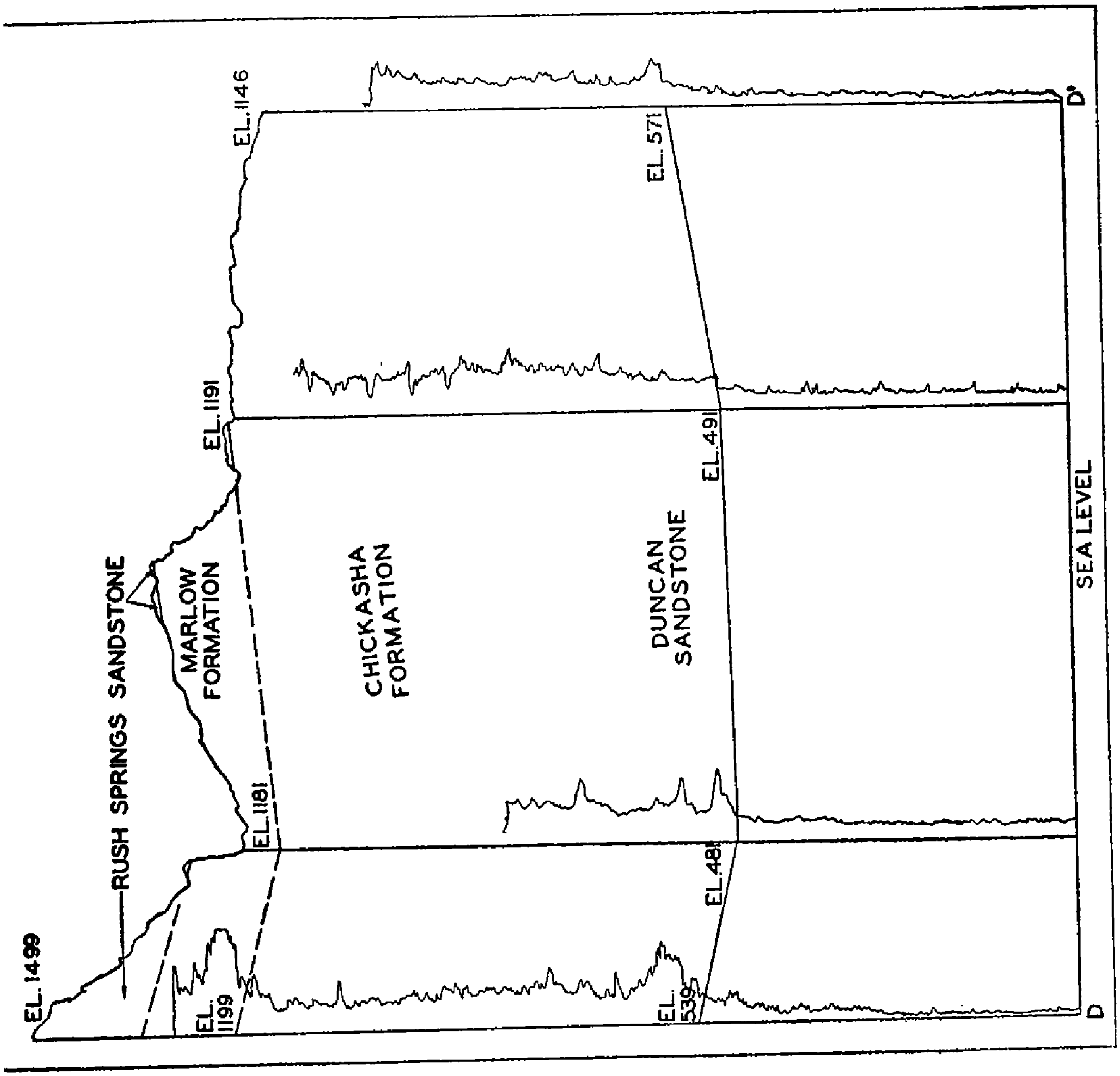


FIG. 3B. Cross sections, Grady and northern Stephens Counties, Oklahoma, based on electric logs. (Continued)


EL. 1499
RUSH SPRINGS SANDSTONE
MARLOW FORMATION
EL. 1199
EL. 1181
EL. 1191
EL. 1146
CHICKASHA FORMATION
DUNCAN SANDSTONE
EL. 539
EL. 481
EL. 491
EL. 571
SEA LEVEL
D
D'

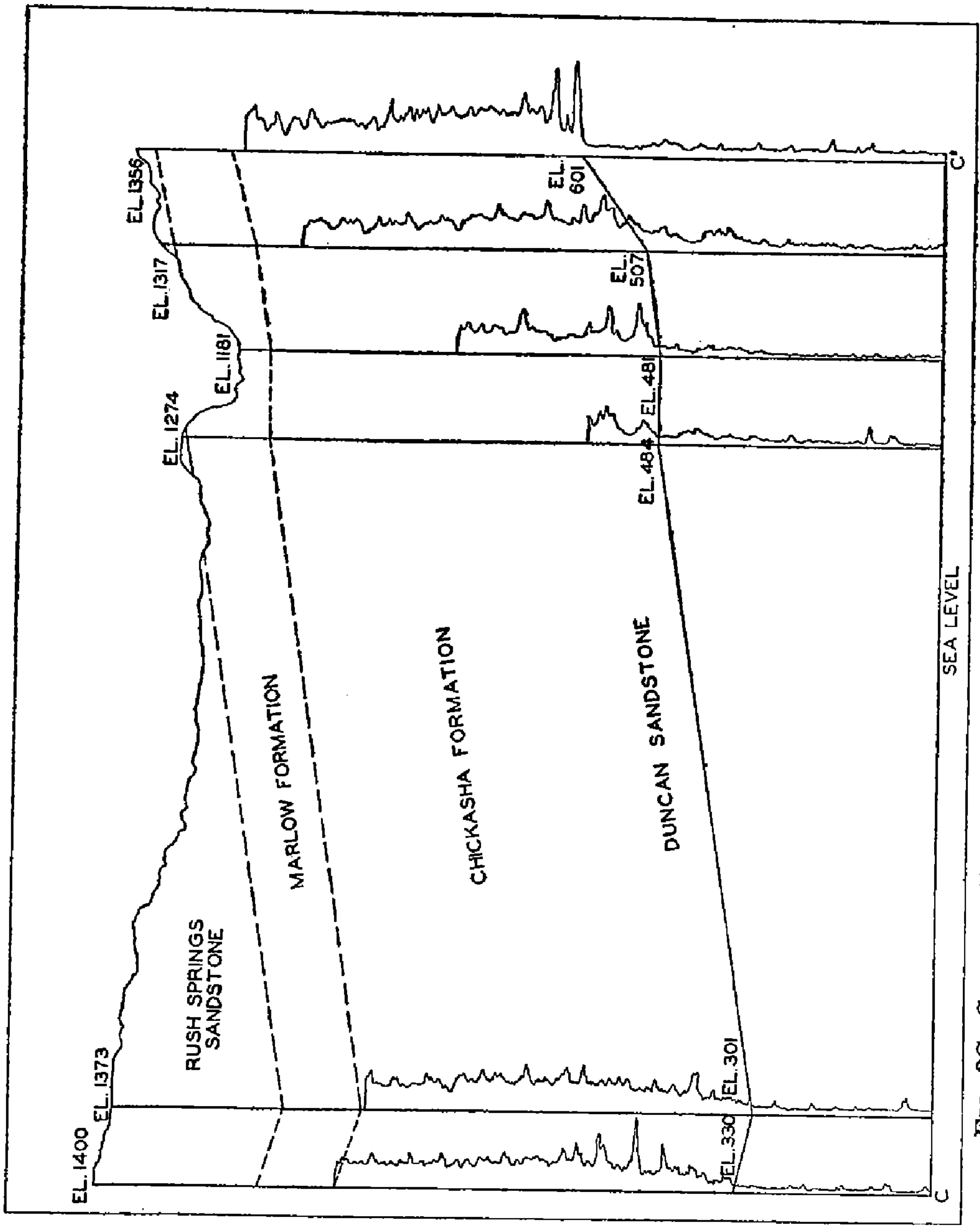
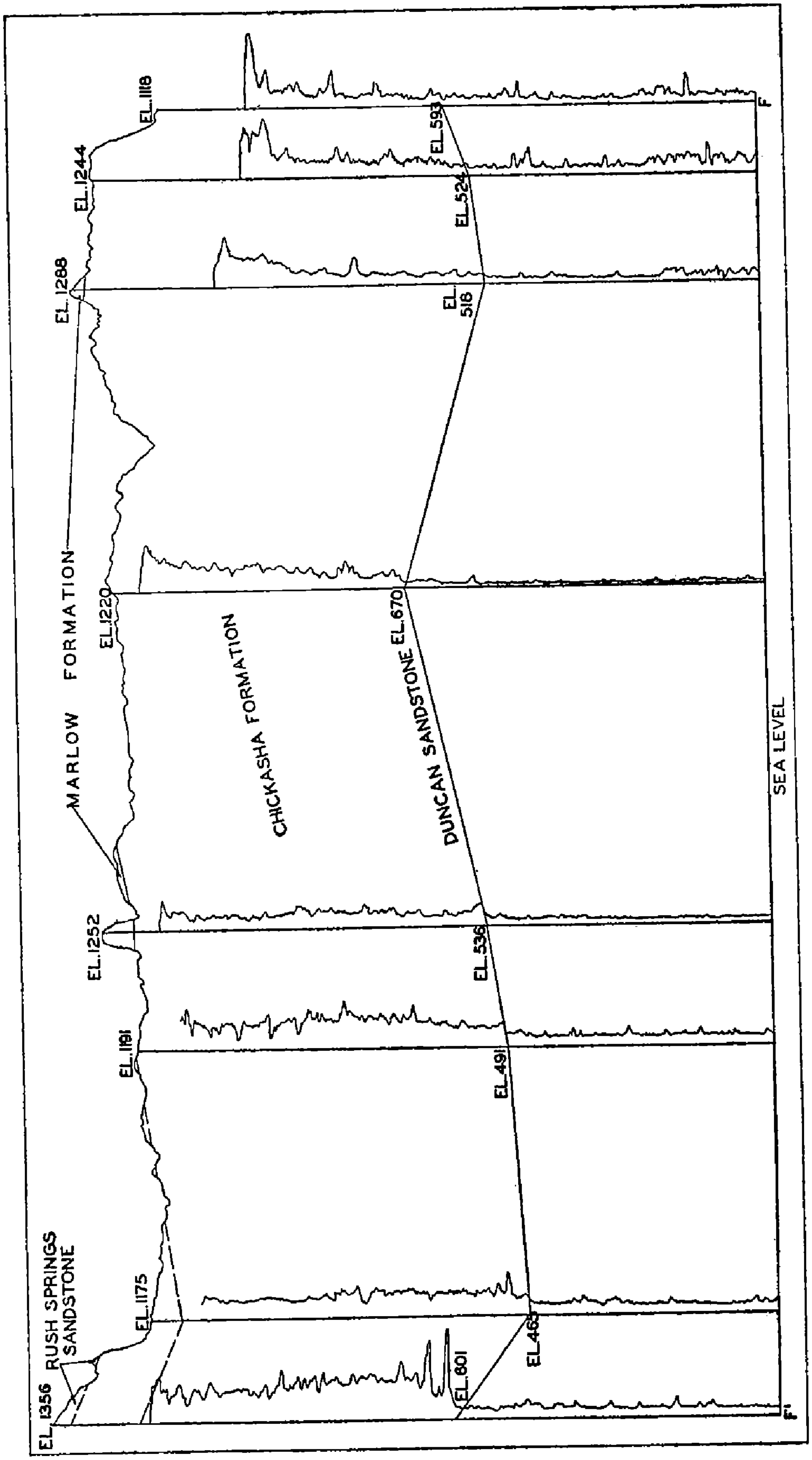
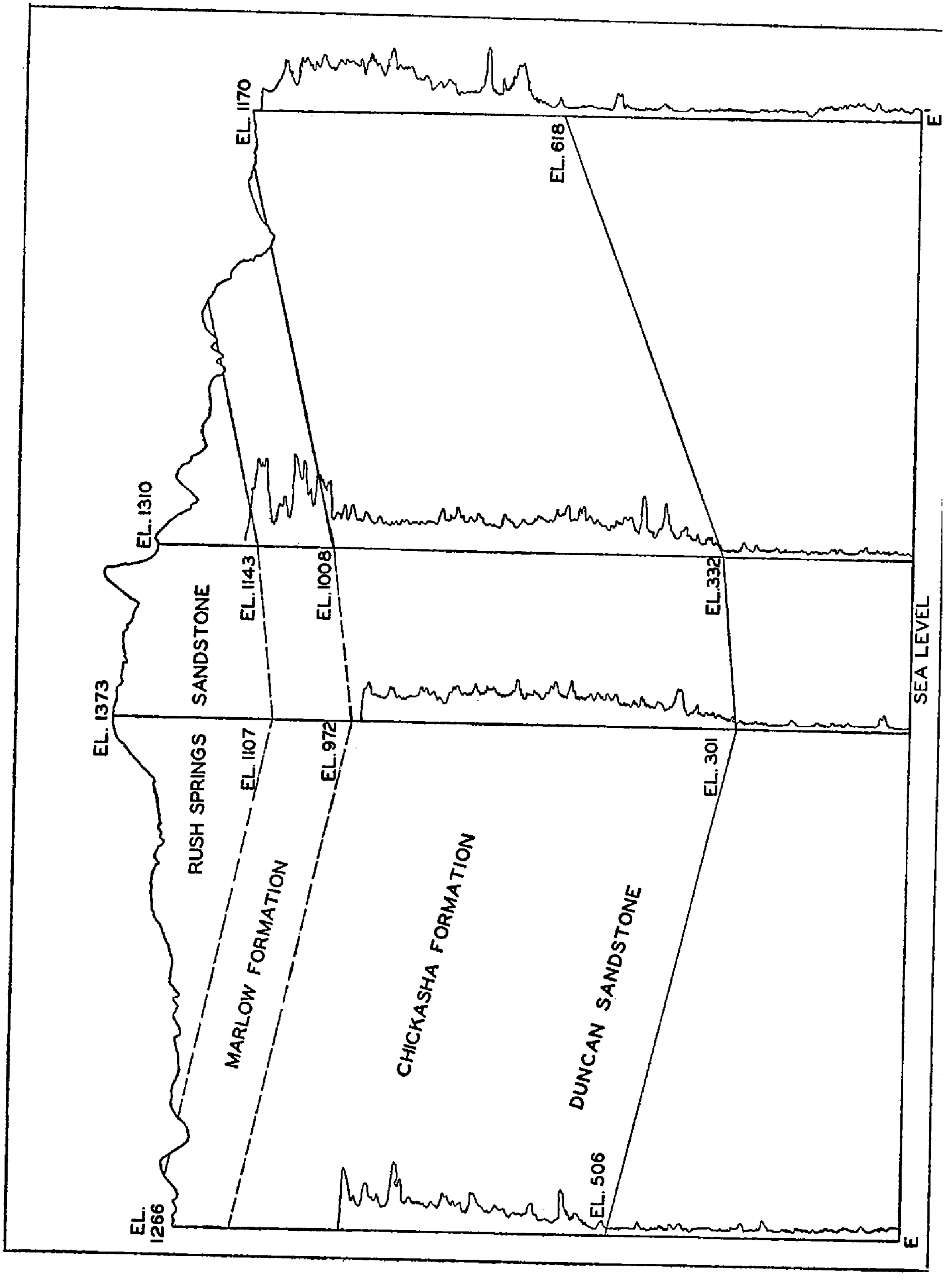


FIG. 3C. Cross sections, Grady and northern Stephens Counties, Oklahoma, based on electric logs. (Continued)


EL. 1356
RUSH SPRINGS SANDSTONE
EL. 1175
EL. 1191
EL. 1252
MARLOW FORMATION
EL. 1220
EL. 1288
EL. 1244
EL. 1118
CHICKASHA FORMATION
DUNCAN SANDSTONE
EL. 601
EL. 465
EL. 491
EL. 536
EL. 670
EL. 518
EL. 524
EL. 593
SEA LEVEL
F
F'


E
E'
EL. 1266
EL. 1373
EL. 1310
EL. 1170
EL. 1107
EL. 1143
EL. 972
EL. 1008
EL. 301
EL. 332
EL. 618
EL. 506
RUSH SPRINGS SANDSTONE
MARLOW FORMATION
CHICKASHA FORMATION
DUNCAN SANDSTONE
SEA LEVEL

STRUCTURAL SUMMARY

Grady County and northern Stephens County lie at the southeastern end of the Anadarko basin, a large structural trough extending northwestward along the north side of the Wichita Mountains into the Texas Panhandle. The rocks dip into this trough southwestward in the northern part of the area and northward in the southern part of the area. Irregularities in the regional dips are related to local structural features, chief of which are the anticlines of the Chickasha gas field and the Carter-Knox oil field.

SURFACE STRATIGRAPHY OF GRADY AND NORTHERN STEPHENS COUNTIES, OKLA.

PERMIAN SYSTEM

El Reno group

The exposed rocks within the confines of the area belong to the middle part of the Permian system and are classified as the El Reno group. As used in this report the El Reno group includes the strata from the base of the Duncan sandstone to the base of the Marlow formation, and includes the following formations (ascending): Duncan sandstone, Chickasha formation, Blaine formation, and Dog Creek shale. Well logs show that the El Reno group has a maximum thickness of about 680 feet in southern Grady County and about 810 feet in northern Grady County. The outcrop of the base of the El Reno lies outside the area covered in this report. It is reported to be unconformable with the underlying Hennessey shale. The upper contact is unconformable with the overlying Whitehorse group and the Dog Creek shale and Blaine gypsum are absent in the southern part of Grady County and northern Stephens County. In Grady and northern Stephens Counties, near the southeastern end of the Anadarko basin, the Duncan sandstone and Chickasha formation consist of deltaic deposits of cross-bedded sandstone, shale, and intraformational siltstone conglomerates that had their source to the southeast. Northward and westward the identity of the Chickasha formation, and to a lesser extent the Duncan sandstone, are lost by lateral gradation into the Flowerpot shale. The lower and middle parts of the group yield small to moderate quantities of water to wells throughout Grady and northern Stephens Counties. At places the water is too highly mineralized for domestic or farm use. The upper part of the group does not yield appreciable water to wells.

Beds in southwest Kansas now considered to be equivalent to the El Reno group were named by Cragin (1896, p. 1-48). These were his Salt Fork division and the lowermost part of his Kiger division. Cragin divided the Salt Fork into the "Harper sandstones, Salt Plain measures, Cedar Hills sandstones, Flowerpot shales and Cave Creek gypsums" (top). The basal bed of the Kiger division he named Dog Creek shales.

For northwestern Oklahoma, Cragin (1897, p. 351-366) revised his classification by expanding the Salt Fork division to include the Dog Creek shale. He also reduced the Harper sandstone and Salt Plain measures to member rank in the Kingfisher formation for which he gave the type locality as Kingfisher, Oklahoma. He placed the Cedar Hills sandstone and Flowerpot shale in the Glass Mountain formation as members, with the type locality as Glass Mountains, Oklahoma. He expanded Cave Creek to include the Medicine Lodge gypsum and overlying Jenkins clay and Shimer gypsum, naming Salt Creek, Blaine County, Oklahoma as the type locality. He divided the Dog Creek shale into the Amphitheater member below and the Chapman member above. He offered the name Stony Hills as a substitute for the name Dog Creek because his Oklahoma type locality was at the Stony Hills, east of Watonga, Oklahoma.

Gould (1902, p. 42-52) did not use the terms Salt Fork and Kiger, but instead divided the beds equivalent to Cragin's Salt Fork, as originally defined, into two divisions under new names, Norman below and Blaine above. His Norman division, named from Norman, Cleveland County, Oklahoma, was equivalent to Cragin's Harper sandstones, Salt Plain measures, Cedar Hills sandstones, and most of his Flowerpot shales. His Blaine division was named for Blaine County, Oklahoma, where several alternating layers of shale and gypsum are well exposed, and included in ascending order; the Ferguson gypsum, type locality Ferguson, Blaine County, Oklahoma; the Magpie dolomite, named for the permanent camp of an Arapahoe chief on Bitter Creek, Blaine County, Oklahoma, the type locality; the Medicine Lodge gypsum; the Altona dolomite, type locality Altona, Kingfisher County, Oklahoma; and the Shimer gypsum. He indicated that the base of the Blaine division is the base of the lowest massive gypsum bed of the Blaine—Ferguson in some places, and as high as Medicine Lodge in others. For beds above the Blaine he introduced the name Woodward division as a substitute for Kiger, with the Dog Creek shale as the basal member. Thus he put the dividing line between Blaine and

Woodward at the horizon Cragin had at first selected to separate Salt Fork from Kiger.

Later, (1905, p. 39) Gould substituted the name Enid division, from Enid, Oklahoma, for the term Norman division, and apparently dropped the names Magpie and Altona as they are not mentioned again.

Clapp (1921, p. 156-164) retained the names Blaine and Enid, and introduced the name Cyril gypsum, which he regarded as the uppermost member of the Blaine formation and as lying immediately under the Whitehorse sandstone of the Woodward formation. In the same year, Reeves (1921, p. 47) correctly placed the Cyril gypsum above the Whitehorse. He defined the base of the Whitehorse as a 2-foot bed of white gypsum overlying the Dog Creek shale.

Sawyer (1924, p. 317) apparently raised the Dog Creek shale to formation rank. He restricted use of this name together with Blaine and Enid to the area west of a line drawn from Carnegie to El Reno, Oklahoma. East of this line he used the name Duncan (type locality Duncan, Stephens County, Oklahoma) as equivalent to the Dog Creek shale, Blaine formation, and the upper part of the Enid formation. He did not name the undifferentiated shales and sandstones below his Duncan sandstone.

Gould (1924, p. 322-341) included in the Dog Creek shale beds belonging to the lower part of the Whitehorse sandstone. These were the Marlow of Sawyer (1924, p. 317). He introduced the name Chickasha for beds below the Blaine formation occupying the same stratigraphic position as the upper part of the Enid. He used the name Duncan in a sense different from Sawyer's, applying it to the lower part of the Enid, probably equivalent to the Harper sandstone of Kansas. He also stated that major subdivisions of the Permian should be based on unconformities, which he recognized at the base of the Quartermaster, Whitehorse, and probably Duncan.

Later Gould (1926, p. 152) published a correlation chart of upper Permian rocks in Kansas, Oklahoma, and Texas. He showed the Duncan sandstone of Oklahoma as equivalent to the Harper sandstone of Kansas and to the San Angelo sandstone of Texas. He correlated the overlying Chickasha formation of the Enid group of Oklahoma with the Salt Plains, Cedar Hills, and Flowerpot shale of Kansas, and with undivided, unnamed gypsiferous shales in Texas. To the next higher beds in these three states he gave the name Blaine. The Dog Creek, above the Blaine, was made the lowest member of the Woodward group in Oklahoma, and correlated with the Dog Creek formation of Kansas and with unnamed, gypsiferous red shales in Texas.

Later in the same year, Gould and Lewis (1926, p. 9) dropped the name Enid and expanded the range of the Woodward group downward to the base of the Duncan and upward to the top of the Permian. Thus the Duncan, Chickasha, and Blaine became formations in his Woodward group.

Gould and Willis (1927, p. 438) published a correlation that was the same as that given by Gould and Lewis in 1926, except that they dropped the term Woodward group and reinstated the name Enid, with the Duncan and overlying Chickasha as members.

This same year Becker (1927, p. 9-18; and 1930, p. 109-118) published a paper in which the Duncan and the Chickasha were given formation rank. His Blaine occupied the same part of the stratigraphic column as the Blaine of most previous reports, but his Dog Creek was extended upward to the base of the Verden sandstone. As the Verden is now regarded as a member of the Marlow formation occurring above the base of the Marlow, it is clear that his Dog Creek included the lower part of that formation.

According to Sawyer (1929, p. 9-11; and 1930, p. 315-317) the section in central Oklahoma should comprise the Duncan sandstone at the base overlain by the Chickasha formation, the latter being the near-shore equivalent to the Flowerpot shale, Blaine formation, and Dog Creek shale of areas to the northwest. The top of the Dog Creek shale was the base of the Marlow member of the Whitehorse formation.

Becker (1930, p. 47) agreed with Sawyer on the equivalence of the Chickasha and Duncan to the Flowerpot, Blaine, and Dog Creek. Further, he stated that the base of the Duncan sandstone corresponds with the base of the Flowerpot of Oklahoma and with the base of the San Angelo in Texas.

Evans (1931, p. 405-439) described the surface geology of the Weatherford area, Oklahoma, and presented a chart in which the Flowerpot shale was shown as equivalent to the Chickasha member of the Enid as classified by Gould and Willis (1927, p. 438). He divided the overlying Blaine formation into the following named members (ascending): Medicine Lodge gypsum, Shimer gypsum, Lovedale gypsum, and Haskew gypsum, with intervening unnamed shale members. The names Lovedale and Haskew were proposed by him, being taken from Lovedale and a now abandoned store at the NE cor. sec. 2, T. 25 N., R. 19 W., both in Harper County, Oklahoma. Evan's Dog Creek shale, of formation rank, comprised the beds above the Blaine and below the Marlow, in agreement with most previous and subsequent reports. It should be observed that the Medicine Lodge and Shimer gypsums of Evans are not the same beds as the Medicine Lodge and Shimer of the Gould classification that had been widely accepted for many years. Gould was of the opinion that the base of the Blaine was not everywhere the same stratigraphic horizon, and he applied the name Ferguson to a gypsum regarded by him as below the Medicine Lodge of Kansas. Evans showed that from the vicinity of El Reno, Oklahoma, northward to Kansas the base of the Blaine is the same horizon; and, hence, that the Ferguson of Oklahoma is the Medicine Lodge of Kansas. Accordingly, the name Ferguson was not needed, and the names Medicine Lodge and Shimer were applied to lower beds than in the Gould classification.

Green (1936, p. 1454-1475) divided the lower part of the Permian of southern Grady County into a basal member, a middle conglomeratic member, and an upper member. To these beds he gave the name Duncan sandstone dropping the name Chickasha and saying: "No unit comparable with the description of the 'Chickasha' can be traced." He agreed with the classification of the Blaine and Dog Creek as given by Evans (1931, p. 405-439) except that he introduced the name Alabaster gypsum for beds below the Shimer and above the Medicine Lodge in the Blaine. According to him, the Blaine and Dog Creek grade into lithologically different sediments and cannot be distinguished south of Canadian County. A similar gradation takes place eastward from Kiowa County. Further, Green stated that strata equivalent to these formations are absent from southern Grady County, having been eroded and overlapped. As he visualized it, "The Duncan sandstone is a wedge which, if it were not eroded and overlapped, would have a total thickness of 600 feet in the northeast corner of Stephens County. In directions north or west, the Duncan sandstone grades irregularly into the Flowerpot shale. These gradations are nearly equal along the top and bottom of the formation, leaving the central part of the sandstone at the points of the wedge. The north point of the wedge is in Kingfisher County and the west point is in Kiowa County."

Brown (1937, p. 1535-1556) regarded the Duncan sandstone as distinctly separable from the overlying Chickasha. He explained the absence of the Blaine and Dog Creek from southern Grady, northern Stephens, and Comanche Counties by overlap of the Marlow on an unconformity at the top of the Chickasha. Where the Blaine and Dog Creek are present he subdivided them according to Green (1936). Included in Brown's paper was a cross-section by Schweer classifying beds from the base of the Flowerpot to the base of the Marlow as the El Reno group. For northwestern Oklahoma Schweer showed the Flowerpot at the base overlain by the Medicine Lodge, Shimer gypsum, Lovedale gypsum, Haskew gypsum, and Dog Creek shale, grading southward into the Duncan sandstone and Chickasha formations of Grady County, Oklahoma.

That same year Green (1937, p. 1515-1533) published a correlation chart which, for the part of the Permian considered here, was the same as his chart of 1936.

King (1942, p. 708, pl. 2) prepared a correlation chart showing the upper part of the Leonard series of north-central Texas near the Red River to be represented by the San Angelo sandstone and overlying Flowerpot shale, Blaine formation, and Dog Creek shale. His chart shows these beds overlying the Clear Fork group and unconformably underlying the Marlow formation of the Whitehorse group. Regarding them he wrote, "(The) deposits are decidedly heterogeneous, with different facies replacing each other laterally along the strike. The facies include dolomitic limestones and gypsums like those in the Blaine, red shales like those in the Dog Creek, and sandstones like those in the San Angelo of Texas and Duncan of Oklahoma."

As used in this report, the El Reno group includes the Permian strata from the top of the Hennessey shale to the base of the Marlow formation. The boundaries are those given by Becker (1929, p. 955) for the El Reno formation, which subsequently has been raised to group rank. The formations comprising the group are (ascending) Duncan sandstone, Chickasha formation, Blaine formation, and Dog Creek shale. The Duncan sandstone corresponds to the Duncan sandstone of Gould, Becker, Sawyer, Brown, and others. The Chickasha formation corresponds to the Chickasha of Brown and is the upper Duncan of Green. The Blaine and Dog Creek comprise the strata assigned to these formations by Brown and Green. They cannot be differentiated in Grady County and therefore are mapped together.

DUNCAN SANDSTONE

The name Duncan sandstone is applied to the strata lying above the Hennessey shale and below the Chickasha formation. At its type locality, near Duncan, Stephens County, Oklahoma, it consists of two or more ledges of sandstone separated by shale. Only the upper part of the formation is exposed in the area covered by this report. These exposures are at the east side of Grady County in Tps. 4, 5, 9, and 10 N., and consist mostly of sandstone, with minor amounts of interbedded shales and intraformational conglomerates. Well-log data show that the Duncan ranges from about 35 to 150 feet in thickness in Grady County. The formation is permeable and yields moderate amounts of water to wells throughout Grady and northern Stephens Counties. In places, however, the water is too highly mineralized for human or stock consumption.

First reference.—Wegeman (1915, p. 44).

Nomenclator.—Gould (1924, p. 325-328).

Type locality.—Designated by Gould (1925, p. 89) as Duncan, county seat of Stephens County, Oklahoma.

Original description.—Wegeman's description reads:

> A series of sandstones and interbedded shale about 40 feet in thickness, which forms an escarpment * * * The individual beds of the group are variable in thickness and extent, but the group as a whole covers a broad area and

> has been traced for about 60 miles from a point north of Foster, a small settlement 18 miles east of the Duncan field, to the north flanks of the Wichita Mountains.

He added that these escarpment-forming sandstones are an excellent horizon marker by which a considerable part of the structure of the Duncan (now Cruce) oil-field structure was defined, but he did not name them.

Gould (1924, p. 325-328) quoted Wegeman's description of the scarp-forming sandstones, which he noted as passing just north of the city of Duncan, and added that the formation ranged up to 250 feet in thickness and consisted in most places of two ledges of heavy white or buff sandstone separated by shale. In places there are three sandstone ledges, and the sandstones locally are dolomitic. Gould pointed out that at the southeastern end of the Anadarko Basin, in Garvin and Stephens Counties, the Duncan forms a prominent scarp facing outward from the axis of the basin, and that the escarpment continues westward and goes around the west end of the Wichita Mountains, although not equally prominent throughout. Northward from the southeastern end of the Anadarko Basin, however, the escarpment becomes much less conspicuous.

History of usage.—Gould (1924, p. 325) assigned the Duncan sandstone to a position between the Lower Enid formation and the Chickasha formation. In the same year, Sawyer (1924, p. 313) applied the name Duncan to all the beds between the Hennessey shale and the base of the Marlow. This usage put the Chickasha formation in the Duncan and has not proved acceptable to the majority of the geologists concerned with the stratigraphy of south-central Oklahoma, and Gould's usage has prevailed.

Distribution.—The Duncan sandstone appears in two outcrops on either side of the Washita River in Tps. 4 and 5 N., R. 5 W., and in the northeastern part of the county in Tps. 9 and 10 N., R. 5 W. Its maximum extent upstream along the Washita River is about 7 miles, and the maximum width in either outcrop is half a mile. The outcrop in the northeastern part of the county is less than 5 square miles in area.

The mapping of the Duncan sandstone as shown on pl. 1 is taken from Brown (1937, p. 1550). The writer has not traced the contact of the Duncan and overlying Chickasha from the type locality of the Duncan to the point where Brown shows it entering Grady County, but has checked the exposures mapped by Brown within the county, and considers that part of the contact to be a valid and mappable boundary.

Thickness.—Reported thicknesses of the Duncan sandstone range from 100 to 250 feet. Gould (1924, p. 328) in naming the Duncan sandstone, reported thicknesses as ranging up to 250 feet in Stephens and Garvin Counties. Becker (1927, p. 112) found a thickness of 150 feet in Grady County. Freie (1930, p. 15-16) measured a total of 180 feet of Duncan, and reported a thickness of about 120 feet in an oil-test well in sec. 8, T. 3 N., R. 7 W. Brown (1937, p. 1535) estimated the thickness of the Duncan in T. 10 N., R. 5 W. to be about 100 feet.

Estimates of the thickness of the Duncan, from electric logs, indicate that the formation is thickest in the southeastern part of the area covered by this report and thinnest in the northern part. It is about 150 feet thick in sec. 29, T. 3 N., R. 5 W.; about 140 feet thick in sec. 26, T. 3 N., R. 7 W.; about 110 feet thick in sec. 28, T. 3 N., R. 7 W.; about 80 feet thick in sec. 30, T. 3 N., R. 8 W.; about 100 feet thick in sec. 7, T. 5 N., R. 8 W.; and about 35 feet thick in sec. 11, T. 6 N., R. 7 W.

Character.—The Duncan is mostly sandstone, with minor amounts of interbedded shales and intraformational siltstone conglomerates. The sandstones at the southeastern end of the Anadarko basin, in northeastern Stephens County, range from nearly white to light buff and are coarse grained, but northward across Grady County they become red and progressively finer. The proportion of sandstone differs greatly from place to place and generally decreases northward. Although the individual sandstone beds can be correlated only across short distances, they are interconnected so that they are a hydrologic unit.

Stratigraphic relation.—The base of the Duncan sandstone lies outside the area covered by this report, and is considered to be unconformable with the underlying Hennessey shale (Beede and Christner, 1926, p. 5; Baker, 1929, p. 192). The contact of the Duncan with the overlying Chickasha in Grady County is considered to be conformable, and probably is gradational (Six, 1930,

p. 386). According to Freie (1930, p. 16 and 40) the contact is transitional, one formation grading into the other in a lenticular fashion. He adds that the relationship of the Duncan and Chickasha is not well understood because of variations in thickness and because of lenticularity of beds. The writer has examined the contact in Grady County and agrees with Freie that it is transitional in character.

Age and fossils.—No identifiable fossils have been collected from the Duncan sandstone in the area covered by this report. The formation is generally regarded as of middle Permian age.

Correlation.—The Duncan sandstone correlates with the lower part of the Flowerpot shale of Oklahoma and with the San Angelo sandstone of Texas.

