PLAN OF STUDY FOR SELECTED TOXIC SUBSTANCES IN THE CALCASIEU RIVER, LOUISIANA

By Dennis K. Demcheck, Charles R. Demas, and Philip B. Curwick

---

U.S. GEOLOGICAL SURVEY

Open-File Report 90-148

Baton Rouge, Louisiana

1990

DEPARTMENT OF THE INTERIOR

MANUEL LUJAN, JR., Secretary

U.S. GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information
write to:

District Chief
U.S. Geological Survey
P.O. Box 66492
Baton Rouge, LA 70896

Copies of this report can be
purchased from:

U.S. Geological Survey
Books and Open-File Reports Section
Federal Center, Building 810
Box 25425
Denver, CO 80225

CONTENTS

ILLUSTRATIONS

TABLES

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
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
foot (ft)	0.3048	meter (m)
foot per foot (ft/ft)	0.3048	meter per meter (m/m)
foot per second (ft/s)	0.3048	meter per second (m/s)
square foot (ft^2)	0.09294	square meter (m^2)
inch (in.)	2.54	centimeter (cm)
	25.4	millimeter (mm)
gallon (gal)	3.785	liter (L)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.59	square kilometer (km^2)
pound (lb)	0.4536	kilogram (kg)
	453.6	gram (g)
ton per day, short	0.9072	megagram per day (Mg)

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.

PLAN OF STUDY FOR SELECTED TOXIC SUBSTANCES IN THE CALCASIEU RIVER, LOUISIANA

By Dennis K. Demcheck, Charles R. Demas, and Philip B. Curwick

ABSTRACT

In 1984 the U.S. Geological Survey established the Toxic Substances Hydrology, Surface-Water Contamination Program. As part of this program, an investigation of the lower Calcasieu River began in 1985 to define the magnitude and distribution of selected toxic substances in the Calcasieu River and the physical and chemical processes that govern their fate.

This report documents the plan of study used to design and implement the investigation of the Calcasieu River. The principal steps were: (1) Developing a preliminary plan of study; (2) modifying the plan of study based on the basis of the reconnaissance results; and (3) determining the methods to be used to communicate the results.

The major elements of the investigation are: (1) Compilation of previous studies of the Calcasieu River by various Federal, State, and local agencies; (2) reconnaissance surveys of chemical constituents in the water column and bottom material; (3) remobilization study to determine how strongly semivolatile organic compounds are bound to bottom material and whether, upon exposure to waters with varying concentrations of dissolved solids, they dissolve into the water column; (4) study of microbial degradation to indicate whether anaerobic bacterial activity is a significant factor in the fate of semivolatile organic compounds in the bottom material; (5) studies of the presence of synthetic organic compounds in the tissues of fish, clams, and crabs to determine if bio-accumulation of these compounds is occurring; (6) volatilization studies of such compounds as bromoform and chloroform to determine the relative importance of dilution and volatilization in the partitioning of the environment; (7) sediment-water interface studies to determine the rate of upward water movement through the bottom material to estimate on-bottom residence time and instream concentrations of selected soluble compounds; and (8) development of a streamflow model to provide a hydrologic framework for water-quality analysis.

Preliminary results were used to select for intensive study of the following substances in water, bottom material, and biota: ammonia, nitrite plus nitrate, chromium, iron, mercury, bromoform, chloroform, 1,2-dichloroethane, hexachlorobenzene, hexachlorobutadiene, naphthalene, octachloronaphthalene, benzopyrene, and benzoperylene.

INTRODUCTION

Background

The Calcasieu River in southwestern Louisiana has been affected heavily by the activities of man. Alterations to the water quality have occurred because of increased discharge of synthetic substances and development of the river as a deep-water ship channel to the Gulf of Mexico. Since World War II, the area has undergone concentrated industrial development in petroleum processing and petrochemical and agricultural-chemical production. The concentration of industry, periodic closure of public oyster beds because of elevated coliform-bacteria concentrations, and waste-discharge permit violations have led to widespread public concern with the water quality of the Calcasieu River (Michael Schurtz, Louisiana Department of Environmental Quality, written commun., 1985; Michael Bastian, U.S. Environmental Protection Agency, written commun., 1985; John Robinson, National Oceanic and Atmospheric Administration, written commun., 1984). The Louisiana Department of Environmental Quality has intensified efforts to formulate a waste-load allocation order for industry along the Calcasieu River. Such efforts, however, require an improved understanding of the dynamics of the Calcasieu River system and movement of toxic substances within this system.

