STATE OF LOUISIANA
DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT
OFFICE OF PUBLIC WORKS

Water Resources
TECHNICAL REPORT NO. 26

WATER RESOURCES OF THE KISATCHIE WELL-FIELD AREA NEAR ALEXANDRIA, LOUISIANA

Prepared by
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
In cooperation with
LOUISIANA DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT
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DAVID C. TREEN, Governor

DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT

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Cooperative projects with

UNITED STATES GEOLOGICAL SURVEY

DOYLE G. FREDERICK, Acting Director

Louisiana District

A. N. CAMERON, Chief

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FACTORS FOR CONVERTING INCH-POUND UNITS TO INTERNATIONAL SYSTEM (SI) OF METRIC UNITS

Multiply	By	To obtain
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second per square mile [($ft^3/s)/mi^2$]	0.1093	cubic meter per second per square kilometer [($m^3/s)/km^2$]
foot (ft)	0.3048	meter (m)
foot per day (ft/d)	0.3048	meter per day (m/d)
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
square foot per day (ft^2/d)	0.09290	square meter per day (m^2/d)
gallon per day per foot [(gal/d)/ft]	0.01242	cubic meter per day per meter [($m^3/d)/m$]
gallon per day per square foot [($gal/d)/ft^2$]	0.04075	cubic meter per day per square meter [($m^3/d)/m^2$]
gallon per minute (gal/min)	0.06309	liter per second (L/s)
	3.785×10^{-3}	cubic meter per minute (m^3/min)
gallon per minute per foot [(gal/min)/ft]	0.2070	liter per second per meter [(L/s)/m]
gallon per minute per square mile [($gal/min)/mi^2$]	0.02436	liter per second per square kilometer [($L/s)/km^2$]
inch (in.)	2.540	centimeter (cm)
inch per year (in/yr)	25.40	millimeter per year (mm/yr)
mile (mi)	1.609	kilometer (km)
million gallons (Mgal)	3.785×10^6	liter (L)
	3.785×10^3	cubic meter (m^3)
million gallons per day (Mgal/d)	3.785×10^6	liter per day (L/d)
	3.785×10^3	cubic meter per day (m^3/d)

To convert temperature in degree Celsius (°C) to degree Fahrenheit (°F), multiply by 9/5 and add 32.

WATER RESOURCES OF THE KISATCHIE WELL-FIELD AREA NEAR ALEXANDRIA, LOUISIANA

By James E. Rogers

ABSTRACT

Sands of Miocene, Pliocene(?), and Pleistocene age contain freshwater in central Rapides Parish, La. In this area the base of fresh ground water ranges from 900 feet to more than 2,500 feet below National Geodetic Vertical Datum of 1929. The principal sources of water are the Carnahan Bayou, Williamson Creek, and Blounts Creek Members of the Fleming Formation of Miocene and Pliocene(?) age and terrace deposits of Pleistocene age.

The hydraulic characteristics of the sand beds in the Fleming Formation are similar. Hydraulic conductivity ranges from 20 to 130 feet per day; and storage coefficient is about 0.0001, which indicates artesian conditions. Transmissivity depends on the thickness of the individual sand beds, which ranges from 30 to about 170 feet. Hydraulic conductivity of the terrace deposits ranges from 170 to 200 feet per day, and transmissivity averages 13,400 feet squared per day. Storage coefficients determined by tests are as high as 0.06 and indicate water-table conditions. After long-term drainage the value probably would approach 0.2.

Prior to 1968, very little ground water was pumped in central Rapides Parish. Production increased greatly in 1968 when the city of Alexandria developed a well field in Kisatchie National Forest about 18 miles south-southwest of the city. Production has been as high as 25 million gallons per day of water for municipal and industrial uses. Thirty-five wells (90-2,078 feet deep) produce the water. Well yields range from 190 to 1,100 gallons per minute. Specific capacities of the artesian wells range from 1.3 to 33.0 gallons per minute per foot of drawdown and of the shallow, water-table wells, from 5.8 to 46.5 gallons per minute per foot of drawdown.

In response to pumping, water levels have declined in all of the sand beds yielding water to the wells. Some of the sand beds are not extensive; and water-level decline has been great enough to require lowering of the pump, thus reducing the pumping rate. Other sand beds are extensive, water-level decline is moderate, and well yields remain the same as when the wells were constructed. In the terrace sand and gravel, water levels declined, 1968-72--a relatively dry period--and recovered partially, 1973-75--a relatively wet period. However, at the end of 1975, water levels were still lower than in 1968.

Water from both shallow and deep wells is soft and low in dissolved soilds. The pH of water from the deeper wells is greater than 7; that of water from the shallow wells is less than 7. A high concentration of carbon dioxide causes water from the shallow wells to be corrosive.

Additional water can be produced from the sand beds in the project area--particularly in areas outside the well field. Spring Creek and the Calcasieu River have high base flow sustained by outflow from the terrace deposits; thus, water from the two sources is similar in quality. The principal difference is greater color and lower carbon dioxide in the streams. The streams are an alternate source rather than an additional source because water taken from the terrace deposits ultimately causes a reduction in streamflow.

INTRODUCTION

The Kisatchie well field, located about 18 mi southwest of Alexandria in the Kisatchie National Forest (Evangeline Division) in central Rapides Parish, yields as much as 25 Mgal/d of water for municipal and industrial uses. The well field is an important source of water for the Alexandria metropolitan area.

The area described in this report coincides with the area shown on the Forest Hill, La., quadrangle (fig. 1). The Kisatchie well field, which has east-west dimensions of about 4 mi and north-south dimensions of about 3 mi, is centrally located in the area and occupies less than 5 percent of the area. There are 24 well sites in the well field; nine sites have more than one well, and one (fig. 2) has a battery of four wells, each screened in a different sand.

During the early 1960's, use of water in Alexandria during peak periods began to approach or exceed the capacity of the city's well fields. About the same time, the Bodcaw Company began studying the area around Alexandria for potential sources of water for a proposed papermill. Because large quantities of water were needed, importation of water from beyond the area near Alexandria appeared to be the most reasonable course of action.

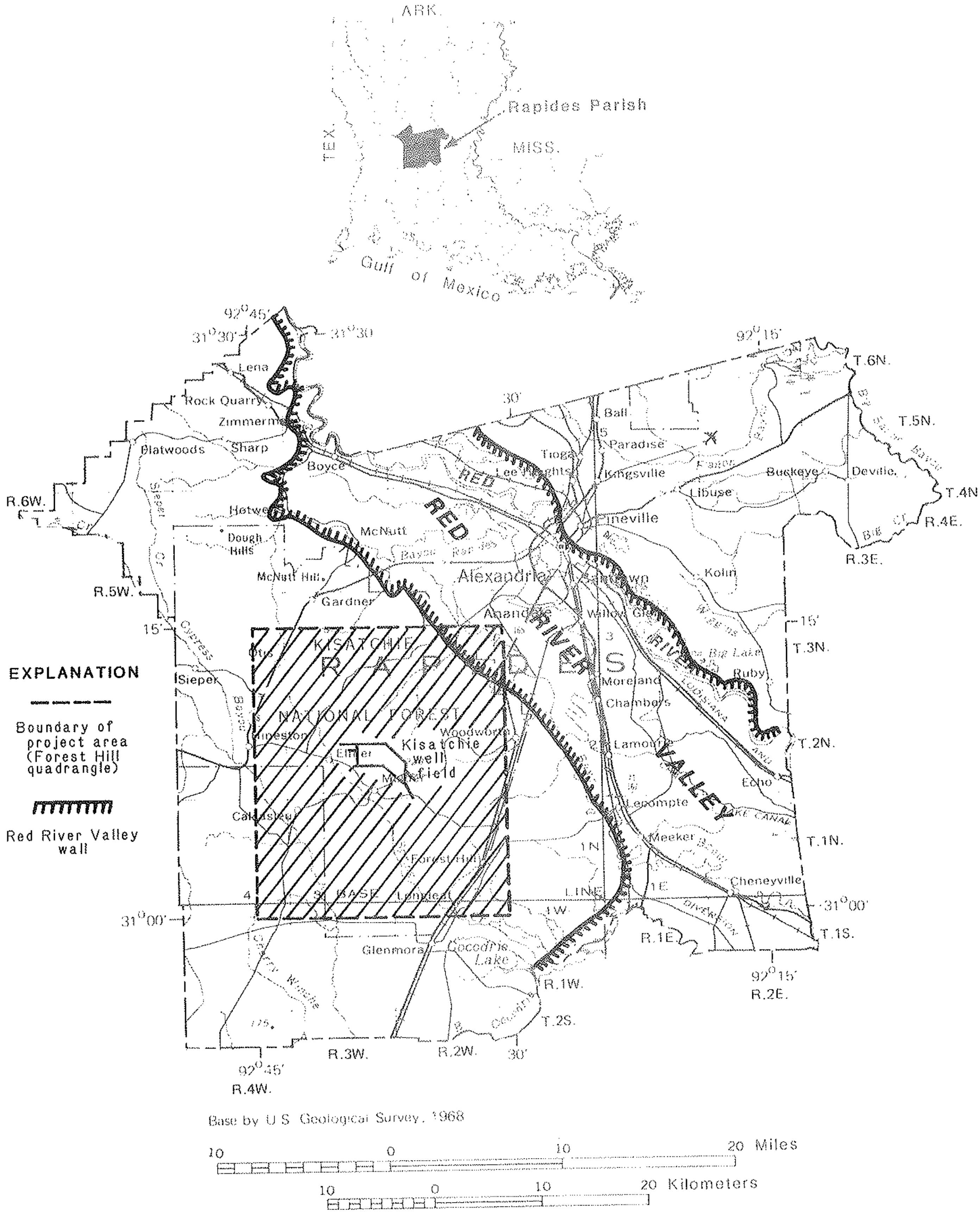

Figure 1.--Location of the project area and Kisatchie well field.

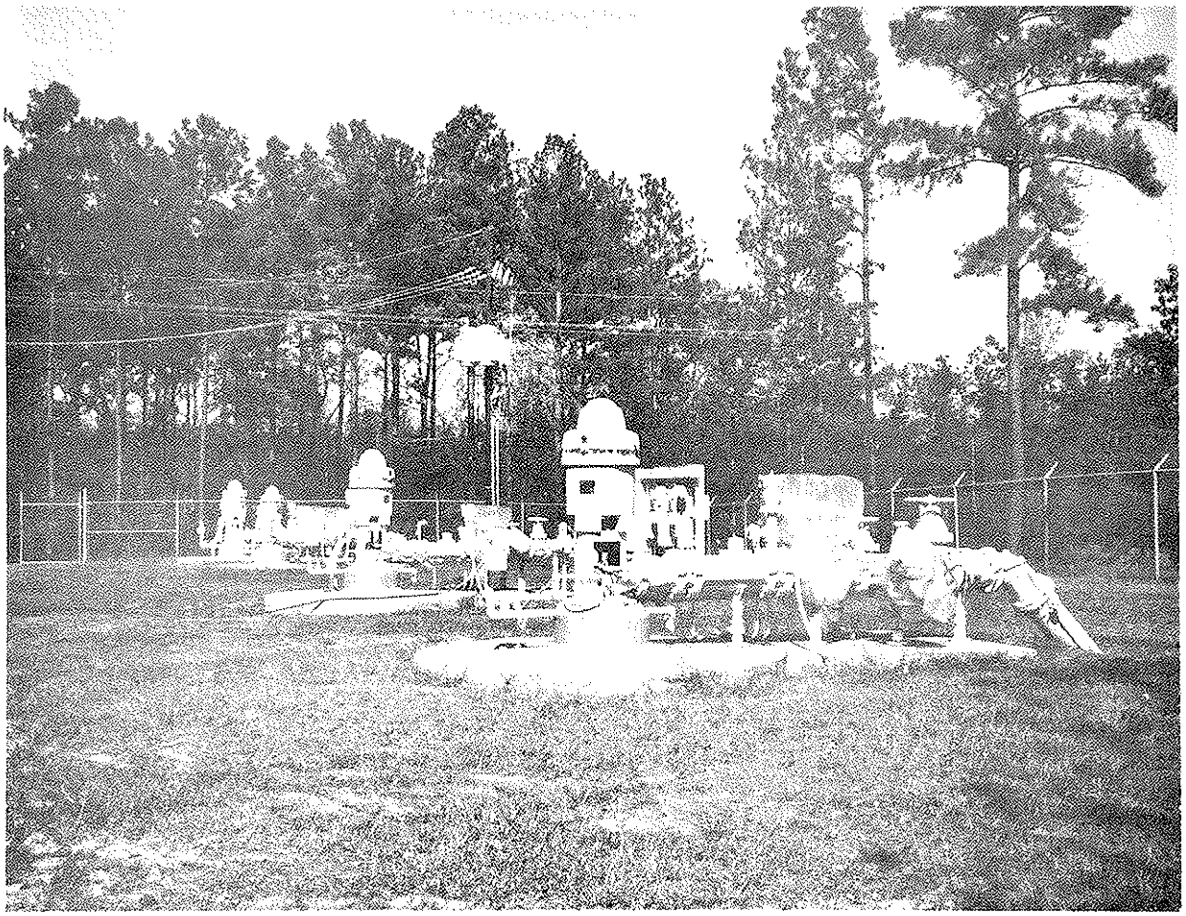

Figure 2.--Battery of wells, Kisatchie well field.
(Left to right: R-933, -913, -936, -939.)

Electrical-log data indicated that freshwater (resistivity greater than 20 ohm-meters) occurs to depths of 2,000 ft or more about 18 mi south-southwest of Alexandria. (See Newcome and Sloss, 1966, pl. 2; fig. 3 is an updated map of the base of freshwater prepared for this report.) In addition, large quantities of water had been developed in that area at Camp Claiborne during World War II. To further appraise the water-resources potential of the area, a test-drilling program was conducted by the city of Alexandria and the Louisiana Department of Transportation and Development, Office of Public Works. The test program provided data that indicated that the water available in the Kisatchie National Forest in central Rapides

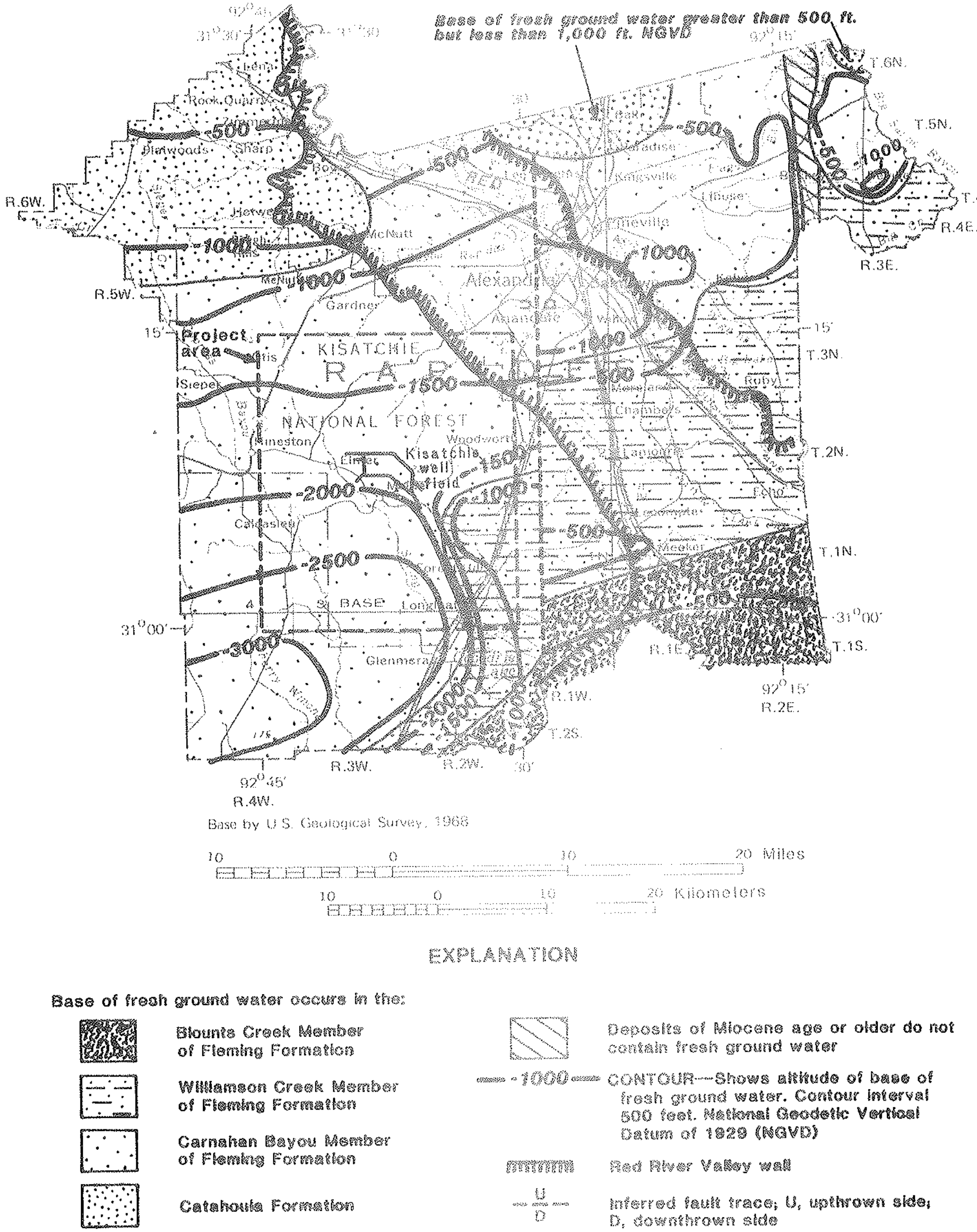

Figure 3.--Altitude of the base of fresh ground water in Rapides Parish.

Parish was generally suitable for the water-supply requirements of the Alexandria area. The Kisatchie well field was constructed in 1967-68, and operations began in the summer of 1968.

Most of the sand beds that yield water at the well field are not affected by pumping outside the area. Only the sands at depths of about 2,000 ft are responding to long-term pumping at Alexandria. Because the well field is located in a relatively isolated, undeveloped area, it presented the opportunity to document the effects of the development of a large water supply. The study was made to document the early response of the aquifers to pumping, to identify possible problems, and to investigate the area for additional or alternate sources of water. The study also provides an indication of the water-resources potential of the adjacent, undeveloped area to the west and southwest that is similar in geology and hydrology.

