Water Resources of the Little River Basin, Louisiana

By M. W. GAYDOS, J. E. ROGERS, *and* R. P. SMITH

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1989

Prepared in cooperation with the Louisiana Department of Public Works and the Louisiana Geological Survey Department of Conservation, Baton Rouge, Louisiana

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON 1973

UNITED STATES DEPARTMENT OF THE INTERIOR

ROGERS C. B. MORTON, *Secretary*

GEOLOGICAL SURVEY

V. E. McKelvey, *Director*

Library of Congress catalog-card No. 73-600030

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402 – Price $3.15 (paper cover)
Stock Number 2401–02416

CONTENTS

	Page
Abstract	1
Acknowledgments	2
Introduction	2
The hydrologic setting	4
Summary of geology	4
Topography and drainage	6
Water use	7
Hydrologic zones	8
Zone A	9
Streams	9
Aquifers	11
Suitability of water	16
Zone B	19
Streams	19
Aquifers	20
Suitability of water	22
Zone C	23
Streams	23
Aquifers	24
Suitability of water	29
Water conditions at population centers	30
Ruston	31
Jonesboro-Hodge	34
Winnfield	35
Tullos-Urania-Olla	37
Jena-Jonesville-Catahoula Lake area	38
Water problems and solutions	40
Problems of availability	40
Floods	42
Pollution	44
Subsurface brine disposal	53
The outlook	54
Future demands	54
Effect of development	54
Summary and conclusions	55
Selected references	58
Index	61

ILLUSTRATIONS

[Plates are in pocket]

PLATE 1. Generalized geologic map and fence diagram of the Little River basin.
2. Geohydrologic maps of the Little River basin.
3. Fence diagrams of the Ruston, Jonesboro, and Winnfield areas.
4. Maps showing flood-prone areas in the Winnfield-Joyce and Jonesboro-Hodge areas.

		Page
FIGURE 1.	Map showing location of the Little River basin	3
2–6.	Graph showing—	
	2. The water-level decline caused by pumping a well screened in the Sparta Sand	33
	3. The amount of storage required to obtain specified draft rates from the Little River	38
	4. Flood profiles of the Dugdemona River	41
	5. Flood profiles of Castor Creek and the Little River	42
	6. Relation of chloride to specific conductance	46
7.	Map showing chloride load carried by streams, November 1965	48
8.	Map showing chloride load carried by streams, November 1967	49
9.	Graph showing dissolved-oxygen content of water from the Dugdemona River	52
10.	Graph showing variations in dissolved-oxygen content of water from the Dugdemona River at Winnfield	53

TABLES

		Page
TABLE 1.	Discharge measurements and calculated chloride loads of streams during the seepage investigations	44
2.	Chemical analyses of ground water	64

WATER RESOURCES OF THE LITTLE RIVER BASIN, LOUISIANA

By M. W. Gaydos, J. E. Rogers, and R. P. Smith

ABSTRACT

The average flow of streams in the Little River basin is high, about 0.65 mgd (million gallons per day) per square mile, but many streams have little or no flow during parts of each year. Consequently, many streams are not dependable supply sources during the low-flow periods without storage.

Streams in the southern part of the basin have sustained low flow and can be developed for municipal and small industrial supplies without storage. In the past, many of the streams were used for old-field brine disposal, but recent State regulations prohibiting continued release of brine to streams have effectively reduced salt loads.

The Wilcox Group, the Sparta Sand, the Cockfield Formation, the Catahoula Sand, the Carnahan Bayou Member of Fisk (1940) of the Fleming Formation, terrace deposits, and alluvial deposits contain fresh water in parts of the basin. Greatest development has been from the Sparta, which also has the greatest potential for future development. Moderately large supplies of good quality water can be obtained from the Cockfield, Miocene (Catahoula and Carnahan Bayou), and terrace and alluvial deposits.

Ground-water quality problems are local rather than basinwide. Locally, water from the Cockfield is highly colored. Hard water is found in some areas, and iron content exceeds the recommended public-supply limit in the outcrop areas of the Sparta and the Cockfield.

In the northern part of the basin (zone A) the 7-day, 2-year flow (lowest average flow for 7 consecutive days occurring on an average of once in 2 years) of Castor Creek and the Dugdemona River near their confluence is 5.4 and 3.1 mgd, respectively. Water from Castor Creek is suitable for most uses with minimum treatment, but water from the Dugdemona River would require extensive treatment to remove color. Wells yielding 200 gpm (gallons per minute) can be constructed at most localities, and wells yielding 2,000 gpm can be constructed where thick massive sands are available.

In the south-central part of the basin (zone B) the Little River has a 7-day, 2-year flow of 17 mgd. No other surface-water supplies are available during dry periods. Wells yielding 100 gpm are possible in most places where the Cockfield contains fresh water. In some places in zone B no fresh ground water can be obtained.

During low-flow periods more than 20 mgd can be obtained from the Little River in most of the extreme southern part of the basin (zone C). The 7-day, 2-year flow of Fish Creek, Trout Creek, and Big Creek is 5.0, 4.7, and 8.4 mgd, respectively. Catahoula Lake could be developed to supply large quantities of water, but brine-disposal regulations must remain effective for the water to be suitable for most uses. Yields of wells may be

as low as a few gallons per minute where only thin sands are available. Yields of 1,000 gpm can be obtained at some locations.

Flood damage in the basin is minor because the broad, flat flood plains are relatively undeveloped.

ACKNOWLEDGMENTS

This study is part of a continuing program of water-resources investigations in Louisiana and was made by the U.S. Geological Survey in cooperation with the Louisiana Department of Public Works and the Louisiana Geological Survey, Department of Conservation.

Well owners, well drillers, and superintendents of municipal water systems supplied much of the data used in the preparation of this report. Electrical logs of oil-test wells were made available by the Louisiana Geological Survey, Department of Conservation. The cooperation of these people and agencies is appreciated.

INTRODUCTION

The Little River basin, in north-central Louisiana, includes all or parts of Bienville, Caldwell, Catahoula, Grant, Jackson, La Salle, Lincoln, Rapides, and Winn Parishes. (See fig. 1.) The irregularly shaped basin has a total area of about 2,800 square miles.

The population in the basin was approximately 70,000 in 1960. More than 30 percent of the people lived in the principal towns of Jonesboro, Winnfield, and Ruston. (Part of Ruston is in an adjoining drainage basin. For this report, however, Ruston is considered to be located entirely within the Little River basin.) Many small communities are scattered throughout the predominantly rural basin. Population density is about 25 persons per square mile, compared to the State average of 72. Population growth has been slow; in most areas, except the principal towns and La Salle Parish, the population has decreased since 1940. In 1960 the basin total was nearly the same as in 1940 and was only 5 percent greater than the 1950 population.

Per capita income is relatively low compared to State and national averages. The economy is based on forest products and oil and gas production. Parts of the basin have been oil-producing areas for more than 40 years. The major industry is associated with the use of wood in the production of paper, pulp, and lumber. Some cattle and poultry are raised. Cotton, corn, and potatoes are grown, but farming has declined in recent years.

The severe water problems of the area result from both natural and manmade causes. Critical low flows result from locally adverse geologic conditions and the poor distribution of rainfall with time

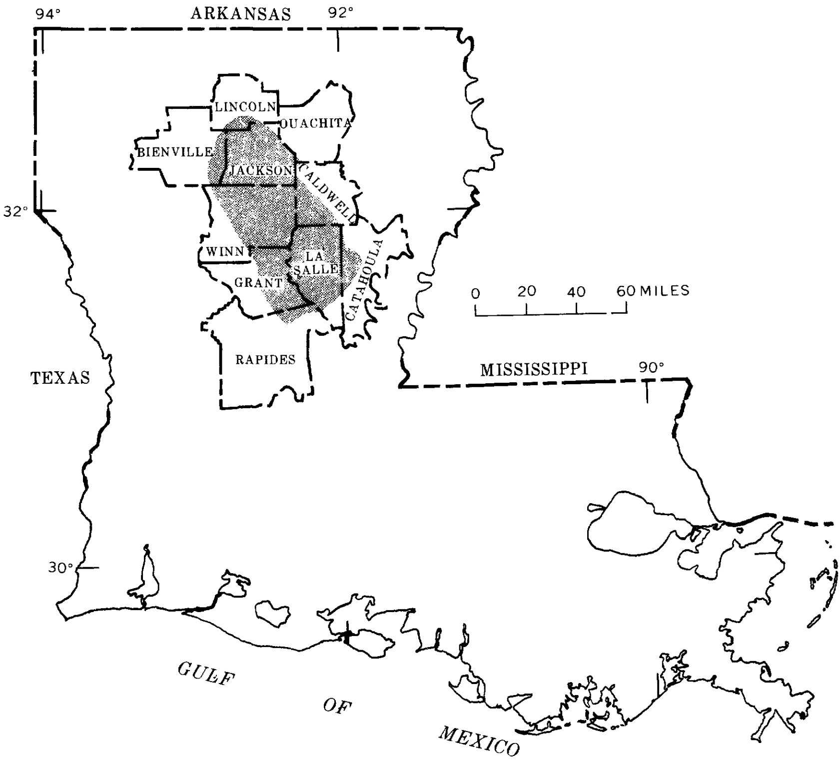

FIGURE 1.—Location of the Little River basin.

in the basin. Although the annual rainfall in the basin has been as much as 80 inches and as little as 30 inches, the average annual rainfall is about 58 inches, about 14 inches of which goes to runoff in streams. The average flow of streams in the basin is comparable to the average flow in other parts of the State, about 1.0 cfs per sq mi (cubic feet per second per square mile). However, during most of the year, variations in flow are extreme, and nearly two-thirds of the basin has little or no runoff during drought periods. The Little River at the Rochelle gaging station typified the extreme low-flow conditions. The flow at this site (drainage area about 1,800 square miles) has been as low as 17 cfs (cubic feet per second), less than 0.01 cfs per sq mi. Such low flow, coupled with large quantities of pollutants discharged into streams by oil-field operations, municipalities, and industries, cause high concentrations of some pollutants.

Pollution of streams by oil-field brine in the area of Winnfield, Tullos, Olla, and Catahoula Lake has been especially severe during low-flow periods. Because the Catahoula Lake area is considered a prime recreational and wildlife center by State and Federal authorities, much concern has been expressed regarding pollution. The State has instituted corrective measures to eliminate salt-water discharge to streams. Industrial effluent in the Jonesboro area pollutes the Dugdemona River.

Because of the poor quality of surface water, ground-water supplies are widely used in the basin. The major sources of ground water are the Sparta Sand, the Cockfield Formation, deposits of Miocene age, terrace deposits, and alluvium. None of these is a source of fresh water for the entire basin; consequently, the amounts of water available vary with local conditions. In an area of the basin northwest of Catahoula Lake, fresh ground water probably cannot be obtained. Declining water levels create potential problems in areas of heavy pumping.

Ground-water quality problems are local rather than basinwide. Salty water is present locally, some water is highly colored, and concentrations of certain chemical constituents are objectionable in some areas.

The average air temperature, a major influence on the temperature of shallow ground water, is 66°F (19°C) at Winnfield. Air temperatures in the basin rarely exceed 100°F (38°C) or drop below 10°F (−12°C). Temperatures have ranged from −15°F (−26°C) to 108°F (42°C) at Ruston, and from 0°F (−18°C) to 109°F (43°C) at Winnfield.

The objectives of this water-resources investigation of the Little River basin were to determine and report the quantity, quality, and distribution of water available, with emphasis on water conditions in developed areas of the basin. This report describes present and potential water problems, suggests possible solutions, and provides estimates of the effects of future development on the water resources.

THE HYDROLOGIC SETTING

SUMMARY OF GEOLOGY

Deposits ranging in age from Paleocene to Holocene are sources of fresh ground water in the Little River basin. The oldest fresh-water-bearing sands are in the Wilcox Group of Paleocene and Eocene ages. The geologic map and the fence diagram of the basin (pl. 1) illustrate the general setting of the Wilcox Group and the younger fresh-water-bearing units. The Wilcox contains fresh water in part of the Bienville Parish section of the basin—in Tps. 14 and 15 N., Rs. 5 and 6 W.

Overlying the Wilcox Group is the Claiborne Group of Eocene age consisting (in ascending order) of the Carrizo Sand, Cane River Formation, Sparta Sand, Cook Mountain Formation, and Cockfield Formation. The principal water-bearing units in this group are the Carrizo Sand, Sparta Sand, and Cockfield Formation. Where the Carrizo Sand is known to occur in the basin, it contains salty water, however. The Carrizo may contain fresh water in the same area in which water from the Wilcox is fresh. Because the Carrizo is not known to contain fresh water in the basin, the formation is not discussed as a source. Locally, the Carrizo is missing, and the Cane River Formation is in contact with the Wilcox.

The Cane River Formation is mostly clay with some marl and some glauconitic sand. The unit retards the movement of water between the underlying Wilcox and Carrizo and the overlying Sparta Sand. Where the Wilcox is salty, the Cane River Formation protects the fresh-water-bearing sands of the Sparta from contamination by salty Wilcox water.

The Sparta Sand is the principal fresh-water-bearing unit in the northern part of the Little River basin. Within the basin it crops out in the southeastern part of Bienville Parish, the southwestern part of Jackson Parish, and the northwestern part of Winn Parish (pl. 1). The unit underlies the remainder of the basin but contains fresh water only in the northern one-third to one-half (pl. 2). The configuration of the base of the Sparta is shown on plate 2.

Overlying the Sparta Sand is the Cook Mountain Formation, which consists of clay, silt, marl, and glauconitic sands. The unit retards the movement of water between the Sparta and the Cockfield Formation. However, because sand is abundant in places in the Cook Mountain, the formation is not as effective a barrier to the movement of water as some of the thicker clayey units.

The Cockfield Formation crops out in much of the north-central part of the basin (pl. 1). In a large part of the outcrop area it is a thin veneer over the older units. In the central part of the basin the Cockfield occurs at greater depths (pl. 2), and in parts of the area it is the only source of fresh ground water.

The Jackson Group of Eocene age and the Vicksburg Group of Oligocene age overlie the Cockfield. The units, which together are 400–700 feet thick, are mostly clay. In much of the area where the units crop out, ground-water supplies are sparse. Only in part of the Jackson outcrop area does the underlying Cockfield contain fresh water.

Deposits of Miocene age overlie the Vicksburg and crop out in the southern part of the basin (pl. 1). Most of the Miocene deposits within the Little River basin are the Catahoula Formation. In the southern part of the basin are the Lena and Carnahan Bayou Members (Fisk, 1940) of the Fleming Formation. The Catahoula Formation and the Carnahan Bayou Member of Fisk (1940) of the Fleming are sources of fresh water in parts of the area. The fence diagram (pl. 1) illustrates their relation to the older units.

The terrace deposits of Quaternary (Pleistocene) age overlie the older Tertiary units along some streams and in some interstream areas (pl. 1). The deposits contain large quantities of fresh water in the southern part of the basin, particularly in southern Grant and La Salle Parishes.

Most of the stream valleys (pl. 1) contain alluvial deposits of Quaternary (Pleistocene and Holocene) age. In places these deposits are only reworked clay of the older Tertiary deposits through which the stream cuts; in other places the deposits are sand and gravel in addition to surficial clay. Where the unit contains coarse material, it is a source of water.

In the northern part of the basin all formations are nearly flat lying, having dips of only about 10 feet per mile toward the south and southeast. Deposits of Miocene age in the southern part of the basin generally dip south and southeast at a rate of 50 feet per mile or more. Local faulting of beds is common, and faults with large displacement occur near salt domes. In a small area in La Salle Parish (T. 9 N., R. 2 E., pl. 1), downfaulting of about 2,600 feet is indicated by correlation of electrical logs. In this faulted area fresh water occurs to depths as great as 1,800 feet below land surface. This is in a part of the basin generally devoid of fresh ground water.

In outcrop areas and locally in the terrace deposits and alluvium, water in the geologic units occurs under water-table conditions. Elsewhere, artesian conditions prevail.

TOPOGRAPHY AND DRAINAGE

The Little River basin is characterized by rounded hills in the north; flat-lying deposits in the central area; dissected terrace deposits in the south, which have been rounded by erosion into low-lying hills similar to those in the north; and flat-lying alluvial deposits in the area between Catahoula Lake and Jonesville. The major stream valleys have been alluviated and form flat-lying areas within the hilly land in the north and within the terrace deposits in the south.

The highest point in the basin, which is also the highest point in the State, is 535 feet above mean sea level at Driskill Mountain on the northwest boundary of the basin in Bienville Parish. The lowest point is about 35 feet above mean sea level, where the Little

River discharges from Catahoula Lake. Although the maximum relief in the basin is 500 feet, maximum local relief is only about 300 feet, and in most of the area local relief is less than 100 feet. The flat-lying areas have relief of 40 feet or less.

The Little River is formed by the confluence of Castor Creek and the Dugdemona River near Rochelle (pl. 2). Castor Creek, about 90 miles long, and the Dugdemona River, about 120 miles long, each drains approximately one-third of the Little River basin. The Little River flows into Catahoula Lake about 60 miles downstream from Rochelle. The surface area of the lake is approximately 33,000 acres at a stage of 36 feet above mean sea level. (The State owns the lakebed area at altitudes of less than 36 feet above mean sea level.) During low-flow periods when the lakebed is dry, the lake is little more than a continuation of the Little River. Outflow from the lake is principally through the Old River and the French Fork Little River which join downstream and flow into the Black River near Jonesville. Because of low altitudes southeast of Catahoula Lake, interchange of flow occurs between the Little River basin and adjoining drainage basins. Consequently, the drainage area downstream from Catahoula Lake cannot be determined.

The principal tributaries of the Little River between Rochelle and Catahoula Lake include Bayou Funny Louis, Fish Creek, Trout Creek, and Big Creek. In addition, Devils Creek, Hemphill Creek, and several smaller streams drain directly into Catahoula Lake from the north; Flagon Bayou flows into the lake from the southwest.

WATER USE

Approximately 23 mgd (million gallons per day) of water from the Little River basin is used for industrial, municipal, and rural supplies. About 20 mgd is obtained from ground-water sources; the remainder from streams, ponds, and small impoundments. Much of the water is discharged to streams after use, but its suitability for reuse is impaired.

Paper, lumber, and oil industries use 14 mgd, more than 60 percent of the total water used in the basin. Industrial use is concentrated in the Jonesboro-Hodge area, where 13 mgd is used. Only about 5 percent of the water is consumed; the remainder is discharged to the Dugdemona River.

Municipal water systems serve nearly 50,000 people in the basin. Ground water, which provides about 5 mgd, is used by more than 20 municipal systems, including all of the principal towns. Two systems obtain water from small impoundments. Georgetown obtains about 16,000 gpd (gallons per day) from an impoundment on an unnamed tributary to the Little River; Waterworks District 3, which supplies part of northern Rapides Parish, obtains about 1.4 mgd from Big Creek. Of this amount, however, 50 percent or more is used outside the Little River basin.

Approximately 50 percent of the 2.4 mgd used for rural supplies is ground water. This water is used in homes; whereas that obtained from surface sources, is used primarily for stock-watering purposes.

A summary of water use in the Little River basin is shown in the following table:

Use (1965)	Surface water (mgd)	Ground water (mgd)	Total (mgd)
Industrial	1.0	13	14
Municipal	1.4	5.2	6.6
Rural:			
Homes	0	1.0	1.0
Stock	1.1	.3	1.4
Total	3.5	19.5	23.0

HYDROLOGIC ZONES

The Little River basin is divided into three hydrologic zones (pl. 1) based on the surface geology, the occurrence of fresh water in the aquifers within each zone, and the low-flow characteristics of streams. Although the average flow of streams throughout the basin is about 1.0 cfs per sq mi of drainage area (0.65 mgd), the low flow of streams per unit area varies significantly from zone to zone. The three seepage investigations (table 1) made during this study helped to define the low-flow characteristics of the streams and to establish the zones.

Zone A (pl. 1), the northern three-fifths of the basin, is the outcrop area of the Sparta Sand, the Cook Mountain Formation, and the Cockfield Formation. Terrace and alluvial deposits cover parts of the outcrop area. The Sparta Sand and the Cockfield Formation, the two most important aquifers in the zone, discharge only small quantities of water to the streams. Streams in zone A, therefore, have very little or no sustained low flow. Within the basin the Wilcox and the Sparta contain fresh water only in zone A.

The Jackson and Vicksburg Groups crop out in zone B in the south-central part of the basin. Thin terrace or alluvial deposits cover parts of the outcrop as in zone A. Most tributaries to the Little River are dry during low-flow periods because ground-water discharge is too low to sustain streamflow. In addition, zone B generally lacks fresh ground water, although fresh-water-bearing sands of the Cockfield underlie small areas of the zone.

Much of zone C, the part of the basin south of the outcrop of the Vicksburg (pl. 1), is covered with terrace deposits or alluvial deposits of Pleistocene age. Deposits of Miocene age crop out or occur at shallow depths in the zone. The terrace and alluvial deposits discharge relatively large amounts of water to the streams. As a result, low flow in the Little River increases through the zone. Tributary streams, including those flowing directly into Catahoula Lake from the north, have highly sustained flows. Each geologic unit that contains fresh water in zone C is the most important source of ground water in some specific part of the zone, but none is an important source of water in all parts of the zone.

ZONE A

STREAMS

The principal streams in zone A (pl. 2) are Castor Creek and the Dugdemona River. The average flow of Castor Creek and the Dugdemona River near their confluence is estimated to be 640 and 630 mgd (990 and 975 cfs), respectively. This quantity of water (about 60 times the amount being used in the entire basin) is sufficient to supply all anticipated needs, but it is not available when or where it is needed. Low flows of streams in the zone are poorly sustained, and the streams cannot supply significant quantities of water without storage. In fact, most tributaries to Castor Creek and the Dugdemona River are dry at some time during the year.

