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Robert H. Dott, Director

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GROUND WATER IN THE POND CREEK BASIN, CADDO COUNTY, OKLAHOMA

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Prepared in cooperation between the
Oklahoma Geological Survey
and the
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1950

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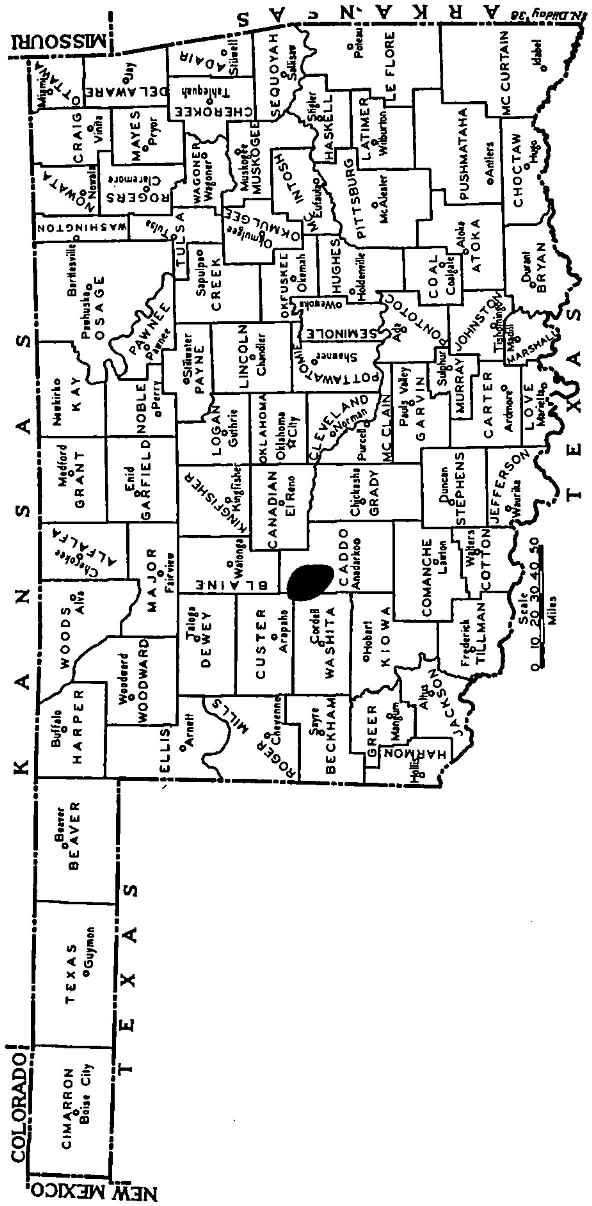

Figure 1. Index Map Showing Location of the Pond Creek Drainage Basin, Oklahoma.

GROUND WATER IN THE POND CREEK BASIN, CADDO COUNTY, OKLAHOMA

By Leon V. Davis

INTRODUCTION

Many inquiries have been received concerning the occurrence of ground water in the Pond Creek drainage basin and the possibilities of its development. These questions resulted from the successful irrigation, in 1949, of 17 acres of canna bulbs with ground water from the Rush Springs sandstone. Requests for information have been answered on the basis of data from current ground-water investigations and from reports by Robert H. Dott 1/ and others. Current data, however, have not been available to the general public.

This report presents preliminary data from an investigation of the ground water in the Pond Creek drainage basin now being made by the Oklahoma Geological Survey and the U. S. Geological Survey as part of a State-wide program under a cooperative agreement that has been in effect since 1937. The primary purpose of the investigations is to evaluate the ground-water resources of the State.

This preliminary survey of the ground-water resources in the Pond Creek Basin included study of drillers' logs of water wells to obtain information on the character and thickness of the water-bearing formations. Sand samples from one well were examined microscopically and were sieved to determine grain sizes. Altitudes of water wells were measured by alidade or by altimeter to provide information for the preparation of a water-table map, and one pumping test was made to de-

1/ Dott, R. H., "Geology of Oklahoma ground-water supplies" in Smith, O. M., "The chemical analysis of the waters of Oklahoma," Oklahoma Agr. and Mech. College, Eng. Exper. Sta. Pub. 52, 1942.

termine the ability of the Rush Springs sandstone to transmit water. Representative samples of well waters were analyzed in the laboratory of the Quality of Water Branch of the U. S. Geological Survey at Stillwater. The surface geology shown in plate 1 was adapted from the geologic map of Oklahoma published in 1926 2/.

TOPOGRAPHY AND GENERAL GEOLOGY

The area covered in this report is the Pond Creek drainage basin upstream from a point 2 miles north of Fort Cobb, Oklahoma, principally in west-central Caddo County but extending short distances into northeastern Washita County and southeastern Custer County. The basin is roughly oval in shape and covers about 320 square miles (fig. 1).

The area is drained by Pond Creek, known locally as Cobb Creek. Pond Creek and two main tributaries, Willow Creek and Spring Creek, are perennial streams whose base flow is maintained by seepage from the Rush Springs sandstone. The banks of the streams are bordered by a fringe of willow, sycamore, cottonwood, and oak trees and underbrush. The uplands and valley slopes are well drained, and most of them have been cleared for cultivation, but scrub oak and grasses have been allowed to retake parts of the cleared areas.

The maximum relief is about 580 feet, the altitude ranging from about 1,240 feet where Pond Creek empties into Washita River to 1,820 feet at the northwest end of the basin. The surface is a moderately rolling plain except along the larger streams where local relief reaches 100 feet or more. Soils are generally sandy, having been derived chiefly from the weathering

2/ Miser, Hugh D., "Geologic map of Oklahoma": U. S. Geol. Survey, 1926.

of the soft Rush Springs sandstone, which is exposed at the surface over most of the basin. In the western part of the basin are many cuestas with steep eastward-facing escarpments and gentle back slopes, most of them having less than 75 feet of relief. These cuestas mark the eastern limit of the main outcrop of the Cloud Chief gypsum, which occurs elsewhere in the basin as thin outliers, in places capping buttes an acre or less in area.

The Pond Creek basin is underlain by a great thickness of sedimentary rocks of Paleozoic age. The Superior Oil Company test well in the southeastern part of the basin, designated as 51-11 Weller in the NW¼ NW¼ NE¼ sec. 11, T. 8 N., R. 12 W., penetrated 17,823 feet of these sediments without reaching the crystalline basement rocks, 3/ which probably are several thousand feet deeper. Although these rocks are largely saturated with water, it is only in the upper few hundred feet that fresh water occurs. These formations dip southwestward toward the axis of the Anadarko structural trough at a rate of 20 to 40 feet per mile. 4/ The axis of this trough extends northwestward across the south edge of Pond Creek Basin.

