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HYDROLOGIC AND QUALITY CHARACTERISTICS OF THE LOWER MISSISSIPPI RIVER

TECHNICAL REPORT NUMBER 5

Prepared by

U. S. DEPARTMENT OF INTERIOR

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in cooperation with

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1971

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UNITED STATES GEOLOGICAL SURVEY

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by

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U.S. Geological Survey

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HYDROLOGIC AND QUALITY CHARACTERISTICS OF THE LOWER MISSISSIPPI RIVER

By Duane E. Everett

ABSTRACT

Maintaining the suitability of its water for municipal and industrial uses must be included in the proper utilization of the lower Mississippi River. Therefore, an understanding of the hydrologic and quality characteristics is necessary. These characteristics include the effects of industrial development on water quality and the ability of the river to assimilate wastes.

The average daily flow of the Mississippi River at Vicksburg is 551,100 cfs (cubic feet per second), ranging from a high of 2,280,000 cfs on May 4, 1927, to a low of 100,000 cfs on October 17, 1939. However, both extremes preceded control structures and probably never again will be approached.

Sediment concentrations in Mississippi River water at Red River Landing range from about 10 to 2,500 mg/l (milligrams per liter). The average annual suspended-sediment load is 750,000 tons per day, ranging from 288,000 tons per day in 1963 to 1,580,000 tons per day in 1951.

Daily variations in chemical quality are small; the maximum observed daily variation in dissolved-solids concentration at St. Francisville is about 10 mg/l. The concentration of dissolved solids ranges from about 150 to 340 mg/l but is less than 300 mg/l 95 percent of the time. Downstream changes are small between the Arkansas-Louisiana State line and Baton Rouge. Below Baton Rouge, mineralization increases significantly, especially during low-flow periods.

Salt-water intrusion into the Mississippi River from the Gulf of Mexico occurs most of the time but becomes a problem upstream only when river discharge is extremely low.

The temperature of the water in the lower Mississippi River ranges from a low of 1° C (Celsius) to a high of 31° C; however, 95 percent of the time the temperature is equal to or less than 28° C. The temperatures are not affected by thermal loading at medium and high flows, but during low-flow periods water temperatures at Luling Ferry are as much as 3° C warmer than at St. Francisville.

Nearly all cities and towns downstream from Donaldsonville use river

water for public supplies. The total municipal pumpage from the river is about 185 million gallons per day.

Industrial demands for water from the Mississippi River have increased from 2.0 bgd (billion gallons per day) in 1960 to 5.0 bgd in 1969. Approximately 95 percent of this water is returned to the river. The dissolved solids discharged to the river by industry between St. Francisville and Luling Ferry (16 miles above New Orleans) have increased from about 4,000 tons per day in 1958 to about 20,000 tons per day in 1969. Municipal effluent adds less than 1 percent to the waste load discharged by industry. Industries also discharge about 1 million pounds per day of organic wastes into the Mississippi River.

Large amounts of oxygen-consuming wastes are discharged into the river between Baton Rouge and New Orleans; however, the decrease in dissolved-oxygen concentrations generally is less than 1.0 mg/l. The largest decreases occur during the summer; dissolved-oxygen levels have been as low as 4.7 mg/l at New Orleans.

Domestic sewage discharged into the Mississippi River causes high bacterial concentrations. In 1962 the coliform content exceeded 5,000 colonies per 100 milliliters about 13 percent of the time at the New Orleans Carrollton Street intake (mile 104) and about 35 percent of the time at the Algiers intake (mile 95).

Time-of-travel studies using fluorescent dye were made on the Mississippi River to develop techniques for tracing the movement of soluable contaminants. Studies show that when the river is flowing at a rate of 600,000 cfs an accidental spill of 1,000 pounds of contaminant at Baton Rouge would have a peak concentration in New Orleans of 0.83 micrograms per liter 60 hours later. The studies also indicate that under average flow conditions the rate of lateral dispersion of bank-injected contaminants would be about 250 feet per mile in straight reaches of the river.

Curves have been developed to estimate concentration and traveltime for various flow rates at any point downstream from Baton Rouge.

INTRODUCTION

The Mississippi River is of vast economic importance to the United States. It is the source of a great quantity of good-quality water suitable for both industrial and municipal uses. It is navigable by oceangoing vessels as far upstream as Baton Rouge, and by barge traffic for nearly the entire length of the river and into the major tributaries such as the Ohio and Missouri Rivers.

Populations of cities and towns near the river and industrial development along the banks of the river, especially in the reach between Baton Rouge and New Orleans, have increased greatly in the past few years and will continue to increase in the years ahead. Accompanying the population and industrial growth is the increase in municipal and industrial wastes discharged into the river.

With the ever-increasing amount of wastes being discharged into the river, the chemical quality of the water, even in a river the size of the Mississippi, could deteriorate to such an extent as to render it unfit for some present-day uses or, at best, increase the cost of treatment for downstream users.

Purpose and Scope

The purpose of this report is to define the chemical and physical characteristics of water in the lower Mississippi River, the ability of the river to assimilate wastes, the effects of recent industrial development on water quality, the suitability of the water for municipal and industrial uses, and the speed at which waste is transported by the river. The reach of the study area is from the Arkansas-Louisiana State line to the Gulf of Mexico (pl. 1, fig. 1), with the major emphasis between Baton Rouge and New Orleans.

Acknowledgments

The report was prepared as a part of the cooperative program between the U.S. Geological Survey and the Louisiana Department of Public Works. Sediment and streamflow data at Red River Landing and salinity data downstream from New Orleans were provided by the U.S. Army Corps of Engineers. They also made discharge measurements at Baton Rouge and New Orleans during the August 1969 time-of-travel study. The Federal Water Quality Administration furnished a large boat that was used in collecting sediment and chemical-quality samples during the study.

STREAMFLOW

The Mississippi River at its mouth has a drainage area in excess of 1.24 million square miles and is exceeded in size by only the Amazon and the Congo Rivers. Of this area, about 1 percent (13,000 square miles) is in Canada, and the rest is located mainly in the central United States. Tributaries to the river extend a great distance, reaching from the State of New York in the east to Wyoming and Montana in the west.

Some of the largest rivers in this country make up the headwaters of the Mississippi. The drainage area, in square miles; the average discharge, in cubic feet per second; and the average unit discharge, in cubic feet per second per square mile for the four largest of these are listed in the following table.

Drainage area and average discharge of major tributaries of the Mississippi River

Tributary	Drainage area (sq mi)	Average discharge (cfs)	Unit discharge (cfs per sq mi)
Missouri River----	529,400	70,100	0.13
Ohio River--------	203,900	255,000	1.25
Arkansas River----	160,500	45,200	.28
Red River---------	91,400	57,300	.63

The lower Mississippi River, in recent geologic time, has cut a number of channels in its effort to reach the Gulf of Mexico, but flood-control measures have now made this reach fairly stable.

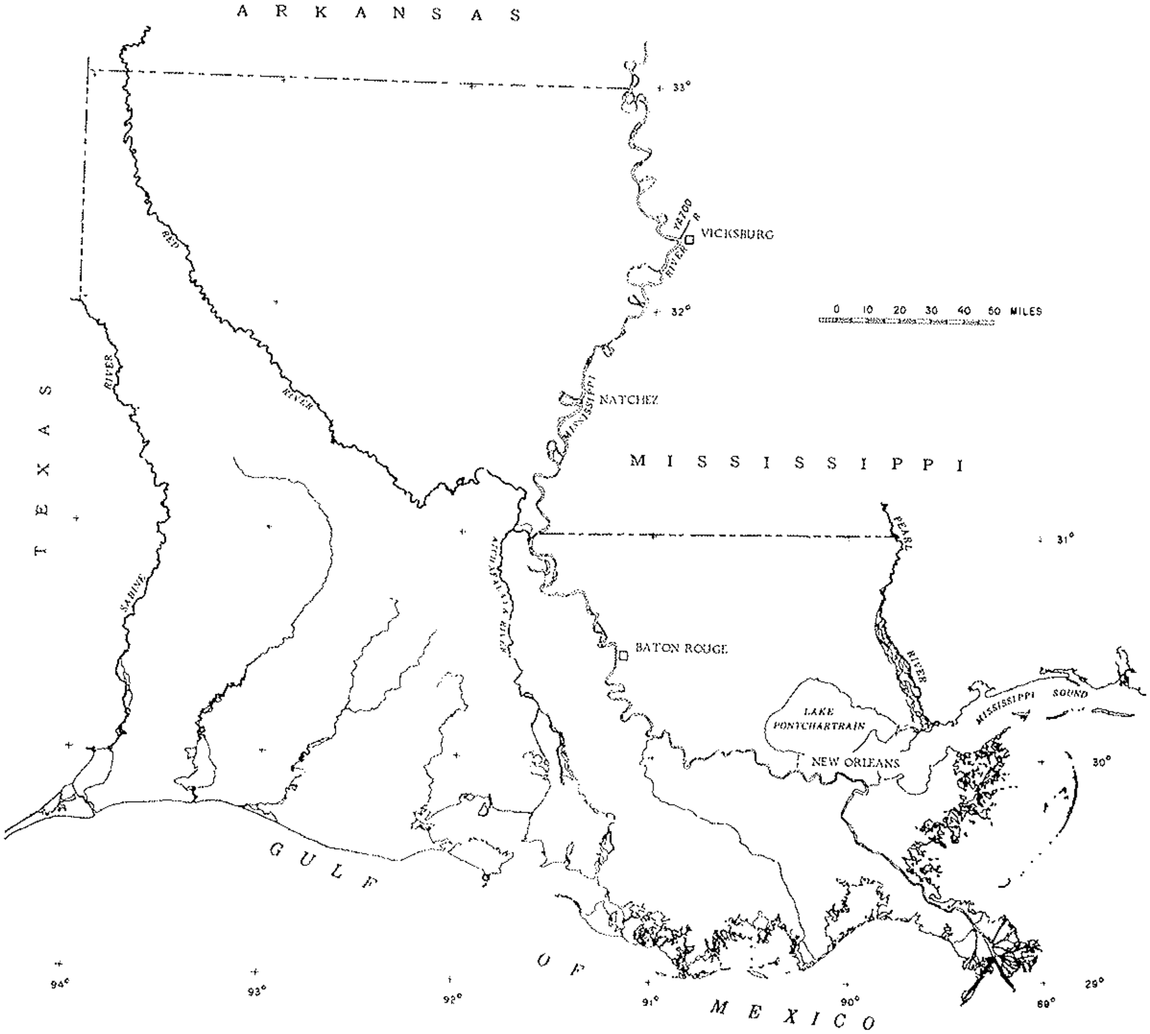

Figure 1.—Study reach of the Mississippi River.

High Flows

Records of annual peak discharges of the Mississippi River at Vicksburg, Miss., have been collected intermittently since 1897, and continuously since 1927. The largest flood during that period occurred on May 4, 1927, when the flow reached 2,280,000 cfs (cubic feet per second) and caused extensive damage in the entire lower Mississippi River valley.

Following this flood, the U.S. Army Corps of Engineers began a vast flood-control program. Flood-control reservoirs were constructed on the major tributaries, and canalization was done on the lower Mississippi River channel. Cutoffs were dug, levees were built, and bank protection was placed to control the river. The canalization not only helped maintain the floods between the banks but, by eliminating 115 miles of river channel through cutoffs between Arkansas City, Ark.,[1] and Angola, La., resulted in a decrease in flood elevation of approximately 7 1/2 feet at Vicksburg. (See fig. 2.) In effect, the cutoffs increased the slope of the river by shortening the distance the water had to travel. This increase in slope caused the velocities to increase and resulted in lower elevations for floods of a given magnitude. Levees have been constructed periodically between Angola and New Orleans since about 1800, but few cutoffs have been dug in this reach. Stage-discharge relationships at Baton Rouge have not changed significantly since the beginning of record in 1925 (fig. 2); however, the elevation of comparable floods may have been lower prior to 1925. Few records of discharge were kept prior to the beginning of levee construction in the Baton Rouge area, but it can be assumed, that owing to the confinement of the river, the flow in the channel and the water-surface elevation has increased.

Unlike canalization, which does not necessarily reduce peak discharges, the storage reservoirs on tributaries are able to store water during high flows, thus reducing the peak discharges in the river. As a result of the increasing number of impoundments, there has been a noticeable reduction in peak discharges, as shown in figure 3.

The magnitudes of peak discharges on the lower Mississippi River in the future probably will not follow the same distribution as those occurring in the past, and therefore a frequency analysis of past record would be of little value. However, it appears that the magnitude of a flood at Vicksburg having a 50 percent chance of being equaled or exceeded in any given year is about 1,300,000 cfs.

When flow in the lower Mississippi River becomes excessive, 1,500,000 cfs at Baton Rouge, it can be partially diverted into the Atchafalaya River through the Morganza and West Atchafalaya Floodways or into the Gulf of Mexico by way of the Bonnet Carre Spillway and the Rigolets.

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[1] Fifty river miles upstream from the Arkansas-Louisiana State line.

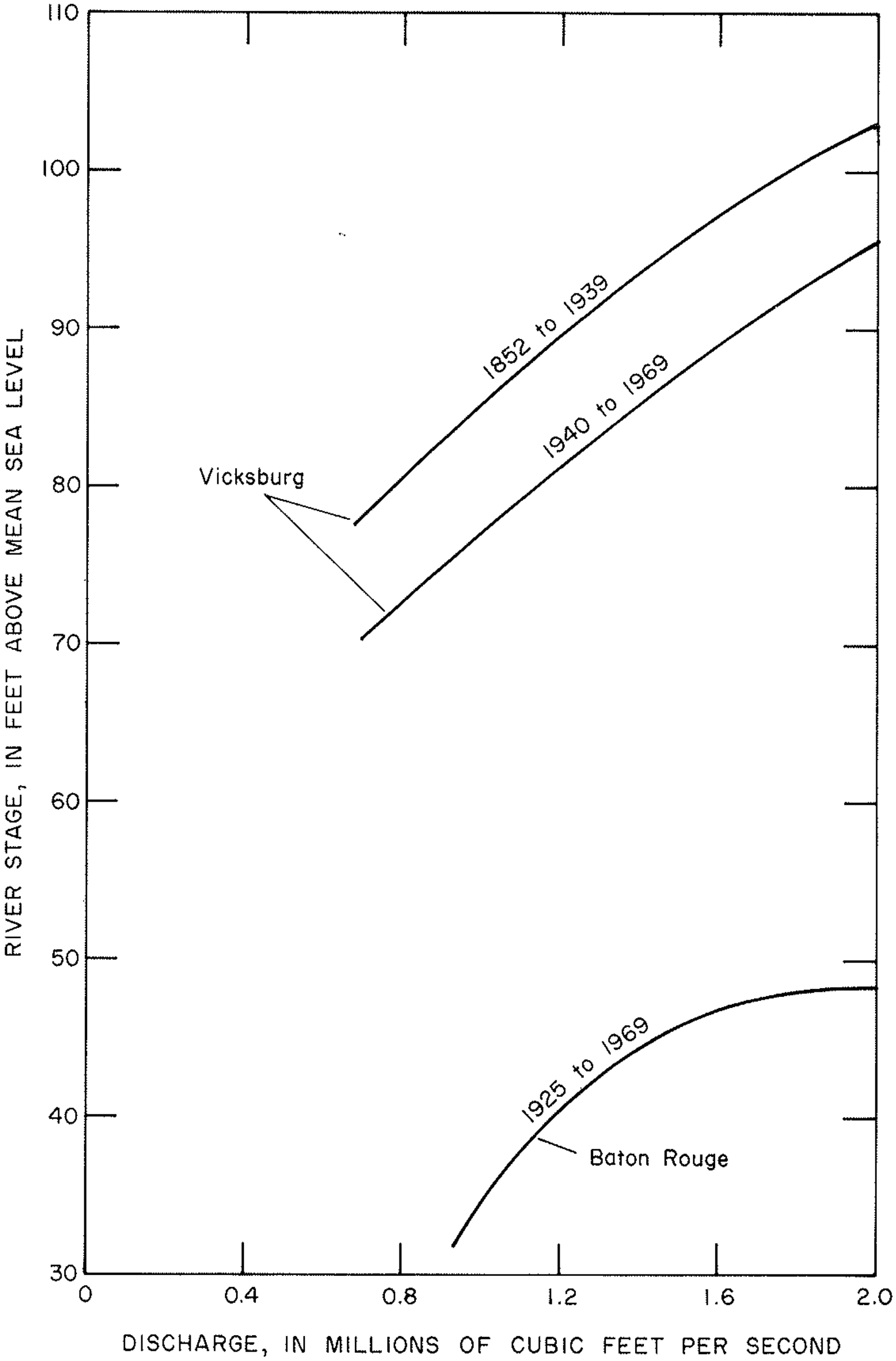

Figure 2.—Average stage-discharge relation for Mississippi River at Vicksburg, Miss., and Baton Rouge, La.

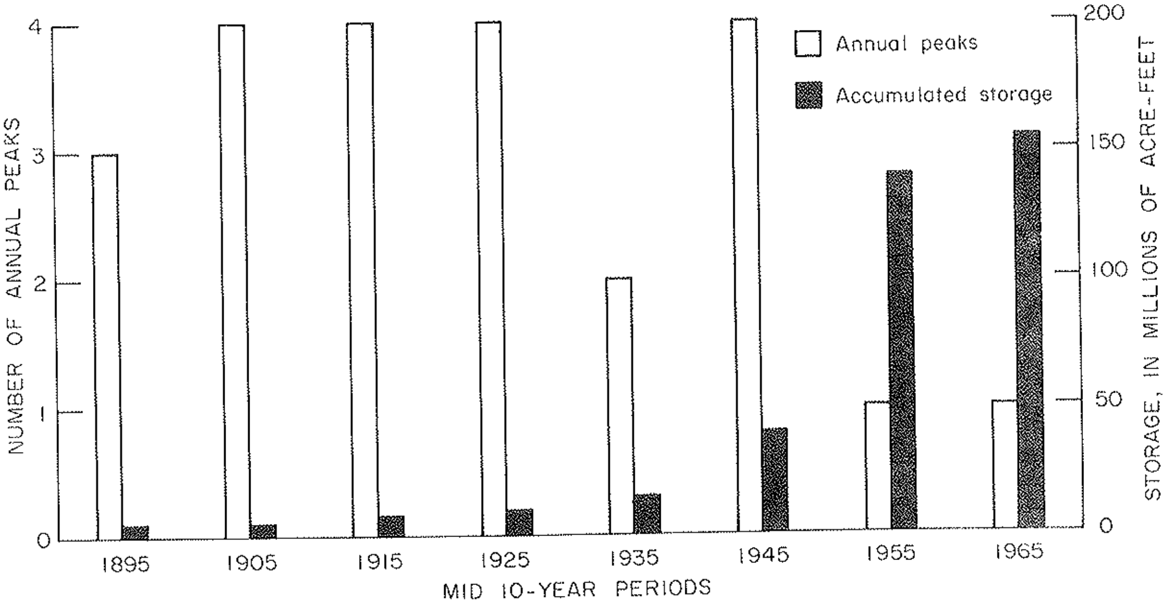

Figure 3.—Number of annual peaks exceeding 1.5 million cubic feet per second and accumulated upstream storage for 10-year time intervals, 1890-1970, Mississippi River at Vicksburg, Miss.

Low Flows

Flow of the lower Mississippi River is affected by diversions into the Atchafalaya River through Old River diversion channel near Coochie, La. Records collected by the U.S. Army Corps of Engineers since 1930 at Red River Landing, a gaging station on the Mississippi River below the diversion, indicate that a minimum daily discharge of 75,000 cfs occurred on November 4, 1939. On this same day the flow into the Old River diversion canal was 13,400 cfs. The minimum daily flow at Vicksburg and Natchez, Miss., during this period was 102,000 and 100,000 cfs, respectively. Discharge measurements of 89,600 and 91,400 cfs were made at Red River Landing on November 3 and 6, 1939. These measurements when added to the 13,400 cfs being diverted into the Atchafalaya River compare favorably with the Vicksburg and Natchez discharges and indicate that the recorded minimum flow of 75,000 cfs for the lower Mississippi River may be somewhat low. A minimum daily flow of 100,000 cfs occurred at Vicksburg on October 17, 1939, and is the lowest daily flow of record. A control structure on the diversion canal was completed in 1963, and minimum flows are now somewhat controlled. As a result, it is doubtful that the daily flow will ever be lower than 100,000 cfs in the lower Mississippi River.

Streamflow records since the completion of storage reservoirs on tributaries indicate that low flows at Vicksburg may have been increased slightly as a result of controlled releases during low-flow periods. However, the length of record is too short and the increase too slight to draw any firm conclusions.

Average Flows

The average flow of the Mississippi River below the diversion channel is probably meaningless as was mentioned for low flows. Conditions that produced these flows, namely uncontrolled diversions, may never exist again. A more realistic appraisal of flow conditions to be expected can be made by using data from the Vicksburg gaging station. Continuous record has been collected at this site since 1931. The average flow of the river during that period was 551,100 cfs. Annual averages ranged from a high of 843,900 cfs for the 1950 water year to a low of 272,000 cfs for the 1931 water year.