Because water-supply and water-quality problems usually are more critical during drought periods, knowledge of low flows is important to water planners. Streamflow characteristics in zone A, which should be considered by water planners, include:

1. Flow equal to or greater than the average flow can be expected to occur only about 25 percent of the days each year. Smaller volumes of water will be available the remainder of the days, as shown in the following tabulation:

Percentage of days that specified flow was equaled or exceeded	*Castor Creek at Tullos (mgd, estimated)*	*Dugdemona River near Winnfield (mgd)*
10	---	1,230
25	580 (average flow)	486 (average flow)
50	110	97
90	6	4

2. Castor Creek and the Dugdemona River were dry for an extended period in 1954. Castor Creek, which has had no flow at some time during each of 16 years of the 26-year period of record, was dry for 183 consecutive days in 1954. In the same year, the Dugdemona River was dry for 90 consecutive days but has been dry in only 2 other years. Most tributaries to these streams are dry for varying periods each year.

3. The amounts of water available from Castor Creek at Tullos and the Dugdemona River near Winnfield during low-flow periods are sufficient only for small development or nonconsumptive uses, as shown by the following summary:

Percent chance of occurrence in any year	*Lowest average flow for 7 consecutive days (mgd)*	
	Castor Creek	*Dugdemona River*
50	5.4	3.1
10	.65	.3
5	.3	.1

There is a 50-percent chance that the average flow of Castor Creek for 7 consecutive days[1] will be as low as 5.4 mgd in any year and a 10-percent chance that the flow will be as low as 0.65 mgd. Minimum flows for longer periods of time and their percent chance of occurrence for the Dugdemona River near Winnfield are listed in the following table.

Summary of low-flow information for the Dugdemona River near Winnfield

Consecutive days	Lowest flow, in million gallons per day, for indicated percent chances of occurrence				
	95	50	20	10	5
7	23	3.1	0.8	0.3	0.1
15	30	4.1	1.0	.5	.2
30	46	5.8	1.5	.6	.3
60	97	9.0	2.4	1.1	.5
90	162	14	3.7	1.8	.9
120	297	19	5.4	2.8	1.4
150	413	28	7.8	3.9	2.1
183	607	41	9.7	5.0	2.7
274	1,150	149	34	23	19

The ratio of the discharge of a stream to drainage area, expressed in cubic feet per second per square mile, can be used to estimate the low flow at ungaged sites. If the ratio is assumed to be constant for a reach of the stream, the discharge at an unmeasured site can be estimated by multiplying the ratio by the drainage area at that point. In zone A these ratios are not constant for the Dugdemona River or Castor Creek. Conservative estimates of discharge for ungaged sites on these streams are made by using the smaller ratio applicable to that particular reach of the stream.

The yield of Castor Creek during low flow decreases from 0.002 cfs per sq mi to 0.001 cfs per sq mi between Chatham and Grayson because most of the tributaries in this part of zone A are dry during low-flow periods, and the stream is flowing over noncontribut-

[1] The lowest average flow for 7 consecutive days occurring at an average interval of 2 years is the 7-day, 2-year flow. There is a 50-percent chance that the average flow for 7 conscutive days will be at least as low as indicated. A summary of 7-day, 2-year flows for selected streams in the basin is listed on plate 2.

ing and low-contributing deposits. The drainage area of Castor Creek increases greatly without a corresponding increase in flow, and as a result, the yield per square mile is reduced. As the yields are not uniform in this reach of Castor Creek, conservative estimates of low flow at points between Chatham and Grayson can be made using the smaller yield figure. Between Grayson and Tullos the yield of Castor Creek increases from 0.001 to 0.009 cfs per sq mi. Although the low-flow yield varies from place to place on Castor Creek and decreases in one downstream interval, the 7-day, 2-year flow increases from about 0.1 mgd at Chatham to 0.2 mgd at Grayson to 5.4 mgd at Tullos.

The yield per square mile of the Dugdemona River during periods of low flow also decreases slightly in one reach. At Quitman the yield is 0.01 cfs per sq mi, whereas at Winnfield it is 0.007 cfs per sq mi. The low-flow regimen of the Dugdemona River in this reach is not natural because flow is controlled by small temporary dams at times during dry periods. In addition, large amounts of ground water are added to the river by industry at Hodge. The 7-day, 2-year flow for the Dugdemona River is 1.1 mgd at Quitman, 2.3 mgd at Jonesboro, 3.1 mgd at Winnfield, and 5.2 mgd at Tullos.

Most tributaries to Castor Creek and the Dugdemona River have a 7-day, 2-year flow of zero. The 7-day, 2-year flow of Garrett Creek, a tributary, which has the largest low-flow yield, is only 10,000 gpd at Jonesboro. Obviously, these streams cannot supply large amounts of water throughout the year without storage.

AQUIFERS

Wilcox Group.—The area where the Wilcox Group contains fresh water in the Little River basin lies entirely within Bienville Parish in parts of Tps. 14 and 158 N., Rs. 5 and 6 W. Sands in the unit are generally fine to very fine grained, lignitic, and often silty. Because no water wells are completed in the Wilcox in the basin, fresh-water-bearing sands in the Wilcox were identified by interpretations of electrical logs of oil-test holes.

Permeabilities of Wilcox sands in northwestern Louisiana range from about 50 to 250 gpd per sq ft (gallons per day per square foot) and average about 100 gpd per sq ft. These values are lower than those in most other Tertiary sands in Louisiana. Permeability values were obtained from three tests in the Wilcox at Saline in Bienville Parish, only a short distance beyond the basin boundary. These tests were on temporary wells screened only in part of the sand, and the wells were probably poorly developed; so test values may not be entirely reliable. However, the permeability values are within the range given for the Wilcox.

In sec. 36, T. 15 N., R. 6 W., near the edge of the basin, the thickest sand in the Wilcox is about 55 feet. Fresh-water-bearing sands are 40 feet thick or less in the remainder of the zone. If the range of permeabilities from adjacent areas is applicable to the 50-foot sand, the transmissibility is between 2,500 and 14,000 gpd per foot. A fully efficient well screened in all of the sand could have a specific capacity ranging from about 1 to 7 gpm (gallons per minute) per foot of drawdown. Yields, therefore, could range from 100 to 700 gpm with 100 feet of drawdown, but the lower yields would be more common for the Wilcox. Yields would be proportionally smaller for the thinner sands, under the same conditions.

Sparta Sand.—The Sparta Sand is the largest source of ground water in most of zone A. The unit underlies all of the basin but contains fresh water only in Bienville, Lincoln, and Jackson Parishes; in the northwestern part of Caldwell Parish; and in the northern two-thirds of Winn Parish. The area where the Sparta contains fresh water is illustrated on the map showing the altitude of the base of fresh water (pl. 2).

The sands of the Sparta are generally fine or medium grained, sometimes with interbeds of lignite, and white or gray because quartz grains predominate.

The thickness of individual sands in the Sparta is variable. More than a hundred electrical logs were used to interpret sand thicknesses and percentage in the fresh-water part of the Sparta in zone A. The thickest sand interval ranged from 20 feet at some localities to 300 feet at others. In most of the area, one or two sands were more than 40 feet thick. The percentage of sand in the Sparta ranges from 15 to 90 and averages slightly less than 50 percent.

The great thickness and high percentage of sand in the Sparta result in considerable interconnection of sand beds. Two sands with large vertical separation—perhaps 100 feet or more—at one locality may merge into a sand 200 or 300 feet thick at a nearby locality. In part of zone A the altitude of water levels in wells points out the areas of interconnection. Where interconnection is pronounced, water levels in the upper part of the Sparta are about the same as those in the lower part of the Sparta. In the Winnfield area, however, water levels in the upper part of the Sparta are higher than those in the lower part of the Sparta, indicating that interconnection in this area is poor or perhaps nonexistent.

Water levels in the Sparta Sand have declined as a result of withdrawal of water for industrial, municipal, and domestic use both within and outside the basin. In relatively undeveloped parts of the basin, water levels have declined as much as 80 feet. In areas of large withdrawals, such as Jonesboro-Hodge, water levels have declined as much as 180 feet. Plate 2 illustrates the configuration of the piezometric or pressure surface in 1962. A reconstruction of what the piezometric surface may have been about 1900 is based on data from Veatch (1906). Water movement in 1900 was from the outcrop areas in Bienville, Winn, and Natchitoches Parishes toward areas of discharge in the Mississippi-Red River Valley systems to the east and southeast. Discharge by pumping has significantly lowered the water level in the Jonesboro-Hodge area and has altered the flow pattern. A steep water-level gradient has been established toward the areas of heavy withdrawal, as shown by the cone of depression at Jonesboro-Hodge and Winnfield. The slope of the piezometric (pressure) surface in eastern Winn and Jackson Parishes toward Ouachita Parish is the result of a large elongated cone developed from withdrawals northeast of the basin boundary.

Pumping tests have been made on sands in the Sparta at Ruston, in the Jonesboro-Hodge area, and at some of the small water districts in the basin. Transmissibility values from these tests cover a wide range, which should be expected from the great range in sand thickness. The tests also show a range in permeability values. Payne (1968, p. A5) reported that in many instances the thicker sands generally had higher permeabilities, as confirmed by some of the aquifer tests. Transmissibilities of the thicker sands may exceed 100,000 gpd per ft. In a few instances the thick sands are silty and fine to very fine grained; as a result, the permeabilities may be less than for sands of similar thickness in other parts of the area.

The range of permeability determined from pumping tests is from 100 to 1,200 gpd per sq ft. The transmissibilities for these sands are 7,000 and 120,000 gpd per ft, respectively. Permeability values of the thicker sands generally range from 400 to 750 gpd per sq ft. The coefficient of storage [2] ranged from 0.0001 to 0.00001.

The specific capacity of wells, a function of hydraulic characteristics of the sand and of well construction, ranged from less than 1 gpm per foot of drawdown to 40 gpm per foot of drawdown after pumping 1 day. Based on hydraulic characteristics of the sands alone, wells with specific capacities of 50–60 gpm per foot of drawdown or more should be possible in some of the sands in the Sparta.

Wells yielding about 2,000 gpm have been constructed in the Sparta in the area west of Hodge. At Ruston and Winnfield some wells yield as much as 1,000 gpm. In the few areas where only thin sands occur in the Sparta, only small-capacity wells can be con-

[2] The coefficient of storage of an aquifer represents the volume of water released from or taken into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface.

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structed. In the areas where the unit contains sands 100 to 300 feet thick—even if the low range of permeability values is assumed for the sands—properly constructed and developed wells can yield more than 1,000 gpm. However, because the sands may thin or pinch out in short distances, tests should be made to determine whether or not the yields can be maintained for a long time.

Cockfield Formation.—The Cockfield Formation is a source of fresh ground water in most of zone A east and southeast of the updip limit of the unit (pl. 1). The formation forms the surface material in this area except where the unit is covered by Pleistocene and Holocene deposits (terrace sands or alluvial clays).

Like the Sparta, the sands of the Cockfield are fine grained, often lignitic, and usually gray or white in appearance. Some of the sands are very silty. The dip of the unit is to the east and southeast (pl. 2).

As the southern limit of zone A coincides with the contact between the Cockfield and the overlying Jackson, the full stratigraphic thickness of the Cockfield is not represented in zone A. Only part of the Cockfield at a locality was usually recorded on electrical logs, but almost half of the logs indicate that massive sand intervals more than 50 feet thick occur in the zone. In Caldwell Parish, half of the electrical logs indicated massive sand beds more than 50 feet thick; many of these sands are more than 100 feet thick, and a few are more than 200 feet thick. In Winn Parish the Cockfield sands are highly variable in thickness, ranging from a few feet to more than 100 feet. In Jackson Parish, few of the electrical logs indicated sands in the Cockfield more than 50 feet thick.

Where both the Sparta Sand and the Cockfield Formation contain fresh water, most or all of the sands of the Cockfield are fresh. In parts of zone A the Cockfield is the only source of fresh water (pl. 2). Because the base of fresh water may be in the Sparta at one locality and in the Cockfield at a nearby locality, contour altitudes on the base of fresh water can change abruptly (pl. 2). The deeper parts of the Cockfield become salty in part of the area, and near Tullos all of the unit contains salty water. In two small areas (pl. 2), fresh-water-bearing sands of the Cockfield extend into zone B before the water becomes salty.

The values for the coefficient of permeability determined from testing at a few sites in zone A ranged from 180 to 450 gpd per sq ft. This range of values is about the same as the lower values determined for the Sparta. The coefficient of storage at one location was 0.0004, indicative of an artesian aquifer. Transmissibility values from the tests ranged from 3,300 to 29,000 gpd per ft. The Cockfield contains much thicker sands than those tested; therefore, much higher transmissibility values can be expected for these sands. For example, if a permeability value of 200 gpd per sq ft is assumed for a sand 200 feet thick, the transmissibility is 40,000 gpd per ft. This value is about 30 percent higher than any previously determined in the area. A properly constructed and developed well screened in an artesian sand with a transmissibility of 40,000 gpd per ft should yield 1,000 gpm with a water-level decline of approximately 50 feet after 1 day of pumping or approximately 70 feet after 1 year of pumping. As the thick sands are not areally extensive, continuous pumping probably would result in water-level declines greater than those predicted from data collected during the early part of a test.

One or more sands in the Cockfield are at least 20 feet thick at most localities. If a permeability of 180 gpd per sq ft (transmissibility of 3,600 gpd per ft) is assumed, a properly constructed and developed well in a 20-foot sand should yield about 60 gpm with a water-level decline of about 50 feet after 1 day of pumping. Greater yields can be obtained if permeability or sand thickness, or both, are higher.

Where the Cockfield forms the surface unit in zone A, two sets of water-level conditions occur. In the sands near the surface, water-table conditions exist; that is, the water surface occurs within the sand. These shallow sands are cut by streams, and water in the sands moves toward the streams. Water levels reflect the topography; that is, water levels are higher under the hills than under valleys. At the same locality where water-table conditions occur, artesian conditions occur in deeper sands. Under artesian conditions the water level in wells will rise to some point above the top of the aquifer. Water levels or the piezometric surface in these deeper sands are not affected by local topography as water moves from areas of recharge toward areas of discharge. Contours of the water-level surface of the Cockfield were not constructed because few data were available.

The Cockfield Formation is used principally for small domestic supplies in areas where the underlying Sparta contains fresh water. In the parts of Zone A where the Cockfield is the principal source of ground water, water from the formation is used for municipal supplies. The towns of Urania, Olla, Clarks, Grayson, and Columbia (which is a few miles beyond the Little River basin boundary) obtain water from the Cockfield. Several of the public-supply wells yield more than 300 gpm; the remainder yield from 100 to 300 gpm. A Cockfield well at Chatham in Jackson Parish had a measured yield of 220 gpm. Higher yielding wells can be constructed at some localities.

Terrace deposits and alluvium.—The terrace and alluvial deposits of Pleistocene age (pl. 1) are minor sources of ground water in zone A. These deposits which occur in and along the valleys of the larger streams are generally less than 50 feet thick. Water-yielding materials are primarily silty fine sand. Locally the deposits are composed of silt or clay and are not a source of water.

A few domestic wells and the public-supply wells at Tullos obtain water from the terrace and alluvium deposits near Castor Creek. Many domestic wells go dry during long drought periods. At Tullos the old municipal wells were located in terrace deposits near Castor Creek. The sands are reported to be fine and silty. Well depths range from about 35 to 42 feet, and yields are about 5 to 9 gpm. The wells are spaced closely; thus, water-level declines are excessive and yields have been reduced. Some of the older wells had yields as great as 30 gpm when they were constructed.

The field coefficient of permeability during one recovery test in the Tullos well field was about 50 gpd per sq ft. This is a reasonable value for a fine-grained silty sand. The potential for greater use of the terrace is small, although wider spacing of wells would permit a slight increase in production. In 1968 the town of Tullos drilled two wells near Olla to obtain a water supply from the Cockfield.

SUITABILITY OF WATER

Streams.—Most variability in the quality of water in streams in zone A has been caused by man's activities. Castor Creek, unlike the Dugdemona River, is little affected by development, as illustrated by a comparison of the quality of water from the two streams. Water from both streams is a soft, sodium bicarbonate type; only small changes in the concentration of most chemical constituents occur as the water moves downstream. The quality of water from Castor Creek is good throughout the reach upstream from Chickasaw Creek. The water usually meets the recommended drinking water standards established by the U.S. Public Health Service (1962) and accepted by the State of Louisiana. It has a very low dissolved-solids content, usually less than 100 mg/l (milligrams per liter) and is suitable for most uses after clarification and chlorination. The quality of Dugdemona River water, on the other hand, is seriously affected by the development in the basin. Occasionally the dissolved-solids content of the water exceeds 500 mg/l, the recommended limit for water to be used for public supply, but most of the time, color is the limiting characteristic of this water. Color has been as high as 600 units, giving the water a dark, coffeelike appearance. Although highly colored water of this type is not known to be harmful, it is unacceptable for public supply and many industrial uses and would require extensive color-removal treatment.

In the past the quality of water from streams in the southern part of zone A has been affected by brine disposal. (See section on "Pollution," p. 44.) Streams that have been used for salt-water disposal include Brushy Creek, Big Branch Creek, Chickasaw Creek, and Pope Creek. Tributaries to Castor Creek and the Dugdemona River in the area unaffected by oil-field brine disposal contain water of good quality. Concentrations of chemical constituents are low, and the water is suitable for most uses with minimum treatment.

Wilcox Group.—Chemical-quality data are not available for water from the Wilcox in the small part of zone A where the unit contains fresh water. The quality of water from three test wells (pl. 2) in the Wilcox (Bi–95A,[3] –95B, and –96) in Bienville Parish near the northwest boundary of zone A (table 2) probably is representative of that available from the Wilcox in zone A.

The quality of water from the Wilcox in zone A is not consistent because this area is near the downdip limit of fresh water in the unit. Water from each of the wells was soft and had a low iron content, but concentrations of most chemical constituents varied. The dissolved-solids content of water from two of the wells exceeded the recommended limit of 500 mg/l; the chloride content of water from well Bi–95B was 340 mg/l, exceeding the recommended limit of 250 mg/l. The high concentrations of these constituents would make the water unsuitable for some uses.

In the Wilcox, as in the other geologic units in the area, temperature generally increases with well depth. In shallow wells, temperatures approximate the average annual air temperature (about 68°F, 20°C). In deeper wells the temperature increases at the rate of about 1°F, 0.5°C, for each 100 feet of increase in depth.

Sparta Sand.—The quality of fresh water in the Sparta Sand in zone A is generally good. In most of the area the water is a soft, sodium bicarbonate type. Hardness is usually less than 10 mg/l; iron, usually less than 0.3 mg/l; fluoride, usually less than 1 mg/l; sulfate, usually less than 50 mg/l; and color, usually less than 15

[3] The prefixes Bi, Ca, Ct, G, Ja, La, L, R, and W are used to designate wells in Bienville, Caldwell, Catahoula, Grant, Jackson, La Salle, Lincoln, Rapides, and Winn Parishes, respectively. The prefixes are used in the tables of well records and tables of analyses but are omitted from the well-location map (pl. 2) of this report.

units (table 2). Each of these concentrations, however, is exceeded in some parts of the zone. Hardness of water in the Sparta is as much as 60 mg/l and in one small area southeast of Jonesboro is more than 100 mg/l.

Water with an iron content in excess of 0.3 mg/l is found, for the most part, in or near the outcrop of the Sparta (pl. 1). As water moves downdip in the Sparta, the iron content decreases. West of Jonesboro the water from many wells has a high iron content, whereas at Jonesboro the iron content is variable. In the area east of Jonesboro the iron content usually does not exceed 0.2 mg/l.

Water from several wells screened in the Sparta contains more than 1.7 mg/l of fluoride, which exceeds the recommended drinking water standards. Consequently, drinking water should be tested so that water with excessive fluoride is not used.

The sulfate content of water from the Sparta in zone A is high in an area southeast of Jonesboro. In well Ja–109A the sulfate content was 272 mg/l; in well Ja–112, 813 mg/l. These wells are within a few miles of the Milam salt dome, which appears to affect the occurrence of fresh water (pl. 2). The high sulfate content may be related to circulation of ground water near the faulted zone around the dome. The source of sulfate may be the Cane River Formation, as the sulfate-bearing cap rock of the dome is about 4,000 feet below land surface. The high sulfate water from well Ja–112 was also hard (125 mg/l).

Color is not a widespread problem in the Sparta in zone A. However, Sparta wells near Chatham and Eros and one well in Jonesboro yield water with objectionable color (in excess of 40 units). Otherwise, the quality of the water in these localities is excellent. A few other occurrences of water with excessive color are recorded (table 2).

Cockfield Formation.—Water from the Cockfield Formation in zone A is generally a soft, sodium bicarbonate type, but some water-quality characteristics vary significantly in parts of the zone. Most of the variations are a result of differences in depth and distance from recharge areas.

In the outcrop area the dissolved-solids content is low, generally less than 100 mg/l, and the water is suitable for most uses. Hardness is generally less than 30 mg/l, and color is less than 15 units. The iron content, however, exceeds the recommended limit for water to be used for public supply. Water with an iron content of more than 1.0 mg/l is common in the outcrop area.

The water has a higher dissolved-solids content downdip, as concentrations of sodium, bicarbonate, and chloride generally increase. The chloride content generally does not exceed 30 mg/l and is not a problem in most of zone A. Iron content, which decreases downdip in the formation, is generally less than 0.2 mg/l.

Water from many wells in the southern part of zone A near Olla and Tullos is highly colored; the color of water from several wells in the area was 200 units or more. Although the highly colored fresh ground water in this area is not known to be harmful, it is not considered suitable for most uses without treatment for color removal.

Terrace deposits and alluvium.—The only chemical analysis of water from either the terrace or alluvium in zone A is from well W–32 (table 2) in the Tullos well field. This well is screened in terrace deposits near Castor Creek. Although the water does not contain an excessive amount of iron, water from most wells in the well field is treated to remove iron, which probably results from the corrosive water reacting with the well casings. Concentrations of other constituents in the water were low; the dissolved-solids content was less than 100 mg/l.

Variations in the quality of water from a unit cannot be predicted from one analysis. However, the pH, dissolved solids, and hardness of water from the terrace deposits or the alluvium probably are low in most areas; the iron content probably is variable.

ZONE B

STREAMS

Streams in zone B have high average flows, but flow deficiencies are severe during low-flow periods. All tributaries to the Little River except Bayou Funny Louis usually are dry during parts of each year.

