HYDROLOGIC FEATURES AND PROCESSES OF THE VERMILION RIVER, LOUISIANA

By Nancy Tucker Baker

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CONVERSION FACTORS AND ABBREVIATIONS

For the convenience of readers who prefer to use metric (International System) units rather than the inch-pound units used in this report, values may be converted by using the following factors:

Multiply inch-pound unit	By	To obtain metric unit
inch (in.)	25.40	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square foot (ft^2)	929.0	square centimeter (cm^2)
square foot (ft^2)	0.09294	square meter (m^2)
foot per second (ft/s)	0.3048	meter per second (m/s)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
mile per hour (mi/h)	1.609	kilometer per hour (km/h)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)

Temperature in degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) as follows: °F = 1.8 X °C + 32.

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "Sea Level Datum of 1929."

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ABSTRACT

The hydrology of the Vermilion River is affected by the climate, the geographic features of the basin, the diversion of water from other basins into the river, the physical characteristics and configuration of drainage channels, and the actions of tides and winds. The river is a coastal stream that flows through the relict deltaic deposits of the Atchafalaya and Red Rivers. Water from the Vermilion River is used primarily for rice irrigation and for the dilution of municipal and industrial effluents.

Prior to flow augmentation from the Atchafalaya River, low discharges were frequent in the Vermilion River. Operation of a pumping plant has increased discharge during low flow and decreased discharge during high flow. Although the Vermilion River is a highly regulated stream, it still exhibits variable flow.

Variable discharges in the Vermilion River are caused, in part, by the effects of tides and winds. Nearly every reach of the river is affected by tides. Diurnal, semidiurnal, and mixed tides occur, but the diurnal tide is the most dominant pattern. Tidal range in the downstream reaches generally is between 1 and 2 feet. Sustained northerly winds can significantly lower river elevation, and sustained southerly winds can significantly raise river elevation, in the downstream reaches.

Incoming tides in the downstream reaches tend to stagnate flow and reduce reaeration coefficients. Reaeration coefficients, calculated for measurements made August 6, 1985, ranged from 0.038 per day in the downstream reaches to 0.723 per day in the upstream reaches. Reaeration potential is reduced in the downstream reaches by incoming tides. Computation of reaeration coefficients for average conditions is difficult because stream velocities are extremely variable. Additional studies are needed to determine velocities, flow patterns, average reaeration coefficients, and frequency and duration of high and low discharges to more completely define the hydrology of the Vermilion River.

INTRODUCTION

The hydrology of the Vermilion River is affected by the geographic features of the basin, the diversion of water from other river basins into the river, the physical characteristics and configuration of drainage channels, and the actions of tides and winds. Interest in the hydrology of the Vermilion River stems partially from the prevalent use of the streamflow as a water resource and the inadequacy of the river to provide that resource. Water availability for rice irrigation and the dilution of effluents are the major concerns in the Vermilion River basin.

Interaction of human activity in the basin and the natural processes of the river result in a complex hydrologic system. Furthermore, the hydrology of the river is continually changing because of the construction and removal of control and diversion structures. Water control structures have been constructed to divert water from other basins into the Vermilion River so that a sufficient discharge can be maintained to supply freshwater for rice irrigation, to dilute effluents, to permit navigation, and to minimize saltwater intrusion.

Present diversions and seasonal variations in precipitation cause widely variable flows, which create the potential for severe water-quality problems during parts of the year. Demcheck and Leone (1983, p. 25) indicate that agricultural runoff, and municipal and industrial effluents may have considerable environmental effect during low flows. Because the river often has extremely low flows, it has a limited assimilative capacity for waste loads. Tidal influences also tend to stagnate flows in the downstream reaches of the river, reducing the assimilative capacity that would otherwise occur.

Because domestic supplies generally are derived from water of the underlying Chicot aquifer, water quality in the Vermilion River has not been a major concern. A recent plan to clean up the river to promote tourism, provide recreation, and preserve aquatic organisms has been developed by the Bayou Vermilion Restoration Foundation in Lafayette, Louisiana.

The present hydrology of the river has not been adequately documented, and knowledge of the natural and controlled hydrologic system is essential for planning and design of water-related activities in the basin. Although data are available for some gaging stations in the basin, only a few years of the most recent discharge record reflect the present hydrology. Realizing the immediate need to study the flow system of the river, and to investigate its assimilative capacity and tidal influences in relation to water quality, the U.S. Geological Survey, in cooperation with the Louisiana Department of Environmental Quality, Office of Water Resources, began a study in 1985 to conduct an intensive survey of the Vermilion River and report on the hydrologic characteristics of the river.

Purpose and Scope

The purpose of this report is to present a general hydrologic overview of the river, describe the hydrologic features and processes of the river, provide references for more specific information regarding the Vermilion River, and identify additional study needs.

The hydrology of the river is presented by defining movement of water during an intensive hydrologic survey of the Vermilion River basin in August 1985, defining the physical characteristics of the river system (Vermilion River, and associated streams and canals) and defining the movement of water within the system in relation to control structure operations, water quality, and factors such as tides and winds that affect water movement. Although the emphasis of this report is on the hydrology of the Vermilion River, pertinent information on physical characteristics as they relate to river hydrology also are discussed.

Acknowledgments

A special thanks is due Mr. Max Forbes, who worked as a liaison between the Louisiana Department of Environmental Quality and the U.S. Geological Survey in the planning, coordination, and execution of the intensive survey phase of the project, as well as furnished invaluable technical assistance on the report. Representatives of the Louisiana Department of Environmental Quality supplied essential information on the area and made available equipment and the use of facilities. Employees of the Teche-Vermilion (Bayou Teche and Vermilion River) Fresh Water District pumping plant at Krotz Springs provided a tour of the pumping plant facilities and detailed explanation of pumping operations. Employees of the U.S. Army Corps of Engineers supplied copies of continuous gage-height records for the years 1983-85 for stations in the Vermilion River basin.

GEOGRAPHICAL LOCATION AND FEATURES

The Vermilion River basin is located in the Gulf Coastal Plain along the central Louisiana coast, about midway between New Orleans and Lake Charles. Vermilion River flows are separated from those of Mermentau River basin to the west by a system of locks on canals crossing the drainage divide. To the east, the basin extends to the western boundary of the Bayou Teche basin. The locations of the Vermilion River and associated streams and canals are shown in figure 1. All but the southern part of the Vermilion River basin is covered by a large expanse of flat-grassland prairie dissected by numerous tributaries and dotted with small groves of oak and other mixed hardwood trees. To the south, the prairie gives way to a band of marshland which extends from east to west along the coastline. The marsh is further subdivided into a freshwater marsh which borders the prairie to the north and a saltwater marsh which forms the coastline adjacent to the Gulf of Mexico.

The Vermilion River lies on the terrace upland west of the escarpment of the Mississippi River alluvial plain. The area is comprised largely of loess-covered alluvial deposits. The most recent soils are part of the Prairie Formation deposited during the late Pleistocene age. The part of the basin east of the Vermilion River is characterized by a distinctive meander belt topography in which a number of abandoned channels and courses are apparent. Saucier (1974) describes this area as part of the upper deltaic plain or lower alluvial plain of the Mississippi River. The part of the basin west of the Vermilion River is characterized by extraordinarily flat topography and predominately clayey deposits. Saucier (1974) describes these soils as a relict deltaic plain of the Red River.

The land is used extensively for production of rice, sugarcane, soybeans, and for pasture. Rice is irrigated with water from the Vermilion River and ground-water sources. Several dairy farms are located in close proximity to the river, and sweet potato and okra farming are also important in the basin. Most manufacturing is concerned with resource oriented products such as food preparation, food canning, petroleum, and petrochemicals.

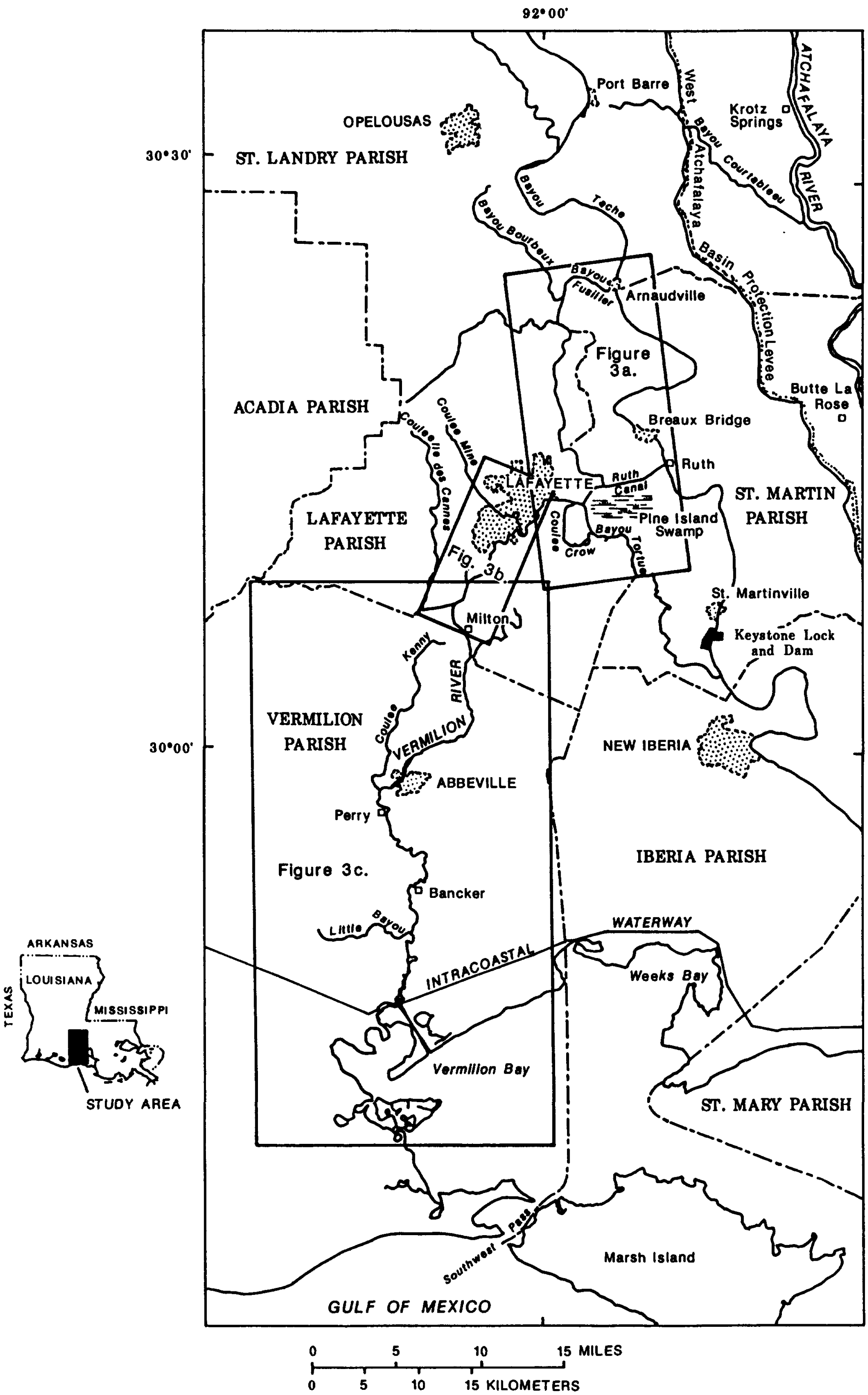


Figure 1.--Vermilion River and associated streams and canals.

The climate is humid-subtropical and is dominated by warm, moist-maritime tropical air from the Gulf of Mexico. Average daily maximum temperature for June, July, and August is 33 °C. The average daily maximum temperature for December, January, and February ranges from 15 to 17 °C. Occasionally, during winter and spring, the passage of a cold front brings in cold continental-polar air from Canada which can produce frost or freeze conditions. Precipitation usually is associated with the passage of warm and cold fronts during winter and spring; however, brief, intense, convective showers are common during summer and fall. Average annual precipitation over the basin ranges from 55 to 60 in. Figure 2 shows the 1951-80 mean monthly precipitation normals for Lafayette, Louisiana. Many of the hydrologic problems in the basin are associated with the response of the river to too much or too little rainfall. Excessive rainfall can cause local flooding upstream. Extended dry periods can be damaging to unirrigated crops in the basin and compound water-quality problems in the river.

Stream channels in the Vermilion River basin are aligned predominately north to south (fig. 1). The present-day (1986) configuration of channels is a result of natural processes and man's effort to control the flow system by digging canals, dredging existing waterways, and building water control and diversion structures.

The headwaters of the Vermilion River are the confluence of Bayou Bourbeux and Bayou Fusilier (fig. 3a). The upper Vermilion River is about 13 mi long and flows south to the city of Lafayette. Elevations of the surrounding topography range from 15 ft above sea level near the headwaters to about 40 ft above sea level at Lafayette. The elevation decreases downstream to about 15 ft above sea level near Abbeville, and to 1 ft above sea level near the mouth. The middle Vermilion River is about 17 mi long and flows from Lafayette to Milton (fig. 3b). The lower Vermilion, 33 mi in length, extends from Milton to the Vermilion Bay (fig. 3c) and is affected by tides; also, records for gaging stations as far upstream as Lafayette show the effects of tides on stage and velocity.

The entire Teche-Vermilion River system is historically a distributary of both the Red and Atchafalaya Rivers. Bayou Fusilier and Ruth Canal function as distributaries of Bayou Teche. Bayou Fusilier and Ruth Canal connect Bayou Teche and the Vermilion River. Bayou Fusilier is a small alluvial stream about 6 mi long. An average of 25 percent of the flow of Bayou Teche is normally diverted through this channel into the Vermilion River (Domingue and others, 1974, p. 13). A concrete weir in the channel permits flow only at stages greater than 10 ft above sea level. Runoff from excessive local rainfall in the upper Vermilion River basin occasionally causes a reversal of flow in Bayou Fusilier toward Bayou Teche. Ruth Canal is about 4 mi long and enters the Vermilion River a short distance upstream from Lafayette. Flow in the canal is regulated by a reinforced concrete control structure with three manually operated gates.

ACTIVITIES AFFECTING HYDROLOGY

Activities that affect hydrology of the Vermilion River are discussed in terms of the development of the river as a resource. A chronological history of the development of the Vermilion River is presented. Refer to figure 1 for stream channel, canal, and control structure locations.

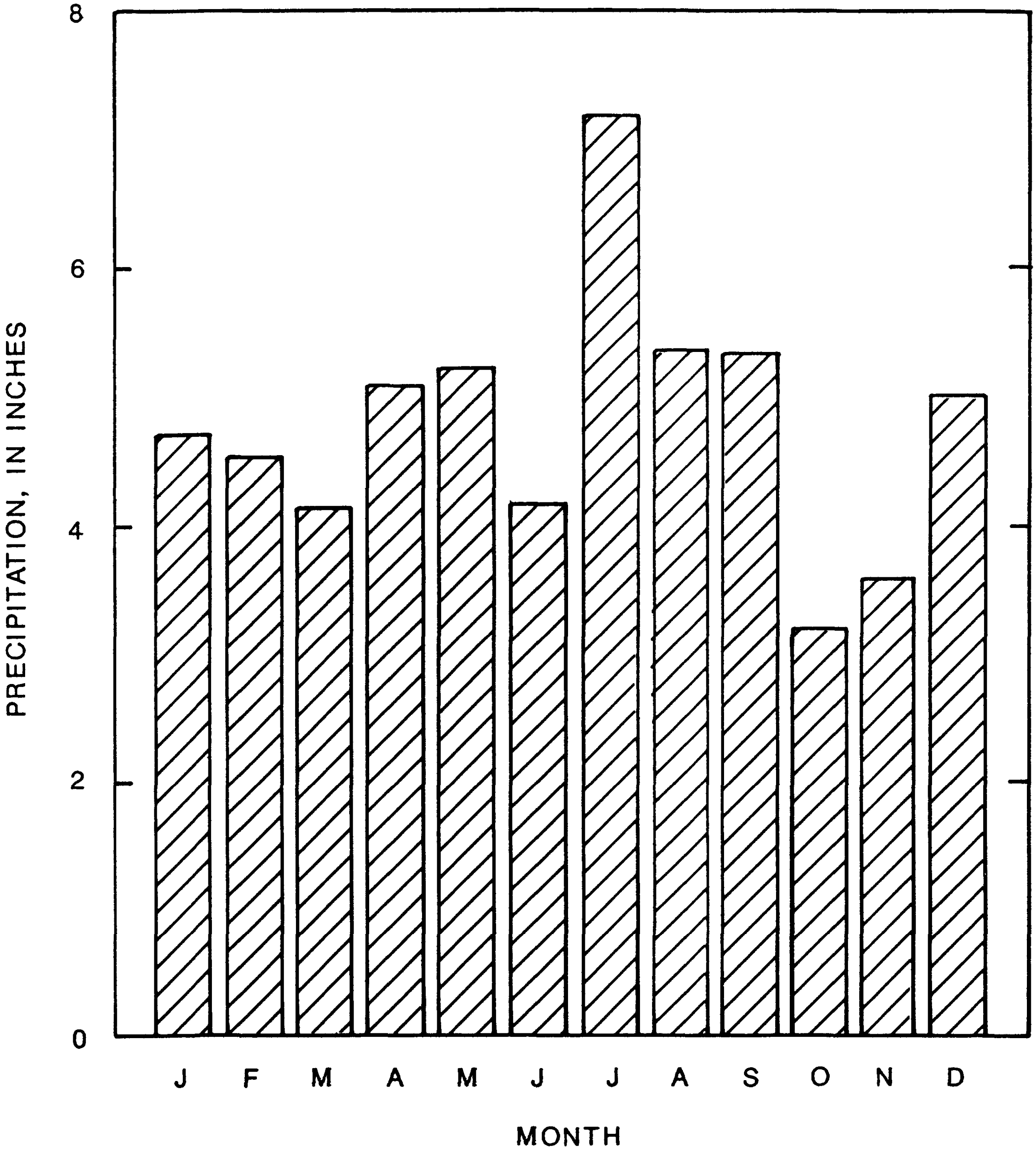


Figure 2.--Mean monthly precipitation normals for Lafayette, Louisiana, 1951-80.