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

In the paragraphs that follow, the geologic formations near enough to the surface to be considered as sources of water supply are described in descending order (pl. 1).

3/ Wheeler, R. R., and Wallace, Louis, Geological significance of world's deepest well bore: World Oil, vol. 128, no. 10, pp. 53-60, 1949.
4/ Sawyer, R. W., "Oil and gas in Oklahoma," Kiowa and Washita Counties: Oklahoma Geol. Survey Bull. 40, vol. 2, p. 319, 1930.

Alluvium

Narrow bands of alluvium, consisting of fine-grained sandy silt eroded from the Rush Springs sandstone mixed with gypsum eroded from the Cloud Chief gypsum, occur along the lower part of Pond Creek and its tributaries. Records of water wells indicate that the alluvium attains a maximum thickness of about 30 feet. Fossils in the alluvium, identified by J. W. Stovall, 5/ show that these sediments were laid down, in part at least, near the end of the "ice age" (late Pleistocene time). The upper part of the alluvium is doubtless of Recent age. Although much of the alluvium is water-saturated, it is so fine-grained that the water in it will not readily enter wells. The gypsum included in the alluvium, being readily soluble, locally may make the water unsatisfactory for some uses.

Terrace Deposits

Coarse gravel has been found at several places in the basin substantially above the creek bottom and is thought to represent deposits of streams that flowed at much higher levels that the present streams. These streams may have had their source in the Rocky Mountains far to the west. The largest such deposit covers about 20 acres in the NW$\frac{1}{4}$ sec. 5, T. 8 N., R. 12 W., and has a maximum thickness of about 25 feet; it is being used as a source of road gravel. Fossil bones and teeth recovered from this gravel deposit were identified by Stovall 6/ as those of a horse and an elephant, Elephas columbi, of Pleistocene age. Most of the gravel deposits are very thin and none contains ground water.

5/ Stovall, J. W., Oral communication.
6/ Stovall, J. W., Oral communication.

PERMIAN

Cloud Chief Gypsum

The Cloud Chief gypsum crops out in the western part of the basin, and also is the cap rock on many small buttes or hills in other parts of the basin. It consists of impure dolomite, gypsum, gypsiferous sandstone, and shale. Some of the sandstones and shales closely resemble the underlying Rush Springs sandstone, from which they can be distinguished most readily by their darker color, greater hardness, and resistance to erosion. The Cloud Chief gypsum is too highly mineralized and too impermeable to constitute an important ground-water reservoir, but it does supply enough water of poor quality for farm and stock use.

Rush Springs Sandstone

The Rush Springs sandstone, which is exposed at the surface over most of the Pond Creek Basin, has been described by Reeves 7/ under the name of Whitehorse sandstone 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 piled up into sand dunes." Sawyer 8/ states that "in places it contains some shale, especially in the lower part." Mechanical analysis of the "shales," however, has shown them to be siltstones.

Cavities described by well drillers as "soft streaks" are reported 9/ to occur in the Rush Springs

7/ Reeves, Frank, Geology of the Cement oil field, Caddo County, Okla.: U. S. Geol. Survey Bull. 726-B. p. 51, 1921.
8/ Sawyer, R. W., Areal geology of a part of southwestern Oklahoma: Am. Assoc. Petroleum Geologists Bull., vol. 8, p. 315, 1924.
9/ Reported by Sawyer Drilling Co., Chickasha, Okla., and Wheeler Drilling Co., Apache, Okla.

sandstone and to have vertical extent of a few inches to 2 feet or more. Examination of drill cuttings shows calcite to be the cementing material in the sands associated with the cavities, and it is inferred that solution and removal of calcite by ground water has caused these openings.

Well logs show the Rush Springs sandstone to be as much as 334 feet thick where none of it has been removed, but it has been eroded in its outcrop area so that thicknesses differ greatly from place to place.

The Rush Springs sandstone contains large amounts of ground water under water-table conditions. It is the major source of water in the Pond Creek Basin, being used for public supply at Eakly, Alfalfa, and Albert, for farm, domestic, and stock water; and for irrigation.

Marlow Formation

The Marlow formation underlies the Rush Springs sandstone. It is about 120 feet thick and is described by Sawyer 10/ as "red, even-bedded sandstones and red shales, with some regular bands of fine white sand, and much disseminated gypsum." This formation is too impermeable to yield more than enough water for stock use. The water from it generally is very hard and is high in calcium, magnesium, and sodium sulfates but is free from magnesium bicarbonate. 11/

10/ Sawyer, R. W., Oil and gas in Oklahoma, Kiowa and Washita Counties: Oklahoma Geol. Survey Bull. 40, vol. 2, p. 317, 1930.
11/ Dott, R. H., "Geology of Oklahoma ground water supplies" in Smith, O. M., Oklahoma Agr. and Mech. College, Eng. Exper. Sta. Pub. 52, p. 45, 1942.

Dog Creek Shale

The Dog Creek shale underlies the Marlow formation and according to Sawyer 12/ is about 150 feet thick in the southern part of the basin and perhaps 300 feet thick in the northern part. It consists mostly of red shale with some silty lenses. Because of its shaly nature it is a poor aquifer and yields only meager supplies to wells. No analyses are available to indicate the chemical character of the water from this formation within the basin, but very hard water is obtained from the Dog Creek shale of northern Grady County.

Blaine Gypsum

The Blaine gypsum underlies the Dog Creek shale and consists of interbedded dolomite, gypsum, and red shale. These beds yield ground water in large quantities at several localities in western Oklahoma where solution channels have been developed, principally in the gypsum, by circulating ground water. 13/ Similar large yields may be developed in the Blaine gypsum in the Pond Creek Basin if it contains such openings.

Available records show only one water well to have been drilled deep enough to penetrate the Blaine gypsum in the Pond Creek Basin. This well in the NW$\frac{1}{4}$ sec. 5, T. 8 N., R. 12 W. was drilled as a test by the Rural Electrification Administration. Drilling and production records are lacking, but the present land owner reports that the well was drilled to a depth of 506 feet and that it flowed a large stream of fresh water until it was plugged back to about 350 feet below the surface. The water probably came from the Blaine gypsum, and the large flow supports the hypothesis that solution cavities are present, making the Blaine worthy of exploration as a source of ground water. Water

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12/ Sawyer, R. W., op. cit.
13/ Schoff, S. L., "Ground-water irrigation in the Duke area, Jackson and Greer Counties, Okla": Oklahoma Geol. Survey Mineral Rept. 18, 1948.

from this source probably is hard but may be suitable for irrigation and some other farm uses.

Pre-Blaine Formations

Rocks of Permian age below the Blaine gypsum consist mostly of shale with some sandy zones. Any water contained in them is likely to be too highly mineralized for either domestic or irrigation use. Rocks older than Permian are deeply brined and contain salt water.