If estimates are based on average flows, both the Little River and Bayou Funny Louis can yield large quantities of water for development. However, the average or greater flow can be expected to occur during only 27 percent of the days in the Little River and 17 percent of the days in Bayou Funny Louis, as shown in the following tabulation:

Percentage of days that specified flow was equaled or exceeded	*Little River near Rochelle (mgd)*	*Bayou Funny Louis at Trout (mgd)*
10	3,680	213
17	------------------	83 (average flow)
27	1,200 (average flow)	------------------
50	290	5.9
90	28	.3

Obviously, only small quantities of water are available during low-flow periods from Bayou Funny Louis, which was dry for 30 consecutive days in 1954. In addition, oil-field brine disposal has affected the flow of the Little River. In 1965 about 10 mgd of brine was discharged to streams in the basin; in 1966 about 5 mgd was discharged. Because of the addition of brine, the natural low flow of the river is less than that indicated by information collected before 1966. A lower figure than 28 mgd should be used for the 90-percent flow. For example, in both 1966 and 1967 the flow was as much as 28 mgd only about 24 percent of the days.

The 7-day, 2-year flow of the Little River near the north boundary of the zone is 17 mgd. Bayou Funny Louis adds about 0.18 mgd to this amount. Consequently, the low flow of the river near the south boundary of zone B is approximately equal to the flow near Rochelle, and the yield per square mile decreases downstream in the zone.

Minimum flows for longer periods of time and their frequency of occurrence for the Little River near Rochelle and Bayou Funny Louis near Trout are listed in the following table.

Summary of low-flow information for two streams in zone B of the Little River basin

Consecutive days	Lowest flow, in million gallons per day, for indicated percent chances of occurrence				
	95	50	20	10	5
			Little River near Rochelle		
7	78	17	9	6.5	5.2
15	94	20	10	7.8	5.8
30	162	23	12	9.0	7.1
60	265	34	15	10	8.4
90	388	44	18	12	9.7
120	549	55	21	15	11
150	808	71	25	18	14
183	1,100	110	32	21	16
274	1,870	465	129	84	68
			Bayou Funny Louis near Trout		
7	1.2	0.18	0.05	0.02	0.01
15	1.6	.24	.07	.03	.01
30	2.1	.35	.10	.05	.02
60	10	.78	.22	.10	.05
90	20	1.2	.39	.20	.10
120	32	1.6	.57	.30	.17
150	52	2.9	.97	.52	.29
183	71	4.3	1.4	.78	.48
274	110	26	12	7.8	4.7

AQUIFERS

Obtaining ground-water supplies is a problem in most of zone B. The Cockfield Formation is a source of supply in a small part of Grand Parish (about 30 or 40 square miles), in northern La Salle Parish (about 100 square miles), and in southern Caldwell Parish (about 40 or 50 square miles (pl. 2). The hydrologic characteristics of the Cockfield as described for zone A apply to zone B. Wells with capacities greater than 100 gpm could be developed in parts of the

Cockfield. In areas where the Cockfield is fresh, it is the most important source of ground water in the zone.

The Jackson Group of Eocene age and the Vicksburg Group of Oligocene age form more than half of the surface outcrop (pl. 1) in zone B. These units are predominantly clay and only yield "seep" water to very shallow wells. Most of these shallow wells go dry during drought periods. Thus, in the parts of zone B where the Vicksburg or Jackson is the surface material and where the Cockfield is salty, dependable supplies of fresh ground water probably cannot be obtained.

In one small area of zone B in T. 9 N., R. 2 E., deposits of Miocene age are exposed at the surface—completely surrounded by surface exposures of the Vicksburg (fig. 2). The Miocene deposits have been downfaulted about 2,600 feet, and fresh water occurs to depths as great as 1,800 feet. This source of fresh ground water is not significant because it occurs only in a 6- or 8-square-mile area in the zone. Large quantities of fresh water (perhaps 150 billion gallons or more) should be available in this small area because some sands are several hundred feet thick. Recharge to the sands probably is minimal; therefore, water probably would be obtained from storage in these sands. Wells have not been constructed in the area, and information is not available on the hydrologic characteristics of the sands. However, high-capacity wells can be constructed. Water-level decline, with use, may limit yields, rate of withdrawal, or the life of a well or well field.

Along some streams, such as the Little River and Bayou Funny Louis, terrace and alluvial deposits of Pleistocene age are of limited areal extent. As in zone A, these deposits are thin, generally less than 40 or 50 feet thick. They are composed of silty very fine sand at some localities; at other localities only a thin layer of clay covers the older Tertiary deposits. Domestic users depend on collection of rainfall in cisterns for their water supply where the sands are inadequate sources of water.

An attempt was made in the 1950's to find ground-water supplies in the terrace and alluvial deposits at Georgetown. Much of the terrace material in that area contained salty water (wells G–152, G–155), and in places where the water was fresh, the sands were thin and very fine grained. As a result, yields would be low, similar to those in the Tullos well field (less than 10 gpm per well. Because the deposits were not adequate to supply economically the needs of the community, a surface-water supply system was installed.

SUITABILITY OF WATER

Streams.—The quality of water from the Little River in zone B is variable. The water, affected by brine disposal in the past, has been unsuitable for most uses for extended periods of time, especially during low flow. Since January 1966, however, the quality of water from the Little River has improved because brine disposal to streams is no longer permitted. (See section on "Pollution," p. 44.)

Bayou Funny Louis has also been affected by oil-field brines. During the time that brine was being released, the chloride content of the water at Trout exceeded 17,000 mg/l during low-flow periods, making the water unsuitable for most uses. In 1967, however, the chloride content had been reduced to less than 175 mg/l at Trout, and further reduction should occur. Additional salty water may enter Bayou Funny Louis downstream from Trout. If pollution abatement measures remain effective, water from Bayou Funny Louis at Trout would be suitable for most uses with minimum treatment.

Water from the Cockfield Formation in the eastern part of zone B near Clarks is similar to that in zone A. The quality of water in this area is good, although color is higher than in zone A. (See table 2, well Ca–55.) In the remainder of the zone, water-quality characteristics, except iron content, vary with location. Iron content is usually less than 0.15 mg/l throughout the zone.

Hard water containing large amounts of sulfate is found near Olla and about 10 miles west of Georgetown. Water of this type probably results from infiltration of some of the water through part of the Jackson Group, which contains sulfate minerals such as gypsum. The hardness of water in these two areas, however, decreases with depth; water in the deeper sands probably has been softened by ion exchange. The sulfate content of water from wells La–122A (146 ft deep) and La–122B (236 ft deep), located at the same site, was high—244 and 199 mg/l, respectively; but hardness decreased from 160 mg/l in the shallow well to 8 mg/l in the deeper well.

Most of the water from the Cockfield in zone B is highly colored. Water with a color in excess of 100 units is commonly found. Water from well La–89 had a color of 800 units; water from well La–86 had a color of 500 units (pl. 2 and table 2). Although this coffeelike color severely limits its usefulness, highly colored water is often used for domestic supplies because no other fresh water is available.

Some water from the Cockfield in zone B contains fluoride in excess of the recommended upper limit. Water from several wells contained more than 2.0 mg/l of fluoride. Fluoride in these amounts may cause mottling of children's teeth; therefore, water from the Cockfield in some areas is unsuitable for human consumption.

The quality of water from two wells screened in the terrace deposits in zone B is variable. Concentrations of all chemical constituents are low (dissolved-solids content was less than 90 mg/l) in water from well La–78, near Jena. The water is corrosive and probably would be active in dissolving iron from steel pipes or well casings. Water from well La–134, in northeastern La Salle Parish, is very hard (220 mg/l) and contains excessive amounts of iron (16 mg/l) and sulfate (212 mg/l). The hardness and sulfate content probably result from contact of the water with the underlying Jackson Group. Because the Jackson or the Vicksburg underlies the terrace and alluvial deposits in zone B, hard high-sulfate water possibly may be found in many parts of the zone.

Many domestic supplies have been obtained from the terrace deposits near Georgetown. In this area, however, some of the water is too salty to use. This salty water may result from oilfield brine disposal because the deposits occur at shallow depths (usually 40 ft or less) and are easily contaminated.

Water-quality information is not available for the alluvium in zone B. Water from well W–32 (table 2), at Tullos, screened in the terrace near Castor Creek, is probably similar to that in the alluvium. Ironstaining from springs discharging from the banks of the Little River indicates that the iron content of water from the alluvium of the Little River in zone B is high.

ZONE C

STREAMS

The estimated average flow of the Little River at its juncture with Catahoula Lake, the farthest downstream point for which a meaningful estimate can be made, is 1,600 mgd. This flow or more can be expected about 25 percent of the days. Big Creek, the largest tributary to the Little River in the zone, has an average flow of 39 mgd. However, this flow or more can be expected to occur only 19 percent of the days. For 50 percent of the days, 19 mgd or less will be available; for 10 percent of the days, 913 mgd or less will be available.

Streams in zone C have better sustained low flow than those in either zone A or zone B; consequently, low flow of the Little River increases in the zone. The 7-day, 2-year flow near Pollock (pl. 2) is

29 mgd, an increase of about 12 mgd between Rochelle in zone B and Pollock. Fish Creek and Trout Creek contribute nearly all of the increase in this reach of the river. Big Creek, which has a 7-day 2-year flow of 12 mgd, empties into the Little River downstream from Pollock. Two other streams, Kitterlin Creek and Clinton Branch, also discharge small amounts of water to the river during low-flow periods. The increasing flow of the Little River through zone C and the importance of the tributaries is illustrated by the following summary of 7-day, 2-year flows:

Location	*Flow (mgd)*
Little River (Rochelle)	17
Fish Creek and Trout Creek	12 (estimated)
Little River (Pollock)	29
Big Creek	13 (estimated)
Little River (inflow to Catahoula Lake)	50–60 (estimated)

In addition, three streams with well sustained low flow discharge directly into Catahoula Lake. The 7-day, 2-year flow of these streams is 1.4 mgd for Devils Creek, 2.8 mgd for Flagon Bayou, and 13 mgd for Hemphill Creek. Although the 7-day, 2-year flow downstream from Catahoula Lake could not be computed, the lowest discharge measured at Archie (pl. 2) for the three seepage investigations was 55 cfs, which would be equivalent to 35 mgd if this rate of flow were sustained for the entire day.

With the exception of Flagon Bayou, tributaries to the Little River or Catahoula Lake with drainage areas greater than 10 square miles have low-flow yields of approximately 0.2–0.5 cfs per sq mi. In contrast, the yields of nearly all of the streams in zone A are less than 0.01 cfs per sq mi, and most tributaries to the Little River in zone B are dry during low-flow periods.

AQUIFERS

Deposits of Miocene age.—Deposits of Miocene age underlie all of zone C and are a source of fresh ground water in most of the zone. Two units of the Miocene supply fresh water in parts of the area. The lowermost unit, the Catahoula Formation, underlies all of zone B. In northern Rapides and southern Grant Parishes, fresh water is obtained from deposits equivalent to the Carnahan Bayou Member (Fisk, 1940) of the Fleming Formation as used by Rogers and Calandro (1965) and Newcome and Sloss (1966). East of the juncture of the Little River with Catahoula Lake, the south boundary of the basin trends northeastward. As a result, little if any of the Carnahan Bayou Member is represented in this part of the basin. Most of the Miocene units are covered by terrace deposits of Pleistocene age (pl. 1); thus the boundary between units is not easily found.

Sand beds of both the Catahoula and the Carnahan Bayou Member (Fisk, 1940) are generally white or gray medium to very fine sand. Some of the sand beds are coarse grained and contain small amounts of fine chert gravel. The beds dip south and southeast at rates of 40–100 feet per mile. Sand beds exposed at the surface about 8 miles north of Pollock occur at depths of about 1,000 feet near the Grant-Rapides Parish boundary south of Pollock (pl. 1).

The occurrence of fresh water in the deposits of Miocene age is varied. Near the updip limit of the Catahoula all of the sands contain fresh water. However, a few miles downdip to the south, the basal sand of the Catahoula contains salty water. Near the Rapides-Grant Parish boundary south of Pollock, the lower half of the Catahoula is salty. A few miles farther south the entire unit is salty.

The base of fresh water is high beneath the Little River (pl. 2), probably the result of ground-water movement from the Miocene deposits into the river. This "salt-water ridge" extends southward across the southwest tip of Catahoula Lake, along what may be an old course of the Little River. All of the Catahoula contains salty water along this ridge, and most of the overlying Carnahan Bayou Member is salty. The base of fresh water becomes much deeper east of the Little River (pl. 2). The Catahoula contains fresh water to depths greater than 700 feet beneath parts of Catahoula Lake and near Jonesville. Beneath Catahoula Lake a number of sands contain fresh water, but near Jonesville only one or two sands are sources of supply. Near Jonesville, sands between the base of the alluvium and the fresh parts of the Catahoula contain salty water.

Aquifer tests within the basin and nearby tests in younger Miocene deposits similar to those in the basin indicate that the lower limit of permeability for the Catahoula sands is approximately 200 gpd per sq ft. Uniform coarse-grained sands in parts of the Catahoula indicate that permeability values as high as 500 or 1,000 gpd per sq ft are possible. A properly constructed and developed well in a 50-foot artesian sand of the Catahoula having a permeability as low as 200 gpd per sq ft would yield 250 gpm, with a drawdown of approximately 50 feet at the end of 1 day.

Near the updip limit of the Catahoula the sand is at shallow depths and in places is saturated in only the lower few feet. Thus, only relatively small yields are possible in these areas.

Farther south the sands are deeper and contain water under artesian pressure. Thus greater yields are possible. At well R–878B (T. 5 N., R. 1 E., pl. 2) the Catahoula contains a virtually undeveloped 56-foot-thick sand. A well yielding 500 gpm or more probably could be constructed at this site. At Alexandria the sand contains salty water. Tests of the Catahoula in T. 8 N., R. 5 E., indicate two sands suitable for development of wells having capacities of 200 gpm or more.

Northern Rapides and southern Grant Parishes are the only parts of the Little River basin where fresh water can be obtained from the Carnahan Bayou Member. During World War II, 16 wells were drilled into the Carnahan Bayou at Camp Livingston, some in Grant Parish, and others in Rapides Parish. Total yield was 2,500 gpm in July 1941. Three months later only 11 wells were pumped, and the yield was 2,400 gpm. Close spacing resulted in excessive interference between the wells (Maher, 1942). Individual wells yielded as much as 350 gpm, but most of the wells yielded about 150 gpm, considerably less than the potential of the sands that were developed. Yields of wells owned by several State institutions are reported to be as much as 500 gpm. Wells with similar yields could be constructed in parts of the Carnahan Bayou in southern Grant and northern Rapides Parishes.

Permeabilities of the sand beds of the Carnahan Bayou at Alexandria, 3–4 miles south of the basin, range from 200 to 1,200 gpd per sq ft and average about 400 to 500 gpd per sq ft. Most of the wells tested yielded between 250 and 800 gpm. A new well in Kisatchie Forest about 12 miles from Alexandria produces 1,100 gpm. Because of the wide range in permeability and transmissibility values in the Carnahan Bayou, these hydrologic characteristics should be determined at potential well sites to aid in design of large-capacity wells.

Water-level data are sparse for Miocene aquifers in the Little River basin, but recent tests have provided some water-level data for the Catahoula (pl. 2). In the area near Sandy Lake, about 6 miles northwest of Jonesville, test wells Ct–38A, –38B, –39A, and –39B, drilled into the Catahoula had water levels 6 to 20 feet above land surface. Deep wells near Jonesville also had water levels a few feet above land surface. Surface altitudes in these areas are about 45 to 55 feet. At a test in northern Rapides Parish the water level in well R–876B in the Catahoula was 92 feet below land surface. At the same location the water level in well R–876A in the Carnahan Bayou Member was 170 feet below land surface. The water level in the Carnahan Bayou was affected by pumping at Alexandria and Pineville, whereas the water level in the Catahoula was not. At another site about 5 miles to the east, the water level in the Catahoula (well R–878B) was 99 feet below land surface, and that in the Carnahan Bayou (well R–878A) was 53 feet below land surface. Well R–878A is screened in a sand 280 feet below land surface. The high water level in the Carnahan Bayou at this location indicates that this sand probably is not connected with those sands used at Alexandria. A few miles to the south of well R–878A, the water level in well R–877 (779 ft deep) in the Carnahan Bayou was 281 feet below land surface. Because of these differences in water level, it is impossible to make a logical water-level map of the Miocene incorporating all of the sands. Insufficient data are available for specific sand intervals to construct meaningful water-level maps.

During World War II, water-level declines at Camp Livingston were greater than anticipated (Maher, 1942). Increased water use at Alexandria also resulted in alarming declines in water levels. Because of possible interference between the pumping at Camp Livingston and at Alexandria and because of the decline in total yield of the Camp Livingston wells, the Army installed a surface-water supply using water from Big Creek near Pollock. All of the camp wells were abandoned. The Camp Livingston surface-water supply is now owned by Waterworks District 3, which supplies water to the area north and east of Pineville.

Terrace deposits.—The terrace deposits of Pleistocene age, which form the surface material over much of zone C (pl. 1), are an important source of ground water in the zone. Unlike the terrace deposits in zones A and B, which are composed of silty fine sand, the deposits in zone C generally consist of clay at the surface underlain by sand and gravel. The terrace deposits range greatly in thickness; they are as much as 100 feet thick in places. Streams cut partially or completely through the unit. The flow of Big Creek, Hemphill Creek, and several other streams in the area during low-flow periods is sustained by ground-water outflow from the terrace deposits. A small amount of this flow may be supplied by the underlying Miocene deposits.

Hydrologic characteristics of the terrace deposits at Trout have been determined. The coefficient of storage was 0.23, which indicates water-table conditions at the test site. In other parts of the area, artesian conditions occur. Transmissibility was 60,000 gpd per ft, and permeability was about 1,600 gpd per sq ft. The permeability value is probably between the mean and the maximum for the terrace deposits. If the hydrologic characteristics from the test at Trout are assumed for a sand and gravel interval that has 60 feet of saturated thickness, wells could be constructed with specific capacities of about 50 gpm per foot of drawdown, in which yields of 500 gpm or more could easily be obtained. A test well at Camp Livingston yielded 401 gpm with 8 feet of drawdown after 72 hours of continuous pumping. The specific capacity was 50 gpm per foot of drawdown. A saturated thickness of 60 feet is not common in the aquifer because drainage to streams reduces the saturated thickness in many places. Thus, well yields of 100 to 200 gpm are more reasonable for much of the area.

At Pollock the municipal well, screened in the terrace material, was test pumped at 90 gpm in 1962. The static water level in this 42-foot well was at 24 feet below land surface. The well at Trout yields 120 gpm; the municipal wells at Jena yield as much as 200 gpm. Because demand is small and the yields adequate in most places, many domestic wells in Grant and La Salle Parishes are completed in the terrace deposits. Yields of more than 100 gpm should be possible by careful selection of well locations. In the Nebo area some well owners report that salty water is obtained from shallow wells.

Because water-level data were too sparse, a regional water-level map for the terrace deposits was not constructed. Water movement in the deposits is toward the streams; therefore, water levels are at lower elevations at the streams than in interstream areas. When land surface is used as the reference point, however, the depth to water in wells near streams is generally much less than in interstream areas.

Alluvium.—Like the terrace deposits, the alluvial deposits of Pleistocene age are an important source of ground water in parts of zone C. About 100 square miles in Catahoula and La Salle Parishes are underlain by a thick section of alluvium (pl. 1). The alluvium thins near the surface contact with deposits of Miocene age (pl. 1). At Jonesville the base of the alluvium is about 115 feet below land surface; at well Ct–38, to the northwest about 6 miles, the base of the alluvium is only 52 feet below land surface.

The alluvium generally consists of silt or clay grading downward into fine sand, coarse sand, then sand and gravel. The alluvium around Catahoula Lake and Jonesville is related to the Mississippi-Ouachita River system. Other alluvium in zone C along the Little River and Big Creek (pl. 1) is derived mainly from older Tertiary deposits and is composed mostly of silty fine sand similar to the alluvial deposits in zones A and B. In places the terrace deposits may have served as source for part of these alluvial deposits. Where this has happened, coarse sand or gravel may be included in the alluvium. In parts of the area northwest of Catahoula Lake the alluvium of streams that cut only part way through the terrace may be surficial sand and clay, and the deeper gravel may be the uneroded part of the terrace deposit.

Hydrologic characteristics of the alluvium in zone C have not been determined. Where similar deposits outside the basin have been tested, the coarse sand and gravel have permeabilities of 1,000–2,000 gpd per sq ft, or more. One of the wells at Jonesville was test pumped at 500 gpm. The fine, silty alluvial sand along parts of the Little River probably has hydrologic characteristics similar to that at the test site in Tullos, discussed earlier in the section on zone A.

Water levels in the alluvium, generally within about 20 feet of land surface, respond to stream stage and to rainfall. Near streams, seasonal water-level fluctuations may be great; whereas some distance from streams, fluctuations may be a few feet or less.

SUITABILITY OF WATER

Streams.—The quality of water from the Little River in zone C and from Catahoula Lake have improved since the pollution abatement measures were put into effect. (See section Pollution). Because much of the inflow to Catahoula Lake is from the Little River, the quality of water from the lake and the river is about the same. Tributaries to the Little River and Catahoula Lake in zone C, with few exceptions, contain water that has a very low dissolved-solids content, usually less than 50 mg/l. Concentrations of all chemical constituents are low; however, the water from streams in zone C requires treatment to remove color and turbidity.

Trout Creek and several streams in the Nebo area (pl. 2) contain water of variable quality because they have been affected by brine disposal. Water from these streams has a high chloride content during low flow and is, therefore, unsuitable for many uses.

Catahoula Formation.—The quality of fresh water from the Catahoula Formation generally is very good. The dissolved-solids content generally is low, and the water is suitable for most uses. However, water with a high iron content is found in some sands. At well G–220 (table 2), which is 125 feet deep, the iron content was 5.3 mg/l. From most of the deeper wells it usually was less than 0.3 mg/l. At well R–876B (1,039 ft deep) water from the Catahoula contained 0.12 mg/l iron. The fresh water from the Catahoula at well Ct–41 (617 ft deep), near Jonesville, had an iron content of 0.43 mg/l.