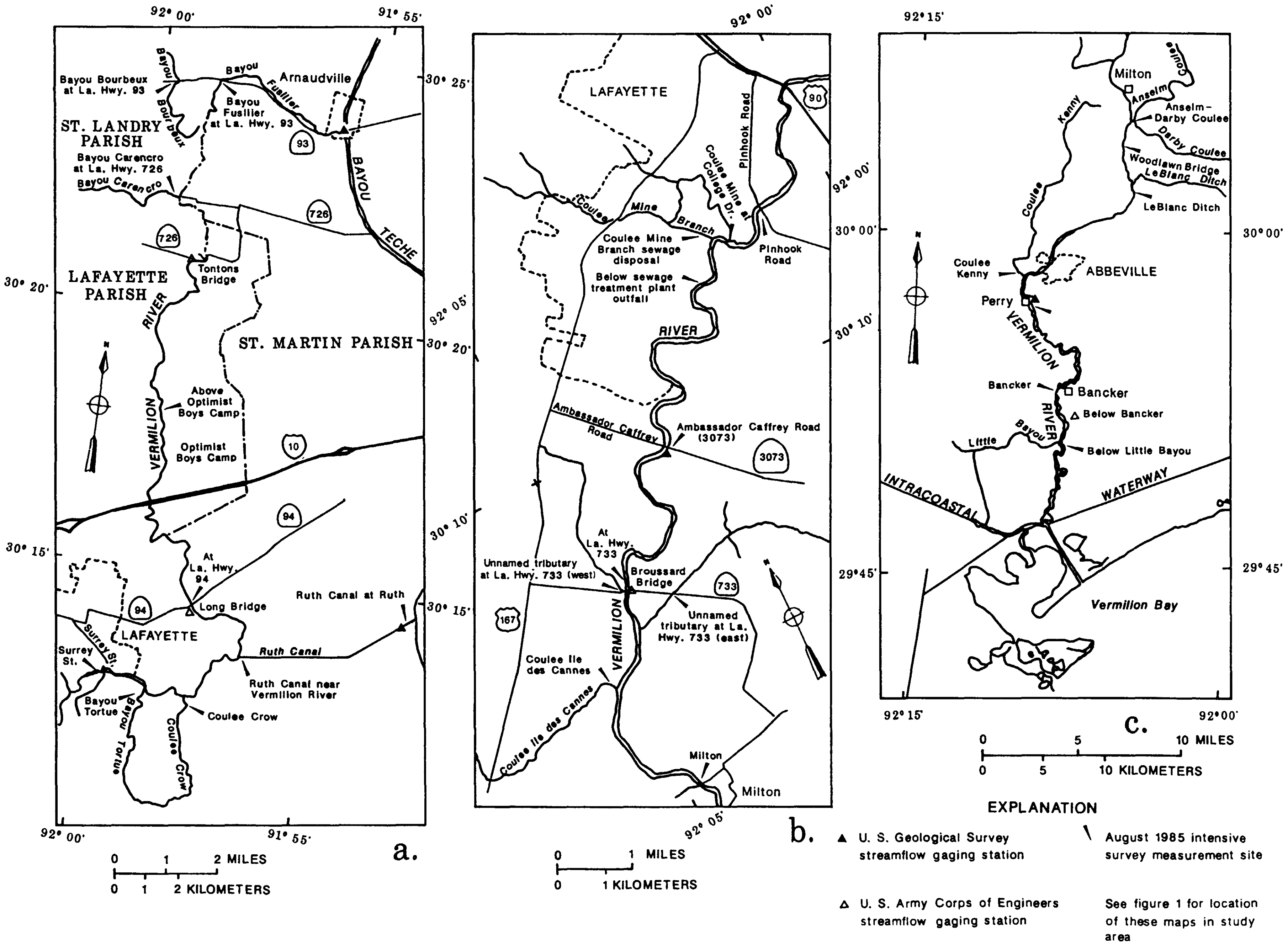


Figure 3.--Established gaging stations and locations for intensive survey measurements in the upper (a), middle (b), and lower (c) Vermilion River.

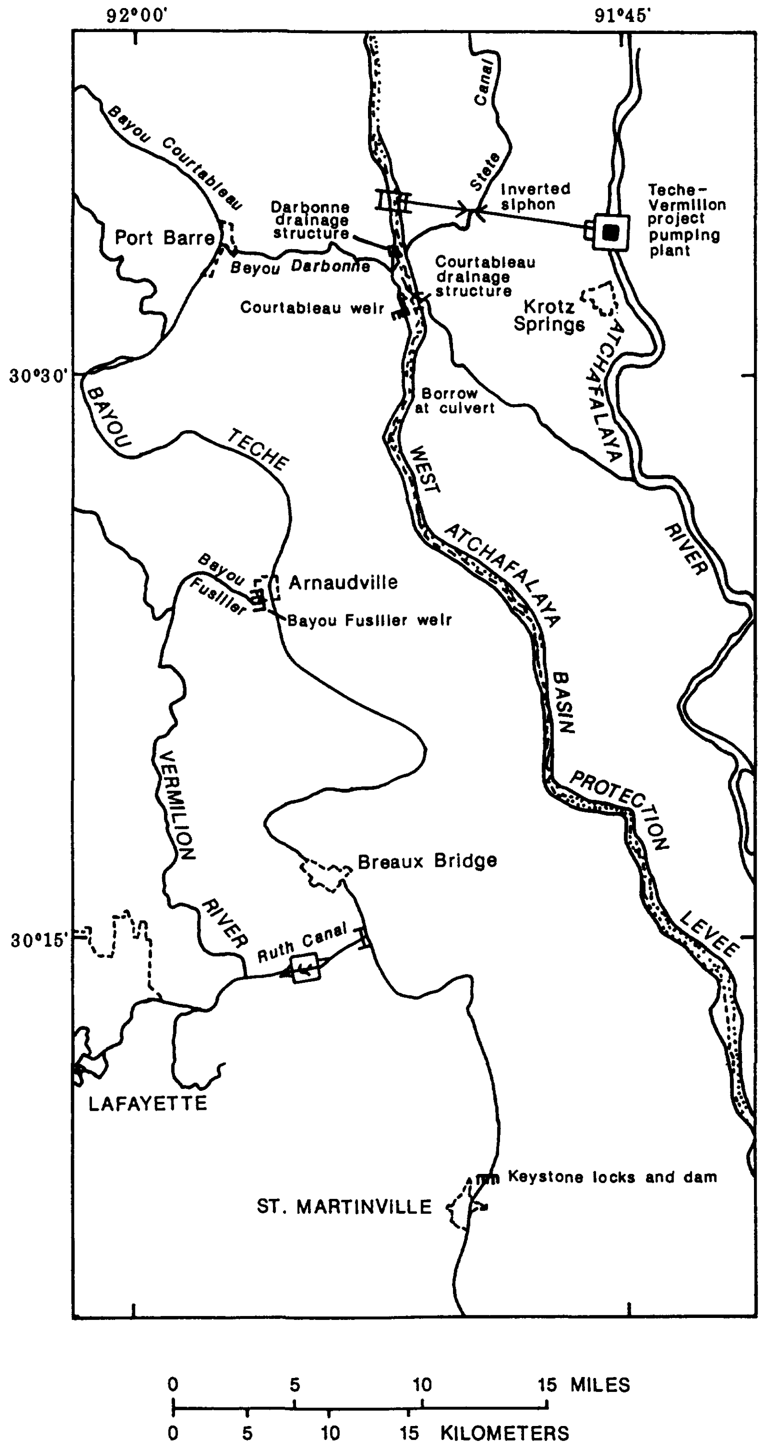
Historical Activity

The Vermilion River has a long history of channel improvements and diversion of water from other basins. About 1896, the channel from Vermilion Bay to Lafayette was dredged to a depth of 5.5 ft (U.S. Army Corps of Engineers, 1981, p. 112). Ruth Canal was built in 1919 by a rice-farming conglomerate to divert water for irrigation from Bayou Teche into the Vermilion River.

In 1957 the Corps of Engineers completed a multipurpose project to improve navigation and flood control, and to increase streamflow for irrigation use in the Vermilion River (U.S. Army Corps of Engineers, 1981, p. 111). Improvements consisted of an 8-ft deep by 80-ft wide navigable channel from Vermilion Bay to the Gulf Intracoastal Waterway and a 9-ft deep by 100-ft wide channel from the Gulf Intracoastal Waterway to Lafayette. Improvements on the non-navigable part of the Vermilion River from Lafayette to Bayou Teche were also completed. In addition, the crest of Keystone Lock and Dam on Bayou Teche was raised to permit increased diversion of water from Bayou Teche through Ruth Canal to the Vermilion River.

Construction of the WABPL (West Atchafalaya Basin Protection Levee) prior to the 1940's reduced flow to the Teche-Vermilion River system and caused water in Bayou Teche and the WABPL borrow pit parallel to the levee (west) to become stagnant during periods of low flow. The resultant low water flows in the Vermilion River, coupled with large withdrawals of water for rice irrigation, caused saltwater to move upstream from Vermilion Bay into the lower river and the adjacent Chicot aquifer. About 25,000 acres of land are affected by saltwater intrusion (Teche-Vermilion Fresh Water District, 1984). The Bayou Darbonne drainage structure was built in 1941 to divert water from the Atchafalaya River and restore some water flow from the Atchafalaya River to Bayou Courtableau (fig. 1) and then to the Bayou Teche and Vermilion River. After the WABPL was eventually extended to Butte LaRose in the 1950's, very little water was diverted from Atchafalaya River to Bayou Teche and Vermilion River.

The Flood Control Act of 1966 authorized the Teche-Vermilion Fresh Water Project (diversion of water from the Atchafalaya River into Bayou Teche and Vermilion River, fig. 4). The diversion (pumping plant, and associated diversion canals) was completed in December 1982. A pumping plant located about 1.5 mi upstream of Krotz Springs on the Atchafalaya River diverts water from the river to Bayou Courtableau at the headwaters of Bayou Teche for further distribution into the Teche-Vermilion River system. Weirs are located on the WABPL borrow pit and on Bayou Fusilier, and control gates are located on Bayou Courtableau, Bayou Darbonne, and Ruth Canal to control water distribution. An 18-ft stage is maintained at the Bayou Courtableau control gate from March 1 to September 30 each year. A 16-ft stage is maintained from October 1 to December 31 and a 17-ft stage from January 1 to the end of February. If too much water is pumped from the Atchafalaya River, the excess can be diverted through the Bayou Courtableau gate and back into the river. From April 1 to August 31, 70 percent of the flow in Bayou Teche is diverted to the Vermilion River through Ruth Canal for rice irrigation. From September 1 to March 31,



EXPLANATION

Water is pumped out of the Atchafalaya River into a canal connecting the Atchafalaya River and the West Atchafalaya Basin Protection Levee (WABPL) borrow pit. From there the water is diverted into the WABPL borrow pit, Bayou Teche through Bayou Courtableau, and the Vermilion River via Bayou Fusilier and Ruth Canal.

Figure 4.--The Bayou Teche-Vermilion River freshwater diversion operations.

only 30 percent of Bayou Teche flow is diverted to Vermilion River. Pumping operations cease during surplus streamflow because drainage from the WABPL borrow pit and Bayou Courtableau, and from the headwaters of Bayou Teche and the Vermilion River provide adequate flow to both the lower parts of Bayou Teche and the Vermilion River.

Continuing Activity

The Teche-Vermilion Fresh Water District, which includes St. Martin, Lafayette, Vermilion, and Iberia Parishes, operates and maintains the Teche-Vermilion diversion operations. The district is still looking for ways to improve the system. A study has been initiated by the Corps of Engineers and partially funded by the District to investigate the environmental and economic benefits of dredging Bayou Teche between Port Barre and Arnaudville (fig. 1). Another study, commissioned by the Bayou Vermilion Restoration Foundation, listed improvement in water quality as top priority and recommends additional flow augmentation from the Teche-Vermilion diversion as well as improving waste treatment facilities and reducing soil erosion in the basin (Department of Planning and Development Management, City of Lafayette, 1984, p. 35).

According to the 1985 inventory of water use in Louisiana, 171 Mgal/d of water was withdrawn from the Vermilion River (Lurry, 1987, table 3). In a breakdown of water use by parish, Lurry (1987, table 1) reported that in 1985 Lafayette Parish pumped 2.16 Mgal/d for rice irrigation, 0.12 Mgal/d for aquaculture, and 0.01 Mgal/d for livestock from surface-water sources. All water for public-supply use, and domestic and industrial uses were pumped from ground-water sources. Vermilion Parish reported pumpages of 288 Mgal/d for rice irrigation, 15.0 Mgal/d for aquaculture, 4.43 Mgal/d for industry, and 0.04 Mgal/d for livestock from surface-water sources. Most of the 171 Mgal/d pumped from the Vermilion River is used for rice irrigation in Vermilion Parish. The pumpage rates listed are for the entire parish and include more stream systems than the Vermilion River.

Appendix 1 lists the organizations that are conducting or recently have conducted activities that affect the hydrology of the Vermilion River. Each listing includes a short summary of the type of activities.

HYDROLOGIC FEATURES AND PROCESSES

The following sections describe the Vermilion River in terms of the physical characteristics of the stream channel, streamflow characteristics, and other factors that affect hydrology.

Physical Characteristics

Physical characteristics of the Vermilion River can be described by defining the shape, size, and slope of the main river channel and associated tributaries. Channel cross sections are used to describe the shape and size of river channels. Most of the cross sections in the Vermilion River have been referenced to sea level. Figures 5 through 11 show representative channel cross sections of selected tributary streams and the main channel from the headwaters to near the mouth of the river. This series of cross sections presents a picture of the volume of water in the system in terms of widths and depths, as well as showing the progression of channel shape and size from the upper to lower reaches of the river. All of the cross-sectional measurements presented in figures 5 through 11 were made August 6, 1985. Because all of the measurements presented in the figures were made within a few hours of one another, cross-sectional areas can be used to compare relative sizes of selected channels.

Figure 5 shows channel cross sections of three tributary streams which comprise the headwaters of the Vermilion River. For these measurements Bayou Fusilier had a cross-sectional area of 157 ft^2, Bayou Bourbeux an area of 39 ft^2, and Bayou Carencro an area of 123 ft^2. Figure 3 shows locations of sites where cross sections were measured.

Incoming and outgoing tides cause continual fluctuation of river stages and a continually changing water-surface slope. During incoming tides the slope is flatter as the river stage rises in the lower reaches. The greatest slopes occur during low tide. The water-surface slope ranged from 0.03 to 0.05 ft/mi between the Surrey Street gage in Lafayette and 30 mi downstream at the gage at Perry during August 1985. Byrne (1977, p. 37) reported that the average water-surface slope for 1963-74 was 0.06 ft/mi for the entire length of the river.

Streamflow Characteristics

Few data are available to describe the streamflow characteristics of the Vermilion River. Because flow augmentation has changed the hydrology of the river, the description of streamflow characteristics for the river in its present hydrologic state is limited to the interpretation of data collected after pumping operations at the Teche-Vermilion pumping plant began in December 1982.