When the well field was completed, the U.S. Geological Survey began a program of data collection and analysis in the project area. Completion data for wells, pumping-test data, and water samples for chemical analyses were collected. Water-level measurements were made regularly, and geohydrologic features of the area were studied. Most of the data collected during the study are tabulated or summarized in the report; and geohydrologic features of the area, including relations between ground water and surface water, are described.

The U.S. Geological Survey made this study in cooperation with the Louisiana Office of Public Works, Department of Transportation and Development and the city of Alexandria. Electrical logs of oil-test wells were made available by the Louisiana Geological Survey, Department of Natural Resources.

The cooperation of Mr. R. L. Lawrence (Superintendent of the Water Department of the city of Alexandria during the study), who provided assistance for measuring wells and manipulating pumping intervals for aquifer tests in the Kisatchie well field, is greatly appreciated. In addition, the consultant for the city, Daigre Engineers, Inc., provided construction data on the wells and pumping records.

HYDROLOGIC FRAMEWORK

Geologic Setting

Sands of Miocene, Pliocene(?), and Pleistocene age contain freshwater in the project area. The Miocene and Pliocene(?) sands are predominantly fine to coarse quartz grains. In some places, fine black chert gravel is mixed with the sand.

Dip of the Miocene and Pliocene(?) beds in the area is toward the Gulf of Mexico at 60 to 140 ft/mi. Regionally, the dip of individual beds increases southward; generally, deep beds have steeper dips than shallow beds. Increasing subsidence gulfward during deposition accounts for increasing dip and for thickening of the Miocene and Pliocene(?) units toward the south. The general configuration of the Tertiary sediments and their relation to the overlying Pleistocene sediments is illustrated on plate 1. Generalized surficial geology of the area is illustrated on plate 3.

Miocene and Pliocene(?) deposits are mapped in central Louisiana on the basis of criteria discussed in reports by Rogers and Calandro (1965) and Newcome and Sloss (1966). Distinctive clayey intervals separate zones containing numerous sand beds. Because these deposits in the subsurface correlate well with the members of the Fleming Formation (Miocene) as mapped by Fisk (1940) at the surface, Fisk's nomenclature is applied to the subsurface units in this study. These members (from oldest to youngest) are Lena, Carnahan Bayou, Dough Hills, Williamson Creek, Castor Creek, and Blounts Creek.[1] The Lena, Dough Hills, and Castor Creek Members are predominantly clayey units. Some of the clays contain calcareous concretions, and the Castor Creek Member has a distinctive fossil assemblage. In some places these clayey units contain one or more sand beds.

Deep wells in the Kisatchie Forest well field are screened in sands of the Carnahan Bayou, Williamson Creek, and Blounts Creek Members. Structure contours for these three water-bearing units are shown on plate 2 and in figures 4 and 5. Two wells in the area are screened in sands that may be in the Castor Creek Member. The occurrence of individual sand beds is not consistent throughout the area. A thick, massive sand at one locality may correlate with numerous thin sands at another locality and with a predominantly silty zone at still another locality. Large water-level declines in some wells may be related to nearby discontinuities (pinchouts) of the producing sand. On the other hand, sand continuity in other intervals is indicated by the widespread response of water levels to withdrawals.

The Miocene and Pliocene(?) deposits are mantled by overlying Pleistocene terrace deposits. In the project area the Pleistocene terrace deposits are nearly flat lying--they have a gentle dip of a few feet per mile toward the Gulf of Mexico. Because of the difference in dip between the Pleistocene and Tertiary deposits,

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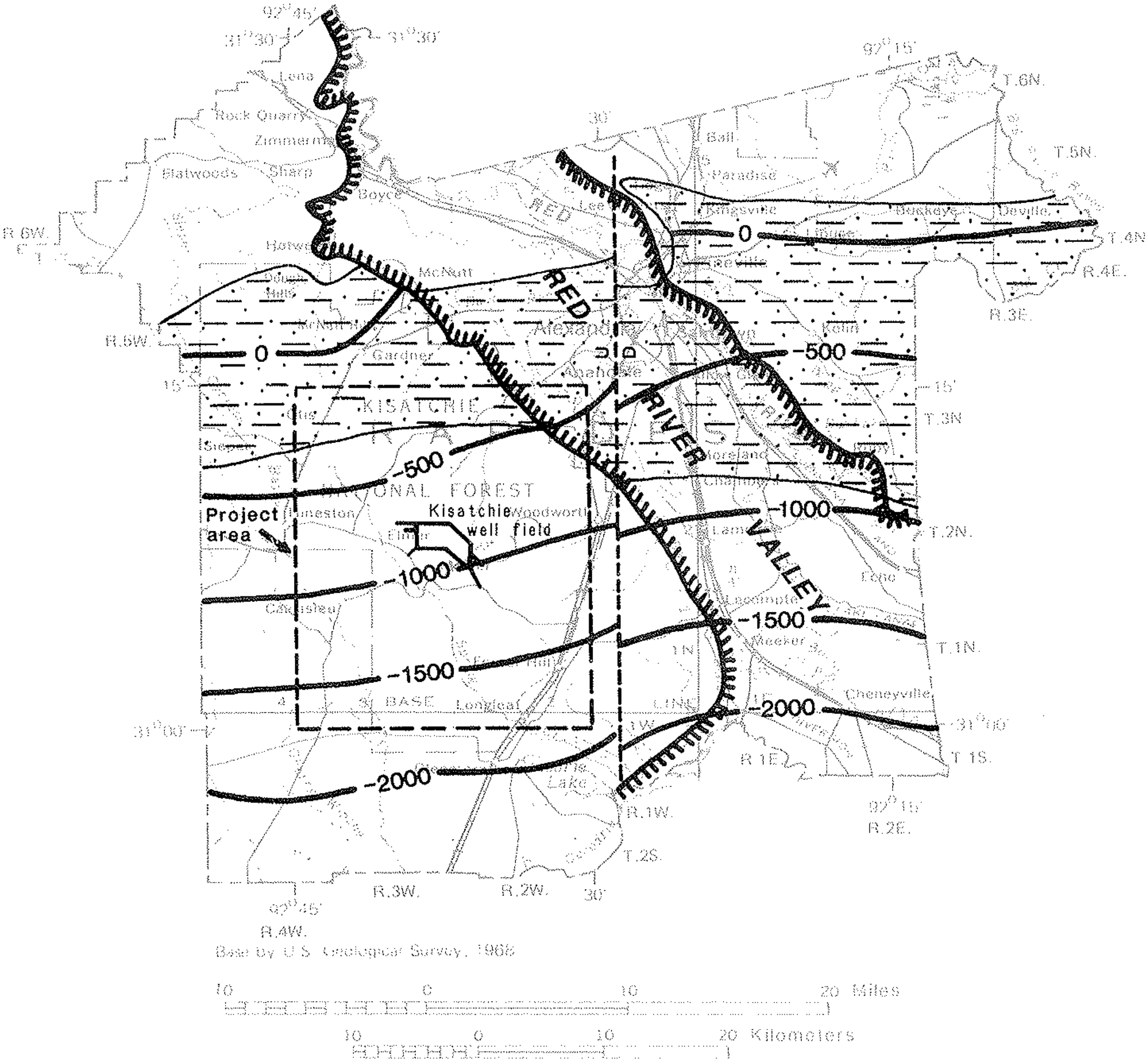
1/The members of the Fleming Formation as mapped by Fisk (1940) are herein adopted for official use by the U.S. Geological Survey. The Blounts Creek Member probably extends into the Pliocene in this area; therefore, the age is considered Miocene and Pliocene(?) in this report.



EXPLANATION

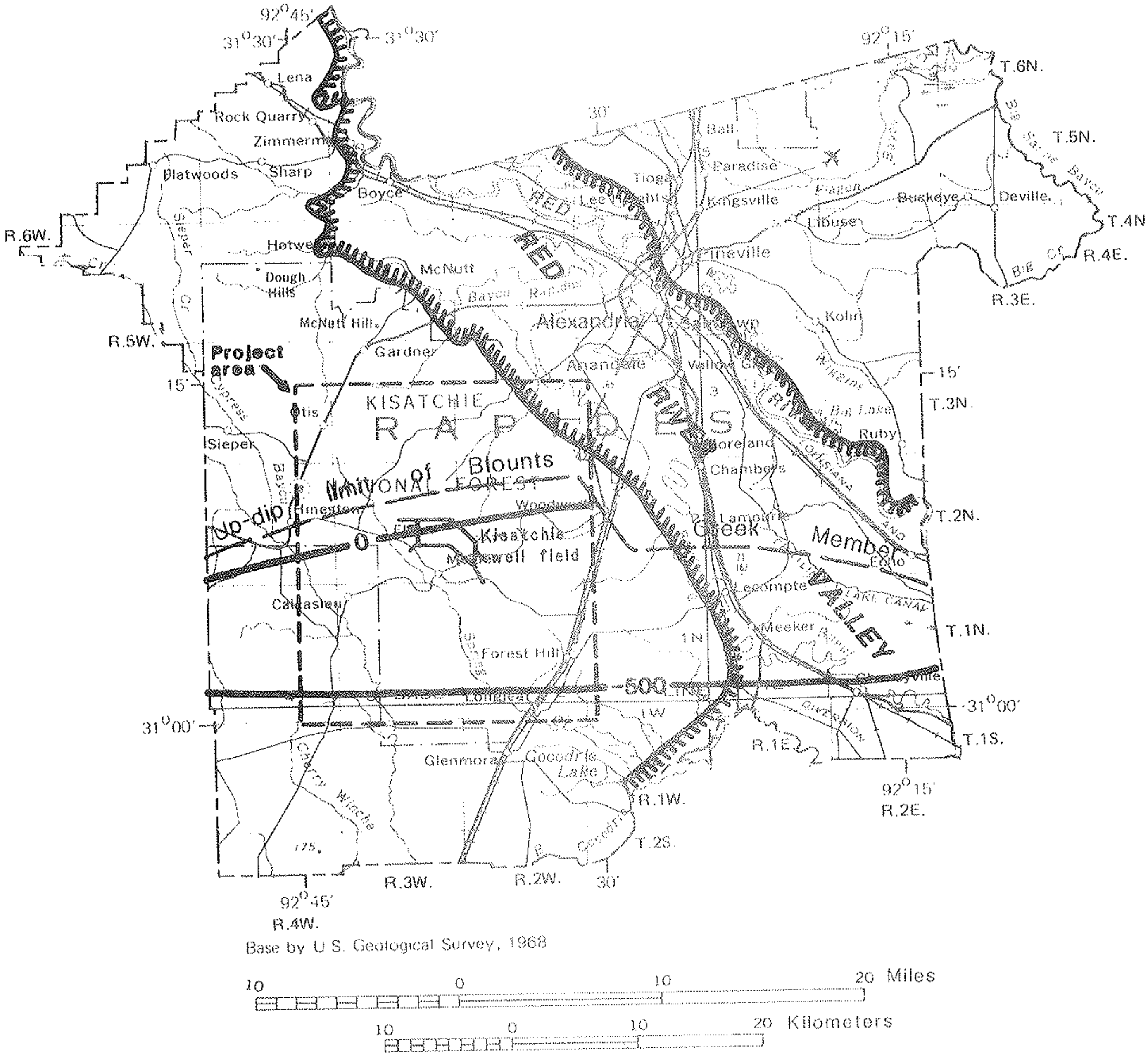
Outcrop or subcrop area of Williamson Creek Member

-500 STRUCTURE CONTOUR--Shows altitude of base of Williamson Creek Member. Contour interval 500 feet. National Geodetic Vertical Datum of 1929

U/D Inferred fault trace; D, downthrown side; U, upthrown side

Red River Valley wall

Figure 4.--Altitude of the base of Williamson Creek Member of the Fleming Formation.



EXPLANATION

—-500— STRUCTURE CONTOUR--Shows altitude of base of Blounts Creek Member. Contour interval 500 feet. National Geodetic Vertical Datum of 1929

Red River Valley wall

Figure 5.--Altitude of the base of Blounts Creek Member of the Fleming Formation.

several sands of the Blounts Creek Member in the vicinity of the well field are in contact with the Pleistocene sand and gravel; whereas in the northern part of the area, some sands of the Williamson Creek Member also are in contact with it.

The Pleistocene terrace deposits are characterized in part of the area by a surficial clay or silty clay underlain by coarse deposits--grading from sand at the top to sand and gravel at the base. The surficial clay ranges in thickness from 0 to about 85 ft (pl. 3). In much of the area the clay was deposited in a relatively thin layer; subsequent erosion has removed the clay cover from about half of the area (pl. 4). Where the clay was removed, sand or gravel is exposed at the surface or underlies a very thin soil profile. Areas without a clay cover have very high rainfall infiltration rates.

Drainage

The project area has three important drains--the Calcasieu River, Spring Creek, and the Castor Creek-Loving Creek system. Spring Creek crosses the project area diagonally from northwest to southeast. Most of the drainage in the well-field area is by tributaries of Spring Creek, principally by Bill Creek, Squyres Branch, Rocky Branch, and Roaring Creek (pl. 4). Part of the drainage from the well field is northward into the headwaters of Brushy Creek, Little Brushy Creek, and Long Branch. Other drainage in the area is by Castor Creek and Loving Creek to the north; Bayou Clear, Little Bayou Clear, Indian Creek, and Barber Creek to the east; and by the Calcasieu River and its tributaries to the southwest (pl. 4).

Precipitation, Evapotranspiration, Infiltration, and Base Flow

Average annual precipitation in the project area is about 58 in. Two precipitation-record stations, Woodworth and Hineston, are on the east and west sides, respectively, of the area (pl. 4). Rainfall data are available for the period since 1956--the same period of time for which streamflow records are available for Spring Creek. At Hineston, precipitation ranged from a low of about 40 in. (1963) to a high of about 83 in. (1961). At Woodworth, precipitation ranged from about 40 in. (1963) to about 80 in. (1961). Rainfall in different parts of the Spring Creek basin may deviate from the station values by small amounts--mostly because of summer showers of varying intensity and distribution.

Precipitation in the area takes various routes once it reaches the land surface. Part of the moisture moves overland to streams as direct runoff, and part moves into the ground. Once the water is underground, evaporation or transpiration by plants may return it to the atmosphere. Water that percolates downward past the root zone moves to the saturated part of the aquifer. Once in the aquifer, virtually all of the water in the Spring Creek basin moves laterally and eventually reappears at the surface as base flow in one of the streams.

Annual runoff for Spring Creek near Glenmora, 1957-68, averaged about 18 in. This period precedes any major pumping from the Kisatchie well field. If the period of record is extended through 1975, average annual runoff is still approximately 18 in. Based on average precipitation of 58 in/yr and assuming that all rainfall in the basin above the gaging station is either returned to the atmosphere by evapotranspiration or measured as streamflow, evapotranspiration in the area averages about 40 in/yr. Average values of precipitation and runoff are more reliable than annual values for determining average evapotranspiration. Using annual values, the delay between infiltration and discharge of water from the shallow aquifer (changes in water in storage) may result in comparing the precipitation of one year with the discharge of water infiltrated in a different year.

The amount of infiltration or recharge to the shallow aquifer is dependent--at least in part--on the quantity of rainfall and on the time of occurrence. If the rainfall occurs during periods of high evapotranspiration (summer), then the amount of infiltration is low. During the winter when evapotranspiration is low, the amount of infiltration is high. During the short period of record for the project area, an average of 4 in. more rainfall occurred in the period November through April than in the remainder of the year. November through April includes most of the nongrowing season, so transpiration is low. The rainfall distribution makes more moisture available during the period of greatest potential for infiltration.

Infiltration rates vary throughout the area because surficial material in some places is clayey and in other places is sandy (pl. 4). The infiltration rate in sandy areas is much higher than the average for the area. In addition to the perennial streams, a number of intermittent streams breach the surficial clay. Where the bed of a creek breaches the surficial clay and is above the water table in the aquifer, as illustrated on plate 3, the creekbed is an area suitable for rapid infiltration. Where the bed of a creek is at or below the water table, the stream gains water from ground-water outflow.

An aquifer test at well R-902[2] (table 8 and pl. 4) illustrates the rapid infiltration of water through the surficial material. The discharge from well R-902, 500 gal/min, was conveyed in unlined ditches. After 30 days pumping, several discharge measurements were made of the flow away from the well. In the road ditch 50 ft from the pumped well, flow was 480 gal/min. As this value is within 5 percent of the well discharge, the measurement by flowmeter may not represent a real change in flow at this point. About 150 ft from the well, flow was 400 gal/min; and in the creek bottom about 1,500 ft from the well, flow was 250 gal/min. Other than pumpage from the well, the creek had no flow. Infiltration of the water did not appear to affect the water levels measured in the observation wells during the first week or two of the test.

The amount of infiltration in the area is difficult to measure directly. However, base flow of Spring Creek--the stream runoff contributed by ground-water discharge--is derived from the terrace deposits. As these deposits are recharged by infiltration of rainfall, base flow is an indirect measure of infiltration. Base flow is determined from analysis of the discharge hydrograph. To translate base-flow quantities into infiltration, the area of infiltration--which coincides with the area contributing ground water to the stream--must be determined. At Spring Creek the ground-water divide is assumed to coincide with the drainage divide of the valley. Thus, the subsurface drainage area is assumed to be equal to the surface drainage area. Because infiltration values derived from base flow do not include water transpired by plants near the stream, the value is a conservative estimate of the infiltration amount.

The average base flow of Spring Creek, 1958-68, at the gaging station near Glenmora (prior to development of the well field) is about 56 ft^3/s or about 0.82 $(ft^3/s)/mi^2$. Based on these values, the average annual infiltration of water subsequently discharged as base flow is 11 in. The range in annual infiltration appears to be from 8 to 13 in. Part of the difference in annual infiltration is related to distribution, intensity, and antecedent conditions for specific rains; and part is related to year-to-year differences in the total rainfall. In addition, some difference occurs because part of the water infiltrated one year appears as base flow in a subsequent year. Large increases in base flow of Spring Creek after wet spring periods show an increased rate of movement of water into and through the aquifer, particularly near the stream. Therefore, as with evapotranspiration, use of average values is more meaningful when determining infiltration.