Data to estimate the average monthly and average annual flow at Vicksburg have been compiled (Jarvis, 1943). The flow between 1817 and 1931 was estimated on the basis of hydrographs of river stages and rainfall-runoff relationships along with the continuous record since 1931. These estimates by Jarvis indicate a decreasing trend in average flows of the Mississippi River at Vicksburg since 1817 (fig. 4). However, this trend is not apparent since the beginning of continuous record in 1931.

Flow Duration

The discharge for selected duration periods for the gaging stations at Vicksburg and Red River Landing is listed in the following table.

Duration of daily discharge, Mississippi River at Vicksburg, Miss., and Red River Landing, La.

Location	Flow, in cubic feet per second, that was equaled or exceeded for indicated percent of time				
	95	75	50	25	5
Vicksburg-----------	158,000	264,000	432,000	791,000	1,280,000
Red River Landing---	131,000	216,000	361,000	642,000	1,020,000

The data at Red River Landing show the effect of the diversion into the Atchafalaya basin and does not represent natural flow conditions. As the lower flows are now more closely controlled, the 95-percent duration flow is expected to increase in the future.

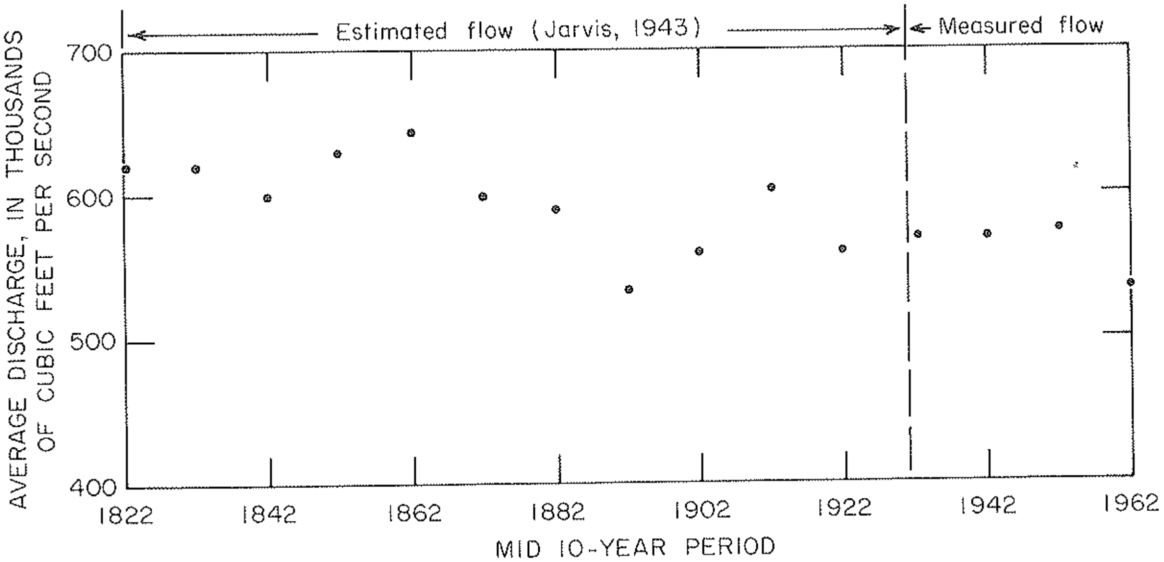

Figure 4.—Average discharge for selected 10-year periods, Mississippi River at Vicksburg, Miss.

SUSPENDED SEDIMENT

Sediment transported by the Mississippi River moves as suspended sediment, or along the bottom as bedload. This report refers only to suspended sediment. An average suspended-sediment load of about 750,000 tons per day is transported past Red River Landing and is ultimately deposited in the Mississippi River Delta or the Gulf of Mexico.

The U.S. Army Corps of Engineers collected sediment samples from the Mississippi River at Baton Rouge from October 1949 through September 1957, and Red River Landing from October 1957 through September 1964 (the Baton Rouge and Red River Landing stations are considered equivalent). Miscellaneous samples at 17 locations on the river were collected by the U.S. Geological Survey during the 1968 and 1969 water years.

The amount of suspended material carried by the river is dependent upon streamflow, turbulence, particle size, and water temperature. Generally, concentrations of sediment at Red River Landing increase as discharge increases (fig. 5); however, the concentration of sediment depends on whether the discharge is increasing or decreasing. On a rising stage, concentrations of sediment are greater than at a corresponding discharge on a falling stage. Peak sediment concentrations in the Mississippi River usually occur before peak discharges. During the initial increase in flow the concentration of sediment increases rapidly, and as long as the supply of sediment particles of a size that the river is capable of transporting is sufficient to meet the carrying capacity of the river, the concentration will continue to rise at a rapid rate. However, because the supply is generally less than the river can transport, the concentration of sediment

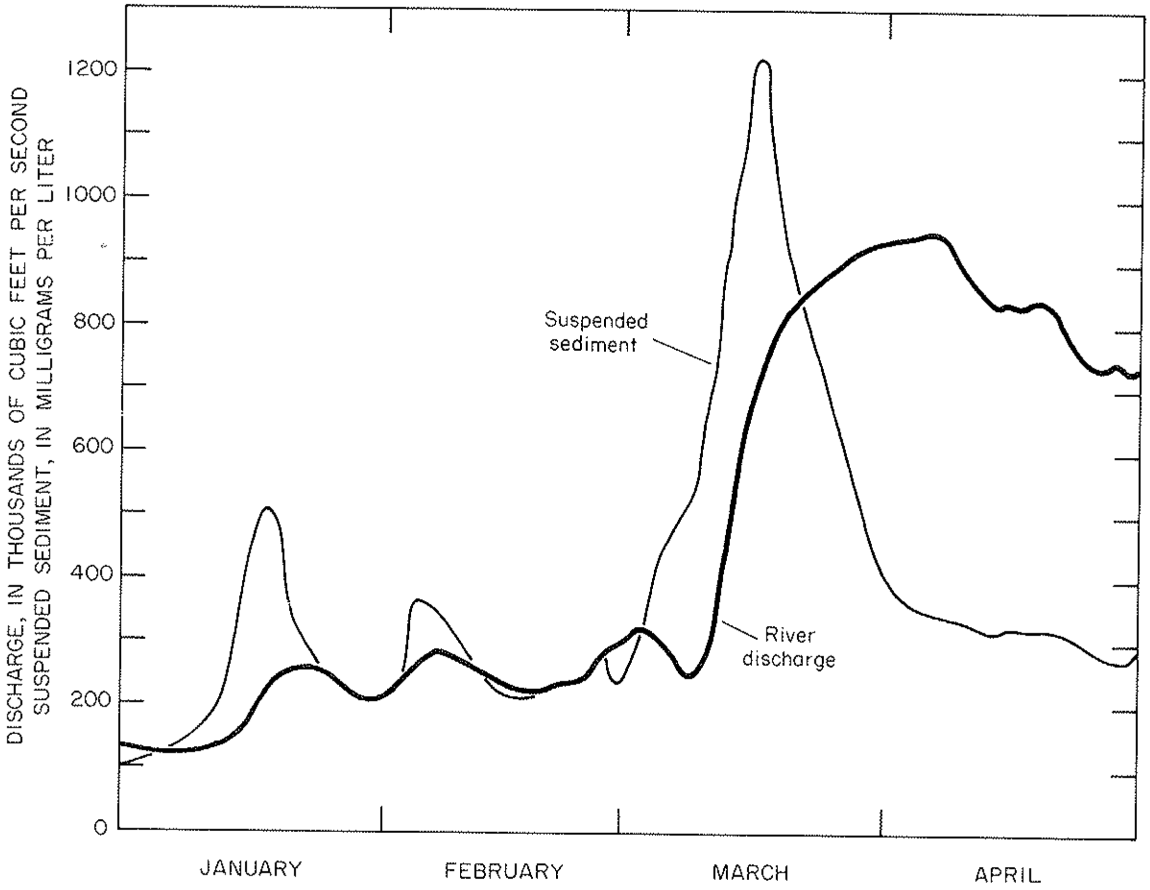

Figure 5.—Relation of suspended sediment to river discharge at Red River Landing, La., January through April 1964.

will decrease as the flow continues to increase and will continue to decrease as the discharge decreases. This is shown in figure 6, where concentration of sediment is plotted with changing river discharge for consecutive days during a flood event on the river at Red River Landing, La. The size and to some degree the shape of the curves in figure 6 depend on flow and antecedent conditions of flow.

Concentrations of sediment in Mississippi River water at Baton Rouge and Red River Landing range from about 10 to 2,500 mg/l (milligrams per liter) with minimum concentrations usually occurring during low-flow periods in the late summer and fall and maximum concentrations occurring during high-flow periods in late winter or early spring. Figure 7 shows the percentage of time concentrations of suspended-sediment are equaled or exceeded. Sediment concentrations were less than 100 mg/l 7 percent of the time and exceeded 1,000 mg/l 8 percent of the time.

The distribution of sediment in the Mississippi River varies greatly with depth (fig. 8). Concentrations of silt and clay size particles

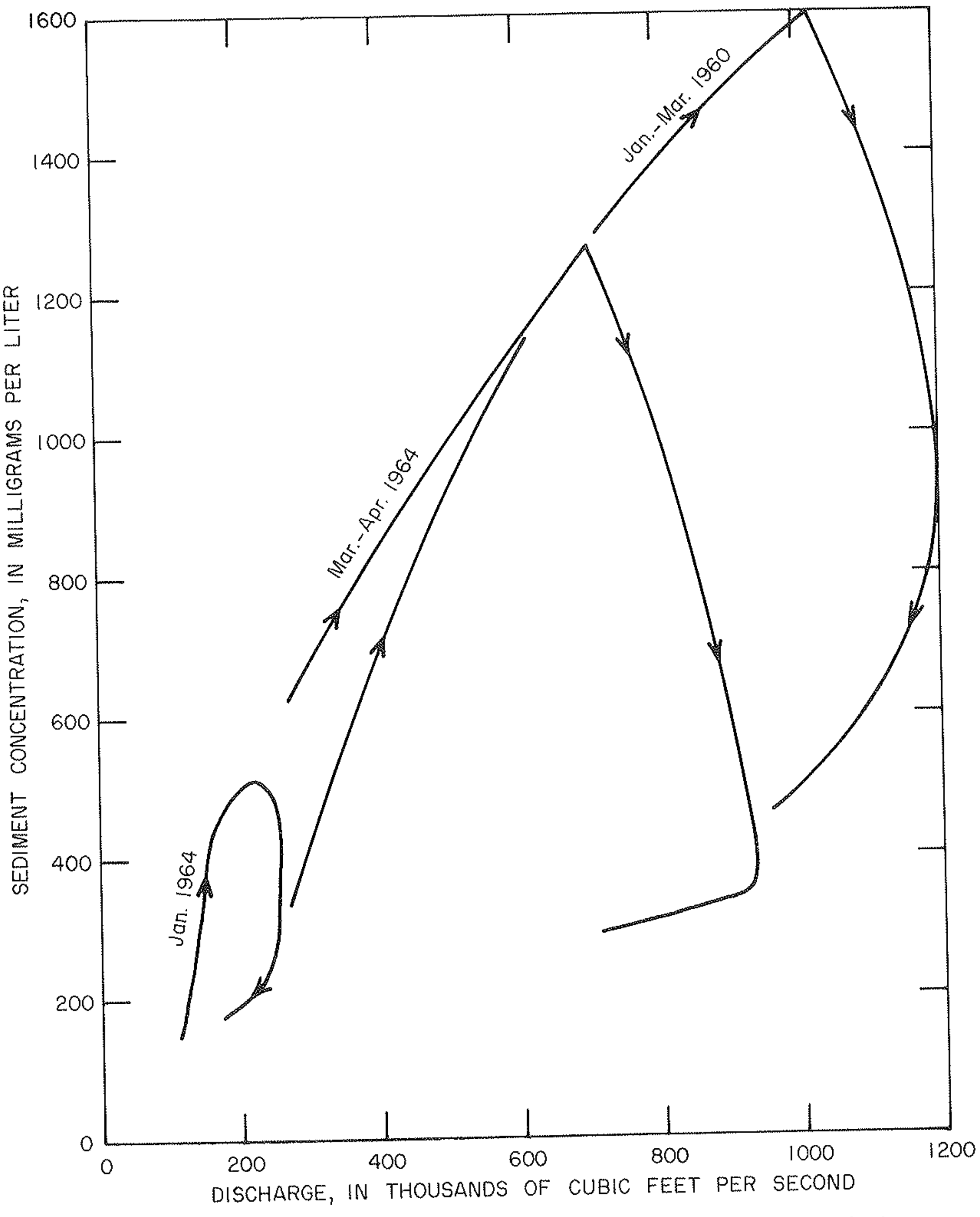

Figure 6.—Relation of sediment concentration to river discharge at Red River Landing, La., for three selected flood events.

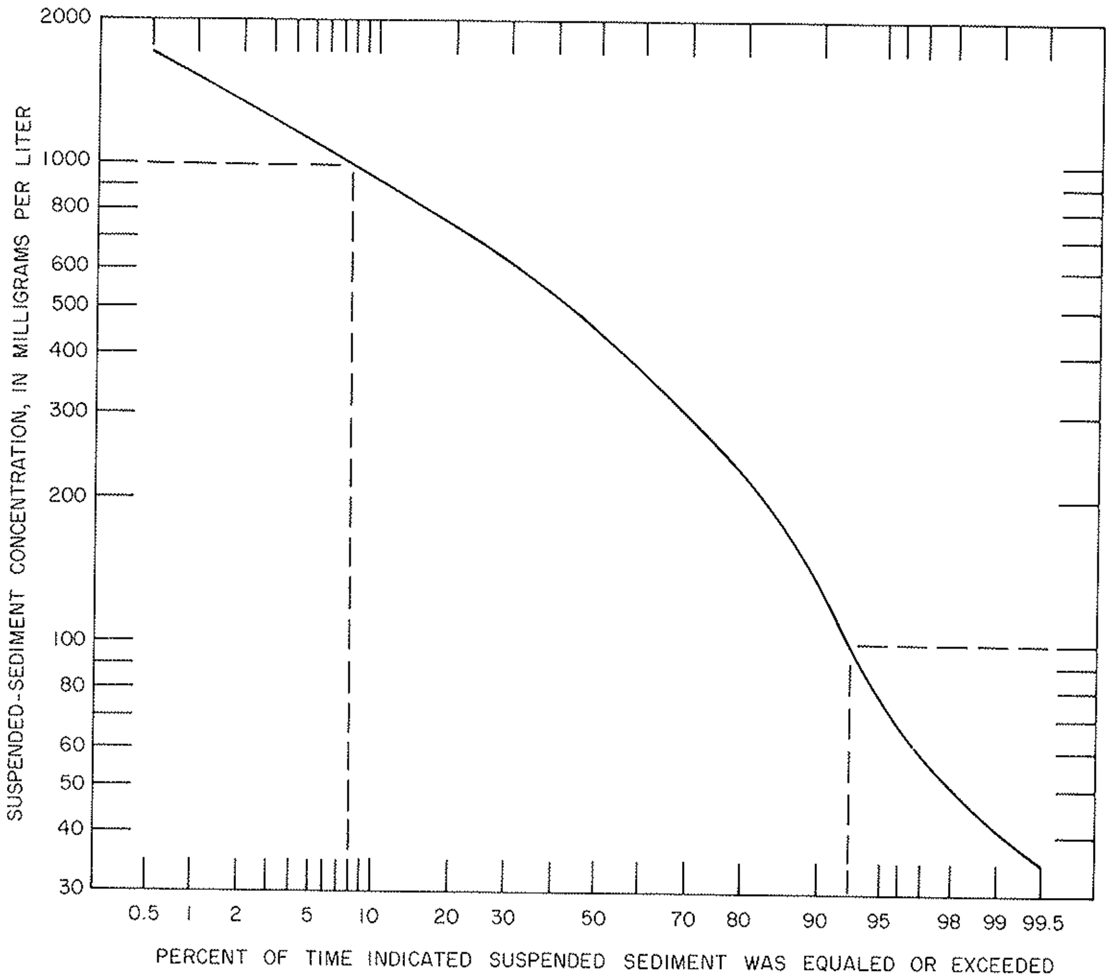

Figure 7.—Duration curve of suspended-sediment concentration at Red River Landing, La., 1949-63.

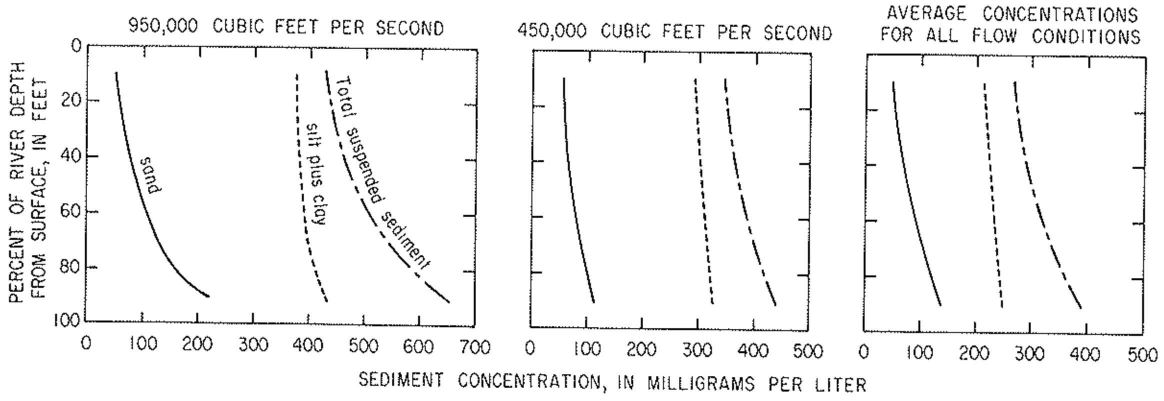

Figure 8.—Variation in sand, silt plus clay, and total suspended sediment with depth at Red River Landing, La.

increase slightly from top to bottom; however, the concentration of sand size particles increases significantly with depth. At a discharge of 950,000 cfs, the concentration of sand size particles near the bottom was more than four times as great as that near the surface. The silt-to-sand ratio at a discharge of 450,000 cfs ranged from about 85-percent silt at the surface to about 62-percent silt near the bottom (fig. 9). The average silt-to-sand ratio for selected flows ranged from about 82-percent silt at the surface to 64-percent silt near the bottom. The following classifications of size have been recommended by the American Geophysical Union Subcommittee on Sediment Terminology (Lane, 1947, p. 937).

Diameter of particle (millimeters)	Classification
2.000-0.062	Sand
.062- .004	Silt
Below .004	Clay

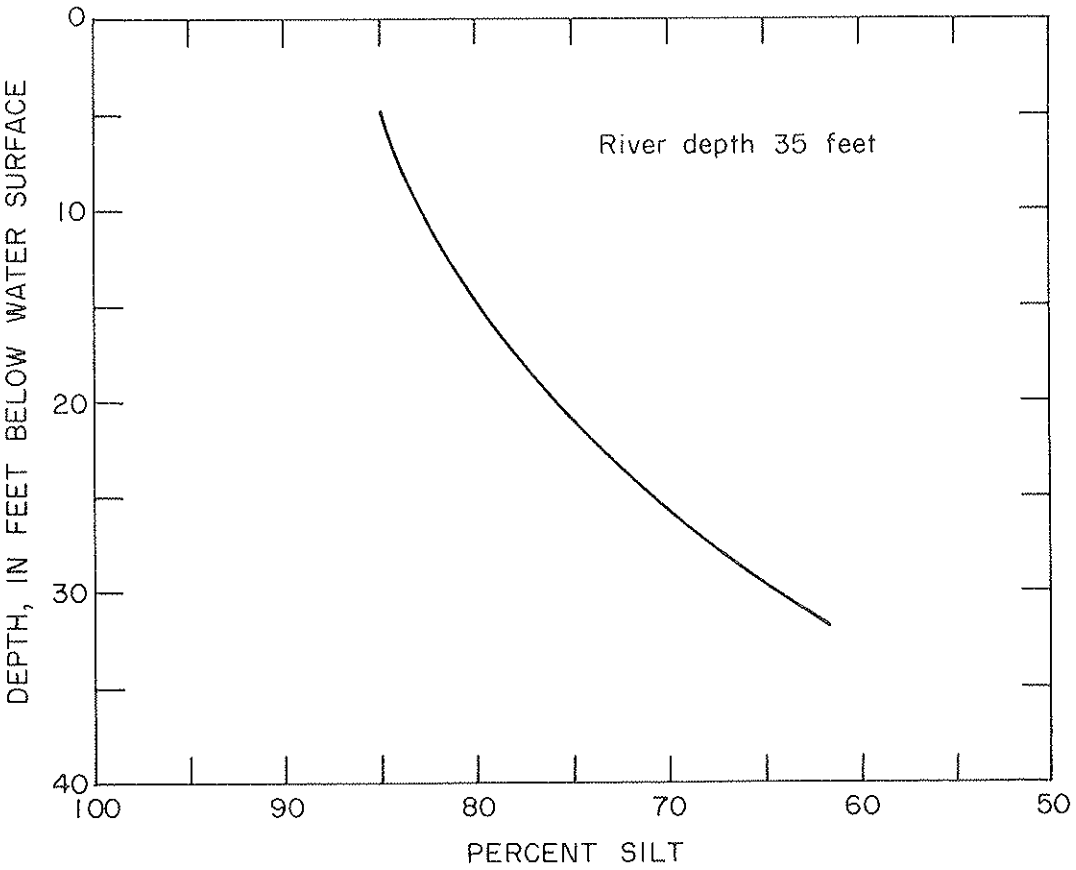

Figure 9.—Relation of silt to sand with depth at a discharge of 450,000 cubic feet per second at Red River Landing, La.