Two continuous discharge stations are presently in operation on the Vermilion River. An additional station is located on Ruth Canal near Ruth. Refer to figure 3 for location of gaging stations in the Vermilion River basin. The two stations at Surrey Street in Lafayette and at Perry, use electromagnetic flowmeters to record a point velocity in the river. A flowmeter was installed at the Surrey Street station in 1982 and at the Perry station in 1985. Because of the affects of tide, a useful stage-discharge relation at such locations does not exist. Therefore, electromagnetic flowmeters were installed where a point velocity-mean cross-section velocity relation was established. This relation in conjunction with a stage-area relation is used in computation of discharge.

The Corps of Engineers operates several recording stage stations and staff gages on the Vermilion River and its tributaries. Appendix 2 lists gaging-station information for gages on the Vermilion River including those operated by the Corps of Engineers. Discharges at various stations were measured intermittently from the early 1930's through the 1940's for a range

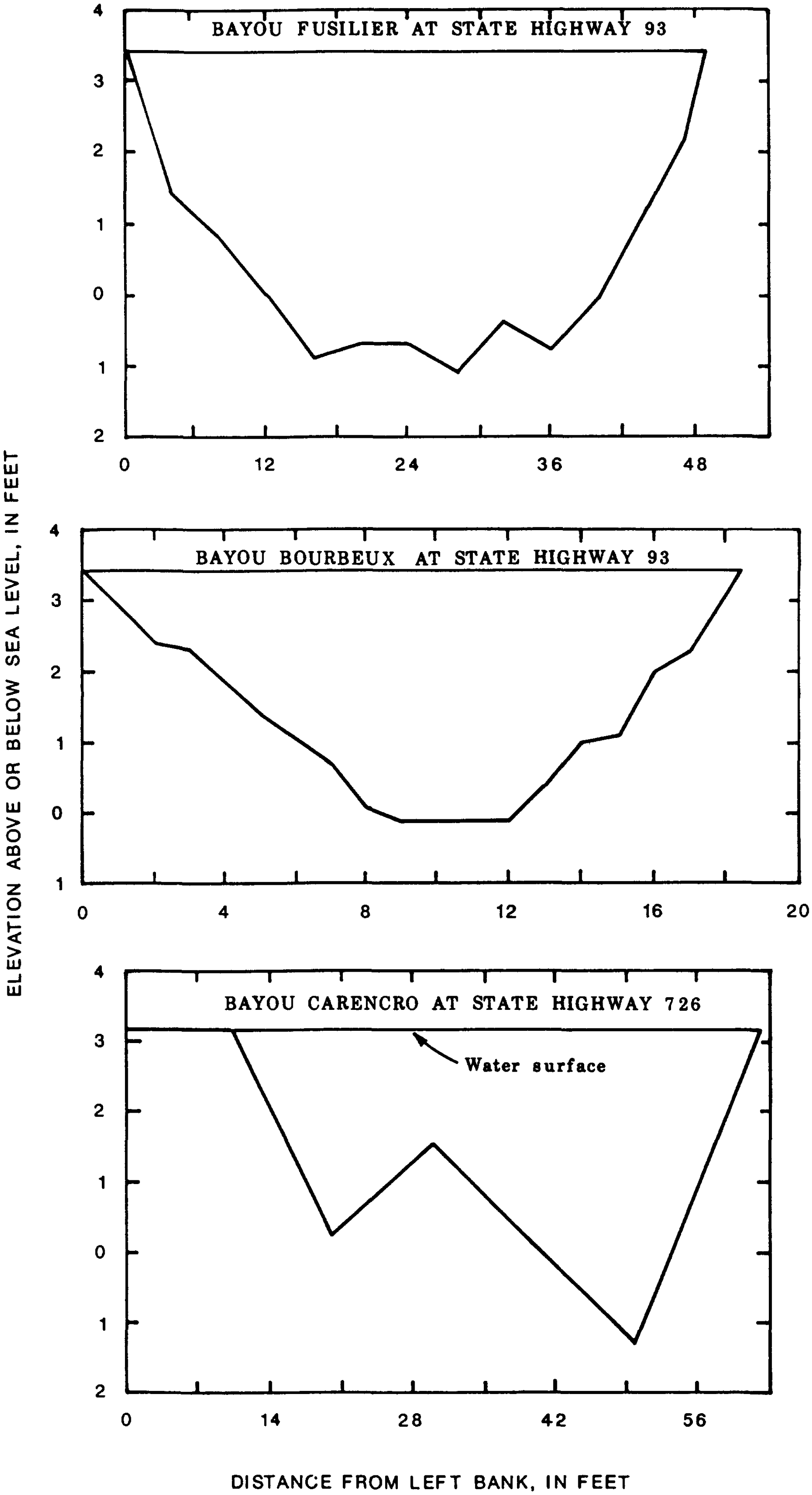


Figure 5.--Representative channel cross sections of three tributary streams forming the headwaters of Vermilion River.

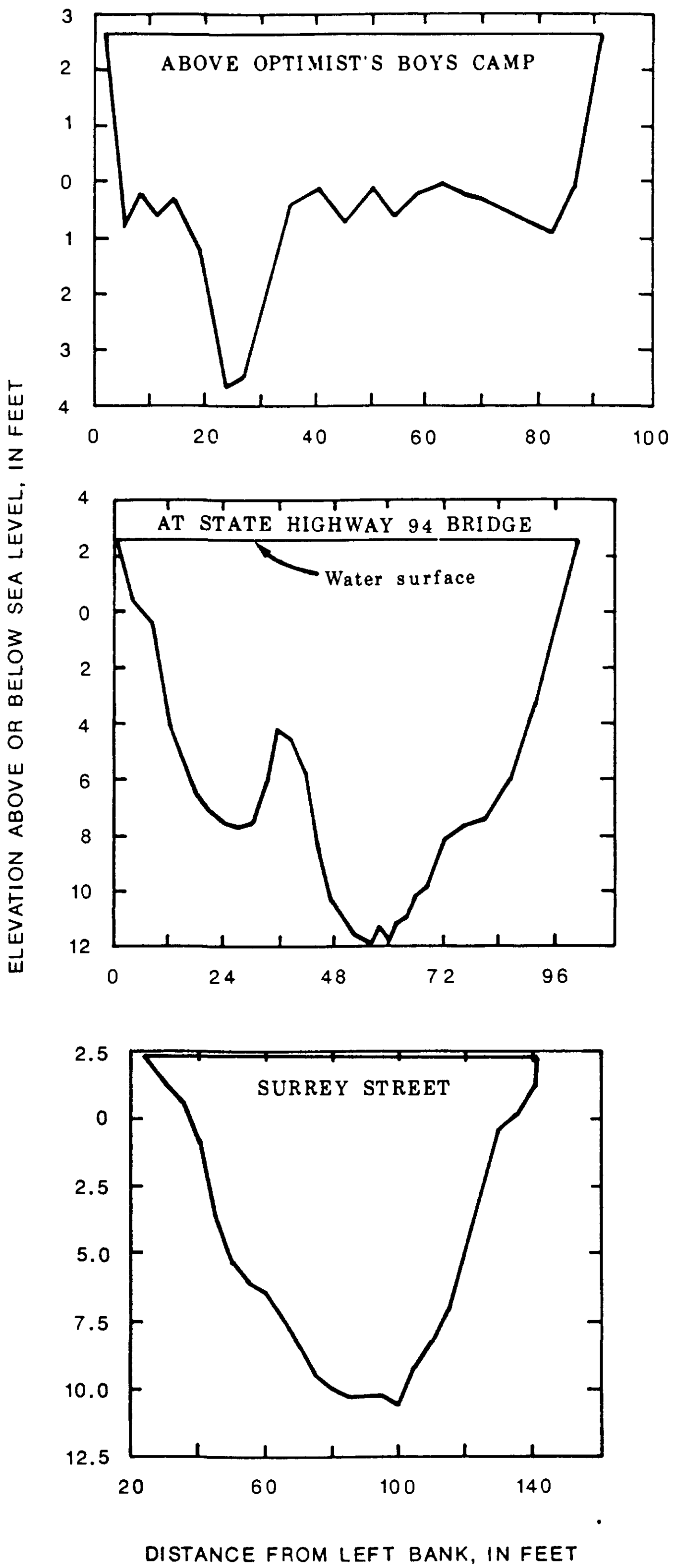


Figure 6.--Representative channel cross sections of the upper Vermilion River, main stem.

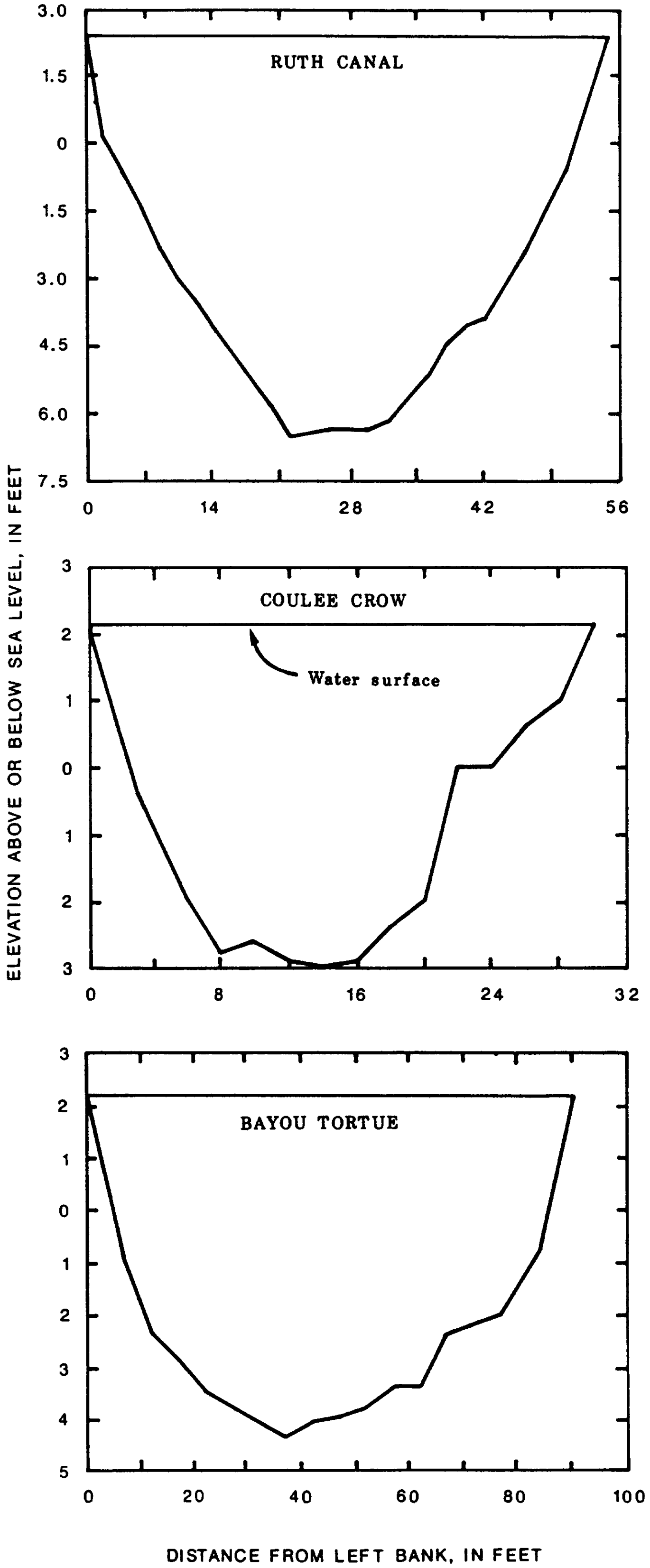


Figure 7.--Representative channel cross sections of tributary streams to the upper Vermilion River.

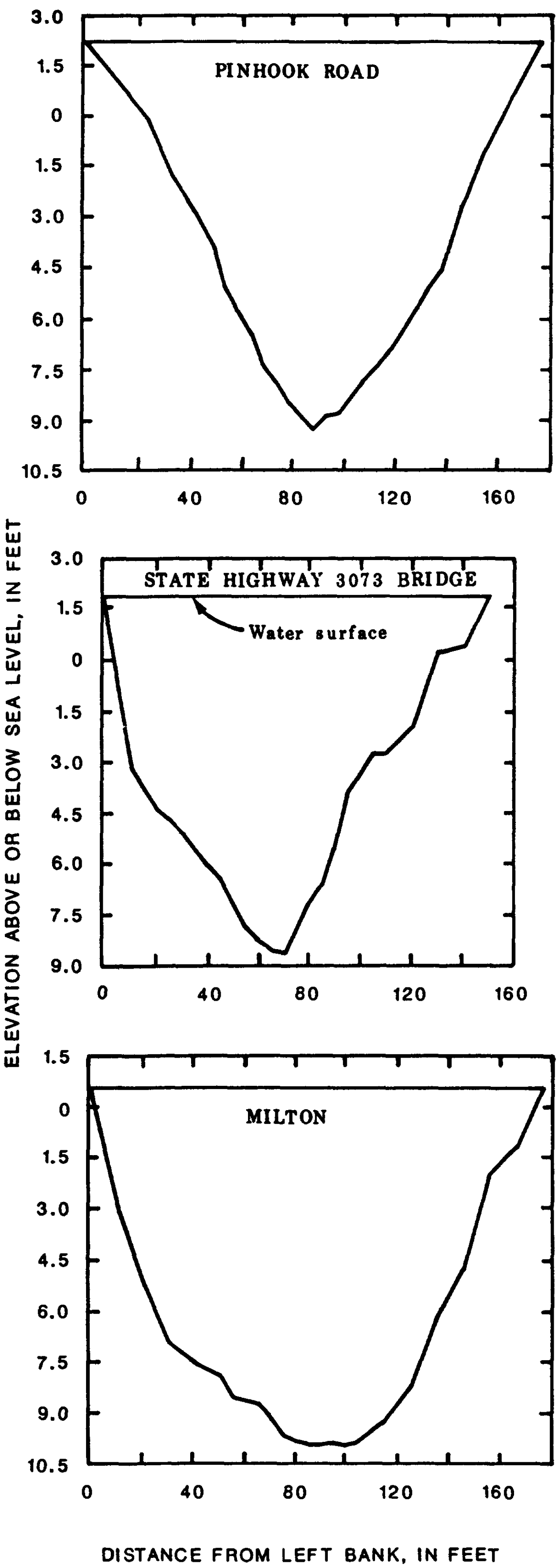


Figure 8.--Representative channel cross sections of the middle Vermilion River, main stem.

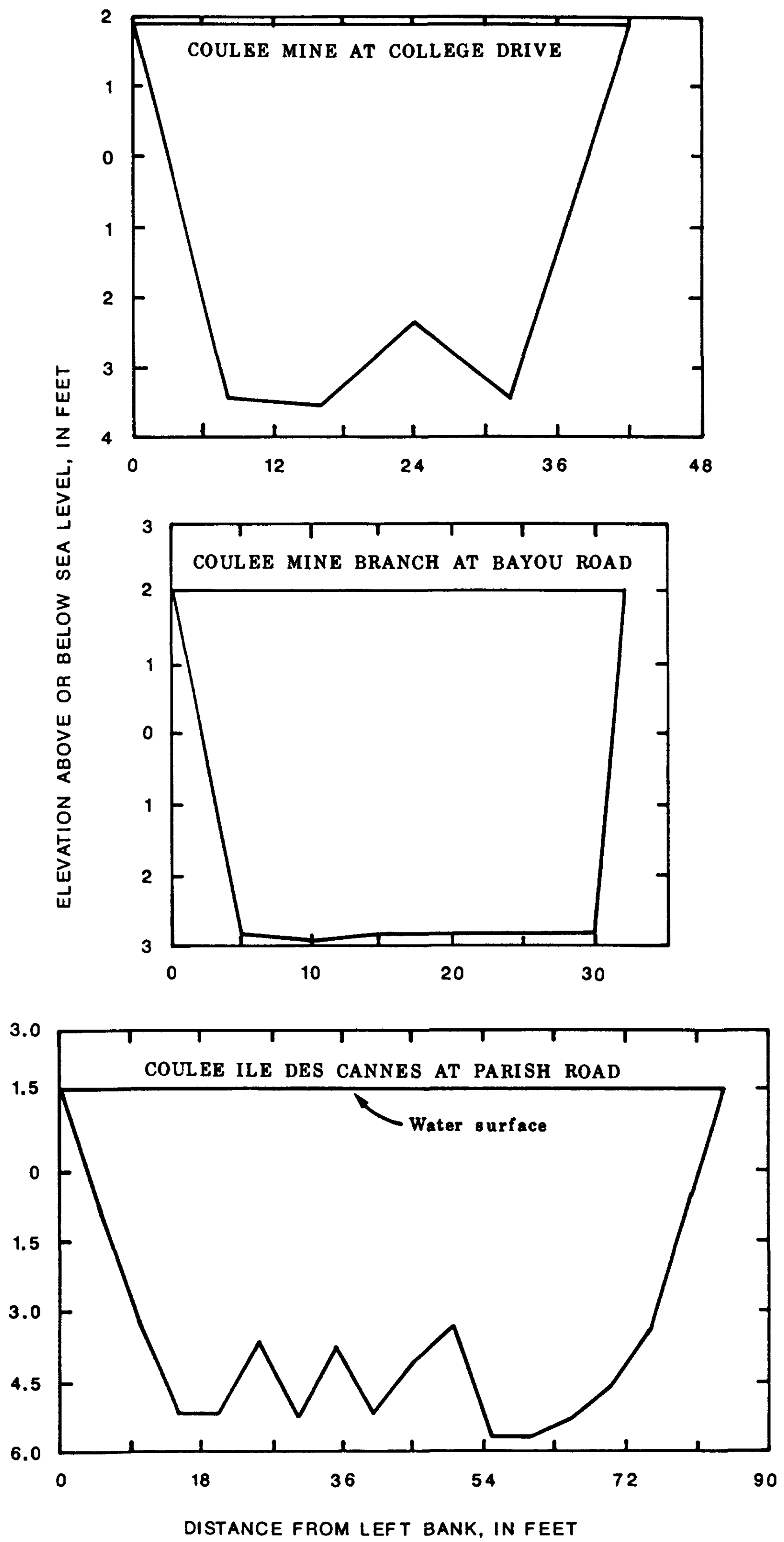


Figure 9.--Representative channel cross sections of tributary streams to the middle Vermilion River.

