STATE OF LOUISIANA

DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT

OFFICE OF PUBLIC WORKS

Water Resources
TECHNICAL
REPORT
No. 14

HYDROLOGY AND WATER QUALITY OF THE ATCHAFALAYA RIVER BASIN

Prepared by

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

In cooperation with

LOUISIANA DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT

OFFICE OF PUBLIC WORKS

1977

UNITED STATES FISH AND WILDLIFE SERVICE

and

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By

Frank C. Wells and Charles R. Demas
U.S. Geological Survey

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The analyses and compilations were made with English units of measurements. The equivalent metric units are given in the text and illustrations where appropriate. English units only are shown in tables where, because of space limitations, the dual system of English and metric units would not be practicable. To convert English units of metric units, the following conversion factors should be used:

Multiply English units	By	To obtain metric units
cubic feet per second (ft^3/s)	0.02832	cubic meters per second (m^3/s)
feet (ft)	.3048	meters (m)
inches (in)	2.540	centimeters (cm)
	25.40	millimeters (mm)
miles (mi)	1.609	kilometers (km)
pounds (lb)	.4536	kilograms (kg)
square feet (ft^2)	.09290	square meters (m^2)
square miles (mi^2)	2.590	square kilometers (km^2)
tons per day	.9072	metric tons per day

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

HYDROLOGY AND WATER QUALITY OF THE ATCHAFALAYA RIVER BASIN

By Frank C. Wells and Charles R. Demas

ABSTRACT

The Atchafalaya River is the largest distributary of the Mississippi River and is an integral part of the Mississippi River and Tributaries project. Overbank siltation and lake accretion have reduced the flood-carrying capacity of the Atchafalaya Basin Floodway from 1.5 million cubic feet per second (42,400 cubic meters per second) to approximately 1 million cubic feet per second (28,300 cubic meters per second). To increase the flood-carrying capacity of the floodway, the U.S. Army Corps of Engineers has proposed to widen the Atchafalaya River main channel to between 80,000 and 100,000 square feet (7,430 and 9,290 square meters).

The Atchafalaya River receives its water from the Red River, the Black River, and the Mississippi River (via the Old River Control Structure), with the Mississippi River supplying over 50 percent of the flow at Simmesport 95 percent of the time. Since completion of the Old River Control Structure, flows have increased approximately 30 percent in the Atchafalaya River.

Since 1964 the average load of suspended sediment transported past Simmesport has been 260,000 tons per day. The maximum and minimum suspended-sediment loads were 2,120,000 and 3,000 tons per day, respectively. Approximately 25 percent of the suspended-sediment load was sand and 75 percent was silt and clay.

Water quality of the Atchafalaya River is controlled by the discharges and chemical quality of the Red, Black, and Mississippi Rivers. The major anion and cation present in the Atchafalaya Basin Floodway are bicarbonate and calcium, respectively. Chemical quality in the Atchafalaya Basin Floodway is closely related to the chemical quality of the Atchafalaya River at Simmesport, La. Differences in concentrations of the major ions between the Atchafalaya River at Simmesport, La., and the swamp areas of the Atchafalaya Basin Floodway are most pronounced during periods of low flow. Dissolved-oxygen concentrations generally exceed 6.0 milligrams per liter in the main channel and major distributaries;

however, dissolved-oxygen concentrations below 4.0 milligrams per liter are common in the Atchafalaya Basin Floodway during periods of low flow. Concentrations of nitrogen and phosphorous, heavy metals, and pesticides in the Atchafalaya Basin Floodway are relatively low. Nutrient and suspended-solids concentrations decrease as distance from the main channel and major distributaries increases.

Tracer studies were made during a relatively low-flow period, 137,000 cubic feet per second (3,880 cubic meters per second) in August 1975. The tracer was injected into the Atchafalaya River approximately 1 mile (1.61 kilometers) below the confluence of the Red River and Old River outflow channel. Complete lateral mixing was first observed at Melville, approximately 32 miles (51.5 kilometers) below the injection site. Traveltimes for water in the distributaries in the west side of the floodway were much longer than in the main channel.

The southeastern part of the Atchafalaya Basin Floodway received the major hydrologic impact of Hurricane Carmen in September 1974. Concentrations of dissolved oxygen below 0.2 milligram per liter were recorded in the area, and concentrations of ammonia nitrogen and organic nitrogen were higher than normal following the hurricane.

INTRODUCTION

The Atchafalaya River basin encompasses approximately 1,800 mi^2 (4,662 km^2) in south-central Louisiana (fig. 1). The Atchafalaya River originates at the junction of Old River and Red River, approximately 5 mi (8.05 km) north of Simmesport, La. From its origin, the Atchafalaya River flows southward in a well-defined channel to the vicinity of Interstate Highway 10 where the river channel divides. South of Interstate 10 the Atchafalaya River becomes a complex system of rivers, bayous, lakes, and manmade canals. Most of the flow of the Atchafalaya River system empties into Atchafalaya Bay, an inlet of the Gulf of Mexico, through the Lower Atchafalaya River and the Wax Lake Outlet.

The Atchafalaya River is the largest distributary of the Mississippi River. As such, the Atchafalaya River basin plays an integral part in the U.S. Army Corps of Engineers' Mississippi River and Tribuatries (MR&T) project. This project provides for flood protection of the alluvial valley of the Mississippi River between Head of Passes, La., and Cape Girardeau, Mo.

The MR&T project design flood is approximately 3 million ft^3/s (84,900 m^3/s). One-half of this design flood is to be carried through the Atchafalaya River basin, and the remainder through the Mississippi River. In order to safely pass floods of this magnitude, the U.S. Army Corps of Engineers has modified a part of the Atchafalaya River basin to accommodate flows in addition to those that will naturally enter the Atchafalaya River. Flood control was accomplished by construction of the West Atchafalaya Floodway and the Morganza Floodway adjacent to the main channel of the Atchafalaya River between Simmesport and Krotz Springs, La.

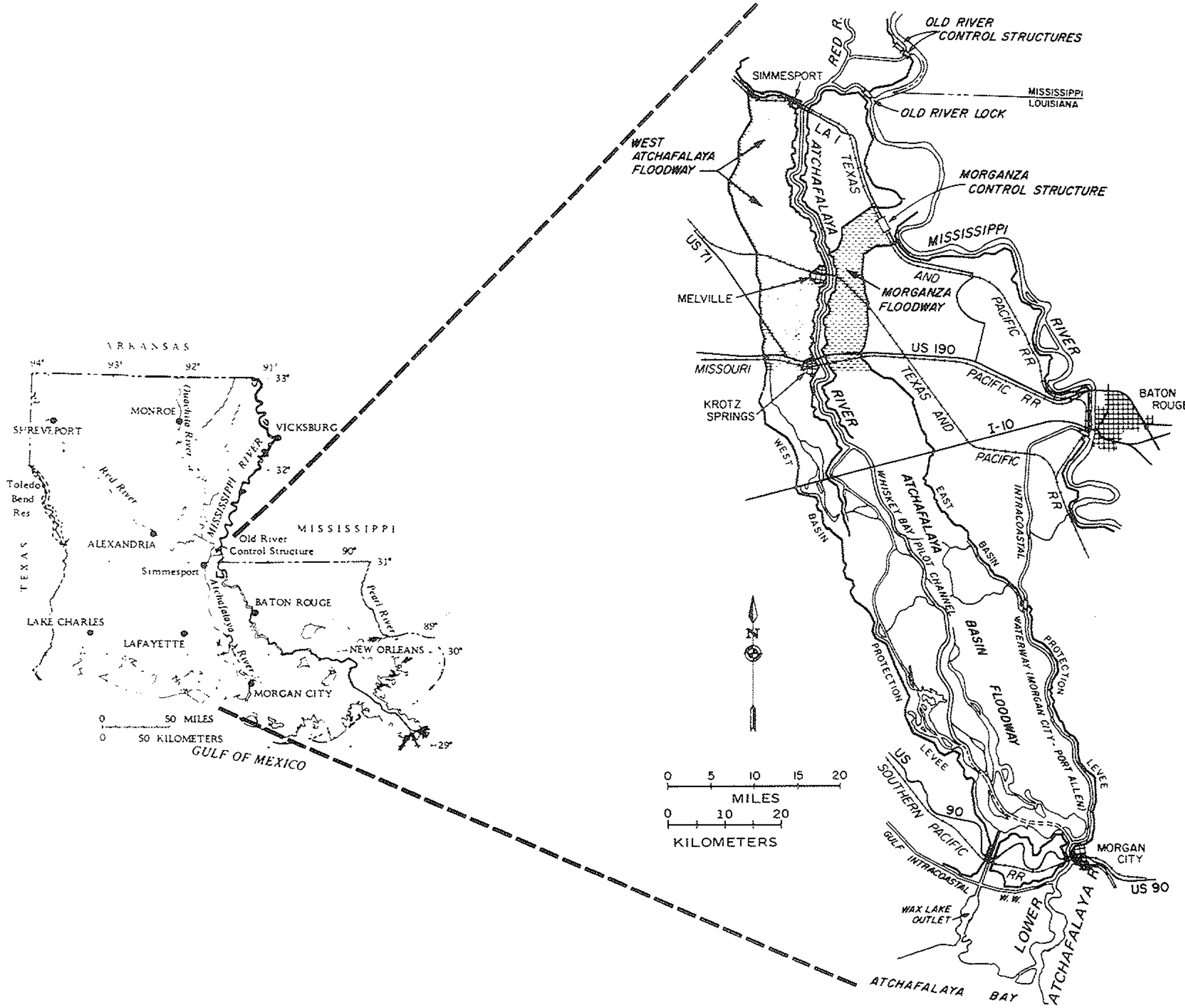


Figure 1.--Location of Atchafalaya River basin.

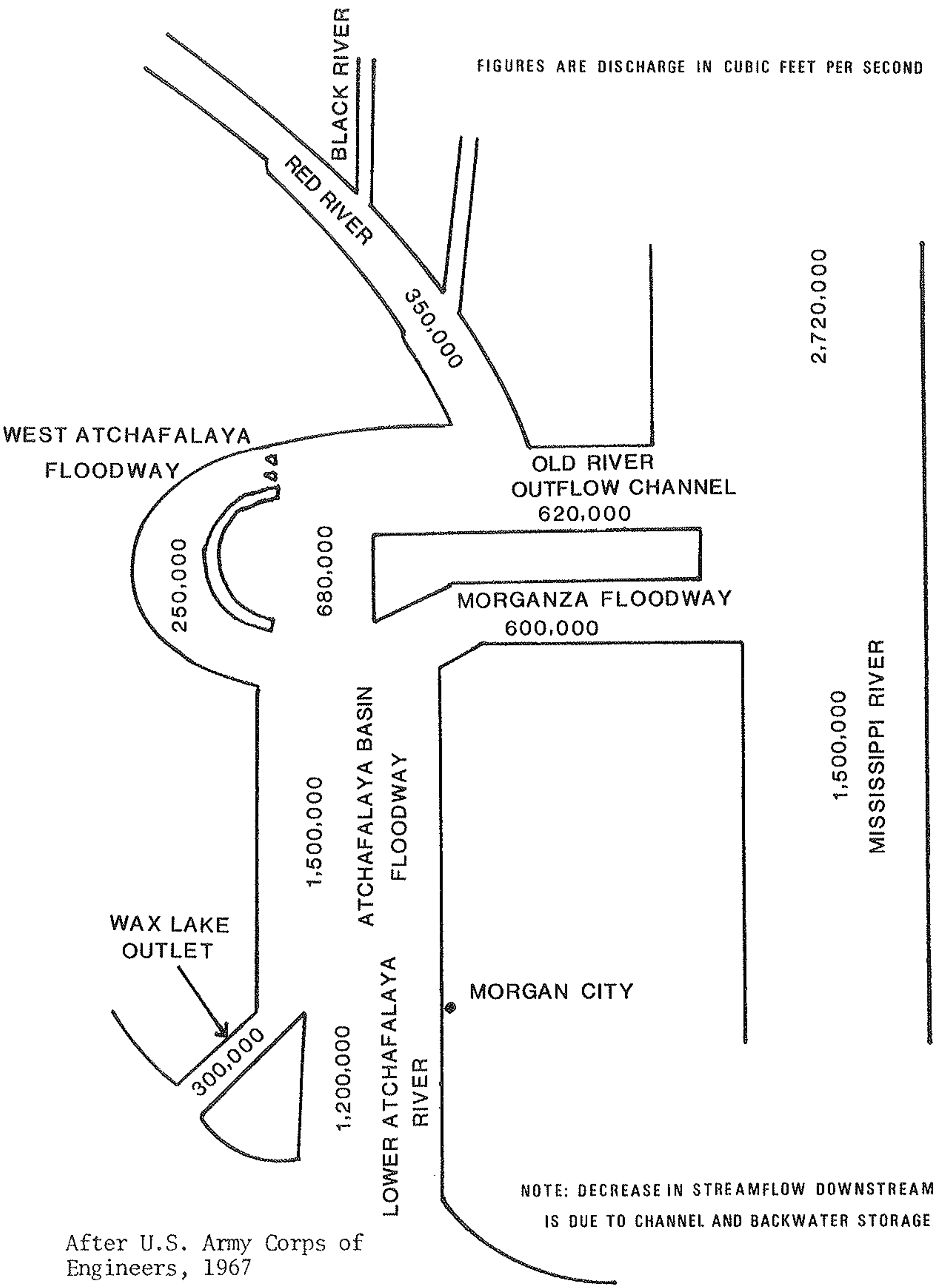
Construction of levees along the main channel of the Atchafalaya River between Simmesport (mile 5) and river mile 52 has also increased the flow capacity of the main channel of the Atchafalaya River in its upper reach.

Near Simmesport, La., the West Atchafalaya Floodway is designed to carry 250,000 ft^3/s (7,080 m^3/s) (fig. 2), and the Atchafalaya River is designed to carry 680,000 ft^3/s (19,200 m^3/s). Near Morganza, La., 35 mi (56.4 km) downstream from the Old River Control Structure, an additional 600,000 ft^3/s (17,000 m^3/s) can be diverted from the Mississippi River into the Morganza Floodway. The Atchafalaya Basin Floodway, the southern extension of these floodways, is approximately 15 mi (24.2 km) wide and extends from just below Krotz Springs, La., to Morgan City, La. Most of the water is discharged from this floodway through the Lower Atchafalaya River at Morgan City, La., and Wax Lake Outlet near Calumet, La. Wax Lake Outlet is a dredged channel with an existing capacity of approximately 300,000 ft^3/s (8,490 m^3/s).

The Atchafalaya Basin Floodway is a low, swampy area composed of many distributaries of the main channel of the Atchafalaya River. These distributaries form a deltaic pattern of small, shallow streams and man-made canals, which empty into Grand Lake and Six Mile Lake. These two interconnected lakes form a stilling basin for water draining into the south end of the floodway. Both Grand Lake and Six Mile Lake have been greatly reduced in size owing to the deposition of sediment. Sediment deposition resulting from overbank flooding has also raised land-surface elevations in the floodway. As a result of this overbank siltation and accretion, the flood-carrying capacity of the floodway has been decreased to approximately 1 million ft^3/s or 28,300 m^3/s (U.S. Army Corps of Engineers, 1974).

To maintain a floodway capable of conveying 1.5 million ft^3/s (42,450 m^3/s) the U.S. Army Corps of Engineers has proposed regulating flows into the distributaries of the Atchafalaya River main channel and increasing the cross-sectional area of the Atchafalaya River main channel to between 80,000 and 100,000 ft^2 (7,430 and 9,290 m^2) from Whiskey Bay Pilot Channel to Morgan City, La. These actions would restrict overbank siltation by confining all of the flow to the main channel except during periods of extremely high flow. A larger and more efficient channel in the Grand Lake-Six Mile Lake area will reduce sediment deposition in the lower part of the floodway.

In compliance with the National Environmental Policy Act of 1969 (Public Law 91-190) the U.S. Army Corps of Engineers is preparing an environmental impact statement (EIS) for the Atchafalaya Basin Floodway before work on the proposed improvements is begun. The EIS will serve to identify, summarize, and evaluate the beneficial and adverse environmental impacts of constructing and maintaining the authorized floodway project. In an effort to assist in the preparation and review of the EIS, the U.S. Fish and Wildlife Service began a limnoligical survey of the basin in July 1973. The biological and water-quality data collected during this study will be used to define the existing aquatic ecosystem within the Atchafalaya Basin Floodway and the possible environmental effects of the proposed improvements on the existing ecosystem.



After U.S. Army Corps of
Engineers, 1967

Figure 2.--Partial discharge-routing diagram for lower Mississippi River project flood.

At the request of the U.S. Fish and Wildlife Service, the U.S. Geological Survey provided technical assistance in the collection, analysis, and interpretation of water-quality data collected in the Atchafalaya River basin. Biological and water-quality data were collected simultaneously by the two agencies in an effort to correlate various water types with their aquatic communities. The work was also supported by the Louisiana Office of Public Works through the Federal-State cooperative water-resources program. Collection of some of the sediment data was supported by funds from the U.S. Army Corps of Engineers.

The purpose of this report is to present a broad evaluation of the hydrology and water quality in the Atchafalaya River basin. The report presents and interprets (a) data collected as a part of the limnological study conducted September 1973-October 1975, (b) water-quality data collected in April 1972 as part of the State's Atchafalaya Basin Study project, and (c) historical records of streamflow, sediment, and water quality at Simmesport, Krotz Springs, and Morgan City.

Special thanks are due Dr. C. F. Bryan of the U.S. Fish and Wildlife Service and his Louisiana State University graduate students. Dr. Bryan selected the monthly sampling stations, and he and his students aided in collection of data; this support was invaluable in accomplishing the overall hydrologic study. Thanks are also extended to the U.S. Army Corps of Engineers for providing streamflow and sediment data for the Atchafalaya River at Simmesport, La.

STREAMFLOW

The Atchafalaya River carries all of the flow of the Red River and approximately 30 percent of the flow of the Mississippi River. That proportion of flow which enters the Atchafalaya River from the Mississippi River is controlled by the Old River Control Structure. Prior to completion of the Old River Control Structure in 1963 the Atchafalaya River has been receiving increasing flows from the Mississippi River. Studies have shown that without the Old River Control Structure the Mississippi River would have changed its course to that of the Atchafalaya River between 1965 and 1975 (U.S. Army Corps of Engineers, 1974). The Old River Control Structure reduced that possibility and now restricts the flow entering the Atchafalaya River. Approximately 95 percent of the time, the flow of water diverted from the Mississippi River makes up more than 50 percent of the total flow of the Atchafalaya River at Simmesport. Fifty percent of the time, the water diverted from the Mississippi River makes up 75 percent or more of the total flow at Simmesport.