IRRIGATION DEVELOPMENT

By the end of 1949, eight irrigation wells, ranging in depth from 199 to 360 feet, had been completed in the Pond Creek Basin. (See table 1 and pl. 1.) All are equipped with turbine pumps, five powered by electric motors and three by gasoline engines. With one exception--where the furrow method is used--sprinkler systems are employed for distributing the water. These consist of a pump to force water into a pipe line from which it is delivered to the plants through perforated pipe sections or rotating sprayers. The line pipes range from 4 to 8 inches in diameter; most of those in use are made of aluminum but a few are of galvanized iron. The pipe sections are 16 or 20 feet in length and so fitted that they may be quickly assembled or taken apart without tools, Valves are so placed that part of the irrigation system may continue in operation without stopping the pump. The pressure required in the sprinkler method depends on the topography and on the length and diameter of the pipe lines.

In the following paragraphs the irrigation wells are described in the order of completion. The essential facts regarding them are summarized in table 1.

PREFACE

James W. Hill, Commander, U.S.N.R., was killed February 13, 1954, in the crash near Denver of his jet fighter, while on a routine training mission with Naval Reserve Aviation Fighter Squadron 711, of which he was commander. Hill had prepared a draft report prior to his death; the report was completed by his Geological Survey colleagues, principally James W Mytton and Garland B. Gott.

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ILLUSTRATIONS

TABLE I. Irrigation wells completed in the Pond Creek Basin prior to 1950.

Location	Owner	Diameter (inches)	Depth (feet)	Depth to water (feet)	Method of lift	Yield (gallons per minute)	Type irrigation	Driller
NW cor. sec. 33, T. 9 N., R. 13 W.	Neil Horn	6	199	37	Turbine, electric	125	Overhead sprinkler	R. M. Wheeler
SW$\frac{1}{4}$SE$\frac{1}{4}$ sec. 27, T. 9 N., R. 13 W.	Virgil Goodwin	7	191	32	Turbine, electric	a 125	Furrow	R. M. Wheeler
NE$\frac{1}{4}$NE$\frac{1}{4}$ sec. 21, T. 10 N., R. 12 W.	W. J. Lineer	16	360	110	Turbine, electric	b 400	Overhead sprinkler	Sawyer Drilling Co.
NW$\frac{1}{4}$NW$\frac{1}{4}$ sec. 28, T. 10 N., R. 12 W.	O. R. Paxton	16	330	60	Turbine, gasoline	b 500	Overhead sprinkler	Sawyer Drilling Co.
SE$\frac{1}{4}$SW$\frac{1}{4}$ sec. 22, T. 11 N., R. 13 W.	Roy Shoop	13	280	60	Turbine, gasoline	c 225	Overhead sprinkler	Sawyer Drilling Co.
Cen. N$\frac{1}{2}$ sec. 12, T. 9 N., R. 12 W.	Fred T. Andrews	16	260	61	Turbine, electric	b 278	Overhead sprinkler e/	Sawyer Drilling Co.
Cen. NE$\frac{1}{4}$ sec. 36, T. 9 N., R. 13 W.	J. W. Dees	10	215	26	Turbine, gasoline	d 250	Overhead sprinkler	R. M. Wheeler
Cen. E$\frac{1}{2}$SW$\frac{1}{4}$ sec. 34, T. 12 N., R. 12 W.	M. F. Smith	13	250	20	Turbine, electric	d 300	Overhead sprinkler	Wayne Hanson

a Rated capacity of pump.
b Reported by driller.
c Result of pumping test.
d Reported by owner.
e To be installed.

from this source probably is hard but may be suitable for irrigation and some other farm uses.

Pre-Blaine Formations

Rocks of Permian age below the Blaine gypsum consist mostly of shale with some sandy zones. Any water contained in them is likely to be too highly mineralized for either domestic or irrigation use. Rocks older than Permian are deeply brined and contain salt water.

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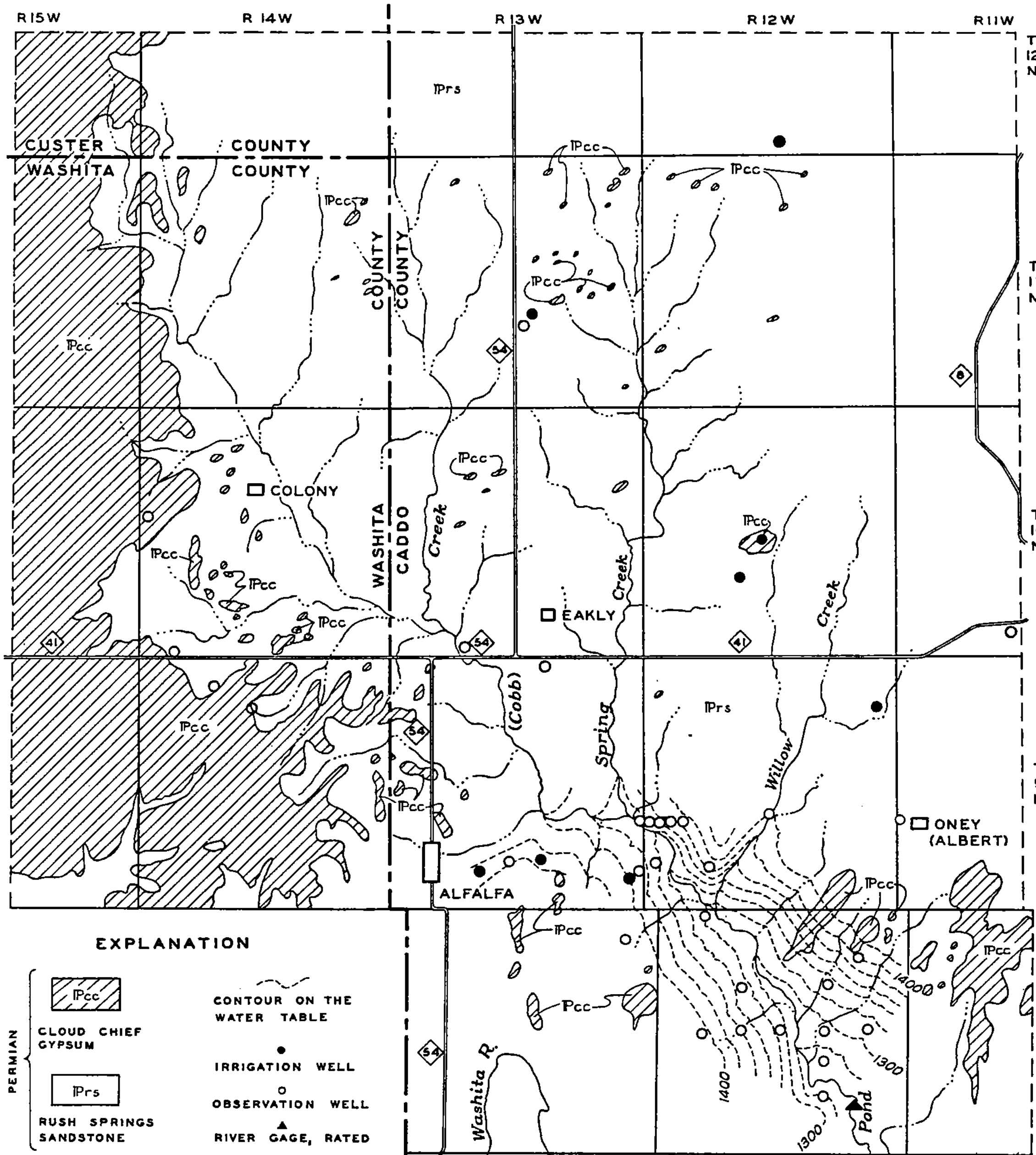

