Water Resources of Clark, Cleveland, and Dallas Counties, Arkansas

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1879-A

Prepared in cooperation with the Arkansas Geological Commission

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By RAYMOND O. PLEBUCH *and* MARION S. HINES

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

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WATER RESOURCES OF CLARK, CLEVELAND, AND DALLAS COUNTIES, ARKANSAS

By Raymond O. Plebuch and Marion S. Hines

ABSTRACT

Clark, Cleveland, and Dallas counties constitute an area of 2,151 square miles in south-central Arkansas. The area is in two physiographic provinces—the Ouachita Mountains of the Ouachita province of the Interior Highlands, and the West Gulf Coastal Plain of the Coastal Plain province. The area is drained by the Ouachita, Saline, and Little Missouri Rivers and their tributaries.

Although some of the streams in the project area can furnish dependable water supplies without storage, the amount of water available for use can be increased by the construction of reservoirs. The average surface-water yield in the area is about 1.4 cubic feet per second per square mile, or a total of about 3,000 cubic feet per second. Generally, the water quality is good; but water from some of the streams, particularly from the smaller tributaries, may require treatment for excessive iron content and high color.

Ground-water yields in the project area vary considerably. The consolidated rocks in the Interior Highlands generally yield less than 10 gallons per minute to wells, precluding the development of large municipal or industrial ground-water supplies in that area.

Of the 17 geologic units present in the Coastal Plain part of the project area, 12 yield water but in varying amounts. Among the formations of Cretaceous age, the Tokio yields good-quality water in the outcrop, but the quality deteriorates downdip; the Brownstown Marl yields small amounts of water for domestic purposes, mainly in the outcrop area; the Ozan Formation yields a highly mineralized water that is generally unsuitable for most purposes; the Nacatoch Sand yields as much as 100 gallons per minute of good-quality water in and near the outcrop, but the water becomes very salty and corrosive at distances ranging from 2 miles downdip from the outcrop in northern Clark County to 17 miles downdip in the southern part of the county.

The formations of Tertiary age offer the best possibilities for ground water, particularly in Dallas and Cleveland Counties. The Wilcox Group contains no thick widespread sands but contains thin sands locally. The quality of the water tends to deteriorate downdip, as the water becomes more mineralized and changes from a bicarbonate to a chloride type. The Carrizo Sand is undeveloped but may yield several gallons of water per minute per foot of drawdown in a large part

of these two counties. High iron content may be a problem in water from the Carrizo. The Cane River Formation yields 50 gallons per minute of good-quality water to each of two wells at Sparkman. Elsewhere, high iron content of the water may be a problem. The Sparta Sand is the best aquifier in the project area, particularly east of central Dallas County. Well yields of 700 gallons per minute or more are possible. With minor treatment, the water is suitable for most purposes. The Cockfield Formation is utilized mainly for domestic supplies, but where the sands are thick, yields of as much as 300 gallons per minute are possible. The Jackson Group is utilized mainly for domestic supplies. In some areas, water from this unit contains such a high concentration of sulfate that it is unpalatable.

The deposits of Quaternary age are thin and generally suitable only for domestic supplies. However, several wells that yield more than 200 gallons per minute have been developed in the alluvium south of Arkadelphia. Transmissibility values are highly variable, and test drilling is advisable to determine if large amounts of water are available at any specific site.

Total water use in the project area in 1965 was about 6 million gallons per day, an increase of about 0.6 million gallons per day since 1960. Slightly more than one-half this amount was derived from surface-water sources. Total water use in the area in 1967 was insignificant compared with the total water available. DeGray Reservoir, now under construction on the Caddo River, will provide 250 million gallons per day for water-supply purposes as compared with the present surface-water use of slightly more than 3 million gallons per day, most of which is used in the Arkadelphia area.

INTRODUCTION

This report is an appraisal of the water resources of Clark, Cleveland, and Dallas Counties, Ark. It provides information on the occurrence, availability, and chemical quality of surface and ground water in sufficient detail to identify, locate, and describe the best potential sources of water. The need for a study was made apparent by the growing industrialization of the State and the resulting increased demand for water information in all areas.

This study, begun in July 1965, was made by the Water Resources Division of the U.S. Geological Survey in cooperation with the Arkansas Geological Commission. The report is based not only on information obtained specifically for this investigation, but also on data collected previously as part of the continuing program of water-resources studies in Arkansas. Several reports of previous geologic and hydrologic studies in the project area are included in the list of references.

Clark, Cleveland, and Dallas Counties, which constitute an area of 2,151 square miles, are in south-central Arkansas (fig. 1). The area, which consists of about 75 percent controlled timberland, is bordered on the north by Montgomery, Hot Spring, Grant, and Jefferson Counties; on the east by Lincoln and Drew Counties; on the south by Nevada, Ouachita, Calhoun, and Bradley Counties; and on the west

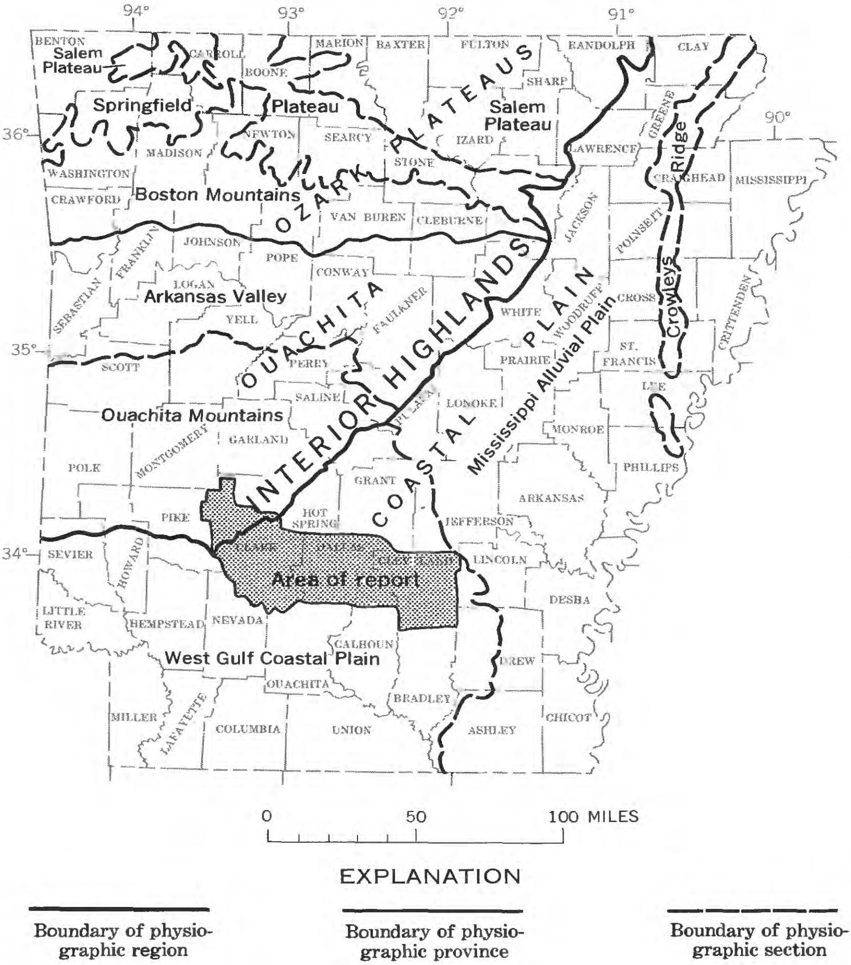

Figure 1.—Location of report and physiographic areas.

by Pike County. The area is in two physiographic provinces—the Ouachita Mountains of the Ouachita province of the Interior Highlands, and the West Gulf Coastal Plain of the Coastal Plain province. About one-third of Clark County lies within the Interior Highlands—the rest of the project area is in the Coastal Plain. Land-surface altitudes range from less than 250 feet in the Coastal Plain to nearly 1,000 feet in northwestern Clark County. The area is drained by the Ouachita, Saline, and Little Missouri Rivers and their tributaries.

WATER RESOURCES

Water is available in the project area from streamflow, precipitation, and underground sources. Streamflow includes inflow from outside the area, runoff from the counties, and base flow which is effluent ground water. Average annual runoff in the counties is about 19 inches, which includes the base-flow component. Ground water is available from wells tapping the water-bearing formations that underlie the area. Ground water that can be used most economically is limited to the perennial yield of the aquifers, which includes the recharge to the aquifers within the counties, plus the underflow from outside the counties. In areas where the base flow of streams is significant, the amount of water available for development is not the total of ground water and surface water, because base flow is included in both. In other areas where the streams have little or no base flow, the total amount of water available for development is the sum of the available surface water, plus the available ground water. Unless surface storage is provided, the major part of streamflow is permitted to flow out of the area and surface-water development is limited to minimum flows.

The contrasting geologic conditions of the two topographically distinct divisions of the Clark-Cleveland-Dallas County area have a definite effect on the water resources of the area. The consolidated rocks have relatively low permeabilities, which limit the amount of ground water available and hinder ground-water movement. In addition, the rocks are highly dissected, and the streams that drain the hills have steep gradients. Surface runoff is rapid and the streams crest and recede quickly, so flow of water from the streams to the ground-water reservoir is inhibited. During high flow, water probably is held only temporarily in bank storage, and at low stage the water is released quickly back to the streams.

In contrast to rocks in the Interior Highlands, some of the Coastal Plain sediments have higher permeabilities that favor the transmission of water, and greater amounts of ground water are available than in the consolidated rocks.

Topography in the Coastal Plain ranges from relatively flat to rolling, and, as a consequence, streams generally are sluggish. Some tributary streams that originate in the Coastal Plain are not sufficiently incised to intersect the water table, and therefore cease to flow during extended dry periods.

SURFACE WATER

SURFACE-WATER SUPPLIES WITHOUT STORAGE

Large amounts of good-quality surface water are available in the project area. The evaluation of surface-water availability is based on records of daily streamflow collected on six of the larger streams in the area for periods ranging from 12 to 38 years and on several measurements of low flow at each of 15 sites on tributary streams (pl. 1, map A).

