Sediment Transport in a Mississippi River Distributary— Bayou Lafourche, Louisiana

Prepared in cooperation with the Louisiana Department of Public Works

Sediment Transport in a Mississippi River Distributary— Bayou Lafourche, Louisiana

By W. HARRY DOYLE, JR.

UNITED STATES DEPARTMENT OF THE INTERIOR

ROGERS C. B. MORTON, *Secretary*

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V. E. McKelvey, *Director*

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GLOSSARY

Bed or streambed. The bottom of a water course.
Bedload. Sediment that moves by rolling or sliding on or near the streambed.

Bedload discharge. The quantity of bedload passing any cross section of a stream in a unit time.

Bed material. The sediment mixture of which the streambed is composed.

Clay. Sediment particles smaller than 0.005 millimeter in size. American Association of State Highway Officials (AASHO) size classification used.

Density of water-sediment mixture. The bulk density, which is the mass per unit volume including both water and sediment.

Depth-integrated sample. A water-sediment mixture that is accumulated continuously in a sampler that moves vertically at an approximately constant transit rate between the surface and a point a few tenths of a foot above the bed of a stream and that admits the mixture at a velocity about equal to the stream velocity at each point in the vertical. Because the sampler intake is a few tenths of a foot above the sampler bottom, there is an unsampled zone just above the bed of the stream.

Discharge-weighted concentration. The dry weight of sediment in a unit volume of stream discharge, or the ratio of dry weight of sediment to the weight of the water-sediment mixture.

Median particle diameter. The particle dimension for which half the sediment by weight is coarser and half is finer.

Sand. Sediment particles between 0.074 and 2 mm in size. AASHO size classification used.

Sediment, fluvial. Fragmental material that originates from weathering of rocks and is transported by, suspended in, or deposited from water.

Sediment concentration. The ratio of the quantity of sediments to the quantity of transporting fluid, expressed as milligrams per liter.

Sediment discharge. The quantity of sediment that is carried past any cross section of a stream in a unit of time.

Sediment load. The sediment that is being moved by a stream. (Load refers to the material itself and not to the quantity being moved.)

Silt. Sediment particles between sand and clay in size (0.005–0.074 mm). AASHO size classification used.

Specific weight of sediment. The dry weight per unit volume of sediment in place. It can be computed from the wet bulk density if the specific gravity of the sediment is known.

Standard deviation. A statistical measure that in sediment analysis is obtained from the formula

$$\frac{1}{2}\left(\frac{d_{84}}{d_{50}} + \frac{d_{50}}{d_{16}}\right)$$

in which d_{16}, d_{50}, and d_{84} denote sizes of material for which 16, 50, and 84 percent by weight, respectively, are finer in a given sample.

Stream discharge. The quantity of water passing through a cross section of a stream in a unit of time. (The water contains both dissolved solids and sediment.)

Suspended-sediment discharge. The quantity of suspended sediment passing through a stream cross section in a unit of time.

Suspended-sediment sampler. A sampler that collects a representative sample of the water with its suspended-sediment load.

Suspended sediment or suspended load. Sediment that is supported by the upward components of turbulent currents and that stays in suspension for appreciable lengths of time.

Total sediment load or total load. The total sediment in transport in a stream.

SEDIMENT TRANSPORT IN A MISSISSIPPI RIVER DISTRIBUTARY— BAYOU LAFOURCHE, LOUISIANA

By W. Harry Doyle, Jr.

ABSTRACT

The installation of a pumping plant at Donaldsonville, La., in 1955 to solve a water-supply problem for the residents along Bayou Lafourche created a sedimentation problem in the bayou. Prior to 1904, when the bayou functioned as a distributary, floodflows periodically scoured the sediment deposited in the channel at lower stages. Nearly constant flows maintained by the pumping plant result in limited transport capacity to move the sediment imposed on the channel.

The total sediment inflow into Bayou Lafourche from February 1955 to July 1966 was determined by two methods. The methods and value for each method are as follows:

Method	Total sediment load for period 1955–66, in tons
Sediment-concentration graphs	866,000
Time-weighted average concentration and discharge	840,000

A gamma probe was used to determine that 311,000 tons has been deposited in the upper part of the bayou since the pumping plant went into operation. The reach used in this study was a 12.5-mile section of Bayou Lafourche beginning at Donaldsonville, La., and extending to Plattenville, La. A prediction equation,

$$\frac{Q_s}{pQ} = 2.566(10)^{-4}\left(\frac{X}{L}\right)^{0.506}(C)^{1.161},$$

where Q_s = tons of sediment per day deposited in distance X,

p = density of water, in slugs per cubic foot, in which mass M in slugs equals weight W in pounds divided by acceleration of gravity g (32.2 ft per sec²),
Q = discharge, in cubic feet per second,
X = length of channel, in feet,
L = study reach length, in feet, and
C = concentration of solids, in milligrams per liter,

was derived to determine the rate of sediment accumulation. A second prediction equation,

$$A_s = \left[\frac{d}{1.61(10)^{-4}\left(\frac{\overline{w}}{V}\right)^{0.505}}\right]^2,$$

where d = particle diameter, in feet (d_{84} for the 0- to 1-foot depth was used),

A_s = area of sediment fill at cross section for the period 1955–66, in square feet,
$\overline{w}$ = particle fall velocity of d_{84} particles, in feet per second, and
V = average velocity in the cross section, in feet per second,

1

was derived to determine the amount of sediment accumulation between 1955 and 1966 at each cross section in the study reach. The correlation coefficients for the above equations were 0.82 and 0.95, respectively.

A comparison of former channel cross sections with the present cross sections enabled the determination of the characteristics of a stable cross section. They are as follows:

1. Cross-sectional area = 160 square feet.
2. Wetted perimeter = 69 feet.
3. Hydraulic radius = 2.3 feet.
4. Width of channel = 66 feet.
5. Slope of channel = 0.000034.
6. n, Manning's roughness coefficient = 0.009.
7. Q, average discharge = 273 cubic feet per second.

The stable channel characteristics were used to design the study reach for stability. Stability, as used here, is the channel cross section and slope that will permit passage of the total sediment inflow without significant scouring or deposition.

INTRODUCTION

OBJECTIVES OF STUDY

The design of any diversion from a natural stream involves a knowledge of the sediment inflow. The channel must be designed to transport the sediment inflow, or sediment excluders must be incorporated in the headworks to eliminate the sediment that cannot be transported. If this is not done, costly periodic dredging is the alternative. In Bayou Lafourche this problem was anticipated when a pumping plant was installed in 1955, and the initial cost estimate of the project included $10,000 per year, which would be used to dredge the channel periodically.

In 1960 the Louisiana Department of Public Works made a study of settling basins that could be used to eliminate the high cost of dredging. They concluded that, because of the high concentration of clay particles in the sediment inflow, it would take a settling basin with a shallow depth over a very large area to settle out any appreciable amount of the incoming sediment. The proposed solution was abandoned because no suitable site for this type of settling basin was available.

This study was made primarily to determine the amount of sediment accumulated in Bayou Lafourche since the beginning of pumping-plant operations. The second objective was to determine if and when a stable channel might evolve and to determine the characteristics of a stable channel based on the past and present rates of pumping. The results of this study should enable realistic anticipation of future changes in the channel of Bayou Lafourche. In addition, the information should provide a basis for planning the design and maintenance of similar channels.

ACKNOWLEDGMENTS

HISTORICAL BACKGROUND

Bayou Lafourche was formerly a main outlet of the Mississippi River but, by the 12th century, was reduced in size by aggradation to that of a minor distributary (J. R. McCormick, Jr., oral commun., 1967). Plantations along the bayou were frequently flooded when high stages of the Mississippi River occurred. A dam across the bayou was completed in 1904 to prevent flooding at Donaldsonville, La., where the bayou joins the river. The dam was intended to be temporary but became a permanent part of the Mississippi River levee.

The dam prevented flooding, but a water-supply problem was created for the dense rural population that had previously depended on the bayou for its fresh-water supply. Sugar refineries and mills along the bayou also experienced the water-supply problem because the bayou had supplied them with large quantities of water during the cane-grinding season (October through December). Bayou Lafourche became stagnant and polluted after the discontinuance of flow from the Mississippi River. Water quality in the lower part of the bayou degraded further because of periodic salt-water intrusion from the Gulf of Mexico. Fresh water could be obtained only from the Mississippi River because no suitable ground water or other surface water was available.

Between 1903 and 1938 several attempts to convey water from the Mississippi River into the bayou by pumping or siphoning were abandoned because they failed to provide a sufficient quantity. The water conveyed from the Mississippi River by pumping carried a high concentration of sediment in suspension; the resulting sediment deposits in the upper part of the bayou could be removed only by costly dredging.

An attempt was made to obtain fresh water from Lake Verret by constructing the Cancienne Canal from the lake to the bayou. The attempt was partially successful during high stages of the lake. However, the stage of Lake Verret was influenced by the Atchafalaya River, and the river's influence ended when the East Atchafalaya

basin protection levee was constructed in 1938; thus, flows from Lake Verret were reduced and were too small to solve the water-supply problem. Several other attempts were made to obtain fresh water by excavating canals to the swamp areas on both sides of Bayou Lafourche. These failed too because past periodic flooding by Bayou Lafourche had created a natural levee and because the land bordering the bayou sloped away from the bayou, a situation making drainage into the bayou impossible.

The water-supply problem that plagued the residents along Bayou Lafourche since 1904 was resolved with the installation of the Walter Lemann, Sr., Pumping Plant at Donaldsonville (fig. 1). The pumping plant was placed in operation in February 1955 with an initial capacity of 300 cfs (cubic feet per second). In March 1961 an additional 100 cfs was provided by the installation of a fourth pump. The water was pumped and siphoned from the Mississippi River over the levee and into Bayou Lafourche. Several dams and floodgates were built along the bayou across the canals leading away from the bayou to prevent loss of water during low stages. These structures were also used to supplement flow in the bayou when canal stages were high.

The pumping of fresh water into Bayou Lafourche has brought many benefits. Fresh water for domestic needs is supplied to Lafourche and Assumption Parishes. Sugar refineries, which in the past had to discontinue operations for several days because of an inadequate water
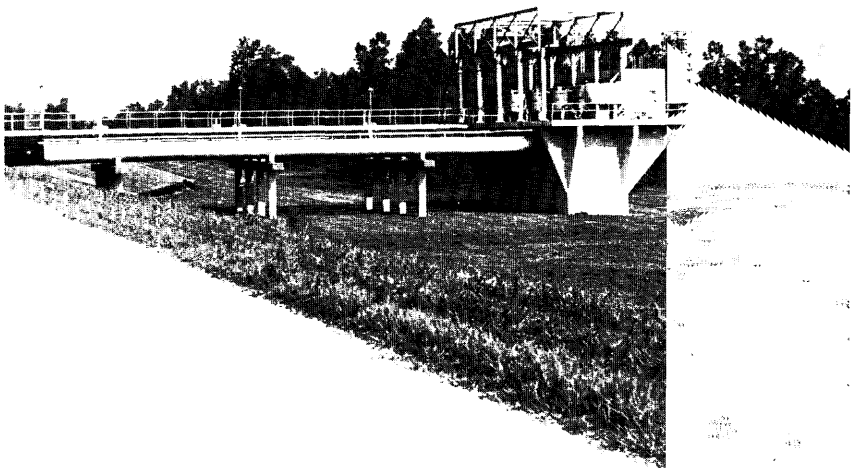

FIGURE 1.—Walter Lemann, Sr., Pumping Plant at Donaldsonville.

supply, can now operate without the risk of a water-supply failure. The pumping plant supplies cooler water of better quality than previously used and, therefore, enables the sugar refineries to operate more economically. A sufficient quantity of water also is available to dilute sugar-mill wastes and to meet the irrigation needs of rice growers. Some cane growers have utilized the water from Bayou Lafourche, and in the future more cane growers probably will depend on the bayou for irrigation water. The continuous supply of fresh water keeps the bayou from being stagnant and polluted and has encouraged many people to build summer pavilions on the bayou.

DESCRIPTION OF BAYOU LAFOURCHE STUDY AREA

The juncture of Bayou Lafourche with the Mississippi River is 175 miles upstream from the head of the passes to the Gulf of Mexico and approximately 80 river miles upstream from New Orleans. Bayou Lafourche flows in a general southeasterly direction from Donaldsonville for 107 miles until it discharges into the Gulf of Mexico about 47 miles west of the mouth of the Mississippi River.

The study reach is from the head of the bayou at Donaldsonville to Plattenville, a distance of about 12.5 miles (fig. 2). The bayou flows in a southwesterly direction in the study reach and gradually turns to a southeasterly direction below Plattenville.

Bayou Lafourche has high banks, which were formed when the bayou functioned as a distributary. These natural levees were formed from deposits by floodwaters and range in elevation from 22 feet at the head to 1 foot at the mouth. The land adjacent to the bayou slopes away from the channel at approximately 1 foot per 1,000 feet nearest the channel and progressively decreases toward marsh areas; therefore, the bayou has no natural drainage area.

The vegetation along the streambanks of Bayou Lafourche is primarily water-thriving plants such as willow trees, water lilies, and water-hyacinths. There is also a thick undergrowth composed of many types of plants. At high stages the vegetation decreases stream velocity, which has an effect on sediment deposition.