Water supply.—The Duncan sandstone occurs under younger formations in most of Grady County and in the northern part of Stephens County, but has been penetrated by only a few wells. These range in depths from a few feet to about 400 feet. The quality of the water is variable. The water is potable in some areas but is too highly mineralized even for stock use in other areas. The quality of the water in different parts of the area is more fully discussed under ground water by localities. Results of two pumping test made on wells penetrating the Duncan sandstone are discussed under the heading Pumping Tests.

CHICKASHA FORMATION

The Chickasha formation, by definition, extends upward from the top of the Duncan sandstone to the base of the Blaine formation. It consists of a heterogeneous mixture of sandstones, shales, siltstones, and intraformational siltstone conglomerates. Many of the siltstone conglomerates are highly cross-bedded. The formation has gradational contact with the underlying Duncan sandstone. It is conformable with the overlying Dog Creek shale and Blaine formation, undifferentiated, where they are present, but is unconformable beneath the Marlow formation where the Dog Creek and Blaine are absent. In Grady and northern Stephens Counties the Chickasha formation ranges in thickness from about 395 feet in sec. 29, T. 3 N., R. 5 W., to about 580 feet in sec. 31,

T. 5 N., R. 8 W. The formation is relatively impermeable and yields only small to moderate quantities of ground water to wells.

First reference.—Gould (1924, p. 325)

Nomenclator.—Gould (1924, p. 329).

Type locality.—Chickasha, county seat of Grady County, Oklahoma (Gould, 1924, p. 329).

Original description.—Gould (1924, p. 329-330) quotes Becker for the description of the beds. Three divisions were recognized:

> 1. An upper purple sandstone member 70 to 80 feet thick, the upper 30 feet of which consist chiefly of loose pink sand in which occur numerous thin lenses of purple "mudstone conglomerate;" the lower portion consists of 40 to 50 feet of heavy purple "mudstone conglomerate" beds separated by thin strata of pink sand.
>
> 2. A middle pink sand member consisting of 50 feet of uncemented pink sand. Occasionally this sand shows cementation on both upper and lower contacts. But the lithologic characteristics are the same as of the pink sand, and not similar in texture or color to the "mudstone conglomerates."
>
> 3. A lower purple sandstone member chiefly composed of "mudstone conglomerates," 50 feet thick, more distinctly stratified than any other portion of the "Purple Series."

History of usage.—The Chickasha formation was known locally as the "purple sandstone," or "purple series," until it was named by Gould in 1924, (p. 325) and defined to include the beds above the Duncan and below the Blaine. Sawyer (1929, p. 10; and 1930, p. 316) recognized that the Blaine formation and the Dog Creek shale are absent at the type locality of the Chickasha, and that the upper limit of the Chickasha, therefore, is the Marlow formation. This interpretation prevailed until 1936 when Green (p. 1454) discarded the name Chickasha, instead applying the term Duncan to all the beds from the top of the Hennessey to the base of the Marlow formation. His proposed classification was essentially the same as Sawyer's of 1924, and was not acceptable. The following year Schweer (in Brown, 1937, p. 1553) reinstated the name Chickasha as defined by Gould.

Distribution.—The Chickasha formation is exposed at the surface in about half of Grady County, mostly in the eastern and

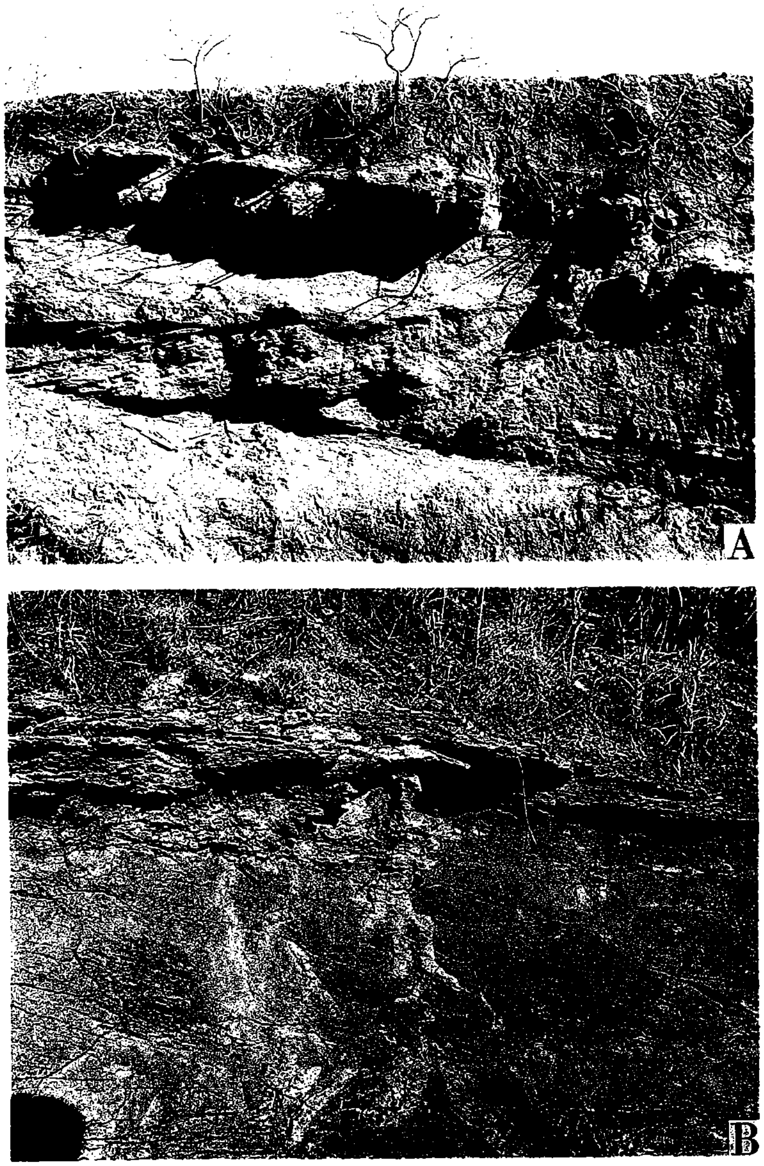


Plate 3. Chickasha formation.
A. Horizontal beds overlying inclined layers, simulating unconformity.
B. "Fossil tree roots" at a local unconformity in the Chickasha formation.

northern parts, and in about half of that portion of Stephens County considered in this report. The outcrop is a broad band circling the southeastern end of the Anadarko basin and having a maximum width of about 30 miles. Within the area of this report the outcrop is narrow at the south and wide at the north.

Thickness.—According to Becker (1930, p. 112) the Chickasha formation at its type locality in the southwestern part of T. 4 N., R. 5 W., and the southeastern part of T. 4 N., R. 6 W. ranges from 135 to 230 feet in thickness. Brown (1937, p. 1536) estimated the thickness to be about 260 feet in T. 4 N., R. 5 W. Gouin (1930, p. 24) found about 200 feet of Chickasha in northern Stephens County. Freie (1930, p. 40) measured 160 feet of Chickasha south of the town of Rush Springs.

Based on studies of electric logs, the thickness of the Chickasha is estimated to be about 395 feet in sec. 29, T. 3 N., R. 5 W.; about 530 feet in sec. 26, T. 3 N., R. 7 W.; about 475 feet in sec. 7, T. 5 N., R. 8 W.; about 580 feet in sec. 31, T. 5 N., R. 8 W.; and about 545 feet in sec. 11, T. 6 N., R. 7 W. The combined thickness of the Duncan sandstone (about 140 feet) and the Chickasha formation (about 530 feet) in sec. 26, T. 3 N., R. 7 W., is about 670 feet— in close agreement with the thickness of 675 feet for these two formations in the same area reported in the American Association of Petroleum Geologists guide book for the Anadarko Basin Field Trip, 1939.

Character.—The Chickasha formation is composed of an extremely heterogeneous mixture of sandstones, shales, siltstones, and siltstone conglomerates. Rocks of identical lithologic character are repeated at many different horizons within the formation, and even small exposures may exhibit abrupt changes in composition and texture. The rocks are cemented principally by iron oxide, although in places the cement is calcium carbonate or gypsum. The sand grains range from coarse to fine, decreasing in size northwestward from the head of the Anadarko basin in Stephens County. Many of the siltstone intraformational conglomerates are highly crossbedded. Some are cemented so that they stand out as projecting ledges along the stream valleys and as the caprock of small buttes.

Approximately the lower third of the Chickasha formation contains many layers of fine-grained soft sandstone interbedded with shale. These sandstone beds are lenticular, and although some of them are as much as 20 feet thick and they may be traced for several miles, they become thinner in one direction or another and disappear into the surrounding shale. The sandy zone is thickest about at the latitude of Middleberg, thinning both northward and southward. It thins down dip also, for logs of wells only about 6 miles to the west show much less sandstone. Thus it appears that the sandy zone is a local facies of the Chickasha formation and is very nearly confined to the area where the sandstone beds crop out. The sandy zone of the Chickasha yields moderate quantities of water to wells penetrating it. At Blanchard, which is in McClain County just east of the Grady County line, a pumping test of a well tapping this part of the Chickasha indicated a sustained yield of about 16 gallons per minute.

Stratigraphic relations.—The relationship of the Chickasha formation to the underlying beds is one of gradation, as discussed under the Duncan sandstone. According to Brown (1937, p. 1541) the Chickasha formation of Grady County is conformable with the overlying Dog Creek shale and Blaine formation, undifferentiated. The writer has mapped this contact in the field and concurs with Brown. Typically, this contact is one of change from highly cross-bedded Chickasha to comparatively even-bedded gypsiferous Dog Creek and Blaine and it is indicative of a change in sedimentation, not of unconformity.

Age and fossils.—No identifiable fossils have been collected from the Chickasha formation in the area of this report. The formation is generally regarded as of middle Permian age.

Correlation.—The Chickasha formation correlates with the middle and upper parts of the Flowerpot shale of Oklahoma and Texas.

Water supply.—The Chickasha formation yields small to moderate quantities of water to wells over much of Grady County and northern Stephens County. The water is found both in lenticular sandstones and in cracks and crevices in shale. In general, the water is suitable for human and stock use, but in some areas it is too highly mineralized even for stock.

DOG CREEK SHALE AND BLAINE FORMATION, UNDIFFERENTIATED

The Dog Creek shale overlies the Blaine formation and the two formations comprise the strata between the Chickasha formation, below, and the Marlow formation, above. They cannot be differentiated in Grady County and therefore are mapped together. The lower contact of the Dog Creek shale and the Blaine formation, undifferentiated, is conformable. The upper contact is unconformable, the formations being absent in T. 3 N. and southward in Grady and northern Stephens Counties. The formations emerge beneath the unconformity in T. 4 N., and thicken northward to about 230 feet in T. 9 N. They consist of dark red even-bedded shales interbedded with fine-grained gypsiferous sandstones that locally grade into pure gypsum. They are not productive of potable ground water in Grady County.

First reference.—For the Blaine formation, Gould (1902, p. 42-49); for the Dog Creek shale, Cragin (1896, p. 39).

Nomenclator.—For the Blaine formation, Gould (1902, p. 42-49); for the Dog Creek shale, Cragin (1896, p. 39).

Type locality.—For the Blaine formation, in Salt Creek (Henquenet's) canyon in northern Blaine County, Oklahoma (Gould, 1924, p. 331); for the Dog Creek shale, Dog Creek, in western Barber County, Kansas.

Original description.—The Blaine formation was originally described by Gould (1902, p. 49) under the name Blaine division. He described it as consisting of red shales with interbedded strata of gypsum and dolomite and as having an average thickness of about 75 feet. He divided it into the following members (ascending): Ferguson gypsum, Magpie dolomite, Medicine Lodge gypsum, Altona dolomite, and Shimer gypsum. The intervening shales were not named.

According to Gould (1905, p. 53) Professor Cragin's original description of the Dog Creek reads:

> "The Dog Creek * * * * consists of some 30 feet, or locally of a less or greater thickness, of dull-red argillaceous shales, with laminae in the basal part and one or two ledges of unevenly lithified dolomite in the upper. The color of these shales resembles that which prevails in most of the divisions below rather than of the terranes above the Dog Creek."

History of usage.—Gould (1902, p. 42) assigned the Blaine division (later Blaine formation) to a position below the Dog Creek shale and above the Norman division (later Enid group). The name has always been used in this sense.

Gypsum is scarce in the Blaine in Grady County, and it is therefore difficult, if not impossible, to distinguish the Blaine from the overlying Dog Creek shale. In this paper the two are described together.

Cragin (1896, p. 39) assigned the Dog Creek to a position below the Red Bluff (later Whitehorse group) and above the Cave Creek gypsums (later Blaine formation). He first called the formation the Dog Creek shales, but in 1897 (p. 351-363) suggested the name Stony Hills for this formation. Because the dolomites that form the Stony Hills in eastern Blaine County, Oklahoma, belong to the Blaine, the name Stony Hills was dropped and the name Dog Creek shales has prevailed. Present usage has dropped the plural, and the formation, now known as the Dog Creek shale, occupies the stratigraphic interval as originally defined by Cragin.

Distribution.—The Dog Creek shale and Blaine formation, undifferentiated, crop out in a band one-eighth mile to 9 miles wide in northwestern and western Grady County. It extends from T. 10 N., R. 9 W. southward to T. 4 N., R. 6 W., and the outcrop is widest in the north.

Thickness.—Brown (1937, p. 1538-1541) reports for the Dog Creek shale and Blaine formation a thickness of 230 feet in T. 9 N., R. 7 W.; 130 feet in the southern part of T. 6 N., R. 7 W., and the northern part of T. 6 N., R. 7 W.; and considers them to be absent in T. 3 N., Rs. 5 and 6 W.

The two formations are shown on pl. 1 as Dog Creek shale and Blaine formation, undifferentiated. They well illustrate the southeastward thinning and disappearance in south-central Grady County of the Dog Creek and Blaine.

Character.—The Dog Creek shale and Blaine formation, undifferentiated, are composed of dark red even-bedded shales interbedded with fine-grained gypsiferous sandstones that locally grade into pure gypsum. Mudstone conglomerates a few feet in thickness occur sparingly through the section. They are local in extent. The lower boundary of the Dog Creek and Blaine in southern Grady County is marked by a bed of conglomeratic mudstone. This boundary in northern Grady County is marked by a bed which at some places is dolomitic sandstone and at other places is gypsiferous sandstone. This bed is at the top of Brown's Chickasha formation and locally has been called the Pocasset bed, from the town of the same name.

Stratigraphic relations.—The Dog Creek shale and Blaine formation, undifferentiated, are conformably underlain by the Chickasha formation and unconformably overlain by the Marlow formation (Brown 1937, p. 1547; Six, 1930, p. 13, and 1930, p. 391; Kite, 1930, p. 196, and 1927, p. 8; Gouin, 1930, p. 211, and 1928, p. 13; Gould and Lewis, 1926, p. 21; Freie, 1930, p. 55; Roth, 1932, p. 688-689, 713; Brown, 1937, p. 1541).

Age and fossils.—No identifiable fossils have been collected from the Dog Creek shale and Blaine formation, undifferentiated, in the area of this report. The formations are generally regarded as of middle Permian age.

Correlation.—The Dog Creek shale and Blaine formation, undifferentiated, are the uppermost beds assigned to the El Reno group and are equivalent to beds of the same name in Kansas and Texas.

Water supply.—The Dog Creek and Blaine yield very little water to wells in Grady County. The water is hard and is high in sulfates and in most places is unsuitable for human consumption.

Whitehorse group

In southwest central Oklahoma upper Permian rocks above the El Reno group and below the Cloud Chief formation are represented by the Whitehorse group, as mapped for this report. This restriction of the group is in accord with usage of the Oklahoma Geological Survey and that used on the geologic map of Oklahoma (Miser, 1954). The Whitehorse group, limited by unconformities below and above, is divided into two formations: the Marlow formation below, and the Rush Springs sandstone above. The Marlow is composed mostly of gypsiferous silty shale and does not yield potable water. The Rush Springs is composed mostly of fine sandstone that yields moderate quantities of water suitable for irrigation and most industrial uses. The Whitehorse group ranges in thickness from about 240 feet to about 410 feet in Grady County.

The name Whitehorse, taken from Whitehorse Springs in northwestern Woods County, Oklahoma, was proposed by Gould (1905, p. 55) as a substitute for Red Bluff, which had been used by Cragin (1896, p. 40) but had proved to be preoccupied.

Cragin at first regarded the Red Bluff as a formation in the Kiger division of Kansas, with the Dog Creek shale below and the Day Creek dolomite, the Hackberry shale, and the Big Cabin sandstone above. A year later (1897, p. 351-366), he made his classification applicable to northwestern Oklahoma by excluding the Dog Creek shale from the Kiger division, dropping the names Hackberry shale and Big Cabin sandstone, and giving the name Taloga to the beds above the Day Creek dolomite. To two layers of gypsum in the upper part of the Taloga he gave the names Old Crow and One Horse.

Gould (1902, p. 42) did not use the term Kiger, but instead used Woodward division for the strata from the base of the Dog Creek shale to the top of the Day Creek dolomite. For the beds above his Woodward division he proposed the names Greer division and Quartermaster formation. Gould regarded his Greer division as probably equivalent to the Hackberry shale and Big Cabin sandstone of Cragin's classification of 1896, not mentioning the name Taloga of Cragin's classification for northwest Oklahoma, published in 1897. He divided the Greer division into an eastern part without subdivisions, later to become known as the Cloud Chief formation, and a western part, which was to become the Blaine formation. These two formations proved to be separated by several hundred feet of intervening strata. Gould subdivided his western Greer into the Chaney, and overlying Kiser, Haystack, Cedartop, and Collingsworth gypsums, the Delphi dolomite, and separating shales. In 1905 (p. 39) Gould substituted the name formation, as applied to the Woodward, for the word division, and finding the name Red Bluff to be preoccupied, proposed the name Whitehorse sandstone member. At this time, also, he changed the name Greer division to Greer formation, and gave the name Mangum to replace Delphi, the dolomite at the top of the western Greer.

Reeves (1921, p. 47) published a correlation of the beds in the Cement area, Caddo County, Oklahoma, using the names Woodward, Greer, Whitehorse, and Day Creek as they had been used by Gould. He stated that a 2-foot bed of gypsum apparently marks the base of the Whitehorse member. In the Greer formation above the Whitehorse member, and therefore above the Woodward formation, Reeves recognized the Cyril gypsum member, which Clapp (1921, p. 156-164) mistakenly had correlated with the uppermost Blaine.

In 1924 Gould (p. 322-341) and Sawyer (p. 312-321) both published on this part of the stratigraphic column. Both omitted the name Woodward, and both used the names Whitehorse and Day Creek in the same order, Gould specifying and Sawyer implying that they should be of formation rank. They applied "Whitehorse" to essentially the same sandstone unit as had Reeves. Both had Dog Creek shale below the Whitehorse and apparently of formation rank, but not for identical parts of the section. Gould regarded the Dog Creek as immediately underlying the Whitehorse, and mentioned an unusual phase, which he described as "fossiliferous, conglomeratic sandstone exposures, which have the appearance of an old stream channel occupying a more or less definite horizon in the upper part of the formation. This sandstone is usually spoken of locally as the 'Channel sandstone,' or the 'Footprint sandstone'." This sandstone has been named Verden by Reed and Meland (1924, p. 150-167). Sawyer gave a new name, Marlow, to the beds immediately under the Whitehorse, including the "footprint" sandstone. Thus he took them out of the Dog Creek as that name had been applied by Gould.

As the Marlow of Sawyer and the upper part of the Dog Creek as used by Gould are above the top of the Dog Creek as used previously, they must be in the lower part of the Whitehorse as that name originally had been applied. Thus, it is clear that both Gould and Sawyer restricted the range of the Whitehorse.

For beds above the Day Creek dolomite, Gould proposed the name Cloud Chief, saying, "This formation, as now understood, includes what was originally described as the 'eastern area' of the Greer." He added that the Cloud Chief is above the Day Creek dolomite where Day Creek is present, or in the absence of Day Creek it is next above the Whitehorse sandstone. Sawyer agreed as to the correlation of the strata, but used Clapp's name Cyril for the gypsum above the Day Creek.

Later Gould (1926, p. 152) published a chart in which he showed the name Woodward in quotation marks, including in it the Dog Creek, Whitehorse, and Day Creek formations. Whether this use of "'Woodward" was intended to reinstate the name or was merely a convenience in preparation of the table is not known. Above the Woodward he had the Cloud Chief (correlated with the Hackberry of Kansas and the Quartermaster formation).

Gould and Lewis (1926, p. 9) expanded the Woodward group (formerly division) upward and downward to equal the Double Mountain formation of Texas. In this usage the Woodward group included all the beds from the base of the Duncan to the top of the Quartermaster formation, which is the uppermost formation of the Permian in Oklahoma. Thus, it included all the Permian of the area of this report. The next year Gould and Willis published a correlation chart that omitted the name Woodward. For central and western Oklahoma they showed the Duncan and Chickasha as parts of the Enid group, and the overlying beds—Dog Creek, Whitehorse, Day Creek, Cloud Chief, and Quartermaster—as upper Permian formations without classification into groups.

In reporting on Grady County, Becker (1927, p. 11; and 1930, p. 111) regarded the base of the Whitehorse sandstone as at the top of the Verden sandstone. He assigned the latter to a position between the Whitehorse and the Dog Creek, but did not make clear its status in stratigraphic classification. He described a sandstone member within the Dog Creek shale and 20 to 40 feet below the Whitehorse, saying: "It is 20 to 25 feet thick, brownish red in color and contains considerable gypsum. It is frequently confused with the base of the Whitehorse. This bed is exposed in a long ledge in the hills south of Verden." Later (1930, p. 47) he apparently changed his view, recognizing for southern Grady County the Marlow as the lower part of the Whitehorse and including in it part of the beds he had formerly assigned to the Dog Creek. The base of the Marlow (i.e. base of Whitehorse) as mapped for the present report is the same as that indicated by Becker in 1930 and by others both before and since. Becker showed Cloud Chief formation overlying the Whitehorse. He made no mention of the Day Creek dolomite, which does not occur in Grady County.

Sawyer (1929, p. 11; and 1930, p. 317) divided the Whitehorse formation into the Marlow member below, and an upper member for which he proposed the name Rush Springs sandstone. He said that the Rush Springs member is the Whitehorse sandstone of Reeves (1921, p. 41). He recognized that dolomites capping hills immediately west of Greenfield, Oklahoma, belong near the contact between the Marlow and Rush Springs members. These were the "Greenfield" limestone of Stephenson (1925, p. 629). To a dolomite, which he regarded as about 40 feet below the top of the Whitehorse, Sawyer gave the name Weatherford, from its occurrence near the town of Weatherford, Oklahoma. Finding no beds equivalent to the Day Creek of Kansas, he showed the Cloud Chief gypsum immediately above the Whitehorse. Below the Whitehorse he had the Dog Creek shale and its near-shore equivalent, Chickasha sandstone. Evans (1931, p. 405-439), suggested that the Whitehorse formation include the Cloud Chief, as a member in addition to the Marlow and Rush Springs, and he introduced the name Relay Creek to replace the name Greenfield, which was preoccupied. His base of the Marlow was the top of the Dog Creek shale; his Marlow-Rush Springs contact was at the top of the upper Relay Creek dolomite; his top of the Rush Springs was the base of the Cloud Chief; and his top of the Cloud Chief was the base of the Day Creek (previously considered as occurring below the Cloud Chief). He agreed with Sawyer that the Weatherford dolomite belongs near the top of the Rush Springs. In a written discussion following Evan's paper, Buckstaff (p. 434) agreed with the main features of Evan's classification but disagreed with some of the details of correlation. He expressed a preference for classing the Whitehorse as a group rather than a formation.

Green (1936, p. 1454-1475) raised the Marlow to formation rank and stated that the top is at a wavy contact, considered by him to be a minor unconformity, about 10 feet above the upper Relay Creek dolomite. This contact was not acceptable to the majority of the geologists familiar with the problem, and the boundary has remained at the top of the Upper Relay Creek, as defined by Evans. Green also gave formation rank to the Rush Springs, "since it has an unconformity at the base and one at the top." He assigned the beds above the Rush Springs to the Quartermaster formation, subdivided into the Cloud Chief member overlain by the Doxey shale and Elk City sandstone members. He stated that the Cloud Chief has sandstone, gypsum, and dolomitic facies. The next year (1937, p. 1525-1533) he corrected his classification, putting the Cloud Chief in the Whitehorse group as the highest formation instead of lowest member of the Quartermaster formation.

Schweer (1937, p. 1553) published a correlation chart which, for Grady County, shows the Whitehorse group composed of the Marlow formation overlain by the Rush Springs sandstone, with the contact between them at the top of the Upper Relay Creek dolomite. He showed the Weatherford dolomite immediately over the Rush Springs sandstone and the Day Creek somewhat higher, both in the Cloud Chief formation.

King (1942, pl. 2) published a correlation chart showing the Guadalupe series of north-central Texas near the Red River to be represented by the Whitehorse group, with unconformities at the top and bottom. In the group he included (ascending) the Marlow formation, the Rush Springs formation, and the Cloud Chief formation.

As used in this report, the name Whitehorse is a group name applied to all Permian strata above the El Reno group and below the Cloud Chief formation. This usage is in accord with usage of the Oklahoma Geological Survey and that used on the geological map of Oklahoma (Miser, 1954). The group is divided into two formations: the Marlow formation at the bottom, and the Rush Springs sandstone at the top.

MARLOW FORMATION

The Marlow formation includes the shales, sandstones, and dolomites that lie below the Rush Springs sandstone and above the Dog Creek shale and Blaine formation, undifferentiated, or above the Chickasha formation where the Blaine and Dog Creek are absent. The formation consists mostly of even-bedded, brick-red, sandy shale, generally gypsiferous. It contains the Verden sandstone member near the middle, which is cross-bedded dolomitic sandstone about 10 feet thick and one-quarter mile wide. The upper Relay and lower Creek dolomite beds mark the top of the Marlow formation and consist of two thin beds separated by 15 to 20 feet of red sandy shale. The Marlow ranges in thickness from 105 feet to 130 feet in Grady and northern Stephens Counties. The formation yields little water to wells in southwestern Oklahoma.

The Marlow formation includes the dolomites, shales, and sandstones that lie above the Dog Creek shale and Blaine formation, undifferentiated, and above the Chickasha formation where the Blaine and Dog Creek are absent.

First reference.—Sawyer (1924, p. 313-315).

Nomenclator.—Sawyer (1924, p. 313-315).

Type locality.—Vicinity of Marlow, Stephens County, Oklahoma.

Original description.—(Sawyer; 1924, p. 313-315).

> ***brick-red shales and even-bedded brick-red sandstone with bands of fine white sand and sandy gypsums. The entire formation is gypsiferous, many of the shales containing veins of satin-spar and the sandstones more or less gypsum. A thin layer of almost pure gypsum about 1 foot thick is found at the top of this formation. The thickness of the Marlow formation is about 120 feet.

History of usage.—The Marlow formation was named in 1924 by Sawyer, who defined it as beds lying between the Duncan sandstone and the Whitehorse sandstone of Reeves (1921, p. 51-56). Sawyer's Duncan included beds now known as the Chickasha formation, and Reeves' Whitehorse was equal to the Rush Springs sandstone. Thus, Sawyer's boundaries for the Marlow are the same as those used in this report. Later, Evans (1931, p. 405-432) suggested that the top of the Marlow should be the top of his Upper Relay Creek dolomite and that the base should be the top of the Dog Creek shale. Green (1936, p. 1469-1491) recognized the top of the Dog Creek shale as the base of the Marlow where the Rog Creek is present. He pointed out, however, that the Dog Creek shale and underlying Blaine formation are absent from southern Grady County, implied that the base of the Marlow in that area is at the top of the Duncan as used by Sawyer. That horizon is the top of the Chickasha formation as used in this report. Green (1936, p. 1471) considered the top of the Marlow to be "*** along wavy lines 8-10 feet above the upper Relay Creek dolomite. This wavy contact represents a slight unconformity. The maximum relief along this unconformity has been found to be as much as 30 feet, *** " The "wavy line" is an uneven but local contact of Rush Springs strata on Marlow strata. The writer considers it to be of minor stratigraphic importance and places the top of the Marlow at the top of the upper Relay Creek dolomite bed.

Distribution.—The Marlow formation crops out as a band ranging from about 0.5 mile to more than 5 miles in width circling the southeast end of the Anadarko basin, just inside the outcrop of the El Reno group.

Character.—The Marlow formation consists of even-bedded fine-grained silty sandstones and shales that are dominantly moderate reddish brown. Interbedded with these strata are several white gypsiferous layers, a few of which can be traced for several miles but none of which is persistent over wide areas. The entire formation is gypsiferous; satin spar occurs at random throughout the entire section.

Thickness.—The thickness of the Marlow formation in the Oklahoma Natural Gas Co. water well 1 in sec. 14, T. 5 N., R. 8 W. is 110 feet, and in the R. H. Roark No. 1 Cast (oil test) in sec. 25, T. 3 N., R. 7 W. it is 130 feet. These thicknesses agree fairly well with those given in previous reports. Sawyer (1924, p. 315) gave the thickness as 120 feet in the southeastern end of the Anadarko Basin; Green (1936, p. 1470), 128 feet in T. 7 N., R. 9 W.; Brown (1937, p. 1542), 105 feet in T. 2 N., R. 6 W.; and the American

Association of Petroleum Geologists Anadarko Basin Field Trip (1939), 110 feet, for southern Grady County.

The *Verden sandstone member* occurs near the middle of the Marlow formation. Its outcrop enters Grady County near Verden and follows the strike of the Marlow southeastward to sec. 18, T. 4 N., R. 5 W. It also crops out in sec. 13, T. 2 N., R. 5 W. in Stephens County. Bass (1939, p. 559), Newell (1940, p. 261-336), and Evans (1948, p. 42-43) have published detailed and adequate descriptions of the lithologic characteristics of the Verden.

According to Bass, the Verden is about 10 feet thick, occupies everywhere the same stratigraphic position within a range of a few feet, and has an outcrop less than 1,000 feet wide at most places. It is characterized by relatively thick beds of medium to coarse-grained sandstone, composed of well rounded quartz and subangular chert grains cemented by calcium carbonate, which makes up 50 percent of the rocks; and interbedded with thin layers of fine-grained, horizontally laminated sandy shale. The sandstone is deeply cross-bedded, most of the beds dipping northward. The sand grains have a wide range in size and are sorted into layers in which grains of a single size predominate. The fine-grained beds contain wave ripple marks and giant ripple marks which trend nearly parallel with the outcrop. Marine fossils are common. Bass thought of the Verden sandstone as one or more spits deposited across the mouth of a broad shallow bay near the shore of a shallow marine sea. He believed that the sediments were probably derived by wave action from conglomerates in the underlying Duncan sandstone (basal Chickasha and Duncan, undifferentiated) which were exposed in the vicinity while the Verden sandstone was being deposited. Newell essentially agreed with Bass as to the origin and occurrence of the Verden.

Evans studied many of the exposures of the Verden and agreed with Bass as to the observable physical characteristics of the rock, but disagreed as to its origin. He regarded the Verden sandstone as a channel deposit laid down by tidal and salinity currents in a strait or pass.

Two persistent dolomitic beds occur at the top of the Marlow formation. These have been designated by Evans (1931, p. 416) as the "Upper Relay Creek and Lower Relay Creek dolomites." He stated, further, that they are separated by approximately 25 feet of red sandstone and shale. In Grady County, however, the interval between them is 15 to 20 feet. Where present, the dolomites range from paper thin to about 4 inches in thickness. Locally, the dolomites grade into gypsum. About 1 foot below the upper Relay Creek dolomite is a bed of pink shale, possibly altered volcanic ash, which ranges up to 1 foot in thickness and often has been referred to as "pink shale." This shale has been known locally by the name Gracemont, from the town of that name in Caddo County (Brown, 1937, p. 543). Where only one dolomitic bed is present and the "pink shale" is below it, the dolomite clearly is Evans' Upper Relay Creek. It should be pointed out that a "pink shale" without associated dolomites is not sufficient to identify the horizon of the Relay Creek, for other shales of this sort occur locally near the middle of the Marlow and in the lower part of the overlying Rush Springs sandstone. A gypsum bed about 18 inches thick occurs within 2 feet above the lower Relay Creek dolomite bed near Agawam School (sec. 28, T. 5 N., R. 7 W.) and at several other localities in Grady and northern Stephens Counties. Known to geologists working in the area as the "Agawam gypsum," this bed helps identify the lower Relay Creek dolomite bed where the upper bed is absent.

Stratigraphic relations.—The Marlow formation in Grady and northern Stephens Counties is underlain unconformably by the Dog Creek shale and Blaine formation, undifferentiated, and by the Chickasha formation where the Dog Creek and Blaine are absent, and overlain conformably by the Rush Springs sandstone (Brown, 1937, p. 1547; Six, 1930, p. 391, and 1930, p. 13; Kite, 1930, p. 196, and 1930, p. 8; Gouin, 1930, p. 211, and 1928, p. 13; Gould and Lewis, 1926, p. 21; Freie, 1930, p. 55; Roth, 1932, p. 688-689, 713). A majority of geologists at the Permian Conference at Norman (1937, edited by Dott, p. 1559-1572) agreed that preponderance of evidence indicates the contact of the Marlow formation with underlying formations in Grady County is unconformable, but there remains disagreement as to the magnitude and type of unconformity. Brown (1937, p. 1534-1556) thinks the Marlow formation overlaps the Dog Creek shale and the Blaine formation eastward; others, while convinced the contact is unconformable, think that no great time interval exists, and that the upper and lower formations are essentially parallel; and some postulate a great time interval at the unconformity. The best evidence of this unconformity, according to Russom (1937, p. 1561), is in the southeast part of T. 2 N., R. 6 W., Stephens County, Oklahoma, where the escarpment of the Duncan sandstone and the Chickasha formation bends northward around the Cruce anticline. The escarpment of the Marlow is unaffected by the folding which caused the Cruce anticline, which means that the uplift is post Duncan-Chickasha, and pre-Marlow. Further, the thickness of the Duncan and Chickasha is less than 200 feet at the north end of the Cruce anticline but more than 600 feet about 8 miles to the west. Also, there is a distinct change in sedimentation from the highly heterogeneous, deltaic, dark red sediments of the Chickasha and Duncan to the light orange, even-bedded sediments of the Marlow formation.

Age and fossils.—The only fossils found in the Marlow formation have come from the Verden sandstone member. According to Bass (1939, p. 572-574) they were mostly pelecypods, together with a few gastropods. They were identified by George H. Girty, of the U. S. Geological Survey, as marine forms of Permian age, resembling those collected at Whitehorse Springs, Oklahoma, and identified by Beede (1902, p. 1-11 of Van Vleet) as late Permian age. Bass reported the best preserved fossils were observed in a small quarry in the SE¼ SE¼ sec. 4, T. 6 N., R. 8 W., three miles northwest of Norge, Grady County. Newell, in 1940, (p. 261-336) reported the occurrence of two pelecypod species, *Dozierella gouldii* (Beede) and *Pleurophorus albequus,* from the locality in sec. 4, T. 6 N., R. 8 W. He agreed that the generic assemblage of the fauna clearly indicates a Paleozoic age.