The three major streams that drain Clark, Cleveland, and Dallas Counties are the Ouachita, Little Missouri, and Saline Rivers. The average flows of the Ouachita and Saline Rivers as they leave the area at its southern boundary are about 6,600 cfs (cubic feet per second), or 4,780,000 acre-feet per year, and 2,560 cfs, or 1,853,000 acre-feet per year, respectively. Most of this flow is contributed by streams outside the boundaries of the three counties. The average streamflow originating within the area ranges from less than 1.2 cfs per sq. mi. in Cleveland County and southern Dallas County, to about 1.6 cfs per sq. mi. in northwestern Clark County (pl. 1, map A). The average yield for the area is about 1.4 cfs per sq. mi., or about 3,000 cfs from the 2,151 square miles of the project area.

Because of seasonal and annual variability of streamflow, only a small percentage of the total surface-water yield is available for water supply on a year-round basis without storage. The water-supply potential of a stream without storage is determined by the frequency with which streamflow recedes to minimal amounts (frequency distribution of annual low flows) and the percentage of time specified flows are available (duration of daily flows). Minimum flows vary from time to time, from stream to stream, and between different points on the same stream. To determine whether streamflow is adequate to satisfy a certain use rate, a statistical analysis of flow data is necessary to determine the amount of flow available on a frequency basis. Results of such an analysis of the magnitude and frequency of annual low flows and the duration of daily flows are presented in table 1 for the six sites in the project area where records of daily discharge have been collected. Data in table 1 may be used in evaluating the water-supply potential at the sites listed. For instance, the low-flow-frequency section of the table indicates that on the average of once in 2 years the lowest average flow for 7 consecutive days (7-day 2-year low flow) for Caddo River near Alpine was 24 cfs or less; on the average of once in 20 years the 7-day 2-year low flow was 9.5 cfs or less. The flow-duration section of table 1 shows that the daily mean flow at this site was equal to or greater than 34 cfs 90 percent of the time (90-percent duration flow). If a water-supply deficiency can be tolerated on the average of once in 2 years, the design use rate can be as much as 24 cfs. However, if a deficiency can be tolerated only about once in 20 years, the design use rate will be only about 9.5 cfs.

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TABLE 1.—*Mean annual flow, frequency of low flows, and duration of daily flows*

Site (pl. 1, map *A*)	National station No.	Station	Drainage area (sq mi)	Mean annual flow adjusted to period 1929–57 (cfs)	Period (days)	Annual low flow, in cubic feet per second, for indicated recurrence interval, in years: 1.2	2	5	10	20
1	7-3595	Caddo River near Alpine.	312	545	7	42	24	16	12	9.5
					15	46	27	17	13	11
					30	58	32	20	15	12
					60	81	40	23	18	14
					120	152	66	36	28	22
2	7-3600	Ouachita River at Arkadelphia (period 1906, 1930–52) [1].	2,311	3,620	7	280	195	137	112	94
					15	360	220	150	123	104
					30	430	255	175	142	118
					60	550	330	220	178	150
					120	1,110	480	305	245	200
2	7-3600	Ouachita River at Arkadelphia (period 1952–63) [2].	2,311	3,620	7	580	305	228	210	205
					15	730	340	245	228	220
					30	960	405	270	250	240
					60	1,500	610	315	280	255
					120	2,050	780	380	315	280
3	7-3615	Antoine River at Antoine.	181	267	7	1.5	.1	.1	0	------
					15	2.2	.2	.1	0	------
					30	4.2	.4	.1	.1	0
					60	8.6	1.1	.1	.1	0
					120	29	5.3	.7	.2	.1
4	7-3616	Little Missouri River near Boughton [3].	1,068	1,480	7	200	75	37	27	21
					15	240	100	50	37	29
					30	290	130	61	49	42
					60	370	190	98	72	58
					120	490	300	170	120	82
5	7-3625	Moro Creek near Fordyce.	216	250	7	0	------	------	------	------
					15	0	------	------	------	------
					30	0	------	------	------	------
					60	.2	0	------	------	------
					120	2.8	.1	0	------	------
6	7-3635	Saline River near Rye	2,062	2,500	7	56	26	13	9	6.6
					15	70	30	15	10	7.7
					30	101	39	18	12	9
					60	161	56	25	17	12
					120	428	133	50	34	24

Site (pl. 1, map *A*)	National station No.	Stream	Daily flow, in cubic feet per second, which was equaled or exceeded for indicated percentage of time: 95	90	80	60	40	20	5	1
1	7-3595	Caddo River near Alpine.	25	34	52	103	230	580	2,200	7,200
2	7-3600	Ouachita River at Arkadelphia (period 1906, 1930–52) [1].	187	250	385	920	2,270	4,500	14,200	37,500
2	7-3600	Ouachita River at Arkadelphia (period 1953–64) [2].	270	335	500	1,250	2,400	4,050	9,700	22,500
3	7-3615	Antoine River at Antoine.	.1	.4	2.4	24	95	273	1,150	4,000
4	7-3616	Little Missouri River near Boughton [3].	74	110	190	400	790	1,800	5,200	14,000
5	7-3625	Moro Creek near Fordyce.	0	0	0	1.8	3.9	267	1,150	3,380
6	7-3635	Saline River near Rye	23	41	84	287	1,190	4,090	11,100	23,600

[1] Regulated by Lakes Hamilton and Catherine.
[2] Severely regulated by Lakes Ouachita, Hamilton, and Catherine.
[3] Regulated by Lake Greeson.

For the 15 sites on tributary streams where only a few measurements of low flow have been made, values of the 7-day 2-year low flow and 90-percent duration flow, as defined above, have been estimated. These estimates are tabulated in table 2 and can be used to compare the low-flow yields of the streams listed.

Most of the low-flow yield of streams in the project area is derived from the Interior Highlands outside the area and does not increase greatly as the streams traverse the Coastal Plain. Tables 1 and 2 reveal that, aside from the three major streams, the Caddo River has by far the greatest water-supply potential of any stream in the area. Tributary streams in Cleveland County and eastern Dallas County have practically no water-supply potential without storage. There is no streamflow at times during each year at the streamflow-measuring site on Moro Creek near Fordyce. During the 15 years for which daily-discharge records have been collected at this site, there has been no flow about 20 percent of the time. L'Eau Frais, Cypress, and Tulip Creeks, eastern tributaries of the Ouachita River, have the greatest low-flow yields of tributary streams lying entirely within the Coastal Plain (table 2).

TABLE 2.—*Water-supply characteristics of selected tributary streams*

[Average streamflow, estimated from pl. 1, Map A]

Site (pl. 1, map *A*)	National station No.	Station	Tributary to	Drainage area (sq mi)	Estimated flow (cfs): Average stream-flow (cfs)	Estimated flow (cfs): 7-day 2-year low flow	Estimated flow (cfs): 90-percent duration flow
7		Bayou DeRoche near Friendship.	Ouachita River	[1] 50	70	[1] <0.01	[1] <0.01
8		Caddo River at Glenwood.	do	192	350	23	32
9		White Oak Creek at Witherspoon.	Saline Bayou	[1] 33	45	[1] .03	[1] .08
10		Saline Bayou near Arkadelphia.	Ouachita River	[1] 39	53	[2] .01	[2] .06
11	7-3601	L'Eau Frais Creek at Joan.	do	79.4	100	1.6	3.1
12	7-3601.6	Cypress Creek at Manning.	do	59.6	75	2.2	2.9
13		Terre Noire Creek near Hollywood.	Little Missouri River.	[1] 33	50	[1] .02	[1] .05
14		Terre Noire Creek near Gurdon.	do	250	340	.2	.8
15		Brushy Creek near Sparkman.	Tulip Creek	[1] 15	18	[1] .03	[1] .1
16		Tulip Creek near Manning.	Ouachita River	[1] 40	48	.8	1.6
17		East Tulip Creek near Princeton.	do	[1] 20	24	1.1	1.3
18	7-3618.5	Tulip Creek near Pine Grove.	do	152	180	1.3	2.4
19	7-3634.4	Derrieusseaux Creek near Rison.	Saline River	[1] 150	170	0	0
20	7-3634.65	Big Creek near Pansy	do	[1] 155	180	<.01	<.01
21	7-3637	Hudgin Creek near Pansy.	do	90.3	100	0	0

[1] Estimated.
[2] Relation not adequately defined.

Upstream reservoirs on the Ouachita and Little Missouri Rivers reduce peak flows and increase minimum flows of these streams and thus improve the water-supply potential of the streams. The low-flow and flow-duration data shown in table 1 for Ouachita River at Arkadelphia (site 2, map *A*, pl. 1) illustrate the effect of Lake Ouachita on low flows. Prior to the impoundment in this reservoir, the 7-day

2-year low flow was 195 cfs, as compared with 305 cfs for the period since impoundment. The low-flow yield of Caddo River will be greatly increased after the completion of multipurpose DeGray Dam, now under construction by the U.S. Army Corps of Engineers. Storage in the reservoir will provide a dependable water-supply release of 387 cfs, or 250 mgd (million gallons per day). Low flows in the Ouachita River below the mouth of the Caddo River will be increased by approximately this same amount.

AUGMENTATION OF LOW FLOW BY STORAGE

The dependable water-supply potential of streams in the project area can be greatly increased by storing water during high-flow periods for use during droughts. In the Interior Highlands and that part of the Coastal Plain characterized by rolling topography, fairly large reservoirs are feasible. In flat areas, storage will be limited largely to in-channel or levied off-channel storage.