Discharge records collected at Krotz Springs and Simmesport, La., since 1935 indicate that the flow at Simmesport, La., has increased approximately 30 percent since the installation of the Old River Control Structure. For example, prior to completion of the control structure the 50-percent flow duration (median flow) was 140,000 ft^3/s (3,960 m^3/s). From 1964 to 1975 the 50-percent flow duration was 190,000 ft^3/s (5,380 m^3/s). (See fig. 3.) Increased flows have been noted during periods of

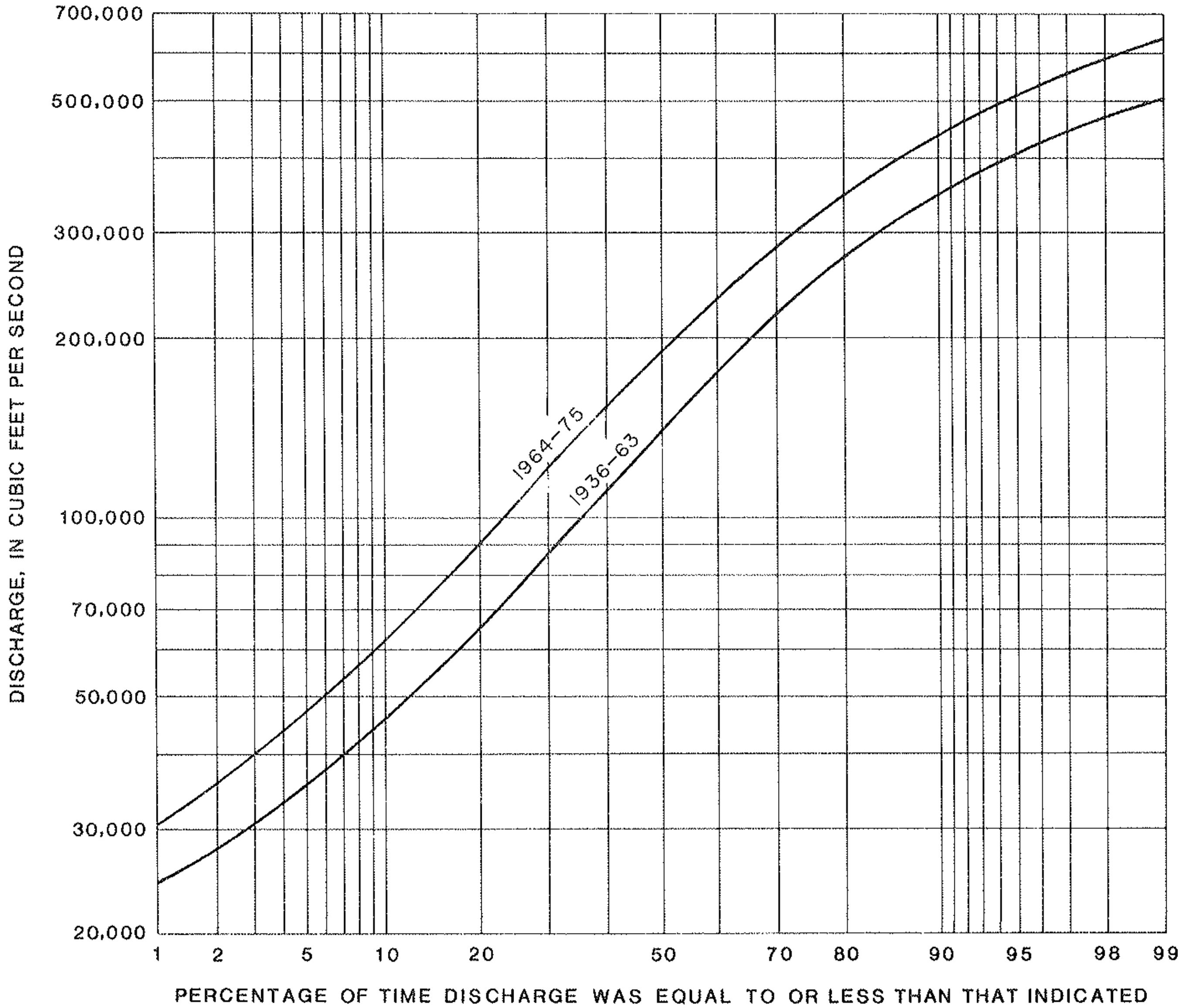


Figure 3.--Duration of discharge for Atchafalaya River at Krotz Springs, 1936-63, and at Simmesport, 1964-75.

both low flow and high flow (fig. 4). For example, from 1964 to 1975 the 7-day Q_{10} low flow (value that the average discharge for 7 consecutive days will be equal to or less than once in 10 years on the average) was 41,000 ft^3/s (1,160 m^3/s). Prior to the operation of the Old River Control Structure, the 7-day Q_{10} low flow was 25,000 ft^3/s (708 m^3/s). Similarly, the 1-day Q_2 high flow (that flow which will be equaled or exceeded on the average of once every 2 years) is currently 430,000 ft^3/s (12,200 m^3/s) as compared to 390,000 ft^3/s (11,000 m^3/s) prior to operation of the control structure. A flood that might be expected to occur on an average of once every 50 years has increased from 600,000 ft^3/s (17,000 m^3/s) to 920,000 ft^3/s (26,000 m^3/s). It should be noted that, although flows have increased since operation of the old River Control Structure began, the magnitude of these increases might have been much greater if the structure had not been built.

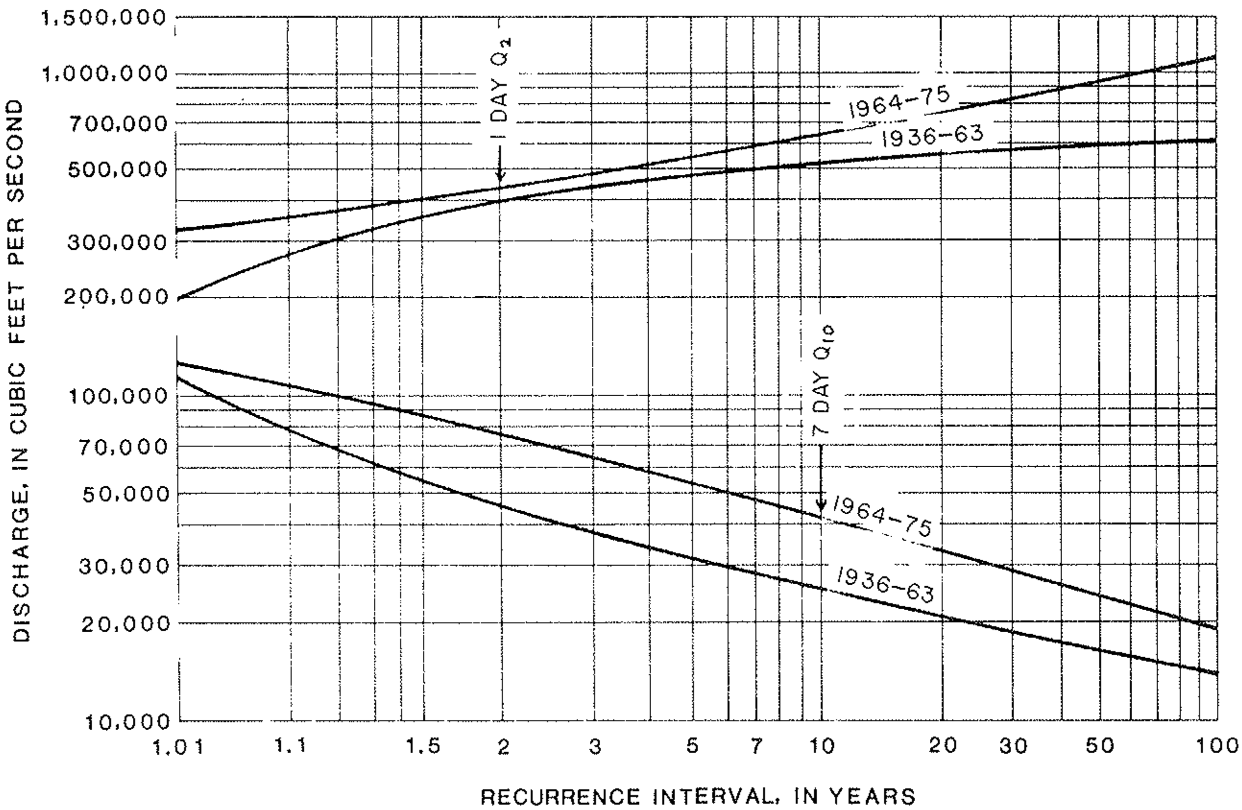


Figure 4.--Recurrence intervals of 7-day low flow and 1-day high flow for Atchafalaya River at Krotz Springs, 1936-63, and at Simmesport, 1964-75.

Because the period of record from 1964 to 1975 is more representative of the present flow conditions at Simmesport, the curves for this period in figures 3 and 4 should be used in analysis of streamflow at Simmesport. Monthly duration of discharge and monthly 1-day Q_2 high flow and 7-day Q_{10} low flow from 1964 to 1975 at Simmesport, La., are given in table 1.

Numerous discharge measurements by the U.S. Army Corps of Engineers in May 1970 and by the U.S. Geological Survey in August 1975 (when discharge at Simmesport was 410,000 and 137,000 ft^3/s, or 11,600 and 3,880 m^3/s, respectively) were used to define the distribution of flow in the major distributaries of the Atchafalaya River basin (fig. 5). Upstream from Interstate 10 the Atchafalaya River divides into two channels, the Whiskey Bay Pilot Channel and the Atchafalaya River. Below this division most of the water flows through the Whiskey Bay Pilot Channel. In May 1970, 70 percent of the flow and in August 1975, 90 percent of the flow passed through the Whiskey Bay Pilot Channel.

Four major distributaries carry water from the Atchafalaya River main channel. The largest of these is the Bayou L'Embarras distributary (West Freshwater Distribution Channel). At discharges of 410,000 and 137,000 ft^3/s (11,600 and 3,880 m^3/s) at Simmesport, La., this distributary carries approximately 10 percent and 5 percent of the flow, respectively. Little Tensas Bayou (East Freshwater Distribution Channel), Bayou Sorrel (East Access Channel), and Bayou Chene-Alligator Bayou-Little Bayou Gonsoulin (West Access Channel), individually, carry less than 3 percent of the flow recorded at Simmesport, La.

Of the flow passing Myette Point, about 85 percent is carried by the main channel of the Atchafalaya River, and the remaining 15 percent is carried by the distributary west of Myette Point (Grand Lake).

In both studies the Lower Atchafalaya River carried 70 percent of the flow out of the basin, and Wax Lake Outlet carried the remaining 30 percent.

Table 1.--Monthly discharge duration and monthly 1-day Q_2 high flow and 7-day Q_{10} low flow values for Atchafalaya River at Simmesport, La., water years 1964-75

[Discharge, in cubic feet per second]

Month	1-day Q_2	7-day Q_{10}	Percentage of time discharge was equal to or less than that shown				
			90	70	50	30	10
October	140,000	40,000	190,000	140,000	110,000	75,000	40,000
November	160,000	38,000	250,000	160,000	115,000	76,000	38,000
December	240,000	54,000	380,000	260,000	180,000	110,000	60,000
January	300,000	60,000	410,000	320,000	250,000	180,000	92,000
February	310,000	82,000	460,000	350,000	260,000	180,000	94,000
March	360,000	110,000	450,000	360,000	300,000	240,000	160,000
April	390,000	160,000	560,000	440,000	360,000	280,000	180,000
May	390,000	140,000	500,000	400,000	350,000	300,000	200,000
June	360,000	71,000	480,000	340,000	250,000	170,000	86,000
July	230,000	58,000	300,000	220,000	170,000	125,000	68,000
August	160,000	52,000	170,000	140,000	120,000	95,000	58,000
September	120,000	51,000	150,000	120,000	95,000	75,000	55,000

SUSPENDED SEDIMENT

Sediment transported by the Atchafalaya River moves as suspended sediment and along the bottom of the river as bedload. This section of the report refers only to suspended sediment. From 1964 to 1974 an average suspended-sediment load of 260,000 tons per day was transported past Simmesport, La., and ultimately deposited in the Atchafalaya Basin Floodway and (or) Atchafalaya Bay.

Suspended-sediment concentrations in the Atchafalaya River at Simmesport generally increase as the river discharge increases. Early storm runoff washes large amounts of suspended sediment into the river, resulting in an increase in suspended-sediment concentrations. In addition, as flow and velocity increase, erosion of the bank and the streambed introduces additional suspended sediment into the stream. Peak sediment concentrations, however, usually occur before peak discharges.

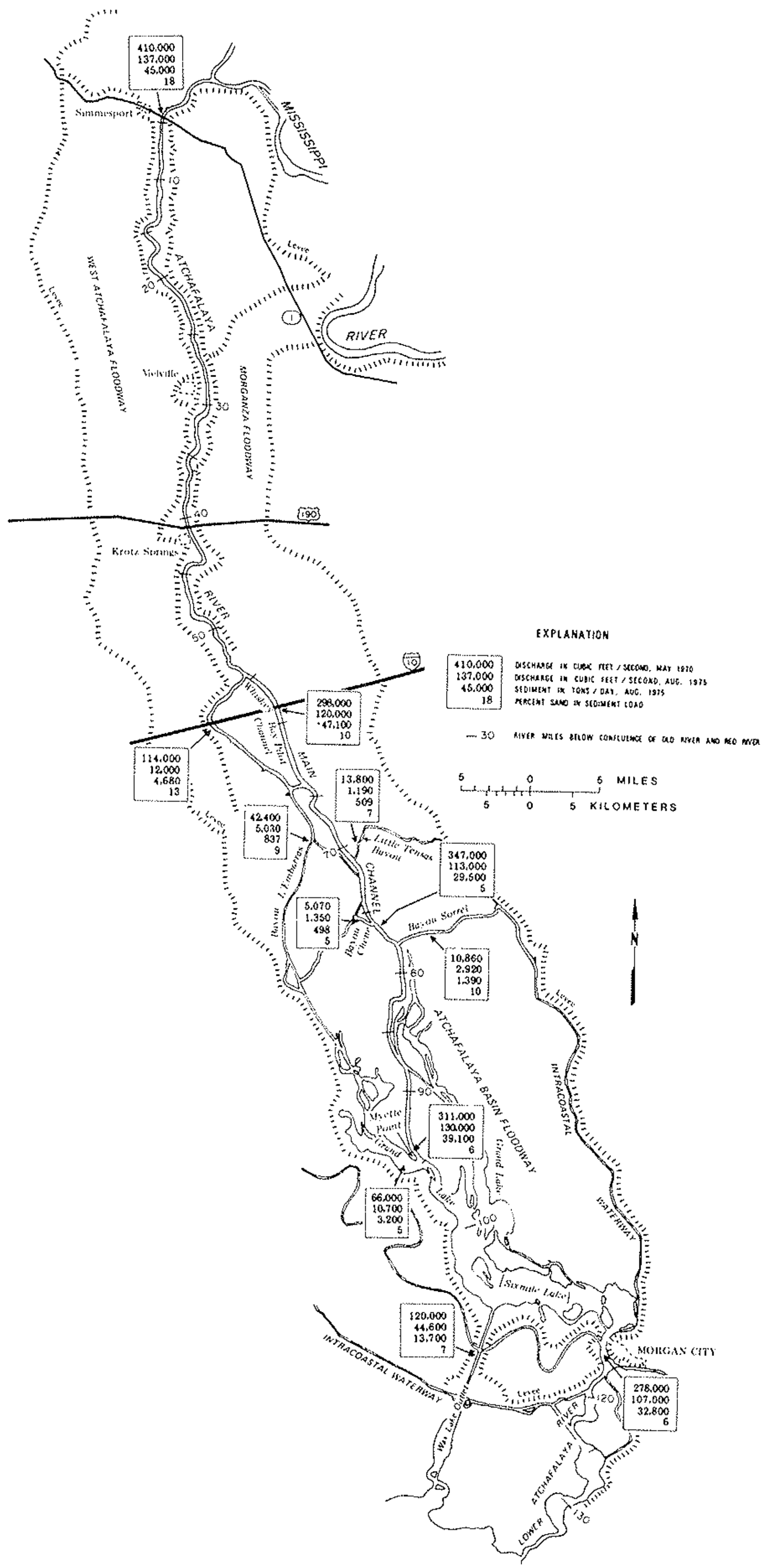


Figure 5.--Distribution of flow and sediment in the main channel and major distributaries of the Atchafalaya River.

At higher flows in a flood event, the concentration of sediment is generally less than the river is capable of transporting. Figure 6 illustrates this situation for three flood events. The size and shape of the sediment curves are dependent upon antecedent flow conditions in the river.

Suspended-sediment loads generally increase as the river discharge increases and decrease as the flow decreases. Suspended-sediment loads (expressed in tons per day) represent the total weight of suspended sediment transported by the river. Although the suspended-sediment concentrations decrease following the initial increase in discharge, the suspended load continues to increase with increasing discharge.

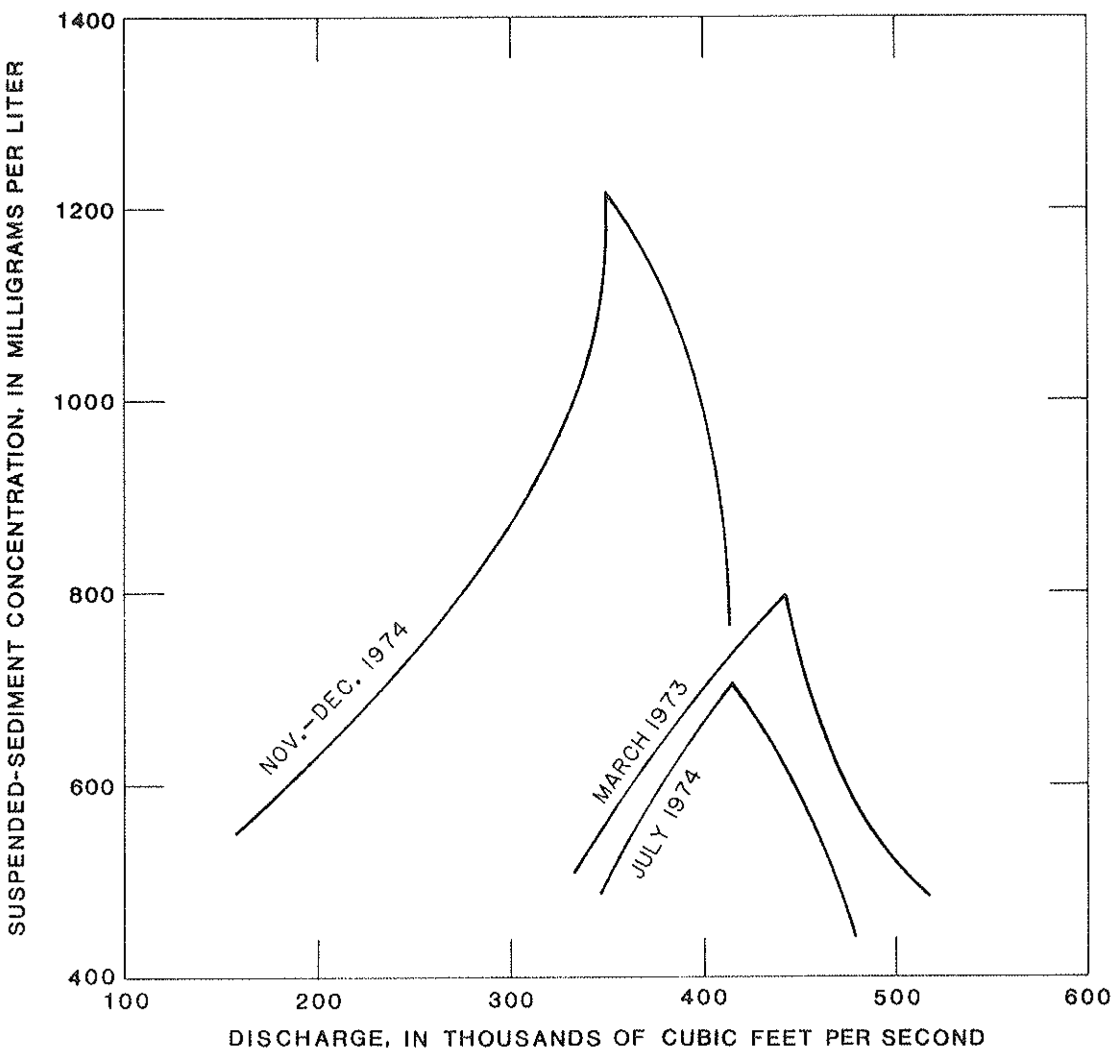


Figure 6.--Relation of suspended-sediment concentration to river discharge for three floods, Atchafalaya River at Simmesport, La.

Eighty percent of the time, suspended-sediment loads in the Atchafalaya River at Simmesport range from 20,000 to 580,000 tons per day. The median suspended-sediment load is 150,000 tons per day. As suspended-sediment loads are directly related to discharge, the lower suspended-sediment loads occur during the low-flow months of September, October, and November (table 2). Higher suspended-sediment loads occur in February, March, April, and May.

Table 2.--Suspended-sediment load duration for Atchafalaya River at Simmesport, La., water years 1964-74

[Load, in tons per day]

Month	Percentage of time values were equal to or less than those shown				
	90	70	50	30	10
Period of record (1964-74)---------	580,000	310,000	150,000	70,000	20,000
October-------------------------	285,000	110,000	45,000	20,000	9,000
November-----------------------	250,000	95,000	50,000	25,000	7,000
December-----------------------	700,000	300,000	150,000	60,000	15,000
January-------------------------	500,000	350,000	230,000	130,000	45,000
February------------------------	720,000	410,000	350,000	140,000	60,000
March---------------------------	1,000,000	600,000	420,000	280,000	140,000
April----------------------------	750,000	500,000	360,000	250,000	140,000
May-----------------------------	780,000	560,000	430,000	320,000	180,000
June-----------------------------	520,000	320,000	180,000	90,000	25,000
July------------------------------	330,000	210,000	140,000	90,000	43,000
August---------------------------	140,000	95,000	70,000	45,000	20,000
September ----------------------	165,000	80,000	45,000	25,000	10,000

The average suspended-sediment load between 1964 and 1974 was 260,000 tons per day, and the average suspended-sediment concentration for the same period was 460 mg/L (milligrams per liter). The minimum load was 3,000 tons per day in November 1964, and the maximum load was 2,120,000 tons per day in March 1968. Over the 11-year period, approximately 25 percent of the suspended-sediment load was sand (particles, 0.062-2.000 mm in diameter), and 75 percent was silt and clay (particles, less than 0.062 mm in diameter). The largest yearly suspended-sediment load occurred in 1974 when 143 million tons of sediment was transported past Simmesport, La.