POND CREEK DRAINAGE BASIN, OKLAHOMA

SHOWING GEOLOGY, IRRIGATION AND OBSERVATION WELLS, AND CONTOURS ON THE WATER TABLE

BY L. V. DAVIS

0 3 6 miles

CONTOUR INTERVAL 20 FEET

1950

GEOLOGY ADAPTED FROM
GEOLOGIC MAP OF OKLAHOMA
COMPILED BY HUGH D. MISER
U. S. GEOLOGICAL SURVEY, 1926

WELL DESCRIPTIONS

Horn well (NW. cor. sec. 33, T. 9 N., R. 13 W.)--The first irrigation well in the Pond Creek drainage basin was drilled for Neil Horn in the spring of 1948 by R. M. Wheeler of Apache. It is 6 inches in diameter and 199 feet in depth. Later, three similar wells were drilled on a line through the first well at intervals of 5 feet. The wells were shot with dynamite and then cleaned to the bottom. They were cased with 6-inch casing to a depth of 20 feet only, and electric turbine pumps were installed in two alternate wells. The static water level is 37 feet below the land surface, and the drawdown with both pumps operating to produce 125 gallons per minute is about 73 feet. Thus the specific capacity is about 1.7 gallons per minute per foot of drawdown. An overhead sprinkler system delivers water for the irrigation of 17 acres of cannas. According to the owner's report, excellent results were obtained during the first two seasons of irrigation. 14/

Goodwin well. ($SW\frac{1}{4}SE\frac{1}{4}$ sec. 27, T. 9 N., R. 13 W.) The Goodwin well was drilled in 1948 by R. M. Wheeler to a depth of 191 feet. The static water level is 32 feet below the land surface. The well is cased with 15 feet of 7-inch casing and is equipped with an electric turbine pump having a rated capacity of 125 gallons per minute. No observations of yield have been made on this well, which was first used in 1949 to irrigate 25 acres of peanuts by the furrow method.

Lineer well. ($NE\frac{1}{4}$ $NE\frac{1}{4}$ sec. 21, T. 10 N., R. 12 W.) The Lineer well was drilled by the Sawyer Drilling Company, of Chickasha, to a depth of 360 feet. It is cased to 12 feet with 16-inch casing and has an electric turbine pump with a rated capacity of 400 gallons per minute. The static water level is 110 feet below the land surface. The drawdown after pumping at a rate of 282 gallons per minute for 4 hours was 61 feet, indicating a specific capacity of 4.62 gallons per minute

14/ Horn, Neil, oral communication.

per foot of drawdown. 15/ The well was completed in 1948 too late to use during the growing season, but in 1949 it supplied water by means of a sprinkler system for 28 acreas of peanuts.

Paxton well. ($NW\frac{1}{4}NW\frac{1}{4}$ sec. 28, T. 10 N., R. 12 W.) The Sawyer Drilling Company drilled the Paxton well late in 1948. It is 330 feet deep, and the static water level is about 60 feet below the land surface. The well is cased with 20 feet of 16-inch casing and equipped with a belt-driven turbine pump powered by a gasoline engine. The driller estimated that the well should yield 500 gallons per minute, but the actual yield has not been measured. In 1949 the well was used to irrigate 32 acres of peanuts by means of a sprinkler system.

Shoop well. ($SE\frac{1}{4}SW\frac{1}{4}$ sec. 22, T. 11 N., R. 13 W.)-The Shoop well was completed early in 1949 by the Sawyer Drilling Company. The well is 280 feet deep, has 13-inch casing to a depth of 15 feet, and is equipped with a turbine pump powered by a gasoline engine through a gear drive. The static water level is 60 feet below the land surface, and the drawdown after pumping for 23 hours and 50 minutes at an average rate of 225 gallons per minute is 179.5 feet, indicating a specific capacity of 1.25 gallons per minute per foot of drawdown. In 1949 the well was used to irrigate 15 acres of peanuts through a sprinkler system. The operator's plans for the future include irrigation of tame grasses to supply pasture during dry periods.

Andrews well. (near center $N\frac{1}{2}$ sec. 12, T. 9 N., R. 12 W.)--The Andrews well was completed in the spring of 1949 to a depth of 260 feet by the Sawyer Drilling Company, which reports that the well produced an average of 278 gallons per minute during a 24-hour test. The well is 16 inches in diameter, has sheet iron casing to a depth of 18 feet, and a static water level 61 feet

15/ Clausen, D. W., Caddo Electric Cooperative, personal communication, November 25, 1949.

below the land surface. A sprinkler irrigation system is to be installed.

Dees well. (near center $NE\frac{1}{4}$ sec. 36, T. 9 N., R. 13 W.)--The Dees well was drilled by R. M. Wheeler early in the summer of 1949. It is 215 feet deep, and the static water level is 26 feet below the surface. The well is cased to a depth of 30 feet with 10-inch casing, and it is equipped with a turbine pump driven by a 35-horsepower gasoline engine through a belt drive. The owner reported that the well yields 250 gallons per minute and that during the 1949 growing season it was pumped 13 hours a day, 6 days a week, for the irrigation of 34 acres of peanuts. The water is delivered through a sprinkler system.

Smith well. (center $E\frac{1}{2}SW\frac{1}{4}$ sec. 34, T. 12 N., R. 12 W.)--The Smith well was drilled by Wayne Hanson late in 1949. It is 250 feet deep, is cased to a depth of 20 feet with 13-inch casing, and is equipped with an electric turbine pump. No observations of the static water level have been made. The owner reported the yield as 300 gallons per minute during a pumping test.

QUALITY OF WATER

The chemical character of the ground water in the Rush Springs sandstone is shown by analyses given in table 2. The analyses were made in the laboratory of the Quality of Water Branch, U. S. Geological Survey, at Stillwater, Oklahoma.