Correlation.—The Marlow formation is the basal member of the Whitehorse group, which is middle Permian in age (King, 1942, p. 754).

Water supply.—The Marlow formation yields very little water to wells in Grady and Stephens Counties—nowhere more than 1 or 2 gallons per minute. The water is extremely hard and is high in sulfate. In most places it is unsuitable for human consumption and is injurious to stock. Some of the water is so mineralized that cattle refuse to drink it. In consequence, most farms in the outcrop area of the Marlow formation depend on cisterns for domestic water and have artificial ponds for stock water.

RUSH SPRINGS SANDSTONE

The Rush Springs sandstone, in Grady and northern Stephens Counties, Oklahoma, includes the sandstones and siltstones lying between the top of the Marlow formation and the base of the Cloud Chief formation. The strata are even to highly cross-bedded, have a light-brown color, and range in thickness from about 136 feet to 300 feet. The Rush Springs yields ground water suitable for most uses. In one test it yielded at the rate of about 1.5 gallons per minute per foot of drawdown in a pumped well.

First reference.—Sawyer (1929; p. 11, 1930, p. 317).

Nomenclator.—Sawyer (1929; p. 11, 1930, p. 317).

Type locality.—The Rush Springs sandstone was named by Sawyer, presumably for the town of Rush Springs in Grady County. Sawyer did not specify a type locality, but stated that his Rush Springs is the Whitehorse sandstone of Reeves (1921, p. 51). Reeves had mentioned a "Whitehorse sandstone cliff which forms the river bluffs 1 mile north of the northeast corner of Tonkawa Township." This description places the locality in sec. 36, T. 7 N., R. 10 W., Caddo County, where almost the full thickness of the formation from the base upward is exposed and the texture and bedding are typical. Although neither Reeves nor Sawyer called this the type locality, it is considered to be acceptable as a type locality.

Original description.—Sawyer (1929, p. 11; 1930, p. 317) briefly described the Rush Springs sandstone as consisting "almost entirely of red cross-bedded sandstone," with "little or no shale or gypsum." Under the name Whitehorse, Reeves (1921, p. 51-52) had described it as "a friable reddish-brown, cross-bedded to regular-bedded sandstone which weathers rapidly, producing a thick soil of sand that is blown about by the wind and in some localities is piled up into sand dunes."

History of usage.—Sawyer classed the Rush Springs as a member of the Whitehorse sandstone, and this classification was followed by Becker (1930, p. 48-50) and others. Later Green (1936,

p. 1458) raised the Rush Springs to formation rank. In this report, the Rush Springs sandstone is classed as a formation of the Whitehorse group.

Distribution.—The Rush Springs sandstone crops out along both sides of Boggy Creek in Tps. 9 and 10 N., R. 8 W. and extends east and south as stringers and outliers in the adjoining townships. South of the Washita River, the Rush Springs sandstone crops out in much of the southwest quarter of Grady County and extends about 3 miles into northern Stephens County: it underlies most of Tps. 3 and 4 N., Rs. 7 and 8 W.; and parts of T. 2 N., Rs. 6 and 7 W.; Tps. 3 and 4 N., R. 6 W.; T. 5 N., Rs. 7 and 8 W.; and T. 6 N., R. 8 W.

Thickness.—The Rush Springs sandstone is about 228 feet thick in a test hole near the NW cor. sec. 33, T. 4 N., R. 8 W.; 280 feet thick in a well (oil test) in sec. 25, T. 3 N., R. 8 W.; 166 feet thick in a well (water test) in the NW¼ sec. 17, T. 3 N., R. 7 W.; 200 feet thick in sec. 26, T. 3 N., R. 7 W.; and 136 feet thick in secs. 5 and 6, T. 9 N., R. 8 W.

The rather wide range in thickness indicated by the figures above is in agreement with thicknesses previously reported. Lehman (1937, p. 1568) reported a thickness of 270 feet in sec. 18, and 210 feet in sec. 30, T. 4 N., R. 7 W.; and he said it ranged from 220 to 230 feet thick in secs. 34 and 35, T. 4 N., R. 7 W. Russom (1937, p. 1568-1569) reported a thickness of 210 feet for the Rush Springs sandstone near the town of Rush Springs. Sawyer assigned a thickness of 240 to 280 feet to the Rush Springs sandstone in Grady County in his original description of the formation. Green (1936, p. 1472) gave a thickness of 160 to 300 feet for the Rush Springs sandstone in the southeast part of the Anadarko basin, the wide range being attributed to pre-Quartermaster erosion.

Character.—The Rush Springs sandstone in Grady and northern Stephens Counties is an even to highly cross-bedded light-brown soft silty sandstone. It is well described by Reeves (1921, p. 52-54), who wrote, "The bedding of the Whitehorse sandstone varies laterally and vertically from regular bedding to very pronounced cross-bedding. In a typical exposure of 100 feet of the sandstone there may be one or more layers of cross-bedded material, the remainder being regularly bedded. The regularly bedded portion usually has conspicuous bedding planes and consists of beds ranging from 1 to 30 feet in thickness and averaging about 10 feet. The thickness of the cross-bedded members ranges from 5 to 40 feet, and that of the oblique layers ranges from a fraction of an inch to 1 or 2 feet. On the truncated edges of these layers rests the overlying horizontal bed, producing the appearance of an unconformity. In some sections this condition is repeated two or three times, and in others at the same stratigraphic position the entire sandstone is horizontally bedded."

Reeves also wrote that the dip of the cross-bedding is to the southwest, and that a regular and irregular type can be distinguished. In the regular type the oblique laminae have plane surfaces, and at any one outcrop all dip in one direction and approximately the same amount. The dip of the laminae decreases toward the base of a cross-bedded stratum, and they thin and merge into the underlying horizontally bedded layers. In the irregular type of cross-bedding the layers dip in every direction, comprising concentric and nonparallel layers, which are commonly less than an inch thick. The vertical extent of such cross-bedded material is normally less than 20 feet, and its length is not more than a few hundred feet.

The Rush Springs sandstone contains a silty shale phase in Grady County. The silty shale forms a broad wedge that is thickest southeast of the town of Rush Springs. As the lower part of the wedge becomes progressively sandier westward, a threefold division, with two sandstones separated by shale, is apparent. The silty phase is a moderate reddish brown whereas the more sandy portion is light brown; and it contains iron-stone concretions approximately following bedding planes.

The sand grains are subangular to subround, and average about 0.124 millimeter in diameter, but range from 0.061 to 0.991 millimeter (table 12). Very coarse, frosted, almost perfectly spherical grains are common. They are most abundant in the lower part of the formation. The rest of the grains are smooth and are covered with a stain of iron oxide. The entire Rush Springs sandstone is remarkable in its homogeneity.

The Rush Springs sandstone was probably deposited in a shallow bay of the Permian sea. The direction of dip of the foreset beds shows that the sediments came from the northwest, and the high degree of sorting and rounding of the sand grains shows that this source was far away.

TABLE 12.

SIEVE ANALYSES OF DRILL CUTTINGS FROM RUSH SPRINGS SANDSTONE SHOWN AS PERCENTAGES OF TOTAL SAMPLE BY WEIGHT (SIZE CLASSIFICATION ACCORDING TO WENTWORTH).

Depth in Feet		0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60
Very coarse sand (1.0 - 2.0 mm)	Well A*	1.78	trace	0.28	0.37	0.21	0.02	1.58	1.17	0.62	0.16	0.15	0.11
	Well B**	5.75	5.33	2.53	1.43	3.86	4.22	8.36	8.36	16.74	5.90	5.02	4.38
Coarse sand (0.5 - 1.0 mm)	Well A	4.70	0.18	1.78	2.00	1.38	0.75	2.89	3.00	2.61	0.44	1.12	0.42
	Well B	11.16	14.32	5.42	6.03	11.08	7.15	12.00	12.00	13.80	7.00	8.32	9.07
Medium sand (0.25 - 0.5 mm)	Well A	12.44	9.32	15.23	14.81	13.10	6.91	7.12	4.24	4.47	3.75	4.06	11.09
	Well B	8.64	8.44	4.46	5.34	6.58	6.52	7.54	7.54	7.12	4.20	8.41	5.64
Fine sand (0.125 - 0.25 mm)	Well A	41.44	47.95	43.48	39.27	37.86	33.92	43.33	35.55	33.82	30.16	45.21	58.02
	Well B	9.48	9.86	9.37	6.32	6.23	6.40	7.92	21.53	6.25	3.87	8.25	4.74
Very fine sand (0.0625 - 0.125 mm)	Well A	21.00	23.24	22.38	26.20	29.78	35.37	27.77	34.14	36.67	37.60	32.63	17.09
	Well B	22.07	25.32	38.53	37.55	27.58	23.12	21.53	21.53	13.05	21.12	23.16	27.10
Silt and clay (0.0625 - — mm)	Well A	18.64	19.31	16.85	17.35	17.68	23.03	17.31	21.90	24.81	27.89	16.83	23.27
	Well B	42.90	36.73	39.69	43.33	44.67	52.59	42.65	42.65	43.04	57.91	46.84	49.07

*Well A—Southwest cor. sec. 26, T. 3 N., R. 7 W.
**Well B—NW¼ sec. 3, T. 2 N., R. 7 W.

TABLE 12.—(Continued)

SIEVE ANALYSES OF DRILL CUTTINGS FROM RUSH SPRINGS SANDSTONE SHOWN AS PERCENTAGES OF TOTAL SAMPLE BY WEIGHT (SIZE CLASSIFICATION ACCORDING TO WENTWORTH).

Depth in Feet		60-65	65-70	70-75	75-80	80-85	85-90
Very coarse sand (1.0 - 2.0 mm)	Well A*	0.13	0.03	0.06	0.15	0.33	1.08
	Well B**	0.72	6.78	1.10	1.20	2.86	6.19
Coarse sand (0.5 - 1.0 mm)	Well A	0.61	0.51	0.30	0.38	1.92	3.52
	Well B	3.57	10.00	4.04	5.36	5.21	9.00
Medium sand (0.25 - 0.5 mm)	Well A	7.06	6.92	7.34	5.06	4.76	3.47
	Well B	4.00	5.68	6.20	5.65	5.77	3.56
Fine sand (0.125 - 0.25 mm)	Well A	33.83	33.76	33.00	24.26	11.72	8.05
	Well B	4.71	9.98	6.53	23.56	12.11	7.66
Very fine sand (0.0625 - 0.125 mm)	Well A	25.39	25.65	31.62	34.94	29.00	32.28
	Well B	28.72	33.28	24.28	21.45	17.33	26.88
Silt and clay (0.0625 - — mm)	Well A	32.98	33.23	28.68	35.21	52.27	51.60
	Well B	58.78	34.28	57.45	42.78	56.72	46.71

Depth in Feet		90-95	95-100	100-105	105-110	110-115	115-120
Very coarse sand (1.0 - 2.0 mm)	Well A*	1.51	1.30	0.92	0.15	2.41	1.92
	Well B**	1.05	5.01	2.73	4.25	1.04	1.21
Coarse sand (0.5 - 1.0 mm)	Well A	5.65	4.28	2.63	0.56	4.87	4.10
	Well B	2.98	4.95	5.24	5.48	3.42	7.28
Medium sand (0.25 - 0.5 mm)	Well A	4.65	5.00	3.95	3.42	4.61	4.67
	Well B	3.46	4.08	3.78	5.96	2.97	4.97
Fine sand (0.125 - 0.25 mm)	Well A	7.33	7.28	7.16	7.12	6.00	6.07
	Well B	6.98	43.45	66.43	66.90	73.35	17.73
Very fine sand (0.0625 - 0.125 mm)	Well A	30.34	34.34	35.96	43.73	29.51	19.46
	Well B	24.40	17.76	5.98	10.00	12.88	10.62
Silt and clay (0.0625 - — mm)	Well A	50.56	47.80	49.38	45.01	52.60	63.78
	Well B	59.13	24.75	15.84	7.41	6.34	58.19

*Well A—Southwest cor. sec. 26, T. 3 N., R. 7 W.
**Well B—NW¼ sec. 3, T. 2 N., R. 7 W.

TABLE 12.—(Continued)

SIEVE ANALYSES OF DRILL CUTTINGS FROM RUSH SPRINGS SANDSTONE SHOWN AS PERCENTAGES OF TOTAL SAMPLE BY WEIGHT (SIZE CLASSIFICATION ACCORDING TO WENTWORTH).

Depth in Feet		120-125	125-130	130-135	135-140	140-145	145-150
Very coarse sand (1.0 - 2.0 mm)	Well A*	0.56	2.21	2.00	0.86	0.44	0.51
	Well B**	2.61	2.50	1.77	1.00	2.90	1.34
Coarse sand (0.5 - 1.0 mm)	Well A	2.36	4.63	3.99	2.12	4.00	6.31
	Well B	6.14	8.98	5.15	6.04	25.78	3.20
Medium sand (0.25 - 0.5 mm)	Well A	3.66	3.83	3.81	2.24	6.10	6.21
	Well B	3.98	4.00	3.98	4.38	5.97	6.91
Fine sand (0.125 - 0.25 mm)	Well A	5.93	6.12	5.81	2.50	6.95	5.75
	Well B	29.07	22.99	58.37	65.00	32.30	70.70
Very fine sand (0.0625 - 0.125 mm)	Well A	32.30	26.91	24.02	22.79	34.96	30.48
	Well B	16.82	17.67	9.52	7.68	10.76	4.73
Silt and clay (0.0625 - — mm)	Well A	55.19	56.30	60.37	69.49	47.55	50.74
	Well B	42.38	43.86	21.21	15.90	22.29	13.12

Depth in Feet		150-155	155-160	160-165	165-170	170-175	175-180
Very coarse sand (1.0 - 2.0 mm)	Well A*	0.17	0.68	0.11	0.11	0.21	0.13
	Well B**	1.00	9.14	4.12	4.12	0.35	10.02
Coarse sand (0.5 - 1.0 mm)	Well A	0.54	2.00	0.83	0.41	0.71	0.51
	Well B	3.92	11.21	11.65	11.65	18.76	12.98
Medium sand (0.25 - 0.5 mm)	Well A	2.30	3.36	2.60	1.96	1.63	1.26
	Well B	11.35	13.75	8.34	8.34	16.55	5.90
Fine sand (0.125 - 0.25 mm)	Well A	8.17	5.75	6.12	29.26	19.65	14.16
	Well B	72.18	42.51	18.70	18.70	10.00	5.57
Very fine sand (0.0625 - 0.125 mm)	Well A	47.04	29.17	31.95	24.17	26.19	26.42
	Well B	3.30	11.34	17.51	17.51	21.10	13.06
Silt and clay (0.0625 - — mm)	Well A	41.78	59.04	58.39	44.09	51.61	57.59
	Well B	3.25	12.05	38.88	38.88	26.14	52.47

TABLE 12.—(Continued)

SIEVE ANALYSES OF DRILL CUTTINGS FROM RUSH SPRINGS SANDSTONE SHOWN AS PERCENTAGES OF TOTAL SAMPLE BY WEIGHT (SIZE CLASSIFICATION ACCORDING TO WENTWORTH).

Depth in Feet		180-185	185-190	190-195	195-200		
Very coarse sand (1.0 - 2.0 mm)	Well A*	0.36	trace	1.10	0.36		
	Well B**	6.46	11.99				
Coarse sand (0.5 - 1.0 mm)	Well A	1.58	0.36	1.91	1.98		
	Well B	12.00	6.38				
Medium sand (0.25 - 0.5 mm)	Well A	3.62	1.52	2.77	3.14		
	Well B	9.30	4.68				
Fine sand (0.125 - 0.25 mm)	Well A	7.81	20.93	52.94	59.52		
	Well B	11.58	7.47				
Very fine sand (0.0625 - 0.125 mm)	Well A	33.98	20.87	19.05	21.31		
	Well B	16.66	14.17				
Silt and clay (0.0625 - — mm)	Well A	52.65	56.32	22.23	13.69		
	Well B	34.00	58.31				

Stratigraphic relations.—The Rush Springs sandstone is underlain conformably by the Marlow formation (Russom, 1937, p. 1567; Brown, 1937, p. 1546) and is overlain unconformably, in the area of this report, by the Cloud Chief formation (Russom, 1937, p. 1568-1569).

Age and fossils.—No fossils have been collected from the Rush Springs sandstone in the area of this report. The formation is generally regarded as of middle Permian age.

Correlation.—The Rush Springs sandstone of west-central Oklahoma is a formation in the Whitehorse group, equivalent to the upper part of the Whitehorse formation in the Cimarron group of Kansas, and to a part of the Whitehorse group of central Texas.

Water supply.—The water in the Rush Springs sandstone is generally suitable for industrial, municipal, and irrigation uses (fig. 12). The formation is the major source of ground water in southwest Grady and northern Stephens Counties and is the source of water supply for Rush Springs and Marlow. In the northwest part of Grady county it furnishes farm, domestic, and stock water, but is too thin and too highly dissected by streams to retain a large quantity of ground water.

The depth to water ranges from a few feet to as much as 80 feet below the surface, depending upon topography and the extent to which the ground water is drained into the perennial streams. The results of a pumping test northeast of the town of Rush Springs, described in detail elsewhere in this report, indicate that this formation will yield about 1.5 gallons of water per minute per foot of drawdown in a well. This figure probably is lower south of the town, because in that area the Rush Springs sandstone is silty, and therefore does not release water readily.

CLOUD CHIEF FORMATION

The name Cloud Chief formation is applied in Grady County to the gypsum and red shale overlying the Rush Springs sandstone. The usage of the term "Cloud Chief formation" rather than "Cloud Chief gypsum" is in accord with the usage of the Oklahoma Geological Survey, and that used on the geologic map of Oklahoma (Miser, 1954). The formation consists of irregular, impure gypsum beds interbedded with gypsiferous shales that do not yield ground water to wells in Grady County. The Cloud Chief is unconformable with the underlying Rush Springs sandstone. The formation crops out in Grady County as widely scattered outliers, so that only its lower part is present. The maximum observed thickness is about 15 feet.

First reference.—Gould (1924, p. 324-341).

Nomenclator.—Gould (1924, p. 324-341).

Type locality.—Town of Cloud Chief, Washita County, Oklahoma.

Original description.—The Cloud Chief was described by Gould (1905, p. 59) under the name "eastern area" of the Greer. He wrote that it was chiefly red clay shale, interstratified at several horizons with red sandstone and gypsums, which are, however, very irregularly bedded and can rarely be traced as continuous or definite ledges.

History of usage.—The name Cloud Chief, as originally defined by Gould (1924, p. 324-341), included the rocks above the Day Creek dolomite and below the Quartermaster formation. Later, Gould and Lewis (1926, p. 24) suggested that "it might be well to consider the Day Creek the basal part of the Cloud Chief gypsum." Sawyer (1929, p. 11; 1930, p. 317) stated that the Cloud Chief underlies the Quartermaster formation and overlies the Whitehorse sandstone. He did not name the Day Creek dolomite as a stratigraphic boundary because it is not present in the area considered by him. Evans (1931, p. 408-432) placed the Day Creek dolomite over the Cloud Chief and said the Cloud Chief should be a member of the Whitehorse formation, but Buckstaff (1931, p. 434-437) did not regard Evans' interpretation of the stratigraphic relations as proved. Green in 1936 (p. 1454, 1458, 1473) divided the Quartermaster in ascending order thus: (1) Cloud Chief member, (2) Doxey shale member, and (3) Elk City sandstone member, but in 1937 (p. 1527-1528) he changed his classification to include the Cloud Chief as the upper member of the Whitehorse group. Schweer (1937, p. 1553) concurred with this classification.

Miser (1954) places the Cloud Chief formation above the Whitehorse group, and this classification is used in this report. The stratigraphic position of the Day Creek dolomite is not pertinent to the study of Grady and Stephens Counties because the bed is not present at the southeast end of the Anadarko basin.

Distribution.—The Cloud Chief formation is present in Grady County as several small outliers in T. 3 N., R. 8 W., and T. 4 N., Rs. 7 and 8 W.

Thickness.—Where present in Grady County, the Cloud Chief has been reduced by erosion to a residual soil in some places, and to a layer a foot or two thick in other places. Locally 15 feet or more remains.

Character.—In Grady County the Cloud Chief formation consists of irregular, impure gypsum beds interbedded with gypsiferous shales, which weather into a light-colored residual soil. This soil is easily distinguished from that developed on the underlying Rush Springs sandstone, and is the basis for mapping some of the outliers of the Cloud Chief.

Stratigraphic relations.—The Cloud Chief formation is underlain unconformably by the Rush Springs sandstone. According to Lehman (1937, p. 1568) and Russom (1937, p. 1568-1569) proof of this unconformity is found in the range of thicknesses of the underlying Rush Springs sandstone, which is taken as evidence of pre-Cloud Chief erosion. Lehman, for example, reported a range from 210 to 270 feet within 1.5 miles.

Age and fossils.—No fossils have been collected from the Cloud Chief formation either in Grady County or elsewhere in Oklahoma. The formation is generally regarded as of late Permian age.

Correlation.—The Cloud Chief formation appears to correlate with the Taloga formation, Day Creek dolomite, and perhaps the upper part of the Whitehorse as these terms are currently used by the Kansas Geological Survey.

Water supply.—The Cloud Chief formation yields no ground water in Grady County.

QUATERNARY SYSTEM

ALLUVIUM AND TERRACE DEPOSITS

Alluvium and terrace deposits are considered under a single heading because their mode of deposition is the same, and, in general, they have the same hydrologic properties.

Alluvium is the material deposited by streams in recent geologic time. It may consist of gravel, sand, and silt or clay in any proportion, and it underlies the flood plains. It is likely but not certain, to be thickest near the middle of a valley. It is thicker along major streams than along small creeks.

Terrace deposits also consist of materials laid down by streams in late geologic time, but are somewhat older than alluvium. Since the time of deposition, the streams have shifted their channels laterally and have cut them to lower levels. The terrace deposits, therefore, are adjacent to and topographically higher than the present streams and the alluvium. They consist of sand, gravel, clay, and mixtures thereof, in irregular layers and in proportions that differ from place to place.

On plate 1 the alluvium is distinguished from the terrace deposits, which are mapped as two units. The terrace deposits are divided into those underlying the first terrace above the flood plain, hereafter called younger terrace deposits, and those under a higher terrace called older terrace deposits. The terrace deposits and the alluvium are the materials laid down during three cycles, each consisting of erosion followed by deposition, in the major valleys of the area covered by this report. At least two such cycles are recorded in the minor valleys.

In the first cycle, broad major valleys were eroded in the bedrock. These are the valleys of the Washita and Canadian Rivers. They were completely alluviated with sands and gravels containing an abundance of quartz, quartzite, chert, flint, jasper, and silicified wood. Such materials probably came from the Rocky Mountains or from the Tertiary deposits of the High Plains, there being no bedrock closer that contains them (Hendricks, 1937, p. 365-372). In general, the older terrace deposits consist of gravel near the base, sands and silts in the middle, and silty clay in the upper part. This is true only in the broadest sense, however, because gravel is not everywhere present at the base, nor is silty clay everywhere present at the top. Silt and sand, the dominant types of sediments, are present in the shape of lenses, either large or small, depending upon the conditions that governed their deposition. In some road cuts, the older terrace deposits can be seen to pass under the younger terrace deposits. Coarse gravel encountered in a few deep wells beginning on the younger terrace deposits is interpreted as buried remnants of the older terrace deposits.

In the second cycle, the streams degraded their channels and carried away much of the older terrace deposits, leaving valleys similar to but smaller than the original valleys. They then refilled the valleys, this time with sediments composed partly of reworked older terrace deposits, but mostly of sands and silts derived from fine-grained sandstones, shales, and gypsums that comprise the bedrock in the area of this report and westward. In many places the younger terrace deposits probably underlie the alluvium along the Washita and Canadian Rivers.

The third cycle was the shortest of the three. Valleys were cut into younger terrace deposits but in a few places they were cut through to the bedrock. They were then partly filled with sand, silt, and clay comprising the recent alluvium. Practically every stream in the area has some alluvium along it, but much of it is thin and not extensive. On plate 1, alluvium under areas less than about one-eighth mile wide has not been shown.

Water supply.—The ground water in the older terrace deposits is generally of better quality than that in the younger terrace deposits and alluvium. Recharge to the older terrace deposits is principally from precipitation on their surface and from runoff coming from adjacent uplands. Where the upper part of the terrace deposits is coarse and permeable, substantial quantities of water may be added. The older terrace deposits are high enough above the streams so that they are not affected by influent seepage of river water, which commonly is highly mineralized. In general, they are not hydrologically connected with the younger terrace deposits. In a pumping test in a well at the Chickasha airport, where the older terrace deposits are about 80 feet thick, it was shown that the deposits are capable of yielding much more than 60 gallons per minute.

A well 108 feet deep at Alex penetrated gravel believed to be a remnant of the older terrace deposits buried under younger terrace deposits, on which the well begins. The Sawyer Drilling Co. reported the yield as 300 gallons per minute with small drawdown.

Ground water in the younger terrace deposits is hard and in places highly mineralized, but generally is of better quality than water in the alluvium. Because the terrace deposits are farther from the stream channels than the alluvium and are higher, they are less likely to receive water from the streams, either as underflow or from flooding during high water. However, hydrologically the first terrace deposits and the alluvium probably function as a single aquifer at most places, with a water table passing from one into the other without great change in slope. Most of the wells now drawing water from the younger terrace deposits are rural, domestic, and stock wells. The public supply wells of Verden tap water in the younger terrace deposits and yield about 25 gallons per minute. Larger yields are doubtless possible in favorable places.

In the area of this report the alluvium generally contains water of poorer quality than that in the terrace deposits but of better quality than that in the bedrock formations, except the Rush Springs sandstone. The alluvium receives water mainly from

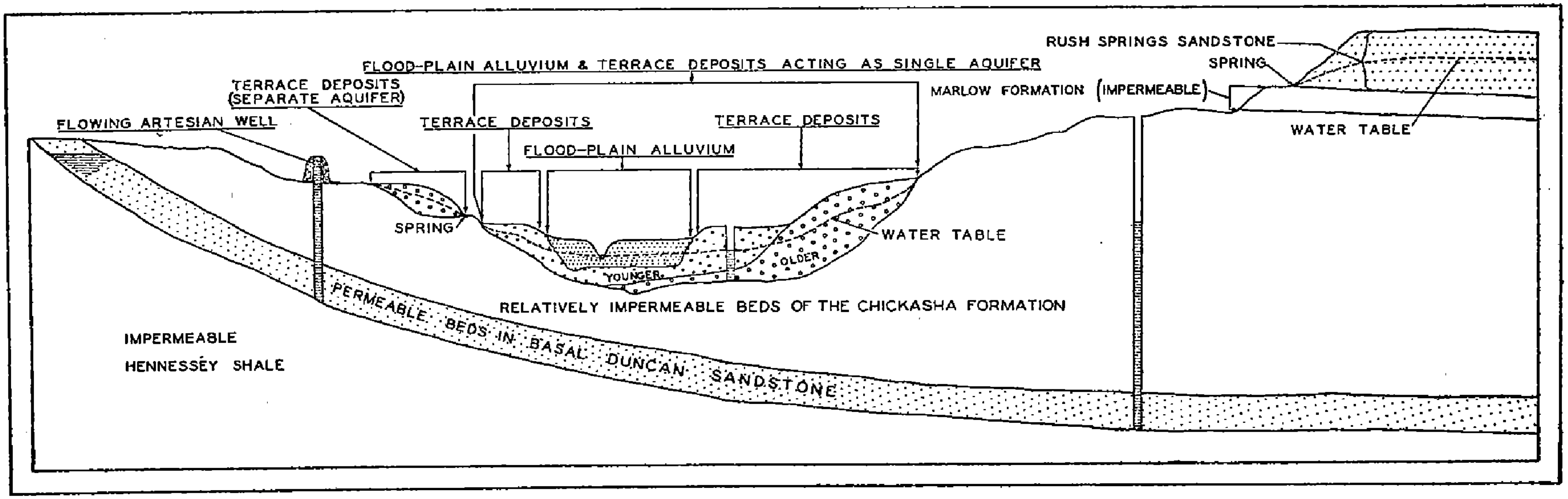


FIG. 5. Diagrammatic sketch showing the relative positions of the ground water aquifers in Grady and northern Stephens Counties, Oklahoma.

precipitation, although at high stages the streams may make substantial but temporary contribution by way of bank storage. When the streams rise over their banks and spread across the flood plains, the percolation of water into the alluvium may be so general that a relatively large increase in stored ground water results. This influx of stream water tends to make the ground water closely resemble the surface water in chemical character.

In many places in Grady and northern Stephens Counties the alluvium is an excellent aquifer, both because the coarse beds in it will transmit water freely and because replenishment of the ground water is likely to be greater in valleys than on the uplands. Wells in the alluvium are generally less than 30 feet deep. Where the bedrock is relatively impermeable and yields only meager supplies of water, many wells for stock water have been drilled into the alluvium along minor streams.

OCCURRENCE AND BEHAVIOR OF GROUND WATER

The basic principles of the occurrence of ground water have been discussed in detail by Meinzer (1923, p. 2-101) from whose report the following summary is adapted in order that the reader may have a better understanding of the ground-water conditions in Grady County.

ROCKS AS RESERVOIRS

The rocks that form the outer crust of the earth—and this includes all the rocks within reach of drilling machines—are at few places if anywhere, solid throughout but contain many open spaces, called voids or interstices. These open spaces are the receptacles that hold the water that is found below the surface of the land and is recovered in part through wells and springs. There are many kinds of rocks, and they differ greatly in the number, size, shape, and arrangement of their interstices and hence in their properties as containers of water. The occurrence of water in the rocks of any region is, therefore, determined by the character, distribution, and structure of the rocks it contains—that is, by the geology of the region—together with the climate and topography.

The amount of water available to wells depends on the saturated thickness and extent of the aquifer and on the permeability and specific yield of the water-bearing materials. The amount of water that can be pumped perennially without progressive depletion of ground water in storage depends on the replenishment of water from precipitation and from the influent seepage from streams in the area of outcrop. These latter factors will be considered further in the section on recharge and discharge.

The amount of water that can be stored in any rock depends upon the volume of rock occupied by open spaces—that is, the porosity of the rock. Porosity is expressed as the percentage of the total volume of rock that is occupied by interstices. A rock is said to be saturated when all its interstices are filled with water. The porosity of a sedimentary rock is controlled by (1) the shape and arrangement of its constituent particles, (2) the degree of assortment of its particles, (3) the cementation and compaction to which it has been subjected since its deposition, (4) the removal of mineral matter through solution by percolating waters, and (5) the fracturing of the rock resulting in joints and other openings. Well-sorted deposits of unconsolidated silt, sand, or gravel have a high porosity, regardless of the size of the grains. Poorly sorted deposits have a much lower porosity because the small grains fill the voids between the large grains, thus reducing the amount of open space. The pore space in some well-sorted deposits of sand or gravel may partially be filled with cementing material, reducing the porosity. Solution channels and fractures may be large and of great practical importance, but they are rarely abundant enough to give an otherwise dense rock a high porosity.

Deep valleys and ravines may materially reduce the storage capacity of a porous and permeable formation by affording low-level outlets for the escape of the water, so that the formation never can be full to the top.

ROCKS AS CONDUITS

Although the the capacity of a rock to contain water is determined by its porosity, its capacity to yield water is determined by its permeability. The permeability of a rock may be defined as its capacity for transmitting water under hydraulic head. It is measured by the rate at which the rock will transmit water through a given cross section under a given difference of head per unit of distance. Rocks that will not transmit water may be said to be impermeable. Some deposits, such as well-sorted silt or clay, may have a high porosity but because of the minute size of the pores will transmit water only very slowly. Other deposits, such as well-sorted gravel containing large openings that communicate freely with one another will transmit water very readily. Part of the water in any deposit is not available to wells because it is held against the force of gravity by molecular attraction—that is, by the cohesion of the water itself and by its adhesion to the walls of the pores. The ratio of (1) the volume of water that a saturated rock will yield by gravity, to (2) its own volume is known as the specific yield of the rock.

Most rocks have numerous interstices of very small size, but some are characterized by a few large openings, such as joints or caverns. In most rocks the interstices are connected, so that the water can move through the rocks by percolating from one interstice to another; but in some rocks the interstices are largely isolated, and there is little opportunity for the water to percolate. The interstices are generally irregular in shape, but different types of irregularities are characteristic of different kinds of rocks.

THE WATER TABLE

Below a certain level the interstices of the permeable rocks are generally saturated with water under hydrostatic pressure. These rocks are said to be in the zone of saturation. Water entering the rocks from the surface is drawn down by gravity to the zone of saturation except as it is held by the molecular attraction of the walls of the interstices through which it descends. The permeable rocks above the zone of saturation are said to be in the zone of aeration, which includes a relatively thin belt of soil water.

The upper surface of the zone of saturation in ordinary permeable soil or rock is called the "water table." Where the upper surface is formed by impermeable rock and artesian conditions are said to exist the water table is absent. If a well is sunk, it remains empty until it enters a saturated permeable bed—that is, until it enters the zone of saturation. Then water flows into the well. If the rock through which the well passes is all permeable the first water that is struck will stand in the well at about the level of the top of the zone of saturation—that is, at about the level of the water table. If the rock overlying the bed in which the first water is struck is impermeable the water, called confined or artesian water is generally under pressure that will raise it in the well to some point above the level at which it was struck.

The water table is not a level surface but has irregularities comparable with and related to those of the land surface, although it is less rugged. It does not remain in a stationary position but fluctuates up and down. The irregularities are due chiefly to local differences in average rates of gain and loss of water, and the fluctuations are due to changes from time to time in gain or loss.

The water table is not to be regarded as a single continuous surface, but rather as a great many small and interconnected surfaces. Each impervious mineral grain that happens to be at the level of the water surface breaks the continuity of the water table. In sandstone the water surfaces are small and close together. Where the ground water is in fissures, fractures, or joints in rocks that otherwise are solid and impervious, the water table consists of small, irregular, rather widely separated water surfaces. Taken all together, such openings are a small fraction of the entire volume of the rock—that is, the effective porosity is low. This is probably the nature of the water table in the shale formations of Grady County.

CONFINED (ARTESIAN) WATER

Artesian or confined conditions are said to exist where a water-bearing bed is overlain by an impermeable or relatively impermeable bed that dips from its outcrop to the discharge area. Water enters the water-bearing bed at the outcrop and percolates slowly downward to the water table and then down the dip in the water-bearing bed beneath the overlying confining bed, when the water exerts considerable pressure against the confining bed. A well drilled through the confining bed into the water-bearing bed releases the pressure and the water rises in the well. Because of loss in head resulting from friction as the water percolates down the dip, the water level will not rise to an elevation as high as that of the water table in the outcrop area. Where the land surface is low enough the artesian pressure may be sufficient to raise the water above the surface, and flowing wells may be obtained.