A statistical analysis of streamflow data collected at daily streamflow-measuring sites in Arkansas provides a method of estimating storage requirements for specific draft rates at sites where only limited streamflow data are available. Figure 2 shows draft-storage diagrams that are applicable to the project area, except Moro Creek basin. However, the relations can be used for the Moro Creek basin by adding 10 percent to the storage values obtained from the curves. Streams in Moro Creek basin are dry about 20 percent of the time and, thus, require additional storage for specific draft rates. These diagrams show draft or use rates for various storage values related to a low-flow index (7-day 2-year low flow) for frequencies of 10 and 20 years. Storage values determined for specific draft rates from the diagram for a 10-year frequency will be deficient on the average of about once in 10 years, and storage determined from the diagram for a 20-year frequency will be deficient about once in 20 years. No adjustment has been made for seepage and evaporation. Seepage losses must be evaluated at the reservoir site, but usually should be less than 10 percent of the total storage capacity. In the project area where mean annual rainfall exceeds evaporation, loss due to evaporation is not a serious factor.

Data required for estimating storage requirements are drainage area above the site, mean annual streamflow, and low-flow index. These data are listed in tables 1 and 2 for the 21 sites shown on map *A* on plate 1. The drainage area at other sites can be determined from the best available maps. The mean annual streamflow can be determined by outlining the drainage area on map *A* on plate 1, and estimating from the lines of equal streamflow by visual inspection. To

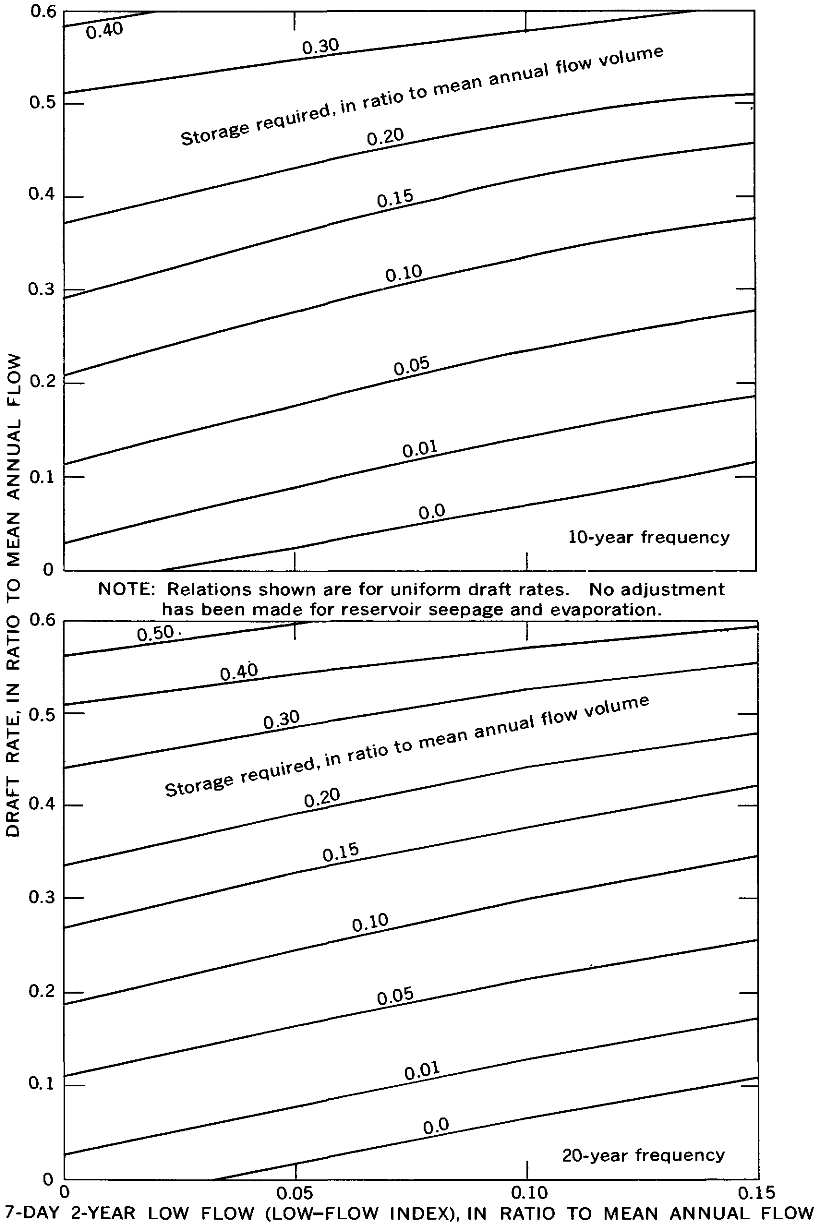

FIGURE 2.—Draft-storage relations for 10- and 20-year frequencies related to 7-day 2-year low flow. Storage requirements for specific draft rates should be increased by 10 percent for Moro Creek drainage basin.

determine the low-flow index, several streamflow measurements during different periods of low flow must be made. These data are than correlated with concurrent streamflow recorded at daily streamflow-measuring sites where the low-flow index is known. If the low-flow index cannot be readily determined, a conservative estimate of storage requirements can be made by assuming that the low-flow index is zero. The storage requirements for a specific site in the project area can be determined by the following procedure.

Assume that it is desired to use water from Tulip Creek on State Highway 8 near Manning (site 16 on map *A*, pl. 1, and in table 2) at the rate of 5 cfs and that a storage deficiency can be tolerated about once in 10 years.

1. Using the best available map, the drainage area is determined as approximately 40 square miles.
2. From the outlined drainage area above the site on map *A* on plate 1, the mean annual streamflow is determined to be about 1.2 cfs per sq. mi., or 48 cfs (1.2×40). This is equivalent to 35,000 acre-feet per year (724×48).
3. The low-flow index (7-day 2-year low flow from table 2) is 0.8 cfs. The ratio of the low-flow index to the mean annual flow is 0.8/48=0.017.
4. The ratio of the draft rate of 5 cfs to the mean annual flow is 5/48=0.10.
5. Using the 10-year frequency diagram in figure 2, the storage required to supply a draft rate of 0.10 of the mean annual flow is determined by interpolation as 0.032 of mean annual flow volume. The storage required is computed as 0.032×35,000=1,100 acre-feet.

QUALITY OF WATER

In the following discussion of quality of surface water, chemical analyses are given for the Ouachita River at Arkadelphia for water year 1965 (Oct. 1, 1964, to Sept. 30, 1965) and for the Saline River at Rye for water year 1960 (Oct. 1, 1959, to Sept. 30, 1960)—the last year of daily sampling. Only spot samples of the smaller tributaries were taken at various times. Year-by-year compilations of analyses of water from sampled streams for the complete period of record may be found in the U.S. Geological Survey water-supply papers and State publications dealing with quality of surface waters, given in the list of references.

Quality-of-water requirements vary according to the water use, particularly among industrial uses. Comparison of data in the text and tables with table 3 will provide sufficient information about water quality for many uses. Water users requiring more detailed information should refer to a publication by the California State Water Pollution Control Board (1952) entitled "Water Quality Criteria."

OUACHITA RIVER

Basically, water from the Ouachita River at Arkadelphia is of excellent quality—soft, low in dissolved-mineral constituents, and of the calcium bicarbonate type. Table 4 shows analyses of the river water during water year 1965 and extremes of certain constituents during the period of record. The extremes given in table 4 indicate that the water consistently has been of good quality throughout the period of record (17 yrs). The only undesirable condition noted was that industrial plants upstream sometimes discharge waste materials into the river, and these materials cause temporary difficulties in water treatment, particularly settling.

Several averages are given in table 4. Weighted average refers to discharge-weighted average. It is computed by multiplying the discharge for a sampling period by the concentrations of individual constituents for the corresponding period and dividing the sum of the products by the sum of the discharges. A discharge-weighted average approximates the composition of water that would be found in a reservoir containing all the water passing a specific location during the water year after thorough mixing in the reservoir. Time-weighted average is computed by multiplying the number of days in the sampling period by the concentrations of individual constituents for the corresponding period and dividing the sum of the products by the total number of days. A time-weighted average represents the composition of water that would be contained in a vessel or reservoir that had received equal quantities of water from the stream each day for the water year.

SALINE RIVER

Table 5 shows the quality of water from the Saline River at Rye during water year 1960—the last year of daily sampling. Several subsequent spot samples indicate no significant change in water quality since that time. Basically, the water is a soft to moderately hard calcium bicarbonate type low in dissolved-chemical constituents. At times, during periods of low flow, the iron content exceeds the 0.3-ppm (parts per million) limit for drinking water recommended by the U.S. Public Health Service (1962). This high iron content, and also high color, limit the usefulness of the water in its untreated state, but with minor treatment the water can be used for most purposes.

LITTLE MISSOURI RIVER

Table 6 shows the quality of water from the Little Missouri River near Boughton during water year 1955 (Oct. 1, 1954, to Sept. 30, 1955)—the last year of daily sampling. The water is soft and of the calcium sodium bicarbonate type and is low in dissolved-mineral con-

