Hydrogeology of a Part of the Grand Prairie Region, Arkansas

By RICHARD T. SNIEGOCKI

ARTIFICIAL RECHARGE OF GROUND WATER—GRAND PRAIRIE REGION, ARKANSAS

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1615–B

Prepared in cooperation with the U.S. Army, Corps of Engineers, and the University of Arkansas

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1964

UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402

CONTENTS

ILLUSTRATIONS

[Plates are in pocket]

TABLES

ARTIFICIAL RECHARGE OF GROUND WATER—GRAND PRAIRIE REGION, ARKANSAS

HYDROGEOLOGY OF A PART OF THE GRAND PRAIRIE REGION, ARKANSAS

By Richard T. Sniegocki

ABSTRACT

The Grand Prairie region of Arkansas is in a subdivision of the Coastal Plain province known as the Mississippi Alluvial Plain. Deposits of Quaternary age in the alluvial plain yield abundant supplies of water for rice irrigation.

The first phase of the study of artificial recharge through wells in the Grand Prairie consisted of the collection and interpretation of detailed geologic and hydrologic information in the vicinity of the proposed recharge-test site. This report is the result of that hydrogeologic investigation.

Test drilling and construction of observation wells were extensive within a 24-square-mile area around the recharge-test site. Geologic sections and isopach maps of various hydrogeologic units show that the deposits of Quaternary age are continuous over a large area. These deposits consist of two major zones—namely, a basal zone of sand and gravel blanketed by an upper zone of very dense, relatively impervious silt and clay. It has not been possible to distinguish with any certainty the Recent from the Pleistocene parts of the Quaternary deposits. Particle-size analyses of samples of the aquifer sand collected near the recharge well show that the material had an effective size of 0.06 to 0.25 mm and a uniformity coefficient of 5.8 to 1.4.

Aquifer coefficients were determined by means of conventional pumping-test methods and by evaluation of drill cuttings from test holes. The coefficient of storage of the aquifer where it is unconfined was determined to be approximately 0.30. Application of this coefficient to the volume of unwatered sand in the Grand Prairie region indicates the removal of at least 2 million acre-feet of water from storage since 1906 as a result of rice irrigation. This large volume of unwatered sand provides potential storage space for an equivalent quantity of water.

Chemical analyses of samples of ground water collected from the Quaternary aquifer show that waters in the project area are of the calcium bicarbonate type. There is some variation in the concentration of dissolved solids and of the individual constituents, but the quality of the ground water is relatively uniform during a pumping season and in different wells within the area.

A part of the hydrogeologic investigation in the project area is continuing. Periodic water-level measurements are made and additional pertinent geologic and hydraulic data are collected and interpreted as they become available from oil tests, irrigation-well drilling, or other work in the area.

INTRODUCTION

PURPOSE AND SCOPE OF THE REPORT

In 1953 the Grand Prairie region of Arkansas was selected for an investigation of the principles of recharging ground-water reservoirs through wells. This region provided a large natural laboratory for making the study.

For proper evaluation and analysis of artificial-recharge test data, detailed hydrogeologic data were needed. Consequently, the initial work on the project consisted of test drilling, installation of observation wells, and collection of ground-water records. A part of this phase of the artificial-recharge study will be continued as long as recharge tests are being made; it includes making periodic water-level measurements and collecting additional geologic data as irrigation wells are installed, oil-test holes are drilled, or other work in the area is done. This report presents the hydrogeologic data collected in connection with the study of artificial recharge through wells. Records and logs of selected wells and test holes (tables 7 and 8) and water-level measurements in selected wells (table 9) are given at the end of this report under "Basic data."

LOCATION AND EXTENT OF THE AREA

The area described in this report includes about 210 square miles in Arkansas County; the Rice Branch Experiment Station of the University of Arkansas is near the center of the area. (See figs. 1 and 2.) The experiment station, including an area of about three-quarters of a square mile in sec. 3, T. 3 S., R. 4 W., is the site of the artificial-recharge tests. Most of the detailed study of the hydrology and subsurface geology has been limited to the station and the surrounding 24 square miles.

WELL-NUMBERING SYSTEM

The well numbers in this report indicate the location of each well with respect to the Federal land survey used in Arkansas. The first number is the township, north or south; the second number is the range, east or west; and the third number is the section in which the well is located. The lowercase letters (a, b, c, d) designate the quarter section, the quarter-quarter section, and the quarter-quarter-quarter section, or 10-acre tract. The letters are assigned counterclockwise, beginning with "a" in the northeast quadrant. If two or more wells are listed within a 10-acre tract, they are numbered serially according to the order in which they are described. (See fig. 3.)

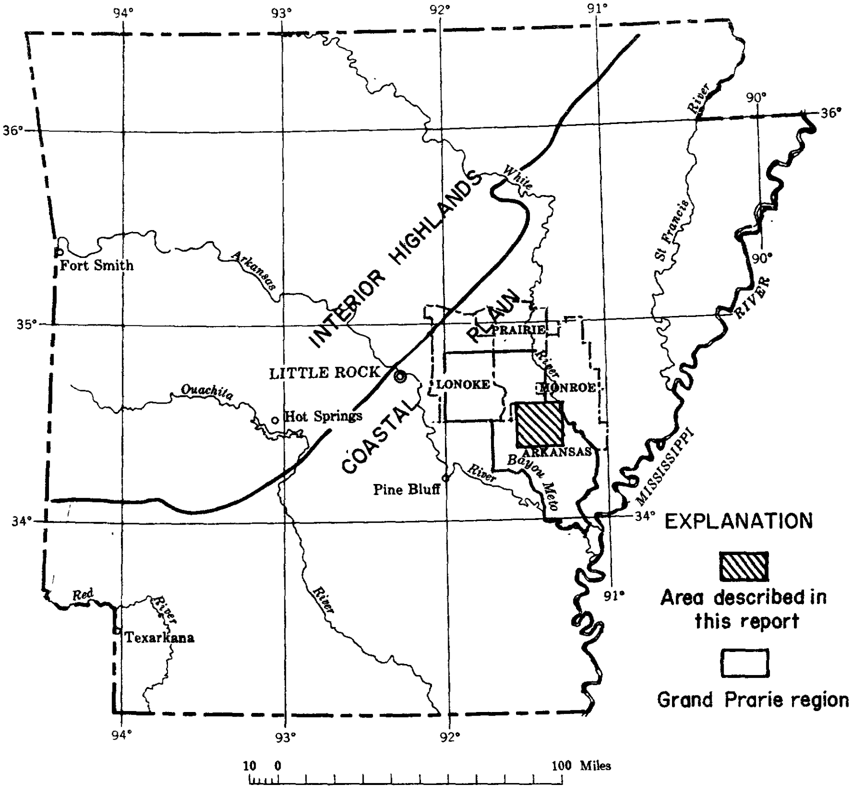


FIGURE 1.—Map of Arkansas showing the location of the area described in this report.

The same numbering system is used for test holes and for wells from which samples were collected. The prefix "L" is used to denote the log of a test hole.

For observation wells that are immediately adjacent to the recharge well, a simplified numbering system is used. These wells have been assigned numbers according to their orientation and (or) use. For example, the third observation well away from the recharge well southward is designated "3–S," and a stilling well inside the recharge well is designated "I."

PREVIOUS WORK ON THE GEOLOGY AND HYDROLOGY OF THE GRAND PRAIRIE

Owen (1860), Call (1891), and Harris (1894) were among the early investigators who studied the geology of areas that include part or all of the Grand Prairie region. Investigations by Nuttall (1821), Warder (1854), Cox (1858), Call (1891), Chamberlin and Salisbury (1891), Veatch (1906), and others have added greatly to the fund of information about the geology and water resources of the lower

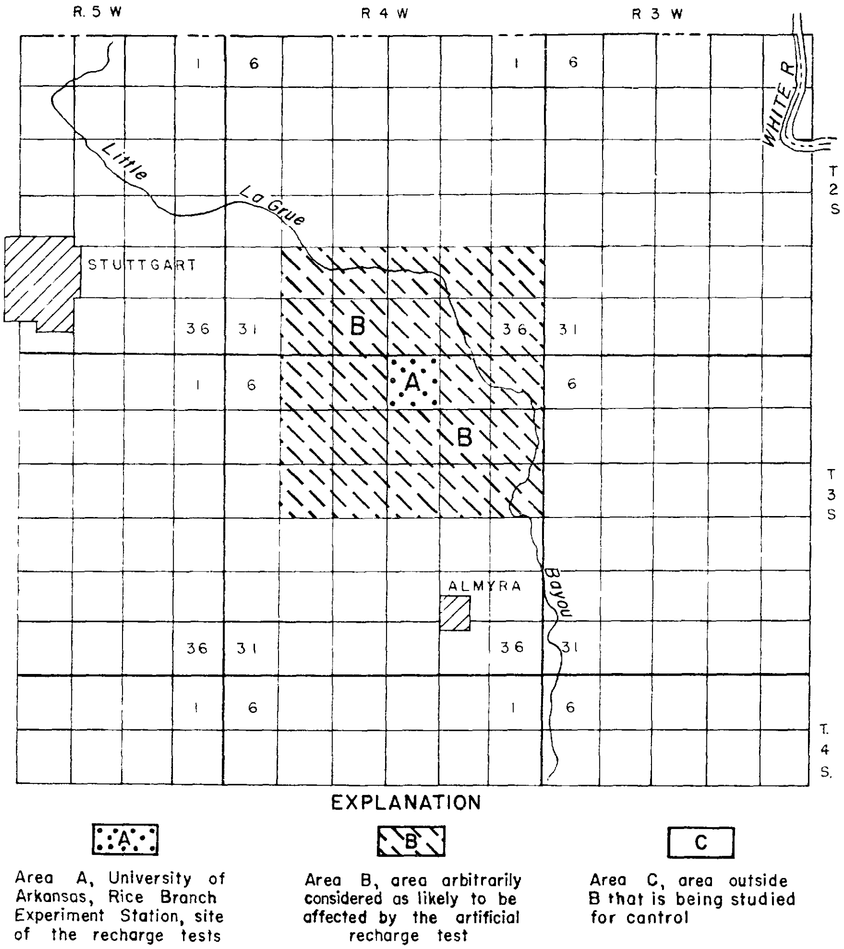


FIGURE 2.—Map of the artificial-recharge area showing the site of the tests and the areas being studied.

Mississippi Valley. Three reports describe the soils of Lonoke and Prairie Counties and part of Arkansas County (Lapham, 1903; Carter and others, 1906; Knobel and others, 1921). Stephenson and Crider (1916) describe the geology and ground water of northeastern Arkansas in a comprehensive report that includes a section on ground water for each of the counties. Clayton (1930) investigated the cost of pumping and duty of water for rice in the Grand Prairie region. A report compiled under the direction of Branner (1937) presents a list of Arkansas water wells. Fiske (1944) made a geologic investigation of the alluvial valley of the lower Mississippi River to ascertain the nature and origin of the valley and to determine the sequence of events in valley evolution.

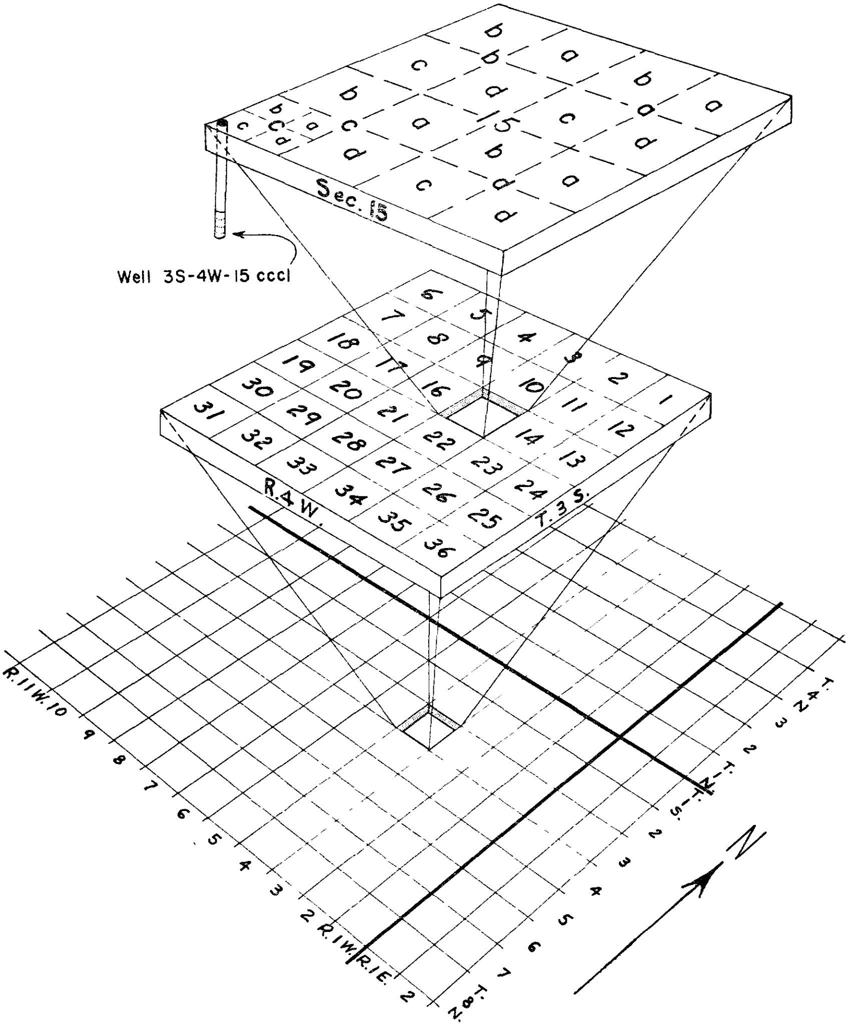


FIGURE 3.—Sketch illustrating the well-numbering system.

Banks have made loans on rice farms in the Grand Prairie region for many years; and, because ground-water supplies play such an important role in rice production, the banks have endeavored to keep themselves informed as to the availability of ground water. The Federal Land Bank of St. Louis has cooperated with the University of Arkansas and the Geological Survey in making periodic water-level measurements and in constructing maps showing water-table contours, depth to water, ground-water recession, and other hydrologic features.

A report by Engler, Thompson, and Kazmann (1945) contains detailed hydrologic information for the Grand Prairie region on the general geologic conditions affecting the ground water, water-level fluctuations, hydraulic constants of the aquifer, natural recharge, and yield of the aquifer.

In 1954 Counts and Engler reported changes in water levels in deposits of Quaternary age in eastern Arkansas from 1938 to 1953. Their report contains three maps of an area of 8,800 square miles which show water-table contours and changes in water levels for 1938 and 1953.

A. R. Gerlow (1958) made an economic appraisal of the reservoir systems in the Grand Prairie region. Capital investments, seasonal costs, and cost per acre irrigated are topics covered by the report that are of particular interest if one is considering a supply of surface water for injection underground.

Two progress reports on the work done on the recharge project during the first 3 years have been released to the open file (Sniegocki, 1954, 1957). The principal papers that discuss all or part of the Grand Prairie region are listed at the end of this report.

ACKNOWLEDGMENTS

Thanks are given to many organizations and individuals whose interest and help in the investigation have made it possible for work on the artificial-recharge project to proceed smoothly and without interruption. The University of Arkansas has a vital interest in the water resources of the State and has taken an active part in the promotion of the study. The U.S. Army, Corps of Engineers, Vicksburg District, has been authorized to reinvestigate surface-water development in the Grand Prairie region, considering artificial recharge as a water-conservation measure. Because of these direct interests in the project, the Corps of Engineers and the University of Arkansas have cooperated with the Geological Survey in nearly all phases of the investigation. Kyle Engler and F. J. Williams have represented the University of Arkansas in the project. J. T. Pegg and F. H. Bayley, 3d, have represented the Corps of Engineers.

The quality-of-water and surface-water aspects of the project are being studied by the Quality of Water Branch and the Surface Water Branch of the Geological Survey.

Quantitative analyses of samples of aquifer materials were made in the hydrologic laboratory of the Geological Survey, Denver, Colo.

Other cooperating governmental agencies are the Arkansas State Health Department, the Arkansas Geological and Conservation Commission, and the U.S. Coast and Geodetic Survey.

L. B. Riley and A. J. Gude of the Geological Survey made X-ray analyses to determine the mineralogy of clay samples collected at the

artificial-recharge site. J. E. Hackett of the Illinois State Geological Survey furnished X-ray data on samples of clay and silt collected from a road cut near Clarendon.

ENVIRONMENT OF THE AREA

SUBDIVISIONS OF THE GRAND PRAIRIE

The Grand Prairie region of Arkansas is in the physiographic province of the United States known as the Coastal Plain and is a part of the subdivision of the province known as the Mississippi Alluviual Plain (Fenneman, 1931). It is an irregular but nearly continuous tract of prairie lying between the White River and Bayou Meto. It extends northwestward from near the confluence of the White and Arkansas Rivers to a short distance beyond Lonoke, Lonoke County. All Arkansas County and parts of Lonoke, Prairie, and Monroe Counties are included in the Grand Prairie region. (See fig. 1.)

The region on the State geologic map is divided into the Recent river flood plains and the Pleistocene terrace or prairie. Both divisions are relatively flat. A prominent escarpment marks the boundary between the plains in many places. The most characteristic feature of the upland areas is the great extent of unusually level land that is nearly treeless and that has been in this condition as far back as historic records reveal. In this sense, these upland areas constitute true prairies. Presumably, at one time the region constituted a single immense area of continuous prairie. Tributary streams have eroded shallow valleys, along which trees grow, so that now there are several prairies separated by timbered areas of slightly lower land.

RELIEF

The relief of the Grand Prairie region is slight, especially away from the principal streams. In many parts of the prairie, the relief is less than 5 feet in a square mile, and in few parts it is as much as 10 feet in a square mile. The relief in areas near a stream differs according to the stream's location with respect to major drainage and is as much as 60 feet, but areas having such relief are rather small.

The Grand Prairie region slopes gently eastward and southeastward from its northwest corner. The altitude is highest, about 250 feet, in the vicinity of Lonoke and the lowest, about 175 feet, in the southern part of the region near Gillette (pl. 2). The average slope is slightly more than 1 foot per mile.

DRAINAGE

The principal streams that drain the Grand Prairie region are Bayou LaGrue and Bayou Two Prairie. Bayou LaGrue heads in the northern part of the region and drains prairie land for its entire length. Bayou Two Prairie heads in land slightly beyond the northwest corner of the prairie. Bayou Meto and the Arkansas and White Rivers are boundary streams and receive direct drainage only from small areas near the boundaries.

Except near the principal streams, the natural drainage of the prairie is rather poor. Many areas, ranging in size from a few acres to a few square miles, are swampy. These areas are timbered and, because they stand out on the landscape as isolated patches, some of them are locally called "islands." Among such areas are Big, Maple, Lost, Angelia, and Deer Islands.

Most of the prairie land is underlain by a stiff relatively impervious clay. Very little water can percolate through it, and, as a result, most of the precipitation evaporates, is transpired, or runs off. Gentle land slopes, allowing for well-spaced levees and only a slight loss of irrigation water by infiltration through the clay cap, are among the principal factors that make the prairie land ideally suited to rice cultivation.

ORIGIN OF THE PRAIRIE LAND

D. G. Thompson of the Geological Survey (written communication, 1930) has postulated two ways in which the prairie land may have originated. It may have been formed by deposition by streams in much the same way that the plain of the Mississippi delta was formed, or it may have been formed by erosion of a land surface that originally was much higher. The fact that the plain slopes southeastward from the northwest corner of the Grand Prairie, which is not far from the point where the Arkansas River emerges from the region of consolidated rocks known as the Interior Highlands, suggests that it was formed by deposition by the river at an earlier stage in its history. There is evidence that at one time the Mississippi River flowed west of Crowleys Ridge and perhaps, at one time or another, flowed across different parts of the entire area between the ridge and the hard rocks of the Interior Highlands. This suggests that the Grand Prairie may have been formed by deposition from the Mississippi rather than the Arkansas River. On the other hand, the Mississippi could have been a degrading river, forming the prairie lands by erosion of a higher surface. Altitudes as great as those of the upper part of the Grand Prairie region are not found for many miles farther north. If the Grand Prairie region once was part of a plain formed by the ancestral Mississippi River, it would be expected that remnants as high as the highest points of the Grand Prairie would be found not far upstream. The composition, color, and depositional features of the subsurface and surficial materials composing the Grand Prairie suggest aggradational streams; the materials were probably brought into the region by both the Arkansas and Mississippi Rivers.

HYDROGEOLOGY

CRETACEOUS DEPOSITS

Formations of Cretaceous age of marine origin underlie the deposits of Tertiary and Quaternary ages at about 3,000 feet below the surface. Within the area considered in this report, no wells are known to tap formations of the Cretaceous system, and electric logs of oil-test holes penetrating these formations show that the water contained in them is salty. No further consideration is given in this report to deposits of Cretaceous age.

TERTIARY DEPOSITS

No formations of Tertiary age crop out in the Grand Prairie, but they everywhere underlie the Quaternary deposits that blanket the region. The contact with the Cretaceous formations has been explored by only a few oil test holes, but it seems to be unconformable.

Rocks of Tertiary age in the Coastal Plain of Arkansas have been divided, in ascending order, into the Midway group of Paleocene age and the Wilcox, Claiborne, and Jackson groups of Eocene age. These deposits consist principally of sand, silt, clay, limestone, and lignite. Their combined thickness may be as great as 3,500 feet. A generalized geologic section of the Tertiary and Quaternary formations in Arkansas County is given in table 1.

TABLE 1.—*Generalized geologic section for Arkansas County*

System	Subdivision	Thickness (feet)	Character of the material	Water-bearing characteristics
Quaternary	Recent and Pleistocene (undifferentiated).	75–200	Relatively impervious silt and clay; 5 to 60 ft thick. Very fine to coarse sand and gravel, interbedded with thin silt and clay lenses; 25 to 140 ft thick.	The sand and gravel beds yield abundant supplies of water and are the principal aquifer in the Grand Prairie region.
Tertiary	Jackson group	100–350	Clay, sand, and lignite.	Not a source of water.
	Clairborne group	750–1,400	Sand, clay streaks, and lignite.	Source of water for deep wells.
	Wilcox group	850–1,200	Sand, clay, chalk, and lignite.	The sand is water bearing, but most of the water probably is salty.
	Midway group	450–750	Blue plastic clay, marl, and limestone.	Not a source of water.

Fossil Mollusca were collected from test-hole cuttings of material underlying deposits of Quaternary age. These were identified by F. Stearns MacNeil of the Geological Survey in February 1959, as follows:

Test hole L2S–3W–31bbb1, 139 to 150 feet:
- *Turritella* cf. *T. clevelandia* Harris (juveniles)
- *Venericardia* (fragments)

Test hole L2S–4W–21ddd1:
- 118 to 123 feet:
  - *Euspira* cf. *E. jacksonensis* Harris and Palmer
  - *Tritiaria albirupina* (Harris)
  - *Turritella clevelandia* Harris
- "Bottom of hole":
  - *Euspira* cf. *E. jacksonensis* Harris and Palmer
  - *Tritiaria albirupina* (Harris)
  - *Turritella clevelandia* Harris
  - *Venericardia* cf. *V. diversidentata* Meyer
  - *Corbula* (fragments)

Test hole L2S–4W–26aaa1, 123 to 130 feet:
- *Turritella* (fragments)
- *Venericardia* (fragments)

Test hole L3S–4W–3dca8, 132 to 140 feet:
- *Turritella* cf. *T. clevelandia* Harris (juveniles)
- *Venericardia* (fragments)

Test hole L3S–4W–11ddc1:
- 118 to 120 feet:
  - *Tritiaria albirupina* (Harris)
  - *Mazzalina* sp. (fragments)
  - *Turritella* cf. *T. clevelandia* Harris
  - *Venericardia* (fragments)
  - *Levifusus moodianus* Cooke
  - *Latirus humilior cognatus* Harris and Palmer
  - *Caricella* sp. (fragments)
  - *Venericardia* sp. (fragments)
  - *Corbula* sp. (fragments)
- 120 to 125 feet:
  - *Euspira* cf. *E. jacksonensis* Harris and Palmer
  - *Levifusus moodianus* Cooke
  - *Mazzalina* sp. (fragments)
  - *Tritiaria albirupina* (Harris)
  - *Caricella* sp. (fragments)
  - *Turritella clevelandia* (Harris)
  - *Venericardia* sp. (juveniles and fragments)
- 125 to 129 feet:
  - *Euspira* sp. (juvenile)
  - *Tritiaria albirupina* (Harris)
  - *Mazzalina* sp. (fragments)
  - *Turritella clevelandia* Harris
  - *Venericardia* cf. *V. diversidentata* Meyer

Test hole L3S–4W–29bbb1:

165 to 170 feet:

Turritella (juveniles) cf. *T. clevelandia* Harris

Venericardia (fragments)

175 to 180 feet: *Turritella* (juveniles and fragments) cf. *T. clevelandia* Harris

180 to 185 feet:

Turritella (juveniles and fragments) cf. *T. clevelandia* Harris

Naticoid (fragment)

Venericardia (fragment)

185 to 190 feet:

Turritella (juveniles and fragments) cf. *T. clevelandia* Harris

Venericardia (fragments)

190 to 195 feet:

Turritella sp. (juveniles)

Mesalia sp. (fragment)

On the basis of MacNeil's identification, the test holes penetrated beds of the Jackson group (late Eocene). The similarity of the fossils suggests that these beds are largely of the same facies. No age or other difference is apparent from the fossils.

The Tertiary rocks, chiefly sand beds in the Claiborne group, are a source of irrigation water in the Grand Prairie region. About 40 so-called "deep wells" tap Tertiary aquifers in this area. The total quantity of water available from this source is equal to only a small fraction of the amount now being pumped from Quaternary aquifers. The wells in Tertiary deposits range in depth from 440 to 1,000 feet, and fresh water probably cannot be obtained at depths much greater than 1,000 feet in the area. Electric logs of oil tests holes suggest that the contact of fresh and salt water is between 800 and 1,000 feet deep. The electric logs also indicate a minor amount of sand and a preponderance of clay in the deeper beds of the Tertiary. Table 2 gives data on a typical "deep well" of this region.

Because of the greater depth to the permeable zones in the formations of Tertiary age as contrasted with the Quaternary deposits and because the Tertiary formations contain less available pore space in which to store water, the Tertiary rocks have not been considered for artificial-recharge tests.

QUATERNARY DEPOSITS

The Quaternary system includes sediments laid down during the Pleistocene and Recent epochs. Pleistocene and Recent deposits have never been satisfactorily differentiated in this region and are considered together in this report.