Prior to 1904, high flows (as high as 100,000 cfs) in the bayou scoured sediment that had accumulated in the channel at lower flows. Figure 3 is a photograph of Bayou Lafourche as it appeared in 1899 (ice shown in the figure is not a common condition). When Bayou Lafourche was a distributary, the channel geometry allowed transportation of the sediment inflow. The flow regime was changed when the pumping plant went into operation. Figure 4 is a photograph of Bayou Lafourche as it appears today. The photograph was taken at approximately the location of the earlier photograph. The change in flow regimes can be noted by observing both photographs. The
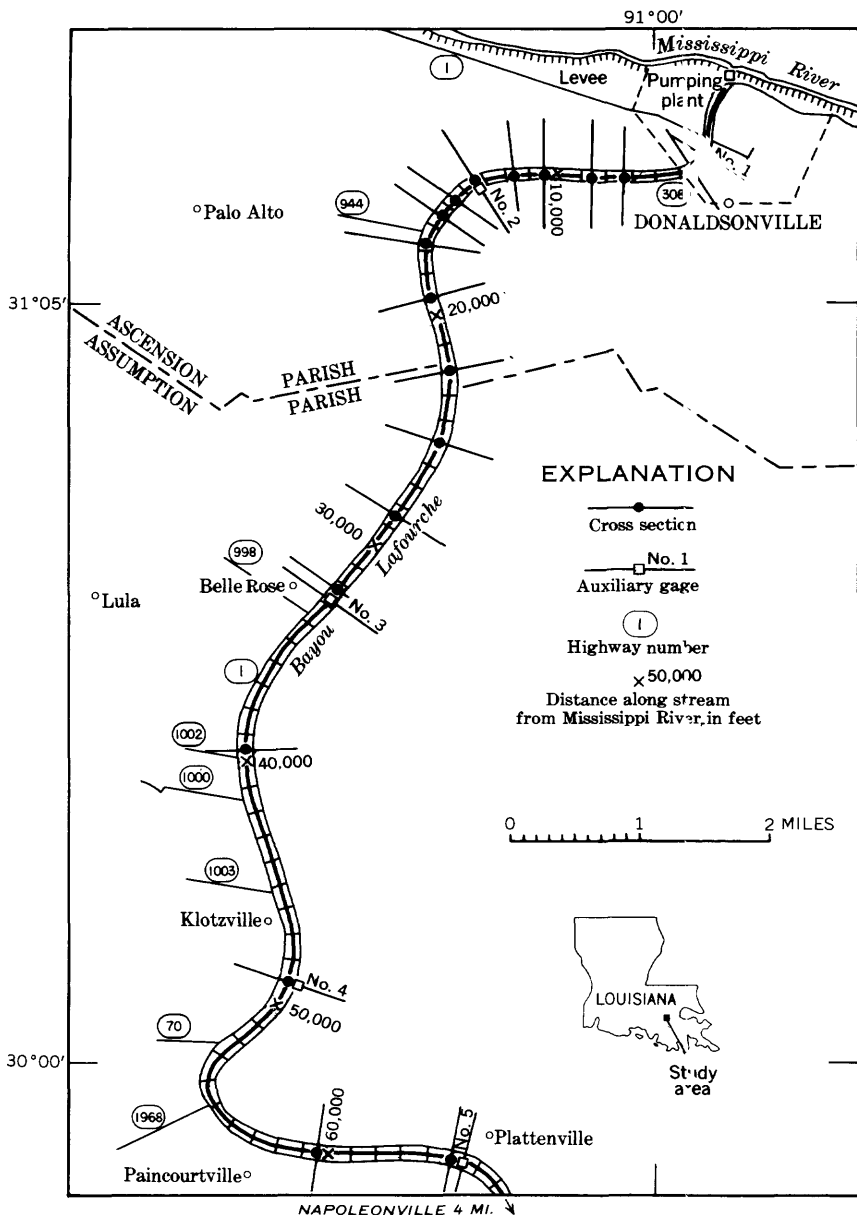
FIGURE 2.—Bayou Lafourche study reach.

concrete pier on the right bank in figure 4 is the same as the center pier of the bridge in figure 3.

Any change in the flow regime of a natural channel will cause adjustment of the channel's slope and boundaries to enable trans-

FIGURE 3.—Bayou Lafourche in 1899 (note ice). The view is downstream from Donaldsonville, La. Photograph, courtesy of Miss Theresa Chapmann, Donaldsonville, La.

portation of the sediment load under the new conditions. If the change in flow regime is extensive, alteration of the channel and flood plain might be far reaching.

From 1904 to 1955 there was little or no flow in the bayou. Since 1955, the pumping plant has supplied controlled flows with a maximum of 400 cfs. Therefore, the lack of periodic high flows since 1904 caused the channel to adjust to a new geometry in order to transport the sediment inflow. The channel has continued to adjust to the changing flow regime and will continue to do so until the channel becomes stable along the entire reach or fills with sediment so that the design flow cannot be carried.

DETERMINATION OF TOTAL SEDIMENT INFLOW

PROCEDURE

Suspended-sediment-concentration data were collected at monthly intervals from December 1958 to July 1966. A suspended-sediment sampler model DH–59 was used to collect depth-integrated samples at four sites in the study reach. The sites were Donaldsonville, Palo Alto, Belle Rose, and Napoleonville, which are 3,000, 16,787, 32,347, and 85,482 feet downstream, respectively. Also, samples were taken 700 feet downstream at Donaldsonville from 1958 to 1963. The samples were collected on the upstream side of the bridge at the center section

FIGURE 4.—Bayou Lafourche in 1968. The view is downstream from Donaldsonville, La.

at each site except the site at 3,000 feet downstream where the sample was taken on the downstream side of a culvert.

The suspended-sediment sample at Donaldsonville was assumed to represent the total sediment concentration because all the material is in suspension at that point. At the other sites farther downstream the measured sediment concentration also is assumed to represent the total sediment concentration because an analysis of the available data by the modified Einstein procedure (Colby and Hubbell, 1961) showed that bedload was only an insignificant 2 to 3 percent of the total sediment discharge. These data and corresponding discharge data were used in the computation of the total sediment inflow into Bayou Lafourche.

The first method used to determine the sediment inflow was to plot sediment-concentration graphs for each year that suspended-sediment data were available. Figure 5 is an example of the sediment-concentration graph for the bayou for 1960. The following procedure was used to determine the sediment-concentration graph:

1. Daily mean discharges were plotted for Bayou Lafourche (fig. 5).
2. The daily stage of the Mississippi River was plotted. The stage was obtained from daily logs recorded at the Donaldsonville pumping plant.
3. The suspended-sediment concentration for the bayou was plotted at the date of occurrence.
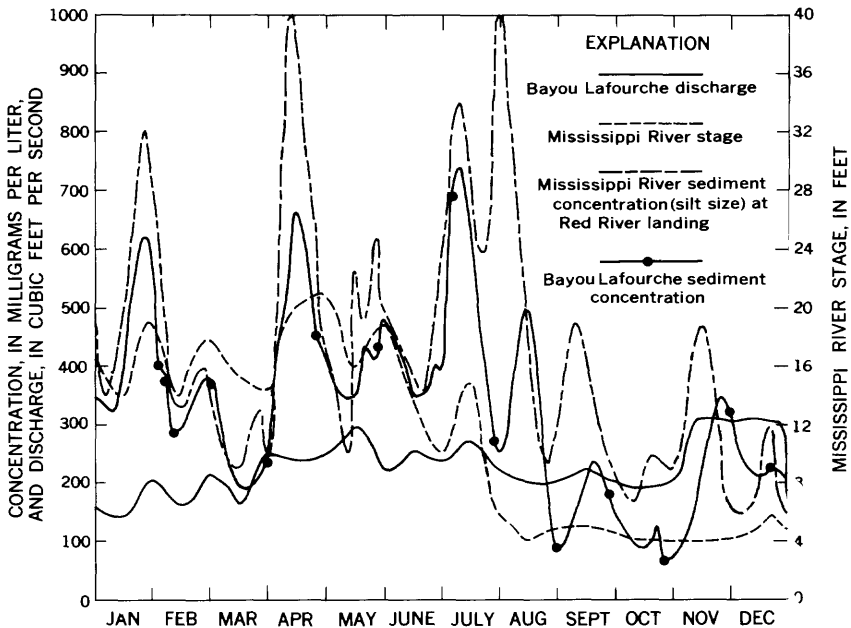
FIGURE 5.—Relation between sediment concentration and water discharge in Mississippi River and Bayou Lafourche.

4. The suspended-sediment concentration in the silt class for the Mississippi River at Red River Landing, 125 miles upstream of Donaldsonville, was plotted (fig. 5).

5. The sediment-concentration graph was drawn using information from steps 1 to 4 as a guideline. The development of the graph was based on the configuration of the bayou discharge graph, the Mississippi River stage graph, the sediment concentration in the bayou, and the sediment concentration of the Mississippi River. Guidelines used to draw the graph were based on several repetitive occurrences. The first is that a rise in concentration in Bayou Lafourche occurs with a rise in concentration in the Mississippi River. Every rise in concentration in the river precedes the rise in concentration in the bayou by several days because the sediment concentration that is measured upstream at Red River Landing requires several days to move downstream to the pump inlet at Donaldsonville. A second guideline in determining the sediment-concentration graph was to observe the Mississippi River stage at Donaldsonville. A rise in stage will be accompanied by a rise in concentration in the bayou because of an increase in velocity and sediment concentration in the river. The peak in concentration will occur prior to the

peak stage recorded for the Mississippi River. The concentration will be declining when the peak stage is obtained. These guidelines, along with suspended-sediment-sampling data, enabled the construction of sediment-concentration graphs for the bayou.

The total sediment inflow (tons per day) into the bayou was determined from the sediment-concentration graphs by:

1. Obtaining the mean discharge for a period where no abrupt changes in discharge and concentrations occur.
2. Obtaining the mean sediment concentration for the same period.
3. Multiplying the mean discharge by the mean concentration for the period and converting this product to a sediment discharge, in tons per day.
4. Multiplying the average sediment discharge by the number of days to obtain the sediment inflow during the period.

The sediment-concentration graphs were used to determine the sediment inflow for the period 1959–66. The sediment inflow for the period 1955–58 was estimated from the average annual sediment inflow calculated for the period 1959–66.

A second procedure was used to compute the total sediment inflow into Bayou Lafourche for the period 1955–66. Table 2 lists the suspended-sediment concentrations from December 1958 to July 1966 and the daily mean discharge for the same day the suspended-sediment samples were taken. The data in table 2 were analyzed by the following procedure:

1. Time-weighted average sediment concentration and discharge were calculated for the period of record.
2. The product of these two values was multiplied by the constant 0.0027 to calculate a time-weighted average daily sediment discharge, in tons per day.

The average daily sediment discharge was assumed to equal the average daily total sediment inflow from February 1955 to July 1966. By assuming this, a total sediment inflow for the period was calculated.

RESULTS

The total sediment inflow into Bayou Lafourche from February 1955 to July 1966 as calculated by the two methods is presented in the following tabulation. The two methods are arranged in order of accuracy, with the most accurate first.

Method	Total sediment load for period 1955–66, in tons
Sediment-concentration graphs	866,000
Time-weighted average concentration and discharge	840,000

The sediment-concentration graph was the most accurate of the two methods for several reasons. Short time intervals, such as 1 to several days, were used to construct the graphs. Shorter time intervals weigh the concentration and discharge data, whereas longer time intervals tend to average out short-term irregularities. The degree to which the irregularities are hidden depends on the time interval used. The graphs are based upon the variation in several other variables, whereas the other method was solely dependent on concentration and discharge data.

The total sediment inflow was approximately the same for each method. This close agreement was because constant-range flow regimes have been maintained during the period 1955–66. The sediment discharge was directly influenced by the flow regime, so that variations for any time interval during this period were generally within a limited range.

SEDIMENT DEPOSITION IN THE STUDY REACH

DEPOSITION CALCULATED FROM SUSPENDED-SEDIMENT-SAMPLING DATA

Suspended-sediment-concentration data at Donaldsonville, Belle Rose, and Napoleonville, La., were used to determine the fraction of the sediment load that deposited within the study reach from February 1955 to July 1966. Time-weighted average sediment concentrations for the period 1959–66 were calculated for Donaldsonville, Belle Rose, and Napoleonville. These values were assumed to apply for the unsampled period, 1955–59. The value at Donaldsonville represents the total suspended load entering the bayou. The part of the total suspended load that deposited between Donaldsonville, Belle Rose, and Napoleonville was calculated as the difference in concentrations between Donaldsonville and the other two stations; equal discharge at all sections was assumed. This assumption was valid because practically no water enters the bayou except through the pumping plant. Also, evaporation and channel losses were considered to be negligible.

Figure 6 shows that 33 percent of the total sediment inflow was deposited in the study reach. The value was obtained by subtracting the value at station 4,500 from the value at station 65,600. The equation for the graph is as follows:

$$Y = 0.00643X^{0.78}, \tag{1}$$

where X = distance to station, in feet, and

Y = percent of total sediment inflow that settles out in X feet.

The total sediment inflow was multiplied by 33 percent to obtain the part that deposited between stations 4,500 and 65,600 for the period 1955–66. These values are as follows:

	Load deposited between 4,500 and
Method	*65,600, in tons*
Sediment-concentration graphs_____	286,000
Time-weighted average concentration and discharge_____	277,000

ANALYSIS OF VARIABLES AFFECTING SEDIMENT DEPOSITION IN BAYOU LAFOURCHE

All the sediment dumped into Bayou Lafourche existed as suspended material in the Mississippi River. The amount of material settling out in the bayou is a function of many variables. Variables on the Mississippi River side of the levee affect the total amount of material that comes into the bayou, and variables on the bayou side affect the amount of the total incoming sediment load that will settle out and where it will be deposited.

The concentration of suspended material in the Mississippi River directly affects the concentration of suspended material in Bayou Lafourche. The following variables indirectly affect the concentration of suspended material in the bayou:

1. Discharge of the Mississippi River.
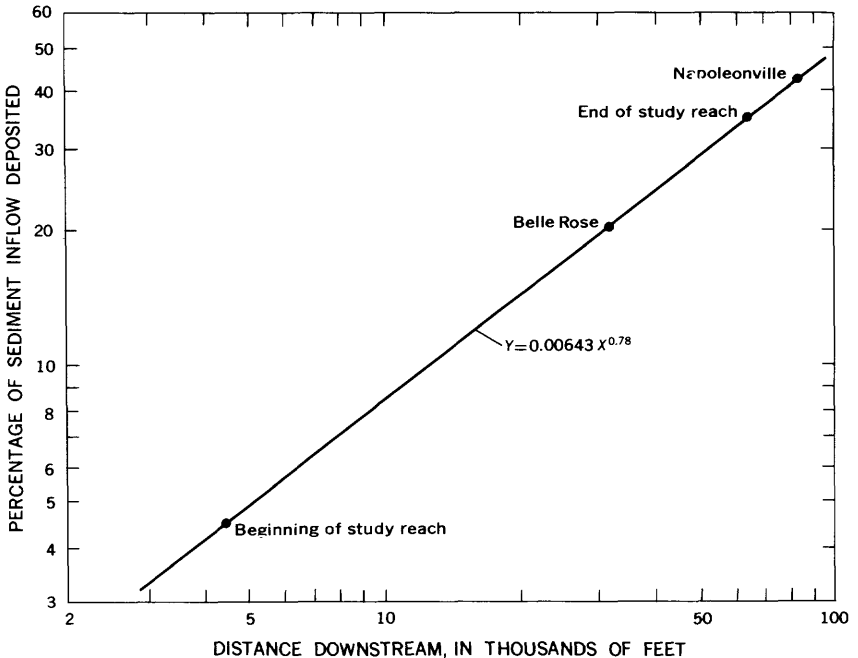2. Rising or falling river stage.
3. Temperature of the river.

FIGURE 6.—Percentage of total sediment inflow deposited in study reach.

4. Season of the year.
5. Any weather conditions contributing to flooding or drought, which would influence the amount and type of flow carried by the Mississippi River.

Some of these variables are interrelated as to their influence on the amount and type of sediment conveyed by the Mississippi River.