2/Wells are numbered consecutively in each parish in Louisiana in the order that data were collected or tabulated. The prefix "R" designates wells in Rapides Parish.

Part of the water that infiltrates the terrace deposits recharges, in turn, the underlying Blounts Creek Member rather than discharging into Spring Creek as base flow. The geology shows the potential for interchange; the existence of interchange between the two aquifers is suggested by water-quality and prepumping water-level similarities. If this amount were large, then the base flow of Spring Creek would not be a good approximation of the amount of water infiltrating the terrace deposits.

Because essentially all of the water in the Blounts Creek Member in the project area is derived from the terrace deposits, outflow from the Blounts Creek Member provides a good estimation of the magnitude of this exchange. Water flows laterally through the Blounts Creek Member toward areal discharge in the Red River Valley. Part of this flow is derived from the terrace deposits in the Spring Creek basin; part from terrace deposits in adjacent areas. Lateral flow that is attributed to infiltration from the terrace deposits beneath the Spring Creek basin is about 1 ft^3/s. In addition, some outflow from the Blounts Creek Member occurs as vertical percolation through the thick clay beds that separate the Blounts Creek Member and the deeper lying Williamson Creek Member. To determine this outflow, vertical permeability of the clay was assumed to be about 0.0001 (gal/d)/ft^2--a value similar to a laboratory determination for permeability of clay of Tertiary age in southern Louisiana. Vertical outflow is as much as 0.06 ft^3/s beneath the Spring Creek basin. Net outflow from the Blounts Creek Member from within the Spring Creek basin is about 1.1 ft^3/s, which is less than 2 percent of the average base flow of Spring Creek. The foregoing modification would make the determination of infiltration of rainfall to the terrace 2 percent greater than the value estimated, and the value of evapotranspiration 0.5 percent less. Potential error in the determinations is greater than the effects of disregarding outflow to the deposits of Tertiary age.

Seepage investigations indicate the amount of water flowing in Spring Creek at various locations during base-flow periods. At U.S. Highway 165 (station 30, table 6 and fig. 6) discharge may be substantial. Discharge decreases at upstream sites until the streambed is above the water table. During base-flow periods, sites farther upstream have no flow. For example, in October 1968 (table 6 and fig. 6) Spring Creek had an instantaneous discharge of 42.5 ft^3/s at the gaging station near Glenmora (station 30). The discharge was successively less at each upstream measuring point (fig. 6), and about 14 mi upstream at Louisiana Highway 488 (station 15) there was no flow. During a period of higher base flow and higher water table (May 1969), discharge was 61.7 ft^3/s near Glenmora and was only 0.02 ft^3/s at Louisiana Highway 488.

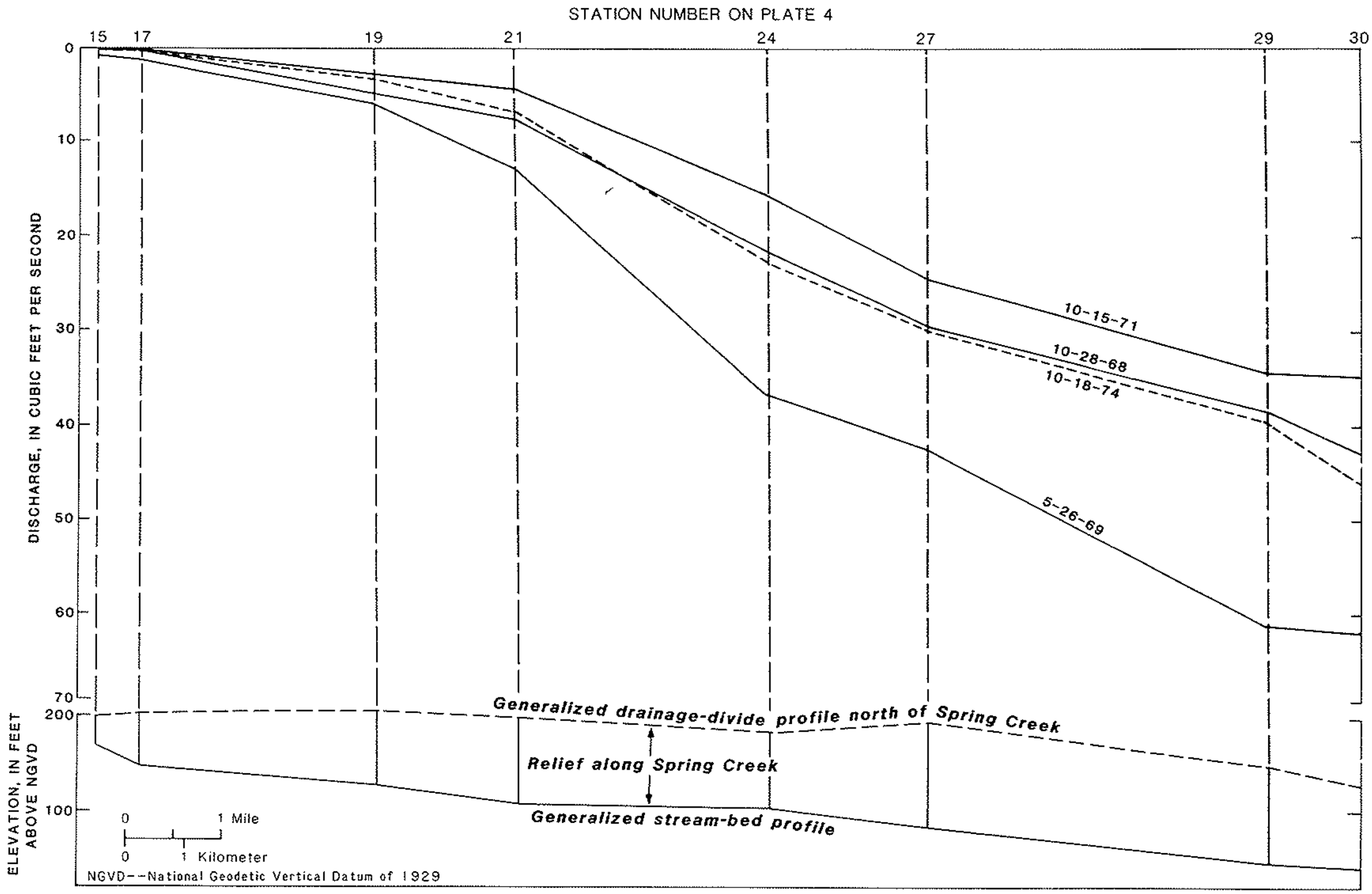


Figure 6.--Instantaneous discharge during four seepage investigations on Spring Creek and generalized profile of streambed and of drainage divide.

In October 1969 the base flow of the Calcasieu River in the project area was measured. Flow increased from 4.91 ft^3/s near Hineston (station 32) to 20.0 ft^3/s near Glenmora (station 34), a distance of about 12 mi. Virtually all of this increase in flow represents discharge from the terrace deposits.

DEVELOPMENT

Camp Claiborne Well Field

The first development of a large well field in the project area was for Camp Claiborne, T. 1 N., R. 2 W., (pl. 4) in 1940-41. According to Maher (1942) nine wells were constructed to depths of 360 to 408 ft. All wells were 12 in. in diameter, had 30 ft of screen, and were gravel walled. The well field was planned to yield 2,000 gal/min for the water needs of the camp. Maximum yield for the well field was expected to be 3,150 gal/min. On May 10, 1940, the yield was 2,062 gal/min; but 1 month later the yield was only 1,040 gal/min. This decline in yield created a serious water shortage for the camp. To alleviate the problem, wells were constructed in the shallow Pleistocene terrace sand and gravel. These new wells had sustained yields of 350 to 570 gal/min, and one well was tested at 1,500 gal/min. Because the quality of the water from the shallow wells was satisfactory, the deep wells were rapidly replaced by shallow wells. By the summer of 1942, only three deep wells were still in use; and all other water was obtained from shallow wells.

The deeper wells failed to produce the quantity of water expected because they were closely spaced, which resulted in excessive water-level declines, and because six of the nine wells were designed improperly. The three wells that were properly designed and constructed maintained their original yield.

Maher (1942) concluded that in the Camp Claiborne area the sands between 200 and 400 ft in depth could yield 2 Mgal/d if wells were properly designed and spaced. He further concluded that the shallow gravel in the area had the potential of yielding 6 Mgal/d. Spacing of one-fourth mile or more was reported to be the minimum suitable for the shallow wells. After Camp Claiborne was closed at the end of World War II, the wells were destroyed.

Testing at Castor Plunge

In 1959 the city of Alexandria explored the possibility of a new well field near Castor Plunge, sec. 29, T. 3 N., R. 2 W., (pl. 4) in Kisatchie National Forest. Tests indicated that wells screened in some sands in the area could yield several hundred gallons per minute. The deepest test well, about 800 ft deep, did not penetrate all of the freshwater section. Tests of the shallow Pleistocene gravel near the Red River Valley showed that it is saturated only in the lower part because nearby streams, such as Castor Creek, provide points of discharge. Following the 1959 testing, the city decided not to develop the Castor Plunge area at that time.

Testing for the Present Well Field

In 1966, potential industrial development near Alexandria led to an evaluation of the area south of Castor Plunge--at Camp Claiborne and the area west of Camp Claiborne--as a possible additional source of water. This area was a promising prospect because of (1) previous development at Camp Claiborne, (2) electrical-log data that indicated freshwater in sands to depths of 2,000 ft or more, and (3) high base flow of streams. Much of this area is in Kisatchie National Forest which made resource and right-of-way permits relatively easy to obtain.

The Louisiana Department of Transportation and Development, Office of Public Works and the city of Alexandria contracted for test holes in the Kisatchie Forest area to determine the extent of sand beds suitable for development of large-capacity wells and to help evaluate the potential of the area.

Test Holes

Six test holes provided information on the deep Miocene sands and the shallow terrace gravels. Five additional test holes provided information on the shallow gravels and the shallow Pliocene(?) and Miocene sands. Data collected are (1) electrical logs and geologic logs to determine sand intervals, (2) sand samples for grain-size analysis, (3) short pumping tests to determine hydraulic characteristics of the aquifer, and (4) water samples for chemical analysis to determine water-quality variation areally and vertically. Although electrical logs of wells in various parts of the parish show thick sands in the Williamson Creek Member and the Carnahan Bayou Member, the number of thick sand beds in the area tested was less than anticipated. The thickest sand interval was in the Carnahan Bayou in well R-844--1,948 to 2,115 ft, including minor clay breaks. Other thick sand beds were found in the test area that appear to correlate with silty zones in nearby areas.

Although only the basal part of the Pleistocene terrace deposits is saturated in the area close to the Red River Valley near Castor Plunge, the saturated thickness is much greater to the south in the Spring Creek basin. The thickness of saturated sand and gravel was promising for development of wells yielding 500 gal/min or more, and the deposits are extensive. Because the potential for developing the quantity of water desired by the city appeared to be good in the Spring Creek basin between U.S. Highway 167 and Hineston--south of Castor Plunge and north of Forest Hill--the city proceeded with development of a well field in the area.

The well field was patterned partly in a loop (fig. 1). Maximum dimensions are about 3.7 mi east to west and 2.8 mi north to south. Deep and shallow test holes were drilled in various parts of the well field to locate sands suitable for high-capacity wells. Thick sands occur in both the lowermost and uppermost parts of the Carnahan Bayou at several localities, in the uppermost part of the Williamson Creek, and in the Blounts Creek. Sands that appear to be of limited areal extent occur in the middle part of the Williamson Creek and in the Castor Creek. The following table (table 1) shows the deep sand intervals more than 30 ft thick and identifies wells screened in the sand at the specific sites.

Six test holes (R-904, R-912, R-917, R-921, R-926, and R-937) in the proposed well-field area were drilled deep enough (more than 2,000 ft) to test the lower part of the Carnahan Bayou. A thick sand in the lower part of the Carnahan Bayou was logged in test holes R-904, R-912, R-917, and R-937. At the location of test hole R-921 the sand is either very silty or contains slightly saline water, and at well R-926 the lower part of the Carnahan Bayou is mostly clay.

Shallow test holes were drilled at other proposed well sites to provide data for construction of production wells in the Pleistocene terrace deposits.

Preliminary Aquifer Tests

As part of the preliminary evaluation of the water-resource potential of the area, temporary wells were made in the test holes. Water samples were collected for chemical analysis and aquifer tests were attempted. These tests were of short duration--only a few hours long--and results are of mixed value. Tests of Pleistocene terrace deposits, in which water-table conditions prevail, were too short for valid results. However, by analogy with similar deposits in other parts of the State, hydraulic-conductivity[3/] values were assumed to be about 270 ft/d or 2,000 (gal/d)/ft^2.

3/Hydraulic conductivity is the volume of water at the existing kinematic viscosity that will move in unit time under a unit hydraulic gradient through a unit area measured at right angles to the direction of flow in an isotropic porous medium. (Adapted from Lohman and others, 1972, p. 4.)

Table 1.--Sand intervals in members of the Fleming Formation interpreted from electrical logs at test sites in the project area

Test hole or well number or name	Location Sec.	T. (N.)	R. (W.)	Sand interval (ft)	Thickness (ft)	Test or production well No.
			BLOUNTS CREEK MEMBER			
R-846	28	2	3	245- 315	70	Test R-846A.
847	24	2	3	218- 253	35	
849	32	2	2	165- 228	63	R-930.
917	27	2	3	240- 280	40	R-903.
926	31	2	2	1/(?)- 190	---	R-925.
				298- 350	52	R-926.
1010	10	1	2	200- 238	38	Test R-1010B.
				248- 290	42	
				335- 365	30	
Hunt Petroleum Corp., Langston No. 1	13	2	2	205- 280	75	
Kirby Petroleum Co., De Bates No. 1	12	1	2	295- 325	30	
				340- 390	50	
				505- 535	30	
				590- 625	35	
			CASTOR CREEK MEMBER			
R-921	24	2	3	2/220- 260	40	
938	26	2	3	2/245- 303	58	R-938.
			WILLIAMSON CREEK MEMBER (UPPER PART)			
R-843	2	2	2	567- 598	31	
846	28	2	3	590- 640	50	Test R-846B.
852	6	1	2	725- 750	25	
				780- 802	22	

912	15	2	3	400- 484	84	R-939.
921	24	2	3	445- 565	120	R-921.
932	22	2	3	419- 473	54	R-932.
1010	10	1	2	{900- 935 {975- 995	35 20	
1011	19	2	2	445- 523	78	Test R-1011A.
Hunt Petroleum Corp., Langston No. 1	13	2	2	595- 640	45	
Kirby Petroleum Co., De Bates No. 1	12	1	2	875- 905	30	
Hunt Oil Co., B. E. Smith Estate No. 1	16	1	2	985-1,020	35	
WILLIAMSON CREEK MEMBER (MIDDLE PART)						
R-917	27	2	3	2/935- 970	35	R-935.
932	22	2	3	2/603- 637	34	
WILLIAMSON CREEK MEMBER (LOWER PART)						
R-845	32	3	3	620- 655	35	Test R-845A.
The California Co., Long Bell Petroleum Co., Inc., No. 1	9	1	3	1,218-1,260	42	
CARNAHAN BAYOU MEMBER (UPPER PART)						
R-845	32	3	3	1,190-1,225	35	Test R-845B.
904	16	2	2	1,340-1,405	65	
912	15	2	3	1,284-1,337	53	R-936.
934	14	2	3	1,255-1,360	105	R-934.
Beard Oil Co., No. 1, U.S.A., 13-13	13	3	3	780- 880	100	
Beard Oil Co., No. 1, B.L.M., 26-5	26	3	3	880- 933	53	
Harvey Schmidt, John E. Ervine, et al	25	3	4	1,058-1,142	84	

See footnotes at end of table, p. 20.

Table 1.--Sand intervals in members of the Fleming Formation interpreted from electrical logs at test sites in the project area--Continued

Test hole or well number or name	Location Sec.	Location T. (N.)	Location R. (W.)	Sand interval (ft)	Thickness (ft)	Test or production well No.
La Gloria Corp., Ada M. Smith No. 1--	28	1	2	2,240-2,315	75	
The California Co., Long Bell Petroleum Co., Inc., No. 1---------	9	1	3	1,885-1,915	30	
				2/2,235-2,285	50	
				2/2,420-2,480	60	
CARNAHAN BAYOU MEMBER (LOWER PART)						
R-844--------------------------------	13	2	3	1,948-2,115	167	Test R-844.
845--------------------------------	32	3	3	1,468-1,498	30	Test R-845C.
852--------------------------------	6	1	2	2/2,180-2,220	---	Test R-852.
904--------------------------------	16	2	2	2,075-2,142	67	
912--------------------------------	15	2	3	1,968-2,060	92	R-933.
917--------------------------------	27	2	3	2,090-2,175	85	
921--------------------------------	24	2	3	2,065-2,170	95	
937--------------------------------	13	2	3	1,965-2,100	135	R-937.
1011--------------------------------	19	2	2	1,985-2,060	75	Test R-1011B.
1056--------------------------------	36	3	4	3/1,480-1,572	92	R-1056.
Beard Oil Co., No. 1, B.L.M., 26-5---	26	3	3	1,505-1,665	160	
Harvey Schmidt, John E. Ervine, et al------------------------------	25	3	4	1,430-1,595	165	
Hunt Petroleum Corp., Langston No. 1-	13	2	2	1,945-1,980 2,010-2,033 2,090-2,120	88	

1/Top uncertain. Sand in Blounts Creek Member in contact with terrace sand and gravel. Total thickness, 135 ft.

2/Sand of limited areal extent.

3/May have slightly saline water near the base of the sand.

Deep aquifer tests included sands in the Carnahan Bayou Member (wells R-844, R-845B, R-845C, and R-852), the Williamson Creek Member (wells R-845A and R-846B), and the Blounts Creek Member (well R-846A). At least one hydraulic-conductivity value was determined for each unit. Several sands contained enough gas to produce anomalous water levels during the course of the test, and values for the hydraulic characteristics for these wells could not be determined. In wells R-845A, R-845B, R-846A, and R-846B, the tests appear to be reliable. Test values that are considered reliable are given in table 2. The hydraulic-conductivity values are within the range of those determined for the units in other parts of the parish (Newcome and Sloss, 1966).