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About 6 miles northwest of Jonesville, water in the shallow and deeper Catahoula sands was tested at two localities. The water from well Ct–38A (pl. 2), 300 feet deep, had an iron content of 0.5 mg/l; whereas the water from well Ct–38B, 478 feet deep, had an iron content of 0.04 mg/l. The iron content of water from well Ct–39A, 352 feet deep, was 0.8 mg/l and from well Ct–39B, 520 feet deep, was 0.03 mg/l. Dissolved-solids content was low, but water in the deeper sands at the localities tested had dissolved solids about three times as great as in water in the shallow sands (table 2). Fluoride content did not exceed the recommended limit in water from any of the Catahoula wells.

Carnahan Bayou Member (Fisk, 1940), Fleming Formation.—The Carnahan Bayou Member contains fresh water in the Little River basin near the Rapides-Grant Parish line north of Pineville. The water is soft and generally has a dissolved-solids content less than 500 mg/l. Water from most wells has an iron content less than 0.3 mg/l. The water is a sodium bicarbonate type suitable for public supply and most industrial uses. Water from wells R–876A and –878A is typical of water from the Carnahan Bayou (table 2).

Terrace deposits.—Few quality-of-water data are available for the terrace deposits in zone C. However, water from the terrace deposits at Jena and Pollock is probably representative of water from zone C. The water is soft, has a very low dissolved-solids content, and is suitable for most uses without treatment. Water from well La–129 (table 2) had the highest dissolved-solids content, 139 mg/l. The iron content of water from all wells was less than 0.10 mg/l, and the color was generally less than 15 units.

Alluvium.—Water-quality data were not collected from the alluvium of the Little River, but field observations indicate that much of the water is hard and has a high iron content. In a few localities, however, well owners report no excessive iron concentrations.

Water from well Ct–47 in the alluvium of the Ouachita-Black Rivers at Jonesville is very hard (312 mg/l) and has a high iron content (8.9 mg/l). (See table 2). The water also would require treatment to remove color to make it suitable for public supply. The water is similar to that obtained from the alluvium in nearby parishes; therefore, it probably is representative of water from the alluvium in all of the Catahoula Lake-Jonesville area.

WATER CONDITIONS AT POPULATION CENTERS

Although the Little River basin is mostly rural, development at several localities is significant. Localities that probably have the most growth potential in the basin include Ruston, Jonesboro-Hodge, Winnfield, the Tullos-Urania-Olla area, and the Jena-Jonesville-Catahoula Lake area. The following sections of this report (1) summarize the water conditions at these population centers, (2) provide detailed ground-water information for each area, and (3) provide estimates of the amount of water obtainable if impoundments were constructed, although surface-water supplies are not currently used.

RUSTON

The principal source of water at Ruston is the Sparta Sand. Wells screened in the Sparta yield as much as 1,180 gpm, and additional wells of similar yield can be constructed in the area. Water from the Sparta in the area is a soft, sodium bicarbonate type and suitable for municipal use without treatment. Some ground-water supplies are available from the Cockfield Formation. Wells screened in this unit probably would yield 100 gpm or less. Water from the Cockfield in the area is generally corrosive and contains objectionable quantities of iron. As no large streams cross the Ruston area, any surface-water supplies must come from outside the basin from such places as Lake D'Arbonne or Lake Claiborne, about 20 miles northeast and northwest of Ruston, respectively.

The fence diagram of the Ruston area (pl. 3) shows the general subsurface picture of the area. Examination of electrical logs of 11 water wells in and near Ruston indicates that one or more Sparta sands at each site are at least 50 feet thick. In five wells the sands are more than 100 feet thick, and in one well the sand is more than 190 feet thick. The sands in the Sparta probably are interconnected in this area. Water levels in the lower part of the Sparta are nearly the same as those in the upper part of the Sparta, although most of the water is produced from the middle and lower sands of the unit.

The hydrologic characteristics of the Sparta Sand, determined at three localities at Ruston and at one location at Grambling, are shown in the following table.

Well	Sand thickness (ft)	Transmissibility (gpd per ft)	Permeability (gpd per sq ft)	Specific capacity (gpm per foot of drawdown after pumping 1 day)	Yield (gpm)
		Ruston			
L–48	110	100,000	900	33	1,180
L–61	50	21,000	400	5.3	421
L–106	67	7,000	100	3.1	430
		Grambling			
L–102	105	37,000	350	9.6	488

Well L–48, which had the highest values for transmissibility and permeability, is approximately 100 percent efficient; thus, it also has a very high specific capacity. By contrast, the permeability value at well L–106 was much lower than typical values for the Sparta in northern Louisiana.

The wide range of transmissibilities in the area also is illustrated by the differences in the specific capacities of the various wells, although part of the difference can be attributed to well construction. Specific capacities of production wells range from about 3 to 40 gpm per foot of drawdown. Because hydrologic characteristics differ, well design should be tailored to the site to be developed.

Water levels are about 300 feet below land surface in parts of the Ruston area, a decline of about 140 feet since 1900, partly from effects of local pumping and partly from the regional effect of pumping by industries. Additional water-level decline will result from the construction of additional wells. The effect of each added well can be determined by constructing time-drawdown or distance-drawdown plots based on the hydrologic characteristics determined by testing the well and aquifer. For example, assume that a 50-foot sand has an average permeability of 350 gpd per sq ft and a transmissibility of 17,500 gpd per ft. As the sands are artesian, the coefficient of storage will be about 0.0001. The water-level decline with time and distance from pumping this well at a continuous rate of 500 gpm is shown in figure 2. The declines at any pumping rate can be estimated from the figure, as water-level decline is proportional to the rate of pumping. The effects of pumping each well in a sand are additive at each site. Thus, where practical, wells should be widely spaced to reduce the amount of interference between them.

Analysis of potential well-field effects should include consideration for long-term regional water-level decline in addition to interference for short periods of time. Continued lowering of water levels at Ruston will result in increased pumping costs. However, from the economic viewpoint this is a small item, compared to the cost of obtaining water from alternate sources. Because of pumping in the area, water levels have been lowered to very near the top of the Sparta. As a result, the upper sand of the Sparta cannot be used for high-capacity wells. With continued water-level decline, the upper part of the Sparta will be dewatered. At nearly all localities, deeper sands in the Sparta are available for development.

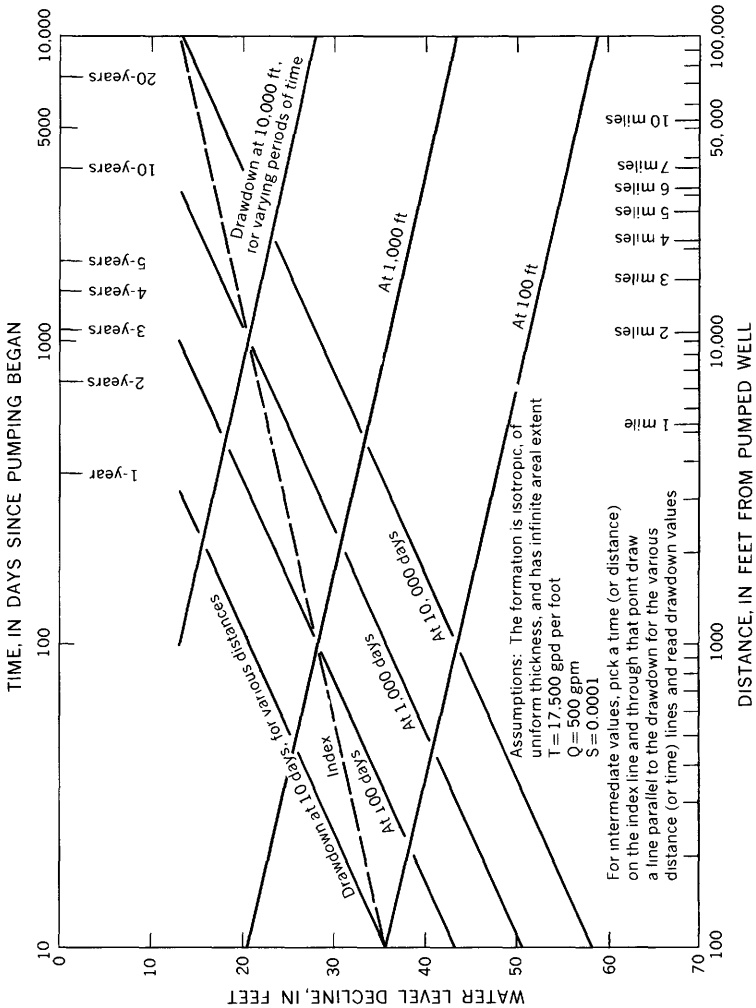

FIGURE 2.—Water-level decline caused by pumping a well screened in the Sparta Sand.

JONESBORO-HODGE

The Sparta Sand is the only source of large ground-water supplies in the Jonesboro-Hodge area. Wells in the Hodge industrial area yield from 500 to 2,100 gpm, although the best municipal well yields only 550 gpm. Water from the Sparta in the area is suitable for most uses without treatment, although the iron content of water from some wells exceeds the recommended public-supply limit.

The fence diagram of the area (pl. 3) shows the general subsurface setting and illustrates the variable sand thicknesses at different localities. In some test holes, 200 to 400 feet of sand was logged in the Sparta between depths of 100 and 500 feet. At other test sites the greatest thickness of individual sand beds was no more than 35 feet.

Beneath the Jonesboro area the sands are generally 60 to 80 feet thick, or less. Yields of wells are lower, in general, than those in the industrial area. Differing yields are a result of differences in hydrologic characteristics and in well design. Tests of the hydrologic characteristics of the Sparta Sand at selected sites in the Jonesboro-Hodge area are summarized in the following table. The highest transmissibility value shown, at well Bi–48,

Well	Sand thickness (ft)	Transmissibility (gpd per ft)	Permeability (gpd per sq ft)	Storage coefficient	Specific capacity (gpm per foot of drawdown after pumping 1 day)	Yield (gpm)
Ja–25	126	41,000	330	1.5×10^{-5}	---	500
43	60	22,000	330	7.3×10^{-5}	---	216
90	60	7,400	120	--------	---	48
91	58	17,000	290	7.6×10^{-5}	6.8	164
106	73	16,000	220	--------	6.6	316
109B	40	11,000	270	--------	1.7	42
139	75	29,000	400	--------	9.0	503
Bi–48	153–200(?)	120,000	780	4.7×10^{-4}	34	2,100

probably is not as high as that of the best sands in the area. Permeability values average about 300 gpd per sq ft for the thinner sands of the Sparta in the Jonesboro area. Electrical logs of wells in the Jonesboro area indicate the presence of thick sandy zones in the Sparta that are presently not utilized locally for wells. Additional large quantities of water probably can be developed in these zones. Low water levels in the area permit construction of only small-capacity wells in the upper part of the Sparta. Wells with higher capacities can be constructed in the deeper sands.

Water levels have declined about 180 feet in the Jonesboro area since 1900. Much of the lowering of water levels has been caused by industrial pumpage in the area. Pumpage from additional wells will result in increased lowering of water levels. Sands to the east of Jonesboro occur at greater depths than those at Jonesboro. Thus, more drawdown (water-level lowering) will be possible for wells developed in this area.

If the quality of water from the Dugdemona River were improved, the river could be an important source of supply. Low flow of the Dugdemona provides only minimal amounts of water, but storage could supply as much as 32 mgd. The following table illustrates storage needed to supply specified draft rates if impoundments were constructed near Quitman or Jonesboro.

Estimated water-storage requirements for the Dugdemona River near Quitman and near Jonesboro

[Storage estimates have not been corrected for evaporation, which presumably would be largely offset by rainfall, and it is assumed that seepage losses would be minimal]

Draft rate		Acre-feet of storage required			
		Near Quitman		Near Jonesboro	
Cubic feet per second	Million gallons per day	10-percent chance of deficiency	5-percent chance of deficiency	10-percent chance of deficiency	5-percent chance of deficiency
10	6.5	1,100	1,300	900	1,100
20	13	3,000	3,200	2,200	2,600
50	32	9,800	10,700	7,200	8,000

As shown, there is a 10-percent chance that a draft rate of 6.5 mgd at Jonesboro could not be supplied in any year, even with 900 acre-feet of storage; a 5-percent chance that the same draft rate could not be supplied with 1,100 acre-feet of storage. Higher draft rates than about 32 mgd (50 cfs) are not considered practical because of the inadequacy of potential storage sites.

WINNFIELD

Ground-water supplies can be obtained from the Sparta Sand and the Cockfield Formation in the Winnfield area. Yields ranging from 160 to 1,000 gpm can be obtained from the Sparta northeast of Winnfield; yields of 200 gpm or more can be obtained from the thickest sands of the Cockfield. The quality of water from both aquifers is generally good, but water from the Cockfield contains objectionable amounts of iron in places.

In general, the sands of the Sparta are thicker than those of the Cockfield in the Winnfield area. However, the Sparta is not a source of fresh water in all of the area. In Winnfield, only the upper 200–300 feet of the Sparta contains fresh water, but this fresh-water interval contains massive sands. A few miles south of Winnfield all the Sparta contains salty water, and the Cockfield is the only large source of ground water. The fence diagram of the area (pl. 3) illustrates the subsurface configuration of the water-bearing units and shows the abrupt changes in the depth of occurrence of fresh water. As in other areas, the sand beds of the Sparta vary in thickness. At well W–28 a massive sand interval is about 240 feet thick, whereas at well W–4 the thickest Sparta Sand is about 40 feet thick. (See pl. 3.) The more massive sands in the area appear to be at Winnfield and to the northeast.

The Cockfield Formation forms the surface or near-surface material at Winnfield. Only the lower 200–300 feet of the unit is present in the area, with sands varying from 20 to 40 feet thick. The Sparta Sand, more than the Cockfield Formation, is a source of large supplies of water because the thicker sand beds can more easily supply the larger quantities, and the iron content of the water is low.

Two tests of the hydrologic characteristics of the Sparta have been made in the Winnfield area. Transmissibilities were 8,000 and 18,000 gpd per ft. The permeabilities were 200 and 600 gpd per sq ft, respectively. Other estimates of transmissibility and permeability were made from specific-capacity data from some wells utilizing methods presented by Meyer (1963, p. 338–340). The estimates of transmissibility ranged from 13,000 to 46,000 gpd per ft, and estimates of permeability ranged from 170 to 640 gpd per sq ft. The specific capacities used for making the estimates ranged from 6.5 to 23 gpm per foot of drawdown. As the specific capacity in wells is less than that calculated from formation constants because of losses in head due to friction, the estimated values for transmissibility and permeability are conservative figures. The Cockfield Formation was not tested, but transmissibilities and permeabilities are probably in the same range as those of the Sparta.

Water levels in the Cockfield probably have not changed appreciably with time because the unit is relatively undeveloped in the area. Water levels in the Sparta Sand, on the other hand, have declined about 60 feet since 1900. Most of this water-level decline is attributed to local pumpage although some regional decline has occurred also.

Two streams in the area, the Dugdemona River and Port de Luce Creek, are potential sources of supply. However, storage facilities will be required because the low flow of the streams is inadequate. Furthermore, the quality of Dugdemona River water must be improved if it is to be used for municipal supply or most industrial purposes. Even if water storage is used, less than 10 mgd can be obtained from Port de Luce Creek.

TULLOS-URANIA-OLLA

Sands of the Cockfield Formation contain fresh water at Urania and Olla. Water from the Cockfield is salty at Tullos, and the only source of fresh ground water is the terrace near Castor Creek and perhaps the alluvium of Castor Creek. Properly constructed and developed wells screening 50 feet of sand of the Cockfield should yield 250 gpm or more. The quality of the water is generally good, but color exceeds 200 units in places. At Olla, where color is presently not a problem in all wells, high pumping rates may move colored water from adjacent areas to a well.

Sand thickness in the Cockfield in the area is variable, ranging from 15 to 130 feet. At many localities the sand beds are 40–60 feet thick.

Two wells in the Cockfield near Olla were tested. The transmissibility at well La–123 was 10,000 gpd per ft, and field coefficient of permeability was 250 gpd per sq ft. At well La–122B, transmissibility was 10,000 gpd per ft, and permeability was about 340 gpd per sq ft. These figures are about the same as those obtained at Clarks, Grayson, and Columbia. The average permeability for the massive Cockfield sands in this area is probably less than 300 gpd per sq ft. The large-capacity wells in the area have yields of 150 to 200 gpm. The yield of these wells is limited by design and not necessarily by the capability of the sand screened.

The terrace near Castor Creek was the source of water for the well field at Tullos. This material is silty fine-grained sand. The field coefficient of permeability is only about 50 gpd per sq ft. Because of the low specific capacities and mutual interference from the close spacing of wells, yields are only about 6 gpm per well. In 1968 Tullos obtained a new public supply from the Cockfield south of Olla.

The potential for future ground-water development in the area is moderately good. Although potential yields are too small for large users of water (such as papermills), a number of small users could obtain water from the Cockfield. Optimum spacing of wells in the Cockfield would be particularly desirable to reduce the effects of mutual water-level lowering between pumping wells. Because only small quantities of water, mainly for domestic or municipal users, have been pumped from the Cockfield in the area, water-level declines have been small—usually pronounced only near production wells.

Surface water is not used for public supply except in the Georgetown area. However, large quantities of water could be obtained from streams if impoundments were constructed. The Little River, Castor Creek, and Chickasaw Creek are potential sources of water in the area. Draft storage curves for selected draft rates are given for the Little River near Rochelle in figure

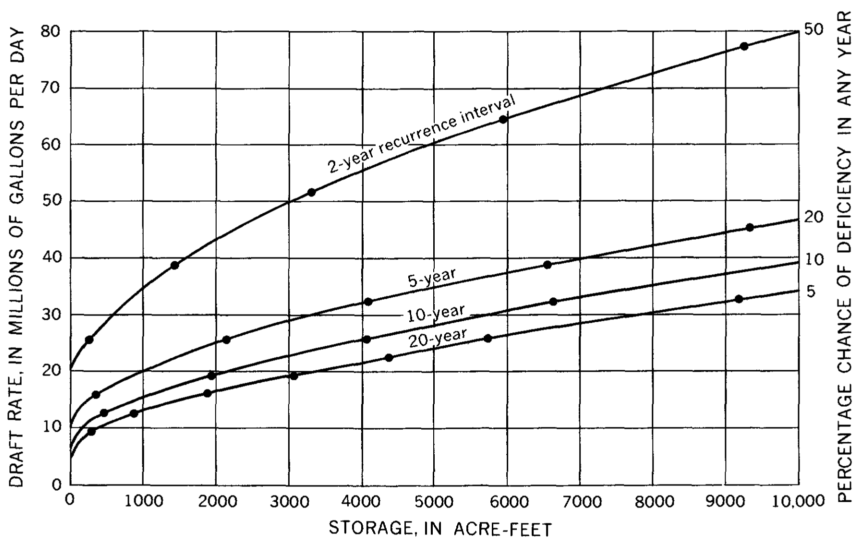

FIGURE 3.—Storage required to supply selected draft rates, Little River near Rochelle.

3. The following table shows the estimated storage required for specified draft rates on the other two streams.

Estimated water-storage requirements for Castor Creek at Tullos and Chickasaw Creek near Urania

[Storage estimates have not been corrected for evaporation, which presumably would be largely offset by rainfall, and it is assumed that seepage losses would be minimal]

Draft rate		Acre-feet of storage required			
		Castor Creek at Tullos		Chickasaw Creek near Urania	
Cubic feet per second	Million gallons per day	10-percent chance of deficiency	5-percent chance of deficiency	10-percent chance of deficiency	5-percent chance of deficiency
10	6.5	800	1,000	1,900	2,000
30	19	2,900	3,700	7,100	7,500
50	32	5,600	6,800	-----	-----
100	65	14,000	16,000	-----	-----

JENA-JONESVILLE-CATAHOULA LAKE AREA

Large supplies of water are available from both ground and surface sources in the Jena-Jonesville-Catahoula Lake area. Most water users in the area depend on ground water.

At Jena fresh ground water can be obtained from the Catahoula Sand of Miocene age and the terrace deposits of Pleistocene age. At Jonesville fresh water can be obtained from one sand of the Catahoula and from the alluvial deposits of Pleistocene age. Fresh-water-bearing sands of the Catahoula occur to depths of 700 or 800 feet beneath the northern part of Catahoula Lake.

As stated in the discussion of zone C, sands in the Catahoula probably have permeabilities of 200 gpd per sq ft or more. Coarse terrace and alluvial deposits probably have permeabilities of 1,000 gpd per sq ft or more.

The Catahoula is not used for municipal or industrial supplies in the area; however, fresh water from the Catahoula may soon be developed at Jonesville. Although the Catahoula sands at Jena are thin and not highly productive, the water is suitable for public supply. However, the municipal supply is obtained from the terrace deposits. Some individual Catahoula sand beds are as much as 100 feet thick beneath Catahoula Lake. If the permeability of a 100-foot sand averages only 200 gpd per sq ft, the transmissibility would be 20,000 gpd per ft, and a well yielding 500 gpm or more is possible. In a properly constructed and developed well the drawdown would be only about 50 feet. At Jonesville the Catahoula should yield more than 200 gpm.

The terrace deposits at Jena are dissected by streams and are of small areal extent. The municipal wells yield 75–200 gpm; the specific capacity of well La–128 was 30 gpm per foot of drawdown. Wells with similar yield and specific capacity can be constructed in parts of the area. However, because the terrace thins in places, testing is necessary to locate suitable well sites.

The wells in the alluvial gravel at Jonesville yield 150–300 gpm, but much larger yields are possible from wells designed for higher yields.

Most streams in this area have highly sustained flow and can be used as sources of water supply. However, to develop a dependable supply from Bayou Funny Louis near Jena, storage will be required. Hemphill Creek and Devils Creek can supply enough water for small communities or industries without storage. Storage requirements for these two streams were not estimated because of the proximity of Catahoula Lake, where large volumes of water can be stored at low cost. In the Jonesville area large quantities of water are available from the Little River or the Black River. Obviously, the usefulness of water from the Little River or Catahoula Lake for public supply or many industrial uses depends on whether brine-disposal regulations continue to be effective. (See section "Pollution," p. 44.)

WATER PROBLEMS AND SOLUTIONS

PROBLEMS OF AVAILABILITY

Fresh water in the Little River basin is not always available when, where, or in the amounts needed.