Because the upper surface of the saturated zone is formed by an impermeable bed and the water in wells will rise above it, the aquifer has no water table. The imaginary surface defined by the height to which artesian water will rise in wells is known as the piezometric surface. Where a water-bearing bed having a water table occurs above the impermeable confining layer, the piezometric surface may be above, below, or at the same level as this water table. Where there is some degree of interconnection between two such aquifers, the relative positions of piezometric surface and water table may be significant. If the piezometric surface is above the water table, the artesian water may be escaping into the unconfined aquifer; where it is lower, the artesian aquifer may be receiving water from the unconfined aquifer. Such interchange might occur through the well itself if it taps both beds or if the casing is not effectively sealed against leakage. Where there is no interconnection between aquifers, the relative positions of piezometric surface and water table have no particular significance except as they may influence a decision as to which type of water to drill for.

Under natural conditions, recharge generally can occur only in the areas of outcrop, where water-table conditions prevail. The lag between the time of precipitation and a corresponding rise of water level in wells is generally greater under artesian than under water-table conditions, and increases with distance from the outcrop. Where this distance is great, the fluctuations due to precipitation are small or nonxistent, and only those due to pumpage or variations in atmospheric pressure are readily evident. Changes in atmospheric pressure may cause changes in water level of a foot or more in artesian wells, the level rising when the pressure is low and declining when it is high.

In Grady County the Chickasha formation forms an impermeable confining bed above the Duncan sandstone. These beds are at altitudes lower than their outcrop areas in Grady and northern Stephens Counties. Thus, the conditions for artesian wells are met. In a few areas in south-central Grady County the altitude of the land surface also is lower than the outcrop, or intake area, and the wells flow at the surface.

DISCHARGE

In Grady and northern Stephens Counties a portion of the ground water is lost by direct evaporation from the shallow-water areas, a larger amount is lost by transpiration from vegetation, and a part is discharged through springs and through effluent seepage along Boggy, Little Washita, Rush, and Little Beaver Creeks where their channels are cut below the level of the water table. Smaller streams receive some discharge from the terrace deposits along the Washita and Canadian Rivers.

The total discharge of ground water from wells in the area is estimated to be several hundred million gallons per year. Impressive as this figure may seem it constitutes only a minor fraction of the total discharge of ground water within the area. The public water supplies of Minco, Tuttle, Verden, Alex, Rush Springs, and

Marlow are obtained from wells, as are, also, several railroad supplies. Ground water is also used as cooling water for several oil and gas pumping stations, and for drilling operations. Most of the unincorporated communities and rural residents obtain their domestic and livestock water supplies from wells.

RECHARGE

Recharge is the addition of water to the underground reservoir. The primary source of such water is precipitation in the form of rain, snow, or hail. Other sources are influent seepage from streams crossing the outcrop, and by movement underground from outside areas.

When water falls on the ground, a part runs off and is carried away by rivers and streams, a part evaporates, a part returns to the atmosphere through transpiration by plants, and a part after sinking into the ground, becomes ground water. The amount of water that sinks into the ground depends upon the character of the surface—its slope, the porosity of the surface soil and bedrock, the degree of saturation of the soil and bedrock, and the amount and type of vegetation. A very porous dry soil will absorb more water in a relatively heavy rain than a tight, heavy soil will absorb. In hot weather, the water may all evaporate before it has time to sink into the ground; and if any does enter the ground. it may soon be lost through transpiration or through evaporation from the soil. Ground water recharge represents the residual after all these higher-priority demands are met. Soil cracks formed during dry weather probably serve to speed up recharge when precipitation occurs after a long dry period.

Under natural conditions, the recharge to an underground reservoir is approximately balanced by the discharge from it. Hence a measure of the natural discharge is a rough measure of the recharge. Pumping or artesian flow from wells upsets this balance and causes a decline of water levels; eventually it diverts toward the wells a part of the natural discharge of springs and streams. This diverted discharge is said to be salvaged. The lowering of the water table or piezometric surface by pumping or artesian flow makes room in the normally saturated part of the aquifer for water that otherwise might go as surface runoff. Thus, where precipitation is more than adequate, withdrawal of water may increase recharge by increasing the receptiveness of the aquifer.

Recharge From Local Precipitation

The annual average precipitation in the area of this report is about 32.5 inches, but only a small fraction of this amount becomes ground water. Recharge is above average in the area underlain by the Rush Springs sandstone because the soil is receptive and the bedrock is relatively permeable. Recharge is also above average in the terrace deposits along the major streams. On the other hand, it is below average in areas underlain by the clays and siltstones of the Chickasha formation, because the soils are clayey and tight, surface drainage is good, and the bedrock is relatively impermeable.

Recharge from subsurface inflow

The movement of water under water-table conditions is primarily in the direction of the general slope of the surface, which in the area of this report is east and southeast. Therefore, water entering the rocks in areas immediately to the west eventually may move into Grady County and contribute to the available supply of ground water. Because the Rush Springs sandstone is the only aquifer in Grady County that is present at the surface west of the area, it follows that only this formation receives substantial subsurface inflow.

The outcrop, or intake area, of the permeable beds in the Duncan sandstone lies in a rough semicircle, mostly beyond the east and south boundaries of the area. Water percolating into them flows down dip under the influence of gravity. Beyond the outcrop area, this is artesian water with few outlets, natural or artificial. Because the outlets are few, and also because the permeabilities of the rocks are low, the quantity of water transmitted in a given period is small. Hence, subsurface inflow from the east and south is relatively unimportant.

Recharge from Streams and Ponds

The alluvium receives water mainly from precipitation, but at times of high water the streams may make substantial but relatively temporary contributions to the ground water by way of bank storage. When the streams overtop their banks and spread across the flood plains, the percolation of water into the alluvium may be so general that a relatively large increase in stored ground water results. Considerable time may elapse before this increment of water can drain into the channel or otherwise be dissipated.

Water in ponds is of minor importance in ground-water recharge because the ponds are generally located on rocks impervious to seepage.

PUMPING TESTS

The amount of water a well will yield depends primarily on the hydraulic properties of the aquifer. These include the permeability, the transmissibility, the coefficient of storage, and the extent of the aquifer. Permeability is defined as the volume of flow per unit time per unit hydraulic gradient. As a field coefficient it usually is expressed as the number of gallons of water per day that can percolate through each mile of the water-bearing bed (measured at right angles to the direction of flow) for each foot of thickness of the bed and for each foot per mile of gradient, at the prevailing temperature of the ground water. The product of the permeability and the thickness of the water-bearing bed is termed transmissibility.

The coefficient of storage is defined as the volume of water released from storage in a vertical prism of the aquifer with a base of 1 foot square as the water level falls 1 foot. Under water-table conditions the coefficient of storage is approximately the same as the specific yield, which may be expressed as the ratio of (1) the volume of water which, after being saturated, the material will yield by gravity to (2) its own volume.

Measurements of the coefficients of permeability, transmissibility, and storage can be made by means of controlled pumping tests. The formulas can be used also to determine the quantity of water that can be pumped from a given well or wells with specified drawdowns in the pumped well or in other wells (Wenzel, 1942). It is evident, therefore, that adequate pumping tests permit making quantitative estimates of the water supply of an aquifer if certain conditions are reasonably satisfied, or, if not satisfied, can be accounted for mathematically: (1) the water-bearing formation is equally permeable in all directions, (2) the formation is of infinite areal extent, (3) the wells penetrate the full thickness of the formation, (4) the coefficient of transmissibility is constant at all places and at all times, and (5) the formation releases water from storage instantaneously with a decline in water level. Any divergence of actual field conditions from these idealized assumptions results in variations and inconsistencies in the alinement of the observed data.

Four controlled pumping tests were made on wells in Grady County. The three principal aquifers were tested. One test was made on alluvium; one test was made on the Rush Springs sandstone; and two tests were made on artesian wells in the Duncan sandstone. All four tests are described in the pages that follow.

Tests of the Duncan Sandstone

The first pumping test in the Duncan sandstone was made at the Oklahoma Natural Gas Co. booster station in sec. 14, T. 5 N., R. 8 W., March 28 and 29, 1946.

The well used in this test had been drilled to a depth of 392 feet, and 8-inch casing was set and cemented from the land surface to 339 feet. The top of the sand is at 340 feet, and the uncased interval between 340 feet and the bottom of the hole at 392 feet contains 34 feet of sandstone and 18 feet of interbedded shale. These strata are interpreted as belonging to the Duncan sandstone. The water in them is under sufficient artesian pressure to rise to, or above, the land surface.

In the absence of compressed air, the well was pumped by gas lift for 12 hours. The discharge was measured by means of a triangular weir box, and was steady at about 80 gallons per minute during the first 20 minutes. The discharge decreased to 60 gallons per minute during the next 20 minutes, and then gradually declined to 47 gallons per minute 5.5 hours after pumping began. Thereafter the discharge remained at 47 gallons per minute to the end of the test, and the average for the pumping period was slightly less than 50 gallons per minute. Efforts to measure the drawdown in the pumping well failed because the discharge pipe leaked.

During the test the drawdown and recovery of the water level in a similar well about 250 feet west of the pumped well were observed regularly (fig. 6). The total drawdown was 34.72 feet after

12 hours of pumping. In the ensuing 12 hours the water level recovered 29.56 feet.

The drawdown and recovery curves were analyzed by means of the Theis nonequilibrium formula (1953, p. 519-524), and values for coefficients of transmissibility and storage were computed. The average transmissibility was about 500 gallons per day per foot and the average coefficient of storage was about 4.6×10^{-4}.

The second pumping test in the Duncan sandstone was made on January 17 and 18, 1950, at the Consolidated Gas Utilities Co. booster station in sec. 22, T. 5 N., R. 8 W. This location is less than 1 mile southwest of the Oklahoma Natural Gas Co. booster station.

The well used for this test had been drilled to a depth of 590 feet, plugged back to 420 feet, and cased to the bottom with 6-inch steel casing. Water is admitted through perforations opposite the sandy zone at 386 to 420 feet. This perforated interval encompasses 8 feet of gypsiferous sandstone from 386 to 394 feet, and 26 feet of fine-grained sandstone from 394 to 420 feet. The aquifer is interpreted as the Duncan sandstone. The water rises under artesian pressure to within a few feet of the land surface.

The well was equipped with an electrically driven turbine pump discharging into an elevated storage tank. The discharge was computed from the rate of rise of the float indicator while the discharge valve was closed. This rate of rise was measured several times at different elevations of water in the tank, and the differences were small. The average discharge was 25 gallons per minute.

The pump was running at 1:25 p. m. when the first water-level measurements were made. Because the pump operated automatically, the time pumping started was unknown. Release of water from the storage tank prevented the pump from being shut off automatically; thus it was possible to have continuous pumping until 5:30 p. m. The pump remained idle overnight and was started at 8:00 a. m. the following morning, pumping continuously until 4:00 p. m. that afternoon.

The only available observation well was 367 feet south of the pumped well. It was equipped with an automatic water-stage

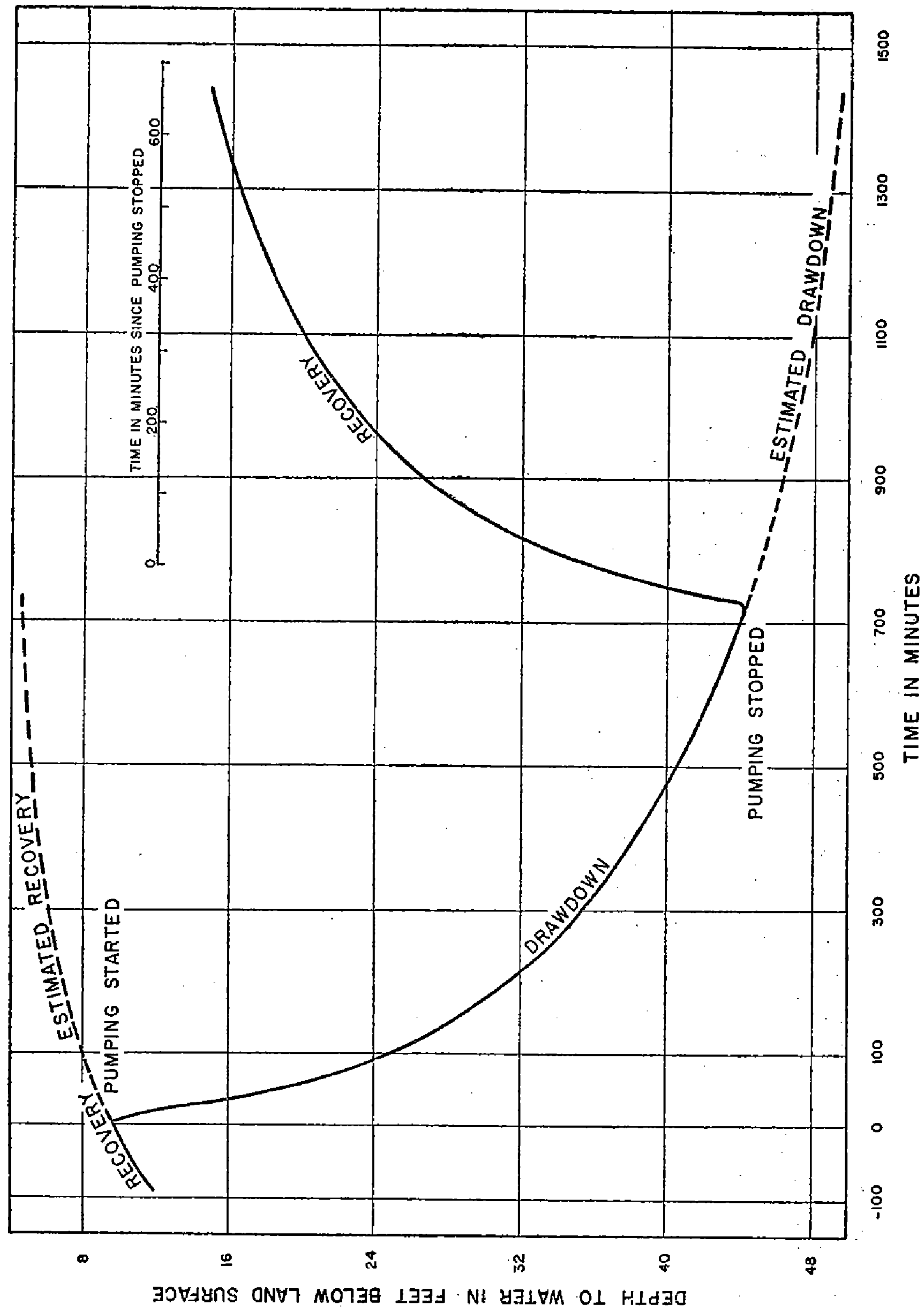


FIG. 6. Fluctuations of water level in the Oklahoma Natural Gas Co. water well 1 produced by pumping well 2, Grady County, Oklahoma.

recorder during the test to record the fluctuations in water level. In addition, several tape measurements of water level were made before the recorder was installed and after it was removed (fig. 7).

Both the recovery curve and the drawdown curve in the observation well were analyzed by the Theis nonequilibrium formula. The average transmissibility was about 1,300 gallons per day per foot and the average coefficient of storage was 1.0 x 10^{-4}.

In both pumping tests the alignment of data was good. The deviations from the theoretical alignment were small and can be accounted for by fluctuations of water level induced by barometric

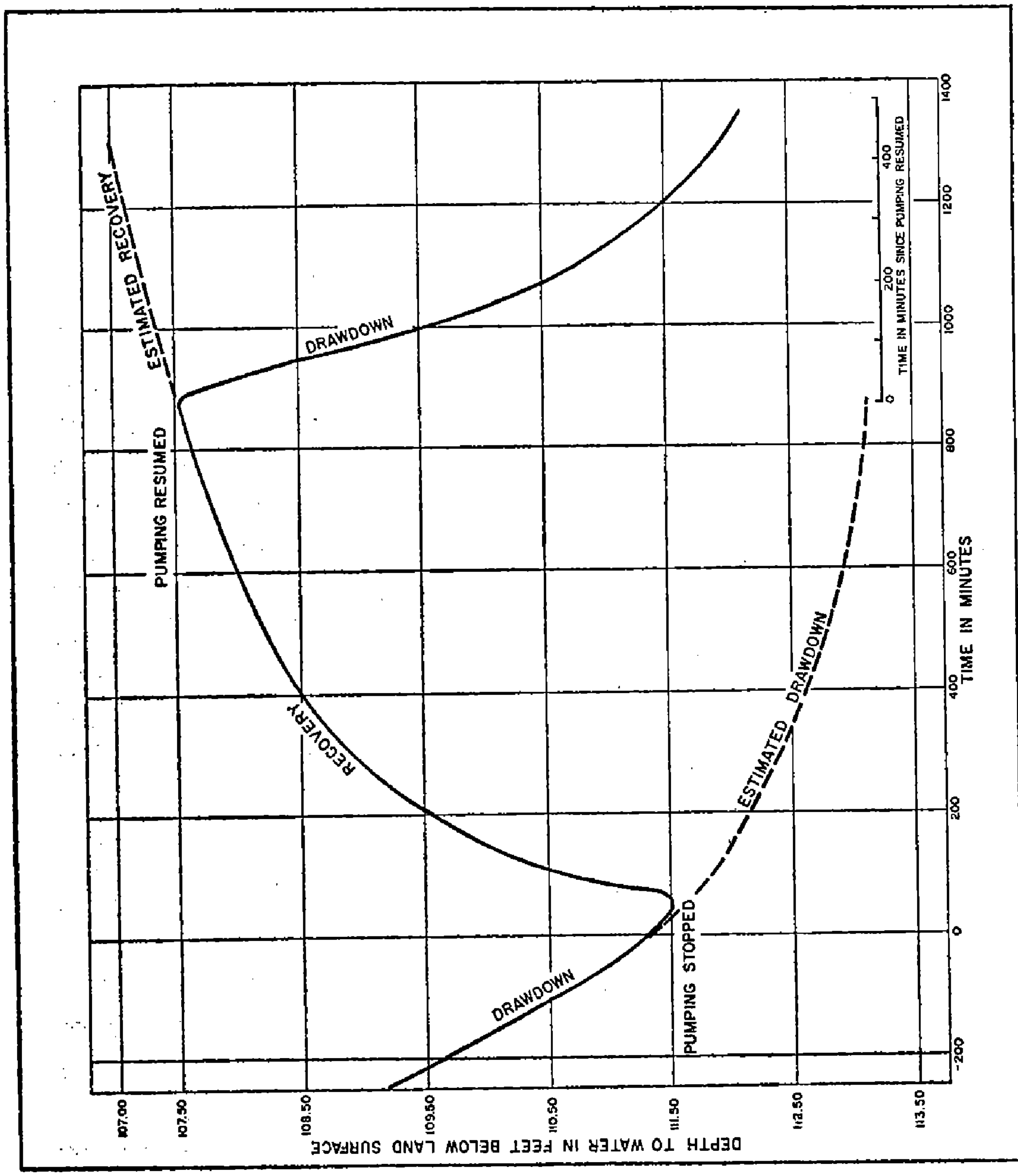


FIG. 7. Fluctuations of water level in the Consolidated Gas Utilities Co. water well 2 produced by pumping well 1, Grady County, Oklahoma.

fluctuations, or by slight inaccuracies in measurements. Nevertheless, the transmissibility as determined by the second test was almost three times greater than that determined by the first test. This large difference cannot be attributed to differences in thickness of water-bearing sand, as the sands are 36 and 34 feet thick, respectively. It is known, however, that the character of the sands differs widely from place to place. Perhaps the divergent results of the two pumping tests reflect difference in grain size and silt content of the aquifer at the two places. As the two tests were made at sites less than 1 mile apart, the average coefficient of transmissibility derived from them does not fairly represent the aquifer as a whole. The figures do show, however, that the transmissibility is low in comparison to that of more productive aquifers, which may range from a few tens of thousands to a few millions of gallons per day per foot.

The coefficients of storage also differed greatly, that from the test at the Oklahoma Natural Gas Co. being four times greater than that from the Consolidated test. Thus, they show a wide range in performance of water-bearing sands that probably are essentially the same beds in the two wells. Both coefficients are so low that the difference between them is only 0.00036. They are convincing evidence that the sands in the Duncan cannot be relied upon to yield large amounts of water. To illustrate, two curves showing theoretical drawdowns around a pumped well have been prepared (fig. 8). The solid-line curve assumes coefficients determined by the Oklahoma Natural Gas Co. test, and the dashed-line curve those determined by the Consolidated Gas Co. test. Both curves assume a continuous pumping rate of 50 gallons per minute for a period of 1 year. Drawdowns at distances ranging from 1 to 22,000 feet from the pumped well are given by the curves.

To obtain 500,000 gallons of water per day, seven wells yielding 50 gallons a minute each would be required. If they were 1,000 feet apart, the drawdown in the middle well at the end of 1 year would be about 460 feet if the coefficients derived from the test at the Oklahoma Natural Gas Co. apply. If the coefficients from the test at the Consolidated Gas Co. apply, the drawdown would be about 250 feet. If the well spacing were 2,000 feet, the drawdown in the middle well would be 370 feet or 217 feet, depending

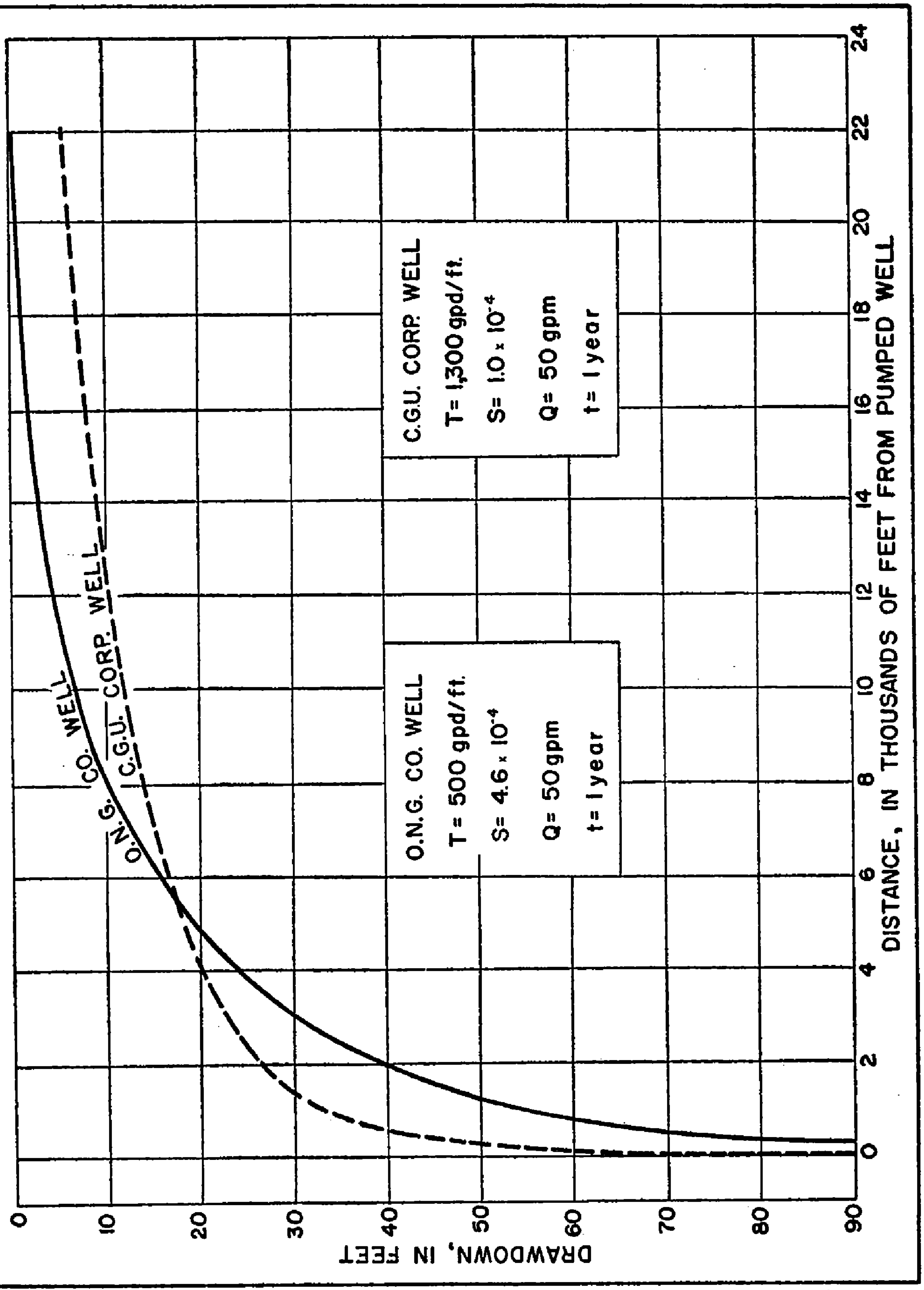


FIG. 8. Curves showing theoretical drawdowns around a pumped well.

on which set of coefficients applies; if the spacing is 4,000 feet, it would be 289 feet or 181 feet; and if the spacing were 6,000 feet, it would be 253 feet or 161 feet. These figures represent only the drawdown from static level. To them should be added the depth to water below the land surface and the drawdown caused by entrance losses (i.e. drawdown caused by friction as water enters the well bore). Even if the coefficient of transmissibility were truly representative for the aquifer, the well spacing necessary to prevent the drawdown from approaching the top of the water-bearing zone within a year would be about half a mile.

Although the two pumping tests indicate that the sands in the Duncan are incapable of yielding large quantities of water continously without creating excessive drawdowns, they are not to be regarded as valueless. Wells yielding 25 to 50 gallons per minute under intermittent pumping could be expected to have many years of useful life. Many wells, widely spaced and pumped intermittently, in the aggregate could draw a considerable volume of water from the sandstones.

Test of the Rush Springs sandstone

The pumping test in the Rush Springs sandstone was made on the water well of the Magnolia Petroleum Co. (4N7W-3-1). The well was drilled to 500 feet and then plugged back to 122 feet below the land surface. Casing 20 inches in diameter was set to 72 feet and cemented in place, and a 19-inch hole reamed to a depth of 122 feet. A stainless-steel liner 8 5/8 inches in diameter was set in the well and the annular space between the liner and the walls of the well bore was filled with gravel. The liner is perforated from 72 to 120 feet below land surface. The well begins on the outcrop of the Rush Springs sandstone and penetrates the entire thickness of the formation, which in this area is a homogeneous, fine-grained massive sandstone. The ground water is under water-table conditions and did not rise in the well above the point at which it was encountered during drilling.

For testing purposes, the well was equipped with a turbine pump driven by a gasoline engine. The bottom of the pump bowls was set 115 feet below the land surface and the well was equipped with an air line and a pressure gage for determining depth to water. Static water level was about 50 feet below the gage, which was set at land surface. The well was pumped continuously from 9:00 a. m., December 22, to 9:00 a. m., December 23, 1948, a period of 24 hours, at an average rate of 163 gallons per minute. The water level at the end of the pumping period was about 96 feet below the gage. Recovery of the water level was observed for 24 hours after pumping ceased and at 9:00 a.m., December 24, 1948, the water level was 52.5 feet below the gage (fig. 9).

The recovery of the water level was analyzed graphically by the Theis formula, and the plotted points fell nearly on a straight line, indicating that the formula is applicable. From this analysis it appears that the coefficient of transmissibility is about 13,000 gallons per day per foot. The coefficient of storage could not be determined from this pumping test because the Theis formula is not adapted to its determination where only the recovery of the water level in the pumped well is available. Inasmuch as water-table conditions exist, for purposes of further computations a value of 0.10 was assumed for the coefficient of storage.

If the coefficients of transmissibility and storage of the aquifer are known, the Theis formula can be used for estimating the drawdown at any place in the aquifer at any time and for any rate of continuous pumping. For convenience in calculation and to provide a safety factor, a value of 10,000 gallons per day per foot was used. This is about 80 percent of the value derived from the pumping test. As indicated above, a value of 0.10 for the coefficient of storage was used. With these assumed coefficients, then, the drawdowns to be expected in the pumped well at the end of 1, 30, 60, 100, 300, and 1,000 days of continuous pumping at 100 gallons per minute were calculated.

The Theis formula usually gives a smaller drawdown than actually occurs in the pumped well because the formula does not make allowance for entrance losses into the well and through the screen, and for the fact that the water is not released from storage instantaneously. To correct for the entrance losses, the drawdown for the first day as computed by the formula was subtracted from the drawdown actually observed. The difference was attributed to entrance and screen losses, and was added to the computed draw-

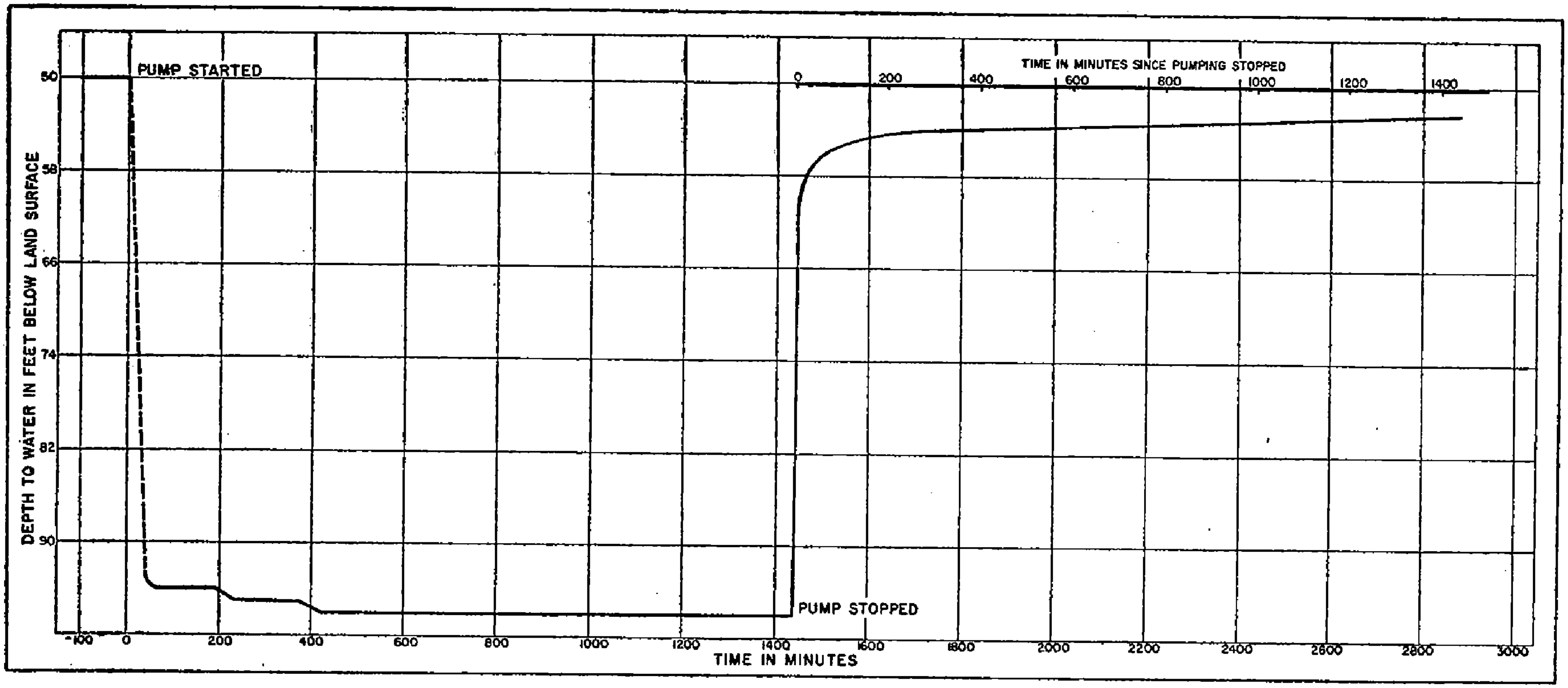


FIG. 9. Drawdown and recovery of the Magnolia Petroleum Co. water well 1 caused by its own pumpage, Grady County, Oklahoma.

downs for the longer periods of pumping. Thus adjusted, the drawdowns at 100 gallons per minute for the Magnolia well are:

Time in days	Drawdown in feet
1	28.6
30	32.5
60	33.3
100	33.9
300	35.2
1,000	36.8

Because the coefficient of storage had to be assumed, a check on the possible error due to over- or under-estimation of it was made. The calculations, therefore, were repeated using 0.01 instead of 0.10 as the coefficient of storage, other factors being unchanged. The resultant drawdowns were within 0.2 foot of these given above for the periods concerned.

The drawdown figures given above are those for an aquifer theoretically of infinite extent, but the boundary of the outcrop of the Rush Springs sandstone is only about half a mile southeast of the Magnolia well. The effect of a boundary is to increase the drawdown because it limits the reservoir from which the well may draw water. Accurate mathematical treatment of the boundary effect is difficult if not impossible because geological boundaries are irregular, but rough calculations can be made indicating the order of magnitude of the effect.

The shortest distance from the Magnolia well to the outcrop of the underlying Marlow formation is about 2,000 feet. If a straight-line boundary 1,000 feet from the well is considered, the effect of the boundary and of thinning of the saturated portions of the aquifer (with consequent reduction in transmissibility) will be roughly approximated. Under this assumption, the increase in drawdown in the pumped well due to the boundary will be 2.4 feet after 1,000 days of pumping at 100 gallons per minute.

If the rate of pumping is increased the drawdown will also be increased, approximately in direct proportion. Doubling the pumping rate, for example, will cause the drawdown to be somewhat more than twice as great, because the effective screen length is shortened as the water level declines, entrance losses are increased, and the saturated portion of the aquifer adjacent to the well is decreased.

The pumping lift in a well is the depth of the static water level below land surface plus the drawdown caused by pumping (including entrance losses). Under natural conditions, the depth to static water level is not constant but varies with changes in the relation of recharge to discharge. The maximum fluctuation of water level during six years of record in well 4N7W-9, which is 1 mile south of the Magnolia well, has been 5.7 feet. At the time of the pumping test the static water level in the Magnolia well was about 50 feet below the land surface. Under the assumed conditions of (1) a pumping rate of 100 gallons per minute, (2) a straight-line boundary 1,000 feet away, and (3) a second pumping well 3,000 feet away, the total drawdown in the Magnolia well at the end of 1,000 days of continuous pumping should not exceed 41 feet, and the total pumping lift should be less than 91 feet to the land surface.

The above analysis does not consider recharge. Presumably, before the 1,000-day pumping period assumed in the analysis had elapsed, recharge from precipitation or other sources would replace the water pumped from the well.