The concentration of dissolved mineral matter that can be tolerated in water depends on the use to which the water is put. The United States Public Health Service 16/ has established standards indicating the upper limits in mineral concentration of magnesium, chlo-

16/ U. S. Public Health Service drinking water standards: Public Health Repts., vol. 61, pp. 371-384, 1946.

rides, sulfates, and dissolved solids in water acceptable for human consumption. Waters of higher mineral concentration may be used for drinking but may cause intestinal disturbance. A comparison of the analyses of water from the Rush Springs sandstone with these standards shows this water to be excellent for human consumption.

Table 3.-Comparison of maximum concentration, in parts per million, of some mineral constituents in water from Rush Springs sandstone with U. S. Public Health Service standards.

	Rush Springs sandstone (p.p.m.)	Limits Established by Public Health Service (p.p.m.)
Magnesium (Mg)	18	125
Chloride (Cl)	49	250
Sulfate (SO_4)	21	250
Total dissolved solids	448	500

The suitability of water for irrigation depends not only on the chemical character of the water, but also on the chemical and physical character of the soil, the method of irrigation used, and the amount of rainfall. More dissolved mineral matter can be tolerated in irrigation water used on sandy soil with good subdrainage than on heavy soil with poor subdrainage. Much of the water is lost through evaporation, either directly from the soil or indirectly through plant use, and the mineral matter is left behind. In tight, heavy soils the mineral concentration may become excessive, but in light sandy soils affording good drainage, like those of the Pond Creek Basin, rains tend to wash out the mineral matter.

Table 2. Analyses of water from wells in the Rush Springs sandstone, Pond Creek Basin, Caddo County, Oklahoma.

Location		Total depth (feet)	Diameter (inches)	Date sampled	Water temperature (°F.)	Parts per million											Specific conductance (micromhos at 25° C.)	Percent sodium
						Calcium (Ca)	Magnesium (Mg)	Sodium and potassium ($Na + K$)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Total hardness as $CaCO_3$	Dissolved solids		
T.N.	R.W.																	
8	12	348	6	3-24-48	63	24	12	2.4	0	99	9.9	14	--	4	109	192	192	4.5
8	13	40	6	3-17-48	62	27	13	29	0	110	16	11	--	75	121	273	273	34
9	12	80	6	3-18-48	61	17	7.6	16	0	72	12	12	0.2	25	74	144	144	32
9	12	90	6	3-18-48	59½	47	18	16	12	206	8.7	10	0.4	15	191	202	389	15
9	12	62.5	8	3-17-48	60	20	10	13	0	99	9.7	14	--	10	91	145	217	24
9	12	120	6	3-24-48	61	36	16	108	0	316	21	49	--	50	157	448	742	60
9	13	--	6	3-24-48	59½	47	8.7	47	0	239	12	9	0.4	40	153	296	455	40
9	13	335	6	8-18-48	60	54	13	15	0	188	20	9	--	40	188	282	407	14
10	12	67	6	3-19-48	60	57	19	21	0	260	16	25	0.1	1	221	280	477	17
10	13	--	6	3-17-48	59½	37	5.2	16	0	145	7.8	14	--	3	114	156	268	24
11	12	110	6	3-19-48	61	73	9.2	22	18	210	5.7	14	--	50	220	290	465	18
12	13	80	6	3-18-48	60½	70	8.0	39	0	326	5.8	11	--	5.0	208	339	554	29

Standards for irrigation water suggested by Magistad and Christianson 17/ fall into three classes:

1. Excellent to good, suitable for most plants under most conditions.
2. Good to injurious, the higher concentrations probably harmful to the more sensitive crops.
3. Injurious to unsatisfactory, probably harmful to most crops and unsatisfactory for all but the most tolerant.

If a water falls in class 3 on any basis, i. e., conductance, salt content, percentage of sodium, or boron content, it should be classed as unsuitable under most conditions.
Should the salts present be largely sulfates, the values for salt content in each class can be raised 50 percent.

Maximum mineral concentrations for these three classes are given in table 4 A. As shown in table 4 B, water in the Rush Springs sandstone falls in class 1, which is suitable for most crops under nearly all conditions. Boron was not determined in the analyses of the waters from the Rush Springs sandstone.

17/ Magistad, O. C., and Christianson, J. E., Saline soils, their nature and management: U. S. Dept. Agr. Circ. 707, p. 9, 1944.

Table 4.--Standards for irrigation water and composition of water from the Rush Springs sandstone.

A. Standards for irrigation water 18/

Water class	Conductance (micromhos at 25° C.)	Salt content Total (p.p.m.)	Per acre-foot (tons)	Sodium (per-cent)	Boron (p.p.m.)
1	1,000	700	1	60	0.5
2	1,000-3,000	700-2,000	1-3	60-75	0.5-2.0
3	3,000	2,000	3	75	2.0

B. Composition of Rush Springs waters

Minimum	144	169	.22	4.5
Average	381	329	.45	26
Maximum	554	596	.81	60

THE WATER TABLE

The water table is defined as the upper surface of the zone of saturation except where that surface is formed by an impermiable body. It is represented by

18/ Op. Cit.

the static water levels in wells. Meager data indicate that the water table in the Pond Creek Basin is a subdued replica of the surface topography, higher under the hills than under the valleys. Under upland areas the water table slopes toward the major valleys at about 10 feet per mile, steepening as it approaches the perennial streams. Along the reach of Pond Creek downstream form Alfalfa to the surface-water gaging station the slope of the water table for about 2 miles on either side of the valley is 60 to 80 feet per mile (pl. 1). Slopes of the water table flanking Spring and Willow Creeks probably are similar.

FLUCTUATIONS OF GROUND-WATER LEVEL

The static water levels in wells indicate the extent to which ground water reservoirs are filled with water. The stage of the water in the reservoir at any time is a reflection of the short-term variations in recharge-discharge relation. A protracted rise in water level, indicates an excess of recharge over discharge and, conversely, a continuing decline indicates excess of discharge. Under natural conditions, a long slow rise of water level would be expected to be followed by a slow decline, in response to variations in precipitation. Heavy withdrawal of water through wells may obscure these natural trends, and a progressive decline may indicate overpumping and danger of ultimate depletion of the reservoir.

Monthly measurements of static water levels in selected farm wells were begun in March 1948. In May a continuous water-stage recorder was installed in an abandoned well on the lower east side of the basin (sec. 11, T. 8 N., R. 12 W.), and in November a second recorder was installed in a well on the west side of the basin (sec. 28, T. 9 N., R. 13 W.). In May 1949, through the cooperation of the George E. Failing Supply Company, Enid, Oklahoma, 8 observation wells were drilled in the lower part of the basin, bringing the total to 29. The locations of the observation wells are shown on plate 1.