There are few historical suspended-sediment data available for the Atchafalaya Basin Floodway. However, records collected by the Corps of Engineers for Wax Lake Outlet and the Lower Atchafalaya River between 1965 and 1971 indicate that approximately 75 percent of the suspended-sediment load at Simmesport was transported through the two outlets. It appears that Grand Lake and Six Mile Lake, which once acted as settling basins or traps for the suspended sediment, have become almost filled.

Since about 1950 an increasing proportion of the suspended-sediment load transported by the river has passed through the Lower Atchafalaya River and Wax Lake Outlet into Atchafalaya Bay (Gagliano and van Beek, 1975).

During the floods of 1973, 1974, and 1975 the combined suspended-sediment loads at Wax Lake Outlet at Calumet and the Lower Atchafalaya River at Morgan City were higher than the suspended-sediment loads at Simmesport. During April and May 1975 the suspended-sediment loads at the Lower Atchafalaya River and Wax Lake Outlet were 85 percent higher than the loads at Simmesport, La. This increase in suspended-sediment load represents a substantial amount of scour in the basin during periods of high flow. During a study of water quality and time of travel in the Atchafalaya basin in August and September 1975, at a discharge of 137,000 ft^3/s (3,880 m^3/s) the suspended-sediment load was 45,000 tons per day at Simmesport. At the Lower Atchafalaya River and Wax Lake Outlet a combined discharge of 152,000 ft^3/s (4,300 m^3/s) and a combined suspended-sediment load of 46,500 tons per day were recorded. It appears from this study that there was no net scour or deposition of sediment along the main channel, although some scour and deposition did occur locally. Additional suspended-sediment data (including sand percentages) recorded during this study are shown in figure 5. During this study the major distributaries--Bayou L'Embarras, Little Tensas Bayou, Bayou Chene, and Bayou Sorrel--each carried less than 4 percent of the suspended-sediment load recorded at Simmesport or Wax Lake Outlet and Lower Atchafalaya River.

WATER QUALITY OF THE ATCHAFALAYA RIVER BASIN

Inorganic Chemical Quality

Atchafalaya River at Simmesport

The Atchafalaya River receives water from three major drainage basins, the Black River, the Red River, and the Mississippi River (via the Old River outflow channel). The chemical quality of the Atchafalaya River at any specific time, therefore, is controlled by the discharge and the chemical quality of each of these rivers. Daily variations in specific conductance in the Atchafalaya River are usually less than 30 micromhos/cm (micromhos per centimeter) at 25°C. A plot of daily specific-conductance values of the Red River at Alexandria, La., the Mississippi River at St. Francisville, La., and the Atchafalaya River at Simmesport, La., for the 1975 water year shows the effects of the Mississippi River and the Red River on the chemical quality of the Atchafalaya River (fig. 7). Daily fluctuations in specific conductance are greater in the Red River than in the Mississippi River, with the daily fluctuations of the Atchafalaya being between those of the other two rivers. Although daily specific-conductance values for the Black River are not available for the 1975 water year, the influence of the Black River can also be noted on the hydrograph. In June and July 1975 when the floodwaters of the Mississippi and Red Rivers began to recede,

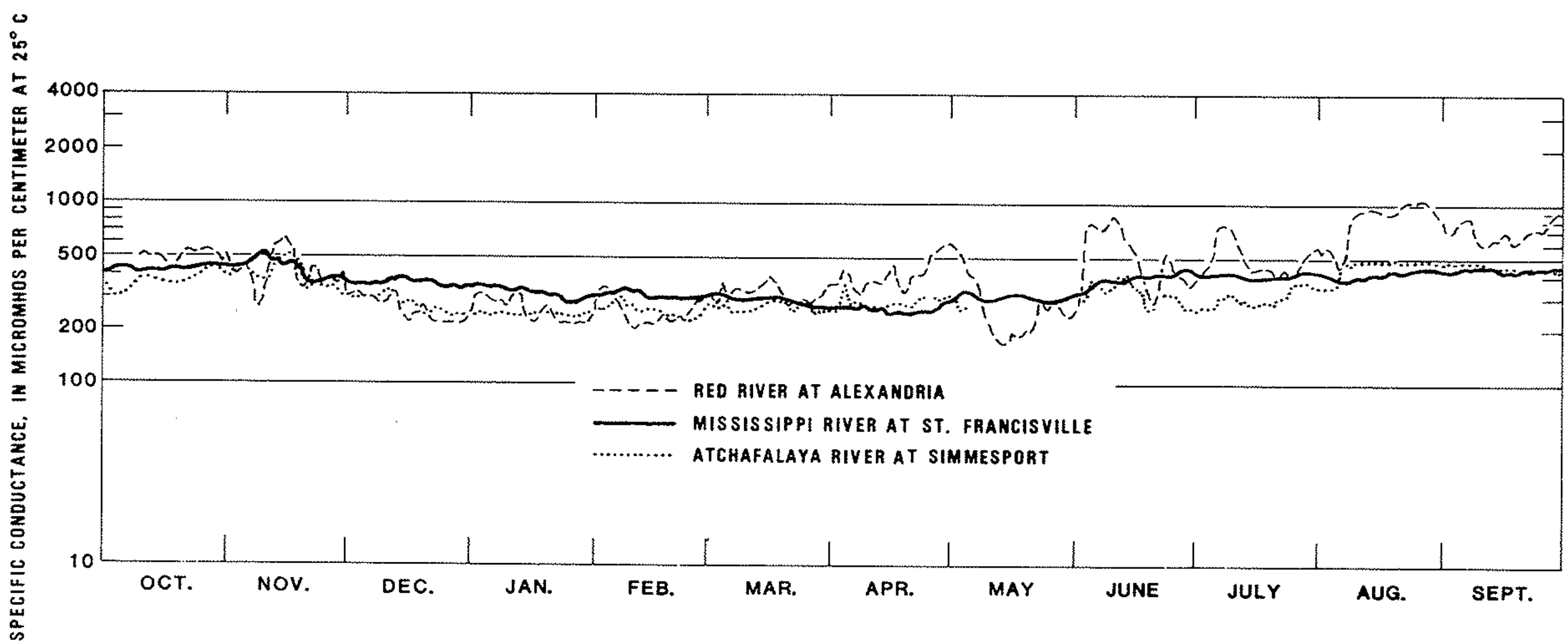


Figure 7.--Daily specific conductance for Red River at Alexandria, Mississippi River at St. Francisville, and Atchafalaya River at Simmesport, 1975 water year.

backwater from the Black River began to drain through the Atchafalaya River basin. Since this water was less mineralized than that of the Red River or the Mississippi River, the specific conductance of the Atchafalaya River was less than that of the Red and Mississippi Rivers.

Specific conductance, a measure of the ability of water to conduct an electric current, is related to the quantity and types of ionized substances in water and can be used to estimate dissolved-solids concentrations as well as concentrations of individual chemical constituents. The relationship between specific conductance and dissolved solids for the Atchafalaya River at Simmesport is shown in figure 8.

The specific conductance of the Atchafalaya River generally varies inversely with discharge. As the river discharge increases, the specific conductance decreases. However, during an initial increase in discharge the specific conductance of the Atchafalaya River also increases. This increase in specific conductance is caused by higher concentrations of dissolved materials being washed into the river during early storm runoff.

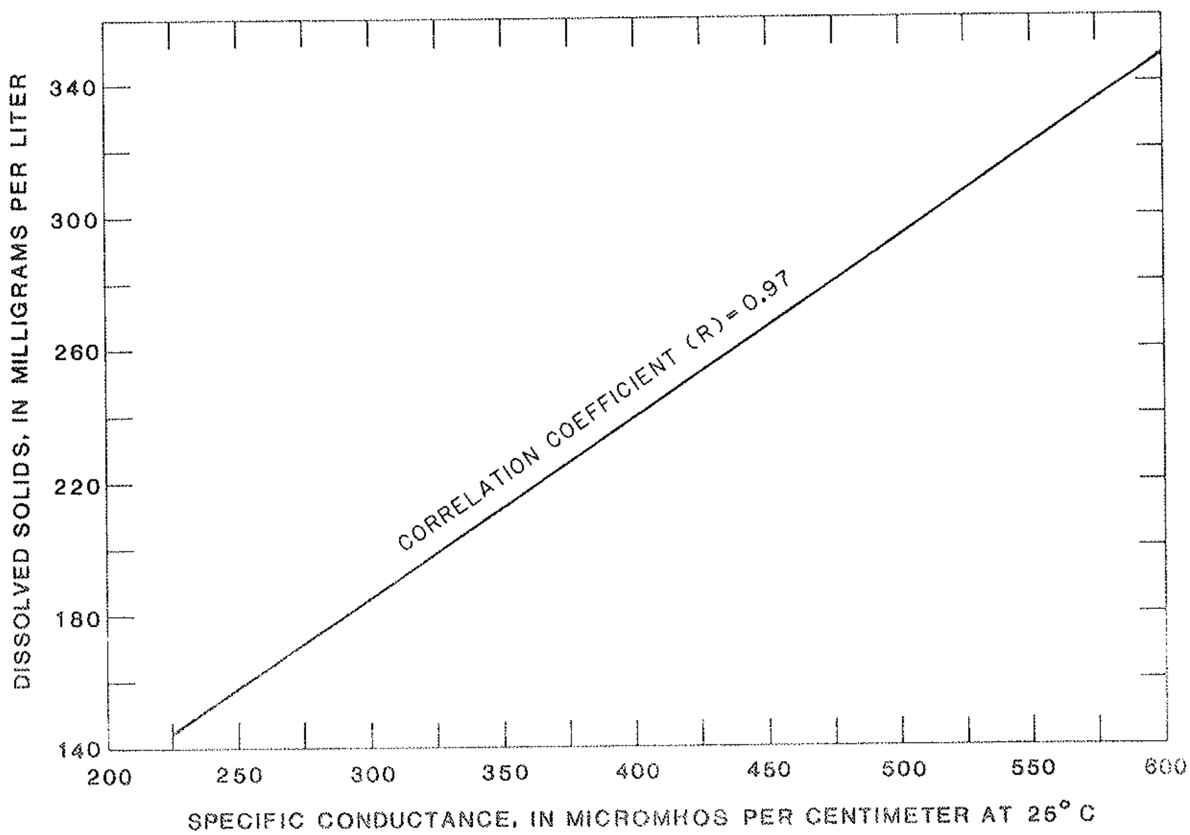


Figure 8.--Relation of specific conductance to dissolved solids for Atchafalaya River at Krotz Springs-Simmesport, La.

Specific conductance in the main channel of the Atchafalaya River generally changes less than 30 micromhos/cm between Simmesport and Morgan City. The greatest changes occur downstream from Myette Point during periods of low flow. For example, at a discharge of 137,000 ft^3/s (3,880 m^3/s), the specific conductance of the river between Simmesport and Myette Point (mile 95) remained constant at 470 micromhos/cm at 25°C. At Morgan City, La., (mile 117) the specific conductance had decreased to 448 micromhos/cm. This decrease between Myette Point and Morgan City was due to less mineralized water entering the river from Grand Lake, which had a specific conductance of 338 micromhos/cm.

Data collected monthly at Krotz Springs, La., during the water years 1966-72 and at Simmesport, La., during the water years 1973-75 were used to define the chemical quality in the upper reaches of the Atchafalaya River. As there is little or no surface-water inflow between the two stations, the chemical quality of the water is assumed to be the same at both locations. The ranges in values and the duration of occurrence of the chemical and physical characteristics of the Atchafalaya River at Krotz Springs and Simmesport are given in table 3.

Table 3.--Variation in chemical and physical characteristics of the Atchafalaya River at Krotz Springs and Simmesport, La., water years 1966-75

[Values, in milligrams per liter except as indicated]

Parameter	Observed value		Percentage of time values were equal to or less than those shown				
	Minimum	Maximum	90	70	50	30	10
Discharge, 1964-75 (ft^3/s)	23,500	781,000	430,000	280,000	185,000	120,000	62,000
Silica	.3	12	---------	---------	---------	---------	---------
Iron	.0	.30	---------	---------	---------	---------	---------
Calcium	20	58	46	40	36	32	27
Magnesium	2.4	18	13	10	8.8	7.4	5.8
Sodium	10	50	32	24	20	16	12
Potassium	1.2	4.6	---------	---------	---------	---------	---------
Bicarbonate	70	172	148	125	112	100	86
Sulfate	20	80	64	50	41	35	27
Chloride	13	66	39	28	23	19	15
Fluoride	.0	.5	---------	---------	---------	---------	---------
Nitrate as N	.0	1.3	---------	---------	---------	---------	---------
Dissolved solids (residue at 180°C)	133	399	285	240	215	190	165
Hardness as $CaCO_3$ (Ca, Mg)	73	200	160	140	120	110	95
Specific conductance (micromhos/cm at 25°C)	187	600	490	400	350	300	250
Temperature (°C)	3.0	31.0	29.0	25.0	17.0	11.5	7.0
Color (platinum-cobalt units)	5	100	30	20	15	10	5

Bicarbonate is the predominant anion followed by sulfate and chloride. Calcium is the predominant cation followed by sodium and magnesium. Calcium concentrations in the Atchafalaya River at Simmesport, La., exceed 36 mg/L 50 percent of the time, and bicarbonate concentrations are greater than 112 mg/L 50 percent of the time. Calcium concentrations in the Mississippi River near St. Francisville exceed 40 mg/L 50 percent of the time, and calcium concentrations in the Red River at Alexandria exceed 36 mg/L 50 percent of the time. Calcium concentrations in the Black River at Jonesville exceed 18 mg/L only 50 percent of the time. (See table 4.)

Table 4.--Variation in chemical characteristics of the Mississippi River at St. Francisville, Red River at Alexandria, and Black River at Jonesville

[Values, in milligrams per liter except as indicated]

Parameter		Percentage of time values were equal to or less than those shown				
		90	70	50	30	10
Specific conductance (micromhos/cm at 25°C)	Mississippi River	490	425	380	335	280
	Red River	1,200	680	500	370	270
	Black River	800	550	400	260	140
Hardness as $CaCO_3$ (Ca, Mg)	Mississippi River	176	156	142	129	112
	Red River	260	165	125	98	83
	Black River	110	85	60	40	25
Calcium	Mississippi River	48	44	40	36	32
	Red River	68	46	36	30	25
	Black River	30	24	18	12	8.6
Sodium	Mississippi River	29	23	19	15	11
	Red River	135	68	47	33	23
	Black River	100	70	50	30	10
Bicarbonate	Mississippi River	156	138	125	111	93
	Red River	158	118	92	78	69
	Black River	74	52	38	25	12
Sulfate	Mississippi River	67	56	48	42	35
	Red River	130	62	41	30	20
	Black River	14	11	9.6	7.8	4.5
Chloride	Mississippi River	31	26	21	18	14
	Red River	200	120	95	50	28
	Black River	200	120	76	50	28

Bicarbonate concentrations in the Mississippi River at St. Francisville and in the Red River at Alexandria exceed 125 and 90 mg/L, respectively, 50 percent of the time. Bicarbonate concentrations in the Black River at Jonesville were less than 74 mg/L 90 percent of the time.

Concentrations of sodium and chloride in the Atchafalaya River at Simmesport exceed 20 and 23 mg/L, respectively, 50 percent of the time. The concentrations of sodium and chloride ions in the Red River and the Black River are generally higher than those found in the Mississippi

River. Sodium and chloride concentrations in the Red River at Alexandria exceed 45 and 95 mg/L, respectively, 50 percent of the time. Sodium and chloride concentrations in the Black River at Jonesville exceed 50 and 76 mg/L, respectively, 50 percent of the time. Sodium and chloride concentrations in the Mississippi River at St. Francisville, La., only exceed 30 mg/L 10 percent of the time.

Because most of the water in the Atchafalaya River at Simmesport is water diverted from the Mississippi River ("Streamflow" section), the Mississippi River has more control on the concentrations of major ions in the Atchafalaya River than the Red or Black Rivers. This controlling influence can be seen in the similarity of the duration of the major ions in the Atchafalaya River and the Mississippi River (tables 3, 4).

Because specific conductance is related to the quantity and types of ions in solution, it can often be used to predict the concentrations of the major anions and cations in solution with a reasonable amount of accuracy. To obtain the best description of the relationship between specific conductance and the major ions in the Atchafalaya River at Simmesport, the least squares regression analysis was used. Figure 9 is a graphical representation of the chemical composition of the water in the Atchafalaya River at Simmesport and shows that bicarbonate is the predominant anion (followed by sulfate and chloride) and calcium is the predominant cation (followed by sodium and magnesium). In addition, by using the curves, concentrations of the major ions can be predicted if the specific conductance of water is known. For example, at a specific conductance of 350 micromhos/cm the following ionic concentrations can be estimated: bicarbonate, 113 mg/L; sulfate, 41 mg/L; chloride, 23 mg/L; hardness, 126 mg/L; calcium, 36 mg/L; magnesium, 9.5 mg/L; and sodium, 18 mg/L. A dissolved-solids concentration of 214 mg/L can be estimated from figure 8. It should be noted that these curves give only a reasonable estimate of ionic concentrations in the Atchafalaya River at Simmesport, not actual values.

Atchafalaya Basin Floodway

The water in the canals, lakes, and bayous of the Atchafalaya Basin Floodway receive their water from one or more distributaries of the Atchafalaya River. Because of this, the chemical quality of the water in these areas is closely related to the chemical quality of the Atchafalaya River at Simmesport.

To define the chemical quality of the Atchafalaya Basin Floodway, 10 locations in 2 areas of the basin were sampled monthly from September 1973 to December 1974. These areas were the Buffalo Cove complex on the west side of the floodway and the Flat Lake-Duck Lake system on the east side of the floodway. (See pl. 1.)

The Buffalo Cove complex is in the west-central part of the basin near Bayou Benoit in Iberia Parish. It is bordered on the north by Little Bayou Gonsoulin-Alligator Bayou-Bayou Chene, on the east by the Atchafalaya River, on the south by Grand Lake, and on the west by Lake

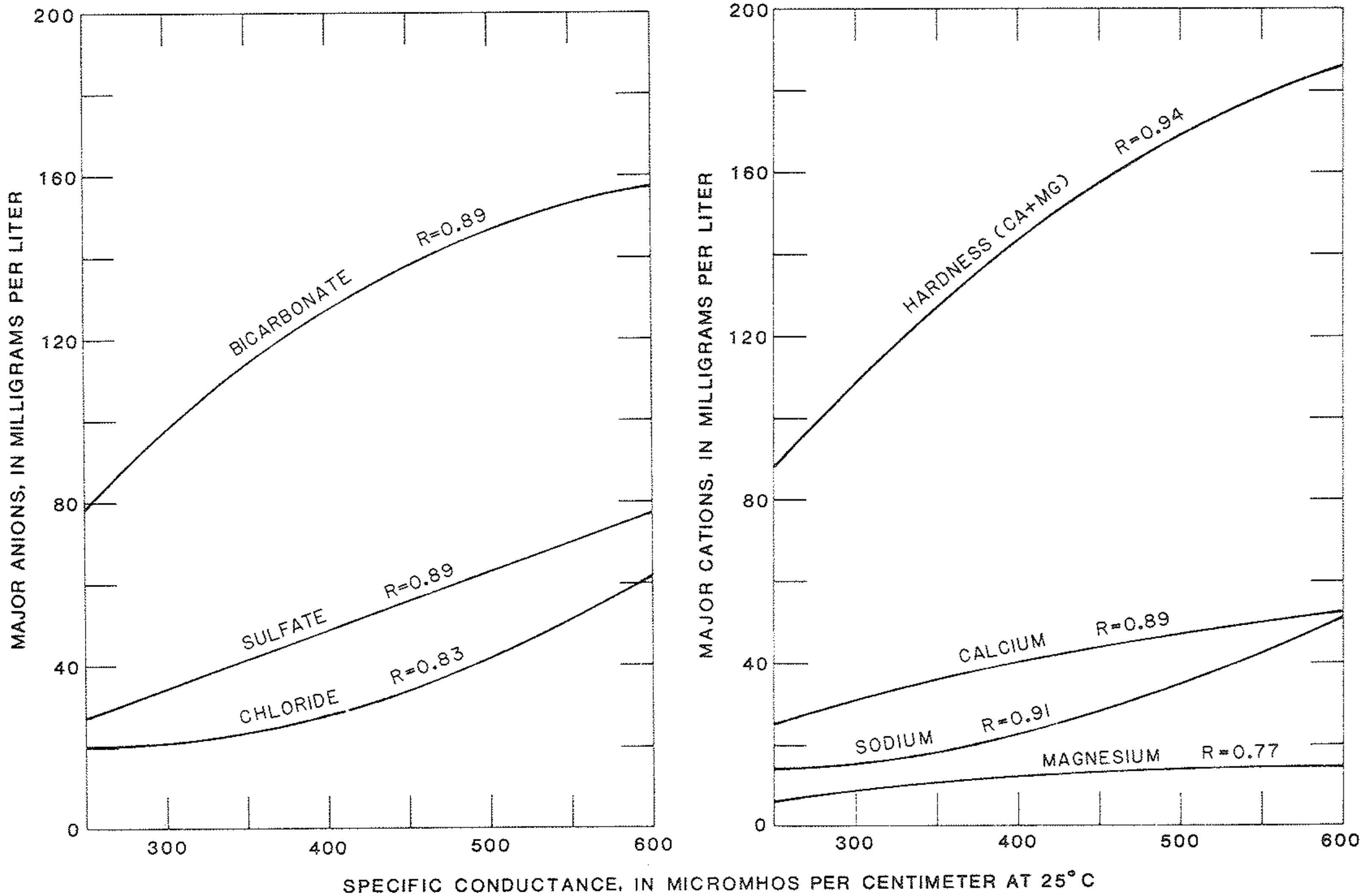


Figure 9.--Relation between specific conductance and major anion and cations for the Atchafalaya River at Simmesport, La.