Test of Terrace Deposits

The pumping test on ground water in terrace deposits was made at the Chickasha airport water well (7N7W-8-2), northwest of Chickasha, on February 26-28, 1946. The well derives water from deposits underlying the second terrace along the Washita River. These deposits are typical of such deposits in the area of this report. They are an isolated remnant of extensive alluvial sediments that formerly extended east and west across the area in the valley of the Washita River. Similar sediments were laid down in the Canadian River valley. The deposits are composed of highly cross-bedded fluvial sands and gravels, lenticular in cross section, overlain in most places by a thick layer of sandy clay. The coarsest materials are generally found in the lower part of the deposit but locally occur higher. The terrace deposit is high enough above the present river to be unaffected by the stage of the stream or the height of the water table under the bottom lands. The terrace deposits are an independent hydrologic unit. They are underlain by impermeable beds, and the water is under water-table or at least semi-artesian conditions.

Three wells of similar construction and about 125 feet apart supply water for the Chickasha airport. The wells were constructed by drilling 24-inch holes to a depth of 80 feet below the land surface, inserting 10-inch casing to the bottom, and filling the annular space outside the casing with gravel. The bottom 10 feet of the casing was perforated. The wells are equipped with turbine pumps, which are operated automatically by a float switch in an elevated storage tank.

As reported by driller R. D. Sawyer, the wells penetrate 42 feet of red clay underlain by 38 feet of sand grading down into gravel.

At the time of the test, the water requirements of the airport were small, and the pumps were operated infrequently. For testing purposes, the middle well was disconnected from the flow line. Water was discharged from it into a stock tank 7 feet in diameter set in the ditch along nearby U. S. Highway 81. The rate of discharge of the pump was obtained by measuring the rate of filling the stock tank, timed by stopwatch.

The first discharge measurement was made immediately after the pump was started and the second was made 35 minutes later. For the next three hours measurements were made at about half-hour intervals, and thereafter to the end of the test they were made hourly. The discharge ranged from 60 to 63 gallons per minute and averaged 61.5 gallons per minute. As the measurements are believed to be accurate to within one gallon, it is plain that the discharge was nearly constant.

Of two other wells nearby, only the one south of the pumped well could be used for observation of ground-water fluctuations. A long period of such observations prior to the pumping test was unobtainable because of the intermittent pumping actuated by the automatic switch. To provide an approximation of the static water level, this switch was opened 2 hours before pumping was to begin. After 1 hour the water level in the observed well had risen 0.05 foot; and in the last half hour it did not change. Pumping began at 3:30 p. m. on February 26 and was continuous until 3:30 p. m. on February 27, a period of 24 hours.

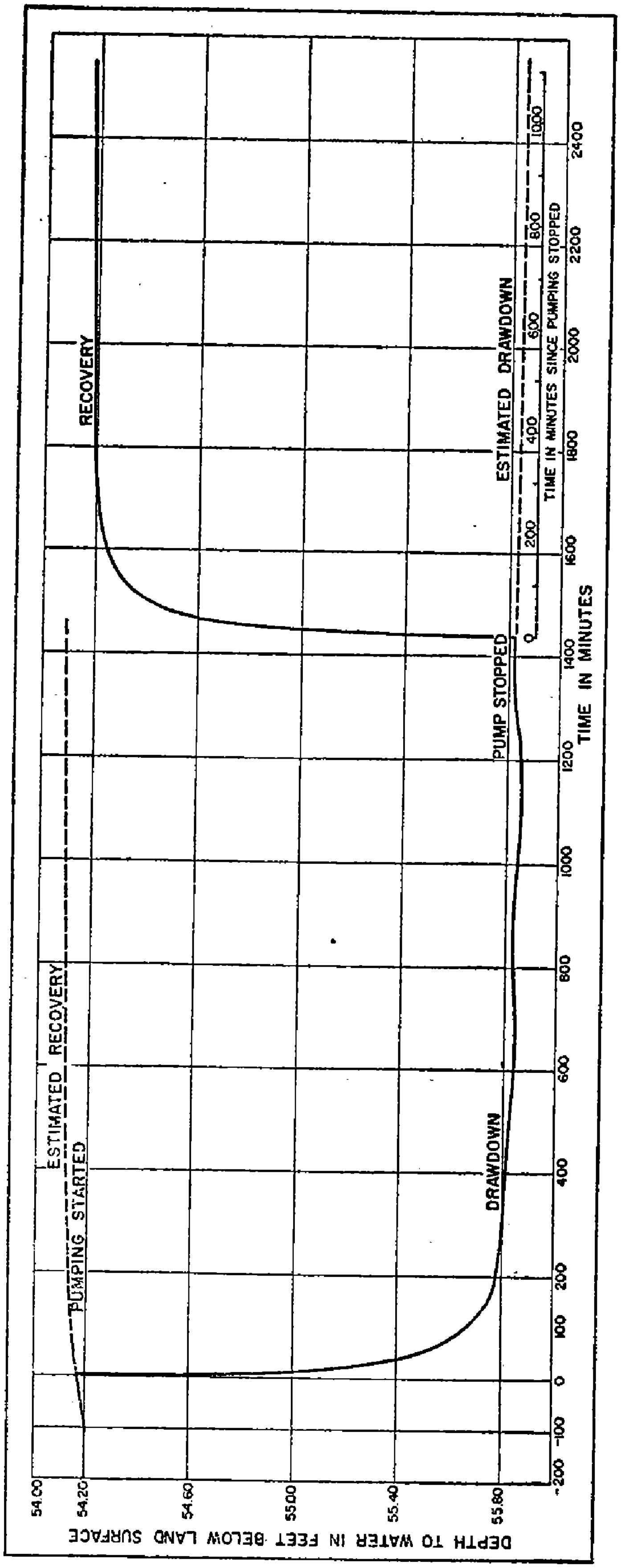


FIG. 10. Fluctuations of water level in the Chickasha airport water well 1 produced by pumping well 2, Grady County, Oklahoma.

Measurements in the observation well were made at 2-minute intervals for half an hour after pumping began and at lengthening intervals thereafter until the 9th hour. For the last 15 hours they were made hourly. During the first 20 hours of pumping, the water level in the observation well declined 1.68 feet, and during the next 4 hours rose 0.03 foot. Measurements of water level were made for about 20 hours after pumping ceased, followed approximately the same schedule as during pumping, and showed a rise to within 0.02 foot of the starting level (fig. 10).

Both the drawdown and recovery of water level were analyzed by the Theis formula to obtain values for the coefficients of transmissibility and storage. The average transmissibility was 18,500 gallons per day per foot and the average coefficient of storage was 2.0×10^{-3}. These values indicate the order of magnitude of the coefficients for the rather small area of terrace deposits at the airport for a short pumping period, and they are not to be regarded as precise. The value of the coefficient of storage, 2.0×10^{-3}, indicates that semiartesian or "leaky aquifer" conditions existed at least during the period of the test, but too few wells were available for observation of ground-water fluctuations in the vicinity of the pumped well to analyze the effect accurately. In the one observed well, an anomalous rise in water level amounting to 0.03 foot occurred during the last four hours of the test. In consequence, the drawdown plotted as a curve on log-log paper corresponds to the ideal drawdown curve for only the early part of the pumping test.

The terrace deposits at the Chickasha airport are capable of yielding considerably more water to a well than the 60 gallons per minute actually pumped during the test, and several such wells could be supplied without causing excessive drawdowns. The yields of individual wells, however, are not the limiting factor in the long-term yield of the aquifer. The supply of water that is perennially available is governed by the rate of replenishment, or recharge, and this rate is believed to be rather low. Davis (1950, p. 22) made a study of the recharge in the Pond Creek basin, northwest of Fort Cobb, for the 2-year period October 1, 1947 through September 30, 1949, and concluded that only about 3 percent of the annual precipitation went into recharge. His estimate is preliminary only, but it affords a starting point for a rough appraisal of the possible recharge at the airport. The nearest Weather Bureau station to the airport is Chickasha where the annual precipitation averages 30.81 inches. If 3 percent of this precipitation goes into recharge, the replenishment at the airport is 0.92 inch per year. This amounts to about 3,350 cubic feet per acre, or about 25,000 gallons.

The terrace deposits at the airport underlie an area of about 868 acres, and this, therefore, is the maximum area through which recharge may take place. For this area, the recharge would be about 22,000,000 gallons a year, a supply more than adequate for the needs of the airport. In terms of continuous pumping, however, it amounts to only about 42 gallons per minute. For the city of Chickasha, for example, it would be quite inadequate. At the average rate of municipal pumpage in 1949—1,674,000 gallons per day (Laine, Schoff, and Dover, 1951, p. 24) —the perennial supply in the terrace deposits at the airport would last the city only about 13 days.

FLUCTUATIONS OF GROUND-WATER LEVEL

As previously stated, the water table is not a stationary surface, but fluctuates up and down in response to gain or loss of water in the aquifer. The rise or fall in the water levels in wells therefore shows to what extent the ground-water reservoir is being depleted or replenished. Much publicity has been given to reports of continued decline of the water table over the United States. In some areas, large quantities of water have been pumped from the ground, exceeding the annual recharge and causing a serious decline of the water table. In Grady and northern Stephens Counties, no such pumpage or decline is discernible. Measurements of depth to water have been made regularly in 11 wells in the area since 1946, and other wells have been measured for shorter periods. A recording gage has been operated in one well, which taps water in the Rush Springs sandstone, since June 1948. The average of the water levels in the 11 wells is shown graphically on figure 11, which gives, also, the precipitation at Marlow.

Fluctuations of ground-water level due to natural causes

The rise and fall of the water table is governed by the rate at which the aquifer receives recharge and the rate at which the ground

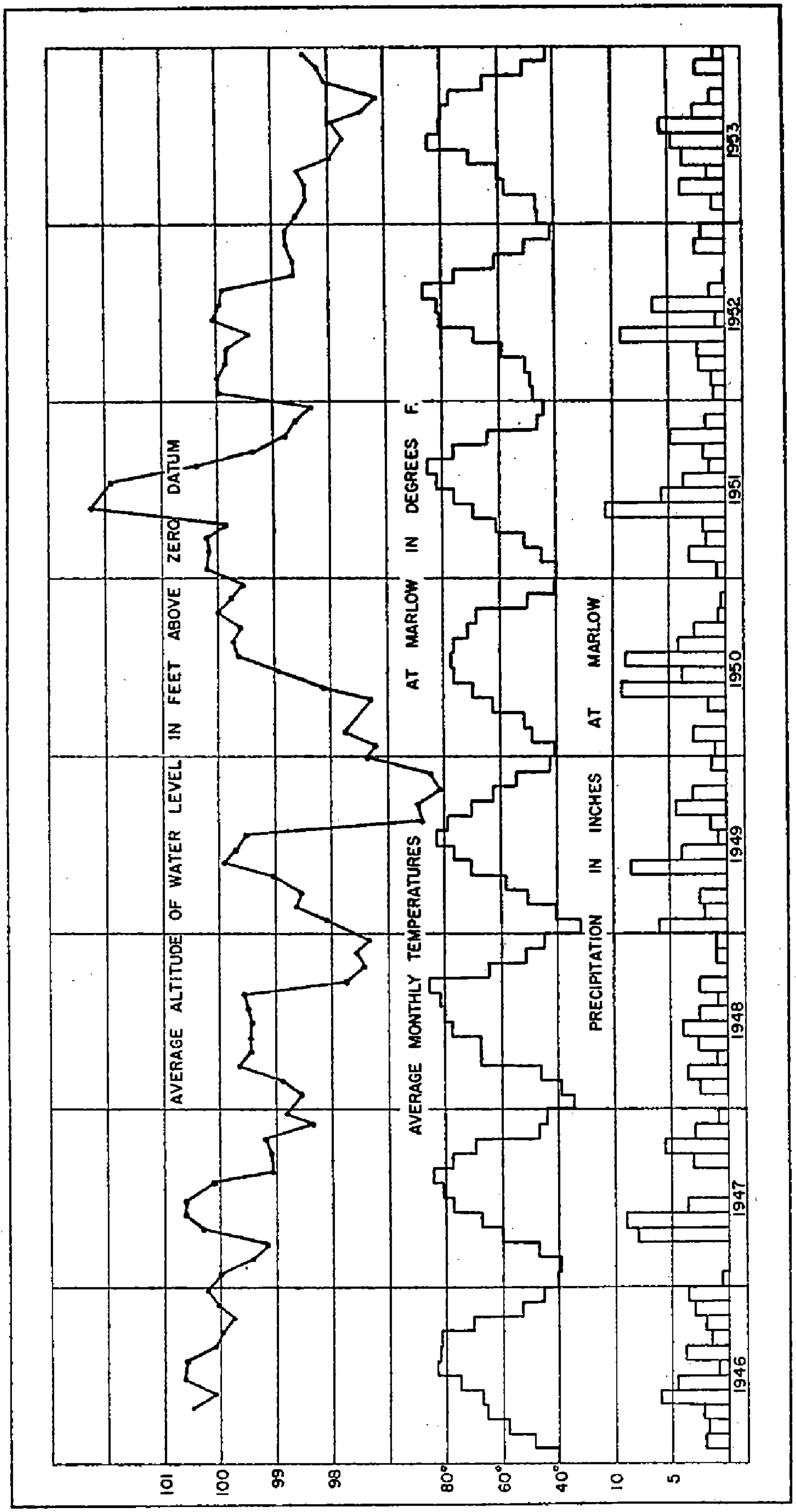


FIG. 11. Graph of water-level fluctuations in observation wells.

water is discharged. The position of the water table at any given time is the net result of the varying effect of recharge and discharge. Under natural conditions over long periods of time the recharge is in approximate balance with the natural discharge. Where there is little or no pumpage the fluctuations generally follow a seasonal pattern, being high during or following that part of the year when precipitation is relatively great, and low after precipitation has been small, or deficient (fig. 11). The peak level of the water table may lag several weeks or even months behind the wet season if the water table is far beneath the surface, or the rocks are so impermeable that the rate of infiltration is very slow.

Although precipitation is the principal factor controlling the elevation of the water table, the relation between the amount of precipitation and the level at which the water stands in wells is complicated by other natural factors. Thus, in addition to precipitation, the rise or decline of water level in Grady and northern Stephens Counties is determined by the amount of ground water discharged by springs and seeps, the amount lost by transpiration by plants, the amount lost by direct evaporation, and the amount of ground water that enters the area by underground seepage. If the recharge exceeds the discharge, as during periods of excessive precipitation, the water table will rise, resulting eventually in increased discharge from springs, seeps, and by evaporation and transpiration. Conversely, if the precipitation is below normal the ground water loss through natural causes tends to decline to below normal values.

DAILY FLUCTUATIONS

A continuous record of water level is available from only one well in the area of this report. This well (4N8W-33) penetrates the Rush Springs sandstone and shows a marked daily fluctuation of water level (fig. 12). Although the Rush Springs sandstone is considered a water-table aquifer in this area—that is, the water in it is not confined by an overlying impermeable formation—the daily fluctuations of ground-water level in it seem to be due in part to changes in barometric pressure, as is commonly true of artesian aquifers. This artesian-like behavior of the water in the Rush Springs sandstone is demonstrated by an experiment made on a well in Caddo County, just west of Grady County, Oklahoma.

During a 5-day period in May 1948, a microbarograph was operated near Caddo County well 8N13W-11, in which an automatic water-stage recorder provided a continuous record of the ground-water level. When converted to the amplitude of a barometer using water instead of mercury and inverted, the barometric fluctuations closely resemble the fluctuations of the hydrograph, except that the vertical range is somewhat greater (fig. 13).

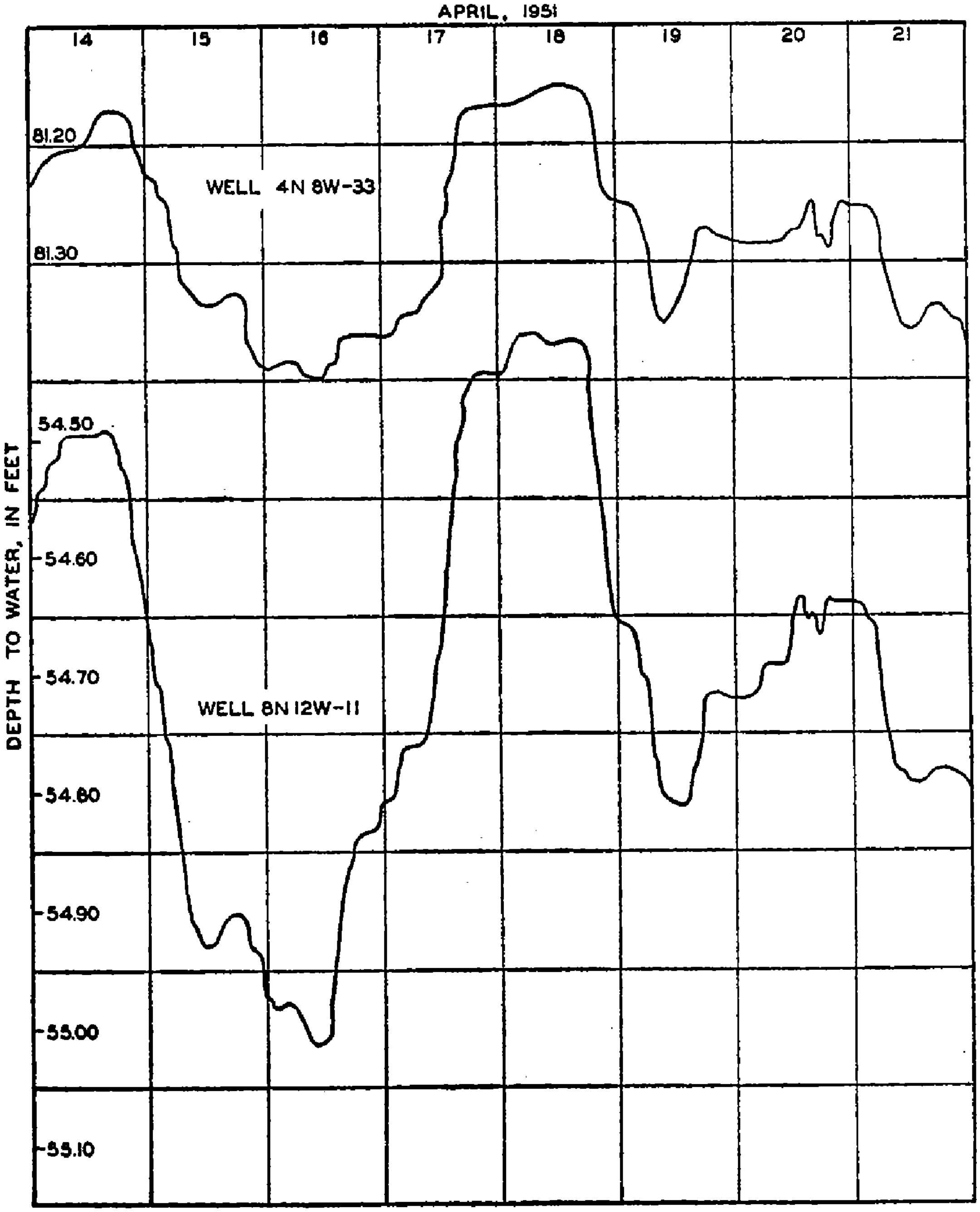


FIG. 12. Comparison of hydrographs of well 8N12W-11 and well 4N8W-33.

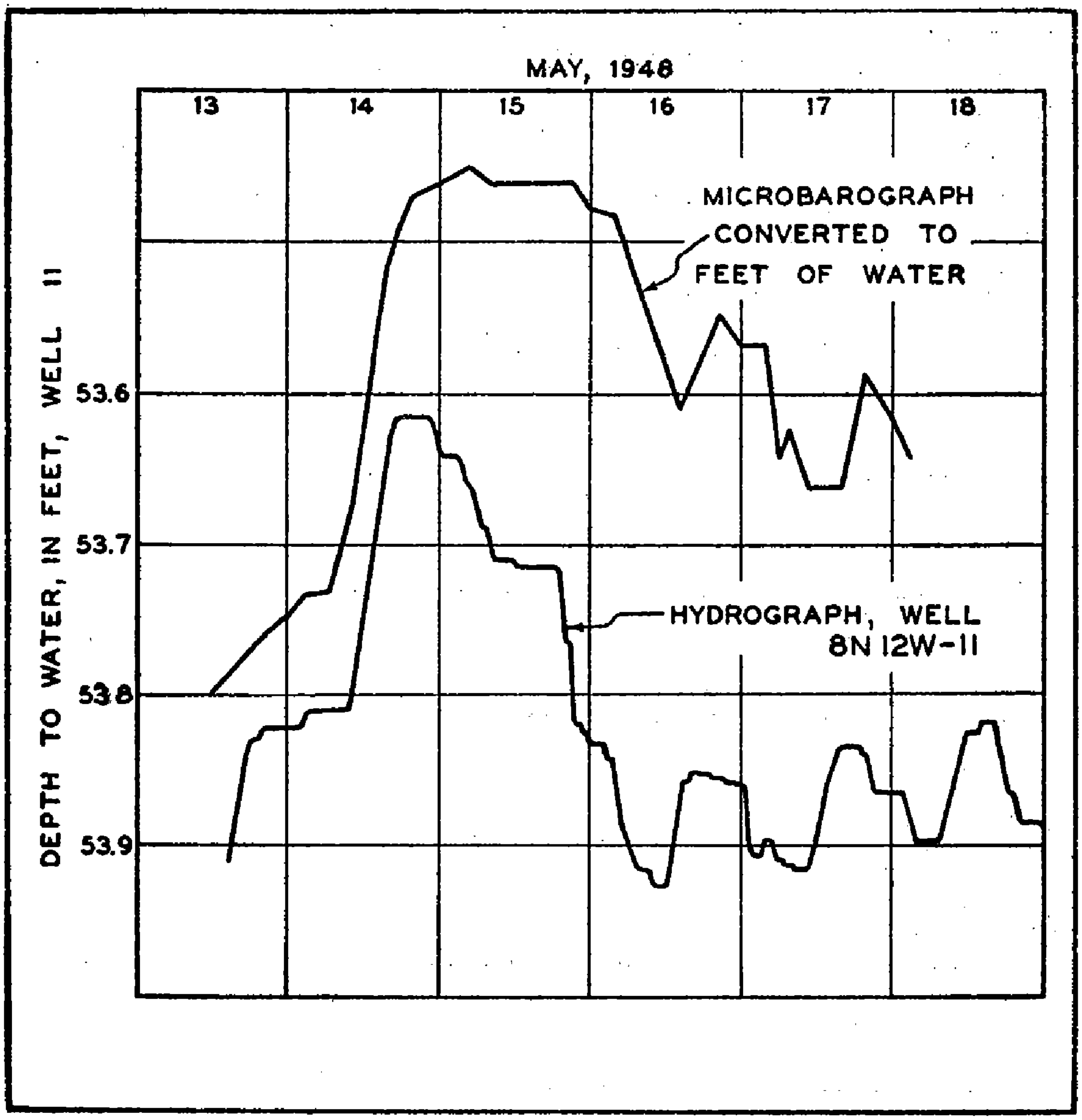


FIG. 13. Comparison of hydrograph with barometric fluctuations.

Likewise, the hydrographs for Caddo County well 8N12W-11 and Grady County well 4N8W-33 for the period April 14-21, 1951, are strikingly similar even in small details, although the two wells are approximately 35 miles apart (fig. 12). As no heavy pumping was in progress anywhere in the area, changes in barometric pressure seem to offer the only plausible explanation for the fluctuations and the close similarity of the hydrographs. The Rush Springs sandstone is very fine grained, and pressure changes doubtless move much more speedily down wells than through the interstices of the rock. The result is a pressure differential between the water in the well and that in the rock, which is equalized by the movement of a small quantity of water from the well into the rock or vice versa. This movement appears as a rise or fall of the water level in the well.

ANNUAL FLUCTUATIONS

Measurements of water levels in wells during the 6-year period 1946 to 1951, inclusive, show the ground-water level in Grady and northern Stephens Counties to have been generally high during June and July (fig. 11). The high peaks occur in response to average yearly periods of maximum precipitation. The peak ground-water level lags behind the period of heaviest precipitation because of the depth of the water table below the ground and the time consumed in the percolation of the water down to the water table. Where the water table is close to the land surface its response to precipitation is rapid and large, and where the water table is comparatively far beneath the surface its response to precipitation is slower and smaller.

In the area of this report, the ground-water level generally begins to rise shortly after the first of the year in response to heavier precipitation, and in March or April the rate of rise increases sharply. The spring rains are typically slow and steady and thus favor infiltration of water into the ground. The spring rise continues until about July, when the yearly decline begins. This decline follows a decrease in recharge, which in turn is due to less precipitation coupled with accelerated evaporation and transpiration. Generally, little or none of the summer and fall rain reaches the water table.

The late fall and winter rains do not have as much effect on the water levels as the spring rains because by fall there is a general deficiency in soil moisture. The soil and bedrock above the water table hold a considerable amount of water by molecular attraction, on the individual particles and in very small voids. This water does not percolate downward to the water table. By autumn much of it for many feet below the surface has been transpired or evaporated and must be replaced before any water can penetrate to the water table. The process of replacement consumes most of the winter rain that sinks into the ground. Thus, while the winter rains do not always cause the water table to rise, they do pave the way for the yearly spring rise of the water table.

Fluctuations of ground-water level due to artificial causes

Removal of ground water from the earth whether by means of wells, improvement of springs, or by deep drainage ditches, will tend to lower the ground-water level. Thus, the ground-water level can be used as an index of the amount of water removed from the ground. However, in Grady and northern Stephens Counties, wells are so scattered and pumpage is in such small amounts that its effect on the ground-water level is not discernible.

COMPOSITION OF GROUND WATER

All natural waters contain mineral matter dissolved from the rocks and soils with which they have come in contact. The quality of dissolved mineral matter in the water depends primarily on the type of rock or soil through which the water has passed, the length of time of contact, and the pressure and temperature conditions. In addition to these natural factors are others connected with human activities, such as use of streams and wells for disposal of sewage and industrial waste, diversion and use of water for irrigation of croplands and many other purposes, and drainage from oil fields.

The mineral constituents and physical properties of ground waters reported in the analyses are those having a practical bearing on the value of the waters for most purposes: silica, iron, calcium, magnesium, sodium, potassium (or sodium and potassium reported together as sodium), carbonate, bicarbonate, sulfate, chloride, fluoride, nitrate, dissolved solids, hardness, specific conductance, and temperature (table 13). The source and significance of these different constituents and properties of ground waters are discussed in the following paragraphs, which are adapted from publications of the Quality of Water Branch of the U. S. Geological Survey.

SILICA

Silica is dissolved from practically all rocks. Some ground waters contain less than 5 ppm of silica and a few contain more than 50 ppm. Silica affects the usefulness of a water because it contributes to the formation of boiler scale. It is usually removed from feedwater for high-pressure boilers. Silica also forms troublesome deposits on the blades of steam turbines. Silica was determined in two water samples from Grady County and found to be 20 ppm from terrace deposits and 18 ppm from the Chickasha and Duncan formations.

IRON

Iron is dissolved from many rocks and soils. On exposure to the air, normal waters that contain more than a few tenths of a part per million of iron soon become turbid with the insoluble reddish ferric oxide produced by oxidation. Iron causes reddish-brown stains on white porcelain or enameled ware and fixtures and on clothing or other fabrics washed in the water. The iron content of the ground waters in Grady County and northern Stephens County was not determined.

CALCIUM

Calcium is dissolved from practically all rocks, but the highest concentrations are usually found in waters that have been in contact with limestone, dolomite, or gypsum. Calcium and magnesium make water hard and are largely responsible for the formation of boiler scale. Ground waters tested for this report contain 10 to 541 ppm of calcium.

MAGNESIUM

Magnesium is dissolved primarily from dolomitic rocks. Like calcium it causes hardness of water. The magnesium in soft waters may amount to only 1 or 2 parts per million. Most of the ground waters in Grady County have been in contact with dolomitic or other magnesium-bearing rocks and contain 6 to 197 ppm of magnesium.

SODIUM AND POTASSIUM

Sodium and potassium are dissolved from practically all rocks. Natural waters that contain only 3 or 4 ppm of the two together are likely to carry almost as much potassium as sodium. As the total quantity of these constituents increases, the proportion of sodium becomes much greater. Moderate quantities of sodium and potassium have little effect on the usefulness of the water for most purposes, but water that contains more than 50 to 100 ppm of the two may require careful operation of steam boilers to prevent foaming. More highly mineralized waters in which the proportion of sodium is high in relation to all the other basic constituents may be unsatisfactory for irrigation. The amount of sodium present in drinking water is watched carefully by doctors in treatment of patients with heart disorders, as such patients are usually placed on a diet containing little sodium salts. Ground waters analyzed for this report range from 1.6 ppm to 779 ppm of sodium and potassium together.

CARBONATE AND BICARBONATE

Carbonate as such is not present in appreciable quantities in most natural waters. Bicarbonate occurs in waters largely through the action of carbon dioxide, which enables the water to dissolve carbonates of calcium and magnesium. Bicarbonate in moderate concentrations in water has no effect on its value for most uses. Together they ranged from 67 to 772 ppm.

SULFATE

Sulfate is dissolved from many rocks and soils and in especially large quantities from gypsum and beds of shale. It is also formed by the oxidation of sulfides of iron. Sulfate in water that contains much calcium and magnesium causes the formation of hard scale in steam boilers and may increase the cost of softening water. The sulfate content of ground waters tested for this report ranged from 3 ppm for water from the Rush Springs sandstone to 2,030 ppm in a sample of water from the Chickasha formation.

CHLORIDE

Chloride is present in all waters, being dissolved from rocks or from natural salt deposits. Sodium chloride is a common constituent in sewage, and any appreciable pollution is marked by an increase of chloride. Chloride in appreciable quantities in water for processing foodstuffs or beverages tends to give a salty taste, and excessive concentrations must be avoided. Water used for human consumption should not contain more than 250 ppm of chloride according to Public Health Service drinking water standards. (Public Health Reports, 1946). In some ground waters sodium chloride is the principal chemical constituent and occurs in such concentrations as to cause the water to be unsatisfactory for most industrial, agricultural, and domestic uses. In ground waters analyzed for this report the chloride ranged from 3.8 ppm to 825 ppm.

FLUORIDE

The importance of fluoride in water for domestic use is becoming more widely recognized (Warkentin, 1942, p. 65-81). In concentrations up to about 1 ppm, fluoride in drinking water has been shown to be beneficial in the prevention of tooth decay in growing children (Dean, 1936). As the concentration increases much above 1.5 ppm, fluoride may cause children's teeth to become mottled, stained, and disfigured. The fluoride content of ground waters tested in Grady and northern Stephens Counties ranged from 0.1 to 0.8 ppm.

NITRATE

Nitrate in water is considered a final oxidation product of nitrogenous material and, in some instances, may indicate previous contamination by sewage or other organic matter. Quantities of nitrate exceeding 45 ppm have been associated with cyanosis in infants ("blue babies") who drink such water (Nelson and Sanders, 1951), and it has been reported that as much as 2 ppm of nitrate in boiler water tends to decrease intercrystalline cracking of boiler steel. The nitrate of ground waters tested in Grady County and northern Stephens County ranged from 0.2 ppm to 352 ppm.

DISSOLVED SOLIDS

The residue left on evaporation of water consists primarily of the mineral constituents that were dissolved and in the water, and it may also contain some organic matter and water of crystallization. These are reported as dissolved solids. Most waters containing less than 500 parts per million dissolved solids are satisfactory for domestic and some industrial uses. The concentration of the dissolved solids in the ground waters tested for this report ranged from 115 to 1,440 ppm.

HYDROGEN-ION CONCENTRATION

The acidity or alkalinity of water is indicated by the hydrogen-ion concentration, expressed in terms of the pH. This value is useful in determining the proper treatment for coagulation that may be necessary at water-treating plants. A pH of 7.0 indicates that the water is neutral, being neither acid nor alkaline. Values below 7.0 denote acidity, whereas values above 7.0 denote alkalinity. The pH values were not determined for the ground waters analyzed for this report. However, the carbonate and bicarbonate concentrations indicate that the pH value of ground water in this area will normally exceed 7.0.

SPECIFIC CONDUCTANCE

The specific conductance of a water is a measure of its ability to conduct a current of electricity. The conductance varies with the concentration and degree of ionization of the different minerals in solution and with the temperature of the water. The specific conductance value as an indication of the total mineral content is used in selecting a water for use in irrigation. Generally the dissolved solids content, in parts per million, is roughly 0.8 times the specific conductance in micromhos. Ground waters tested for this report show specific conductance from a low of 35.5 to a high of 2,200 micromhos at 25°C.

HARDNESS

Hardness is the characteristic of water that receives the most attention with reference to industrial and domestic use. It is usually recognized by the quantity of soap required to produce lather. Hard water is objectionable because it forms a scale in boilers, water heaters, radiators, and pipes, thereby decreasing the rate of heat transfer and creating the possibility of boiler failure and loss of flow. Hardness is caused almost entirely by compounds of calcium and magnesium. Other constituents such as iron, manganese, aluminum, barium, strontium, and free acid also cause hardness, but they are not found in appreciable quantities in most natural waters. Water that has a hardness of less than 50 parts per million is usually rated as soft, and its treatment for removal of hardness is seldom justified. Hardness between 50 and 150 parts per million does not seriously interfere with the use of water for most household uses, but softening may be profitable for laundries and other industries. When hardness exceeds 150 parts per million. softening is generally desirable for most uses. The hardness of the ground waters in Grady and northern Stephens Counties ranges from 58 to 1,650 ppm in the samples tested.

CORROSIVENESS

The corrosiveness of a water is that property which makes it aggressive to metal surfaces. Oxygen, carbon dioxide, free acid, and acid-generating salts are the principal corrosive constituents in water. In a general way, very soft waters of low mineral content are more corrosive than hard waters containing appreciable quantities of carbonates and bicarbonates of calcium and magnesion. A corrosive water, which is generally one of low pH, typically attacks iron, resulting in "red water." Corrosion causes the deterioration of water pipes, steam boilers, and water-heating equipment. Many waters that do not appreciably corrode cold-water lines will aggressively attack hot-water lines, owing to the change in chemical composition of the heated water.

TEMPERATURE

With the great expansion in air conditioning and the continued importance of water in industrial cooling processes, the temperature of water supplies has become one of the most important physical characteristics to be considered in a water supply. The temperature of ground water at depths more than about 30 feet generally varies only slightly during the year, being likely to be a degree or two higher than the mean annual air temperature (Van Orstrand, 1935, p. 88). However, where static water levels are near the surface the water temperature may fluctuate somewhat with the seasonal variations of air temperature, and some temperature change may result from infiltration from streams or artificial recharge of warm air-conditioning water to the ground-water aquifer. McCutchin (1930, p. 20) found the lowest temperature in a well generally is about 100 feet below the surface. Below the 100-foot level the temperature of the ground water increases with depth because the temperature of the rocks of the earth increases downward.

The average temperature of the ground water as discharged at forty-four wells in Grady County was 61.0° F.—measured with a field pocket thermometer (table 13). The lowest temperature was 59° F. and the highest temperature was 72° F.

TABLE 13.

ANALYSIS OF WATER FROM WELLS AND SPRINGS IN GRADY AND STEPHENS COUNTIES, OKLA.