Water-supply problems are most critical in zone B. As fresh ground water is not available in parts of the zone, surface-water supplies must be considered the alternate source. However, streams in the zone, with the exception of the Little River, are dry during parts of the year. During these dry periods virtually no fresh water is available. Domestic water users have partially alleviated their problem by collecting rainfall in cisterns.

In zone B the principal alternatives for relieving the water shortage are (1) storage of surface water during wet periods to satisfy demands during dry periods, or (2) import of water from another zone or from outside the basin when economically feasible. Water-shortage problems are further complicated by the general lack of potential storage sites.

In zone A, water-supply problems are not so clear cut or severe. Ground-water availability varies with location, whereas surface-water availability is affected by seasonal variations. Sands in the Sparta and the Cockfield are thin in places, and only small quantities of water, sufficient for domestic users, can be obtained. In places where the units contain thick sand beds, the potential for increased development is excellent.

Streams in zone A have limited development potential. Although average flows are high, most streams are dry during parts of the year. Draft rates in excess of about 5 mgd cannot be obtained in the zone without storage during most low-flow periods. There is a 5-percent chance that less than 0.5 mgd will be available from either Castor Creek or the Dugdemona River in any year. Furthermore, water from the Dugdemona River will probably not be suitable for supply unless the patterns of waste release are drastically altered.

Ground-water availability is variable in zone C. Near the boundary with zone B, supplies are adequate for domestic users. Farther south, where terrace gravels are thick or where thick sands of Miocene age contain fresh water, supplies are adequate for small towns and for domestic users. Along the salt-water ridge that underlies the Little River, fresh ground-water supplies are adequate for domestic users only. At Jonesville adequate ground-water supplies are available from the alluvium. However, this water is hard, contains objectionable quantities of iron, and is of limited value to industries without treatment. One deep-lying

Miocene sand near Jonesville contains soft water that could be developed for municipal or small industrial use.

The most important surface-water problem in zone C is to obtain water of good quality. Large quantities of surface water for municipal or industrial uses can be obtained from the Little River downstream from Pollock and from Catahoula Lake, if brine-disposal regulations continue to be effective.

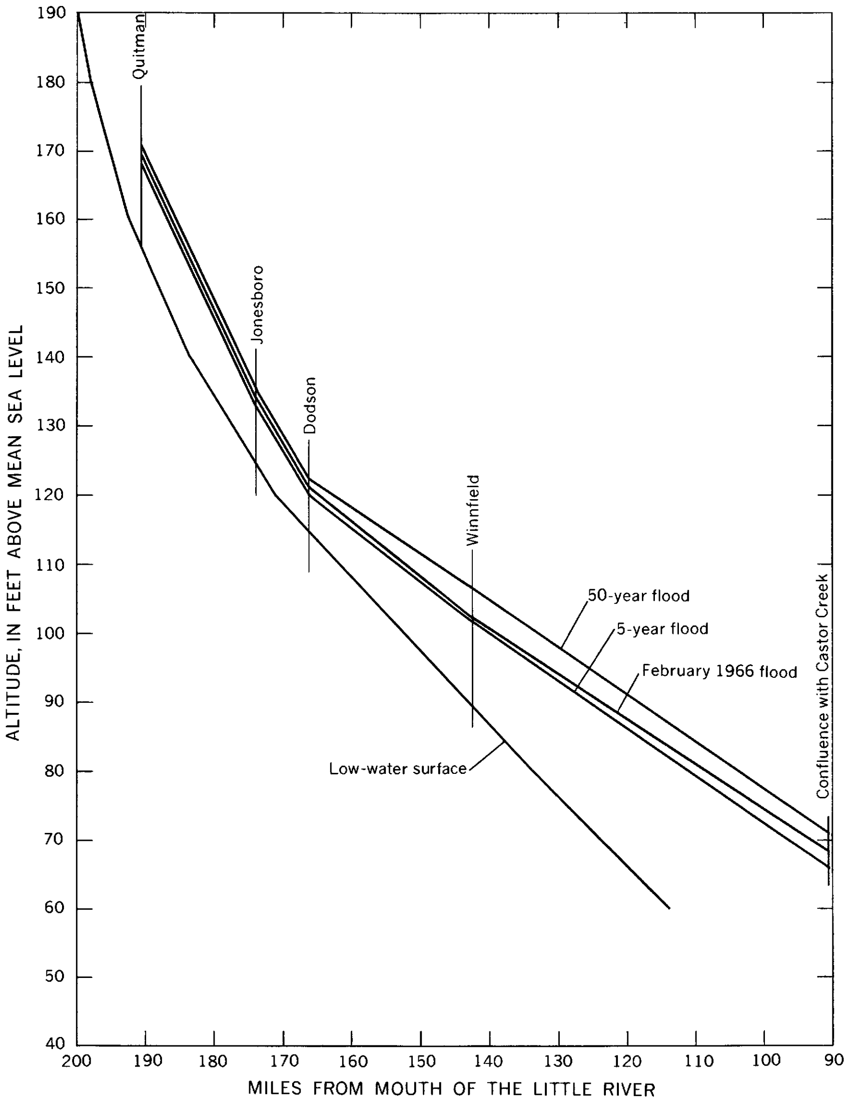

FIGURE 4.—Flood profiles of the Dugdemona River.

FLOODS

Floods in the Little River basin are usually caused either by widespread, prolonged rains or by intense local rains. In addition, high-water stages in the Red River or Black River basins cause flooding in the Catahoula Lake area. Many of the smaller streams that have shallow channels inundate all or part of their flood plain several times each year. Streams having deeper channels flood almost every year.

Flood profiles (figs. 4 and 5) along Castor Creek, the Dugdemona River, and the Little River illustrate water stages during a 50-year and a 5-year flood. (A 50-year flood has a 2-percent chance of occurring in any given year, that is, one such flood could be expected every 50 years. A 5-year flood is one that has a 20-percent chance of occurring in any given year.) The approximate inundated area near these streams can be estimated by using a topographic map and stages from the flood profiles. For example,

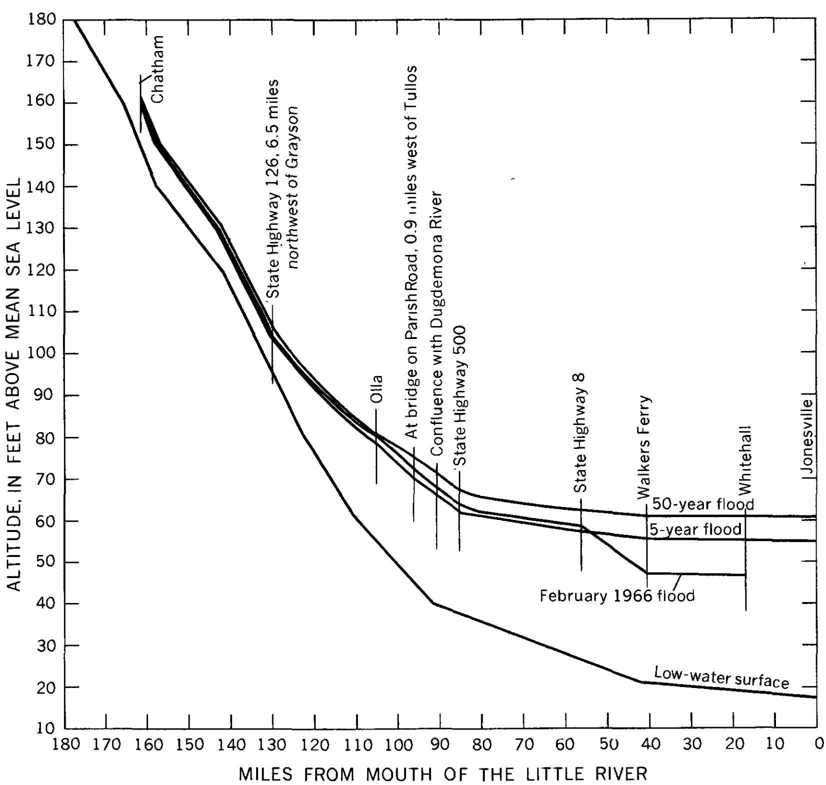

FIGURE 5.—Flood profiles of Castor Creek and the Little River.

the approximate areas that are occasionally flooded near Winnfield and Jonesboro-Hodge are illustrated on plate 4.

Most flood plains in the basin are broad and flat. Therefore, large increases in discharge are accompanied by small increases in stage. A 50-year flood in the Little River basin has about twice the discharge of a 5-year flood, but the stage of a 50-year flood is only about 2–5 feet higher. It is important to note that a given flood rarely has the same magnitude over the entire basin. Local conditions such as rainfall intensity, channel slope, and channel depth cause significant differences. The flood of February 1966, for example, was about equal to a 5-year flood in the downstream reaches of Castor Creek and the Dugdemona River, whereas it was about equal to a 20-year flood near Jonesboro. Furthermore, the flood on Big Creek at Pollock for the same period was nearly three times the magnitude of a 50-year flood on Big Creek. See following table.

Location	Date	Altitude (feet above mean sea level)	Discharge (cfs)	Recurrence interval (years)
Castor Creek at Chatham	May 17, 1953	162.80	5,150	10
	July 23, 1958	162.10	4,050	5
	Feb. 10, 1966	162.96	5,420	11
Castor Creek near Grayson	Apr. 3, 1945	105.19	16,100	16
	Apr. 11, 1947	106.14	21,200	[1] 1.02
	May 17, 1953	105.54	18,000	26
	May 3, 1958	103.01	6,370	2
	Feb. 12, 1966	104.06	10,600	5
Dugdemona River near Jonesboro	Jan. 1, 1945	136.40	30,600	[1] 1.26
	May 17, 1953	135.31	23,500	42
	Feb. 11, 1966	134.63	19,400	19
Dugdemona River near Dodson	Feb. 11, 1966	121.15	-----	----
Dugdemona River near Winnfield	Jan. 3, 1945	104.00	25,000	11
	May 19, 1953	104.92	27,100	14
	Feb. 13, 1966	102.95	19,500	6
Little River near Rochelle	Sept. 24, 1958	62.11	31,900	4
	Feb. 13, 1966	64.01	-----	----
	Feb. 14, 1966	-----	44,700	8
Bayou Funny Louis near Trout	May 17, 1953	104.77	32,700	[1] 3.21
	Aug. 14–15, 1966	101.13	9,120	30
Big Creek at Pollock	Apr. 29, 1953	94.72	23,500	[1] 3.33
	Apr. 26, 1958	91.83	10,200	[1] 1.45
	Feb. 10, 1966	94.19	20,500	[1] 2.91

[1] Ratio of peak discharge to that of 50-year flood.

Damage from flooding is minimal because most flood plains in the basin are primarily forested; consequently, most flood damage is to roads and bridges. Because flood plains are frequently inundated, structures that can be damaged by high water should not be constructed in these areas or should be protected by levees.

POLLUTION

Severe pollution problems in the basin have resulted from natural causes and man's activities. Large quantities of pollutants are discharged to streams by towns and industries. Because flow is extremely low in parts of the basin, discharge of pollutants has caused high concentrations of some chemical constituents.

Pollution of streams by oil-field brines in the southern half of the basin has been severe. The main stem of the Little River, several tributaries, and the Catahoula Lake region, long considered a prime recreation and wildlife center, have been most seriously affected. In 1966 the State prohibited brine disposal to streams, significantly reducing salt loads in most streams.

Information collected during the seepage studies illustrates the salt-load reduction (table 1). Most of the chemical-quality data

TABLE 1.—*Discharge measurements and calculated chloride loads of streams during the seepage investigations*

Map No. (pl. 2)	Stream	1965 Discharge (cfs)	1965 Chloride (tons per day)	1966 Discharge (cfs)	1966 Chloride (tons per day)	1967 Discharge (cfs)	1967 Chloride (tons per day)
1	Castor Creek	-----	-----	1.53	0.0	0.05	0.0
2	Moody Creek	0	0.0	0	.0	0	.0
3	Sweetwater Creek	.07	.0	.05	.0	.05	.0
4	White Oak Creek	0	.0	0	.0	0	.0
5	Bills Creek	.15	.0	.02	.0	0	.0
6	Castor Creek	[1]39	.40	3.0	.0	.26	.0
7	Messer Creek	0	0	0	.0	0	.0
8	Richland Creek	-----	-----	0	.0	0	.0
9	Hurricane Creek	.17	.0	0	.0	0	.0
10	Black Bayou	.50	.0	0	.0	0	.0
11	Piney Creek	0	.0	0	.0	0	.0
12	Caney Creek	.99	.0	.04	.0	0	.0
13	Beaucoup Creek	-----	-----	0	.0	0	.0
14	Flat Creek	-----	-----	0	.0	0	.0
15	Big Creek	-----	-----	.04	.0	.03	.0
16	Richland Creek	[2].02	.0	.01	.0	0	.0
17	Sandy Creek	0	.0	0	.0	0	.0
18	Beech Creek	.05	.0	.12	.0	.06	.0
19	Chickasaw Creek	.48	.78	.13	.0	0	.0
20	---do	.98	2.67	.62	.13	.01	.0
21	---do	3.25	116	.77	5.26	.08	1.34
22	Castor Creek	74.9	184	11	14	4.12	1.55
24	Cypress Creek	.77	.0	1.42	.17	.72	.07
26	Dukedall Creek	0	.0	0	.0	0	.0
27	Brush Creek	.30	.0	0	.0	0	.0
28	Dugdemona River	[1]10	.51	7.0	.58	8.57	1.40
29	Muddy Creek	.06	.0	0	.0	0	.0
30	Burnt Cabin Creek	.03	.0	.17	.0	0	.0
31	Fouse Bayou	.21	.0	.05	.0	0	.0
32	Unnamed	-----	-----	-----	-----	.01	.0
33	Lick Creek	0	.0	0	.0	0	.0
34	Big Creek	0	.0	0	.0	0	.0
35	Cypress Creek	0	.0	0	.0	0	.0
36	Hurricane Creek	0	.0	0	.0	0	.0
37	Little Creek	0	.0	0	.0	0	.0
38	Garfish Creek	-----	-----	0	.0	0	.0
39	Kyiaies Creek	-----	-----	.03	.0	0	.0
40	Dugdemona River	[2]30	2.27	7.80	.57	9.01	1.00
41	Kiesche Creek	0	.0	.04	.0	0	.0
42	Miller Branch	0	.0	0	.0	0	.0
43	Port de Luce Creek	.39	5.33	0	.0	0	.0
44	Brushy Creek	.56	20	.06	.23	.93	.06
45	Dry Creek	.08	.0	.02	.0	.05	.0
46	Big Branch	.05	1.89	.10	3.5	[2].01	.40
47	Dugdemona River	58	112	12	4.53	14	1.80
48	Pope Creek	.29	8.53	[2].001	.0	0	.0

See footnotes at end of table.

TABLE 1.—*Discharge measurements and calculated chloride loads of streams during the seepage investigations*—Continued

Map No. (pl. 2)	Stream	1965 Discharge (cfs)	1965 Chloride (tons per day)	1966 Discharge (cfs)	1966 Chloride (tons per day)	1967 Discharge (cfs)	1967 Chloride (tons per day)
49	Little River	[1]102	788	29	45	19	19
50	Jones Creek	-----	-----	0	.0	0	.0
51	Bear Creek	.30	.0	0	.0	0	.0
52	Cross Creek	-----	-----	0	.0	0	.0
53	Indian Creek	0	.0	.03	.0	0	.0
54	Cypress Creek	[2].01	.0	-----	-----	-----	-----
55	Bayou Funny Louis	[2].1	.0	0	.0	-----	-----
56	Salty Creek	0	.0	0	.0	-----	-----
57	Unnamed No. 2	-----	-----	0	.0	-----	-----
58	Unnamed No. 3	-----	-----	0	.0	-----	-----
59	Unnamed No. 4	-----	-----	0	.0	-----	-----
60	Cow Creek	[2].01	.0	0	.0	-----	-----
61	Little Cow Creek [3]	0	.0	0	.0	-----	-----
62	Unnamed [3]	0	.0	0	.0	-----	-----
63	Adams Creek [3]	-----	-----	0	.0	-----	-----
64	Safety Creek [3]	-----	-----	0	.0	-----	-----
65	Unnamed [3]	-----	-----	0	.0	-----	-----
66	Unnamed	0	.0	.01	.0	-----	-----
67	Mill Creek	.21	.0	.29	.0	.05	.0
68	Unnamed No. 5	-----	-----	0	.0	-----	-----
69	Bayou Funny Louis	[1]1.7	.0	.51	.0	.14	.0
70	Little Creek	-----	-----	0	.0	0	.0
71	---do	.02	.0	.02	.0	0	.0
72	Fish Creek	5.23	.27	5.30	.04	3.62	.02
73	Trout Creek	7.54	11	7.70	14	4.68	5.38
74	Little River	31	-----	54	122	47	50
75	Hurricane Creek	1.14	.02	1.02	.45	.50	.33
76	Big Creek	[1]13	.14	14	.18	9.14	.09
77	---do	25	.25	20	.24	30.5	.26
78	Kitterlin Creek	.37	.0	.19	.0	0	.0
79	Horsepen Creek	0	.0	0	.0	0	.0
80	Clear Branch	.06	.0	.03	.0	0	.0
81	Clear Creek	4.69	.05	5.16	.08	4.37	.07
82	Clinton Branch	.16	.0	.28	.0	0	.0
84	Flagon Bayou	12	.15	12	.20	1.91	.03
85	Routh Creek	.05	.02	0	.0	0	.0
86	Devils Creek	3.18	11	2.93	11	1.31	4.32
87	Hemphill Creek	18	6.82	16	4.22	18	4.30
88	---do	20	37	17	5.64	22	16
89	Sandy Run	0	.0	0	.0	0	.0
90	Gelvin Creek	2.69	.02	2.00	.02	1.05	.01
91	Jones Branch	.20	.0	.32	.0	.25	.0
92	Hickory Branch	0	.0	0	.0	0	.0
93	Unnamed	0	.0	0	.0	0	.0
94	Doyle Branch	.64	.0	.76	.01	.63	.0
95	Unnamed	0	.0	0	.0	0	.0
96	Earl Creek	.18	.0	.16	.0	.08	.0
97	Old River	5.26	.53	6.25	.61	3.61	.42
98	Little River	59	76	55	15	78	43

[1] Computed from station records.
[2] Field estimate.
[3] Tributaries to Bayou Funny Louis omitted from map.

were obtained from individual samples, but the salt loads were calculated as tons of chloride per day. Salt-load values in this report imply, therefore, that the chloride content of water from a given stream remained constant throughout the day and that the calculated tonnage actually passed the sampling point. Obviously, these values are only approximate. By contrast the calculated loads near Rochelle represent actual daily loads because a chemical-quality monitor has continuously recorded specific conductance since 1965. Chloride concentrations and loads for the period were calculated from the relation between the chloride concentration and the specific conductance of water from the Little River (fig. 6).

The sources and quantities of brine in the basin and the significant salt-load reduction are better understood if three parts of the basin are considered separately. These are (1) the area upstream from Rochelle, about two-thirds of the basin (zone A); (2) the area between Rochelle and the confluence of the Little River and Big Creek; and (3) the Catahoula Lake region (pl. 2).

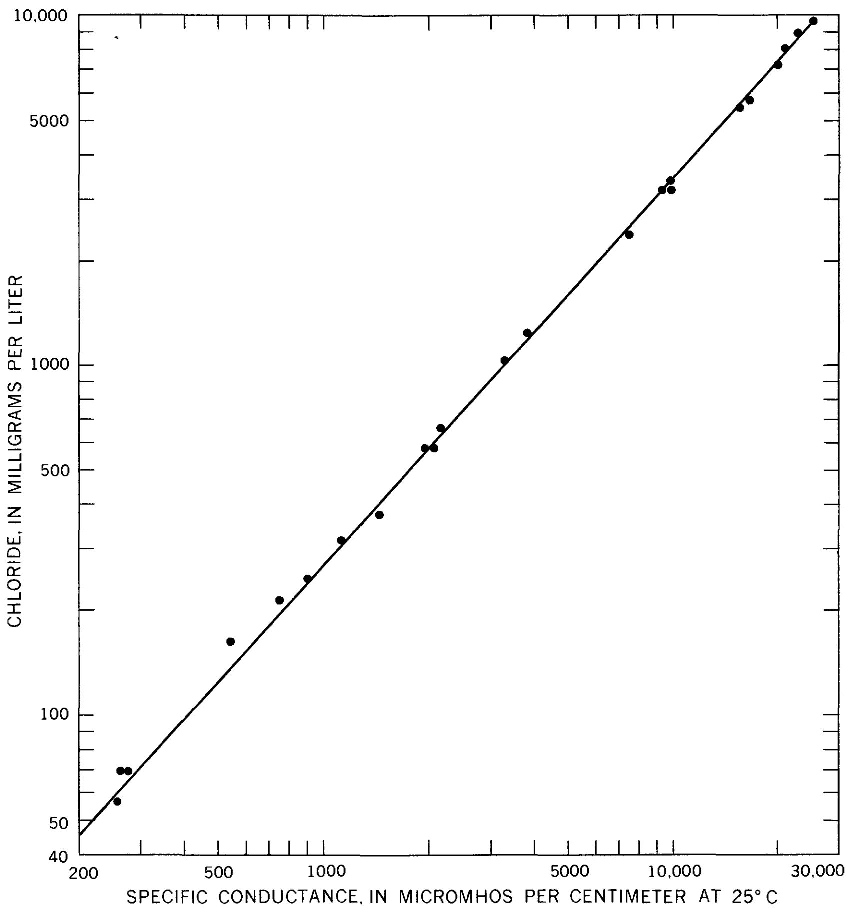

FIGURE 6.—Chloride content of water from the Little River is related to the specific conductance of the water.

The salt loads at Rochelle have been drastically reduced since January 1965, as shown in the following table. The average daily

Salt loads of water from the Little River at Rochelle, January 1965 to September 1967

Chloride content	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1965												
Mg/l	1,750	500	280	570	6,700	5,400	4,400	9,000	4,100	4,800	5,500	8,700
Tons per day	7,750	4,540	2,000	7,760	1,400	1,120	729	785	1,940	766	1,060	935
1966												
Mg/l	270	82	440	720	105	1,350	2,950	1,770	3,000	800	760	440
Tons per day	1,440	2,990	1,010	3,790	1,270	1,470	600	254	186	218	108	678
1967												
Mg/l	175	130	160	90	96	90	300	350	350	----	----	----
Tons per day	266	323	246	536	552	450	104	41	23	----	----	----

load of chloride exceeded 700 tons from January 1965 through June 1966; the highest average load was 7,760 tons per day during April. Daily chloride concentrations greater than 5,000 mg/l were common during this period. In contrast, the chloride concentration did not exceed 500 mg/l in the first 9 months of 1967; average loads were 41 and 23 tons per day during August and September, respectively.