Through 2 years of record, from March 1948 to March 1950, the depth to the water table has not changed by more than 3 feet in any of the wells, and has changed less than 1 foot in most of them. Pumping of water for irrigation has had no apparent effect on water levels in the observed wells.

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 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. During a 5-day period in May 1948, a microbarograph was operated near Caddo County well 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. 2).

Likewise, the hydrographs for wells 11 and 14 for the period December 24-30 are strikingly similar even in small details, although the two wells are 8 miles apart (fig. 3). As no heavy pumping was in progress anywhere in the area and no precipitation had occurred for several weeks, changes in barometric pressure seem to offer the only plausible explanation for the fluctuation 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. It is probably significant that in well 14, where the depth

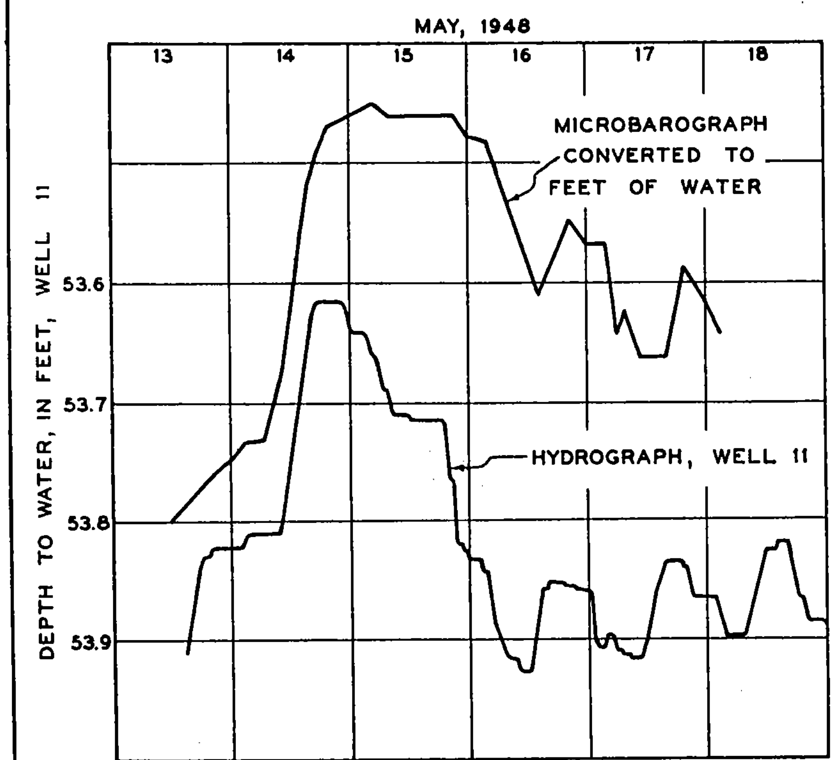

FIGURE 2: - COMPARISON OF HYDROGRAPH WITH BAROMETRIC FLUCTUATIONS

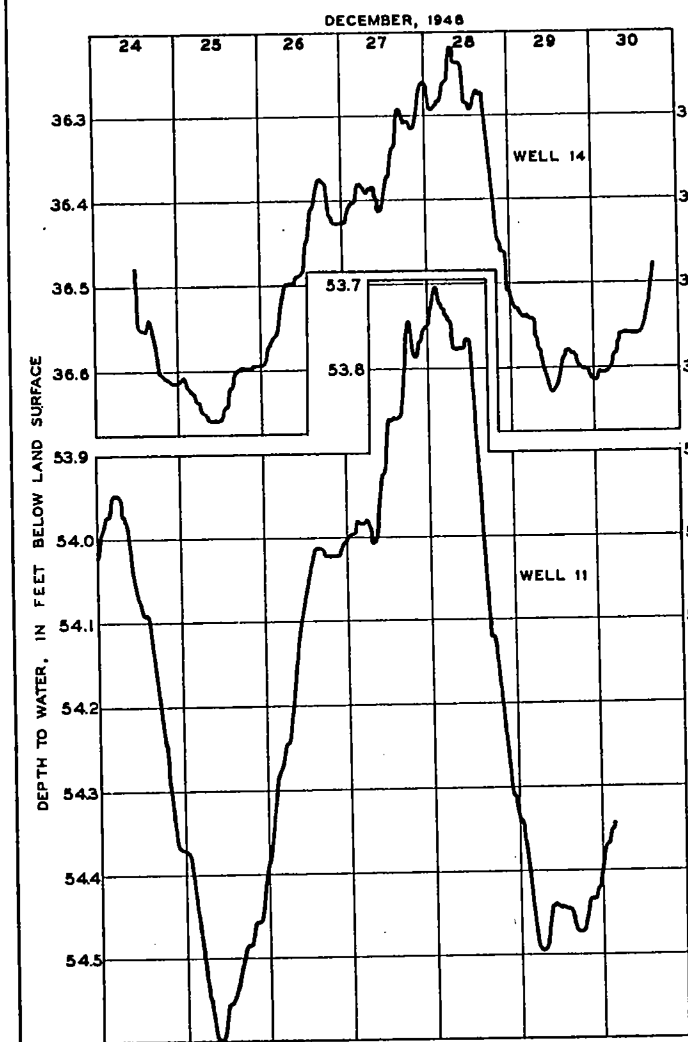

FIGURE 3: COMPARISON OF HYDROGRAPHS
OF WELLS 11 & 14,
POND CREEK DRAINAGE BASIN,
CADDO COUNTY, OKLAHOMA

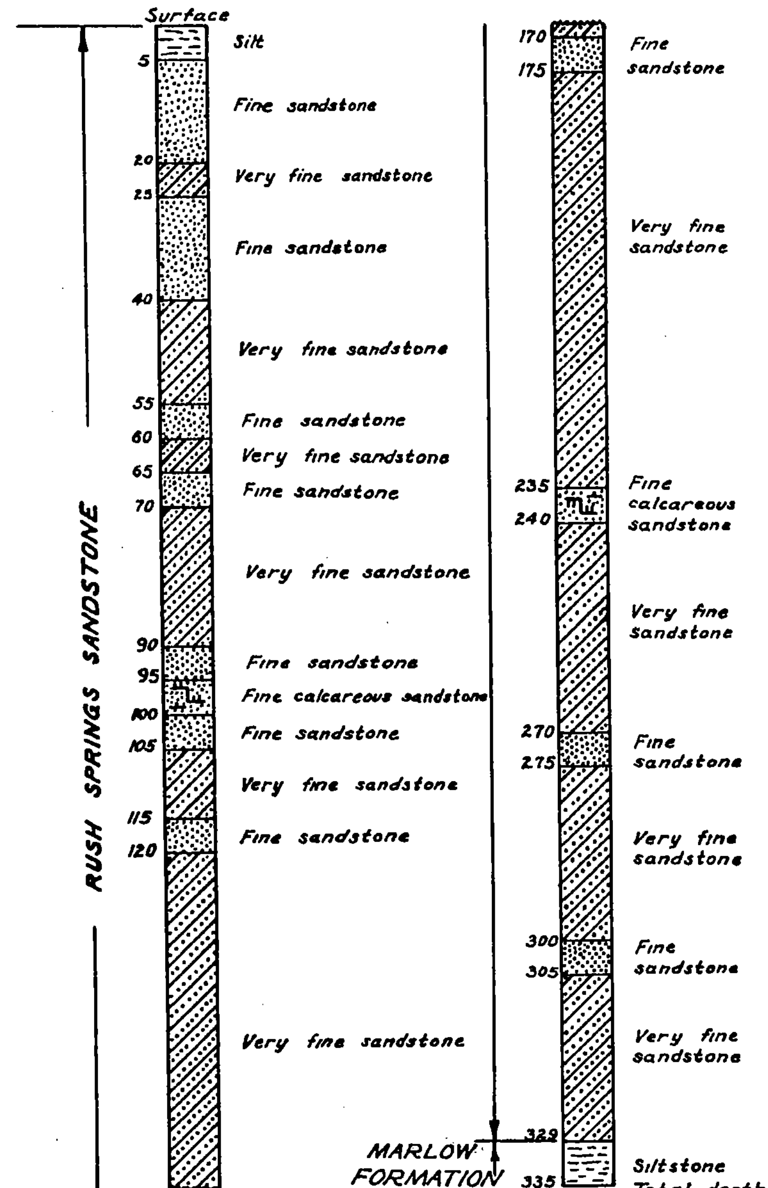

Figure 4.—Graphic log illustrating character of Rush Springs sandstone, Caddo County well 14.

to water is 38 feet, the fluctuations of water level were only about half as great as in well 11, where the depth to water is 54 feet. In other words, the greater the thickness of unsaturated rock over the water table the more the changes in barometric pressure are retarded and the greater the resulting effect on the observed water level in the wells.

TEST DRILLING

To obtain samples representing the full thickness of the Rush Springs sandstone, the Geological Survey had a test hole drilled about 3 miles east of Alfalfa (SE cor. sec. 28, T. 9 N., R. 13 W.) in August 1948. This hole was 335 feet deep. It began about 5 feet below the top of the formation and passed out of it into the underlying Marlow formation at 329 feet. Figure 4 is a graphic log of the well based on microscopic examination and mechanical analyses of the drill cuttings. The Rush Springs at this locality consists mostly of very fine sandstone with some silt and some calcium carbonate cement. Included are layers of fine sandstone and two layers of calcareous sandstone.

While drilling at a depth of about 98 feet, the bit abruptly dropped 6 inches, and at 237 feet a similar drop of 14 inches occurred. As the graphic log (fig. 4) shows, the sandstone at these depths is calcareous and it therefore is probable that the bit dropped into cavities created in the rock by the solution and removal of calcareous cement by circulating ground water.

PUMPING TEST

In April 1949 a pumping test was made in the Shoop well to determine the coefficient of transmissibility of the Rush Springs sandstone. The geologic conditions at the test site are fairly representative of the Pond

Creek Basin, for the Rush Springs sandstone lies immediately below a light, sandy, highly permeable soil. The driller's log shows that the well penetrated fine sandstone from the surface to the bottom at 280 feet. The static water level at the beginning of the test was 60 feet below the land surface.

