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

WATER RESOURCES
TECHNICAL REPORT
NO. 35

ANALYSIS OF THE LOW-FLOW CHARACTERISTICS OF STREAMS IN LOUISIANA

Prepared by
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
In cooperation with
LOUISIANA DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT
OFFICE OF PUBLIC WORKS

1985

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Water Resources

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By

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EXPLANATION OF SYMBOLS AND TERMS

$7Q_2$ — 7-day 2-year low flow is the discharge for 2-year recurrence interval taken from a frequency curve of annual values of the lowest mean discharge for 7 consecutive days, in cubic feet per second (ft^3/s).

$7Q_{10}$ — 7-day 10-year low flow is the discharge for 10-year recurrence interval taken from a frequency curve of annual values of the lowest mean discharge for 7 consecutive days, in cubic feet per second (ft^3/s).

$7Q_{20}$ — 7-day 20-year low flow is the discharge for 20-year recurrence interval taken from a frequency curve of annual values of the lowest mean discharge for 7 consecutive days, in cubic feet per second (ft^3/s).

A — Contributing drainage area, in square miles (mi^2).

P — Mean annual rainfall, in inches (in.), base period 1931-60.

S — Channel slope, in feet per mile (ft/mi), measured between two points along the main channel...one at 10 percent of the channel length, and the other at 85 percent of the channel length. Channel length is measured upstream from the site to the basin divide.

S_e — Standard error of estimate is the range of error to be expected for about two-thirds of the observations, usually expressed as a percentage.

$7Q_i$ — Lowest mean discharge for 7 consecutive days, in cubic feet per second, representing the 2-, 10-, or 20-year recurrence interval.

K — Constant used to adjust the equation discharges to the actual discharge.

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

Multiply	By	To obtain
foot (ft)	0.3048	meter (m)
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
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 [$(m^3/s)/km^2$]
inch (in.)	25.40	millimeter (mm)
inch per year (in/yr)	25.40	millimeter per year (mm/yr)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)

ANALYSIS OF THE LOW-FLOW CHARACTERISTICS OF STREAMS IN LOUISIANA

By Fred N. Lee

ABSTRACT

The U.S. Geological Survey, in cooperation with the Louisiana Department of Transportation and Development, Office of Public Works, used geologic maps, soils maps, precipitation data, and low-flow data to define four hydrographic regions in Louisiana having distinct low-flow characteristics. Equations were derived, using regression analyses, to estimate the $7Q_2$, $7Q_{10}$, and $7Q_{20}$ flow rates for basically unaltered stream basins smaller than 525 square miles. Independent variables in the equations include drainage area (square miles), mean annual precipitation index (inches), and main channel slope (feet per mile). Average standard errors of regression ranged from ± 44 to ± 61 percent. Graphs are given for estimating the $7Q_2$, $7Q_{10}$, and $7Q_{20}$ for stream basins for which the drainage area of the most downstream data-collection site is larger than 525 square miles. Detailed examples are given in this report for the use of the equations and graphs.

INTRODUCTION

According to Judge (1979), Louisiana has 2.2 million acres of inland water surface (7 percent of the total State area) and is ranked fifth in the nation in ratio of total inland water-surface area to total-land area. Although water is plentiful in Louisiana, a growing population is beginning to stress the quantity and quality of the State's water resources. Industry, municipalities, and agriculture all require an adequate supply of water for their varied needs.

Of particular importance is an assessment of water resources during periods of low flow. In response to increasing needs for low-flow information, the U.S. Geological Survey in Louisiana began operating a low-flow network in 1954. In the early years of this program, requests for low-flow information were infrequent, but in recent years population growth and increasing environmental awareness have stimulated requests for this type of information. Examples of the need for low-flow data are water-resources information required for the design of waste-treatment plants and information needed in planning for extreme low-flow periods, such as droughts. Of particular importance is the 7-day 10-year low flow ($7Q_{10}$) which is the basis for the design of most waste-treatment plants.

More often than not, low-flow information is requested for sites at which no discharge data are available. Low flow for these sites has been estimated by drainage-area ratios, comparison to nearby low-flow sites, and one-time discharge measurements. The purpose of this study is to derive equations and graphs so a uniform method of estimating low flows is available on a statewide basis.

Low-flow information is available for gaging stations in approximately 60 percent of the State (pl. 1). Data for these sites were used in this study to derive equations and graphs for estimating low flow where discharge measurements are not available. This report presents those equations and graphs and provides examples showing how the methods can be used to estimate low flow in ungaged streams. Collection of the data used in this study and the subsequent analysis were conducted by the U.S. Geological Survey as part of a cooperative program of water-resources studies with the Louisiana Office of Public Works, Department of Transportation and Development.

LITERATURE REVIEW

Recently, several investigators have been successful in defining regression equations to estimate the 7-day low-flow discharge for various recurrence intervals. Bloxham (1981) used a regression analysis to develop equations for estimating the $7Q_2$ and $7Q_{10}$ (see definition of terms) in the Piedmont area of South Carolina. Independent variables used by Bloxham were contributing drainage area (mi^2), mean basin elevation (ft), and discharge at the 95 percent duration (ft^3/s). In comparison to results of similar studies in other states, the results were excellent; average standard errors of estimate ranged from ± 27 percent for the $7Q_2$ to ± 34 percent for the $7Q_{10}$.

Bingham (1982) used contributing drainage area (mi^2), mean annual precipitation (in.), and a streamflow recession index (days per log cycle) in his equations for natural streams in Alabama. The recession index, which is a measure of the discharge capability of the contributing aquifer system, was estimated from stream-hydrograph recessions of storms that occurred during winter months (dormant period). This index represents the number of days required for the recession limb of a discharge hydrograph (below direct storm runoff) to go through one log cycle on a base 10 plot. Bingham plotted recession indexes for individual gaging stations on a map of Alabama to identify regional boundaries, which generally followed geologic boundaries. Values for specific sites were picked from the recession-index map and used in the final regression analyses. Average standard errors of estimate for the Bingham study were ± 40 percent for the $7Q_2$ and ± 44 percent for the $7Q_{10}$.

Armbruster (1976) derived equations to estimate the $7Q_{10}$, $7Q_{20}$, and $7Q_{50}$ for ungaged streams in the Susquehanna River basin in Pennsylvania. He used contributing drainage area (mi^2), mean annual precipitation (in.), and a relative soils index (in.) in his regression analysis. The soils index, based on Soil Conservation Service soil maps, is basically an index of the infiltration capacity of the soil. The average standard errors of estimate ranged from ± 48 percent for the $7Q_{10}$ to ± 66 percent for the $7Q_{50}$.

Three previous studies have presented low-flow information for Louisiana streams. Page (1963) presented flow duration and annual-frequency information for continuous- and partial-record stations. Cook (1968) presented duration and frequency curves for continuous-record stations. Forbes (1980) presented annual and monthly statistics of low flow for continuous-record stations and annual statistics for partial-record stations but did not develop equations for estimating low flow in ungaged areas. For continuous-record stations, Forbes used the log-Pearson type III distribution for his analysis to define the $7Q_2$, $7Q_{10}$, and $7Q_{20}$ low flows. For the partial-record sites, statistics were determined by a regression of discharges with the discharges at continuous-record stations. Low-flow statistics ($7Q_2$, $7Q_{10}$, and $7Q_{20}$), computed by Forbes (1980) for the partial-record sites, were used in this study as part of the data set.

GENERAL DESCRIPTION OF HYDROGRAPHIC REGIONS OF THE STATE

Louisiana has a humid-subtropical climate. Annual rainfall ranges from about 46 in. in the northwest part of the State to a maximum of about 68 in. in the southeast. Temperatures are moderate year round with coldest temperatures during January or February and hottest temperatures during July or August. Minimum streamflows usually occur during September and October.

There are five major river basins draining Louisiana: (1) Pearl River, (2) Mississippi River, (3) Red River-Atchafalaya River system, (4) Sabine River, and (5) Calcasieu River (fig. 1). These rivers carry flow from most of the other streams within the State to the Gulf of Mexico.

For this study, the State was divided into four hydrographic regions. Region 1 (fig. 1 and pl. 1) is that area of the State where the $7Q_{10}$ is zero on most of the streams. In this report, no difference is noted between zero flow and a dry channel. Most streams in region 1 are typically shallow, and channel beds are, for the most part, underlain by clay and silt. In the southern part of the State within the upper part of the coastal plain, the soils in region 1 are underlain by a relatively impermeable subsoil that serves as a barrier between stream channels and underlying aquifer systems. Subsoils in region 1 in the northern part of the State are made up of clay, silt, and sandy clay. Most streams in this area flow across these subsoils of low permeability and connections to the aquifer systems are poor. Most of the water that might enter the stream system from the aquifer is lost to evapotranspiration before low-flow runoff can occur.

Region 2 (fig. 1 and pl. 1) is that part of the State where the streams have high, sustained, year-round flows. Stream channels in this region are deeply incised into shallow sand and gravel deposits allowing good connection to the aquifer systems. These high-yielding aquifers provide an abundance of water to these streams to maintain high, sustained flows during low-flow periods.

Region 3 (fig. 1 and pl. 1) is the part of the State where the sustained flow in streams is moderate to poor during low-flow periods of the year. Streams in this region flow across clay and silty sand and are poorly connected to low-yielding aquifer systems.

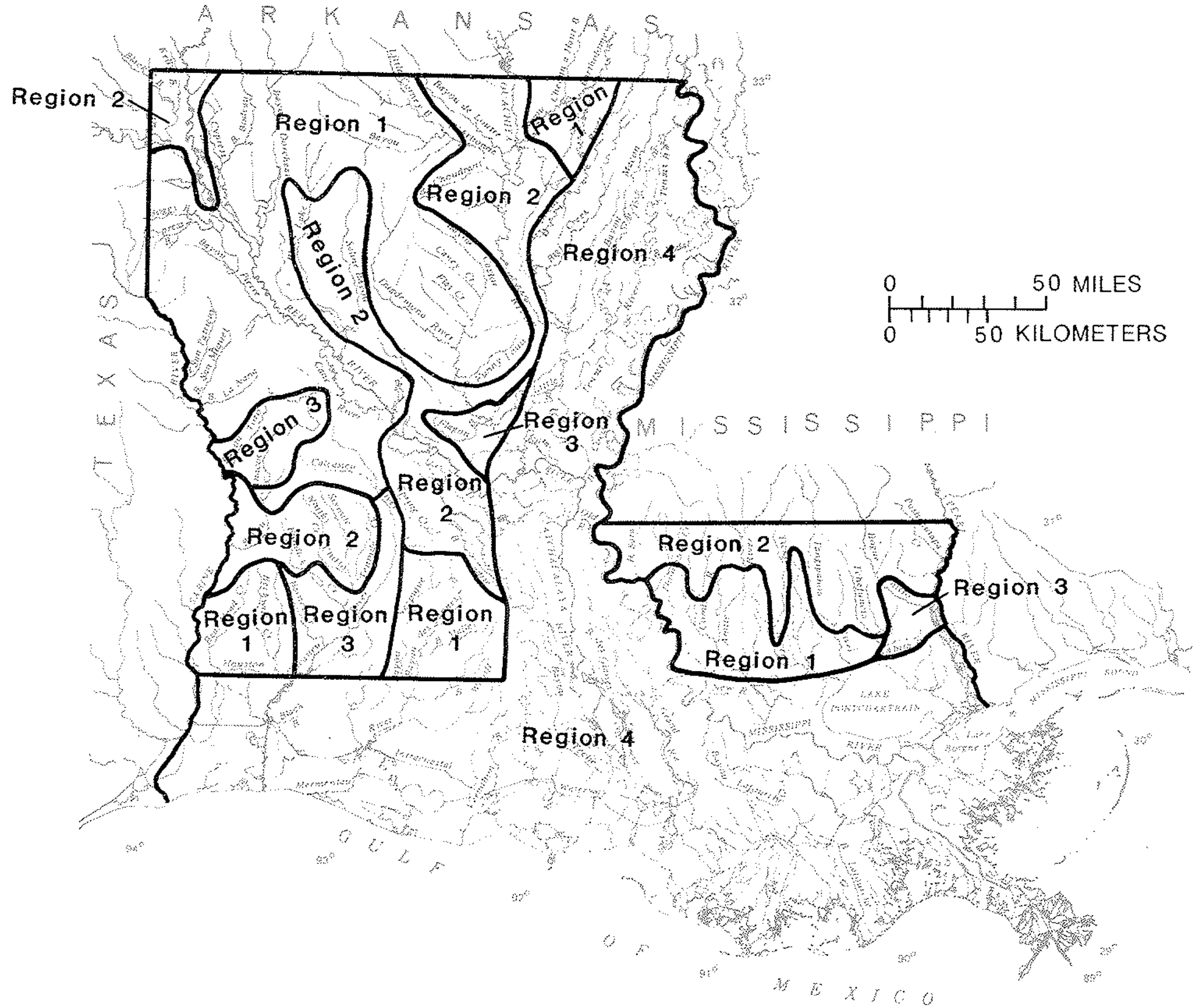


Figure 1.--Regions where low-flow characteristics have been defined.

Region 4 (fig. 1 and pl. 1), the undefined area of the State (Mississippi River Delta and lower-coastal zone), does not have sufficient data to define the low-flow characteristics. Many of the stream channels in this region have been modified by man. In addition, drainage divides are difficult to identify because many of the streams interconnect. Those streams in the lower-coastal zone are affected by tide, and a stage-discharge relationship is difficult, if not impossible, to define. Limited data that are available in region 4, although not used in the regression analyses for this study, are included in this report. (See table 3.)

DATA SOURCES

Low-flow data used in this report came from two sources: regular discharge (continuous record) stations and partial-record sites. The $7Q_2$, $7Q_{10}$, and $7Q_{20}$ flows for regular stations were updated through the 1981 water year, by fitting the logarithms of the annual minimum 7-day low flow to a Pearson Type III distribution (Hutchison, 1975). These updated values were compared to those statistics developed by Forbes (1980) to determine if changes had occurred. This comparison indicated that no significant change had occurred in the 7-day low-flow values as shown by Forbes.

As the low-flow discharges for the regular stations had not changed, it was assumed that the relations between the regular stations and the partial-record sites, developed by Forbes (1980), were still applicable, and discharges used in this report for partial-record sites are those developed by Forbes.

DATA EVALUATION

Low-flow data for streams in regions 1, 2, and 3 were evaluated before statistical analysis was undertaken. This screening consisted of searching the records to identify those streams where controls or other man-made changes affect streamflow. Specific changes with respect to controls, dredging, and diversion of streamflow (into or out of the channel), were noted. Those streams significantly affected by man's activities were not used for the study because natural-flow conditions were required for the regression analyses.

Man-made changes such as dredging, sand and gravel mining, and new or increasing ground-water pumping from shallow stream-affected aquifers can cause a consistent change in the magnitude of a hydrologic event with time. Data for modified streams, if included in a regression analysis, can create biased and inaccurate results. A trend analysis of streamflow data was used to pinpoint changes caused by these man-made influences and to show the approximate time the change began.

The annual 1-day low flow for each continuous gaging station was used in a trend analysis. In this analysis, the 1-day low flow was plotted versus the corresponding year, on rectangular coordinate graph paper and a straight line was drawn through these points. If the slope of this line was either positive or negative, the stream was rejected from further analysis. Figure 2, which shows the 1-day low flow for Bundick Creek near Dry Creek, La., is an example of a declining trend (slope is negative); thus, that stream was not used in the analysis. Figure 3 shows the 1-day low flow for Tangipahoa River near Robert, La. This is an example of a stream that has neither a declining trend nor an ascending trend (slope is neither negative nor positive) and the data would be consistent enough for further analysis.