The variables on the bayou side can be categorized into four groups with several variables in each group. The groups and variables are as follows:

1. Geometry of the channel:
    (a) Width.
    (b) Mean depth.
    (c) Cross-sectional area.
    (d) Slope.
    (e) Bed form.
2. Characteristics of flow:
    (a) Discharge into bayou.
    (b) Velocity of flow.
    (c) Turbulence.
3. Characteristics of fluid:
    (a) Density.
    (b) Viscosity.
    (c) Difference in specific weights where a lighter and a heavier fluid are in contact along a fluid surface or interface.
4. Characteristics of the suspended sediment:
    (a) Concentration of sediment.
    (b) Concentration of sand, silt, and clay.
    (c) Dry unit weight.
    (d) Characteristic size.
    (e) Particle density.
    (f) Shape factor.
    (g) Relative standard deviation of the size distribution.
    (h) Fall velocity.

It is seen that many variables, on both the Mississippi River side and the bayou side of the levee, affect the sediment flow into and through the bayou. Because of a paucity of data, an analysis of the effect of many of the variables was not possible.

Several dimensionless pi terms were developed from variables with available data. A pi term is an expression in which several variables are grouped together in dimensionless form. The pi terms developed are as follows:

$$\text{pi}_1 = \frac{A_s u^2}{Q^2 p_f^2} \qquad\qquad \text{pi}_2 = C_c$$

$$\text{pi}_3 = C_s \qquad\qquad \text{pi}_9 = \frac{\bar{w}Qp_f{}^2}{u^2}$$

$$\text{pi}_4 = C \qquad\qquad \text{pi}_{10} = \frac{Wu}{Qp_f}$$

$$\text{pi}_5 = \frac{V(R)p_f}{u} = \mathbf{R} \qquad\qquad \text{pi}_{11} = \frac{Q_s}{p_f g Q}$$

$$\text{pi}_6 = \frac{A_c u^2}{Q^2 p_f{}^2} \qquad\qquad \text{pi}_{12} = \frac{d}{A_s{}^{0.5}}$$

$$\text{pi}_7 = \frac{D_c u}{Qp_f} \qquad\qquad \text{pi}_{13} = \frac{\bar{w}}{V}$$

$$\text{pi}_8 = \frac{du}{Qp_f} \qquad\qquad \text{pi}_{14} = \frac{X}{L}$$

In the above terms the various symbols are defined as follows:

A_s = area of sediment fill in channel cross section for the period 1955–66, in square feet,

u = dynamic viscosity, in pound-seconds per square foot,

Q = discharge in bayou, in cubic feet per second,

p_f = density of fluid, in slugs per cubic foot,

C_c = concentration of clay in sediment samples, in percent,

C_s = concentration of sand in sediment samples, in percent,

C = concentration of solids, in milligrams per liter,

V = average velocity through channel cross section, in feet per second,

R = hydraulic radius, in feet,

d = particle diameter, in feet,

$\bar{w}$ = fall velocity of particles, in feet per second,

W = width of channel cross section, in feet,

Q_s = sediment load deposited in a specified distance X, in pounds per second,

$\mathbf{R}$ = Reynolds number,

g = acceleration of gravity, equal to 32.2 feet per second^2,

X = distance of channel, in feet, in which deposition occurs,

L = reference length, in feet, equal to the length of the study reach,

A_c = area of channel, in square feet, and

D_c = depth of channel, in feet.

Several of the pi terms were analyzed in respect to determining the objectives of this report. The dependent terms "pi_i" and "pi_{12}" were correlated with the independent pi terms "5," "6," "7," "8," "9," "10," and "13" to determine if there were either linear or non-

linear relationships between the terms. The dependent term "pi_1" showed no significant correlation as a result of this analysis. An attempt was also made to see if there was a correlation between the independent terms "pi_4" and "pi_{14}" and the dependent term "pi_{11}."

TEMPERATURE EFFECT ON SEDIMENT DEPOSITION

The water temperature of Bayou Lafourche as a function of time is illustrated in figure 7. The curve was developed from water-temperature data of the Mississippi River for several years of record and represents the average daily temperatures for the period. In the upstream part of the bayou the water temperature is approximately equal to that of the river. Therefore, the graph can be used to obtain an average water temperature for the bayou for any period during the year.

The influence that water temperature has on the sediment load in a stream channel was illustrated in a study made at the St. Anthony Falls Hydraulic Laboratory in Minneapolis, Minn., under the supervision of Lorenz G. Straub, Director (Straub and others, 1958). Experiments were performed in the laboratory with the water temperature ranging from 34.5° to 86°F. The total suspended load and the total sediment load were measured throughout the range in temperature. Both suspended and total sediment load increased as the temperature of the water decreased. Results showed that the total
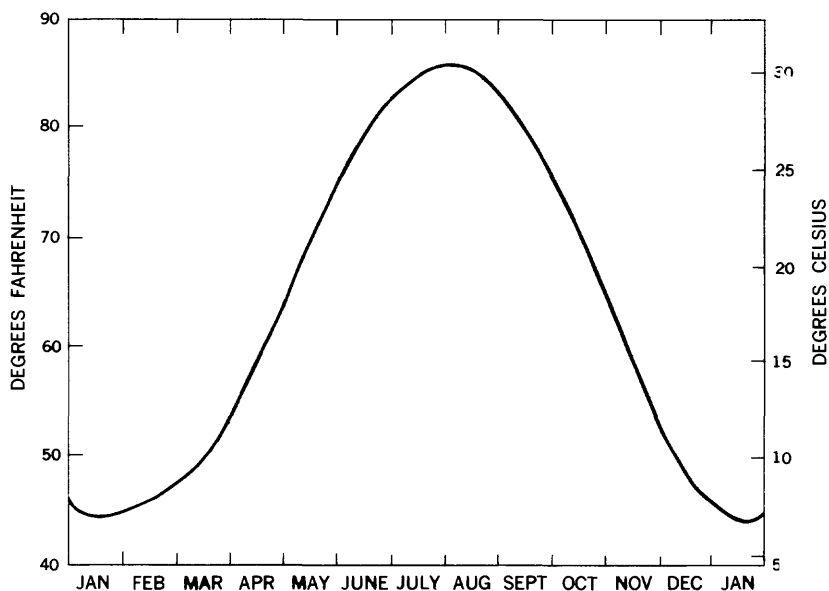

FIGURE 7.—Bayou Lafourche average daily water temperature.

sediment load increased about 200 percent when the temperature of the water was decreased from 86° to 34.5°F.

It is reasonable, then, to expect that during late fall and winter the sediment transport capacity of Bayou Lafourche increases. During this time the average water temperature is about 47°F, while from June to September it is above 80°F. Therefore, sediment particles in a given size range will be deposited farther downstream during colder months.

EQUATIONS DEVELOPED BY DIMENSIONAL ANALYSIS TO DETERMINE THE RATE AND AMOUNT OF SEDIMENT ACCUMULATION

The rate of sediment accumulation in the bayou can be determined by the following dimensionless equation developed by multiple regression analysis:

$$\frac{Q_s}{pQg} = 1.845(10)^{-7} \left(\frac{X}{L}\right)^{0.506} (C)^{1.161}, \qquad (2)$$

where Q_s = sediment, in pounds per second, deposited in distance X,

Q = discharge, in cubic feet per second,

p = density of water, in slugs per cubic foot,

X = length of channel, in feet,

C = concentration of suspended sediment at inlet of study reach, in milligrams per liter,

L = length of study reach equal to 61,100 feet, and

g = acceleration of gravity equal to 32.2 feet per second^2.

Using the value for g and converting the units of Q_s from pounds per second to tons per day, equation 2 may be expressed in the following form:

$$\frac{Q_s}{pQ} = 2.566(10)^{-4} \left(\frac{X}{L}\right)^{0.506} (C)^{1.161}. \qquad (3)$$

Equation 3 can be used to predict the weight of material that will fall out in a certain length of the stream channel if the independent variables p, Q, C, and X, are known. The equation cannot be used to determine the size of the material falling out or how the settled load will be distributed. If the study reach becomes stable, the equation will not be applicable but can be utilized at unstable sections farther downstream.

Figure 8 illustrates the graphical representation of equation 3 for one value of X (85,482 ft). The rate of sediment deposition (Q_s) from Donaldsonville to Napoleonville can be estimated, given the concentration of suspended solids at Donaldsonville and assuming equal water discharge. Similar graphs were plotted from other lengths (16,787 and 32,347 ft) in the study reach, and equation 3 was developed
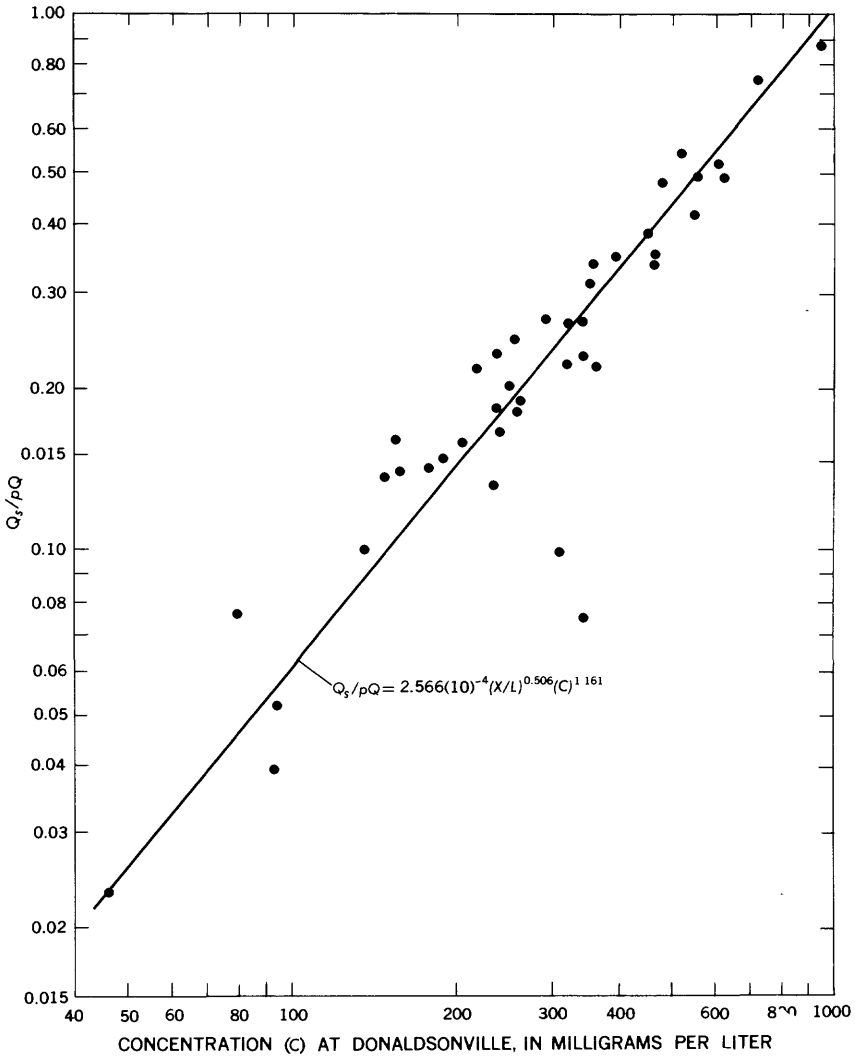
FIGURE 8.—Graph for predicting sediment deposition in Bayou Lafourche from Donaldsonville to Napoleonville.

to apply to all lengths. The correlation coefficient for equation 3 equaled 0.82.

The following relation was developed to predict the area of sediment fill:

$$A_s = \left[\frac{d}{1.61(10)^{-4}\left(\dfrac{\bar{w}}{\bar{V}}\right)^{0.505}}\right]^2, \tag{4}$$

where d = particle diameter, in feet (d_{84} for the 0- to 1-foot depth was used and is the diameter for which 84 percent by weight is finer in a given sample),

A_s = area of sediment fill at cross section for the period 1955–66, in square feet,

$\bar{w}$ = fall velocity of d_{84} particles in the 0- to 1-foot zone, in feet per second, computed from Stokes' equation (Baver, 1956), and

V = average velocity in the cross section, in feet per second.

Figure 9 illustrates the relationship between d divided by $(A_s)^{0.5}$ and $\bar{w}$ divided by V. The correlation coefficient for equation 4 was 0.95. This equation is based on the assumption that the particles in the 0- to 1-foot zone in the middle and lower part of the study reach are similar to particles deposited in the upper part in the past. An analysis of the sediment deposited in the channel verifies that a step change is occurring in the range of sizes being deposited. Under the existing conditions the equation can be used to determine the area of sediment fill at any cross section in the study reach since 1955 if the following information about the cross section is known:

1. The size of the particles in the streambed at the 0- to 1-foot depth.
2. The mean velocity.

The equation is not applicable to other streams unless variables such as sediment discharge and bedform, which would affect the area of sediment fill, are considered. It would be applicable for streams where

$$A_s = \left[\frac{d}{1.61(10)^{-4} \left(\frac{\bar{w}}{V} \right)^{0.505}} \right]^2$$
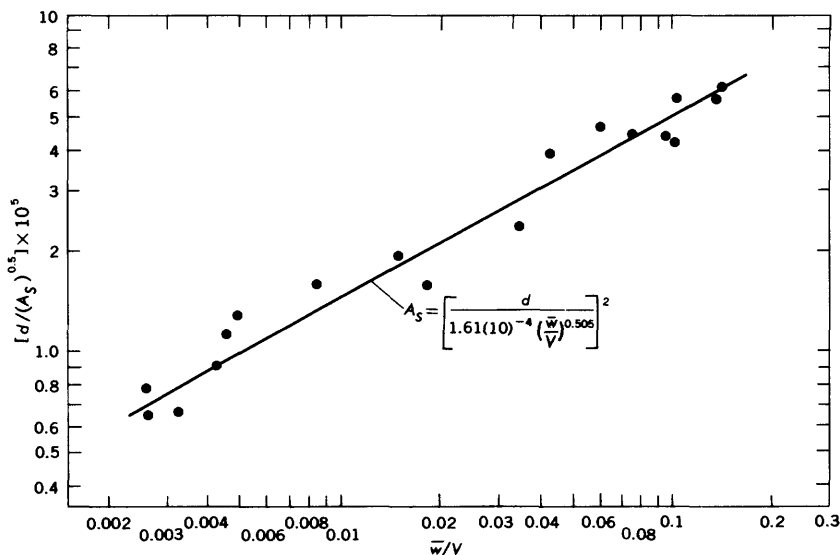
FIGURE 9.—Graph for predicting area of sediment fill.

conditions are similar to those in Bayou Lafourche. If yearly determinations of sediment accumulation are desired, core samples cf the streambed in the 0- to 1-foot zone will have to be taken annually; the amount deposited can be calculated by subtracting the previous sediment accumulation from the present.