Hydrologic conditions in the aquifer are neither strictly water-table nor strictly artesian. Although the Rush Springs sandstone is generally considered to contain water under water-table conditions, the water level fluctuates in response to barometric pressure, indicating some of the properties of an artesian aquifer. Only the Rush Springs in the immediate vicinity of the Shoop well could be tested, obviously, but the result of the test may be considered indicative of the transmissibility of the formation throughout the basin. Differences in yields of wells in the Pond Creek Basin indicate that this test yielded a conservative figure for the transmissibility.

At the time of the test the well was equipped with a turbine pump with the bowls set at a depth of 240 feet, powered by a gasoline engine burning butane. The pump was operated from 10:40 a. m., April 4, to 10:30 a. m. April 5, 1949, the average yield for the 23 hours and 50 minutes being 225 gallons per minute. Measurements of the water level were made during the pumping period in a second well approximately 600 feet distant, but the water level was not affected by the pumping. Instead a slight rise was observed, probably corresponding with a decline in barometric pressure as recorded by a microbarograph. At the end of the pumping period, the water level in the pumped well was about 240 feet below the surface, as determined by air-pressure gage, indicating a drawdown of 180 feet and a specific capacity of 1.2 gallons per minute per foot of drawdown. During the ensuing 10 hours the water level recovered about 177.5 feet, rising to within 2.5 feet of the static level at the beginning of the test (table 5).

Table 5.-Recovery of water level in the Shoop well

Time of test	Depth to water (feet)	Recovery (feet)
April 4, 1949, 10:40 a.m. started pump	a 60	
April 5, 1949, 10:30 a.m. stopped pump	a 240	0
10:31 a.m.	a 201.5	38.5
10:31½ a.m.	a 174	66
10:35 a.m.	a 140	100
10:40 a.m.	a 120	138
10:57 a.m.	b 73.74	166.26
11:15 a.m.	b 68.99	171.01
11:30 a.m.	b 67.48	172.52
12:00 noon	b 66.02	173.98
1:00 p.m.	b 64.70	175.30
2:00 p.m.	b 64.06	175.94
3:00 p.m.	b 63.65	176.35
4:00 p.m.	b 63.33	176.67
7:00 p.m.	b 62.73	177.27
9:00 p.m.	b 62.49	177.51

a Air-pressure guage measurement.
b Tape measurement.

The drawdown in the Shoop well was rapid at first, and initially the recovery of the water level after pumping stopped was correspondingly rapid. When plotted on semi-logarithmic paper the recovery measurements should, theoretically, yield a straight line. Those for the last 7.5 hours yielded such a line, but this part of the recovery curve does not represent the conditions in and adjacent to a pumping well where the saturated thickness of water-bearing material locally is reduced by the drawdown. The first part of the recovery curve yielded a curved line whose slope increased as the water level approached equilibrium, this part of the recovery comes closer to representing conditions in a pumping well. Analyzed by the Theis 19/ nonequilibrium formula, this part of the curve indicates a coefficient of transmissibility of 5,000 gallons per day per foot. The coefficient of transmissibility is defined as the number of gallons of water a day that percolates under prevailing conditions through each mile of the water-bearing bed (measured at right-angles to the direction of flow) for each foot per mile of hydraulic gradient. It is a measure of the ability of the aquifer to transmit and yield water to wells.