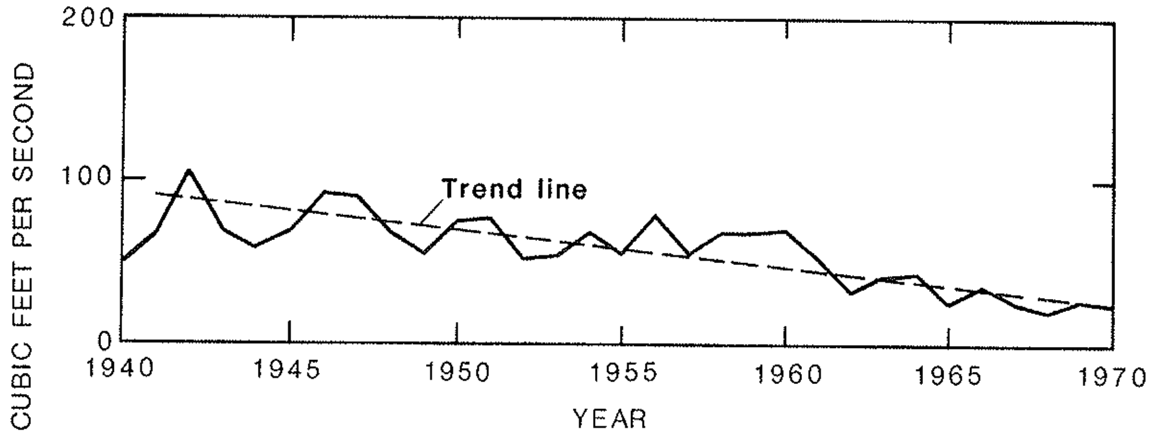


Figure 2.--The trend of the 1-day annual low flow for Bundick Creek near Dry Creek, La. (1940-70).

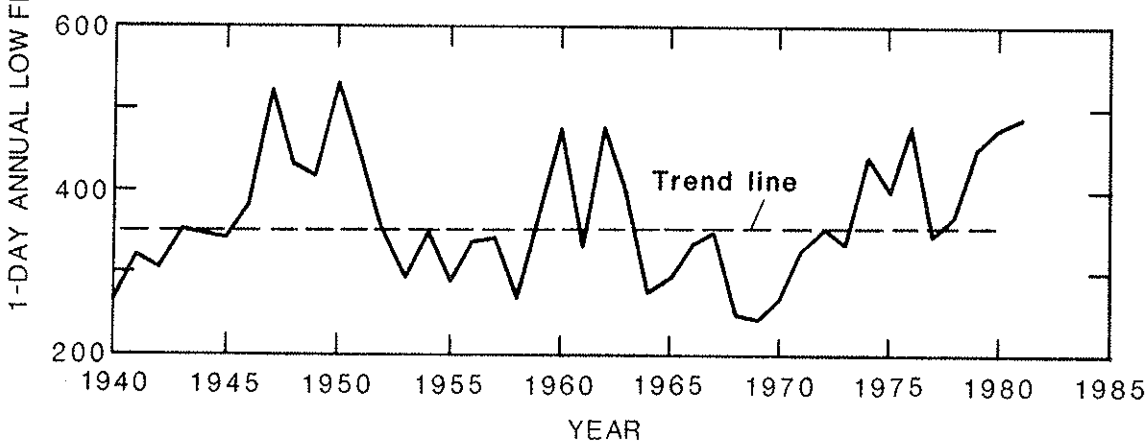


Figure 3.--The trend of the 1-day annual low flow for the Tangipahoa River near Robert, La. (1940-81).

PRELIMINARY REGIONALIZATION

As explained previously in this report, Louisiana was divided into four hydrographic regions. Region 1 was identified as the areas where most streams have zero low flows (intermittent streams) and region 4 lacks sufficient data for a regression analysis. Regions 2 and 3 have sustained streamflow (perennial streams); the analyses of data for these two regions are explained later in this report.

Region 1

A tabulation of the $7Q_{10}$ for all streams within the State showed that a large percentage of the streams had $7Q_{10}$ values of zero. When these values were plotted on a State map, the possibility of enclosing streams with $7Q_{10}$ equal to zero within regional boundaries became apparent. This region is referred to as region 1 in figure 1 and on plate 1 and is predominantly in the northern and extreme southern parts of the State. Streamflow sites within region 1 where the $7Q_{10}$ is equal to zero are shown in table 1.

Those stream-flow sites within region 1 that have $7Q_{10}$ low flows larger than zero are listed in table 2 and shown on plate 2. Many of these streams have well-defined channels and are connected hydraulically to low-yielding aquifer systems. Streams in region 1 that are not shown in table 2 are considered to have no flow except during periods of rainfall excess. It should be noted here that some of the larger streams in region 1 that also drain parts of regions 2 and 3 may have flow at the $7Q_{10}$ flow range. If no data collection site is available on such streams, then judgement must be used in making an assessment of the flow. (Low-flow statistics on some intermittent streams in this region were reported by Forbes, 1980.)

Inspection of plate 2 shows that many of the streams in region 1 that do have $7Q_{10}$ flow are near the boundaries of regions 2 or 3. This indicates that these streams are in transition zones and are probably influenced by more than one hydrologic region.

Tables 1 and 2 show that the $7Q_2$ ranges from 0 to 12 ft^3/s in region 1. Although the $7Q_2$ is larger than zero at 87 of the 167 data-collection sites (52 percent), no estimating equations were derived because 49 of the 87 sites have $7Q_2$ of 0.2 ft^3/s or less.

The following table shows the probability of streams in region 1 having flow in certain categories. Of the 167 sites where streamflow data are available, 87 (52 percent) have streamflow larger than zero at the $7Q_2$ flow rate. At the $7Q_{10}$ flow rate this percentage drops to 24, and at the $7Q_{20}$ flow rate only 19 percent of the streams have flow.

Low flow probability for sites in region 1

Flow category (ft^3/s)	Number of sites in category	Probability of occurring (percentage)
7 day, 2 year ($7Q_2$)		
0.0	81	49
0.1 - 0.2	48	30
>.3	38	21
7 day, 10 year ($7Q_{10}$)		
0.0	127	76
0.1 - 0.2	27	16
>.3	13	8
7 day, 20 year ($7Q_{20}$)		
0.0	133	81
0.1 - 0.2	22	12
>.3	12	7

Table 1.--The $7Q_2$ data in region 1 where the $7Q_{10}$ is equal to zero

Station No.	Area	$7Q_2$	Station No.	Area	$7Q_2$
7344450	78.0	0.0	7352250	53.1	0.1
7344460	9.8	.0	7352280	57.0	.1
7348730	46.4	.1	7352300	46.1	.1
7348760	49.8	.1	7352370	15.7	.1
7348800	66.9	.0	7352750	13.3	.0
7348900	16.1	.0	7352800	93.9	.0
7348970	12.8	.0	7353500	47.0	.0
7349460	80.6	.0	7353800	40.1	.1
7349600	63.9	.0	7354500	5.3	.2
7349795	88.9	.0	7354800	19.1	.0
7349796	31.9	.0	7355350	15.1	.2
7349840	17.2	.0	7364101	48.0	.0
7349845	26.0	.0	7364106	17.0	.4
7351000	79.0	.0	7364210	88.0	6.2
7351500	66.0	.0	7364300	271.0	.0
7351670	59.6	.0	7364505	17.0	.1
7351720	17.7	.0	7364800	30.0	.0
7351760	26.6	.0	7364837	9.0	.0
7351900	35.1	.1	7364870	47.0	.0
7352200	38.6	.1	7364900	68.9	.2

Table 1.--The $7Q_2$ data in region 1 where the $7Q_{10}$ is equal to zero--Continued

Station No.	Area	$7Q_2$	Station No.	Area	$7Q_2$
7365000	355.0	0.1	7382700	82.6	0.0
7365100	63.3	.1	7386000	37.1	.0
7365300	43.9	.0	7386500	19.0	1.2
7365500	178.0	2.1	8009950	10.9	.0
7366000	462.0	3.4	8010000	131.0	1.2
7366200	208.0	.1	8010100	94.5	.0
7367600	16.0	.0	8010200	48.2	.1
7368750	22.9	.0	8011600	14.4	.0
7370250	5.0	.0	8011800	43.9	.1
7370400	24.7	.0	8011900	28.7	.0
7370500	271.0	.0	8012800	37.4	.0
7370550	89.0	.2	8012880	168.0	.0
7370600	127.0	.0	8014885	4.4	.0
7370650	41.5	.0	8014890	4.8	.0
7370700	58.0	.1	8016200	28.3	.0
7370750	47.6	.1	8016500	34.9	.1
7370790	95.3	.3	8016700	45.6	.1
7370820	117.0	.0	8016800	177.0	.0
7370980	20.0	.0	8016990	15.3	.0
7371000	2.1	.1	8017000	50.5	.1
7371050	19.5	.0	8022600	27.7	.0
7371950	24.0	.0	8022700	26.9	.0
7372130	7.0	.1	8022765	91.5	.0
7372160	11.0	.0	8023100	76.5	.0
7372300	11.0	.2	8023150	44.6	.0
7372500	92.0	.1	8023250	29.2	.0
7373800	23.9	.1	8023270	8.5	.0
7373850	9.3	.0	8023280	5.7	.0
7373950	17.6	.1	8023400	80.2	.0
7373960	11.2	.1	8023500	154.0	.0
7376290	26.6	.0	8023700	33.4	.0
7376275	7.6	.1	8024000	111.0	.0
7377180	7.7	.0	8024030	45.9	.0
7377755	-----	.0	8024040	200.0	.0
7377770	15.3	.1	8024060	3.2	.0
7377782	45.0	.0	8024070	6.8	.0
7377800	65.7	.0	8024080	12.5	.0
7377842	-----	.0	8024200	130.0	.3
7380117	1.8	.1	8025220	5.1	.1
7380118	20.4	.0	8028800	15.4	.2
7380130	20.7	.0	8029700	25.9	.0
7380160	20.3	.0	8030400	8.8	.0
7380180	28.5	.0			

Table 2.--Stations in region 1 where the $7Q_{10}$ is greater than zero

Station No.	Area	$7Q_2$	$7Q_{10}$	$7Q_{20}$
[a]7348000	3137.0	12.0	1.6	0.9
7348780	15.2	.6	.3	.3
7349030	19.5	.8	.5	.4
7349200	35.1	.3	.2	.2
7351700	19.5	.5	.3	.2
7351703	10.9	.2	.1	.1
[a]7353000	1386.0	5.5	.2	.0
7354200	51.1	.5	.2	.2
7354625	61.9	.3	.1	.1
7355180	44.4	.4	.2	.1
7355366	4.2	.2	.1	.0
7365850	54.0	.4	.1	.0
7370200	60.0	.4	.1	.0
[a]7370800	923.0	7.7	2.0	1.3
7370930	46.0	.5	.1	.1
7371800	81.0	.2	.1	.1
7372100	31.0	.2	.1	.0
7372110	24.0	.2	.1	.1
7373650	7.0	.5	.3	.3
7373965	------	.2	.1	.1
7375600	25.3	.2	.1	.1
7375680	13.7	.2	.1	.1
7376100	47.4	.5	.4	.4
7376200	110.0	5.3	4.0	3.7
7376500	79.5	4.7	2.7	2.3
7376510	11.3	.8	.4	.3
7376520	40.6	1.6	.9	.8
7376602	14.7	.9	.3	.2
7377100	26.3	.2	.1	.1
7377220	9.5	.2	.1	.1
7377250	114.0	6.7	4.4	3.9
7378700	19.5	.3	.2	.1
8012650	18.7	.3	.2	.1
8012780	57.6	.2	.1	.0
8013600	5.8	.3	.1	.1
8015200	42.7	.2	.1	.0
8016300	76.0	1.5	.6	.4
8016400	148.0	1.5	.3	.2
8016600	82.2	.2	.1	.0
8025180	9.2	.5	.2	.2
8025200	52.1	1.1	.2	.1
8025370	12.3	.5	.2	.1

[a] See table 7.

Region 4

Region 4 is the area of the State where only limited low-flow data are available (pl. 1). Low-flow statistics for streams in region 4 where data are available are listed in table 3. No effort was made to use these streams in the regression analyses because of the sparsity of streamflow-data sites in the region, and because most of the streams where data are available are regulated. Low-flow statistics for these streams should be considered representative only of the period of record and are presented in this report for informational purposes only.

REGRESSION ANALYSES

Data from both regions 2 and 3 (pl. 1) were initially combined in regression analyses to derive equations for estimating the $7Q_2$, $7Q_{10}$, and $7Q_{20}$ flows. Initial independent variables tested were drainage area, mean annual rainfall, main channel slope1/, stream hydrograph recession index (Bingham, 1982), soils index (Armbruster, 1976), and discharge at the 95-percent duration (Bloxham, 1981). Drainage area, mean annual rainfall, and the main channel slope proved significant at the 95-percent confidence level. However, the regression analyses using the combined data from regions 2 and 3 yielded standard errors of estimate that were excessive.

A plot of the regression-estimated $7Q_2$, $7Q_{10}$, and $7Q_{20}$ discharges versus the actual $7Q_2$, $7Q_{10}$, and $7Q_{20}$ discharges showed that the data were layered in two groups. Least square fits of these data (actual $7Q_2$, $7Q_{10}$, and $7Q_{20}$ versus the computed $7Q_2$, $7Q_{10}$, and $7Q_{20}$) for each individual group gave regression lines that were approximately parallel to each other. This indicated that other variables were needed if all the data were to be used as one population in the analyses. Other variables tested had little effect on results of the additional regression analyses; therefore, a geographical regionalization technique was used.

Tentative boundaries for regions 2 and 3 were delineated based on geologic and soil maps of the State. Data for sites within these tentative boundaries were then used in separate regression analyses to derive equations for estimating the $7Q_2$, $7Q_{10}$, and $7Q_{20}$ flows for each region. Final regional boundaries were established by varying (adding or subtracting) sites along a common boundary between regions 2 and 3 until a minimum standard error of estimate was reached for both regions.

1/ See "Explanation of symbols and terms" p. V.

Table 3.--Low-flow data for streams in the undefined area of Louisiana (region 4)

Station No.	Stream name	Area (mi^2)	7-Day Q_2	7-Day Q_{10}	7-Day Q_{20}	Remarks
7367700	Boeuf River near Ark.-La. stateline	785	35	1.0	0.0	Severely regulated.
7368000	Boeuf River near Girard	1226	36	13	9.4	Do.
7368520	Big Creek at Holly Ridge	171	.2	.1	.0	----------
7368540	Big Creek near Mangham	347	20	19	18	----------
7368560	Little Creek near Mangham	25.1	.0	.0	.0	----------
7369200	Turkey Creek at Winnsboro	101	.3	.2	.2	----------
7369500	Tensas River at Tendal	309	8.6	4.2	3.6	Regulated.
7369640	Bayou Vidal at Quimby	160	.1	.0	.0	----------
7369700	Bayou Macon near Kilbourne	504	43	7.7	4.0	Severely regulated.
7370000	Bayou Macon near Delhi	782	90	45	37	Do.
7380400	Bayou Lafourche at Donaldsonville	(a)	128	78	66	Regulated.
7382750	Bayou Waukska near Lebeau	95	1.4	1.1	1.0	----------
7383500	Bayou des Glaises Diversion Channel at Moreauville.	270	12	5.0	3.9	Regulated.
7384000	West Protection Levee Borrow Pit Channel near Plaucheville.	321	13	5.7	4.6	Do.
7385500	Bayou Teche at Arnaudville	1531	173	98	83	Do.
7385700	Bayou Teche at Keystone Lock near St. Martinville.	(a)	86	20	.9	Do.

a/ Indeterminate.

Low Flow At Ungaged Sites

The regression analyses for regions 2 and 3 resulted in log-linear equations of the form:

$$\log (7Q_i) = \log a + b \log A + c \log (P-35) + d \log S$$

Independent variables used in the equations are drainage area, A; mean annual precipitation, P; and the channel slope, S; a, b, c, and d are the regression constant and coefficients, respectively. A constant of 35 was subtracted from the mean annual precipitation so that the range in the regression coefficients for each recurrence interval would be small. (For a description of the independent variables see "Explanation of symbols and terms.") These equations can be used to estimate the $7Q_2$, $7Q_{10}$, and $7Q_{20}$ low flows for sites in regions 2 and 3 where low-flow data have not been collected. The methodology is explained in detail in the section, "Examples of the use of the equations and graphs."