The study area (fig. 1) includes the Calcasieu River from near Kinder to Cameron, Louisiana, a distance of about 65 mi. The upper Calcasieu River, referred to in this report, extends from Kinder, Louisiana, to the saltwater barrier. The lower Calcasieu River extends from the saltwater barrier to the Gulf of Mexico. The study reach (about 13 mi) to be emphasized (fig. 2) extends from the saltwater barrier, upstream from Lake Charles, to Burton Landing, Louisiana, just north of the Intracoastal Waterway. The major components of the lower Calcasieu River system in the area of emphasis are the Calcasieu River Ship Channel, Lake Charles, Prien Lake, Moss Lake, and Bayou d'Inde.

Toxic Substances Hydrology, Surface-Water Contamination Program

The U.S. Geological Survey (Survey) established a Toxic Substances Hydrology, Surface-Water Contamination Program in 1984 because little information was known about the distribution, transport, and fate of toxic substances in rivers and lakes. The toxic substances program was designed to address the following objectives:

1. Research fundamental physical, chemical, and biological processes that govern the movement and fate of toxic substances in surface waters; and develop improved methods for analysis of toxic substances.

2. Perform detailed river basin investigations to determine the occurrence, magnitude, and distribution of classes of toxic substances in different hydrologic settings; gain understanding of governing processes; and improve methods of study through field experience.