Fausse Point Cut. It is a relatively young area, having assumed its present physiography in the past 35 years (Gagliano and van Beek, 1975).

The Flat Lake-Duck Lake complex is located in the southeast corner of the basin just north of Morgan City. The study area is bordered on the north by Little Bayou Sorrel; on the east by the Morgan City-Port Allen Intracoastal Waterway; and on the west by Six Mile Lake, Grand Lake, and the Atchafalaya River. The physiography of this region is similar to that of the Buffalo Cove area approximately 35 years ago (Gagliano and van Beek, 1975).

The monthly sampling stations were classified as riverine, east swamp, and west swamp according to their location and hydrologic characteristics. The riverine stations are located in wide, willow-lined distributaries of the Atchafalaya River. These distributaries are the major sources of water for the adjacent swamps. Water in the distributaries is generally turbid. Stations WC, WG, WF, and WI are examples of riverine stations (pl. 1).

The east and west swamp stations are located in bayous or lakes lined with cypress and tupelo-gum trees. Aquatic plants are generally quite dense along the shores and in shallow waters. Water is generally clear except during periods of high flow. Stations WA, WB, and WD on the west side and EA, EB, and EC on the east side are examples of swamp stations. (See pl. 1.) Due to varying elevations in the backswamp areas, river water flows into these areas at varying discharges. Thus, the term "high flow" is used to describe the varying discharges at which river water directly affects the backswamp areas, and the term "low flow" is used to describe the varying discharges at which little or no effects occur.

For the east swamp, west swamp, and riverine stations, data collected monthly were used in a least squares regression analysis to obtain a relation between specific conductance and the major ions. These relations were compared with the corresponding relations established for the Atchafalaya River at Simmesport to see if any differences exist (figs. 10 and 11). The differences noted in the relationships established for the major ions are due to differences in the chemical composition of the water.

During periods of high flow when conductance values are low, more water from the main stem of the river reaches the distributaries and swamp areas of the floodway than during periods of low flow. This water undergoes little change in chemical composition as it moves from the river, through the distributaries, and into the swamp areas. Evidence of the similarity in composition can be seen in the specific conductance-major ion relationships. At specific-conductance values below 350 micromhos/cm, very little difference exists in the concentrations of the major ions throughout the Atchafalaya River basin. For example, analyses made in April 1974 at a discharge of 445,000 ft^3/s (12,600 m^3/s) at Simmesport, La., showed very little difference in the chemical composition of the water between the Atchafalaya River main channel, the riverine stations, and the east and west swamp stations (table 5). The specific conductance of the water ranged from 281 to 298 micromhos/cm with very little difference in the concentrations of calcium, hardness, sulfate, chloride, or bicarbonate from station to station.

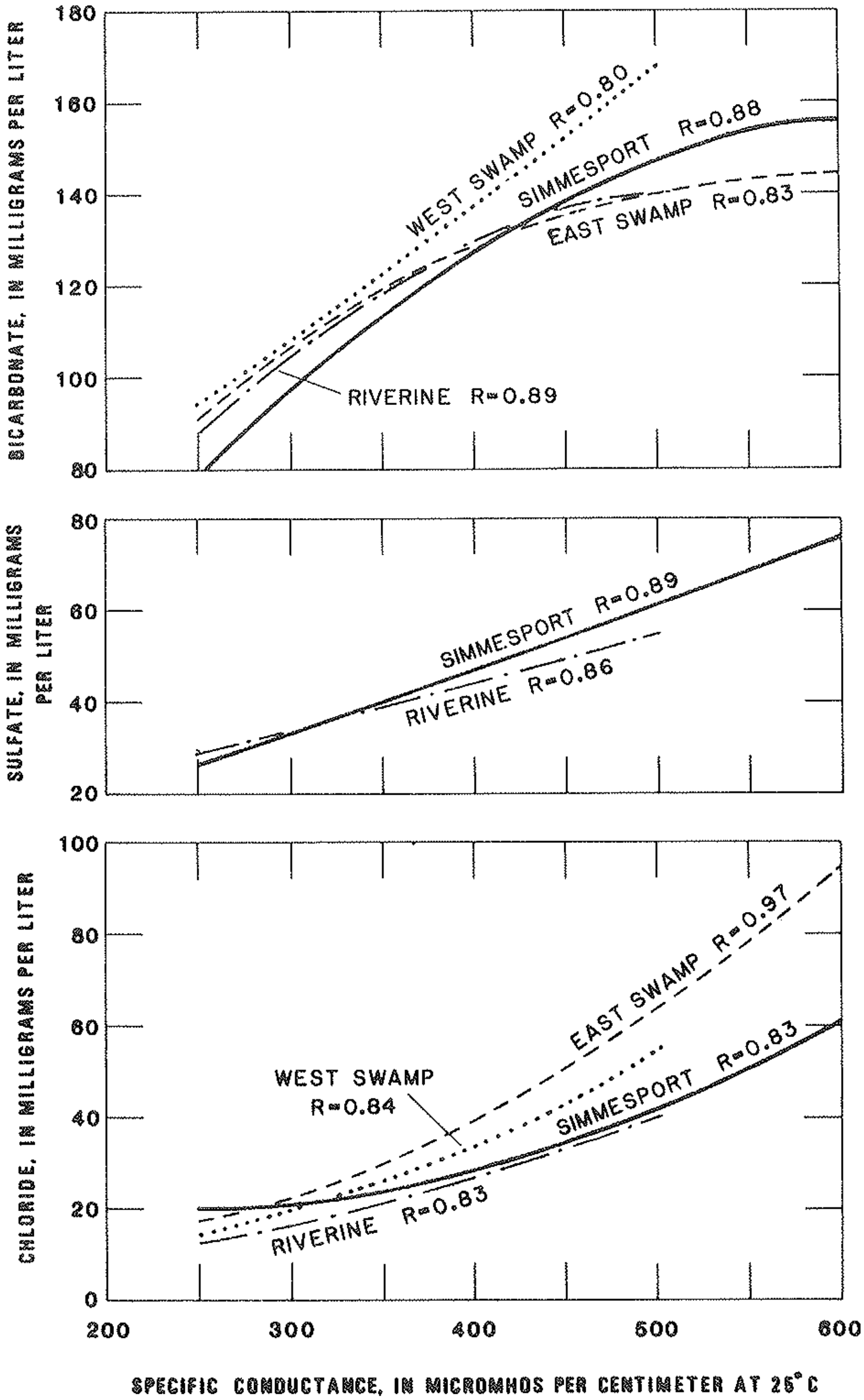


Figure 10.--Relation of specific conductance to major anions in the Atchafalaya Basin Floodway and Atchafalaya River at Simmesport, La.

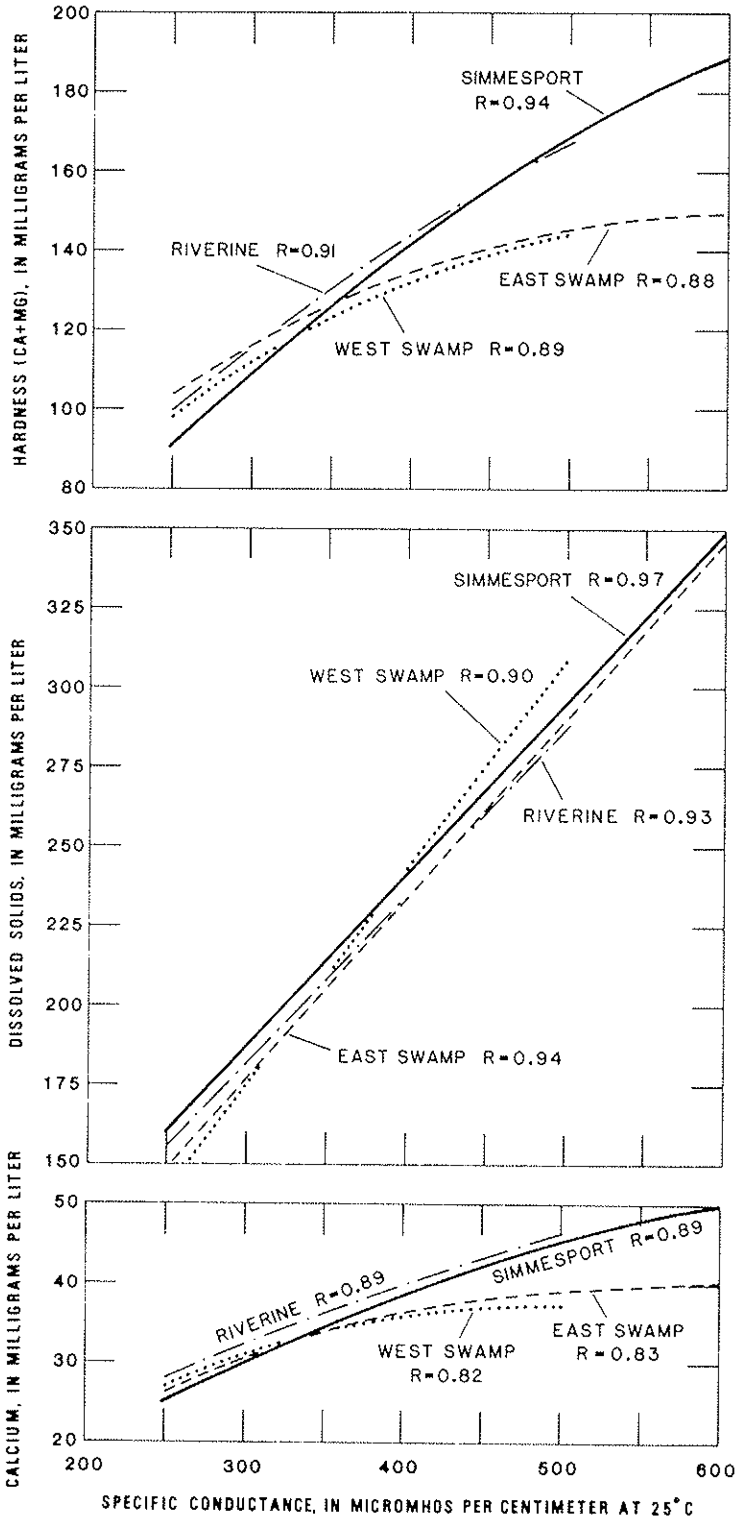


Figure 11.--Relation of specific conductance to major cations and dissolved solids in the Atchafalaya Basin Floodway and Atchafalaya River at Simmesport, La.

Table 5.--Concentration of major ions in the Atchafalaya River basin at different flow conditions

[Concentrations are for samples collected in April 1974 except those in parentheses, which were collected in August 1975. All values except specific conductance are in milligrams per liter]

Station	Specific conductance (micromhos/cm at 25°C)	Bicarbonate	Sulfate	Chloride	Hardness as $CaCO_3$ (Ca, Mg)	Calcium
Simmesport--	(470)	(139)	(59)	(37)	(160)	(42)
RA ---------	285 (466)	100 (130)	37 (60)	14 (38)	100 (170)	33 (48)
WI ---------	(472)	(132)	(54)	(41)	(160)	(43)
WA---------	284	99	34	16	99	30
WB ---------	287 (323)	100 (104)	34 (8.7)	17 (38)	100 (100)	33 (27)
WC---------	287	100	32	16	100	32
WD---------	286 (393)	102 (120)	34 (11)	17 (48)	102 (110)	29 (30)
WG---------	286	103	35	15	103	32
WF ---------	298	102	35	17	102	31
EA ---------	294 (363)	98 (124)	32 (24)	18 (34)	120 (120)	31 (33)
EB----------	281 (840)	100 (110)	31 (24)	17 (180)	110 (140)	33 (38)
EC ----------	288 (448)	98 (122)	30 (50)	18 (37)	120 (140)	31 (38)

During periods of low flow, less water from the Atchafalaya River main channel enters the distributaries and swamp areas of the floodway. The distributaries, however, contain primarily river water, and only slight changes in the water quality are noted between the river and the riverine stations. Evidence for this similarity is reflected in the specific conductance-major ion relations developed for the Atchafalaya River at Simmesport and the riverine stations, which show only minor differences in concentrations of major ions.

During periods of low flow very little water from the main stem of the river reaches the swamp stations. The water quality at the swamp stations may then vary greatly from that found in the river or the distributaries. An example of the difference in the water quality between the Atchafalaya River, the riverine stations, and the swamp stations during low-flow periods can be seen by again examining table 5. In August 1975 at a discharge of 137,000 ft^3/s (3,880 m^3/s) and a specific conductance of 470 micromhos/cm at Simmesport, La., the specific conductance at selected stations in the Atchafalaya River basin ranged from 323 micromhos/cm in the Buffalo Cove area (station WB) to 840 micromhos/cm in Little Bayou Sorrel (station EB). The concentration of the major ions at the stations also varied considerably.

Figures 10 and 11 show that the major difference in the chemical composition of the water between the river and the swamp areas of the basin occur when the specific conductance exceeds 375 micromhos/cm.

The concentration of dissolved solids (fig. 11) increases at all stations during low flow, but there is often considerable variation in the major ions from station to station. These variations in chemical composition occur because local environmental conditions have a greater impact on chemical composition when less water from the main stem of the river reaches the riverine and swamp areas.

For the bicarbonate ion (fig. 10) during periods of low flow, concentrations at the riverine and east swamp stations are only slightly lower than the bicarbonate concentrations in the Atchafalaya River. At the west swamp stations the bicarbonate ion concentrations are slightly higher than at the other stations. The west swamp stations receive almost no inflow of freshwater from the distributaries in the area, and the decomposition of organic matter in these areas causes the bicarbonate concentrations to increase.

During periods of low flow, calcium concentrations are generally lower and chloride concentrations are generally higher in the swamp areas of the basin than in the Atchafalaya River or the distributaries (figs. 10 and 11). This difference in concentrations between the river and the swamp areas occurs because the river is having less effect on the swamp areas of the basin during low flow. Calcium concentrations increase slightly in the swamp areas of the floodway as conductance values exceed 375 micromhos/cm. The major ion to increase in concentration during low flow is chloride. This increase in chloride concentrations is probably related to oil and natural-gas production in the swamp areas of the floodway. Spillage and (or) leakage of brine from these operations have caused chloride concentrations to exceed 150 mg/L in the Little Bayou Sorrel area. Chloride concentrations of 250 mg/L have been recorded in the Bayou Sorrel oil field in the northeastern part of the floodway.

Reliable sulfate-specific conductance relationships could not be developed for the east and west swamp stations. Because there is only a small inflow of freshwater into the swamp areas during low-flow periods, a reducing environment exists in the swamp areas of the basin. A low redox potential is common in the water in the swamp areas (Bryan, in Bryan and others, 1974). Under these conditions the sulfate ion (SO_4) can be reduced to hydrogen sulfide (H_2S) or sulfide ion. This reduction of sulfate causes lower sulfate concentrations in the swamp area of the basin. Sulfate reduction in natural waters is commonly associated with sulfate-reducing bacteria of the genus Desulfovibrio. These bacteria oxidize organic matter utilizing sulfate as the oxidizing agent. The sulfate is reduced to sulfide in the reaction (Clifton, 1957).

A water-quality survey was conducted throughout the floodway in August 1975 to define the concurrent characteristics of the water for many locations (pl. 1). Results of the survey also were used to determine if the specific conductance-major ion relations established at the monthly sampling stations might be applicable to other areas in the Atchafalaya Floodway. Water samples were collected and stream-discharge measurements were made in the main channel of the Atchafalaya River and its major distributaries. Additional water samples were collected in the swamp areas east and west of the river. These sampling stations in the Atchafalaya Floodway were again classified as riverine, east swamp, and west swamp stations.

The specific conductance in the Atchafalaya River at Simmesport during the water-quality survey was 470 micromhos/cm. Approximately 60 percent of the dissolved solids in the river water was contributed by the Mississippi River. The Red River and the Black River accounted for approximately 30 and 10 percent of the dissolved solids, respectively.

The specific conductance of water in the river and distributaries downstream from Simmesport ranged from 388 to 472 micromhos/cm. The specific conductance of water in the east and west swamp areas was generally lower than that in the river except in areas receiving drainage from oil fields. The specific conductance in the west swamp area ranged from 232 to 393 micromhos/cm, while specific-conductance values in the east swamp areas of the basin ranged from 282 to 835 micromhos/cm.

The relations between specific conductance and major ions developed for the monthly sampling stations were used to see how accurately concentrations in the floodway could be predicted from specific conductance observed during the August survey. The results of the comparison, presented in table 6, indicate fairly good agreement between predicted concentrations and observed concentrations. For example, the specific conductance of water in the west swamp areas ranged from 232 to 393 micromhos/cm, with an average of 346 micromhos/cm. Using the specific conductance-major ion relations established for this area (figs. 10, 11), the concentrations of hardness should range from 97 to 133 mg/L. The observed values were 100 and 140 mg/L. Based on the average conductance of 346 micromhos/cm, the average hardness should be 124 mg/L. The observed average concentration was 120 mg/L.

Table 6.--Predicted and observed concentrations from the water-quality survey, August 1975[1/]

[Values, in milligrams per liter except as indicated]

Parameter		Atchafalaya River at Simmesport, La.[2/]	Riverine stations			East swamp stations			West swamp stations		
			Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum
Specific conductance (micromhos/cm at 25°C).		470	388	441	472	282	347	455	232	346	393
Bicarbonate-----	Predicted--	137	126	135	138	100	117	135	102	121	135
	Observed --	135	116	127	135	101	121	155	104	129	155
Chloride -------	Predicted--	38	26	33	38	19	30	52	12	26	33
	Observed --	37	32	36	41	15	31	64	14	30	48
Sulfate---------	Predicted--	58	46	49	60	-----	---	---	-----	---	---
	Observed --	59	43	51	52	6.3	18	50	8.7	13	18
Calcium -------	Predicted--	44	34	41	43	28	32	37	25	34	36
	Observed --	43	30	41	48	26	32	39	27	33	38
Hardness as $CaCO_3$ (Ca, Mg).	Predicted--	163	137	153	162	108	122	140	97	124	133
	Observed --	160	130	150	170	95	117	140	100	120	140

[1/] Samples that had a specific conductance greater than 600 micromhos/cm were not used in compiling this table.

[2/] Discharge, 137,000 ft^3/s.

The major differences between observed and predicted concentrations generally occur at higher specific-conductance values. For example, in both the east and west swamp stations the predicted maximum bicarbonate concentrations were 135 mg/L. The observed maximum bicarbonate concentrations were 155 mg/L. In the east swamp and west swamp stations the observed maximum chloride concentrations were also somewhat higher than the predicted values.

Lower Atchafalaya River and Wax Lake Outlet

The water quality in the Lower Atchafalaya River at Morgan City and Wax Lake Outlet at Calumet is very similar to that at Simmesport. The major changes in water quality in the main channel of the river generally take place downstream from Myette Point (mile 95). Drainage from the west swamp areas through Grand Lake and the east swamp areas from American Pass, Six Mile Lake, and Flat Lake generally produce changes of less than 30 micromhos/cm at Wax Lake Outlet and the Lower Atchafalaya River at Morgan City (p. 16).