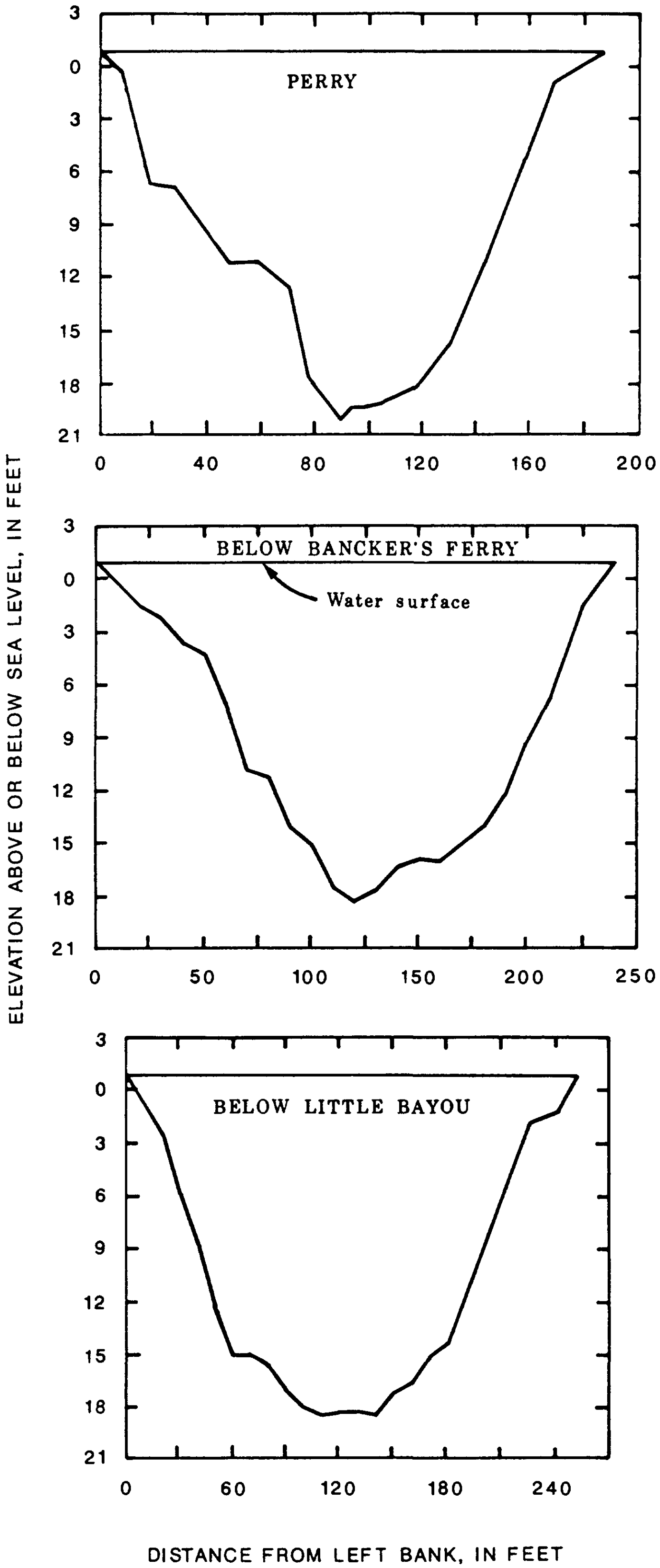
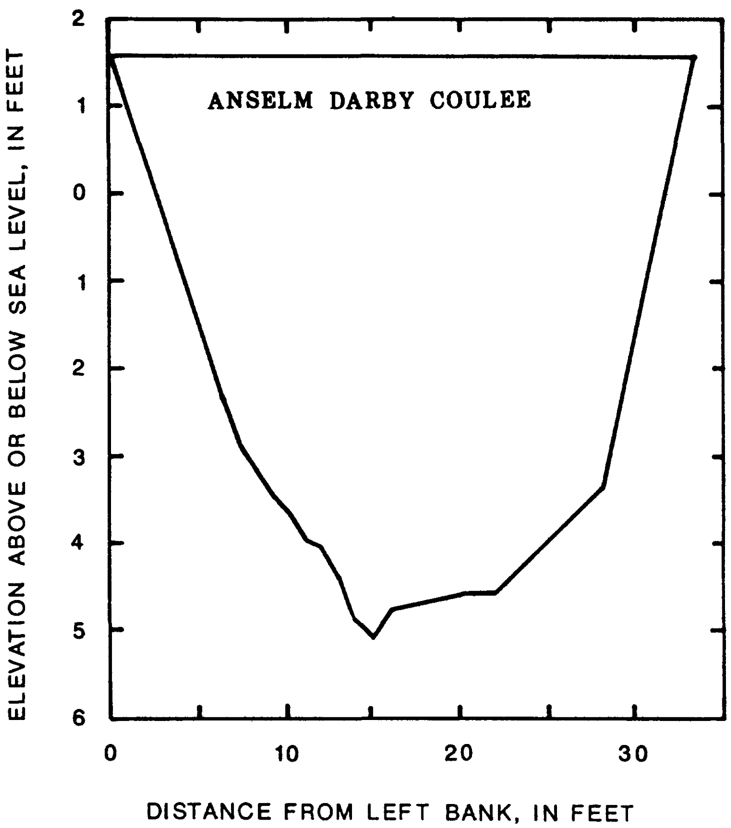


Figure 10.--Representative channel cross sections of the lower Vermilion River, main stem.



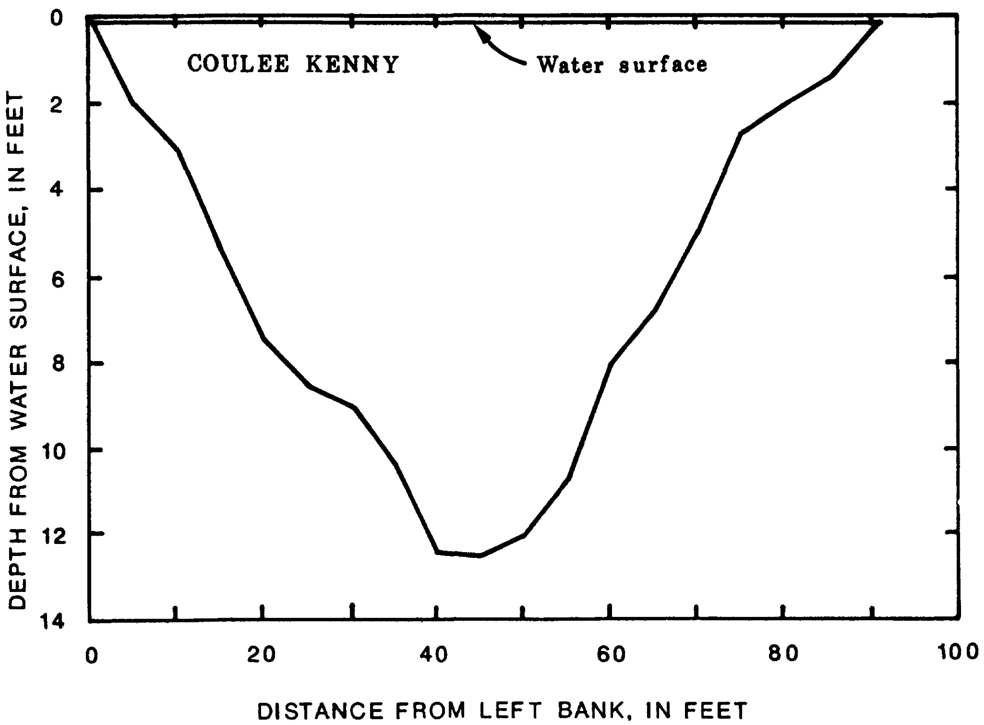


Figure 11.--Representative channel cross sections of tributary streams to the lower Vermilion River.

of discharges. Because the measurements were made only during high flow conditions, the data are of limited value in describing streamflow characteristics. However, stage data might be used in conjunction with channel geometry, discharge measurements, and a one-dimensional flow model to simulate discharges in selected reaches of the river (Schaffranek and others, 1981). A one-dimensional flow model simulates the unsteady flow in singular riverine or estuarine reaches and in networks of reaches composed of interconnected channels (Schaffranek and others, 1981, p. 1). Use of a one-dimensional flow model will be addressed further in the section on needs for additional studies.

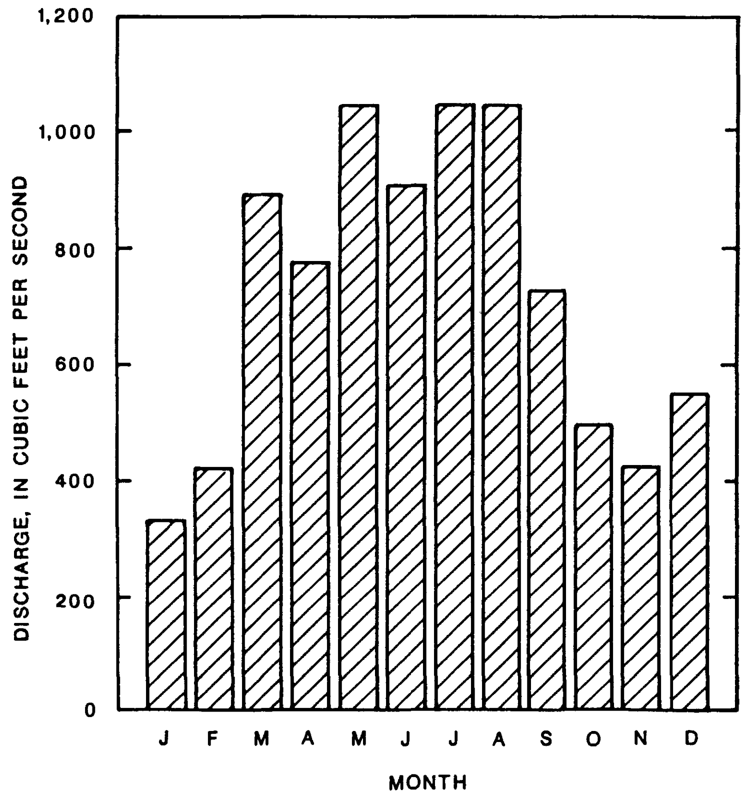
Streamflow Prior to Flow Augmentation from the Atchafalaya River

Data collected prior to flow augmentation from the Atchafalaya River can be used to describe the past history and to present an overview of the seasonal flow of the river. The only long-term continuous discharge station in operation on the Vermilion River is the Surrey Street station in Lafayette. The station has been operating since December 1967. Because computed discharges at this site are poor for discharges less than 1,000 ft^3/s and only fair for higher discharges (U.S. Geological Survey, 1984, p. 389), continuous-record stations on the neighboring Bayou Teche will also be used to indicate the seasonal distribution of flow in Vermilion River.

Figures 12 and 13 show the mean monthly discharges for the Vermilion River at the Surrey Street station in Lafayette and the station on Ruth Canal, and Bayou Teche at Arnaudville and at Keystone Lock and Dam. Locations are on figures 3 and 4. Discharges shown in the two figures are listed in table 1. Controlled diversions from Bayou Teche to the Vermilion River, and large withdrawals from the Vermilion River for rice irrigation in the spring and from Bayou Teche for sugarcane processing in late summer and early fall alter the natural flow of both basins. Discharge of Bayou Teche decreases in the summer and fall months, and greater discharges occur in winter and spring; discharge on the Vermilion River decreases during fall and winter and increases during spring and summer. Table 1 also indicates that the maximum diversion of water through Ruth Canal occurs in April, May, and June and coincides with rice irrigation demand and with availability of water in Bayou Teche.

Flow statistics on frequency and duration for Bayou Teche are listed in table 2. The 7-day, 10-year low-flow rate is a frequently used streamflow statistic in waste dilution computations. Because of control structures in Bayou Teche and diversions to the Vermilion River, it is difficult to establish an accurate figure for the 7-day, 10-year low flow. The discharges given in table 2 are for comparing relative values and are valid only for the period of record used to compute the values. No attempt has been made to establish a 7-day, 10-year low-flow value for sites on the Vermilion River.

Demcheck and Leone (1983, p. 5) indicate that the flow of Vermilion River often is too low to dilute and assimilate waste loads. The poorest water-quality conditions would be expected to occur during extreme low flow when tidal effects are most pronounced. The river can best assimilate waste



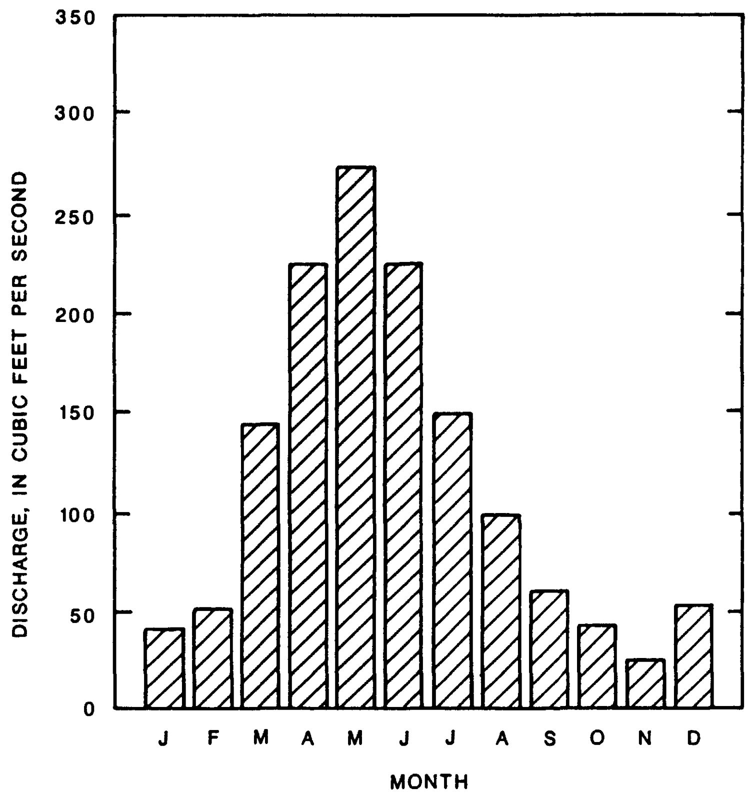


Figure 12.--Mean monthly discharge for Vermilion River at Surrey Street in Lafayette (1969-82) and Ruth Canal (1963-82) prior to flow augmentation from the Atchafalaya River.