The Quaternary deposits in Arkansas County consist of alluvium and range in thickness from 75 to 200 feet. They blanket all the Grand Prairie region. Two major zones may be recognized in them throughout the prairie—a basal zone made up of sand or sand and gravel and

TABLE 2.—*Hydrologic data for a typical "deep well" in the Grand Prairie region, Arkansas*

Well number: 4S-5W-1baal
Altitude: 193 ft above mean sea level
Owner: Charles McDougal
Driller: Layne-Arkansas Co.
Date drilled: April 1938
Depth to water: 44.22 ft (4/7/48)

Use of water: Irrigation
Design yield of well: 1,400 gpm
Screen: 10-in. shutter, 125 ft
Screen setting: Approximately 804–929 ft
Total depth of finished well: 933 ft

Driller's log

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Quaternary:			Tertiary—Continued		
Topsoil and clay	40	40	Gumbo	10	516
Sand and gravel	5	45	Shale, soft	14	530
Clay	5	50	Shale, hard	5	535
Sand, fine, yellow	25	75	Shale, soft	5	540
Clay	3	78	Gumbo	20	560
Sand and gravel	37	115	Shale, soft	30	590
Tertiary:			Shale, hard	29	619
Clay	25	140	Rock	1	620
Sand and shale with gravel	15	155	Gumbo rock	18	638
Gumbo, with boulders	45	200	Shale, hard	10	648
Shale, hard, chippy	100	300	Sand, hard	26	674
Gumbo	9	309	Gumbo, tough	2	676
Shale (boulders at 317, rock at 321, boulders at 327)	18	327	Rock	2	678
Shale, hard	8	335	Gumbo	7	685
Shale, sandy	35	370	Sand and shale	3	688
Boulders and shale	15	385	Sand, hard	38	726
Sand, fine	15	400	Shale	14	740
Sand, hard	18	418	Sand	19	759
Gumbo	7	425	Shale	3	762
Shale, hard	5	430	Sand	22	784
Shale, extra hard	3	433	Shale	3	787
Shale, hard	7	440	Sand, hard-packed	140	927
Sand, fine	10	450	Gumbo	2	929
Sand, hard	56	506	Sand	6	935
			Clay, tough	1	936

Chemical analysis of water

[Chemical constituents in parts per million. Date of collection: 5/24/50. Appearance of water: clear]

Silica (SiO_2)	13	Nitrate (NO_3)	2.0
Total iron (Fe)	.44	Dissolved solids	190
Aluminum (Al)	1.6	Hardness as $CaCO_3$:	
Calcium (Ca)	20	Total	69
Magnesium (Mg)	4.7	Noncarbonate	0
Sodium (Na)	41		
Potassium (K)	3.4	Percent sodium	55
Bicarbonate (HCO_3)	180	Temperature °F	77
Sulfate (SO_4)	3.2	Specific conductance at 25°C (micromhos)	318
Chloride (Cl)	7.0		
Fluoride (F)	.0	pH	6.8

Hydraulic data

Date of aquifer test	April 7, 1948
Length of test hr	6
Pumping rate gpm	2,250
Storage coefficient (approximately)	0.00045
Coefficient of transmissibility gpd per ft	140,000
Average field coefficient of permeability of water-bearing section (approximately) gpd per sq ft	800

an upper zone made up of silt and clay. The basal zone consists of very fine to coarse sand and gravel interbedded complexly with thin clay and silt lenses. The basal zone ranges in thickness generally from 25 to 140 feet in the Grand Prairie. The gravel ranges from very fine to very coarse, and the pebbles consist of chert and other chalcedonic rocks, orthoquartzite, metaquartzite, quartz, and felsitic igneous rocks. A zone of sand, gravel, and clay balls is present in some localities. Cobbles and boulders are common in the lower part of the basal zone lying upon or near the top of the Tertiary deposits.

The upper zone consists of a very dense, relatively impervious layer of dark-reddish-brown clay overlain and underlain by layers of clay and silt of different shades of tan, gray, blue, red, and brown. These layers range in thickness from about 5 to 60 feet and are remarkably continuous and very nearly impervious over much of the Grand Prairie region.

Fossil specimens collected from test-hole cuttings of Quaternary age were examined by Porter Kier and J. P. E. Morrison of the U.S. National Museum and by N. J. Silberling and D. W. Taylor of the Geological Survey. The results of these examinations are as follows:

Test hole L2S–4W–26aaa1, 115 to 120 feet: Crinoid columnal
Test hole L3S–4W–3dca1:
- 57 to 60 feet: Indeterminate fragments
- 55 to 60 feet: *Viviparus* sp.

Test hole L3S–4W–3dca8:
- 45 to 55 feet: Indeterminate fragments
- 55 to 60 feet:
  - *Viviparus* sp.
  - *Probythinella lacustris* (Baker)
- 105 to 110 feet:
  - *Viviparus* sp.
  - *Cincinnatia cincinnatiensis* (Anthony)
- 110 to 115 feet: *Probythinella lacustris* (Baker)
- 120 to 125 feet:
  - *Probythinella lacustris* (Baker)
  - *Cincinnatia cincinnatiensis* (Anthony)
- 130 to 132 feet:
  - *Probythinella lacustris* (Baker)
  - *Cincinnatia cincinnatiensis* (Anthony)

Test hole L3S–4W–3dca9, 65 to 75 feet: *Viviparus* sp.
Test hole L3S–4W–3dcd1, 70 to 75 feet: Crinoid columnal
Test hole L3S–4W–4aad1, 90 to 95 feet: Polygyridae indet.
Test hole L3S–4W–8aaa1, 60 to 64 feet: Indeterminate fragments
Test hole L3S–4W–13ccc1, 110 to 115 feet: Crinoid columnal
Test hole L3S–4W–16bbb1:
- 37 to 41 feet: *Viviparus subpurpureus* (Say)
- 145 to 148 feet: Crinoid columnal

Test hole L3S–5W–1ddd1, 85 to 88 feet: *Zonitoides arboreus* (Say)

The crinoid columnals are of marine origin but are undiagnostic as to age. Their worn appearance indicates their detrital character and emphasizes the probability of alluvial deposition. *Viviparus*, *Probythinella*, and *Cincinnatia* are fresh-water snails that are living today in Arkansas, commonly in a quiet-water habitat. *Viviparus subpurpureus* (Say) has been reported as a fossil in beds classified as post-Wisconsin in age. *Zonitoides* and Polygyridae are land snails, also found living today in Arkansas. Accordingly, the stratigraphic range of the listed species must be Pleistocene to Recent.

Wood and charcoal fragments were recovered from a depth of 50 feet during drilling of an irrigation well at the northeast edge of the Grand Prairie region (1N–10W–22abb1). A radiocarbon age determination on the fragments was made by Meyer Rubin and W. G. Schlecht of the Geological Survey. Their findings indicated the wood to be 5,515±160 years old. If it is assumed that the material surrounding the fragments is of the same age and that the duration of the Recent has been approximately the last 10,000 years, the sediments in this locality, at least to a depth of 50 feet, must be Recent in age.

The basal zone of the deposits of Quaternary age is an apparently continuous aquifer throughout the Grand Prairie, and from it most of the irrigation wells derive water, principally for the irrigation of rice. Rice has been grown in this area since 1904. Since 1915 the yearly rice acreage has not been less than 100,000 acres and has averaged more than 135,000 acres. The concentrated pumping of water from deposits of Quaternary age to irrigate this large rice acreage has caused a substantial overdraft on the ground-water supply. The average annual water-level decline in this region from 1910 to 1958 was approximately 1 foot.

The result of this overdraft or dewatering may be seen by examining figures 4 and 5, which show contour lines on the ground-water suface at intervals of approximately 10 years and the change in water levels for the period 1915 to 1954. The ever-deepening and increasing size of the cone of water-level depression, as much as 65 feet in its center in 1954, indicates the result of overpumping.

SITUATION AROUND THE RECHARGE SITE

The distribution, relationship, and lithologic character of the beds of Quaternary age in the vicinity of the recharge site are illustrated in the generalized isometric diagram shown in plate 1. The recharge site is a few hundred feet north of test hole L3S–4W–3dcd1. Several features shown within the area portrayed in this diagram are noteworthy.

The aquifer is continuous and relatively homogeneous around the recharge site, and in this respect it is probably similar to the aquifer throughout the Grand Prairie. A few thin lenses of silt, clay, and clay balls are interbedded in the sand and constitute the only interruptions in the continuity of the aquifer.

The basal zone has been divided into two parts in plate 1—a coarse, gravelly bluish-gray sand that is generally thicker over depressions in the top of the Tertiary deposits and an overlying bluish-gray sand that generally becomes progressively finer grained upward. Test-hole data indicate that the sand and gravel in the basal zone is complexly interfingered with the overlying bluish-gray sand. The line dividing these units in plate 1 is therefore drawn arbitrarily upon a gently undulating surface that approximates the horizon at which the grain size of the material definitely increases.

Two other sands, lithologically different from the sand of the basal zone, are present (pl. 1). They are a yellowish-brown very fine to medium sand and a dark-reddish-brown or salmon-red very fine to fine sand that at some places is silty to clayey. Within the area included in plate 1, their predominantly red, reddish-brown, or yellowish-brown colors are in marked contrast to the blue, bluish-gray, or grayish-brown colors of the sand of the basal zone. This contrast in color may result from a difference in the source area of the deposits, the bluish materials coming from the Mississippi and Ohio Rivers drainage systems and the reddish materials coming from the Arkansas River drainage system. The yellowish-brown and reddish-brown sands are considered to be environmentally related to the upper zone, which is composed of reddish-brown silt and clay, rather than to the basal sand.

In many places the dark-reddish-brown sand grades laterally into dark-reddish-brown clay and silt. The horizontal distribution and interfingering of the red clay, silt and sand beds suggests fluvial deposition in the form of bars or small bar plains. The clay, being finer, represents the backwater or tail-water facies of a bar deposit, and the coarser sand represents the facies of deposition where the currents were stronger.

About 30 feet of the upper zone may be seen in a road cut on the west side of the White River near Clarendon, Ark., in sec. 36, T. 1 N., R. 4 W. (See pl. 2.) Here the lateral gradation of the dark-reddish-brown sediments from clay to sand is readily apparent, particularly because the more clayey zones tend to resist erosion and form small distinct pinnacles. A vertical gradation that is not apparent in test-hole cuttings also may be observed. The light-yellowish-brown silty clay that occurs at many places at the surface and overlies the reddish sediments grades downward into the red material without any sharp division. This gradation suggests that there is depositional continuity between the two differently colored sediments and that the color change is the result of weathering. Weathering and poor drainage

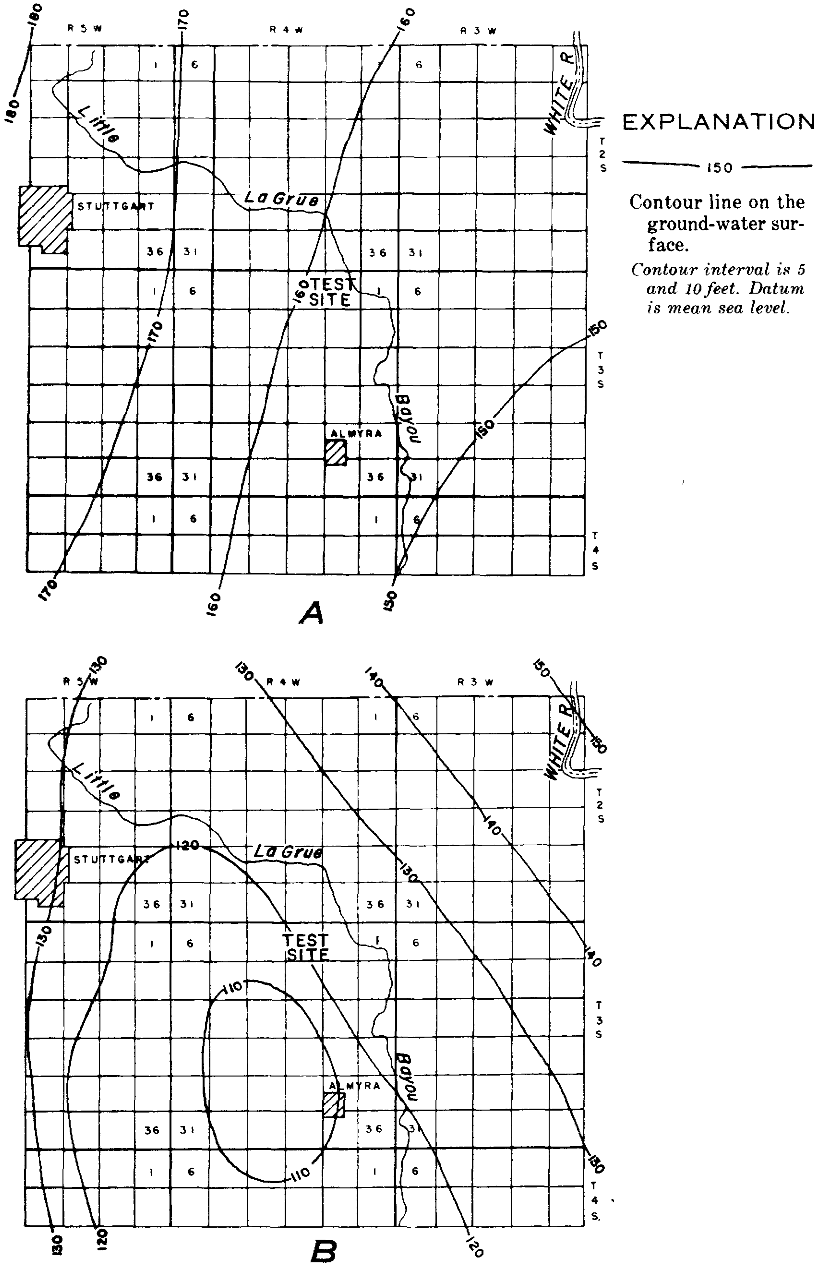
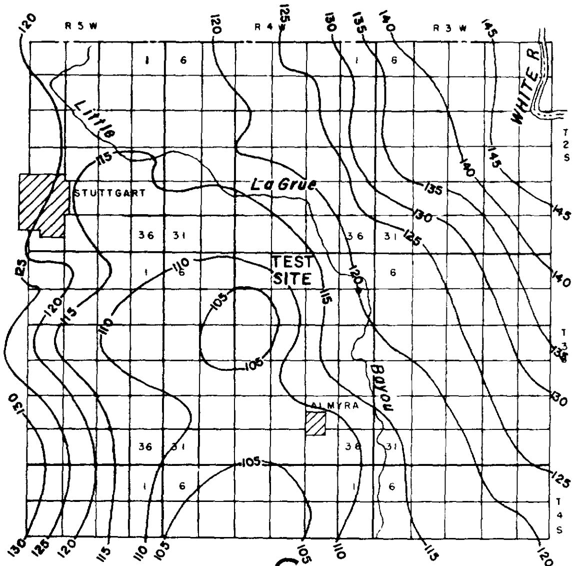


FIGURE 4.—Map of the artificial-recharge area showing the approximate contours on the ground-



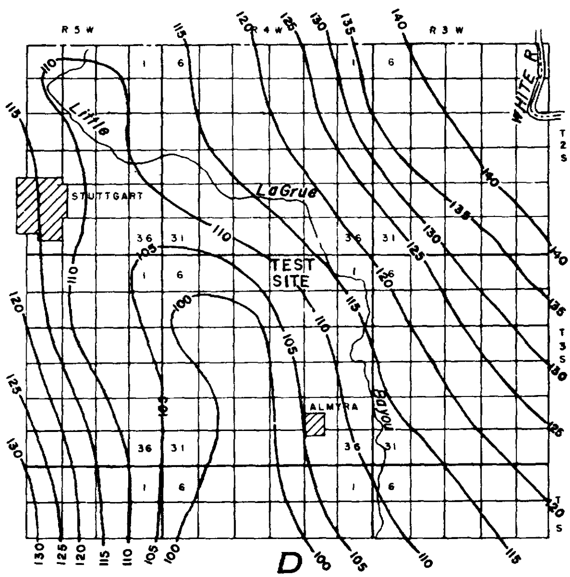
C

EXPLANATION

150

Contour line on the ground-water surface.

Contour interval is 5 and 10 feet. Datum is mean sea level.



D

water surface (*A*) before 1915, (*B*) in fall of 1938, (*C*) in spring of 1948, and (*D*) in March 1954.

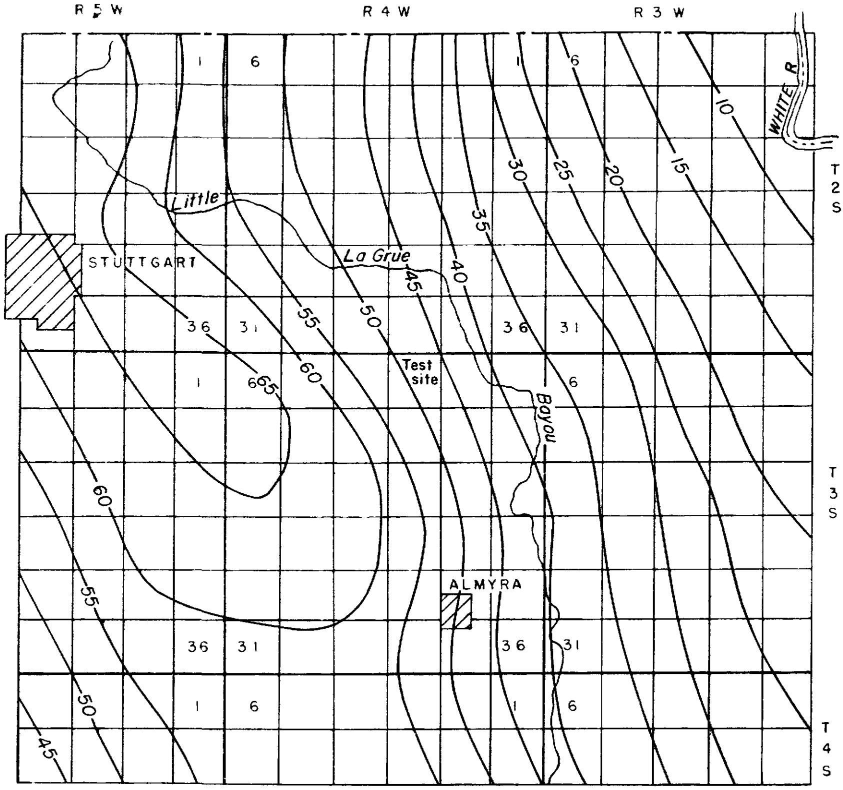


FIGURE 5.—Map of the artificial-recharge area showing lines of equal decline of water levels in deposits of Quaternary age from 1915 to 1954.

are indicated also in the light-yellowish-brown clay by many small iron nodules, which weather out on the surface and give rise to the local term "buckshot" soil.

A sudden change in the calcareous content of the upper zone is a persistent feature in the project area. Generally a change from noncalcareous to calcareous material may be observed in the upper few feet of the dark-reddish-brown clay. Test-hole cuttings in the project area show the entire section of deposits of Quaternary age to be calcareous below the shallow noncalcareous zone. Commonly a zone of calcareus concretionary material is fund 10 to 15 feet below the horizon at which the sediments become calcareous. Presumably, downward leaching has removed the carbonate material and caused secondary deposition in the form of concretions below the maximum depth of weathering, as is suggested by color changes in the sediments.

In view of the relative impermeability of the upper zone, there is is some uncertainty as to whether weathering and leaching has progressed to depths of 10 to 20 feet. The calcareous nature of the upper zone may not be a depositional characteristic and ground water from an artesian aquifer may have moved upward and caused the upper zone to become enriched with calcareous material up to the horizon at which the sediments become noncalcareous (oral communication, J. E. Hackett, Illinois State Geological Survey, 1957).

In some areas the salmon-red sand is very near the surface and is in contact with the coarser bluish-gray sand of the principal aquifer. Although the red sand may be interfingered with silt and clay and is highly crossbedded and laminated, some natural recharge is likely where the red sand is near the surface—certainly more recharge than in areas where silt and clay above the red sand is thicker or where the red sand is missing. Extensive test drilling would be necessary to determine the thickness and areal extent of the red sand and its proximity to the surface, but such information is necessary if the areas of natural recharge are to be located and if the possibilities of artificial recharge by water spreading or trenching are to be investigated.

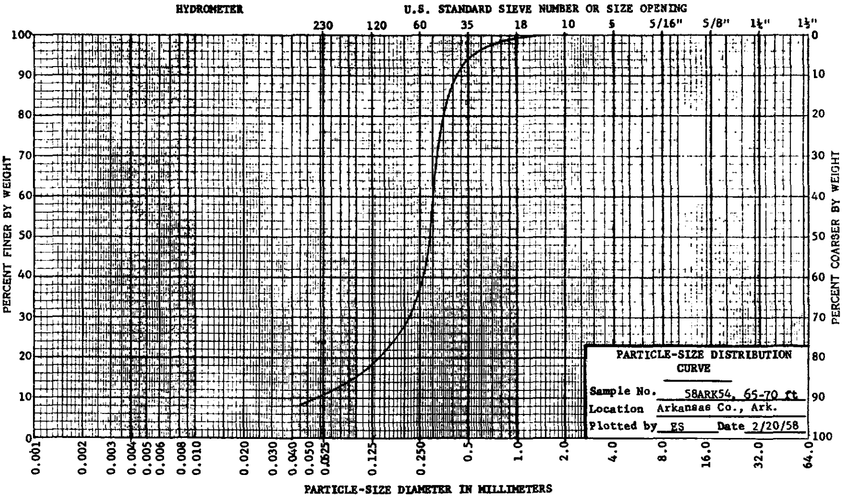
The Grand Prairie region map (pl. 2) shows the areal distribution of the red-sand facies of the upper zone. It is obvious that the data available are meager and the spacing of control points is poor. However, the map presents a generalized picture of the depositional features of the sand facies and should be helpful in planning a test-drilling program to investigate further the distribution of the red sand.

PARTICLE-SIZE DISTRIBUTION

Fourteen samples of water-bearing materials of Quaternary age were collected for mechanical (particle-size) analysis from test hole L3S–4W–3dca14 drilled by the Corps of Engineers at the artificial-recharge site. These were disturbed samples, as they were obtained by bailing inside a 5-inch casing. Upon arrival at the hydrologic laboratory of the Geological Survey, the samples were air dried, and the lumps of material gently separated into individual particles. Particle sizes smaller than 0.0625 mm were determined by the hydrometer method of wet analysis, and sizes larger than 0.0625 mm were determined by wet-sieve analysis.

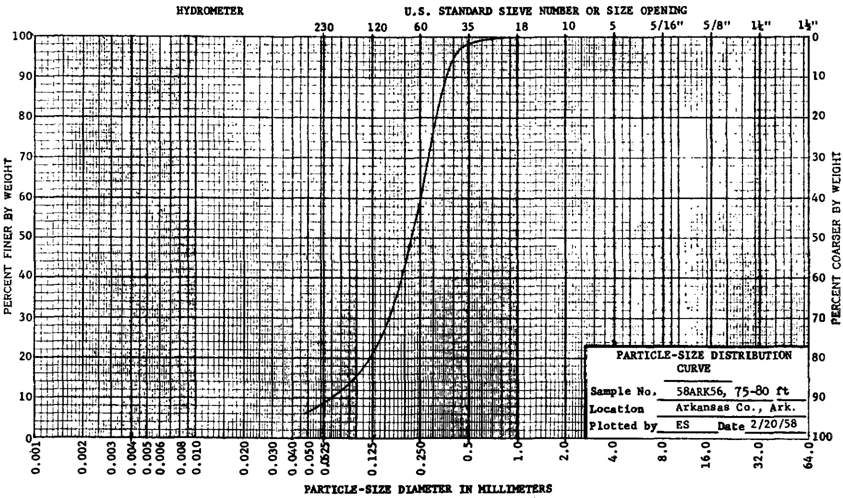
The percentage of the particles smaller than a given size were calculated cumulatively and plotted as a curve, with the particle size, in millimeters, as the abscissa and the cumulative percentage, by weight, of particles smaller than the size shown as the ordinate. The semilogarithmic plots of these data are shown in figures 6 through 9.

Although some variation in particle size is evident in the data presented for the samples analyzed, the materials are remarkably uniform in size, a situation that is somewhat unusual in alluvial deposits.



PERCENT OF SIZE

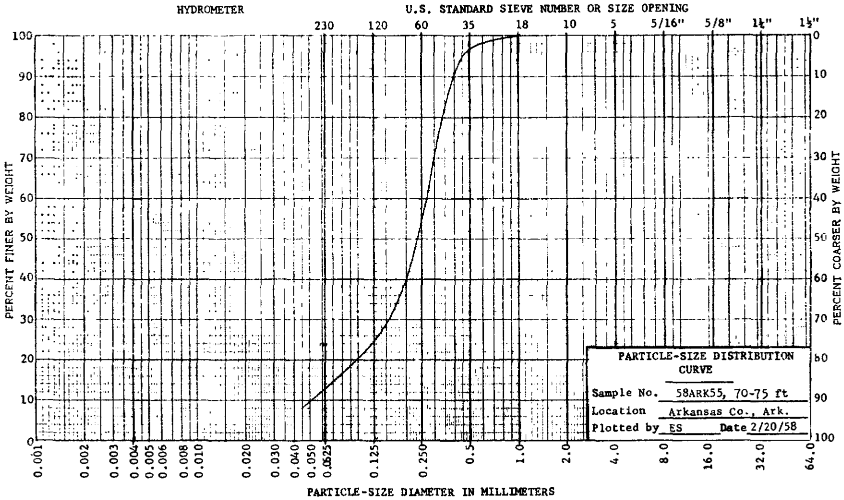
CLAY SIZES <0.004 mm	SILT SIZES 0.004 - 0.0625 mm	SAND SIZES V.fine .0625-.125	Fine .125-.25	Medium .25-.5	Coarse .5-1	V.Coarse 1-2	GRAVEL SIZES V.fine 2-4	Fine 4-8	Medium 8-16	Coarse 16-32	V.Coarse 32-64
10.8		7.3	18.1	58.0	5.2	0.3	0.3				



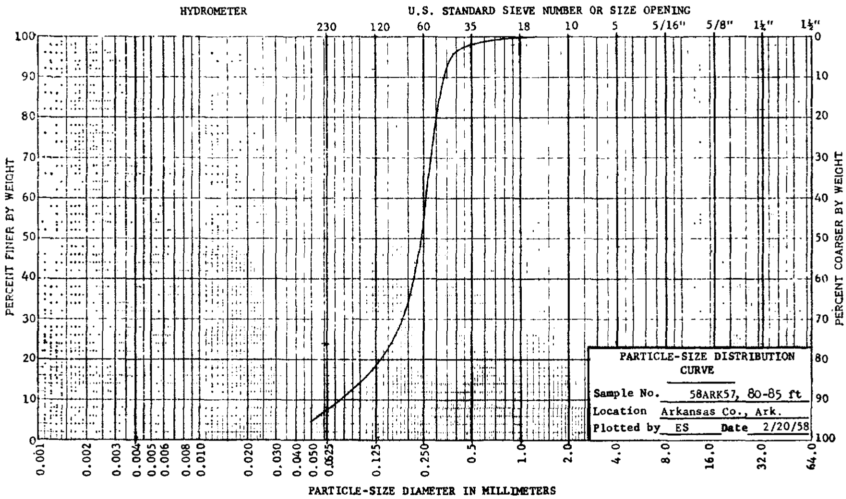
PERCENT OF SIZE

CLAY SIZES <0.004 mm	SILT SIZES 0.004 - 0.0625 mm	SAND SIZES V.fine .0625-.125	Fine .125-.25	Medium .25-.5	Coarse .5-1	V.Coarse 1-2	GRAVEL SIZES V.fine 2-4	Fine 4-8	Medium 8-16	Coarse 16-32	V.Coarse 32-64
9.0		11.6	38.5	39.7	1.2						

FIGURE 6.—Graphs showing results of particle-size

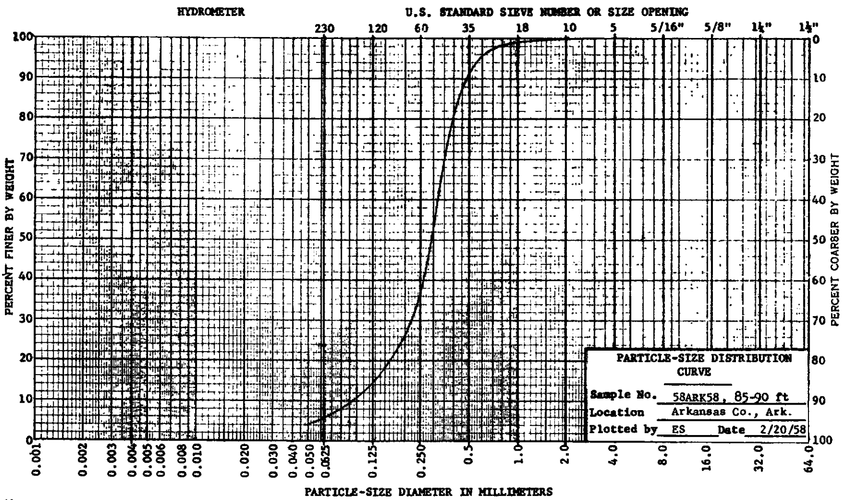


	CLAY SIZES	SILT SIZES	SAND SIZES					GRAVEL SIZES				
	<0.004 mm	0.004 - 0.0625 mm	V.fine .0625-.125	Fine .125-.25	Medium .25-.5	Coarse .5-1	V.Coarse 1-2	V.fine 2-4	Fine 4-8	Medium 8-16	Coarse 16-32	V.Coarse 32-64
PERCENT OF SIZE	13.4		11.3	28.6	43.4	3.2	0.1					



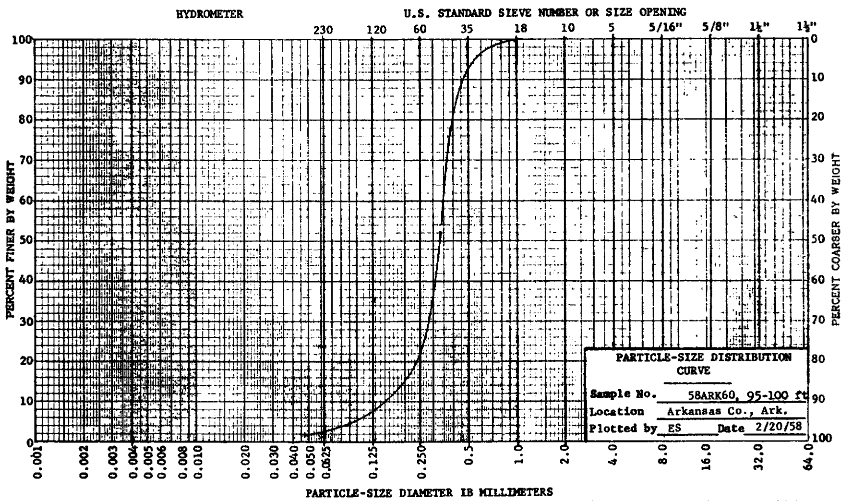
	CLAY SIZES	SILT SIZES	SAND SIZES					GRAVEL SIZES				
	<0.004 mm	0.004 - 0.0625 mm	V.fine .0625-.125	Fine .125-.25	Medium .25-.5	Coarse .5-1	V.Coarse 1-2	V.fine 2-4	Fine 4-8	Medium 8-16	Coarse 16-32	V.Coarse 32-64
PERCENT OF SIZE	7.8		11.1	34.9	44.7	1.4	0.1					

analyses of test-hole samples collected from 65 to 85 feet.