Constituent or physical property	Source or cause	Significance
Silica (SiO_2)	Dissolved from almost all rocks and soils, generally in small amounts from 1 to 30 ppm. High concentrations, as much as 100 ppm, generally occur in highly alkaline waters.	Forms hard scale in pipes and boilers. Carried in steam of high pressure boilers to form deposits on blades of steam turbines. Inhibits deterioration of zeolite-type water softeners.
Iron (Fe)	Dissolved from almost all rocks and soils. May also be derived from iron pipes, pumps, and other equipment. More than 1 or 2 ppm of soluble iron in surface waters generally indicates acid wastes from mine drainage or other sources.	On exposure to air, iron in ground water oxidizes to reddish-brown sediment. More than about 0.3 ppm stains laundry and utensils reddish brown. Objectionable for food processing, beverages, dyeing, bleaching, ice manufacture, brewing, and other processes. U.S. Public Health Service drinking water standards recommend that iron should not exceed 0.3 ppm. Larger quantities cause unpleasant taste and favor growth of iron bacteria.
Manganese (Mn)	Dissolved from some rocks and soils. Not as common as iron. Large quantities commonly associated with high iron content and with acid waters.	Same objectionable features as iron. Causes dark-brown or black stain. U.S. Public Health Service drinking water standards recommend that manganese should not exceed 0.05 ppm.
Calcium (Ca) and magnesium (Mg).	Dissolved from almost all soils and rocks but especially from limestone, dolomite, and gypsum. Calcium and magnesium are found in large quantities in some brines. Magnesium is present in large quantities in sea water.	Causes most of the hardness and scale-forming properties of water; soap consuming (see hardness). Waters low in calcium and magnesium are desired in electroplating, tanning, dyeing, and in textile manufacturing.
Sodium (Na) and potassium (K).	Dissolved from almost all rocks and soils. Found also in ancient brines, sea water, some industrial brines, and sewage.	Large amounts, in combination with chloride, give a salty taste. High sodium content commonly limits use of water for irrigation. Sodium salts may cause foaming in steam boilers.
Bicarbonate (HCO_3) and carbonate (CO_3).	Action of carbon dioxide in water on carbonate rocks such as limestone and dolomite.	Bicarbonate and carbonate produce alkalinity. Bicarbonates of calcium and magnesium decompose in steam boilers and hot-water facilities to form scale and release corrosive carbon dioxide gas. In combination with calcium and magnesium cause carbonate hardness.
Sulfate (SO_4)	Dissolved from rocks and soils containing gypsum, iron sulfides, and other sulfur compounds. Commonly present in mine waters and in some industrial wastes.	Large amounts have a laxative effect on some people and, in combination with other ions, give a bitter taste. Sulfate in water containing calcium forms a hard scale in steam boilers. U.S. Public Health Service drinking water standards recommend that the sulfate content should not exceed 250 ppm.
Chloride (Cl)	Dissolved from rocks and soils. Present in sewage and found in large amounts in ancient brines, sea water, and industrial brines.	Large quantities increase the corrosiveness of water and, in combination with sodium, give salty taste. U.S. Public Health Service drinking water standards recommend that the chloride content should not exceed 250 ppm.

TABLE 3.—*Significance of dissolved-mineral constituents and physical properties of natural waters*

Constituent or physical property	Source or cause	Significance
Fluoride (F)	Dissolved in small to minute quantities from most rocks and soils.	Fluoride in drinking water reduces the incidence of tooth decay when the water is consumed during the period of enamel calcification. However, it may cause mottling of the teeth depending on the concentration of fluoride, the age of the child, the amount of drinking water consumed, and the susceptibility of the individual. The maximum concentration of fluoride recommended by the U.S. Public Health Service for Arkansas is about 1.2 ppm; 0.9 ppm is considered to be the optimum concentration.
Nitrate (NO_3)	Decaying organic matter, legume plants, sewage, nitrate fertilizers, and nitrates in soil.	Nitrate encourages growth of algae and other organisms that produce undesirable tastes and odors. Concentrations much greater than the local average may suggest pollution. U.S. Public Health Service drinking water standards recommend that nitrate content should not exceed 45 ppm, as there is evidence that higher concentrations may cause methemoglobinemia in infants, the so-called "blue-baby" disease, that sometimes is fatal. Nitrate has shown to be helpful in reducing intercrystalline cracking of boiler steel.
Dissolved solids	Chiefly mineral constituents dissolved from rocks and soils. Includes any organic matter and some water of crystallization.	U.S. Public Health Service drinking water standards recommend that the dissolved solids should not exceed 500 ppm. Waters containing more than 1,000 ppm of dissolved solids are unsuitable for many purposes.
Hardness as $CaCO_3$	In most waters nearly all the hardness is due to calcium and magnesium. All the metallic cations other than the alkali metals also cause hardness.	Consumes soap before a lather will form, and deposits soap curd on bathtubs. Hard water forms scale in boilers, water heaters, and pipes. Hardness equivalent to the bicarbonate and carbonate is called carbonate hardness. Any hardness in excess of this is called noncarbonate hardness. In general, waters of hardness up to 60 ppm are considered soft; 61 to 120 ppm, moderately hard; 121 to 180 ppm, hard; more than 180 ppm very hard.
Percent sodium and sodium-adsorption-ratio.	See sodium	Values for these properties are used with specific conductance values to determine the suitability of water for irrigation use.
Specific conductance (micromhos at 25°C).	Mineral content of the water.	Specific conductance is a measure of the capacity of water to conduct an electric current. This property varies with concentration and degree of ionization of the constituents, and with temperature (therefore reported at 25°C).
Hydrogen-ion concentration (pH).	Acids, acid-generating salts, and free carbon dioxide lower the pH. Carbonates, bicarbonates, hydroxides, phosphates, silicates, and borates raise the pH.	A pH of 7.0 indicates neutrality of a solution. Higher values denote increasing alkalinity; lower values, increasing acidity. pH is a measure of the activity of the hydrogen ions. Corrosiveness of water generally increases with decreasing pH. However, excessively alkaline waters may also attack metals.
Temperature		Affects usefulness of water for many purposes. Most users desire water of uniformly low temperature. In general, temperature of shallow ground water shows some seasonal fluctuation, whereas temperature of ground water from moderate depths remains near the mean annual air temperature of the area. In very deep wells, water temperature generally increases about 1°F for each 60-ft increment of depth.

TABLE 3.—*Significance of dissolved-mineral constituents and physical properties of natural waters*—Continued

326-756 O—69——3

TABLE 4.—*Chemical analyses, in parts per million, of water from the Ouachita River, water year October 1964 to September 1965*

LOCATION.--At gaging station fastened to downstream side of center pier of bridge on State Highway 8 at Arkadelphia, Clark County, 800 feet upstream from Missouri Pacific Railroad bridge.
DRAINAGE AREA.--2,311 square miles.
RECORDS AVAILABLE.--Chemical analyses: October 1948 to September 1965.
Water temperatures: October 1946 to September 1960, October 1961 to September 1965.
EXTREMES, 1964-65.--Dissolved solids: Maximum, 70 ppm Oct. 1-31; minimum, 37 ppm Feb. 9-26.
Hardness: Maximum, 36 ppm May 1-31; minimum, 20 ppm Feb. 9-28.
Specific conductance: Maximum daily, 127 micromhos Oct. 24; minimum, 48 micromhos Jan. 10, Feb. 10.
Water temperatures: Maximum, 88°F June 29, 30; minimum, 44°F Dec. 23.
EXTREMES, 1948-65.--Dissolved solids: Maximum, 263 ppm May 9, 10, 1963; minimum, 26 ppm Dec. 17-23, 1959.
Hardness: Maximum, 65 ppm Nov. 21, 1963; minimum, 10 ppm Feb. 25-28, 1962.
Specific conductance: Maximum daily, 550 micromhos May 10, 1963; minimum daily, 27 micromhos Jan. 27, 1949.
Water temperatures (1948-60, 1961-65): Maximum, 99°F July 7, 1955; minimum, 35°F Jan. 7, 19, 20, 1960, Jan. 14, 1964.
REMARKS.--Samples were collected biweekly for iron and were filtered clear when collected. Records of discharge for water year October 1964 to September 1965 furnished by District Office, Corps of Engineers, Vicksburg, Miss.

Date of collection	Mean discharge (cfs)	Silica (SiO_2)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Lithium (Li)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$		Total acidity as H^{+1}	Specific conductance (micromhos at 25°C)	pH	Color
																			Calcium, magnesium	Noncarbonate				
Oct. 1-31, 1964......	2600	6.9			0.00	8.6	2.0	3.7	0.8		37	0	4.2	3.2	0.1	0.7	--	70	30	0		81	8.1	6
Nov. 1-30...	1650	5.1			.00	10	1.0	3.6	1.0		34	0	7.6	2.1	.1	.6	0.04	50	29	1		79	7.4	5
Dec. 1-31...	2470	6.4			.00	7.9	1.9	4.1	1.2		29	0	8.4	3.5	.2	1.1	.05	54	28	4		78	7.4	5
Jan. 1-31, 1965......	3680	6.5			.00	7.0	1.8	3.6	1.0		26	0	8.4	1.4	.0	.9	A.06	46	25	4		79	7.4	10
Feb. 1-8....	1368	5.4			.00	7.6	1.7	4.1	.9		28	0	6.4	4.0	.0	.8	.10	45	26	3		79	7.5	3
Feb. 9-28...	8428	6.1			.00	6.5	1.0	3.1	.9		22	0	5.2	2.2	.1	.9	.19	37	20	2		61	7.5	11
Mar. 1-31...	3685	7.6			.00	5.6	2.7	3.6	.8		24	0	6.2	2.3	.0	.8	.00	49	25	6		64	7.6	5
Apr. 1-30...	1201	5.9			.00	8.0	2.2	4.6	1.0		30	0	6.4	3.3	.1	.7	A.00	52	29	4		82	7.7	0
May 1-31....	728	5.2			.00	9.0	3.3	4.4	1.0		35	0	9.0	3.1	.3	1.0	A.00	57	36	8		91	7.8	0
June 1-30...	876	5.6			.00	8.6	2.2	4.4	1.0		33	0	7.0	2.8	.2	1.3	.14	54	30	4		88	7.8	0
July 1-31...	2134	5.4			.00	8.4	2.6	3.3	.8		35	0	5.4	1.8	.2	1.0	A.00	56	32	3		79	7.8	0
Aug. 1-31...	2775	6.2			.02	8.3	2.0	3.3	.8		35	0	5.0	2.4	.3	1.0	.05	48	28	0		80	7.2	8
Sept. 1-30..	2606	8.4			.01	8.6	1.8	3.2	.6		34	0	5.4	1.6	.2	.9	.09	47	29	1		78	7.2	6
Weighted average....	--	6.5			0.00	7.6	1.9	3.6	0.9		29	0	6.2	2.3	0.1	0.9	0.07	49	27	3		74	7.4	6
Time-weighted average....	2560	6.3			0.00	8.1	2.1	3.8	0.9		31	0	6.6	2.5	0.1	0.9	0.05	52	29	3		78	7.5	4
Tons per day.	--	45			0.02	53	13	25	6.2		204	0	43	16	0.9	6.2	0.49	342	--	--		--	--	--

A Total phosphorus as PO_4.