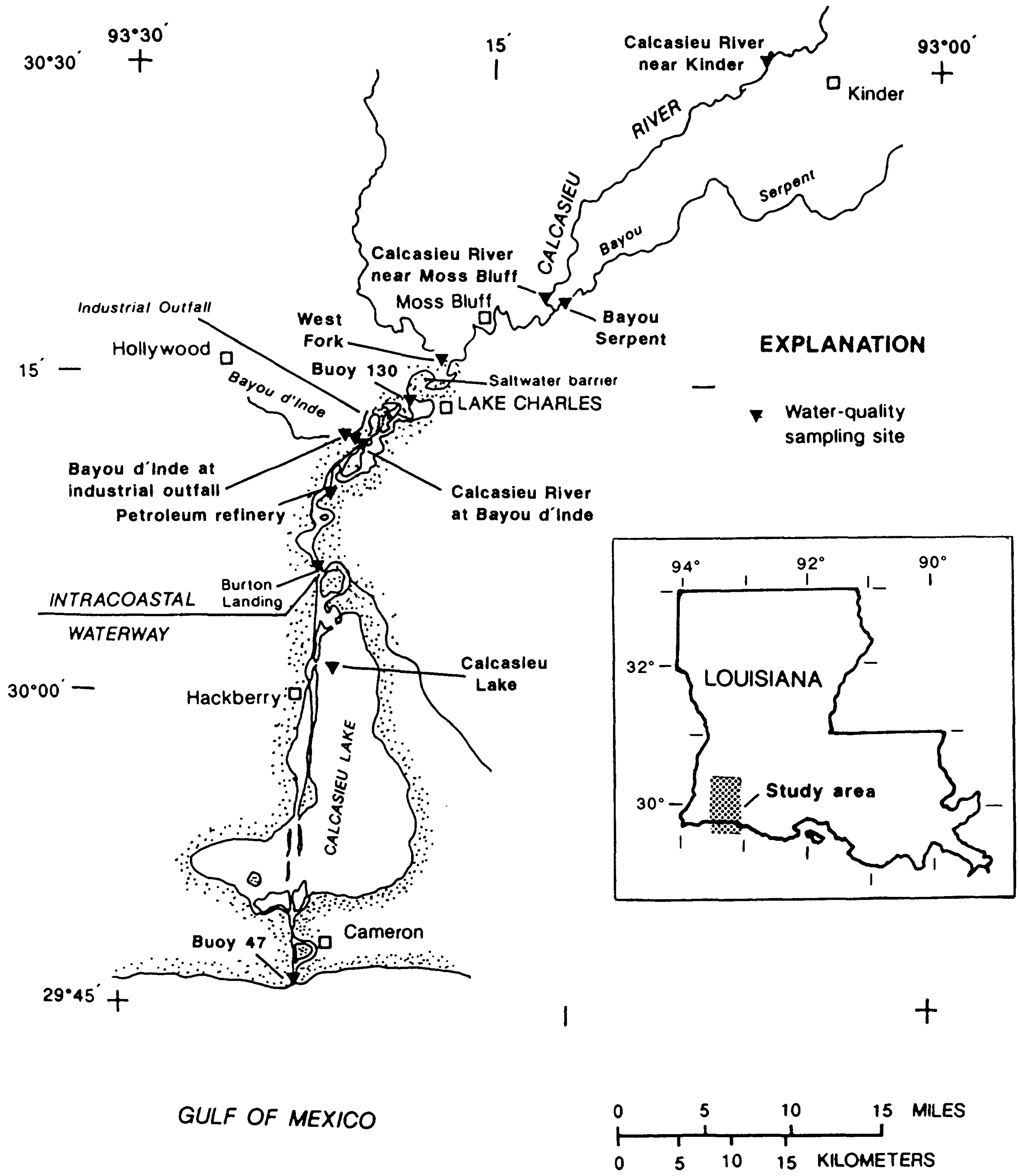

Figure 1.--Calcasieu River study area and water-quality sampling sites.