PERCENT OF SIZE

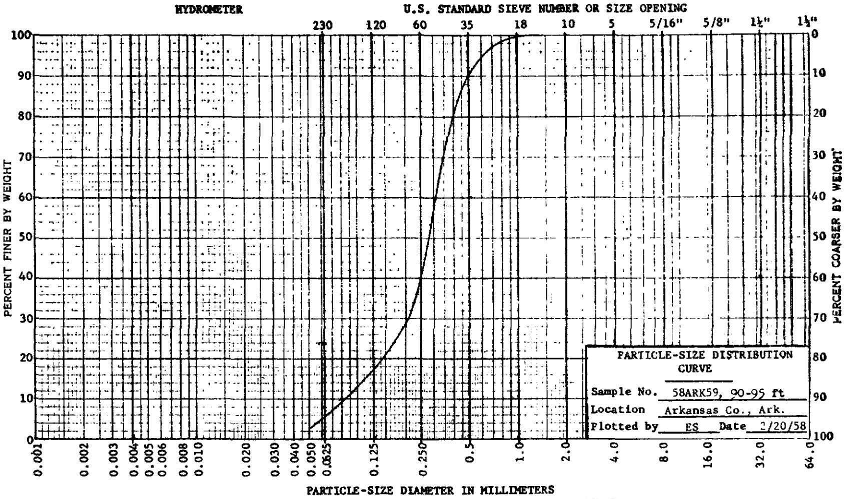
CLAY SIZES <0.004 mm	SILT SIZES 0.004 - 0.0625 mm	SAND SIZES V.fine .0625-.125	Fine .125-.25	Medium .25-.5	Coarse .5-1	V.Coarse 1-2	GRAVEL SIZES V.fine 2-4	Fine 4-8	Medium 8-16	Coarse 16-32	V.Coarse 32-64
5.8		8.2	22.1	55.6	7.7	0.1	0.5				



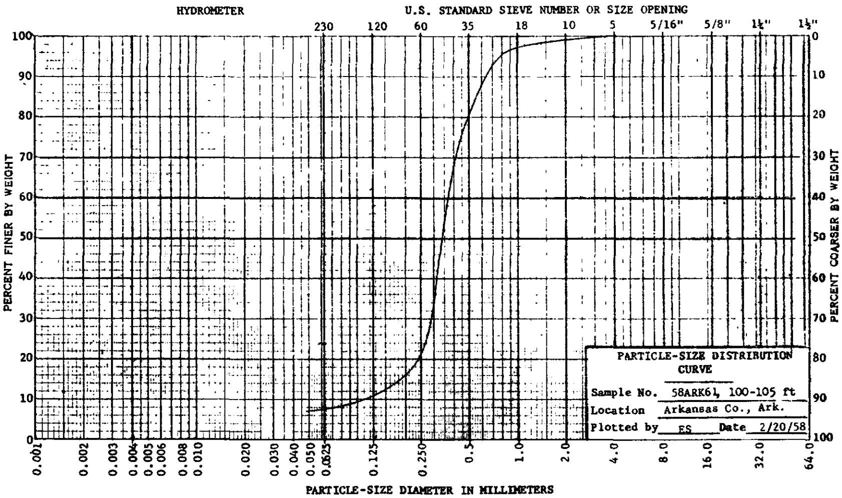
PERCENT OF SIZE

CLAY SIZES <0.004 mm	SILT SIZES 0.004 - 0.0625 mm	SAND SIZES V.fine .0625-.125	Fine .125-.25	Medium .25-.5	Coarse .5-1	V.Coarse 1-2	GRAVEL SIZES V.fine 2-4	Fine 4-8	Medium 8-16	Coarse 16-32	V.Coarse 32-64
2.6		4.5	13.7	72.3	6.8	0.1					

FIGURE 7.—Graphs showing results of particle-size

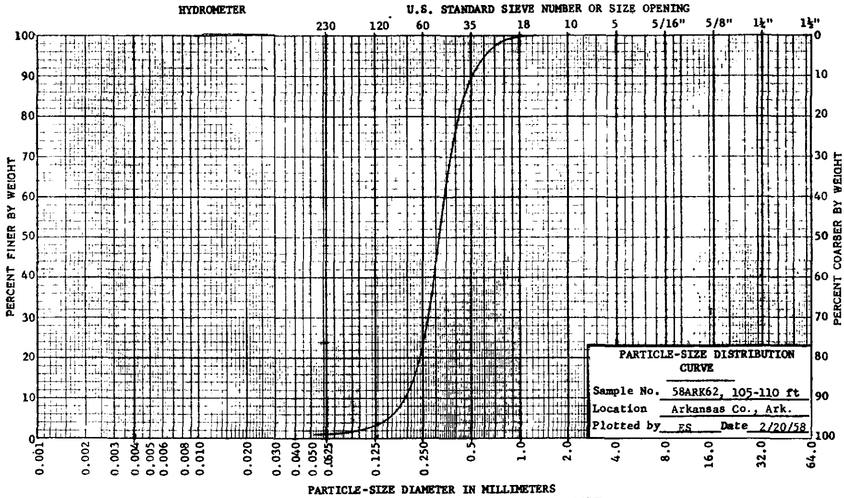


PERCENT OF SIZE	CLAY SIZES	SILT SIZES	SAND SIZES					GRAVEL SIZES				
	<0.004 mm	0.004 - 0.0625 mm	V.fine .0625-.125	Fine .125-.25	Medium .25-.5	Coarse .5-1	V.Coarse 1-2	V.fine 2-4	Fine 4-8	Medium 8-16	Coarse 16-32	V.Coarse 32-64
	5.3		11.8	23.9	50.1	8.8	0.1					



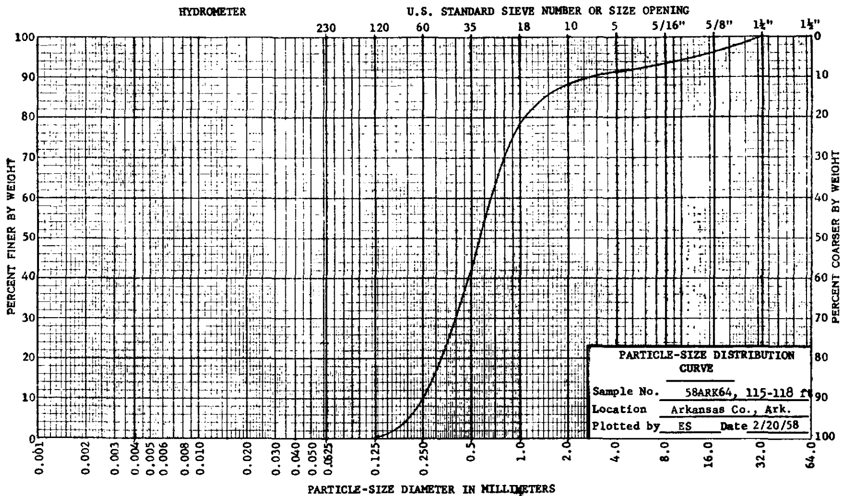
PERCENT OF SIZE	CLAY SIZES	SILT SIZES	SAND SIZES					GRAVEL SIZES				
	<0.004 mm	0.004 - 0.0625 mm	V.fine .0625-.125	Fine .125-.25	Medium .25-.5	Coarse .5-1	V.Coarse 1-2	V.fine 2-4	Fine 4-8	Medium 8-16	Coarse 16-32	V.Coarse 32-64
	7.4		3.0	9.5	61.8	15.7	1.5	1.1				

analyses of test-hole samples collected from 85 to 105 feet.



PERCENT OF SIZE

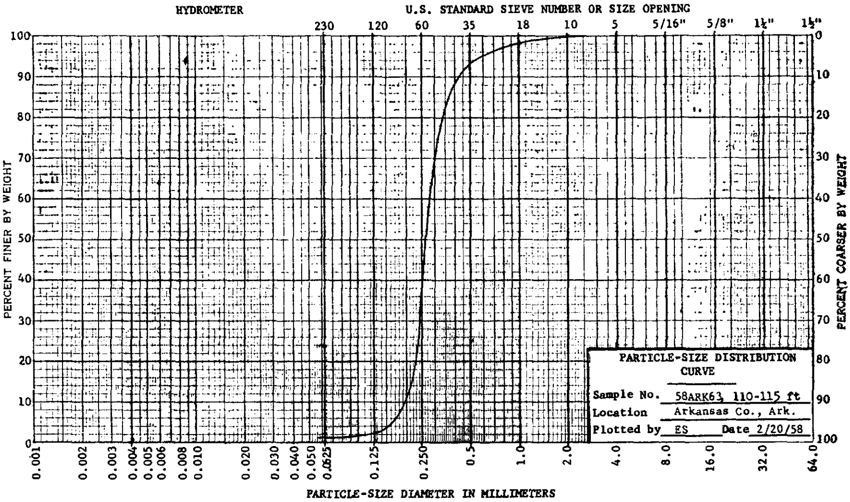
CLAY SIZES <0.004 mm	SILT SIZES 0.004 - 0.0625 mm	SAND SIZES V.fine .0625-.125	Fine .125-.25	Medium .25-.5	Coarse .5-1	V.Coarse 1-2	GRAVEL SIZES V.fine 2-4	Fine 4-8	Medium 8-16	Coarse 16-32	V.Coarse 32-64
1.5		0.9	20.1	67.6	9.5	0.4					



PERCENT OF SIZE

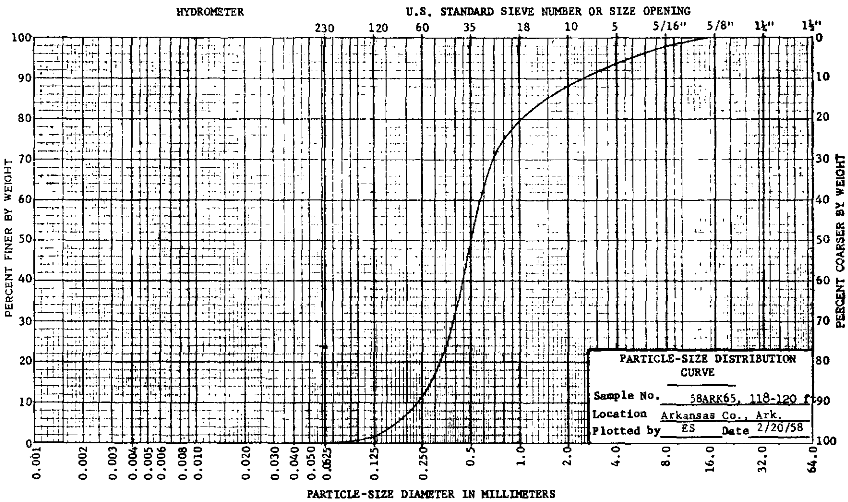
CLAY SIZES <0.004 mm	SILT SIZES 0.004 - 0.0625 mm	SAND SIZES V.fine .0625-.125	Fine .125-.25	Medium .25-.5	Coarse .5-1	V.Coarse 1-2	GRAVEL SIZES V.fine 2-4	Fine 4-8	Medium 8-16	Coarse 16-32	V.Coarse 32-64
		0.1	10.5	32.2	35.9	9.6	2.7	1.7	3.3	4.0	

FIGURE 8.—Graphs showing results of particle-size



PERCENT OF SIZE

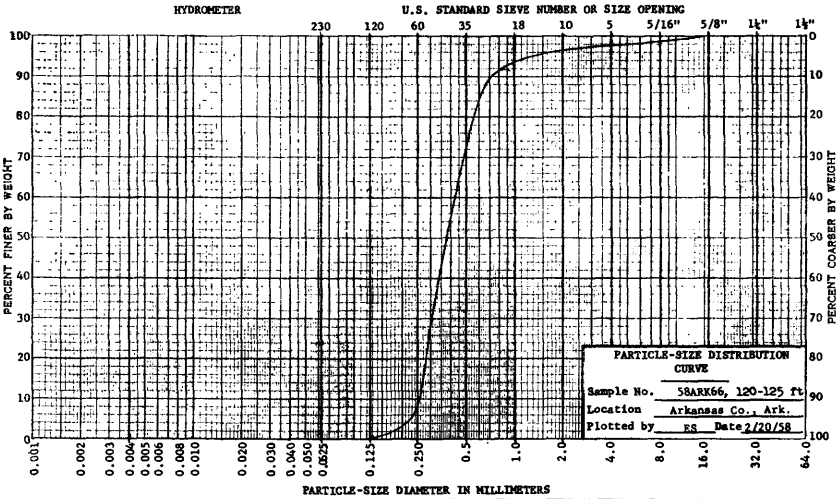
CLAY SIZES <0.004 mm	SILT SIZES 0.004 - 0.0625 mm	SAND SIZES V.fine .0625-.125	Fine .125-.25	Medium .25-.5	Coarse .5-1	V.Coarse 1-2	GRAVEL SIZES V.fine 2-4	Fine 4-8	Medium 8-16	Coarse 16-32	V.Coarse 32-64
0.7		0.7	33.2	59.0	4.9	1.0	0.5				



PERCENT OF SIZE

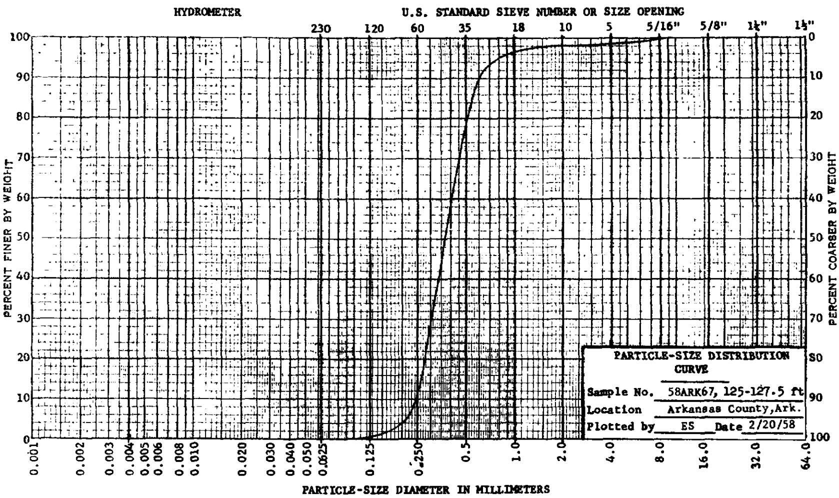
CLAY SIZES <0.004 mm	SILT SIZES 0.004 - 0.0625 mm	SAND SIZES V.fine .0625-.125	Fine .125-.25	Medium .25-.5	Coarse .5-1	V.Coarse 1-2	GRAVEL SIZES V.fine 2-4	Fine 4-8	Medium 8-16	Coarse 16-32	V.Coarse 32-64
0.2		0.7	9.9	37.5	31.7	8.6	5.2	3.6	2.6		

analyses of test-hole samples collected from 105 to 120 feet.



PERCENT OF SIZE

CLAY SIZES	SILT SIZES	SAND SIZES					GRAVEL SIZES				
<0.004 mm	0.004 - 0.0625 mm	V.fine .0625-.125	Fine .125-.25	Medium .25-.5	Coarse .5-1	V.Coarse 1-2	V.fine 2-4	Fine 4-8	Medium 8-16	Coarse 16-32	V.Coarse 32-64
		0.1	7.9	64.2	21.4	2.8	1.3	1.2	1.1		



PERCENT OF SIZE

CLAY SIZES	SILT SIZES	SAND SIZES					GRAVEL SIZES				
<0.004 mm	0.004 - 0.0625 mm	V.fine .0625-.125	Fine .125-.25	Medium .25-.5	Coarse .5-1	V.Coarse 1-2	V.fine 2-4	Fine 4-8	Medium 8-16	Coarse 16-32	V.Coarse 32-64
0.4		0.4	9.5	67.7	18.2	1.8	0.6	1.1	0.3		

FIGURE 9.—Graphs showing results of particle-size analyses of test-hole samples collected from 120 to 127.5 feet.

Extreme care was used to make sure that the bailer was picking up material at the bottom of the 5-inch casing. New lengths of casing were added as bailing progressed and the hole deepened. A head of clear water was maintained over the bailer as it was being operated to avoid upward heave. Each sample removed from the bailer was carefully mixed and quartered. The data probably are reasonably representative of the particle-size characteristics of the aquifer at the artificial-recharge site.

The average of the uniformity coefficients of samples analyzed is 3.0, and the average of the effective sizes is 0.15 mm (uniformity coefficient and effective size defined by Meinzer, 1923, p. 45–46). The material gradually becomes coarser with depth, increasing in effective size from about 0.05 to 0.25 mm (table 3). Although the material

TABLE 3.—*Log of test hole L3S–4W–3dca14 and uniformity coefficients and effective sizes of selected samples*

Log of test hole L3S-4W-3dca14

[About 1,260 ft north of section-line road and about 50 ft west of access road. Surface altitude, 203 ft]

	Thickness (feet)	Depth (feet)
Road fill, soil, silt, light-gray; contains organic material	1	1
Clay, very silty; variegated from light gray to medium reddish brown to light yellowish brown; contains small iron nodules	9	10
Clay, dark-reddish-brown; contains light-gray streaks	1	11
Clay, dark-reddish-brown, very calcareous; contains calcareous nodules; contains sandy to silty lenses at 30 ft and shell fragments at 35 ft	29	40
Clay, medium- to dark-brown, very calcareous; contains some bluish-gray clay and shell fragments	3	43
Silt, clayey to sandy, light-bluish-gray, micaceous, very calcareous; contains iron-stain zones and thin clay lenses	7	50
Sand, very fine to fine, slightly to very silty, micaceous, light-bluish-gray, very calcareous; may contain some clay	15	65
Sand, fine to medium, light-bluish-gray; calcareous in part; contains some very fine and very coarse sand; well-rounded, slightly frosted crystal quartz grains are the predominant mineral	5	70
Sand, fine to medium, dark-bluish-gray; calcareous in part; contains some very fine and coarse sand; dark-bluish-gray clay lens at 74 ft	5	75
Sand, fine to medium, dark-bluish-gray; calcareous in part; contains some very fine and coarse sand; contains thin medium-yellowish-brown and bluish-gray clay lenses at 78 ft	5	80
Sand, fine to medium, dark-bluish-gray; calcareous in part; contains wood fragments at 83.5 ft	5	85
Sand, fine to medium, light-bluish-gray; calcareous in part; contains silt and very fine to very coarse sand; a dark-reddish-brown clay lens at 87 ft	5	90
Sand, fine to medium, light-bluish-gray; calcareous in part; contains some fine and some coarse sand; well-rounded slightly frosted crystal quartz grain are the predominant mineral	5	95
Sand, fine to medium, light-bluish-gray· calcareous in part· contains some very fine and coarse sand	5	100
Sand, fine to coarse, light-bluish-gray; calcareous in part; contains some very fine and very coarse sand; lenses of very clayey sand, clay, and clay balls at 102 to 104 ft	5	105
Sand, fine to medium, light-bluish-gray; calcareous in part; contains some very fine and coarse sand; contains scattered clay balls and clay	5	110
Sand, fine to medium, light-bluish-gray; calcareous in part; contains scattered very fine, coarse, and very coarse sand	5	115
Sand, medium to very coarse, light-bluish-gray; calcareous in part; contains some fine sand and about 10 percent very fine to medium gravel	3	118
Sand, medium to very coarse, light-bluish-gray; calcareous in part: contains some very fine sand and about 10 percent very fine to medium gravel	2	120
Sand, medium to coarse, light-bluish-gray: calcareous in part: contains some fine and larger amounts of very coarse sand to medium gravel: contains scattered pebbles	5	125
Sand, medium, light-bluish-gray: calcareous in part; contains coarse to very coarse sand and scattered very fine to fine gravel	2.5	127.5
Boulders, cobbles, and pebbles at top of deposits of Tertiary age. Silt, very clayey, very sandy, medium-olive-gray; contains many badly weathered fossil shells	0.5	128

Uniformity coefficients and effective sizes of selected samples

Sample interval (feet)	Uniformity coefficient	Effective size (mm)	Sample interval (feet)	Uniformity coefficient	Effective size (mm)
65–70	5.4	0.06	100–105	3.2	.11
70–75	5.3	.05	105–110	1.8	.19
75–80	3.7	.07	110–115	1.4	.20
80–85	3.5	.07	115–118	2.6	.25
85–90	2.7	.10	118–120	2.4	.25
90–95	3.7	.09	120–125	1.8	.25
95–100	2.2	.15	125–127.5	1.7	.25

is very uniform in its physical characteristics, breaks in deposition occur in the form of thin discontinuous clay lenses and clay-ball zones. The log of the test hole from which the samples were collected for analysis is shown in table 3.

MINERALOGY OF THE CLAY-SIZE PARTICLES

X-ray analysis was used to determine the mineralogy of clay and silt samples collected from two localities in the Grand Prairie region. The minerals in the samples collected from test hole L3S–4W–3dca14 (table 3) are listed in the approximate order of relative abundance within the specimen as follows: MAJOR, Minor, (Trace), and (Questionable?).

Test hole L3S–4W–3dca14

At 74 feet: QUARTZ, Feldspar (Mica?), and (Montmorillonite?)
At 78 feet: QUARTZ, Feldspar (Montmorillonite), (Mica), and (Kaolinite).
At 102 to 104 feet: QUARTZ, (Feldspar), (Mica), (Kaolinite), and (Montmorillonite?)

Six samples of the upper-zone clay and silt deposits were collected from the roadcut near Clarendon (sec. 36, T. 1 N., R. 4 W.). Following is a general description of the samples and their stratigraphic position within the section:

Sample and description	*Depth (feet below land surface)*
1. Silt, gray; contains some very fine sand and oxidized particles; has a loesslike appearance	0. 2–0. 4
2. Silt, yellowish-brown; contains oxidized material; has a loesslike appearance	1. 5
3. Silt, yellowish-brown; contains some very fine sand; has a loesslike appearance	2. 5
4. Silt, light-yellowish-brown; contains fresh organic fragments; has a loesslike appearance	2. 5–3
5. Silt, clayey, dark-reddish-brown; forms pinnacles, in part, upon weathering; contains evidence of bedding	5
6. Clay, silty, dark-reddish-brown; forms pinnacles upon weathering; contains evidence of bedding	8

According to Dr. H. D. Glass, of the Illinois Geological Survey, Clay Mineralogy Section (written communication, 1958), the X-ray traces indicated that montmorillonite was the predominant clay mineral in the samples. Abundant feldspar was indicated, and orthoclase was more prevalent than plagioclase. Small amounts of illite and poorly crystallized kaolinite also were indicated. All samples contained moderate amounts of quartz. The mineralogy of all six samples is similar, but there are some minor differences. Samples 1 through 4 have a strong resemblance to loess, both visually and by X-ray-trace comparisons, whereas samples 5 and 6 show the similarity only in the X-ray trace. The increase in illite content of samples 5 and 6 is probably the greatest difference between samples 1 to 4 and samples 5 and 6.

A clay sample collected from a test hole at the recharge site also was analyzed by the Clay Mineralogy Section of the Illinois Geological Survey. The clay, which came from a depth of about 18 feet, was dark reddish brown, very silty, calcareous, and contained many white specks. A very low quartz content, the presence of calcite, and increased amounts of illite and kaolinite are the principal differences in this analysis as compared with those of samples 1 through 6. Also, there was less feldspar in this sample.

The clay-lens material from test hole L3S–4W–3dca14 may have been contaminated as drilling progressed. The lenses were interbedded with sand and silt, and bailer agitation undoubtedly caused some mixing. As a result, an X-ray analysis of these samples might show a deceptively high quartz content.

If part of the quartz was added by contamination, the analyses of uncontaminated lens material at depth may be similar to those of the upper-zone materials. Thus, the entire section of Quaternary deposits at this location could be of one age, either all Pleistocene or all Recent. If the samples were uncontaminated or only slightly contaminated, the differences in the analyses are striking. Quartz in clay-size particles is characteristic of glacial "rock flour." Furthermore, the relative percentage of true clay minerals becomes very small. Thus, there is some real evidence that the lower unit is of Pleistocene age and the upper clay materials may be all or partly Recent in age.

CONFIGURATION OF THE BASAL SURFACE

The configuration of the base of the Quaternary deposits was controlled by the configuration of the Tertiary land surface just prior to the deposition of the Quaternary materials. The Tertiary surface and the present topography control the thickness of the Quaternary deposits. The configuration of the top of the Tertiary deposits is shown by contour lines on plate 3.

The upper surface of the Tertiary deposits was formed principally by erosion. The difference in elevation between the highest and lowest points on that surface is 75 feet, which is nearly the same as the difference in elevation between the highest and lowest points of the present land surface. However, in contrast to the gently undulating present surface, with its broad flat-topped divides, the Tertiary surface was much more rugged and had a well-integrated drainage system. For this reason, wells drilled to the bottom of Quaternary deposits within a mile or so of each other may have very different depths.

The altitude of this basal surface has economic importance. Wells bottomed in Quaternary deposits over Tertiary highs will penetrate relatively thin saturated sections of aquifer and have relatively low yields. Also, wells on these highs will be the first to be abandoned as water levels decline.

CONFIGURATION OF THE WATER TABLE

The configuration of the water table in the area is shown by contour lines on the water table as of March–April 1959 (pl. 4). The contour interval is 2 feet in the area of more intensive study and 4 feet elsewhere. The contours are based upon water levels measured in 107 wells and elevations determined by leveling by the Coast and Geodetic Survey and the Corps of Engineers or from topographic maps. A large ground-water trough extends northwestward across the central part of the region. Since 1928 the trough has become wider and deeper, but it seems to be elongating northwest-westward and southeastward more rapidly than it is expanding in other directions, probably because there is less irrigable land and consequently less pumping on the west along southeastward-trending Bayou Meto and on the east along southeastward-trending Bayou LaGrue and the White River.