GAMMA-PROBE INVESTIGATION

SOIL-MECHANICS THEORY OF STRESS DISTRIBUTIONS IN SOILS

Several theories and relations were used to determine the amount of sediment deposited in the bayou study reach since 1955. These were (1) the theory concerning the gamma probe, (2) the theory of soil mechanics on stress distributions in soils, and (3) the theory and relations from soil physics. References (U.S. Army Corps Engineers, 1965; Spangler, 1966; Baver, 1956) supply a detailed explanation of each of these theories.

The gamma probe and theory on stress distributions in soils were used to define the 1903 and 1955 cross sections at several locations in the study reach. A basic understanding of stress distributions in soils is necessary to an understanding of the use of the gamma probe; therefore, this theory will be presented in the following paragraphs.

In 1885 Boussinesq developed a solution for the problem of stress distribution in a semi-infinite elastic medium when acted upon by a point load applied at the surface of the mass (Spangler, 1966). The Boussinesq solution is very useful in estimating stresses in the undersoil due to foundation loads applied near the soil surface, even though soil seldom is isotropic and homogeneous and is not an elastic material. The Boussinesq principles of stress distribution in a soil mass were used as guidelines for delineating the 1903 and 1955 cross sections of Bayou Lafourche.

The distribution of the vertical pressure on any horizontal plane in the soil beneath a concentrated load is represented by a bell-shaped surface. Directly beneath the load on the vertical axis is the maximum ordinate of stress, while downward and outward from this point the stress decreases in all directions. The stress theoretically would be zero at infinity, but for practical purposes it may be considered to reach a zero value at a relatively small finite distance. At shallow depths, the maximum pressure ordinate is relatively high, but it decreases as the depth increases. Thus, as depth increases, the bell-shaped surface flattens out.

The stress surface for a series of horizontal planes at various depths is plotted in figure 10A. Points of equal stress on the various planes are connected, and a surface of revolution having a bulb shape is developed. This surface often is called the bulb of pressure. At each point on the pressure bulb the pressure is the same. Inside the bulb, pressures are greater than at a point on the bulb surface; and outside
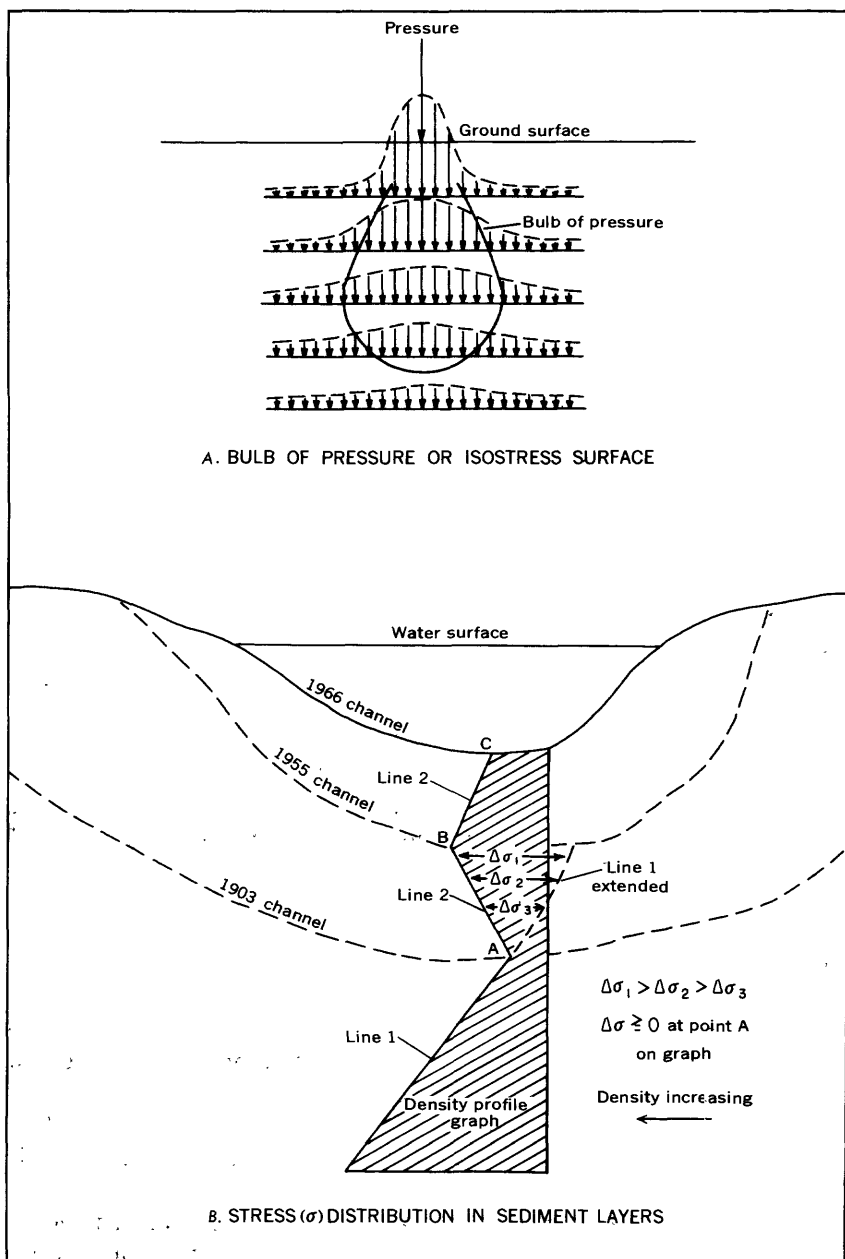
FIGURE 10.—Stress diagram of sediment deposition.

the bulb surface, pressures are less. This illustration is for a given value of pressure, but any number of bulbs of pressure may be drawn for any applied load.

The material deposited at each cross section in the study reach was considered to be an infinite number of point loads. The distribution of the vertical pressure on any horizontal plane beneath any 1955 cross section would have a stress diagram similar to that in figure 10A for each point load. The magnitude of pressure across each horizontal plane would depend upon the type and amount of material deposited in the bayou since 1955. As depth increases below a 1955 cross section, the pressure on each horizontal plane created by the 1955–66 material would decrease.

The 1903–55 material was different from the material deposited since 1955. If it were not, the stresses created by the 1955–66 material could not have been determined. Although the magnitude of the stresses cannot be determined, it was possible to determine how the stresses were distributed. This was done by observing how the density of the layer changed with depth. The density of each increment below the 1955 cross sections was directly related to the overburden load above the increment and to the stress increase caused by the 1955–66 material.

Material deposited prior to 1903 was mostly fine clay to coarse silt with very little sand. Consequently, each layer had a density less than the layer below it. This is illustrated by line 1 of the density-profile graph below the 1903 cross section shown in figure 10B. From 1903 to 1955 the only sediment deposited in the bayou was brought in by the several attempts to pump or siphon water from the Mississippi River. During the period 1903–55, decayed vegetation mixed with the sediment deposits to make a very porous, highly organic sediment layer. The density of this layer was different from the density of the pre-1903 material. In figure 10B the extension of line 1 between the 1903 and 1955 cross sections illustrates how the density would have changed if the flow regime had not been altered. In 1955, when the pumping plant began operation, sediment similar to pre-1903 material was deposited. The density of the layers above the 1955 cross section is represented by line 2 from B to C. The stress created by the material deposited in the channel after 1955 caused the density of the 1903–55 layer to change. This is illustrated by line 2 from A to B.

Material deposited after 1955 compressed the porous 1903–55 layer. The upper part of the organic layer was compressed to a greater degree than the lower part because the stress created by the 1955–66 material was greater at the top and decreased as depth increased. The variation in the increased stresses in the 1903–55 layer is illustrated by the symbols $\Delta\sigma_1$, $\Delta\sigma_2$, and $\Delta\sigma_3$ in figure 10B. The increased

stresses in the 1903–55 layer were reflected by the change in density of this layer; therefore, in figure 10B the density-profile reverses at A and exemplifies the increased stresses. The layers below the 1903 cross section also have increased stresses and densities because of the 1955–66 material, but only the change in density in the 1903–55 layer due to stress increases could be determined.

The gamma probe measures both the liquid and solid phase of the soil. Relations from soil physics were used to calculate the solid phase so that the sediment deposition determined from previously discussed methods could be compared to the sediment deposition calculated by the gamma-probe method. The gamma probe was initially calibrated by measuring materials of known specific weights, constructing a curve of specific weight versus gamma-probe counts, and utilizing the curve to determine specific weights of unknown materials.

The gamma probe was used in June and July 1966 to obtain density profiles at 18 stations in the study reach (fig. 2). These stations represent an average channel cross section for that part of the study reach in which they are located. At each station the 1903 and 1955 channel cross sections were delineated by the Boussinesq stress theory.

Data were collected at each cross section to determine the 1966 channel area. This gave a general indication of change in geometry with distance downstream. Six to seven vertical profiles were taken with the gamma probe at each cross section so that the variation in density of the inplace material might be determined and compared to successive positions across the channel. Density profiles at each station are shown in figures 18 to 35.

VERIFICATION OF 1903 AND 1955 CROSS SECTIONS

An analysis of bottom samples from several cross sections was made to verify the positions of the 1903 and 1955 cross sections determined with the gamma probe. The size and type of material in each sediment layer was determined. This analysis enabled a differentiation of the zones of sediment fill for the periods 1903–55 and 1955–66. When the 1955 cross section was reached, several of the soil samples showed definite changes in type and size of material. Below the 1955 cross section the material was largely organic and decomposed vegetation. Below the 1903 cross section, material was detected similar to the post-1955 material.

Several earlier surveys by the Louisiana Department of Public Works were analyzed and compared to the gamma-probe work. Several of the earlier stations were at or near stations used in this study. For example, the cross section at station 4,500 had previously been surveyed in 1951, 1955, 1958, and 1963 so that changes in sediment accumulation from 1955 to 1966 could be determined. A good

correlation was shown between these surveys and the gamma-probe survey at the stations compared.

CALCULATION OF CHANNEL AREAS

The 1966 channel area (for a reference elevation representing the mean discharge) at each cross section was determined from the gamma-probe survey. The 1955 channel area was also calculated for each cross section using the same reference elevation, and the difference between the 1955 and 1966 cross-sectional areas was equal to the sediment deposition for the 11-year period.

Each cross section was considered as representative of the average cross section for the part of the study reach between it and one-half of the distance upstream and one-half of the distance downstream to the next cross section. The distance multiplied by the area of sediment fill since 1955 produced the volume of sediment fill. The average saturated unit weight at each cross section was converted to a dry unit weight. The dry unit weight was multiplied by the volume of sediment fill to obtain the weight of sediment deposited in the subreach. The summation of weight of sediment in the subreaches equaled the total weight of sediment deposited in the study reach.

RESULTS

The sediment accumulation determined by the gamma probe for the period February 1955 to July 1966 was 311,000 tons (table 3). A comparison of this value with the values obtained from the methods previously discussed is shown in the following tabulation. The percentage error is based on the gamma-probe value of 311,000 tons.

Method	Load deposited in study reach, in tons	Percentage error
Sediment-concentration graphs_____ _ __ __ ___	286,000	−8
Time-weighted average concentration and discharge_____	277,000	−11

Both methods were less than the gamma-probe value. The fact that part of the suspended load was not measured when the suspended-sediment samples were collected probably contributed to the underestimation. The values determined by the two methods were based on a small amount of data for each of several variables. If continuous data for the variables were available, a more accurate determination of the sediment inflow and deposition in the bayou could be made.

CHARACTERISTICS OF 1955–66 SEDIMENT DEPOSITION

Figure 11 illustrates the particle-size distribution of the 1955–66 sediment deposition in the 0- to 1-foot layer at several cross sections. The diameters used for these comparisons were the d_{16}, d_{35}, d_{50}, d_{65},
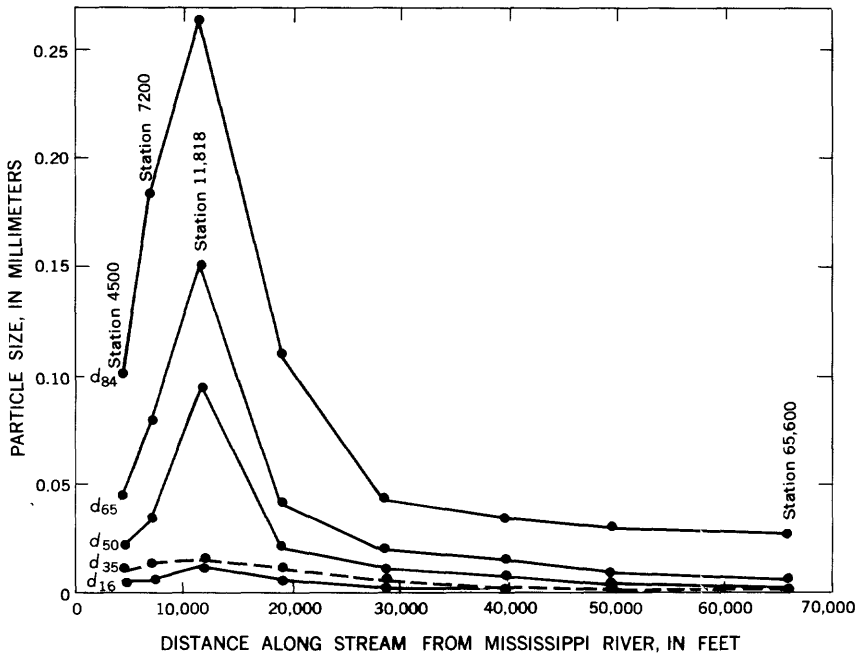
FIGURE 11.—Change in particle-size distribution of 1955–66 sediment fill (0- to 1-ft depth).

and d_{84} sizes of material, which are defined as the diameters for which 16, 35, 50, 65, and 84 percent by weight, respectively, are finer in a given sample. Contrary to expectations, the particle size of the deposited material increases until station 11,818 is reached and decreases thereafter. One explanation is that only selected samples of deposited material were taken, and their positions could have been in some part of the streambed that had a wedge of sand being transported through it. Another factor is that, since 1955, bedload movement could have transported the larger particles downstream to station 11,818 from the stable reach upstream.

Figure 12 exhibits the density changes of the streambed from station 4,500 to 65,600. These values are average saturated unit weights of the 1955–66 sediment deposition. The density of the deposited sediment decreases as distance downstream increases because the larger particles remained upstream and compacted to a greater degree than the particles deposited downstream.

The 1955–66 sediment fill generally decreases as distance downstream increases because most of the sediment inflow has been deposited in the upper part of the study reach (fig. 13).