Data used to develop the equations in this report are from both regular discharge gaging stations and partial-record gaging stations. The 7-day low flows for the partial-record sites used in the regression analyses were developed by correlating concurrent discharge measurements made at the partial-record sites with those for nearby regular discharge gaging stations. (See Forbes, 1980.) Since the partial-record site data are derived from correlations with other streamflow station data, it has an inherent error due to the scatter of the points about the best-fit line. Regression equations were developed, using only regular discharge station data to see what effects the partial-record sites had on the equations. The equations developed using only the regular discharge stations were significantly different from the equations presented in subsequent section of this report and resulted in a lower standard error of estimate. However, to obtain a better geographic coverage of stations, both partial-record and regular discharge stations were used in the analysis.

Region 2

A total of 90 data sites (20 regular discharge stations and 70 partial-record stations) were used to define the equations for estimating low flow in region 2. These sites are shown on plate 1 and the data are listed in table 4. Data for some sites shown in region 2 on plate 1 were not used in the analysis but are also listed in table 4. These data were eliminated from the analyses for reasons such as man-affected channel changes; period of record too short to give an adequate estimate of the $7Q_2$, $7Q_{10}$, and $7Q_{20}$; a positive or negative trend; and drainage area or slope that could not be defined. Contributing drainage area, A, and channel slope, S, were measured from U.S. Geological Survey quadrangle maps. The mean annual rainfall index, P, was taken from the isohyetal map of Louisiana, shown in figure 4 (Neely, 1976). This rainfall represents the mean annual rainfall at the data site for the base period 1931 to 1960 and is used only as an index value in the regression analyses.

Table 4.--Data for region 2 used to define the equations for estimating low flows

Station No.	7-day $7Q_2$	7-day $7Q_{10}$	7-day $7Q_{20}$	Area (mi^2)	Precipitation (in.)	Slope (ft/mi)	Remarks
	cubic feet per second						
2489300	44.0	38.0	37.0	72.3	60	12.2	Partial record.
2489400	90.0	72.0	68.0	158	61	12.0	Do.
2489440	2.3	1.8	1.7	14.2	61	19.0	Do.
2489470	4.3	3.3	3.0	12.8	60	16.6	Do.
2490000	2.5	1.2	1.1	12.1	61	15.7	Continuous record.
2491200	20.0	18.0	17.0	50.1	62	8.2	Partial record.
2491350	11.0	8.6	8.1	42.2	62	10.2	Do.
2491700	17.0	12.0	11.0	44.2	62	11.5	Do.
2491720	5.0	3.9	3.7	9.4	62	19.7	Do.
7347000	3.0	1.4	1.2	116	48	4.2	Continuous record.
7347500	6.3	3.0	2.5	364	48	2.2	Do.
7349100	1.6	.6	.4	43.6	50	7.7	Partial record.
7350800	.9	.4	.3	19.0	46	3.2	Do.
7351250	.6	.3	.2	19.7	46	12.8	Do.
7352000	11.0	4.5	3.5	154	50	6.1	Continuous record.
7352040	.5	.4	.4	4.4	51	23.7	Partial record.
7352060	1.3	1.0	.9	12.8	52	17.1	Do.
7352100	25.0	13.0	10.0	293	52	3.1	Do.
7352400	3.7	2.7	2.4	21.1	52	10.9	Do.
7352500	14.0	6.7	5.9	423	50	3.9	Continuous record.
7352600	1.3	.7	.6	21.5	50	7.9	Partial record.
7352700	2.5	1.7	1.5	27.9	50	9.4	Do.
7355000	6.9	5.2	4.8	18.0	58	13.9	Continuous record.
7355005	2.2	1.7	1.7	5.2	58	16.9	Do.
7355150	8.1	6.9	6.6	114	56	5.4	Partial record.
7355200	6.5	4.3	3.8	26.4	56	16.5	Do.
7372600	4.3	2.7	2.4	30.0	57	10.8	Do.
7372720	4.1	3.1	2.9	29.0	57	11.0	Do.
7372900	3.0	2.3	2.1	12.0	57	18.4	Do.
7373000	13.0	7.4	6.2	51.0	58	11.3	Continuous record.
7373050	.8	.4	.3	6.5	57	20.6	Partial record.
7373250	15.0	13.0	12.0	35.3	58	12.6	Do.
7373251	12.0	9.5	8.8	39.0	58	10.1	Do.
7373263	4.1	3.8	3.7	17.0	58	14.0	Do.
7373296	.8	.7	.7	4.3	57	28.7	Do.
7373300	19.0	15.0	14.0	104	56	8.7	Do.
7373440	2.2	1.6	1.5	11.1	56	21.5	Do.
7373450	19.0	15.0	14.0	99.3	56	9.2	Do.
7373500	3.7	2.6	2.4	35.3	57	11.8	Continuous record.
7373570	4.4	3.6	3.4	31.3	57	12.9	Partial record.
7373590	11.0	8.1	7.4	66.6	56	9.7	Do.
7373610	1.6	1.2	1.1	10.4	56	16.1	Do.
7374650	4.5	3.8	3.6	16.4	62	12.3	Do.
7374700	24.0	20.0	19.0	53.1	61	11.4	Do.

Table 4.--Data for region 2 used to define the equations for estimating low flows--Continued

Station No.	7-day $7Q_2$	7-day $7Q_{10}$	7-day $7Q_{20}$	Area (mi^2)	Precipitation (in.)	Slope (ft/mi)	Remarks
	cubic feet per second						
7375000	42.0	33.0	31.0	95.5	61	7.1	Continuous record.
7375050	50.0	38.0	36.0	145	62	6.4	Partial record.
7375150	24.0	17.0	16.0	76.5	62	7.4	Do.
7375310	31.0	24.0	23.0	59.6	63	8.2	Do.
7375400	6.7	5.4	5.1	25.5	63	12.1	Do.
7375424	15.0	8.9	7.8	38.4	63	10.2	Do.
7375426	9.7	7.1	6.6	31.2	63	10.6	Do.
7375460	9.3	7.5	7.0	24.4	63	11.9	Do.
7375470	6.6	4.8	4.4	27.9	63	8.9	Do.
7375800	37.0	32.0	30.0	89.7	60	8.7	Continuous record.
7375850	62.0	55.0	53.0	136	64	7.6	Partial record.
7375930	11.0	9.6	9.2	45.0	64	9.4	Do.
7375960	88.0	75.0	72.0	220	64	7.2	Do.
7376000	92.0	75.0	70.0	247	60	6.3	Continuous record.
7376150	2.9	1.9	1.7	32.2	57	9.4	Partial record.
7376800	27.0	23.0	22.0	123	62	7.2	Do.
7377050	17.0	16.0	15.0	54.3	64	8.3	Do.
7377200	4.7	4.4	4.3	27.3	59	12.5	Do.
7377400	27.0	20.0	19.0	88.0	58	7.7	Do.
7377410	9.3	9.2	9.1	25.7	59	11.5	Do.
7377500	43.0	34.0	32.0	145	58	8.1	Continuous record.
7377700	4.7	3.6	3.4	42.4	56	9.7	Partial record.
7381800	39.0	30.0	28.0	68.3	61	8.4	Continuous record.
7382000	78.0	52.0	47.0	240	62	5.1	Do.
7382235	6.6	5.4	5.0	10.4	58	16.9	Partial record.
7382238	8.5	7.0	6.6	10.7	58	20.7	Do.
7382244	3.4	2.6	2.4	5.0	58	28.1	Do.
8013450	8.8	6.4	5.7	79.7	58	3.9	Do.
8013650	1.8	.9	.7	22.0	55	11.0	Do.
8013700	1.7	1.0	.8	22.1	55	10.5	Do.
8013720	19.0	12.0	9.9	128	56	6.8	Do.
8013900	17.0	11.0	10.0	88.6	56	9.0	Do.
8013950	7.6	5.7	5.2	34.4	56	10.9	Do.
8014000	53.0	36.0	32.0	171	58	6.7	Continuous record.
8014200	14.0	9.4	8.2	94.2	58	5.4	Do.
8014500	153	110	102	510	59	5.8	Do.
8014550	3.1	2.5	2.3	14.9	55	19.3	Partial record.
8014800	17.0	13.0	12.0	120	55	7.7	Continuous record.
8025700	5.9	4.3	4.0	33.7	54	9.6	Partial record.
8025800	.7	.5	.5	2.1	54	47.8	Do.
8025900	3.2	2.2	2.0	18.0	54	18.7	Do.
8026300	1.6	1.3	1.2	6.3	54	17.6	Do.
8028700	1.8	1.1	1.0	13.1	56	11.4	Continuous record.
8028750	2.1	1.6	1.5	7.7	55	9.4	Partial record.

Table 4.--Data for region 2 used to define the equations for estimating low flows--Continued

The Following Stations Were Not Used Because of the Reason Given Under Remarks

Station No.	Remarks
2490100	Urban influence.
2490105	Do.
7346400	Low flow not defined adequately for region 2.
7352730	Zero flow.
7352870	Do.
7355005	Low flow not defined adequately for region 2.
7366350	Do.
7366400	Do.
7367300	Do.
7369000	Regulated.
7373400	Low flow not defined adequately for region 2.
7373520	Do.
7376602	Do.
7383000	Regulated.
8013650	Low flow not defined adequately for region 2.
8013750	Zero flow.
8014800	Declining trend of 1-day flow.
8015000	Do.
8026200	Low flow not defined adequately for region 2.
8027730	Do.
8027740	Do.
8028000	Regulated.
8028200	Do.
8028300	Low flow not defined adequately for region 2.
8028350	Do.

Equations for estimating the $7Q_2$, $7Q_{10}$, and $7Q_{20}$ flows for region 2 are shown below:

$$7Q_2 = 1.40 \times 10^{-5} A^{1.09} (P-35)^{2.58} S^{0.55} \quad (1)$$

$$7Q_{10} = 1.22 \times 10^{-6} A^{1.10} (P-35)^{3.15} S^{0.68} \quad (2)$$

$$7Q_{20} = 5.29 \times 10^{-7} A^{1.11} (P-35)^{3.35} S^{0.73} \quad (3)$$

where A = contributing drainage area (mi2),
P = mean annual rainfall index (in.), and
S = main channel slope (ft/mi).

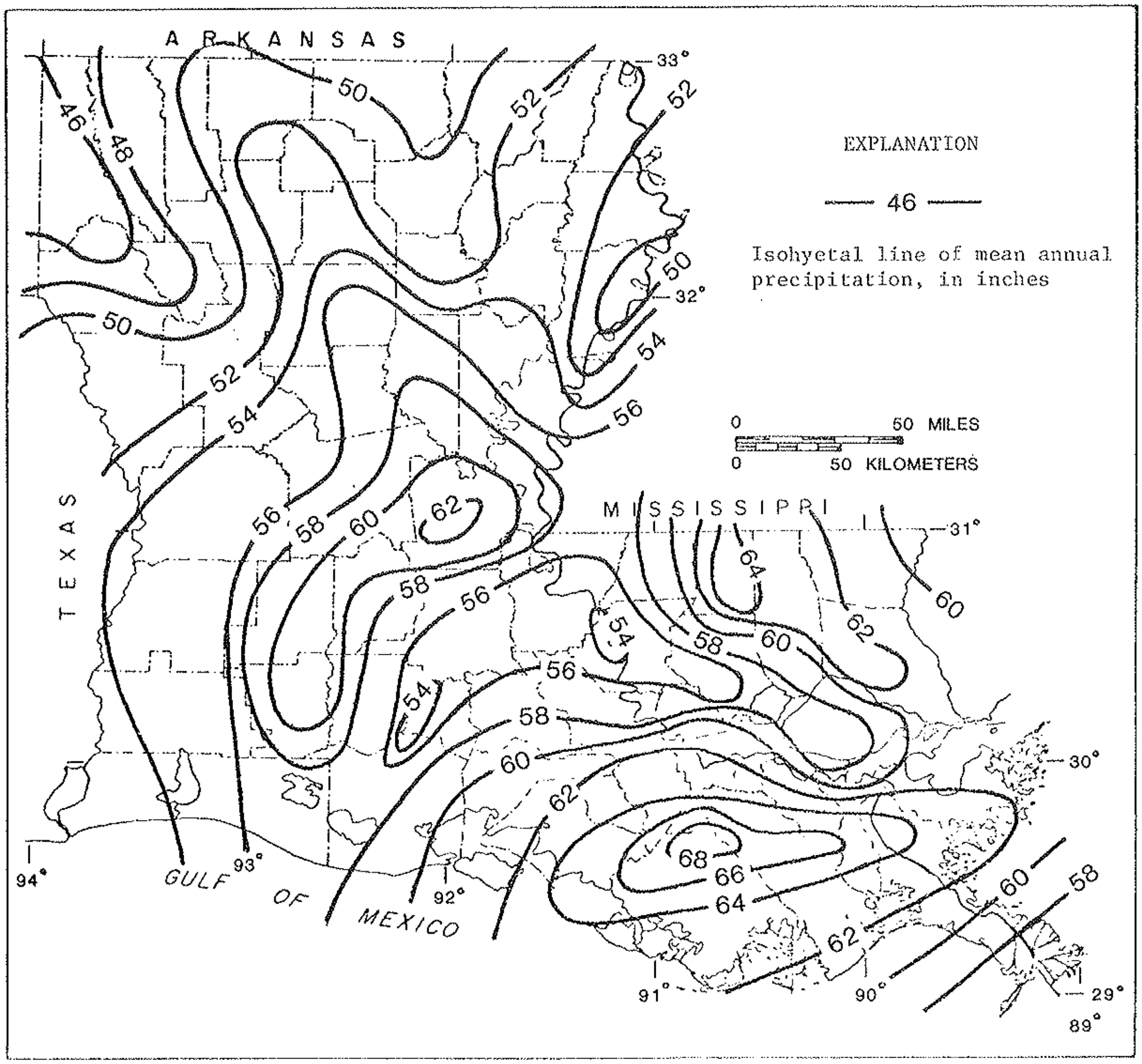


Figure 4.--Mean annual precipitation for Louisiana for the base period, 1931-60. [From Neely, 1976.]

Average standard errors of regression (comparing discharges computed from the equations to the actual discharges for 90 data sites defined for region 2) are ± 44 percent for $7Q_2$, ± 50 percent for $7Q_{10}$, and ± 54 percent for $7Q_{20}$. These standard errors are comparable to those for similar studies in other areas documented in the "Literature Review" section of this report. All independent variables are significant at the 95 percent confidence level.

Discharge values for deriving the equations ranged from 0.5 to 153 ft^3/s for the $7Q_2$, with 78 percent between 0.5 and 20 ft^3/s; 0.3 to 110 ft^3/s for the $7Q_{10}$, with 68 percent between 0.3 and 10 ft^3/s; and 0.2 to 102 ft^3/s for the $7Q_{20}$, with 72 percent between 0.2 and 10 ft^3/s.

Independent variables ranged from 2.1 to 510 mi^2 for drainage area, with 56 percent between 2.1 and 40 mi^2; 46 to 64 in. for mean annual rainfall, with 90 percent between 51 and 65 in.; and 2.2 to 47.8 ft/mi for channel slope, with 79 percent between 2.2 and 15 ft/mi.

Region 3

A total of 26 data sites (one regular discharge station and 25 partial-record stations) were used to define equations for estimating low flow for region 3. These sites are shown on plate 1 and the data are listed in table 5. Data for some sites shown in region 3 on plate 1 and listed in table 5 were not used in the regression analyses. (See section, Region 2.)

Equations for estimating $7Q_2$, $7Q_{10}$, and $7Q_{20}$ flows for region 3 are shown below:

$$7Q_2 = 9.14 \times 10^{-4} A^{1.03} (P-35)^{0.56} S^{0.96} \quad (4)$$

$$7Q_{10} = 2.37 \times 10^{-4} A^{1.01} (P-35)^{0.85} S^{0.94} \quad (5)$$

$$7Q_{20} = 1.04 \times 10^{-4} A^{1.03} (P-35)^{0.98} S^{1.02} \quad (6)$$

Average standard errors of estimate (comparing discharges computed from the equations to the actual discharges for 26 data sets defined for region 3) are ±45 percent for $7Q_2$, ±58 percent for $7Q_{10}$, and ±61 percent for $7Q_{20}$.