The annual flow of ground water into this trough has been estimated in two ways (Engler, Thompson, and Kazmann, 1945, p. 45). One method consisted of computations based on the permeability, hydraulic gradient, and area of cross section through which the water flows. The second method consisted of balancing the volume of water pumped with the volume taken from storage by dewatering plus the inflow to the region during a certain period. The two methods gave comparable figures. On the basis of all available data, the annual inflow to the water-bearing beds of Quaternary age in the Grand Prairie region is estimated to be 135,000 acre-feet (Engler, Thompson, and Kazmann, 1945, p. 46).

The rice-irrigation season usually begins late in April and ends in early September. Thus, the water-level measurements used in constructing the water-table map for March–April 1959 (pl. 4) reflect conditions just before a new pumping season began and after a period of recovery from the previous irrigation season. Contour lines drawn on the basis of June or August water-level measurements would be much more intricate, owing to coalescing cones of depression around the pumped wells.

THICKNESS AND AREAL EXTENT OF THE SAND AND GRAVEL

Plate 5 is a map of the artificial-recharge area showing the thickness of the sand and gravel deposits of Quaternary age that yielded water to wells and were saturated prior to development of the aquifer. It indicates the continuity of the more permeable zone in the area.

A comparison between the map showing the configuration of the upper surface of the Tertiary deposits (pl. 3) and plate 5 shows a striking similarity, because the sand and gravel filled irregularities in a land surface sculptured on beds of Tertiary age; hence, these deposits are thickest where the top of the Tertiary deposits is deepest. On the other hand, the upper surface of the sand and gravel is relatively flat.

THICKNESS AND AREAL EXTENT OF THE DEWATERED ZONE

Plate 6 is a map of the artificial-recharge area showing the thickness of the deposits of Quaternary age below the top of the blue-gray sand that had been dewatered as of 1954. The heavy lines on the map represent the eastern boundary of the area in which the water level has declined below the base of the confining beds. Ground water within the areas enclosed by the heavy lines in sec. 30, T. 3 S., R. 3 W., and sec. 6, T. 4 S., R. 3 W., was still under artesian head in 1954. As water levels continue to decline, these areas will become smaller and only intermittently artesian and eventually will disappear. The construction of profiles through sections 30 and 6 showing the top of the Tertiary deposits, the ground-water surface, and the thickness of the aquifer reveal that the artesian condition is due to a local thickening of the aquiclude, whereby the top of the zone of saturation and the base of the aquiclude come into contact with each other.

Plate 6 was used to compute the water-storage potential in the dewatered part of the aquifer. By substitution of numerical values in the following formula, it was determined that approximately 600,000 acre-feet of water could be stored underground in the area covered by plate 6.

$$\frac{\begin{pmatrix}\text{Average thickness of}\\ \text{dewatered sand, in feet}\end{pmatrix}\begin{pmatrix}\text{Square miles of}\\ \text{dewatered sand}\end{pmatrix}(5{,}280)^2\ (0.30)\ (7.48)}{325{,}851} = \text{Acre-feet of storage,}$$

where

0.30 = coefficient of storage, as determined from aquifer tests;
325,851 = number of gallons per acre-foot;
7.48 = number of gallons per cubic foot.

The area shown on plate 6 is about 30 percent of the total area in the Grand Prairie in which the upper part of the aquifer has been dewatered. The computations indicate a dewatered volume of about 300 billion cubic feet having a storage potential of about 2 million acre-feet of water for the entire Grand Prairie. On the assumption of a duty of water for rice irrigation of 1.8 acre-feet (Engler, Thompson, and Kazmann, 1945, p. 23) and an average of 160,000 acres of rice in the region, it is estimated that the 2 million acre-feet of water that might be stored underground would be enough to irrigate rice fields in the Grand Prairie for 7 years. The computations signify also that at least 2 million acre-feet of water has been withdrawn from the aquifer.

THICKNESS AND AREAL EXTENT OF THE SATURATED ZONE

Plate 7 is a map of the area showing the thickness of the saturated section remaining in the deposits of Quaternary age that was yielding water to wells as of December 1954. The thickness of the saturated section is controlled by the topography of the buried upper surface of the Tertiary deposits and the configuration of the water table; this relation explains the similarity of plate 7 to plates 3 and 4. The thickest saturated sections remaining are over depressions in the buried top of the Tertiary deposits.

The thickness of the saturated section remaining in the aquifer is one of the most important factors in estimating the yield and future life of irrigation wells in this area. The aquifer below the water table must be sufficiently thick to permit the establishment of gradients necessary to move the required quantity of water into the wells. Furthermore, the saturated thickness must provide also for seasonal drawdown, annual decline in the water level, and other fluctuations.

A saturated section of less than 25 feet generally will not yield sufficient water to a well for economical rice irrigation. Any area where the saturated thickness is less than 25 feet may be therefore considered seriously depleted. Well yields range from 250 to 700 gpm in areas that have a saturated section of 25 to 40 feet remaining. Wells yielding less than 300 gpm, however, are not considered economical in this area. Obviously, the aquifer has been partly depleted in much of the area, and continued decline of the water level would cause a serious depletion in much more of the area within a short time.

Well yields range from 700 to 1,500 gpm in the areas that have a saturated thickness of 40 feet or more.

CHEMICAL QUALITY OF THE GROUND WATER

In June 1954, a program of weekly sampling of three irrigation wells on the Rice Branch Experiment Station (area "A") was started. Sampling continued through the irrigation season. These samples were analyzed to determine whether the quality of the ground water changed with time as a result of pumping; but subsequent analyses agreed closely with the initial analyses. (See table 4.) In addition, 12 samples were collected from wells in areas "B" and "C." The results of these analyses indicate that there are differences in quality of the water but that waters in the entire area sampled are of the calcium bicarbonate type.[1] (See table 5.) Locations of the wells sampled are shown in figure 10.

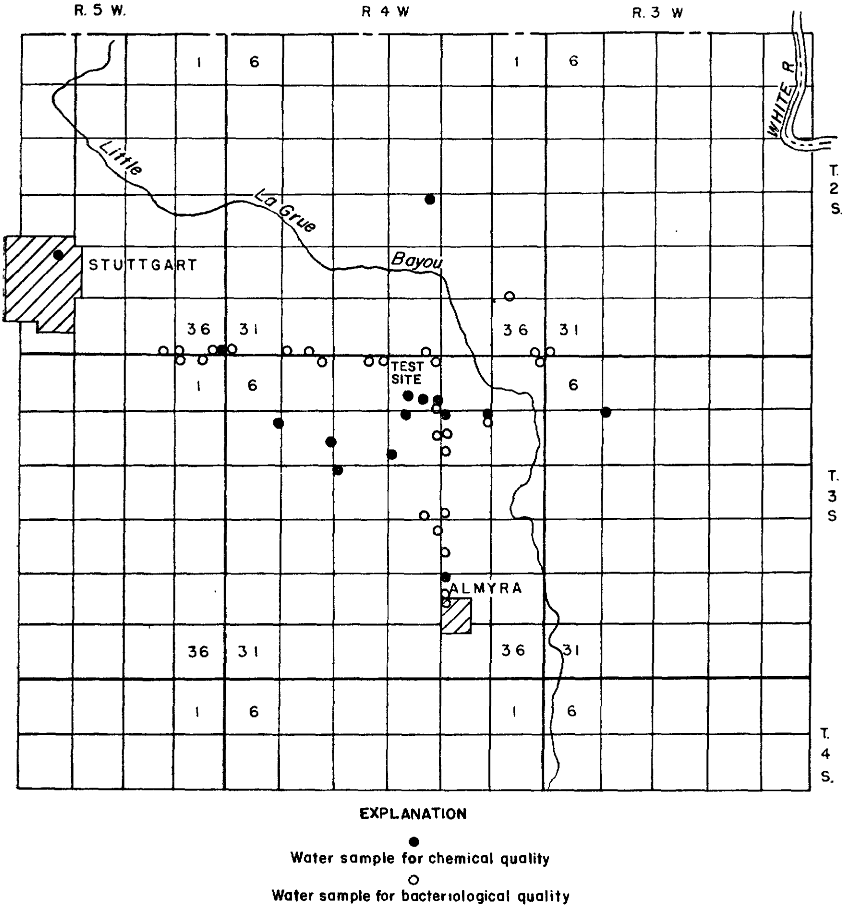


FIGURE 10.—Map of the artificial-recharge area showing the location of sampling points.

---

[1] Experiments have shown that waters high in calcium bicarbonate are detrimental to rice cultivation in Arkansas. About 1936, decreased rice yields in certain areas of the Grand Prairie region were noted. This decrease in yields was attributed to excessive lime in the soils. Soils in the Grand Prairie region under virgin conditions are acid, having a pH of about 5.0. Application of irrigation water high in calcium and magnesium bicarbonate causes the soil pH to rise, owing to precipitation of calcium and magnesium. When the soil pH exceeds 7.2–7.5, yields of rice begin to fall off rapidly. Application of about 1.8 acre-feet of "shallow-well" water, the average yearly application of ground water to rice, is equivalent to the application of about three-fourths of a ton of lime per acre. After rice is grown for 8 of 15 growing seasons, the soil pH may rise to 7.6–8.0. Some of the older rice soils in the area have a pH of about 8.2. These alkaline soils cannot be reclaimed by any known simple or economical treatment because of poor internal soil drainage. It has been recommended that rice be cultivated on a particular field only once every 3 or 4 years, according to soil type. Such a practice should prevent excessive accumulation of calcium and magnesium when crops that remove these materials from the soil are rotated with rice (R. L. Beacher, Arkansas Univ., personal communication, 1956).

TABLE 4.—*Chemical analyses of water from irrigation wells on the Rice Branch Experiment Station, area "A"*

[Analyses by U.S. Geol. Survey. Chemical constituents in parts per million]

Date of collection	Time	Temperature (°F)	Iron (total Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$		Percent sodium	Specific conductance (micromhos at 25° C)	pH
													Total	Noncarbonate			
West well, No. 3S-4W-3cad																	
6-3-54		65	1.9	87	28	50	474	0	13	24	2.5	482	332	0	25	796	7.6
7-14-54		65	2.0	89	27	51	476	0	20	24	2.3	477	333	0	25	786	7.4
7-18-54		65	2.6	87	26	51	474	0	15	22	1.3	485	324	0	25	802	7.5
8-6-54		65	2.1	86	26	49	476	0	14	24	1.7	486	322	0	25	796	7.7
8-28-54		65	.98	93	24	50	468	0	16	25	1.9	479	330	0	25	784	7.5
9-1-54		65	1.8	69	24	51	402	0	17	25	1.2	426	270	0	29	687	8.0
9-14-54		65	1.2	92	25	51	472	0	18	24	1.2	474	332	0	25	786	7.4
Middle well, No. 3S-4W-3dca																	
3-17-54	6:15 a.m.	64	1.4	87	27	48	456	0	12	28	2.1	486	328	0	24	648	7.8
Do	7:17 a.m.	64	1.2	84	26	49	450	0	9.2	29	2.6	468	316	0	25	761	7.4
Do	8:02 a.m.	64	1.6	85	27	47	448	0	11	28	2.7	461	323	0	25	760	7.4
Do	10:00 a.m.	64	1.3	85	27	47	452	0	12	28	3.1	468	323	0	23	716	7.4
Do	11:55 a.m.	64	1.5	86	28	47	452	0	15	27	2.6	458	330	0	23	782	7.4
Do	2:35 p.m.	64	.0	87	27	48	460	0	13	26	.5	487	328	0	24	776	7.5
Do	3:00 p.m.		1.4	85	29	48	454	0	12	28	2.4	462	331	0	24	773	7.5
Do	8:00 p.m.	64	.0	85	28	48	455	0	11	27	.5	490	327	0	24	772	7.4
6-3-54		66	2.4	86	24	48	458	0	13	25	2.5	457	313	0	25	764	8.0
7-21-54		65	1.0	87	26	49	460	0	18	24	.5	453	324	0	25	768	7.5
7-28-54		65	.3	84	26	48	456	0	12	23	1.0	475	316	0	24	773	7.4
8-6-54		65	2.1	84	24	48	450	0	14	24	1.4	470	308	0	25	777	7.7
8-28-54		65	2.2	86	27	49	450	0	12	26	.9	471	326	0	25	765	7.4
9-1-54		65	.57	88	25	49	456	0	13	26	1.1	463	322	0	25	766	7.4
9-14-54		65	1.6	88	27	49	456	0	12	28	1.9	466	330	0	24	765	7.4

East well, No. 3S-4W-3dda

8-13-28	....	64	1.4	68	22	47	391	0	11	20	1.7	398	260	0	28	....	......
6-3-54	....	66	1.8	78	26	48	422	0	14	25	3.0	465	302	0	26	745	7.8
7-14-54	....	65	.90	87	26	50	450	0	26	26	1.9	462	324	0	25	767	7.4
7-21-54	....	65	1.5	85	26	50	446	0	25	25	3.1	456	319	0	25	763	7.4
7-28-54	....	65	7.4	83	29	50	448	0	22	25	1.9	468	326	0	25	765	7.5
8-6-54	....	65	.54	48	23	49	336	0	19	25	2.9	380	214	0	33	618	8.1
8-28-54	....	65	2.3	83	28	49	446	0	18	24	1.8	473	322	0	25	775	7.6
9-1-54	....	65	.83	86	25	50	440	0	23	26	1.2	476	318	0	25	769	7.4
9-14-54	....	65	.60	87	25	49	440	0	20	26	2.4	471	320	0	25	763	7.3

TABLE 5.—*Chemical analyses of water from irrigation wells on the Rice Branch Experiment Station, areas "B" and "C"*

[Analyses by U.S. Geol. Survey. Chemical constituents in parts per million]

Well	Date of collection	Temperature (°F)	Iron (total Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$: Total	Hardness as $CaCO_3$: Noncarbonate	Percent sodium	Specific conductance (micromhos at 25°C)	pH
2S-4W-22aab1	6-4-54	65	0.12	88	24	51	452	0	23	24	2.5	460	318	0	26	779	7.7
2S-5W-28abd1	2-27-52	65	1.5	72	16	30	317	0	22	14	.0	318	246	0	21	523	7.4
36ddd1	6-3-54	67	2.3	81	20	43	384	0	32	22	1.7	425	284	0	25	697	7.7
3S-3W-8bbb1	6-4-54	65	1.8	100	33	61	500	0	19	58	2.2	561	385	0	26	946	7.7
3S-4W-7aad1	6-3-54	65	1.9	65	19	43	368	0	8.4	18	1.8	371	240	0	28	610	8.2
8daa1	6-3-54	65	1.9	88	19	48	414	0	17	27	2.0	445	298	0	26	720	8.2
10bab1	6-3-54	65	1.8	78	21	52	412	0	11	25	1.8	436	281	0	27	716	7.7
10ccb1	6-3-54	65	1.8	72	20	49	388	0	14	28	1.5	420	262	0	29	687	8.1
11aaa1	6-3-54	66	1.7	82	26	53	460	0	11	32	3.2	477	312	0	27	787	7.9
11bbb1	6-3-54	....	1.6	73	21	53	402	0	9.4	30	1.8	432	268	0	30	705	7.6
16bbb1	6-3-54	65	1.7	77	23	42	386	0	19	22	2.2	414	286	0	24	683	7.5
26bbb1	6-4-54	65	1.6	68	18	39	358	0	3.4	24	1.5	366	244	0	26	616	7.6

The analyses show that the concentration of practically all the constituents varies from well to well and with time in the same well. The variations in concentration of calcium and bicarbonate, however, affect the total mineral content more than the variations in concentration of the other constituents. The quality of the ground water is relatively uniform during a pumping season and from place to place in the area.

BACTERIOLOGICAL QUALITY OF THE GROUND WATER

Hydrologic investigations in an area generally do not include bacteriological studies of the water. However, untreated turbid water may be put into the recharge well and, consequently, directly into the ground-water reservoir. To provide a basis for observing changes in bacteriological quality of the water in the vicinity of the recharged well, 30 samples from domestic supplies were collected by Mr. Sam Dickey, Sanitarian of the Arkansas State Health Department, prior to any recharge runs. Laboratory examination indicated that about one-fifth of the domestic supplies sampled were contaminated generally from faulty water-handling facilities. The owners of the contaminated supplies were informed so that they might remedy the situation. The results of this preliminary sampling are given in table 6, and the locations of the sampling points are given in figure 10.

TABLE 6.—*Results of bacteriological analysis of domestic supplies*

Location number	Date sampled in 1954	Collection point	Result of examination
B2S-3W-31cccl	Nov. 23	Sink hydrant	Safe.
B2S-4W-25cdcl	do	do	Do.
31cccl	Oct. 16	Pump hydrant	Do.
32cccl	Oct. 14	do	Do.
32dccl	Oct. 18	Yard hydrant	Do.
34dcd1	Oct. 12	Pump hydrant	Unsafe.
36ddcl	Nov. 23	do	Safe.
B2S-5W-35ddcl	Oct. 14	do	Do.
36cccl	do	Sink hydrant	Do.
36ddcl	do	Pump hydrant	Do.
B3S-4W-1aaal	Nov. 23	do	Do.
3aaal	Oct. 12	Tub hydrant	Unsafe.[1]
3aaa2	do	Pump hydrant	Safe.
3ddd1	Oct. 18	Yard hydrant	Do.
4aaal	Oct. 14	Pump hydrant	Do.
4abal	do	Kitchen hydrant	Unsafe.
5aabl	do	Pump hydrant	Do.
10addl	Oct. 18	do	Do.
11aaal	Nov. 24	do	Safe.
11bccl	Oct. 18	do	Do.
11cbcl	do	do	Unsafe.
B3S-4W-14cccl	do	do	Safe.
14ccc2	do	do	Do.
15dcd1	do	Yard hydrant	Do.
22aad1	do	Pump hydrant	Do.
23cbb1	do	Kitchen hydrant	Do.
26bcd1	Nov. 23	Sink hydrant	Do.
26cbb1	Oct. 18	Pump hydrant	Unsafe.
B3S-5W-1bbb1	Oct. 14	Kitchen hydrant	Do.
1abb1	do	Pump hydrant	Safe.

[1] Water softener disinfected and a sample collected Nov. 23, 1954 showed the water to be safe for drinking and free from coliform organisms at the time of sampling.

HYDROLOGIC PROPERTIES OF DEPOSITS OF QUATERNARY AGE

AQUIFER TESTS

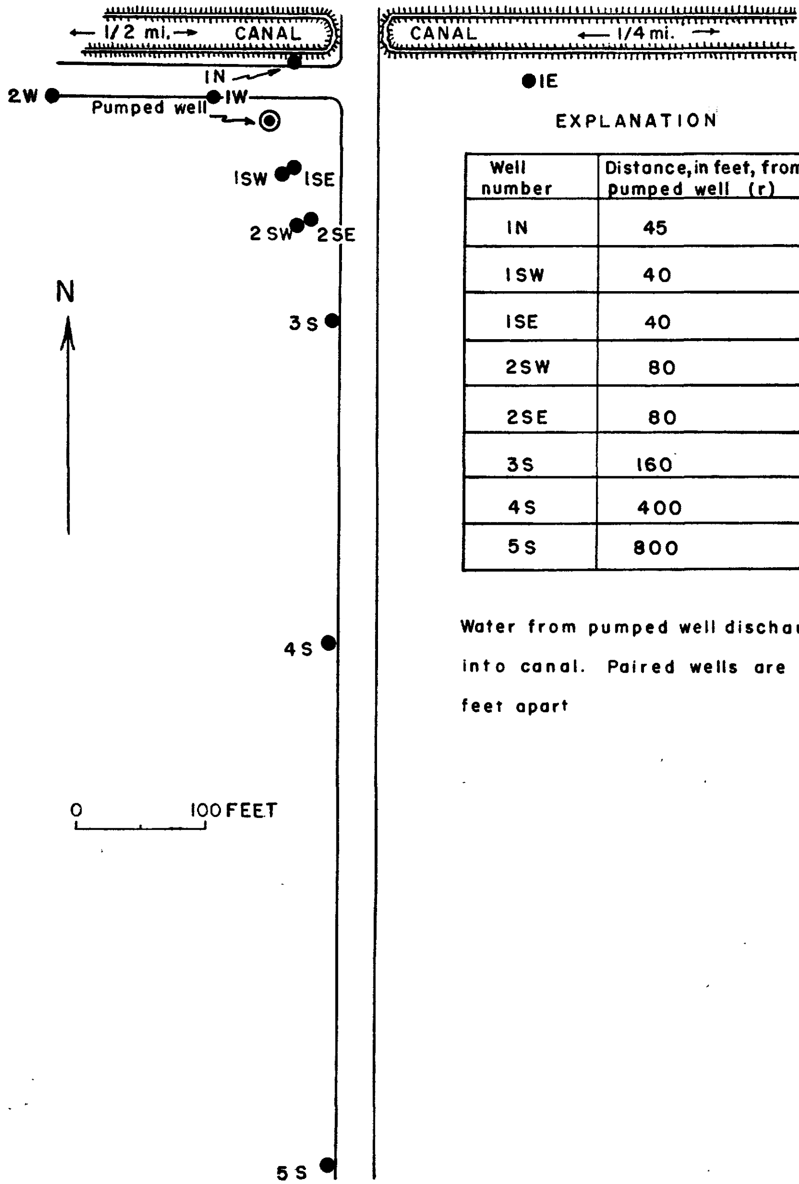
The quantity of ground water that a water-bearing material will yield and the rate at which the water will move through the material depend in part upon the physical and hydrologic properties of the material. These properties differ greatly with changes in the size, shape, number, and degree of interconnection of the interstices. The rate of movement of the water is further influenced by the density and viscosity of the water and by the hydraulic gradient. As sediments in nature generally are not homogeneous, a wide range in these properties is characteristic.

The capacity of a water-bearing material for transmitting water under a hydraulic gradient is known as its permeability. Meinzer's coefficient of permeability (the Meinzer unit, or meinzer) may be defined as the gallons of water per day, at 60°F, that moves laterally through each mile of water-bearing bed under investigation (measured at right angles to the direction of flow) for each foot of thickness of the bed and for each foot per mile of hydraulic gradient (Stearns, 1928, p. 148). The field coefficient of permeability is the same except that it is measured at the prevailing water temperature. The coefficient of transmissibility is a similar measure for the entire thickness of the water-bearing formation and may be defined as the gallons of water per day, at the prevailing temperature, transmitted through each mile strip extending the height of the aquifer under a hydraulic gradient of 1 foot to the mile; it is the field coefficient of permeability multiplied by the thickness of the aquifer, in feet.

The coefficient of storage of an aquifer is the volume of water it releases from or takes into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface. The specific yield of an aquifer is the ratio of (1) the volume of water which will yield to gravity after the aquifer is saturated to (2) the total volume of the rock (Meinzer, 1923, p. 28). Under water-table (unconfined) conditions, such as those in the most heavily pumped parts of the Grand Prairie region, the coefficient of storage is practically equal to the specific yield of the material dewatered during pumping.

An aquifer test was made in March 1954 at the site of irrigation well 3S–4W–3dca1 at the Rice Branch Experiment Station. The well was pumped at a rate of 480 gpm for 32 hours. Measurements of discharge were made with an orifice meter loaned by the Layne-Arkansas Co., Stuttgart, Ark. Measurements of drawdown and recovery were made with a steel tape and sounding weight in eight observation wells. Their locations with respect to the pumped well are shown in figure 11. A geologic section was constructed from the data collected when the observation wells were installed. (See fig. 12 and pl. 8.) Wells 1–W, 2–W, 2–N, and 1–E were drilled after completion of the aquifer test.

When an aquifer test is made on a pumped well constructed so that its screen does not completely penetrate the water-producing bed,



Well number	Distance, in feet, from pumped well (r)
IN	45
ISW	40
ISE	40
2SW	80
2SE	80
3S	160
4S	400
5S	800

Water from pumped well discharged into canal. Paired wells are 4 feet apart

FIGURE 11.—Sketch map showing the location of observation wells and the pumped well.

adjustments of the observed drawdowns and recoveries of the observation wells may be necessary (Jacob, 1944). The pumped well in this test is screened only in the lower part of the aquifer; hence, because of the convergence of the flow lines as they approach the well screen, the loss of head along the bottom of the bed is less than along the top of the bed. Both differ from the head loss that would occur if the penetration were complete, especially when the bed is irregularly stratified (pls. 1, 8, and fig. 12). The inhomogeneities of stratification give a vertical permeability that is many times smaller than the average horizontal permeability. In order to correct these differences in permeability, "paired wells" 1–SW and 2–SW were screened at the bottom and 1–SE and 2–SE were screened at the top of the saturated zone (pl. 8). The difference in head of these wells is shown in figures 14–16, in which the graphic average of the difference in head was used to correct for the partial-penetration effects of the pumped well.

If the Theis (1935) graphical method is used for determining the coefficient of transmissibility under water-table conditions, the drawdown and recovery should be adjusted for the decrease in depth of flow. The mathematical analysis of this correction is given in a paper by Jacob (1944). At the beginning of the test, the saturated

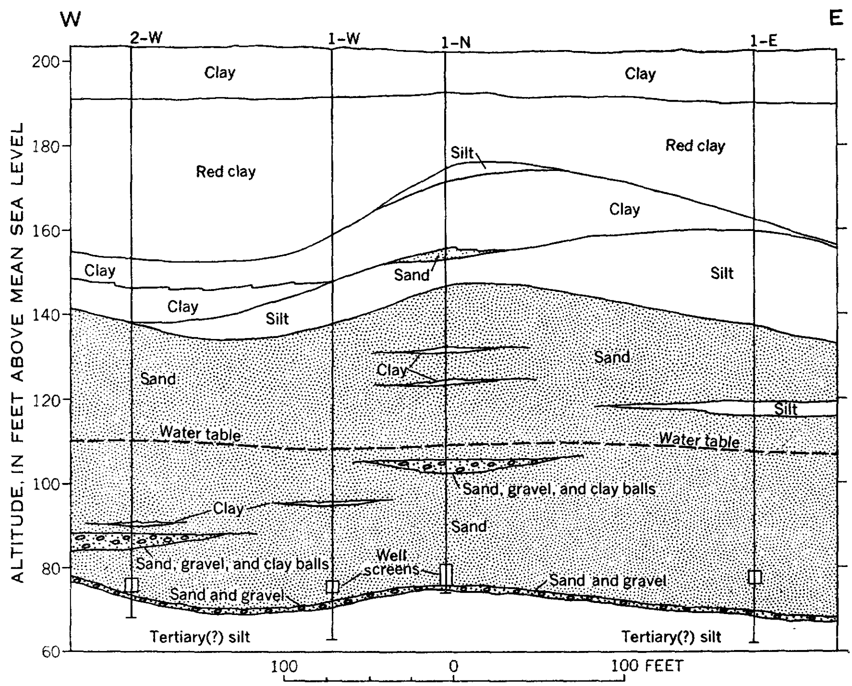


FIGURE 12.—Geologic section between observation wells 1–E and 2–W, Rice Branch Experiment Station, Arkansas

thickness of the water-bearing material at the test site was 35 feet. Consequently, the correction for the decrease in depth of flow was used and may be expressed as follows:

$$s_c = s - \frac{s}{2m},$$

in which

s_c=corrected drawdown for decrease in depth of flow, in feet;
s=observed drawdown, in feet;
m=saturated thickness of the aquifer, in feet.

The correction ranged from 0.01 to 6.35 feet.

Some of the widespread and continuous fluctuations of the water levels in wells in the Grand Prairie are due to changes in atmospheric pressure. These fluctuations range from a fraction of an inch to about a foot and may last from a few hours to several days. They may be demonstrated by comparing graphs of water-level fluctuations from recording gages with barograms made at the Rice Branch Experiment Station. A barograph was maintained at the test site also during the aquifer test. The barometric efficiency of the observation wells and aquifer has been computed to be about 89 percent. Thus, a 0.1-inch change in the mercurial barometer will be reflected in a water-level change in wells of about 0.1 foot in the reverse direction. Well 5–S (pl. 8) was far enough from the pumped well so that it was not affected by the pumped well during the period of pumping. Regular measurements were made in well 5–S during the period of the test, and the observed fluctuations were used to correct the water-level measurements made in the other seven observation wells. Well 5–S was used as an "index well," which allowed for correction of the fluctuation of the water level caused by atmospheric-pressure changes and which made it possible to correct water-level measurements for regional changes in the water table due to other causes. These corrections ranged from +0.1 to −0.66 foot.