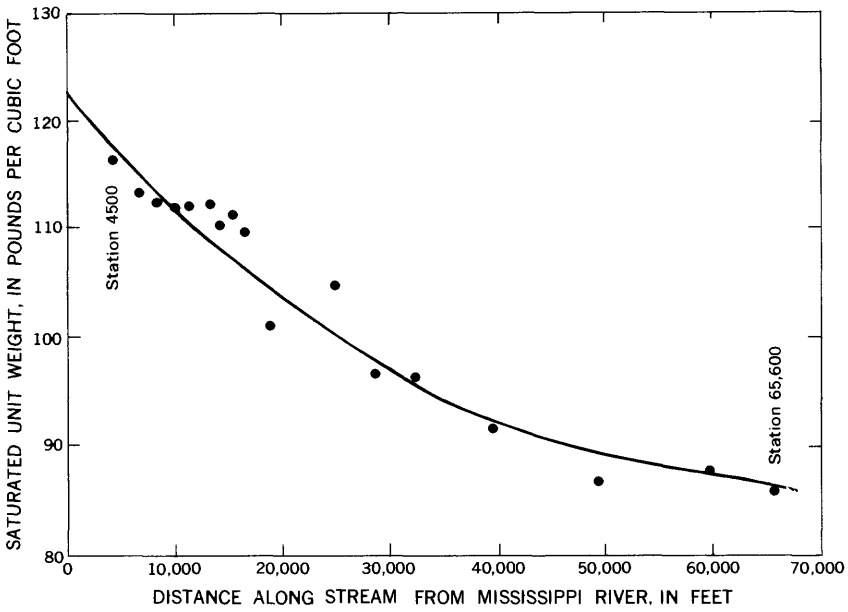The percentage of sand, silt, and clay (as determined by the hy-

FIGURE 12.—Saturated unit weight of sediment deposition (period 1955–66).
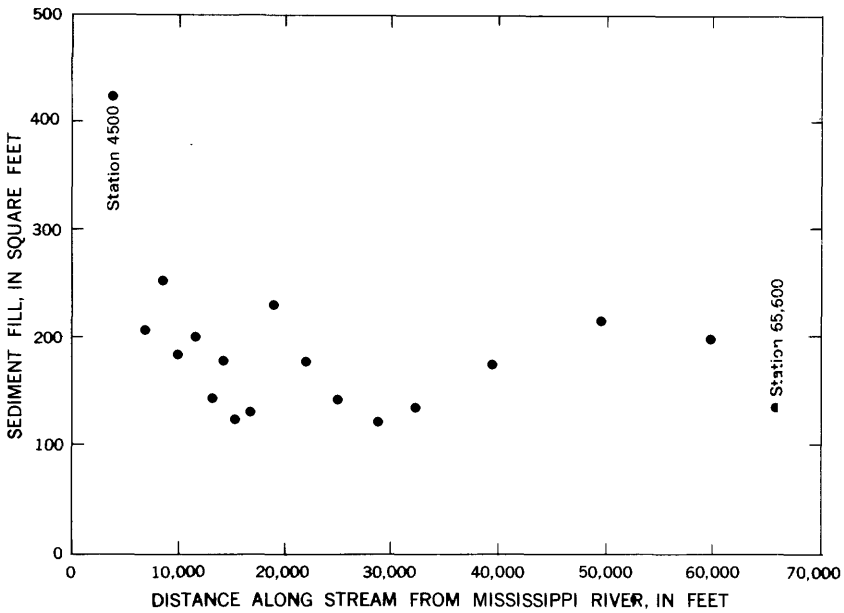

FIGURE 13.—Area of sediment fill in channel cross sections.

drometer method; AASHO classification of soils) at several cross sections for the 1955–66 sediment layer is shown in figure 14. In general, the average content of clay increases and the average content of sand decreases as distance downstream increases, but in the upper part of the study reach the opposite is true. This reversal is due to bedload movement, reworking of the deposited sediment, and changing geometry of the channel. The average silt content remains about the same throughout the study reach.

A greater percentage of the total sediment inflow has deposited in the upper part of the study reach where, as a result, the channel area has decreased more than at downstream stations. This is illustrated in figure 15. The 1966 cross-sectional areas were computed for the 1966 mean discharge (273 cfs) based on stage-area relations for each cross section.

DETERMINATION OF STABLE CHANNEL

STABILIZED-CHANNEL THEORY

There are two schools of thought, one empirical and the other theoretical, that are being utilized in the design of stable channels. The two different theories being used today are (1) the Regime Theory of India and (2) the Limiting Tractive Force Theory. The regime theory concept was used in this report to verify the stability of the
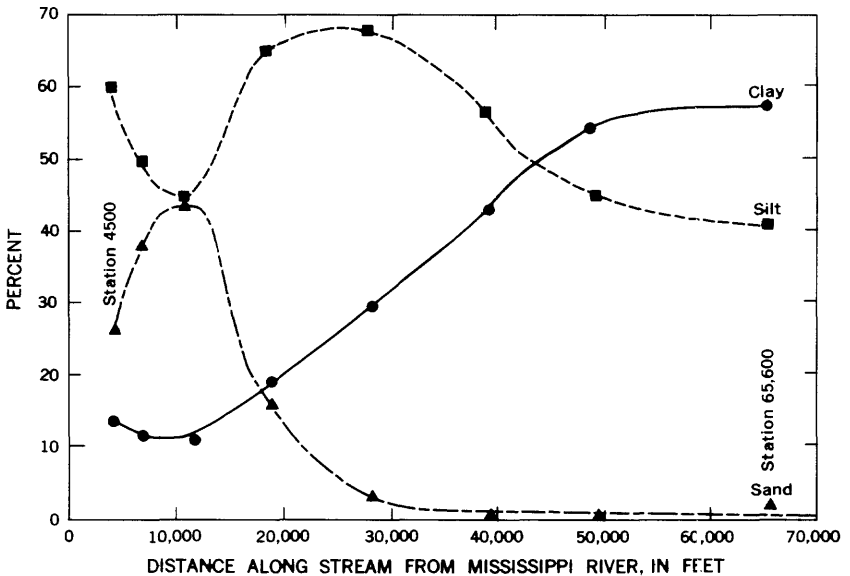

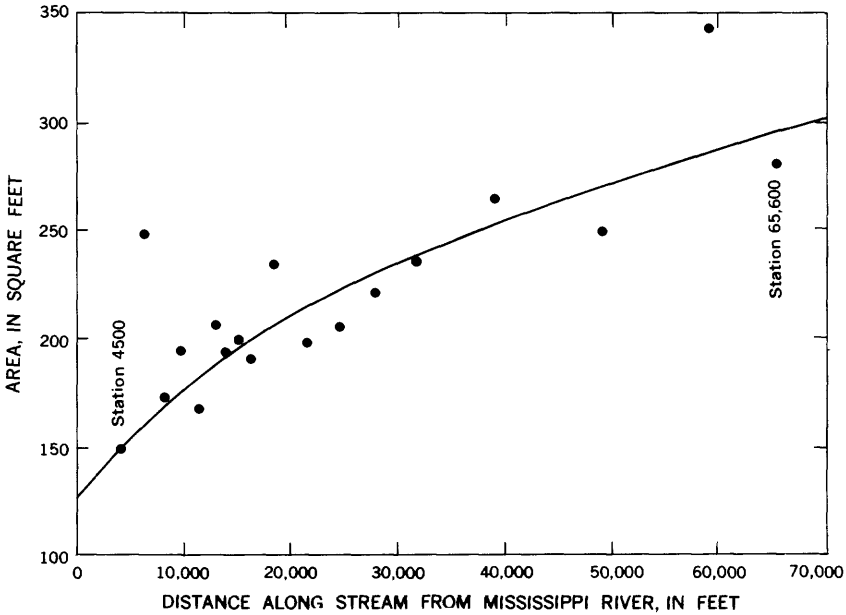FIGURE 14.—Percentage of sand, silt, and clay in 1955–66 sediment layer.

FIGURE 15.—1966 channel cross-sectional areas.

upper part of the study reach. An analysis of previous cross sections supports the assumption of stability in the upper part of the study reach.

The regime equations of India are valid for only a limited range of conditions. The conditions are (1) that the channel has sand beds and cohesive or slightly cohesive banks and (2) that a high concentration of sediment is not imposed on the channel for sustained periods of time, the upper range of sediment concentrations usually being less than 500 mg/l (milligrams per liter). Because similar conditions exist in Bayou Lafourche, the regime theory was used for verification of the assumed stable section.

Kennedy (1895) initiated the Regime Theory of India when he developed the following equation for the regime velocity:

$$V_0 = cD^n,$$

where D was the average depth of the channel exclusive of side slopes. The regime velocity, V_0, is the velocity at which stability is sustained. The channels were assumed to have horizontal beds between side slopes. Kennedy's values for c varied from 0.67 to 0.91, and the values of n, from 0.52 to 0.64, according to where the data were collected. Since n was not constant, there was no means available to contrast the behavior of silts of different degrees of fineness. Other researchers

have determined values for c and n, but much variation exists between the values.

Lacey (1930), using Kennedy's original data and the hydraulic mean depths of stable channels, developed several relations to calculate the complete hydraulic data of a stable channel. Lacey's original equations have been modified, as new data were collected, until they are as follows:

$$V_0 = 1.15473 \ (fR)^{0.5},$$

$$Qf^2 = 4.000 \ V_0{}^6,$$

$$SL = 0.0003759 \ f^{1.5}R^{0.5},$$

$$P = \frac{8Q^{0.5}}{3},$$

$$A = 1.260\frac{Q^{5/6}}{f^{1/3}},$$

$$R = 0.47247\frac{Q^{1/3}}{f^{1/3}}, \ \text{and}$$

$$V_0 = 0.7937\frac{Q^{1/6}}{f^{1/3}},$$

where R = the hydraulic mean depth,
$\quad V_0$ = the regime velocity,
$\quad f$ = the Lacey silt factor,
$\quad Q$ = the discharge,
$\quad SL$ = the slope,
$\quad p$ = the wetted perimeter, and
$\quad A$ = channel area.

A relation for f, the silt factor, was also developed,

$$f = \frac{3}{4}\frac{V_0{}^2}{R}.$$

The silt factor depends only upon the size of the sediment particles being carried and not upon the concentration of silt load being transported by the stream. An estimate of the silt factor, f, can be determined from the equation

$$f = 8(d)^{0.5},$$

where d is the diameter, in inches, of the predominant type of silt being transported through the section.

Figure 16 illustrates how the accumulated percentages of different sizes of the incoming material change as the distance downstream increases. Approximately 98 percent of the material entering the
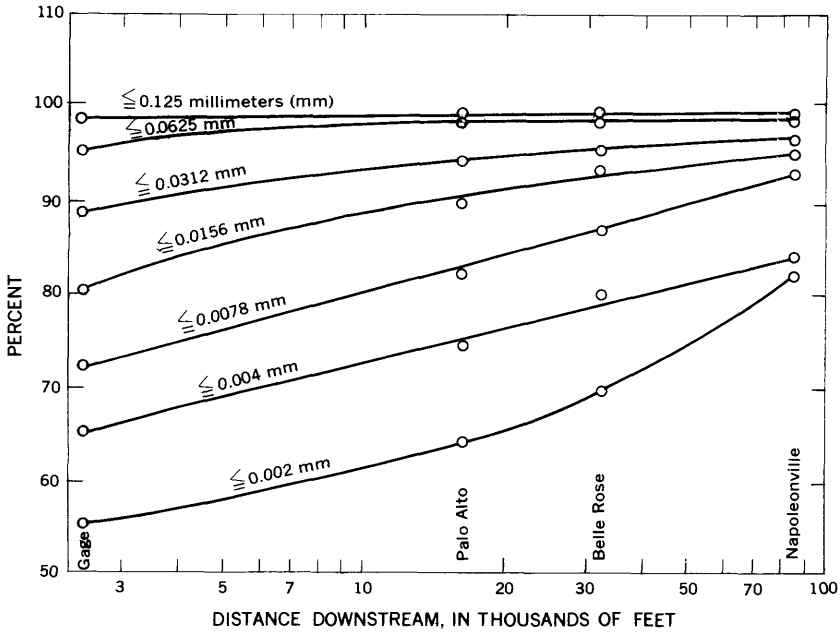
FIGURE 16.—Accumulated percentage of incoming suspended material.

bayou is smaller than 0.125 mm (millimeter). The values used to plot the graphs were obtained from particle-size distributions of the incoming suspended material for several of the years in the period 1955–66. The silt factor, f, in Lacey's equation $Qf^2 = 4.000V_0^6$, was computed for the particle size of 0.125 mm; if the bayou can transport this size, it will be in a stable condition, as 98 percent of the incoming material is finer. The regime velocity, V_0, was computed for the mean discharge of 273 cfs. The regime velocity equaled 1.67 fps (feet per second) and is the velocity at which neither scour nor deposition will occur.

STABLE-CHANNEL CHARACTERISTICS

An analysis of previous cross sections at station 4,500 showed that the channel had not been scoured or filled appreciably for the period 1963–66. Thus, the channel conditions at station 4,500 (fig. 18) may be considered representative of stable conditions for the limited range of pumpage into the bayou since 1955. The characteristics of the stable channel will approximate the following:

1. Cross-sectional area = 160 square feet.
2. Wetted perimeter = 69 feet.
3. Hydraulic radius = 2.3 feet.
4. Width of channel = 66 feet.
5. Slope of channel = 0.000034.

6. n, Manning's roughness coefficient $= 0.009$.

7. Q, average discharge $= 273$ cfs.

In the above description of a stable channel, n equals 0.009. The dominant factor affecting the roughness coefficient is the bed form. The bed form in parts of the channel is extremely smooth, but a detailed analysis is not available to estimate it throughout the study reach. Another factor contributing to the low n value is that 90 percent or more of the streambed material is composed of fine silt and clay. The hydraulic characteristics were computed for the mean discharge of 273 cfs. The computed velocity at the stable section was 1.70 fps. The regime velocity calculated from Lacey's equation $Qf^2 = 4.000V_0{}^6$ was 1.67 fps. This close agreement of values supports the conclusion that station 4,500 is stable. Other hydraulic data— width, depth, and slope—were computed using Lacey's equations but did not agree with the observed values. Actual discharge measurements in the study reach were not available, due primarily to the difficulty in obtaining an accurate discharge measurement. The unconsolidated streambed material makes it difficult to define the actual bottom of the channel; therefore, the only discharge measurements made are at a culvert at station 3,000.

WATER-SURFACE PROFILES IN THE STUDY REACH

Figure 17 illustrates the water-surface slope at high and medium stages and the streambed profile (obtained from a fathometer run made on July 20, 1966) along the thalweg. Thalweg is defined as a line following the deepest part of the stream. Between stations 13,350 and 32,347 the slope is 0.0001 at medium stages. Below station 32,347 the slope is flatter, as shown in figure 17. At higher stages the slope for the entire reach is 0.000034.