Figure 12 shows the minor differences that occur in the chemical composition of the water between Lower Atchafalaya River and Wax Lake Outlet and that at Simmesport, La. Concentrations of bicarbonate, sulfate, hardness, and calcium are slightly less at Morgan City for a similar specific conductance than at Simmesport; chloride concentrations are slightly higher at Morgan City, La. Concentrations of magnesium at the two stations are approximately the same.

By examining the relation of specific conductance to major ions established for the east swamp and west swamp areas (figs. 10, 11) of the Atchafalaya Floodway, the differences in the chemical composition of the water between Simmesport and Morgan City can be explained. For example, hardness and calcium concentrations in the swamp areas of the basin are generally lower than those found at Simmesport. Drainage from the swamp areas through the Lower Atchafalaya River and Wax Lake Outlet results in slightly lower hardness and calcium concentrations at these locations than those found at Simmesport. Similarly, chloride concentrations in the swamp areas of the basin are generally higher than those in the river at Simmesport, so drainage from the swamps causes higher concentrations of chloride at the Lower Atchafalaya River and Wax Lake Outlet. Although a specific conductance-sulfate relationship could not be developed for the swamp areas of the floodway, sulfate concentrations are generally lower in these areas than in the river (p. 24). This causes lower sulfate concentrations at the Lower Atchafalaya River and Wax Lake Outlet. Bicarbonate concentrations are generally lower in the east swamp areas of the basin and higher in the west swamp areas than those found in the Atchafalaya River at Simmesport. Because there is a much larger quantity of water draining from the east swamp areas of the floodway, this water has a more pronounced effect on the river flowing through the Lower Atchafalaya River and Wax Lake Outlet. Consequently, the bicarbonate concentrations for the Lower Atchafalaya River and Wax Lake Outlet are generally lower than the concentrations at Simmesport.

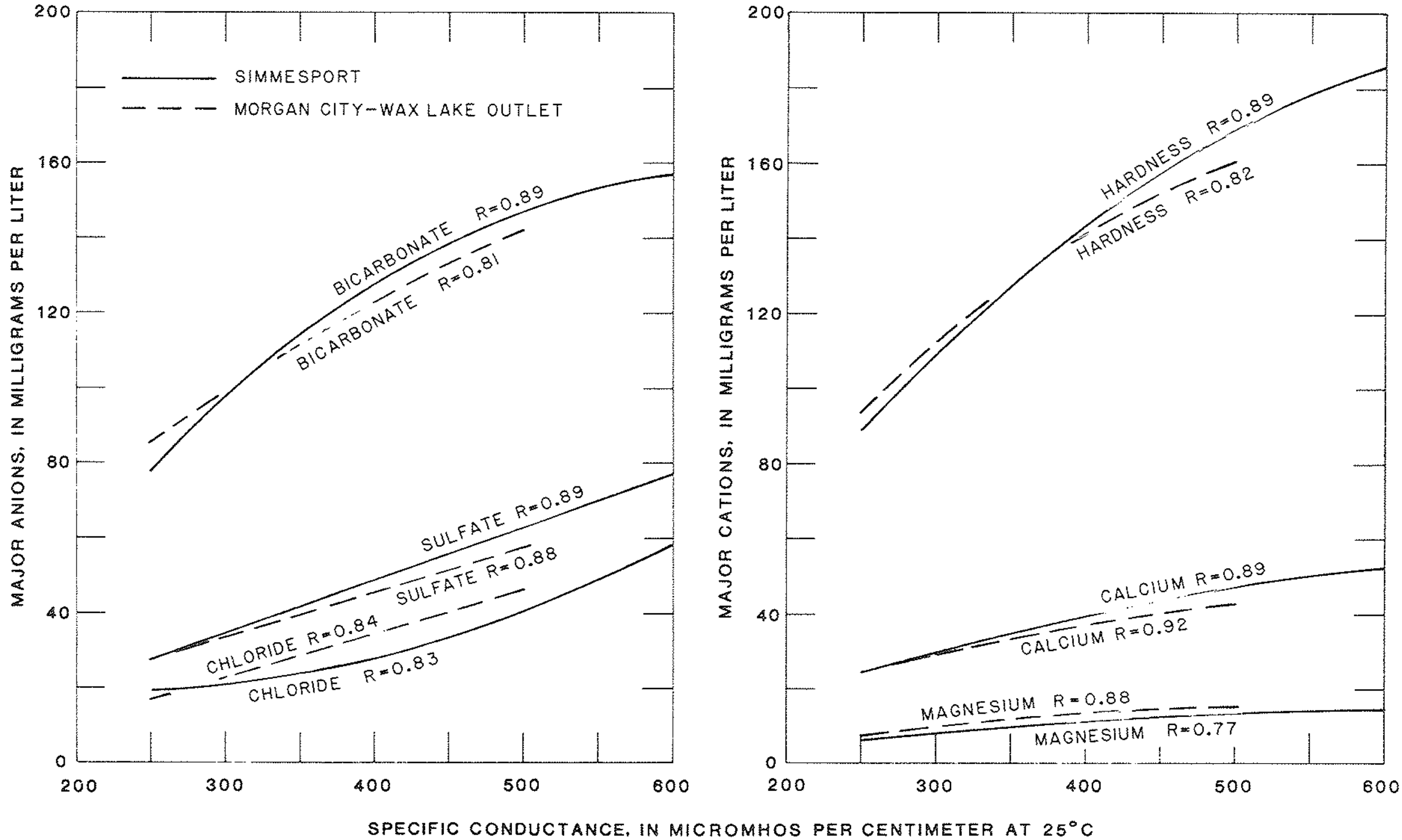


Figure 12.--Relation between specific conductance and major anions and cations in the Atchafalaya River at Simmesport and Lower Atchafalaya River at Morgan City and Wax Lake Outlet at Calumet.

Temperature

Information on stream temperature is vitally important to the proper utilization of water resources. Temperature affects the use of surface water for industrial and recreational uses, biochemical-reaction rates, oxygen-saturation levels, stream-reaeration rates, and aquatic life.

Water temperatures of the Atchafalaya River at Krotz Springs-Simmesport, La., range from 3.0° to 31.0°C. Ninety percent of the time the water temperature at these locations is equal to or less than 29.0°C, and 50 percent of the time it is equal to or less than 17.0°C (table 7). Average monthly temperature, monthly variations in temperature, and monthly duration of temperature for the Atchafalaya River at Krotz Springs-Simmesport are given in table 7. The average monthly temperatures were highest in August and lowest in January. From March to June the average monthly temperatures increase 5.0°C per month; from September to November the average monthly temperatures decrease approximately 7.0°C each month.

Table 7.--Monthly variation, monthly duration, and average monthly water temperatures for Atchafalaya River at Krotz Springs-Simmesport, La.

[Temperature, in degrees Celsius]

Month	Range in temperature	Average monthly temperature	Percentage of time values equaled or exceeded those shown				
			90	70	50	30	10
January ------	3.0- 9.0	8.0	6.5	7.0	8.0	8.5	9.0
February -----	5.5-13.5	9.0	6.5	8.0	9.0	10.0	11.5
March -------	8.5-15.5	11.5	9.5	11.0	11.5	12.0	14.5
April --------	10.5-21.5	16.5	13.0	14.5	15.5	17.0	20.0
May ---------	17.0-25.0	21.5	19.0	20.5	21.5	23.0	24.0
June ---------	24.0-30.5	26.5	24.5	25.5	26.5	28.0	29.0
July ---------	26.5-31.0	29.5	28.0	28.5	29.0	30.0	30.5
August -------	27.0-30.5	30.0	28.5	29.0	29.5	30.0	30.5
September----	25.0-30.0	28.0	26.5	27.0	28.0	28.5	29.5
October ------	15.5-26.0	21.5	17.0	20.0	23.0	24.0	25.5
November ----	5.0-19.5	14.0	13.0	13.5	14.0	15.0	16.5
December ----	4.0-13.0	9.5	7.0	8.5	9.5	10.5	12.0
Period of record (water years 1953-55 and 1975)-------	3.0-31.0	----	7.0	11.5	17.0	25.0	29.0

Dissolved Oxygen

Dissolved-oxygen concentrations are of primary importance in the Atchafalaya River basin. Fish and other aquatic life require adequate levels of dissolved oxygen for egg and larvae development and normal growth and activity. There is no specific dissolved-oxygen concentration that is favorable to all species and ecosystems. However, low dissolved-oxygen concentrations are unfavorable to almost all aquatic organisms.

The National Academy of Sciences-National Academy of Engineering Committee on Water Quality Criteria (1973) has selected 4 mg/L[1/] as the lowest acceptable oxygen concentration for freshwater aquatic life and wildlife. However, in areas such as the "black waters" draining the swamps of the southeastern part of the United States the natural level of dissolved oxygen may sometimes be less than 4 mg/L.

The principal source of oxygen in the Atchafalaya River basin is reareation of the water from atmospheric oxygen. The solubility of oxygen in water is inversely related to temperature. As the temperature of the water increases, the amount of atmospheric oxygen the water is capable of holding decreases. Oxygen also is produced in some areas of the basin as a byproduct of photosynthesis.

Periodic measurements of dissolved oxygen in the Atchafalaya River at Simmesport, La., the Lower Atchafalaya River at Morgan City, and Wax Lake Outlet at Calumet show that dissolved-oxygen concentrations are relatively high (near saturation). The highest concentrations occur during the cool winter months, and the lowest concentrations occur during the warm summer months. Dissolved-oxygen concentrations at Simmesport have ranged from 5.9 mg/L (70-percent saturation) to 11.5 mg/L (97-percent saturation). In the Lower Atchafalaya River and Wax Lake Outlet, dissolved-oxygen concentrations have ranged from 4.1 mg/L (60-percent saturation) to 12.0 mg/L (97-percent saturation). The saturation levels of dissolved oxygen in the Atchafalaya River at Simmesport are generally above 75 percent; those in the Lower Atchafalaya River and Wax Lake Outlet are generally above 65 percent.

The Atchafalaya River is the primary supplier of oxygen to the swamp areas in the basin. Dissolved-oxygen concentrations are generally high in the main channel of the river all year. Over an 11-month period, dissolved-oxygen concentrations at station RA ranged from 4.4 mg/L (57-percent saturation) to 8.3 mg/L (82-percent saturation). The major distributaries that supply water to the swamp areas of the basin have relatively high oxygen concentrations all year; however, the dissolved-oxygen concentrations at the riverine stations are usually slightly less than those found in the main channel of the river. Periodic sampling over a 16-month period showed that the dissolved-oxygen concentrations at stations WC, WF, and WG ranged from 2.9 mg/L (36-percent saturation) to 9.0 mg/L (94-percent saturation). The highest dissolved-oxygen concentrations in both the main channel of the river and the riverine stations occur during the high-flow winter months. The lowest concentrations occur during the low-flow summer months.

Dissolved-oxygen concentrations at the swamp stations are generally dependent upon temperature and flow conditions. During periods of high flow a sufficient supply of freshwater reaches the swamp stations, and dissolved-oxygen concentrations are maintained at a high level. During the low-flow summer months smaller quantities of water reach these areas.

1/ The U.S. Environmental Protection Agency (1976) recommends a minimum concentration of 5.0 mg/L of dissolved oxygen to maintain good fish populations.

Dissolved-oxygen concentrations decline to low levels in the swamp areas because of the increased effect of organic degradation and the lack of a sufficient supply of oxygen from the river or from photosynthetic production.

Stratification of both dissolved oxygen and temperatures are common at the swamp stations during the summer months. Dissolved-oxygen concentrations and temperatures generally decrease gradually with depth. A sharp thermocline usually does not exist in the Atchafalaya River basin.

Dissolved-oxygen concentrations of less than 4.0 mg/L are very common at both the east and west swamp stations during the low-flow summer months. Dissolved-oxygen concentrations are slightly lower on the west side during these periods. West swamp stations WA and WB are almost devoid of a supply of freshwater during periods of low flow. Station EB in Little Bayou Sorrel rarely receives highly oxygenated water from the river. Dissolved-oxygen concentrations at station EB are probably more dependent on temperature than flow conditions in the river. Periodic sampling over a 16-month period at station EB showed that dissolved-oxygen concentrations ranged from 1.2 mg/L (15-percent saturation) in June 1974 to 5.9 mg/L (56-percent saturation) in February 1974.

During the water-quality survey conducted in August 1975, dissolved-oxygen concentrations were higher at the riverine stations than in the east or west swamp areas. Dissolved-oxygen concentrations and percent-saturation levels, specific conductance, temperature, and pH values measured during the survey are shown on plate 1. Dissolved-oxygen concentrations in the riverine stations ranged from 4.4 mg/L (57-percent saturation) to 8.0 mg/L (106-percent saturation). No concentrations were less than 4.0 mg/L.

The stations located in the west swamp area of the basin had the lowest dissolved-oxygen concentrations, ranging from 0.1 mg/L (1-percent saturation) to 7.2 mg/L (100-percent saturation). Approximately 80 percent of the stations sampled in this area had dissolved-oxygen concentrations of less than 4.0 mg/L.

Dissolved-oxygen concentrations in the east swamp were not as low as those in the west swamp areas. Concentrations in the east swamp area ranged from 1.1 mg/L (14-percent saturation) to 9.8 mg/L (134-percent saturation), with approximately 55 percent of the stations sampled having dissolved-oxygen concentrations greater than 4.0 mg/L.

The eastern areas of Grand Lake had the highest dissolved-oxygen concentrations found during the water-quality survey, with values ranging from 8.7 mg/L (118-percent saturation) to 9.8 mg/L (134-percent saturation). The high concentrations are a result of primary production of oxygen by photosynthesis. The greatest stratification of dissolved oxygen and temperature were also noted in those areas. Figure 13 shows the degree of stratification for dissolved oxygen and temperature at two locations in Grand Lake. Stratification was greater near Big Bayou Pigeon than Little Bayou Pigeon because the measurements near Big Bayou Pigeon were made later in the day, giving water more time to heat up and allowing for more oxygen production by photosynthesis.

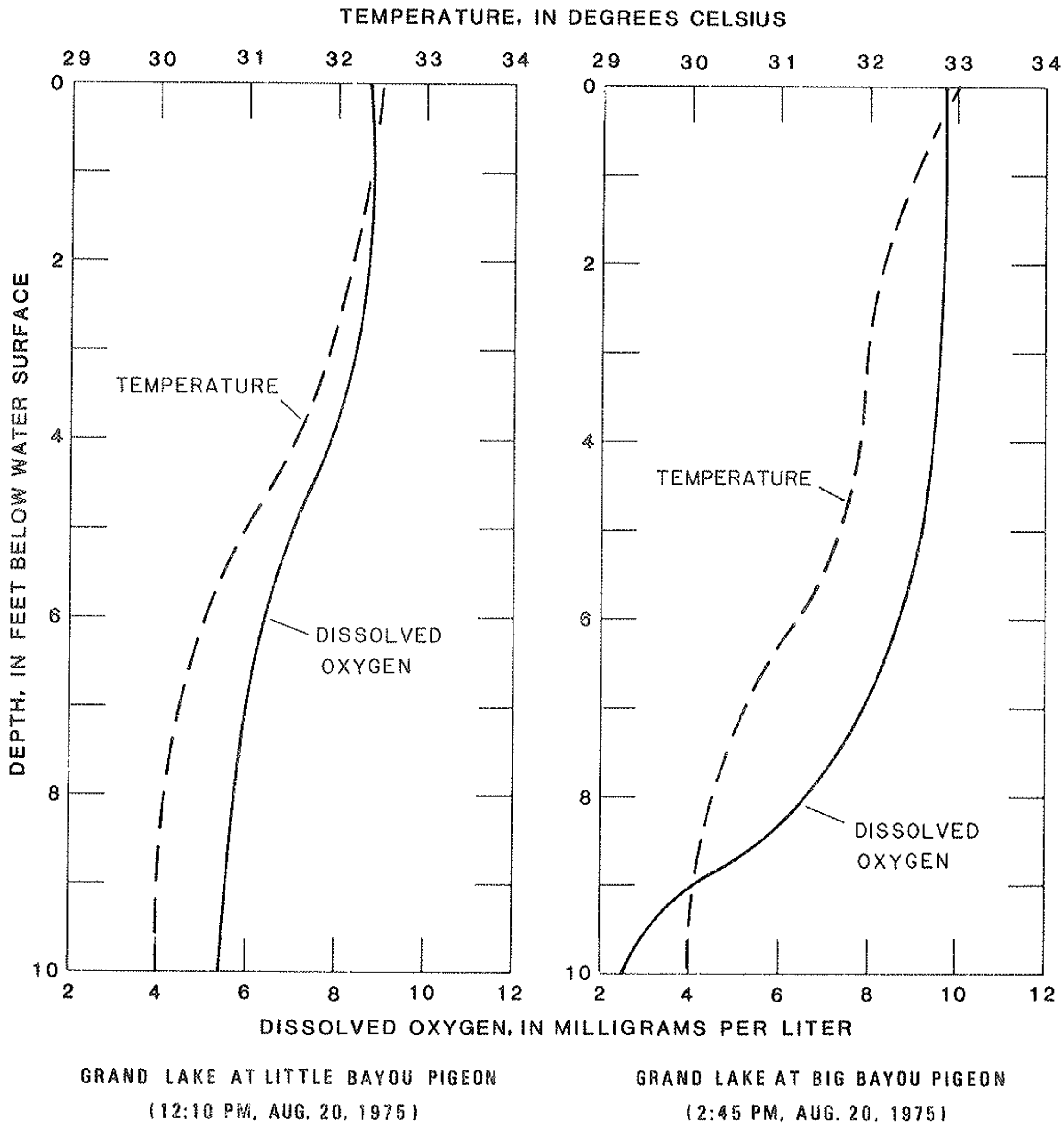


Figure 13.--Variation with depth of temperature and dissolved oxygen at selected locations in Grand Lake.

Oxygen production from photosynthesis is common during summer and fall in both Grand Lake and Flat Lake. Water bodies in which primary production takes place usually have wide fluctuations of dissolved oxygen during a 24-hour period. As photosynthetic activity occurs in the presence of sunlight, maximum dissolved-oxygen concentrations usually occur during late afternoon hours. Concentrations may exceed saturation levels at these times. Minimum concentrations occur during early morning hours just before sunrise (Reid, 1961). Diel studies conducted at three stations in Flat Lake showed that dissolved-oxygen peaks generally occur between 4 and 6 p.m., whereas minimum values generally occur between 4 and 7 a.m.

Nutrients

Concentrations of nitrogen and phosphorus are relatively low in the Atchafalaya River basin. Total nitrogen concentrations in the Atchafalaya River basin are generally less the 1.5 mg/L. Total phosphorus concentrations are generally less the 0.15 mg/L. Concentrations of ammonia nitrogen and nitrite nitrogen are generally less than 0.05 mg/L. Nitrate nitrogen and organic nitrogen generally account for more than 90 percent of the total nitrogen present. Both organic nitrogen and nitrate nitrogen in water are a result of inflow of nitrogenous compounds from the watershed and as part of the normal biological processes of the aquatic environment. Decomposition of organic matter yields organic nitrogen compounds. The end product of aerobic decomposition of organic nigrogen is nitrate nitrogen. Nitrate nitrogen is the form of nitrogen most easily taken up by aquatic green plants.

Nitrate nitrogen concentrations at Simmesport, La., ranged from 0.28 to 1.3 mg/L. Nitrate nitrogen concentrations at the riverine stations in the Atchafalaya Basin Floodway ranged from 0.23 to 1.0 mg/L; those at the east swamp and west swamp stations ranged from 0.01 to 0.93 and 0.00 to 0.63 mg/L, respectively. Lowest concentrations of nitrate nitrogen generally occur in swamp areas during periods of low flow. Nitrate nitrogen concentrations at station EB, which receives very little inflow of freshwater, were less than 0.20 mg/L in 80 percent of the samples analyzed. Concentrations of nitrate nitrogen in the Lower Atchafalaya River and Wax Lake Outlet are similar to those at Simmesport, La. Nitrate concentrations at these two locations have ranged from 0.24 to 1.1 mg/L.

There are three primary reasons why nitrate nitrogen values may decrease in the swamp areas during low flow. Little inflow of freshwater into these areas prevents these areas from becoming replenished with nitrate nitrogen. Nitrate nitrogen is a valuable nutrient used in the assimilation of organic food matter by plants. Certain bacteria can also reduce nitrate nitrogen to nitrous oxide, nitrogen, and (or) ammonia.