Lateral distribution of sediment does not follow the same pattern as vertical distribution. Sediment inflow from tributaries does not mix laterally for many miles or until the water has moved through one or more meanders. However, data from 17 sampling sites on the river show that the concentration of sediment generally is only slightly greater in the river channel than along the banks.

Sediment concentrations decrease as water moves downstream during low-flow periods and increases as the water moves downstream during high-flow periods (table 1). The decrease during low-flow periods is due in large part to sand deposition because the velocity and turbulence of the river are not great enough to keep the larger particles in suspension. However, during high-flow periods when the velocity and turbulence of the river are greater, some scouring of the riverbed occurs and the sediment concentration increases downstream.

The average annual suspended-sediment load for the period of record, 1949-64, was 750,000 tons per day, ranging from 288,000 tons per day in 1963 to 1,580,000 tons per day in 1951. In 1950, the highest flow year during this period, approximately 45 percent of the total annual load of 548 million tons, (1 1/2 million tons per day) was discharged during the high-flow months of January, February, and March. This amounted to about 2,700,000 tons per day for this 3-month period.

Table 1.--Downstream changes in sediment concentrations at different water discharges, based on field data collected by the U.S. Geological Survey

River mile above Head-of-Passes	River discharge (cfs)			
	950,000	600,000	330,000	186,000
	Sediment concentration (mg/l)			
505 (Arkansas-Louisiana State line)	---	---	301	200
434	380	---	298	---
385	411	---	282	200
366	386	---	277	150
355	393	---	253	160
313	459	---	250	150
267	476	---	254	105
236 (Baton Rouge)	484	380	238	61
225	460	371	---	54
206	492	362	224	38
176	554	383	238	36
150	553	368	211	34
120	580	373	191	32
104 (New Orleans)	617	378	193	35
80	---	391	---	32

The hydrographs of figure 10 show the relation between flow and sediment load. Although sediment load for a given discharge may vary because of antecedent conditions, in general, sediment load increases as flow increases and decreases as flow decreases. Yearly loads, however, may be approximated from the relation between average annual flows and annual sediment loads (fig. 11) because during the course of a year both high and low flows occur, masking the effects of antecedent conditions.

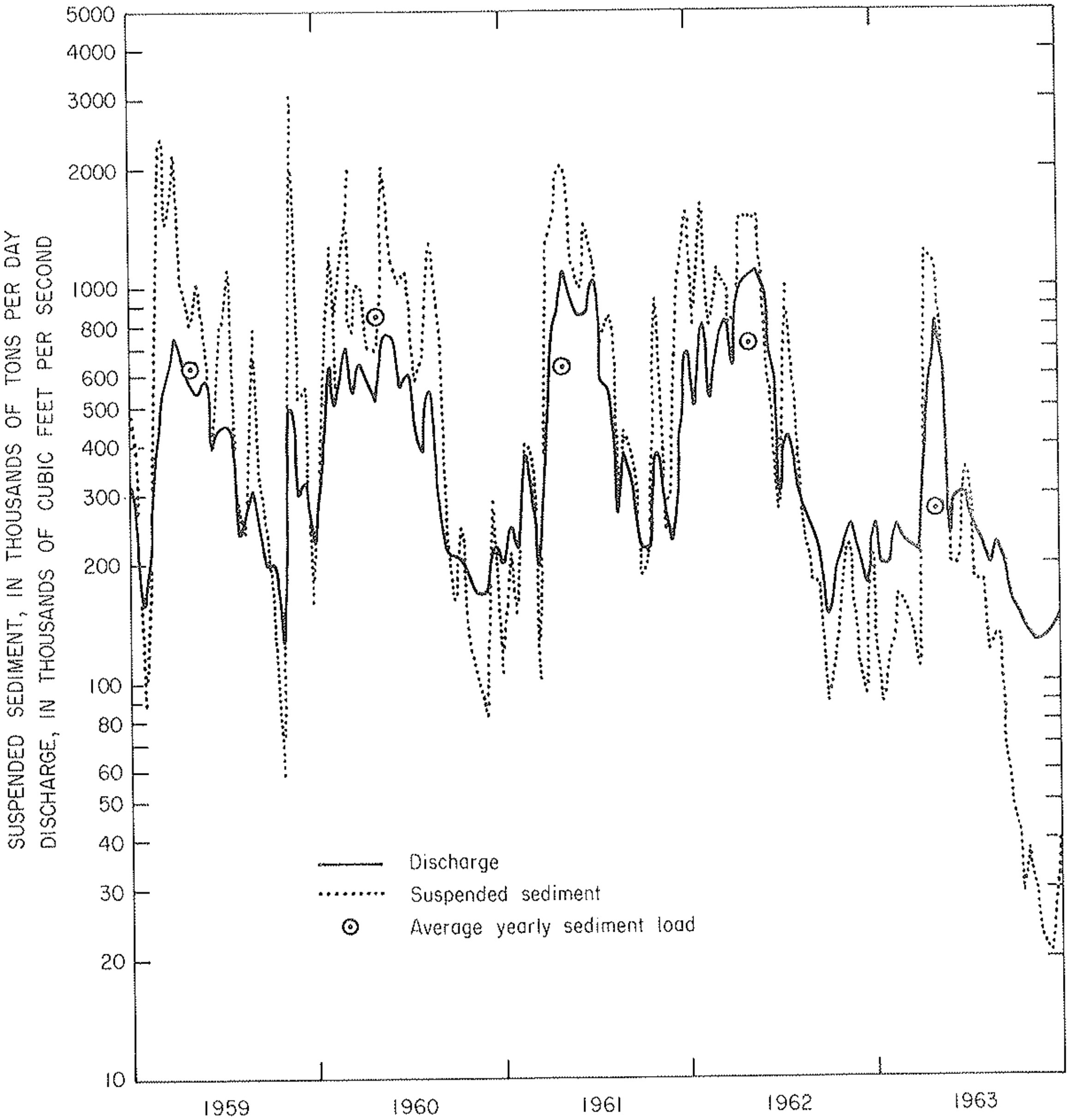

Figure 10.—Relation of suspended-sediment load to discharge at Red River Landing, La., 1959-63.

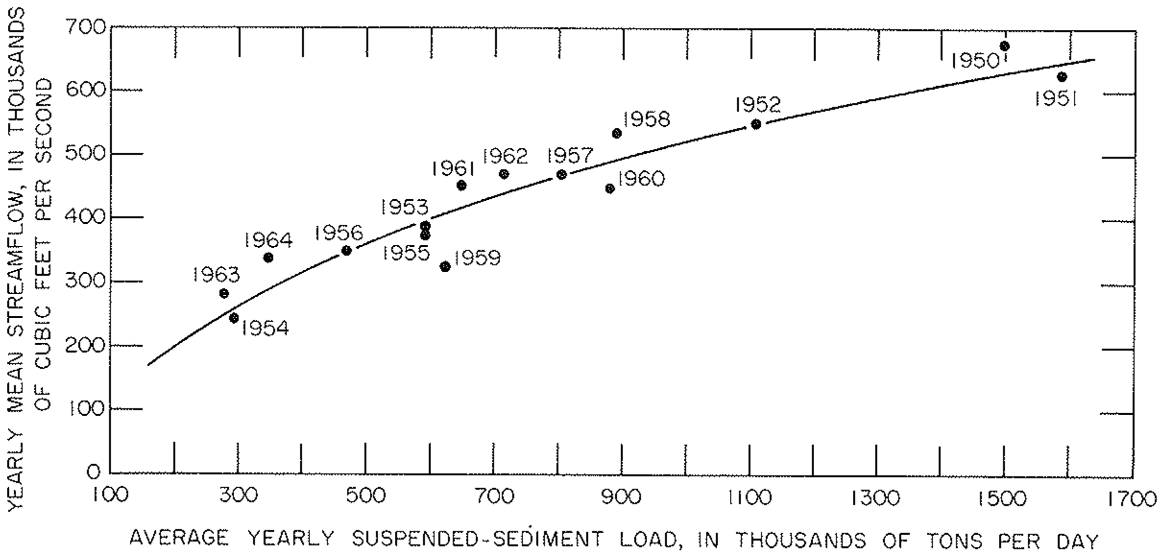

Figure 11.—Relation of yearly mean streamflow to yearly average suspended-sediment load at Red River Landing, La.

CHEMICAL QUALITY

The chemical quality of water in a flowing stream varies with fluctuations in river discharge. Daily fluctuations in Mississippi River discharge are small, and therefore daily variations in chemical quality are small. The maximum observed daily variation in concentration of dissolved solids was about 10 mg/l.

Mineralization of the river water changes very little as the water moves downstream from the Arkansas State line (mile 505) to Baton Rouge, (mile 236) (table 2). At a discharge of 186,000 cfs the specific conductance decreased from 502 micromhos at mile 505 to 473 micromhos at mile 236. The decrease was due mainly to inflow from the Yazoo and Big Black Rivers, which are less mineralized. No appreciable differences in mineralization were found with depth, and the only cross-sectional differences were found downstream from Vicksburg. At mile 434 about 3 miles below the mouth of the Yazoo River the concentrations of chloride, sulfate, and bicarbonate were less along the left bank (table 2). Again, this was due to dilution by inflow from the less mineralized Yazoo River. In the reach of the river between Baton Rouge and Belle Chasse (mile 76) the specific conductance increased from 473 to 568 micromhos. Chemical constitutents accounting for most of this increase were chloride, sulfate, sodium, and calcium. Chloride showed the greatest increase, increasing from 28 to 47 mg/l. The increase was due to industrial and municipal waste effluents.

Data collected at St. Francisville are used to define the chemical quality of the Mississippi River before it enters the Baton Rouge-New Orleans industrial area. Ranges in concentrations of the chemical and physical characteristics of the Mississippi River near St. Francisville

Table 2. --Chemical analyses of water collected in September 1968 from 14 locations on the Mississippi River, to show downstream changes in river quality

Location (river mile)	Specific conductance (micromhos)	Bicarbonate (mg/l)	Sulfate (mg/l)	Chloride (mg/l)	Hardness (mg/l)	pH
505 (Arkansas-Louisiana State line)	502	172	70	28	184	7.7
442	505	176	69	29	184	7.7
434 (Yazoo River)						
near left bank	469	168	63	25	174	7.8
near center	501	174	69	28	181	7.8
near right bank	502	176	69	28	183	7.8
385	491	175	66	27	182	7.8
366	471	175	70	27	182	7.8
355	470	176	68	27	181	7.9
313	470	173	67	28	181	7.8
267	471	174	66	28	182	7.8
236 (Baton Rouge)	473	178	67	28	184	8.0
225						
near left bank	520	178	67	39	190	7.9
near center	503	178	66	30	184	7.9
near right bank	494	177	66	28	182	7.9
206	536	178	67	40	186	7.9
150	543	178	--	--	195	8.0
137	542	180	--	--	190	8.0
120	539	180	70	42	194	8.0
104 (New Orleans)	537	182	71	42	196	7.9
76	568	182	76	47	198	8.2

Table 3.--Variation in chemical and physical characteristics of the Mississippi River near St. Francisville, La., with the range of streamflow, 1954-68

Chemical constituents, in milligrams per liter; discharge in thousands of cubic feet per second

Characteristics	Range in concentration	Percent of time values were equal to or less than those shown										
		95	90	80	70	60	50	40	30	20	10	5
Silica	2.6-15	-----	---	---	---	---	---	-----	-----	-----	-----	-----
Calcium	25-61	50	48	46	44	42	40	38	36	34	32	31
Sodium	7.1-50	33	29	26	23	21	19	17	15	13	11	10
Magnesium	2.7-24	15	14	13	12	11	10	9.5	9.0	7.8	6.8	6.2
Bicarbonate	69-174	164	156	146	138	131	125	118	111	103	93	86
Sulfate	28-89	73	67	61	56	52	48	45	42	39	35	33
Chloride	11-44	35	31	28	26	23	21	20	18	16	14	13
Fluoride	.1-1.0	-----	---	---	---	---	---	-----	-----	-----	-----	-----
Nitrate	.2-7.9	-----	---	---	---	---	---	-----	-----	-----	-----	-----
Hardness	85-257	185	176	165	156	149	142	136	129	122	112	105
Dissolved solids	152-342	300	283	264	250	240	230	220	210	200	185	174
Specific conductance[1]	194-645	535	490	450	425	400	380	360	335	310	280	260
Color[2]	5-100	50	---	---	15	---	10	-----	-----	-----	-----	-----
Temperature (° C)	1-31	28	27	26	23	21	18	14	11	9	7	5
Discharge	-------	1,000	900	710	570	450	360	290	240	195	150	130

[1] Micromhos at 25° C.

[2] Units of the platinum-cobalt scale.

and duration of occurrence are shown in table 3. The river water contains a variety of ions, but calcium and bicarbonate generally predominate.

The dissolved-solids content of water from the river varies inversely with streamflow and is less than 300 mg/l 95 percent of the time (fig. 12). The percentage of individual chemical constituents in the dissolved-solids content of the river water also change as river discharge changes (table 3). The percentage of sodium and chloride increases from 8 percent at high flow (1,000,000 cfs) to 12 percent at low flow (130,000 cfs). Calcium and bicarbonate decreases from 23 percent and 32 percent, respectively, at high flow to 18 percent and 28 percent, at low flow. The percentage of sulfate and magnesium remains fairly constant at all flow conditions.

Specific conductance, a measure of the ability of water to conduct an electrical current, is related to the number and types of ionized substances in solution. Because of simplicity of determination, conductance is used to estimate dissolved-solids content and hardness (fig. 13) as well as the concentrations of several chemical constituents (fig. 14). Dissolved-solids content in milligrams per liter of Mississippi River water is about 63 percent of the conductance. Although the relationships of dissolved-solids content and hardness to specific conductance were excellent, the relationship of individual ions, such as sulfate and chloride, to conductance was less precise. For example, at a conductance of 400 micromhos

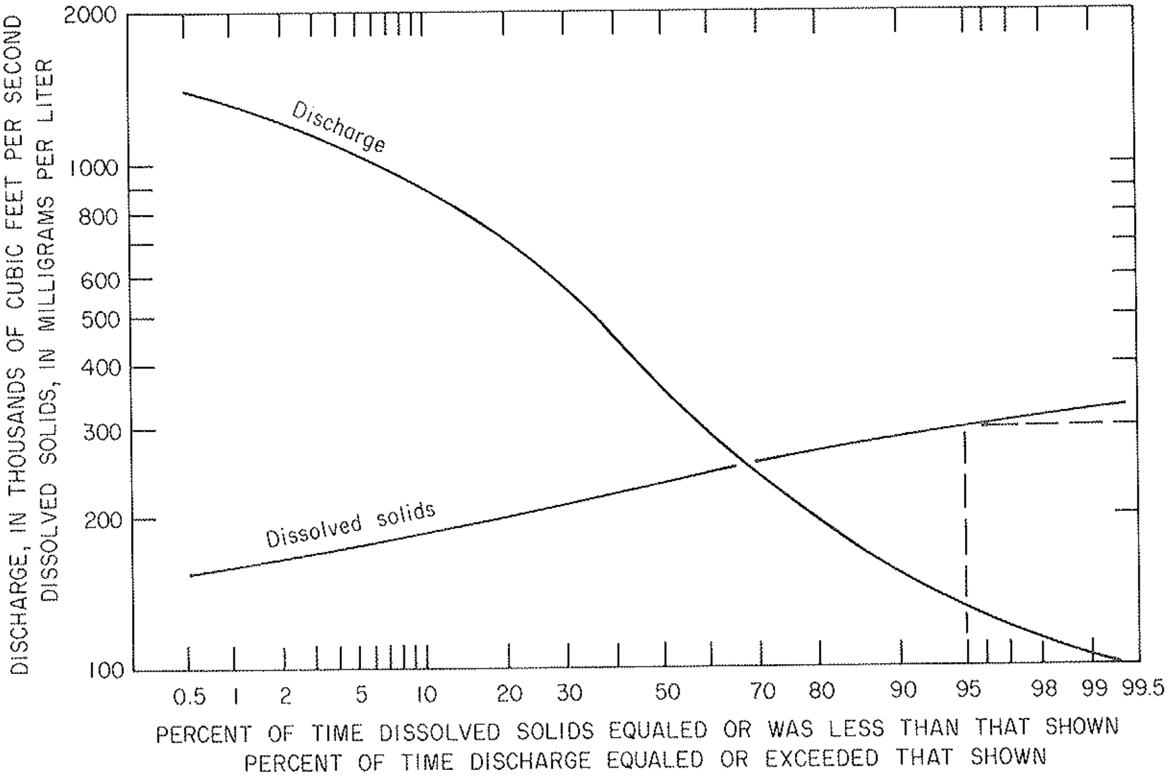

Figure 12.—Duration curves of dissolved solids and discharge for Mississippi River near St. Francisville, La., 1954-68.

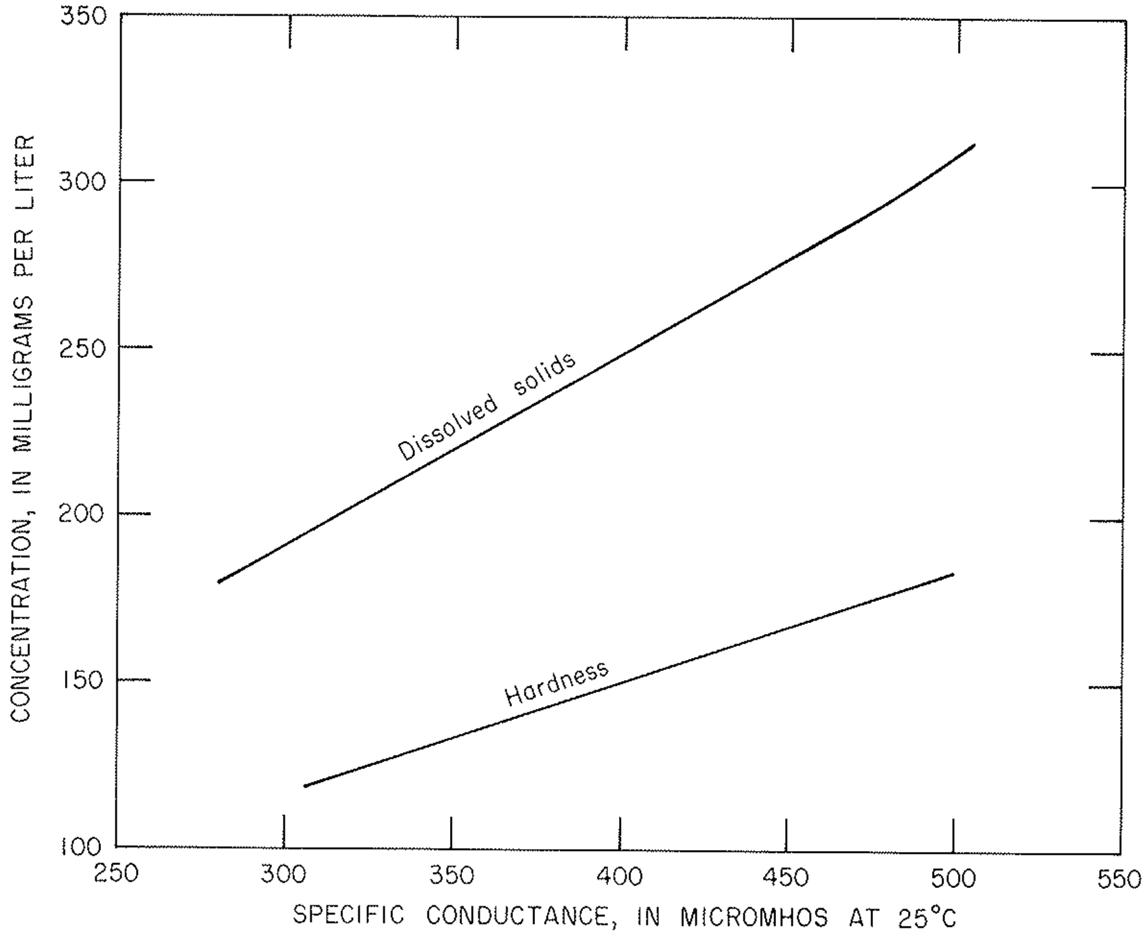

Figure 13.—Relation of specific conductance to dissolved solids and hardness for Mississippi River near St. Francisville, La.