[Analytical results in parts per million except as indicated]

Location Well No.	Depth (feet)	Aquifer	Date of collection	Temperature (°F)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na) + Potassium (K)	Bicarbonate (HCO_3)
T. 3 N., R. 5 W.									
3N5W-4	91	Duncan sandstone	6-10-47	63	....	33	54	48	238
3N5W-8	250	........do........	7-15-50	68	....	12	36	37	236
T. 3 N., R. 7 W.									
3N7W-16	60	Rush Springs sandstone	4- 3-46	61.5	....	66	24	24	360
3N7W-17-2	70	........do........	....do....	61	....	55	19	57	344
3N7W-26	200	........do........	7-28-48	61	....	62	27	40	155
3N7W-26-2	200	........do........	....do....	61	....	....	....	....	148
T. 3 N., R. 8 W.									
3N8W-2	100	Rush Springs sandstone	1-23-46	60.5	....	68	44	44	192
3N8W-3-1	53	........do........	....do....	60	....	78	78	28	326
3N8W-4	40	........do........	4- 5-46	....	....	68	37	49	163
3N8W-9	95	........do........	....do....	60.5	....	83	15	17	160
3N8W-15	45	........do........	....do....	....	....	....	....	....	114
T. 4 N., R. 7 W.									
4N7W-3-1	122	Rush Springs sandstone	12-23-48	60	....	87	14	12	257
4N7W-5	21	........do........	1-24-46	59	....	90	10	6.2	278
4N7W-9-1	97	........do........	2- 4-46	59	....	61	7.5	34	250
4N7W-16	41	........do........	....do....	60	....	29	14	21	74
4N7W-29-1	20	........do........	4- 5-46	....	....	100	46	3.2	207
4N7W-29-2	25	........do........	7- 7-50	....	....	88	19	17	229
T. 4 N., R. 8 W.									
4N8W-10	100	Rush Springs sandstone	4- 5-46	62	....	48	12	70	196
4N8W-14	105	........do........	4- 6-46	....	....	68	16	20	276
4N8W-15	18	........do........	4- 4-46	60.5	....	57	29	29	248
4N8W-17	50	........do........	4- 5-46	62	....	299	57	78	192
4N8W-20	80	........do........	4- 5-46	61	....	279	13	110	118
4N8W-23-1	40	........do........	2- 6-46	60	....	364	33	22	198
4N8W-23-2	60	........do........	2- 7-46	59.5	....	100	17	1.6	199
4N8W-23-3	60	........do........	2- 7-46	60	....	37	22	59	312
4N8W-23-4	31	........do........	4- 4-46	60.5	....	144	20	163	137
4N8W-25-1	14	........do........	2- 6-46	60.5	....	10	8.1	18	96
4N8W-26	60	........do........	....do....	59	....	68	28	94	288
4N8W-27	40	........do........	4- 4-46	61	....	64	17	15	203
4N8W-28-1	Spring	........do........	....do....	61.5	....	274	20	9.7	238
4N8W-28-2	33	........do........	....do....	61	....	63	30	62	150
4N8W-29	46	........do........	4- 4-46	61.5	....	215	22	9.2	254
4N8W-33-1	53	........do........	8- 3-46	....	....	82	20	23	224
4N8W-33-1	148	........do........	....do....	....	....	304	20	46	90
4N8W-33-1	252	........do........	....do....	....	....	541	31	144	99
4N8W-36	72	........do........	2- 6-46	60	....	58	22	19	278

TABLE 13.—(Continued)

ANALYSIS OF WATER FROM WELLS AND SPRINGS IN GRADY AND STEPHENS COUNTIES, OKLA.

[Analytical results in parts per million except as indicated]

Carbonate (CO$_3$)	Sulfate (SO$_4$)	Chloride (Cl)	Fluoride (F)	Nitrate (NO$_3$)	Dissolved solids		Hardness as CaCO$_3$		Percent sodium	Specific conductance (micromhos at 25°C)
					Residue on evaporation at 180°C	Sum	Calcium magnesium	Noncarbonate		
T. 3 N., R. 5 W.										
7	27	108	0.1	28	570	....	304	98	26	979
9	11	26	....	1.7	264	249	178	0	31	462
T. 3 N., R. 7 W.										
0	3	9	....	5	335	....	263	....	....	....
0	13	17	....	25	378	....	216	....	....	....
0	14	109	0.2	70	429	398	266	138	25	706
....	15	114	0.6	70	....	....	263	....	....	674
T. 3 N., R. 8 W.										
0	21	43	....	255	704	....	350	....	....	....
0	68	61	....	189	748	....	515	....	....	....
0	13	64	....	236	694	....	322	....	....	....
0	60	32	....	84	487	....	268	....	....	....
0	68	102	....	352	....	....	596	....	....	....
T. 4 N., R. 7 W.										
0	53	23	....	4	365	320	274	64	9	560
0	24	12	....	11	344	....	266	....	....	....
0	15	8	....	30	329	....	183	....	....	....
0	14	53	....	33	305	....	130	....	....	....
0	176	54	....	21	603	....	438	....	....	....
0	95	26	....	14	463	372	298	110	11	625
T. 4 N., R. 8 W.										
0	14	12	....	223	476	....	170	....	....	....
0	12	18	....	19	342	....	236	....	....	....
0	95	10	....	9	420	....	262	....	....	....
0	449	183	....	330	1,490	....	980	....	....	....
0	591	183	....	24	1,260	....	750	....	....	....
0	876	9	....	5.5	1,400	....	1,040	....	....	....
0	140	5	....	9.6	436	....	320	....	....	....
0	31	7	....	17	327	....	183	....	....	....
0	532	43	....	86	1,060	....	442	....	....	....
0	10	4	....	2	115	....	58	....	....	....
0	221	8	....	1	558	....	274	....	....	....
0	46	9	....	43	367	....	230	....	....	....
0	536	8	....	28	993	....	766	....	....	....
0	60	36	....	211	638	....	280	....	....	....
0	385	10	....	30	874	....	627	....	....	....
0	224	34	0.1	5	456	370	286	103	15	584
0	777	40	0.4	1	1,640	1,230	840	767	11	1,660
0	1,570	52	0.4	0.2	....	2,390	1,480	1,400	17	2,200
0	12	6	....	33	306	....	235	....	....	....

Location Well No.	Depth (feet)	Aquifer	Date of collection	Temperature (°F)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na) + Potassium (K)	Bicarbonate (HCO_3)
T. 5 N., R. 5 W.									
5N5W-18	300+	Duncan sandstone	7-13-50	64	....	29	40	29	286
5N5W-20	72	........do........	6-10-47	64	....	38	67	56	207
5N5W-36	36	Terrace sediments	....do....	....	....	80	109	26	588
T. 5 N., R. 6 W.									
5N6W-12	105	Terrace sediments	8- 4-51	....	26	102	84	35.4	604
T. 5 N., R. 7 W.									
5N7W-33	92	Rush Springs sandstone	1-24-46	61	....	77	6.6	6.2	220
T. 5 N., R. 8 W.									
5N8W-14-1	379	Duncan sandstone	8-29-45	65	....	52	11	181	202
5N8W-14-2	392	........do........	3-29-46	63	18	62	14	171	250
5N8W-22	420	........do........	1- 5-50	....	....	....	....	....	274
T. 6 N., R. 5 W.									
6N5W-16	80	Chickasha formation	7-30-50	68	....	50	45	8.7	240
T. 6 N., R. 6 W.									
6N6W-36	29	Terrace sediments	6-10-47	64	....	40	197	53	626
T. 6 N., R. 7 W.									
6N7W-33	300	Duncan sandstone	7-29-50	72	....	98	36	279	180
6N7W-34	80	Chickasha formation	....do....	68	....	84	104	40	303
T. 6 N., R. 8 W.									
6N8W-18	80	Rush Springs sandstone	7-17-50	70	....	36	15	17	113
T. 7 N., R. 5 W.									
7N5W-4	32	Chickasha formation	6-10-47	....	....	20	40	68	321
T. 7 N., R. 6 W.									
7N6W-16	105	Chickasha formation	6-10-47	....	....	26	61	7.4	292
7N6W-27	185	........do........	....do....	....	....	93	61	51	480
7N6W-32	200	........do........	7-30-50	70	....	46	54	79	306
T. 7 N., R. 7 W.									
7N7W-8	80	Terrace sediments	2-27-46	63	20	79	31	60	436
7N7W-26	24	........do........	6-10-47	....	....	31	24	137	219

TABLE 13.—(Continued)

ANALYSIS OF WATER FROM WELLS AND SPRINGS IN GRADY AND STEPHENS COUNTIES, OKLA.

[Analytical results in parts per million except as indicated]

Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids		Hardness as $CaCO_3$		Percent sodium	Specific conductance (micromhos at 25°C)
					Residue on evaporation at 180°C	Sum	Calcium magnesium	Noncarbonate		
					T. 5 N., R. 5 W.					
8	35	8.8	....	2.2	310	293	237	0	21	510
14	15	64	0	240	664	....	370	178	19	1,110
74	67	18	0.1	3	714	....	648	42	8	1,120
					T. 5 N., R. 6 W.					
0	65	63	0.2	16	720	690	600	105	10	1,130
					T. 5 N., R. 7 W.					
0	14	8	....	33	332	....	219	....	....	....
					T. 5 N., R. 8 W.					
10	322	36	....	....	717	....	175	....	....	....
0	307	36	0.2	....	758	731	212	....	63	1,100
....	....	40	....	....	....	....	193	....	....	....
					T. 6 N., R. 5 W.					
12	29	38	....	36	386	337	310	94	6	625
					T. 6 N., R. 6 W.					
73	134	85	0.2	160	1,120	1,050	910	274	10	1,950
					T. 6 N., R. 7 W.					
0	640	130	....	22	1,330	1,270	392	245	61	1,800
0	55	103	....	340	1,060	875	637	388	12	1,370
					T. 6 N., R. 8 W.					
0	64	13	....	14	264	215	152	59	20	375
					T. 7 N., R. 5 W.					
11	20	41	0.3	2	....	360	214	0	42	785
					T. 7 N., R. 6 W.					
17	14	17	....	32	407	....	316	48	5	789
63	60	22	0	1.5	648	....	403	0	19	965
15	161	40	....	11	598	557	337	61	34	904
					T. 7 N., R. 7 W.					
0	49	26	0	3	481	483	324	....	32	804
15	159	73	0.5	....	563	547	176	0	62	998

Location Well No.	Depth (feet)	Aquifer	Date of collection	Tem-pera-ture (°F)	Silica (SiO_2)	Cal-cium (Ca)	Mag-nesium (Mg)	Sodium (Na) + Potas-sium (K)	Bicar-bonate (HCO_3)
			T. 7 N., R. 8 W.						
7N8W-7	45	Alluvium	7- 6-50	....	....	40	65	34	266
			T. 8 N., R. 5 W.						
8N5W-9	38	Chickasha formation	6- 6-47	....	....	....	....	....	154
8N5W-25	70	........do........	4-23-48	60	....	99	59	49	456
8N5W-31	Spring	........do........	1-13-48	....	....	58	54	31	474
			T. 8 N., R. 6 W.						
8N6W-22	60	Chickasha formation	6- 6-47	....	....	10	21	88	219
			T. 8 N., R. 7 W.						
8N7W-23	40	Chickasha formation	6- 6-47	....	....	21	22	56	217
			T. 8 N., R. 8 W.						
8N8W-30	28	Terrace sediments	7-18-50	72	....	30	36	68	367
			T. 9 N., R. 5 W.						
9N5W-12	49	Duncan sandstone	6- 4-47	....	....	19	41	52	151
			T. 9 N., R. 6 W.						
9N6W-3	65	Terrace sediments	7- 5-50	....	....	71	19	28	148
9N6W-16	27	Chickasha formation	6- 4-47	....	....	34	14	25	159
			T. 9 N., R. 7 W.						
9N7W-22	42	Chickasha formation	6- 6-47	....	....	469	116	779	72
			T. 9 N., R. 8 W.						
9N8W-9	36	Rush Springs sandstone	6- 6-47	....	....	122	37	16	49
			T. 10 N., R. 5 W.						
10N5W-27	37	Terrace sediments	6- 6-47	....	....	41	12	14	126
			T. 10 N., R. 6 W.						
10N6W-22	27	Terrace sediments	6- 6-47	....	....	....	....	....	107
10N6W-28	49	........do........	4-20-48	61	....	60	34	43	211
10N6W-32	42	........do........	6-21-48	60.5	....	50	16	70	193
			T. 10 N., R. 7 W.						
10N7W-22	50	Alluvium	7- 5-50	....	....	61	14	12	199
			T. 10 N., R. 8 W.						
10N8W-34	34	Rush Springs sandstone	6- 6-47	....	....	34	13	11	105

TABLE 13.—(Continued)

ANALYSIS OF WATER FROM WELLS AND SPRINGS IN GRADY AND STEPHENS COUNTIES, OKLA.

[Analytical results in parts per million except as indicated]

Carbonate (CO$_3$)	Sulfate (SO$_4$)	Chloride (Cl)	Fluoride (F)	Nitrate (NO$_3$)	Dissolved solids		Hardness as CaCO$_3$		Per cent sodium	Specific conductance (micromhos at 25°C)
					Residue on evaporation at 180°C	Sum	Calcium, magnesium	Noncarbonate		
T. 7 N., R. 8 W.										
15	154	10	....	28	521	477	367	124	17	761
T. 8 N., R. 5 W.										
0	16	9	....	60	....	....	291	....	....	....
0	69	50	0	100	618	651	490	116	18	1,010
0	19	17	0	1.5	396	414	366	0	15	724
T. 8 N., R. 6 W.										
42	19	21	0.3	3	284	312	111	0	63	545
T. 8 N., R. 7 W.										
14	39	13	0.2	6	252	278	143	0	46	616
T. 8 N., R. 8 W.										
0	51	11	....	1.7	393	379	223	0	40	651
T. 9 N., R. 5 W.										
20	26	34	0	120	338	386	216	59	34	710
T. 9 N., R. 6 W.										
6	44	29	....	120	452	390	255	124	19	619
9	15	17	0.2	15	317	207	142	0	28	534
T. 9 N., R. 7 W.										
0	2,030	825	0.5	5	4,440	4,260	1,650	1,590	51	5,450
T. 9 N., R. 8 W.										
9	393	18	0.4	2	796	621	456	402	7	1,060
T. 10 N., R. 5 W.										
10	17	9	0.1	40	208	204	152	33	16	355
T. 10 N., R. 6 W.										
....	20	9	....	120	....	....	312	....	....	....
0	65	30	0.8	120	474	457	290	116	24	730
0	42	54	....	80	450	407	191	32	44	701
T. 10 N., R. 7 W.										
8	25	4	....	36	280	258	210	33	11	428
T. 10 N., R. 8 W.										
8	26	14	0.2	20	215	178	138	39	15	422

SUITABILITY FOR IRRIGATION

Whether a water is satisfactory for irrigation depends on several factors in addition to the mineral content of the water, among them the amount of water applied to the soil, the amount and distribution of rainfall, and the drainage and physical and chemical characteristics of the soil. The following paragraphs on this subject have been adapted from a publication by Wilcox (1948).

Any method for the interpretation of the analysis of water to be used for irrigation is based on the presumption that the water will be used under average conditions as related to quantity, soil permeability, drainage, climate, and crops.

All waters used for irrigation carry varying quantities of chemicals that are referred to as dissolved salts. If their concentration is not too great, some of the dissolved salts favor the growth of plants; others are harmful to plant growth and to soils. The total concentration of dissolved salts may vary from a few to many thousand parts per million, but most irrigation waters are in the range of 100 to 1,500 parts per million. The more important constituents of these waters are calcium, magnesium, and sodium, known as cations; and bicarbonate, sulfate, and chloride, known as anions. Potassium, carbonate, nitrate, silica, and boron are usually present, but ordinarily only in low concentrations. Small quantities of other substances may be found in some waters, but their effect on the quality of the water for irrigation is not important, and they are usually not considered in an analysis.

The diagram shown in figure 14 can be used in estimating the suitability of a water to be used in irrigation. Two factors, percentage of sodium and electrical conductivity, are considered. Sodium, if present in too large proportion in irrigation water, has an adverse effect on the physical properties of the soil. The percentage of sodium is calculated by the following formula, where calcium (Ca), magnesium (Mg), and sodium (Na) are expressed in parts per million:

$$\text{Sodium percentage} = \frac{\dfrac{\text{Na}}{23} \times 100}{\dfrac{\text{Ca}}{20} + \dfrac{\text{Mg}}{12.2} + \dfrac{\text{Na}}{23}}$$

NOTE: The denominators in the above equation are the combining weights of the individual constituents and their purpose of the formula is to convert parts per million to equivalents per million.

Values for percentage of sodium ranging from 0 to 100 appear on the left side of the diagram. The conductivity is the ability of a water to conduct electric current, and it varies with the amount and kinds of dissolved salts. It is a rough measure of the total mineral content (dissolved solids) in the water. In chemical analyses it is reported as specific conductance in micromhos at 25°C. Values for electrical conductivity appear along the bottom of the diagram.

To use the diagram, locate the point corresponding to the values for percent sodium and conductivity as shown in the analysis. The position of this point determines the quality classification to which the water is assigned.

The percentage of sodium and the electrical conductance of 40 samples of ground water are given in table 14. They have been used in plotting the positions of the waters on the diagram (fig. 14), which indicates that 19 waters can be classified as excellent to good; 16 as good to permissible; 3 as permissible to doubtful; 1 as doubtful to unsuitable; and 1 as unsuitable.

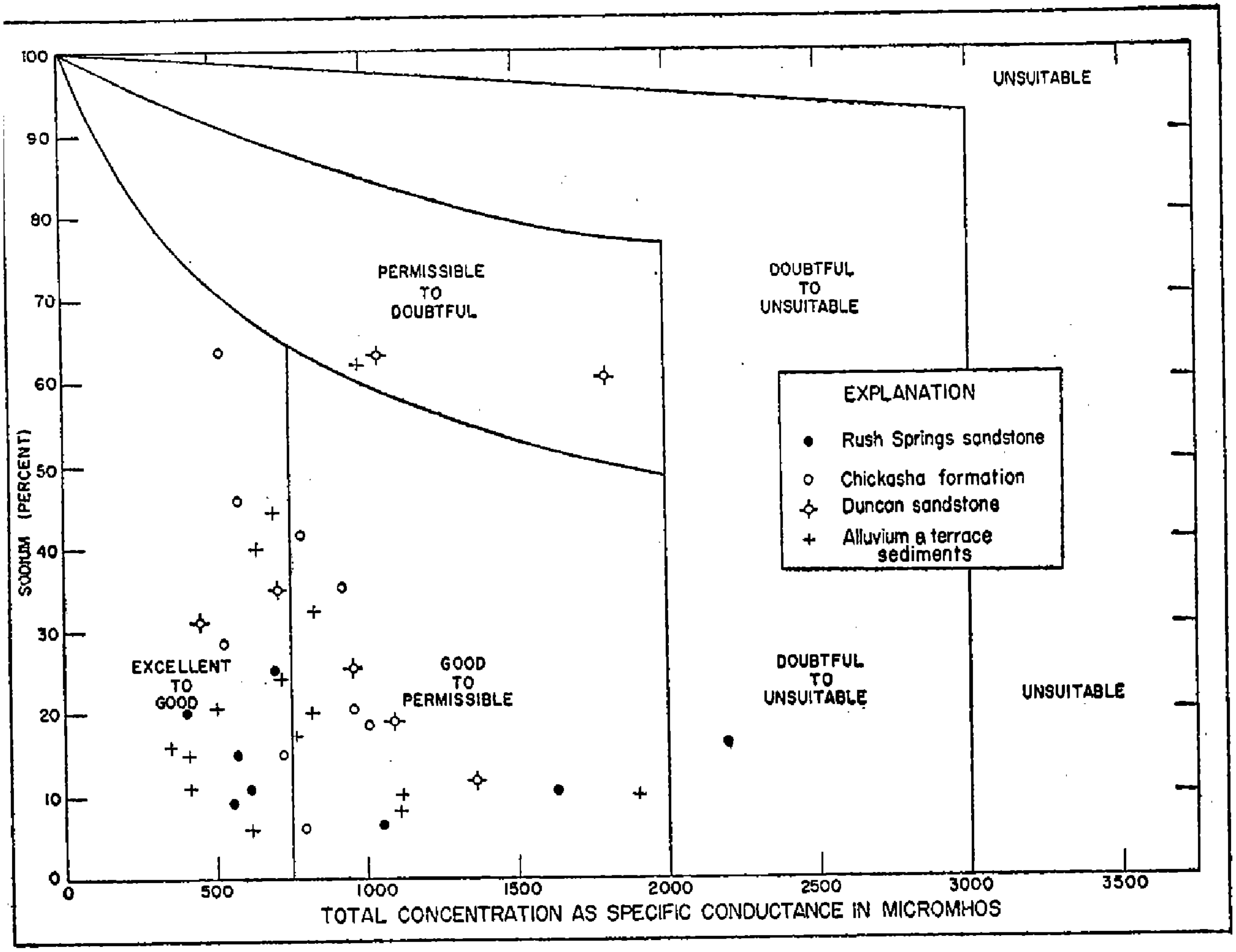


FIG. 14. Diagram for estimating the suitability of a water for irrigation use.

TABLE 14.

SPECIFIC CONDUCTANCE AND SODIUM PERCENTAGE OF GROUND WATER IN GRADY AND NORTHERN STEPHENS COUNTIES, OKLA.

Well number	Specific conductance (micromhos at 25° C.)	Percent sodium	Aquifer
3N5W- 4 SE¼SW¼	979	26	Duncan sandstone
3N5W- 8 W½ SE¼	462	31	................do............
3N7W-26 SW¼SW¼	706	25	Rush Springs sandstone
4N7W- 3 NW¼NW¼NW¼	560	9	............do............
4N7W-29 SE¼SE¼	625	11	............do............
4N8W-33 NW¼NW¼NW¼	584	15	............do............
4N8W-33 NW¼NW¼NW¼	1,660	11	............do............
4N8W-33 NW¼NW¼NW¼	2,200	17	............do............
5N5W-18 NW¼NW¼	510	21	Washita terrace sediments
5N5W-20 NW¼SW¼	1,110	19	Duncan sandstone
5N5W-36 NE¼NW¼	1,120	8	Alluvium
5N6W-12 NE¼SE¼	1,130	10	Washita terrace sediments
5N8W-14 NE¼	1,100	63	Duncan sandstone
6N5W-16 NE¼SE¼	626	6	Alluvium
6N6W-36 NW¼NW¼	1,950	10	Washita terrace sediments
6N7W-33 SE¼SE¼	1,800	61	Duncan sandstone
6N7W-34 NE¼SE¼	1,370	12	............do............
6N8W-18 SE¼	375	20	Rush Springs sandstone
7N5W- 4 SE¼SE¼	785	42	Chickasha formation
7N6W-16 SE¼NE¼	789	5	............do............
7N6W-27	965	19	............do............
7N6W-32 NE¼NE¼	904	34	............do............
7N7W- 8 NE¼SE¼NW¼	804	32	Washita terrace sediments
7N7W-26 SW¼NE¼	998	62	............do............
7N8W- 7 NE¼SE¼NW¼	761	17	Alluvium
8N5W-25 NE¼NW¼	1,010	18	Chickasha formation
8N5W-31 NW¼SE¼	724	15	............do............
8N6W-22 NW¼NW¼	545	63	............do............
8N7W-23 NW¼NW¼	616	46	............do............
8N8W-30 SE¼SW¼	651	40	Washita terrace sediments
9N5W-12 SW¼SW¼	710	34	Duncan sandstone
9N6W- 3 NE¼NE¼	619	19	Washita terrace sediments
9N6W-16 NE¼NE¼	534	28	Chickasha formation
9N7W-22 SE¼SE¼	5,450	51	............do............
9N8W- 9 NW¼NW¼	1,060	7	Rush Springs sandstone
10N5W-27 NW¼SW¼	355	16	Terrace sediments
10N6W-28 NW¼NW¼	730	24	Terrace of Canadian River
10N6W-32 NW¼NW¼	701	44	............do............
10N7W-22 NE¼NW¼	428	11	Alluvium of Boggy Creek
10N7W-34 NE¼NW¼	422	15	Alluvium

SUITABILITY FOR HUMAN CONSUMPTION

Standards by which to judge the chemical suitability of waters for human consumption have been established by the U. S. Public Health Service (1946) and are applicable to water used on interstate carriers and public-water supplies. They indicate the maximum concentration, in parts per million, that should be tolerated in some of the constituents generally found in water. Suggested limits for selected constituents are as follows:

	Parts per million
Iron (Fe) and manganese (Mn) together	0.3
Magnesium (Mg)	125
Chloride (Cl)	250
Sulfate (SO_4)	250
Fluoride (F)	1.5
Dissolved solids	500 1,000 (permitted)

By the above standards, 6 of the 21 samples from the Chickasha formation and Duncan sandstone proved unsatisfactory; 12 of the 38 samples from the Rush Springs sandstone proved unsatisfactory; and 2 of the 11 samples from the terrace materials proved unsatisfactory.

PRESENT DEVELOPMENT OF GROUND-WATER SUPPLIES

Much of the water used in the area of this report for farm, municipal, industrial, railroad, and irrigation purposes is obtained from wells. Although streams and farm ponds furnish large amounts of stock water, they generally are supplemented by wells. In the present ground-water investigation, records of 104 water wells were obtained. Of these, 55 are farm wells used for domestic and stock purposes, 3 are wells used only for stock, 6 are wells used for public supplies, 7 are industrial wells, 2 are used for observation wells, and 21 appeared to be unused. In addition, records of 2,974 shot holes drilled by geophysical crews were obtained, and 1 record of a spring. Table 15 records data on the wells. The shot-hole logs may be examined in the open files of the Ground Water Branch of the U. S. Geological Survey at Norman, Oklahoma.

TABLE 15.

RECORDS OF WELLS AND SPRINGS IN GRADY AND NORTHERN STEPHENS COUNTIES, OKLA.

1. Depth: F, flowing well; R., reported.
2. Aquifer: All., alluvium; C, Chickasha formation; D, Duncan sandstone; R S, Rush Springs sandstone; T d, terrace deposits.
3. Pumps: B, bucket and rope; C, cylinder; T, turbine; J, jet.
   Power: A, air-lift; E, electric motor; G, gasoline or natural gas; H, hand; W, windmill.
4. Use: D, domestic; I, industrial; N, not used; O, observation; P, public; S, stock.
5. Well logs in Appendix A: Dr. log, driller's log; samp. log, sample log.
   Chemical analyses of water table 13: anal.

Well No.	Location in section	OWNER	Depth (feet)	Diameter (inches)	Depth to static water level below land surface (feet) (1)	Date	Probable aquifer (2)	Method of lift (3)	Use of water (4)	REMARKS (5)
			TOWNSHIP 2 NORTH, RANGE 7 WEST							
2N7W-										
3	NW¼NW¼NW¼	Town of Marlow	162	8	40, R	3-15-50	R S	E, T	P	Dr. log, samp. log.
			TOWNSHIP 3 NORTH, RANGE 5 WEST							
3N5W-										
4	SE¼SW¼	..................Brooks	91	6	60, R	6-10-47	D	H, C	D, S	Anal.
8	W½SE¼	Carter Oil Co.	250	6	95, R	7-15-50	D	G, C	I, D	Dr. log, anal. Co. City water supply
			TOWNSHIP 3 NORTH, RANGE 5 WEST							
3N7W-										
16	SE¼SW¼	H. C. Basinger	60	6	33, R	4- 3-46	R S	W, C	D, S	Anal.
17-1	SE¼NW¼	E. E. Nixey	301	6	29.10	4-24-46	R S	....	N	Dr. log. Duncan test hole.
17-2	NE¼NW¼	...........do............	70	6	30, R	4- 3-46	R S	W, C	D, S	Anal. Goes dry during drought.
26	SW¼SW¼SW¼	U.S.G.S.	200	6	55.21	7-28-48	R S	....	N	Anal. U.S.G.S. test hole.

TABLE 15.—(Continued)

RECORDS OF WELLS AND SPRINGS IN GRADY AND NORTHERN STEPHENS COUNTIES, OKLA.

Well No.	Location in section	OWNER	Depth (feet)	Diameter (inches)	Depth to static water level below land surface (feet) (1)	Date	Probable aquifer (2)	Method of lift (3)	Use of water (4)	REMARKS (5)
		TOWNSHIP 3 NORTH, RANGE 8 WEST								
3N8W-										
2	SE¼SE¼SE¼	Bill Carsar	100	6	74, R	1-23-48	R S	W, C	D, S	Dr. log, anal.
3-1	SW¼SW¼SE¼	O. L. May	53	6	17.30	1-23-48	R S	W, C	D, S	Dr. log, anal.
3-2	NW¼SW¼SE¼	............do............	33	6	14, R	1-23-48	R S	W, C	D, S	
4	SE¼NE¼	D. T. McCoy	40	6	22, R	4- 5-46	R S	W, C	D, S	Anal.
9	SE¼SE¼	G. W. Wade	95	6	14.45	4- 5-46	R S	H, C	D, S	Dr. log, anal.
11	NE¼NE¼	Nora Stinson	64	6	53.78	1-23-46	R S	W, C	D, S	
12	NE¼NW¼	Fleet Jones	94	6	31, R	1-23-46	R S	W, C	D, S	
15	SE¼SE¼SW¼	G. N. Horning	45	6	34, R	4- 5-46	R S	W, C	D, S	Anal.
22	NW¼NE¼SE¼	....	350	10	80, R	11- 3-45	R S	....	N	Dr. log.
		TOWNSHIP 4 NORTH, RANGE 7 WEST								
4N7W-										
3-1	NW¼NW¼NW¼	Magnolia Petroleum Co.	122	10	50.01	10-28-48	R S	E, T	I	Dr. log, anal. Drilled to 158 feet, plugged back to 122 feet.
3-2	SW¼SW¼NW¼	............do............	136	10	63.50	3- 1-49	R S	E, T	I	Dr. log. Drilled to 297 feet, plugged back to 136 feet.
5	NW¼NE¼	....................Simmons	22	8	12.80	1-24-46	R S	B	D, S	Dr. log, anal.
9-1	SE¼NE¼	E. T. Blades	97	6	54.02	2- 4-46	R S	W, C	D, S	Dr. log, anal.
9-2	SE¼SW¼	M. L. Hill	77	6	5.04	4-24-46	R S	B	D, S	Dr. log.
16	NE¼NE¼NW¼	N. L. Davis	41	6	27.36	2- 4-46	R S	B	D, S	Dr. log, anal.
23	SW¼NW¼	....	70	6	49.44	8-29-45	R S	W, C	D, S	Dr. log.
29-1	SW¼SW¼	W. W. Mobley	20	24	13.60	4- 5-46	R S	B	D	Dr. log, anal.
29-2	SW¼SW¼	............do............	69	6	19.85	3- 1-49	R S	B	D	............do............
29-3	SE¼	Town of Rush Spirngs	25	48	12.80	7- 7-50	R S	E, T	P	Dr. log.
30	SW¼SW¼SE¼	A. Melton	67	12	57.88	9- 5-44	R S	....	N	

TABLE 15.—(Continued)

RECORDS OF WELLS AND SPRINGS IN GRADY AND NORTHERN STEPHENS COUNTIES, OKLA.

Well No.	Location in section	OWNER	Depth (feet)	Diameter (inches)	Depth to static water level below land surface (feet) (1)	Date	Probable aquifer (2)	Method of lift (3)	Use of water (4)	REMARKS (5)
		TOWNSHIP 4 NORTH, RANGE 8 WEST								
4N8W-										
6	NE¼SE¼	....	22	6	11.67	5-27-46	R S	B	D, S	Dr. log.
10	SW¼SE¼	G. C. Spears	100	6	73, R	4- 5-46	R S	W, C	D, S	Dr. log, anal.
14	SW¼NW¼	J. M. Pendley	105	6	50, R	4- 5-46	R S	W, C	D, S	............do............
15	SE¼SE¼	Jack Adams	18	6	15, R	4- 4-46	R S	H, C	D, S	............do............
17	NW¼SW¼	....................Dalcey	50	6	32, R	4- 5-46	R S	W, C	D, S	............do............
20	SW¼SW¼	Nellie Williams	80	6	66, R	4- 5-46	R S	W, C	D, S	............do............
21	SE¼SE¼NE¼	H. J. Sweany	200	6	73.63	4-11-46	R S	....	N, O	Dr. log.
23-1	SW¼SE¼	....................Barnett	40	6	17.63	2- 6-46	R S	H	D, S	Dr. log, anal.
23-2	NE¼NE¼	C. F. Green	60	6	49.91	2- 7-46	R S	B	D, S	............do............
23-3	NW¼NE¼	Consolidated Gas Utilities Co.	60	6	48, R	2- 7-46	R S	E, T	I	............do............
23-4	SW¼SW¼	D. T. Hood	31	6	24.73	4- 4-46	R S	B	D	............do............
25-2	SW¼NW¼	Q. L. Merideth	8	30	5.08	5-27-46	R S	....	N, O	Dr. log.
26	SE¼NE¼	....................Barnett	60	6	55.61	2- 6-46	R S	H	D, S	Dr. log, anal.
27	SW¼SE¼	A. O. Savage	40	6	35, R	4- 4-46	R S	W, C	D, S	............do............
28-1	SE¼NW¼	Cletis Doyle	....	....	....	4- 4-46	R S	....	N	Anal. Spring, est. yield 200 gpm
28-2	NW¼NW¼	............do............	33	6	27, R	4- 4-46	R S	W, C	D, S	Dr. log, anal.
29	NE¼NW¼	R. V. Smith	46	6	30, R	4- 4-46	R S	W, C	D, S	............do............
33	NW¼NW¼NW¼	U.S.G.S.	254	7	80.20	6-27-48	R S	....	N, O	Dr. log, anal.
36	NW¼NE¼	James Howell	72	6	47.20	2- 6-46	R S	B	D, S	............do............
		TOWNSHIP 5 NORTH, RANGE 5 WEST								
5N5W-										
18	NW¼NW¼NW¼	Town of Alex	300+	8	15.60	7-13-50	D	E, T	P	Anal.
20	NW¼SW¼	Clifford Ball	70	6	62, R	6-10-47	....do....	W, C	D, S	Dr. log, anal.
36	NE¼NW¼	....................Norville	36	6	18, R	6-10-47	T d	E, J	....do....	............do............

TABLE 15.—(Continued)

RECORDS OF WELLS AND SPRINGS IN GRADY AND NORTHERN STEPHENS COUNTIES, OKLA.