At medium stages and below there is an increase in the water-surface slope between stations 13,350 and 32,347. This is mainly due to the differences in elevation of the streambed along the study reach (fig. 17). Natural controls exist at station 14,500 and 55,845 that contribute to the shaping of the water-surface profile. At low and medium stages the controls cause the water-surface slope to change along the study reach. At high stages the controls are drowned out so that a more uniform water-surface slope occurs. Sediment accumulation in the upper part of the study reach also causes variation in water-surface slopes.

REQUIREMENTS FOR STABILITY IN THE STUDY REACH

The sediment required in each study reach to attain stability is shown in table 1. When the study reach becomes stable, the slope of the channel will approximately equal the slope of the water surface
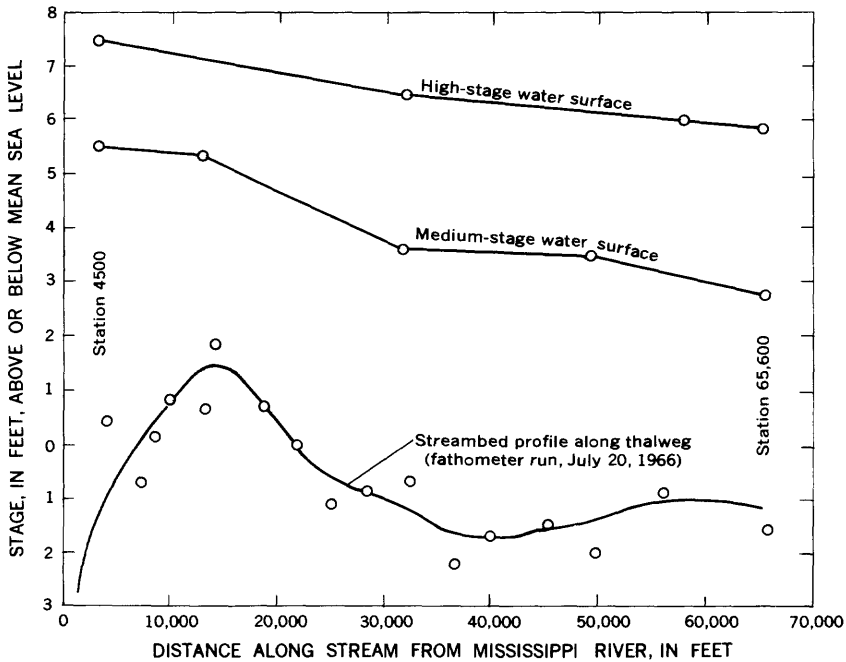
FIGURE 17.—Bayou Lafourche water-surface and streambed profiles.

at high stages. There will be no abrupt change in the water-surface slope as there now exists at low and medium stages. At present, all controls are drowned out at high stages. The effect of these controls will diminish at the low and medium stages when the study reach

TABLE 1.—*Sediment fill required for stability*

Station	Area filled by sediment (sq ft)	Distance, along study reach, to which cross section applies (feet)	Sediment (tons)	Accumulated sediment (tons)
4,500	0			
7,200	97	2,150	9,080	9,080
8,800	22	1,500	1,440	10,520
10,200	39	1,509	2,560	13,080
11,818	13	1,650	934	14,014
13,500	51	1,341	2,980	16,994
14,500	36	1,000	1,570	18,564
15,500	42	1,138	2,080	20,644
16,775	32	1,750	2,440	23,084
19,000	96	2,612	11,400	34,484
22,000	68	3,000	8,800	43,364
25,000	94	3,250	13,300	56,664
28,500	133	3,650	21,700	78,364
32,300	160	5,500	38,300	116,664
39,500	184	8,550	68,500	185,164
49,400	136	10,000	59,200	244,364
59,500	248	8,600	92,900	337,264
65,600	178	3,550	27,500	364,764

becomes stable. The area of the unstable section will decrease until it equals the area of the stable cross section. The amount of sediment fill needed to attain stability will equal the present area of the channel at the mean discharge plus any increase in area due to a changed water-surface slope minus the area of the stable cross section. As previously explained, each cross section represents one-half of the distance between it and the next upstream and downstream cross section. This distance was used to determine the total volume of material that will be deposited in each part of the study reach when stability is attained. The volume of sediment fill was converted to a weight basis by multiplying the volume by 87.1 lb per cu ft (pounds per cubic foot), which is the average dry unit weight of the sediment in the streambed at the stable station 4,500. When material of similar density appears throughout the study reach, stability will be attained. The amount of material necessary to produce stability in the study reach was computed to be 365,000 tons.

Deposition of the sand-size particles will determine the rate of aggradation within the study reach. Only 4 percent of the incoming material (fig. 16) enters as sand (greater than 0.074 mm in size), most of which falls out within the first 25,000 feet of the channel. Figure 14 was used to calculate the amount of the material deposited as sand in the upper 25,000 feet of the study reach since 1955. A comparison of the actual amount to that calculated by using figure 14 showed close agreement.

The time when the study reach attains stability cannot be accurately estimated. As it depends on the deposition rate of the sand, which is low, a long period will be required. Stability will be attained when the slope changes in the lower part of the study reach, so that the incoming sand load will pass these sections.

CONCLUSIONS

The total yearly sediment inflow into Bayou Lafourche can be determined with reliable accuracy from either of the following methods:
1. Yearly sediment-concentration graphs.
2. Time-weighted average concentration and discharge data.
The gamma probe can be used to determine the sediment accumulation in any part of the study reach since 1903 and 1955. Sediment deposition in the channel for any period can be determined if the gamma probe is used at the same stations at the start and end of the period. So far, this method has only been applied to a former distributary where conditions were suitable for using the gamma probe.

Flow would have to be eliminated from the channel for a period of time so that conditions conducive to the formation of a layer, such as the 1903–55 layer, could be established.

The following two equations may be used to predict sedimentation changes in the study reach:

$$\frac{Q_s}{pQ} = 2.566(10)^{-4}\left(\frac{X}{L}\right)^{0.506}(C)^{1.161}$$ (3)

and

$$A_s = \left[\frac{d}{1.61(10)^{-4}\left(\frac{\bar{w}}{V}\right)^{0.505}}\right]^2.$$ (4)

The correlation coefficients for equations 3 and 4 were 0.82 and 0.95, respectively.

Equation 3 can be used to determine daily rates of sediment accumulation in any part of the study reach. It cannot be used to determine the size of the material deposited or how the settled load will be distributed. Equation 3 applies to Bayou Lafourche only and should be applied to other channels with caution.

Equation 4 can be used to determine the area of sediment fill at any cross section in the study reach since 1955. Smaller time intervals of sediment accumulation can be determined if the equation is applied at the beginning and the end of the time interval. Equation 4 was developed for a study reach undergoing a step change that is characteristic of sediment deposition. The discharge entered at only one point and remained constant throughout the study reach. Caution must also be exercised in applying this equation to other streams.

The information and conclusions in this report should be applicable to the design of other distributaries for water supply and pollution control. Given the size, shape, and slope of other former distributaries into which water is to be diverted from the Mississippi River, the techniques presented in this report may be used to predict time rates of deposition along the channel. A few of the major considerations for other distributary studies are:

1. What will be the rate of pumping?
2. What levels of sediment concentration are present in the source water?
3. Does the distributary have a natural drainage area besides the channel itself?

The material that comes into Bayou Lafourche is very fine. Any sand and large silt-size particles that enter the bayou are deposited and bring the reach in which they are deposited closer to stability. The results of this study show that the upper part of the study reach

will aggrade for a long period of time. It will become stable as the sand brought into the bayou is moved downstream. This can happen only if the slope changes in the lower end of the study reach. A small desilting basin at the pumping plant would probably prevent the sand from entering the bayou entirely. However, if the present rate of pumping is changed for any considerable length of time, the flow regime would be changed, and a reevaluation of the conditions existing in the bayou would be necessary.

SUPPLEMENTAL INFORMATION

TABLE 2.—*Bayou Lafourche sediment-concentration and water-discharge data*

Date	Daily mean bayou discharge (cfs)	Instantaneous Donaldsonville concentration (mg/l)	Instantaneous Palo Alto concentration (mg/l)	Instantaneous Belle Rose concentration (mg/l)	Instantaneous Napoleonville concentration (mg/l)
12– 5–58	358	154	134	143	55
1–27–59	349	174	136	118	73
3–30–59	243	337	256	262	149
4–30–59	284	229	219	181	136
5–28–59	232	542	461	288	245
6–26–59	118	468	340	([1])	129
7–28–59	115	504	395	181	117
8–25–59	([1])	177	207	185	162
10–30–59	330	607	([1])	433	256
1–29–60	208	627	([1])	282	([1])
2– 4–60	208	407	([1])	301	([1])
2– 9–60	148	385	([1])	165	([1])
2–12–60	156	288	([1])	117	([1])
3– 1–60	216	374	([1])	196	([1])
3–31–60	248	245	([1])	124	101
4–26–60	257	455	([1])	259	213
5–27–60	251	440	([1])	297	180
7– 7–60	248	689	([1])	([1])	([1])
7– 8–60	([1])	([1])	([1])	361	194
7–29–60	216	275	([1])	([1])	155
8–31–60	210	92	([1])	84	64
9–26–60	208	182	([1])	210	104
10–24–60	196	67	([1])	([1])	([1])
11–29–60	310	326	([1])	([1])	([1])
12–22–60	340	234	([1])	([1])	([1])
1–31–61	208	142	([1])	([1])	([1])
2– 2–61	216	67	([1])	([1])	([1])
2–17–61	196	([1])	([1])	([1])	([1])
3–22–61	266	648	([1])	([1])	([1])
4–21–61	303	373	([1])	([1])	([1])
5–26–61	387	429	([1])	([1])	([1])
6–22–61	200	470	([1])	([1])	([1])
6–27–61	240	370	295	377	201
7–21–61	216	233	297	163	69
8–25–61	240	202	149	128	90
9–21–61	123	240	157	80	316
10–31–61	366	339	309	314	285
11–17–61	248	912	571	547	294

[1] No record.

TABLE 2.—*Bayou Lafourche sediment-concentration and water-discharge data*—Con.

Date	Daily mean bayou discharge (cfs)	Instantaneous Donaldsonville concentration (mg/l)	Instantaneous Palo Alto concentration (mg/l)	Instantaneous Belle Rose concentration (mg/l)	Instantaneous Napoleonville concentration (mg/l)
1–19–62	290	287	(1)	341	291
2–16–62	248	347	(1)	178	125
4–25–62	290	304	(1)	259	234
5–24–62	232	285	(1)	140	95
6–21–62	232	707	(1)	638	174
7–16–62	471	252	(1)	240	122
8–14–62	303	231	(1)	203	100
9–17–62	200	93	(1)	68	56
10–15–62	310	202	(1)	188	373
11–19–62	400	81	(1)	88	248
12–27–62	312	45	(1)	120	161
1–22–63	228	151	(1)	187	274
2–13–63	291	46	(1)	38	30
3–13–63	236	151	(1)	100	30
3–16–63	252	(1)	(1)	(1)	(1)
4–16–63	276	235	(1)	160	117
5–16–63	356	135	(1)	1,040	96
6–17–63	337	145	(1)	130	48
7–19–63	294	(1)	(1)	(1)	(1)
8–21–63	314	62	(1)	599	(1)
9–24–63	220	27	(1)	116	23
12– 4–63	300	25	(1)	17	33
12–18–63	346	35	(1)	43	35
1–28–64	220	67	(1)	53	132
3– 5–64	189	214	(1)	115	44
4–16–64	238	350	(1)	228	111
5–22–64	241	314	(1)	177	126
6–23–64	335	213	(1)	274	88
7–28–64	371	192	(1)	562	222
8–20–64	318	41	(1)	105	32
9–24–64	331	52	(1)	88	68
10–29–64	495	30	(1)	28	44
11–17–64	476	19	(1)	34	36
12–23–64	410	253	(1)	166	121
1–20–65	411	596	(1)	371	223
2–24–65	264	548	(1)	266	201
3–30–65	423	50	(1)	50	112
4–27–65	263	453	(1)	310	204
5– 7–65	206	259	(1)	351	112
5–26–65	162	249	(1)	91	73
7– 6–65	240	353	(1)	279	198
8– 2–65	381	318	(1)	175	161
9– 8–65	308	79	(1)	69	25
10–12–65	142	486	(1)	113	(1)
11– 3–65	370	121	(1)	79	(1)
12– 6–65	360	55	(1)	145	(1)
1– 5–66	300	40	(1)	(1)	(1)
2– 3–66	236	184	(1)	(1)	(1)
3– 9–66	33	317	(1)	(1)	(1)
4– 7–66	417	134	(1)	(1)	(1)
5– 5–66	246	388	(1)	(1)	(1)
6– 7–66	217	336	(1)	(1)	(1)
7–12–66	227	194	(1)	(1)	(1)

[1] No record.

TABLE 3.—*Gamma-probe determination of sediment fill*

Station	Specific weight of solids (lb per cu ft)	Distance, along study reach, to which cross section applies (feet)	Area filled by sediment (sq ft)	Constant	Sediment (tons)
4,500	87.10	1,350	419.10	1/2000	24,640
7,200	82.00	2,150	205.55	1/2000	18,119
8,800	80.70	1,500	250.22	1/2000	15,142
10,200	79.26	1,509	182.50	1/2000	10,913
11,818	79.60	1,650	197.90	1/2000	12,996
13,500	80.10	1,341	141.80	1/2000	7,616
14,500	76.92	1,000	175.30	1/2000	6,742
15,500	78.33	1,138	122.10	1/2000	5,442
16,775	75.67	1,750	129.80	1/2000	8,594
19,000	62.40	2,612	226.70	1/2000	18,473
22,000	64.63	3,000	175.90	1/2000	17,051
25,000	67.39	3,250	139.43	1/2000	15,267
28,500	55.31	3,650	118.39	1/2000	11,910
32,300	54.42	5,500	133.30	1/2000	19,896
39,500	47.00	8,550	173.20	1/2000	34,640
49,400	38.73	10,000	214.30	1/2000	41,488
59,500	39.60	8,600	195.55	1/2000	33,298
65,600	36.56	3,550	132.25	1/2000	8,578

NOTE.—Total amount of sediment fill equals 310,805 tons.