The Theis (1935) method was used in computing the transmissibility and storage coefficients from the data collected during the test. Extensive discussions of the method may be found in many publications of the Geological Survey and other agencies. It is not the purpose of this report to outline the method in detail but only to discuss its application to this study.

The transmissibility and coefficient of storage, according to the Theis method, may be expressed as follows:

$$T = \frac{114.6QW(u)}{s_c} \text{ and } S = \frac{uT}{1.87r^2t},$$

in which

T=coefficient of transmissibility, in gallons per day per foot;
S=coefficient of storage (dimensionless);
Q=pumping rate, in gallons per minute;
t=time, in days;
s_c=corrected drawdown or recovery, in feet;
r=distance of observation well from the pumped well, in feet;
$u=\frac{1.87r^2S}{Tt}$;

$$W(u)=-0.577216-log_e u+u-\frac{u^2}{2\cdot 2!}+\frac{u^3}{3\cdot 3!}-\frac{u^4}{4\cdot 4!}\cdots\cdots\cdots$$

It is the so-called well function of u.

Three logarithmic profiles of the cone of depression were plotted at 1,020, 1,440, and 1,920 minutes (figs. 13, 14, 15). These curves were then matched to a logarithmic type curve of the well function [$W(u)$ plotted against u], and match-point values for $W(u)$, u, s_c, and r^2/t were read from the two curves. When these values are substituted in the proper formulas, the coefficient of transmissibility is found to be about 70,000 gpd (gallons per day) per ft; and the coefficient of storage is found to be about 0.15 at 1,020 minutes, 0.17 at 1,440 minutes, and 0.18 at 1,920 minutes.

The average of the coefficient of permeability, which is determined by dividing the coefficient of transmissibility by the thickness of the saturated materials (35 feet), was found to be about 2,000 gpd per sq ft.

An aquifer test was made near the artificial-recharge site in 1941 (Engler, Thompson, and Kazmann, 1945, p. 35). The permeability was determined to be about 1,900 gpd per sq ft, and the coefficient of transmissibility for a saturated thickness of about 90 feet was 171,000 gpd per ft. The apparent value of the storage coefficient increased from about 0.014 after the first hour of pumping to about 0.11 at the end of a 32-hour pumping period.

The true value of S was not obtained during the short aquifer test of 1954, as indicated by the fact that the apparent value of S was still rising as late as the last measurement 1,920 minutes after pumping began. This change in the value of S will be discussed in later reports that deal with cones of elevation under recharge conditions. The T value however is probably valid even though the pumping period was too short for the determination of S.

A producing irrigation well is located 69 feet north of well 3S–4W–8daa1 (Carle well). Frequent checks on the discharge of the producing well in May 1955 showed that the pumping rate, Q, was about 840 gpm. The recording gage installed on the Carle well has been

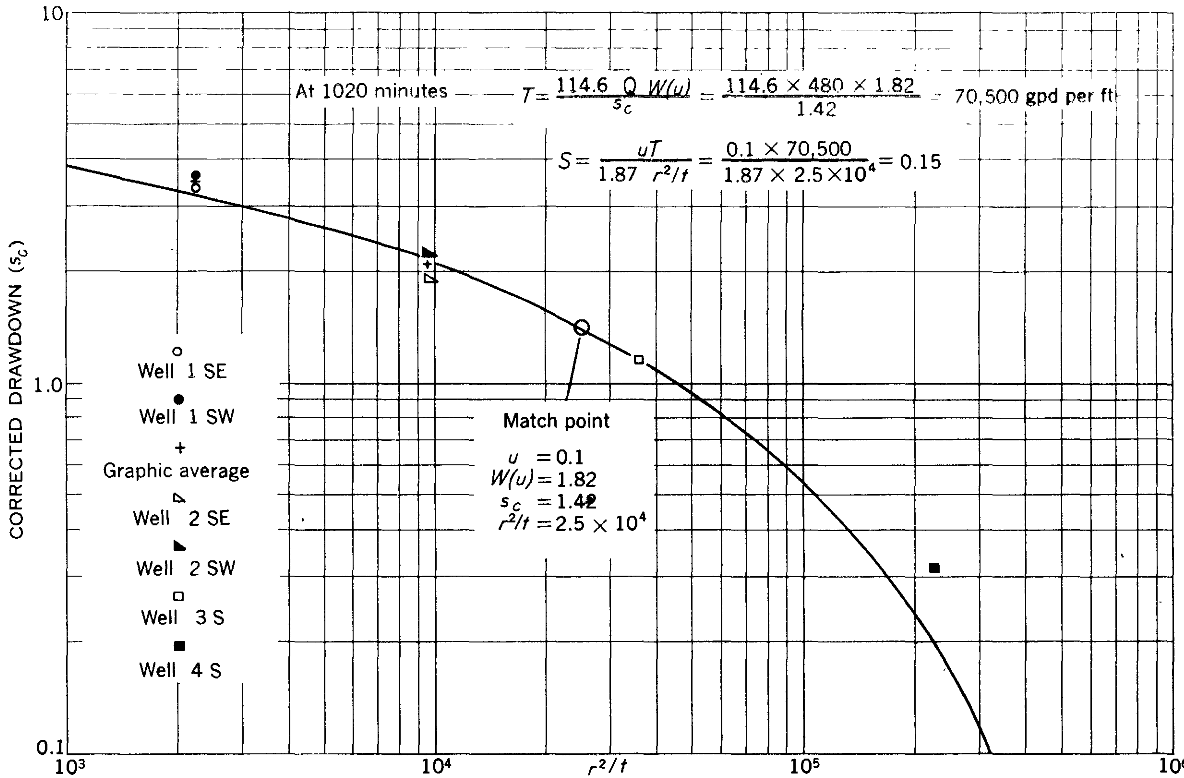


FIGURE 13.—Logarithmic plot of s_c versus r^2/t at 1,020 minutes.

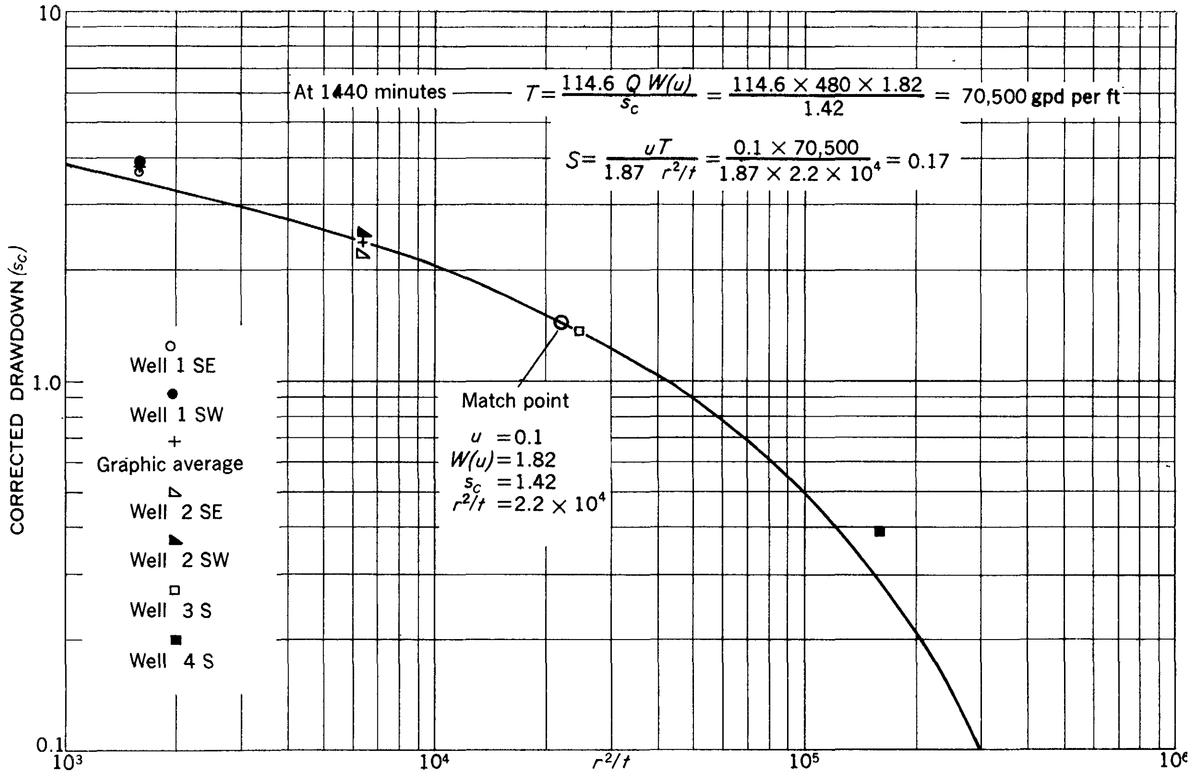


FIGURE 14.—Logarithmic plot of s_c versus r^2/t at 1,440 minutes.

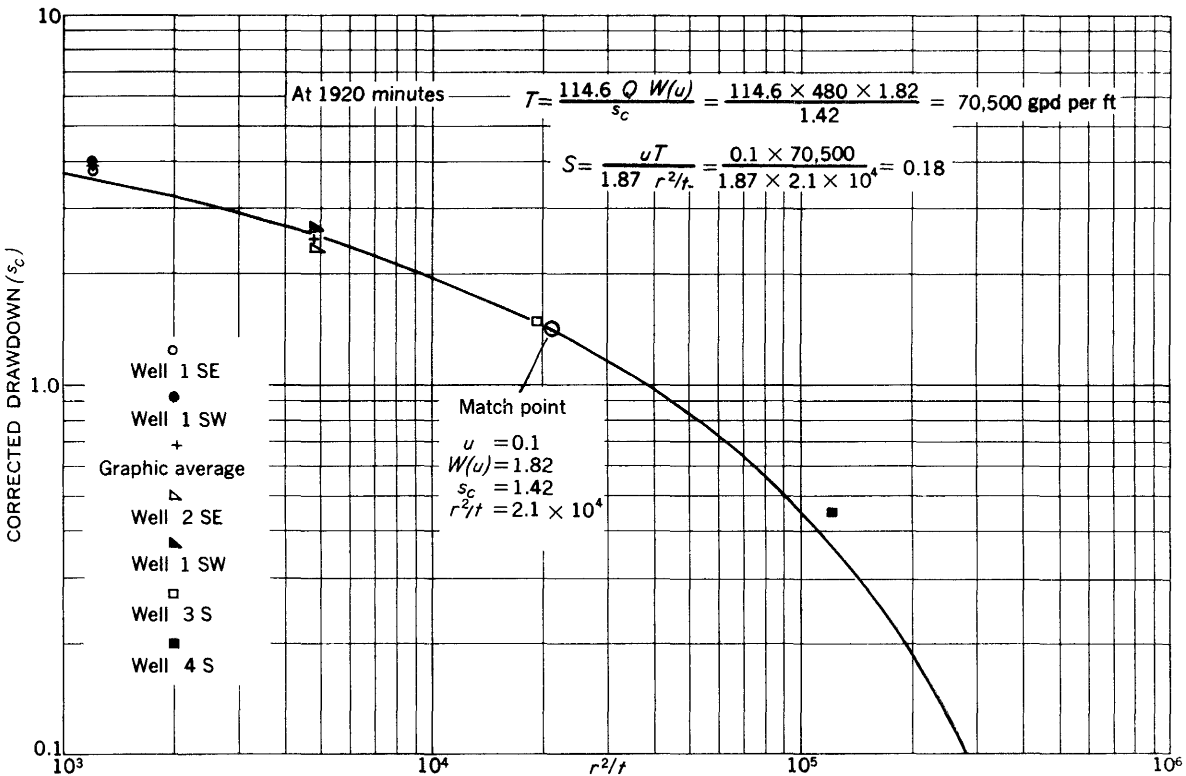


FIGURE 15.—Logarithmic plot of s_c versus r^2/t at 1,920 minutes.

kept in continuous operation since its installation; consequently, records of drawdown and time, as the producing well is pumped, are available (fig. 16). By means of data picked from the recorder chart, the coefficients of storage and transmissibility for two separate pumping periods were computed. The coefficient of transmissibility was found to be 83,000 gpd per ft and the apparent value of the storage coefficient was about 0.0047 for the 10-day pumping period.

The 20-day pumping period indicated that the coefficient of transmissibility was about 82,000 gpd per ft and the apparent value of the storage coefficient was about 0.045. The values of S suggest that the aquifer was just beginning to be dewatered during the first test and that dewatering was well under way during the second.

COEFFICIENT OF TRANSMISSIBILITY BY TEST-HOLE EVALUATION

A system, similar to that devised by E. C. Reed, State Geologist of Nebraska, and used by C. F. Keech and V. H. Dreeszen (1959), was used to determine the approximate coefficient of transmissibility of the saturated part of the deposits of Quaternary age in the area. Each lens or layer of material penetrated in drilling a test hole is examined and assigned a coefficient of permeability within the following range:

Type of material	*Field coefficient of permeability (gpd per sq ft)*
Clay and silt	0
Sand, very fine, silty	100–900
Sand, very fine	900–1, 400
Sand, fine to medium	1, 400–1, 500
Sand, medium	1, 500–1, 600
Sand, medium to coarse	1, 600–1, 900
Sand, coarse	1, 900–2, 000
Sand, very coarse	2, 000–2, 100
Gravel	2, 100–3, 000

A lithologic description, such as "sand, fine to medium," does not account for sorting, particle shape, packing, and other features related to permeability. This classification, however, is empirical. Lower or higher values of permeability within the given range may be assigned to a particular layer of material according to the observed factors controlling permeability and upon the experience and judgment of the observer.

After each lens or column of material of similar physical characteristics, a field coefficient of permeability is assigned and each coefficient is multiplied by the thickness, in feet, of the material. This number is the coefficient of transmissibility for the material, in gallons per day per foot. The sum of the coefficients of transmissibility of all beds is the coefficient of transmissibility of the aquifer. (See fig. 17.) A map such as figure 17 should be helpful in planning any extensive artificial-recharge operations.

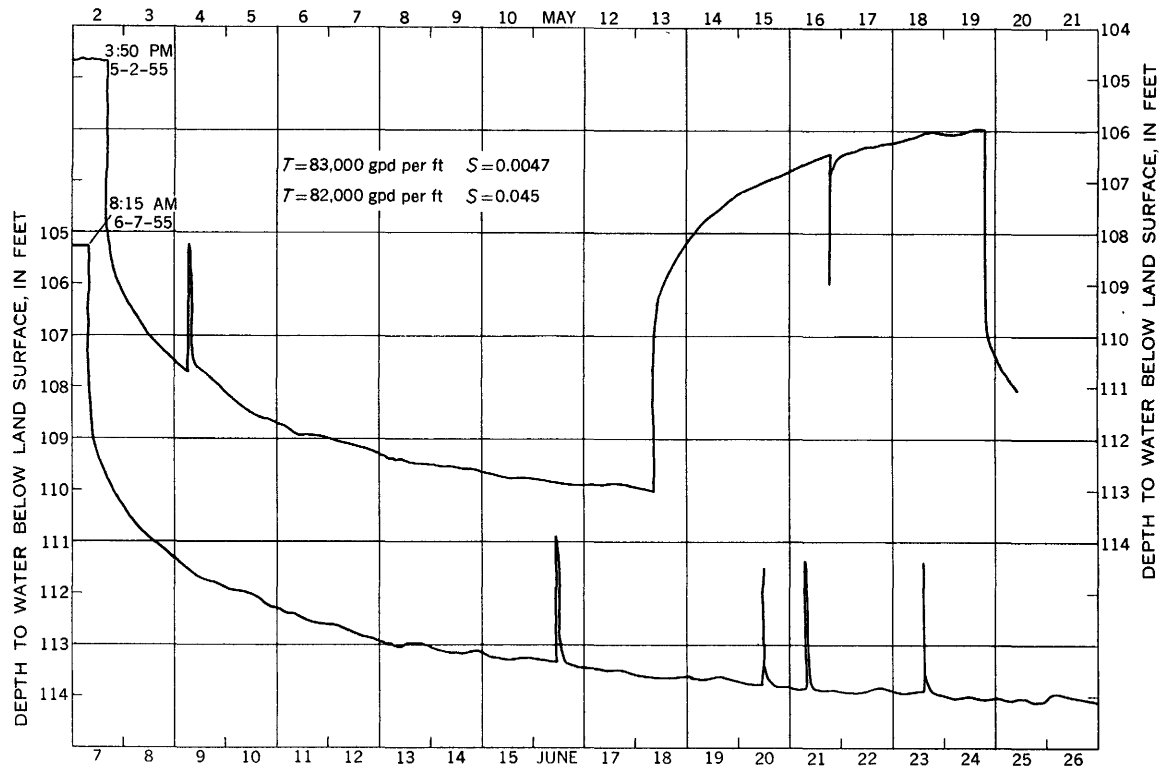


FIGURE 16.—Generalized hydrograph of the Carle well, 3S-4W-8daal, May and June 1955, showing drawdown, recovery, and pumping interruptions.

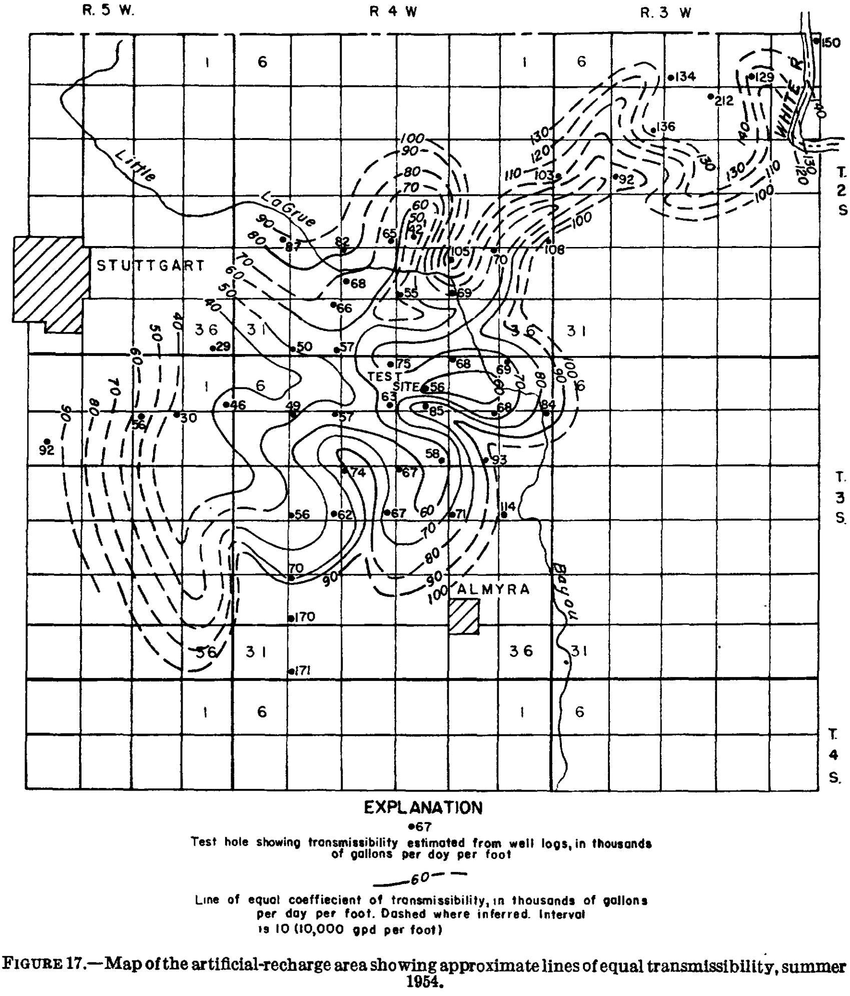


FIGURE 17.—Map of the artificial-recharge area showing approximate lines of equal transmissibility, summer 1954.

Transmissibility is controlled by permeability and saturated thickness of aquifer materials. The saturated thickness in the project area is controlled by natural recharge, the withdrawal of water for rice irrigation, and the configuration of the base and surface of the Quaternary deposits.

Thus the pattern of lines of equal transmissibility (fig. 17) reflects the influence of the configuration of the top of the Tertiary deposits (pl. 3), the thickness of the saturated zone in the deposits of Quaternary age (pl. 7), and the configuration of water table (pl. 4).

SUMMARY AND CONCLUSIONS

Several important conclusions may be drawn from this investigation of the hydrogeology of a part of the Grand Prairie region. These are:

1. The data collected during this investigation were not adequate to differentiate Quaternary deposits into deposits of Pleistocene and Recent age. However, pebbles of gneiss, granite, and other crystalline rocks in the basal unit were probably derived from glaciated areas and transported by the ancestral Mississippi River, and clay lenses in the unit made up dominantly of clay-sized quartz particles and only trace amounts of the clay minerals suggest that all or part of the basal unit is Pleistocene in age. On the other hand, the prevalence of red color in much of the clay and silt unit suggests that the unit was derived from sediments deposited by the Arkansas River, which carries a silt and clay load of red sediment, whereas the sediment load of the Mississippi River is gray. Furthermore, the slope of the Grand Prairie is southeastward—the direction of flow of the Arkansas River. Radiocarbon age determinations of organic material from the upper unit gave an age of about 5,500 years. Together, these facts suggest that the upper unit was derived partly or entirely from the Arkansas and White Rivers and that these upper materials are partly or entirely of Recent age.
2. Additional shallow test holes will be needed to determine more accurately the areal extent, thickness, and proximity to the surface of the red sand. If this sand was deposited as bar plains, as postulated in this report, it may be expected that its occurrence will be erratic; thus, the need for many closely spaced test holes is evident. A detailed geologic study of the red sand might reveal small local natural recharge areas in the Grand Prairie not hitherto known. If the red sand occurs over a large enough area close to the surface and is fairly permeable, the possibility of artificial recharge by water spreading should be investigated.
3. Aquifer materials in the vicinity of the recharge-test site are exceptionally uniform for continental deposits. A sand sample taken from an interval of 110 to 115 feet had a uniformity coefficient of 1.4. Many sands that have been highly graded for use in rapid sand filters are not much more uniform in particle size. The uniformity coefficient of filter sands frequently is about 1.2. All conditions involved in the deposition of the aquifer materials must have been relatively constant for a considerable period of time.

4. This investigation of the recharge-test site should be helpful in interpreting data collected during artificial-recharge tests. All water-level measurements will require correction for barometric effect. This correction may be as great as 1 foot and would be of considerable significance in water-level measurements made in wells in which recharge effects may be only a few hundredths of a foot. The aquifer around the recharge-test site apparently is continuous, and geologic boundaries need not be considered in hydraulic evaluation of test results. Clay lenses in the aquifer will compound the normal differences between vertical and horizontal permeability. The mineralogical composition of these clays will have to be considered in any geochemical interpretation, because the montmorillonite and kaolinite may be involved in ion-exchange reactions with the water that is recharged.
5. The water-storage potential in the dewatered part of the aquifer in the Grand Prairie is about 2 million acre-feet. The dewatered part of the aquifer at the recharge-test site was about 35 feet thick, and the water level was about 95 feet below the land surface. Thus, sufficient head is available that water may be injected by gravity flow, and injection by pumping may not be required.

SELECTED BIBLIOGRAPHY

Branner, G. C., 1937, List of Arkansas water wells: Arkansas Geol. Survey Inf. Circ. 11, 142 p.

Brown, R. H., 1953, Selected procedures for analyzing aquifer test data: Am. Water Works Assoc. Jour., v. 45, no. 8, p. 844–866.

Call, R. E., 1891, The geology of Crowley's Ridge: Arkansas Geol. Survey Ann. Rept. for 1889, v. 2, p. 283.

Carter, W. T., Jr., Meeken, F. N., Smith, H. C., and Worthen, E. L., 1906, Soil survey of Prairie County, Arkansas: U.S. Dept. Agriculture Bur. Soils Field Operations.

Chamberlin, T. C., and Salisbury, R. D., 1891, On the relationship of the Pleistocene to pre-Pleistocene formations of the Mississippi Basin south of the limit of glaciation: Am. Jour. Sci., 3d ser., v. 41, p. 357–377.

Clayton, B. S., 1930, Progress report on the cost of pumping and duty of water for rice on the Grand Prairie of Arkansas: U.S. Bur. Public Roads for 1928, 37 p.

Cooper, H. H., Jr., and Jacob, C. E., 1946, A generalized graphical method for evaluating formation constants and summarizing well-field history: Am. Geophys. Union Trans., v. 27, p. 526–534.

Counts, H. B., and Engler, Kyle, 1954, Changes in water levels in deposits of Quaternary age in eastern Arkansas from 1938 to 1953: Arkansas Univ. Agr. Expt. Sta. Rept., Ser. 42, 11 p.

Cox, E. T., 1858, First report of a geological reconnaissance of a part of the State of Arkansas: Little Rock, Ark., p. 193–256.

Engler, Kyle, 1948, Ground-water resources of the Grand Prairie region: U.S. Corps Engineers, Vicksburg District, p. B–1—B–6.

Engler, Kyle, Thompson, D. G., and Kazmann, R. G., 1945, Ground-water supplies for rice irrigation in the Grand Prairie region, Arkansas: Arkansas Univ. Agr. Expt. Sta. Bull. 457, 56 p.

Engler, Kyle, 1958, Water levels in rice irrigation wells in the Grand Prairie region: Arkansas Farm Research, Arkansas Univ. Agr. Expt. Sta., v. 7, no. 3, p. 12.

Fenneman, N. M., 1931, Physiography of western United States: New York, McGraw-Hill Book Co., 1st ed., 534 p.

Fiske, H. N., 1944, Geological investigation of the alluvial valley of the lower Mississippi River: Mississippi River Comm., Vicksburg, Miss., 78 p.

Fricke, T. J., 1948, Irrigation in the Grand Prairie region: Corps of Engineers, U.S. Army, Vicksburg District, p. C–1—C–40.

Gerlow, A. R., 1958, Reservoir systems in the Grand Prairie: Arkansas Farm Research, Arkansas Univ. Agr. Expt. Sta., v. 7, no. 4, p. 2.

Harris, G. S., 1894, The Tertiary geology of southern Arkansas: Arkansas Geol. Survey Ann. Rept. for 1892, v. 2, p. 10–15.

Jacob, C. E., 1944, Notes on determining permeability by pumping tests under water-table conditions: U.S. Geol. Survey open-file rept., 25 p.

Keech, C. F., and Dreeszen, V. H., 1959, Geology and ground-water resources of Clay County, Nebraska: U.S. Geol. Survey Water-Supply Paper 1468, 157 p.

Knobel, E. W., Lonnsbury, Clarence, Davis, L. V., Fowler, E. D., and Gake, A. W., 1921, Soil survey of Lonoke County, Arkansas: U.S. Dept. Agriculture Bur. Soils Field Operations, p. 1279–1327.

Lapham, J. E., 1903, Soil survey of the Stuttgart area, Arkansas: U.S. Dept. Agriculture Bur. Soils Field Operations, p. 611–622.

Meinzer, O. E., 1923a, The occurrence of ground water in the United States, with a discussion of principles: U.S. Geol. Survey Water-Supply Paper 489, 321 p.

——— 1923b, Outline of ground-water hydrology, with definitions: U.S. Geol. Survey Water-Supply Paper 494, 71 p.

Nuttall, Thomas, 1821, Observation on the geological structure of the valley of the Mississippi: Acad. Nat. Sci., Philadelphia Jour., v. 2, pt. 1, p. 14–52.

Owen, D. D., 1860, Second report of a geological reconnaissance of the middle and southern counties of Arkansas: Philadelphia, Pa., 153 p.