Postconstruction Aquifer Tests

Miocene and Pliocene(?) deposits.--After permanent wells were constructed for the well field, 36-hour aquifer tests were made on wells screened in the Miocene and Pliocene(?) sands. The transmissivity values determined from eight one-well tests and one interference test range from 670 to 11,600 ft^2/d or 5,000 to 87,000 (gal/d)/ft. Of the original tests, the interference test provided the only value for a storage coefficient of the deep sands. Values for transmissivity, hydraulic conductivity, and permeability of the deep sands are summarized in table 2.

Production wells in the area were screened in thick sand beds. Tests of these wells provide an indication of the potential of the well and of the sand bed, but these tests did not reveal that some sand beds were more extensive than others. Correlation of sand beds in the area might have revealed the continuity of some and the lack of continuity of others.

The less continuous sand beds probably would not have been utilized if the wells had not been constructed already. Wells screened in these less extensive sand intervals have undergone much greater water-level decline than would have been expected, based on hydraulic characteristics determined from the pumping tests. The decline was much greater than experienced in wells screened in the more continous sand intervals.

After the well field had been in production several years, the deep sands were tested by pumping one well and observing water-level changes in a production well screened in the same sand. Results are given in table 2. These values should be representative of larger areas than values determined by one-well tests. As could be expected, because even the more continuous sand beds pinch out in one or more directions, discharge boundaries were observed in each of the long tests.

Table 2.--Hydraulic characteristics of sands of members of the Fleming Formation of Miocene and Pliocene(?) age, Kisatchie well-field area

Well No.	Unit	Transmissivity 1/		Hydraulic conductivity	
		(ft^2/d)	[(gal/d)/ft]	(ft/d)	[(gal/d)/ft^2]
		A.--DATA FROM TEST WELLS			
R-845A-----	Williamson Creek Member------	1,470	11,000	40	300
845B-----	Carnahan Bayou Member--------	2,070	15,500	60	450
846A-----	Blounts Creek Member---------	3,480	26,000	50	350
846B-----	Williamson Creek Member------	3,610	27,000	70	550
		B.--DATA FROM PRELIMINARY TESTS OF PRODUCTION WELLS			
R-903 2/----	Blounts Creek Member---------	1,340	10,000	49	370
930------	-----do----------------------	6,280	47,000	100	760
932------	Williamson Creek Member------	7,080	53,000	130	1,000
933------	Carnahan Bayou Member--------	6,680	50,000	70	500
934------	-----do----------------------	9,090	68,000	90	650
935------	Williamson Creek Member------	670	5,000	20	150
936------	Carnahan Bayou Member--------	3,480	26,000	70	500
937------	-----do----------------------	11,630	87,000	110	830
938------	Castor Creek(?) Member-------	1,340	10,000	20	170
		C.--DATA FROM INTERFERENCE TESTS USING PRODUCTION WELLS			
R-933 3/---	Carnahan Bayou Member--------	8,800	66,000	90	700
936 4/---	-----do----------------------	3,600	27,000	70	520
939 5/---	Williamson Creek Member------	10,000	75,000	120	900

1/Transmissivity is the rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of an aquifer under a unit hydraulic gradient.

2/Storage coefficient (S) is 9.7×10^{-5}. Storage coefficient is the volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head.

3/R-937, pumped well; storage coefficient is 1.6×10^{-4}.

4/R-934, pumped well; storage coefficient is 1.5×10^{-4}.

5/R-932, pumped well; storage coefficient is 1.3×10^{-4}.

Pleistocene terrace deposits.--After the decision was made to construct a well field, two test-production wells and several observation wells were drilled in the terrace aquifer. Long pumping tests on wells R-901 and R-902 provided reliable data on the sites tested and provided insight on the magnitude of values that could be expected in other parts of the well field. Well R-902 was pumped for 30 days. The test data matched the type curve after 2 days pumping. No departure trend from the curve was observed for the remainder of the test. Transmissivity was 13,400 ft^2/d or 100,000 (gal/d)/ft at each site; hydraulic conductivity was 170 ft/d or 1,300 $(gal/d)/ft^2$ at well R-901 and 200 ft/d or 1,500 $(gal/d)/ft^2$ at well R-902. The storage coefficient was 0.07 at well R-901 and 0.06 at well R-902. Data from these tests were an aid in designing the well field. Subsequently, tests were made on each of the shallow production wells to determine the proper size for the permanent pump. These tests were of short duration and provided well-response data but not hydrologic characteristics of the aquifer.

Corroborating evidence for the transmissivity of the Pleistocene terrace deposits was obtained by analyzing the relationships between the deposits and the flow of Spring Creek. Because outflow from the terrace deposits supplies virtually all the base flow of Spring Creek, conditions are favorable for estimating diffusivity, transmissivity divided by storage coefficient ($\frac{T}{S}$), of the terrace deposits. Rorabaugh (1960) presented a method for determining diffusivity, using the stream hydrograph. One of his assumptions is that the stream fully penetrates the aquifer. Although Spring Creek does not fully penetrate the deposits in the project area, the diffusivity value determined by Rorabaugh's method should be a close approximation to the actual value. Data for his equation,

$$\frac{T}{a^2S} = 0.933\frac{\log\frac{Q_1}{Q_2}}{t_2-t_1},$$

are as follows:

a=10,000 ft (average distance from Spring Creek to the drainage divide);
t=time, in days;
Q=discharge, in cubic feet per second;
t_2-t_1=1,400 days (decline of base-flow discharge across one log cycle);
Q_1, Q_2=discharge at t_1 and t_2, respectively.

Diffusivity was 66,600 ft^2/d. If storage (S) for the water-table aquifer is assumed to be 0.2 (based on an estimate for gravity drainage on a seasonal basis), the transmissivity is 13,300 ft^2/d or 100,000 $(gal/d)/ft^2$. This value is nearly the same as that determined by pumping tests for the areas around wells R-901 and R-902.

Water Quality

Water quality was an important consideration to the city when choosing a water source. During the original testing in 1966, seven water samples were collected from deposits of Tertiary age, and three from the terrace deposits for chemical analysis. Silica and dissolved-solids concentrations were higher in water from some of the older deposits than in water from the shallow terrace deposits, but concentrations were not objectionable for most uses. Except for a sample from the Blounts Creek Member (well R-846A, table 9), the pH of the water from the deeper sands was greater than 7. Generally, the quality of water in both the shallow and deep sands was suitable for the city's needs.

The creeks in the area that had a high base flow were also considered as a potential source of water for the city. The chemical quality of water from the streams is discussed in the section "Surface-Water Potential," "Quality."

All of the water from the wells in the Kisatchie well field is low in dissolved-solids content and in most individual constituents (table 9). All of the water is soft except for that from three wells screened in sands adjacent to calcareous beds of the Castor Creek Member. Iron concentration is low except in four of the shallow wells.

Fluoride concentrations in water fom several deep wells (table 9) is near the upper limit of acceptability for public supplies (U.S. Environmental Protection Agency, 1976). Combining water from deep and shallow wells results in a mixture that has acceptable fluoride concentrations.

Water from the deep sands of the Williamson Creek and Carnahan Bayou Members differs from that in the shallow sands (terrace deposits) as follows:

Property or constituent	Deep sands	Shallow sand
pH (field), in units------------------------	7.5-8.7	4.8-6.3
Carbon dioxide, in milligrams per liter----	<10	>30
Dissolved soilds, in milligrams per liter--	>200	<110
Bicarbonate, in milligrams per liter-------	>200	<75

Water from the Blounts Creek Member is intermediate in chemical character because of local recharge to the unit by water from the terrace deposits.

Because the pH of water from the shallow wells was found to be low, tests were made to determine whether or not carbon dioxide was the cause. The results are given in table 3.

Table 3.--Field determinations of selected water-quality parameters, Kisatchie well field, November 12-14, 1969

[Except as footnoted, wells are screened in the terrace aquifer]

Well No.	Pumping rate (gal/min)	pH (units)	Carbon dioxide (CO_2)	Hydrogen sulfide (H_2S)	Alkalinity	Temperature (°F)
			Milligrams per liter			
R-901----	575	4.9	51	----	9	66.0
902----	450	5.1	56	----	15	66.0
903 1/ --	460	7.3	7	----	212	69.5
905----	525	5.1	51	----	13	67.0
906----	650	5.0	30	----	6	66.5
908----	520	5.2	52	----	23	68.0
910----	525	5.7	70	----	47	67.5
911----	500	5.2	62	----	20	67.5
914----	550	5.5	40	----	22	65.0
915----	650	5.3	37	----	14	66.0
916----	450	5.6	70	----	27	67.5
917----	390	5.8	72	----	40	68.0
918----	550	5.8	70	----	43	67.0
919----	310	6.3	53	----	119	69.0
920----	520	5.1	33	----	11	66.5
921 2/ --	675	7.8	3	0.3	288	73.0
922----	800	5.5	36	----	12	67.0
923----	500	4.8	48	----	5	66.0
924----	580	5.2	65	----	26	68.0
925 3/ --	775	5.6	61	----	30	67.5
926 1/ --	450	7.8	5	----	188	69.0
929----	600	6.0	56	----	86	69.5
932 2/ --	-----	7.6	--	Odor	278	----
933 4/ --	1,150	7.8	--	.3	238	97.0
936 4/ --	680	7.8	--	.3	434	85.5
937 4/ --	1,050	8.0	--	.2	250	97.5
938 5/ --	-----	7.2	--	----	228	69.0
939----	750	7.7	--	.2	268	72.0

1/Well screened in Blounts Creek Member, Fleming Formation.
2/Well screened in Williamson Creek Member, Fleming Formation.
3/Well screened in terrace and in Blounts Creek Member, Fleming Formation.
4/Well screened in Carnahan Bayou Member, Fleming Formation.
5/Well screened in Castor Creek(?) Member, Fleming Formation.

The high carbon dioxide concentration causes water from the shallow wells to be corrosive. Mixing water from the deep and shallow wells produces a composite water supply that is much less corrosive than the shallow water alone.

Water from one well in the Blounts Creek (well R-930, table 9) is almost identical to water from the terrace deposits. This results from movement of water from the terrace deposits into and downdip within the Blounts Creek Member. Similar conditions prevail in the Blounts Creek in other parts of the area.

Well Characteristics

Well Construction

Three test-production wells were constructed in 1966: two to test the terrace deposits and one to test a sand below the terrace. These wells were completed with 12-inch casing and 8-inch screen and lap pipe. After the decision was made to construct the well field, all other wells in the terrace deposits (22) were constructed with 18-inch surface casing and 12-inch screen and lap pipe. Twelve deep wells were constructed with 12- and 8-inch casing and 8-inch screen. Construction data on wells and test holes are given in table 8.

Well Yields

Well yields depend on the hydraulic characteristics of the sand screened, the amount of sand screened, various construction features of the well such as gravel pack and diameter of screen, completeness of well development, and pump design. The wells in the Kisatchie well field were constructed similarly, so the principal differences in yield are hydraulic characteristics of the sand, well development, and pump design.

Test yields for wells screened in the terrace deposits ranged from 500 to 1,000 gal/min. Most permanent pumps were chosen for a yield of 500 to 750 gal/min. Tests on the deeper wells ranged from 300 to 1,000 gal/min. Initial production from the permanent pumps ranged from 300 to 1,100 gal/min.

In some deep wells, water-level declines have been great enough to require reduction of yields to keep water levels above the pump intakes. At other wells, such as R-933 and R-937, the yield of 1,000 to 1,100 gal/min has been maintained for 10 years. The difference in performance in these instances is related largely to sand continuity (extent of aquifer) rather than changes in specific capacity.

After 10 years of production, four wells (R-903, R-907, R-917, and R-935) are either out of service or seldom used because of low yields or declining water levels. The yield of well R-903 had declined from 430 to 150 gal/min before the pumping schedule was changed to an intermittent basis.

Specific Capacity

The specific capacity of a well depends on the hydraulic characteristics of the aquifer, the duration of pumping, and the design and construction of the well. Preliminary pumping tests were made on most of the wells in the Kisatchie Forest well field to determine the specific capacity--that is, the number of gallons per minute produced for each foot of drawdown. These data aided in selecting the size of the permanent pump. A change in specific capacity indicates that some change has occurred in the well or aquifer. For example, a decline in specific capacity can be caused by encrustation of the screen or invasion of fine material into a gravel pack. It could also be caused by a reduction in the saturated thickness of a water-table aquifer, owing to water-level decline.

Specific capacities of the deep wells in the Kisatchie well field range from 1.3 to 33 (gal/min)/ft of drawdown. The shallow wells have specific capacities that range from 11 to 46 (gal/min)/ft of drawdown. Determinantions of specific capacity were made for each well at the time of construction and at various times since then (table 4). For many wells the specific capacity in 1976 was virtually the same as in 1968 when production started in the well field. Small variations in specific capacity occur at most wells (table 4). However, 11 wells--five deep and six shallow--show a decline in specific capacity. The amount of dewatering in the vicinity of the shallow wells is not significantly different between wells with declining specific capacity and those with stable specific capacity. Therefore, the amount of decrease in saturated thickness in the water-table aquifer does not appear to be a major factor in the change in specific capacity at this time.

Cause of decline in specific capacity in five deep wells has not been determined. Possibly, because the pumps are water lubricated, mixing of waters of slightly different quality has caused precipitation that partially blocks the screens. Perhaps sand invasion of the gravel pack has contributed to the decline.

Table 4.--Specific-capacity measurements of production wells, Kisatchie well field

[Most tests were of approximately 24 hours duration. Underlined values are from tests of 12 hours duration]

Well No.	Specific capacity [(gal/min)/ft]									
	1966	1976	1968	1969	1970	1971	1972	1973	1975	1976	1977
R-901--	17.9 (Dec.)		22.9 (June)					22.9 (Nov.)		19.2 (Aug.)	
902--	24.8 (Dec.)		26.3 (Sept.)		23.1 (Aug.)			29.3 (Dec.)		16.6 (Apr.)	
										23.5 (Aug.)	
903--			4.8 (Oct.)		3.4 (Aug.)			1.6 (Dec.)			
905--		21.8 (May)	23.6 (June)		26.8 (Dec.)			14.2 (Nov.)	16.9 (Mar.)	15.6 (Apr.)	
										15.8 (Aug.)	
906--		15.8 (June)	12.9 (June)			13.2 (Jan.)		13.5 (Nov.)		15.9 (Apr.)	
907--		36.3 (June)	44.1 (June)			46.5 (Jan.)		36.2 (Nov.)		30.5 (Apr.)	
908--		17.7 (June)	21.3 (Oct.)	21.8 (Apr.)				17.8 (Dec.)		16.0 (Apr.)	
909--		19.6 (Aug.)	23.1 (June)					17.1 (Nov.)			19.3 (Mar.)
910--		20.2 (Aug.)	21.0 (Sept.)		17.0 (Aug.)			20.0 (Nov.)			
911--		19.3 (July)	25.4 (Aug.)		21.3 (Aug.)			18.8 (Dec.)		16.3 (Aug.)	
913--		14.5 (Aug.)				10.4 (Jan.)		13.3 (Dec.)			12.9 (Mar.)
						13.6 (Aug.)					
914--		17.7 (Sept.)	19.6 (July)			17.8 (Jan.)		13.5 (Dec.)		13.2 (Apr.)	
915--		15.1 (Sept.)	15.7 (Aug.)					15.0 (Dec.)		14.3 (Apr.)	
916--		20.9 (July)	20.6 (July)		15.0 (Aug.)	20.4 (Apr.)		16.2 (Dec.)			16.1 (Mar.)
917--		14.7 (Sept.)	13.0 (Oct.)		10.9 (Aug.)			10.9 (Nov.)		6.5 (Apr.)	
										7.5 (July)	
918--		16.8 (July)	19.2 (Oct.)		21.6 (Aug.)	23.7 (Apr.)		24.6 (Dec.)		21.4 (Sept.)	
919--			10.8 (May)						6.2 (Mar.)	6.5 (Apr.)	
										5.8 (Aug.)	
920--		20.8 (June)	22.6 (June)					20.2 (Dec.)		16.1 (Apr.)	
										18.1 (Aug.)	
921--			24.1 (Jan.)							22.6 (Aug.)	
922--		35.0 (June)	39.9 (June)					37.9 (Dec.)		37.9 (Apr.)	
923--		23.2 (June)	25.8 (June)		25.3 (Aug.)			23.1 (Dec.)		20.4 (Apr.)	
924--		29.9 (Apr.)	36.1 (July)					35.1 (Nov.)		30.6 (Apr.)	
										34.9 (Sept.)	
925--		23.9 (June)						26.3 (Nov.)		21.7 (May)	
										24.0 (July)	
										22.7 (Sept.)	
926--		5.6 (Oct.)	5.5 (June)	7.4 (Apr.)	6.8 (Nov.)						3.7 (Mar.)
927--		29.3 (Apr.)	42.4 (June)			46.2 (Aug.)		41.7 (Dec.)		36.1 (Sept.)	
928--		29.5 (May)	42.4 (July)					27.9 (Dec.)	27.4 (Mar.)	28.3 (Apr.)	
										33.3 (Aug.)	
										30.7 (Sept.)	
929--		28.5 (May)	27.4 (June)					31.2 (Nov.)		27.1 (July)	
930--		17.4 (Sept.)	20.7 (June)		9.5 (Nov.)						a/6.6 (Mar.)
932--		17.4 (Nov.)	16.3 (Aug.)				22.0 (Mar.)			18.2 (Apr.)	
933--		23.2 (Dec.)					24.3 (Mar.)			16.3 (Aug.)	
934--			18.1 (Apr.)			26.4 (Mar.)	23.5 (Mar.)		16.8 (Mar.)		13.0 (Mar.)
935--			2.8 (May)		2.0 (Aug.)					1.3 (Apr.)	
			3.1 (Oct.)								
936--			11.3 (Mar.)				12.0 (Mar.)				11.1 (Mar.)
937--			29.3 (Mar.)				33.0 (Mar.)			29.2 (Apr.)	
938--			5.2 (Apr.)						3.3 (Mar.)		a/2.3 (Mar.)
			5.1 (Oct.)								
939--			15.3 (Apr.)				21.6 (Mar.)		20.2 (Mar.)		24.9 (Mar.)

a/Estimated.