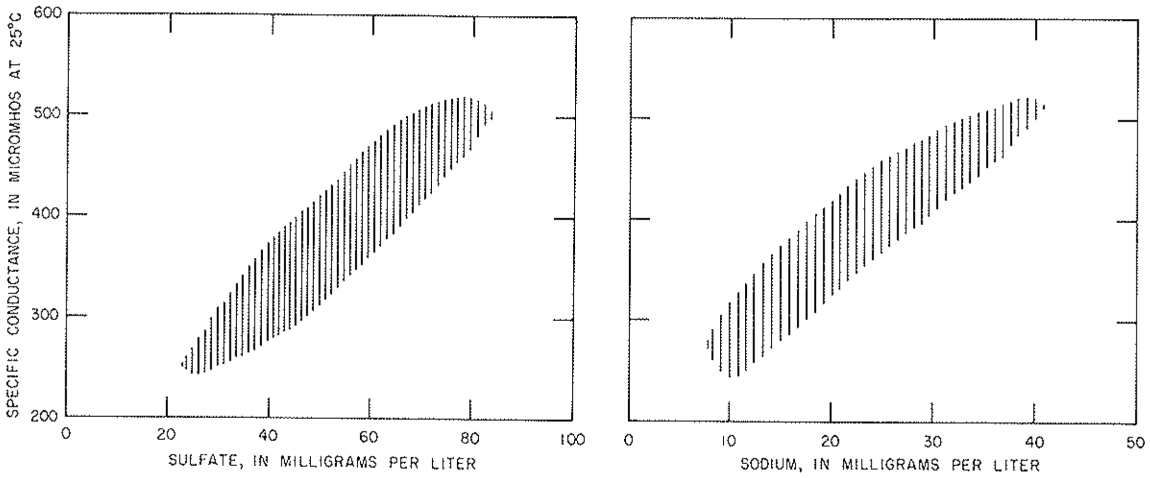

Figure 14.—Relation of specific conductance to sodium and sulfate for Mississippi River near St. Francisville, La.

the concentration of sulfate varied from 44 to 68 mg/l. Conductance also is inversely related to discharge (fig. 15) and decreases as discharge increases. However, this relation varies depending on whether the discharge is increasing or decreasing. On a rising stage the conductance is greater than at a corresponding discharge on a falling stage. (See fig. 15.)

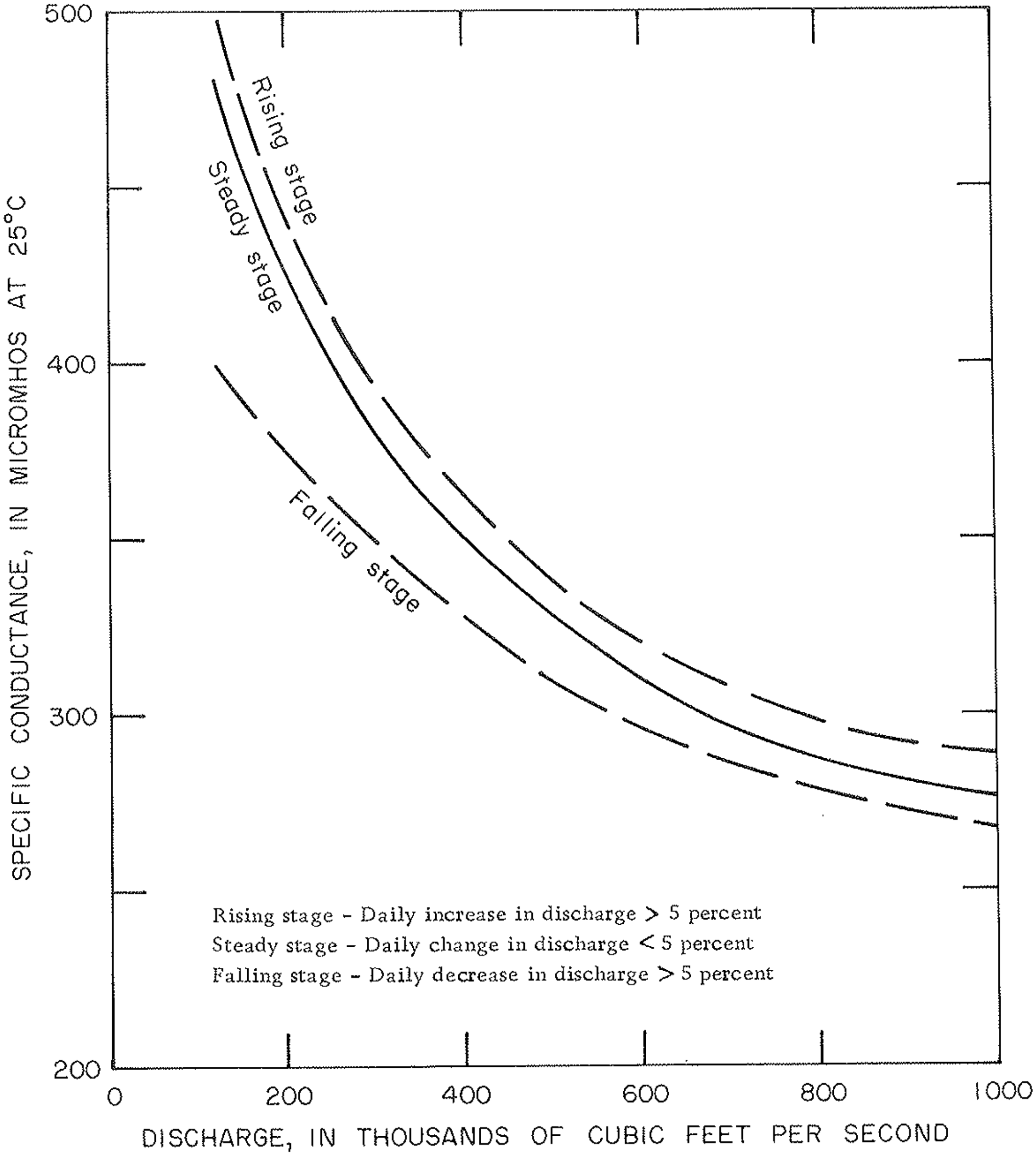

Figure 15.—Relation of specific conductance to discharge for Mississippi River near St. Francisville, La.

Monthly discharge and specific-conductance duration curves (fig. 16) show the relationship between discharge and specific conductance, and the percent of time they exceed or are less than values shown. For example, during the month of April discharge exceeded 400,000 cfs, and specific conductance was less than 390 micromhos, 90 percent of the time, based on records from 1954 to 1967. This conductance corresponds to a dissolved-solids content of about 250 mg/l (fig. 13).

Salt-Water Intrusion

The bed of the lower Mississippi River is below sea level, and therefore salt water from the Gulf of Mexico intrudes some distance upstream most of the time. The extent of the intrusion depends on flow in the river, flow duration, wind velocity and direction, riverbed configuration, tides, and shape of the river channel. The most important of these is riverflow.

Because salt water is more dense than fresh water, it moves beneath fresh water, usually as a wedge, and is detectable on the bottom many miles upstream from where fresh water is found on the surface. The salt-water wedge in the Mississippi River is well defined (fig. 17) with very little mixing occurring at the fresh-salt water interface. For example, at mile 40 the chloride concentration increased from 130 mg/l at a depth of 70 feet to 4,500 mg/l at a depth of 75 feet. This is typical of rivers having deep and wide channels with a large fresh-water discharge.

Since 1929, the maximum extent of salt-water intrusion occurred in October 1939 when the wedge was detected by the Corps of Engineers at mile 120, approximately 15 miles upstream from New Orleans. During this period the river discharge was low, ranging from 75,000 to 90,000 cfs for 30 consecutive days. On one other occasion in the last 30 years, October 1940, the salt-water wedge penetrated upstream past the Kenner Hump at mile 115. This happened when the discharge was slightly less than 100,000 cfs for a period of a few days. During 1952-54 and 1956 the salt-water wedge moved up the Kenner Hump but did not pass this point because the discharge was not less than 100,000 cfs for any appreciable length of time. The movement of a typical salt-water wedge in the Mississippi River and a hydrograph of discharge at Red River Landing are shown in figure 18 (unpublished data, U.S. Army Corps of Engineers). From September 18 to October 17 the discharge decreased, and the blunt-nosed wedge moved upstream and continued to move upstream even though the discharge was fairly constant from October 17 to November 9, thus indicating that the wedge depends not only on discharge but also on flow duration. Figure 19 illustrates the general relation between flow duration and upstream migration of the salt-water wedge. The example in figure 19 shows an upstream migration of the salt-water wedge for 39 miles during a 15-day period in 1941 when the discharge was constant at 150,000 cfs. The maximum upstream migration of the salt-water wedge at different discharges has not been determined because constant discharges do not prevail for long enough periods of time. Also, the rate of this migration is not constant for all

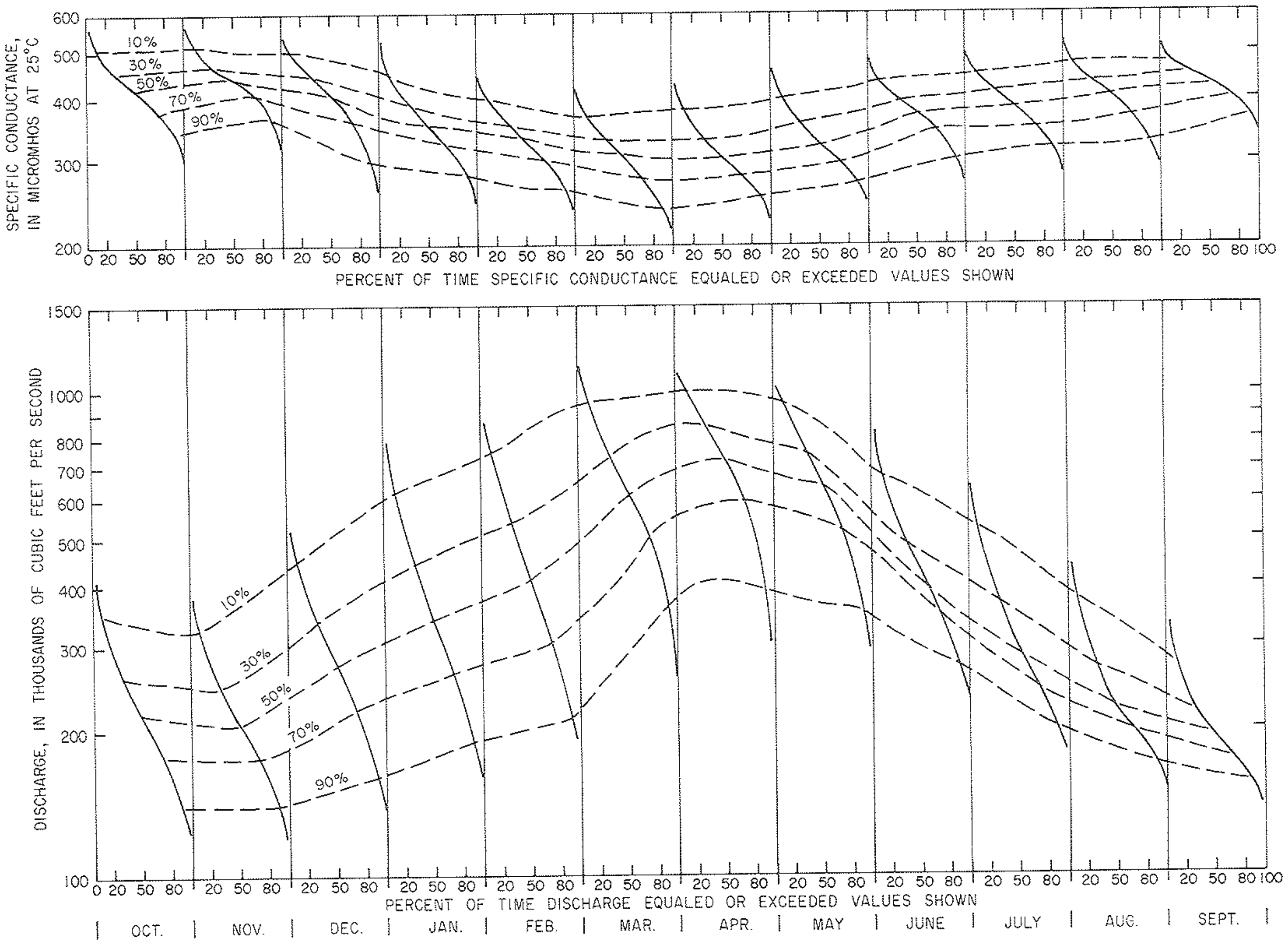

Figure 16.—Monthly duration curves of specific conductance for Mississippi River water near St. Francisville, La., and discharge at Red River Landing, La.

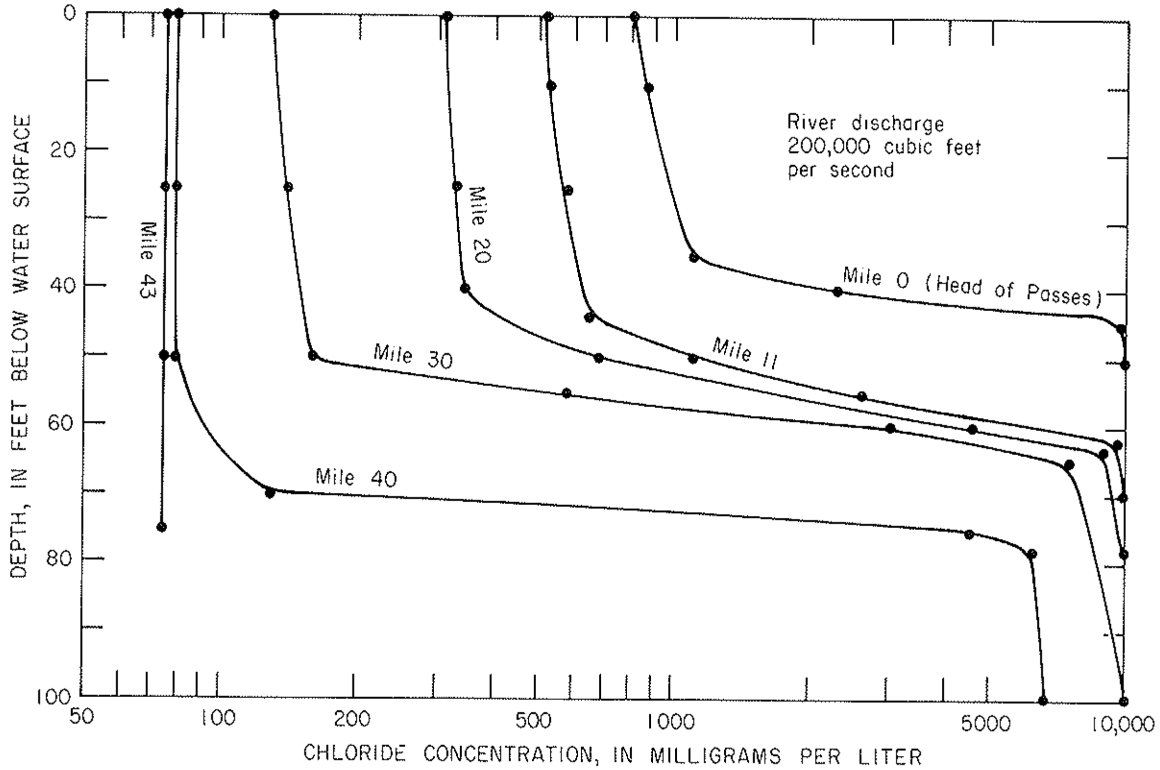

Figure 17.—Vertical distribution of chloride concentrations between river mile 0 and 43 during October 1969.

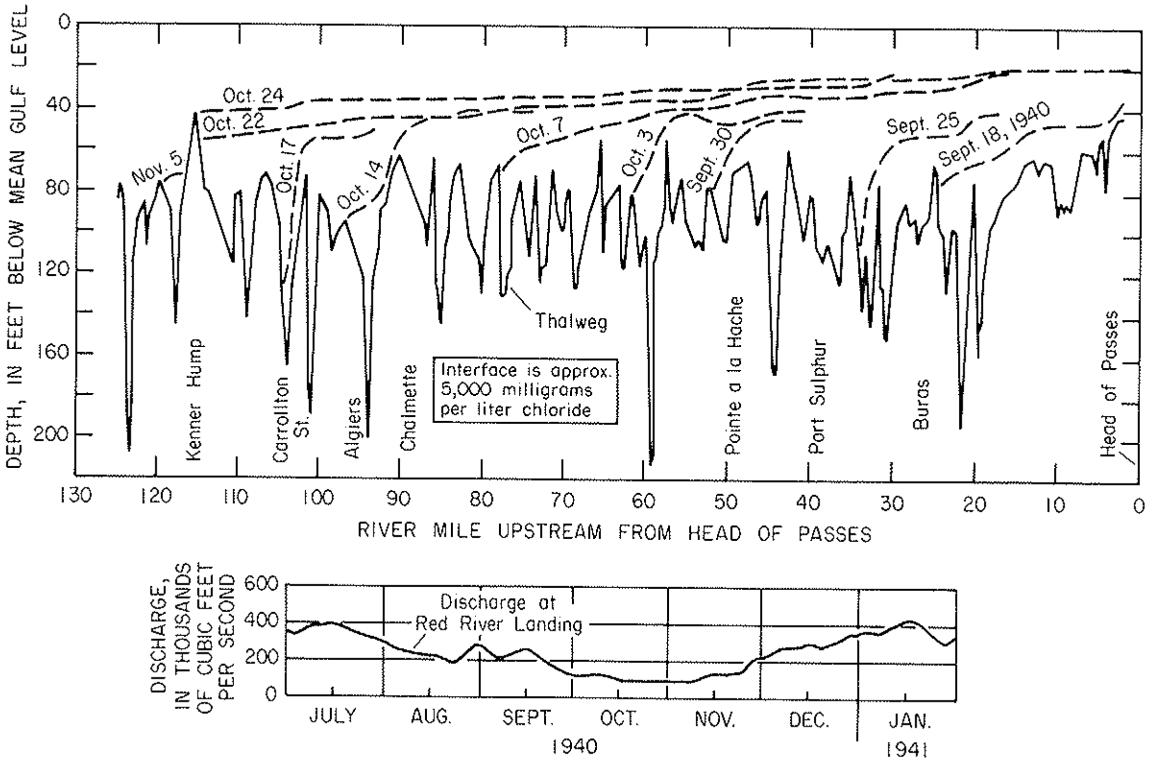

Figure 18.—Migration of salt-water wedge with change in river discharge at Red River Landing, La. (Modified after U.S. Army Corps of Engineers, unpublished data.)

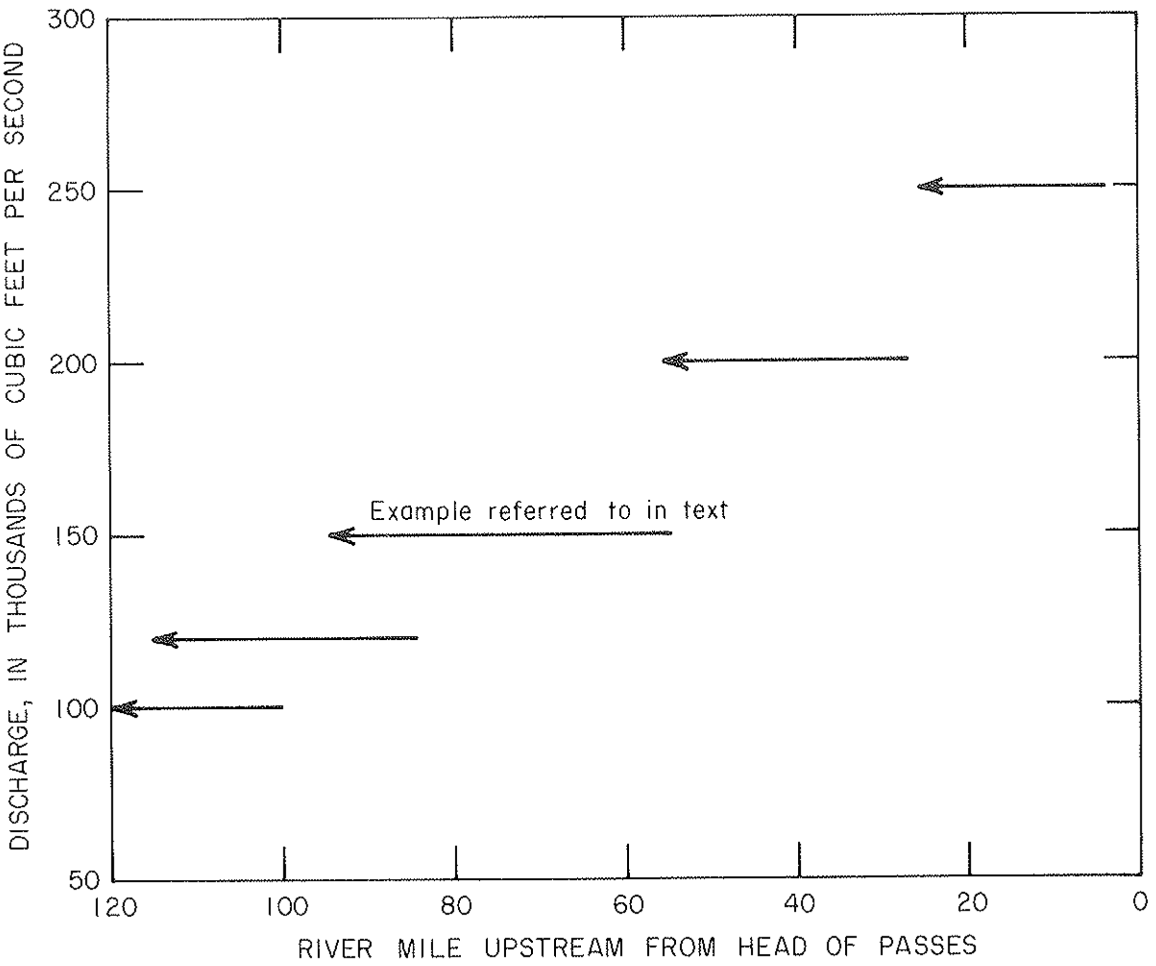

Figure 19.—Selected examples of upstream migration of the salt-water wedge at constant discharges.

reaches of the river because of the nonuniformity in elevation of the riverbed. During the high-flow periods in the winter and spring, the salt-water wedge is pushed downstream. During extremely high flows the wedge is ultimately pushed into the Gulf of Mexico.