TABLE 5.—*Chemical analyses, in parts per million, of water from the Saline River, water year October 1959 to September 1960*

Location.—At gaging station at bridge on State Highway 15, 4 miles southwest of Rye, Cleveland County, and 5 miles upstream from Hudgin Creek.
Drainage area.—2,062 square miles.
Records available.—Chemical analyses: October 1946 to September 1947, October 1948 to September 1955, November 1957 to September 1960.
Water temperatures: October 1946 to September 1947, October 1948 to September 1955, October 1958 to September 1959.
Extremes, 1946–47, 1948–55, 1958–59.—Dissolved solids: Maximum, 186 ppm July 13–15, 1955; minimum, 18 ppm Jan. 11–14, 1950.
Hardness: Maximum, 77 ppm Jan. 24, 30, 1949; minimum, 8 ppm June 1–7, 9–10, 1947.
Specific conductance: Maximum daily, 534 micromhos Jan. 18, 1949; minimum daily, 20 micromhos June 24, 1947.
Water temperatures: Maximum, not determined; minimum, 35°F Jan. 6, 1959.
Remarks.—Records of specific conductance of daily samples (1946–47, 1948–55, 1958–59) available in district office at Little Rock, Ark. Records of discharge for water year October 1959 to September 1960 given in Water-Supply Paper 1711.

Date of collection	Mean discharge (cfs)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Dissolved solids residue at 180° C)	Hardness as $CaCO_3$		Specific conductance (micromhos at 25° C)	pH	Color
											Calcium, magnesium	Noncarbonate			
Oct. 27, 1959	189	17	3.4	9.2	1.3	54	30	2.5	0.8	100	56	12	154	7.8	15
Nov. 24	491	14	3.6	7.1	2.2	40	28	4.0	.6	94	50	17	131	7.4	------
Dec. 17	2,920	6.0	2.1	3.6	2.3	17	17	2.5	.4	44	24	10	72	6.8	30
Jan. 13, 1960	3,920	6.8	1.8	3.8	1.2	18	15	3.0	.4	42	24	10	72	6.6	18
Feb. 10	4,670	5.5	1.5	2.9	.9	15	11	2.2	.3	38	20	7	58	6.6	22
Mar. 16	8,010	4.9	1.2	2.7	.8	13	11	2.2	.2	41	17	6	53	6.5	18
Apr. 12	743	8.9	3.0	6.0	.9	34	16	3.5	.2	59	34	6	105	6.9	5
May 10	2,920	8.3	1.0	5.5	1.9	31	9.0	2.2	1.2	44	24	0	82	6.8	40
June 7	711	9.3	2.2	4.8	1.0	36	10	2.5	.3	57	32	2	88	6.6	10
July 6	12,600	4.6	.8	2.2	2.6	15	6.0	2.0	1.4	27	15	2	45	6.4	60
Aug. 2	189	9.8	2.6	12	1.8	42	20	5.5	1.0	92	35	0	124	6.8	15
Aug. 30	80	5.4	1.5	4.9	1.1	24	11	1.5	.0	37	20	0	65	6.6	12
Sept. 21	73	9.2	2.8	13	.9	52	16	4.5	.0	91	34	0	136	6.9	10

TABLE 6—*Chemical analyses, in parts per million, of water from the Little Missouri River, water year October 1954 to September 1955*

LOCATION.--At gaging station at bridge on U. S. Highway 67, 2 miles northeast of Boughton, Nevada County, and 8.7 miles downstream from Antoine Creek.
DRAINAGE AREA.--1,070 square miles.
RECORDS AVAILABLE.--Chemical analyses: October 1947 to September 1955.
Water temperatures: October 1947 to September 1955.
EXTREMES, 1954-55.--Dissolved solids: Maximum, 75 ppm Oct. 4, 11, 17, 23, 25-26; minimum, 24 ppm Sept. 1-7, 9-15, 17-27, 29-30.
Hardness: Maximum, 52 ppm July 17-18, 23; minimum, 15 ppm Sept. 1-7, 9-15, 17-27, 29-30.
Specific conductance: Maximum daily, 421 micromhos Jan. 6; minimum daily, 37.7 micromhos Sept. 3.
Water temperatures: Maximum, 86°F Aug. 29; minimum, 39°F Jan. 29.
EXTREMES, 1947-55.--Dissolved solids: Maximum, 121 ppm Feb. 14-23, 1954; minimum, 24 ppm Sept. 1-7, 9-15, 17-27, 29-30, 1955.
Hardness: Maximum, 96 ppm June 6-8, 1951; minimum, 12 ppm June 1-6, Aug. 6-10, 11-20, Sept. 1-10, 21-30, 1953.
Specific conductance: Maximum daily, 421 micromhos, Jan. 6, 1955; minimum daily, 30.5 micromhos June 5, 1953.
Water temperatures: Maximum, 94°F July 29, 1948; minimum, not determined.
REMARKS.--Values reported for dissolved solids are sums of determined constituents. Records of specific conductance of daily samples available in district office at Fayetteville, Ark. Records of discharge for water year October 1954 to September 1955 furnished by district office, Corps of Engineers, Vicksburg, Miss.

Date of collection	Mean discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue on evaporation at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Non-carbonate	Specific conductance (micromhos at 25°C)	pH	Color
Oct. 1-3, 5-10, 12-14, 16, 18-22, 24, 27-31, 1954	921			6.4	1.8	2.9		24	6.0	3.2		1.4	34	23	4	71.8	7.5	35
Oct. 4, 11, 17, 23, 25-26	852			12	3.0	12		32	5.6	24		2.2	75	42	16	159	7.4	35
Nov. 1-30	701			4.1	2.1	2.9		21	5.2	3.0		.8	28	19	2	60.2	7.1	20
Dec. 1-24, 26-28	1,038			5.8	1.8	3.0		24	3.8	3.8		1.0	31	22	2	63.2	6.7	22
Dec. 25, 29-31	3,405			10	2.4	4.0		34	5.0	6.2		1.2	46	35	7	93.1	6.9	34
Jan. 1-5, 8-11, 13, 15-19, 21-29, 31, 1955	1,002			8.8	1.0	4.1		26	7.4	9.0		1.1	44	26	4	80.7	7.0	--
Jan. 7, 14, 20	1,413			13	1.4	8.8		36	4.2	15		1.5	62	38	9	137	7.2	25
Feb. 1-4, 6-8, 10, 12-19, 22-27	2,061			7.5	1.6	3.5		25	3.0	5.0		1.4	34	25	5	73.4	7.0	25
Feb. 5, 9, 11, 20-21, 28	2,623			12	2.3	11		37	4.4	20		1.9	70	39	9	142	7.3	38
Mar. 1-6, 8-20, 22-30	3,661			6.6	1.6	3.3		22	5.0	5.0		.9	33	23	5	65.3	6.7	30
Apr. 1-4, 10, 16, 18-30	2,324			6.7	1.4	3.1		24	3.4	2.8		.6	30	22	3	64.5	6.9	15
Apr. 5-9, 11-15, 17	4,047			12	1.8	4.3		38	6.2	5.5		.6	49	37	6	98.0	7.2	22
May 1-25, 29-30	1,152			7.8	1.7	3.6		29	4.4	4.0		.6	36	26	3	75.7	6.9	22
June 1-2, 4-8, 10-27, 29-30	777			6.8	.6	4.2		22	2.6	5.5		1.3	32	19	1	66.6	6.2	15

TABLE 6.—*Chemical analyses, in parts per million, of water from the Little Missouri River, water year October 1954 to September 1955*—Continued

Date of collection	Mean discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue on evaporation at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color
July 1-10, 12-14, 16, 19-22, 24-31, 1955....	708			6.0	0.7	3.0		20	0.6	4.0		1.2	25	18	1	56.7	7.0	12
July 17-18, 23..........	1,032			19	1.0	3.6		63	.8	3.5		.9	60	52	0	122	7.3	23
Aug. 1-25, 27-31.......	602			4.9	.8	3.4		21	.6	4.5		.6	25	16	0	53.1	7.2	10
Sept. 1-7, 9-15, 17-27, 29-30	547			5.0	.7	3.2		19	1.4	4.0		.7	24	15	0	51.7	7.1	15
Average	a 1,604			8.6	1.5	4.7		29	3.9	7.1		1.1	41	28	4	85.2	--	23

a Mean discharge for water year October 1954 to September 1955, 1,411 cfs.

stitutents. During the period of record, the reported dissolved-mineral constituents have been consistently within the limits set by the U.S. Public Health Service (1962).

CADDO RIVER

Quality-of-water records are available for the Caddo River at a site 6 miles north of Arkadelphia for the period October 1949 to September 1952. These records indicate water of excellent quality. The water is soft and of the calcium sodium bicarbonate type and is very low in dissolved-chemical constituents. Caddo River water consistently meets the dissolved-mineral limitations of the U.S. Public Health Service (1962) except for occasional iron concentrations in excess of 0.3 ppm.

TRIBUTARY STREAMS

Table 7 gives chemical analyses of water from selected tributary streams in the project area. These analyses are of spot samples, and at times the actual quality may differ from that shown. Most of the tributary streams have good-quality water. The water ranges from a sodium bicarbonate to a sodium calcium bicarbonate type and generally is soft to moderately hard. High iron (more than 0.3 ppm) and color may be a problem, but with minor treatment the water is suitable for most purposes.

An exception to the above is Saline Bayou. The water in the bayou is a sodium chloride type. At times of low flow the chloride content of the water may exceed 1,500 ppm and total dissolved solids may exceed 2,500 ppm. This may represent seepage of saline water from underlying geologic units.

Moro Creek south of Fordyce is another example of a stream with poor-quality water, although this fact is not readily apparent from the analysis given. Fordyce discharges sewage into the creek, and at times the dissolved-oxygen content falls below 5 ppm, probably about the lowest limit at which fish life can be sustained. The fact that Moro Creek has no flow 20 percent of the time is a contributing factor to poor water quality downstream from Fordyce. Sewage accumulation during periods of no flow causes serious overloading of the stream when flow is present.