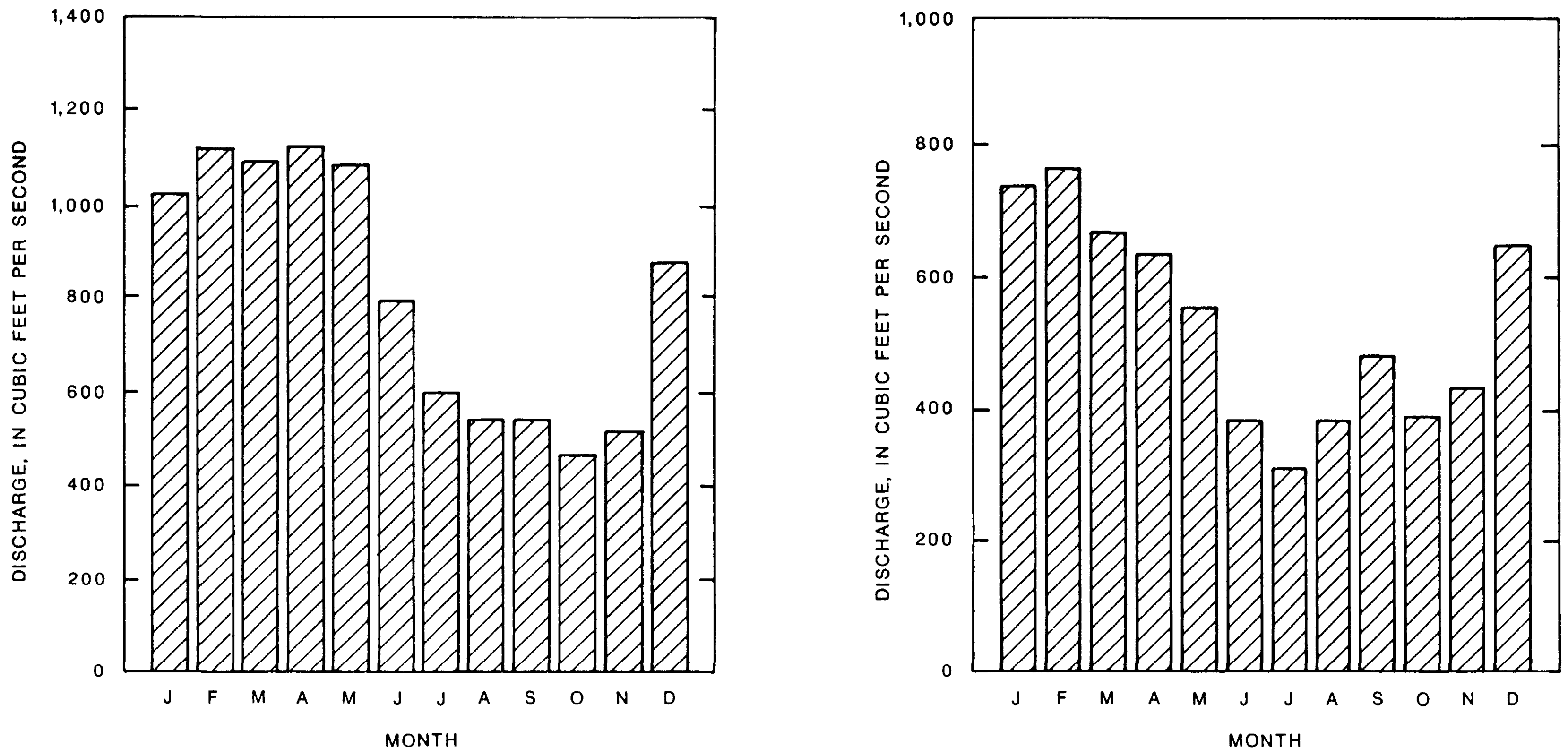


Figure 13.--Mean monthly discharge for Bayou Teche at Arnaudville (1950-82) and Keystone Lock and Dam (1964-82) prior to flow augmentation from the Atchafalaya River.

Table 1.--Mean monthly discharges for Bayou Teche at Arnaudville and Keystone Lock and Dam, and Vermilion River at Lafayette and Ruth Canal

[All values in cubic feet per second]

Month	Arnaudville 07385500[a] (1950-82)[b]	Keystone Lock and Dam 07385700 (1964-82)	Lafayette 07386880 (1969-82)	Ruth Canal 07386700 (1960-82)
January-------	1,022	741	333	41
February------	1,117	766	423	51
March---------	1,090	671	895	114
April---------	1,121	637	775	224
May-----------	1,083	551	1,046	273
June----------	792	383	911	224
July----------	600	309	1,048	149
August--------	543	382	1,046	99
September-----	542	478	728	60
October-------	469	388	497	42
November------	519	431	427	25
December------	878	649	552	52

[a] Station name and downstream order number.
[b] Period of record.

loads during periods of intense and frequent rainfall. Demcheck and Leone reported zero flow on August 8, 1980, on the Vermilion River near Lafayette. Other discharge measurements, listed in table 3, reflect the high degree of variability in streamflow in the Vermilion River.

Calandro (1981) also reported on the variability of stream velocity in the Vermilion River. By injecting dye into the river he measured the movement of the dye cloud and was able to determine time of travel of water in the stream. Calandro found that during the period November 1-20, 1978, it took 438 hours for the dye to travel 17.5 mi. The instantaneous discharge at the time of injection was 200 ft^3/s. However, based on stage records for Surrey Street, Calandro estimated that tidal fluctuations caused the discharge to vary from approximately 375 ft^3/s upstream to approximately 200 ft^3/s downstream. Calandro found that during the period June 28-30, 1979, it took 42 hours for dye injected into the Vermilion River at Surrey Street to travel 14 mi. The instantaneous discharge at the time of injection was 375 ft^3/s, and stage records show that daily mean discharges varied from a low of 150 ft^3/s to a high of 300 ft^3/s. Calandro's investigation shows that in November it took about 25 hours for the dye to travel 1 mi while in June it took only 3 hours to travel 1 mi. Even though the range in discharges occurring during the two periods were similar, tidal fluctuations caused highly variable flows.

Table 2.--Site information and flow statistics (frequency and duration) for Bayou Teche at Arnaudville and Keystone Lock and Dam

[All values in cubic feet per second, except as noted]

Station no.	Station name	Approximate drainage area (square miles)	Period of record	Maximum flow	Minimum flow	7-day low flows			Percent of time flow is exceeded				
						2-year	10-year	20-year	10	25	50	70	90
07385500	Arnaudville	1,530	1950-82	4,630	53	191	108	89	1,350	1,120	834	508	245
07385700	Keystone Lock and Dam	Indeterminate	1964-82	3,970	no flow	133	28	8	955	705	487	292	157

Table 3.--Discharge measurements made during 1980 on the Vermilion River 1.5 miles upstream from Lafayette, Louisiana

[Source: Demcheck and Leone, 1983, fig. 1]

Date (1980)	Discharge (cubic feet per second)
April 10	3,300
May 12	477
May 17	2,350
August 8	0

Streamflow After Flow Augmentation from the Atchafalaya River

Descriptions of streamflow characteristics for the Vermilion River after flow augmentation from the Atchafalaya River are based on gaging-station records obtained after 1982 and data collected during the intensive survey in August 1985. Tables 4 through 7 give the daily mean discharges for stations located at Surrey Street and at Perry. The 1985 discharges at Perry show that flow increased downstream during February, March, and April but decreased slightly in May. The net loss in May is a result of withdrawals for rice irrigation.

Several negative values of discharge, which represent upstream flows, occur at both locations. Negative flows caused by the actions of tides and wind are observed at the Surrey Street gaging station. Occasionally, during high negative discharges water is observed flowing down Bayou Fusilier and the upper Vermilion River and flowing into Pine Island Swamp about 1.5 mi north of the Surrey Street station. When the combination of high tides, sustained southerly winds, and high stages occur, a reversal of flow is occasionally observed at the Surrey Street gaging station as the water flows northward and empties into the swamp (A.H. Devillier, U.S. Geological Survey, oral commun., 1986).

This situation occurs at Perry during periods of low flow. Negative values occur in the lower reaches of the river where the water is virtually stagnant except for incoming tide. Sustained southerly winds, incoming tides, or a combination of both can reverse the water slope and cause flows in an upstream direction.

Monthly mean discharges for the Vermilion River at Surrey Street for 1983-85 are listed in table 8. A comparison of mean monthly discharges prior to and after flow augmentation from the Atchafalaya River (table 9) shows that in most months discharges have increased since pumping operations began after the plant was installed. However, mean monthly discharges were greater for April, August, and September before the pumping plant was installed. It is impossible to establish if this is a trend because so few data are available since pumping began. Precipitation was well below normal during 1984-85

Table 4.--Daily mean discharge for the Vermilion River at Surrey Street in Lafayette, Louisiana, for the 1983 water year[1]

[Source: U.S. Geological Survey, 1983, LA-83-2, p. 211. Discharge, in cubic feet per second]

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept
1	102	159	1730	2870	2280	---	----	424	2060	2160	751	-----
2	101	126	2010	4000	2830	---	----	476	1880	2090	736	-----
3	69	350	771	4410	2810	---	----	896	2010	1880	228	-----
4	43	226	-1450	4330	2740	---	----	1040	2150	1680	1430	-----
5	19	136	2770	4240	1110	---	----	924	1690	1500	2260	-----
6	-45	36	3470	4140	977	---	----	821	987	1660	2210	-----
7	571	153	3480	4040	3280	---	----	792	910	1980	2010	-----
8	1430	84	3410	3930	3290	---	----	995	1140	1890	1830	-----
9	1380	30	3320	3820	3150	---	----	884	1400	1680	1660	788
10	1280	136	3210	3710	2490	---	----	789	1240	1380	1610	703
11	957	-68	3110	3590	3360	---	----	802	839	1160	1520	814
12	357	206	2930	3450	3270	---	----	781	358	965	1230	888
13	674	213	2740	3300	3140	---	2190	721	-122	730	1420	830
14	319	-93	2600	3150	2990	---	2120	666	-326	579	1820	758
15	142	185	2300	2990	2820	---	1990	287	-351	635	1610	659
16	271	-39	2640	2800	2640	---	1790	1070	-326	806	1360	618
17	82	112	2550	2640	2420	---	1610	709	1430	911	1170	695
18	88	90	2410	2480	2200	---	1470	781	763	922	1020	719
19	100	148	2260	2420	1980	---	1290	1010	1110	913	1070	407
20	148	136	2100	-209	1760	---	1080	414	1430	935	1020	-1340
21	126	229	1980	2390	----	---	1010	-2620	1270	1040	870	1050
22	184	308	1840	3340	----	---	935	-2200	897	1010	770	1790
23	151	259	1540	3320	----	---	1150	-183	1140	948	681	1600
24	72	348	1230	3270	----	---	1130	2170	356	937	495	-----
25	84	152	1050	3260	----	---	879	2650	88	837	-319	-----
26	182	42	-389	3190	----	---	725	2750	----	778	793	-----
27	25	391	-3620	3070	----	---	630	2710	----	730	620	-----
28	77	1290	706	2930	----	---	617	3170	----	757	-480	-----
29	54	1810	3420	2790	----	---	562	3140	----	658	354	-----
30	104	1640	4040	2670	----	---	487	3020	2210	610	----	-----
31	61	----	3980	2550	----	---	----	2850	----	654	----	-----
Total	9208	8795	64138	98881	----	---	----	32739	----	35415	----	-----
Mean	297	293	2069	3190	----	---	----	1056	----	1142	----	-----
Maximum	1430	1810	4040	4410	----	---	----	3170	----	2160	----	-----
Minimum	-45	-93	-3620	-209	----	---	----	-2620	----	579	----	-----

[1] No gage-height record, February 21 through April 12, June 26-29, August 30 through September 8, September 24-30.

Table 5.--Daily mean discharge for the Vermilion River at Surrey Street in Lafayette, Louisiana, for the 1984 water year[1]

[Source: U.S. Geological Survey, 1984, LA-84-1, p. 389. Discharge, in cubic feet per second]

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept
1	---	---	1250	693	784	1460	723	850	902	1440	879	699
2	---	---	1130	615	677	1280	377	659	881	1420	808	583
3	---	---	972	610	635	1150	730	693	860	1300	714	608
4	---	---	1140	538	867	938	865	836	790	1170	806	772
5	---	---	1120	532	785	912	786	639	713	1080	833	713
6	---	---	987	488	742	962	718	537	625	1030	835	493
7	---	---	1070	546	531	813	619	543	672	989	1040	388
8	---	---	721	511	369	807	671	890	741	928	1070	336
9	---	578	621	201	394	813	907	946	825	979	1040	420
10	---	617	336	1060	1550	701	879	839	873	1130	979	382
11	---	565	632	1850	1780	720	719	723	937	1120	893	363
12	---	290	1700	1760	1520	564	747	785	997	1020	905	446
13	---	383	1770	1580	1920	744	892	781	1010	999	886	409
14	---	411	1870	1340	2290	751	907	754	1010	981	886	335
15	---	450	1870	1140	2280	678	934	719	992	913	857	284
16	---	602	1800	1380	2240	715	833	644	1030	868	873	320
17	---	574	1720	1170	2150	720	780	574	1070	756	868	188
18	---	362	1570	1160	1960	602	722	518	1130	807	847	209
19	---	694	1380	1880	1790	601	689	460	1170	869	807	180
20	---	898	1200	1900	1580	1400	635	298	1200	887	777	209
21	---	1150	893	1690	1420	1380	462	980	1180	868	770	174
22	---	790	951	1410	1270	1220	870	1220	1090	820	769	183
23	---	884	840	1160	1150	997	947	1510	1050	757	923	776
24	---	1300	782	958	1020	1020	850	1810	1000	758	1140	1150
25	---	1220	507	1040	918	1230	702	1690	934	823	968	1270
26	---	824	461	1480	574	1170	545	1520	766	831	870	1150
27	---	930	347	1330	1320	987	606	1480	777	877	951	904
28	---	1530	872	1180	1790	1020	801	1440	967	1140	1010	685
29	---	1790	1220	1060	1660	909	567	1320	861	1150	941	580
30	---	1640	1010	949	-----	770	840	1160	1060	1120	833	414
31	---	----	796	862	-----	718	-----	975	---	955	1010	-----
Total	---	----	33538	34073	37966	28752	22323	28793	28113	30785	27788	15623
Mean	---	----	1082	1099	1309	927	744	929	937	993	896	521
Maximum	---	1790	1870	1900	2290	1460	947	1810	1200	1440	1140	1270
Minimum	---	----	336	201	369	564	377	298	625	756	714	174

[1] No gage-height record, October 1 through November 8.

Table 6.--Daily mean discharge for the Vermilion River at Surrey Street in Lafayette, Louisiana, for the 1985 water year[1]

[Source: U.S. Geological Survey, 1985, LA-85-1, p. 358. Discharge, in cubic feet per second]

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept
1	435	1520	741	430	1390	1480	1070	959	970	----	---	935
2	394	996	540	1170	1200	2220	1030	1260	939	----	---	926
3	395	1070	1200	818	900	2250	951	1310	820	1220	---	780
4	339	996	1430	638	1000	1820	726	1110	800	1630	---	983
5	268	921	1460	529	1100	1760	778	940	741	1440	---	1250
6	352	869	1890	349	1670	1570	883	849	810	1380	---	1290
7	321	738	1730	296	1850	1260	797	896	884	1390	835	1460
8	312	647	1410	257	1650	1130	890	1040	---	1160	1000	1560
9	302	584	1240	197	1410	1070	690	1980	---	1120	1180	1180
10	352	573	1010	234	1080	926	638	1650	---	961	1250	1080
11	445	569	808	323	657	682	639	1550	---	961	1150	1360
12	436	457	684	244	2110	594	661	1340	---	960	910	1480
13	389	350	445	80	1790	498	705	1130	---	994	866	1340
14	-715	277	249	95	1990	781	710	1050	---	1040	861	1410
15	-41	229	315	138	1750	865	682	1270	---	----	399	1140
16	1500	695	226	-94	1400	772	677	1190	---	----	512	855
17	430	1270	163	379	941	841	636	1060	---	----	1410	696
18	1600	855	121	1880	780	743	560	1010	---	----	1760	620
19	2080	851	133	2030	592	645	589	911	---	----	1450	600
20	2130	745	85	1720	406	-372	700	830	---	----	1360	561
21	1790	536	21	1370	319	402	659	922	---	----	1360	588
22	-673	401	152	997	295	2150	603	1360	---	----	1170	579
23	-2970	276	146	837	218	2240	693	1320	---	----	1110	517
24	134	242	74	718	557	1920	824	1850	---	----	1180	590
25	2750	169	157	623	659	1640	875	1830	---	----	1260	407
26	3690	197	77	637	1660	1420	747	1580	---	----	1170	479
27	4050	116	15	103	2120	1230	828	1170	---	----	1130	422
28	3210	405	15	884	2050	1100	1060	1010	---	----	996	380
29	2280	222	61	1940	-----	971	1030	1010	---	----	938	316
30	1600	447	57	1780	-----	975	955	951	---	----	885	7.1
31	1690	-----	-115	1460	-----	1060	-----	893	---	----	1030	-------
Total	29275	18223	16540	23062	33544	36643	23286	37231	---	----	----	25791.1
Mean	944	607	534	744	1198	1182	776	1201	---	----	----	860
Maximum	4050	1520	1890	2030	2120	2250	1070	1980	---	----	----	1560
Minimum	-2970	116	-115	-94	218	-372	560	830	---	----	----	7.1

[1] No gage-height record, June 8 through July 2, July 15 through August 6.