Sniegocki, R. T., 1954, Progress report on studies of artificial recharge in the Grand Prairie region, Arkansas: U.S. Geol. Survey open-file rept., 113 p.

——— 1957, Progress report on studies of artificial recharge in the Grand Prairie region, Arkansas, 1956: U.S. Geol. Survey open-file rept., 207 p.

Stearns, N. D., 1928, Laboratory tests on physical properties of water-bearing materials: U.S. Geol. Survey Water-Supply Paper 596–F, p. 121–176.

Stephenson, L. W., and Crider, A. F., 1916, Geology and ground waters of northeastern Arkansas: U.S. Geol. Survey Water-Supply Paper 399, 35 p.

Theis, C. V., 1935, 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., v. 16, p. 519–524.

Veatch, A. C., 1906, Geology and underground water resources of northern Louisiana and southern Arkansas: U.S. Geol. Survey Prof. Paper 46, 389 p.

Warder, J. A., 1854, A geological reconnaissance of the Arkansas River: Cleveland, Ohio, 22 p.

Wenzel, L. K., 1942, Methods for determining permeability of water-bearing materials, with special reference to discharging-well methods: U.S. Geol. Survey Water-Supply Paper 887, 192 p.

BASIC DATA

TABLE 7.—*Records of selected wells in Arkansas County*

Well number: See description of well numbering system in text.
Owner or tenant: U.S.G.S., U.S. Geological Survey; U.S.C.E., U.S. Army, Corps of Engineers; U.A., University of Arkansas.
Type of well: B, bored; D, drilled.
Type of pump: J, jet; N, None; T, turbine.

Type of power: E, electric; G, gas or diesel; N, none.
Use of water: I, irrigation; O, observation.
Altitude above mean sea level: Instrument altitude if reported in tenths or hundreds of feet; altitude for all others from topographic maps.
Depth to water below measuring point: Not corrected for barometric influence.

Well	Owner or tenant	Type of well	Depth of well (feet)	Diameter of well (inches)	Method of lift		Use of water	Measuring point			Measurement	
					Type of pump	Kind of power		Description	Distance above or below land surface (feet)	Altitude above mean sea level (feet)	Depth to water level below measuring point (feet)	Date
2S-3W- 5ddb1		D			T	G	I	Hole in turbine base	+0.5	210	72.77	3-25-59
9dcc1	A. Trice	D	158		T	G	I	Edge of pit	+.5	206	67.18	Do.
18cab1		D			T	E	I	End of discharge	+4.0	207.70	77.52	Do.
19bcc1	R. Daugherty	D	159		T	G	I	do	+5.0	210.08	84.18	4- 1-59
22dba1	C. B. Stephens	D			T	G	I	Hole in turbine base	.0	213	64.24	3-25-59
31bab1	F. W. Richenbach	D			T	E	I	do	+1.0	208.96	84.58	4- 1-59
31bbb1	U.S.G.S	D	127	2	N	N	O	Top of pipe	+2.0	209.31	85.23	Do.
34baa1		D			T	G	I	Edge of pit	.0	200	65.07	3-25-59
2S-4W- 3aaa1	R. Shumard	D	145	18-10	T	G	I	Hole in turbine base	+.5	207	86.94	4- 2-59
3ddb1		D			T	E	I	do	+1.5	213	93.08	Do.
5cbb1		D			T	E	I	Edge of pit	+1.0	217	104.29	Do.
11dbb1		D			T	E	I	Hole in pit side	+1.0	214.04	90.37	Do.
13bba1	A. Blair	D	160		T	G	I	Edge of pump base	+1.0	213.04	85.80	Do.
17dca1	Freudenberg	D			T	E	I	Edge ofj pit	+.5	206	93.17	Do.
19ddd1	U.S.G.S	D	138	2	N	N	O	Top ofj pipe	+1.5	207.69	97.17	4-1-59
20cda1		D			T	E	I	End of discharge	+5.0	208.16	97.24	4-2-59
21ddd1	U.S.G.S	D	116	2	N	N	O	Top of pipe	+2.0	201.36	87.85	Do.
23baa1	F. Endres	D			T	G	I	End of discharge	+4.0	217.74	94.69	Do.
24ddd1	U.S.G.S	D	129	2	N	N	O	Top of pipe	+3.0	205.27	77.22	4-1-59
26aaa1	do	D	118	2	N	N	O	do	+2.0	204.39	84.65	Do.
26ccc1	do	D	114	2	N	N	O	do	+1.5	198.20	84.38	Do.
26dab1	H. McPherson	D	124		N	N	I	Edge of pit	.0	200	85.73	Do.
27ccc1	U.S.G.S	D	112	2	N	N	O	Top of pipe	+1.5	203.14	91.47	Do.
28bbb1	do	D	127	2	N	N	O	do	+2.0	203.84	92.11	4-2-59
29cbc1	L. Krumpen	D	133		T	E	I	Hole in turbine base	+1.0	206.62	97.98	4-1-59
29ccc1	do	D			T	E	I	do	+1.5	206.87	99.30	Do.
30bcc1	J. Daugherty	D			T	G	I	Edge of pit	.0	209.72	100.56	4-2-59
32aaa1	U.S.G.S	D	116	2	N	N	O	Top of pipe	+2.0	206.38	96.75	4-1-59
32ccc1	do	D	127	2	N	N	O	do	+2.0	214.41	108.72	Do.
35ada1	H. McPherson	D			T	G	I	Edge of pit	.0	202.48	88.73	Do.
36aaa1	A. Robinett	D		24-12	T	E	I	Hole in turbine base	+.5	210.36	86.68	Do.

36bab1	A. Robinett	D			T	G	I	Hole in turbine base	+.0	209.54	91.42	Do.
36cda1	F. G. Lubkemann	D	131		T	E	I	Edge of pit	+1.0	209.94	91.44	Do.
2S-5W-3ccd1		D			T	E	I	Hole in turbine base	+2.0	218	112.90	4-2-59
3daa1	N. Rogers	D			T	E	I	do	+1.5	218	111.85	Do.
13ccc1	F. Freudenberg	D			T	E	I	Side of Turbine base	+1.2	208	98.70	4-1-59
16dcc1	C. E. Pettit	D			T	E	I	Hole in turbine base	+1.0	218	103.89	4-2-59
23cdc1	H. Bull	D			T	E	I	do	+1.5	212	101.64	Do.
24cdc1	C. S. Rich	D			T	E	I	Side of turbine base	+1.5	209.30	100.17	Do.
36aaa1		D			T	G	I	End of discharge	+9.0	218.93	110.39	Do.
3S-3W-6daa1	L. C. Berg	D	130		T	G	I	Hole in turbine base	.0	207.06	86.13	3-26-59
7adc1		D			T	G	I	End of discharge	+4.0	214.79	95.69	Do.
8bbb1		D			T	E	I	Hole in turbine base	.0	204.97	82.92	Do.
9ddd1		D	148		T	G	I	Side of turbine base	+.5	206	80.82	3-25-59
16dad1		D			T	G	I	Edge of pit	+.5	204	83.83	Do
28aba1		D			T	E	I	End of discharge	+7.5	217	91.50	Do
31dda1		D			T	E	I	Edge of pit	+1.0	207	91.10	Do.
35dcb1		D			T	G	I	Edge of pit	.0	195	76.48	Do.
3S-4W-1ada1	Steck	D	150		T	G	I	Hole in turbine base	+.6	206.32	87.41	3-26-59
1bba2	U.S.G.S	D	117	2	N	N	O	Top of pipe	+1.5	204.64	88.43	Do.
2bbb1	do	D	116	2	N	N	O	do	+2.0	199.63	89.08	Do.
3cab1	Univ. Arkansas	D	130	24-12	T	E	I	Hole in turbine base	.0	203	96.64	Do.
3dbd2(2-N)	U.S.G.S., U.S.C.E., U.A.	D	129	2	N	N	O	Top of pipe	+3.0	206	97.52	3-10-59
3dca1 ("PW")	Univ. Arkansas	D	130	18-12	T	E	I	do	+3.0	206.23	98.07	Do.
3dcd1 (5-S)	U.S.G.S., U.S.C.E., U.A.	B	123	2	N	N	O	do	+3.5	205.09	96.70	2-23-59
3dda1	Univ. Arkansas	D			T	E	I	do	+1.2	203	95.13	3-26-59
4aad1	U.S.G.S	D	127	2	N	N	O	do	+2.0	206	97.29	4-1-59
4ddd1	do	D	118	2	N	N	O	do	+2.0	199	96.09	3-31-59
5dac1	R. B. Oliver	D			T	G	I	Hole in turbine base	.0	210.31	105.33	Do.
7add1		D		18-12	T	E	I	do	+.5	207.98	106.00	4-2-59
8aaa1	U.S.G.S	D	127	2	N	N	O	Top of pipe	+2.0	208.41	104.17	3-31-59
8bbb1	do	D	127	2	N	N	O	do	+2.0	208.85	105.29	Do.
8daa1	A. Carle	D	150	24-12	N	N	I	Edge of cover	.0	207.07	102.00	2-9-59
10bab1	G. Sebree	D	128	24-12	T	E	I	Edge of pit	+1.0	202	96.02	3-31-59
10ccb1	G. Sebree	D		24-12	T	E	I	Hole in turbine base	.0	208.41	104.40	Do.
10ddd1	U.S.G.S	D	122	2	N	N	O	Top of pipe	+1.0	203.13	95.93	Do.
11aaa2	do	D	117	2	N	N	O	do	+2.0	201.73	89.84	3-26-59
11bbb1	C. A. Franzen	D		24-12	T	E	I	Hole in turbine base	+.5	201.03	91.25	Do.
11ddc1	U.S.G.S	D	117	2	N	N	O	Top of pipe	+1.5	191.78	78.29	Do.
12aaa1	do	D	127	2	N	N	O	do	+2.0	200.84	83.27	Do.
13ccc1	do	D	127	2	N	N	O	do	+2.0	196	86.91	Do.
13dbd1	H. Bennett	D			T	G	I	Hole in turbine base	.0	195	82.60	Do.
14ccc1	U.S.G.S	D	127	2	N	N	O	Top of pipe	+2.0	205.26	94.88	Do.
16bbb2	do	D	128	2	N	N	O	do	+1.0	209.17	107.30	3-31-59
16ddc1	do	D	127	2	N	N	O	do	+2.0	204.84	102.62	3-26-59
17ccc1	do	D	129	2	N	N	O	do	+3.0	210.65	109.22	Do.
17ddd1	do	D	127	2	N	N	O	do	+2.0	203.16	103.38	Do.
19bdd1		D			T	G	I	End of discharge	+4.0	209	112.88	Do.
26bbb1	F. T. Hill	D		24-12	T	G	I	Hole in turbine base	+.8	207	104.53	Do.

TABLE 7.—*Records of selected wells in Arkansas County*—Continued

Well	Owner or tenant	Type of well	Depth of well (feet)	Diameter of well (inches)	Method of lift: Type of pump	Method of lift: Kind of power	Use of water	Measuring point: Description	Measuring point: Distance above or below land surface (feet)	Measuring point: Altitude above mean sea level (feet)	Measurement: Depth to water level below measuring point (feet)	Measurement: Date
3S-4W- 28ddb1	Briggs and Reed	D	144		T	E	I	Side of turbine base	+.5	207.23	106.58	4-2-59
29bbb1	U.S.G.S	D	130	2	N	N	O	Top of pipe	+2.0	209.01	104.99	3-26-59
31dcc1		D			T	E	I	Edge of pit	.0	195	95.38	4-1-59
32ccc1	U.S.G.S	D	127	2	N	N	O	Top of pipe	+2.0	188	88.42	Do.
3S-5W- 1ddd1	do	D	127	2	N	N	O	do	+2.0	212.48	108.35	3-31-59
2add1		D			T	G	I	Edge of pit	+1.0	210	107.64	4-1-59
3bbb1	F. Hederich	D	125		N	N	I	do	.0	215	102.33	3-26-59
4abb1	C. S. Rich	D	138		T	E	I	do	+.5	212	98.76	4-1-59
9bbc1	D. Roth	D	120		T	E	I	Hole in turbine base	.0	212	95.06	Do.
10bab1		D			T	E	I	Edge of pit	.0	210	103.32	3-31-59
11aaa1	U.S.G.S	D	117	2	N	N	O	Top of pipe	+2.0	215	109.99	Do.
11bba1	do	D	117	2	N	N	O	do	+2.0	212	106.94	Do.
13cba1		D			T	E	I	Hole in turbine base	+1.0	208	90.52	4-1-59
15bba1	Luebke	D	130		T	G	I	do	.0	207	96.40	Do.
35aba1		D			N	N	I	Edge of pit	+.5	202	90.99	Do.
36aba1		D			T	G	I	Hole in turbine base	.0	196	88.03	Do.
4S-3W- 5aaa1		D			T	E	I	Side of turbine base	+.5	203	89.35	3-25-59
7ada1		D			T	G	I	Hole in turbine base	+1.0	197	90.63	Do.
8cdc1		D			N	N	I	Edge of pit	+.5	198	92.82	Do.
11baa1	B. B. Bean	D			T	E	I	do	.0	194	77.08	Do.
4S-4W- 1cbc1		D			T	G	I	Hole in turbine base	.0	198	94.94	Do.
2abb1	J. Neukan	D			T	E	I	Edge of pit	+1.0	200	97.43	Do.
2bab1	H. Neukan	D	150		T	G	I	Hole in turbine base	.0	198	98.01	Do.
3cbc1	Briggs & Reed	D			N	N	I	Edge of pit	.0	200	104.33	Do.
9daa1		D			T	G	I	do	.0	200	104.88	Do.
11daa1		D			T	E	I	Hole in turbine base	+1.5	191	90.51	Do.
4S-5W- 12bbd1		D			T	G	I	Edge of pit	.0	196	87.14	4-1-59

TABLE 8.—*Logs of selected wells and test holes*

[See description of well-numbering system in text. L denotes log]

	Thickness (feet)	Depth (feet)
L 2S-3W-2aac1		
[750 ft south and 750 ft west of northeast corner of sec. 2. Surface altitude, 157 ft. Boring section record, U.S. Army Corps of Engineers, Mississippi River Commission, Vicksburg, Miss.]		
Sand, silty, fine, friable, light-brown; contains a small percentage of clay and light-gray streaks	6.5	6.5
Sand, silty, fine, friable, mottled tan and gray; contains interbedded silty-clay strata	3	9.5
Sand, clayey to silty, soft, brown	1	10.5
Clay, silty to sandy, soft, mottled	3	13.5
Sand, fine; contains interbedded brown silty clay	2	15.5
Clay, silty, brown and gray mottled	13	28.5
Clay, silty to sandy, gray; brown streaks	2.5	31
Sand, fine, compact, permeable, light-gray	14.5	45.5
Sand and gravel, light-grayish-brown; fine to medium sand containing 10 percent gravel up to 1 inch in diameter; contains thin silty clay layer at 45.5 ft	4	49.5
Sand, medium to coarse, light-grayish-brown; contains 5 percent gravel up to 1 inch in diameter	6.5	56
Sand and gravel, medium to coarse sand; contains 15 percent gravel up to 1.5 inches in diameter	2.5	58.5
Sand and gravel; coarse sand containing 15 percent gravel	4	62.5
Sand and gravel; coarse sand containing 50 percent gravel	12	74.5
Sand and gravel; medium to coarse sand containing 15 percent gravel up to 1 inch in diameter	3	77.5
Gravel; contains 25 percent coarse sand	2	79.5
Sand, medium to coarse, light-grayish-brown; contains scattered gravel	4	83.5
Sand, coarse, light-grayish-brown; contains 5 percent gravel up to 1 inch in diameter	1.5	85
Sand and gravel; coarse sand containing 15 percent gravel up to 1 inch in diameter	3.5	88.5
Sand and gravel; coarse sand containing 25 percent gravel up to 1.5 inches in diameter	5	93.5
Sand, fine, compact, light-brown; contains scattered gravel	10	103.5
Sand, fine to medium, loose, light-grayish-brown; contains scattered gravel	3	106.5
Sand, medium to coarse, light-grayish-brown; contains 5 percent gravel	2	108.5
Sand and gravel; medium to coarse sand containing 35 percent gravel up to 2.5 inches in diameter	2	110.5
Sand and gravel; coarse sand containing 25 percent gravel up to 2 inches in diameter	5	115.5
Sand, medium, compact, light-brown; contains scattered gravel	2.7	118.2
Claystone, hard, gray	1.8	120
Clay, sand, compact, gray; contains sand lenses and fossils	3	123
L 2S-3W-4ccd1		
[1,000 ft east of west corner of sec 4. Surface altitude, 210 ft. Boring section record, U.S. Army, Corps of, Engineers, Mississippi River Commission, Vicksburg, Miss.]		
Silt, clayey, compact, mottled gray and tan	1.5	1.5
Clay, silty, mottled gray and tan; contains concretions	9	10.5
Clay, red; contains calcareous nodules	20	30.5
Clay, silty; mottled gray and brown changing to mottled bluish-gray; contains small snail shells	17	47.5
Clay, silty, bluish-gray; contains concretions	5	52.5
Silt, clayey, bluish-gray	4	56.5
Clay, silty, bluish-gray	7	63.5
Silt, clayey, bluish-gray	1	64.5
Sand, fine, loose, gray	23	87.5
Sand, fine, loose, gray; contains scattered gravel	6	93.5
Sand and gravel; fine to medium sand containing from 1 to 5 percent gravel up to 3 inches in diameter	62	155.5
Sand, fine, clayey to silty, dark-gray; contains fossils	8.5	164
L 2S-3W-8ddb1		
[1,250 ft north and 1,300 ft southeast of southeast corner of sec. 8. Surface altitude, 193 ft. Boring section record, U.S. Army, Corps of Engineers, Mississippi River Commission, Vicksburg, Miss.]		
Loam, silty, mottled gray and tan; contains clay	2.5	2.5
Clay, silty, reddish-tan to gray	8	10.5
Clay, reddish-brown and gray	7	17.5
Clay, silty, reddish-brown and gray	1	18.5
Silt, reddish-brown; interbedded with clay	2.5	21
Silt, grayish-tan; contains decayed vegetable matter and concretions	6.5	27.5
Clay, tannish-gray	12	39.5
Clay, silty, gray; with black and brown streaks	13.5	53
Mud, silty, soft, gray	7.5	60.5
Sand, very fine to fine, dark-gray; contains silt	29	89.5
Sand and gravel; fine to coarse sand containing from 2 to 50 percentf gravel up to 3 inches in diameter	57	146.5
Sand, medium, gray; contains scattered gravel	6	152.5
Clay, tough, gray	5.5	158

TABLE 8.—*Logs of selected wells and test holes*—Continued

L 2S-3W-18cbb1

[2,000 ft north of southwest corner of sec. 18, on east side of road right-of-way, State highway 146. Surface altitude, 205 ft. Boring section record, U.S. Army, Corps of Engineers, Mississippi River Commission, Vicksburg, Miss.]

	Thickness (feet)	Depth (feet)
Clay, silty, stiff, damp, mottled red and gray	3	3
Clay, silty, mottled red and tan; contains a few concretions	4.5	7.5
Clay, firm, red	4	11.5
Silt, friable, dry; contains 15 percent clay laminations	2.5	14
Clay, firm, damp, reddish-brown	4.5	18.5
Silt, friable, dry, grayish-tan; contains 5 to 20 percent clay laminations	14.5	33
Sand, fine, gray; contains 1 percent clay laminations	10.5	43.5
Clay, silty, mottled gray and tan; contains 30 percent silty fine sand	2	45.5
Sand, fine, loose, damp, grayish-tan	12.5	58
Sand, medium, silty, grayish-tan; contains 30 percent clay laminations, 5 percent gravel up to 0.25 inch in diameter, and a thin lignite layer at 62.5 ft	5	63
Sand, medium, silty, grayish-tan; it contains 2 percent clay laminations	3	66
Sand, fine, gray; contains lignite specks and 2 percent gravel up to 1 inch in diameter	10	76
Sand, fine, gray; contains lignite specks	5.5	81.5
Sand, fine, gray; contains 2 percent clay laminations	8.5	90
Sand, fine, gray; contains lignite specks and 1 percent gravel up to 1 inch in diameter	27.5	117.5
Sand and gravel; medium sand containing 10 percent gravel up to 1.5 inches in diameter; contains 40 percent clay laminations	1	118.5
Sand and gravel; medium sand containing 5 to 10 percent gravel up to 2.5 inches in diameter	23	141.5
Tree trunk, punched through wood with chisel and bailer	1.5	143
Sand and gravel; medium sand containing 10 percent gravel up to 2 inches in diameter	4.5	147.5
Clay, tough, dark-gray	2	149.5
Sand, coarse, brownish-gray; contains clay laminations	1	150.5
Clay, tough, gray	4.5	155

L 2S-3W-31bbb1

[31 ft south of east-west section-line road and 49 ft east of north-south section-line road. Surface altitude 205 ft]

	Thickness (feet)	Depth (feet)
Soil, slightly clayey to moderately silty, light-yellowish-brown; contains roots	1	1
Silt, very clayey, light-yellowish-brown	1	2
Clay, very silty, light-yellowish-brown	3	5
Silt very clayey, very light-yellowish-brown to light-gray	2	7
Clay, slightly to moderately silty, dark-reddish-brown	13	20
Silt, fine-textured, dark-reddish-brown	25	45
Silt, very clayey, fine-textured, light-grayish-brown, slightly calcareous	20	65
Sand, very fine to fine, slightly clayey to silty, medium-reddish-brown, slightly calcareous in part; contains interbedded clay	10	75
Sand, fine to medium, light-bluish-gray, slightly calcareous in part	35	110
Sand, medium to coarse; similar to sand above; contains wood fragments at 122 feet; contains interbedded silt zones at 127 feet	29	139
Silt, very clayey, dark-bluish-gray; contains some sand	11	150

L 2S-4W-19ddd1

[23 ft west of north-south section-line road and 68 ft north of east-west section-line road. Surface altitude, 206 ft]

	Thickness (feet)	Depth (feet)
Soil, dark-bluish-gray	1	1
Clay, sticky, greenish-gray	11	12
Clay, slightly silty in part, reddish-brown, moderately calcareous	13	25
Clay, silty, yellowish-brown, moderately calcareous	15	40
Clay, reddish-brown, moderately calcareous; contains many fossils	20	60
Clay, dark-brown, moderately calcareous; contains fossils	5	65
Clay, dark-gray to yellowish-brown	10	75
Sand, very fine to medium, gray	45	120
Sand, medium to very coarse, gray; contains some gravel and clay balls; contains a cobble zone at 147 ft	27	147
Clay, dark-bluish-gray	3	150

TABLE 8.—*Logs of selected wells and test holes*—Continued

L 2S-4W-21ddd1

[20 ft north of east-west section-line road and 125 ft west of north-south section-line road. Surface altitude, 201 ft]

	Thickness (feet)	Depth (feet)
Soil, yellowish-brown; contains organic material	1	1
Clay, yellowish-brown, moderately calcareous; contains reddish-brown and greenish-gray zones	59	60
Sand, very fine, silty, reddish-gray; contains some clay	15	75
Sand, fine to medium, reddish-gray	5	80
Sand, fine to coarse, gray; contains thin clay lenses at 82 ft	10	90
Sand, medium to very coarse, gray; contains scattered gravel	20	110
Sand, coarse, gray; contains fine gravel	8	118
Clay, bluish-gray; contains shell fragments	5	123

L 2S-4W-22cdd1

[2,000 ft east of common west corner, county road right-of-way. Surface altitude, 193.5 ft. Boring section record, U.S. Army, Corps of Engineers, Mississippi River Commission, Vicksburg, Miss.]

	Thickness (feet)	Depth (feet)
Silt, clayey, dark-tan	1.5	1.5
Clay, silty, mottled gray and tan	5.5	7
Silt, sandy, friable, pink	9	16
Clay, silty, dull-red	7	23
Silt, clayey, tan	19.5	42.5
Clay, silty, stiff, bluish-gray	3	45.5
Sand, fine, silty, tan to gray; contains 2-inch clay layer at 75.5 ft	30.5	76
Sand, fine, gray	27	103
Sand and gravel; fine to medium sand containing 8 percent gravel up to 2 inches in diameter	8.5	111.5
Clay, sandy, glauconitic, greenish-gray; contains fossils	6.5	118

L 2S-4W-24ddd1

[50 ft west of north-south section-line road and 21 ft north of east-west section-line road. Surface altitude, 205 ft]

	Thickness (feet)	Depth (feet)
Soil and fill; very clayey, light-yellowish-brown silt	1	1
Silt, very clayey, medium-reddish-brown	1	2
Clay, very silty, light-gray to medium-reddish-brown; poor sample	18	20
Clay, slightly silty, dark-reddish-brown; poor sample recovery	25	45
Sand, very fine, slightly silty, medium-reddish-brown	24	69
Clay, slightly silty, dark-bluish-gray, slightly calcareous	1	70
Sand, very fine to medium, light-reddish-brown, slightly calcareous in part	10	80
Sand, very fine to medium, light-bluish-gray, slightly calcareous in part; contains subrounded crystal quartz as predominant mineral and some dark-colored mineral grains	25	105
Sand, medium to very coarse; similar to sand above; contains less than 5 percent very fine gravel; lignite fragments, a cobble zone at 145 ft	40	145
Silt, very clayey, dark-bluish-gray	3	148

L 2S-4W-26aaa1

[35 ft west of north-south section-line road, 99 ft south of east-west section-line road, and 58 ft north of irrigation well. Surface altitude, 203 ft]

	Thickness (feet)	Depth (feet)
Soil, yellowish-brown; contains iron stain	1	1
Clay, yellowish-gray to yellowish-brown; contains iron stain	9	10
Clay, plastic, reddish-brown	10	20
Clay, plastic, gray to greenish-gray, slightly calcareous in part	25	45
Sand, very fine to fine, lignitic, gray	20	65
Sand, fine to medium, light-brown, slightly calcareous in part	12	77
Sand, medium to coarse, light-brown	13	90
Sand, medium to coarse, light-bluish-gray, slightly calcareous in part; may contain a thin silt lens at 93 ft	25	115
Sand, coarse to very coarse, lignitic; similar to sand above; contains a cobble zone at 123 ft	8	123
Silt, very clayey, light-bluish-gray; contains some mica and glauconite	7	130

TABLE 8.—*Logs of selected wells and test holes*—Continued

	Thickness (feet)	Depth (feet)
L 2S-4W-26bbc1		
[54 ft south of east-west section-line road and 15 ft east of north-south section-line road. Surface altitude, 200 ft]		
Soil, yellowish-brown	1	1
Clay, yellowish-brown	9	10
Clay, reddish-brown; moderately calcareous in lower part	8	18
Clay, silty, greenish-gray, slightly calcareous	7	25
Clay, silty, reddish-brown, very calcareous	29	54
Sand, very fine to medium, gray; contains a thin red clay lens at 55 ft	36	90
Sand, fine to coarse, gray; contains clay balls from 110 to 114 ft	35	125
Sand, coarse; contains some gravel, clay balls, and a few wood fragments	13	138
Clay, bluish-gray; contains boulders	3	141
L 2S-4W-26ccc1		
[56 ft northeast of road intersection and 48 ft west of a big tree. Surface altitude, 195 ft]		
Silt, clayey, buff	3	3
Clay, light-greenish-gray	7	10
Clay, red to greenish-gray	3	13
Clay, red, very calcareous	7	20
Clay, gray, very calcareous; contains pebbles and clay balls from 25 to 28 ft	16	36
Silt, sandy, gray, very calcareous	19	55
Sand, fine to medium, gray, lignitic in part	46	101
Sand, medium to coarse, lignitic	14	115
Sand and gravel; contains a boulder zone at 123 ft	8	123
Clay, light-bluish-gray	6	129
L 2S-4W-27ccc1		
[9 ft east and 22 ft north of road intersection on north side of road right-of-way. Surface altitude, 200 ft]		
Silt, clayey, light-gray	2	2
Clay, light-gray	10	12
Clay, bright-red	3	15
Clay, bright-red, very calcareous	14	29
Clay, silty in part, bluish-gray, very calcareous	3	32
Silt, clayey, bluish-gray	12	44
Silt, clayey; contains black muck	13	57
Silt, light-bluish-gray, very calcareous	4	61
Sand, fine to coarse, dark-gray; contains interbedded silt from 70 to 75 ft	50	111
Sand and gravel; contains a boulder zone at 120 ft	9	120
Clay, dark-bluish-gray (?)	-------	-------
L 2S-4W-28bbb1		
[25 ft east of north-south section-line road and 25 ft south of east-west section-line road. Surface altitude, 203 ft]		
Soil, yellowish-brown	1	1
Clay, silty, yellowish-brown to reddish-brown, moderately to very calcareous	79	80
Sand, fine to medium, gray	15	95
Sand, fine to coarse, gray	25	120
Sand, medium to very coarse; contains scattered gravel; contains clay balls and fine gravel in lower part	12	132
Clay, bluish-gray	2	134
L 2S-4W-28cbb1		
[1,900 ft north and 15 ft east of center line of road, on southwest corner of county road right-of-way. Surface altitude, 193.5 ft. Boring section record, U.S. Army, Corps of Engineers, Mississippi River Commission, Vicksburg, Miss.]		
Clay, silty, light-tan with gray streaks	4.5	4.5
Silt, clayey, light-tan and gray	1	5.5
Clay, silty, tan and gray	2.7	8.2
Clay, stiff, reddish-brown	1.3	9.5
Clay, silty in part, reddish-brown	14	23.5
Silt, sandy, grayish-tan; contains small amount of clay	4	27.5