In the 1965 seepage investigation, approximately 97 percent of the total salt load of 788 tons at Rochelle was added to the streams in the Winnfield-Urania-Rochelle area (table 1). The largest identifiable sources of salty water in the basin were Chickasaw Creek, 116 tons; Hemphill Creek, 37 tons; Brushy Creek, 20 tons; and Trout Creek, 11 tons (fig. 7).

The effects of pollution-abatement measures are apparent in results of the seepage studies of 1966 and 1967. In November 1966 the total chloride load at Rochelle was 45 tons per day, or only 6 percent of the 1965 total. Salt loads declined to 5.2 tons in Chickasaw Creek, and to 0.2 tons in Brushy Creek. About 27 tons of salt, 60 percent of the total, came from the Winnfield-Urania-Rochelle area. In the November 1967 seepage investigation the chloride load at Rochelle was 19 tons per day (fig. 8). This is less than 3 percent of the 1965 total, and less than the amount added by Brushy Creek alone in that year.

Even though a drastic reduction in salt loads in the basin is obvious, especially at Rochelle, at least three undesirable conditions persisted through September 1967:

1. The chloride content of Little River water was still high during low-flow periods and exceeded tolerable limits for many uses. The salt may have come from natural salt seeps, from brine disposal in the Winnfield-Urania-Rochelle area, or from salty ground water polluted by previous brine disposal. No salt seeps large enough to produce the observed salt loads were found, and no sources of salty water were identified.

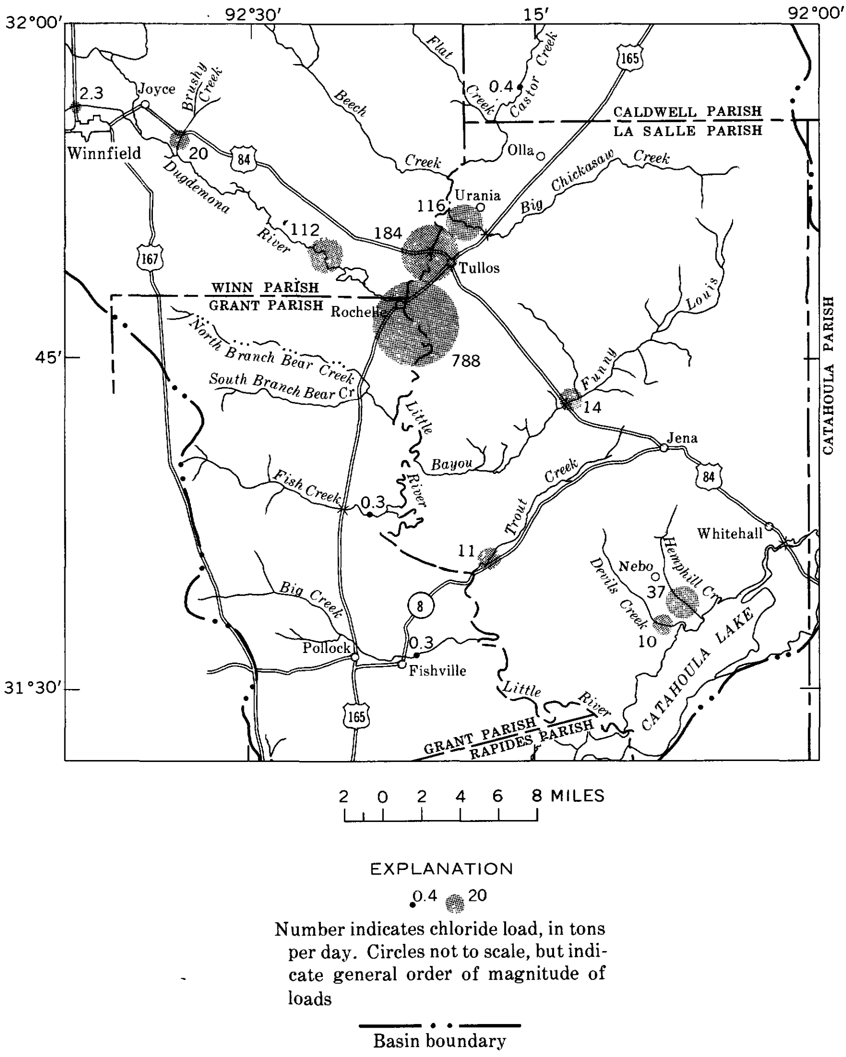

Figure 7.—Chloride load of streams during seepage investigation, November 1965.

2. The chloride content of Little River water increased between Rochelle and Pollock. The salt loads at Pollock in both the 1966 and the 1967 seepage studies were more than double those at Rochelle. The average chloride content of water entering the Little River between these points exceeded 400 mg/l in November 1967. Salty water from Trout Creek was responsible for about 20 percent of the total. Although

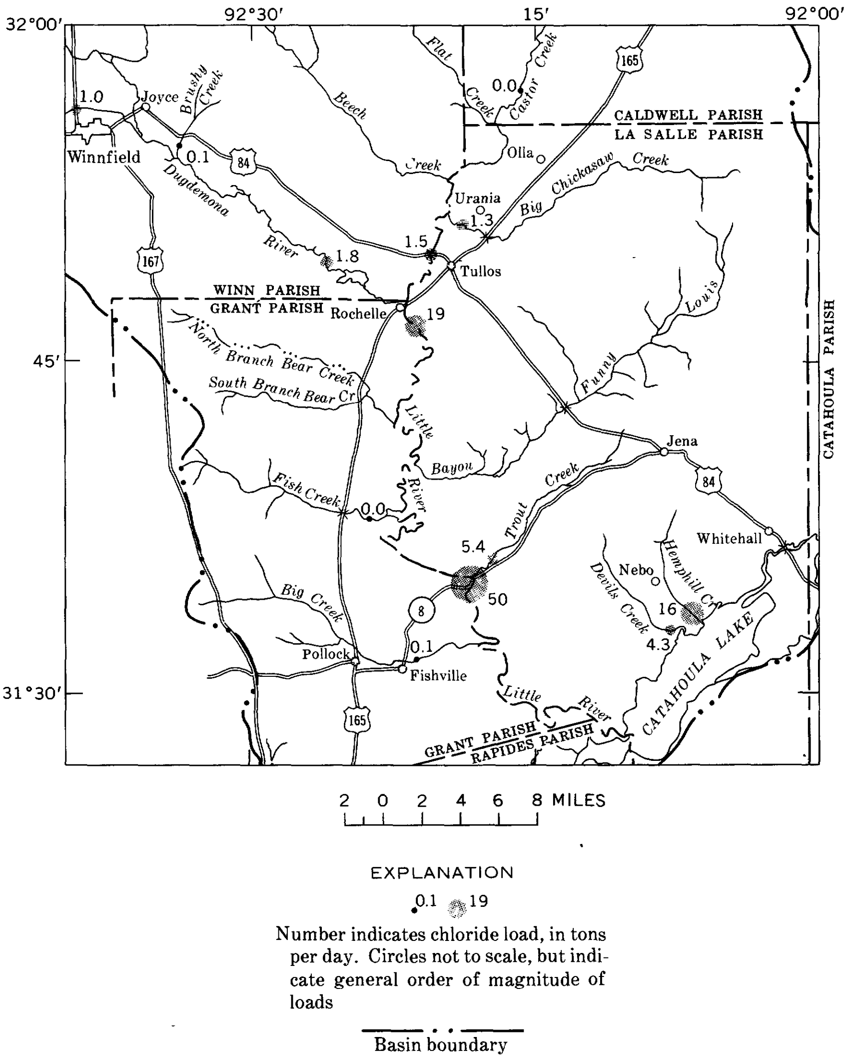

FIGURE 8.—Chloride load of streams during seepage investigation, November 1967.

other sources of salty water were not identified, most of the remainder of the salt load may have come from Bayou Funny Louis and Little Creek.

3. Water from Devils Creek and Hemphill Creek carried more chloride than the Little River at Rochelle, which represents drainage from two-thirds of the basin. The salt load of the two streams was more than 20 tons; whereas the load at

Rochelle was 19 tons. The salt load of water from Hemphill Creek during the 1967 study was only half that of 1965, but the 1967 load was almost triple that for 1966. In a 3.7-square mile part of its drainage area, water with an average chloride content of more than 1,000 mg/l entered the stream. Another stream in the Nebo area, Hurricane Creek, also contained salty water during these periods.

Further reductions in salt loads in the basin should be attainable because the chloride content of unpolluted streams is usually less than 10 mg/l. Reducing pollution now seems mainly a matter of identifying the remaining sources of salty water and eliminating them if possible. Where high chloride concentrations are the result of natural salt seeps that cannot be eliminated, chloride concentrations can be reduced by dilution. The flow of many streams is very low during parts of the year, and storage would be required to obtain enough water for dilution. Although reduction of concentrations by dilution is complex and costly, impoundments constructed to alleviate some of the basin's water-availability problems also may supply water for dilution.

Pollution is not now a major ground-water problem in the Little River basin. Some of the salty water in terrace deposits near Georgetown and in the area northwest of Catahoula Lake may be the result of pollution. However, some salt-water occurrences in ground water are natural and predate the recent pollution by oil-field brine.

Another serious water-pollution problem in the basin is caused by the discharge of municipal and industrial wastes into the Dugdemona River. The relatively high content of decomposable organic material in the water results in low dissolved oxygen, high biochemical oxygen demand, color, and odors. The dissolved-oxygen content of Dugdemona River water was used to locate sources of pollution and to evaluate the effect of pollution of the river. Biochemical oxygen demand was also determined at these sites. Because much waste released to the river decomposes slowly, meaningful relationships between dissolved oxygen and biochemical oxygen demand could not be developed. Profiles drawn from dissolved-oxygen information collected in 1966–67 illustrate pollutional loading and natural purification in the stream at flows less than 65 mgd (fig. 9). This dissolved-oxygen information is summarized in the following table. Oxygen deficiencies in Dugdemona River water upstream from Hodge probably were caused by

Dissolved-oxygen content, in milligrams per liter, of water from the Dugdemona River at selected sites

Date	State Highway 147 near Hodge	State Highway 4 near Jonesboro	State Highway 126 near Dodson	Near Calvin	Near Winnfield
1966					
Nov. 11	--------	--------	1.0	3.8	4.5
Dec. 12	6.2	4.8	5.9	6.2	6.2
1967					
Jan. 18	5.4	3.2	5.0	5.5	5.7
Mar. 15	4.5	1.3	4.4	4.8	5.2
Apr. 12	4.8	.9	4.2	4.8	--------
June 14	4.3	2.7	3.3	3.3	4.6
July 19	4.3	2.1	3.8	4.2	4.4
Aug. 23	3.0	1.5	3.0	3.3	4.6
Oct. 10	4.7	3.3	4.0	4.2	4.4
1968					
Mar. 18	7.6	5.2	5.4	5.8	5.8
Mar. 27	6.2	5.9	4.9	5.7	7.7
Apr. 17	5.1	3.6	3.1	3.7	3.7
May 1	5.8	3.7	4.4	5.1	5.3
May 8	6.0	4.4	5.2	5.3	5.4
May 15	5.4	5.0	5.1	5.1	5.1
May 22	6.4	6.4	6.0	5.9	5.7
May 29	6.5	6.0	5.8	5.6	5.5

discharge of municipal wastes. The water usually had a dissolved-oxygen content of about 50–60 percent of saturation;[4] the highest dissolved-oxygen content observed was only about 75 percent of saturation. In contrast, streams free of oxygen-consuming pollutants are nearly saturated.

Pollution from industrial sources occurs about 2 miles upstream from State Highway 4 between Hodge and Jonesboro (pl. 2); the lowest dissolved-oxygen content was usually found in this reach of the river. Although the dissolved-oxygen content of the water was reduced by about 1.5 to 2.5 mg/l between Hodge and Jonesboro, by the time the water reaches Winnfield, oxygen levels were about the same as at Hodge.

Most published water-quality standards classify water having a dissolved-oxygen content less than 4.0 mg/l and (or) a biochemical oxygen demand greater than 4.0 mg/l as a poor source of supply (California State Water Quality Control Board, 1963, p. 93). Water from the Dugdemona River at Winnfield usually had a dissolved-oxygen content greater than 4.0 mg/l during a period in 1967–68. (See fig. 10.) Water from some reaches of the river upstream from Winnfield, however, had a dissolved-oxygen content less than 4.0 mg/l during low-flow periods. At flows less than about 65 mgd, dissolved-oxygen content probably is less

[4] Percent saturation is the dissolved-oxygen content of a water in ratio to the amount of oxygen that would be in solution at the same temperature and pressure conditions, if the water were 100 percent saturated.

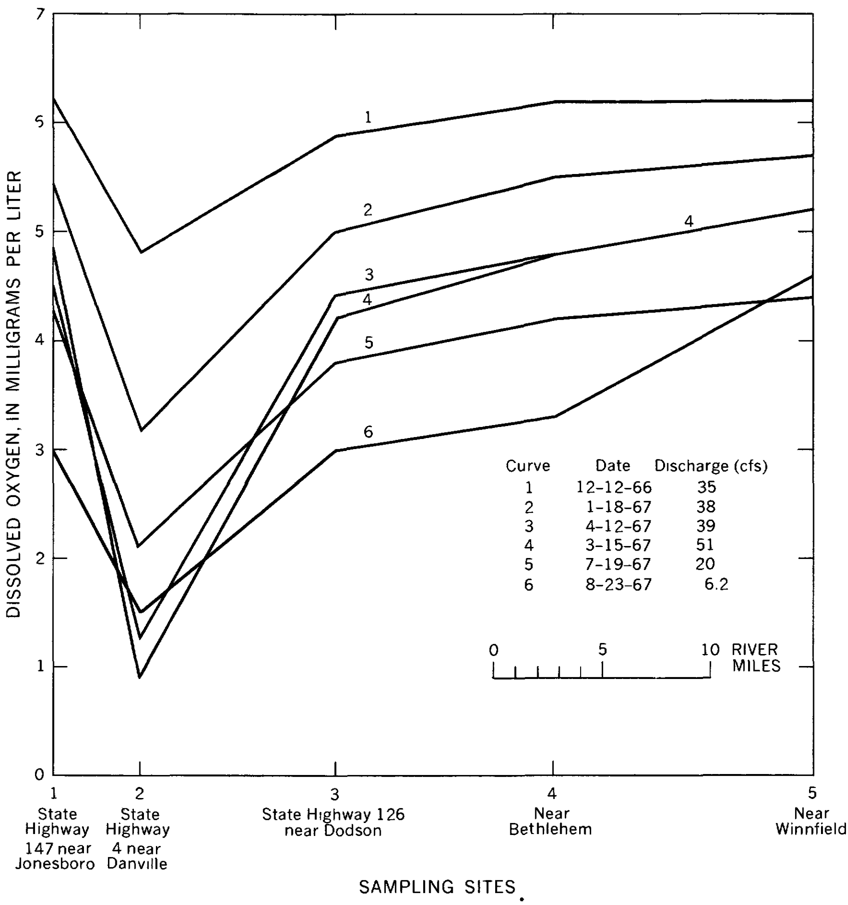

FIGURE 9.—Dissolved-oxygen profiles, Dugdemona River, 1966–67.

than 4.0 mg/l in some reach of the river between Hodge and Winnfield; at higher flows the minimum dissolved-oxygen content is usually not less than about 4.5 mg/l.

Available solutions to dissolved-oxygen problems are augmenting streamflow, aeration to increase dissolved-oxygen content, or waste treatment to reduce oxygen demand. A solution to the Dugdemona River pollution problem, however, would be complex. Sufficient water to dilute waste effectively probably cannot be stored in the Jonesboro-Hodge area. Industrial wastes are retained in oxidation ponds, and releases are controlled with the intention that large quantities will be released during high flow. However, critical periods occur when these ponds are full, and flow of the river is not sufficient to dilute the amount of waste released.

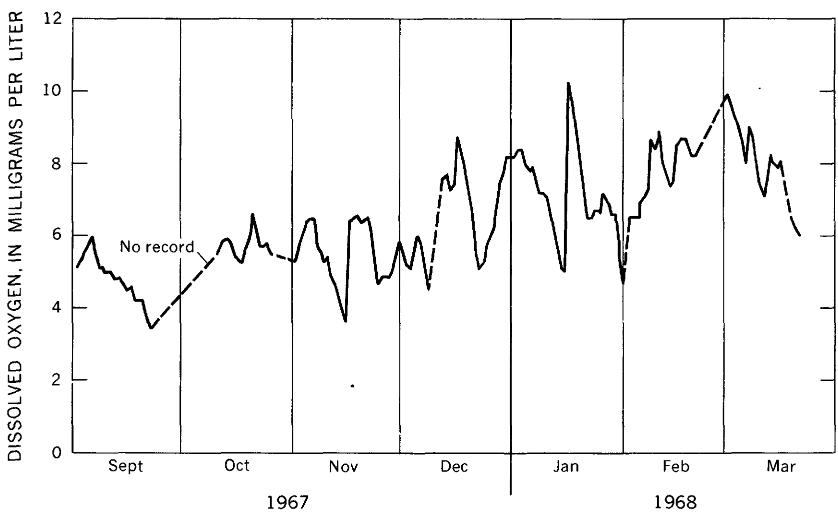

FIGURE 10.—Dissolved-oxygen content of water from the Dugdemona River near Winnfield.

Because of the waste release patterns, dissolved-oxygen deficiencies exist at both high and low flow. Therefore, unless waste-release patterns are drastically altered or wastes more adequately treated, water from the Dugdemona River has limited value.

SUBSURFACE BRINE DISPOSAL

The Louisiana Department of Conservation regulates the subsurface disposal of oil-field brines and other waste. Hough (1965, p. 2) states: "The Department requires that the salt water be injected into a sand which carries salt water and that the injected water will not displace any fresh water which may be carried in the sand at a higher level. Also the injected water must not be put into a sand which produces oil and gas."

In the Little River basin any sands below the Wilcox can be be used for brine disposal without threatening fresh groundwater supplies. However, most of these sands occur at depths of 2,000–10,000 feet or more, which may make them economically undesirable for brine disposal.

Because the Wilcox Group contains salty water in nearly all of the Little River basin except in a small area in Bienville Parish, the unit may be considered suitable for brine disposal. The Cane River Formation, which overlies the Wilcox, is an effective barrier to the rapid movement of salty water between the Wilcox and the fresh-water-bearing Sparta Sand.

In the parts of the basin where the Sparta is salty (pl. 2 , the unit has potential for brine disposal, but any disposal should be far downdip from fresh-salt water interfaces. Where the Sparta is salty and the Cockfield is fresh, the intervening Cook Mountain Formation should be examined closely before considering the Sparta for disposal. Where the Cook Mountain is mostly clay, brine discharge into the Sparta should not threaten fresh-water supplies. Where the Cook Mountain interval is largely sand, silt, or silty clay, vertical movement of injected brine would be possible and brine disposal should be made into a deeper formation. Where water in the Cockfield is also salty, upward movement of brine from the Sparta would not be of concern.

Where the Cockfield contains only salty water, disposal of brine into this unit far downdip from fresh-salt water interfaces would not threaten fresh-water supplies. The thick, clayey interval of the overlying Jackson and Vicksburg would protect fresh-water-bearing sands above these units.

It is questionable whether or not brine should be disposed into the deposits of Miocene age in the Little River basin. The lateral distances are generally small from areas where the aquifers contain salty water to areas of fresh water. Safe disposal may be possible in some areas, but each proposal should be considered individually. Anywhere in zone C, disposal of brine into any sand deeper than the Miocene is a satisfactory alternative to protect fresh-water-bearing units.

THE OUTLOOK

FUTURE DEMANDS

On the basis of population trends, demands for water will probably increase slowly in the immediate future. The principal exception is at Ruston, where population has doubled since 1940. Past industrial development, however, indicates that adding one large water consumer can rapidly alter water demand. In addition, an increased population resulting from new industry would also require more water. As water users may be induced to move into areas with good potential for future development, past rates of development are not necessarily reliable indicators of future water demands.

EFFECT OF DEVELOPMENT

Man's activities have affected water supply and water quality in the Little River basin, and future development probably will cause additional problems.

The most serious effect of development on ground-water supplies is the declining water levels in the Sparta Sand, a result of large-scale withdrawals since 1900. Comparison of the piezometric maps of 1900 and of 1962 shows the extent of decline (pl. 2). The decline is the natural result of pressure adjustment in the artesian aquifer to the withdrawal of water. An adverse effect is the limitation that lower water levels impose on development of the shallow Sparta sands. Where water levels are low, well development in the shallow sands is difficult, and yields of wells are restricted by the amount of drawdown possible when the well is pumping. Thus, a well with a specific capacity of 5 gpm per foot of drawdown would be limited to a yield of 200 gpm if only 40 feet of drawdown were available.

Deeper sands in the Sparta can be developed in most areas, and the water-level decline poses no immediate threat to supplies. Future large-scale development, however, will result in additional water-level declines similar to past declines. If such declines occur at present centers of pumping, water levels may be lowered to the extent that well yields would be drastically reduced. However, if new centers of pumpage were located some distance from present pumping centers, interference between the centers would be reduced considerably, and greater long-term withdrawals would be possible.

The effect of oil-field brine disposal and other industrial and municipal wastes on the water quality of streams has been severe, and although there has been some abatement, future development may cause even greater problems.

Sustained withdrawal of significant amounts of water for consumptive use from streams that could provide adequate supplies would increase the effect of pollution because less water would be available for waste dilution. In fact, the entire flow of some streams during dry periods probably would be effluent from towns or industries. If water of poorer quality were returned to streams after use, the quality of water downstream obviously would be affected, possibly making it unfit for reuse.