EFFECTS OF THE WELL FIELD

Large withdrawals of water from the Kisatchie well field began in August 1968. Annual pumpage from 1968 through 1978 was as follows:

Year:	Annual pumpage (Mgal)	Year:	Annual pumpage (Mgal)
1968-------	1,977	1975-------	5,309
1969-------	5,145	1976-------	5,988
1970-------	5,785	1977-------	6,197
1971-------	6,432	1978-------	6,889
1972-------	6,085	1979-------	6,951
1973-------	5,940	1980-------	6,603
1974-------	6,368		

Average rate of withdrawal from the field has been about 16 Mgal/d. Under extreme demands, pumpage has been as much as 25 Mgal/d.

The deep wells are pumped most of the time; seldom are all of the shallow wells pumped at the same time. Pumping of the shallow wells is rotated so that water-level declines are distributed throughout the well field. Even though most of the shallow wells are designed to pump 500 to 750 gal/min, pumpage averaged over the first 8 years of operation ranged from about 100 to about 300 gal/min. Average pumpage in many of the deeper wells more nearly approaches design capacity of 500 to 1,100 gal/min.

These large withdrawals from the well field have altered water levels in the aquifers and have slightly modified the ground water-surface water relationships in the shallow aquifer.

Water Levels

Predevelopment

Water-level data for various water-bearing sands of the Fleming Formation in the project area were collected, 1966-68. These data, which are measurements made prior to completion of the Kisatchie well field, are given in the following table.

Initial water levels in test wells or production wells screend in sands of members of the Fleming Formation of Miocene and Pliocene(?) age

Well No.	Depth (ft)	Location			Water level		Date
		Sec.	T. (N.)	R. (W.)	Feet below land surface	Feet above NGVD1/	
CARNAHAN BAYOU MEMBER							
R-844 2/--	2,010	13	2	3	133.0	97.3	4- 6-66
845B---	1,215	32	3	3	109.6	131.8	4-13-66
845C---	1,494	32	3	3	100.8	140.6	4-20-66
852----	2,216	6	1	2	25.6	146.9	6- 2-66
933 2/--	2,056	15	2	3	130.6	94	12-26-67
934 3/--	1,350	14	2	3	111.4	112	12-15-67
936 3/--	1,336	15	2	3	108.4	117	3- 4-68
937 2/--	2,078	13	2	3	134.4	90	3-28-68
WILLIAMSON CREEK MEMBER							
R-845A---	654	32	3	3	136.3	105.1	4-28-66
846B 4/-	636	28	2	3	140.0	72.4	4-17-66
921 4/--	558	24	2	3	120.9	73.0	1- 3-68
932 4/--	466	22	2	3	113.8	71	11-27-67
935----	968	27	2	3	108	97	5- 8-68
939 4/--	482	15	2	3	140	85	4-15-68
BLOUNTS CREEK MEMBER							
R-846A---	310	28	2	3	52.7	159.7	5-19-66
903----	277	27	2	3	60.1	145	11-27-66
926----	344	31	2	2	64.9	148	10- 4-67
930----	225	32	2	2	44.6	150	9-26-67
938 5/--	299	26	2	3	58.0	147	4-18-68

1/National Geodetic Vertical Datum of 1929.
2/Basal sand of Carnahan Bayou Member.
3/Uppermost sand of Carnahan Bayou Member.
4/Uppermost sand of Williamson Creek Member.
5/May be screened in Castor Creek Member.

Water levels in wells were contoured for the Carnahan Bayou (pl. 2), the Williamson Creek (pl. 5), and the Blounts Creek (pl. 5) Members. The contours for the Carnahan Bayou show that the water was moving toward Alexandria where a cone of depression had developed as a result of pumping. The water-level contours for the Williamson Creek show a similar response to pumping at Alexandria and at Lecompte. However, some of the upper sands of the Williamson Creek do not extend as far north as Alexandria and are not influenced by pumping at Alexandria. The water-level contours for the Blounts Creek show that water is moving toward the Red River Valley, mostly because of natural discharge, although some municipal pumpage occurs at Cheneyville and to the east. Water levels in wells in the Blounts Creek in the project area are much higher than in wells in the deeper sands because of local recharge from the terrace deposits.

Because the Pleistocene terrace deposits form most of the surface in the project area, infiltration of rainfall occurs locally. These deposits discharge water within the area to perennial streams, such as Spring Creek, and by evapotranspiration in the valley bottoms. Some water moves from these deposits into the Blounts Creek. Over long periods of time and under natural conditions, infiltration of rainfall into the shallow terrace aquifer balances outflow from the aquifer. Annual and seasonal changes in the rate of water inflow or outflow result in temporary changes in the amount of water stored in the aquifer. These changes in storage cause changes in elevation of the water table and are shown by changes in water levels in wells.

The generalized configuration of the water table in the terrace deposits before production from the Kisatchie well field began is illustrated by contours on plate 3. As water levels flucturate over a range of no more than a few feet from year to year, both old and recent water-level measurements were used in constructing the water-level contours. Most water-level measurements used for the map were made before production from the well field began. Some later measurements in wells south of Spring Creek were used because Spring Creek acts as a boundary to the expansion of the cone of depression. Relatively stable data points for water levels occur where contour lines cross perennial streams. Stage variations at low flow generally are less than 1 ft.

The configuration of the water table (pl. 3) indicates that in the well-field area the ground-water drainage divide is approximately the same as the surface drainage divide of Spring Creek. Spring Creek is the principal drain, but some water moves northward toward Brushy Creek, Little Brushy Creek, and Long Branch.

Postdevelopment Trends

Water levels have been measured in wells in the Kisatchie well field and in observation wells in the area since the well field went into production in August 1968 (fig. 7). After a few measurements had been made, some pumping water levels appeared to be too high, and some nonpumping water levels appeared to be too low. These anomalous values probably came from measurements made shortly after a pump had started or shortly after it had stopped. To make the water-level measurements more meaningful, the practice of measuring water levels after a minimum of 24 hours of pumping or recovery was established. Pumping and nonpumping water levels are plotted on plate 6. Water levels for all of the production wells are listed in table 10.

Miocene and Pliocene(?) aquifers.--Nonpumping water levels have declined in wells in the artesian sand beds of Miocene and Pliocene(?) age as cones of depression were developed in response to pumping. Nonpumping water levels declined about 70 ft in well R-933 in the basal Carnahan Bayou sand between 1968 and 1975. In the uppermost Carnahan Bayou sand, nonpumping levels in wells declined about 190 ft in well R-934 during the same period. Water-level decline in wells in the uppermost Carnahan Bayou was more than 2 1/2 times as great as that in the lower part even though more water is produced from the basal Carnahan Bayou. The cone of depression in the lower part of the Carnahan Bayou at Alexandria showed a noticeable expansion toward the Kisatchie well field from 1968 to 1975 (pl. 2).

The nonpumping water level in wells R-921, R-932, and R-939, screened in the uppermost Williamson Creek, declined about 120 to 130 ft between 1968 and 1975. Well R-935, which is screened in a relatively isolated sand in the Williamson Creek, had a nonpumping water-level decline of about 170 ft between 1968 and 1972. Pumpage from well R-935 was reduced in 1972, and by 1975 the nonpumping water levels had recovered to about 25 ft below the 1968 static water level (table 10).

Water levels in wells in the Blounts Creek were nearly the same as those of the overlying Pleistocene terrace deposits prior to development of the well field. Sands of the Blounts creek are in contact with the terrace aquifer within the project area. Since pumping began, water-level decline in wells in the Blounts Creek has been greater than that in the terrace deposits (pl. 6). Well R-936 had a decline in nonpumping water levels of about 60 ft between 1968 and 1975. Well R-938, which may be screened in the Castor Creek rather than the Blounts Creek, had a water-level decline of about 70 ft between 1968 and 1972. Reduced pumpage from well R-938 has permitted water-level recovery, and 1975 levels were only about 25 ft lower than the 1968 nonpumping water levels. In 1979, nonpumping water levels were nearly the same as in 1975.

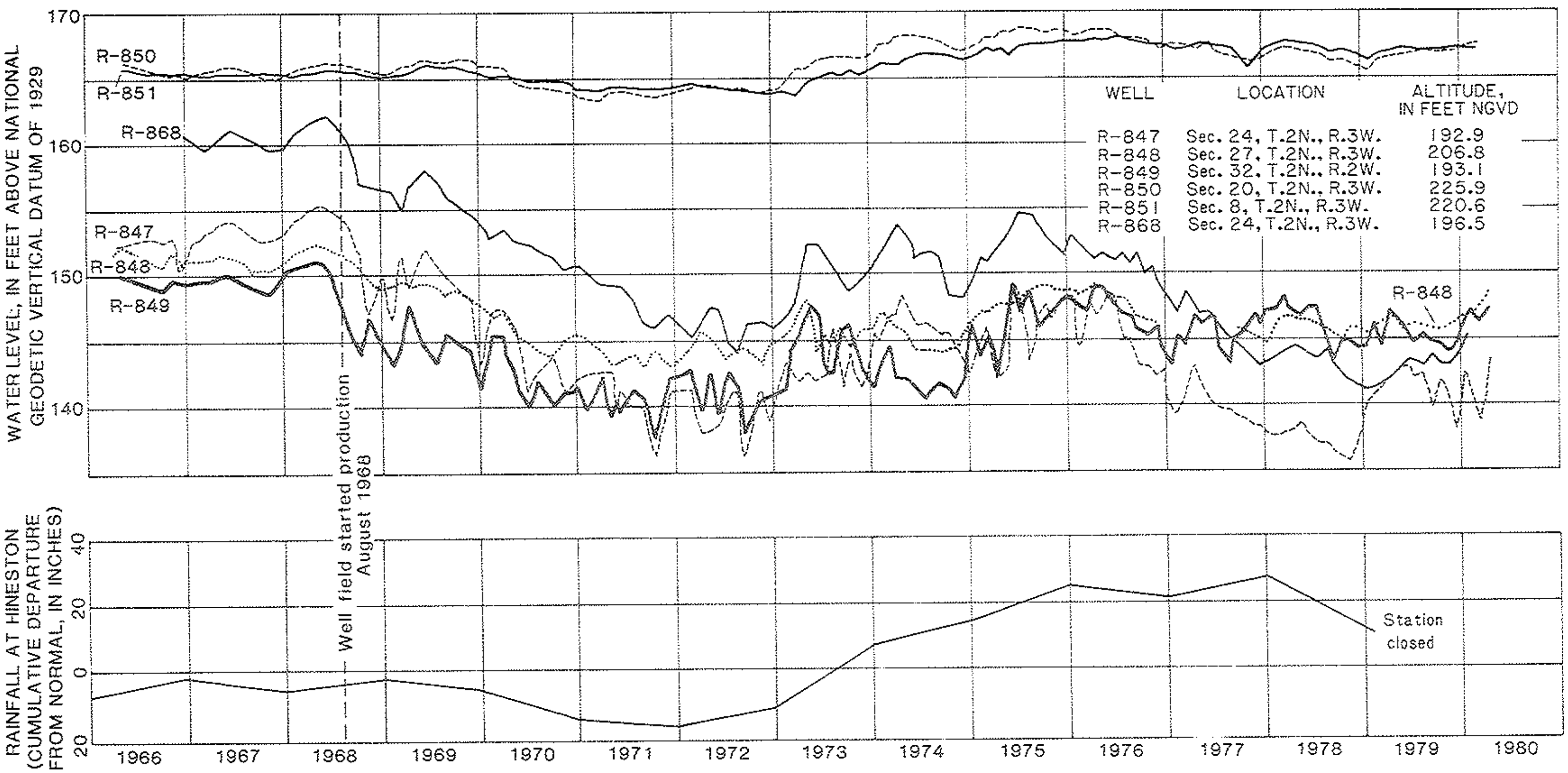


Figure 7.--Water levels in observation wells in the terrace aquifer, Kisatchie well field.

Terrace deposits.--Wells screened in the terrace deposits depend on infiltration of rainfall to maintain water supplies. The surficial material of the deposits is heterogeneous--in some places, clay; in other places, sand or gravel form the surface. Thus, the rate of infiltration can vary widely from place to place.

Water produced initially from the terrace deposits, which are under water-table conditions, is obtained from storage. Near a producing well the upper part of the aquifer drains, and water-level declines establish a gradient that moves water laterally through the aquifer toward the well. With the passage of time, infiltration replaces some of the water withdrawn by the well and slows the rate of water-level decline. The area of ground-water diversion around the well expands until the amount of water provided by infiltration is as great as the amount of water withdrawn from the well. At this time, water levels tend to stablize or fluctuate within a relatively narrow range--depending on the timing of recharge and withdrawals.

Water levels in observation wells (fig. 7) declined 10 to 15 ft through 1972. At well R-868, which is about 1,000 ft from the nearest pumping well, the decline in water level at the end of 1972 was 15 ft. In 1973 and 1974, rainfall was above average, and large amounts of water infiltrated the aquifer. In July 1975, water levels in well R-868 were only 6 or 7 ft lower than in 1968.

At observation wells R-850 and R-851, which are 2 1/2 and 3 mi, respectively, outside the well field, water levels began declining early in 1970 and remained at relatively low levels through 1972. The decline, at first, had the appearance of being caused by pumping at the well field. However, cumulative departure of rainfall at a nearby station (Hineston) indicated that the water-level decline might be caused by rainfall deficiency. During the very wet years of 1973 and 1974, water levels rose in the two observation wells, and in mid-1975 the levels were 1 to 3 ft higher than in 1966 (fig. 7). The rainfall deficiency in 1970 and 1971, illustrated by the cumulative departure curve (fig. 7), also caused the water levels in the observation wells in the well field to be lower than under average rainfall conditions.

Hydrographs of both pumping and nonpumping water levels for the shallow production wells (pl. 6) show a decline with continued production. The average decline in the nonpumping level of all of the shallow wells was about 10 ft at the end of 1972. Most of the decline resulted from the growth of the individual cones of depression and the coalescing of adjacent cones in response to pumping from the well field, but some of the decline would have occurred naturally because the period was relatively deficient in rainfall. Above average precipitation in 1973 and 1974 resulted in increased recharge to the aquifer and thus a reduction in the size of the area of diversion necessary to intercept enough water to supply the shallow wells of the well field. Nonpumping water levels in July 1975 were nearly the same as the prepumping levels in 1968 in some wells and only a few feet lower in others. Variations may result from local differences in recharge and from different amounts of pumpage from various wells.

Changes in Streamflow

The flow of Spring Creek consists of two components. High flows of relatively short duration are caused by direct (overland) runoff of rainfall; low flows, of longer duration, are sustained by discharge from the terrace deposits. What effect, then, does the pumpage in Kisatchie well field have on the flow of Spring Creek? Prior to development of the well field, unsaturated sand and gravel occurred above the water table in the terrace deposits. Lowering the water table by pumping will not induce more infiltration of rainfall, so direct runoff characteristics of the basin and high flow of the stream should not change. Water levels in the terrace deposits are not lower enough to induce flow of water from Spring Creek into the deposits. Thus, the only way that pumpage from the well field alters the flow of Spring Creek is by intercepting water before it reaches the stream. Cones of depression developed around pumping wells divert water to the wells that otherwise would be discharged to Spring Creek.

Measurable changes may occur in low flows. Comparison of discharge measurements given in table 5 suggests that base flow in the upper reaches of Spring Creek near the well field may have declined slightly. From 1968 through 1970, a period when pumpage should have had little effect on base flow, four of five low-flow measurements show that 83 percent of low flow entered Spring Creek downstream from the Melder measuring site. The fifth measurement was made in a period of relatively high flow. For 1971 through 1974, 10 low-flow measurements show that 85 percent or more of the discharge was derived downstream from Melder. The percentage difference is not significant. Data for 1976-78 fail to confirm this shift; increase in flow downstream from Melder is 83 percent or less. Variations in annual precipitation may account for these changes in discharge.

In 1970 the minimum flow of Spring Creek was a new low of record. Rainfall was low but not as low as in 1959, 1962, 1963, or 1965. The new low value may have resulted from cumulative departure of rainfall from average or from distribution of rainfall during the year (rather than from pumpage at the well field); however, the low values may have been a combination of all factors.

Table 5.--Discharge of Spring Creek and tributaries in the project area at low flow

[Measuring site: Number in parentheses is location number on plate 4]

Date	Measuring site				
	Spring Creek near Glenmora (30)	Spring Creek at Melder (21)	Rocky Branch near Melder (22)	Roaring Creek near Melder (23)	Spring Creek near Melder (19)
	Discharge (ft^3/s) for dates shown				
10-28-68	42.5	7.24	0.46	0.90	----
5-26-69	61.7	12.5	1.08	2.46	5.68
6-16-70	31.0	5.21	.36	----	----
8-17-70	28.0	4.69	.12	----	----
10-08-70	28.4	4.58	.02	----	----
9-03-71	36.4	5.42	----	.80	----
10-13-71	36.2	4.31	.16	.64	----
10-15-71	34.4	4.32	.11	.60	----
11-16-71	31.9	4.59	.11	.55	----
6-14-72	44.3	6.22	.26	1.20	----
8- 8-72	33.4	4.95	.05	.63	----
8-29-72	34.5	4.92	.24	.67	----
9-18-72	33.3	4.00	.07	.69	----
10- 6-72	31.9	4.30	.09	.48	1.98
10-18-74	45.7	6.67	.37	.99	3.06
9- 1-76	46.0	8.96	.84	1.85	4.04
9-22-76	41.2	7.29	.51	1.43	2.36
11- 5-76	37.9	6.51	.44	1.81	1.65
7-12-77	45.0	----	----	----	----
7-13-77	----	7.87	.50	1.45	----
9-29-78	37.3	5.04	.27	1.41	2.24

The amount of water being diverted from the terrace deposits by pumping in the Kisatchie well field is about 12 Mgal/d (about 18 ft^3/s). Although this volume is about 66 percent of the magnitude of extreme low flows of Spring Creek, measurable changes in the flow regimen of the creek are hard to identify. Why, then, is there a lack of change in base flow during the dry period as mentioned previously? Much of the recharge to the terrace deposits occurs in the winter and early spring when rainfall is high and evapotranspiration is low. Part of the recharge goes into storage by partially filling the cones of depression around the wells rather than discharging to Spring Creek. Changes in base flow caused by reduced outflow from the terrace deposits during the rainy season would be masked by the rapid succession of rains. During the late summer and early fall, water pumped from the terrace deposits is derived largely from storage, and the areas of ground-water diversion enlarge. Succeeding periods of recharge put water back into storage. Several unusually dry years in succession might allow the influence of pumping to markedly reduce the flow in the upper reaches of Spring Creek at Melder.