Table 7.--Daily mean discharge for the Vermilion River at Perry, Louisiana, for the 1985 water year[1]

[Source: U.S. Geological Survey, 1985, LA-85-1, p. 362. Discharge, in cubic feet per second]

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept
1	---	----	---	---	2700	4090	1430	1230	441	533	----	573
2	---	----	---	---	1630	3370	1650	1690	368	635	----	872
3	---	----	---	---	1160	2150	707	1390	438	2000	----	439
4	---	----	---	---	1380	2270	647	575	392	1210	----	844
5	---	----	---	---	3680	1950	953	785	462	1410	----	1350
6	---	----	---	336	2980	1300	551	711	742	1270	385	1330
7	---	----	---	653	2230	1180	1680	1090	603	809	31	1270
8	---	----	---	503	1890	1050	1150	1000	613	1080	577	1440
9	---	----	---	272	1790	802	1320	1430	414	722	-251	1080
10	---	----	---	811	1790	637	952	1480	543	596	-353	1250
11	---	----	---	799	7200	402	1570	1150	708	432	-477	1670
12	---	----	---	247	3620	295	1150	855	752	300	-622	----
13	---	----	---	96	2550	-22	1190	777	321	8.0	-659	----
14	---	----	---	447	2550	1080	1450	1060	434	73	-742	----
15	---	616	---	382	2270	525	1820	1630	435	440	485	----
16	---	804	---	1090	1850	987	1860	867	312	489	5050	----
17	---	635	---	5530	2290	1310	950	1360	230	------	3640	----
18	---	712	---	2670	2030	401	1120	179	924	------	2260	----
19	---	1020	---	1900	1710	628	1410	692	1990	------	1970	----
20	---	394	---	1440	1340	3340	1180	517	782	------	2290	----
21	---	448	---	868	1080	8440	658	920	843	------	1490	----
22	---	-19	---	1070	992	3950	653	1280	844	------	618	----
23	---	-59	---	1100	821	2800	1330	1580	840	------	458	----
24	---	-78	---	1120	2050	2630	1570	1390	794	------	500	----
25	---	-77	---	1160	3900	2260	906	1320	728	------	609	----
26	---	-374	---	1010	4050	1240	393	1110	742	------	506	----
27	---	----	---	2220	2710	1510	1470	868	845	------	180	----
28	---	----	---	4890	2270	1050	1490	807	493	------	621	----
29	---	----	---	2320	---	1250	1490	678	647	------	377	----
30	---	----	---	2430	---	1040	1180	615	639	------	346	----
31	---	----	---	2540	---	2480	---	539	---	------	170	----
Total	---	----	---	---	66513	56395	35880	31575	19319	------	----	----
Mean	---	----	---	---	2375	1819	1196	1019	644	------	----	----
Maximum	---	----	---	---	7200	8440	1860	1690	1990	------	----	----
Minimum	---	----	---	---	821	-22	393	179	230	------	----	----

[1] No gage-height or velocity record, October 1 through November 14, November 27 through January 5, July 17 through August 5, September 12-30.

Table 8.--Monthly mean discharges for the Vermilion River at Surrey Street in Lafayette, Louisiana, for the 1983-85 water years

[All values in cubic feet per second]

Month	1983	1984	1985
January	3,190	1,099	744
February	-----	1,309	1,198
March	-----	927	1,182
April	-----	744	777
May	1,059	929	1,201
June	-----	937	-----
July	1,142	993	-----
August	-----	896	-----
September	-----	543	860
October	-----	-----	944
November	-----	-----	607
December	2,069	1,082	534

Table 9.--Comparison of mean monthly discharges for Vermilion River at Surrey Street in Lafayette, Louisiana, prior to and after flow augmentation from the Atchafalaya River

Month[1]	1969-82	1983-85
January	333	1,678
February	423	1,253
March	895	1,055
April	775	761
May	1,046	1,063
June	911	937
July	1,048	1,067
August	1,046	896
September	728	701
October	497	944
November	427	607
December	552	1,228

[1] Not all water years are represented each month because of missing data.

resulting in lower discharges on both the Vermilion River and Bayou Teche. Analysis of percent of time flows occurred for the Vermilion River at Surrey Street prior to and after construction of the Teche-Vermilion pumping plant (table 10) shows that pumping operations have increased low flows. Since pumping operations began, high flows have been reduced in many instances. This is due in part to the lower than normal precipitation during 1984-85, and in part to the diversion of water from the Vermilion River through Ruth Canal and Bayou Fusilier into Bayou Teche and the WABPL borrow pit during high flows.

As part of the cooperative program with the Louisiana Department of Environmental Quality, Office of Water Resources, water quality and discharge measurements were made at several locations on the main stem of the Vermilion River and on several tributary streams in August 1985. August is historically a period of low flow and a time when the system is particularly susceptible to the effects of agricultural runoff, and municipal and industrial effluents. Measurements were made in August to assess the quality of water (to be accomplished by the Office of Water Resources), and to investigate the hydrologic properties of the Vermilion River during low flow. Results of the discharge measurements are given in table 11. The measurements show the variability of flow in the Vermilion River during the period of data collection.

Tide Characteristics

Nearly the entire Vermilion River system is subject to tides of the Gulf of Mexico. Slight fluctuations in water elevations caused by tides are recorded daily as far upstream as Tontons Bridge, 9 mi north of Lafayette. However, the reaches most affected by tidal fluctuations are downstream of Abbeville, where the tidal range in the river, the difference in water level between high tide and low tide, generally is greater than 1 ft.

Several tidal patterns are present in the Vermilion River. Diurnal tides, with one high and one low water period in a tidal day (24 hours 50 minutes), are the most dominant patterns. Semidiurnal and mixed tides also occur. Semidiurnal tides have two high water and two low water periods in a tidal day. Mixed tides are generally semidiurnal in nature but with relatively large differences between adjacent high and low water periods. Figures 14 through 16 show examples of tide patterns for three recording water-level gages in the Vermilion River.

Figure 14 shows an example of diurnal-tide elevations for gages at Lafayette, Perry, and Bancker for June 1-3, 1985. Although the tidal range is relatively small at Lafayette, a distinct tidal fluctuation can be seen. The tidal range is 1.7 ft at Perry and 2 ft at Bancker. Lag time for the 12 mi reach between Bancker and Perry is about 14.5 hours or 1.2 h/mi. The lag between Perry and Lafayette is about 33 hours for the 29 mi reach, which is about 1.1 h/mi. The lag time rate is fairly constant because the river channel is relatively constant in shape and size, although the decrease in river size between Perry and Lafayette is reflected in the slightly lower lag time rate between those two gaging stations.

Table 10.--Comparison of percent of time flows occurred for the Vermilion River at Surrey Street in Lafayette, Louisiana, prior to (1969-82) and after (1983-85) flow augmentation from the Atchafalaya River

[P, prior to; A, after]

Month[1]	Period of record	Percent of time flow exceeded (cubic feet per second)					
		10	25	50	70	90	95
January---	P	1,960	1,240	518	302	122	27
	A	3,600	2,780	1,380	724	247	130
February--	P	2,570	1,650	710	329	119	68
	A	2,830	2,180	1,570	1,010	565	373
March-----	P	1,830	1,180	706	459	208	108
	A	1,800	1,280	973	782	593	510
April-----	P	2,880	1,340	615	355	157	74
	A	958	851	734	669	573	526
May-------	P	2,420	1,120	695	452	174	37
	A	1,930	1,350	970	801	510	350
June------	P	1,670	1,010	665	475	200	81
	A	1,600	1,190	973	817	350	4
July------	P	1,290	743	398	201	78	37
	A	1,730	1,240	990	870	724	646
August----	P	1,240	534	173	56	<1	<1
	A	1,600	1,230	960	839	685	385
September-	P	2,000	1,000	295	78	<1	<1
	A	1,340	1,020	583	420	294	230
October---	P	1,120	381	93	14	<1	<1
	A	2,130	1,100	308	105	23	4
November--	P	1,220	530	136	51	<1	<1
	A	1,250	819	411	219	110	33
December--	P	1,850	1,050	375	185	42	<1
	A	2,990	1,890	1,100	642	73	17

[1] Not all water years are represented each month because of missing data.

Table 11.--Discharge measurements made during an intensive survey on the Vermilion River, August 6, 1985

[ft^3/s, cubic feet per second; ft^2, square feet; ft/s, feet per second; S, steady; F, falling; R, rising]

Station name	Time	Discharge (ft^3/s)	Area (ft^2)	Average velocity (ft/s)	Stage change
Bayou Fusilier at State Highway 93	0710	216	157	1.38	S
Bayou Bourseau at State Highway 93	0817	4.6	38.9	.12	S
Bayou Carencro at State Highway 726	0915	0	123	0	S
Vermilion River above Optimist's Boys Camp	1052	255	290	.88	F
Vermilion River at State Highway 94	0823	272	882	.31	F
Ruth Canal at Ruth (Bayou Teche Side)	0805	479	373	1.28	-
Ruth Canal near Vermilion River	0805	459	320	1.43	F
Coulee Crow at Vermilion River	0820	11.6	94.1	.12	F
Bayou Tortue at Vermilion River	0945	-24.7	399	-.06	F
Vermilion River at Surrey Street	1000	776	879	.88	S
Vermilion River at Pinhook Road	1255	794	1,070	.74	S
Coulee Mine at College Drive	1120	0	170	0	S
Coulee Mine Branch at Bayou Road	1225	3.6	140	.03	S
Vermilion River below sewage treatment plant outfall	1450	743	758	.98	R
Vermilion River at State Highway 3073, Ambassador Caffery Road	0805	779	884	.88	F
Vermilion River at State Highway 733	0955	862	1,160	.74	F
Unnamed tributary west at State Highway 733	0700	0.4	1.0	.40	S
Unnamed tributary east at State Highway 733	0740	1.6	16.6	.09	F
Coulee Ile Des Cannes at Parish Road	1020	30.2	461	.07	F
Vermilion River at Milton	1220	529	1,240	.43	R
Anselm-Darby Coulee at Vermilion River	1254	[a]-5.6	116	[a].05	R
Vermilion River at Woodlawn Bridge	0912	993	1,280	.78	F
Vermilion River at LeBlanc ditch	1410	672	1,440	.47	R
Vermilion River at Perry	0745	1,250	1,870	.67	R
Vermilion River at Bancker Ferry	1320	696	2,510	.28	F
Vermilion River below Little Bayou	1030	[b]-1,250	3,010	-.42	R
Vermilion River below Little Bayou	1530	2,320	2,960	.78	F

[a] Flow changed from upstream to downstream during measurement; discharge is net; and velocity is net discharge/area.
[b] Upstream flow in all parts of cross section.

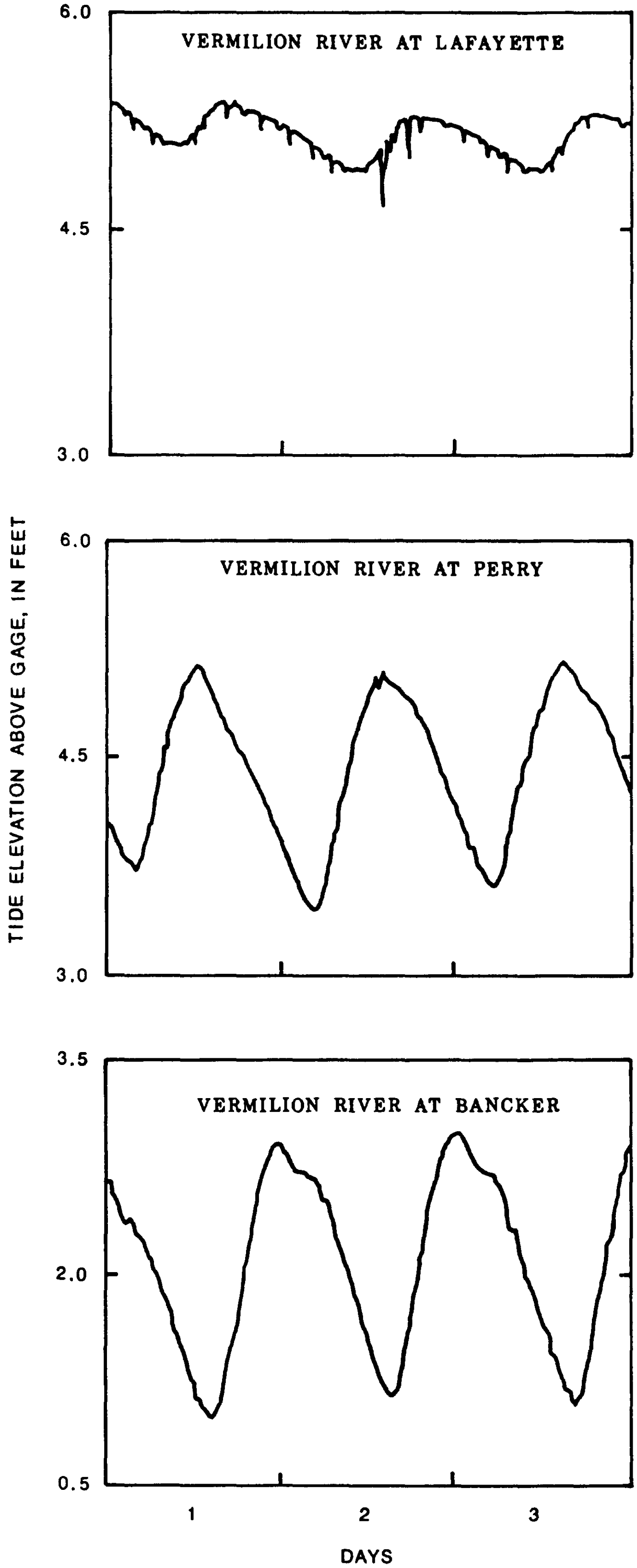


Figure 14.--Diurnal tide elevations for Vermilion River at Lafayette, Perry, and Bancker, June 1-3, 1985.

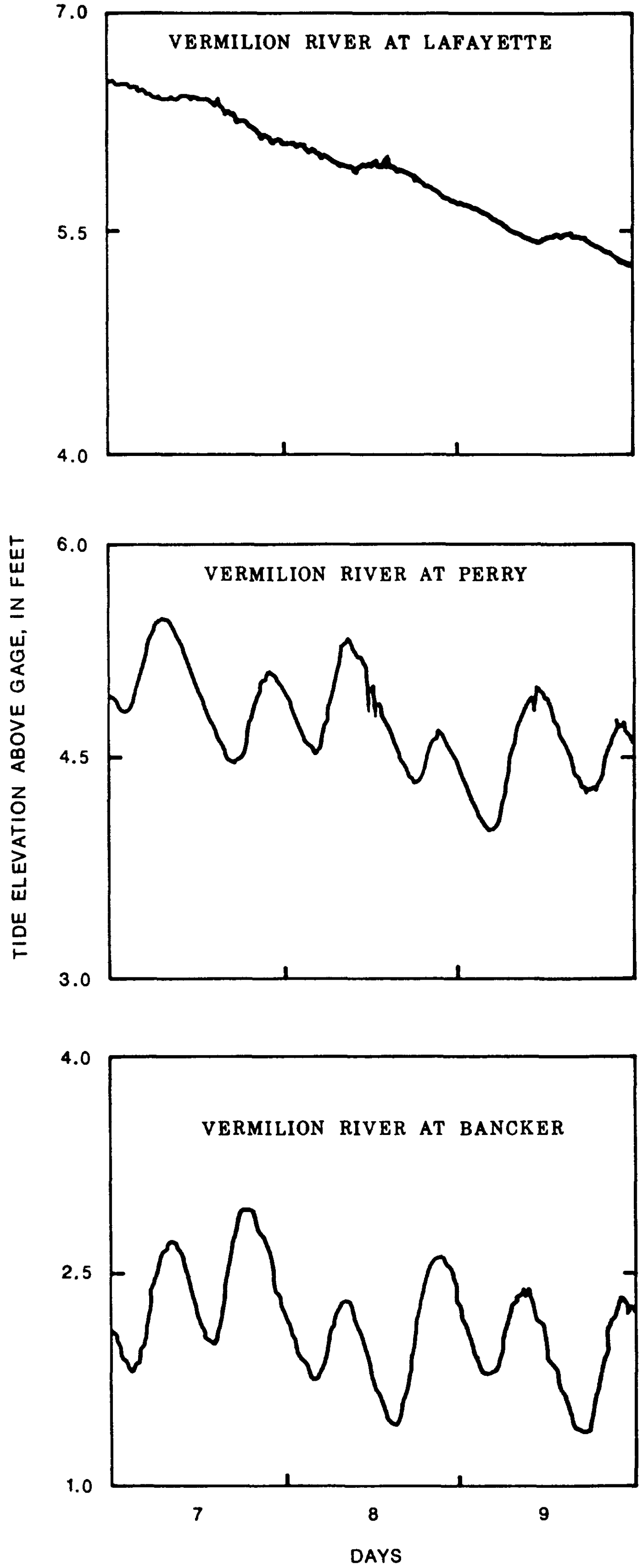


Figure 15.--Semidiurnal tide elevations for Vermilion River at Lafayette, Perry, and Bancker, March 7-9, 1985.