TABLE 7.—*Chemical analyses of water from selected tributary streams in Clark, Cleveland, and Dallas Counties, Ark.*

[Chemical constituents, in parts per million]

Station and date of collection	Mean discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)
Bayou DeRoche near Friendship:									
June 19, 1963	0.106	3.8	0.34	3.2	1.3	4.4	0.8	24	1.2
Aug. 13, 1963	.05	3.2	.12	4.0	.9	3.3	1.1	22	1.0
Saline Bayou near Arkadelphia:									
June 19, 1963	.048	3.0	.94	155	35	790	7.8	26	30
Aug. 13, 1963	1.40	5.4	.68	19	5.9	49	2.3	48	5.4
L'Eau Frais Creek at Joan:									
July 21, 1964	2.14	7.9	.56	1.4	.8	1.3	1.1	7	3.0
Moro Creek near Fordyce:									
Nov. 1, 1965	4.4	24	.48	22	8.0	80	12	248	6.0
Tulip Creek near Pine Grove:									
Nov. 1, 1965	4.43	16	.64	2.1	.8	2.4	1.8	12	2.4
Terre Noire Creek near Gurdon:									
Nov. 1, 1965	1.36	10	.34	32	3.2	40	3.8	110	25

Station and date of collection	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 180° C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color
Bayou DeRoche near Friendship:									
June 19, 1963	2.4	0.0	0.2	29	14	0	50	7.5	1
Aug. 13, 1963	2.0	.1	.3	30	14	0	46	7.5	5
Saline Bayou near Arkadelphia:									
June 19, 1963	1,550	.2	.2	2,730	531	510	4,940	7.0	4
Aug. 13, 1963	97	.5	.3	225	72	32	411	7.1	11
L'Eau Frais Creek at Joan:									
July 21, 1964	3.0	.0	.5	32	6	1	26	6.6	40
Moro Creek near Fordyce:									
Nov. 1, 1965	37	.3	17	332	88	0	544	7.6	45
Tulip Creek near Pine Grove:									
Nov. 1, 1965	2.7	.1	.3	28	8	0	41	7.1	44
Terre Noire Creek near Gurdon:									
Nov. 1, 1965	44	.3	.1	224	93	3	358	7.8	31

GROUND WATER AND ITS QUALITY

Ground water is extremely important to the economies of Clark, Cleveland, and Dallas Counties. Exclusive of the municipalities of Arkadelphia and Alpine in Clark County, all municipal, institutional, and domestic supplies and most industrial supplies are obtained from ground-water sources. The geology of the area has a direct influence on the availability of this ground water. The Interior Highlands is underlain by consolidated rocks of low permeability. In contrast, the Coastal Plain is underlain by a thick sequence of generally more permeable unconsolidated sediments which dips gently to the southeast. In this report, 18 geologic units have been differentiated in the project area—one in the Interior Highlands and 17 in the Coastal Plain. The lithologic and water-bearing characteristics of these units and their vertical relationships are summarized in table 8. In addition, the distribution of the units is shown on the geologic map (pl. 1, map *B*). Persons interested in a more detailed discussion of the geology are referred to the list of references at the back of this report.

INTERIOR HIGHLANDS

Ground water in the Interior Highlands is obtained from a thick sequence of sandstones and shales of Mississippian and Pennsylvanian age (pl. 1, map *B*). The primary porosity of these rocks has been destroyed by compaction due to deep burial, deformation pressures, or both. Therefore, ground water occurs principally in secondary openings such as joints, fractures, solution channels, and separations along bedding planes, and its availability at any point depends largely upon the degree to which the rocks have been broken. Limited supplies of ground water are available at most places because secondary openings have developed in nearly all of the rocks. Because of the low permeabilities of these sandstones and shales, wells seldom yield more than 5–10 gpm (gallons per minute), and the development of large municipal or industrial supplies generally is not feasible. Most wells are less than 100 feet deep, and water levels range from 5 to 35 feet below land surface. Normally, maximum water-level fluctuations do not exceed 10–20 feet during a specific year, although the levels in isolated wells may fluctuate more, depending on local conditions.

Several factors control the depth to water in the consolidated rocks of the Interior Highlands. Precipitation has a direct effect, as periods of heavy rainfall are accompanied by corresponding decreases in depth to water. Conversely, dry periods are coincident with increases in depth to water. Depth to water also generally is related directly to the topography of the area. The depth to water is greater in wells on the crests or slopes of ridges or hills than in wells in the nearby valleys.

Ground water moves in the direction of the slope of the water table. In the Interior Highlands the slope of the water table is controlled mainly by geologic structure, and the water generally moves toward the synclinal axes and away from the anticlinal axes.

The rocks of the Interior Highlands yield water of variable quality. The water from six wells was either a calcium magnesium sodium bicarbonate or a sodium bicarbonate type. Iron content ranged from 0 to 0.80 ppm; hardness, from 6 to 197 ppm; and dissolved solids, from 34 to 292 ppm. Median values were iron, 0.33 ppm; hardness, 38 ppm; and dissolved solids, 192 ppm. Water from very shallow wells generally is less mineralized than that from deeper wells, probably because it has been in contact with the rock minerals for a shorter time than water from the deeper wells.

TABLE 8.—*Geologic column in Clark, Cleveland, and Dallas Counties, Ark.*

Age	Group	Formation	Thickness (feet)	Lithology and water-bearing characteristics
Quaternary		Alluvium and terrace deposits	0–40	Silt, clay, sand, and gravel. Yields as much as 240 gpm of water to wells in the Arkadelphia area. Utilized only for small domestic supplies in other areas.
Tertiary	Jackson		0–200	Clay, with minor amounts of sand. Yields only small quantities of water to domestic wells.
	Claiborne	Cockfield Formation	0–210	Silt and lignitic clay with interbedded sand. Utilized mainly for domestic supplies, but may yield in excess of 300 gpm of water to wells where sand beds are well developed.
		Cook Mountain Formation	0–170	Gray silt and clay. Not important as a source of water.
		Sparta Sand	0–800	Very fine to medium sand with interbedded sandy lignitic clay. Yields as much as 700 gpm of water to wells.
		Cane River Formation	0–540	Sand, clay, and sandy clay. Aquifer characteristics unknown, but yields 50 gpm to municipal wells at Sparkman, Ark.
		Carrizo Sand	0–200	Fine to medium sand with some clay and lignite. Not particularly utilized as a source of water at present, but an important potential aquifer. May yield several gallons per minute per foot of drawdown.
	Wilcox		0–710	Complexly interfingered beds of clay, sandy clay, sand, and lignite. Utilized only for small domestic supplies in report area.
	Midway		0–560	Blue-gray to blue-black clay. The lower part is calcareous. Does not yield water to wells.
Upper Cretaceous		Arkadelphia Marl	0–100	Dark-gray fossiliferous marl. Does not yield water to wells.
		Nacatoch Sand	0–220	Chiefly quartz sand; some glauconitic sand and gray clay. Yields as much as 100 gpm of good-quality water in the outcrop area and for a short distance downdip. Water then rapidly becomes salty and unusable.
		Saratoga Clay	0–50	Chiefly white sandy chalk; some sandy marl and clay. Does not yield water to wells.
		Marlbrook Marl	0–115	Dark, pure marl. Does not yield water to wells.
		Ozan Formation	0–150	Dark sandy micaceous marl and marly sand. Yields small amounts of highly mineralized water for domestic purposes. Some of the water is not suitable for domestic purposes.
		Brownstown Marl	0–140	Marl with numerous sandy beds. Yields small amounts of water for domestic purposes.
		Tokio Formation	0–200	Intertonguing beds of gray clay and quartz sand, with some lignite and a basal gravel. All wells constructed to give small yields. Formation yields 100–300 gpm southwest of project area.
Mississippian and Pennsylvanian		Undifferentiated	?	Sandstones and shales. Yields normally are not more than 5–10 gpm.

Chemical contamination of ground water in the Interior Highlands is not extensive. Contamination generally occurs on a localized basis and is most often due to seepage from septic tanks, barnyards, or outdoor toilets. It often is evidenced by high nitrate content of the water. Only one sample, from a shallow dug well, showed an excessive nitrate concentration (68 ppm). Proper well location, sealing, and curbing will often eliminate this problem.

COASTAL PLAIN

Of the 17 geologic units exposed in the Coastal Plain part of the project area (pl. 1, map *B*; table 8), five either do not yield water to wells or yield such minor amounts that they are unimportant as sources of supply. These unproductive units are the Marlbrook Marl, the Saratoga Clay, and the Arkadelphia Marl of Late Cretaceous age, and the Midway Group and Cook Mountain Formation of Tertiary age.

WATER-BEARING UNITS OF LATE CRETACEOUS AGE

TOKIO FORMATION

The Tokio Formation, which directly overlies consolidated rocks of Mississippian and Pennsylvanian age, crops out in a southwestward-trending mile-wide band in west-central Clark County bordering the Interior Highlands (pl. 1, map *B*). The outcrop broadens southwest of the project area. The formation, which attains a maximum thickness of 200 feet in the subsurface, consists of intertonguing beds of gray clay and quartz sand, some lignite, and a rather persistent basal gravel.

Maximum prospective well yields from the Tokio Formation in Clark County are unknown, as the few wells tapping this formation are small-yield domestic and stock wells. However, southwest of the project area the formation yields from 100 to 300 gpm of water to wells.

Except in the outcrop, water in the Tokio is under artesian conditions. Water levels in the outcrop area range from 30 to 40 feet below land surface. Four to 5 miles downdip to the southeast of the outcrop area, water levels in several wells are within a few feet of land surface. In topographically low places in this area wells may flow.

The Tokio Formation yields a calcium sodium bicarbonate water in the outcrop area, but the water changes to a sodium chloride type downdip. In six samples the iron content ranged from 0.02 to 3.1 ppm; hardness, from 26 to 203 ppm; and chloride content, from 7.0 to 1,200 ppm. In five samples the dissolved-solids content ranged from 66 to 1,810 ppm. The chloride and dissolved-solids contents are low in the outcrop area and increase gradually downdip.