Concentrations of organic nitrogen at the riverine stations ranged from 0.00 to 0.61 mg/L; those at the east and west swamp stations ranged from 0.00 to 0.83 and 0.00 to 0.61 mg/L, respectively. The highest concentrations of organic nitrogen generally occurred during periods of low flow.

Concentrations of total phosphorus in the Atchafalaya River at Simmesport have ranged from 0.11 to 0.40 mg/L; total phosphorus concentrations in the Lower Atchafalaya River and Wax Lake Outlet are very similar, ranging from 0.09 to 0.53 mg/L.

Concentrations of total phosphorus are generally less than 0.45 mg/L at the riverine stations and less than 0.20 mg/L at the east and west swamp stations. Orthophosphorus concentrations are generally less than 0.20 mg/L at the riverine stations and less than 0.10 mg/L at the east and west swamp stations.

Concentrations of nitrogen during the water-quality survey were similar to those found at the monthly sampling stations. Nitrate nitrogen concentrations were highest in riverine areas and lowest in swamp areas. Nitrate nitrogen concentrations in the riverine areas ranged from 0.29 to 0.52 mg/L. However, approximately 90 percent of the stations sampled in the east swamp areas of the basin had nitrate nitrogen concentrations of less than 0.10 mg/L. No nitrate nitrogen was found in the west swamp areas of the basin.

The highest concentrations of organic nitrogen found were during the water-quality survey in the west swamp areas of the basin. Organic nitrogen concentrations in this area ranged from 0.62 to 1.2 mg/L. Organic nitrogen concentrations in the riverine stations and east swamp areas ranged from 0.39 to 1.2 and 0.33 to 1.2 mg/L, respectively.

Concentrations of total phosphorus were also higher in the west swamp areas during the water-quality survey. Total phosphorus concentrations ranged from 0.09 to 0.41 mg/L. Total phosphorus concentrations in the riverine and east swamp areas of the basin were less than 0.15 mg/L.

Three studies were conducted in the Buffalo Cove area at varying discharges to evaluate changes in water quality as water passed through swamp areas in the Atchafalaya Floodway. These studies were conducted in March 1975 at a discharge of 558,000 ft^3/s (15,800 m^3/s), in April 1975 at a discharge of 691,000 ft^3/s (19,600 m^3/s), and in June 1975 at a discharge of 433,000 ft^3/s (12,300 m^3/s) at Simmesport, La. The investigations began in the Bayou Chene-Alligator Bayou-Little Bayou Gonsoulin distributary and terminated in the swamp area north of Buffalo Cove Lake (swamp study station WA, pl. 1), a distance of 7.2 mi (11.6 km) through the swamp. The parameters investigated included dissolved oxygen, nutrients, and suspended solids.

Figure 14 shows percent saturation of oxygen versus distance into the swamp. The percent saturation of oxygen decreases as distance from the distributary increases. The smallest change in saturation levels occurred during April at the highest discharge, and the greatest decrease occurred during the June study at the lowest discharge. The slight increase in dissolved-oxygen saturation from mile 4.5 to mile 7.5 is due in part to possible photosynthetic influences, as well as their greater proximity to Lake Fausse Pointe Cut, which overflows its banks during periods of high water.

Nutrient concentrations generally decrease as distance into the swamp increases (fig. 15). This condition was best shown during the June 1975 study when concentrations of total phosphorous decreased from 0.16 mg/L in Bayou Chene to 0.08 mg/L at mile 7.2, and concentrations

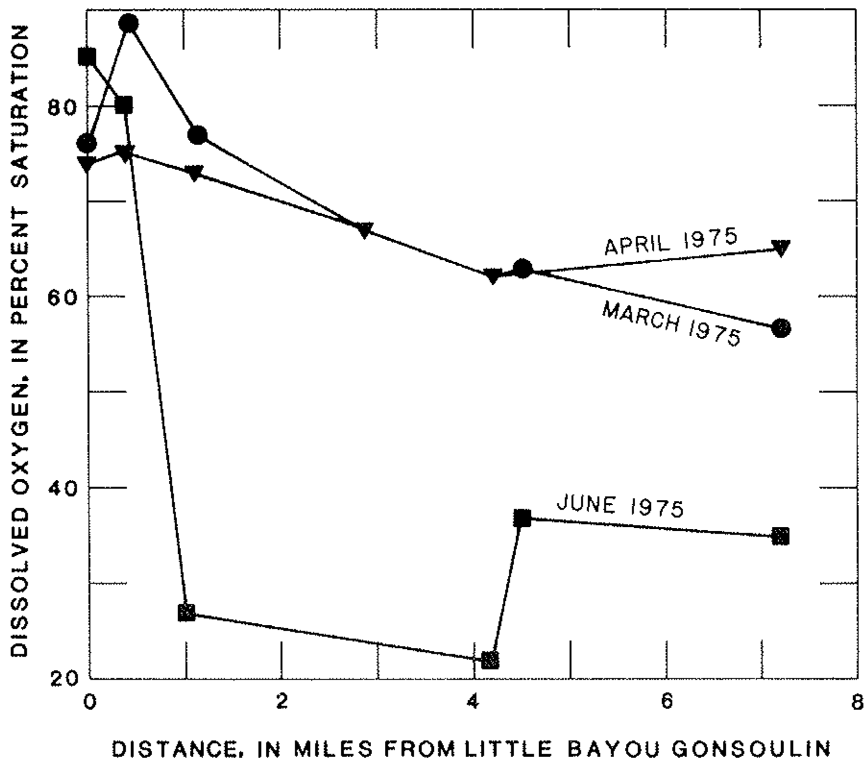


Figure 14.--Variations in percent saturation of dissolved oxygen versus distance into Buffalo Cove swamp area.

of nitrate nitrogen and total organic nitrogen decreased from 0.74 to 0.36 and 0.62 to 0.46 mg/L, respectively. Only minor changes were noted during periods of high flow.

Figure 16 shows the concentration of suspended solids in water versus distance traveled through the swamp for three different river stages. At all three stages there was a noticeable decrease in the concentration of suspended solids as distance into the swamp increases. The most dramatic decrease occurred during June 1975 when approximately 83 percent of the suspended solids settled out by mile 4.3. In contrast, during peak flows, only 42 percent of the suspended solids settled out by mile 4.3. In all cases the slight rise in concentration at mile 7.2 is probably due to inflows from Lake Fausse Pointe Cut.

Heavy Metals

Although only a limited number of samples collected from the Atchafalaya basin have been analyzed for heavy metals, the concentrations are low. Concentrations of dissolved arsenic, cadmium, chromium, cobalt, copper, and lead have been less than 10 $\mu g/L$ (micrograms per liter). The total concentrations of these metals (unfiltered samples) have not exceeded 20 $\mu g/L$. Total-mercury concentrations have not exceeded 1.1 $\mu g/L$, and dissolved-mercury concentrations have not exceeded 0.4 $\mu g/L$.

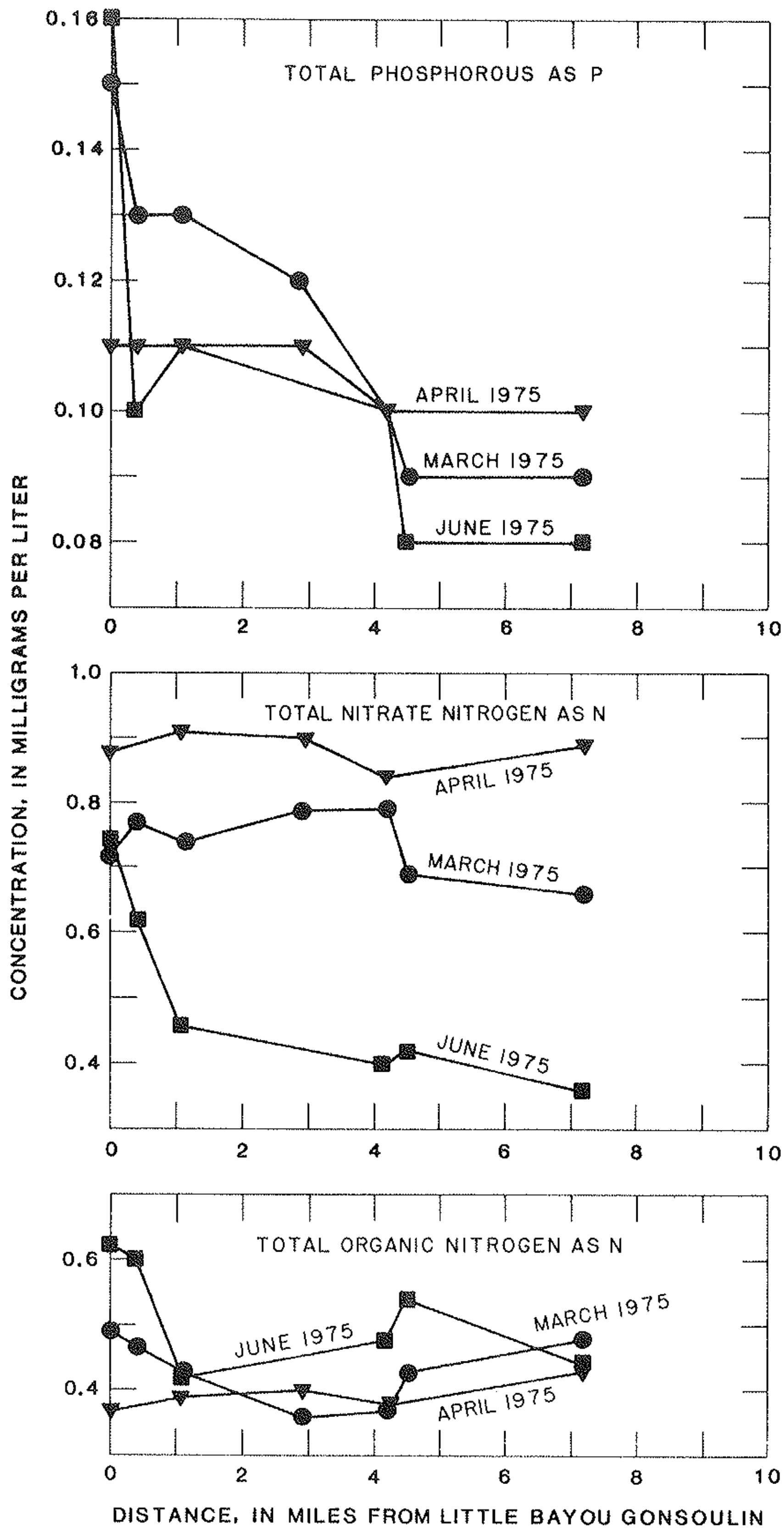


Figure 15.--Variation in major nutrient concentrations versus distance into Buffalo Cove swamp area.

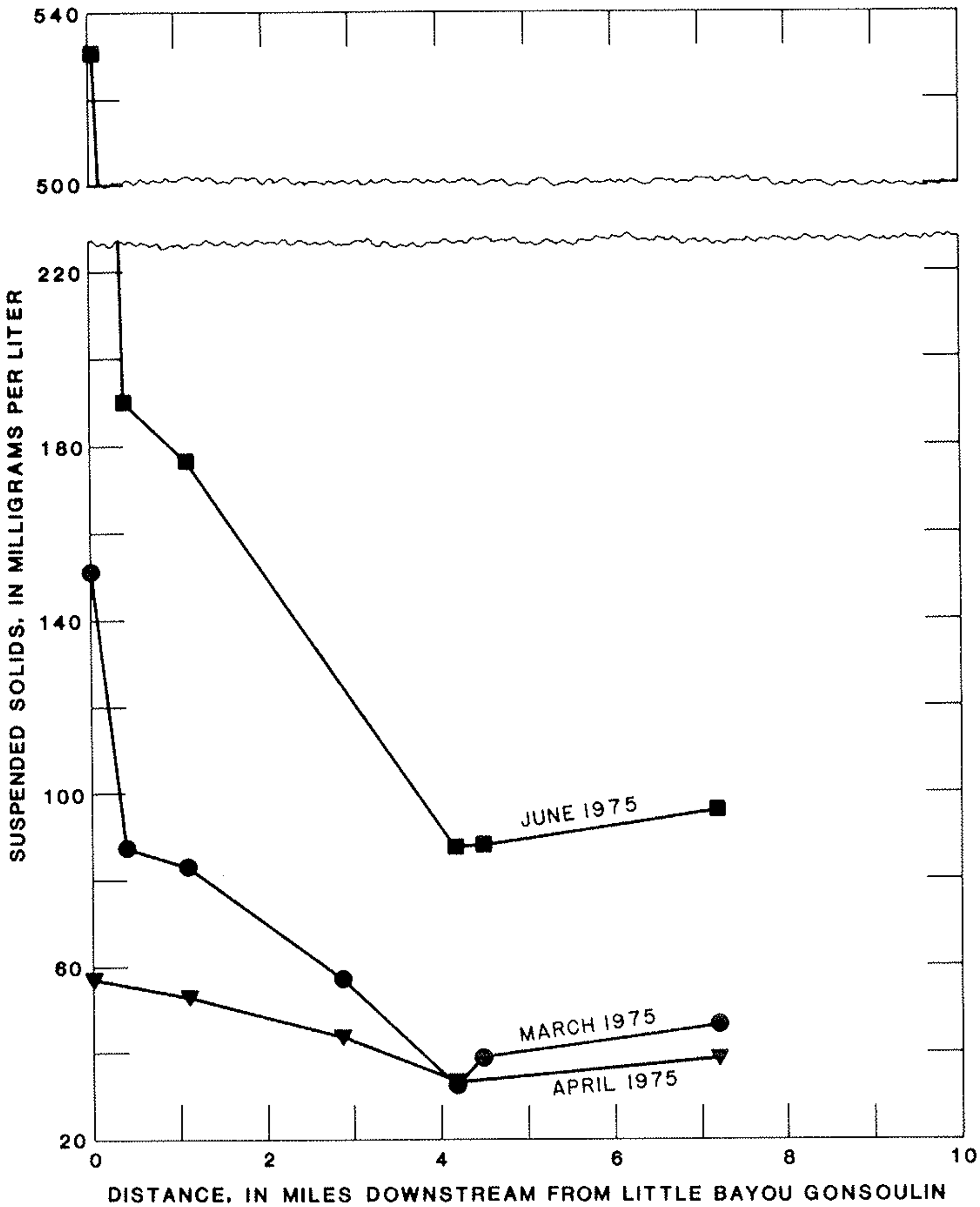


Figure 16.--Variations in concentrations of suspended solids versus distance into Buffalo Cove swamp area.

Concentrations of dissolved iron, dissolved manganese, and dissolved and total zinc are generally less than 50 µg/L. Concentrations of total manganese and total iron generally exceeded 100 and 1,000 µg/L, respectively. The recommended limits of metals in public-water-supply sources and for freshwater aquatic life and wildlife are given in table 8

(National Academy of Sciences-National Academy of Engineering Committee on Water Quality Criteria, 1973). None of the dissolved metals in the Atchafalaya River basin has exceeded these recommended limits.

Table 8.--Recommended limits for maximum concentration of metals[a,b] in public-water-supply sources and for freshwater aquatic life and wildlife and observed concentrations of total metals in Atchafalaya River basin samples

[Concentrations are in micrograms per liter]

Constituent	Recommended maximum concentration in public-water-supply sources	Recommended maximum concentration for freshwater aquatic life and wildlife	Observed concentrations of total metals in the Atchafalaya River basin (1973-75)		
			Minimum	Maximum	Average
Arsenic -----	100	------	2	6	4
Cadmium ---	10	[c]30	0	3	.9
Chromium---	50	50	<10	40	10
Copper------	1,000	(d)	4	11	7
Cyanide-----	20	30	.00	.01	.00
Lead--------	50	30	0	21	10
Mercury-----	2	.2	.00	.12	1.1
Zinc --------	5,000	(d)	0	90	40

[a]National Academy of Sciences-National Academy of Engineering Committee on Water Quality Criteria, 1973.

[b]Alternative criteria may be found in "Quality Criteria for Water" (U.S. Environmental Protection Agency, 1976).

[c]Cadmium should not exceed 30 µg/L in water having a hardness (as $CaCO_3$) exceeding 100 mg/L or 4 µg/L in water having a hardness (as $CaCO_3$) of 100 mg/L or less.

[d]Maximum concentration must be determined using the receiving water in question and the most sensitive important species in the locality.

Analyses of bed-material samples collected throughout the Atchafalaya River basin have shown that concentrations of heavy metals in the bed material are also relatively low. Arsenic concentrations have not been found in excess of 4 µg/g (micrograms per gram), and concentrations of cadmium have been less than 10 µg/g in all samples analyzed. Mercury concentrations in bed material have not exceeded 0.3 µg/g. Copper, lead, and nickel are commonly found in the bed material, but concentrations of these metals have not exceeded 30 µg/g. Chromium concentrations in bed material have ranged from 0 to 60 µg/g, and concentrations of Zinc have ranged from 12 to 57 µg/g.

Pesticides

Pesticides include the many organic compounds used in controlling undesirable plants and insects. Among them are chlorinated hydrocarbons, organophosphorus compounds, and the chlorophenoxy herbicides. The recommended limits for maximum concentrations of pesticides in public-water-supply sources and for freshwater aquatic life and wildlife are given in table 9.

Table 9.--Recommended limits for maximum concentration of pesticides in public-water-supply sources and for freshwater aquatic life and wildlife[1,2]

[Concentrations are in micrograms per liter]

Constituent	Recommended maximum concentration in public-water-supply sources	Recommended maximum concentration for freshwater aquatic life and wildlife
Chlorinated hydrocarbon insecticides		
Aldrin	1	0.01
Chlordane	3	.005
DDT	50	.002
Dieldrin	1	.006
Endrin	.5	.003
Heptachlor	.1	.002
Heptachlor epoxide	.1	.002
Lindane	5	.02
Toxaphene	5	.01
Organophosphate insecticides		
Diazinon	100	0.009
Ethion	100	.02
Malathion	100	.008
Methyl parathion	100	------
Parathion	100	.0004
Trithion	100	------
Chlorophenoxy herbicides		
2,4-D	20	4
Silvex	30	2.5
2,4,5-T	2	------

[1]National Academy of Sciences-National Academy of Engineering Committee on Water Quality Criteria, 1973.

[2]Alternative criteria may be found in "Quality Criteria for Water" (U.S. Environmental Protection Agency, 1976).

Chlorinated hydrocarbons are an important group of synthetic organic insecticides because of their vast number, wide use, great stability, and toxicity in the environment. Chlorinated hydrocarbons sampled in the Atchafalaya River basin include aldrin, chlordane, DDD, DDE, DDT, dieldrin, endrin, heptachlor, heptachlor epoxide, lindane, and toxaphene. These compounds, where detected in the basin, have occurred in concentrations of less than 0.1 µg/L. Dieldrin and endrin, the most commonly occurring chlorinated hydrocarbons, were detected in less than 50 percent of the samples analyzed.

The regulations that have been imposed to restrict the use of chlorinated hydrocarbons have caused the number and usage of organophosphorus insecticides to increase in recent years. Organophosphorus insecticides sampled in the Atchafalaya River basin include parathion, methyl parathion, malathion, and diazinon. These compounds were found in concentrations of less than 0.1 µg/L.

Chlorophenoxy herbicides are used in the control of aquatic plants in streams and reservoirs. The compounds most commonly used are 2,4-D, 2,4,5-TP (silvex), and 2,4,5-T. The herbicide most commonly used in the Atchafalaya River basin in the control of water hyacinth (Eichornia) is 2,4-D. Concentrations of these chlorophenoxy herbicides have not been detected in excess of 0.1 µg/L at Simmesport, La.

In the Atchafalaya Basin Floodway, chlorophenoxy herbicides were present in over 50 percent of the samples analyzed. The most common herbicide found, 2,4,5-T, occurred in approximately 55 percent of the samples. Concentrations ranged from 0.00 to 0.12 µg/L. Concentrations of 2,4-D in the floodway were found in approximately 40 percent of the samples and ranged from 0.00 to 0.30 µg/L.

Samples collected in April 1975 from the bed of the Lower Atchafalaya River contained no detectable concentrations of aldrin, heptachlor, heptachlor epoxide, or lindane. Chlordane and endrin occurred in less than 20 percent of the samples and did not exceed 3 µg/g. Dieldrin, DDD, DDE, and DDT were present in 50 percent of the bed-material samples, Concentrations of dieldrin did not exceed 0.3 µg/g. Concentrations of DDD, DDE, and DDT in the bed material ranged from 0.0 to 2.1, 0.0 to 0.8, and 0.0 to 1.2 µg/g, respectively.