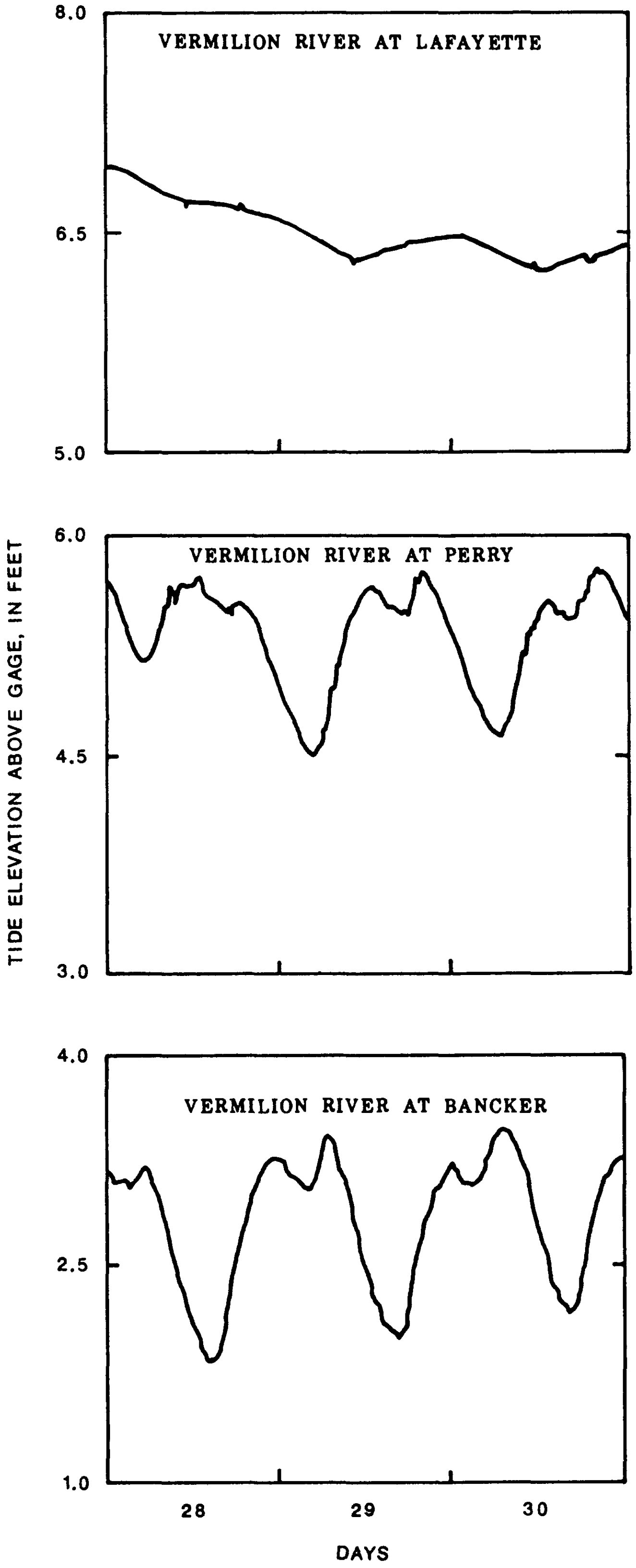


Figure 16.--Mixed tide elevations for Vermilion River at Lafayette, Perry, and Bancker, August 28-30, 1985.

An example of semidiurnal tides for March 7-9, 1985, is shown in figure 15. Tidal fluctuations are barely discernible at the Lafayette station, but the semidiurnal nature of the tide can be seen at the other two stations. The tidal range at Perry is about 1 ft, and the range at Bancker is 1.3 ft. Lag time rates are similar to the lag times of the diurnal tide pattern. An example of mixed-tide patterns that occurred during August 28-30, 1985, is shown in figure 16. Gages at Bancker and Perry show a large peak followed by a small valley, a small peak, and then a large valley. The range of the large peak at Bancker is 1.5 ft and 1 ft at Perry. Lag time rates are similar to the other tide patterns.

Wind Characteristics

Although wind is usually not considered one of the more important factors affecting inland streamflow, it can play a substantial role in the flow of coastal streams. Hurricanes are probably the most visible example of winds that can affect a coastal stream, but sustained medium velocity winds can also significantly influence water levels of rivers. In the coastal streams of Louisiana, sustained northerly winds push water into the Gulf of Mexico away from the coast drawing water out of stream channels lowering water levels near the mouths of the rivers. Conversely, sustained southerly winds push water from the gulf toward the coast and into stream channels, thus increasing water levels. Hurricanes located in the gulf are examples of extreme sustained winds. They often produce storm surges which when concurrent with high tides can inundate large areas of land adjacent to the coast.

Average wind conditions for the Vermilion River basin can be estimated from wind speeds and directions recorded by the National Weather Service at Lake Charles and Baton Rouge. The Vermilion River lies about midway between the two locations, and wind conditions are expected to be similar to the average conditions for Lake Charles and Baton Rouge. Table 12 gives the average and extreme wind conditions for both Lake Charles and Baton Rouge. Lake Charles has slightly higher average wind speeds than Baton Rouge because of its proximity to the coast. In the Vermilion River basin, wind speeds and wind directions are similar to those at Lake Charles because it is located closer to the coast than Baton Rouge. Prevailing directions are generally from the south for Lake Charles and from the southeast for Baton Rouge. Winds from a northerly direction should be similar in timing and magnitude for all three locations.

The effects of wind on water levels in the Vermilion River are depicted in the following examples:

1. The maximum water level recorded for the gage at Bancker was 6.46 ft on September 4, 1973, and was caused by a hurricane.

2. Sustained northerly winds caused a significant drop in water level at the gage at Bancker during February 26-29, 1984 (fig. 17). Water levels declined nearly 5 ft in 30 hours. Average wind speed at Lake Charles was 20.7 mi/h on February 27 and 15.5 mi/h at Baton Rouge. The fastest mile wind speed observed at Lake Charles was 28 mi/h from a northwesterly direction and 20 mi/h at Baton Rouge. Table 13 gives the recorded wind speeds and directions for Lake Charles and Baton Rouge on February 27, 1984.

3. Table 14 gives the wind speeds and directions for Lake Charles during March 3-4, 1983. Sustained southerly winds caused a significant rise in water levels (fig. 18). Water levels rose 1.5 ft in 12 hours at Bancker without the influence of runoff caused by precipitation. The fastest wind speed at Lake Charles was 35 mi/h out of the southeast on March 4. Average wind speed on March 4 was 16.3 mi/h.

Table 12.--Mean and extreme wind conditions at Baton Rouge and Lake Charles, Louisiana

[Wind speed in miles per hour; N, north; NE, northeast; S, south; SE, southeast; SSW, south-southwest; E, east; ENE, east-northeast; W, west]

[Source: National Oceanic and Atmospheric Administration, 1984]

Wind	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Baton Rouge, Louisiana													
Mean speed-------	9.1	9.4	9.5	9.0	7.8	6.7	5.9	5.6	6.7	6.7	7.8	8.4	7.7
Prevailing direction, 1963-----	N	NE	SE	SE	SE	SE	W	E	NE	NE	N	SE	SE
Fatest 1-minute observation[1]													
Direction ---	27	25	13	25	17	3	3	32	6	33	33	18	6
Speed--------	35	35	35	35	48	40	41	37	58	40	31	30	58
Year---------	1983	1970	1964	1964	1967	1964	1980	1975	1965	1964	1977	1966	Sept. 1965
Lake Charles, Louisiana													
Mean speed	10.2	10.4	10.7	10.3	9.0	7.6	6.4	6.1	7.3	7.6	9.0	9.6	8.7
Prevailing direction, 1963-----	N	S	S	S	S	SSW	SSW	SSW	ENE	ENE	ENE	NE	S
Fatest 1-minute observation[1]													
Direction ---	32	25	18	6	32	16	12	11	36	27	32	15	32
Speed--------	58	40	40	44	43	38	35	46	40	37	35	32	58
Year---------	1962	1971	1973	1973	1973	1974	1974	1964	1971	1984	1975	1982	Jan. 1962

[1] Direction (in tens of degrees) from which wind is blowing.

Reaeration

Although high concentrations of organic substances have often been measured in the Vermilion River during periods of low flow (Demcheck and Leone, 1983; Domingue and others, 1974), little has been done to determine the rate at which the stream can assimilate the organic substance. Any body of water with a supply of oxygen has the ability to assimilate organic substances. Organic substances are generally introduced into a stream from domestic and industrial wastewater effluents, and runoff from agricultural or natural sources. One of the ways of defining a streams ability to assimilate organic substances is to measure the dissolved-oxygen concentration in the stream. A healthy stream has an adequate supply of dissolved oxygen. Stream characteristics such as the amount of dissolved solids, temperature, suspended sediment, biological organisms, and the discharge also affect the ability of a stream to assimilate organics. This ability to break down organic substances is termed the reaeration potential of the stream.

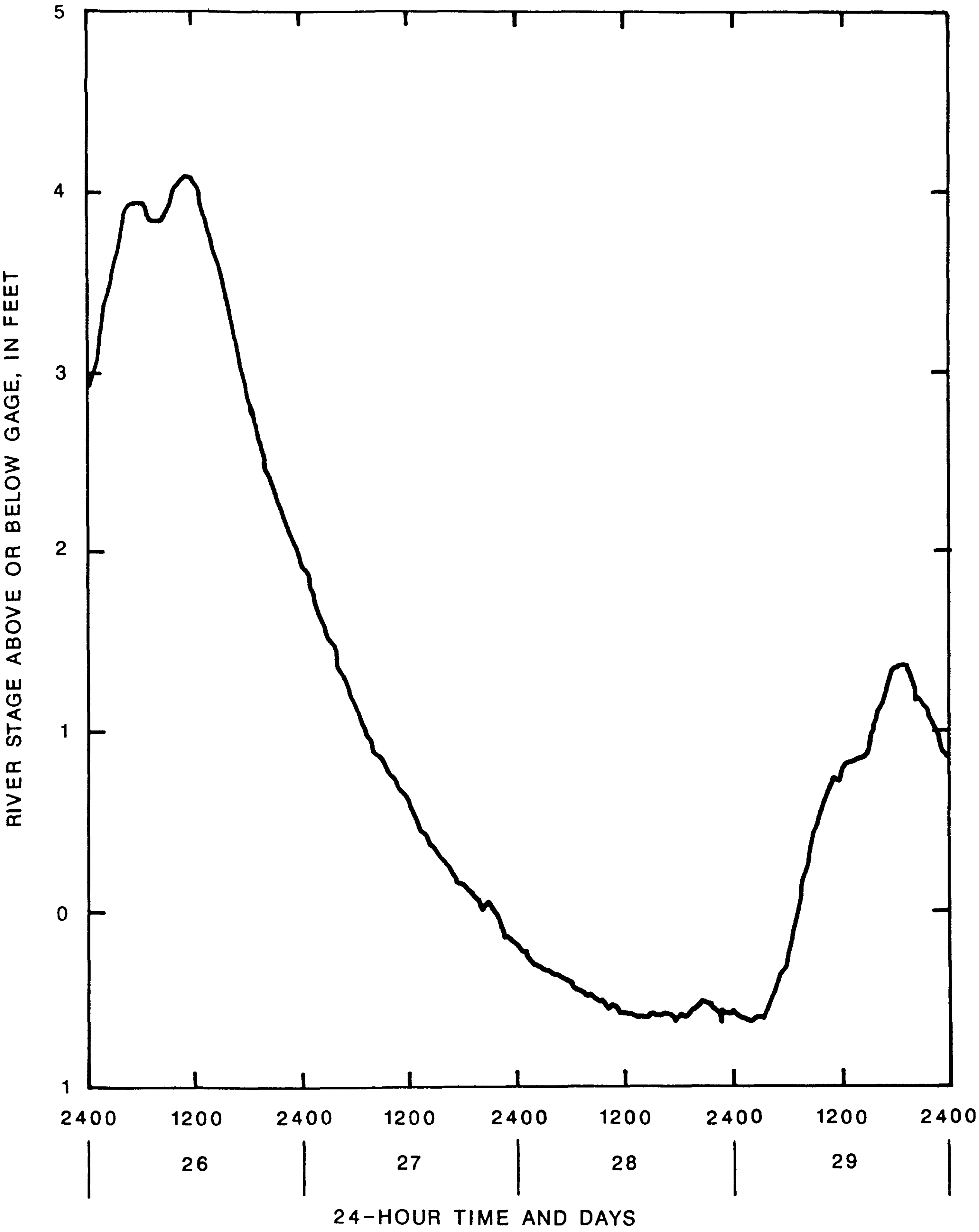


Figure 17.--Effect of sustained northerly winds on stage of Vermilion River below Bancker, February 26-29, 1984.

Table 13.--Observed wind speeds and directions at Lake Charles and Baton Rouge, Louisiana, February 27, 1984

[Source: National Oceanic and Atmospheric Administration, 1983-84]

	Lake Charles		Baton Rouge	
Hour	Direction[1] (degrees)	Speed (miles per hour)	Direction[1] (degrees)	Speed (miles per hour)
0300	260	15	230	12
0600	270	15	240	12
0900	290	16	240	16
1200	310	20	270	16
1500	310	24	270	17
1800	310	20	250	15
2100	310	16	300	14
2400	280	14	290	12

Lake Charles: Average speed = 20.7
Direction[1] = 310
Fastest mile[2] = 28

Baton Rouge: Average speed = 15.5
Direction[1] = 310
Fastest mile[2] = 20

[1] Direction from which wind is blowing.
[2] Fastest recorded speed for which a mile of wind passes a station.

Table 14.--Observed wind speeds and directions at Lake Charles, Louisiana, March 3-4, 1983

[Source: National Oceanic and Atmospheric Administration, 1983-84]

Date	Hour	Direction[1] (degrees)	Speed (miles per hour)
March 3------	1500	130	17
	1800	130	10
	2100	130	10
March 4------	0000	120	8
	0300	130	11
	0600	120	13
	0900	130	18
	1200	150	24
	1500	170	20
	1800	170	13
	2100	60	6

March 4: Average speed = 16.3
Direction[1] = 160
Fastest mile[2] = 35

[1] Direction from which wind is blowing.
[2] Fastest recorded speed for which a mile of wind passes a station.