Because the maximum chloride concentration normally found in the river is about 50 mg/l, and this concentration persists only about 2 percent of the time, any chloride substantially above this amount in the lower reaches generally indicates salt-water intrusion. Fresh water flowing downstream mixes with salt water at the interface causing increased chloride concentrations at or near the surface downstream from the leading edge of the wedge. Figure 20 relates the discharge at Red River Landing to the beginning of increasing chloride concentrations at plant intakes along the river (intakes usually are about 10 feet below mean low water). Concentrations at these plants may increase with steady discharge and will

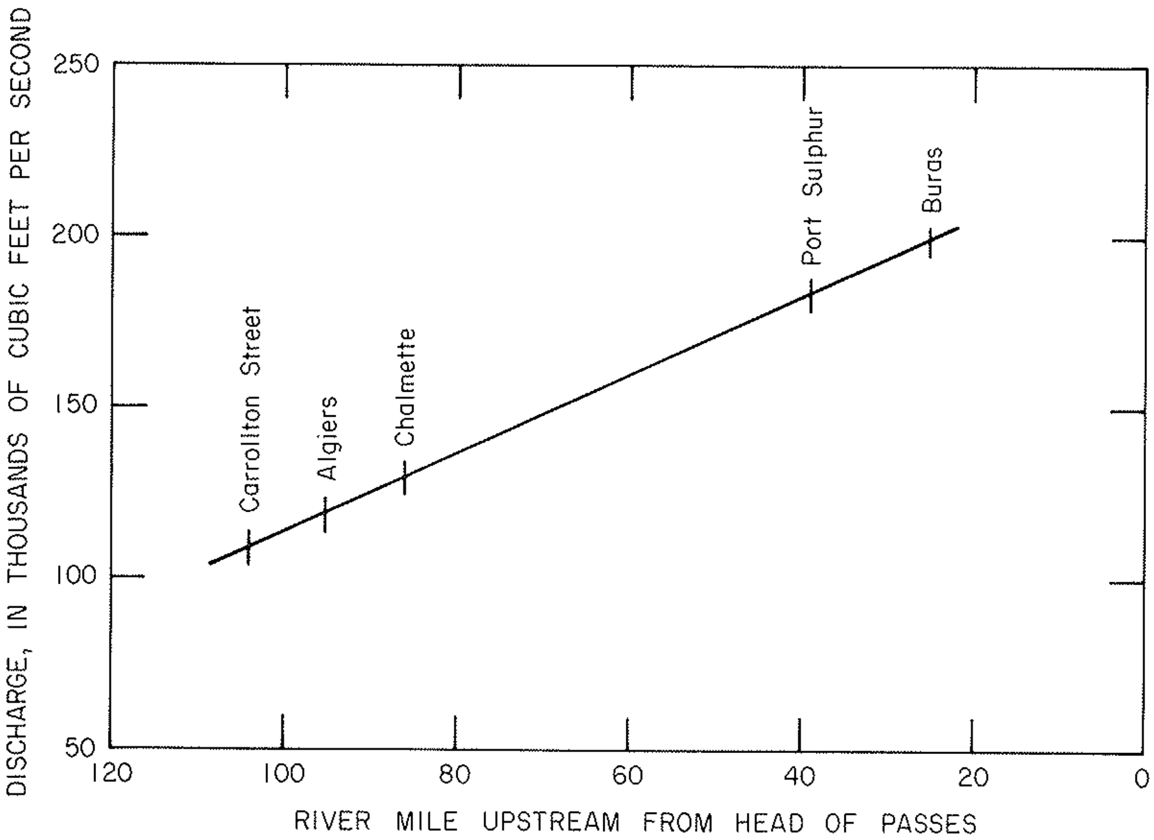

Figure 20.—Relation of discharge at Red River Landing, La., to initial observance of salt water at plant intakes along the Mississippi River. Plant intakes are about 10 feet below mean low water.

increase with a decreasing discharge. The maximum observed chloride concentrations at the Carrollton Purification Plant (mile 104), Algiers Purification Plant (mile 95), and Port Sulphur (mile 39) for discharges ranging from less than 100,000 to 180,000 cfs are listed in the following table. Salt-water intrusion is not a problem as far upstream as Port Sulphur

Maximum chloride concentrations at varying discharges for three locations on the Mississippi River

Discharge (cfs)	Chloride concentration (mg/l)		
	Carrollton (river mile 104)	Algiers (river mile 95)	Port Sulphur (river mile 39)
100,000 or less--	360	600	2,200
110,000----------	180	400	1,600
120,000----------	120	250	1,200
140,000----------	---	---	400
180,000----------	---	---	200

when the discharge is greater than 180,000 cfs. The percentage of time that some salt water will be present at different locations along the river, based on discharge records at Red River Landing, is shown in figure 21.

Temperature

Water temperatures of the Mississippi River near St. Francisville range from 1°C (Celsius) to 31°C. Since 1954, 95 percent of the time

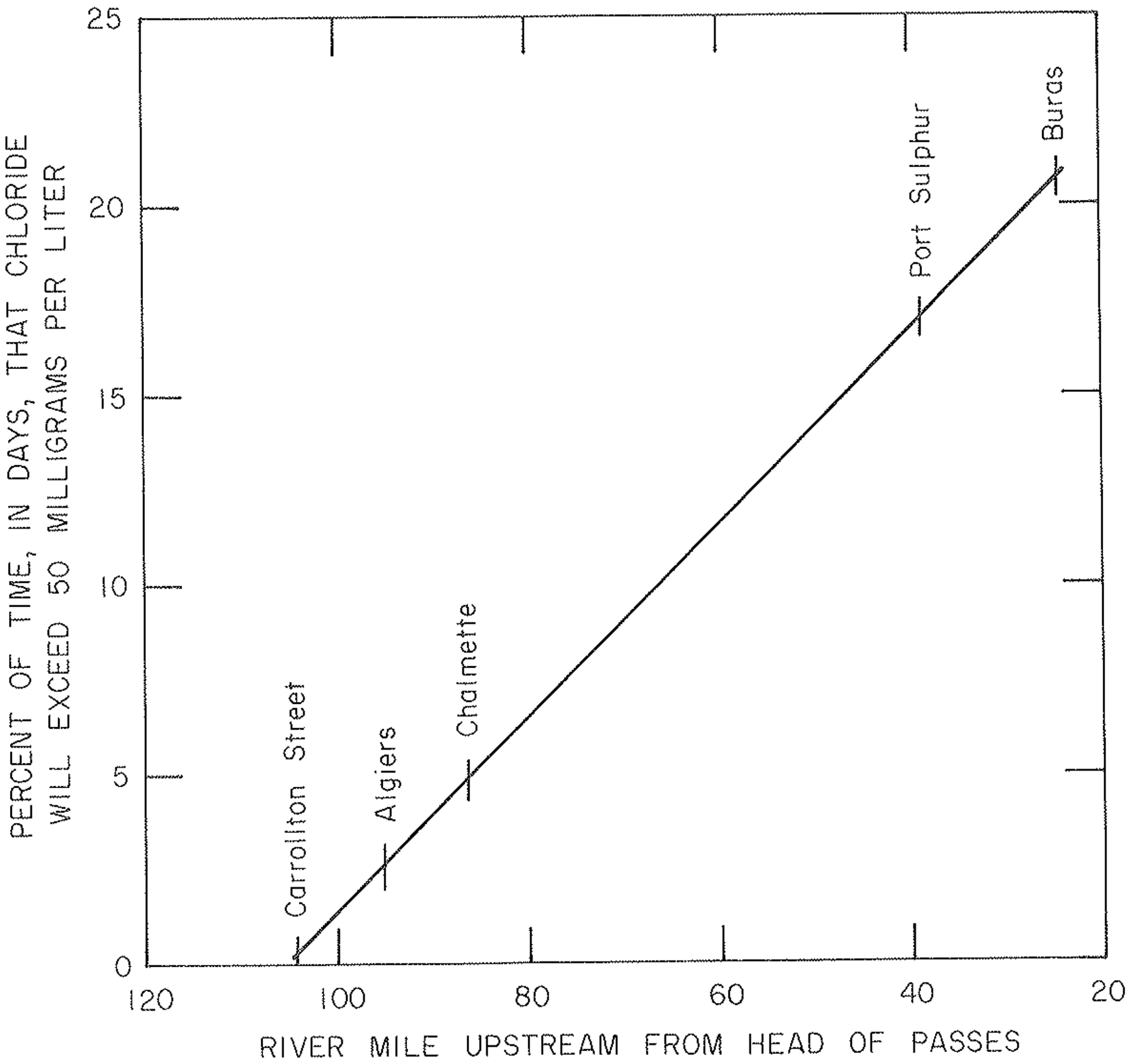

Figure 21.—Percentage of time salt water will be at plant intakes at different locations along the Mississippi River.

the temperature was equal to or less than 28° C, and 50 percent of the time it was equal to or less than 18° C (table 2). Monthly variations in temperature are shown in figure 22. Average monthly temperatures were highest in July and August and lowest in January. From March to June average temperatures increase 5° to 6° C each month, while from September to December, average temperatures decrease 5° to 6° C each month. From June to July the average increase is about 3° C, and from August to September the average decrease is about 3° C.

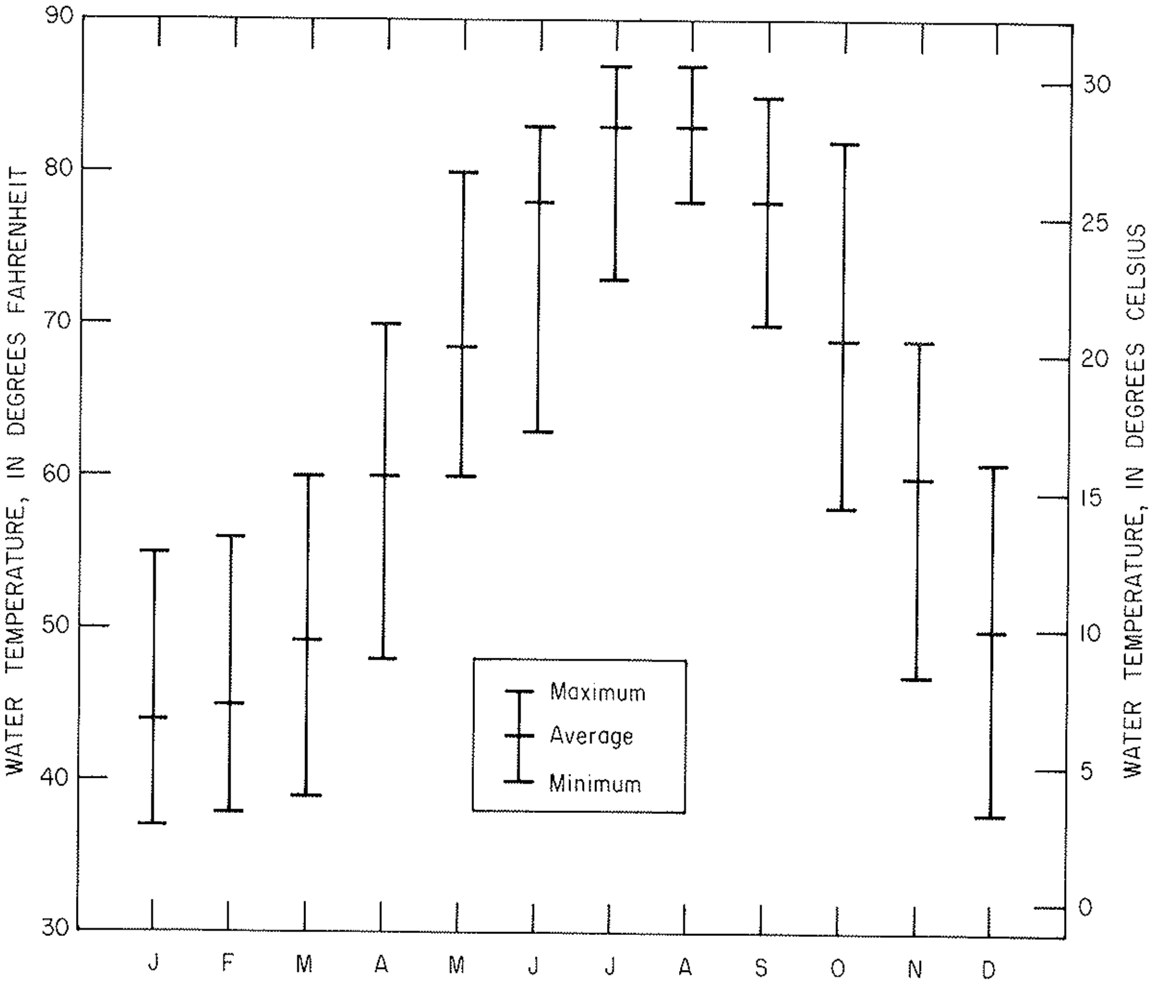

Figure 22.—Monthly variations in water temperature in the Mississippi River near St. Francisville, La., 1954-68.

RIVER USE

The Mississippi River has great value as a navigational waterway, as a source of water for industries and municipalities along its banks, and for disposal of industrial and municipal wastes. In Louisiana, approximately 5 bgd (billion gallons per day) of water is withdrawn from the river for industrial and municipal uses (Dial, 1970). Approximately 95 percent of this water is returned to the river as waste water.

Public Supplies

Nearly all the cities and towns downstream from Donaldsonville, La., use Mississippi River water for public supplies. The total municipal pumpage from the river between Donaldsonville and Belle Chasse, La., is about 185 mgd (million gallons per day). Pumpage by parish between Baton Rouge and Belle Chasse follows:

Parish	Pumpage from river (mgd)
Ascension	0.73
Assumption	.62
Jefferson	39.30
Orleans	127.37
Plaquemines	3.58
St. Bernard	6.09
St. Charles	2.95
St. James	.99
St. John the Baptist	1.35
Total	182.98

Limits recommended by the U.S. Public Health Service (1962) for water used on interstate carriers for drinking purposes, commonly cited as standards for domestic use, are shown in table 4. Ranges in concentration of Mississippi River water upstream from New Orleans are well within the acceptable limits. During extended periods of extremely low flow, salt water moves upstream from the Gulf of Mexico, increasing the chloride content of the water at New Orleans to objectionable levels. Concentration of chloride at the intakes to the Algiers and Carrollton Street treatment plants have been as high as 620 and 360 mg/l, respectively. However, these occurrences are infrequent and of short duration. Since 1928, concentrations above 250 mg/l have occurred once at the Carrollton Street plant and five times at the Algiers plant. Other objectionable characteristics of the water are hardness, turbidity, taste, and odor; but these are readily removed by treatment. Treatment varies from plant to plant but, in general, includes softening, clarification, treatment with activated carbon, and chlorination. Potassium permanganate is added to the water at New Orleans to remove taste- and odor-causing organic compounds.

Table 4.--Suitability of Mississippi River water for public supply

Chemical characteristics	Range in concentration, in milligrams per liter (Luling Ferry, La.)			Maximum acceptable concentration USPHS standards (mg/l)
	Minimum	Average	Maximum	
Dissolved solids	126	229	344	500
Hardness	86	141	210	-----
Sulfate	28	50	93	250
Chloride	10	23	60	250
Nitrate	.0	2.7	6.5	45
pH (units)	6.8	7.5	8.1	-----
Fluoride	.0	.3	1.2	[a] 1.2
Iron	.00	.04	.23	.3

[a] Varies with mean temperature in sense that higher temperature results in more water intake.

Industrial Uses

Industrial demands for Mississippi River water have increased rapidly in the last 10 years. The total water withdrawn from the river by industrial and thermal-electric plants between Baton Rouge and Port Sulphur has increased from about 2.0 bgd in 1960 to about 5.0 bgd in 1969. Presently, about 2.0 bgd is being used for cooling at steam-electric powerplants, and about 3.0 bgd by industrial plants. Nearly all the water used by electric powerplants and about 90 percent (2,700 mgd) of the water used by industry is returned to the river; an estimated 280 mgd is actually consumed. In addition to surface water, approximately 175 mgd of ground water is also used. The largest users of water exclusive of electric powerplants are chemical and petrochemical plants.

Quality of water requirements for industrial uses vary by industry and even among industries producing the same product. Therefore, no attempt is made in this report to define water-quality requirements for the industries that use Mississippi River water. However, the water is suitable for most industrial uses when hardness and turbidity have been reduced.

Waste Disposal and Assimilation

The Mississippi River is important to industry not only as a source of water but also as a means of waste disposal. The total waste water discharged into the river by industrial and electric powerplants is about 4.8 bgd, or about 7,500 cfs. During low flow this amounts to about 7.5 percent of the total flow of the river. The three types of wastes discharged into the river are chemical (inorganic and organic), bacterial, and thermal. However, very little bacterial waste is discharged into the river by industry.

Inorganic Waste Disposal

The total dissolved solids discharged into the river by industry between St. Francisville and Luling Ferry has increased from about 4,000 tons per day in 1958 to about 20,000 tons per day in 1969. (See fig. 23.)

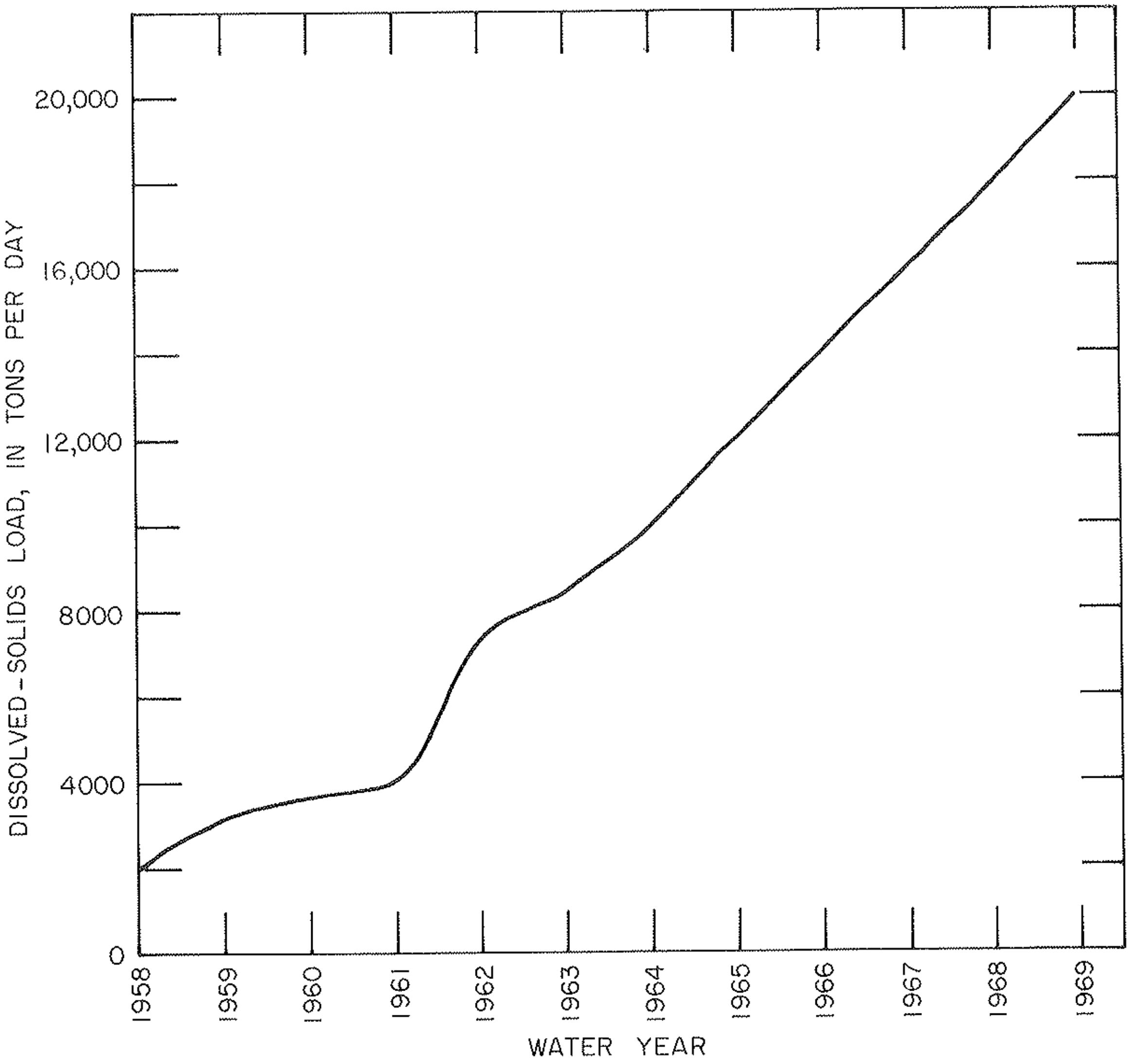

Figure 23.—Increase in dissolved-solids load between St. Francisville and Luling Ferry, Louisiana, 1958-69 water years.