The Tokio Formation is important in that it offers a less highly mineralized water than some of the shallower formations in the area between the outcrop and the town of Okolona (T. 8 S., R. 22 W.).

BROWNSTOWN MARL

The Brownstown Marl unconformably overlies the Tokio Formation. Northeast of the Tokio outcrop it rests directly on rocks of Mississippian and Pennsylvanian age. The Brownstown Marl crops out in an interrupted northeast-southwest-trending band across central Clark County (pl. 1, map *B*). In the stream valleys it is covered by deposits of Quaternary age. The formation attains a maximum thickness of 140 feet in the subsurface and in Clark County contains numerous sandy and sandy clay beds. In places the sand contains small quantities of chert pebbles, which occur within hard calcareous sandstone lenses.

The Brownstown Marl, being rather impermeable, is not important as an aquifer in Clark County; however, it will yield small amounts of water for domestic purposes, mainly in the outcrop area. Downdip, the amount of sand decreases, and the chances of obtaining water are poorer.

Reported water levels in the Brownstown range from 35 to 60 feet below land surface. Well yields of 15–25 gpm have been reported from the Brownstown, but these probably are greater than yields that can normally be expected.

The Brownstown Marl yields water that is either a calcium sodium bicarbonate or a sodium bicarbonate type. In three samples collected in 1966, the iron content ranged from 0.16 to 5.0 ppm; hardness, from 6 to 90 ppm; and dissolved solids, from 206 to 247 ppm.

OZAN FORMATION

The Ozan Formation unconformably overlies the Brownstown Marl. It crops out in central Clark County in an interrupted belt paralleling the Brownstown outcrop (pl. 1, map *B*). The Ozan attains a maximum thickness of 150 feet in the subsurface. The formation resembles the underlying Brownstown Marl, but may be differentiated from it either by a glauconitic sand bed at the base, if present, or by the prevalence of smooth convex oyster shells.

Only a few small-capacity domestic wells withdraw water from the Ozan Formation in Clark County. Some of the wells flow. Total pumpage from the Ozan in Clark County was about 0.13 mgd in 1965 (Halberg and Stephens, 1966).

Water from the Ozan, even in the outcrop area, generally contains more than 1,000 ppm dissolved solids. Generally, the water is unsuitable for most uses, particularly downdip from the outcrop. Unfortunately, except in one area, no better aquifer is available in central Clark County in the area between the hard rocks of the Interior Highlands and the outcrop of the Nacatoch Sand. In T. 8 S., R. 22 W., between the outcrop of the Tokio Formation and the town of Okolona, the Tokio offers better quality water. Surface water, however, is available wherever small reservoirs are feasible.

NACATOCH SAND

The Nacatoch Sand crops out as a 3- to 5-mile-wide low ridge extending southwestward from Arkadelphia in Clark County (pl, 1, map *B*). It is overlain by deposits of Quaternary age in some of the valleys. The formation, which attains a maximum thickness of about 220 feet in the subsurface in Clark County, consists of three distinct lithologic units. The lower unit consists of interbedded gray clay, sandy clay and marl, dark clayey fine-grained sand, and hard irregular concretionary beds; and it contains lenses of calcareous fossiliferous slightly glauconitic sand. The middle unit consists of a dark-greenish sand which contains coarse grains of glauconite and weathers to lighter shades of green. It is generally fossiliferous where it is glauconitic. This middle unit also contains irregular concretionary beds. The upper unit is composed of unconsolidated gray fine-grained quartz sand that is commonly crossbedded. Locally, the sand is massive and contains a few hard lenses and beds of fossiliferous sandy limestone. This upper unit is the principal water-bearing part of the Nacatoch.

Map *C* on plate 1 gives the altitude of the top of the Nacatoch in the subsurface by means of contour lines. The approximate depth to the top of the Nacatoch can be determined by adding to the altitude of the land surface the values read from the contour lines where the top of the Nacatoch is below sea level, or by subtracting from the altitute of the land surface the values read from the contour lines where the top of the formation is above sea level. The main water-bearing part is directly below the top of the formation.

Well yields of as much as 100 gpm are obtainable from the Nacatoch Sand in Clark County, although most wells are designed for small capacities. Flowing wells that yield 1 or 2 gpm are obtainable in the lower stream valleys, particularly east of U.S. Highway 67. Total pumpage from the formation in 1965 was about 0.44 mgd (Halberg and Stephens, 1966).

The chemical characteristics of water from the Nacatoch Sand are variable. The chloride content of the water in the outcrop in Clark County normally is low; but it increases rapidly downdip from the outcrop, and the water becomes unsuitable for most uses within 2–17 miles from the outcrop. This increase of chloride is illustrated by map *D* on plate 1, in which zones of chloride content of water from the Nacatoch are shown. In particular, between Arkadelphia and Curtis the chloride content increases from 31 to 7,560 ppm within 3 miles. If pumpage from the Nacatoch is increased greatly in the area just west of the fresh-water–brackish-water demarcation line, high-chloride water could move updip and contaminate the fresh-water zone. However, there is no evidence of this occurring.

In 30 water samples, the iron content ranged from 0.02 to 7.4 ppm, and the chloride content ranged from 7.0 to 7,560 ppm. In 28 samples the hardness ranged from 6 to 2,690 ppm; and in six samples the dissolved-solids content ranged from 92 to 12,300 ppm.

WATER-BEARING UNITS OF TERTIARY AGE

WILCOX GROUP

The Wilcox Group, which conformably overlies the Midway Group, crops out in a discontinuous band as much as 9 miles wide in southeastern Clark County (pl. 1 map *B*). In many places it is covered by terrace and alluvial deposits of Quaternary age. The unit becomes progressively thicker downdip from the outcrop and attains a maximum thickness of 710 feet in eastern Cleveland County. The Wilcox Group in the project area consists of complexly interfingered beds of clay, sandy clay, sand, and lignite. The sand beds generally are thin and are not persistent over large areas. At any specific location the amount of sand in the unit may range from practically none to 60 percent.

Map *E* on plate 1 shows the altitude of the top of the Wilcox Group by means of contour lines. The unit dips southeastward at about 40 feet per mile.

Minor aquifers exist in the Wilcox Group, but the complexity of the interfingering beds precludes the prediction of a depth to a water sand at any specific location. At the present time, the Wilcox Group is utilized only for a few domestic supplies in and near the outcrop area. The depths of the wells differ, and water levels range from 6 to 90 feet below land surface. Total pumpage from the unit in the project area was about 0.07 mgd in 1965 (Halberg and Stephens, 1966).

Water in the minor Wilcox aquifers generally is a sodium bicarbonate type along the outcrop area, where the water is low in dissolved solids. Downdip there is an increase in dissolved solids, and the water becomes a sodium chloride type. Map *E* on plate 1 shows the eastern limit of use of the Wilcox Group as a source of water containing less than 1,000 ppm dissolved solids. Fortunately, east of this line, better and shallower aquifers are available.

CARRIZO SAND

The Carrizo Sand, which is underlain by the Wilcox Group and overlain by the Cane River Formation, is the basal formation of the Claiborne Group in Arkansas. It has not been definitely identified at the surface in the project area (Clark County) because much of the area is blanketed by alluvium and terrace deposits of Quaternary age. However, by means of electric-log projections, its position of outcrop and its subcrop beneath the Quaternary deposits have been estimated and are shown on map *B* on plate 1. In an area north of Vaden (southeastern Clark County) a massive sand is overlain by what appears to be the typical ironstone beds of the Cane River as found farther to the south, but the identification of this sand as the Carrizo is not definite.

The Carrizo Sand consists mainly of very fine to medium sand, although it does contain some clay and lignite. Because it was deposited on an irregular Wilcox surface, its thickness varies considerably over short distances, ranging from about 60 feet to 200 feet.

Map *F* on plate 1 shows the altitude of the top of the Carrizo Sand by means of contour lines. Although not extensively utilized in the project area at present, the Carrizo is an important potential aquifer in much of the area and should be capable of yielding at least several gallons of water per minute per foot of drawdown.

Little is known about the quality of water in the Carrizo in the project area. In adjacent areas it generally is soft, although treatment for iron removal sometimes is desirable for some uses. Electric logs indicate that water from the Carrizo Sand in south-central Dallas County and southern Cleveland County probably contains more than 1,000 ppm dissolved solids, which would make it unsuitable for most purposes. (See map *F*, pl. 1.)

CANE RIVER FORMATION

The Cane River Formation of the Claiborne Group is underlain by the Carrizo Sand and overlain by the Sparta Sand. The limits of its outcrop, as shown on map *B* on plate 1, are tentative and are based mainly on electric-log projections. In much of the projected outcrop area, the Cane River Formation is covered by deposits of Quaternary age. The Cane River Formation, which attains a maximum thickness of about 540 feet in the subsurface, consists of sand, clay, and sandy clay and contains numerous ironstone layers of different thicknesses.

Map *G* on plate 1 shows the altitude of the top of the Cane River Formation by means of contour lines. The formation dips to the east and southeast at an average rate of 35 feet per mile. In the project area, little is known about the water-bearing characteristics of the Cane

River Formation, as it is utilized only for a few domestic supplies and one municipal supply. The town of Sparkman, in Dallas County, has two operating wells, each yielding 50 gpm, in the Cane River. The wells are reported to be 250 feet deep. Total pumpage from the Cane River Formation in Dallas County in 1965 was about 0.06 mgd (Halberg and Stephens, 1966).

Water-quality data on the Cane River Formation in the report area are limited. The water from the two wells at Sparkman is soft, and the iron concentrations are 0.10 and 0.17 ppm, respectively—well within the 0.3-ppm limit advocated by the U.S. Public Health Service (1962). In other areas, however, water from the Cane River sometimes is high in iron content, and treatment for iron removal is desirable for some uses.