TABLE 8.—*Logs of selected wells and test holes*—Continued

	Thickness (feet)	Depth (feet)
L 2S-4W-28cbb1—Continued		
Clay, silty, grayish- to reddish-tan; contains concretions	17	44.5
Silt, sandy, reddish-tan	4	48.5
Clay, tough, brown	5	53.5
Silt, clayey, compact to friable, brown	2	55.5
Clay, tough, brown	6	61.5
Sand, very fine, silty, compact, brown	22	83.5
Sand, fine, silty in part, grayish-brown to gray	4	87.5
Sand, fine to medium, contains scattered gravel and compact gray and brown clay balls	4.5	92
Sand and gravel, medium to coarse sand containing 20 to 25 percent gravel up to 1 inch in diameter; contains scattered clay balls	10	102
Sand, medium, gray; contains scattered gravel	15.5	117.5
Sand and gravel; contains approximately 75 percent rocks and gravel, with rocks up to 6 inches in diameter	1	118.5
Clay, sandy, glauconitic, mottled dark and light-gray	.7	119.2
Rock, grayish-brown; difficult to break through	1	120.2
Clay, mottled dark-green and dark-gray; may contain glauconite	3.8	124
L 2S-4W-32aaa1		
[24 ft west of north-south section-line road and 70 ft south of east-west section-line road. Surface altitude, 204 ft]		
Silt, clayey, gray	14	14
Clay, bright-reddish-brown, slightly calcareous	1	15
Clay, bright-reddish-brown, very calcareous	19	34
Clay, gray, very calcareous	5	39
Silt, clayey, light-gray, slightly calcareous	10	49
Clay, silty, bluish-gray to brown, slightly calcareous	38	87
Sand, fine to coarse, dark-gray	9	96
Sand and gravel; lignitic in part	11	107
Sand, fine to medium, lignitic	5	112
Sand and gravel; contains cobble and boulder zone at 124 to 125 ft	13	125
Clay, bluish-gray	4	129
L 2S-4W-32cbb1		
[Irrigation well on the E. Tallman farm; data from U.S. Army, Corps of Engineers]		
Soil	4	4
Clay, red, brown	5	9
Clay, brown	6	15
Clay, red, and sand	15	30
Clay, red	20	50
Sand, red	5	55
Clay, blue	5	60
Clay, red, and sand	8	68
Sand, light-brown	3	71
Sand, water	4	75
Sand, clean, gray	22	97
Sand, clean, good	23	120
Sand and gravel, coarse	13	133
Boulders and clay	4.5	137.5
L 2S-4W-32ccc1		
[25 ft west of north-south section-line road and 300 ft north of east-west section-line road. Surface altitude, 213 ft]		
Soil, light-tan	1	1
Clay, reddish-brown to yellowish-brown; contains iron(?) nodules	19	20
Clay, reddish-brown, moderately to very calcareous	45	65
Clay, dark-gray to yellowish-brown	25	90
Sand, very fine to fine, lignitic, gray	25	115
Sand, fine to coarse, gray; contains some fine gravel in lower part	22	137
Clay, dark-bluish-gray	3	140

TABLE 8.—*Logs of selected wells and test holes*—Continued

L 2S-4W-32dcc2

[Irrigation well on the Gilbert Franzen farm; 5 miles east of Stuttgart]

	Thickness (feet)	Depth (feet)
Topsoil and hardpan	5	5
Clay, red	35	40
Sand	10	50
Sand with clay	20	70
Clay, blue	10	80
Sand, fine, dry	10	90
Sand, fine	10	100
Sand, fine, dirty	5	105
Sand, good; contains rocks at 135 ft	30	135
Sand, fine, silty, black	1	136
Sand; blue clay at 139 ft	3	139

L 2S-4W-32ddd1

[32 ft west of north-south section-line road and 528 ft north of east-west section-line road. Surface altitude, 200 ft]

	Thickness (feet)	Depth (feet)
Soil, light-brown	1	1
Clay, yellowish-brown	11	12
Clay, reddish-brown, very calcareous; contains yellowish-brown zones	48	60
Clay, silty, light-yellowish-brown	25	85
Sand, fine to very coarse, gray; contains clay balls and gravel in lower part	42	127
Clay, dark-bluish-gray	3	130

L 2S-5W-36dcc1

[2,000 ft west and 80 ft north of southeast corner of sec. 36. Surface altitude, 210 ft. Boring section record, U.S. Army, Corps of Engineers, Mississippi River Commission, Vicksburg, Miss.]

	Thickness (feet)	Depth (feet)
Clay, silty, mottled gray and tan	10	10
Silt, pink; contains 10 percent clay laminations	7.5	17.5
Clay, silty in part, reddish-brown	19.5	37
Silt, friable, tan to pink; contains 20 percent clay laminations	6.5	43.5
Sand, fine, loose, dry	4.5	48
Clay, silty, dull-red	8.5	56.5
Silt, friable, damp, tan	1	57.5
Clay, stiff, dull-red	4	61.5
Silt, clayey, reddish-brown	2.5	64
Clay, silty, reddish-brown	1.5	65.5
Sand, fine, silty, pink	2.5	68
Clay, silty, dull-red	3	71
Sand, fine, silty, reddish-brown	10	81
Sand, fine; contains 1 percent gravel	16.5	97.5
Clay, firm, dark-brown; contains 30 percent sand laminations	2	99.5
Sand and gravel; fine to medium sand containing 1 to 15 percent gravel up to 3 inches in diameter	16.5	116
Clay, silty, bluish-gray; contains fossils and sandy laminations	24.5	140.5
Sand, fine, silty, green; contains 1 percent clay laminations; contains hard rock at 143 ft	2.5	143

L 3S-4W-1bba1

[77 ft north of irrigation well and 34 ft south of east-west section-line road. Surface altitude, 202 ft]

	Thickness (feet)	Depth (feet)
Clay, silty, very light gray to reddish-brown	6	6
Clay, light-greenish-gray	4	10
Clay, bright-reddish-brown	5	15
Clay, bright-reddish-brown, very calcareous	25	40
Clay, soft, greenish-gray, moderately calcareous	5	45
Silt, light-gray; contains some sand	14	59
Sand, very fine to fine; contains a muck zone from 75 to 80 ft	21	80
Sand, medium to coarse, lignitic	22	102
Sand and gravel; medium sand to fine gravel	11	113
Sand, medium to coarse	14	127
Clay, dark-bluish-gray	1	128

TABLE 8.—*Logs of selected wells and test holes*—Continued

	Thickness (feet)	Depth (feet)
L 3S–4W–2bbb1		
[53 ft east of north-south State highway 30 and 93 ft south of east-west section-line road. Surface altitude, 195 ft]		
Soil, silt, slightly clayey, light-yellowish-brown to dark-brown; contains organic matter	1	1
Silt, moderately clayey, nodular, light-yellowish-brown; contains many small concretions	1	2
Clay, very silty, granular, light-yellowish-brown to dark-reddish-brown; contains some very fine sand	2	4
Clay, medium-gray; contains scattered iron(?) nodules	6	10
Clay, dark-reddish-brown, slightly calcareous; contains light-gray streaks	7	17
Clay, dark-reddish-brown, very calcareous	2	19
Clay, slightly silty, light-yellowish-brown to medium-reddish-brown, very calcareous	7	26
Silt, slightly clayey to slightly sandy, light-grayish-brown, very calcareous; contains small white concretions	17	43
Sand, very fine, silty, light-yellowish-brown, moderately calcareous in part; contains some mica flakes and lignite fragments; contains a thin medium-bluish-gray silt lens at 73 ft	42	85
Sand, fine to medium, light-bluish-gray; similar to sand above	10	95
Sand, medium to coarse, similar to sand above; contains scattered very fine to fine gravel and some pebbles and cobbles; a boulder zone at 123 ft	29	124
Silt, very clayey, glauconitic, dark-greenish-gray; contains pebbles	6	130
L 3S–4W–3dbd1		
[1,345 ft north of east-west section-line road and 45 ft north of experiment station irrigation well. Surface altitude, 203.1 ft. Aquifer-test well 1–N]		
Dirt fill along canal; moderately silty mottled dark-reddish-brown to yellowish-brown to gray clay	5	5
Clay, moderately silty, light-yellowish-brown to light-gray; contains iron or manganese nodules	5	10
Clay, dark-reddish-brown; contains black organic-appearing streaks and gray streaks	2	12
Clay, dark-reddish-brown, similar to above except very calcareous; may contain shell fragments from 20 to 25 ft	16	28
Silt, very clayey, dark-reddish-brown, very calcareous	2	30
Silt, clayey to slightly sandy, dark-reddish-brown, very calcareous	1	31
Clay, dark-reddish-brown, very calcareous; contains organic-appearing streaks and many shell fragments at 37 ft	6	37
Clay, slightly silty, fossiliferous, light-gray to medium-reddish-brown, very calcareous; contains much organic matter	1	38
Clay, slightly silty, very fossiliferous, medium-brown, very calcareous; contains much organic matter	2	40
Clay, slightly silty, medium-brown, calcareous	1	41
Clay, very silty, fossiliferous, medium-bluish-gray, calcareous; contains much organic matter	2	43
Clay, slightly silty, dark-brown, calcareous	3	46
Clay, slightly silty, fossiliferous, medium-gray, calcareous	1	47
Sand, very fine to medium, light-brown, calcareous; contains medium-brown interbedded silty clay lenses	2	49
Silt, slightly sandy in part, light-grayish-brown, calcareous; contains some iron staining and more sand in lower part	4	53
Silt, slightly sandy, medium-gray, calcareous; contains some mica flakes	2	55
Sand, very fine, micaceous, medium-gray, calcareous; may contain some silt	13	68
Sand, very fine to medium, micaceous, light-gray; slightly calcareous in part; contains subrounded slightly frosted crystal quartz grains as predominant mineral, with scattered black grains, calcareous grains, and lignite fragments	2	70
Sand, fine to medium, similar to sand above, with some very coarse sand and very fine gravel	8	78
Sand, medium; similar to sand above in composition; contains a medium-gray silty clay lens at 78 ft	6	94
Sand, medium to coarse; similar to sand above; contains some coarse gravel	3	97
Sand and clay balls, very heterogeneous; fine to medium sand; clay balls range from 0.25 to 2 in. in diameter; contains blue-gray and dark-reddish-brown clay lenses; contains some fine to coarse gravel and silt balls	3	100
Sand, medium; contains slightly frosted subrounded crystal quartz grains as the predominant mineral, with scattered dark minerals, calcareous grains, and lignite fragments	18	118
Sand, medium to coarse, similar to sand above; contains less than 5 percent very coarse sand and very fine to coarse gravel; contains cobbles up to 3 inches in diameter	10	128
Silt, very clayey to moderately sandy, glauconitic, dark-greenish-gray; contains a few shell fragments	1	129

TABLE 8.—*Logs of selected wells and test holes*—Continued

	Thickness (feet)	Depth (feet)
L 3S-4W-3dbd2		
[11 ft west of north-south road and 200 feet north of proposed site for recharge unit. Surface altitude, 203 ft. Aquifer-test well 2-N]		
Soil and road fill; mottled light-yellowish-brown to reddish-brown to light-gray clay	2	2
Clay, slightly silty, light-yellowish-brown	8	10
Clay, very sticky, dark-reddish-brown	5	15
Clay, very sticky, dark-reddish-brown, very calcareous	15	30
Clay, moderately to very silty, medium-yellowish-brown to light-gray, moderately calcareous	10	40
Silt, moderately to very clayey, slightly micaceous, light-brown, very calcareous	15	55
Silt, slightly clayey, coarse-textured, dark-bluish-gray, very calcareous	10	65
Sand, very fine to fine, light-gray, very calcareous in part; may contain lignite and mica	10	75
Sand, fine to medium, light-bluish-gray, very calcareous in part; contains a thin light-gray silty clay lens at 102 ft	30	105
Sand, medium to very coarse; similar to sand above; contains less than 5 percent very fine gravel and a few pebbles and cobbles in lower part	28	133
Silt, very clayey, dark-bluish-gray; contains a few shell fragments	7	140
L 3S-4W-3dca2		
[903 ft north of east-west section-line road and 400 ft south of experiment station irrigation well. Surface altitude, 202.8 ft. Aquifer-test well 4-S]		
Road fill and soil; contains moderately silty medium-brown clay	1	1
Clay, moderately to very silty; variegated in color from light-brown to light-yellowish-brown to light-reddish-brown; contains iron staining	8	9
Clay, dark-reddish-brown; contains blackish-colored streaks and light-gray bentonitic-appearing streaks	1	10
Clay, dark-reddish-brown, very calcareous; contains blackish streaking and siderite(?) concretions at 19 ft	12	22
Silt, very sandy, light-yellowish-brown, calcareous; contains very fine sand and may contain some clay	3	25
Silt, very clayey, light-yellowish-brown, very calcareous in part; contains small limy concretions	1	26
Clay, very silty in upper part, light-yellowish-brown to light-yellowish-gray, lime content increases downward	9	35
Silt, micaceous, fluffy, laminated in lower part, light-yellowish-brown, calcareous; coarser textured in lower part with some iron staining	5	40
Silt, slightly sandy, micaceous, light-grayish-brown, calcareous; very coarse textured, laminated in part; contains iron-stain streaks; a clayey lens at 43 ft	5	45
Silt, very clayey, micaceous, light-yellowish-gray, calcareous; contains some very fine sand and iron staining	3	48
Silt, slightly clayey to slightly sandy, micaceous, laminated, medium-blue-gray, calcareous; may contain some glauconitic sand	2	50
Sand, very fine to medium, light-gray; slightly calcareous in part; contains some mica and darker colored minerals	7	57
Sand, medium to coarse, light-bluish-gray; slightly calcareous in part; contains well-rounded crystal quartz grains as predominant mineral and some gravel; gastropod shells at 62 ft	6	63
Sand, very fine to medium, similar to sand above; contains lignite fragments and some very fine to very coarse gravel; wood fragments at 79 ft	17	80
Sand, very fine to medium, similar to sand above; contains very fine to fine sand at 82 ft and clay lens at 84 ft	10	90
Sand, very fine to medium, similar to sand above; contains a slightly sandy light-grayish-green very calcareous silt lens at 93 ft	5	95
Sand, medium to coarse; similar to sand above; contains some very fine and very coarse sand; contains rootlets and possibly a clay lens at 98 ft	3	98
Sand, medium to coarse; similar to sand above; contains a few dark-reddish-brown clay balls	2	100
Sand, medium to coarse; contains well-rounded quartz grains as predominant mineral and some coarse to very coarse gravel	23	123
Sand and gravel; coarse to very coarse sand and approximately 5 percent fine to coarse gravel; contains cobbles up to 3 inches in diameter from 125 to 126 ft	3	126
Clay, very silty to sandy, dark-brownish-green; contains very fine to fine sand and may be glauconitic	1	127
L 3S-4W-3dca3		
[1,143 ft north of east-west section-line road and 160 ft south of experiment station irrigation well. Surface altitude, 202.9 ft. Aquifer-test well 3-S]		
Road fill and soil; contains medium-brown very silty clay	1	1
Silt, very clayey; variegated colors, chiefly light-yellowish-brown	2	3
Clay; variegated from light-yellowish-brown to light-gray to dark-reddish-brown; may contain some silt	7	10
Clay, dark-reddish-brown; contains blackish-colored streaks and light-gray bentonite-like streaks	3	13

TABLE 8.—*Logs of selected wells and test holes*—Continued

	Thickness (feet)	Depth (feet)
L 3S-4W-3dca3—Continued		
Clay, dark-reddish-brown, very calcareous; contains small limy concretions	10	23
Silt, very sandy, medium-reddish-brown, calcareous; contains very fine sand	2	25
Sand, very fine, very silty, light-yellowish-brown, calcareous	1	26
Silt, very clayey to moderately sandy, medium-reddish-brown, slightly calcareous in part; may be interbedded silt, clay, and very fine sand	4	30
Silt, very clayey, light-yellowish-brown, slightly calcareous	2	32
Clay, slightly silty in part, light-grayish-brown, very calcareous; contains small limy concretions	2	34
Clay, light-brownish-gray, calcareous; contains lighter colored zones and iron-stain streaks	1	35
Silt, slightly sandy, laminated, light-yellowish-gray, calcareous; contains very fine sand	12	47
Silt, slightly clayey, micaceous, light-yellowish-gray, calcareous; may contain some very fine sand; contains iron-stain streaks	1	48
Silt, slightly clayey to slightly sandy, calcareous medium-gray with greenish-gray color in part; contains very fine sand and mica	4	52
Sand, very fine, very silty, somewhat laminated and micaceous, light-gray, calcareous	8	60
Sand, very fine to fine; light-bluish-gray when wet; slightly calcareous in part; quartz grains predominate; contains dark-colored mineral grains, lignite fragments, limy grains, and some mica	5	65
Sand, very fine to medium; similar to sand above; contains a slightly silty medium-blue-gray clay lens at 71 ft	20	85
Sand, fine to coarse; similar mineral content as sand above; contains some very fine sand and a little gravel	5	90
Sand, medium to coarse; same mineral aggregate as sand above; contains some limy dark-reddish-brown clay balls at 96 ft	6	96
Sand, gravel, and clay balls; medium to coarse sand with a little very coarse sand; fine to very coarse gravel and limy dark-reddish-brown clay balls up to 2 inches in diameter; contains about 10 percent gravel and clay balls	14	110
Sand, medium to very coarse; contains a little medium-sized gravel with some fine to coarse gravel at 116 ft; contains many lignite fragments at 120 ft; contains cobbles up to 2 inches in diameter at 128 ft	18	128
Clay, very silty, glauconitic, dark-brownish-green; may be slightly micaceous; contains some very fine sand	1	129
L 3S-4W-3dca4		
[1,263 ft north of east-west section-line road and 40 ft south of experiment station irrigation well. Surface altitude, 202.8 ft. Aquifer-test well 1-SW]		
Soil, silt, dark-brown; contains organic-appearing streaks and some clay	1	1
Clay, slightly silty to very silty; variegated in color from light-gray to medium-reddish-brown to light-yellowish-brown; contains small iron or manganese nodules	9	10
Clay, dark-reddish-brown; contains light-gray bentonitic-appearing streaks and blackish-colored streaks	2	12
Clay, dark-reddish-brown, very calcareous; may contain dark-brown calcite or siderite concretions in lower part	18	30
Silt, very clayey to very fine sandy, dark-reddish-brown, very calcareous; contains chalky zones that may be badly weathered shell fragments	2	32
Clay, dark-reddish-brown, calcareous; contains interbedded silty clay lenses; contains shell fragments at 34 ft and 39 ft	8	40
Clay, slightly silty, medium-brown, calcareous	1	41
Clay, moderately silty, medium-gray, calcareous; contains interbedded silty light-yellowish-brown clay and a few shell fragments	1	42
Silt, slightly clayey, light-yellowish-brown, calcareous; contains many iron-stain streaks and may contain some very fine sand	5	47
Silt, clayey to sandy, medium-gray, calcareous; contains very fine sand, iron-stain zones, and some mica; contains a green sandy zone in upper part	6	53
Silt, moderately sandy, light-gray, calcareous; contains very fine sand	2	55
Sand, very fine, slightly micaceous, light-gray; slightly calcareous in part; may contain some silt; consists predominantly of slightly frosted subrounded crystal quartz grains	7	62
Sand, fine to medium, slightly micaceous; similar to sand above; contains a slightly silty medium-gray clay lens at 73 ft; contains some very coarse sand	23	85
Sand, medium; contains some fine sand and fine to coarse gravel	10	95
Sand, medium to coarse, brownish, slightly calcareous in part; contains some very coarse sand and fine to coarse gravel and a thin interbedded brownish-red silty clay lens	5	100
Sand, medium to coarse; contains some very coarse sand and a small amount of coarse gravel; contains many dark-reddish-brown clay balls at 101 ft and a silty clay lens at 104 ft	8	108
Sand, medium, well-sorted, slightly calcareous in part; contains well-rounded slightly frosted crystal quartz grains as predominant mineral with scattered darker colored grains; some medium to coarse sand	12	120
Sand, medium to coarse; contains some fine to very coarse gravel, very coarse sand, and a few cobbles	8	128
Clay, very silty, glauconitic, slightly micaceous, dark-greenish-gray; contains bluish-gray sandstone cobbles	1	129

TABLE 8.—*Logs of selected wells and test holes*—Continued

	Thickness (feet)	Depth (feet)
L 3S-4W-3dca8		
[12 ft south of east-west road and 50 ft west of irrigation well and 100 ft west of proposed site for recharge unit. Surface altitude, 203 ft. Aquifer-test well 1-W]		
Clay, slightly silty, mottled light-yellowish-gray to light-yellowish-brown to dark-reddish-brown	12	12
Clay, very sticky, dark-reddish-brown; very calcareous in lower part	33	45
Clay, medium-gray, very calcareous	5	50
Clay, dark-gray, very calcareous; contains many shell fragments	5	55
Silt, coarse-textured, dark-bluish-gray, very calcareous	10	65
Sand, very fine to medium, light-bluish-gray, very calcareous in part	30	95
Sand, medium to coarse; similar to sand above; contains a little very coarse sand; contains shell fragments at 102 ft; contains a thin silty clay lens at 107 and 122 ft and a cobble zone at 132 ft	37	132
Silt, very clayey, dark-bluish-gray; contains shell fragments	8	140
L 3S-4W-3dca9		
[13 ft north of east-west road and 225 ft west of north-south road and 200 ft west of proposed site for recharge unit. Surface altitude, 203 ft. Aquifer-test well 2-W]		
Silt, very clayey, light-gray; contains iron-stain streaks	1	1
Clay, moderately silty, mottled light-gray to dark-reddish-brown to light-yellowish-brown; contains iron-stain streaks	11	12
Clay, very tight and sticky, dark-reddish-brown; very calcareous in lower part; contains a few shell fragments at 37 ft	38	50
Clay, very sticky, dark-brown, very calcareous	7	57
Clay, silty; dark-bluish-gray very calcareous clay balls, sand, and shells; paludal zone	8	65
Sand, fine to medium, light-bluish-gray, very calcareous in part; contains subangular slightly frosted crystal quartz grains as predominant mineral, and some lignite fragments; a thin silty clay lens at 113 ft	50	115
Sand, fine to medium; similar to sand above; contains clay balls, lignite, interbedded clay lenses, and some coarse sand	3	118
Sand and gravel; very fine to very coarse sand with approximately 10 percent very fine to fine gravel; contains some lignite fragments and a few pebbles; contains a cobble zone at 130 ft	12	130
Silt, very clayey, dark-bluish-gray; may contain glauconite	5	135
L 3S-4W-3dcd1		
[503 ft north of east-west section-line road and 800 ft south of experiment station irrigation well. Surface altitude, 201.6 ft. Aquifer-test well 5-S]		
Road fill and soil; contains slightly silty light-brown to gray clay	2	2
Clay, light-grayish-brown; contains some silt and iron-stain streaks	7	9
Clay, dark-reddish-brown	1	10
Clay, dark-reddish-brown, very calcareous; contains blackish-colored streaks; contains siderite(?) concretions at 19 ft	16	26
Silt, slightly clayey to slightly sandy, light-yellowish-brown	3	29
Clay, slightly silty, variegated light-yellowish-brown; contains blackish zones	1	30
Clay, slightly silty, variegated light-yellowish-brown, brown, calcareous; contains small lime concretions and whitish zones	4	34
Silt, clayey, laminated, light-yellowish-gray to light-yellowish-brown, calcareous; contains mica and iron staining and may contain very fine sand at 42 ft	11	45
Sand, very fine, light-yellowish-brown, calcareous in part; contains some silt, mica, and black mineral zones	1	46
Sand, very fine to fine, light-yellowish-brown; contains predominantly quartz minerals; darker mineral aggregate in lower part	7	53
Sand, very fine, light-brownish-gray; slightly calcareous in part; may contain some silt	6	59
Sand, very fine to very coarse, medium-brownish-gray; slightly calcareous in part; contains well-rounded crystal quartz grains as predominant mineral and lignite fragments and some gravel	11	70
Sand, medium to coarse; similar to sand above; contains scattered very coarse gravel	20	90
Sand, fine to medium, bluish colored, slightly calcareous in part; contains some gravel and may contain some slightly silty clay lenses	3	93
Clay, very slightly silty, variegated light-bluish-gray to medium-reddish-brown, moderately calcareous; may contain lignite fragments	2	95
Sand, fine to medium, light-bluish-gray, slightly calcareous in part; contains quartz as predominant mineral, lignite fragments, and limy grains	19	114
Sand, fine to coarse; similar to sand above; contains some very coarse gravel at 119 ft	6	120
Sand and gravel; medium to coarse sand to very coarse gravel; contains about 10 percent gravel; lower part contains cobbles up to 2 inches in diameter	1	121
Clay, very silty, dark-brownish-green; may contain glauconite, mica, and very fine sand	1	122