Additionally, about 4,000 tons per day is discharged to the river between Luling Ferry and Port Sulphur. The dissolved solids added to the river by industry is fairly constant, but the percentage of total load varies with discharge (fig. 24). For example, when the discharge is 600,000 cfs, industrial wastes account for 6 percent of the dissolved-solids load between Baton Rouge and Luling Ferry; but when the discharge is 100,000 cfs, they account for 21 percent of the load.

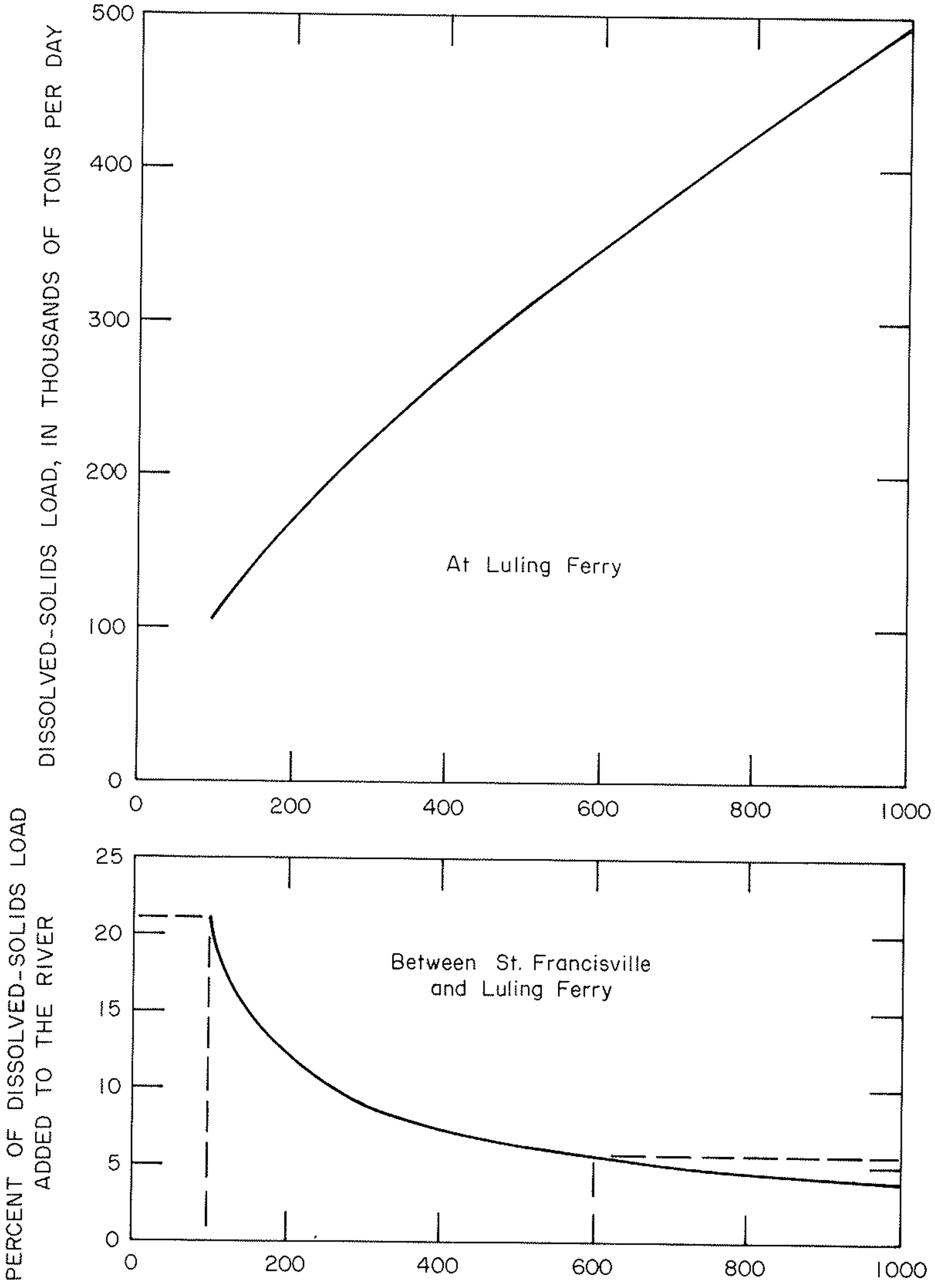

Figure 24.—Relation of dissolved-solids load to discharge at Luling Ferry, La., and percent of dissolved-solids load added to the Mississippi River by industry between St. Francisville, La., and Luling Ferry, La., 1969.

Industrial discharge of inorganic waste has little effect on water quality during high-flow periods because of dilution, but during low-flow periods the effects are significant. The increase in dissolved solids concentrations between St. Francisville and Luling Ferry vary from about 7 mg/l when the discharge is 1 million cfs to about 70 mg/l when the discharge is 100,000 cfs (fig. 25). Most of the increase is due to sodium chloride and sulfuric acid; about 9,000 tons per day or about 45 percent of the waste is chloride and about 6,000 tons per day or about 30 percent is sulfate. Increases in concentrations of chloride and sulfate between

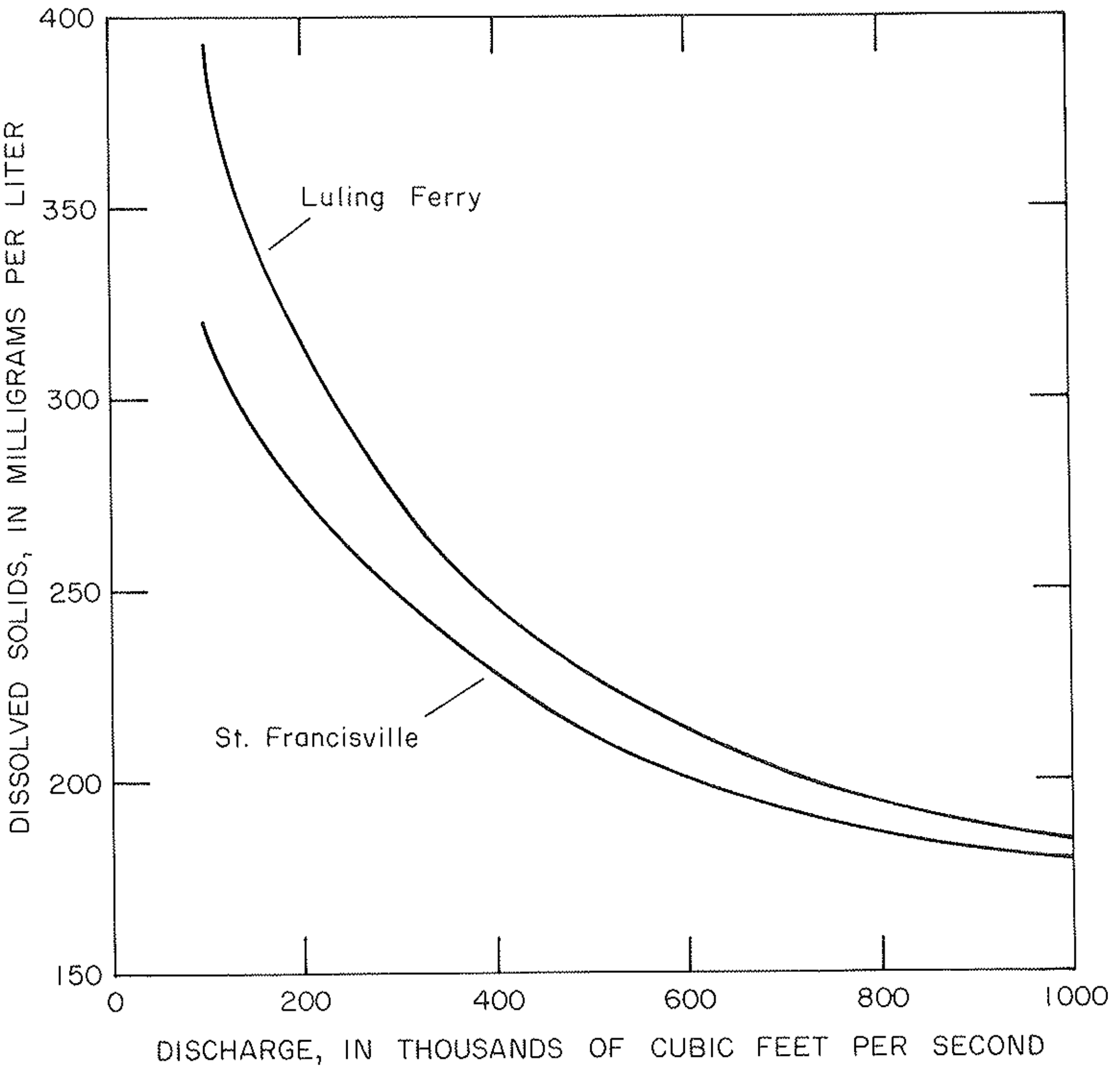

Figure 25.—Relation of dissolved-solids concentration to discharge at St. Francisville, La., and Luling Ferry, La.

St. Francisville and Luling Ferry for the 1969 water year are shown in figure 26. During October when the minimum discharge for the year occurred, the chloride and sulfate differences between St. Francisville and Luling Ferry were as much as 17 and 13 mg/l, respectively.

Municipalities also discharge inorganic waste to the river, but compared to industry, the amount is insignificant.

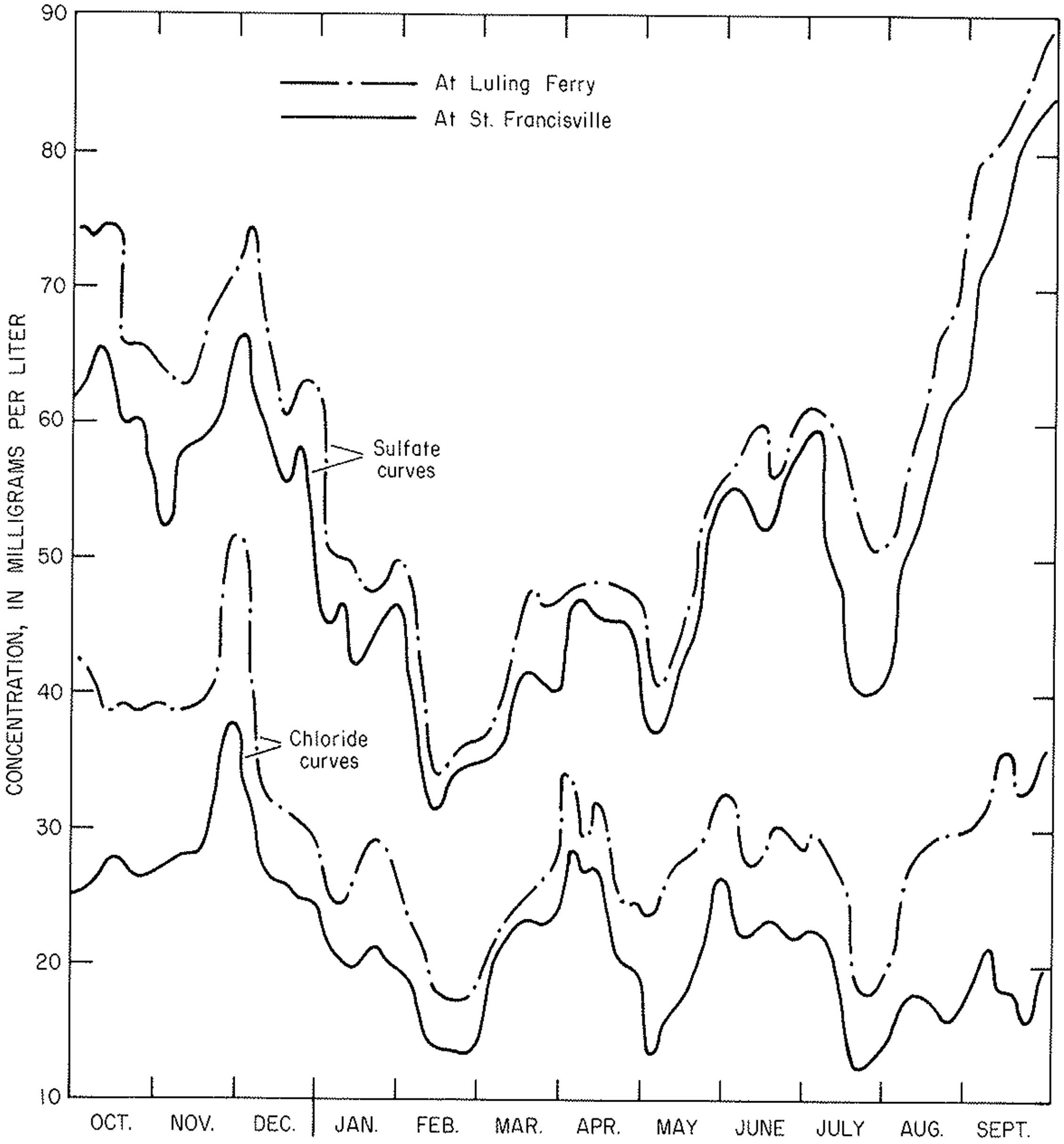

Figure 26.—Chloride and sulfate concentrations at St. Francisville, La. and Luling Ferry, La. for the 1969 water year.

Acidic Waste Assimilation

Many industries along the Mississippi River discharge acidic wastes into the river. At present, these wastes have very little effect on the pH of the water. In the future, however, any large increases in acid wastes discharged to the river, especially during low flows, could lower the pH downstream, causing the water to be corrosive.

The buffering capacity of water, the ability of the water to resist a change in pH, is determined by the quantity of acid or base required to change the pH of the water. Because most of the waste discharged to the Mississippi River between Baton Rouge and New Orleans is acidic, only acid-buffering curves are shown in figure 27. These curves show the effect of acid-waste disposal on the pH of Mississippi River water at varying flow and quality conditions. The buffering capacity of the water is greatest during periods when the dissolved-solids content is high and the discharge is low. For example, four equivalents of acid as hydrogen ion would lower the pH of 1,000 gallons of water approximately 0.8 and 1.7 pH units when the discharge is 100,000 and 650,000 cfs, respectively.

Based on these buffering-capacity curves and river discharge, the ability of the river to assimilate acidic waste also can be determined (fig. 28). For example, a continuous discharge of 26,000 tons per day of concentrated (40-percent) hydrochloric acid effluent into the river would

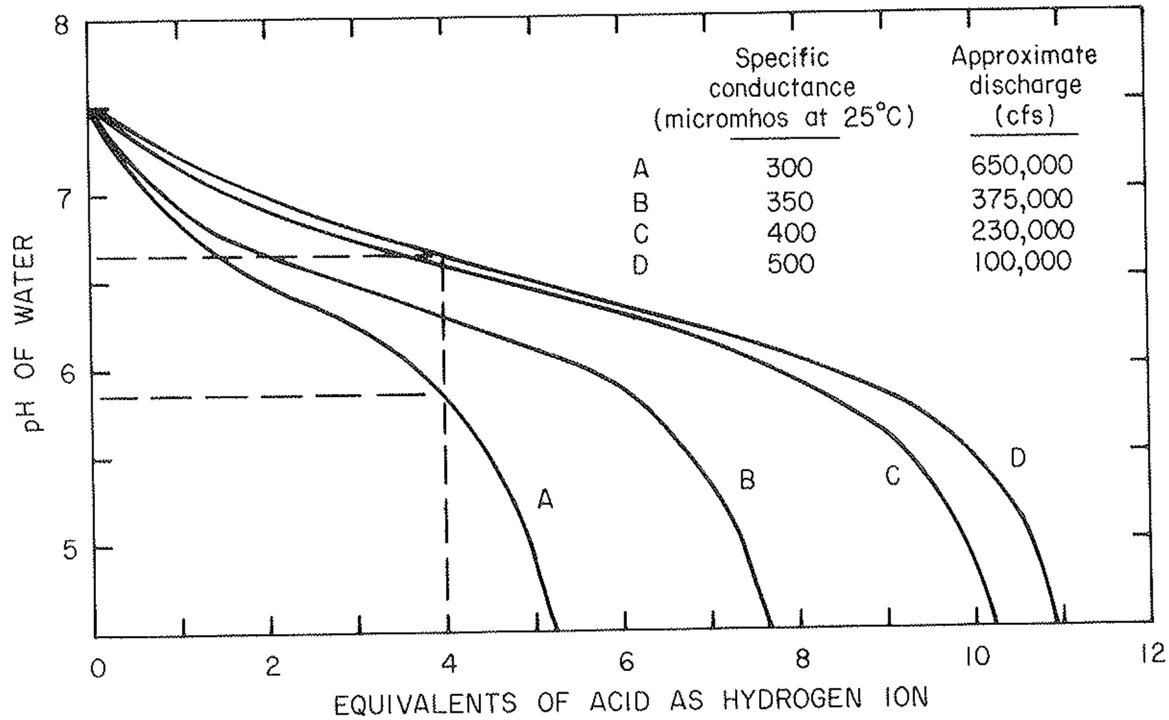

Figure 27.—Buffering-capacity curves for Mississippi River water showing amounts of acid necessary to produce a given pH change in a thousand gallons of water.

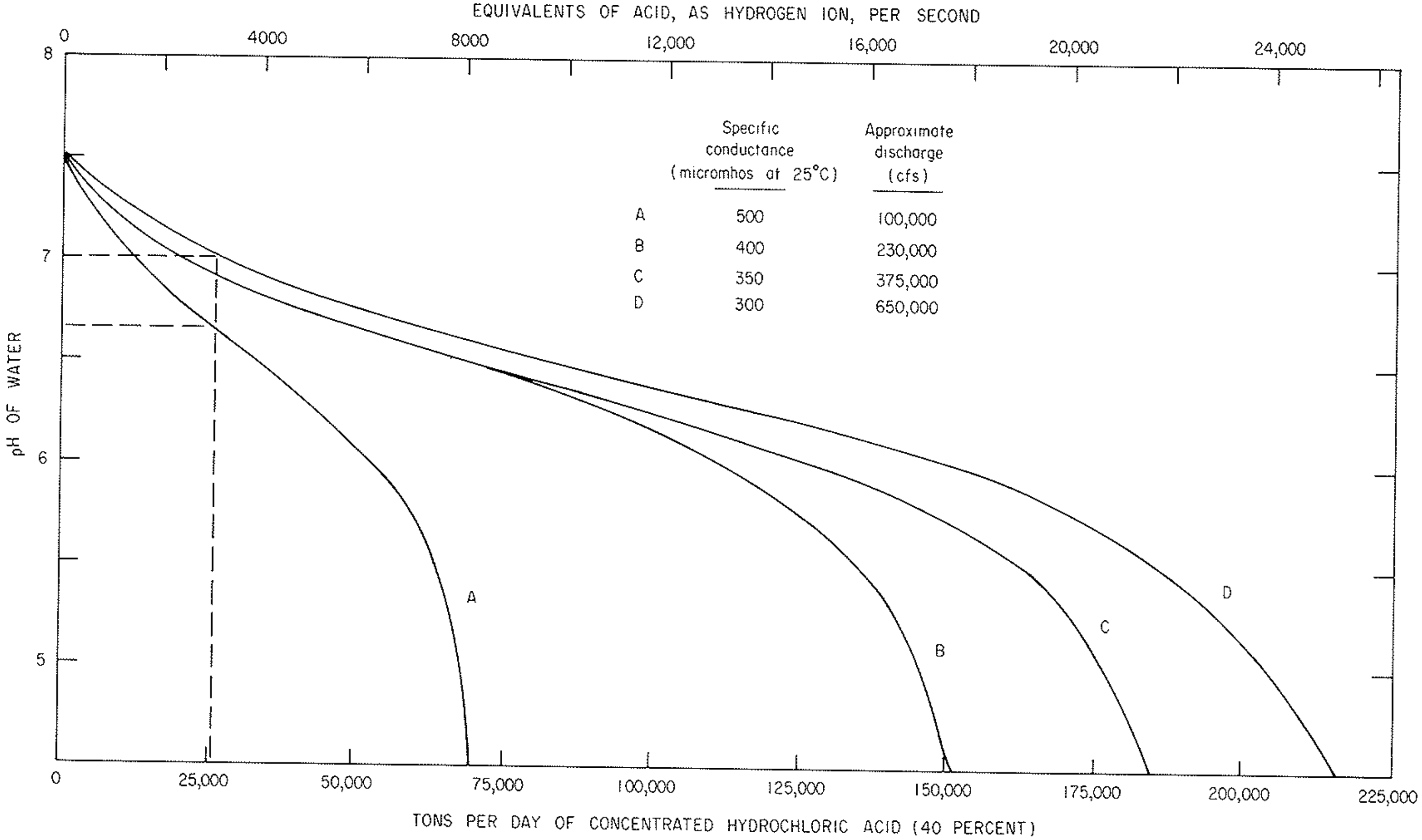

Figure 28.—Acid-waste assimilation capacity curves.

lower the pH, downstream after mixing, approximately 0.8 and 0.5 pH units when the discharge is 100,000 and 650,000 cfs, respectively. However, the pH in the immediate vicinity of the discharged waste would be much lower. Discharge ranges used in figure 28 would be expected to occur approximately 75 percent of the time. The large amount of acid required to lower the pH of Mississippi River water indicates that the river is not easily affected by acidic wastes. The Mississippi assimilates great quantities of acidic waste each day with very little effect on the river.