Using the coefficient of transmissibility of 5,000, estimates were made of the probable drawdown in the Shoop well at the end of 10 and 20 days of continuous pumping at rates of 225, 250, and 300 gallons per minute (table 6).

For efficient operation, the drawdown in this well should not exceed about 2/3 of the thickness of the water-bearing sand. As the saturated Rush Springs sandstone at the Shoop site is estimated to be 265 feet thick, the drawdown should not exceed 177 feet. It is evident, therefore, that 225 gallons per minute is about as much as should be expected from the Shoop well.

19/ Theis, C. V., The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using ground-water storage: Am. Geophys. Union Trans., pp. 419-524, 1935.

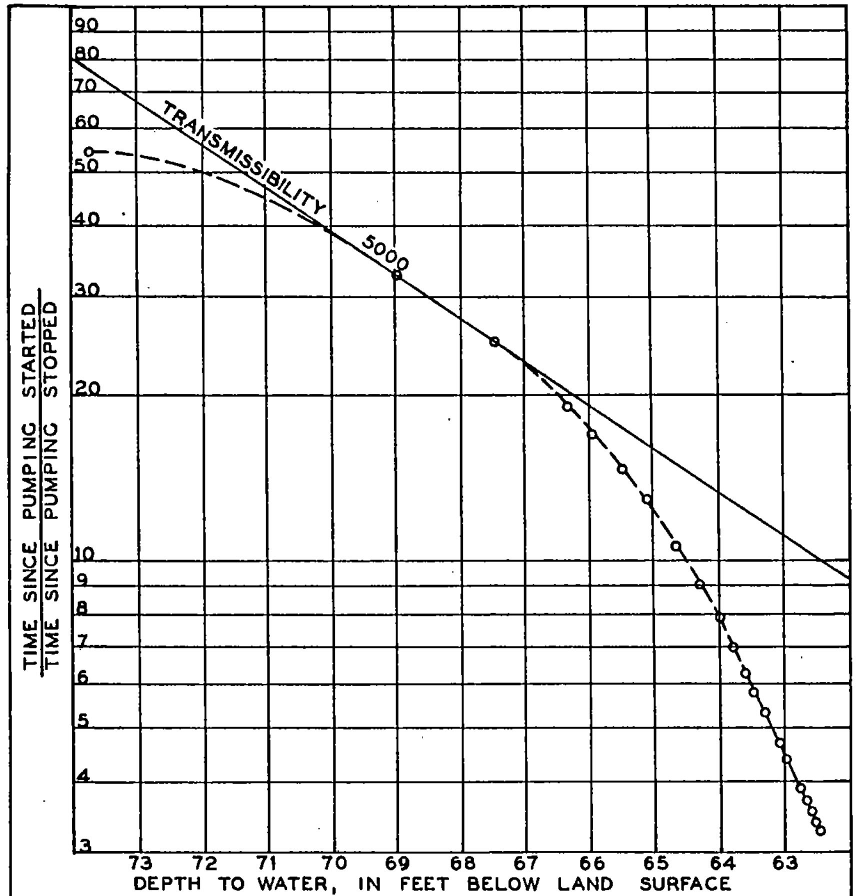

FIGURE 5: SEMILOG GRAPH OF THE RECOVERY OF THE WATER LEVEL IN THE SHOOP IRRIGATION WELL

CADDO COUNTY, OKLAHOMA

Table 6.-Estimated drawdown, in feet, in Shoop well, after 10 and 20 days of continuous pumping.

Yield (gallons per minute)	Drawdown after 10 days (feet)	Drawdown after 20 days (feet)
225	180	185
250	200	205
300	240	245

RECHARGE AND DISCHARGE

Of the water that falls on the surface of the earth, a part runs off and flows away in rivers; some is returned to the atmosphere by evaporation; some is used by plants and eventually returned to the atmosphere; and some percolates down through the soil and underlying rocks to the water table, becoming ground water. The addition of water to underground reservoirs in this manner is called recharge. This replenishment makes ground water a natural resource that can be harvested annually.

In the zone of saturation water moves under the influence of gravity from higher to lower altitudes at rates ranging from a few inches to several hundred feet per day. Ultimately it discharges from the aquifer through springs or into streams, or in some cases into the sea. Such discharge is called natural discharge. To it generally must be added the artificial discharge of water through wells or other man-made structures for recovering ground water. The natural discharge approximately balances the recharge, and a measurement of the natural discharge, therefore, is a reliable index to the recharge. Withdrawal of ground water by pumping may reduce the natural discharge, but this diversion of water from one type of discharge to the other is not necessarily undesirable, unless the diverted natural discharge served a practical and economic purpose.

An analysis of precipitation records for the Weather Bureau stations at Fort Cobb and Weatherford, which are near the southeast and northwest ends, respectively, of the Pond Creek Basin, indicates that about 1,053,000 acre-feet of water fell in the basin in the 24 months from October 1, 1947, to October 1, 1949. During this same period, the total discharge of Pond Creek, as measured by a recording gage near Fort Cobb, was 100,300 acre-feet. At low stages the flow of the creek represents the natural discharge of ground water from the Rush Springs sandstone. A study of a hydrograph representing the stream flow indicates that the ground-water discharge was 31,626 acre-feet, that the surface runoff was 68,672 acre-feet, and that the remaining 952,700 acre-feet was lost by evaporation, was used by plants, or went into ground-water storage.

As the recharge to the ground-water reservoir in the Rush Springs sandstone must be great enough to sustain the natural discharge, it must have been at least 31,626 acre-feet during the 24 months, or 15,813 acre-feet per year. Stated in other terms, this is 49.42 acre-feet annually per square mile, and is equal to 0.93 inch of rain, or about 3 percent of the average precipitation.

CONCLUSIONS

The principal aquifer in the Pond Creek Basin is the Rush Springs sandstone, of Permian age, which attains a thickness of 335 feet where it is not eroded. For most practical purposes, the ground water may be considered as occurring under water-table conditions. The eight widely scattered wells that had been completed by the fall of 1949 indicate that the formation

probably will yield sufficient water for irrigation throughout the basin. Results of one pumping test show that 225 gallons per minute is the maximum yield that may be expected from the well tested, but other data suggest that in some places in the basin higher yields may be obtained. Recharge and discharge of water to and from the aquifer are approximately balanced. Static water levels have not been measurably affected by pumping, because the wells are few and have been operated only a short time. The water of the Rush Springs sandstone is of good quality for domestic and irrigation use, and for some industrial uses.

The Blaine gypsum may yield water in quantities adequate for irrigation, provided the gypsum layers are cavernous, but this possibility is as yet untested.