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FIGURES 18–35
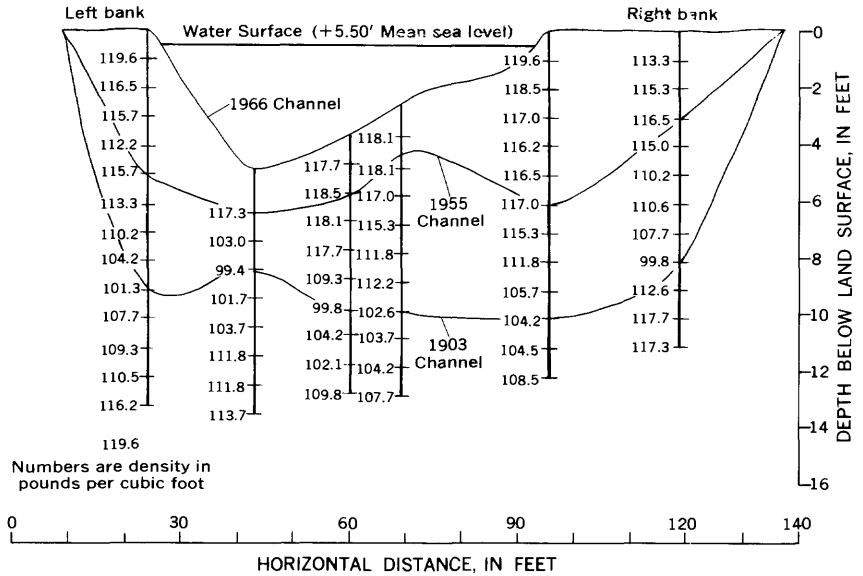
FIGURE 18.—Cross section showing density of sediment in Bayou Lafourche at station 4,500.
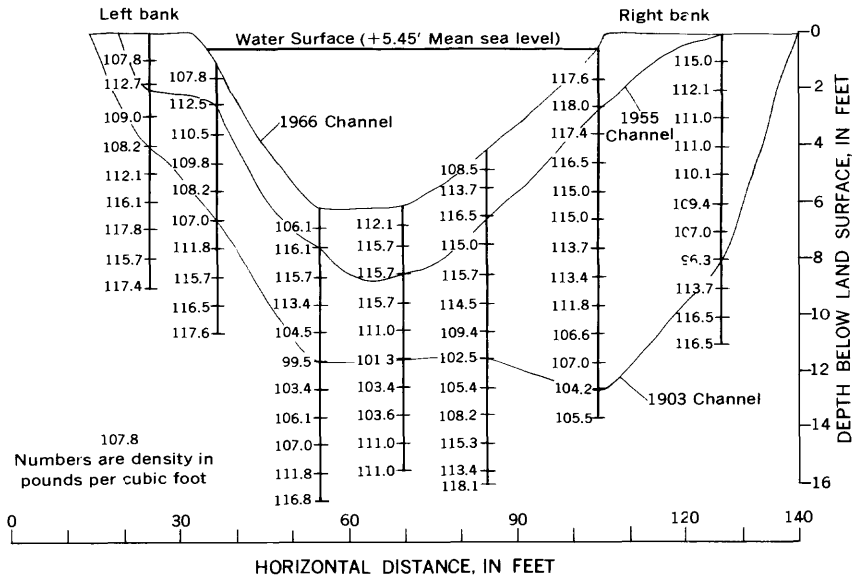
FIGURE 19.—Cross section showing density of sediment in Bayou Lafourche at station 7,200.
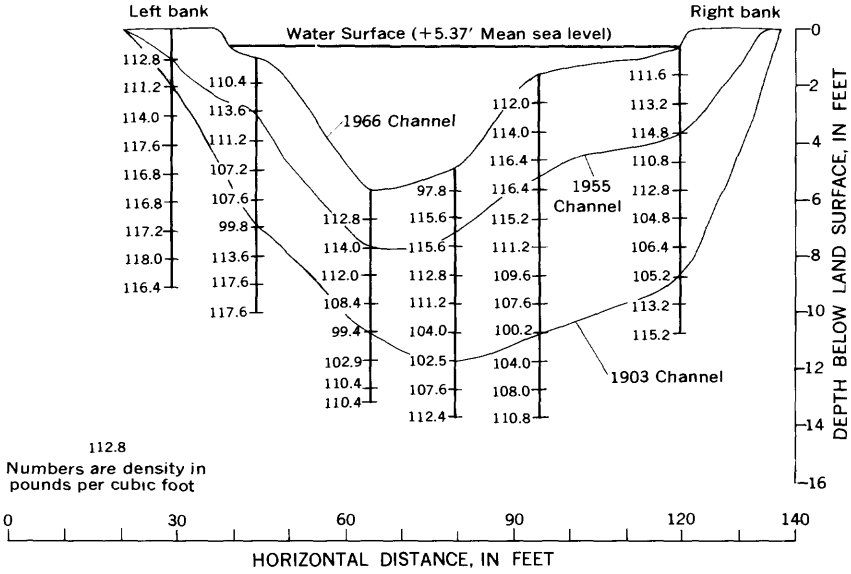
FIGURE 20.—Cross section showing density of sediment in Bayou Lafourche at station 8,800.
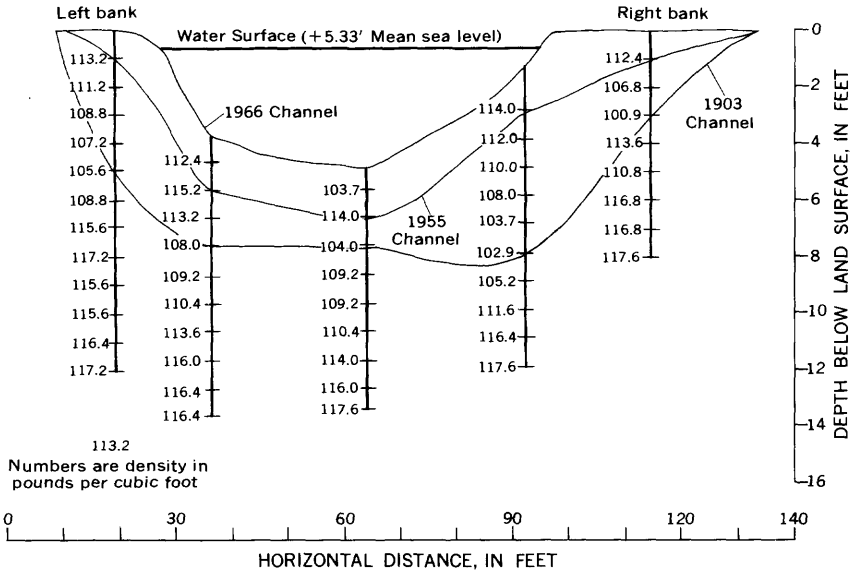
FIGURE 21.—Cross section showing density of sediment in Bayou Lafourche at station 10,200.
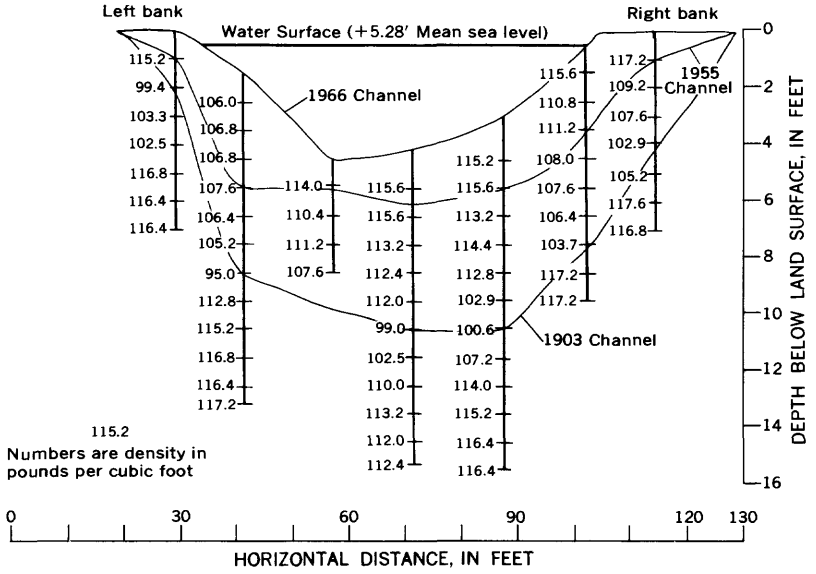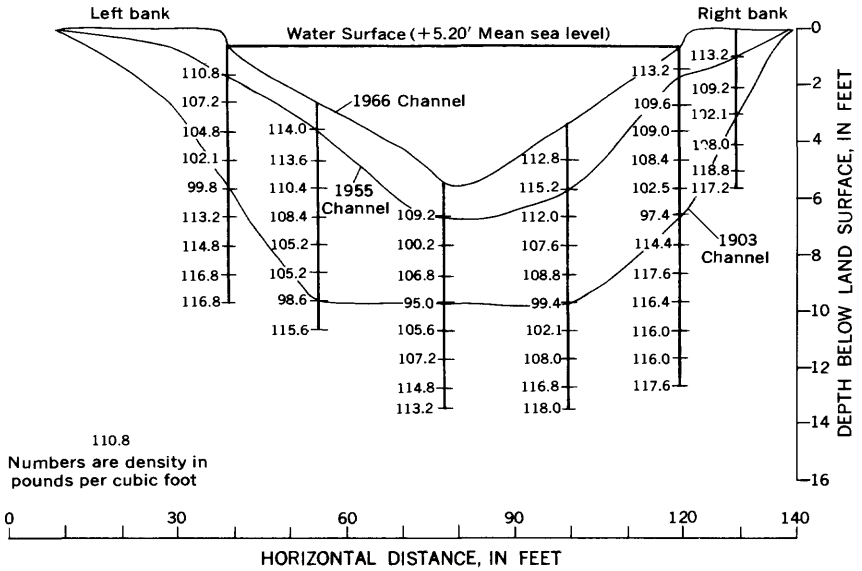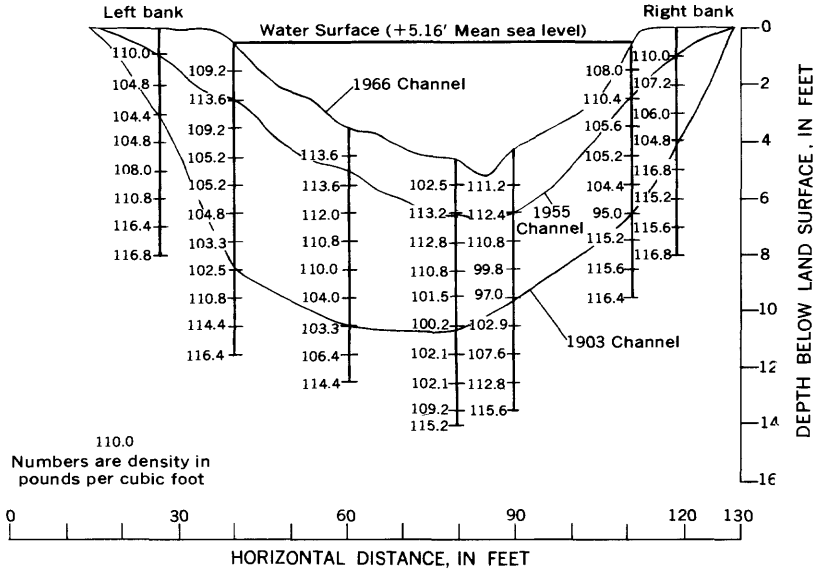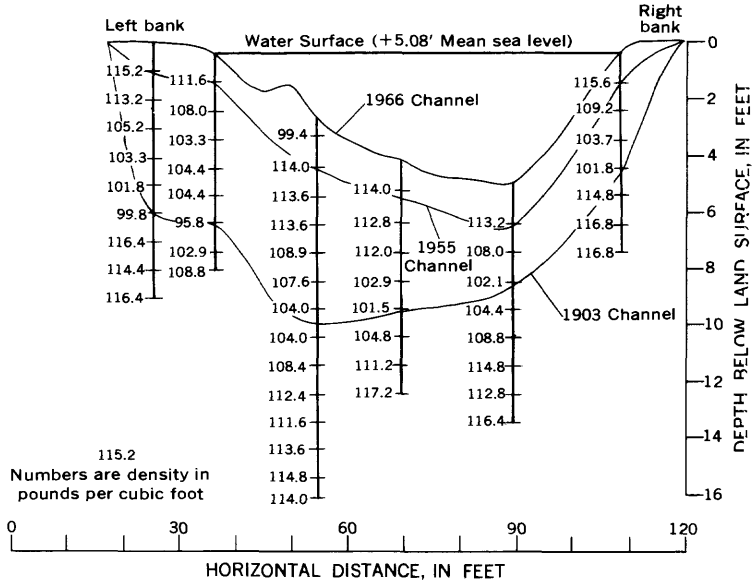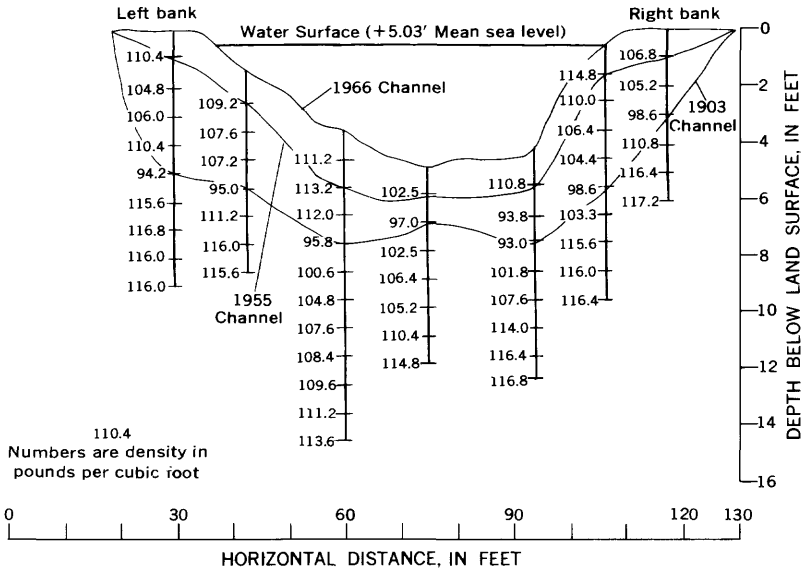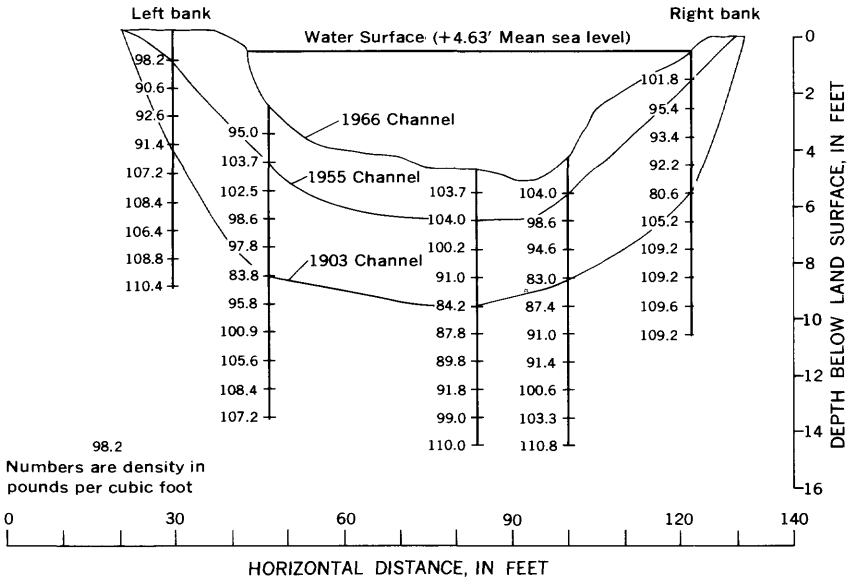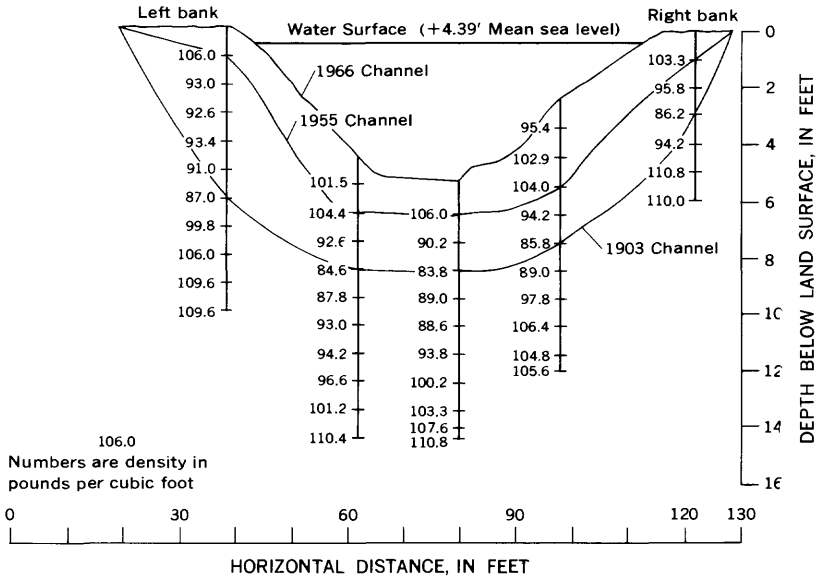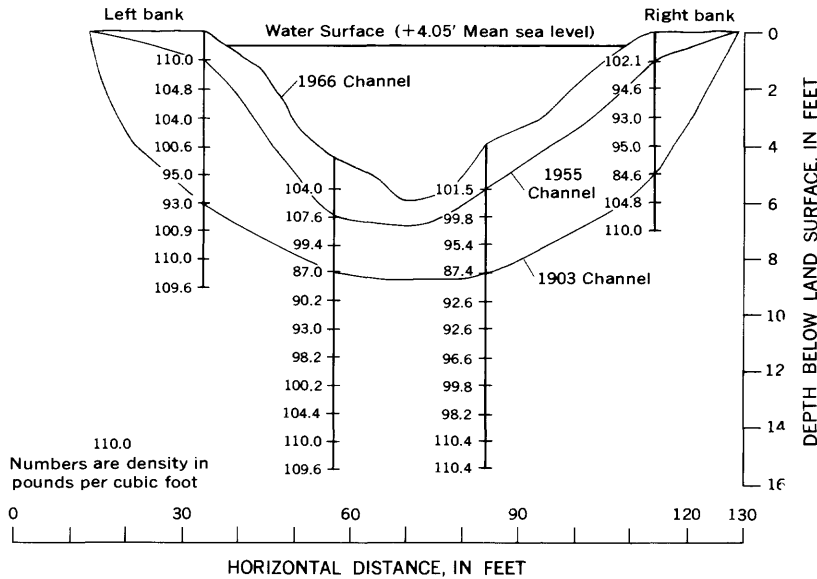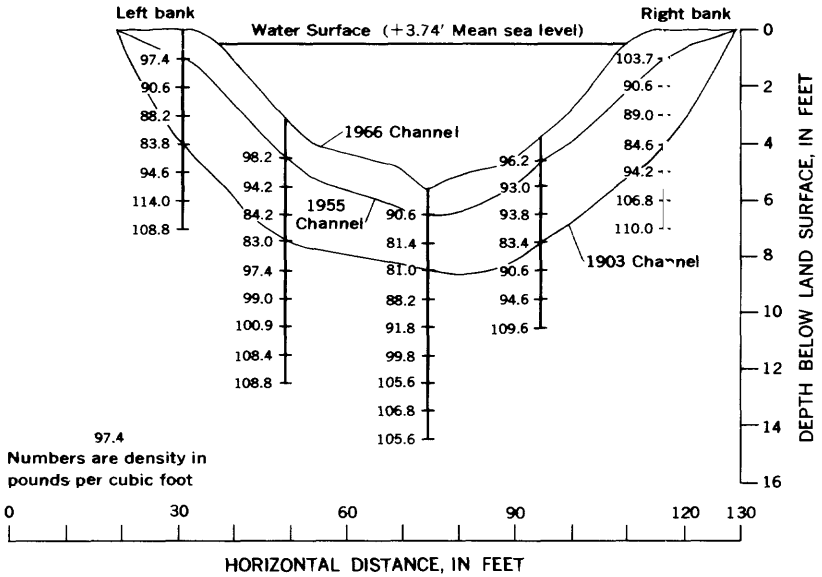
FIGURE 22.—Cross section showing density of sediment in Bayou Lafourche at station 11,818.
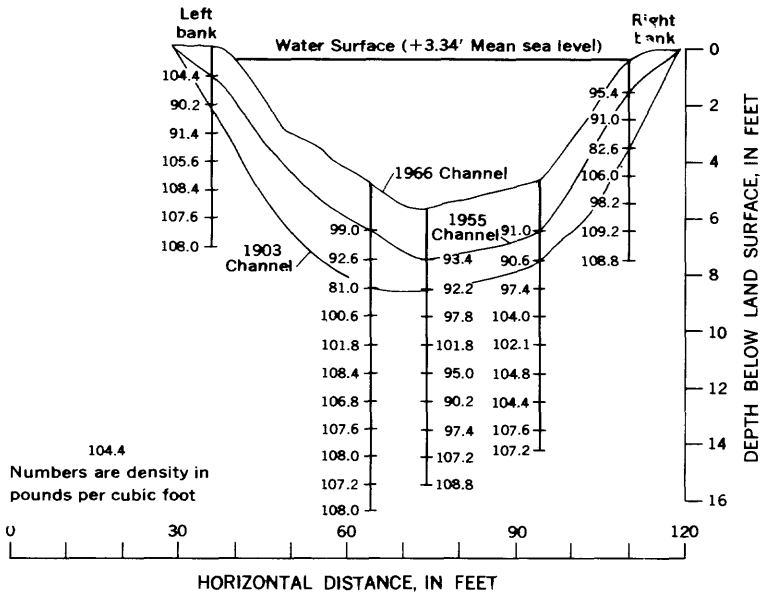