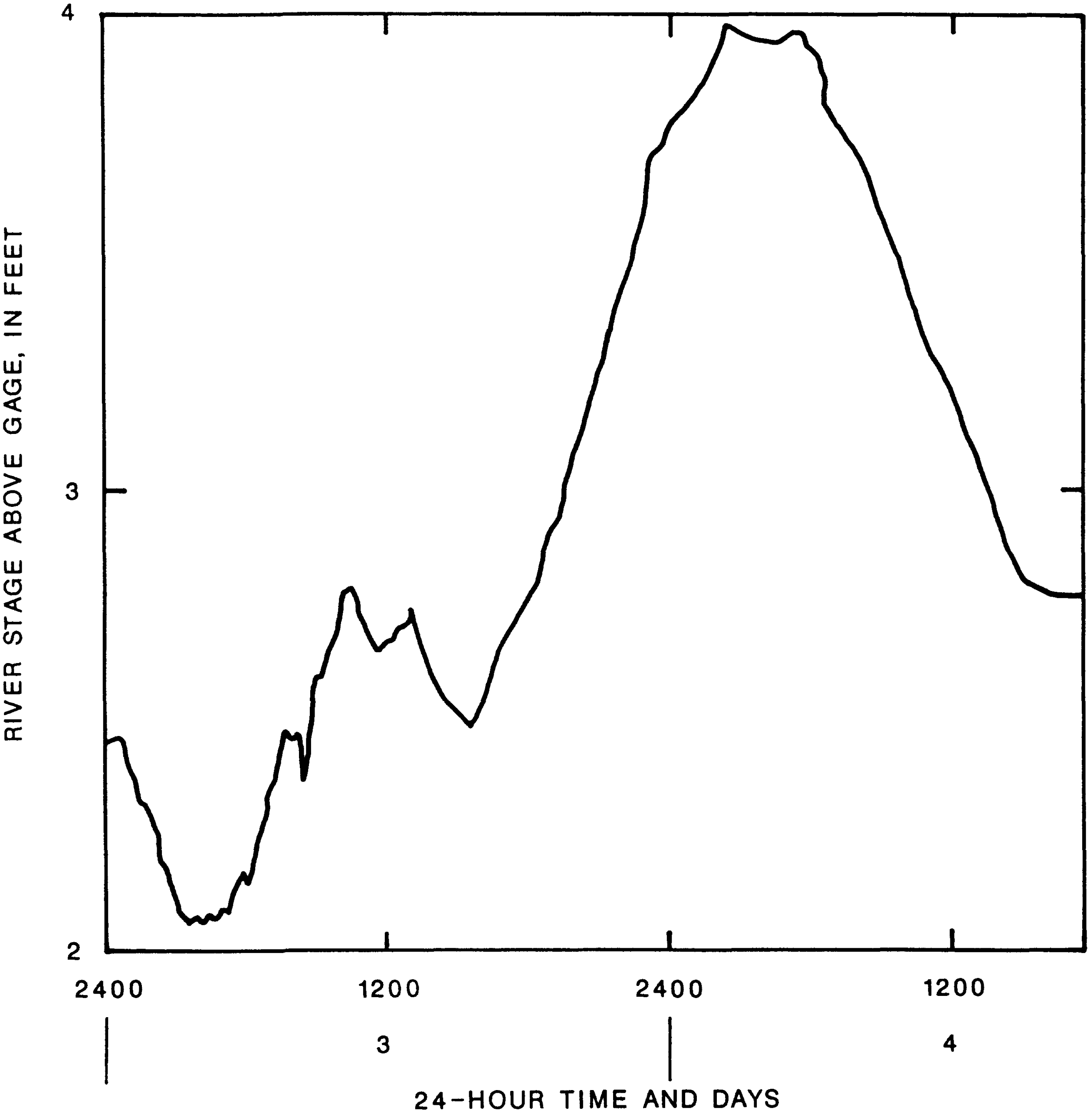


Figure 18.--Effect of sustained southerly winds on stage of Vermilion River below Bancker, March 3-4, 1983.

Reaeration potential is commonly expressed by the equation:

$$r = k_2(Cs-C), \qquad (1)$$

where

r is the rate of oxygen absorption per unit time,
Cs is the dissolved-oxygen concentration of the stream at saturation,
C is the actual concentration of oxygen in the stream (Cs-C is the oxygen deficit), and
k_2 is the reaeration coefficient.

The reaeration coefficient is a function of the biological, physical, and hydraulic properties of the stream. Depth and velocity are significant factors in determining reaeration rates. The oxygen concentration in the stream and the oxygen concentration at saturation are relatively simple to determine, but the reaeration coefficient is commonly difficult to determine.

Several methods have been used to calculate reaeration coefficients. Three widely accepted techniques for measuring the reaeration coefficients of streams are: (1) The dissolved-oxygen balance technique, (2) the disturbed equilibrium technique, and (3) the tracer technique. Several prediction equations also have been developed to calculate reaeration coefficients. Thackston and Krenkel (1969) reviewed several empirical methods of computing reaeration coefficients and also developed their own method. The most widely used formulas are those of O'Conner and Dobbins (1958) Churchill and others (1962), and Thackston and Krenkel (1969). Each of these methods assumes relatively constant velocities for determining reaeration coefficients--a condition not often present in the coastal streams of Louisiana. The deep channels, low velocities, and tidal and wind actions of the Vermilion River system make both measurement and empirical computation of reaeration coefficients, for average river conditions, difficult. The Vermilion River has widely variable velocities, and the reaeration coefficient may vary throughout a day.

The Churchill formula is considered the most reliable method for deep, low velocity streams. The Thackston and Krenkel (1969), and O'Conner and Dobbins (1958) equations are reliable for streams less than 1 ft deep. The Vermilion River is a deep and low velocity stream; thus, the Churchill formula was selected for computing reaeration coefficients. The Churchill formula is expressed by the equation:

$$k_2 = 5.026(1.0241)^{T-20}\left(\frac{u^{0.969}}{h^{1.673}}\right), \qquad (2)$$

where

T is temperature in degrees Celsius,
u is the average velocity in feet per second, and
h is the mean depth in feet of the stream.

Calculated reaeration coefficients based on hydrologic variables measured on the Vermilion River during August 1985 are listed in table 15. Reaeration coefficients are generally higher in the upstream reaches of the river and decrease downstream as the river becomes deeper. At the Highway 94 site, velocity was less and depth was greater than at either of the adjacent upstream or downstream sites, resulting in a smaller reaeration coefficient. The Churchill formula produces a reaeration coefficient for a day, but the values computed for the Vermilion River can be considered valid only for the time the measurements were made. Continually changing velocities are caused by diversions and by the release of municipal and industrial effluents, and by the actions of winds and tides.

Table 15.--Reaeration coefficients computed by the Churchill formula, and associated parameters measured during an intensive survey for several locations on the Vermilion River, August 6, 1985

Measurement location	Approximate time of measurement	Average velocity, u (foot per second)	Mean depth, h (feet)	Temperature (degrees Celsius)	Reaeration coefficient per day (k_2/d)
Above Optimist's Boys Camp----------------	1100	0.88	3.2	25.5	0.723
At Highway 94---------	0815	.31	8.8	26.5	.050
At Surrey Street------	1000	.88	7.6	27.0	.175
At Pinhook Bridge-----	1300	.74	6.1	28.0	.220
Below sewage treatment plant outfall-------	1445	.98	7.3	28.0	.214
At Highway 3073-------	0800	.88	5.9	28.0	.276
At Highway 733--------	1000	.74	6.4	30.5	.216
At Milton-------------	1245	.43	7.1	31.0	.108
At LeBlanc ditch------	1415	.47	8.3	32.0	.093
At Woodlawn Bridge----	0800	.78	8.4	28.0	.135
At Perry--------------	0745	.65	7.2	28.0	.147
At Bancker Ferry------	1345	.28	10.4	31.5	.038
Below Little Bayou----	1515	.78	11.9	30.5	.080

NEED FOR ADDITIONAL STUDIES

If the Vermilion River is to be used as a source of water in a manner that preserves that resource, then, quantification of streamflow characteristics is essential so that planners can make informed decisions for the optimal use of the river. Additional studies needed to more completely define the hydrology of the river are:

1. Collection of more data--Collection of accurate streamflow data are imperative. Accurate records of inflows, diversions, and effluent discharges are needed to improve measurements of streamflow and to define the hydrology of the river.

2. One-dimensional flow simulation--Data are available for simulating streamflow of the Vermilion River. Calibration and simulation of flow have been started for the upper reaches of the river, and data are now available to begin calibration of the model for the lower reaches (G.J. Arcement, U.S. Geological Survey, oral commun., 1986). Model results will provide estimates of discharges and velocities along various reaches of the river, which can be extended in time to provide data for estimates of expected frequency and duration of high and low flows.

3. Time of travel at selected locations--The dye-tracer technique can be used to define time of travel for selected reaches of the Vermilion River. This type of study is valuable for determining the movement of contaminants in the stream system. The dye-tracer technique was used for one study (Calandro, 1981) on the Vermilion River prior to augmentation of flow from the Atchafalaya River. The study provided a feasible method for defining flow patterns for the Vermilion River and that could be used to further define the present hydrology.

4. Determination of reaeration coefficients--A study of reaeration of coastal streams in Louisiana has begun as part of a cooperative program with the Louisiana Department of Environmental Quality. Information from that study, upon completion, and other methods of measuring reaeration rates in tidally affected streams may provide improved estimates of reaeration rates for the Vermilion River in the future.

SUMMARY AND CONCLUSIONS

The hydrology of the Vermilion River is affected by the geographic features of the basin, the diversion of water from other basins into the river, the physical characteristics and configuration of drainage channels, and the actions of tides and winds. The river is a coastal stream that flows through the relict deltaic deposits of the Atchafalaya and Red Rivers. Its water is used primarily for rice irrigation and for the dilution of municipal and industrial effluents.

Interaction of human activity in the Vermilion River basin and the natural processes of the river result in a complex hydrologic system. During the last century, the natural flow of the Vermilion River has been altered continually by dredging existing waterways, constructing canals, and diverting water from other basins. Because the greatest withdrawals for rice irrigation coincide with the lowest natural flow, augmentation of flow from other river basins has been necessary. During the early 1900's, flow augmentation from Bayou Teche through Ruth Canal was sufficient for rice irrigation. As the population in and around the city of Lafayette and rice production increased, more water was needed to assimilate wastewater from the city, meet the increased demand for irrigation, permit navigation, and minimize saltwater intrusion. The river frequently experienced low flows, which increased the potential for severe water-quality problems. In December 1982, the Teche-Vermilion diversion (pumping plant and associated diversion canals) began operating; freshwater is diverted from the Atchafalaya River into the Vermilion River to improve water quality and to supplement water for irrigation. Plans are being considered to further increase the water pumped from the Atchafalaya River so that improved quality of water can be attained.

Prior to flow augmentation from the Atchafalaya River, low discharges were frequent in the Vermilion River. Operation of the pumping plant has increased discharge during low flow, and diversion operations have decreased discharge during high flow. Although the Vermilion River is a highly regulated stream, it still exhibits variable flow.

Variable discharges in the Vermilion River are caused, in part, by the effects of tides and winds. In the upstream reaches the difference in water level between high and low tide is a few inches, but in downstream reaches the tidal range generally is between 1 and 2 ft. Tides can be either diurnal, semidiurnal, or mixed. The diurnal tide is the most dominant. Sustained northerly winds can significantly lower water levels, and southerly winds can significantly raise water levels in the downstream reaches.

Reaeration potential is reduced in the downstream reaches of the river by incoming tides. Reaeration coefficients calculated for measurements made August 6, 1985, ranged from 0.038 per day in the downstream reaches to 0.723 per day in the upstream reaches. Computation of reaeration coefficients for average conditions is difficult because stream depths and velocities are extremely variable. Additional data are needed on the Vermilion River to quantify streamflow characteristics, such as stream velocity, flow patterns, long-term or average reaeration coefficients, and frequency and duration of high and low discharges, to more completely define the hydrology.

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GLOSSARY

Gulf Coast Low Water Datum--a chart datum.--Specifically, the tidal datum designated for the coastal waters of the gulf coast of the United States. It is defined as "Mean Lower Low Water" when the type of tide is mixed and "Mean Low Water" when the type of tide is diurnal.

Mean Lower Low Water--a tidal datum.--The average of the lowest low water height for each tidal day observed over the National Tidal Epoch. For stations with shorter series (less than 19 years), simultaneous observational comparisons are made with a control station in order to derive the equivalent of a 19-year datum.

Mean Low Water--a tidal datum.--The average of all the low water heights observed over the National Tidal Datum Epoch. For shorter series, a computation as described above in "Mean Lower Low Water" is followed.

National Tidal Epoch--a specific 19-year Metonic cycle.--The Metonic cycle was defined by the 5th century BC astronomer, Meton, as occurring between occasions when the full and new moon occur on the same day. The absolute length of the cycle is 235 lunations. A lunation or synodical month, is the period between two successive new moons and averages 29 days, 12 hours, 44 minutes, and 2.8 seconds in length.

Appendix 1.--Organizations with hydrologic activities in the Vermilion River

[The following information will be useful to anyone interested in or conducting investigations in the Vermilion River basin]

Organization	Comments
City, Local, Parish	
1. City of Lafayette Department of Planning and Development Management 705 W. University Avenue P.O. Box 4017-C Lafayette, LA 70502 Telephone: (318) 261-8426	Engaged in policy making and issues for the development of the Vermilion River in terms of water quality and diversion operations. Contact for the Bayou Vermilion Task Force.
2. Teche-Vermilion Fresh Water District 315 South College, Suite 170 Lafayette, LA 70503 Telephone: (318) 265-5740	Operates and maintains the Teche-Vermilion Fresh Water Project which includes the Atchafalaya River pumping plant and associated diversion canals.
State	
1. Louisiana Department of Environmental Quality Office of Water Resources Water Pollution Control Division P.O. Box 44091 Baton Rouge, LA 70804-4091 Telephone: (504) 342-6363	Conducts water-quality surveys in connection with determining waste load allocations.
2. Louisiana Department of Transportation and Development P.O. Box 3648 Lafayette, LA 70502 Telephone: (504) 379-1478	Provides technical assistance to local governments in matters of drainage, flood control, and navigation. Conducts drainage improvement projects, generally on non-navigable streams.
3. Louisiana Department of Wildlife and Fisheries Office of Coastal and Marine Resources Seafood Division P.O. Box 15570 Baton Rouge, LA 70895 Telephone: (504) 342-5876	Engaged in monitoring and appraisal of seafood resources, including habitats.

Appendix 1.--Organizations with hydrologic activities in the Vermilion River--Continued

Organization	Comments
State--Continued	
4. Louisiana Office of State Climatology Department of Geography and Anthropology Louisiana State University Baton Rouge, LA 70803 Telephone: (504) 388-6870	Provides wind, temperature, evaporation, and precipitation data for Louisiana weather stations.
Federal	
1. U.S. Army Corps of Engineers New Orleans District Chief, Hydraulics and Hydrology Branch, LMNED-H P.O. Box 60267 New Orleans, LA 70160-0267 Telephone: (504) 862-2420	Operates water-level recorders on the Vermilion River. Maintains the navigable channels (depth and width) downstream of Lafayette.
2. U.S. Environmental Protection Agency Chief, Water Quality Management Branch, 6W-Q 1201 Elm Street Dallas, TX 75270 Telephone: (214) 767-2668	Responsible for implementation of the Clean Water Act. Works with State agencies on water-quality programs. Issues National Pollution Discharge Elimination System (NPDES) permits.
3. U.S. Geological Survey Water Resources Division P.O. Box 66492 Baton Rouge, LA 70896 Telephone: (504) 389-0281	Operates water-level recorders in the Vermilion River basin. Analyzes water samples for water-quality constituents. Conducted hydrologic studies of the Vermilion River.
4. National Oceanic and Atmospheric Administration (NOAA) National Ocean Service Estuarine and Ocean Physics Branch Chief, Tide and Current Predictions Section, N/OMA132 6001 Executive Blvd. Rockville, MD 20852 Telephone: (301) 443-8060	Provides tide predictions and information on NOAA tide gages.

Appendix 2.--Description of gaging stations on the Vermilion River

[ft, feet; MSL, mean sea level; MLG, mean low gulf]

Location	Recorder	Operated by (station number)	Comments
Vermilion River near Bancker, 3 miles south of Bancker.	Automatic recorder, zero of gage set to 0.0 ft MLG, referenced to temporary benchmarks.	U.S. Army Corps of Engineers New Orleans District (67875)	Gage was referenced to Benchmark 57V91[a], Quad N290921, sequence No. 245, line 107, by the USGS. The zero of the gage was found to be -0.67 ft MLG. To convert gage readings to (MLG to MSL) plus 0.67 ft (gage correction)].
Vermilion River at Perry, Highway 82 bridge.	Automatic recorder, zero of gage set to -3.34 ft MSL, referenced to Benchmark 57V25, Quad M290921, sequence no. 233, line 107.	U.S. Geological Survey Louisiana District (07386980)	Gage referenced to Benchmark in 1984.
Vermilion River at Broussard, Highway 733.	Automatic recorder, zero of gage set to 0.0 ft MLG, referenced to temporary benchmarks.	U.S. Army Corps of Engineers New Orleans District (67450)	
Vermilion River at Surrey Street in Lafayette.	Automatic recorder, zero of gage set to -2.85 ft MSL.	U.S. Geological Survey Louisiana District (07386880)	
Ruth Canal at Ruth------	Automatic recorder, zero of gage set to 0.0 ft MSL.	U.S. Geological Survey Louisiana District (07386705)	
Ruth Canal at Ruth------	Automatic recorder, zero of gage set to 0.0 ft MSL.	U.S. Geological Survey Louisiana District (07385700) (staff gage, 67300)	
Vermilion River at Long Bridge, Highway 94.	Automatic recorder, zero of gage set to 0.0 ft MSL.	U.S. Army Corps of Engineers New Orleans District (67225)	
Vermilion River at Tontons Bridge, Highway 726.	Automatic recorder, zero of gage set to 0.0 ft MSL.	U.S. Army Corps of Engineers New Orleans District (67150)	

[a] Benchmark referred to is described in the U.S. Department of Commerce publication "Vertical Geodetic Control," Quad N290921 (Jan. 1984).