Organic Waste Disposal

Industries discharge about 1 million pounds per day of organic wastes into the Mississippi River between Baton Rouge and New Orleans. These wastes have an adverse effect on water quality because they impart disagreeable tastes and odors to the water, are toxic, and consume dissolved oxygen as they are decomposed. Fish are also affected by these wastes and have a distinct oily taste. Among the wastes that cause tastes and odors in water are those from chemical plants, petrochemical plants, oil refineries, pulpmills, and papermills.

Municipalities along the banks of the river discharge both raw and treated sewage into the river. The average daily contribution of organic matter per person is equivalent to about 0.17 pound per day of BOD (biochemical oxygen demand) (Hardenberg, 1963). BOD is a measure of the oxygen required to break down decomposable organic matter by aerobic bacterial action. Based on a population of about 1 1/2 million, the total BOD load discharged into the river by municipalities is about 250,000 pounds per day, most of it in the New Orleans area.

Organic Waste Assimilation

Dissolved oxygen is needed for aquatic life and for natural purification of rivers. The two main functions which control dissolved-oxygen levels in the Mississippi River are (1) amount of oxygen-consuming wastes entering the river and (2) reaeration of the river from atmospheric oxygen. The net result of these two reactions is a gradual decrease in dissolved-oxygen levels downstream from Baton Rouge (fig. 29). The total oxygen use is equal to the difference in oxygen load between Baton Rouge and New Orleans plus reaeration between the two locations. To provide an insight to the total oxygen use and reaeration at different discharges and temperatures, the following table of data collected in 1969 is presented.

Oxygen use and reaeration at different discharges and temperatures for the Mississippi River

Discharge (cfs)	Temperature (° C)	Reaeration (tons)	Oxygen load differences between Baton Rouge and New Orleans (tons)	Total oxygen use (tons)
200,000	23.5	496	324	820
400,000	30.0	552	648	1,200
500,000	28.0	432	608	1,040

Note.--Oxygen load differences were computed as follows: Oxygen load differences=0.0027 times discharge, in cubic feet per second, times difference in oxygen concentrations, in milligrams per liter. Reaeration coefficients (Tennessee Valley Authority, 1962) were arbitrarily selected for the computation. The similarity of the oxygen-use figures with differing temperatures and discharges indicate that the calculations are reasonable because the oxygen-demanding wastes discharged to the river are fairly constant.

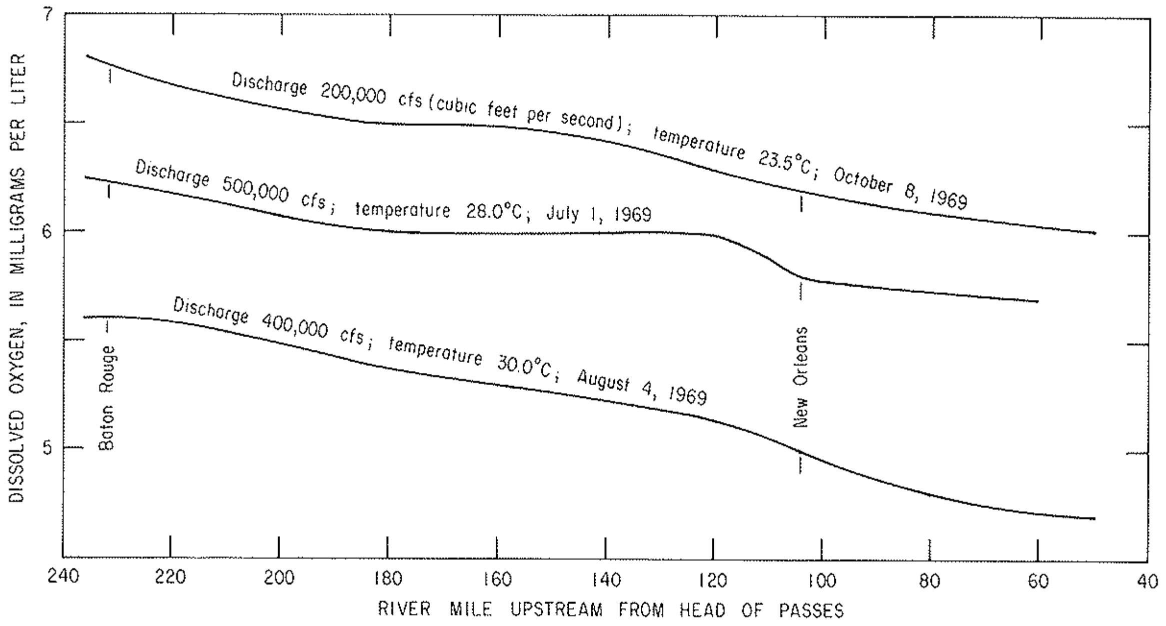

Figure 29.—Downstream changes in dissolved-oxygen concentrations.

Although large amounts of oxygen-consuming wastes are discharged to the river between Baton Rouge and New Orleans, the decrease in dissolved-oxygen concentrations generally is less than 1.0 mg/l. The largest decreases occur during the summer because the rate of organic decomposition and, accordingly, oxygen use increase with increasing temperature. Also, the ability of the river to dilute wastes is less because low-flow periods generally occur during the summer. During these low-flow periods the dissolved-oxygen concentration at New Orleans is as low as 61 percent of saturation, which is lower than the recommended limits of 75 percent as set forth by the Louisiana Stream Control Commission (1968). Dissolved-oxygen concentration at New Orleans during the 1969 water year was greater than 70 percent of saturation about 80 percent of the time (fig. 30). Only on two occasions of short duration was saturation less than 65 percent.

Sanitary Waste

Municipal use of surface and ground waters between Baton Rouge and New Orleans is 185 and 35 mgd, respectively. Approximately 60 to 70 percent of this water is discharged to the river. If 70 percent or about 158 mgd were dumped into the river with a 5- to 10-percent increase in dissolved solids, it would add less than 1 percent to the waste load discharged by industries. More important is the discharge of organic and bacterial wastes into the river.

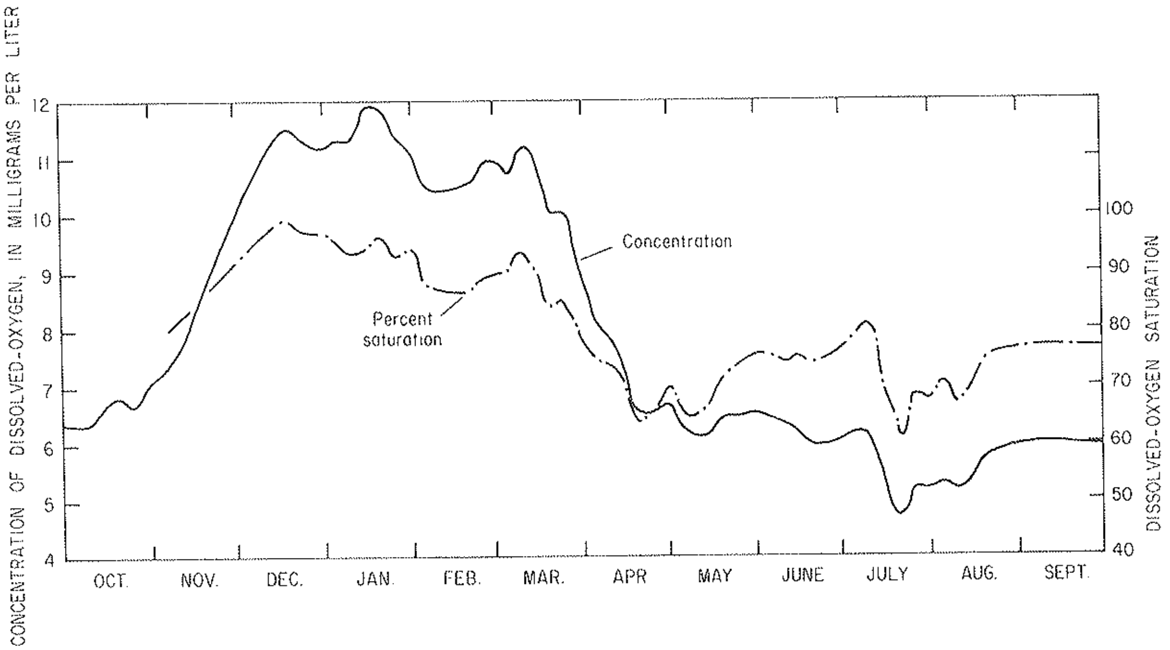

Figure 30.—Dissolved-oxygen concentration and percent saturation for Mississippi River at New Orleans, La., for the 1969 water year.

Domestic sewage discharged into the Mississippi River is the cause of a high bacterial concentration. The highest concentrations occur in the vicinity of New Orleans. Bacteria analyses by the New Orleans Sewerage and Water Board show that coliform bacteria concentrations increase as the water moves downstream past New Orleans. In 1962 the coliform content exceeded 5,000 colonies per 100 ml (milliliters) about 13 percent of the time at the Carrollton Street intakes (mile 104), and about 35 percent of the time at the Algiers intakes (mile 95). The maximum bacteria concentrations are not known, but downstream from New Orleans, coliform colonies greater than 500,000 per 100 ml have been reported (oral communication, Louisiana State Board of Health, 1970).

Thermal Waste

Approximately 95 percent of the 5.0 bgd of water withdrawn from the river is used for industrial cooling and is returned to the river with an increased thermal load. Heated water that is returned to the river by one industry is used by other industries farther downstream; consequently, the temperature of the water continues to rise as it is reused. The effect of this heated water after complete mixing is not discernible during medium- or high-flow periods, but during low-flow periods, water temperatures at Luling Ferry are as much as 3° C warmer than at St. Francisville.

In September 1969, at a discharge of 250,000 cfs, the effects of heated effluent from a generating station near river mile 200 on the temperature of the river water were determined. Downstream, after complete mixing, the effects of the heated effluent were not significant; but at the outfall, water temperatures near the surface were as much as 14° C (25° F) higher than background temperatures of the river water. Very little vertical mixing occurred because the heated water was less dense and floated on the surface. Isotherms of the heated water plume and temperatures at different locations in the plume at 1-, 5-, and 10-foot depths are shown on plate 2.

WATER MOVEMENT

A great increase in municipal and industrial wastes discharged to the Mississippi River has accompanied population and industrial growth. Also, the chance of an accidental spill of toxic chemicals into the river has increased greatly. Therefore, it has become increasingly important to know the rate of downstream movement and how wastes mix longitudinally and laterally in the river. Dye studies in 1965 and 1969 were used to determine time of travel and dispersion characteristics of the river. Time-of-travel studies were used to describe the movement and dilution of soluble materials.

Time of Travel and Longitudinal Dispersion

Time-of-travel information can be used in preventing water-supply contamination from accidental spills of toxic chemicals. By using the time of arrival, duration, and concentrations of the contaminant at downstream locations, withdrawal of water can be discontinued until after the contaminant has passed. The results of these studies are applicable to soluble contaminants with dispersion characteristics similar to those of the injected dye.

Time of travel of solutes varies with discharge; therefore, time-of-travel determinations at different discharges are needed in order to develop the relationship. This relationship is assumed to be a straight line in the medium- and low-flow ranges of discharge. Using dye as a tracer, longitudinal dispersion and velocity characteristics of the lower Mississippi River between Baton Rouge and New Orleans were determined in September 1965 (Stewart, 1967) and August 1969 when the discharge at Baton Rouge was 240,000 and 365,000 cfs, respectively. A discharge of 240,000 cfs is equaled or exceeded 70 percent of the time, and a discharge of 364,000 cfs is equaled or exceeded 50 percent of the time. Variations in travel-time with discharge for the leading edge, peak, and trailing edge of the dye cloud are shown in figure 31.

The duration (time of passage) of a contaminant at a site is inversely related to discharge because as discharge increases, velocity increases. As velocity increases, longitudinal dispersion decreases at any downstream location because the contaminant has had less time to disperse. Longitudinal dispersion patterns are variable, especially for long reaches of the river, but an approximate duration of a contaminant at a downstream site can be estimated by subtracting the time the leading edge passes from the time the trailing edge passes (pl. 3). If an accidental spill of chemicals occurred at river mile 190 when the discharge was 450,000 cfs, the leading edge and peak of the contaminant would arrive at mile 104 in about 47 and 51 hours, respectively, and the trailing edge, defined as 5 percent of the peak concentration, would pass in 57 hours, hence 10 hours duration or passagetime.

Data collected during the time-of-travel studies were used to develop techniques for determining the maximum possible peak concentration at any point downstream from a dye injection or waste spill.

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

where unit concentration is the peak concentration resulting from 1 pound of dye in 1 cfs of water, assuming 100 percent recovery. Knowing the elapsed time a contaminant has been in the water from plate 3, the unit concentration (fig. 32), and river discharge at sampling site, the maximum peak concentration can be computed. For example, if 1.000 pounds of contaminant were spilled in the Mississippi River at Baton Rouge when the discharge was 600,000 cfs, the peak would arrive at New Orleans in 60 hours

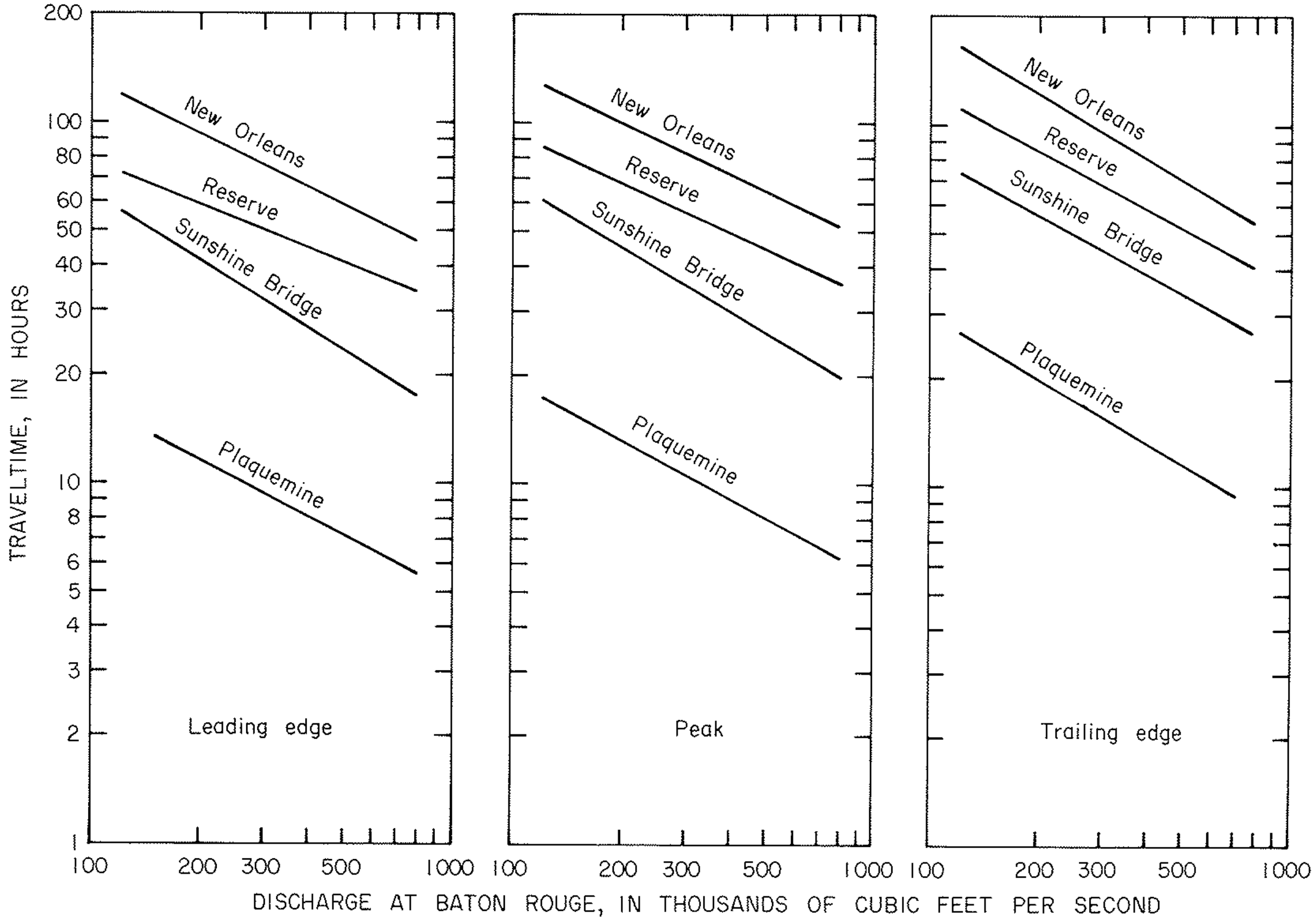

Figure 31.—Variation in traveltime with discharge for leading edge, peak, and trailing edge of dye cloud from Baton Rouge, La., to downstream sampling sites.

(pl. 3) and the unit concentration would be 500 μg/l (micrograms per liter) (fig. 32). The peak concentration at New Orleans would be about 0.83 μg/l.

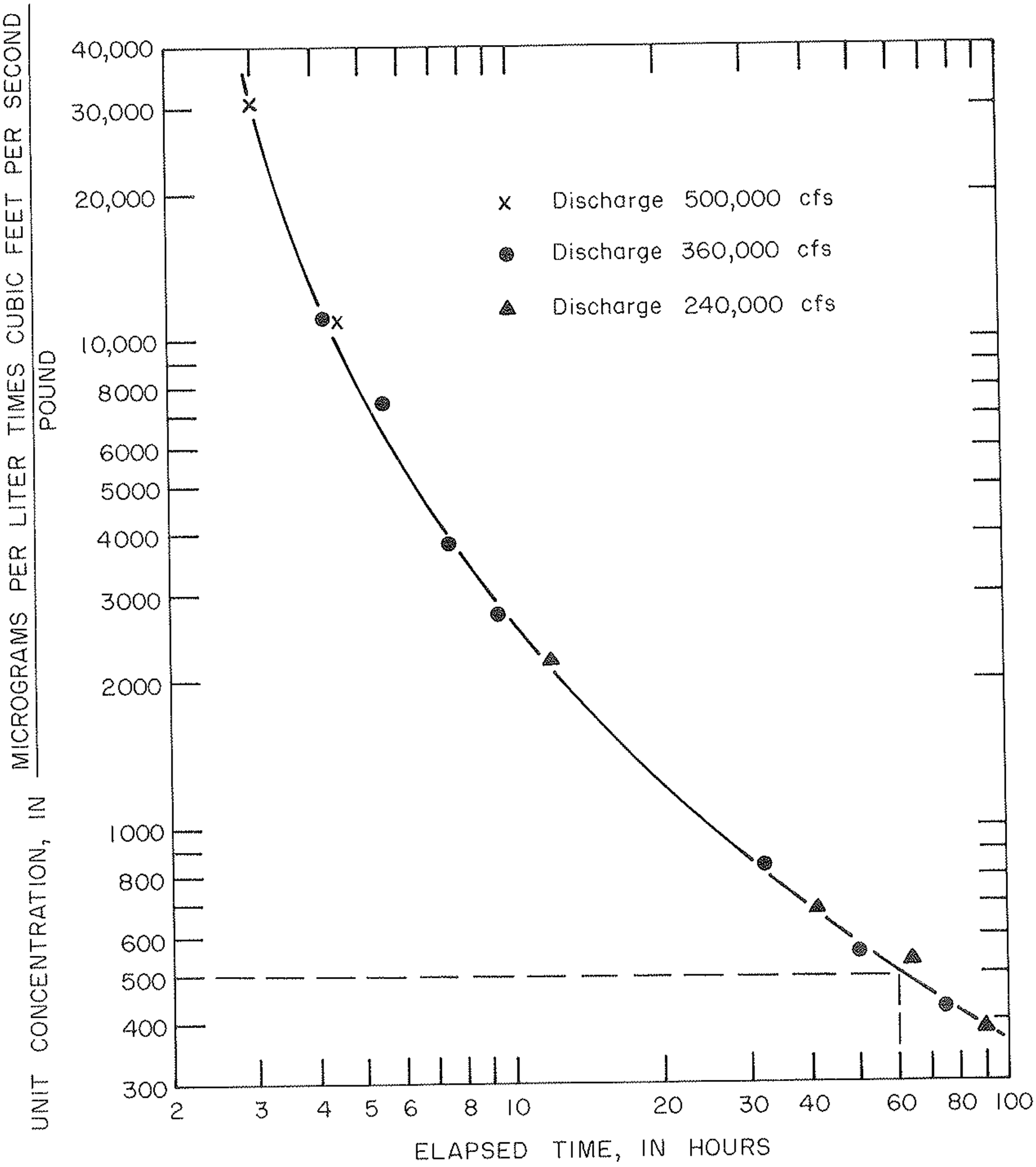

Figure 32.—Attenuation of unit concentration with traveltime.