Well No.	Location in section	OWNER	Depth (feet)	Diameter (inches)	Depth to static water level below land surface (feet) (1)	Date	Probable aquifer (2)	Method of lift (3)	Use of water (4)	REMARKS (5)
TOWNSHIP 5 NORTH, RANGE 6 WEST										
5N6W-										
12	NE¼SE¼	Town of Alex	105	30	30, R	7-13-50	T d	E, T	P	Dr. log, anal.
TOWNSHIP 5 NORTH, RANGE 5 WEST										
5N7W-										
5	SE¼SE¼	....	18	5	10.74	4-29-47	All.	....	N	Dr. log.
33	SE¼SW¼	C. W. West	92	6	61.40	1-24-46	R S	B	D, S	Dr. log, anal.
TOWNSHIP 5 NORTH, RANGE 8 WEST										
5N8W-										
13-1	NW¼NW¼NW¼	Oklahoma Natural Gas Co.	365	7	F	8-28-45	D	....	N	Dr. log.
13-2	NW¼NW¼NW¼	............do............	365	7	....do....	....do....	....do....	....	....do....	
14-1	NW¼NE¼	............do............	379	6	....do....	....do....	....do....	A	I	Anal.
14-2	NW¼NE¼	............do............	392	8	....do....	3-29-46	....do....	....do....	....do....	Dr. log, samp. log, anal.
24	SE¼SE¼	Kit Farwell	409	8	30, R	8-20-44	....do....	G, C	D	Dr. log, anal.
TOWNSHIP 6 NORTH, RANGE 5 WEST										
6N5W-										
16	NE¼SE¼	....	80	6	14.40	7-30-50	C	H, C	D, S	Dr. log, anal.
TOWNSHIP 6 NORTH, RANGE 6 WEST										
6N6W-										
36	NW¼NW¼	R. E. Finnerty	29	8	10.95	6-10-47	All.	B	....do....	............do............

TABLE 15.—(Continued)

RECORDS OF WELLS AND SPRINGS IN GRADY AND NORTHERN STEPHENS COUNTIES, OKLA.

Well No.	Location in section	OWNER	Depth (feet)	Diameter (inches)	Depth to static water level below land surface (feet) (1)	Date	Probable aquifer (2)	Method of lift (3)	Use of water (4)	REMARKS (5)
				TOWNSHIP 6 NORTH, RANGE 7 WEST						
6N7W-										
10	NW¼NW¼NW¼	....	157	6	53.38	4-11-46	C	E, J	D	Dr. log.
33	SE¼SE¼SE¼	W. C. Camp	300	7	F	7-29-50	D	E, T	D, S	Dr. log, anal.
34	NE¼SE¼	....	80	6	48.60	....do....	C	E, J	....do....	............do............
				TOWNSHIP 6 NORTH, RANGE 8 WEST						
6N8W-										
18	SE¼SE¼	....	80	6	73.00	7-17-50	R S	B	....do....	............do............
				TOWNSHIP 7 NORTH, RANGE 5 WEST						
7N5W-										
4	SE¼SE¼	....	32	6	30.23	6-10-47	C	W, C	....do....	............do............
				TOWNSHIP 7 NORTH, RANGE 6 WEST						
7N6W-										
16	SE¼NE¼	T. R. McCalla	105	6	85, R	....do....	....do....	....do....	S	............do............
27	SE¼SW¼	....	185	6	18, R	....do....	....do....	H, C	D, S	............do............
32	NW¼NE¼	....	200	8	10, R	7-30-50	C	W, C	S	Dr. log, anal.
33	NW¼NE¼	....................Penny	305	6	60, R	5-25-49	....do....	E, J	D	Dr. log.
				TOWNSHIP 7 NORTH, RANGE 7 WEST						
7N7W-										
8	NE¼SE¼NW¼	City of Chickasha	80	10	54, R	2-17-46	T d	E, T	P	Dr. log, anal.
17	SW¼SE¼NE¼	U.S.G.S.	20	1.25	5.65	6- 1-48	....do....	....	O	Dr. log. Drilled for obs. well.
26	SW¼NE¼	............do............	24	1.25	2,47	6-10-47	....do....	....	....do....	............do............
28	NE¼NE¼	Armour & Co.	200	8	25, R	6- 1-46	C	....	N	Dr. log.

TABLE 15.—(Continued)

RECORDS OF WELLS AND SPRINGS IN GRADY AND NORTHERN STEPHENS COUNTIES, OKLA.

Well No.	Location in section	OWNER	Depth (feet)	Diameter (inches)	Depth to static water level below land surface (feet) (1)	Date	Probable aquifer (2)	Method of lift (3)	Use of water (4)	REMARKS (5)
					TOWNSHIP 7 NORTH, RANGE 8 WEST					
7N8W-										
6-1	NE¼SE¼SE¼	....	97	6	24, R	5-17-48	T d	....	N	Dr. log. Test hole by Sawyer Drilling Co. Now plugged.
6-2	NE¼NE¼SW¼	....	98	6	27, R	5-16-48	....do....	....	....do....	............do............
6-3	NE¼NE¼NE¼	....	32	6	25, R	5-15-48	....do....	....	....do....	............do............
6-4	NW¼NW¼SW¼	....	31	6	26, R	....do....	....do....	....	....do....	............do............
7	SW¼SE¼	Town of Verden	45	8	32, R	7- 6-50	....do....	E, T	P	Anal.
					TOWNSHIP 8 NORTH, RANGE 5 WEST					
8N5W-										
9	SW¼SE¼	....................Prince	38	6	18.63	6- 6-47	C	B	D, S	Dr. log, anal.
25	NE¼NW¼NW¼	J. H. Killmar	70	6	39, R	4-23-48	....do....	....do....	....do....	............do............
					TOWNSHIP 8 NORTH, RANGE 6 WEST					
8N6W-										
22	NW¼NW¼	Frank Baker	60	6	36.70	6- 6-47	....do....	....do....	....do....	............do............
					TOWNSHIP 8 NORTH, RANGE 7 WEST					
8N7W-										
23	NW¼NW¼	...................Stanley	40	6	22, R	6- 6-47	C	H, C	D, S	Dr. log, anal.
					TOWNSHIP 8 NORTH, RANGE 8 WEST					
8N8W-										
30	SE¼SW¼	....	28	12	20, R	7-18-50	T d	B	....do....	............do............
					TOWNSHIP 9 NORTH, RANGE 5 WEST					
9N5W-										
1	SE¼SE¼	L. L. Poor	75	6	28, R	1-15-50	D	....	N	Dr. log.
12	SW¼SW¼	J. T. Evans	49	6	21.18	6- 4-47	....do....	B	D, S	Dr. log, anal.

TABLE 15.—(Continued)

RECORDS OF WELLS AND SPRINGS IN GRADY AND NORTHERN STEPHENS COUNTIES, OKLA.

Well No.	Location in section	Owner	Depth (feet)	Diameter (inches)	Depth to static water level below land surface (feet) (1)	Date	Probable aquifer (2)	Method of lift (3)	Use of water (4)	Remarks (5)
TOWNSHIP 9 NORTH, RANGE 6 WEST										
9N6W- 8	NE¼NE¼	U.S.G.S.	39	6	38.20	7-22-48	T d	....	N	Dr. log. Test hole, plugged.
16	NE¼NE¼	....................Schults	27	5	25, R	6- 4-47	C	W, C	D, S	Dr. log, anal.
TOWNSHIP 9 NORTH, RANGE 7 WEST										
9N7W- 22	SE¼SE¼	John Osborn	42	6	22.80	....do....	....do....	B	S	............do............
TOWNSHIP 9 NORTH, RANGE 8 WEST										
9N8W- 9	NW¼NW¼	....................Kucera	36	6	17, R	....do....	R S	H, C	D, S	............do............
TOWNSHIP 10 NORTH, RANGE 6 WEST										
10N6W- 22	SE¼SE¼	A. J. Curlee	27	48	23.74	6- 4-47	T d	W, C	D, S	Dr. log, anal.
28	NW¼NW¼	U.S.G.S.	49	6	25.00	7-20-48	....do....	....	N	Dr. log, samp. log, anal. Test hole, plugged.
32	NE¼NE¼	............do............	42	6	25.75	7-21-48	....do....	....	....do....	............do............
TOWNSHIP 10 NORTH, RANGE 8 WEST										
10N8W- 30	NE¼NW¼	E. Spencer	34	6	32.24	6- 6-47	R S	B	D, S	Dr. log, anal.

DOMESTIC AND STOCK WELLS

Most of the private wells used for domestic and stock purposes, whether on farms or in small towns, are drilled wells 3 to 10 inches in diameter. Most are cased with galvanized-iron casing, but some have oil-field steel casing. In many wells the casing extends only deep enough to protect the well against caving. Although most rural wells are less than 100 feet deep, a few in the Rush Springs sandstone, in the Chickasha formation and Duncan sandstone are much deeper, the maximum being about 400 feet. Most of the wells are equipped only with a rope and bucket, but some have electrically driven pumps. A few have hand pumps or windmills. Most of the wells yield ample water for rural use, but some are reported to fail during drought.

WELLS USED FOR PUBLIC SUPPLIES

With the exception of Chickasha, all towns in Grady County are supplied with water from wells through waterworks including power-driven pumps, elevated storage tanks, and water mains. The wells are mostly constructed in alluvium and generally are gravel packed and of larger size and yield than the farm and stock wells. Turbine pumps are used to lift the water directly from the well into elevated storage tanks. The water is given no special treatment, being kept in a closed-water system from aquifer to user. Some of the smaller towns have no public water systems, but depend on private wells. The following paragraphs summarize significant data regarding the public supplies in each town.

Alex

Until 1924 the Alex water supply consisted of individual privately owned wells. In 1924 a bond issue was authorized for construction of the present municipal water and sewer system. A well was not drilled, but a lease was obtained at $25 per year for use of water from a well on the C. M. Story farm in the NW cor. sec. 18, T. 5 N., R. 5 W. This well had been drilled as a water supply for an oil test. It was cased with oil-field casing 8 inches in diameter and is reported to have been 480 feet deep. Under the bond issue, it was equipped with an electrically driven turbine pump rated at 100 gallons per minute.

Under continued use the capacity of the well and the quality of the water slowly declined, and in 1947 a new well 105 feet deep was drilled within the city limits in block 7. This is a gravel-packed well 30 inches in diameter with a screen 10 inches in diameter, and is equipped with an electrically driven pump of 300 gallons-per-minute capacity. The well taps water in the alluvium of the Washita River. The static water level is about 30 feet below the land surface.

The water is pumped into an elevated storage tank having a capacity of 30,000 gallons, which affords a maximum pressure of 60 pounds and a minimum pressure of 40 pounds per square inch, depending on topography. The distribution system consists of 6- and 4-inch water mains, and there are 15 fire hydrants. According to city water superintendent R. Griskell, the consumption of water from 1930 through 1946 was about 1.296 millions of gallons monthly and 15.552 millions of gallons annually. Since 1946 it has been about 1.8 millions of gallons monthly and 21.6 millions of gallons annually. In 1950 the maximum daily consumption was about 120,000 gallons and the average about 60,000.

The population of Alex in 1950 was 563 (Table 10).

Amber

There is no municipal water system in Amber. Water is obtained from privately owned wells about 40 feet deep. As the quality of the ground water is poor, some cisterns are used for storage of rain water.

Bradley

The Bradley water supply consists of individual privately owned wells 60 to 200 feet deep. Most have hand pumps or rope and bucket, but some are equipped with electrically driven pumps. The water is hard, and therefore some cisterns are used for storing soft rain water.

Cox City

There is no municipal water system at Cox City. The Carter Oil Co. has a well reported to be about 250 feet deep, which is pumped by a rod-line jack-pump from a central power plant. The water goes into a 1,000-gallon storage tank and is used by company employees. Other residents depend on private wells, which are generally less than 100 feet deep.

Dutton

About 10 people live at Dutton. One well 20 feet deep supplies water to a filling station and a home, and another about 35 feet deep furnishes water to a cotton gin.

Farwell

Three houses and one store are served by one well 409 feet deep at Farwell. An electrically powered pump raises water and pumps it about 400 yards to a storage tank of about 50 gallons capacity, whence the water is drawn as needed.

Marlow

The water supply at Marlow first came from a privately owned well 24 feet deep and about 4 feet in diameter. The well was owned by J. W. Leddy who permitted his neighbors free use of the water. The maximum capacity of the well is not known, but it is reported that as much as 20 barrels per day were withdrawn from it. In the fall of 1892 or spring of 1893, two wells for public use were dug, one of them at Main street and Broadway, and the other at Main street and Second avenue. These wells were about 40 feet deep, about 4 feet in diameter, and were cased with rock masonry. The water is reported as strongly "gyppy," and in consequence many families constructed cisterns for storage of rain water.

In 1906, the population of Marlow had grown to approximately 1,700 people and additional water was needed. A dam was constructed across Whitehorse Creek at the north edge of town and an elevated tank of 90,000 gallons capacity erected. Because of the continued growth of the town and because Whitehorse Creek did not flow throughout the year a well was drilled at the east edge of the town site. The lake and the well sufficed until about 1918 when two other wells were drilled nearby. The water in these wells was hard.

In an effort to find soft water, the city in 1926 let a contract to the Illinois Petroleum Corp., of Duncan, Oklahoma, for the drilling of a test well in the N½NE¼SE¼ sec. 4, T. 2 N., R. 7 W. The well was drilled to a depth of 641 feet and found water much softer than that from the older drilled wells. In 1930 five more wells were drilled on the same plot of land and a reservoir was constructed. This reservoir is about 100 feet above the city and affords ample water pressure without use of a booster pump. The old elevated storage tank was no longer needed and so was dismantled.

In 1937, the ground-water supply was augmented by the drilling of two wells to depths of 136 and 150 feet, in the NE¼SW¼ sec. 3, T. 2 N., R. 7 W. Subsequently, six additional wells have been drilled also in the NW¼ of sec. 3. The aquifer is the Rush Springs sandstone.

In 1952, the water system at Marlow consisted of three wells in sec. 4, eight in sec. 3, and three at the east edge of town. The last three are the original drilled wells yielding hard water and were maintained for standby service only. All pumps were electrically driven turbines. There were two reservoirs, of 250,000 and 500,000 gallons capacity, at the well field northeast of town. The wells pump into 4- and 6-inch pipelines feeding into about half a mile of 8-inch line leading to the reservoirs. The line from the reservoirs into town is 10 inches in diameter and 16,000 feet long.

The three wells at the east edge of town pump into two reservoirs of 250,000 and 80,000 gallon capacity. Like the wells, these two reservoirs are used only in emergencies.

Lateral mains in town were 4, 6, and 8 inches in diameter, and the average pressure was about 45 pounds per square inch. The estimated capacity of the system was about 800 gallons per minute, and the estimated consumption ranged from 150,000 to 600,000 gallons per day. The water was pumped directly from the wells into the system without treatment.

Middleberg

The school and the several families at Middleberg obtain water from private wells 75 to 100 feet deep. Some wells have hand-operated pumps, some have electrically driven pumps, and others have only rope and bucket.

Minco

The first city water system at Minco was put in service in 1908, and seven wells have been drilled for the city since that time. Only the two newest wells, completed in 1948, are still in service. These two are gravel packed and about 50 feet deep, tapping water in the alluvium of Boggy Creek, and are equipped with electrically powered turbine pumps. One has a capacity of 35 gallons per minute and the other 45 gallons per minute. The city also has a contract with the Rock Island Railroad for pumping water during emergencies from a water well just north of the city limits. The Rock Island well is a dug well 20 feet in diameter and about 54 feet deep tapping water in terrace deposits along the Canadian River. It is equipped with a turbine pump powered by an electric motor.

The water is distributed by gravity from a 50,000 gallon tank 120 feet above the land surface. The water mains are 6- and 2-inches in diameter and serve 390 taps and 27 fire hydrants with a maximum pressure of 55 pounds per square inch and a minimum pressure of 37 pounds per square inch. The maximum daily consumption is about 85,000 gallons and the average is about 60,000 gallons.

Ninnekah

The water supply at Ninnekah consists of individual privately owned wells, 80 to 190 feet deep. Most have rope and bucket, but some have pumps powered by electricity. The school and the Baptist church have automatic electrically driven pumps, with pressure storage tanks.

Norge

Six privately owned wells, each about 30 feet deep, supply water to residents of Norge. The water contains large quantities of dissolved sulfates and therefore most of the homes have cisterns for storage of rain water.

Pocasset

The domestic water supply at Pocasset consists of rain water stored in cisterns. Ground water is too highly mineralized for human consumption.

Rocky Ford

Three water wells equipped with rope and bucket supply water to two houses and one store at Rocky Ford. The best well is at the store. It is 60 feet deep and has a static water level 23 feet below the land surface.

Rush Springs

The domestic water supply at Rush Springs came from individual family wells until 1914, when a privately owned distribution system was installed using water from a well in the Rush Springs sandstone. In 1917 the municipality took over operation of the water system and contracted with the Chicago, Rock Island, and Pacific Railroad Co. for water pumped from a well located near the northeast corner of Rush Springs. This well is an improved spring in the Rush Springs sandstone, and consists of a basin approximately 20 feet square and 6 feet deep fitted with an overflow pipe. The railroad company and the city both pumped the water through 6-inch pipelines about 0.25 mile long into elevated storage tanks with capacities of 50,000 gallons. About 1927 the city constructed the present municipal well by improving a spring about 600 feet west of the railroad well (block 17, Rush Springs townsite). It is about 25 feet deep and 4 feet in diameter.

The present distribution system consists of two pumps, one electrically driven and the other gas powered, pumping water both to the railroad and to the city reservoirs. Distribution of city water is through 6- and 4-inch mains allowing a maximum pressure of 45 pounds per square inch at fire hydrants. The town is not metered and the number of taps is not known. The maximum consumption is estimated as about 330,000 gallons per day and the average as about 240,000 gallons per day.

Tuttle

The municipal water system at Tuttle was installed in the latter part of 1926. A well 18 inches in diameter and 65 feet deep was drilled in March of that year in block 39, Tuttle townsite. The well taps water in the Canadian River terrace deposits and had a capacity of 50 gallons per minute. About 1946, the well failed due to sand entering the bore hole and a new well was drilled nearby to a depth of 65 feet. The original well was retained for standby service only, the new one being used as the prime source of supply. Both are equipped with electrically driven turbine pumps feeding water through a 6-inch line into an elevated storage tank holding 60,000 gallons.

Distribution is through 8- and 4-inch mains affording a maximum pressure of 56 pounds per square inch and a minimum pressure of 40 pounds per square inch. There are approximately 20 fire hydrants and 270 metered taps. The average consumption, according to H. L. McCraken, city clerk, is about 60,000 gallons per day.

Verden

In 1928 a bond issue was authorized for construction of a municipal water system at Verden. A well was drilled just northeast of the townsite in the SW¼SE¼ sec. 7, T. 7 N., R. 8 W. It was 39 feet deep and tapped water in terrace deposits along the Washita River. It had an original capacity of about 25 gallons per minute, but under continued use the capacity declined, and the well failed in 1937. Two wells were then drilled in the same 40-acre tract to depths of 45 feet. The wells are equipped with electrically driven turbine pumps which feed water directly into a 50,000-gallon elevated storage tank at the south edge of town. The water is distributed by gravity from the reservoir through 4-inch mains to 10 fire hydrants and approximately 90 taps. According to J. M. Thrasher, water superintendent, the maximum consumption is about 50,000 gallons per day and the average is about 40,000 gallons per day.

Tabler

The water supply at Tabler is obtained from privately owned wells about 120 feet deep tapping water in the Chickasha formation.

INDUSTRIAL WELLS

There are relatively few industrial water wells in Grady County and northern Stephens County, Oklahoma. Oil companies occasionally construct wells to supply drilling rigs with water; two natural gas pumping stations tap water in the Duncan sandstone and pumping installations in the Carter-Knox oil field tap water in the same formation. One natural gas pumping station, and one natural gas and oil processing plant and pumping station tap water in the Rush Springs sandstone.

GROUND WATER BY LOCALITIES

The following paragraphs offer brief descriptions of the geology and ground-water resources by townships. The rock formations are identified by name and their approximate distribution in the township is indicated. For descriptions of their lithologic character and thickness the reader is referred to the section on surface stratigraphy. The yield and quality of water that may be expected in the township are indicated. Wells recorded in 1936 by the Works Progress Administration project known as the State Mineral Survey (SMS) are summarized. In almost every township a few unusually deep wells were recorded which have been omitted in averaging.

T. 2 N., R. 5 W.

Surface geology: Chickasha formation. Wells yield moderate supplies of hard water. SMS record: 98 wells, 25 to 150 feet deep, average 75 feet; average depth to water, 52 feet.

T. 2 N., R. 6 W.

Surface geology: Chickasha formation in the southern part; Marlow formation in irregular east-west band approximately from sec. 13 to sec. 19, and in the northeastern part; and Rush Springs sandstone in the north-central and northwestern parts. Rush Springs sandstone is generally too thin to yield much water to wells except approximately in secs. 5 and 6. In the rest of the township rural wells obtain sufficient water for domestic and stock use from the Chickasha formation, and locally from the Marlow. The ground water is hard. SMS record: 122 wells, 20 to 162 feet deep, average 57 feet; average depth to water, 38 feet.

T. 2 N., R. 7 W.

Surface geology: Chickasha formation in the southern part; Marlow formation in irregular east-west band approximately from sec. 18 to sec. 25; and Rush Springs sandstone in the northern one-third. Rush Springs sandstone is generally too thin to yield much water to wells except approximately in secs. 1 to 5 inclusive, where yields up to 25 gallons per minute may be expected. Town of Marlow has its well field in sec. 3 and draws upon water in the

Rush Springs sandstone. In the rest of the township rural wells obtain meager quantities of water of fair to poor quality from the Chickasha, and locally from the Marlow. SMS record: 66 wells, 20 to 154 feet deep, average 65 feet, average depth to water, 48 feet.

T. 2 N., R. 8 W.

Surface geology: Chickasha formation, except for Marlow formation in northeastern part. Yields meager quantities of hard water from the Chickasha, and locally from the Marlow. Some water is present in alluvium along Buckhorn Creek. SMS record: 111 wells, 20 to 150 feet deep, average 61 feet; average depth to water, 40 feet.

T. 3 N., R. 5 W.

Surface geology: Chickasha formation, except for Marlow formation in extreme southwestern part. Chickasha formation and Duncan sandstone yield moderate amounts of hard water for industrial, municipal, and rural wells. Marlow is too thin to be water bearing. Some rural wells tap water in alluvium along Rush Creek. SMS record: 61 wells, 20 to 189 feet deep, average 94 feet, average depth to water, 60 feet.

T. 3 N., R. 6 W.

Surface geology: Marlow formation in northeastern two-thirds, except where the Chickasha formation crops out in irregular bands along both sides of Rush Creek. Rush Springs sandstone southwestern one-third. Chickasha yields moderate amounts of hard water to rural wells. Marlow yields meager amounts of water of poor quality to farm wells. Rush Springs too thin except in secs. 18, 19, and 29 to 33, inclusive, where moderate yields may be expected. Alluvium along Rush Creek supplies hard water to farm wells. SMS record: 92 wells, 20 to 173 feet deep, average 68 feet; average depth to water, 45 feet.

T. 3 N., R. 7 W.

Surface geology: Rush Springs sandstone. Yields moderate amounts of hard water to rural wells, but larger yields may be expected from properly constructed wells tapping water in the lower part of the formation. Chickasha formation and Duncan sandstone have not been tested for ground water. Alluvium along

Rush Creek contains small amounts of water suitable for rural use. SMS record: 101 wells, 20 to 180 feet deep, average 68 feet; average depth to water, 42 feet.

T. 3 N., R. 8 W.

Surface geology: Chickasha formation in south part of secs. 31 and 32, Marlow in irregular east and west band from sec. 36 to sec. 30, Rush Springs over remainder of township except for outlier of Cloud Chief formation in sec. 5. Chickasha and locally the Marlow yield meager supplies of hard water to farm wells. Rush Springs sandstone yields moderate supplies where not too thin. Alluvium along Buckhorn Creek contains water suitable for farm use. Cloud Chief formation does not contain ground water. SMS record: 132 wells, 20 to 160 feet deep, average 60 feet; average depth to water, 37 feet.

T. 4 N., R. 5 W.

Surface geology: Chickasha formation and Duncan sandstone, which yield water of poor quality and in meager quantities to rural wells. Some ground water is available in alluvial material along streams, especially in secs. 1-3, 9-12, and 16. SMS record: 59 wells, 28 to 150 feet deep, average 70 feet; average depth to water, 48 feet.

T. 4 N., R. 6 W.

Surface geology: Chickasha formation and Dog Creek shale and Blaine formation, undifferentiated, in northeastern half; Marlow formation in southeastern half except for Rush Springs sandstone in sec. 31, and parts of secs. 29, 30, and 32. Chickasha and locally the Marlow yield water of poor quality and in meager quantities. Rush Springs too thin to yield ground water except in west part of sec 31. SMS record: 76 wells, 20 to 150 feet deep, average 70 feet; average depth to water, 51 feet.

T. 4 N., R. 7 W.

Surface geology: Marlow formation in northeastern part, Rush Springs in remainder except for outliers of Cloud Chief formation in secs. 7, 18, 19, and 30. Marlow locally yields small quantities of poor quality water to rural wells. Rush Springs yields water to industrial, municipal, and domestic wells. Yields of 100 gallons per minute or more can be expected from properly located wells.

The city of Rush Springs gets its water supply from a well in the Rush Springs sandstone in sec. 29, and the Magnolia Petroleum Co. gets water for industrial use from wells in sec. 3. Cloud Chief formation does not contain ground water. SMS record: 95 wells, 15 to 133 feet deep, average 77 feet; average depth to water, 47 feet.

T. 4 N., R. 8 W.

Surface geology: Marlow formation in parts of secs. 1-4, 10-14. Rush Springs in remainder of township except for outliers of Cloud Chief formation in secs. 19, 20, and 28-35. The Duncan sandstone will probably yield water of fair quality at about 25 gallons per minute, but has not been developed. Marlow will yield small quantities of poor quality water locally. Where moderately thick, Rush Springs sandstone yields fair quality water to industrial and farm wells. Cloud Chief formation does not contain ground water. SMS record: 105 wells, 20 to 160 feet deep, average 69 feet; average depth to water, 47 feet.

T. 5 N., R. 5 W.

Surface geology: Chickasha formation and Duncan sandstone, which yields water of poor quality and in meager quantities to rural wells. Alluvial material along Washita River may yield as much as 300 gallons of water per minute at some locations, but most wells yield much less. SMS record: 91 wells, 19 to 155 feet deep, average 57 feet; average depth to water, 35 feet.

T. 5 N., R. 6 W.

Surface geology: Chickasha formation, and Dog Creek shale and Blaine formation, undifferentiated. Small area of Rush Springs sandstone in sec. 31. Chickasha yields water of poor quality to rural wells. Alluvial material along Washita River will yield as much as 300 gallons per minute at Alex, but most wells yield much less. Alluvium along smaller streams also yields water to rural wells, in quantities sufficient for domestic and stock use. SMS record: 88 wells, 15 to 133 feet deep, average 64 feet; average depth to water, 40 feet.

T. 5 N., R. 7 W.

Surface geology: Chickasha formation, and Dog Creek shale and Blaine formation undifferentiated, in northern, northeastern, and eastern parts. Marlow formation in an irregular band from sec. 36 to sec. 18, Rush Springs sandstone in southwestern part and as scattered outliers in west-central part. Chickasha yields water of poor quality to rural wells. The Duncan sandstone, not exposed, will probably yield as much as 25 gallons per minute of fair quality water. Marlow locally yields water of very poor quality to a few rural wells. Rush Springs yields water of fair quality to rural wells where thick enough to contain ground water. Alluvium along streams contains water of fair quality and is developed for a few stock wells. SMS record: 88 wells, 14 to 210 feet deep, average 76 feet; average depth to water, 47 feet.

T. 5 N., R. 8 W.

Surface geology: Dog Creek shale and Blaine formation, undifferentiated, on the north side of the Little Washita River in secs. 1 and 12, and as an inlier in the southeastern part. Marlow formation occurs in an irregular pattern over the eastern and northern parts, and Rush Springs sandstone in the southwestern and west-central parts and also on the stream divides generally, Cloud Chief formation occurs as thin outliers in secs. 18-20, 29, and 30. The Duncan sandstone yields water of fair quality at about 25 gallons per minute to industrial wells about 400 feet deep. The water is under artesian pressure and will flow at the surface in some places. Rush Springs yields ground water to industrial and domestic wells where thick enough to contain ground water. The Cloud Chief formation does not contain ground water. Alluvium along the streams contains ground water of fair quality and yields sufficient water for farm wells. SMS record: 71 wells, 20 to 180 feet deep, average 70 feet; average depth to water, 49 feet.

T. 6 N., R. 5 W.

Surface geology: Chickasha formation, which yields hard water to farm, domestic, and stock wells. Alluvium material along streams yields sufficient water for stock use. SMS record: 82 wells, 25 to 125 feet deep, average 69 feet; average depth to water, 45 feet.

T. 6 N., R. 6 W.

Surface geology: Chickasha formation, which yields hard water to farm wells. Ground water in alluvial materials along the Washita River is variable in quality and quantity; yields of several hundred gallons per minute may be obtainable locally. Present development is for farm wells. SMS record: 70 wells, 20 to 160 feet deep, average 72 feet; average depth to water, 47 feet.

T. 6 N., R. 7 W.

Surface geology: Chickasha formation in eastern part, and Dog Creek shale and Blaine formation, undifferentiated, in western part, except for deeply eroded Marlow formation in the west-central part of the township. The Chickasha formation yields hard water to domestic and stock wells. The Duncan sandstone, not exposed, contains water under artesian pressure and probably will yield as much as 25 gallons per minute. Marlow does not yield ground water. Alluvial material along the streams yields sufficient water to supply domestic and stock wells, and locally secs. 1, 2, 11, and 12 may supply larger quantities. The water is of fair to poor quality. SMS record: 88 wells, 20 to 210 feet deep, average 68 feet; average depth to water, 45 feet.

T. 6 N., R. 8 W.

Surface geology: Dog Creek shale and Blaine formation, undifferentiated, in extreme northeastern and southeastern parts. Marlow formation in an irregular pattern in the northern, eastern, and south-central parts. Rush Springs sandstone as irregular tongues and outliers on divides in most of the township. Marlow locally yields small quantities of very poor quality water. Rush Springs sandstone yields water of fair quality to farm wells where thick enough to contain ground water. Alluvium along streams yields hard water to stock wells. SMS record: 81 wells, 20 to 180 feet deep, average 65 feet; average depth to water, 45 feet.

T. 7 N., R. 5 W.

Surface geology: Chickasha formation which yields meager quantities of hard water to farm wells. Privately owned wells at Middleberg derive water from this formation. Alluvium along streams contains sufficient water to supply stock wells in some places. SMS record: 83 wells, 18 to 196 feet deep, average 74 feet; average depth to water, 50 feet.

T. 7 N., R. 6 W.

Surface geology: Chickasha formation, which yields meager quantities of hard water to farm wells. Alluvial material along streams contains sufficient ground water to supply stock wells. The water is variable in quality and locally may be highly mineralized. SMS record: 69 wells, 20 to 180 feet deep, average 81 feet; average depth to water, 57 feet.

T. 7 N., R. 7 W.

Surface geology: Chickasha formation in the eastern part, and Dog Creek shale and Blaine formation, undifferentiated, in the western part of the township. The Chickasha yields meager supplies of hard water. Wells tapping artesian water from the Duncan sandstone, not exposed, may be expected to yield 25 to 50 gallons per minute. Locally, water from this formation may be too highly mineralized for most uses. Water in alluvial material along streams ranges in quality from fair to very poor, and the yield from a few gallons per minute to more than 50 gallons per minute. SMS record: 92 wells, 20 to 177 feet deep, average 58 feet; average depth to water, 41 feet.

T. 7 N., R. 8 W.

Surface geology: Dog Creek shale and Blaine formation, undifferentiated, in the northeastern two-thirds; Marlow formation in remainder except for an irregular band of Rush Springs sandstone extending along the stream divide from sec. 31 to sec. 33. Chickasha formation yields sufficient quantities of hard water for domestic and stock use. Marlow yields water to wells only in secs. 31 and 32, and the water is of very poor quality. Rush Springs sandstone is too thin to yield ground water. Alluvial material along the Washita River and its tributaries contains water of uneven quality; water from sediments under the terraces is of better quality than water from flood plain alluvium. Yields from the alluvium range from a few gallons per minute to 25 gallons per minute. The town of Verden derives its water supply from this source. SMS record: 86 wells, from 20 to 75 feet deep, average 39 feet; average depth to water, 27 feet.

T. 8 N., R. 5 W.

Surface geology: Chickasha formation, which yields meager quantities of hard water to farm wells. In some places the alluvium along streams yields sufficient water to supply stock wells. SMS record: 77 wells, 24 to 190 feet deep, average 69 feet; average depth to water, 48 feet.

T. 8 N., R. 6 W.

Surface geology: Chickasha formation, which yields meager quantities of hard water to farm wells; locally the water is highly mineralized. Alluvium along streams contains sufficient water, in places, to supply stock wells. SMS record: 76 wells, 25 to 200 feet deep, average 79 feet; average depth to water, 50 feet.

T. 8 N., R. 7 W.

Surface geology: Chickasha formation in the eastern part, and Dog Creek shale and Blaine formation, undifferentiated, in the western part of the township. The Chickasha yields meager quantities of hard water, locally highly mineralized. Artesian water from the Duncan sandstone, not exposed, is generally too highly mineralized for domestic or stock consumption. Alluvium along streams contains sufficient water, in places, to supply stock wells. SMS record: 81 wells, 20 to 170 feet deep, average 57 feet, average depth to water, 40 feet.

T. 8 N., R. 8 W.

Surface geology: Dog Creek shale and Blaine formation, undifferentiated, except for small outliers of Marlow formation in secs. 1, 2, 4, 5, 8, 9, 18, and 19. The Dog Creek and Blaine yield small quantities of hard water, locally highly mineralized. Artesian water in the Duncan sandstone, not exposed, is probably too highly mineralized for stock consumption. Marlow formation is too thin to contain ground water. Ground water in the alluvial material ranges in quality from fair to very poor, the better water being under the higher terraces. Existing farm wells obtain ample water for domestic and stock use; locally wells of appropriate design probably could obtain much higher yields. SMS record: 71 wells, 20 to 100 feet deep, average 34 feet; average depth to water, 25 feet.

T. 9 N., R. 5 W.

Surface geology: Chickasha formation except for a small area of Duncan sandstone in sec. 1. These formations yield small quantities of hard water to farm wells. Alluvium along the streams contains small quantities of water suitable for domestic use. SMS record: 95 wells, 20 to 126 feet deep, average 63 feet; average depth to water, 41 feet.

T. 9 N., R. 6 W.

Surface geology: Chickasha formation in eastern part, and Dog Creek shale and Blaine formation, undifferentiated, in the western part of the township. The Chickasha formation yields small quantities of hard water to farm wells. Wells tapping artesian water in the Duncan sandstone, not exposed, may be expected to yield as much as 25 gallons per minute. Alluvial materials along the streams locally contain sufficient water for stock wells, and the terrace sediments in the north part will yield as much as 50 gallons per minute. The terrace sediments are the source of the municipal water supply for the town of Tuttle, Oklahoma. SMS record: 76 wells, 18 to 154 feet deep, average 62 feet; average depth to water, 38 feet.