Discharge values used in the analyses ranged from 0.4 to 9.6 ft^3/s for $7Q_2$, with 83 percent between 0.4 and 5.0; 0.2 to 5.7 ft^3/s for $7Q_{10}$, with 93 percent between 0.2 and 5.0; and 0.2 to 5.1 ft^3/s for $7Q_{20}$, with 93 percent between 0.2 and 3.0. Independent variables ranged from 3.7 to 360 mi^2 for drainage area, with 69 percent between 3.7 and 50; 51 to 62 in. for mean annual rainfall, with 72 percent between 52 and 58 in.; and 4.3 to 21.9 ft/mi for channel slope, with 73 percent between 4.3 and 15.

Sensitivity Analysis

The results of a sensitivity test of the estimating equations for regions 2 and 3 are listed in table 6. The test was designed to determine the percentage of error for the following conditions:

1. Area changed by ±10 and ±20 percent.
2. Precipitation changed by ±1 and ±2 in. for 48 and 62 in. average rainfall.
3. Channel slope changed by ±10 and ±20 percent.

Test results tabulated in table 6 indicate that precipitation is the most sensitive variable for region 2. For example, if actual annual precipitation is 48 in/yr, overestimating it by 2 in. can result in overestimating the $7Q_2$, $7Q_{10}$, and $7Q_{20}$ low flows by 45, 57, and 62 percent, respectively. However, if the actual annual precipitation is 62 in/yr, then the error associated with a 2 in/yr overestimate of precipitation produces errors in the $7Q_2$, $7Q_{10}$, and $7Q_{20}$ low flows of only 20, 25, and 27 percent, respectively. The tests in which area and channel slope were varied show that, as these variables are over or underestimated by a given percentage, the associated $7Q_2$, $7Q_{10}$, and $7Q_{20}$ low flows are increased or decreased by approximately the same amount.

Table 5.--Data for region 3 used to define the equations for estimating low flow

Station No.	7-Day $7Q_2$	7-Day $7Q_{10}$	7-Day $7Q_{20}$	Area (mi^2)	Precipitation (in.)	Slope (ft/mi)	Remarks
	cubic feet per second						
2491820	0.7	0.4	0.4	15.0	62	15.8	Partial record.
2491850	.7	.3	.3	8.8	62	14.1	Do.
2491870	.8	.4	.4	9.0	62	17.4	Do.
2491900	.7	.3	.2	13.5	62	11.5	Do.
7354000	.9	.4	.4	21.4	54	15.3	Continuous record.
7354100	6.4	3.6	3.0	140	54	7.9	Partial record.
7354690	.7	.3	.2	11.2	54	17.7	Do.
7354700	7.4	2.8	2.0	360	54	4.3	Do.
7355360	.4	.2	.2	3.7	57	21.9	Do.
7369360	2.1	.9	.9	64.7	53	7.1	Do.
7373133	1.7	1.1	1.0	13.6	58	17.2	Do.
7373200	.9	.5	.4	32.0	58	5.6	Do.
7373235	1.8	1.1	.9	12.0	59	16.5	Do.
7373264	.6	.5	.4	8.5	58	19.8	Do.
7375200	2.3	1.4	1.2	17.4	62	10.4	Do.
7375210	2.5	2.1	2.0	16.8	62	11.6	Do.
7375220	.7	.4	.3	28.9	60	6.5	Do.
8012700	1.5	.9	.8	37.1	56	8.9	Do.
8013200	2.0	1.6	1.5	51.4	58	6.0	Do.
8015600	1.5	1.0	.9	111	56	4.3	Do.
8015700	1.1	.6	.5	23.1	57	8.6	Do.
8025390	1.7	1.1	.9	15.0	52	14.9	Do.
8025600	5.2	2.1	1.6	187	53	4.7	Do.
8025606	9.6	5.7	5.1	193	53	5.1	Do.
8027500	2.3	1.3	1.1	40.6	54	9.6	Do.
8027550	1.6	.9	.8	40.0	55	12.2	Do.

The following stations were not used because of the reason given under remarks

Station No.	Remarks
2491750	Low flow not adequately defined.
2492200	Do.
7354300	Do.
7366350	Do.
7369000	Regulated.
8011950	Slope not defined.
8014885	Zero flow.
8014890	Do.
8015200	Do.
8015800	Slope not defined.
8026700	Zero flow.
8027500	Regulated.

Table 6.--Sensitivity tests of equations

[Average percentage error in computed low flows for indicated errors in the parameters A, area; S, slope; and P, precipitation]

Area	7-day	Equation	±10 percent error		±20 percent error		±1-inch error		±2-inch error	
			A	S	A	S	P = 48	P = 62	P = 48	P = 62
2	Q_2	1	+11 -11	+6 -5	+22 -22	+11 -12	+21 -19	+10 -9	+45 -35	+20 -18
2	Q_{10}	2	+12 -11	+7 -7	+23 -22	+14 -14	+26 -22	+12 -11	+57 -41	+25 -22
2	Q_{20}	3	+11 -11	+7 -7	+22 -22	+14 -15	+28 -23	+13 -12	+62 -43	+27 -23
3	Q_2	4	+10 -10	+9 -9	+21 -21	+19 -20	a/+3 a/-3	b/+2 b/-3	a/+6 a/-6	b/+3 b/-5
3	Q_{10}	5	+11 -10	+10 -10	+21 -19	+19 -19	a/+5 a/-4	b/+5 b/-3	a/+9 a/-9	b/+8 b/-6
3	Q_{20}	6	+10 -12	+10 -12	+19 -21	+19 -21	a/+5 a/-5	b/+4 b/-4	a/+11 a/-11	b/+8 b/-8

a/ Based on P = 54 inches.

b/ Based on P = 60 inches.

Test results using equations for region 3 are also shown in table 6. These tests indicate that as the error in a variable increases or decreases, the resulting $7Q_2$, $7Q_{10}$, and $7Q_{20}$ low flows increase or decrease by approximately the same amount.

LARGE STREAMS

As a general rule, streams with large drainage areas traverse more than one hydrologic region and are affected by all regions crossed. For this study, streams with drainage areas larger than 525 mi^2 at the most downstream data point are considered large streams. These streams were not used in the regression analyses but were analyzed on an individual site basis, although the drainage area at some data-collection locations may have been less than 525 mi^2.

Data for the $7Q_2$, $7Q_{10}$, and $7Q_{20}$ flow for sites on the streams at locations shown in figure 5 are listed in table 7. Graphs for determining low flows at points between data sites on each stream require that two things be known: (1) The $7Q_2$, $7Q_{10}$, and $7Q_{20}$ flows at specific sites along each stream, and (2) drainage area upstream from the ungaged site.

For each data site along a stream, the $7Q_2$, $7Q_{10}$, and $7Q_{20}$ were plotted versus the drainage area at that point along the stream. Figures 6 through 19 show graphs for the streams listed in table 7 that have more than one data collection site. Inspection of table 7 shows that many of the streams are regulated. Caution is advised when using these graphs where streamflow regulation is a factor, because the data used to derive them represent unnatural past conditions that may not reflect future conditions.

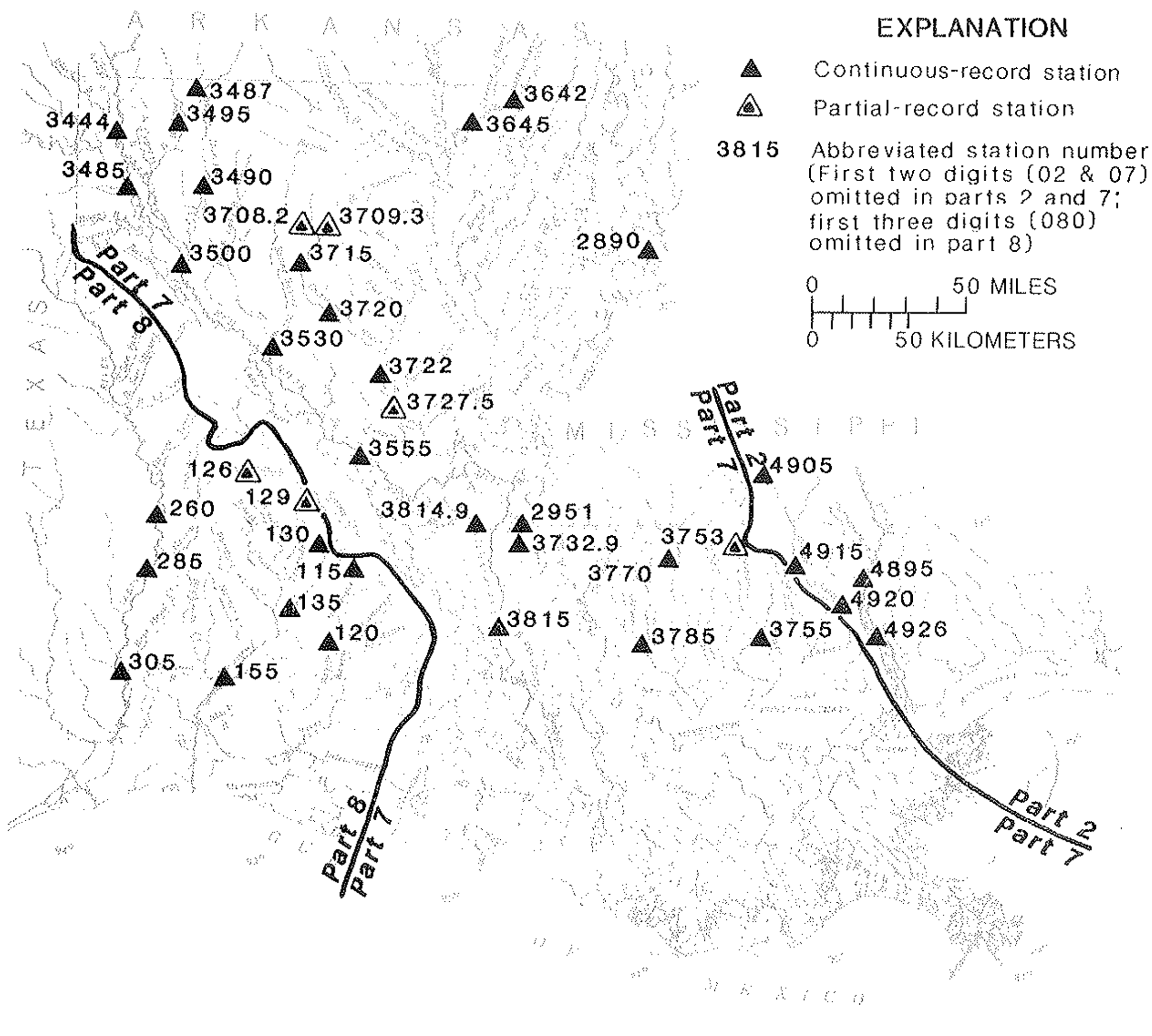


Figure 5.--The low-flow sites on streams having drainage basins larger than 525 mi^2 and more than one data point.

Table 7.--Data for streams in Louisiana where the drainage area of the furthermost downstream data point is larger than 525 square miles

Station No.	Stream name	Area (mi^2)	7-Day Q_2	7-Day Q_{10}	7-Day Q_{20}	Remarks
2489500	Pearl River near Bogalusa----------	6,570	1,620	1,320	1,100	--------------------
2492600	Pearl River at Pearl River---------	8,590	2,250	1,940	1,860	--------------------
2490500	Bogue Chitto near Tylertown, Miss--	502	238	187	176	--------------------
2491500	Bogue Chitto at Franklinton--------	985	530	400	370	--------------------
2492000	Bogue Chitto near Bush-------------	1,210	611	460	425	--------------------
7375300	Tangipahoa River near Kentwood-----	237	124	103	98.0	--------------------
7375500	Tangipahoa River at Robert---------	646	368	284	264	--------------------
7377000	Amite River near Darlington--------	580	235	197	190	--------------------
7378500	Amite River near Denham Springs----	1,280	397	304	284	--------------------
7289000	Mississippi River at Vicksburg, Miss.	1,118,160	184,000	127,000	114,000	Some regulations.
7295100	Mississippi River at Tarbert Landing.	1,124,900	180,000	142,000	131,000	Do.
7373290	Mississippi River at Red River Landing.	1,125,000	139,600	100,800	92,600	Do.
7344400	Red River near Hosston-------------	57,041	3,130	1,650	1,220	Regulated.
7348500	Red River at Shreveport------------	60,613	2,540	1,150	885	Do.
7350500	Red River at Coushatta-------------	63,362	3,010	1,330	1,020	Do.
7355500	Red River at Alexandria------------	67,500	3,440	1,650	1,310	Do.
7381490	Atchafalaya River at Simmesport----	93,289	64,600	26,000	18,500	Some regulations.
7381500	Atchafalaya River at Krotz Springs-	93,329	44,300	24,150	20,100	Do.
8012600	Calcasieu River near Slagle--------	48.1	0.1	0.0	0.0	--------------------
8012900	Calcasieu River at Hineston--------	436	8.3	4.1	3.4	--------------------
8013000	Calcasieu River near Glenmora------	499	27.0	18.0	17.0	--------------------
8013500	Calcasieu River near Oberlin-------	753	55.0	37.0	34.0	Slightly regulated.
8015500	Calcasieu River near Kinder--------	1,700	300	202	186	Moderately regulated.

8026000	Sabine River near Burkeville, Tex--	7,482	165	73.0	53.0	Severely regulated.
8028500	Sabine River near Bon Weir, Tex----	8,229	458	283	246	Moderately regulated.
8030500	Sabine River near Ruliff, Tex------	9,329	737	432	377	Do.
8011500	Boggy Bayou near Pine Prairie------	51.3	.0	.0	.0	Tributary to Bayou Nezpique.
8012000	Bayou Nezpique near Basile---------	527	2.9	.5	.3	Slightly regulated.
7348700	Bayou Dorcheat near Springhill-----	605	2.4	.8	.6	---------------------
7349000	Bayou Dorcheat near Minden---------	1,097	1.8	.0	.0	Loss to aquifer.
7349500	Bodcau Bayou near Sarepta----------	546	1.8	.2	.1	Slightly regulated.
7350000	Loggy Bayou near Ninock------------	2,628	26.0	.0	.0	Do.
7364200	Bayou Bartholomew near Jones-------	1,187	95.0	46.0	38.0	Do.
7364500	Bayou Bartholomew near Beekman-----	1,645	131	59.0	47.0	Do.
7370820	Dugdemona River near Quitman-------	117	.3	.0	.0	---------------------
7371500	Dugdemona River near Jonesboro-----	347	5.0	1.1	.6	Moderately regulated.
7372000	Dugdemona River near Winnfield-----	654	7.0	.2	.0	Do.
7372200	Little River near Rochelle---------	1,899	30.7	14.9	12.5	Slightly regulated.
7372750	Little River near Pollock----------	2,254	52.0	23.0	19.0	Do.
7368500	Big Colewa Bayou near Oak Grove----	42.0	.0	.0	.0	Do.1/
7368520	Big Creek at Holly Ridge-----------	171	.2	.1	.0	(1)
7368540	Big Creek near Mangham-------------	347	20.0	19.0	18.0	(1)
7348000	Twelvemile Bayou near Dixie--------	3,137	12	1.6	.9	(2)
7353000	Saline Bayou near Clarence---------	1,386	5.5	2.0	0	(2)
7370800	Castor Creek (Bayou Castor) at Tullos.	923	7.7	2.0	1.3	(2)

1/ In undefined area of the State.

2/ Individual sites with drainage areas greater than 525 mi^2. See table 2 also.