TABLE 8.—*Logs of selected wells and test holes*—Continued

	Thickness (feet)	Depth (feet)
L 3S-4W-3ddb1		
[138 ft east of north-south road and 200 ft east of proposed site for recharge unit and about 35 ft south of east-west canal. Surface altitude, 203 ft. Aquifer-test well 1-E]		
Soil, silty to slightly sandy, dark-gray to dark-yellowish-gray; contains much clay	1	1
Clay, slightly to moderately silty, light-yellowish-brown to dark-reddish-brown; contains iron-stain streaks and iron nodules	11	12
Clay, very sticky and tight, dark-reddish-brown, noncalcareous	2	14
Clay, very sticky and tight, dark-reddish-brown, very calcareous	26	40
Clay, slightly silty, light-yellowish-brown to light-grayish-brown, very calcareous	2	42
Silt, slightly clayey, very coarse-textured, light-yellowish-brown, moderately calcareous; may contain some very fine sand	11	53
Silt, slightly clayey to slightly sandy, medium-bluish-gray, moderately calcareous	12	65
Sand, very fine to medium, light-bluish-gray, very calcareous in part; contains subangular slightly frosted crystal quartz grains as predominant mineral and many dark-colored mineral grains	18	83
Silt, clayey to slightly sandy, dark-bluish-gray very calcareous	2	85
Sand, fine to medium, light-bluish-gray, very calcareous; contains some coarse sand, lignite fragments, and white limy grains	10	95
Sand, medium to very coarse; similar to sand above; contains scattered very fine gravel; a cobble zone at 133 ft	38	133
Silt, clayey to slightly sandy, micaceous, dark-bluish-gray; may contain glauconite	7	140
L 3S-4W-4aad1		
[114 ft northwest of irrigation well and 0.2 mile south of east-west State highway. Surface altitude, 203 ft]		
Silt, slightly clayey, medium-brown	3	3
Clay, very silty, light-yellowish-brown; contains some very fine sand in part	7	10
Clay, dark-reddish-brown, slightly calcareous	2	12
Clay, dark-reddish-brown, very calcareous	31	43
Clay, slightly to moderate silty, light-yellowish-brown, very calcareous	6	49
Silt, light-bluish-gray, slightly calcareous	6	55
Clay, slightly silty in part, medium brown, slightly calcareous	10	65
Clay, medium-brown, very calcareous	20	85
Sand, very fine, light-bluish-gray, slightly calcareous in part; contains lignite fragments	5	90
Sand, fine to coarse, similar to sand above; contains scattered gravel; contains a thin clay lens at 102 ft	40	130
Sand and gravel; fine to very coarse sand containing about 10 percent very fine to coarse gravel; contains a cobble and boulder zone at 136 ft	6	136
Silt, very clayey to sandy, dark-bluish-gray	4	140
L 3S-4W-4ddd1		
[274 ft east of bridge and 23 ft north of east-west section-line road. Surface altitude, 197 ft]		
Soil and fill, silty, dark-brown	1	1
Silt, clayey, light-yellowish-brown	6	7
Clay, slightly silty, light-yellowish-brown to light-brownish-gray	3	10
Clay, dark-reddish-brown	1	11
Clay, dark-reddish-brown, very calcareous	13	24
Clay, slightly silty in part, mottled dark-reddish-brown, moderately to very calcareous	11	35
Silt, slightly sandy, medium-yellowish-brown, very calcareous	13	48
Clay, slightly silty in part, medium-bluish-gray, very calcareous	7	55
Clay, hard, medium-brown, very calcareous	20	75
Sand, very fine to medium, light-bluish-gray, slightly calcareous in part	15	90
Sand, fine to coarse, similar to above	5	95
Sand, medium to very coarse, similar to sand above; contains less than 5 percent very fine gravel	10	105
Sand, fine to medium; contains many lignite fragments	10	115
Sand and gravel; fine to very coarse sand containing about 40 percent fine to medium gravel; contains a few pebbles; a boulder zone at 124 ft	9	124
Silt, clayey to sandy, dark-bluish-gray; may contain glauconite	2	126

TABLE 8.—*Logs of selected wells and test holes*—Continued

	Thickness (feet)	Depth (feet)
L 3S-4W-8aaa1		
[176 ft west of north-south section-line road and 262 ft south of east-west section-line road. Surface altitude, 205 ft]		
Soil, silt, slightly sandy to slightly clayey, dark-brown	1	1
Clay, slightly to very silty, light-yellowish-brown	13	14
Clay, dark-reddish-brown	1	15
Sand, very fine to fine, dark-reddish-brown; contains scattered clay balls up to one-fourth inch in diameter	45	60
Silt, very clayey, dark-bluish-gray, very calcareous; contains clay balls up to one-half inch in diameter and many fossil fragments	10	70
Sand, very fine to fine, slightly calcareous in part; contains a mucky bluish-black soil zone at 74 ft; a clay lens at 81 ft	12	82
Sand, very fine to medium, slightly calcareous in part; contains less than 5 percent very fine gravel; a silty clay lens at 93 ft and scattered clay balls at 98 ft	25	107
Silt, very clayey, medium-brown	1	108
Sand, fine to medium, light-bluish-gray, slightly calcareous in part; contains scattered coarse to very coarse sand; contains a thin light-yellowish-gray silty clay lens at 123 ft and 139 ft and a boulder zone at 142 ft	37	145
Silt, very clayey to slightly sandy, slightly micaceous, dark-bluish-gray; may contain glauconite	6	151
L 3S-4W-8bbb1		
[25 ft south of east-west section-line road and 89 ft east of north-south section-line road. Surface altitude, 207 ft]		
Soil, silt, slightly clayey, fine-textured, slightly micaceous, light-yellowish-brown	2	2
Silt, slightly clayey, light-gray; contains some very fine sand in lower part	7	9
Clay, slightly silty, mottled dark-reddish-brown to light-yellowish-brown, very calcareous	31	40
Clay; similar to clay above (?); poor sample recovery; drilling action indicated clay	28	68
Sand; poor sample recovery; hole plugged; drilling action indicated medium sand with a few pebbles; contains cobble and boulder zone at 135 ft	67	135
Clay; poor sample recovery; drilling action indicated clay	5	140
L 3S-4W-10ddd1		
[41 ft west of north-south State highway 30 and 101 ft north of east-west section-line road. Surface altitude, 201 ft]		
Soil, silt, slightly clayey, medium-brown; contains iron stains and organic material	1	1
Silt, moderately clayey, very light yellowish gray	1	2
Clay, dark-reddish-brown	3	5
Clay; poor sample recovery; drilling action indicated clay	70	75
Sand; poor sample recovery; drilling action indicated very fine to fine sand	15	90
Sand; poor sample recovery; drilling action indicated fine to medium sand with some gravel	15	105
Sand, very fine to medium; not a representative sample	5	110
Sand, medium to coarse, light-bluish-gray; contains a few pebbles and cobbles; a boulder zone at 126 ft	16	126
Silt, very clayey to slightly sandy, dark-greenish-gray; contains some glauconite	3	129
L 3S-4W-11aaa1		
[309 ft west of north-south section-line road and 272 ft south of east-west section-line road. Surface altitude, 200 ft]		
Soil, silty to moderately sandy, medium-brown; contains organic matter	1	1
Silt, moderately clayey, medium-yellowish-brown	1	2
Clay, very tough and plastic, dark-reddish-brown	3	5
Clay, slightly silty, light-yellowish-brown	10	15
Clay, very sticky, dark-reddish-brown, very calcareous	63	78
Sand, fine to medium; contains lignite fragments and a few pebbles	30	108
Sand, fine to coarse; contains some gravel; a cobble and boulder zone in lower part	18	126
Clay, greenish-gray	3	129

TABLE 8.—*Logs of selected wells and test holes*—Continued

	Thickness (feet)	Depth (feet)
L 3S-4W-11ddc1.		
[899 ft west of north-south section-line road and 30 ft north of east-west section-line road. Surface altitude, 195 ft]		
Soil, moderately clayey to slight sandy, medium-yellowish-brown; contains organic material	1	1
Clay, slightly silty, light- to medium-yellowish-brown	6	7
Clay, dark-reddish-brown	3	10
Clay, dark-reddish-brown, very calcareous	15	25
Clay, moderately silty, very soft and sticky, light-yellowish-brown, very calcareous	30	55
Sand; poor sample recovery; drilling action indicated very fine sand	10	65
Sand, very fine to medium, light-bluish-gray, very calcareous in part; contains subangular to subrounded slightly frosted crystal quartz as principal mineral and many dark-colored mineral grains	20	85
Sand, medium to very coarse; similar to sand above	25	110
Sand and gravel; fine to very coarse sand with medium gravel; similar to sand above	8	118
Silt, very clayey, dark-bluish, gray; contains many fossils and some mica	11	129
L 3S-4W-12aaa1.		
[70 ft south and 24 ft west of road intersection. Surface altitude, 196 ft]		
Silt, clayey, gray	3	3
Clay, silty, light-greenish-gray	7	10
Clay, gray to reddish-brown	2	12
Clay, reddish-brown, very calcareous	63	75
Silt, clayey, very calcareous	5	80
Sand, very fine, silty, gray	20	100
Sand, medium to coarse	23	123
Sand and gravel, coarse sand; contains a boulder zone at 144 ft	21	144
Clay, dark-bluish-gray (?)	----------	--------
L 3S-4W-13ccc1.		
[156 ft north of east-west section-line road and 36 ft east of north-south section-line road. Surface altitude, 194 ft]		
Clay, very silty, mottled dark-reddish-brown to light-gray; contains whitish-colored zones	1	1
Clay, very sticky, dark-reddish-brown; contains iron(?) nodules	3	4
Clay, moderately silty, light-yellowish-brown	8	12
Clay, very sticky, dark-reddish-brown; very calcareous in lower part	23	35
Clay, light-yellowish-brown to light-brown; poor sample recovery	28	63
Sand, very fine to fine, lignitic, light-bluish-gray, very calcareous in part; contains subangular slightly frosted crystal quartz grains as predominant mineral and some coarse to very coarse sand in lower part	42	105
Sand, medium to coarse; similar to sand above; contains about 10 percent very fine gravel	5	110
Sand and gravel; medium to coarse sand containing about 40 percent very fine to coarse gravel; contains some very coarse sand and a few pebbles and cobbles	5	115
Sand, medium to coarse; similar to sand above; contains some very coarse sand, a little gravel, and lignite fragments	29	144
Cobbles, sand, and gravel; contains bluish-green quartzite, sandstone, chert, and other white quartzitic rocks	1	145
Silt, very clayey, dark-bluish-gray	1	146
L 3S-4W-14ccc1		
[34 ft north of east-west section-line road and 573 ft east of north-south section-line road. Surface altitude, 203 ft]		
Soil, slightly clayey light-yellowish-brown silt	1	1
Clay, slightly silty, mottled dark-reddish-brown to medium-gray	3	4
Silt, slightly clayey to moderately sandy, light-yellowish-brown	11	15
Clay, dark-reddish-brown, very calcareous	10	25
Clay; poor sample recovery; drilling action indicated clay	55	80
Sand; hole plugged; drilling action indicated fine sand	5	85
Sand, fine to medium, light-bluish-gray; very calcareous in part; contains lignite fragments and subangular slightly frosted crystal quartz grains as predominant mineral	25	110
Sand, medium to coarse; similar to sand above; contains a cobble and boulder zone at 137 ft	27	137
Silt, clayey, dark-bluish-gray; contains many fossil fragments	13	150

TABLE 8.—*Logs of selected wells and test holes*—Continued

	Thickness (feet)	Depth (feet)
L 3S-4W-15bbb1		
[50 ft east of east end of bridge and 50 ft south of east-west section-line road. Surface altitude, 197 ft]		
Soil; slightly sandy dark-brown, silt; contains organic material	3	3
Clay, moderately silty, light-grayish-brown	4	7
Clay, very silty, light-yellowish-brown; contains iron-stain streaks	5	12
Silt, slightly clayey, light-gray	6	18
Sand, very fine, silty, slightly micaceous, light-yellowish-brown; contains lignite fragments	27	45
Sand, very fine, slightly silty, light-reddish-brown	15	60
Silt, slightly sandy in part, slightly micaceous, light-grayish-brown; contains a clay lens at 63 ft	8	68
Sand, very fine to medium, lignitic, slightly micaceous; poor sample in lower part	47	115
Sand, fine to medium; similar to sand above; contains some coarse to very coarse sand and a few pebbles and cobbles; boulder zone at 136 ft	21	136
Silt, very clayey to slightly sandy, dark-bluish-gray	4	140
L 3S-4W-16bbb1		
[113 ft east of north-south section-line road and 140 ft west of irrigation well. Surface altitude, 205 ft]		
Soil; slightly clayey light-yellowish-brown silt; contains organic material	2	2
Silt, very clayey, light-yellowish-brown; contains some very fine sand	8	10
Sand, very fine, silty, light-reddish-brown; thin silty clay lenses interbeded; contains a very light-brown clay lens at 53 ft	78	88
Sand, very fine to medium, light-yellowish-brown, slightly calcareous in part; contains scattered very fine gravel	11	99
Sand, gravel, and clay balls; contains very fine to very coarse sand, very fine to fine gravel, and clay balls up to one-fourth inch in diameter	6	105
Sand, medium to very coarse, lignitic; contains less than 5 percent very fine to medium gravel	25	130
Sand, fine to medium, similar to sand above; contains a silty clay lens at 132 ft	10	140
Sand, medium to very coarse; similar to sand above; contains less than 5 percent very fine to fine gravel	8	148
Silt, clayey, slightly micaceous, dark-bluish-gray	3	151
L 3S-4W-16ddc1		
[370 ft east of St. Louis and Southwestern Railroad and 36 ft north of east-west section-line road. Surface altitude, 205 ft]		
Silt, moderately clayey, light-yellowish-brown; contains roots and other organic material	1	1
Silt, moderately clayey, medium-brown; contains lighter-colored zones	1	2
Silt, slightly to very clayey, coarse textured, light-brown to light-yellowish-gray; contains some very fine sand and iron-stain streaks	10	12
Sand, very fine, moderately silty, light-reddish-brown; contains some mica and many orange grains; a thin medium-bluish-gray silty clay lens at 63 ft	58	70
Sand, very fine to medium, light-bluish-gray, very calcareous in part; contains lignite fragments and some mica	34	104
Clay, clay balls, wood fragments, and very fine to medium sand; very heterogeneous mixture	1	105
Sand, fine to medium, light-bluish-gray, very calcareous in part; contains about 5 percent coarse to very coarse sand in upper part	35	140
Sand, medium to coarse; similar to sand above; contains many lignite fragments; a cobble and boulder zone at 143 ft	3	143
Silt, very clayey, dark-bluish-gray; contains some glauconite	7	150
L 3S-4W-17ccc1		
[21 ft north of east-west section-line road and 42 ft east of north-south section-line road. Surface altitude, 208 ft]		
Soil; slightly clayey light-yellowish-brown silt; contains iron-stain streaks	1	1
Silt, slightly to moderately clayey, light-yellowish-brown; contains iron-stain streaks and iron(?) nodules; some sand in lower part	9	10
Silt, slightly clayey to moderately sandy, very light-yellowish-brown; contains very fine to fine sand	5	15
Sand, very fine, very silty, very light-yellowish-brown; contains a few iron-stain streaks and some mica; may contain a thin silty clay lens at 62 ft and 87 ft	73	88

TABLE 8.—*Logs of selected wells and test holes*—Continued

	Thickness (feet)	Depth (feet)
L 3S-4W-17ccc1—Continued		
Silt, slightly clayey to sandy, medium-yellowish-brown, slightly calcareous; contains clay balls and very fine to fine sand	2	90
Sand, very fine to fine; slightly calcareous in part; contains interbedded medium-reddish-brown to medium-bluish-gray silty clay	5	95
Sand, very fine, slightly silty, light-yellowish-brown; contains a few orange sand grains	10	105
Sand, very fine to fine, light-bluish-gray, slightly calcareous in part; contains a thin silty clay lens at 105 ft	5	110
Sand, fine to medium, lignitic, light-bluish-gray; contains subangular to subrounded slightly frosted crystal quartz grains as predominant mineral; wood fragments and medium-brown silty clay at 126 ft; scattered coarse to very coarse sand and scattered very fine to fine gravel from 130 to 135 ft	31	141
Silt, slightly to moderately clayey, dark-bluish-gray to greenish-gray	9	150
L 3S-4W-17ddd1		
[31 ft north of east-west section-line road and 268 ft west of bridge. Surface altitude, 200 ft]		
Soil, silt, moderately clayey, light-yellowish-brown; contains organic material	1	1
Silt, moderately clayey, light-yellowish-brown	7	8
Clay, slightly silty in part, dark-reddish-brown	7	15
Clay, dark-reddish-brown, very calcareous	15	30
Sand, very fine, silty, light-reddish-brown, very calcareous	20	50
Sand, very fine to fine, light-bluish-gray, very calcareous in part; contains many dark-colored grains; scattered clay balls at 72 ft and a bluish-gray silt lens at 77 ft	29	79
Sand, gravel, clay, and clay balls; very heterogeneous	3	82
Sand, very fine to medium(?); lost circulation	38	120
Sand, medium to coarse(?); no circulation	20	140
Hole completely lost—pulled out.		
Tertiary probably at about 145 ft.		
L 3S-4W-29bbb1		
[58 ft south of east-west section-line road and 76 ft east of north-south section-line road. Surface altitude, 205 ft]		
Soil, silt, moderately clayey, light-yellowish-brown; contains roots	1	1
Silt, moderately clayey to slightly sandy, medium-yellowish-brown; contains iron(?) nodules. Thought to be fill material	2	3
Clay, moderately to very silty, nodular, light- to medium-yellowish-brown; contains many iron(?) nodules, pebbles, cobbles, and some sand. Thought to be, and later verified, as fill material	7	10
Clay, dark-reddish-brown; contains black streaking	5	15
Clay, dark-reddish-brown, slightly calcareous; contains a few shell fragments in lower part	10	25
Silt, very sandy, medium-reddish-brown, moderately calcareous	5	30
Sand, very fine, very silty, dark-reddish-brown, very calcareous	20	50
Clay, very sticky, medium-brown, very calcareous; may contain some interbedded very fine medium-reddish-brown sand	5	55
Clay, moderately silty, sticky, medium-blue-gray, very calcareous	5	60
Sand, very fine, very silty, medium-reddish-brown, very calcareous; contains black organic paludal material in upper part and wood fragments in lower part	15	75
Sand, very fine to fine (with some medium), light-yellowish-brown to light-bluish-gray, very calcareous in part; contains subangular crystal quartz as predominant mineral, and lignite fragments	25	100
Sand, very fine to medium; similar to sand above, very calcareous in part; contains scattered coarse to very coarse sand and scattered very fine gravel	10	110
Sand and gravel; very fine to medium sand and approximately 35 percent very fine to coarse gravel; very calcareous in part; contains a few cobbles; a thin silt lens at 112 ft	5	115
Sand and gravel; similar to above deposit with about 40 percent gravel; very calcareous in part; contains many cobbles	5	120
Sand, very fine to fine (with some medium), lignitic, light-bluish-gray, very calcareous in part; contains scattered very coarse gravel; a cobble zone from 142 to 144 ft	24	144
Clay, very silty, slightly micaceous, dark-bluish-gray; may contain glauconite; a boulder at 153 ft	11	155
Silt, very clayey, dark-bluish-gray; contains some sand and many shell fragments in upper part; a boulder at 171 ft	30	185

TABLE 8.—*Logs of selected wells and test holes*—Continued

	Thickness (feet)	Depth (feet)
L 3S-4W-32ccc1		
[340 ft east of north-south section-line road and 25 ft north of east-west section-line road. Surface altitude, 192 ft]		
Silt, coarse-textured, light-yellowish-brown; contains very light-gray streaks and some clay	1	1
Silt, slightly to very clayey, nodular, light-yellowish-brown; some light-yellowish-gray to medium-reddish-brown in lower part; contains iron stain and iron(?) nodules	9	10
Clay, dark-reddish-brown; contains black streaks and light-gray streaks	8	18
Silt, very coarse-textured, micaceous, light-brown, moderately calcareous; contains interbedded silty clay	25	43
Clay, very silty, micaceous, light-brownish-gray, very calcareous	2	45
Clay, slightly silty in part, light-gray, very calcareous	4	49
Clay, sticky, dark-reddish-brown, very calcareous	5	54
Clay, very silty, light-bluish-gray, very calcareous; contains many dark-colored specks	1	55
Clay, slightly silty, very soft, medium-brown, moderately calcareous	3	58
Sand, fine to very coarse, light-bluish-gray, very calcareous in part; contains clay balls and subangular crystal quartz as predominant mineral	7	65
Sand, medium to coarse; similar to sand above; contains scattered very coarse sand and scattered gravel and pebbles	10	75
Sand and gravel; fine to very coarse sand with about 20 percent very fine to fine gravel; contains a few pebbles and cobbles; wood fragments in lower part	10	85
Sand and gravel; similar to deposit above; contains about 40 percent very fine to very coarse gravel; contains many pebbles and cobbles	20	105
Sand and gravel; similar to deposit above; contains about 25 percent gravel	10	115
Sand, fine to very coarse: similar to sand above; contains less than 10 percent gravel	15	130
Sand, very fine to very coarse: similar to sand above; contains many lignite fragments; cobble zone in lower part	32	162
Silt, very clayey, slightly sandy in part, dark-bluish-gray	4	166
L 3S-5W-1ddd1		
[38 ft west of north-south section-line road and 187 ft north of east-west section-line road. Surface altitude, 208 ft]		
Soil; slightly sandy very dark-gray, moderately calcareous silt; contains much organic material	1	1
Clay, moderately silty, mottled light-yellowish-brown to medium-reddish-brown	9	10
Silt, slightly clayey, medium-reddish-brown; contains interbedded light-reddish-brown clay	5	15
Sand, very fine, silty, slightly micaceous, light- to medium-reddish-brown, moderately calcareous in part; contains subrounded slightly frosted crystal quartz grains as predominant mineral	66	81
Clay, slightly silty, granular, medium-brown, very calcareous; contains a few fossil fragments in upper part	7	88
Sand, very fine to medium, light-brownish-gray to light-bluish-gray, very calcareous in part; contains subrounded slightly frosted crystal quartz as predominant mineral and lignite fragments	27	115
Sand, medium to coarse, similar to above; contains a few pebbles and cobbles; contains a cobble and boulder zone at 132 ft	17	132
Silt, very clayey, dark-bluish-gray	3	135
L 3S-5W-11aaa1		
[74 ft south of east-west section-line road and 31 ft west of north-south section-line road. Surface altitude, 213 ft]		
Silt, slightly clayey, coarse-textured, granular in part, light-yellowish-brown	2	2
Clay, slightly silty, mottled light-yellowish-brown to light-gray; contains iron stains	8	10
Clay, slightly silty, dark-reddish-brown; contains black streaks	5	15
Sand, very fine, silty, dark-reddish-brown, very calcareous; contains subrounded crystal quartz as predominant mineral and some pyrite or mica	50	65
Clay, slightly silty, dark-brown, very calcareous	23	88
Silt, slightly clayey to moderately sandy, medium-bluish-gray to greenish-gray, very calcareous	3	91
Sand, very fine to medium, lignitic, light-bluish-gray, very calcareous in part; contains a little coarse to very coarse sand; a cobble and boulder zone at 127 ft	36	127
Silt, moderately clayey to very sandy, medium-grayish-green; contains many black-colored grains; boulder at 136 ft	9	136

TABLE 8.—*Logs of selected wells and test holes*—Continued

	Thickness (feet)	Depth (feet)
L 3S-5W-11bba1		
[746 ft east of north-south section-line road and 70 ft south of east-west section-line road. Surface altitude, 210 ft]		
Silt, slightly clayey, light-yellowish-brown	1	1
Clay, slightly silty, mottled light-gray to medium-yellowish-brown	3	4
Silt, slightly clayey, mottled yellowish-brown to light-gray	6	10
Clay, very sticky, slightly silty in part, dark-reddish-brown	5	15
Clay, very sticky, dark-reddish-brown, very calcareous	39	54
Clay, very soft, sticky, medium- to dark-brown, very calcareous	21	75
Silt, moderately clayey to very sandy, dark-yellowish-brown, moderately calcareous	8	83
Clay, dark-bluish-gray	1	84
Sand, very fine to coarse (slightly silty in upper part), light-bluish-gray, very calcareous in part; contains subangular crystal quartz as predominant mineral and scattered very coarse sand in lower part	21	105
Sand and gravel; very fine to medium sand containing about 10 percent very fine gravel; similar to sand above in composition	15	120
Sand and gravel; similar to deposits above; contains approximately 30 percent very fine to fine gravel; cobble and boulder zone at 127 ft	7	127
Silt, very clayey, dark-bluish-gray	1	128

TABLE 9.—*Water-level measurements in selected wells*

[In feet below land-surface datum, corrected for barometric influence]

Date	Water level	Date	Water level	Date	Water level
		3S-4W-2bbb1			
1954		*1955*—Con.		*1956*—Con.	
Aug. 3	86.12				
6	86.14	July 6	86.50	Mar. 26	86.86
30	86.38	18	86.74	Apr. 18	88.16
Oct. 25	86.10	Aug. 1	86.76	June 21	87.08
Nov. 12	85.82	15	86.17	Aug. 16	87.35
Dec. 1	86.36	29	86.31	Oct. 8	87.41
30	86.50	Sept. 12	86.13		
		27	86.58	*1957*	
1955		Oct. 10	86.76	Mar. 19	87.36
Jan. 24	85.56	25	86.94	Oct. 21	87.67
Feb. 23	86.35	Nov. 14	87.13	Dec. 13	87.51
Mar. 8	86.32	28	87.00		
12	86.51	Dec. 15	86.84	*1958*	
28	86.18			Mar. 19	87.32
Apr. 11	86.44	*1956*		July 10	87.58
26	86.63	Jan. 4	86.85	*1959*	
May 11	86.45	17	86.85		
26	86.60	Feb. 14	86.90	Mar. 26	87.59
June 6	86.66	28	86.60		
20	86.57	Mar. 13	86.94		
		3S-4W-3ddb1 (1-E)			
1954		*1955*—Con.		*1956*—Con.	
Sept. 16	97.68				
Oct. 26	95.03	Aug. 1	96.98	Mar. 13	94.24
Dec. 1	94.59	15	96.85	27	94.04
30	94.34	29	98.37	June 21	98.50
		Sept. 12	97.12	Aug. 16	99.97
1955		27	97.33	Oct. 8	98.88
Jan. 24	93.86	Oct. 10	97.56		
Feb. 23	93.75	25	95.49	*1957*	
Mar. 9	93.75	Nov. 15	95.22	Mar. 19	96.95
29	93.62	28	94.41	Oct. 21	97.69
Apr. 11	93.53	Dec. 14	94.60	Dec. 13	95.51
26	94.49				
May 11	94.07	*1956*		*1958*	
26	95.86	Jan. 9	94.39	Mar. 25	97.24
June 6	94.62	20	94.29	July 10	99.90
20	96.50	Feb. 7	94.18		
July 6	97.37	21	94.34	*1959*	
19	96.48	Mar. 6	94.28	Mar. 30	96.43

TABLE 9.—*Water-level measurements in selected wells*—Continued

3S-4W-4aad1

Date	Water level
1954	
Aug. 6	95.30
31	94.82
Sept. 15	94.61
Oct. 26	94.69
Nov. 12	94.67
Dec. 1	94.79
30	94.95
1955	
Jan. 25	94.78
Feb. 25	94.88
Mar. 12	94.77
28	94.76
Apr. 11	94.75
26	94.98
May 12	94.83
26	94.97
June 6	94.95
21	95.03
1955—Con.	
July 6	94.91
19	95.09
Aug. 1	95.04
15	95.19
29	96.22
Sept. 12	95.49
27	95.34
Oct. 11	95.20
25	95.27
Nov. 15	95.33
28	95.18
Dec. 14	95.03
1956	
Jan. 4	95.03
17	95.01
Feb. 13	95.24
28	95.40
Mar. 27	95.19
1956—Con.	
Apr. 18	94.51
June 21	95.44
Aug. 15	95.67
Oct. 8	95.62
Dec. 11	95.43
1957	
Mar. 26	95.73
July 11	95.82
Oct. 21	95.85
1958	
Jan. 17	95.78
Mar. 19	95.92
July 10	96.01
1959	
Apr. 1	95.88

3S-4W-4ddd1

Date	Water level
1954	
Aug. 3	94.73
6	94.45
31	94.34
Sept. 15	94.02
Oct. 26	94.15
Nov. 12	94.11
Dec. 1	94.21
30	93.42
1955	
Jan. 25	92.88
Feb. 25	94.01
Mar. 8	93.92
12	93.95
28	94.03
Apr. 11	94.22
26	93.83
May 12	93.82
26	93.80
June 6	94.26
1955—Con.	
June 20	94.21
July 6	94.32
19	94.34
Aug. 1	94.45
15	94.69
29	94.90
Sept. 12	94.73
27	94.65
Oct. 11	94.72
25	94.92
Nov. 15	94.98
28	94.40
Dec. 14	94.76
1956	
Jan. 4	94.51
17	94.52
Feb. 13	94.60
28	94.56
Mar. 27	94.79
1956—Con.	
Apr. 18	94.24
June 21	94.54
Aug. 15	95.01
Oct. 8	94.97
Dec. 11	95.16
1957	
Mar. 26	94.42
July 11	93.97
Oct. 21	94.87
1958	
Jan. 17	94.58
Mar. 19	94.37
July 10	94.56
1959	
Mar. 31	94.44