Bacteria[1/]

Concentrations of fecal coliform and fecal streptococci bacteria have been determined for waters in the Atchafalaya River basin since November 1972. Fecal coliform and fecal streptococci bacteria are excellent indicators of fecal pollution from warmblooded animals.

Concentrations of fecal coliform bacteria in samples from the Atchafalaya River basin ranged from less than 5 to 2,400 colonies per 100 mL (milliliters). The highest concentrations occurred in the Atchafalaya River at Simmesport, with approximately 70 percent of the samples having concentrations ranging from 200 to 2,000 colonies per 100 mL. Concentrations of fecal coliform bacteria were lowest in the Atchafalaya Basin Floodway, with less than 200 colonies per 100 mL in 65 percent of the samples.

Concentrations of fecal streptococci bacteria ranged from less than 5 to 7,200 colonies per 100 mL in samples from the Atchafalaya River

1/Criteria for bacteria are listed in "State of Louisiana Water Quality Criteria" (Louisiana Stream Control Commission, 1973).

basin, with 75 percent of the samples having concentrations of less than 200 colonies per 100 mL. Highest concentrations were found in samples from the west swamp areas. Cattle graze in the higher elevations of the swamp and may be the source of the high concentrations of fecal streptococci.

Concentrations of total coliform bacteria in the Atchafalaya River basin ranged from 30 to 10,000 colonies per 100 mL in the samples analyzed. The highest concentrations occurred in samples from the riverine stations, with 55 percent of the samples having concentrations greater than 2,000 colonies per 100 mL.

The probable source of fecal contamination can be determined by establishing a ratio between fecal coliform and fecal streptococci bacteria (Geldreich and Kenner, 1969). In human fecal material the ratio of fecal coliform to fecal streptococci is at least 4 to 1. In the fecal material of other warmblooded animals, the ratio of fecal coliform to fecal streptococci is significantly less. In the Atchafalaya River basin, for approximately 75 percent of the bacteria samples, this key ratio was less than 4 to 1, indicating that the majority of fecal pollution in the basin is from nonhuman sources.

TIME OF TRAVEL OF SOLUTES IN THE ATCHAFALAYA RIVER

Atchafalaya River Main Channel

Time-of-travel information can be used in preventing contamination of public water supplies from accidental spills of toxic chemicals. By knowing the time of arrival, duration, and concentration of the contaminant at downstream locations, withdrawals of water can be discontinued until after the contaminant has passed.

At 11 a.m. on August 26, 1975, 1,600 lb (860 kg) of rhodamine WT, a fluorescent water tracer, was injected into the Atchafalaya River approximately 1 mi (1.6 km) below the confluence of the Red River and the Old River outflow channel. The purpose of this injection was to determine the traveltimes, the maximum concentrations, the dispersion characteristics, and the duration of the tracer cloud as it moved downstream. The results of this study apply only to those solutes whose density and behavior characteristics are similar to those of water. Additional consideration must be taken with materials that are not soluble in water.

The duration (time of passage) and traveltime of solutes vary with discharge. During periods of low flow the velocities in the river are less, and the traveltime of the river between two points is longer than during periods of medium or high flow. Since the traveltime of the river is longer during low flows, a solute or contaminant will have more time to disperse longitudinally than during periods of medium or high flows. This study, which was conducted at a discharge of 137,000 ft^3/s or 3,880 m^3/s (equaled or exceeded approximately 65 percent of the time), is representative of slow traveltimes. Additional studies needed to define the traveltime during periods of medium and high flow have not been conducted.

When a liquid waste is injected into a river, it begins to mix longitudinally, laterally, and vertically. Both longitudinal and lateral dispersion were examined during this study. Lateral mixing is important to downstream users of water. Without lateral mixing, a contaminant could greatly affect a user on one side of the river and have almost no influence on a user on the opposite bank. For this study the tracer was injected into the center of the Atchafalaya River approximately 7 mi (11.3 km) upstream from Simmesport. Samples were collected at Simmesport and Melville to see if lateral dispersion of the tracer had occurred across the width of the river. At Simmesport the tracer had dispersed toward both banks, and the tracer cloud was approximately 1,100 ft (336 m) wide. The tracer had moved to within 100 ft (30.5 m) of the left bank, and to within 200 ft (61.0 m) of the right bank; however, maximum concentrations occurred near the center of the river. The peak concentrations of tracer in the center of the river at Simmesport were much greater than those concentrations observed near the left and right banks (fig. 17).

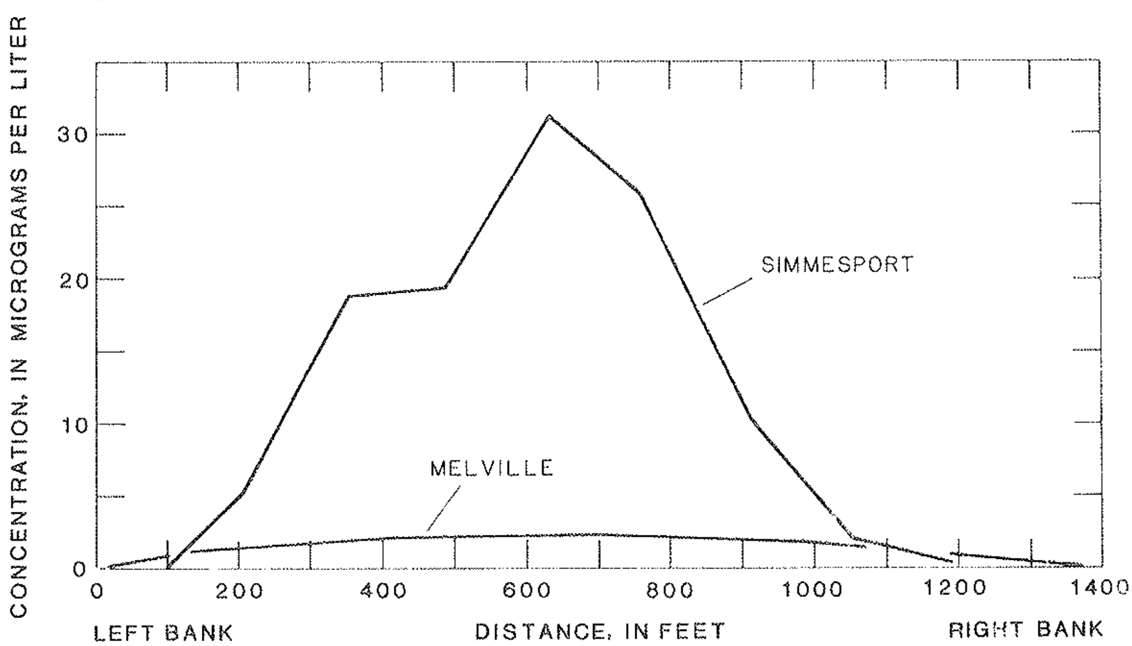


Figure 17.--Lateral dispersion of water tracer at Simmesport and Melville, La.

At Melville, approximately 32 mi (51.5 km) below the injection site, the tracer had dispersed across the entire width of the river. The concentrations of tracer in the center of the river were only slightly higher than the concentrations observed near the left and right bank.

Seven locations were selected along the main channel of the Achafalaya River to determine traveltime and longitudinal dispersion. Sampling locations were located at Simmesport (river mile 5), Melville (river mile 30), Krotz Springs (river mile 42), river mile 74, Myette Point (river mile 95), Morgan City (river mile 118), and just upstream from Sweetbay Lake (river mile 125). The traveltime of the leading edge, peak concentration, and trailing edge of the tracer are shown in figure 18. The leading edge of the tracer reached Krotz Springs approximately 24 hours after injection and reached Morgan City approximately 75 hours after injection. Similarly, the traveltimes for the peak concentrations and trailing edge of the tracer can be determined from figure 18.

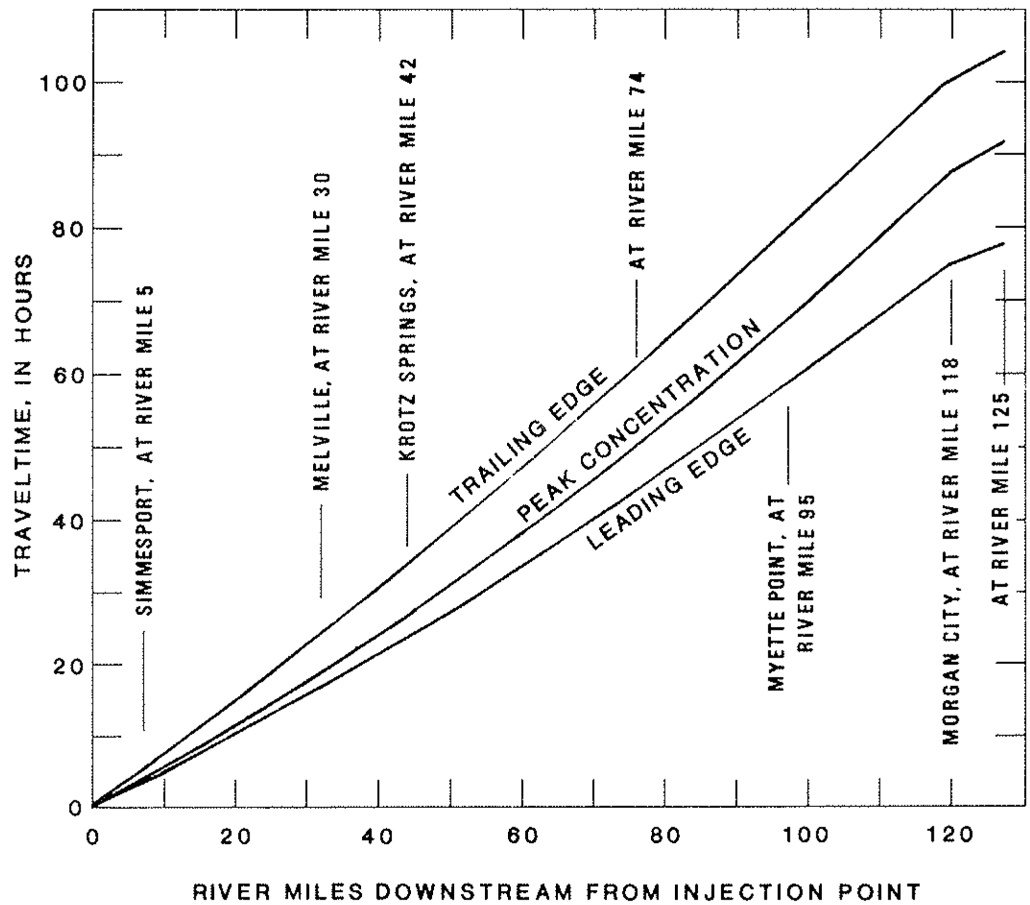


Figure 18.--Traveltime of the leading edge, peak concentration, and trailing edge of water tracer in the Atchafalaya River main channel at a discharge of 137,000 ft^3/s (3,880 m^3/s).

Longitudinal dispersion, or duration of the dye cloud, can be measured in the number of miles occupied by a contaminant or tracer cloud or by the time necessary for the cloud to arrive and to pass a selected site is useful in developing plans for minimizing the effects of contamination. Figure 18 can be used to calculate the approximate longitudinal dispersion of a cloud passing a point at a discharge of approximately 137,000 ft^3/s (3,880 m^3/s) if the time and place of injection of the contaminant are known. For example, assume an accidental spill of a contaminant occurred at Melville at a discharge of approximately 137,000 ft^3/s (3,880 m^3/s) and that the longitudinal dispersion was needed at Morgan City. Using figure 18, it is estimated that the leading edge would arrive at Morgan City in approximately 58 hours (75 hours at Morgan City minus 17 hours at Melville). Similarly, the trailing edge of tracer would pass Morgan City in approximately 75 hours. Hence, the passage time or longitudinal dispersion would be 17 hours (75 hours minus 58 hours). Data from an additional time-of-travel study conducted on the Atchafalaya River at a higher discharge would permit almost any travel-time and longitudinal-dispersion characteristics to be determined for the Atchafalaya River.

In addition to knowing how long a contaminant would be present at a site, it is equally important to know when the peak concentration of the contaminant will arrive and to be able to predict the magnitude of the peak concentration. The arrival time of the peak concentration can be determined from figure 18 in the same manner as was done previously for the leading edge.

The peak concentration can be determined from the following equation:

$$\text{Peak concentration} = \frac{\text{unit concentration times weight of contaminant spilled}}{\text{discharge at the sampling site}}$$

where unit concentration is the peak concentration resulting from 1 lb (0.45 kg) of tracer in 1 ft^3/s (0.028 m^3/s) of water, assuming 100-percent recovery. Knowing the elapsed time a contaminant has been in the water (fig. 18), the unit concentration (fig. 19), and the river discharge, the maximum peak concentration can be computed. For example, if 1,000 lb (454 kg) of a contaminant were spilled in the river at Melville at a discharge of 137,000 ft^3/s (3,880 m^3/s), the peak concentration would arrice in Morgan City in 58 hours. The unit concentration would be 440 µg/L, and the peak concentration at Morgan City would be

$$\text{Peak concentration} = \frac{440 \times 1{,}000}{137{,}000} = 3.2\ \mu g/L.$$

Atchafalaya Basin Floodway

In addition to the tracer sampling in the main channel of the Atchafalaya River, samples were also collected in the major distributaries west of the main channel. Samples were collected in Bayou La Rompe just upstream from its junction with the Atchafalaya River, Lake Fausse Pointe Cut upstream from its junction with Little Bayou Gonsoulin, Little Bayou Gonsoulin upstream from its junction with Lake Fausse Pointe Cut, and in Grand Lake near Myette Point.

At river mile 55 the main channel of the Atchafalaya River divides into two channels: Whiskey Bay Pilot Channel forms the east channel, and the Atchafalaya River-Upper Grand River-Bayou La Rompe system forms the west channel. These two channels merge again at approximately river mile 74. The east channel is 19 mi (30.6 km) long, and the west channel is 23.5 mi (37.8 km) long. At the time of the study the Whiskey Bay Pilot Channel was carrying approximately 90 percent of the flow in the river.

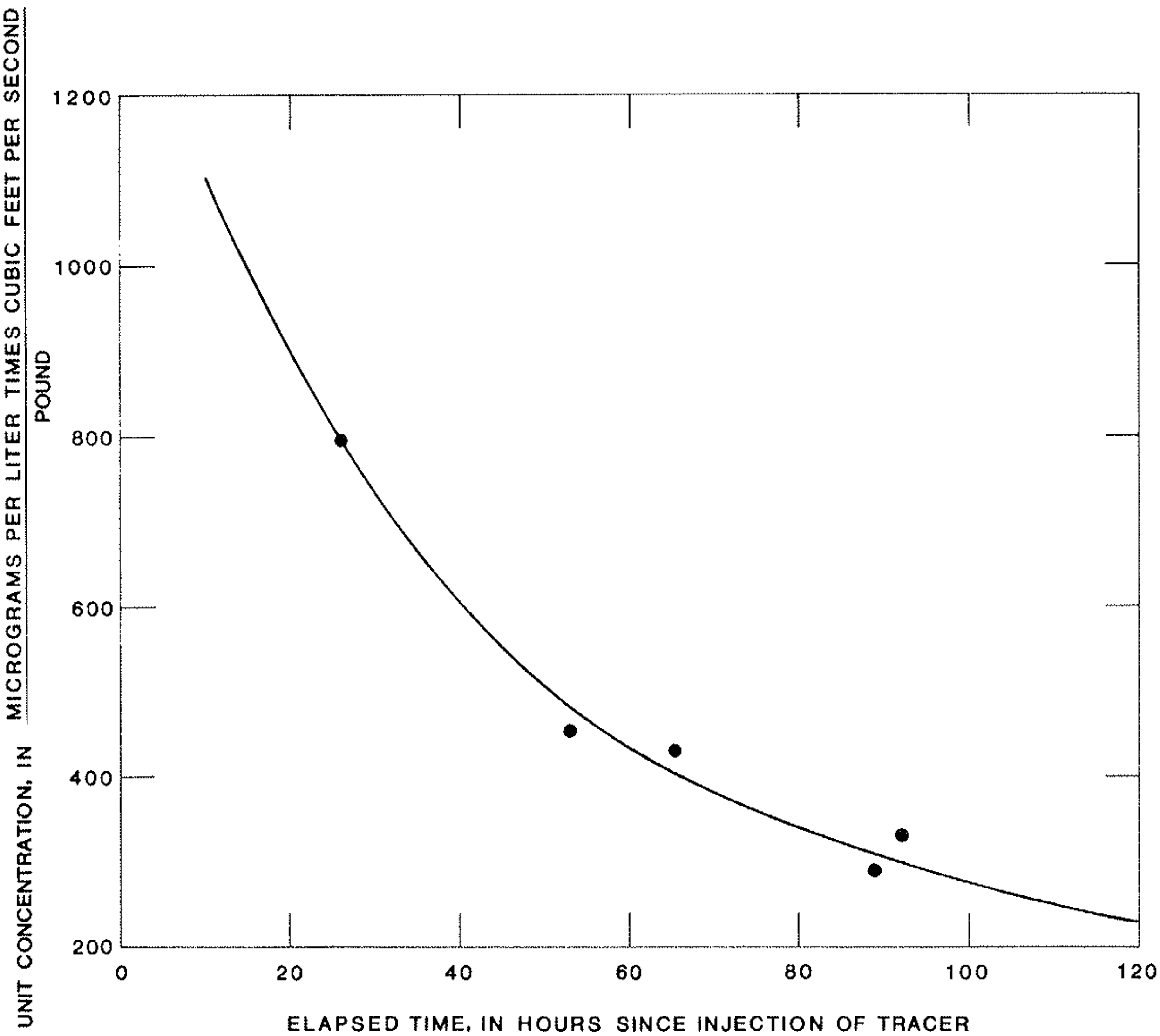


Figure 19.--Unit concentration attenuation curve for the Atchafalaya River.

Figure 20 shows traveltimes of the leading edge, peak concentration, and trailing edge of the tracer for the Whiskey Bay Pilot Channel and the Atchafalaya River-Upper Grand River-Bayou La Rompe system. The traveltime in the west channel is much longer than that in the Whiskey Bay Pilot Channel. The trailing edge of the tracer in the Whiskey Bay Pilot Channel had passed mile 74 (61 hours traveltime) before the leading edge of dye in the west channel had arrived at mile 74 (65 hours traveltime). The duration of the tracer cloud in the Whiskey Bay Pilot Channel at mile 74 was 17 hours, and the duration of the tracer cloud in the west channel was 26 hours.