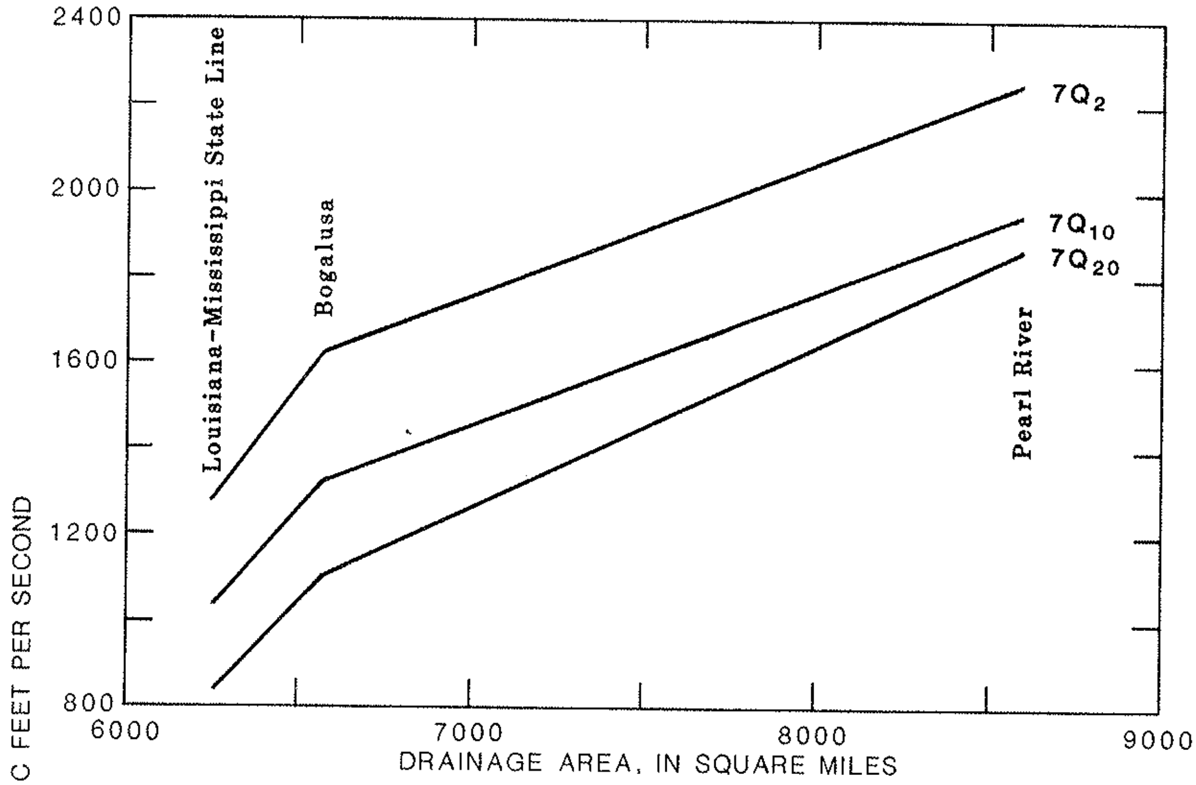


Figure 6.--The $7Q_2$, $7Q_{10}$, and $7Q_{20}$ flows versus the drainage area for the Pearl River.

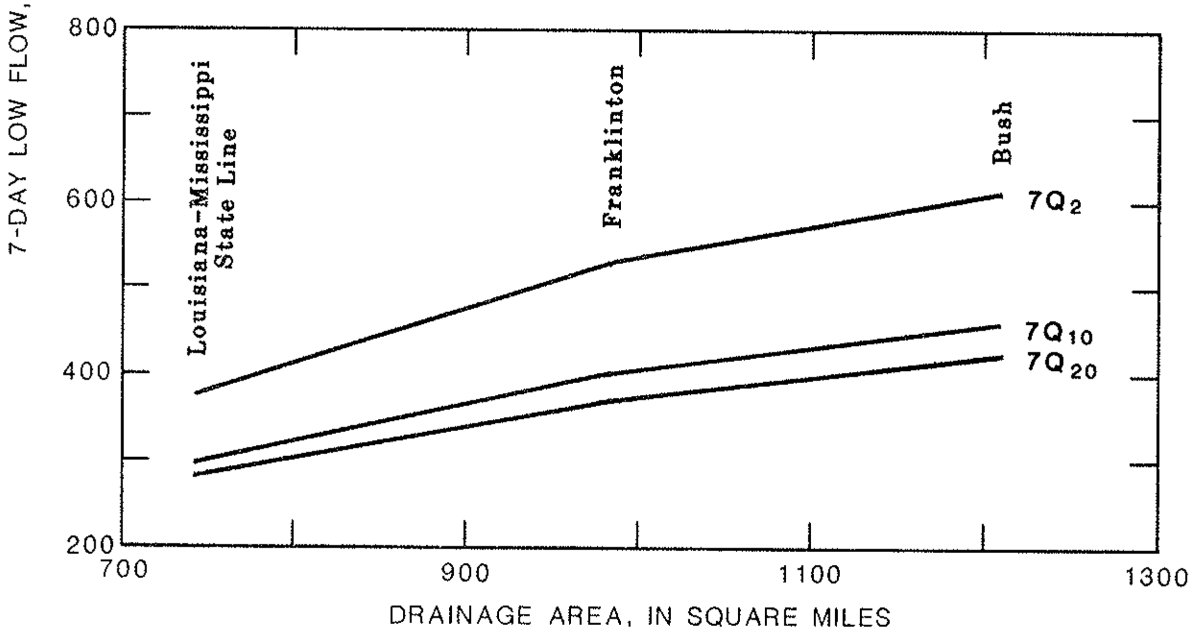


Figure 7.--The $7Q_2$, $7Q_{10}$, and $7Q_{20}$ flows versus the drainage area for the Bogue Chitto.

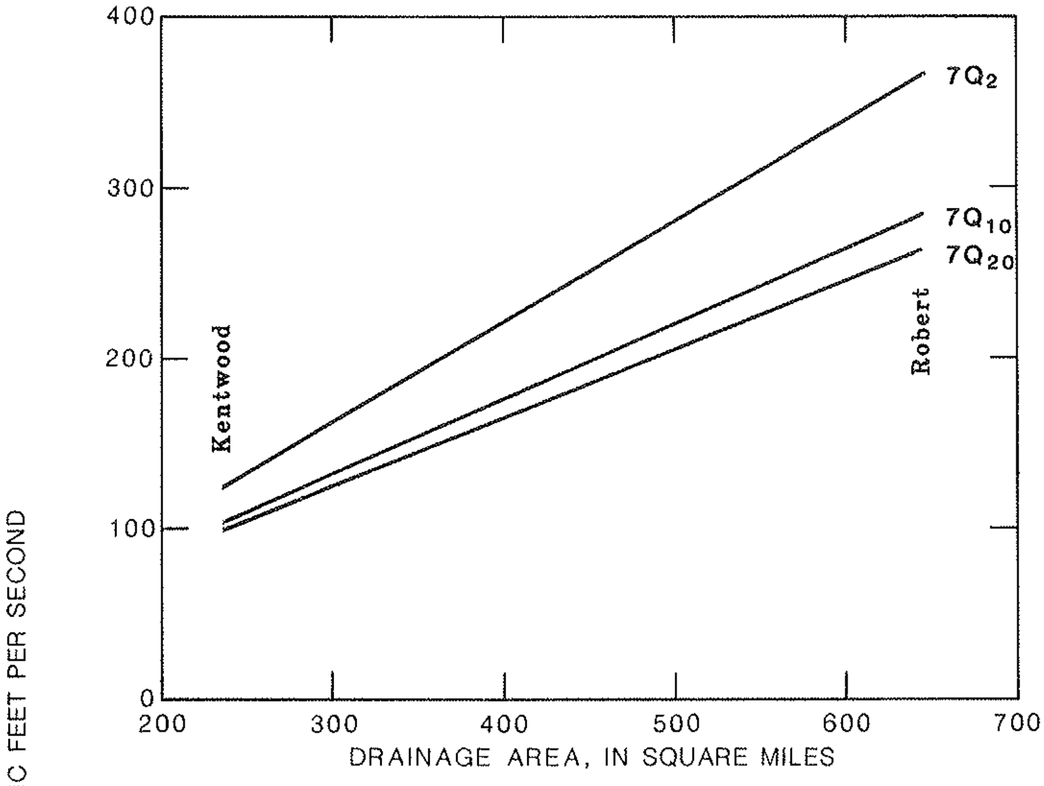


Figure 8.--The $7Q_2$, $7Q_{10}$, and $7Q_{20}$ flows versus the drainage area for the Tangipahoa River.

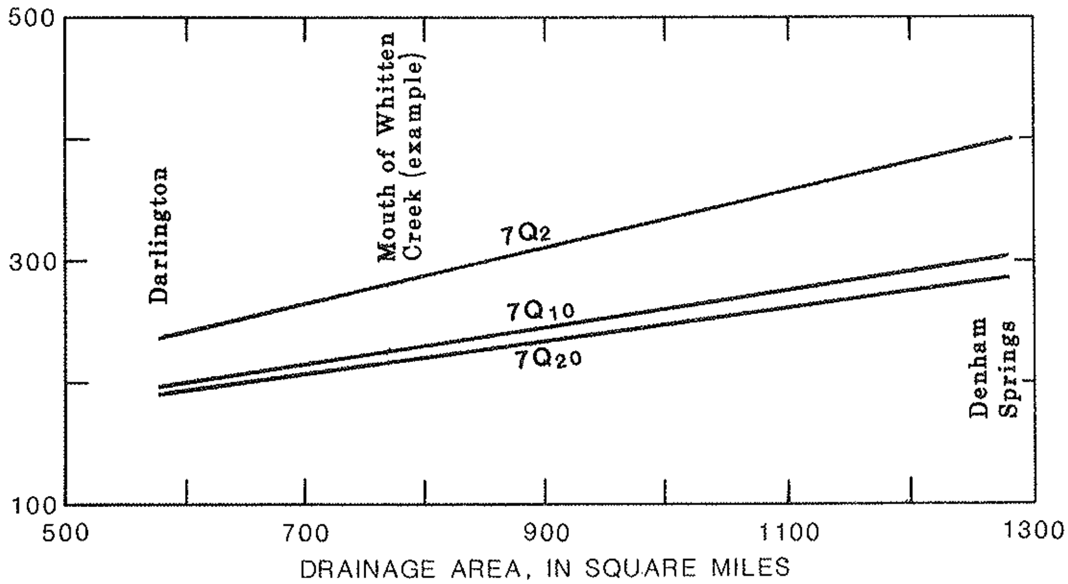


Figure 9.--The $7Q_2$, $7Q_{10}$, and $7Q_{20}$ flows versus the drainage area for the Amite River.

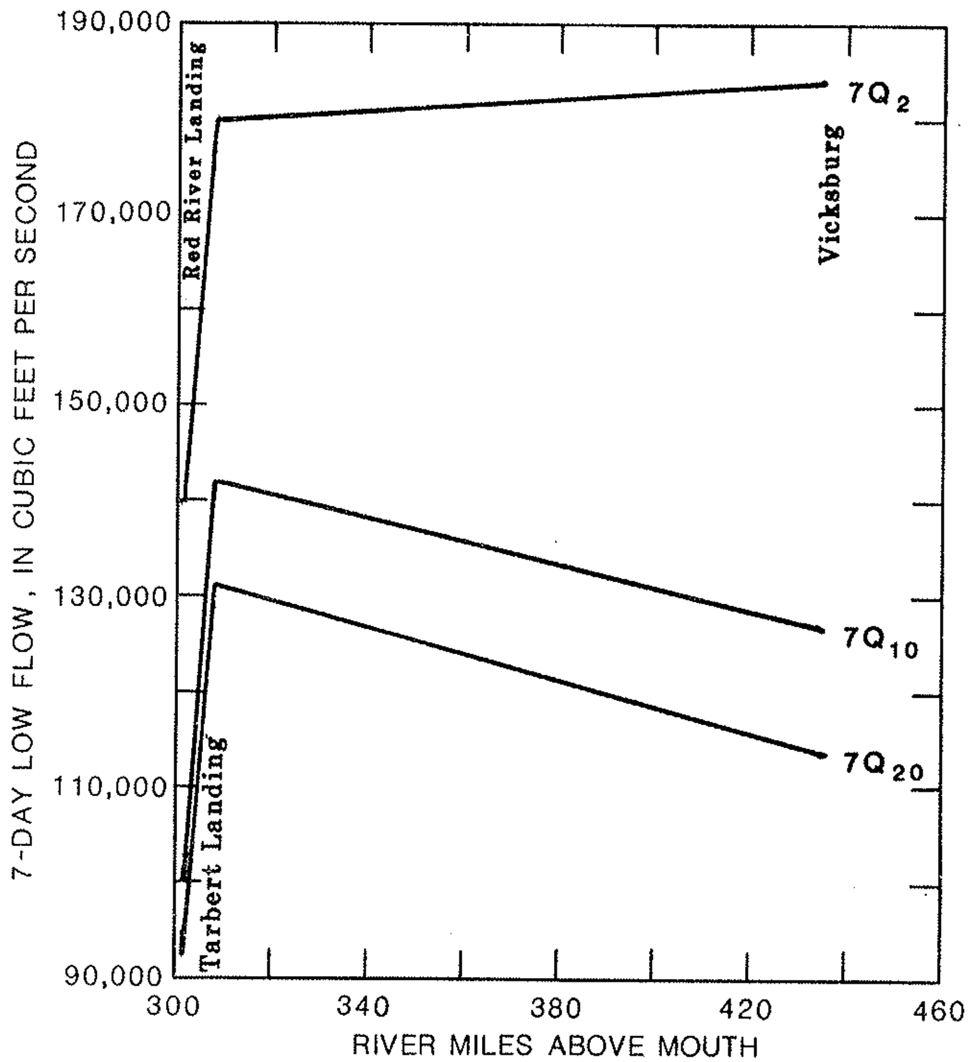


Figure 10.--The $7Q_2$, $7Q_{10}$, and $7Q_{20}$ flows versus the river miles above mouth of the Mississippi River.

Although these graphs cannot be used to estimate low flows on other streams that are ungaged, estimates can be made for other locations along the same stream by assuming that a linear relationship exists between the gaged and ungaged sites. The drainage area upstream from the ungaged site must be known. The discharge is obtained for the ungaged site by entering the graph with the drainage area and reading the $7Q_2$, $7Q_{10}$, and $7Q_{20}$ directly from the graph.