SPARTA SAND

The Sparta Sand of the Claiborne Group overlies the Cane River Formation and is overlain by the Cook Mountain Formation. It crops out in a north-south-trending band 13–27 miles wide in western and central Dallas County (pl. 1, map *B*). Much of the formation is blanketed by a veneer of materials of Quaternary age. Map *H* on plate 1 shows, by means of contour lines, the altitude of the top of the Sparta Sand and also the thickness of the formation.

The Sparta Sand, which attains a maximum thickness of 800 feet in the subsurface in Cleveland County, consists mainly of gray very fine to medium sand with interbedded sandy lignitic clay. In some places it is divided into an upper and a lower sand, and in other places the sand is distributed uniformly throughout the formation.

The Sparta Sand is one of the major aquifers in Arkansas, as well as in several adjacent states. In the outcrop area it is tapped primarily by shallow domestic wells. Pumpage in the outcrop area is negligible, as most of the area consists of controlled timberland. East of the outcrop area, however, the Sparta is extensively used as a source of municipal, industrial, institutional, and domestic supplies. The municipalties of Carthage and Fordyce in Dallas County and Rison in Cleveland County utilize water from the Sparta. Total pumpage from the Sparta Sand in the project area in 1965 was about 0.93 mgd (Halberg and Stephens, 1966).

In the project area the Sparta is capable of yielding as much as 700 gpm of water to wells. Two pumping tests gave coefficients of transmissibility for the Sparta of 24,000 and 115,000 gpd (gallons per day) per foot. This wide range of transmissibility indicates that aquifer tests are necessary to determine proper well spacing in any specific area.

Water levels in the Sparta Sand in 1966 ranged from 4 to 30 feet below land surface in the outcrop area. Farther east the levels were

105 feet below land surface at Carthage, 120 feet at Fordyce, and 151 feet at Rison. The water is under artesian conditions, except in the outcrop area.

Water from the Sparta Sand generally is of good quality and with minor treatment is suitable for most uses. In 14 samples iron content ranged from 0.02 to 21 ppm, and hardness, from 6 to 102 ppm. The dissolved-solids content in 13 samples ranged from 34 to 533 ppm. Median values were iron, 1.6 ppm; hardness, 23 ppm; and dissolved solids, 127 ppm.

Water from one well showed some evidence of local contamination—a nitrate content of 52 ppm.

COCKFIELD FORMATION

The Cockfield Formation of the Claiborne Group overlies the Cook Mountain Formation and underlies the Jackson Group. It crops out in a southeast-trending band 6–15 miles wide spanning the Dallas–Cleveland County line (pl. 1, map *B*). A narrow strip down the center of the outcrop is covered by deposits of Quaternary age. Map *I* on plate 1 shows, by means of contour lines, both the altitude of the top and the thickness of the formation.

The Cockfield Formation, which attains a thickness of 200 feet in the subsurface in Cleveland County, consists mainly of silt and lignitic clay with interbedded sand. The sand beds generally are relatively thin, but in certain areas they are of considerable thickness.

The Cockfield Formation is utilized mainly as a source of domestic water supplies in the project area. However, one town, Kingsland, utilizes Cockfield water. Total pumpage from the Cockfield Formation in the project area was about 0.12 mgd in 1965 (Halberg and Stephens, 1966).

The Cockfield Formation is an excellent source of domestic supplies, and, where the sands are relatively thick, well yields of more than 300 gpm are possible.

Except in the outcrop, water in the Cockfield Formation is under artesian conditions. Water levels in the formation range from about 8 to 130 feet below land surface.

Water from the Cockfield Formation is of good quality and with minor treatment is suitable for most purposes. In eight samples, iron content ranged from 0.01 to 2.5 ppm; hardness, from 6 to 96 ppm; and dissolved solids, from 53 to 346 ppm. Median values were iron, 0.03 ppm; hardness, 14 ppm; and dissolved solids, 202 ppm.

JACKSON GROUP

Exposures of the Jackson Group, which overlies the Cockfield Formation, are limited to Cleveland County in the project area (pl. 1, map *B*). This unit, which consists of gray, brown, and green silty clay, and some lignite and sand, attains a thickness of about 200 feet in the county.

The Jackson Group yields only small amounts of water and is utilized only for domestic purposes in the project area. Pumpage from this unit in Cleveland County in 1965 was about 0.04 mgd (Halberg and Stephens, 1966).

Water levels in the Jackson Group range from 6 to 60 feet below land surface.

The Jackson Group yields water of varying quality. The major complaint is that some of the water contains large amounts of sulfate, due to the presence of gypsum, which renders it unpalatable. In four samples, iron content ranged from 0.24 to 37 ppm; hardness, from 27 to 1,500 ppm; dissolved solids, from 198 to 2,650 ppm; sulfate, from 37 to 1,030 ppm; and chloride, from 9 to 600 ppm. Median values were iron, 0.78 ppm; hardness, 419 ppm; dissolved solids, 1,009 ppm; sulfate, 455 ppm; and chloride, 50 ppm.

ALLUVIUM AND TERRACE DEPOSITS OF QUATERNARY AGE

Alluvium and terrace deposits of Quaternary age blanket much of the Coastal Plain part of the project area (pl. 1, map *B*). These deposits consist of silt, clay, sand, and gravel and attain a thickness of about 40 feet.

The Quaternary deposits over most of the area are suitable for, and are utilized only for, small domestic supplies. However, in the flood plain of the Ouachita River south of Arkadelphia, several industrial wells, each of which yields 240 gpm, have been developed for the National Gypsum Co. Pumping tests on these wells gave transmissibility values of 14,935 and 13,200 gpd per foot, respectively. Coefficient of storage values were 0.0032 and 0.0038. Tests on another well several miles southwest of the above wells gave a transmissibility of about 3,000 gpd per foot. It is evident that transmissibility values differ greatly from place to place in the alluvium. Because low transmissibility indicates low yield per foot of drawdown, test drilling and aquifer tests are necessary to determine quantities of water available and proper well spacing at any specific site.

Pumpage from the deposits of Quaternary age in the project area in 1965 was about 0.16 mgd (Halberg and Stephens, 1966).

Water in the deposits of Quaternary age is under water-table conditions, and water levels range from 1 to 18 feet below land surface.

The quality of water from the deposits of Quaternary age is variable. In seven samples, iron content ranged from 0.04 to 27 ppm; hardness, from 22 to 476 ppm.; dissolved solids (6 samples), from 72 to 1,210 ppm; and sulfate, from 0 to 591 ppm. Median values were iron, 0.38

ppm; hardness, 54 ppm; dissolved solids, 304 ppm; and sulfate 21 ppm.

Two samples had sulfate contents of 477 and 591 ppm. The wells from which the samples were taken are at the National Gypsum Co.'s plant at Arkadelphia, and the sulfate may represent local contamination from the plant, as a sulphate process is used.

TOTAL WATER USE

Total water use in the project area in 1965 was about 6 mgd, an increase of about 0.6 mgd since 1960. About 3.5 mgd was derived from surface-water sources, principally the Ouachita River. Most of the water used was in the Coastal Plain part of the area, where about 3.32 mgd was used for public supplies and by self-supplied industries. Total water use in the area in 1965 was insignificant compared with the total water available. DeGray Reservoir alone will provide 250 mgd for water-supply purposes as compared with the 1965 surface-water use of slightly more than 3 mgd, most of which was in the Arkadelphia area.

CONCLUSIONS

Although some of the Interior Highland streams have dependable water supplies without storage, the amount of water available could be increased by the construction of reservoirs. The DeGray Dam and Reservoir, under construction on the Caddo River near Arkadelphia, will provide a dependable water supply of 387 cfs (250 mgd). Reservoirs also are feasible in the more rolling parts of the Coastal Plain.

The average surface-water yield in the project area is about 1.4 cfs per square mile, or about 3,000 cfs from the 2,151 square miles of the project area.

Ground-water yields in the project area range considerably. The consolidated rocks of the Interior Highlands generally yield less than 10 gpm to wells, although larger amounts may be obtained locally. The low yields generally preclude the development of large municipal or industrial ground-water supplies.

Of the 17 geologic units present in the Coastal Plain part of the project area, 12 yield water in varying amounts. Among the formations of Cretaceous age, the Tokio yields good-quality water in the outcrop, but the quality deteriorates downdip; the Brownstown Marl yields small amounts of water for domestic purposes, mainly in the outcrop area; and the Ozan Formation yields a highly mineralized water that is generally unsuitable for most purposes, both in the outcrop and downdip from the outcrop. No fresh water is available below the Ozan, except from the Tokio Formation in T. 8 S., R. 22 W. Surface water, however, is available wherever small reservoirs are feasible.

The Nacatoch Sand yields as much as 100 gpm of good-quality water in and near the outcrop, but the water becomes very salty and corrosive 2–17 miles downdip.

The formations of Tertiary age offer the better possibilities for water, particularly in Dallas and Cleveland Counties. The Wilcox Group contains no major widespread sands but contains minor sands. The quality of the water tends to deteriorate downdip. The Carrizo Sand is undeveloped but over a large part of these two counties may yield several gallons per minute per foot of drawdown. High iron content may be a problem in water from the Carrizo. The Cane River Formation yields 50 gpm of good-quality water to each of two wells at Sparkman. Elsewhere, high iron content may be a problem. The Sparta Sand is the best aquifer in the project area, particularly east of central Dallas County. Well yields of 700 gpm or more are possible. With minor treatment the water is suitable for most purposes. The Cockfield Formation is utilized mainly for domestic supplies, but where the sands are thick yields of as much as 300 gpm are possible. The Jackson Group is utilized mainly for domestic supplies. In some areas water from this unit contains such a high concentration of sulfate that it is unpalatable.

The deposits of Quaternary age are thin and generally suitable only for domestic supplies. However, several wells that yield in excess of 200 gpm have been developed in the alluvium south of Arkadelphia. Transmissibility values are highly variable, and test drilling and aquifer tests are advisable to determine if large amounts of water are available at any specific site.

Total water use in the project area is negligible compared with water available. Surface-water use alone in the Arkadelphia area is slightly more than 3 mgd. DeGray Reservoir, when completed, will provide about 83 times this amount of water for water-supply purposes.

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