The traveltime was also measured through the Bayou L'Embarras-Lake Long-Lake Fausse Pointe Cut-Grand Lake system. This system represents

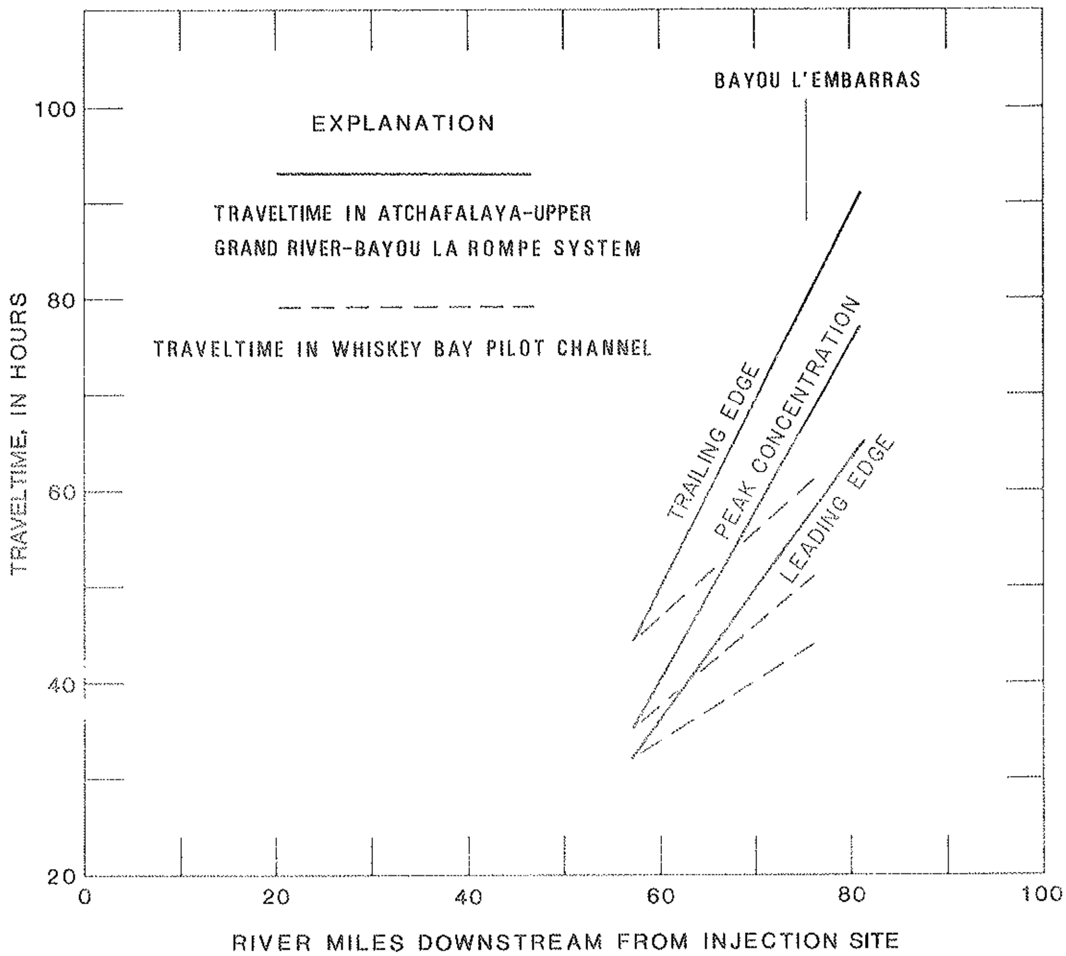


Figure 20.--Traveltime of the leading edge, peak concentration, and trailing edge of tracer for the Whiskey Bay Pilot Channel and the Atchafalaya River-Upper Grand River-Bayou La Rompe system.

a length of 47 mi (75.6 km) of waterway. The discharge in the upper reach of this system in Bayou L'Embarras was 5,030 ft^3/s (142 m^3/s). The discharge in Grand Lake near Myette Point was 10,700 ft^3/s (303 m^3/s). The traveltime through this distributary system is also much lower than that in the Atchafalaya River main channel (fig. 21). The tracer cloud in the main channel of the river had passed Myette Point (80 hours traveltime) before the leading edge of the tracer cloud traveling through the Lake Fausse Point system had reached Myette Point (97 hours traveltime). The duration time of the tracer cloud in the main channel of the river at Myette Point was 21 hours long, and the tracer cloud in Grand Lake at Myette Point was 63 hours long.

The traveltime was also measured through the West Access Channel (Bayou Chene-Alligator Bayou-Little Bayou Consoulin system). The traveltime of the leading edge, peak concentration, and trailing edge of the tracer cloud through the West Access Channel is shown in figure 22.

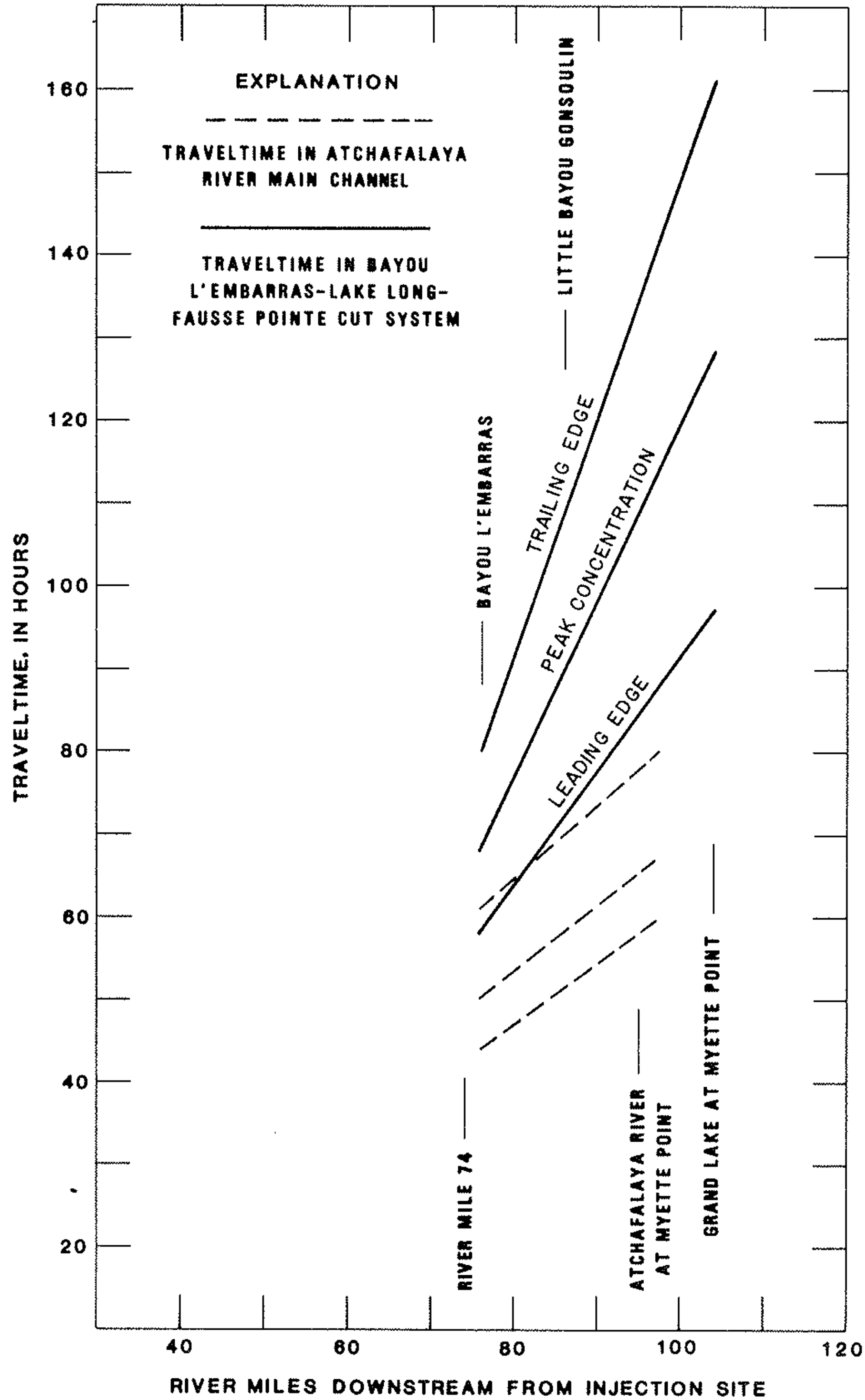


Figure 21.--Traveltime of the leading edge, peak concentration, and trailing edge of tracer in the Atchafalaya River main channel and the Bayou L'Embarras-Lake Long-Lake Fausse Pointe Cut system.

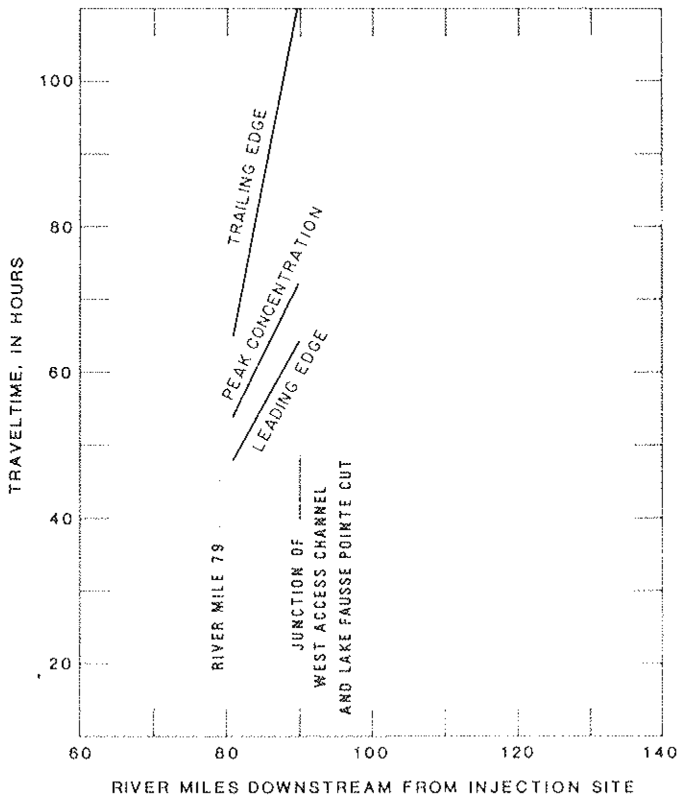


Figure 22.--Traveltime of the leading edge, peak concentration, and trailing edge of tracer in the West Access Channel.

When the tracer entered Bayou Chene at river mile 79, its duration time was 17 hours. When the tracer reached the junction of Lake Fausse Pointe Cut, its duration was 47 hours. The discharge in this distributary was 1,350 ft^3/s (38.2 m^3/s).

WATER-QUALITY CONDITIONS IN THE ATCHAFALAYA BASIN FLOODWAY FOLLOWING HURRICANE CARMEN, SEPTEMBER 1974

Hurricane Carmen crossed the Louisiana coast just west of Morgan City, La., in the early morning hours of September 8, 1974. Once inland, the hurricane followed a northwestward course passing just west of the Atchafalaya River basin. Hurricane-force winds were recorded near the coastal areas south of Morgan City, La., and a total rainfall of 4.28 in (109 mm) was recorded in that city as a result of the storm.

Following Hurricane Carmen, routine sampling on September 10, 1974, in Duck Lake and Flat Lake revealed that hydrologic concitions in these locations were normal. The dissolved-oxygen concentration at station EA, in Duck Lake, was 6.9 mg/L (83-percent saturation), and concentrations in Flat Lake ranged from 6.4 mg/L (76-percent saturation) at station EC 1 to 8.6 mg/L (102-percent saturation) at station EC 4. However, observations in Little Bayou Long and Bayou Postillion on September 14 and 15 indicated that water quality in these locations had deteriorated.

The water had become extremely colored, sulfide gas was detectable in the air, and numerous dead fish were noticed on the surface of the water.

Further investigations in the southeastern part of the Atchafalaya River basin on September 17, 18, and 19 revealed that water quality had deteriorated in an area bordered on the north by Little Bayou Pigeon, on the west by Grand Lake, on the east by the Intracoastal Waterway, and on the south by Morgan City, La. Investigations on the west side of the basin around the Buffalo Cove area indicated that this area had not been affected by the storm.

Hurricane Carmen had its greatest effect on water-quality conditions in the area of Bayou Postillion, Old River, Bayou Long, and Middle Fork Bayou. Dissolved-oxygen concentrations in Bayou Long, Middle Fork Bayou, and Old River were less than 0.2 mg/L, and dissolved-oxygen concentrations in Bayou Postillion ranged from 0.0 to 2.5 mg/L. The low dissolved-oxygen concentrations were due to abnormal demands on oxygen created by a large increase in decomposing organic matter in the waters. This demand is reflected in abnormally high values of biochemical oxygen demand in Old River and Bayou Postillion of 4.1 and 4.3 mg/L, respectively. Specific-conductance values in this area were higher than normal, ranging from 420 micromhos/cm in Bayou Postillion to 560 micromhos/cm in Bayou Long. The pH values in the normally alkaline water ranged from 6.6 in Middle Fork Bayou to 6.9 in Bayou Postillion. Sulfide concentrations in this area ranged from 0.7 mg/L in Old River to 4.1 mg/L in Middle Fork Bayou. Sulfide odor was noticeable in the air in Middle Fork Bayou.

Concentrations of both nitrate nitrogen and nitrite nitrogen were low in this area. Nitrite is a relatively unstable compound and is not commonly found in the Atchafalaya River basin. Nitrate nitrogen is generally found in waters in the basin that are replenished by water from the Atchafalaya River. Concentrations of ammonia nitrogen and organic nitrogen, on the other hand, were found to be higher than normal. Ammonia nitrogen concentrations ranged from 0.19 mg/L in Old River to 0.66 mg/L in Middle Fork Bayou. Organic nitrogen concentrations ranged from 0.94 mg/L in Middle Fork Bayou to 1.0 mg/L in Old River and Bayou Postillion.

Water-quality investigations in other areas of the basin affected by the storm showed similar results. Dissolved-oxygen concentrations of less than 1.0 mg/L were common throughout the area following the storm. The pH of the water was generally less than 7.0. Nitrite and nitrate nitrogen concentrations were less than 0.05, while concentrations of ammonia nitrogen and organic nitrogen ranged from 0.13 to 0.41 and 0.86 to 0.97 mg/L, respectively.

Examination of data collected at the monthly sampling station in Duck Lake shows how the water quality in the southeastern part of the Atchafalaya Floodway was affected by the storm. Data collected over a 16-month period at station EA in Duck Lake show that dissolved-oxygen concentrations ranged from 3.4 mg/L (41-percent saturation) to 10.2 mg/L (88-percent saturation). Dissolved-oxygen concentrations at this station on September 17 and 19 were 0.7 mg/L (9-percent saturation) and

1.4 mg/L (17-percent saturation), respectively. On September 10, 1 week prior to the storm, the dissolved-oxygen concentration at station EA in Duck Lake was 6.9 mg/L (83-percent saturation).

Over the 16-month sampling period the lowest pH value (6.7) and the highest specific-conductance value (433 micromhos/cm) were recorded at station EA in Duck Lake following the hurricane. Likewise, the highest concentrations of ammonia nitrogen (0.19 mg/L), organic nitrogen (0.83 mg/L), and total organic carbon (14 mg/L) and the lowest concentration of nitrate nitrogen (0.01 mg/L) were recorded following the storm.

This deterioration in water quality was probably due to the introduction of large amounts of organic matter into the water as a result of the storm. This increase in organic matter was probably caused by wave action stirring organic matter off the bottom of the bayous. The additional organic material increased the biochemical oxygen demand in the water resulting in lower dissolved-oxygen values.

The higher concentrations of ammonia nitrogen and organic nitrogen along the lower concentrations of nitrate nitrogen may be due in part to bacterial action. The lack of nitrate nitrogen may be due to denitrification. The main product of denitrification under slightly aerobic conditions is ammonia, and under anaerobic conditions the main product is nitrogen. Both ammonia and nitrogen can be converted to organic nitrogen by nitrogen-fixing bacteria. Organic nitrogen can also be a result of decomposition of organic matter. While organic nitrogen is usually converted to nitrate nitrogen, the lack of dissolved oxygen in the water would prevent the formation of nitrate nitrogen.

In the weeks following the storm the inflow of freshwater was not sufficient to provide rapid recovery of water-quality conditions. Dissolved-oxygen concentrations in Old River and Bayou Postillion had increased to approximately 1.5 mg/L by October 9, and the specific conductivity had decreased to approximately 300 micromhos/cm. Dissolved-oxygen concentrations at sampling locations in Middle Fork Bayou and Bayou Long had increased slightly to approximately 0.5 mg/L on October 11, and the specific-conductance values at these two locations had decreased to approximately 400 micromhos/cm. Chemical analyses of water from Old River and Middle Fork Bayou showed that concentrations of ammonia nitrogen, biochemical oxygen demand, and sulfide had decreased. Additional information on water-quality conditions in the Atchafalaya River basin following Hurricane Carmen may be found in the report by Bryan, Demont, Sabins, and Newman (1976).

FINDINGS AND CONCLUSIONS

The Atchafalaya River receives its water from the Red River, the Black River, and the Mississippi River by way of the Old River Control Structure. Ninety-five percent of the time the Mississippi River supplies at least 50 percent of the flow of the Atchafalaya River at Simmesport, La. Since completion of the Old River Control Structure, approximately 30 percent of the flow of the Mississippi River is diverted to the Atchafalaya River. Since 1964, the 50-percent flow duration (median flow) of the Atchafalaya River has increased from 140,000 to 190,000 ft^3/s (3,960 to 5,380 m^3/s). The 7-day Q_{10} low flow has increased from 25,000 to 41,000 ft^3/s (708 to 1,160 m^3/s). Similarly, the 1-day Q_2 high flow has increased from 390,000 to 430,000 ft^3/s (11,000 to 12,200 m^3/s).

Upstream from Interstate 10 the Atchafalaya River divides into the Whiskey Bay Pilot Channel and the Atchafalaya River. At discharges of 410,000 and 137,000 ft^3/s (11,600 and 3,880 m^3/s) at Simmesport, La., the Whiskey Bay Pilot Channel carries 70 and 90 percent of the water, respectively. The largest distributary of the Atchafalaya River (West Freshwater Distributary Channel) generally carries less than 10 percent of the flow that passed Simmesport, La. The East Freshwater Distribution Channel, the East Access Channel, and the West Access Channel each generally carry less than 4 percent of the flow passing Simmesport. Approximately 70 percent of the flow out of the basin is carried by the Lower Atchafalaya River at Morgan City. The remaining 30 percent is carried through Wax Lake Outlet.

The average suspended-sediment load transported past Simmesport, La., is 260,000 tons per day. The median suspended-sediment load is 150,000 tons per day. The maximum recorded suspended-sediment load was 2,120,000 tons per day (March 1968), and the minimum suspended-sediment load was 3,000 tons per day (November 1964). Approximately 25 percent of the suspended-sediment load is sand and 75 percent is silt and clay. Data collected from the August 1975 stream survey indicates that, at relatively low discharges, no net scouring or depositing of sediment is occurring within the study area. At the time of the survey, less than 4 percent of the sediment load measured at Simmesport was carried through any one of the four major distributaries.

The chemical quality of the Atchafalaya River is controlled by the discharge and chemical quality in the Red, Black, and Mississippi Rivers. The dominant anion and cation present in the Atchafalaya River at Simmesport are bicarbonate and calcium, respectively. Because the water in the Atchafalaya Basin Floodway originates from one or more of the distributaries of the Atchafalaya River, the chemical quality in these areas is closely related to the chemical quality of the Atchafalaya River at Simmesport, La. Differences in the inorganic chemical quality between the Atchafalaya River at Simmesport and the west and east swamp areas are more pronounced during periods of low flow.

The primary source of oxygen in the Atchafalaya Basin Floodway is the Atchafalaya River. Dissolved-oxygen concentrations remain relatively high in the main channel and riverine distributaries (ranging from 5.9 to 11.5 mg/L); however, dissolved-oxygen concentrations below 4.0 mg/L are common in swamp areas during low-flow conditions when the water is warm.

Concentrations of nitrogen and phosphorus compounds in the Atchafalaya River basin are relatively low, generally less than 1.5 and 0.15 mg/L, respectively. Similarly, concentrations of chlorinated hydrocarbons, organophosphorous insecticides, and chlorophenoxy herbicides are generally less than 0.1 µg/L. Heavy metals also were found only in low concentrations. Concentrations of dissolved and total arsenic, cadmium, chromium, cobalt, copper, and lead have been less than 10 and 20 µg/L, respectively. Total and dissolved mercury concentrations were not detected in excess of 1.1 and 0.4 µg/L, respectively. In swamp areas of the basin, concentrations of nutrients and suspended solids decrease as distance from the main channel and major distributaries increase.

Concentrations of fecal coliform and fecal streptococci bacteria in the Atchafalaya Basin Floodway generally occur in concentrations of less than 200 colonies per 100 mL. The highest concentrations of fecal coliform occur in the Atchafalaya River main channel, and the highest concentrations of fecal streptococci occur in the west swamp areas of the basin. Most fecal pollution in the Atchafalaya River basin is from nonhuman sources.

Time-of-travel information gathered at a discharge of 137,000 ft^3/s (3,880 m^3/s) indicates incomplete lateral mixing at Simmesport, La., of waters from the Red Red and the Mississippi River. Complete lateral mixing is obtained at Melville, La., approximately 32 mi (51.5 km) downstream from the point of injection. Information on traveltimes of the leading edge, peak concentrations, and trailing edge of the tracer cloud was obtained during the study. Traveltime was much slower in the distributaries in the west side of the floodway than in the main channel of the Atchafalaya River. The duration time of the tracer cloud in the Atchafalaya River main channel at Myette Point was 21 hours, and the tracer cloud in Grand Lake at Myette Point was 63 hours.

The major impact of Hurricane Carmen in September 1974 occurred in the southeastern part of the Atchafalaya Basin Floodway. Dissolved-oxygen concentrations of less than 0.2 mg/L and relatively high ammonia nitrogen 0.19 to 0.66 mg/L) and organic nitrogen (0.94 to 1.0 mg/L) were recorded in this area of the basin. Sulfide was present in concentrations exceeding 4.0 mg/L. Recovery was impeded by the small amount of inflow of freshwater into this part of the floodway following the hurricane.

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