FIGURE 23.—Cross section showing density of sediment in Bayou Lafourche at station 13,500.

FIGURE 24.--Cross section showing density of sediment in Bayou Lafourche at station 14,500.

FIGURE 25. Cross section showing density of sediment in Bayou Lafourche at station 15,500.

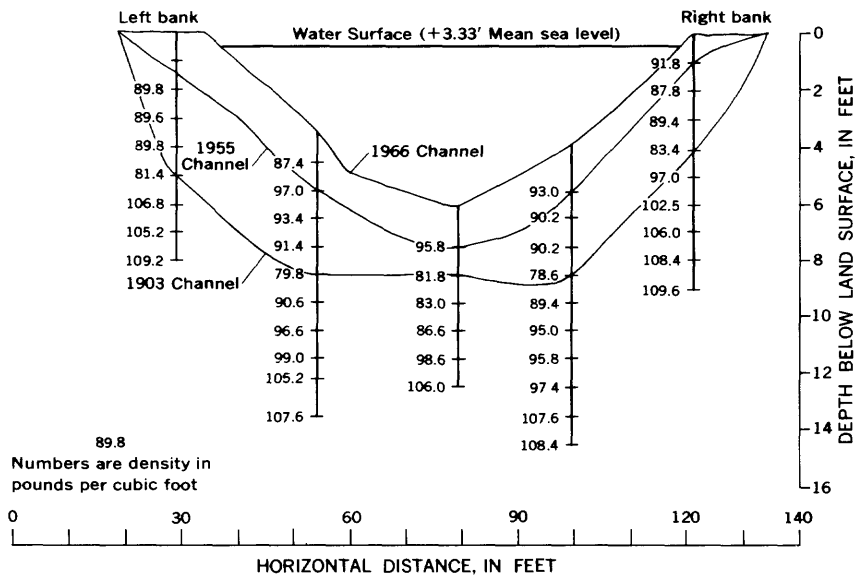FIGURE 26.—Cross section showing density of sediment in Bayou Lafourche at station 16,775.

FIGURE 27.—Cross section showing density of sediment in Bayou Lafourche at station 19,000.

FIGURE 28.—Cross section showing density of sediment in Bayou Lafourche at station 22,000.

FIGURE 29.—Cross section showing density of sediment in Bayou Lafourche at station 25,000.

FIGURE 30.—Cross section showing density of sediment in Bayou Lafourche at station 28,500.

FIGURE 31.—Cross section showing density of sediment in Bayou Lafourche at station 32,300.

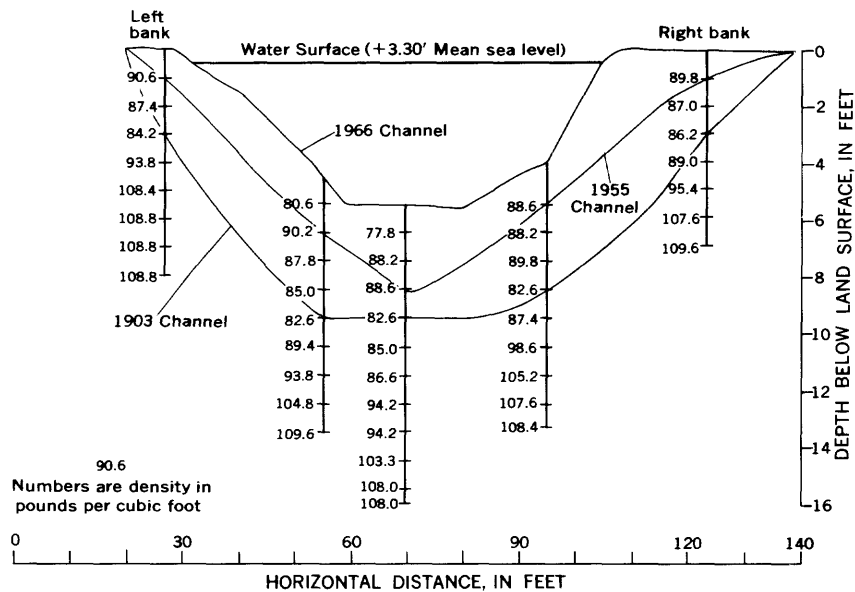FIGURE 32.—Cross section showing density of sediment in Bayou Lafourche at station 39,500.

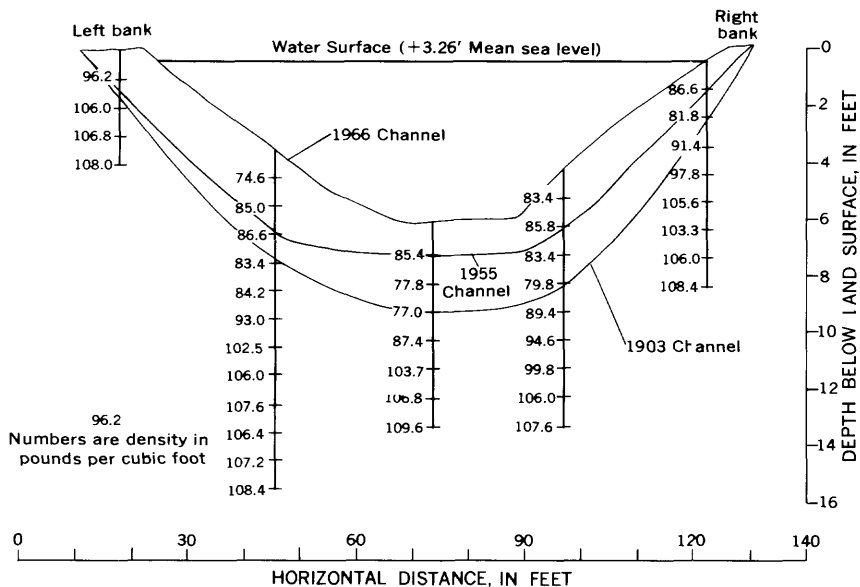FIGURE 33.—Cross section showing density of sediment in Bayou Lafourche at station 49,400.

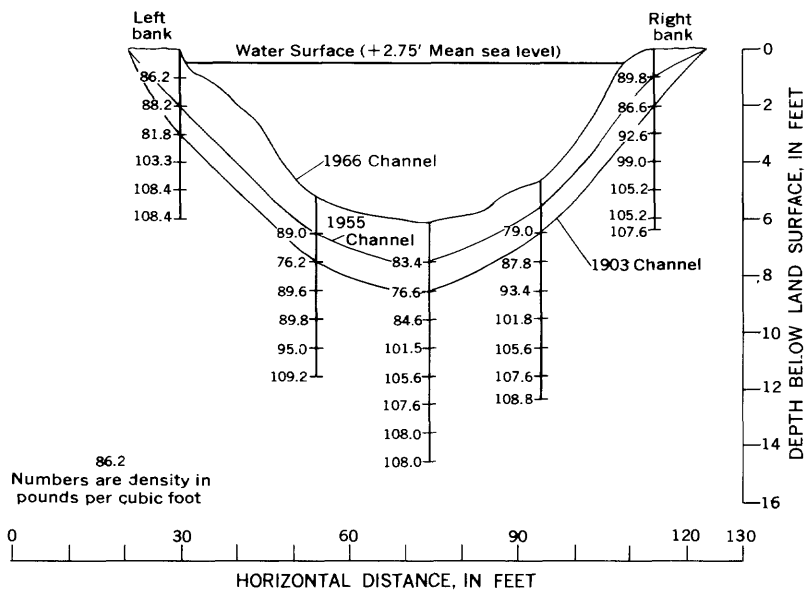FIGURE 34.—Cross section showing density of sediment in Bayou Lafourche at station 59,500.

FIGURE 35.—Cross section showing density of sediment in Bayou Lafourche at station 65,600.