The effect of storage on water quality is complex. Chemical and physical reactions in a reservoir alter the quality of stored water. Evaporation and seepage losses also affect quality. An evaluation of the effect of storage on water quality of streams in the basin is beyond the scope of this report. Probably no drastic changes in water quality would occur if reservoir sites were properly cleared.

SUMMARY AND CONCLUSIONS

The average discharge of streams in the Little River basin is relatively high, about 0.65 mgd (1 cfs) per square mile of drainage area. However, many streams have periods of low flow or no flow. These streams cannot be used as reliable public-supply sources without storage. At present, surface water is used for public supply in only two small areas; the total used is only about 1.4 mgd.

Streams in the southern part of the basin have sustained low flow and can be developed for municipal and small industrial supplies without storage. Potential for development is greatest in this area, but in the past many of the streams were used for oil-field brine disposal. Water from Catahoula Lake, the Little River upstream from the lake, and several tributaries has been unfit for public supply and many industrial uses. State regulations prohibiting surface disposal of brines have been effective in drastically reducing salt loads in these streams.

In zone A the average flow of Castor Creek is about 640 mgd (990 cfs); the average flow of the Dugdemona River is about 630 mgd (975 cfs). The 7-day, 2-year flow of the streams is 5.6 and 3.1 mgd, respectively. Each stream has been dry for 90 consecutive days or more. Water from Castor Creek would require only minimum treatment to make it suitable for most uses, but water from the Dugdemona River would require extensive treatment. Water from the Dugdemona probably cannot be used unless drastic changes in waste-release patterns are made.

In zone B, with the exception of the Little River, no surface-water supplies are available during dry periods. Storage or importing water either from another zone or from areas outside the basin is required.

More than 20 mgd (31 cfs) can be obtained from the Little River during low-flow periods in most areas of zone C. Fish Creek, Trout Creek, and Big Creek can supply large quantities of water without storage. The 7-day, 2-year flow of these streams is about 5.0, 4.7, and 8.4 mgd, respectively. Catahoula Lake could be developed to supply large quantities of water. Obviously if water from streams in the zone is to be used for public supply, prohibitions against surface disposal of brine must remain effective.

Surface-water supplies can be developed at Jonesboro-Hodge, Winnfield, Tullos, and Jonesville. However, as stated perviously, water from the Dugdemona River would require extensive treatment to make it suitable for public supply. Consequently, surface-water supplies probably will not be obtained from the Dugdemona River at Jonesboro or Winnfield.

The Wilcox Group, the Sparta Sand, the Cockfield Formation, the Catahoula Sand, the Carnahan Bayou Member of the Fleming Formation, terrace deposits, and alluvial deposits contain fresh water in parts of the Little River basin. Each unit, except perhaps the Wilcox, is the principal source of ground water in at least one area of the basin.

Greatest development has been from the Sparta, and greatest potential for future development is in the Sparta. Moderately large supplies of good quality water can be developed from the Cockfield, Miocene, and terrace and alluvial deposits. Quality-of-water problems are local rather than basinwide. Color of water from the Cockfield is high in some places, and iron is present in objectionable quantities in the outcrop areas of the Sparta and the Cockfield. In all units, variable sand thicknesses make preliminary testing desirable before developing large ground-water supplies.

In zone A, wells yielding 200 gpm can be developed at most localities, and wells yielding 2,000 gpm can be developed where thick massive sands are available. In zone B, wells yielding 100 gpm can be developed in most of the area where the Cockfield contains fresh water. In the remainder of zone B, yields of a few gallons per minute are possible in some places, and no ground water is available at other places. Potential yields of wells in zone C may range from only a few gallons per minute to 1,000 gpm or more because of variable aquifer thickness. However, yields greater than 200 gpm are possible in most of the zone.

Water levels have declined in the Sparta as a result of extensive development of the unit within and near the basin. Additional large-scale development would cause additional water-level decline and result in increased pumping costs and declining yields from shallow wells in the Sparta. Therefore, additional development should be spaced to minimize water decline at both new and old well fields.

In or near each population center, ground water is available for development. The Sparta is a source of ground water at Ruston, Jonesboro-Hodge, and Winnfield. In addition, some development of the Cockfield is possible at Ruston and Winnfield. In the Tullos-Urania-Olla area the Cockfield can provide fresh ground water. At Tullos the Cockfield contains salty water, but at Olla and Urania the unit contains fresh water. The Catahoula Sand contains one or more fresh-water-bearing sands in the Jena-Jonesville-Catahoula Lake area. Terrace deposits are a source of fresh water at Jena, and alluvial deposits are an additional source of fresh water at Jonesville. Water from the alluvial deposits in the Jonesville area, however, is hard and contains objectionable quantities of iron.

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INDEX

[Italic page numbers indicate major references]

Page

Acknowledgments ---- 2
Air temperatures ---- 4
Alexandria ---- 26, 27
Alluvial deposits ---- 9
  Zone C ---- *28*
Aquifers, Zone A ---- *11*
  Zone B ---- *20*
  Zone C ---- *24*
Area, Little River basin ---- 2

Bayou Funny Louis ---- 7, 19, 22, 39
Big Creek ---- 7, 8, 27
Black River ---- 7, 30, 39
Brine disposal, subsurface ---- *53*
Brines, pollution ---- 44

Camp Livingston ---- 26, 27, 28
Cane River Formation ---- 5, 53
Carnahan Bayou Member ---- 6, 24, 26, 27, 30
Carrizo Sand ---- 5
Castor Creek ---- 7, 9, 10, 11, 16, 37, 38
Catahoula Formation ---- 5, 25, 39
Catahoula Lake ---- 3, 4, 7, 25, 28, 29, 39
  water conditions ---- 38
Chatham ---- 11
Chickasaw Creek ---- 16, 38
Clarks ---- 22, 37
Clinton Branch ---- 24
Cockfield Formation ---- 4, 8, *14*, 31, 36, 37, 54
Color of water ---- 22, 37, 57
Columbia ---- 37
Cook Mountain Formation ---- 5, 8, 54
Corrosive water ---- 23

Devils Creek ---- 7, 39
Discharge, average for streams in basin ---- 55
Dissolved oxygen, streams in basin ---- 50
Drainage ---- *6*
Driskill Mountain ---- 6
Dugdemona River ---- 4, 7, 9, 10, 16, 35, 36

Economy, Little River basin ---- 2
Eocene deposits ---- 5, 21

Fish Creek ---- 7, 24
Flagon Bayou ---- 7, 24
Fleming Formation ---- 6, 24, 30
Floods ---- *42*
Fluoride in water ---- 22
French Fork Little River ---- 7

Garrett Creek ---- 11
Geology, summary ---- *4*

Page

Georgetown ---- 7, 21, 22
Grambling ---- 31
Grayson ---- 11, 37
Ground water, availabilty near towns ---- 57
Ground water, sources in basin ---- 56

Hemphill Creek ---- 7, 24, 27, 39
Hodge ---- 11
  water conditions ---- 34
Holocene deposits ---- 4, 6
Hydrologic setting ---- *4*
Hydrologic zones ---- *8*

Jackson Group ---- 5, 8, 21
Jena ---- 30
  water conditions ---- 38
Jena-Jonesville-Catahoula Lake area
    water conditions ---- *38*
Jonesboro ---- 4
  water conditions ---- 34
Jonesboro-Hodge ---- 13
  water conditons ---- *34*
Jonesville ---- 7, 25, 26, 28, 29, 30, 38
  water conditions ---- 38

Kisatchie Forest ---- 26
Kitterlin Creek ---- 24

Lake Claiborne ---- 31
Lake D'Arbonne ---- 31
Lena Member ---- 6
Little River ---- 19, 22, 29, 38, 39, 40
Low-flow characteristics ---- 8
Low flow information, population
    centers ---- 32, 34, 36, 37, 39
  summary ---- 56
  Zone A ---- *9*
  Zone B ---- *19*
  Zone C ---- *23*

Miocene deposits ---- 5, 9, 21, *24*
Mississippi-Ouachita River system ---- 28

Nebo ---- 28, 29

Old River ---- 7
Oligocene deposits ---- 5, 21
Olla ---- 3, 22
  water conditions ---- 37
Ouachita River ---- 30

Paleocene deposits ---- 4
Pineville ---- 26, 27, 30

517-910 O - 73 - 5

	Page
Pleistocene deposits	6, 9, 21, 24, 27, 39
Pollock	24, 27, 28
Pollution	*44*
Population, Little River basin	2
Port de Luce Creek	36
Quality of water, Cockfield Formation	18
Dugdemona River	16
Sparta Sand	17
terrace deposits and alluvium	19
Wilcox Group	17
Zone A	*16*
Zone B	*22*
Zone C	*29*
Quaternary deposits	6
Quitman	11
Rainfall, average annual	3
Relief	7
Rochelle	3, 7
Ruston	13
water conditions	*31*
Saline	11
Salt loads, Little River	47
streams in basin	44
Sandy Lake	26
Seepage investigation	8, 44
Sparta Sand	4, 8, *12*, 31, 34, 36, 53
quality of water	17
water-level decline	55
Streams, Zone A	*9*
Zone B	*19*
Zone C	*29*
Stream flow, average	3
Structure	6
Surface-water sources in basin	56
Terrace deposits	6, 9, 27, 30
Zone C	27
Terrace deposits and alluvium, Zone A	16
Tertiary deposits	28
Topography	*6*
Trout	22, 27
Trout Creek	7, 24
Tullos	3, 10, 11, 14, 29, 37
water conditions	37
Tullos-Urania-Olla, water conditions	*37*
Urania, water conditions	37
Vicksburg Group	5, 8, 9, 21
Water availabilty	40
Water conditions, population centers	*30*
Water impoundments	7
Water-level decline, Jonesboro-Hodge area	34
Ruston area	32
Sparta Sand	57
Water needs, increased	54
Water problems and solutions	*40*
Water storage, Castor Creek	38
Chickasaw Creek	38
Dugdemona River	35
Little River	38
Water systems, municipal	7
Water use	7
summary	8
Waterworks District 3	8, 27
Wilcox Group	4, *11*, 53
Winnfield	3, 10, 11, 12, 13
water conditions	*35*
Zone A	8, *9*
Zone B	8, *19*
Zone C	9, *23*

TABLE 2

TABLE 2.—*Chemical analyses of ground water*

[Geologic unit: Tw, Wilcox Group; Ts, Sparta Sand; Tc, Cockfield Formation; Tct, Catahoula Formation: Tcb, Carnahan Bayou Member of Fleming Formation of Fisk (1940); Qt, upland terrace deposits; Qal, alluvial deposits]

Well No.	Date of collection	Depth (ft)	Geologic unit	Constituents, in milligrams per liter: Silicia (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids: Calculated	Dissolved solids: Residue at 180°C	Hardness as $CaCO_3$	Specific conductance (micromhos at 25°C)	pH	Color
Zone C																					
T. 5 N., R. 1 E.																					
R-315 ------	11-26-41	785	Tcb	44	0.84	4.4	3.1	63	2.6	136	0	9.3	32	0.8	0.0	----	225	24	----	----	----
336 ------	8-27-46	606	Tcb	44	.16	1.4	1.0	210		487	11	.8	29	1.5	.5	----	548	8	829	8.3	----
345 ------	8-26-46	201	Tcb	34	.10	3.0	1.3	8.5		15	0	10	6.0	.1	.0	----	79	13	65	5.7	----
349A -----	---do---	351	Tcb	42	.83	3.1	.4	26		66	0	4.7	5.0	.1	.2	----	122	9	133	6.2	----
380 ------	11-26-41	54	Qt	20	.50	1.2	.7	5.2	1.6	21	0	1.5	5.8	.4	.0	----	49	6	----	----	----
746 ------	7-14-58	632	Tct	25	.08	0	0	69		166	0	2.0	5.6	1.4	.2	----	----	0	280	8.1	50
878A -----	8-17-67	280	Tcb	50	.27	.9	.2	19	1.4	45	0	6.6	3.5	.0	.1	84	104	3	96	6.1	5
878B -----	2-20-68	1,046	Tct	43	.12	.0	.0	98	.8	171	0	.2	49	1.3	.9	277	284	0	439	7.6	10
T. 5 N., R. 2 E.																					
R-766 ------	7-12-68	80	Qt	30	0.19	36	16	76	1.7	276	0	12	58	0.2	0.2	366	370	155	626	8.0	5
780 ------	4- 6-62	86	Qt	29	.83	26	9.4	34	1.0	159	0	.2	29	.2	.1	207	242	103	380	7.5	30
884 ------	7-12-68	211	Tcb	36	.10	12	2.4	446	5.5	216	0	.2	586	.9	2.5	1,200	----	40	2,250	7.8	5
T. 5 N., R. 3 E.																					
R-783 ------	7-12-68	96	Qt	24	4.4	173	53	828	9.4	439	0	3.2	1,480	0.2	2.5	2,790	----	650	5,150	7.6	5
870 ------	7-12-68	231	Tcb	35	.45	22	7.1	735	9.4	354	0	.2	994	1.0	.2	1,980	----	84	3,590	8.0	5
T. 5 N., R. 1 W.																					
R-876A -----	7- 4-67	328	Tcb	44	0.18	1.1	0.5	55	1.6	122	0	8.0	9.9	0.2	0.1	180	207	5	246	7.2	5
876B -----	6-27-67	1,039	Tct	45	.12	.0	.0	62	.6	133	0	.0	14	.6	.0	188	190	0	258	7.2	5
877 ------	7-22-67	779	Tcb	54	.33	.6	.1	57	1.0	120	0	7.6	12	.4	.0	192	212	2	236	7.3	5

T. 6 N., R. 1 E.																					
G–27	3–21–55	397	Tct	47	0.27	2.2	0.0	271	3.3	198	0	0.1	315	1.1	0.0	740	746	6	1,320	7.7	10
131	3–26–68	365	Tct	50	.22	3.3	1.9	324	3.9	196	0	.2	381	.0	.2	862	860	16	1,590	7.1	10
180	3–28–69	558	Tct	38	.07	.6	.1	112	2.0	198	0	.2	58	2.4	.1	311	325	2	503	7.3	5
203	5–10–63	43	Qt	12	.02	2.1	.9	3.7	1.8	10	0	6.6	3.2	.0	.4	36	48	9	48	5.9	5
209	1–11–68	332	Tct	41	.09	6.0	.7	405	3.3	187	0	.2	516	1.2	.0	1,070	----	18	1,970	7.8	5
257A	5–29–69	348	Tct	41	.04	.0	.0	70	1.2	184	0	.0	4.3	.9	.0	208	249	0	303	7.9	5
257B	5–22–69	498	Tct	39	.12	.4	.0	98	1.3	182	0	.0	40	2.1	.0	271	276	1	409	7.7	20
258	3–28–69	294	Tct	42	.07	.9	.2	102	2.0	256	0	.0	9.2	1.2	.1	284	295	3	419	7.5	5
T. 6 N., R. 2 E.																					
G–219	2– 7–68	247	Tct	21	0.25	13	4.7	880	6.0	197	0	3.4	1,280	0.4	----	2,310	----	52	4,210	7.5	5
200	2– 7–68	125	Tct	53	5.3	1.2	.2	27	.6	46	0	5.4	16	.0	0.0	126	122	4	138	6.4	5
221	2– 7–68	300	Tct	44	.06	10	2.2	680	4.8	246	0	.2	920	.7	----	1,780	----	34	3,200	7.6	15
T. 6 N., R. 3 E.																					
La–120	1–10–68	100	Tct	32	0.15	6.0	1.0	7.5	0.8	31	0	0.0	8.5	0.0	0.0	71	71	19	75	6.4	0
T. 6 N., R. 1 W.																					
G–143	9– 2–56	820	Tct	14	----	23	6.6	907	----	256	0	0.0	1,310	----	----	----	----	----	----	8.2	----
225	3–28–58	473	Tct	46	0.11	.2	.1	56	0.9	138	0	.4	6.2	0.4	0.0	178	182	1	227	7.6	5
253	3–21–69	332	Tct	38	.42	.9	.2	41	1.1	103	0	.0	5.7	.1	.0	138	151	3	172	7.1	10
T. 7 N., R. 1 E.																					
G–210	1– 8–68	180	Tct	37	4.7	56	13	1,300	10	210	0	9.8	2,050	0.4	----	3,580	----	193	6,470	7.6	10
218	2– 1–68	145	Tct	43	.14	4.4	1.0	36	1.1	109	0	1.6	3	.3	0.1	145	146	15	187	6.9	5
T. 7 N., R. 2 E.																					
La–114	1–10–68	240	Tct	39	0.07	0.2	0.1	84	0.8	146	0	0.2	42	0.3	0.0	239	246	1	367	7.5	5
117	1–30–68	84	Tct	41	.66	5.8	.9	83	1.2	99	0	.6	86	.2	.0	268	269	18	440	7.6	5
119	1–10–68	212	Tct	38	.09	16	4.1	755	5.1	191	0	1.4	1,080	.8	.0	1,990	----	57	3,720	7.4	5
T. 7 N., R. 3 E.																					
La–110	1–30–68	220	Tct	41	0.38	6.0	1.5	40	2.3	114	0	8.4	8.9	0.1	0.0	164	165	21	220	7.4	5
111	1–10–68	258	Tct	44	.02	.8	.0	48	1.1	115	0	9.8	5.1	.1	.0	166	170	2	207	7.3	0
T. 7 N., R. 4 E.																					
La–100	3–26–68	260	Tct	46	0.03	0.3	0.3	69	2.9	180	0	0.4	2.4	0.5	0.0	211	209	2	293	7.6	0

TABLE 2.—*Chemical analyses of ground water*—Continued

Well No.	Date of collection	Depth (ft)	Geologic unit	Silicia (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids: Calculated	Dissolved solids: Residue at 180°C	Hardness as $CaCO_3$	Specific conductance (micromhos at 25°C)	pH	Color
				Constituents, in milligrams per liter																	
Zone C—Continued																					
T. 7 N., R. 6 E.																					
Ct-46 ------	4-19-68	716	Tct	53	0.39	0.4	0.0	70	1.5	133	0	15	20	0.1	0.0	226	225	1	307	6.8	10
T. 7 N., R. 1 W.																					
G-119 ------	12- 2-42	148	Tct	----	10(?)	15	161	----	----	----	----	50	10	----	----	----	----	116	----	7.8	----
181 ------	2-26-68	353	Tct	27	.29	3.9	1.8	338	2.8	229	0	.0	413	1.1	0.0	901	----	17	1,700	7.2	30
T. 7 N., R. 2 W.																					
G-147A -----	3-16-62	344	Tct	21	0.39	0.5	0.2	146	1.8	206	0	0.4	108	0.9	0.3	387	412	2	657	7.3	60
226 ------	3-28-68	120	Qt	33	.02	4.0	2.2	15	1.0	44	0	2.0	9.3	.1	.1	89	90	19	100	6.7	5
T. 8 N., R. 2 E.																					
La-109 -----	1- 8-68	194	Tct	36	0.30	7.8	0.6	172	2.4	206	0	0.2	150	1.0	0.0	471	269	18	440	7.6	5
T. 8 N., R. 3 E.																					
La-78 ------	3- 3-60	149	Qt	42	0.09	5.0	0.1	12	1.0	34	0	5.0	5.5	0.2	0.2	88	89	13	87	5.9	5
125 -----	12- 4-67	217	Tct	48	.14	6.1	2.1	84	1.7	110	0	47	48	.2	.1	291	290	24	445	6.4	5
128 -----	1- 8-68	100	Qt	37	.02	3.0	.4	7.5	.6	25	0	.2	3.8	.0	.1	65	67	9	58	5.7	5
129 -----	12-13-67	136	Qt	46	.03	8.0	2.9	24	.8	61	0	6.2	21	.1	.1	139	141	32	180	7.3	5
T. 8 N., R. 4 E.																					
La-94 ------	1-10-68	524	Tct	41	0.07	2.0	0.2	188	2.5	211	0	0.0	166	0.7	0.0	504	506	6	866	7.9	0

T. 8 N., R. 5 E.																					
Ct–38A ------	10–26–67	300	Tct	49	0.51	2.8	1.0	49	2.7	96	0	19	18	0.0	0.0	188	187	10	250	6.7	10
38B ------	10–24–67	478	Tct	40	.04	1.1	.5	248	2.3	276	0	2.4	210	.2	.3	641	636	5	1,110	7.7	5
39A ------	11–15–67	352	Tct	46	.80	4.0	2.4	58	2.6	116	0	22	21	.0	.0	213	211	20	287	6.4	0
39B ------	11–13–67	520	Tct	37	.03	1.2	.7	231	2.0	312	0	19	180	.4	.1	625	636	6	1,070	7.7	10
T. 8 N., R. 6 E.																					
Ct–41 ------	3–21–68	617	Tct	42	0.43	0.5	0.2	90	.04	209	0	0.0	22	0.3	0.0	258	278	2	355	7.7	5
47 ------	7–25–68	125	Qal	32	8.9	82	26	20	2.5	389	0	6.2	18	.3	1.4	380	403	312	653	7.6	5
50A ------	9–20–68	230	Tct	43	.20	4.0	1.2	131	1.7	190	0	4.2	98	.5	.0	378	373	15	627	7.1	10
50B ------	9–19–68	542	Tct	49	1.1	1.0	.1	64	.5	114	0	19	20	.0	.0	210	218	3	293	6.6	20
T. 9 N., R. 4 E.																					
La–96 ------	1–10–68	137	Tct	40	0.01	1.5	0.1	196	1.8	300	0	91	60	0.6	0.0	539	641	4	845	8.0	0
136 ------	3–26–68	140	Tct	23	.10	2.9	1.6	237	3.0	411	0	10	122	.6	.3	602	686	14	1,070	8.1	20
T. 9 N., R. 5 E.																					
Ct–7 ------	7–27–68	230	Tct	48	1.6	12	4.9	23	2.5	68	0	19	21	0.1	0.0	164	169	50	222	6.7	5
Zone B																					
T. 9 N., R. 1 W.																					
G–217 ------	9–12–67	185	Tc	21	2.5	220	62	250	10	291	0	760	240	0.1	3.0	1,710	----	805	2,450	7.5	0
224 ------	3–27–68	250	Tc	13	.14	2.9	.7	425	2.0	648	33	182	120	3.2	1.1	1,100	----	10	1,740	8.6	150
T. 9 N., R. 2 W.																					
G–216 ------	9–12–67	380	Tc	11	0.16	0.8	0.0	366	0.9	544	0	8.8	238	1.3	0.0	895	----	2	1,570	8.2	100
222 ------	3–22–68	212	Tc	34	9.9	10	4.1	440	2.8	209	0	620	150	.0	.0	1,360	----	42	2,080	7.8	5
T. 10 N., R. 3 E.																					
La–132 ------	1–30–68	374	Tc	11	0.15	1.0	0.4	374	1.0	533	19	236	66	0.6	2.0	973	----	4	1,540	8.4	80
T. 11 N., R. 2 E.																					
La–122A ----	6–12–67	146	Tc	11	0.07	40	15	290	4.7	506	0	244	76	0.6	0.4	931	939	160	1,460	7.6	5
122B ----	6– 9–67	236	Tc	13	.06	1.8	.9	298	1.5	457	15	199	30	.6	.2	785	796	8	1,260	8.5	10
123 ------	6–27–67	381	Tc	13	.04	1.0	.1	186	.8	341	15	.6	7.9	.6	.7	438	469	3	726	8.4	150
137 ------	3–27–68	238	Tc	47	.19	49	24	128	12	357	0	150	31	.6	.8	618	622	220	1,030	7.6	5