T. 9 N., R. 7 W.

Surface geology: Dog Creek shale and Blaine formation, undifferentiated, except for Chickasha formation in the southeast part and a few scattered outliers of Marlow formation in the northwestern and north-central parts. The Chickasha formation yields small quantities of hard water to farm wells. Artesian water in the Duncan sandstone, not exposed, is probably highly mineralized. Marlow yields no ground water. Alluvium along the streams locally may contain sufficient quantities of hard water to supply stock wells. SMS record: 61 wells, 14 to 148 feet deep, average depth to water, 32 feet.

T. 9 N., R. 8 W.

Surface geology: Dog Creek shale and Blaine formation, undifferentiated, underlie the valleys, extending nearly to their heads. Marlow formation caps the stream divides as long narrow fingers or outliers, and in the north-central and northwestern part is overlain by the Rush Springs sandstone. Dog Creek and Blaine yield small quantities of hard water to farm wells. Locally the water is highly mineralized. Marlow yields very small quantities of very hard water to a few wells in the northern and northwestern parts. Rush Springs sandstone generally is too thin to contain ground water, except in parts of secs. 4 and 5. Alluvium along streams contains hard water. It is developed in many places for stock use. SMS record: 74 wells, 20 to 125 feet deep, average 42 feet; average depth to water, 30 feet.

T. 10 N., R. 5 W.

Surface geology: Chickasha formation, except for a small area of Duncan sandstone in the southeastern part. These formations yield small quantities of hard water to farm wells. Alluvial materials along the Canadian River yield moderate quantities of water to rural wells. SMS record: 51 wells, 15 to 120 feet deep, average 60 feet; average depth to water, 38 feet.

T. 10 N., R. 6 W.

Surface geology: Chickasha formation and Duncan sandstone underlying alluvial materials. The Chickasha formation yields sufficient quantities of hard water for farm wells. The Duncan sandstone contains artesian water and yields of as much as 25 gallons per minute may be expected from wells. The Dolese Co. water well in sec. 35 taps this artesian water. Alluvial materials yield as much as 50 gallons per minute and the quality ranges from fair to poor. SMS record: 42 wells, 20 to 150 feet deep, average 41 feet; average depth to water, 29 feet.

T. 10 N., R. 7 W.

Surface geology: Dog Creek shale and Blaine formation, undifferentiated, except for small tongues of Marlow capping the stream divides in the southwestern part. Dog Creek and Blaine yield small quantities of hard water to rural wells. Marlow formation yields no water. Alluvial materials yield as much as 45 gallons per minute of hard water in places. SMS record: 53 wells, 20 to 105 feet deep, average 35 feet; average depth to water, 27 feet.

T. 10 N., R. 8 W.

Surface geology: Dog Creek shale and Blaine formation, undifferentiated, underlie the valleys. Marlow formation caps the divides except that the Rush Springs sandstone covers the highest parts of them, mostly in the western half. Dog Creek and Blaine yield meager amounts of hard water to rural wells; Marlow locally yields poor quality water; and Rush Springs sandstone is too thin to be water bearing except in the extreme southwestern part. Alluvial materials generally contain enough water to supply stock wells. SMS record: 82 wells, 20 to 95 feet deep, average 38 feet; average depth to water, 29 feet.

POTENTIAL DEVELOPMENT OF GROUND WATER

The investigation of the ground water in Grady and northern Stephens Counties has shown that the occurrence of ground water is controlled largely by local precipitation, the topography of the surface, and the type and character of the different aquifers.

The Duncan sandstone is geologically the oldest fresh-water aquifer. Only a few wells tap this source of ground water, and, although the total quantity of stored water is large, the yields are small and wide spacing of wells is necessary to minimize mutual interference.

The Rush Springs sandstone contains very large quantities of ground water in storage and the topography of the surface and the texture of the sandstone are favorable for recharge. The ground water is obtainable at moderate depths and yields of 100 to 200 gallons per minute may be expected. With the exception of the municipal water supply at Rush Springs and two industrial well fields this aquifer is undeveloped as a source of ground water. Large areas adjacent to paved highways and railroads remain undeveloped.

The alluvium and terrace materials along the Washita and Canadian Rivers are capable of yielding relatively large amounts of ground water, which, however, is generally inferior in quality to the water contained in the Rush Springs sandstone. The physical conditions under which these materials were deposited were such that great variation in the type and texture of the materials, both horizontally and vertically, is typical. For these reasons, wells in the alluvium and terrace materials differ widely in yield. However, where coarse gravel in a buried channel can be located, yields of as much as 300 gallons per minute are obtainable. The municipal well at Alex is in such a channel, and others may be located by means of test drilling.

Ground water in quantities sufficient for farm, domestic, and stock use is available at moderate depths throughout most of the area covered by this report. The quality is suitable for most purposes except the ground water in the Marlow formation and locally in the Chickasha formation and the Duncan sandstone is too highly mineralized for animal or human consumption.

Appendix A

LOGS OF WELLS AND TEST HOLES

2N7W-3

City of Marlow water supply well No. 11. N½ sec. 3. Driller's log.

	Thickness (feet)	Depth (feet)
Rush Springs sandstone		
Shale, sandy, hard	18	18
Sandstone, hard, brown	15	33
Sandstone, soft, muddy	12	45
Sandstone and shale, broken	17	62
Sandstone, brown	9	71
Shale, sandy, brown	3	74
Sandstone, coarse	20	94
Shale, sandy, brown	4	98
Sandstone and shale, broken	9	107
Sandstone, coarse	14	121
Shale, sandy	5	126
Sandstone, coarse	14	140
Sandstone and shale, hard, broken	12	152
Sandstone, with thin streaks of hard red shale	8	160
Shale, hard	2	162

2N7W-3

City of Marlow municipal water supply well No. 11. N½ sec. 3. Sample log.

Rush Springs sandstone		
Sand	2	2
Shale, sandy	43	45
Sandstone, very fine, with much silt	25	70
Sandstone, medium grained	20	90
Silt, sandy	15	105
Sand, very fine to medium	15	120
Shale	5	125
Sand, medium, with many large grains, much gypsum	15	140
Silt, sandy	10	150
Sand, medium, with many large grains, much gypsum	12	162

2N7W-3

City of Marlow water supply well. N½ sec. 3. Composite driller's log of wells 2, 3, 4, 6, 7, 8, 9, 10, 11, and 13.

Rush Springs sandstone		
Top soil	4	4
Sandy layer, red	52	56
Red bed	4	60
Sand, caving	5	65
Sandy layer, red	20	85
Sand, water-bearing	13	98
Quicksand	7	105
Red bed	15	120
Sandy layer, red	12	132
Red bed	25	157

3N5W-8

Oil field water supply well, SE¼SW¼ sec. 4. Driller's log.

	Thickness (feet)	Depth (feet)
Sandstone and shale	75	75
Sandstone	20	95
Shale	10	105
Sandstone	10	115
Shale and sandstone	120	235
Sandstone	15	250

3N7W-15

Domestic farm well, SE¼SW¼ sec. 16. Driller's log.

Rush Springs formation		
Sandstone, very fine and soft	60	60

3N7W-17-1

Test hole drilled for City of Duncan, SE cor. NW¼ sec. 17. Driller's log.

Rush Springs sandstone		
Soil	5	5
Sand, shaly, hard, red	10	15
Sand, very fine, red to buff, mostly clean but with a few very thin shale breaks, water below 43 feet	75	90
Clay, sandy, red	18	108
Sand, fine, shaly, red	17	125
Clay-shale, sandy, red	10	135
Sand, with shale streaks	31	166
Marlow (?)		
Clay-shale, red, sticky, green streaks	35	201

3N7W-26

United States Geological Survey test well, SW¼SW¼ sec. 26. Sample log.

Rush Springs sandstone		
Sand, fine, loose	15	15
Shale, silty	180	195
Sand, hard, medium	5	200

3N8W-3-1

Domestic farm well, SW¼SW¼ sec. 3. Driller's log.

Rush Springs sandstone		
Sand, fine, loose, with gray streaks (gypsite?)	53	53

3N8W-2

Domestic farm well, SE¼SW¼ sec. 2. Driller's log.

Rush Springs sandstone		
Sand	8	8
Sandstone	27	35
Shale	30	65
Sandstone	35	100

3N8W-9

Domestic farm well, SE¼SE¼ sec. 9. Driller's log.

Rush Springs sandstone		
Sandstone, hard, with soft streaks	94	94

3N8W-22

Old well record, Cen. N½NW¼NE¼ sec. 22. Driller's log.

	Thickness (feet)	Depth (feet)
Rush Springs sandstone		
Soil and sand	40	40
Sand	66	106
Sand and shale	132	238
Sand, soft, water	22	260
Sand, hard	30	290
Sand and shale	60	350

4N7W-3-1

Magnolia Oil Co. Gailbreath No. 1. Water test hole, NW cor. NE¼ sec. 3. Driller's log.

Rush Springs sandstone		
Sand, surface	4	4
Clay, red	6	10
Silt	5	15
Marlow formation (?)		
Shale, with sand streaks	15	30
Sandstone, soft	5	35
Sandstone, soft, with streaks sandy clay	15	50
Sandstone, soft	5	55
Sandstone, hard	5	60
Sandstone, soft	5	65
Sandstone and shale	93	158

4N7W-3-2

Magnolia Oil Co. Gailbreath No. 2. Water test hole, SW cor. NE¼ sec. 3. Driller's log.

Rush Springs sandstone		
Soil	8	8
Sandstone, soft	12	20
Sandstone	5	25
Sandstone, hard	5	30
Sandstone, soft	13	43
Clay, sandy	12	55
Sandstone, soft	10	65
Marlow formation (?)		
Sandstone, hard, shaly	10	75
Lime (?), sandy	145	220
Sandstone, thin lime streaks	10	230
Lime (?), sandy, with streaks of sandstone	11	241
Sandstone and shale, with streaks of limestone (?)	56	297

4N7W-5

Domestic farm well, NW¼NE¼ sec. 5. Driller's log.

	Thickness (feet)	Depth (feet)
Rush Springs sandstone		
Sandstone, medium	21	21

4N7W-9-1

Stock well, SE¼NE¼ sec. 9. Driller's log.

Rush Springs sandstone		
Soil, sandy, loose	4	4
Sandstone, hard	40	44
Sandstone, fine, silty	15	59
Sandstone, fine	38	97

4N7W-9-2

Stock well, SE¼SW¼ sec. 9. Driller's log.

Rush Springs sandstone		
Soil, sand, loose	14	14
Clay	6	20
Sandstone	56	76

4N7W-16

Domestic farm well, NE¼NW¼ sec. 16. Driller's log.

Rush Springs sandstone		
Soil	2	2
Sandstone, medium hard, fine	39	41

4N7W-23

Domestic farm well, SW¼NW¼ sec. 23. Driller's log.

Rush Springs sandstone		
Soil	4	4
Sandstone, silty	66	70

4N7W-24

Domestic water well, SE¼NW¼ sec. 29. Driller's log.

Rush Springs sandstone		
Sand, soft	15	15
Ironstone	1	16
Sand, fine	28	44
Cavity	1	45
Sand, fine, soft	24	69

4N7W-29-1

Domestic water well, SW¼NE¼ sec. 29. Driller's log.

Rush Springs sandstone		
Soil, sandy, loose	4	4
Sandstone, soft, fine	16	20

4N7W-29-3

City of Rush Springs municipal water supply well, SE¼ sec. 29. Driller's log.

	Thickness (feet)	Depth (feet)
Rush Springs sandstone		
Sand, fine to medium, loose	25	25

4N8W-6

Domestic water well, NE¼SE¼ sec. 6. Driller's log.

Rush Springs sandstone		
Sandstone, fine, hard	23	23

4N8W-10

Domestic farm well, SW¼SE¼ sec. 10. Driller's log.

Rush Springs sandstone		
Sand, fine, some hard streaks	100	100

4N8W-14

Domestic farm well, SW¼NW¼ sec. 14. Driller's log.

Rush Springs sandstone		
Sandstone, fine, with some hard streaks	105	105

4N8W-14

Domestic farm well, SW¼NW¼ sec. 14. Driller's log.

Rush Springs sandstone		
Sand, fine, soft	105	105

4N8W-15

Domestic farm well, SE¼SE¼ sec. 15. Driller's log.

Rush Springs sandstone		
Soil	2	2
Sand, loose, fine	16	18

4N8W-17

Domestic farm well, NW¼SW¼ sec. 17. Driller's log.

Rush Springs sandstone		
Soil, sandy	5	5
Sand, fine	45	50

4N8W-20

Domestic farm well, SW¼SW¼ sec. 20. Driller's log.

Cloud Chief formation		
Gypsum and soil	4	4
Rush Springs sandstone		
Sand, fine, soft	76	80

4N8W-21

Henry J. Sweany water well, SE¼SE¼NE¼ sec. 21. Drilled by Sawyer Drilling Co. in September, 1944. Driller's log.

	Thickness (feet)	Depth (feet)
Rush Springs sandstone		
Soil	1	1
Clay, red, sandy	10	11
Sandstone, soft, red	189	200

4N8W-23-1

Domestic farm well, SW¼SE¼ sec. 23. Driller's log.

Rush Springs sandstone		
Sand, fine, loose	22	22
Sand, fine	18	40

4N8W-23-2

Domestic farm well, NW¼NE¼ sec. 23. Driller's log.

Rush Springs sandstone		
Soil, sandy	12	12
Sandstone, fine, soft	48	60

4N8W-23-3

Domestic farm well, NE¼NE¼ sec. 23. Driller's log.

Rush Springs sandstone		
Soil, sandy	15	15
Sandstone, fine, soft	45	60

4N8W-23-4

Domestic farm well, SW¼SW¼ sec. 23. Driller's log.

Rush Springs sandstone		
Soil	3	3
Sand, hard	28	31

4N8W-25-1

Domestic farm well, SW¼NW¼ sec. 25. Driller's log.

Rush Springs sandstone		
Sand, fine, loose	14	14

4N8W-25-2

Stock well, NW¼SW¼ sec. 25. Driller's log.

Rush Springs sandstone		
Sand, fine, loose	8	8

4N8W-26

Domestic farm well, SE¼NE¼ sec. 26. Driller's log.

	Thickness (feet)	Depth (feet)
Rush Springs sandstone		
Soil, sandy, loose	6	6
Sandstone, fine, soft.	54	60

4N8W-27

Domestic farm well, SW¼SE¼ sec. 27. Driller's log.

Rush Springs sandstone		
Sand, fine, loose	14	14
Sandstone, soft	26	40

4N8W-28-2

Domestic farm well, NW¼NW¼ sec. 28. Driller's log.

Rush Springs sandstone		
Sand, loose	5	5
Sand, fine, soft	28	33

4N8W-29

Domestic farm well, NE¼NW¼ sec. 29. Driller's log.

Rush Springs sandstone		
Soil, sandy	3	3
Sand, fine	19	22
Sand, silty	8	30
Sand, fine, soft	16	46

4N8W-33

United States Geological Survey observation well, NW¼NW¼ sec. 33. Driller's log.

Rush Springs sandstone		
Sand, fine, light brown	17	17
Shale, silty, moderate reddish-brown	15	32
Sand, fine, some hard and soft streaks	64	96
Cavity	14	110
Sand	118	228
Marlow formation (?)		
Shale (?)	36	264

4N8W-36

Domestic farm well, NW¼NE¼ sec. 36. Driller's log.

Rush Springs sandstone		
Soil, sandy	2	2
Sand, loose, fine	19	21
Sandstone	51	72

5N5W-20

Domestic farm well, NW¼SW¼ sec. 20. Driller's log.

	Thickness (feet)	Depth (feet)
Chickasha formation		
Shale, with hard and soft sand streaks	70	70

5N5W-36

Domestic farm well, NE¼NW¼ sec. 36. Driller's log.

Washita River alluvium		
Surface soil	8	8
Clay	18	26
Sand, some gravel	10	36

5N6W-12

City of Alex municipal water supply well, NE¼ SE¼ sec. 12. Driller's log.

Washita River terrace		
Top soil	12	12
Clay, sandy	28	40
Sand, fine	58	98
Gravel	7	105

5N6W-18

City of Alex municipal water supply well, NW¼NW¼ sec. 18.

Chickasha formation and Duncan sandstone		
Shale and sandstone, interbedded	300	300

5N6W-33

Magnolia Oil Co. water well. SW¼SE¼ sec. 33. Driller's log.

Chickasha formation and Duncan sandstone		
Sandstone, shaly	50	50
Sandstone, water	25	75
Sandstone and shale	27	102
Sandstone, water	7	109
Shale and sandstone	156	265
Sandstone	3	268
Shale, red	81	349

5N7W-5

Stock well, SE¼SE¼ sec. 5. Log from examination of walls of dug well.

Washita River alluvium		
Soil	4	4
Clay, sandy	14	18

5N7W-33

Domestic farm well, SE¼SW¼ sec. 33. Driller's log.

Rush Springs sandstone		
Sand, fine, soft	92	92

5N8W-13-1

Oklahoma Natural Gas Co. water well, NW¼NW¼ sec. 13. Driller's log.

	Thickness (feet)	Depth (feet)
Surface soil	8	8
Clay	22	30
Clay shale, red	71	101
Shale, sandy, streaks of sand, purple streaks	15	116
Shale, sandy	22	138
Sandstone	25	163
Shale, sandy, red and purple	5	168
Sand, silty, red and purple	30	198
Sand, medium, gypsiferous	10	208
Sand, fine	10	218
Sand, silty, gypsiferous	30	248
Shale, red and purple	5	253
Sand, fine, gypsiferous	3	256
Shale, red and purple	26	282
Sand, fine, silty	20	302
Shale, red	3	305
Sand, fine, silty	7	312
Shale, red	5	317
Sand, medium, few shale streaks	15	332
Shale, some gypsum	14	346
Sand, medium	19	365

5N8W-14-2

Oklahoma Natural Gas Co. water well No. 2. NE cor. NW¼NE¼ sec. 14. Drilled by Sawyer Drilling Co. Driller's log.

Soil	3	3
Gypsum	1	4
Sandstone	2	6
Shale, sandy	2	8
Sandstone, red	7	15
Sandstone, blue	3	18
Sandstone, red	17	35
Shale and gypsum	7	42
Sandstone, red	9	51
Sandstone and shale, broken	33	84
Sandstone, red	4	88
Sandstone and shale, gypsum stringers	27	115
Shale	17	132
Sandstone, dark red	6	138
Sandstone and shale, broken	12	150
Sandstone, brown	6	156
Sandstone and shale, broken	19	175
Sandstone, hard	6	181
Shale, sandy	6	187
Sandstone, brown	75	262
Shale, sandy	13	275
Shale, hard	3	278
Sand and shale	12	290
Sandstone, hard and fine	15	305
Shale	33	338
Sandstone, fine	7	345
Sandstone, coarse, light brown	11	356
Shale, hard	3	359
Sandstone, fine, hard	13	372
Sand, coarse	16	388
Shale	4	392

5N8W-14-2

Oklahoma Natural Gas Co. water well No. 2. NE. cor. NW¼NE¼ sec. 14. Drilled by Sawyer Drilling Co. Log compiled from examination of drill cuttings.

	Thickness (feet)	Depth (feet)
Soil	3	3
Gypsum	1	4
Sandstone, red	2	6
Shale, sandy	2	8
Sandstone, fine, red	7	15
Sandstone, fine, blue	3	18
Sandstone, fine	17	35
Shale, gypsum streaks	7	42
Sandstone, fine, red	9	51
Shale, with thin sandstone streaks	33	84
Sandstone, fine, red	4	88
Shale, sandstone streaks, gypsum stringers	22	110
Clay-shale, red	30	140
Shale, sandy, with streaks of sandstone, some purple, some red	15	155
Shale, sandy, red	15	170
Shale, sandy, red, gypsum streaks	5	175
Sandstone, red, gypsum streaks	30	205
Shale, sandy, red and purple	5	210
Sandstone, silty, red and purple, with gypsum streaks	30	240
Sandstone, medium grained, silty, red	10	250
Sandstone, fine, red	10	260
Sandstone, silty, gypsiferous	30	290
Sandstone, fine, gypsiferous	10	300
Shale, red to purple	5	305
Sandstone, fine, silty, gypsiferous	5	310
Shale, red and purple	25	335
Sandstone, fine, silty, gypsiferous	5	340
Sandstone, medium, glauconitic, gypsiferous	15	355
Shale, red	3	358
Sandstone, fine, silty	7	365
Shale, red	6	371
Sandstone, medium, buff	14	385
Shale, red, gypsiferous	7	392

5N8W-24

Farwell water well, SW cor. sec. 24. Drilled by Sawyer Drilling Co. in August, 1944. Driller's log.

Soil	3	3
Sandstone, red	2	5
Red beds	30	35
Sandstone, red	5	40
Red beds	40	80
Sandstone, red	3	83
Red beds, thin streaks of gypsum	67	150
Sandstone, red	15	165
Red beds and gypsum	75	240
Sandstone, broken and red beds	90	330
Red beds	20	350
Sandstone, reddish brown	50	400
Red beds	9	409

6N5W-16

Domestic farm well, NE¼SE¼ sec. 16. Driller's log.

	Thickness (feet)	Depth (feet)
Chickasha formation		
Clay, sandy, hard streaks	24	24
Clay, sandy	22	46
Sand and shale, broken	34	80

6N6W-36

Domestic farm well, NW¼ NW¼ sec. 36. Driller's log.

Washita River terrace		
Clay	24	24
Sand	3	27

6N7W-10

Sawyer water well, NW¼ NW¼ sec. 10. Driller's log.

Washita River terrace		
Soil	3	3
Clay	9	12
Clay, sand and gravel	3	15
Chickasha formation and Duncan sandstone		
Red beds	15	30
Sandstone	2	32
Red beds	43	75
Sandstone	4	79
Red beds	6	85
Sandstone and shale, broken	36	121
Sandstone	3	124
Sandstone and shale, broken	5	129
Sandstone	13	142
Sandstone and shale, broken	8	150
Shale	5	155
Shale, sandy	7	162
Sandstone and shale, broken	3	165
Sandstone	20	185
Sandstone and shale, broken	6	191
Sandstone	14	205
Sandstone and shale, broken	13	218
Sandstone	24	242
Shale	4	246
Sandstone	5	251
Shale	2	253
Sandstone	7	260
Sandstone and shale, broken	10	270
Sandstone	10	280
Sandstone and shale, broken	10	290
Sandstone	5	295
Sandstone and shale, broken	15	310
Sandstone	15	325

6N7W-33

Domestic water well, SE¼SE¼ sec. 33. Driller's log.

Little Washita River alluvium		
Clay, sandy, surface	14	14
Sand, very fine	21	35

	Thickness (feet)	Depth (feet)
Chickasha formation and Duncan sandstone		
Sandstone and shale	105	140
Shale, sandy	14	154
Sandstone, brown	55	209
Sandstone, coarse	14	223
Sandstone, hard	5	228
Sandstone and shale	41	269
Shale	17	286
Sand	14	300

6N7W-34

Domestic water well, NE¼SE¼ sec. 34. Driller's log.

Chickasha formation		
Clay and hard rock	48	48
Sandstone and shale, broken	32	80

6N8W-18

Domestic water well, SE¼SE¼ sec. 18. Driller's log.

Rush Springs sandstone		
Surface soil	6	6
Sand, very fine	79	85

7N5W-4

Domestic farm well, SE¼SE¼ sec. 4. Log estimated from bedrock outcrops.

Chickasha formation		
Clay and mudstone with interbedded, soft sandstone layers	32	32

7N6W-16

Domestic farm well, SE¼NE¼ sec. 16. Driller's log.

Chickasha formation		
Clay and shale	90	90
Interbedded sandstone and shale	115	205

7N6W-27

Domestic water well, SE¼SW¼ sec. 27. Driller's log reported by Sawyer Drilling Co.

Surface soil	9	9
Sandy clay and sand	15	24
Shale and sandstone, broken	40	64
Shale, sandy	14	78
Sandstone, very hard	2	80
Shale and sandstone, broken	50	130
Shale, sandy, very hard	3	133
Shale, sandy, white flakes	33	166
Shale and sandstone, broken	19	185

7N6W-32

Domestic farm well, NW¼NE¼ sec. 32. Log estimated from bedrock outcrops.

	Thickness (feet)	Depth (feet)
Washita River terrace		
Sandy clay and sand	35	35
Chickasha formation		
Interbedded shale, mudstone, and sandstone	165	200

7N6W-33

Penny water well, NE¼ sec. 33, drilled by Sawyer Drilling Co. in 1949. Driller's log.

Chickasha formation and Duncan sandstone		
Soil	10	10
Sandstone	5	15
Shale, sandy	3	18
Sandstone	8	26
Sandstone and shale, broken	4	30
Shale, sandy	15	45
Sandstone	5	50
Shale, sandy	25	75
Sandstone, brown, soft (water sand)	12	87
Shale, sandy	18	105
Sandstone and shale, broken	25	130
Shale, sandy	40	170
Sandstone, hard	1	171
Shale, sandy	15	186
Sandstone, hard	2	188
Shale, sandy	8	196
Sandstone, very hard	1	197
Shale, sandy	15	212
Sandstone, very hard	2	214
Shale, sandy	28	242
Sandstone and shale	6	248
Shale, sandy	29	277
Sandstone and shale, broken	5	282
Shale, sandy	10	292
Shale, sandy, very hard	2	294
Sandstone, very hard	1	295
Shale, sandy, white flakes	2	297
Shale, sandy, multi-colored	8	305

7N7W-6

Chickasha Airport terrace test well No. 4, SW cor. sec. 6. Drilled by the Sawyer Drilling Co. Driller's log.

Washita River terrace		
Clay, red	14	14
Sand, medium coarse	5	19
Sand, coarse	9	28
Gravel and coarse sand	2	30
Dog Creek shale and Blaine formation, undifferentiated		
Red beds	2	32

7N7W-6

Chickasha Airport terrace test well No. 2, SE cor. sec. 6. Drilled by the Sawyer Drilling Co. Driller's log.

	Thickness (feet)	Depth (feet)
Washita River terrace		
Clay, red	38	38
Sand, fine	7	45
Sand, medium coarse	10	55
Sand, coarse	10	65
Sand, very coarse	21	86
Clay, red	2	88
Sand and gravel	8	96
Dog Creek shale and Blaine formation, undifferentiated		
Red bed	1	97

7N7W-6

Chickasha Airport terrace test well No. 1, SE cor. NE¼ sec. 6. Drilled by the Sawyer Drilling Co. Driller's log.

Washita River terrace		
Clay, red	49	49
Sand, fine	3	52
Sand, medium coarse	23	75
Sand, very coarse	20	95
Sand and gravel	2	97
Dog Creek shale and Blaine formation, undifferentiated		
Red beds	1	98

7N7W-8

City of Chickasha airport water well, NE¼ sec. 8. Driller's log.

Washita River terrace		
Clay, red	42	42
Sand, fine	14	56
Sand, coarse	15	71
Sand and gravel	9	80

7N7W-17

United States Geological Survey observation well, SE¼NE¼ sec. 17. Sample log.

Washita River alluvium		
Sandy clay	16	16
Sand, fine	4	20

7N7W-26

United States Geological Survey observation well, SW¼NE¼ sec. 26. Driller's log.

Washita River alluvium		
Clay, sandy	22	22
Sand, very fine	2	24

7N7W-28

Armour and Co. test hole drilled by Sawyer Drilling Co. June, 1946, NE¼ sec. 28. Driller's log.

	Thickness (feet)	Depth (feet)
Washita River terrace		
Soil	5	5
Quicksand	25	30
Sand, coarse and gravel	35	65
Chickasha formation		
Shale, red	10	75
Shale and sand	10	85
Sandstone, red	12	97
Shale and sand	15	112
Sandstone, red	8	120
Sand and shale, broken	25	145
Sandstone, soft	15	160
Sandstone, hard	4	164
Sandstone, soft	9	173
Sandstone, hard	7	180
Sandstone, soft	15	195
Sandstone, hard	5	200

7N8W-6-1

Test hole drilled by Sawyer Drilling Co. NE cor. SE¼SE¼ sec. 6. Driller's log.

Washita River terrace		
Clay, red	38	38
Sand, fine	7	45
Sand, coarse	10	55
Sand, coarse, some fine gravel	31	86
Clay	2	88
Gravel, to ½″ diameter	8	96
Dog Creek shale and Blaine formation, undifferentiated		
Red beds	1	97

7N8W-6-2

Test hole drilled by Sawyer Drilling Co. NE. cor. SW¼ sec. 6. Driller's log.

Washita River terrace		
Clay, red	49	49
Sand, fine	3	52
Sand, fine to coarse	23	75
Sand, very coarse	7	82
Sand, very coarse, fragments of shells, some gravel	13	95
Gravel, to ½″ diameter	2	97
Dog Creek shale and Blaine formation, undifferentiated		
Red beds	1	98

7N8W-6-3

Test hole drilled by Sawyer Drilling Co. 600 feet west of NE. cor. sec. 6. Driller's log.

Washita River terrace		
Clay	28	28
Dog Creek shale and Blaine formation, undifferentiated		
Red beds	4	32

7N8W-6-4

Test hole drilled by Sawyer Drilling Co. NW. cor. SW¼SW¼ sec. 6. Driller's log.

Washita River terrace		
Clay, red	5	5
Clay, yellow	9	14
Sand, fine	4	18
Sand, very coarse	10	28
Gravel	2	30
Dog Creek shale and Blaine formation, undifferentiated		
Red bed	1	31

7N8W-18

Verden municipal water well, SW¼SE¼ sec. 18. Driller's log.

Washita River alluvium		
Clay	17	17
Clay, sandy	11	28
Sand, very fine	13	41
Sand, coarse, with gravel	4	45

8N5W-9

Domestic farm well, SW¼SE¼ sec. 9. Driller's log as reported by owner.

Chickasha formation		
Fine sand	20	20
Sandstone and shale	18	38

8N5W-25

Domestic farm well, NE¼NW¼ sec. 25. Driller's log as reported by owner.

Chickasha formation		
Clay	8	8
Sandy clay with sand streaks	32	40
Hard clay	5	45
Sandstone and clay	25	70

8N6W-22

Domestic farm well, NW¼NW¼ sec. 22. Driller's log as reported by farm tenant.

Chickasha formation		
Surface	10	10
Shale and clay	46	56
Sandstone	6	62

8N7W-23

Domestic farm well, NW¼NW¼ sec. 23. Well log estimated from bedrock outcrops.

Chickasha formation		
Interbedded clay, mudstone conglomerate and sandy streaks	40	40

8N7W-31

Chickasha airport terrace test well No. 3, SE¼SE¼ sec. 31. Drilled by the Sawyer Drilling Co. Driller's log.

	Thickness (feet)	Depth (feet)
Dog Creek shale and Blaine formation, undifferentiated.		
Clay, red	28	28
Red beds	4	32

8N8W-30

Domestic farm well, SE¼SW¼ sec. 30.

Washita River terrace		
Loose sand	28	28

8N8W-35

Test well drilled by Sawyer Drilling Co., NE¼ sec. 35. Driller's log.

Soil and sand	15	15
Red beds	210	225
Shale, gypsum and sandstone	75	300
Shale, some sandstone streaks	160	460
Sand, fine, salt water	35	495
Shale	15	510

9N5W-1

Domestic farm well, SE¼SE¼ sec. 1. Log estimated from bedrock outcrops.

Chickasha formation and Duncan sandstone		
Interbedded sandstone and clay shale	75	75

9N5W-12

Domestic farm well, SW¼SW¼ sec. 12. Driller's log reported by owner.

Fine soft sand	49	49

9N6W-3

Tuttle municipal water supply well, NW¼NE¼ sec. 3. Driller's log as reported by city officials.

Canadian River terrace		
Surface	5	5
Sandy clay and sand	55	60
Sand	5	65

9N6W-8

United States Geological Survey test well, NE¼NE¼ sec. 8. Sample log.

Canadian River terrace		
Surface soil	3	3
Clay	17	20
Sandy clay	19	39

9N6W-16

Domestic farm well, NE¼NE¼ sec. 16. Driller's log as reported by tenant.

Sand and clay	20	20
Clay and sandstone	7	27

9N7W-22

Stock well, SE¼SE¼ sec. 22. Driller's log reported by owner.

	Thickness (feet)	Depth (feet)
Interbedded shale and sand	42	42

9N8W-9

Domestic farm well, NW¼NW¼ sec. 9. Driller's log reported by owner.

Rush Springs sandstone		
Fine sand	36	36

10N5W-27

Domestic farm well, NW¼SW¼ sec. 27. Driller's log.

Canadian River terrace		
Sand and clay	20	20
Sand	15	35
Sand and gravel	2	37

10N6W-22

Domestic farm well, SE¼SE¼ sec. 22. Driller's log.

Canadian River terrace		
Sand and clay	20	20
Sand and gravel	7	27

10N6W-28

United States Geological Survey test well, NW¼NW¼ sec. 28. Sample log.

Canadian River terrace		
Surface	3	3
Sandy clay	43	46
Sand	3	49

10N6W-32

Domestic farm well, NE¼NE¼ sec. 32. Driller's log.

Canadian River terrace		
Sand and clay	25	25
Sand	20	45
Sand and gravel	4	49

10N6W-32

United States Geological Survey test well, NE¼NE¼ sec. 32. Sample log.

Canadian River terrace		
Sandy clay	40	40
Sand	2	42

10N6W-35

Dolese Bros. Co. water well No. 1, NW¼NW¼ sec. 35. Driller's log. Completed in 1948.

Canadian River terrace		
Sand and gravel	28	28

	Thickness (feet)	Depth (feet)
Chickasha formation and Duncan sandstone		
Red beds	104	132
Sandstone, fine, water	20	152
Red bed	18	170
Sandstone, water	20	190
Red bed	5	195
Sandstone, fine, water	35	230
Red bed	10	240
Sandstone, fine, water	50	290
Red bed	50	340
Sandstone	7	347
Red bed	43	390
Shale, sandy	15	405
Red bed	10	415
Shale, sandy	15	430
Red bed	21	451

10N7W-21

Minco municipal water supply well, SW¼SE¼ sec. 21. Driller's log as reported by town residents.

Canadian River terrace		
Sandy clay and sand	45	45

10N7W-21

Railroad well at Minco, NE¼SE¼ sec. 21. Driller's log as reported by town residents.

Canadian River terrace		
Sandy clay and sand	54	54

10N7W-22-1

Minco municipal water supply well, NE¼NW¼ sec. 22. Driller's log as reported by town residents.

Canadian River terrace		
Sandy clay and sand, some gravel at bottom	50	50

10N7W-22-2

Minco municipal water supply well, NE¼NW¼ sec. 22. Driller's log as reported by town residents.

Canadian River terrace		
Sandy clay and sand, some gravel at bottom	52	52

10N8W

Domestic farm well, NE¼NW¼ sec. 30. Driller's log.

Rush Springs sandstone		
Fine sand	34	34

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