Lateral Dispersion

When a liquid waste is introduced into a river, it immediately begins to disperse not only longitudinally but also laterally and vertically providing the density of the waste is similar to that of water. The degree to which lateral mixing occurs is important to downstream users of water. Without lateral mixing, the effluent from one plant could feed directly into the intakes of a downstream plant on the same bank but miss that of a plant on the opposite bank. Lateral mixing in the Mississippi River between Baton Rouge and Plaquemine was studied on two occasions to determine how wastes move through river meanders and how far downstream it must move before it has dispersed across the river.

When the discharge was 364,000 cfs, dye was injected into the river at mile 229 about 1,000 feet from the right bank at the point of maximum flow in the channel (fig. 33). As the dye cloud moved downstream, it began to disperse laterally toward the center and the right bank of the river. The extent of lateral dispersion and peak concentrations at four downstream sampling sites are shown in figure 33. At the first sampling section, site 1, mile 219, the dye cloud had moved through the outside section of a 120-degree meander. Although the dye had migrated across the river, concentrations were much higher in the middle of the river and along the right bank. At site 2, mile 215, the maximum concentration of the dye cloud had moved across the river with the thalweg, and concentrations were greater along the left bank than along the right bank. At mile 212 (site 3) concentrations were almost uniform across the river except along the left bank where they were slightly less. At mile 208 (site 4) lateral dispersion was essentially complete.

When the discharge was 550,000 cfs, dye was injected into the river at the same location, but this time it was injected about 300 feet from the left bank (fig. 34). As the dye cloud moved downstream, it began to disperse laterally at a slow rate. Figure 34 shows the extent of lateral dispersion and peak concentration at the three downstream-sampling sites used for this study. At site 1, 5 miles downstream from the injection point, dye had dispersed about 1,300 feet from the bank or about one-third of the distance across the river, but dispersion was not uniform. Maximum concentrations occurred about 300 feet from the bank (fig. 34). The rate of lateral dispersion in this reach of the river was about 260 feet per mile. Had the channel been straight, the dye cloud probably would have dispersed to the full width of the river about 15 miles downstream but not uniformly. Maximum concentrations would still have been in the left half of the river. As the dye cloud moved through the inside of the first meander, concentrations at mile 219, site 2, were greatest about 900 feet from the left bank where the peak concentration was 2.2 μg/1. Although dye had migrated across the river, concentrations near the right bank were only 0.10 μg/1 or about 5 percent of peak concentrations. Between sites 2 and 3, the dye moved through meanders totaling about 360 degrees. At site 3, the dye was essentially dispersed.

No attempt was made to determine the rate of vertical dispersion; however, it was complete 5 miles downstream from the injection point.

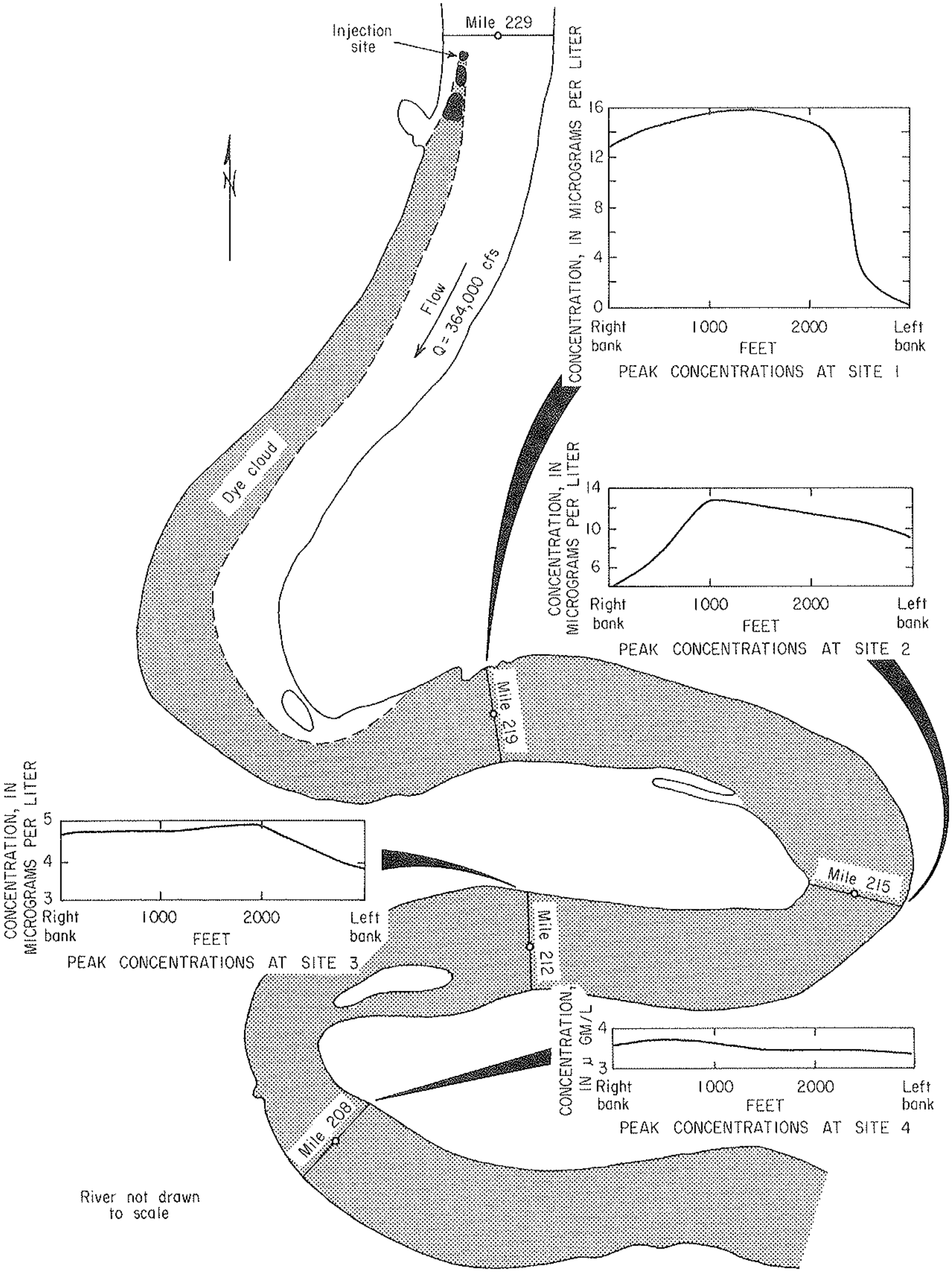

Figure 33.—Lateral dispersion of a contaminant discharged into the Mississippi River at the point of maximum flow.

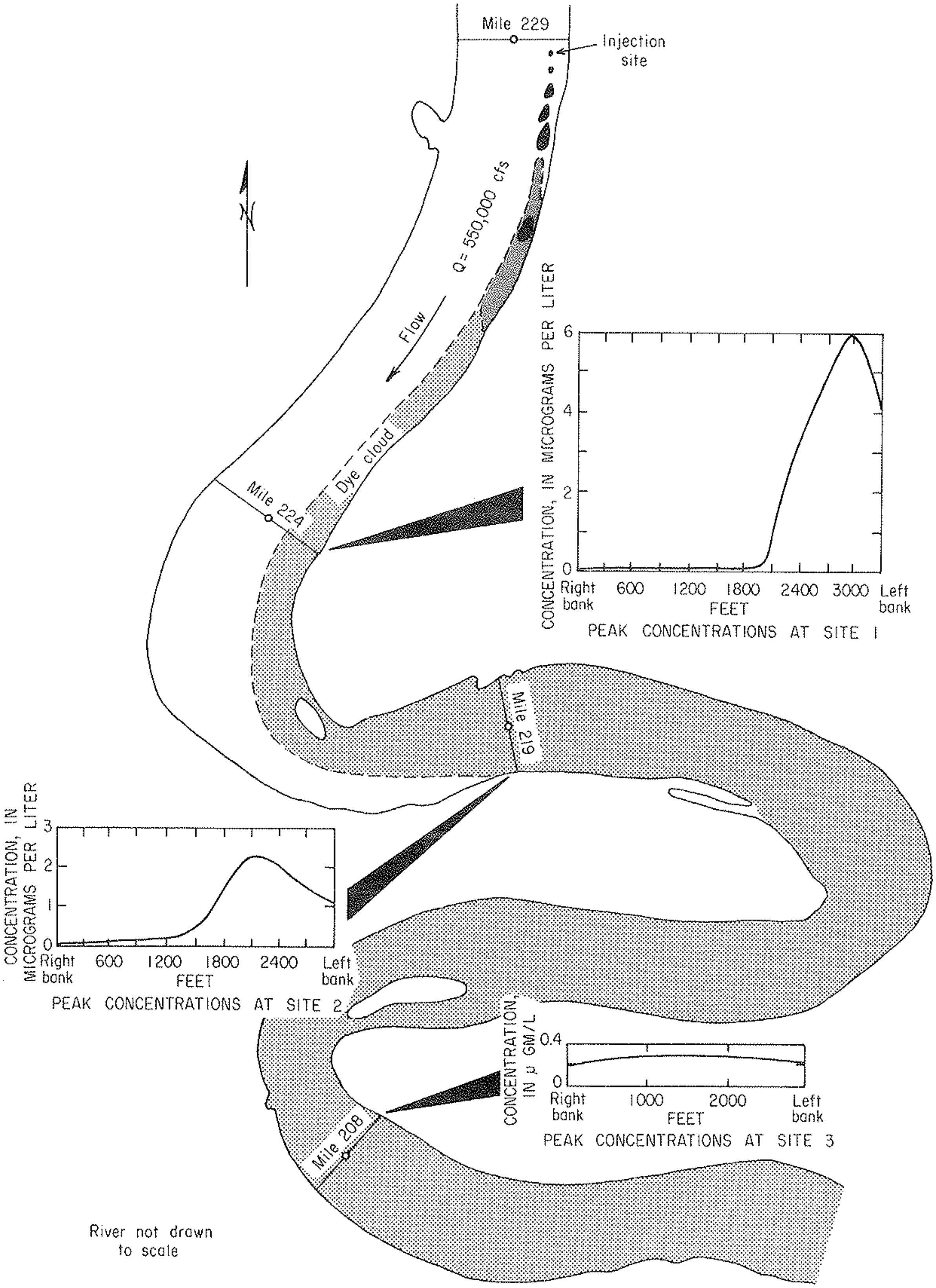

Figure 34.—Lateral dispersion of a contaminant discharged into the Mississippi River near the bank.

FINDINGS AND CONCLUSIONS

Peak flows of the Mississippi River have been reduced by flood-control reservoirs constructed on upstream tributaries and by floodways through which flood flows may be diverted to the Atchafalaya River and Lake Pontchartrain. In the past the low flow of the lower Mississippi River has been less than 100,000 cfs on several occasions. However, with the completion of the Old River Control Structure near Coochie, La., the chances of the flow being this low again are greatly reduced.

Sediment concentrations at Red River Landing and Baton Rouge range from about 10 to 2,500 mg/1; minimum concentrations usually occur during low-flow periods in the late summer and fall, and maximum concentrations occur during high-flow periods in late winter and early spring. The average annual suspended sediment load is about 750,000 tons per day.

Salt-water intrusion into the Mississippi River from the Gulf of Mexico becomes a problem only when there is a sustained low-flow. The upstream movement of the salt-water wedge mixes with fresh water at the interface causing increased chloride concentrations as far upstream as Port Sulphur when the flow reaches 180,000 cfs and upstream as far as the New Orleans Carrollton Street Purification Plant when discharge drops to 120,000 cfs.

Heated water effluent to the river has very little effect on average river water temperatures at medium and high flows, but during low-flow periods, water temperatures at Luling Ferry are as much as 3° C warmer than at St. Francisville.

Industrial use of Mississippi River water has increased from 2.0 bgd in 1960 to 5.0 bgd in 1969. About 95 percent of this water or about 7,500 cfs is returned to the river as waste water. During periods of extremely low flow this amounts to about 7.5 percent of the total flow of the river.

The 20,000 tons per day of inorganic waste discharged to the river by industry has little effect on water quality during high-flow periods because of dilution; however, during low-flow periods these effects are significant. Chloride and sulfate wastes account for most of this waste discharge; about 9,000 tons per day (45 percent) is chloride and about 6,000 tons per day (30 percent) is sulfate. The increase in dissolved solids concentrations between St. Francisville and Luling Ferry varies inversely with the flow of the river; the increase ranges from about 7 mg/1 when the discharge is 1 million cfs to about 70 mg/1 when the discharge is 100,000 cfs.

The Mississippi River assimilates great quantities of acidic waste each day with very little effect on the river. A continuous discharge to the river of 26,000 tons per day of 40 percent hydrochloric acid would, after mixing, lower the pH approximately 0.8 pH units when the discharge is 100,000 cfs.

Although large amounts of oxygen-consuming wastes are discharged to the river between Baton Rouge and New Orleans, the decrease in dissolved-oxygen concentrations generally is less than 1.0 mg/l. Dissolved oxygen saturation at New Orleans during the 1969 water year was greater than 70 percent about 80 percent of the time. Only on two occasions of short duration was saturation less than 65 percent.

As a result of time-of-travel studies using fluorscent dye, peak concentrations at any point and traveltime between points for a contaminant spill can be estimated at most discharges and at any place between Baton Rouge and New Orleans.

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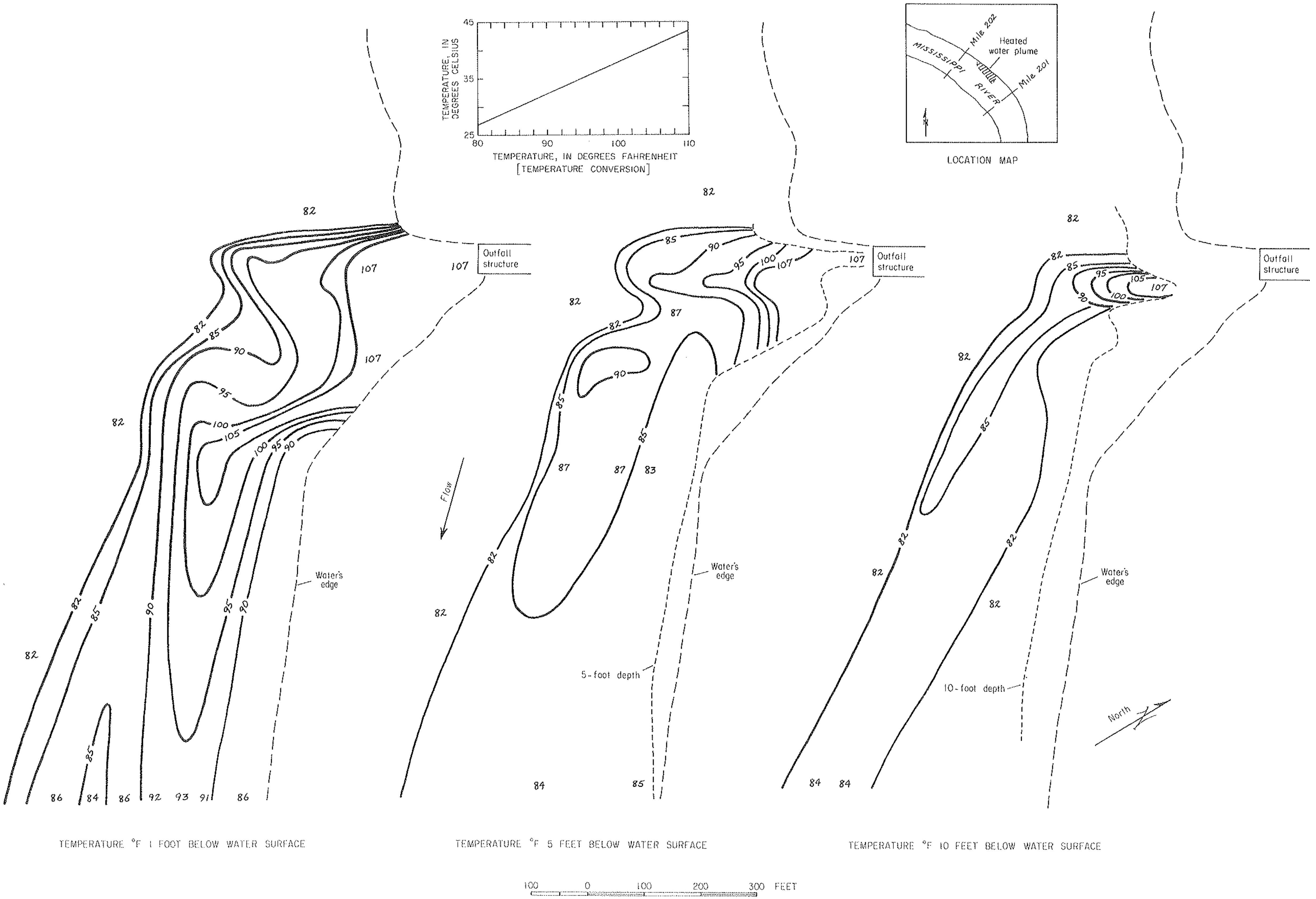

TEMPERATURE °F 1 FOOT BELOW WATER SURFACE

TEMPERATURE °F 5 FEET BELOW WATER SURFACE

TEMPERATURE °F 10 FEET BELOW WATER SURFACE

PLATE 2. HEATED WATER PLUME AT 1-, 5-, AND 10-FOOT DEPTHS AT A GENERATING STATION ON THE MISSISSIPPI RIVER NEAR RIVER MILE 200, LOUISIANA.

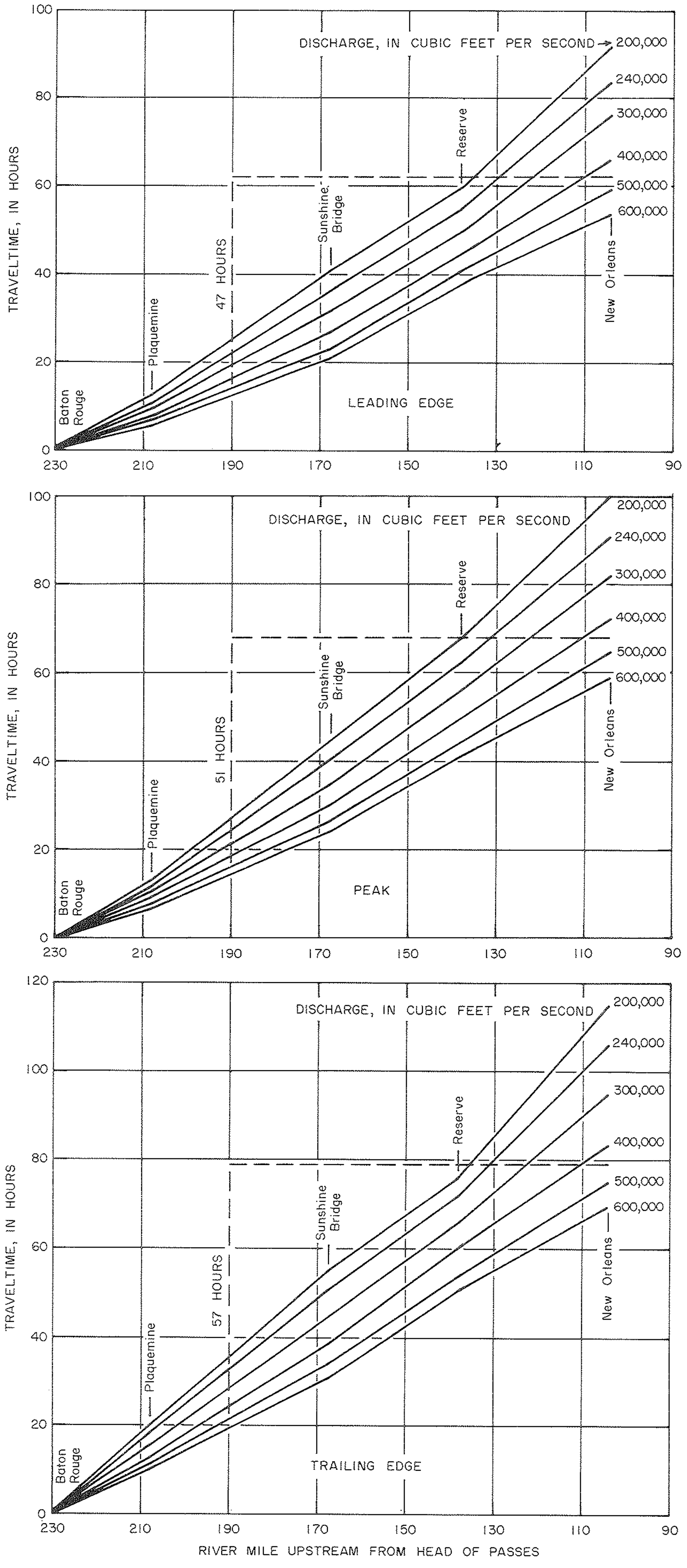

PLATE 3. CURVES SHOWING TIME OF TRAVEL AND PASSAGETIME OF A CONTAMINANT AT DOWNSTREAM LOCATIONS ALONG THE MISSISSIPPI RIVER.