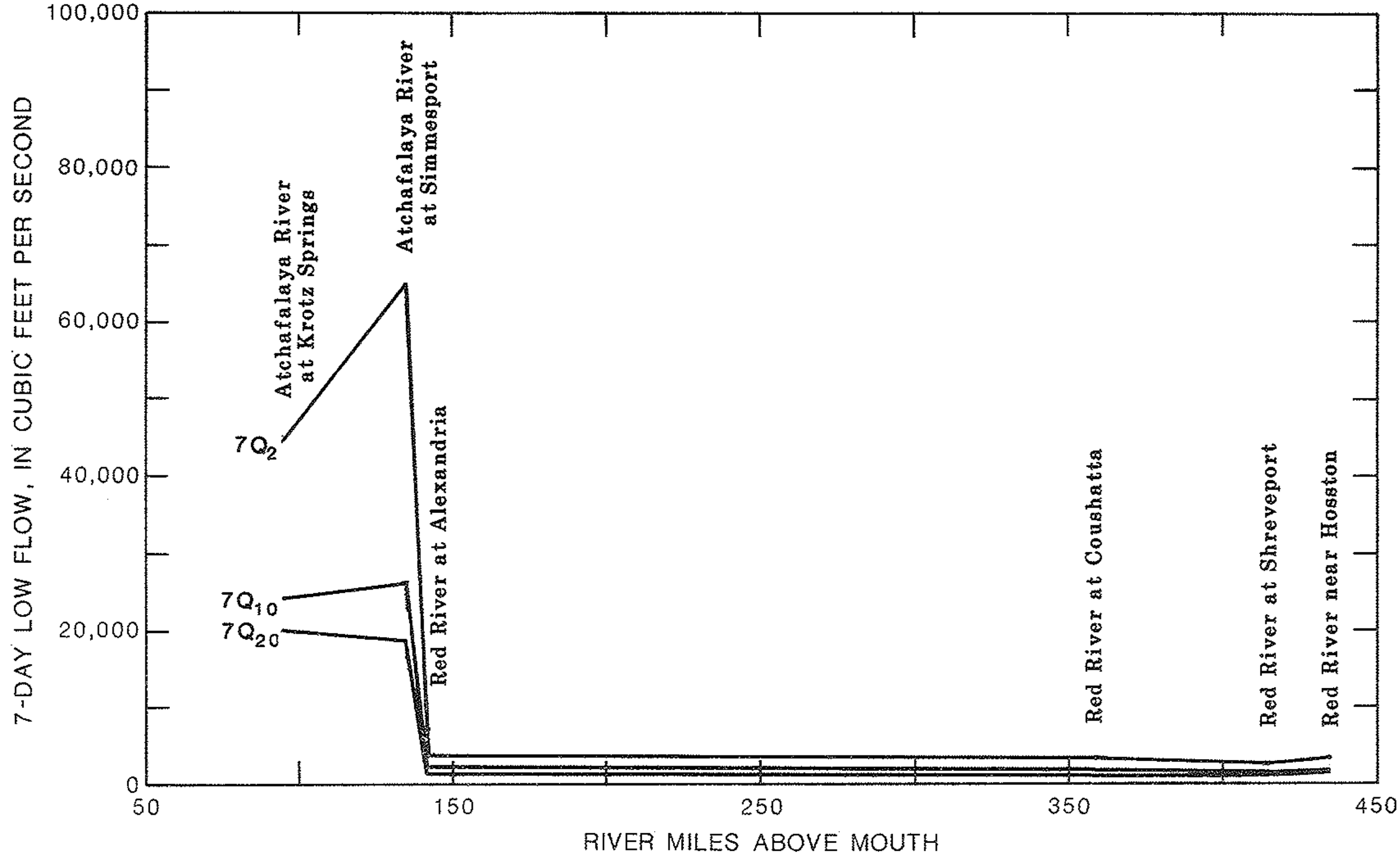


Figure 11.--The $7Q_2$, $7Q_{10}$, and $7Q_{20}$ flows versus the river miles above mouth of the Atchafalaya River-Red River.

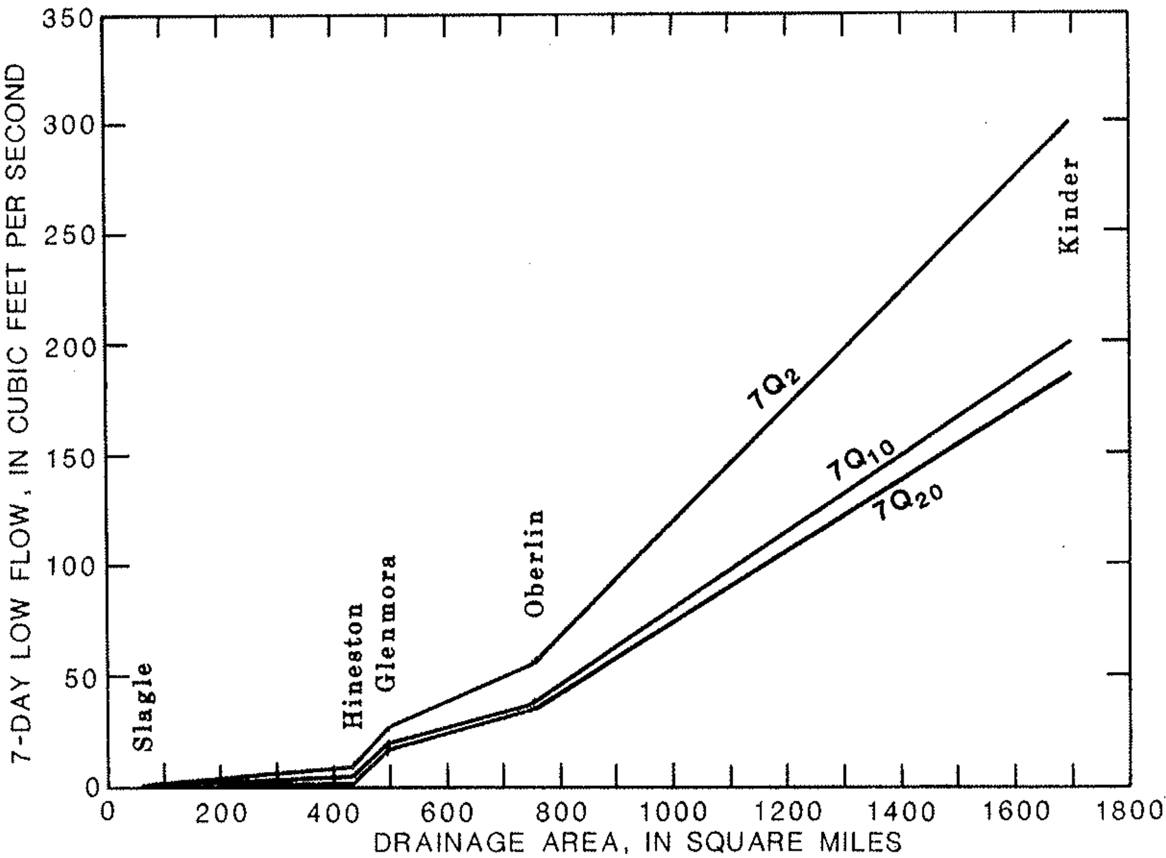


Figure 12.--The $7Q_2$, $7Q_{10}$, and $7Q_{20}$ flows versus the drainage area for the Calcasieu River.

LIMITATIONS OF USE OF EQUATIONS AND GRAPHS

Equations in this report were designed to estimate the $7Q_2$, $7Q_{10}$, and $7Q_{20}$ low flows for natural streams in Louisiana in low-flow regions 2 and 3. Use of the equations should be limited to the ranges in low-flow discharges, drainage area, mean annual rainfall, and channel slopes that were used to derive them. These equations should not be used on streams where flow has been significantly affected by regulation or other activity of man.

Graphs developed for large streams where the drainage area of the most downstream data site is larger than 525 mi^2 are applicable only for those streams for which they were developed. Although it is assumed that a linear relationship exists between adjacent sites on the same stream, when an interpolation is made at a location between the two sites caution should be used because large-scale tributary inflow could influence the accuracy of the results.

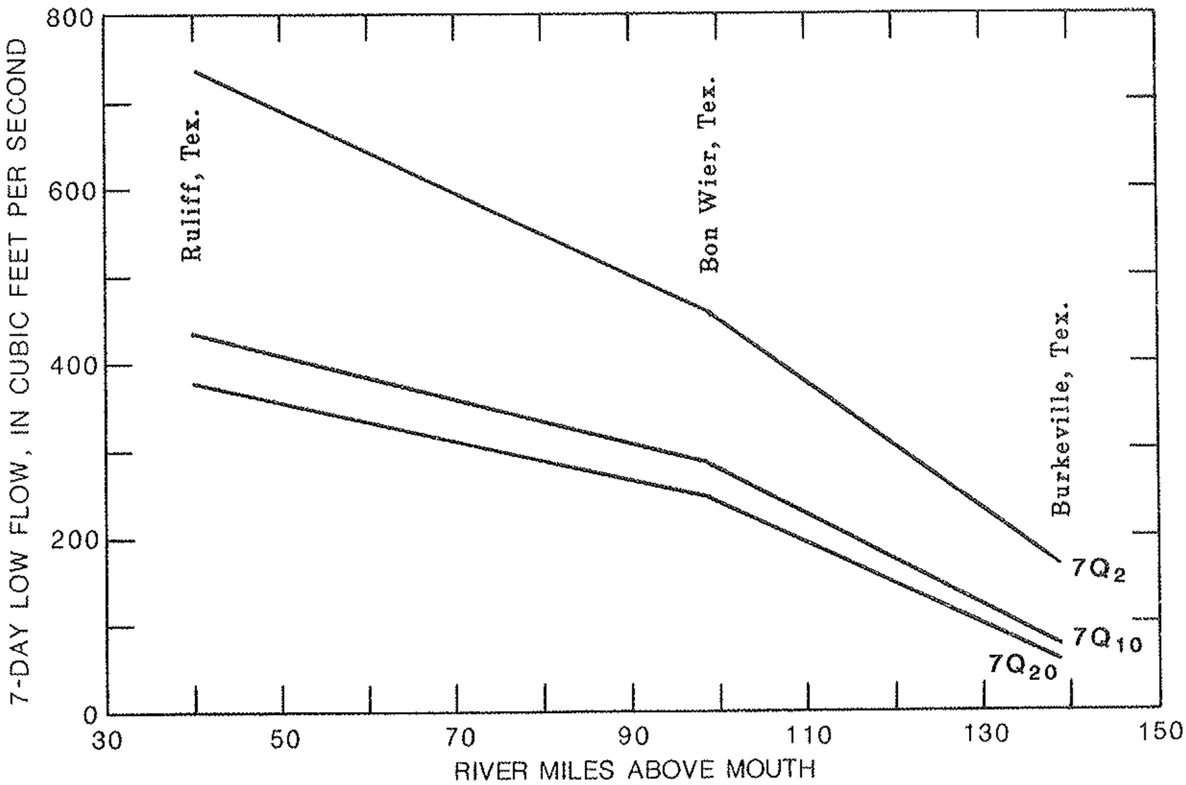


Figure 13.--The $7Q_2$, $7Q_{10}$, and $7Q_{20}$ flows versus the river miles above mouth of the Sabine River.

CONCLUSIONS

Regression equations derived from low-flow data, drainage area, mean annual rainfall, and channel slope can be used to estimate $7Q_2$, $7Q_{10}$, and $7Q_{20}$ low flows for natural, ungaged streams in Louisiana. Standard errors of estimate, comparing the estimated discharges to the actual discharges, are between ± 44 and ± 61 percent in low-flow regions 2 and 3, which is within the range of error shown by similar studies in other areas. Region 1 includes the area of the State where most streams have zero flow much of the year and no equations for estimating low flows were given. Low-flow characteristics for region 4 (the Mississippi River Delta and the lower-coastal area) have been defined only at gaged sites.

Graphs developed for large streams where the drainage area of the most downstream data-collection site is larger than 525 mi^2 can be used to estimate low flow along these streams between sites where point data are available.

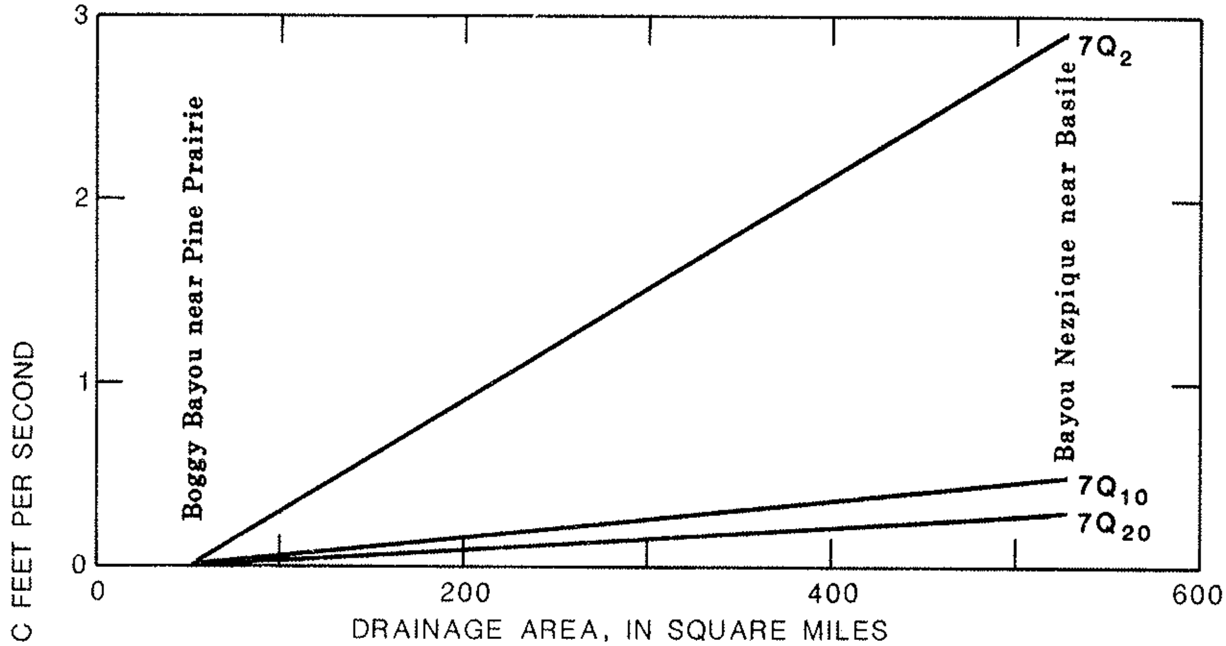


Figure 14.--The $7Q_2$, $7Q_{10}$, and $7Q_{20}$ flows versus the drainage area for Bayou Nezpique-Boggy Bayou.

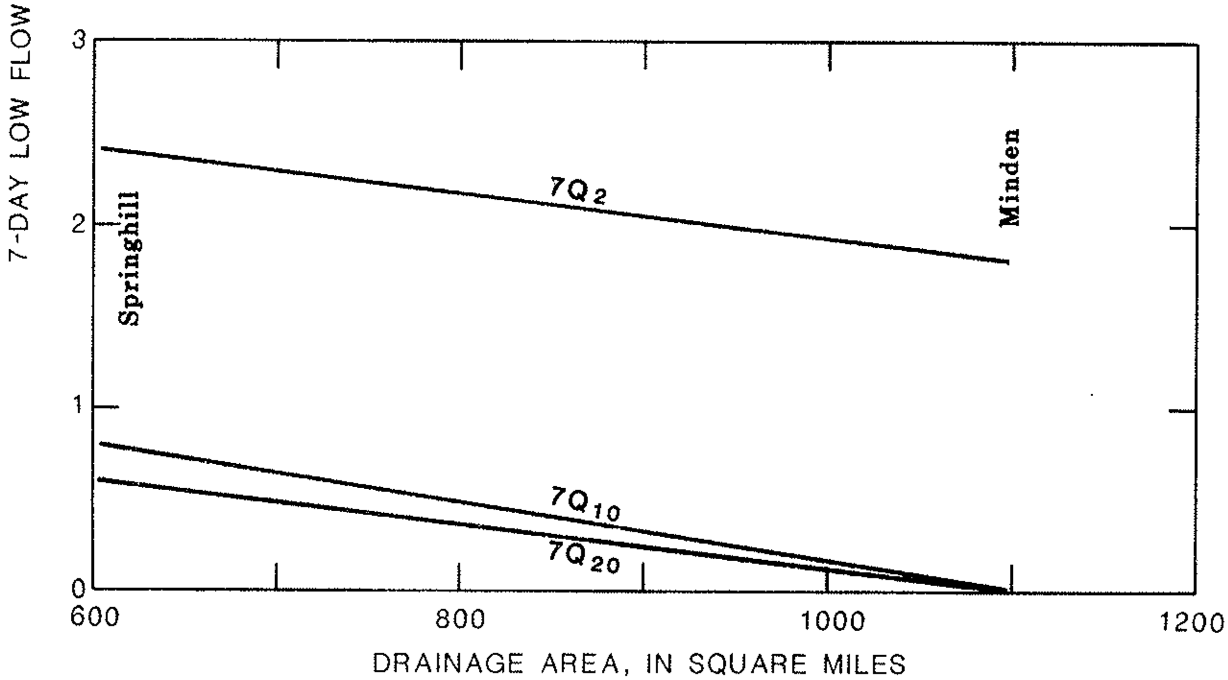


Figure 15.--The $7Q_2$, $7Q_{10}$, and $7Q_{20}$ flows versus the drainage area for Loggy Bayou-Bayou Dorcheat.