GROUND-WATER POTENTIAL

Data at two sites within the present well field indicate that all of the sand intervals suitable for public-supply wells have not been utilized. At test hole R-1011, which was drilled adjacent to well R-906, sand occurs below the terrace deposits at depths from 445 to 522, 1,985 to 2,022, and 2,035 to 2,060 ft. The 445- to 522-foot interval probably correlates with the interval screened in wells R-921, R-932, and R-939. The sand intervals, 1,985-2,022 and 2,035-2,060 ft, correlate with the interval screened at well R-937, which is about 1 mi away. The total sand thickness is less than at well R-937; thus, specific capacity of a well screened in the two sands might be slightly less. The electrical log of well R-917 indicates a sand from 2,090 to 2,175 ft. This sand correlates with the interval screened in well R-933 about 1 1/4 mi away.

A short distance outside the well field but near the supply line, data from test hole R-904 indicate that thick sand intervals occur in the terrace deposits to a depth of 148 ft; at the top of the Carnahan Bayou between 1,340 and 1,405 ft; and at the base of the Carnahan Bayou between 2,075 and 2,142 ft. The uppermost Carnahan Bayou interval correlates with that screened at wells R-934 and R-936; the basal Carnahan Bayou, with that at wells R-933 and R-937.

By extending the well field, two to three times the water developed in the present well field could be pumped. Sands that can yield enough freshwater for public or industrial supplies occur south, southwest, and west of the well field. Several sands suitable for screening for public-supply wells should occur at most sites. The map of the base of fresh ground water (fig. 3) shows that freshwater occurs to depths greater than 2,500 ft below NGVD (National Geodetic Vertical Datum of 1929) to the south and southwest of the well field.

East of the well field the Carnahan Bayou contains saltwater-bearing sands (fig. 3). To the northeast some sand beds within the Williamson Creek contain salty water. Faulting or pinchout of sand beds may retard movement of salty water toward the well field in some sand beds. However, the proximity of salty water in sand beds within the Miocene east or northeast of the well field should be considered before developing wells in those areas.

Based on an average rainfall infiltration rate to the terrace aquifer in the Spring Creek basin of 11 in/yr (35.8 Mgal/d), the average sustained yield from the terrace aquifer is about 360 (gal/min)/mi^2. Outside the basin the average value may be higher or lower. As this water sustains the base flow of the streams, large-scale pumping could reduce base flow substantially. Development of the water supply to intercept the full "sustained yield" of the basin by use of wells probably would be impractical. In addition, making perennial streams into intermittent streams would be considered undesirable by many.

As mentioned earlier, infiltration on an annual basis for the period of record has been as low as 8 in. and as high as 13 in. Several dry years in succession reduce the potential yield of the aquifer; several wet years raise it. Pumpage--at least to some extent--can be maintained through periods of lower potential by water removed from storage in the aquifer (water levels are lowered). However, if yields are to be sustained for long periods, recharge must exceed pumpage at least part of the time.

Throughout most of the area south, southwest, and west of the well field, terrace sand and gravel suitable for screening public-supply wells occurs. Potential yield per well should be as great as in the present well field. The yields of wells in the terrace deposits in the abandoned well field at Camp Claiborne, southeast of the Kisatchie well field, were as large as those developed in the Kisatchie well field.

The potential yield of the terrace deposits in the area of the present well field can be enhanced. Because some of the intermittent streams breach the clay cover of the terrace deposits, infiltration could be increased by installing a number of small dams to retain rainfall runoff and allow more time for water to move into the terrace deposits. The additional water in storage would permit some of the wells to be pumped at higher rates for longer periods of time. Because some of the water would move downstream in the subsurface, the effectiveness of such a system would depend on the amount of water that could be diverted to wells.

The shallow aquifer in and near the well field probably could be modeled with enough accuracy to evaluate the effects of proposed stresses on the aquifer. In particular, the effects of different rates of withdrawal or different well-field configurations could be shown. Because the response of the aquifer to cumulative changes in rainfall is great, additional study of infiltration rates would be desirable.

Modeling of the deeper aquifers also is possible. Because of the potential for interchange of water between the sand beds through the intervening clay, a model of 3-dimensional flow probably would be necessary to adequately represent the system. Fewer data for the various parameters exist for these aquifers than for the shallow aquifers; thus, a model of these deeper aquifers would be less precise. However, use of the model, even under these limitations, could enhance the understanding of the flow system and point to areas where additional data are needed.

SURFACE-WATER POTENTIAL

Amount

Streams in the area are an alternate source of water. The largest surface-water supplies in the area are Spring Creek near Glenmora and the Calcasieu River near Glenmora. The average flow of Spring Creek near Glenmora for 18 years of record is 91.2 ft^3/s or 58 Mgal/d. This is more than 2 1/2 times present pumpage from the Kisatchie well field. Average flow of the Calcasieu River near Glenmora for 31 years of record is 710 ft^3/s or 459 Mgal/d. The drainage area of the Clacasieu River above the gaging station near Glenmora is much larger than the Spring Creek basin; thus floodflows from the larger drainage area contribute to the high average flow. However, these floodflows are of short duration and cannot be utilized without storage.

Neither the Calcasieu River nor Spring Creek have sites within the project area suitable for large reservoirs. Thus, a more meaningful measure of the two streams as a potential source of water is their base flow. Changes in low flow occur from year to year and have considerable significance on determining how much water can be developed. Base-flow data for Spring Creek and the Calcasieu River area are summarized in the following table adapted from Forbes (1980).

Magnitude and frequency of annual low flow on Spring Creek and on the Calcasieu River

Consecutive days	Spring Creek near Glenmora (Drainage area 68.3 mi^2)					
	Lowest flow and recurrence interval, in years					
	Q_2		Q_{10}		Q_{20}	
	(ft^3/s)	(Mgal/d)	(ft^3/s)	(Mgal/d)	(ft^3/s)	(Mgal/d)
1	38	24	30	19	28	18
7	39	25	30	19	28	18
14	39	25	30	19	28	18
30	41	26	32	21	30	19
60	43	28	33	21	31	20
120	47	30	35	23	33	21

Magnitude and frequency of annual low flow on Spring Creek and on the Calcasieu River--Continued

Consecutive days	Calcasieu River near Glenmora (Drainage area 499 mi^2)					
	Lowest flow and recurrence interval, in years					
	Q_2		Q_{10}		Q_{20}	
	(ft^3/s)	(Mgal/d)	(ft^3/s)	(Mgal/d)	(ft^3/s)	(Mgal/d)
1	26	17	18	12	16	10
7	27	17	18	12	16	10
14	29	19	18	12	16	10
30	33	21	19	12	16	10
60	42	27	20	13	17	11
120	67	43	24	16	19	12

The values are the lowest discharge that will occur for the tabulated number of consecutive days on the average of once in 2 years (Q_2), once in 10 years (Q_{10}), and once in 20 years (Q_{20}); or put another way, the lowest discharge that will occur for the listed number of consecutive days in 50 percent of the years (Q_2), 10 percent of the years (Q_{10}), or 5 percent of the years (Q_{20}). All of the low flow of Spring Creek and most of the low flow of the Calcasieu River near Glenmora originates as outflow from the terrace deposits in the project area. The sustained flow of Spring Creek at the gaging station is greater than that of the Calcasieu River near Glenmora.

The amount of water available from Spring Creek during low-flow periods decreases upstream from the gaging station near Glenmora. Seepage investigations (table 6) show that flow 5 3/4 mi upstream is about half that at the gaging station. Flow 8 1/2 mi upstream is only one-fifth or one-sixth that at the gaging station.

Table 6.--Discharge of streams in the project area determined during seepage investigations

Map No. (pl. 4)	Measuring site	Discharge (ft^3/s) for dates shown					
		10-28-68	5-26-69	10-29-69	10-15-71	10-18-74	11-19-75
1	Clear Creek at Forest Road 240 near Alexandria-------	3.09	4.71	-----	2.54	3.86	-----
2	Brushy Creek on Forest Road 240 near Alexandria-------	1.64	2.54	-----	1.70	2.46	-----
3	Castor Creek below Cypress Branch near Alexandria----	5.97	9.93	6.58	-----	8.74	-----
4	Castor Creek at Castor Plunge near Alexandria----	6.86	10.6	6.36	1/7.55	8.71	2/26.1
5	Little Brushy Creek near Alexandria----------------	3.25	4.81	-----	1.74	3.43	-----
6	Long Branch at Forest Road 275 near Alexandria-------	5.41	7.77	-----	4.83	5.99	-----
7	Long Branch at Little Brush Creek near Alexandria-----	6.54	8.81	-----	5.42	7.05	-----
8	Long Branch near Alexandria----------------	8.71	11.3	9.39	1/8.66	9.35	-----
9	Loving Creek near Alexandria----------------	3.91	4.96	4.02	1/4.46	3.97	7.79
10	Little Bayou Clear at Woodworth----------------	-----	2.46	-----	.99	-----	3.02
11	Bayou Clear at Woodworth----	-----	14.6	-----	8.61	-----	14.6
12	Indian Creek near Woodworth-	-----	5.12	-----	3.27	-----	4.89
13	Spring Creek at Highway 1199 near Hineston--------	-----	<.01	-----	0	-----	-----
14	Spring Creek at Highway 488 near Hineston---------	0	3/.02	-----	<.01	0	-----
15	Spring Creek above Elmer----	<.01	.10	-----	.01	3/.01	-----
16	Unnamed tributary above Elmer---------------------	.25	.81	-----	.07	-----	-----
17	Spring Creek at Elmer-------	.38	1.19	-----	.20	.50	-----
18	Bill Creek at Elmer---------	0	3/.02	-----	-----	0	-----
19	Spring Creek near Melder----	-----	5.68	-----	-----	3.06	-----
20	Squyres Branch at Melder----	0	3/.02	-----	-----	0	-----
21	Spring Creek at Melder------	7.24	12.5	-----	4.32	6.67	-----
22	Rocky Branch at Melder------	.46	1.08	-----	.11	.37	-----
23	Roaring Creek near Melder---	.90	2.46	-----	.60	.99	-----
24	Spring Creek below Roaring Creek near Melder---------	21.3	36.4	-----	15.6	22.4	-----
25	Campground Creek near McNary---------------------	.11	.58	-----	.04	.25	-----
26	Mill Creek near McNary------	1.90	3.34	-----	1.57	3.51	-----
27	Spring Creek near McNary----	29.1	42.0	-----	24.10	29.5	-----
28	Germany Creek near McNary---	1.46	2.86	-----	1.86	2.01	-----
29	Spring Creek west of Longleaf------------------	38.0	60.7	-----	34.0	39.0	-----
30	Spring Creek near Glenmora--	42.5	61.7	36	34.4	45.7	56
31	Barber Creek near Glenmora--	-----	------	-----	5.83	-----	8.25
32	Calcasieu River at Hineston-	-----	------	4/4.91	-----	-----	53.1
33	Calcasieu River at Calcasieu-----------------	-----	------	4/11.5	-----	-----	65.9
34	Calcasieu River near Glenmora-------------------	25.0	281	4/20.0	47.0	47.0	91.0
35	Valentine Creek near Gardner--------------------	-----	------	-----	-----	-----	5/21.4

1/Measured 10-18-71.
2/Castor Creek below Long Branch near Alexandria.
3/Estimated.
4/Measured 10-28-69.
5/Includes flow of Stracener Branch.

Table 7 shows the increase in flow of the Calcasieu River across the project area at various times. Base flow of the Calcasieu River at Hineston in October 1969 was about one-fourth the flow at the gaging station near Glenmora 12 mi downstream. Obviously, site selection is important when considering either of these streams as a source of water.

Table 7.--Discharge measurements of the Calcasieu River at Hineston and near Glenmora

Date	Discharge, in cubic feet per second		
	At Hineston1/	Near Glenmora2/	Increase3/
10-21-53	4.86	4/22	17
9-28-54	3.65	4/16	12
10-28-63	2.82	4/18	15
7- 1-64	11.3	37.9	26.6
4-29-65	39.1	4/64	25
8-30-65	14.6	37.7	23.1
4- 6-66	74.9	4/112	37
12- 6-66	40.0	74.8	34.8
4-10-67	42.2	4/68	26
8-29-67	19.6	39.6	20.0
11-29-67	5.89	25.9	20.0
9-17-68	44.3	4/90	46
10- 3-68	8.85	4/28	19
10-28-69	4.91	20.0	15.1
11-19-75	53.1	4/91	38
11- 1-78	5.22	22.3	17.1

1/Station 32 on plate 4.
2/Station 34 on plate 4.
3/In reach.
4/Average daily discharge.

Some smaller streams in the area--Indian Creek, Bayou Clear, Little Bayou Clear, Long Branch, and Loving Creek (table 6)--have sustained base flow from the terrace deposits. Base flow from the project area of these streams and Spring Creek measured during a seepage investigation in the spring of 1969 was about 120 ft^3/s or 78 Mgal/d. The investigation was made after several weeks of no rainfall but during a period of relatively high base flow. Other measurements during the fall of 1969 after long, dry periods indicate that base flow was only 60 percent as great as in the spring. The years 1973-75 had greater than average rainfall. More water infiltrated the terrace deposits during those years, and as a result, more water was discharged from these deposits to the streams. On November 19, 1975, discharge measurements were made of all of the major streams flowing out of the area. Discharge from the same streams that were measured in 1969 was 112 ft^3/s or 72 Mgal/d. This is almost as much as the spring measurement in 1969. In addition, discharge was measured on the Calcasieu River and on Valentine Creek. Discharge on the Calcasieu River increased 25 ft^3/s (16 Mgal/d) between Hineston and the gaging station near Glenmora (table 6). Discharge of Valentive Creek was about 15 ft^3/s or 9.5 Mgal/d. If water from these two streams is included in base flow from the project area, the summation of instantaneous discharge values on November 19, 1975, was 152 ft^3/s or 98 Mgal/d. For a low-flow period, this value is a close approximation of daily discharge.

Because water moves from the terrace deposits to the streams, development of one source places limitations on development of the other. Increased development of the terrace deposits would decrease outflow from the terrace to nearby streams and decrease the potential for development of the streams. Most of the water presently pumped from the terracce deposits is removed from the project area; thus it is unavailable to maintain stream discharge. Increased pumpage from either surface source or from the terrace deposits would result in reduced flow of the streams--most noticeably during base-flow periods.

Quality

Water in the streams is very low in dissolved constituents (table 11). During base-flow periods when the water is derived from the terrace deposits, the quality of water in the streams is nearly the same as that in the terrace. The principal differences are (1) the water in the streams has a slight color--probably from decaying vegetation and (2) the water in the terrace deposits contains much more carbon dioxide. Except for an increase in suspended sediment, the water quality in the streams is much the same during high-flow periods as during low flow. The concentration of silica in the Calcasieu River decreases as flow increases. The concentrations given in table 11 for the various streams at various rates of discharge show the small range of variability between streams and between low and high rates of discharge.

SUMMARY AND CONCLUSIONS

The need for additional municipal and industrial supplies of water in the Alexandria, La., area led to the consideration of nearby sources by the city. One area investigated was the central Rapides Parish area south-southwest of Alexandria. Base flow of streams in the area is high, and freshwater-bearing sands occur to depths of 2,500 ft or more.

Tests were made to determine the water quality and some of the hydraulic properties of the various water-bearing sands. Quality of water from sands of Miocene, Pliocene(?), and Pleistocene age was suitable for the proposed use. The water is soft and low in dissolved solids. Water from deep tests had pH greater than 7; that from shallow tests, less than 7. Subsequently, it was determined that the low pH of the shallow water was caused by high concentrations of dissolved carbon dioxide. The shallow water is corrosive. Mixing with water of high pH from the deeper sands results in a mixture with pH approaching 7. This water is less corrosive.

Hydraulic conductivity of sand beds of Miocene and Pliocene(?) age ranges from 20 to 130 ft/d. Hydraulic conductivity of the sand and gravel of Pleistocene age ranges from 170 to 200 ft/d. Sand beds thick enough to supply well yields of more than 500 gal/min were found in much of the area. When the well field was developed, design yields of wells screened in sand beds of Miocene and Pliocene(?) age ranged from 350 to 1,100 gal/min. Wells screened in the Pleistocene terrace deposits were designed to yield 500 to 750 gal/min. Sustained pumping rates from the well field have been as high as 23 Mgal/d for brief periods.

Water levels have declined in response to pumping. In some of the deep wells, water-level declines are as much as 190 ft in the nonpumping level. Pumps have been lowered or pumping rates have been reduced in several wells. The greatest water-level declines are in wells in sands that probably have limited areal extent. In wells in more extensive sand beds the decline has been much less--as low as 70 ft. Yields of wells screened in the extensive sand beds remain the same. Water levels in the Pleistocene terrace deposits declined about 15 ft between 1968 and 1972. Increased rainfall in 1973-75 increased recharge of water to the deposits. Water levels in 1976 were lower than in 1968, but higher than in 1972.

Rainfall infiltration appears to range between 8 and 13 in/yr. For an average infiltration rate of 11 in/yr, sustained yield from the terrace deposits is 360 (gal/min)mi^2. This yield must include not only water discharged from wells but also water that appears as base flow in the streams. A series of wet years increases temporarily the potential yield per square mile, and a series of dry years lowers this potential.

Expansion of water production in the central Rapides Parish area is possible. A few sites in the present well field could sustain production from additional wells. The terrace deposits southeast of the Kisatchie well field at the site of the former Camp Claiborne well field and in the area south and west of the present well field could sustain a number of wells with capacities similar to existing wells. In the area south-southwest of the present well field, fresh ground water extends to 2,500 ft or more below land surface. Potential exists for developing additional water supplies from deep sand beds in this area.

An alternate source of water is from streams in the area. Because potential for surface storage in the area is small, most of the yield would be from base flow. Base flow is sustained by outflow from the terrace deposits. Base-flow yields from the area were 120 ft^3/s in the spring of 1969, 71 ft^3/s in the fall of 1969, and 112 ft^3/s in November 1975. However, base flow of streams may be measurably reduced if there is extensive development of wells in the terrace deposits.