TABLE 2.—*Chemical analyses of ground water*—Continued

Well No.	Date of collection	Depth (ft)	Geologic unit	Constituents, in milligrams per liter: Silicia (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids: Calculated	Dissolved solids: Residue at 180°C	Hardness as $CaCO_3$	Specific conductance (micromhos at 25°C)	pH	Color
Zone B—Continued																					
T. 11 N., R. 4 E.																					
Ca-38 ------	8-30-67	630	Tc	13	0.10	7.8	2.6	940	4.0	826	0	0.0	939	0.8	----	2,310	----	30	4,080	7.9	40
La-134 -----	2-27-68	63	Qt	57	16	64	15	96	4.4	117	0	212	84	0.3	0.0	591	606	220	886	6.4	5
T. 12 N., R. 4 E.																					
Ca-55 ------	2-21-68	520	Tc	15	0.09	0.7	0.1	167	0.6	382	11	10	22	0.4	1.0	406	----	2	707	8.5	60
Zone A																					
T. 10 N., R. 1 E.																					
W-32 ------	7-18-58	74	Qt	18	0.25	0.0	0.0	13	----	10	0	1.0	11	0.9	0.2	49	71	0	62	5.9	20
60 ------	3-20-63	215	Tc	8.7	.07	1.8	.4	255	1.2	517	0	.0	92	.9	.0	615	689	6	1,070	7.7	1,000
84 -------	10-20-64	168	Tc	11	.07	.7	.1	201	1.6	451	12	.0	38	.8	.3	490	518	2	800	8.5	200
86 -------	2-15-65	451	Tc	11	.28	.6	.9	269	1.1	559	0	.0	92	.7	.3	659	696	5	1,100	8.2	200
T. 10 N., R. 2 E.																					
La-86 ------	3-10-60	510	Tc	15	0.46	0.0	0.0	327	2.7	736	0	0.8	74	3.6	0.3	794	962	0	1,310	7.9	500
86 ------	12-12-68	510	Tc	12	.18	3.6	.7	397	2.0	716	20	.8	180	1.8	.2	970	----	12	1,650	8.4	300
88 ------	10-19-64	487	Tc	12	.25	.0	.0	164	.8	407	7	.0	11	.7	.2	397	430	0	649	8.4	100
T. 10 N., R. 2 W.																					
W-89 ------	3-20-68	180	Tc	45	0.23	3.4	1.6	47	1.4	136	0	0.0	5.5	0.1	0.0	171	176	15	226	7.5	5
96 ------	10-25-67	253	Tc	11	.05	1.2	.2	170	.7	329	11	46	20	.4	.0	422	436	4	710	8.6	80

T. 10 N., R. 3 W.																					
W-90 ------	9-12-67	142	Tc	16	0.17	36	6.8	296	4.7	348	0	349	103	0.1	3.5	986	----	118	1,550	7.5	10
100 -----	1-15-68	168	Tc	11	.01	1.7	.4	228	2.0	284	4	192	58	.0	.9	638	645	6	1,050	8.3	5
T. 11 N., R. 1 E.																					
W-93 ------	9-14-67	101	Tc	63	4.8	8.9	3.1	15	2.7	77	0	0.4	6.2	0.1	0.1	138	140	35	147	6.6	5
94 ------	9-14-67	325	Tc	48	5.3	9.7	6 3	67	4.2	110	0	64	34	.1	.1	287	283	50	411	6.8	10
T. 11 N., R. 2 E.																					
La-45 ------	10-20-64	160	Tc	12	0.15	1.0	0.1	158	0.7	404	7	0.0	11	0.8	0.3	392	424	3	655	8.4	150
133 -----	2- 1-68	200	Tc	18	.07	19	8.1	226	3.9	417	0	192	34	.2	.2	706	722	81	1,110	7.6	15
T. 11 N., R. 1 W.																					
W-91 ------	9-13-67	160	Tc	48	5.4	5.2	2.7	9.2	2.5	48	0	0.0	3.1	0.1	0.1	95	98	24	94	6.3	10
T. 11 N., R. 2 W.																					
W-28 -------	7-22-68	480	Ts	11	0.19	1.2	0.0	188	0.9	389	0	2.4	66	0.5	0.0	462	480	3	798	7.8	20
109 ------	7-22-68	600	Ts	11	.08	.8	.0	188	.3	460	0	1.0	23	.9	.9	453	483	2	765	7.9	100
T. 11 N., R. 3 W.																					
W-2 -------	3-25-55	122	Tc	32	0.83	7.6	2.3	29	2.5	2,011	0	29	29	0.2	1.0	301	305	28	466	7.0	35
18 -------	12-20-49	552	Ts	12	.00	1.0	1.2	140	5.6	298	18	7.8	24	.1	.8	355	357	8	573	8.7	30
87 ------	8- 8-68	770	Ts	12	.10	.8	.0	142	.4	266	0	18	49	.1	.1	353	362	2	603	7.8	50
T. 11 N., R. 4 W.																					
W-81 ------	1-16-68	269	Ts	12	0.09	0.0	0.0	200	0.5	267	0	0.6	150	0.2	0.4	496	558	0	890	8.2	50
114 ------	9- 4-68	700	Ts	20	.17	38	2.0	152	1.0	254	0	22	145	.2	.0	505	501	103	897	7.7	10
T. 12 N., R. 2 E.																					
Ca-50 ------	1-31-68	276	Tc	13	2.6	0.0	0.0	106	0.4	224	0	24	22	0.2	0.1	276	292	0	470	8.2	15
T. 12 N., R. 3 E.																					
Ca-5 -------	1- 4-60	430	Tc	28	1.8	10	5.6	55	2.3	149	0	11	23	0.4	1.1	210	215	48	329	8.0	0
10 ------	2-26-68	300	Tc	26	.14	1.0	.9	85	2.1	188	0	3.8	21	.5	1.5	235	243	6	375	6.9	5
40 ------	8-30-67	412	Tc	13	.04	.0	.0	116	.5	274	0	4.8	11	.1	.0	280	287	0	461	8.0	5
T. 12 N., R. 4 E.																					
Ca-54 ------	2-21-68	420	Tc	17	0.07	13	4.3	184	3.2	421	0	80	11	0.2	3.1	523	530	50	849	7.6	5

TABLE 2.—*Chemical analyses of ground water*—Continued

Well No.	Date of collection	Depth (ft)	Geologic unit	Constituents, in milligrams per liter												Dissolved solids		Hardness as $CaCO_3$	Specific conductance (micromhos at 25°C)	pH	Color
				Silicia (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Calculated	Residue at 180°C				
Zone A—Continued																					
T. 12 N., R. 1 W.																					
W-103 ------	3-22-68	325	Ts	32	0.27	0.0	0.0	73	0.5	184	0	0.0	6.0	0.4	0.0	203	202	0	300	7.9	5
T. 12 N., R. 2 W.																					
W-65 ------	9-13-67	420	Ts	13	0.03	0.4	0.0	110	0.6	250	0	24	7.0	0.2	0.2	278	278	1	459	7.8	10
92 ------	9-13-67	180	Tc	11	.03	1.2	.7	222	1.1	569	0	.0	12	1.6	.6	530	571	6	889	7.7	80
T. 12 N., R. 3 W.																					
W-75 ------	10-25-67	310	Ts	13	0.06	1.0	0.1	129	0.5	268	17	0.0	29	0.3	0.0	322	326	3	551	8.7	30
113 ------	8-16-68	541	Ts	16	.43	.7	.1	274	.3	297	0	34	226	.2	.0	697	699	2	1,250	8.1	50
T. 12 N., R. 4 W.																					
W-101 ------	1-16-68	117	Ts	9.8	0.04	3.2	0.0	228	1.9	522	24	0.0	32	1.0	0.0	557	594	8	974	8.7	240
T. 13 N., R. 1 E.																					
W-71 ------	8-31-67	417	Ts	10	0.07	0.7	0.1	178	0.8	463	0	0.0	7.2	1.4	0.0	426	448	2	704	8.0	30
T. 13 N., R. 2 E.																					
Ca-22 ------	8-31-67	632	Ts	10	0.01	1.4	0.6	476	1.5	1,080	31	0.4	63	6.5	0.9	1,120	----	6	1,830	8.5	250
T. 13 N., R. 3 E.																					
Ca-57 ------	2-27-68	380	Tc	42	1.1	3.3	2.1	64	1.1	150	0	9.0	16	0.3	0.0	212	216	17	302	7.0	20

T. 13 N., R. 4 E.																					
Ca-34 ------	1-14-66	435	Tc	17	0.54	0.8	0.0	120	1.6	300	0	8.2	7.8	0.6	0.6	305	332	2	511	7.5	50
36 ------	6-30-66	413	Tc	43	2.8	13	6.2	50	2.8	129	0	22	20	.3	.0	221	209	58	313	6.7	5
49 ------	2- 1-68	474	Tc	35	1.2	1.1	.1	88	.8	191	0	18	16	.3	.1	253	250	3	414	7.1	10
T. 13 N., R. 1 W.																					
W-105 -----	6-14-68	386	Ts	10	0.26	2.0	0.0	250	1.2	657	0	0.0	6.0	1.7	0.1	595	640	5	980	8.2	160
T. 13 N., R. 2 W.																					
W-63 ------	9-13-67	376	Ts	10	0.07	1.5	0.1	288	2.2	664	0	35	29	2.0	0.1	695	701	4	1,120	8.2	80
T. 13 N., R. 3 W.																					
W-41 ------	3-20-68	456	Ts	15	0.07	0.5	0.2	145	0.4	307	5	32	11	0.3	0.6	361	362	2	526	8.4	60
T. 13 N., R. 4 W.																					
W-77 ------	10-26-67	527	Ts	13	0.12	0.8	0.2	220	0.7	225	14	0.0	200	0.3	0.0	560	577	3	1,050	8.7	30
97 ------	11-16-67	165	Ts	41	.07	.4	.0	36	1.3	83	0	5.6	5.0	.2	.5	131	138	1	160	6.7	5
T. 13 N., R. 5 W.																					
W-98 ------	11-16-67	92	Ts	17	0.02	1.0	0.6	2.1	0.7	6	0	0.4	2.5	0.0	0.7	28	42	5	25	5.3	5
111 -----	8- 5-68	204	Ts	18	.11	1.3	.7	4.3	.4	13	0	.2	4.0	.0	.0	35	36	6	30	5.9	10
T. 14 N., R. 1 E.																					
Ja-101A ----	4-18-66	126	Tc	55	1.1	6.9	2.4	12	2.0	54	0	4.8	5.3	0.1	0.0	116	114	27	120	6.1	15
101B ----	5-12-66	432	Ts	45	.0	.5	.7	270	2.0	699	0	3.4	12	2.0	.6	680	681	4	1,090	8.2	10
T. 14 N., R. 3 E.																					
Ca-45 -----	9- 1-67	525	Ts	10	0.06	2.6	0.9	500	2.5	1,200	0	0.0	99	5.5	0.0	1,210	----	10	1,980	8.2	150
46 ------	9- 1-67	210	Tc	43	3.1	14	4.6	14	2.6	57	0	24	11	.1	.1	141	145	54	194	6.4	5
T. 14 N., R. 2 W.																					
Ja-111 -----	9-13-67	336	Ts	10	0.18	1.0	0.1	238	1.2	431	9	99	20	1.1	0.0	591	590	3	947	8.3	20
114 ------	10-26-67	318	Ts	11	.06	2.2	1.1	288	1.9	513	24	152	26	2.2	2.0	762	775	10	1,240	8.5	30
T. 14 N., R. 3 W.																					
Ja-62 ------	1-16-63	450	Ts	13	0.16	0.0	0.0	78	0.7	172	0	24	5.5	0.1	0.2	207	267	0	340	7.7	15
109A ----	1-17-67	306	Ts	17	.41	33	14	194	3.4	330	0	272	26	.1	.1	723	740	142	1,130	7.6	0
109B ----	2- 2-67	540	Ts	14	.43	.0	.0	98	.7	209	0	36	3.0	.2	.1	255	268	0	402	----	30

TABLE 2.—*Chemical analyses of ground water*—Continued

Well No.	Date of collection	Depth (ft)	Geologic unit	Silicia (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids: Calculated	Dissolved solids: Residue at 180°C	Hardness as $CaCO_3$	Specific conductance (micromhos at 25°C)	pH	Color
Zone A—Continued																					
T. 14 N., R. 3 W.—Continued																					
112 ------	10–25–67	230	Ts	11	.04	34	9.7	461	7.7	274	0	813	66	.2	6.0	1,540	----	125	2,320	7.6	5
119 ------	3–20–68	240	Ts	11	.05	.2	.1	130	1.2	299	9	4.0	6.2	.1	2.2	311	333	1	552	8.4	5
T. 14 N., R. 4 W.																					
Ja–133 -----	7–22–68	318	Ts	17	0.04	0.6	0.1	85	0.9	178	0	28	7.8	0.1	0.0	228	234	2	360	7.9	5
T. 14 N., R. 5 W.																					
Bi–99 ------	2– 6–68	261	Ts	32	0.74	3.8	1.3	6.0	1.6	16	0	13	3.2	0.1	0.0	69	70	15	69	5.5	0
100 ------	2– 6–68	90	Ts	14	.01	3.0	1.3	5.7	1.0	4	0	.2	14	.0	3.0	44	62	13	76	5.3	5
102A ----	2–26–68	181	Ts	41	.06	4.7	1.3	14	3.7	48	0	5.8	4.3	.0	1.8	101	102	17	107	6.6	15
102B ----	2–19–68	292	Ts	38	1.2	3.0	.6	13	3.1	39	0	3.2	4.5	.0	.3	85	83	10	89	7.4	30
T. 14 N., R. 6 W.																					
Bi–95A ----	8–10–67	258	Tw	16	0.09	1.9	0.1	302	1.3	593	24	95	15	1.4	0.4	749	753	5	1,190	8.5	30
95B -----	8–28–67	718	Tw	13	.27	3.2	.5	425	1.4	538	12	.4	340	1.0	.2	1,060	----	10	1,880	8.4	5
96 ------	9– 9–67	690	Tw	15	.22	.5	.2	103	.3	242	13	.4	5.3	.1	.1	257	255	2	406	8.4	10
T. 15 N., R. 3 E.																					
Ca–51 ------	2– 1–68	500	Ts	12	0.18	0.0	0.0	262	0.6	607	15	0.2	30	1.4	1.3	636	656	0	1,030	8.5	180
52 ------	2– 1–68	130	Tc	14	31	3.0	1.8	10	2.8	27	0	12	24	.0	.6	81	97	15	131	5.6	10

T. 15 N., R. 1 W.																					
Ja-45 ------	1-26-60	102	Tc	44	1.6	5.0	0.9	9.9	2.5	38	0	0.4	6.1	0.1	0.1	88	98	16	91	6.3	5
103 ------	6-26-66	938	Ts	14	.14	.7	.1	200	1.0	299	20	10	127	.4	.0	500	506	2	877	8.6	30
104A ----	7-13-66	310	Ts	10	.51	3.8	.1	260	3.0	678	0	1.0	11	3.1	.0	625	662	10	1,030	7.8	80
104B ----	7- 7-66	780	Ts	15	.43	.4	.2	160	3.0	342	10	22	19	.5	.0	398	416	2	649	8.5	50
T. 15 N., R 2 W.																					
Ja-4 -------	3-24-55	534	Ts	13	0.06	0.3	0.2	109	1.6	230	0	36	8.5	0.0	2.5	----	297	2	464	7.3	0
110 ------	1-17-68	510	Ts	34	.49	5.7	2.1	60	2.0	159	0	17	7.4	.1	.1	206	211	23	308	7.0	10
T. 15 N., R. 3 W.																					
Ja-38 ------	1-27-60	518	Ts	22	1.0	0.0	0.0	88	0.8	182	0	26	10	0.3	0.8	239	239	0	359	7.9	10
43 ------	1-26-60	370	Ts	32	.12	.0	.0	71	1.0	147	0	19	9.2	.3	.8	206	210	0	300	7.4	10
44 ------	1- 9-63	505	Ts	27	.20	.9	.2	101	1.1	191	0	18	30	.1	.0	273	282	3	435	7.4	15
91 ------	3-21-68	510	Ts	26	.13	.4	.0	85	1.1	179	0	27	8.9	.1	.1	237	241	1	372	7.6	15
106 -----	9- 9-66	328	Ts	37	.35	.5	.9	63	1.8	143	0	20	7.3	.1	.1	201	202	5	288	6.7	0
116 -----	11-16-67	250	Ts	12	.03	5.5	2.0	140	2.2	327	0	48	8.6	.7	.2	380	401	22	628	7.5	5
T. 15 N., R. 4 W.																					
Ja-42 ------	9- 2-60	348	Ts	38	0.31	15	3.8	56	4.2	126	0	22	36	0.4	0.0	238	257	53	391	6.7	40
105A ----	7-22-66	588	Ts	44	.35	1.9	.8	80	1.3	169	0	32	12	.0	.1	255	265	8	373	7.1	20
105B ----	7-26-66	330	Ts	62	1.8	12	3.2	25	3.2	82	0	26	7.5	.0	.2	179	183	43	218	6.3	30
T. 16 N., R. 1 W.																					
Ja-6 -------	11-15-67	751	Ts	12	0.07	0.0	0.0	152	0.3	282	12	24	32	0.4	0.4	372	392	0	621	8.6	60
73 ------	11-15-67	120	Tc	23	15	3.2	3.4	10	1.5	54	0	.2	1.0	.0	.0	69	62	22	83	6.5	0
T. 16 N., R. 3 W.																					
Ja-88 ------	10-26-67	445	Ts	13	0.01	0.5	0.2	100	0.8	209	0	36	7.9	0.2	0.3	262	254	2	409	8.0	5
T. 16 N., R. 4 W.																					
Ja-99 ------	3-22-68	607	Ts	26	0.02	0.0	0.0	79	0.8	163	0	26	5.2	0.1	0.1	217	220	0	332	7.5	5
T. 16 N., R. 5 W.																					
Bi-101 -----	1-17-68	300	Ts	15	2.3	11	3.0	54	4.5	155	0	21	8.6	0.0	2.8	196	209	40	352	7.7	20
T. 17 N., R. 2 W.																					
Ja-136 -----	1-15-69	731	Ts	12	0.23	2.8	0.0	135	0.6	244	16	2.0	44	0.3	1.6	334	331	7	536	8.8	50

TABLE 2.—*Chemical analyses of ground water*—Continued

Well No.	Date of collection	Depth (ft)	Geologic unit	Silicia (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids: Calculated	Dissolved solids: Residue at 180°C	Hardness as $CaCO_3$	Specific conductance (micromhos at 25°C)	pH	Color
				Constituents, in milligrams per liter																	
Zone A—Continued																					
T. 17 N., R. 3 W.																					
Ja–100	3–22–68	500	Ts	16	0.10	0.4	0.0	82	0.9	186	0	14	6.6	0.2	0.1	212	212	1	358	7.7	15
T. 17 N., R. 4 W.																					
L–50	11–15–67	360	Ts	10	0.22	1.6	1 0	140	0.7	250	0	86	13	0.4	1.6	377	395	8	618	7.6	15
62	1–18–68	340	Ts	24	2.6	28	8.8	26	2.8	169	0	21	5.8	.2	.2	200	206	106	324	7.2	5
T. 17 N., R. 5 W.																					
L–88	11–15–67	100	Tc	53	2.0	6.0	2.2	14	1.8	42	0	4.4	11	0.1	0.0	114	117	24	117	6.3	5
T. 18 N., R. 2 W.																					
L–49	11–15–67	160	Tc	9.9	0.19	4.0	1.9	100	2.0	266	0	13	4.0	0.2	0.6	267	269	18	440	7.8	5
63	8– 5–68	645	Ts	12	.07	1.6	.0	104	.8	223	0	31	15	.3	.0	275	285	4	449	7.8	15
T. 18 N., R. 3 W.																					
L–1	3–23–55	637	Ts	25	0.17	1.4	0.3	72	1.0	168	0	13	8.0	0.1	0.8	206	210	5	316	7.8	10
48	5–14–68	758	Ts	41	.20	1.1	.3	58	1.5	124	0	14	8.5	.5	.0	186	187	4	252	7.4	5
102	5–19–67	601	Ts	34	.23	1.0	.1	65	1.6	132	0	28	5.8	.1	.5	201	183	3	262	7.1	10
106	12–27–67	766	Ts	24	.12	.0	.0	61	.3	136	0	11	7.7	.1	.0	171	178	0	161	7.4	0
T. 18 N., R. 4 W.																					
L–8	3–16–60	525	Ts	7.4	0.40	0.0	0.0	45	2.3	112	0	1.8	4.8	0.1	1.0	123	125	0	190	7.4	10
34	12–16–59	644	Ts	38	2.7	3.8	1.1	29	3.3	92	0	.0	46	.1	.5	128	166	14	192	6.8	50
T. 18 N., R. 5 W.																					
L–53	1–18–68	550	Ts	50	0.50	12	1.0	25	2.9	88	0	15	4.9	0.1	0.4	154	158	34	188	7.7	5

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