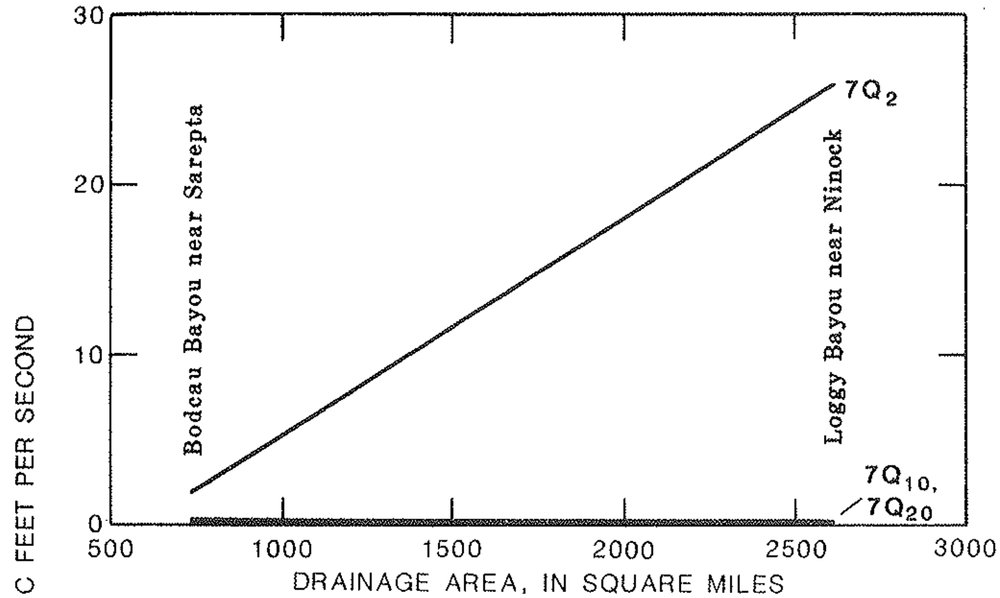


Figure 16.--The $7Q_2$, $7Q_{10}$, and $7Q_{20}$ flows versus the drainage area for Bodcau Bayou-Loggy Bayou.

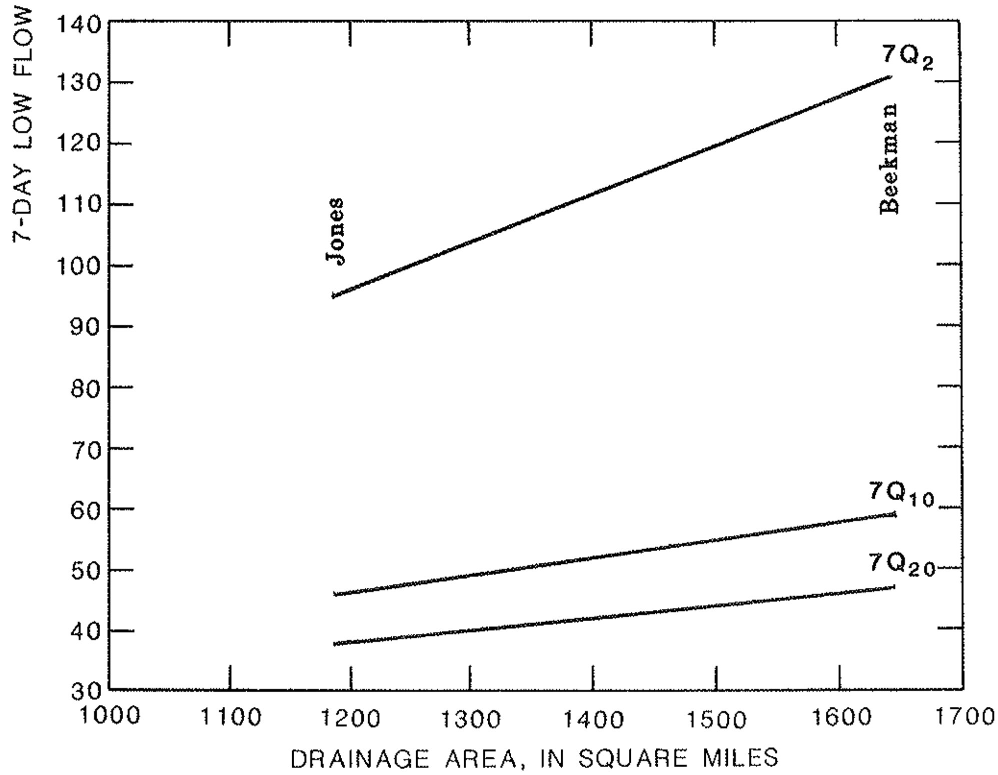
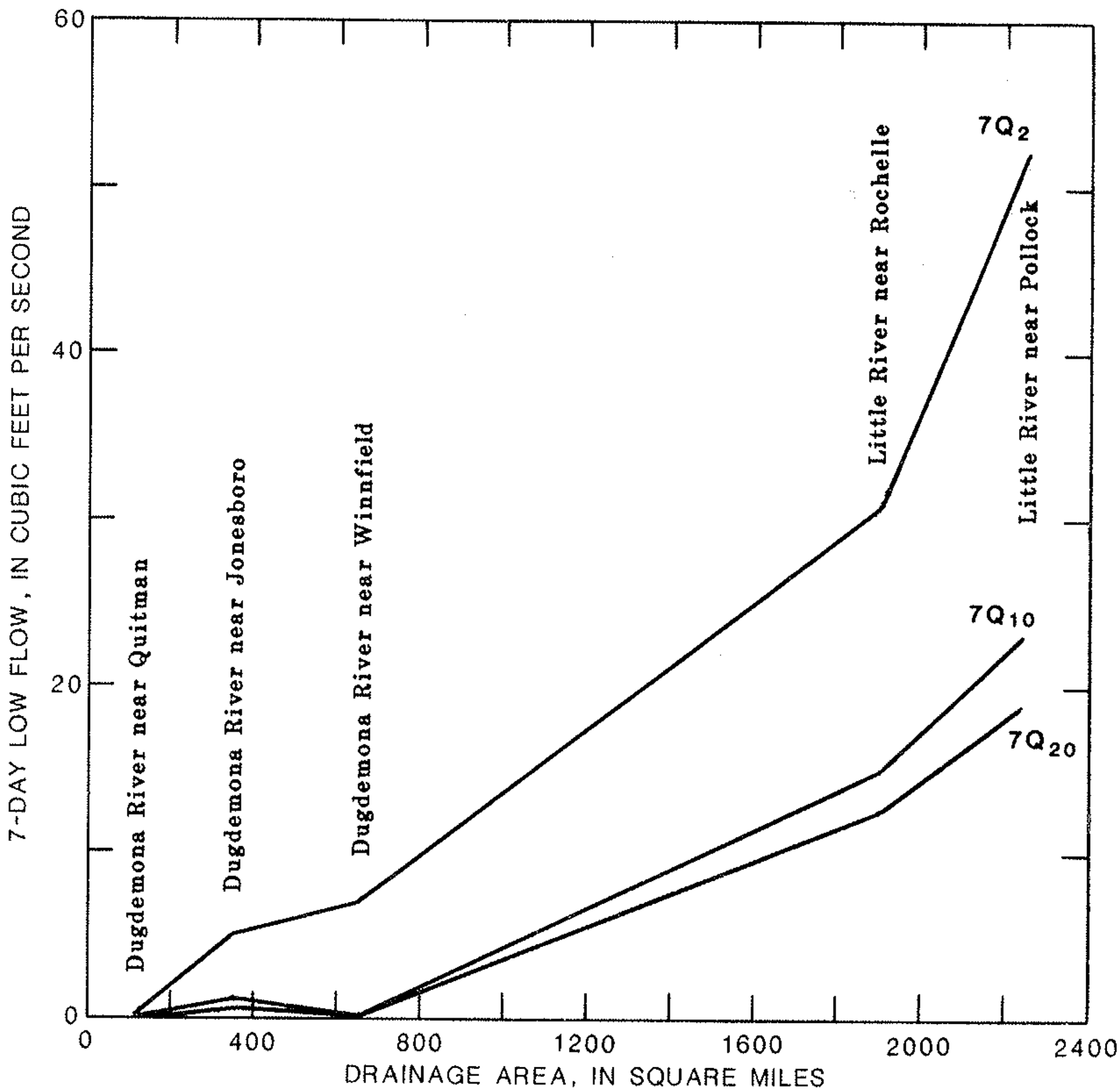
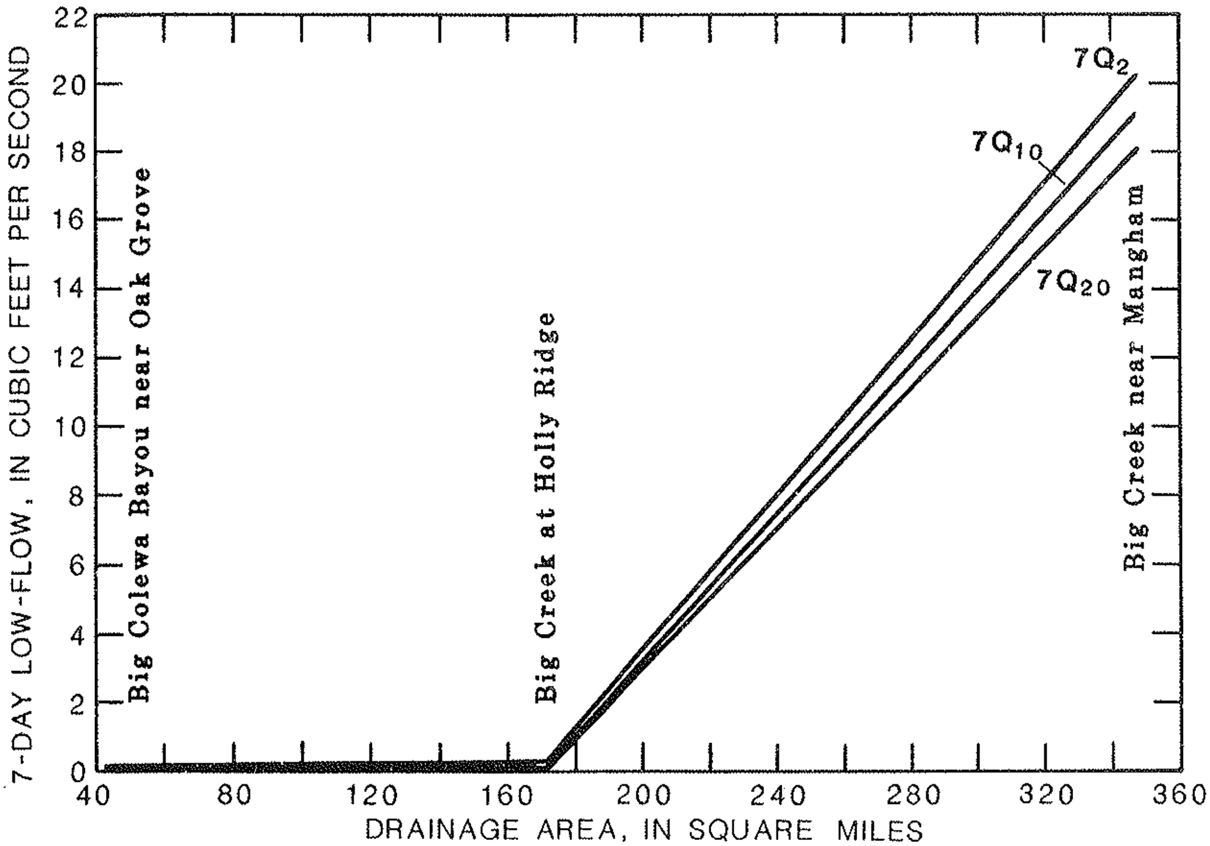


Figure 17.--The $7Q_2$, $7Q_{10}$, and $7Q_{20}$ flows versus the drainage area for Bayou Bartholomew.



Figures 18.--The $7Q_2$, $7Q_{10}$, and $7Q_{20}$ flows versus the drainage area for Dugdemona River-Little River.



Figures 19.--The $7Q_2$, $7Q_{10}$, and $7Q_{20}$ flows versus the drainage area for Big Creek-Big Colewa Bayou.

EXAMPLES OF THE USE OF THE EQUATIONS AND GRAPHS

The following are step-by-step procedures for using this report to estimate the $7Q_2$, $7Q_{10}$, and $7Q_{20}$ discharges in regions 1, 2, or 3.

Region 1

Condition 1: The $7Q_2$, $7Q_{10}$, and $7Q_{20}$ are needed at a site on a stream where no streamflow data have been collected.

Procedure: 1. As no streamflow data are available on this stream, assume the $7Q_2$, $7Q_{10}$, and $7Q_{20}$ are all equal to 0 ft^3/s.

Condition 2: The $7Q_2$, $7Q_{10}$, and $7Q_{20}$ are needed at a site on a stream where streamflow data have been collected.

Procedure: 1. Refer to table 1 or 2 for the $7Q_2$, $7Q_{10}$, and $7Q_{20}$ flows.

Condition 3: The $7Q_2$, $7Q_{10}$, and $7Q_{20}$ are needed at an ungaged location on a stream that has one data-collection site where the $7Q_2$, $7Q_{10}$, and $7Q_{20}$ discharges are all larger than 0 ft^3/s. The ungaged location is upstream from the gaged site.

Procedure:

1. The drainage area and discharge at the drainage divide are equal to zero.
2. Assume that the $7Q_2$, $7Q_{10}$, and $7Q_{20}$ discharges vary linearly between the gaged site and the drainage divide.
3. Using a simple linear interpolation of the drainage areas, compute the $7Q_2$, $7Q_{10}$, and $7Q_{20}$ discharges at the ungaged site.

Detailed example for condition 3:

1. Assume the following for the gaged site:

$$A = 50 \text{ mi}^2,$$
$$7Q_2 = 2.0 \text{ ft}^3/\text{s},$$
$$7Q_{10} = 1.5 \text{ ft}^3/\text{s}, \text{ and}$$
$$7Q_{20} = 1.0 \text{ ft}^3/\text{s}.$$

2. Assume the drainage area is 25 mi^2 at the ungaged site.
3. Compute the drainage area ratio: $\frac{25}{50} = 0.5$
4. Compute the $7Q_2$, $7Q_{10}$, and $7Q_{20}$ at the ungaged site as follows:

$$7Q_2 = 0.5 \text{ X } 2.0 = 1.0 \text{ ft}^3/\text{s}$$
$$7Q_{10} = 0.5 \text{ X } 1.5 = 0.75 \text{ ft}^3/\text{s}$$
$$7Q_{20} = 0.5 \text{ X } 1.0 = 0.5 \text{ ft}^3/\text{s}.$$

Condition 4: The $7Q_2$, $7Q_{10}$, and $7Q_{20}$ are needed at an ungaged site on a stream that has two data-collection points where the $7Q_2$, $7Q_{10}$, and $7Q_{20}$ are larger than 0 ft^3/s. The ungaged site is between the two points where data are available and a simple interpolation scheme is used.

Procedure:

1. Compute the difference in drainage area between the upstream and downstream gaged sites.
2. Compute the difference in drainage area between the ungaged site and the downstream gaged site.
3. Establish a ratio between these differences, using the difference between the ungaged site and the downstream gaged site as the numerator.
4. Multiply this ratio by the absolute value of the differences in the $7Q_2$, $7Q_{10}$, and $7Q_{20}$ discharges between the upstream and downstream gaged site.
5. If the $7Q_2$, $7Q_{10}$, and $7Q_{20}$ at the downstream gaged site are more than the $7Q_2$, $7Q_{10}$, and $7Q_{20}$ at the upstream gaged site, then subtract the values computed in step 4 from the discharges at the downstream site.
6. If the $7Q_2$, $7Q_{10}$, and $7Q_{20}$ at the downstream gaged site are less than the $7Q_2$, $7Q_{10}$, and $7Q_{20}$ at the upstream gaged site, then add the values computed in step 4 to the discharges at the downstream site.