Because development of wells in the terrace deposits can reduce base flow, the streams are an alternate source of water rather than an additional source of water. This interrelationship should be considered whenever additional development is planned. This stream-aquifer system is complex, but potential effects could be anticipated by mathematical modeling. A digital model of the terrace deposits at an adequate scale would allow prediction of long-term effects of present development and allow anticipation of problems by testing the effects on the system of proposed developments. The model would be a useful tool in long-term planning of resource development.

The deeper aquifers also could be modeled but with less precision because less information is available for them. A 3-dimensional model would be required because of the potential for interchange of water between sand beds through intervening clay. The model would enhance understanding of the flow system and point out areas where additional data are needed. The effects of additional wells on the system could be simulated.

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HYDROLOGIC DATA

Tables 8-11

Table 8.--Data for selected test wells and production wells, Kisatchie Forest area, Rapides Parish, La.

[Aquifer: Qt, terrace deposits, undifferentiated; Tf, Miocene, Fleming Formation; Tfb, Blounts Creek; Tfw, Williamson Creek; and Tfc, Carnahan Bayou Members of Fleming Formation. Wells were drilled by Layne-Louisiana Co. except as noted by following symbols under remarks: B, L. P. Blevins; E, Edington Drilling Co.; H, L. B. Henry Plumbing & Heating Co.; T, Doyle Thomas]

Well No.	Location			Depth (ft)	Casing diameter (in.)	Aquifer	Screen		Hydrologic data					Elevation (ft)	Remarks
												Water level			
	Sec.	T. (N.)	R. (W.)				Length (ft)	Diameter (in.)	Date	Yield (gal/min)	Specific capacity [(gal/min)/ft]	Feet below land surface datum	Feet above NGVD		
R-842---	20	3	2	1,699	-----------	---	--	------	-----	-----	----	-----	---	198.3	E; test hole only.
843---	2	2	2	110	7- 4	Qt	10	2 1/2	3-66	36	3.1	70.6	141	211.3	E; test hole to 1,888 ft.
844---	13	2	3	2,010	7- 4- 2 1/2	Tfc	10	2 1/2	4-66	35	1.2	133.0	97	230.3	E; test hole to 2,283 ft.
845A--	32	3	3	654	4- 2 1/2	Tfw	20	2 1/2	4-66	33	.6	136.3	105	241.4	E; test hole to 1,961 ft.
845B--	32	3	3	1,215	4- 2 1/2	Tfc	20	2 1/2	4-66	34	1.0	109.6	132	241.4	Do.
845C--	32	3	3	1,494	4- 2 1/2	Tfc	20	2 1/2	4-66	34	1.8	100.8	141	241.4	Do.
846A--	28	2	3	310	7- 4- 2 1/2	Tfb	20	2 1/2	5-66	41	2.1	52.7	160	212.4	E; test hole to 2,498 ft.
846B--	28	2	3	636	7- 4- 2 1/2	Tfw	20	2 1/2	5-66	35	1.5	140.0	72	212.4	Do.
847---	24	2	3	105	4- 2	Qt	10	2	4-66	54	6.0	39.8	153	192.9	E; test hole to 268 ft.
848---	27	3	3	105	1 1/4	Qt	3	1 1/4	4-66	-----	----	55.2	152	206.8	E; test hole to 195 ft.
849---	32	2	2	105	4- 1 1/2	Qt	10	1 1/2	5-66	34	3.6	43.0	150	193.1	E; test hole to 239 ft.
850---	20	2	3	116	1 1/2	Qt	3	1 1/4	5-66	-----	----	58.3	168	225.9	E; test hole to 247 ft.
851---	8	2	3	131	1 1/4	Qt	3	1 1/4	5-66	-----	----	54.9	166	220.6	E; test hole to 203 ft.
852---	6	1	2	2,216	7- 4- 2 1/2	Tfc	20	2	6-66	40	.6	25.6	147	172.5	E; test hole to 2,302 ft.
868---	25	2	3	104	4	Qt	5	2	12-66	-----	----	35.8	161	196.5	H; test hole to 117 ft.
901---	32	2	2	120	12- 8	Qt	30	8	12-66	500	17.9	1/ 45	137	182	H.
902---	24	2	3	109	12- 8	Qt	35	8	9-68	500	26.3	2/ 40	160	200	B.
903---	27	2	3	277	12- 8	Tfb	28	8	11-66	143	6.0	60	140	200	H.
904---	16	2	2	2,170	-----------	---	---	------	-----	-----	----	-----	---	230	Test hole only.
905---	19	2	2	134	18-12	Qt	26	12	5-67	1,000	21.8	49	154	203	
906---	19	2	2	135	18-12	Qt	26	12	6-67	800	15.8	57	154	211	
907---	12	2	2	117	18-12	Qt	21	12	6-67	1,000	36.3	54	156	210	
908---	13	2	3	138	18-12	Qt	26	12	6-67	503	17.7	72	148	220	
909---	13	2	3	127	18-12	Qt	26	12	8-67	1,000	19.6	52	158	210	
910---	14	2	3	142	18-12	Qt	26	12	8-67	781	20.2	64	156	220	
911---	14	2	3	120	18-12	Qt	26	12	7-67	961	19.3	54	156	210	
912---	15	2	3	2,085	-----------	---	---	------	-----	-----	----	-----	---	-----	Test hole only.
913---	15	2	3	133	18-12	Qt	26	12	8-67	680	14.5	60	680	225	
914---	15	2	3	96	18-12	Qt	15	12	8-67	1,000	17.7	28	177	205	
915---	22	2	3	90	18-12	Qt	16	12	9-67	855	15.1	23	167	190	
916---	22	2	3	116	18-12	Qt	15	12	7-67	837	20.9	53	152	205	
917---	27	2	3	112	18-12	Qt	21	12	9-67	548	14.7	53	147	200	Test hole to 2,271 ft.
918---	26	2	3	98	18-12	Qt	15	12	7-67	896	16.8	39	166	205	
919---	26	2	3	123	18-12	Qt	26	12	5-68	305	10.8	53	152	205	

920---	25	2	3	136	18-12	Qt	26	12	6-67	1,000	20.8	45	175	220	
921---	24	2	3	558	12- 8	Tfw	104	8	1-68	1,000	24.1	121	79	200	
922---	30	2	2	140	18-12	Qt	26	12	6-67	1,000	35.0	36	154	190	
923---	30	2	2	122	18-12	Qt	26	12	6-67	1,000	23.2	40	160	200	
924---	30	2	2	129	18-12	Qt	26	12	4-67	1,000	29.9	62	150	212	
925---	32	2	2	186	18-12	{Qt / Tfb}	42	12	6-67	1,000	23.9	62	151	213	
926---	32	2	2	344	12- 8	Tfb	42	8	10-67	503	5.6	65	145	210	
927---	29	2	2	122	18-12	Qt	26	12	4-67	1,000	29.3	58	152	210	
928---	30	2	2	174	18-12	Qt	42	12	5-67	1,000	29.5	65	145	210	
929---	29	2	2	164	18-12	Qt	42	12	5-67	1,000	28.5	69	146	215	
930---	32	2	2	225	12- 8	Tfb	42	8	9-67	1,000	17.4	45	150	195	
931---	15	2	3	842	----------	---	---	------	-----	-----	----	-----	---	-----	Test hole only.
932---	22	2	3	466	12- 8	Tfw	47	8	11-67	1,000	17.4	114	76	190	
933---	15	2	3	2,056	12- 8	Tfc	84	8	12-67	1,000	23.2	130	95	225	
934---	14	2	3	1,350	12- 8	Tfc	62	8	4-68	1,000	18.1	3/111	109	220	
935---	27	2	3	968	12- 8	Tfw	32	8	5-68	350	2.8	108	92	200	
936---	15	2	3	1,336	12- 8	Tfc	50	8	3-68	1,000	11.3	108	117	225	
937---	13	2	3	2,078	12- 8	Tfc	103	8	3-68	1,000	28.4	134	86	220	
938---	26	2	3	299	12- 8	Tf4/	52	8	4-68	502	5.2	58	147	205	
939---	15	2	3	482	12- 8	Tfw	72	8	4-68	602	15.3	140	85	225	
1010A-	10	1	2	180	4	Qt	10	3	4-73	19	----	72	143	215	T; test hole to 1,980 ft.
1010B-	10	1	2	288	4	Tfb	10	3	4-73	23	----	73	142	215	Do.
1011A-	19	2	2	494	4	Tfw	15	2 1/2	5-73	25	3.6	253	42	211	T; test hole to 2,274 ft.
1011B-	19	2	2	2,010	4	Tfc	10	2 1/2	5-73	27	----	186	25	211	Do.
1056--	36	3	4	1,555	2	Tfc	10	2	5-74	10	----	174	66	240	T; test hole to 1,615 ft.

1/Water level measured 11-66.
2/Water level measured 12-66.
3/Water level measured 12-67.
4/Castor Creek(?) Member.

Table 9.--Chemical analyses of water from selected wells

[Noncarbonate hardness for all analyses, 0 mg/L]

Well no.	Location T.	Location R.	Location Sec.	Depth of well (feet)	Date of sample (Yr Mo D)	Specific conductance (micromhos)	pH (units)	Temperature (°C)	Color (platinum-cobalt units)	Hardness (as $CaCO_3$)	Calcium, dissolved (as Ca)	Magnesium, dissolved (as Mg)	Sodium, dissolved (as Na)	Potassium, dissolved (as K)	Bicarbonate (as HCO_3)	Carbonate (as CO_3)	Sulfate, dissolved (as SO_4)	Chloride, dissolved (as Cl)	Flouride, dissolved (as F)	Silica, dissolved (as SiO_2)	Solids, residue at 180°C, dissolved	Solids, sum of constituents, dissolved	Nitrogen, nitrate, total (as NO_3)	Nitrogen, nitrate, dissolved (as NO_3)	Iron, dissolved (as Fe)	Manganese, dissolved (as Mn)
										Milligrams per liter															Micrograms per liter	
										UPLAND TERRACE DEPOSITS																
R- 843	2N	2W	2	110	66-03-11	37	6.3	20.0	5	8	2.1	0.7	3.7	1.4	17	0	0.2	2.8	0.0	28	49	47	----	0.10	10	---
R- 847	2N	3W	24	105	66-04-15	46	5.9	19.5	5	10	3.0	.6	3.9	.8	16	0	4.0	1.9	.0	23	55	45	----	.10	180	---
R- 849	2N	2W	32	105	66-05-02	31	5.7	19.0	10	5	2.0	.0	3.7	1.0	12	0	.2	3.2	.0	17	48	34	----	.40	1200	---
R- 901	2N	2W	32	120	66-12-02	33	5.5	19.5	0	6	1.4	.5	3.0	1.4	13	0	.8	2.8	.0	21	43	37	----	.20	60	---
				120	69-02-10	32	6.9	19.0	5	8	2.0	.7	4.0	1.4	16	0	.0	3.1	.1	19	37	38	0.20	----	60	20
R- 902	2N	3W	24	109	69-02-10	45	6.4	19.0	5	7	1.6	.7	5.8	1.2	21	0	1.4	.5	.0	24	50	45	.10	----	20	20
R- 905	2N	2W	19	134	69-08-08	62	6.0	----	0	18	6.3	.6	6.2	1.2	30	0	.6	3.5	.1	30	70	64	.10	----	40	10
R- 906	2N	2W	19	135	69-04-22	32	5.5	20.0	5	5	1.6	.2	2.5	1.4	10	0	.0	3.0	.3	14	34	29	1.2	----	90	70
R- 907	2N	2W	19	117	71-11-03	76	6.1	----	0	4	1.0	.4	16	1.2	42	0	1.2	3.9	.1	35	86	80	.00	----	----	---
R- 908	2N	3W	13	138	69-04-02	59	5.9	----	5	12	3.8	.6	6.0	1.0	30	0	.2	2.0	.1	31	71	61	1.1	----	1800	620
R- 909	2N	3W	13	127	69-04-22	83	5.5	20.0	5	11	3.6	.5	6.4	1.4	26	0	.0	4.8	.5	28	65	58	.10	----	30	20
R- 910	2N	3W	14	142	69-02-26	132	6.8	20.0	5	31	8.8	2.2	16	1.6	60	0	1.0	12	.1	38	111	110	.10	----	20	10
R- 911	2N	3W	14	120	69-02-13	61	7.2	20.0	10	13	3.4	1.1	6.0	1.6	26	0	.8	6.1	.2	27	69	59	.10	----	110	20
R- 913	2N	3W	15	133	69-02-13	37	6.5	18.0	5	8	2.0	.7	4.0	1.7	14	0	.2	2.8	.0	20	46	39	----	.60	50	20
				133	72-03-15	42	4.8	19.0	0	10	2.0	1.2	4.0	1.3	15	0	.2	4.0	.3	22	54	42	.30	----	140	10
R- 914	2N	3W	15	96	69-04-02	29	6.0	18.0	5	8	1.9	.8	2.2	1.0	11	0	.2	3.1	.0	14	34	28	----	.30	650	20
R- 915	2N	3W	22	90	69-05-15	61	6.2	----	0	4	1.6	.0	13	1.0	32	0	.0	4.2	.1	19	50	55	.00	----	30	20
R- 916	2N	3W	22	116	69-02-13	80	6.3	20.0	5	15	3.7	1.4	8.4	1.7	30	0	.2	5.4	.1	27	70	63	.10	----	10	10
R- 917	2N	3W	27	112	69-02-26	71	6.4	20.0	5	15	5.0	.6	8.6	1.3	29	0	.2	6.6	.0	28	68	64	----	.10	40	20
R- 918	2N	3W	26	98	69-02-13	96	7.2	20.0	10	22	5.8	1.8	12	1.4	41	0	.6	9.0	.1	31	86	82	----	.20	160	20
R- 919	2N	3W	26	123	69-04-02	49	6.2	----	10	12	2.8	1.2	4.5	1.2	20	0	.2	3.8	.0	29	65	53	----	.70	40	20
R- 920	2N	3W	25	136	69-04-02	35	6.0	----	5	6	1.2	.7	4.0	1.0	15	0	1.2	2.1	.0	22	57	39	.10	----	40	20
R- 922	2N	3W	25	140	71-08-23	63	6.3	19.0	5	21	6.2	1.3	3.5	1.0	32	0	.2	2.0	.1	28	64	58	.00	----	430	120
R- 923	2N	2W	30	122	69-02-10	26	6.0	19.0	5	7	1.3	.9	2.6	.9	10	0	.6	1.8	.0	16	32	29	.10	----	30	20
R- 924	2N	2W	30	129	69-02-10	77	6.6	20.0	5	15	3.8	1.3	9.5	1.8	31	0	1.2	7.7	.1	31	79	71	.00	----	30	10
R- 925 1/	2N	2W	31	186	69-02-10	73	6.9	20.0	15	15	4.2	1.1	9.6	1.2	36	0	1.2	4.5	.1	37	81	77	.20	----	60	40
R- 927	2N	2W	29	122	69-02-26	61	5.3	20.0	5	10	3.8	.1	8.9	1.2	28	0	.2	4.6	.0	35	71	68	.00	----	10	10
R- 928	2N	2W	30	174	69-08-08	110	6.3	----	0	14	4.0	1.0	19	1.3	53	0	.4	6.9	.1	30	94	89	.10	----	60	20
R- 929	2N	2W	20	164	71-08-24	96	6.4	20.0	5	20	6.0	1.2	12	.6	42	0	.0	7.6	.1	48	94	96	.00	----	270	20
R-1010A	1N	2W	10	180	73-04-13	74	6.3	21.0	0	11	2.8	1.0	11	1.7	37	0	2.2	3.9	.0	48	85	89	.20	----	2000	70

FLEMING FORMATION

BLOUNTS CREEK MEMBER																										
R- 846A	2N	3W	28	310	66-05-19	103	6.0	----	5	23	8.5	0.4	10	3.1	44	0	6.8	2.6	0.2	62	120	116	----	0.10	500	---
R- 903	2N	3W	27	277	66-11-23	335	7.4	20.5	5	150	47	7.1	19	3.0	217	0	5.6	4.0	.1	28	221	221	----	.09	480	---
				277	69-02-26	343	7.9	21.0	5	140	48	5.9	20	2.4	214	0	6.2	3.8	.1	25	211	216	0.00	----	100	70
R- 926	2N	2W	31	344	69-04-04	369	7.6	21.0	5	55	17	3.1	66	2.1	229	0	5.4	5.9	.3	14	227	228	.70	----	0	60
R- 930	2N	2W	32	225	69-02-26	87	6.5	20.0	10	20	5.9	1.3	10	1.6	40	0	6.4	3.0	.2	40	95	88	.10	----	1300	120
R-1010B	1N	2W	10	288	73-04-10	112	5.5	21.0	10	28	7.5	2.2	11	2.0	44	0	14	3.4	.1	50	134	112	.30	----	660	75
CASTOR CREEK MEMBER																										
R- 938	2N	3W	26	299	69-04-02	381	7.4	----	10	96	30	5.1	52	2.7	233	0	4.8	6.1	0.2	18	229	234	0.10	----	140	110
WILLIAMSON CREEK MEMBER																										
R- 845A	3N	3W	32	654	66-04-28	373	7.6	----	5	7	2.7	0.1	87	1.6	212	0	4.8	14	0.2	33	267	248	----	0.10	300	---
R- 846B	2N	3W	28	636	66-05-17	480	7.9	----	10	16	5.0	.9	110	6.2	288	0	.0	14	1.1	17	306	299	----	.10	100	---
R- 921	2N	3W	24	558	69-04-02	488	8.1	----	10	14	4.6	.6	120	1.2	296	0	.4	15	1.1	14	298	301	0.80	----	80	80
R- 932	2N	3W	22	466	69-04-02	469	7.5	23.0	5	18	6.2	.6	110	1.6	284	0	1.2	14	1.0	13	295	285	.20	----	40	20
R- 935	2N	3W	27	968	70-04-07	526	8.7	25.5	0	14	4.3	.8	120	1.3	269	18	.0	13	1.2	18	311	309	.00	----	90	10
R- 939	2N	3W	15	482	69-04-02	451	7.7	22.0	10	20	6.2	1.1	110	1.6	273	0	.8	14	2.0	14	280	281	.10	----	40	40
				482	71-11-14	416	6.7	----	0	14	4.7	.5	98	2.5	259	0	.6	12	.4	21	268	268	.00	----	----	---
R-1011A	2N	2W	19	494	73-05-24	493	8.3	----	5	16	5.8	.4	120	1.2	303	0	5.6	15	1.1	19	316	317	.20	----	110	20
CARNAHAN BAYOU MEMBER																										
R- 844	2N	3W	13	2010	66-04-06	449	7.7	----	30	2	0.8	0.0	110	3.4	252	0	12	13	1.0	52	345	313	----	0.00	350	---
R- 845B	3N	3W	32	1215	66-04-23	701	8.6	----	15	4	1.6	.0	180	2.2	403	14	5.2	15	1.4	21	444	438	----	.20	60	---
R- 845C	3N	3W	32	1494	66-04-20	638	7.8	----	15	1	.4	.0	160	2.3	380	0	11	12	1.1	53	440	422	----	.10	230	---
R- 852	1N	2W	6	2216	66-06-02	709	8.1	----	10	0	.0	.0	180	1.2	404	0	.0	32	1.7	60	487	474	----	.10	290	---
R- 933	2N	3W	15	2056	69-02-13	427	8.1	----	10	0	.0	.0	100	1.5	246	0	12	11	1.1	46	304	298	0.40	----	100	20
R- 934	2N	3W	14	1350	69-02-26	716	8.5	30.0	10	5	1.4	.4	180	2.5	416	22	1.2	12	1.1	42	479	473	.10	----	70	0
R- 936	2N	3W	15	1336	69-02-13	682	7.7	29.0	20	8	3.1	.1	180	2.3	440	0	1.6	13	1.0	37	450	450	.20	----	70	60
R- 937	2N	3W	13	2078	69-08-08	444	8.0	----	0	2	.5	.2	110	1.0	258	0	10	13	.9	47	319	309	.10	----	40	20
R-1011B	2N	2W	19	2010	73-05-16	616	8.3	----	20	4	1.4	.1	150	1.5	357	0	1.2	29	1.2	55	473	416	.30	----	500	50
R-1056	3N	4W	36	1555	74-05-03	323	7.9	----	10	5	1.5	.3	76	1.6	164	0	32	7.8	.4	53	266	254	.05	----	120	0

1/ Well screened in terrace aquifer and in Blounts Creek Member, Fleming Formation.

Table 10.--Water levels in production wells, Kisatchie well field

[Water levels are in feet below land surface. Underlined values are pumping levels. Pumping rates are in gallons per minute]

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Month of measurement and pumping rate (when pumping level measured)
								Well R-901					
1966--	----	-----	----	-----	-----	-----	-----	-----	-----	-----	{44.8 / 72.2}	-----	Nov., 500.
1968--	----	-----	----	42.5	42.7	{44.6 / 1/66.4}	-----	-----	-----	-----	-----	-----	June, 500.
1969--	----	71.2	----	48.8	56.8	71.4	-----	46.9	49.5	-----	-----	73.8	Feb. and June, 535; Dec., no measurement.
1970--	48.4	----	----	48.4	60.4	51.2	76.2	51.5	-----	-----	51.7	76.8	May, no measurement; July, 550; Dec., 525.
1971--	51.5	73.5	51.1	74.1	-----	78.6	52.2	51.3	73.1	-----	74.7	50.4	Feb., no measurement; Apr., 500; June, 475; Sept., 425; Nov., 450.
1972--	----	48.9	77.0	80.1	-----	77.2	49.9	55.0	80.2	-----	53.6	51.1	Mar., 450; Apr., 475; June, 400; Sept., 525.
1973--	----	49.0	----	79.6	81.8	76.4	78.0	45.7	45.9	45.4	{71.1 / 47.1}	72.1	Apr., 525; May, June, and Dec., 550; July, no measurement; Nov., 400.
1974--	76.9	49.1	45.2	80.7	77.1	71.3	71.6	-----	77.4	72.0	71.9	48.6	Jan., no measurement; Apr., 475; May and June, 375; July, Oct., and Nov., 350; Sept., 400.
1975--	44.7	44.2	45.3	77.2	71.0	45.0	48.2	42.9	42.2	44.6	44.4	38.2	Apr., no measurement; May, 450.
1976--	42.8	39.4	33.1	36.5	-----	69.3	-----	{72.3 / 44.9}	-----	-----	-----	-----	June and Aug., no measurement.
1977--	----	-----	45.2	-----	-----	-----	-----	-----	-----	-----	-----	-----	
1978--	----	-----	----	-----	-----	-----	-----	-----	43.9	-----	-----	-----	
1979--	----	-----	----	-----	{42.4 / 65.7}	-----	-----	-----	-----	-----	-----	-----	May, no measurement.
1966--	----	-----	----	-----	-----	-----	-----	-----	-----	-----	-----	{39.6 / 62.8}	Dec., 500.
1968--	----	-----	----	37.2	37.1	-----	-----	-----	{1/41.7 / 60.7}	-----	-----	-----	Sept., 500.
1969--	----	60.9	----	40.7	49.6	40.3	-----	86.5	91.4	-----	-----	1/76.6	Feb., 440; Aug. and Sept., no measurement.
1970--	45.0	-----	----	51.5	83.1	60.0	69.6	{48.2 / 68.7}	-----	-----	51.8	67.7	May, no measurement; July, 575; Aug. and Dec., 475.
1971--	52.2	68.2	71.2	69.7	-----	39.5	48.7	50.3	72.4	-----	68.8	53.2	Feb., no measurement; Mar. and Apr., 400; Sept., 500; Nov., 550.

Well R-902													
1972--	----	50.8	65.9	72.5	54.5	72.0	50.2	49.6	72.2	-----	49.6	64.0	Mar., 500; Apr. and June, 530; Sept. and Dec., no measurement.
1973--	----	68.4	----	45.5	47.8	44.5	70.2	65.7	64.3	42.7	-----	{47.3 / 64.3}	Feb., July, Aug., Sept., and Dec., no measurement.
1974--	45.3	68.0	44.8	43.7	42.4	59.5	-----	43.8	45.6	45.2	45.5	67.7	Feb., no measurement; June and Dec., 500.
1975--	47.2	45.8	45.0	71.0	69.1	-----	43.2	69.6	43.5	71.5	72.0	49.1	Apr., Oct., and Nov., no measurement; May and Aug., 450.
1976--	41.7	-----	42.0	{41.9 / 68.9}	-----	-----	71.0	{70.9 / 50.7}	-----	-----	-----	-----	Apr., 450; July, 475; Aug., no measurement.
1977--	----	-----	45.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	
1978--	----	-----	----	-----	-----	-----	-----	-----	70.4	-----	-----	-----	Sept., 300.
1979--	----	-----	----	-----	47.8	-----	-----	-----	-----	-----	-----	-----	
Well R-903													
1966--	----	-----	----	-----	-----	-----	-----	-----	-----	-----	59.9	-----	
1968--	----	-----	----	59.7	-----	-----	-----	-----	-----	{1/ 61.4 / 151.5}	-----	-----	Oct., 430.
1969--	----	113.1	----	71.5	87.8	72.5	-----	107.9	76.6	-----	-----	78.3	Feb., 460; Aug., no measurement.
1970--	68.2	-----	----	73.7	121.6	137.9	135.0	{74.5 / 192.8}	-----	-----	209.2	58.6	May, June, and Aug., 400; July, no measurement; Nov., 325.
1971--	78.8	-----	95.5	{204.9 / 84.4}	-----	215.2	73.9	62.4	68.4	-----	74.2	71.7	Apr., no measurement; June, 350.
1972--	----	217.7	79.4	68.7	219.3	193.6	63.4	60.7	67.1	-----	64.5	201.7	Feb. and June, 300; May and Dec., 275.
1973--	----	60.2	----	60.7	52.1	198.6	53.5	55.2	69.2	37.2	-----	{57.8 / 186.6}	June, 275; Dec., 200.
1974--	31.8	232.0	51.3	-----	56.1	185.1	-----	206.6	217.2	46.1	44.8	42.7	Feb., 350; June, 200; Aug. and Sept., 250.
1975--	45.6	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	
1976--	59.2	67.6	67.1	58.2	-----	-----	76.7	(2)	(2)	-----	-----	-----	
1977--	----	-----	63.1	-----	-----	-----	-----	-----	-----	-----	-----	-----	
1978--	----	-----	----	-----	-----	-----	-----	-----	51.8	-----	-----	-----	
1979--	----	-----	----	-----	50.1	-----	-----	-----	-----	-----	-----	-----	
Well R-905													
1967--	----	-----	----	-----	{48.6 / 94.6}	-----	-----	-----	-----	-----	-----	-----	May, 1,000.

1/Less than 24 hours pumping or recovery time.
2/Measurements not representative.

Table 11.--Water-quality data for several streams in the project area

Date of collection	Discharge (ft^3/s)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness	Noncarbonate hardness	Specific conductance (micromhos/cm)	pH (units)	Color (platinum-cobalt units)
		Milligrams per liter																
LOVING CREEK NEAR ALEXANDRIA																		
4-12-66	--------	20	0.10	2.0	0.7	4.1	1.0	14	0.6	4.0	0.0	0.6	39	8	0	34	---	30
7-25-66	3.8	20	.01	2.5	.4	2.6	.9	14	.0	3.1	.1	.0	33	8	0	34	---	20
12- 6-68	5.9	16	.02	2.0	.7	3.4	1.1	14	.8	3.5	.0	.1	35	8	0	38	6.7	15
CALCASIEU RIVER AT HINESTON																		
9-17-68	44	16	0.11	4.0	0.5	4.0	0.3	14	0.2	5.0	0.1	0.0	37	12	1	46	---	60
CALCASIEU RIVER NEAR GLENMORA																		
10-14-43	--------	----	----	---	---	---	---	28	---	8.0	---	----	--	30	7	69	---	--
5-18-44	--------	16	0.12	4.6	1.6	3.8	1.2	19	2.3	5.0	0.8	1.0	46	18	2	56	6.8	--
8-26-52	26	26	.05	3.3	2.1	7.7	2.4	26	2.5	8.2	.1	1.5	67	17	0	93	6.3	--
9-23-52	22	30	.17	4.2	2.0	8.0	.4	30	1.8	7.2	.3	.8	70	19	0	82	6.8	--
10-28-52	19	30	.16	4.1	1.7	8.7	1.6	28	1.6	7.5	.0	.5	70	17	0	78	6.6	--
12-15-52	100	18	.35	3.2	1.2	4.5	---	12	4.5	5.8	---	.8	44	13	3	55	6.4	--
1-27-53	990	8.4	.55	1.6	.8	3.5	---	8	2.7	3.2	---	.5	25	7	1	32	6.0	--
4- 4-53	1,960	9.2	.26	2.1	.8	3.3	---	9	2.1	3.8	---	.2	26	9	1	38	6.0	--
5- 7-53	203	19	.50	3.8	1.5	4.1	---	18	1.5	5.0	---	1.2	46	16	1	56	6.8	--
7- 7-53	70	17	.37	3.6	.8	4.6	1.5	20	1.9	5.2	---	.5	45	13	0	56	7.2	--
8- 4-53	133	10	.47	2.0	.8	2.8	1.3	10	1.7	3.5	1.5	1.5	29	9	1	42	6.8	--
9-16-53	31	24	.37	3.8	1.6	7.2	1.6	26	1.3	6.2	---	1.2	60	16	0	68	6.7	--
12-11-59	41	20	.04	4.1	.7	5.8	1.4	20	.8	6.8	.2	.1	50	12	0	57	---	20
2- 2-60	600	11	.24	2.5	.9	3.4	.8	8	2.0	6.6	.1	.2	32	10	3	40	---	80
4- 4-60	403	19	.15	5.4	1.1	7.8	.9	24	3.0	9.0	.1	.2	59	18	0	74	---	50
6- 1-60	39	21	.38	9.5	1.5	6.9	1.4	36	8.2	7.2	.0	.0	77	30	0	92	---	60
7-11-60	126	7.4	.24	2.5	.4	.9	.9	7	1.0	2.6	.1	.3	20	8	2	31	---	80
1-31-66	2,760	6.8	.12	1.5	.3	2.5	.6	4	4.0	1.0	.0	.4	47	5	0	27	---	60
8-31-66	27	24	.04	4.1	1.2	6.4	1.4	23	3.2	5.1	.0	.3	67	15	0	61	---	20
3-14-68	94	23	.00	3.7	1.2	5.0	3.8	22	2.2	7.9	.0	.1	61	14	0	64	---	20
5- 1-68	1,170	6.5	.02	2.0	1.2	1.6	.8	9	2.8	1.5	.0	.2	21	16	3	30	---	60
9- 3-68	33	21	.06	4.3	.8	7.1	1.2	24	.1	6.0	.0	.2	54	14	0	62	---	20
11-13-68	42	22	.02	4.1	1.2	6.5	1.5	24	2.6	6.0	.0	.0	56	15	0	65	7.0	20
3-21-69	5,100	4.8	.08	1.2	1.0	1.5	1.1	4	2.0	2.0	.1	.7	16	7	4	24	5.8	50
8-15-69	52	23	.00	5.1	1.0	7.6	1.3	27	1.8	7.6	.1	.2	61	17	0	73	6.6	15
12-27-72	2,120	3.4	.07	2.4	.5	2.9	1.0	9	3.6	3.8	.1	.09	22	8	0	35	6.2	30
1-30-73	2,050	2.5	.16	2.7	.3	2.7	.7	8	3.4	2.8	.1	.2	20	8	1	33	6.2	30
4-17-73	1,420	1.8	.14	2.3	.5	2.3	1.2	10	.4	2.5	.1	.2	17	8	0	31	6.1	50
8-23-73	64	25	.23	3.8	1.6	7.0	1.6	23	4.2	7.6	.0	.2	56	16	0	67	7.2	35
11- 6-73	218	17	.23	2.8	.4	4.4	1.4	14	1.6	5.6	.1	.0	40	9	0	45	7.1	10
2- 7-74	885	13	----	---	---	---	---	9	3.4	5.2	.1	----	--	--	-	38	6.3	60
5- 8-74	96	24	----	5.0	1.0	6.3	1.2	21	2.7	6.1	.1	----	57	17	0	60	6.8	40
8-14-74	46	23	.21	3.6	1.2	6.0	1.5	24	3.5	6.8	.1	.09	58	14	0	66	7.2	40
10-10-74	29	29	----	5.2	1.3	---	1.6	26	3.2	8.4	.1	----	--	18	0	75	6.9	30
2-14-75	672	12	.13	3.6	.6	3.6	.8	8	3.0	4.7	.0	.09	32	11	5	41	6.4	90
4-10-75	695	9.9	----	3.4	.8	4.5	1.4	12	4.4	5.2	.0	----	36	12	2	49	6.4	60

SPRING CREEK NEAR GLENMORA																		
11-24-59	47	22	0.05	2.5	0.7	5.3	1.3	19	0.4	4.3	0.1	0.1	46	9	0	47	---	--
3-10-60	79	20	.07	2.0	.5	6.2	1.0	15	2.6	4.7	.1	.2	38	7	0	42	---	--
8- 8-60	50	25	.05	3.9	.1	5.1	.9	16	6.1	.1	.1	.4	50	10	0	45	---	--
2- 1-66	90	18	.04	1.5	.3	4.5	1.1	12	.2	2.8	.0	.2	48	5	0	38	---	10
9- 1-66	79	25	.05	2.0	.7	5.3	1.4	19	.2	3.4	.0	.1	50	8	0	44	---	0
12-29-66	724	27	.04	2.9	.7	5.0	1.4	17	1.6	5.0	.0	.2	51	10	0	43	---	20
7-12-67	49	26	.00	2.7	.8	5.3	.1	18	.4	6.0	.0	.1	51	10	0	46	---	10
11- 2-67	54	23	.03	2.9	.2	4.7	2.4	18	1.6	4.4	.0	.1	48	8	0	42	---	20
5- 1-68	89	19	.01	1.6	1.0	3.9	1.0	16	.0	3.2	.0	.0	38	8	0	40	---	40
9- 3-68	50	23	.00	2.6	.4	6.2	1.0	22	1.2	4.8	.0	.2	50	8	0	48	---	15
11-13-68	41	21	.01	2.2	.6	4.7	1.6	18	1.6	3.9	.0	.1	45	8	0	44	---	10
3-10-69	72	17	.01	2.4	.7	4.3	1.1	14	2.6	4.4	.0	.0	40	9	0	42	---	10
7-17-69	45	25	.02	2.3	.5	5.4	1.0	18	.8	3.7	.0	.1	48	8	0	46	---	10
LONG BRANCH NEAR ALEXANDRIA																		
2- 2-60	23	21	0.08	2.7	0.3	5.8	1.2	16	2.4	4.2	0.1	0.6	46	8	0	50	---	20
6- 1-60	15	13	.10	2.1	.4	6.9	1.2	23	1.0	3.0	.0	.0	39	7	0	47	---	20
6- 1-61	-------	12	.05	1.7	.7	2.3	.7	8	2.6	2.6	.0	.1	27	8	0	32	---	20
9- 7-61	24	20	.00	3.0	.1	5.5	1.2	18	.2	4.7	.1	.1	44	8	0	46	---	8
4-12-66	-------	13	.22	3.5	.3	3.2	1.3	14	.6	4.2	.1	.4	48	10	0	38	---	60
7-25-66	9.7	27	.02	2.9	.4	5.1	1.0	20	.8	3.4	.1	.0	59	9	0	49	---	15
12- 6-68	12	21	.03	2.4	.7	5.3	1.2	18	2.0	4.0	.0	.1	46	9	0	47	6.9	20
7-24-69	12	26	.02	2.8	.2	5.7	1.3	19	.8	4.2	.1	.5	51	8	0	49	6.3	10
CASTOR CREEK AT CASTOR PLUNGE NEAR ALEXANDRIA																		
4-12-66	-------	23	0.09	2.5	0.7	6.4	1.5	22	0.8	4.8	0.0	0.4	49	9	0	44	---	20
7-25-66	6.9	26	.02	2.9	.7	5.2	1.0	21	1.2	4.0	.2	.0	52	10	0	47	---	15
12- 6-68	10	20	.07	2.5	.7	5.3	1.3	18	1.4	3.8	.1	.1	44	9	0	49	7.0	30
3-28-69	12	19	.04	2.4	.7	4.8	1.1	18	1.4	2.8	.0	.2	41	9	0	46	6.3	10