Detailed example for condition 4. For this example assume the following:

Upstream gaged site	Downstream gaged site	Ungaged site
$A = 75\ mi^2$	$A = 200\ mi^2$	$A = 150\ mi^2$
$7Q_2 = 3.0\ ft^3/s$	$7Q_2 = 5.0\ ft^3/s$	
$7Q_{10} = 2.5\ ft^3/s$	$7Q_{10} = 3.5\ ft^3/s$	
$7Q_{20} = 1.9\ ft^3/s$	$7Q_{20} = 2.8\ ft^3/s$	

1. $200\ mi^2 - 75\ mi^2 = 125\ mi^2$
2. $200\ mi^2 - 150\ mi^2 = 50\ mi^2$
3. $50/125 = 0.4$
4. $7Q_2 = 0.4 \times (5.0-3.0) = 0.8\ ft^3/s$,
   $7Q_{10} = 0.4 \times (3.5-2.5) = 0.4\ ft^3/s$, and
   $7Q_{20} = 0.4 \times (2.8-1.9) = 0.4\ ft^3/s$.
5. $7Q_2 = 5.0 - 0.8 = 4.2\ ft^3/s$ at the ungaged site,
   $7Q_{10} = 3.5 - 0.4 = 3.1\ ft^3/s$ at the ungaged site, and
   $7Q_{20} = 2.8 - 0.4 = 2.4\ ft^3/s$ at the ungaged site.

Region 2

Condition 1: The $7Q_2$, $7Q_{10}$, and $7Q_{20}$ are needed at a site on a stream where no data have been collected and the drainage area is less than 525 mi^2.

Procedure:

1. Determine the drainage area, channel slope, and mean annual rainfall at the site.

2. Substitute these values into equations 1, 2, and 3 and perform the indicated mathematical operations to estimate the $7Q_2$, $7Q_{10}$, and $7Q_{20}$, respectively.

Detailed example: Assume A = 100 mi^2, P = 55 in., and S = 5 ft/mi.

1. $7Q_2 = 1.40 \times 10^{-5} A^{1.09} (P-35)^{2.58} S^{0.55}$
   $7Q_2 = 1.40 \times 10^{-5} (100)^{1.09} (55-35)^{2.58} (5)^{0.55}$
   $7Q_2 = 10.7 \text{ ft}^3/\text{s}$

2. $7Q_{10} = 1.22 \times 10^{-6} A^{1.10} (P-35)^{3.15} S^{0.68}$
   $7Q_{10} = 1.22 \times 10^{-6} (100)^{1.10} (55-35)^{3.15} (5)^{0.68}$
   $7Q_{10} = 7.2 \text{ ft}^3/\text{s}$

3. $7Q_{20} = 5.29 \times 10^{-7} A^{1.11} (P-35)^{3.35} S^{0.73}$
   $7Q_{20} = 5.29 \times 10^{-7} (100)^{1.11} (55-35)^{3.35} (5)^{0.73}$
   $7Q_{20} = 6.5 \text{ ft}^3/\text{s}$

Condition 2: The $7Q_2$, $7Q_{10}$, and $7Q_{20}$ are needed on a stream that has two data sites (stations 1 downstream and 2 upstream) where the $7Q_2$, $7Q_{10}$, and $7Q_{20}$ are known (table 4). Drainage area of the site is less than 525 mi^2 and the site is upstream of station 2.

Procedure:

1. Determine the drainage area, rainfall, and channel slope for all 3 sites.

2. Using equations 1, 2, and 3, compute the $7Q_2$, $7Q_{10}$, and $7Q_{20}$ flows for all 3 sites.

3. Refer to table 4 and find the $7Q_2$, $7Q_{10}$, and $7Q_{20}$ for sites 1 and 2.

4. Divide the equation discharge values for sites 1 and 2 by the $7Q_2$, $7Q_{10}$, and $7Q_{20}$ values from step 3, above, to obtain ratios (K values).

5. Plot the ratios versus the drainage area for sites 1 and 2 on rectangular coordinate graph paper.

6. Connect the plotted K values with a straight line and extend these lines to the drainage area of the ungaged site to obtain the K values to be used in adjusting the equation discharges at the ungaged site.

Detailed example: Station 1: A = 284, P = 58, S = 5.2
Station 2: A = 148, P = 58, S = 8.1
Ungaged site: A = 100, P = 58, S = 10.5

Station 1

Computed: $7Q_2 = 1.40 \times 10^{-5} (284)^{1.09} (58-35)^{2.58} (5.2)^{0.55}$
$7Q_2 = 53$ ft^3/s
Actual: $7Q_2 = 58$ ft^3/s (from table 4)
Computed: $7Q_{10} = 1.22 \times 10^{-6} (284)^{1.10} (58-35)^{3.15} (5.2)^{0.68}$
$7Q_{10} = 36$ ft^3/s
Actual: $7Q_{10} = 39$ ft^3/s (from table 4)
Computed: $7Q_{20} = 5.29 \times 10^{-7} (284)^{1.11} (58-35)^{3.35} (5.2)^{0.73}$
$7Q_{20} = 34$ ft^3/s
Actual: $7Q_{20} = 37$ ft^3/s (from table 4)

Obtain ratios by dividing the equation discharges by the table 4 discharges:

$7Q_2$ ratio - 53/58 = 0.92
$7Q_{10}$ ratio - 36/39 = 0.92
$7Q_{20}$ ratio - 34/37 = 0.92

Station 2

Computed: $7Q_2 = 1.40 \times 10^{-5} (148)^{1.09} (58-35)^{2.58} (8.1)^{0.55}$
$7Q_2 = 33$ ft^3/s
Actual: $7Q_2 = 47$ ft^3/s (from table 4)
Computed: $7Q_{10} = 1.22 \times 10^{-6} (148)^{1.10} (58-35)^{3.15} (8.1)^{0.68}$
$7Q_{10} = 24$ ft^3/s
Actual: $7Q_{10} = 34$ ft^3/s (from table 4)
Computed: $7Q_{20} = 5.29 \times 10^{-7} (148)^{1.11} (58-35)^{3.35} (8.1)^{0.73}$
$7Q_{20} = 22$ ft^3/s
Actual: $7Q_{20} = 32$ ft^3/s (from table 4)

Obtain ratios by dividing the equation discharges by the table 4 discharges:

$7Q_2$ ratio - 33/47 = 0.70
$7Q_{10}$ ratio - 24/34 = 0.70
$7Q_{20}$ ratio - 22/31 = 0.70

Plot the ratios for stations 1 and 2 to obtain K values for the ungaged site (steps 5 and 6):

$7Q_2$ K value = 0.62
$7Q_{10}$ K value = 0.62
$7Q_{20}$ K value = 0.62

Compute the discharges for the ungaged site by using equations 1, 2, and 3 and the ratios (K values):

$$7Q_2 = 1.40 \times 10^{-5} (100)^{1.09} (58-35)^{2.58} (10.5)^{0.55} K_2$$
$$7Q_2 = 25 \times 0.62 = 15.5 \text{ ft}^3/\text{s}$$

$$7Q_{10} = 1.22 \times 10^{-6} (100)^{1.10} (58-35)^{3.15} (10.5)^{0.68} K_{10}$$
$$7Q_{10} = 18.6 \times 0.62 = 11.5 \text{ ft}^3/\text{s}$$

$$7Q_{20} = 5.29 \times 10^{-7} (100)^{1.11} (58-35)^{3.35} (10.5)^{0.73} K_{20}$$
$$7Q_{20} = 17.8 \times 0.62 = 11.0 \text{ ft}^3/\text{s}$$

Region 3

Use same procedure as for region 2, except use equations 4, 5, and 6.

Large Streams

Condition 1: The $7Q_2$, $7Q_{10}$, and $7Q_{20}$ are needed for the Amite River at the mouth of Whitten Creek.

Procedure:

1. Determine the drainage area for the Amite River at the confluence of Whitten Creek.

2. Pick the $7Q_2$, $7Q_{10}$, and $7Q_{20}$ values directly from the curves.

   $7Q_2 = 280 \text{ ft}^3/\text{s}$
   $7Q_{10} = 226 \text{ ft}^3/\text{s}$
   $7Q_{20} = 216 \text{ ft}^3/\text{s}$

SELECTED REFERENCES

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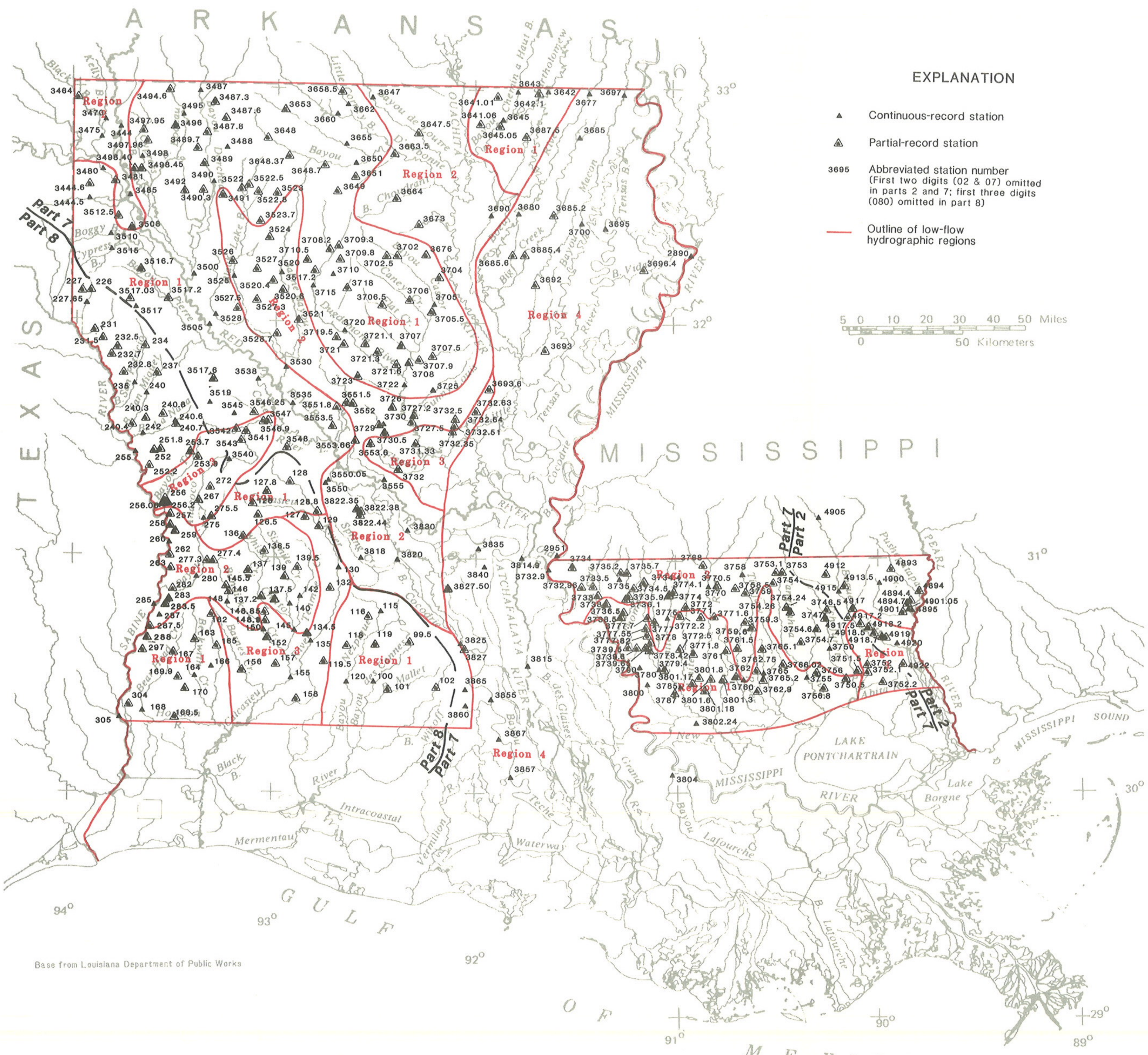

PLATE 1. LOCATION OF GAGING STATIONS FOR WHICH LOW-FLOW DATA ARE AVAILABLE AND THE FOUR LOW-FLOW HYDROGRAPHIC REGIONS IN LOUISIANA.

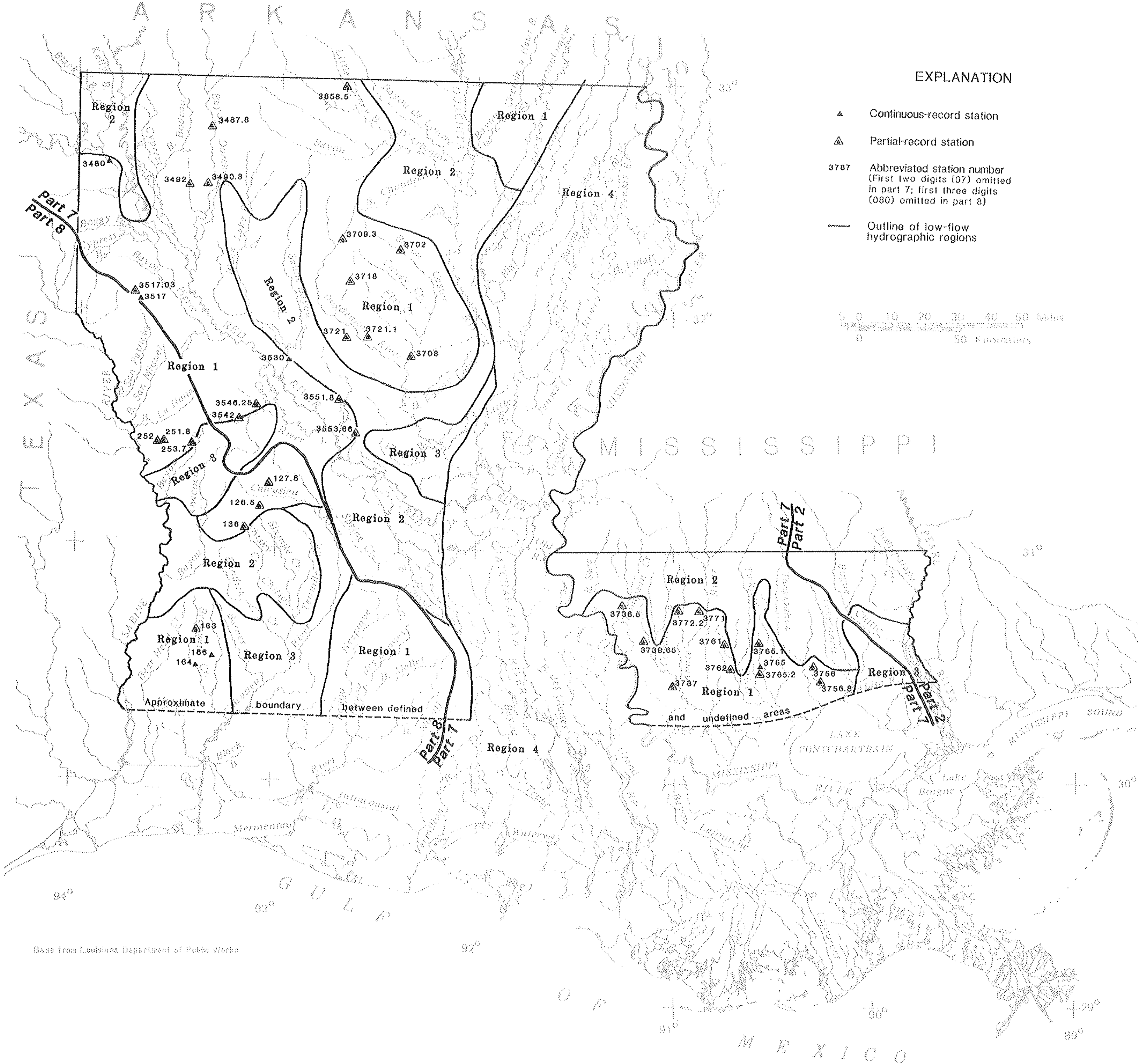

PLATE 2. GAGING STATIONS IN REGION 1 OF LOUISIANA WHERE THE $7Q_{10}$ LOW FLOW IS GREATER THAN ZERO CUBIC FEET PER SECOND.