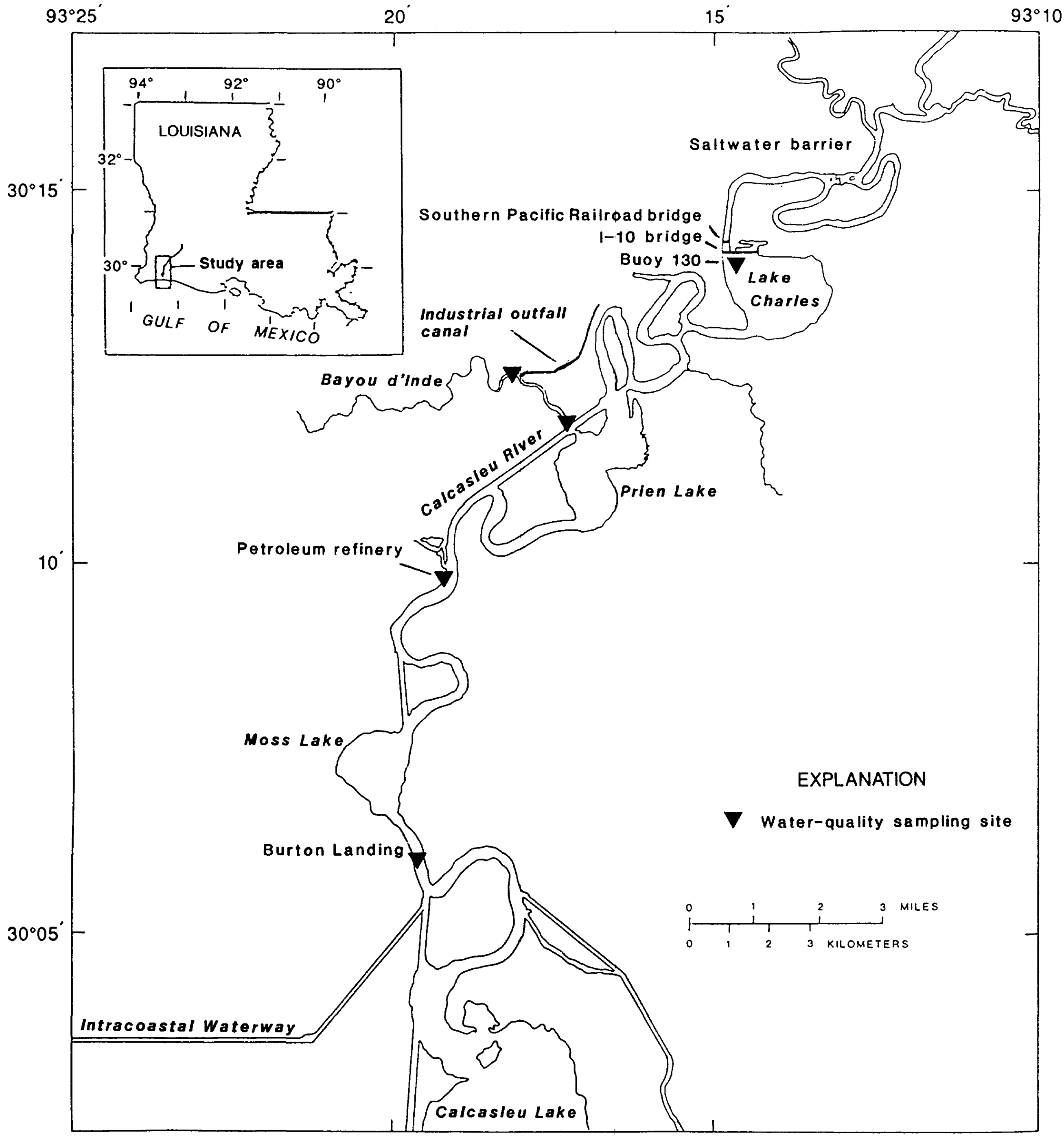

Figure 2.--Calcasieu River area of emphasis, Louisiana.

The Calcasieu River project began April 1985 as one of the first river basin investigations selected for the Toxic Substances Hydrology, Surface-Water Contamination Program. The Calcasieu River was selected for study for several reasons: (1) The upper Calcasieu River is a relatively unaffected stream that has been monitored by the Survey for selected water-quality constituents since 1944. (2) The river has a short reach where saltwater-freshwater interactions can be investigated. (3) Industrial activity and its associated effluents in the Lake Charles area enable the investigators to study the transport and fate of selected constituents downstream.

The concentration of industries in the Greater Lake Charles area and the clustering of industry along the Calcasieu River are shown in figure 3. The industrial category, principal products, and wastewater characteristics monitored as required by Louisiana Department of Environmental Quality discharge permits are given in table 1.

Purpose and Scope

The purpose of this report is to present a plan of investigation of selected toxic substances in the Calcasieu River. The plan describes how the study will achieve the goals of the Survey's Toxic Substances Hydrology, Surface-Water Contamination Program.

The report documents how various sources of information have been compiled to produce a coherent project plan. The principal steps used to design and implement the investigation included: (1) Developing a preliminary plan of study; (2) modifying the plan of study on the basis of the reconnaissance results; and (3) determining the methods to be used to communicate the results. The plan of study encompasses the period from the conceptualization of the project to the stage where sufficient data have been collected to determine the final products of the project.

Modifications to the plan of study also become necessary because no proposal or plan of study can anticipate all the findings and problems that will occur. As available methodologies change, especially in the collection and analysis of synthetic organic compounds, the project design may require additional changes to incorporate those improvements.

Previous Investigations

The effects of chemical loading in the Calcasieu River generally are localized between the saltwater barrier north of Lake Charles (fig. 3) and the Intracoastal Waterway. Although large amounts of chemical effluents are discharged to the river, analysis of water samples generally fail to detect concentrations of synthetic organic compounds (Michael Bastian, U.S. Environmental Protection Agency, written commun., 1985; Michael Schurtz, Louisiana Department of Environmental Quality, oral commun., 1985). A reason for this could be that synthetic organic compounds are initially bound to suspended clays and naturally occurring organic compounds; but as freshwater mixes with seawater, the synthetic compounds are precipitated out of the water column and finally deposited in the bottom sediments (W.E. Pereira, U.S. Geological Survey, oral commun., 1985). A previous study (Steinheimer and others, 1981) of the bottom material has confirmed the occurrence of synthetic organic compound contamination in the Calcasieu River.

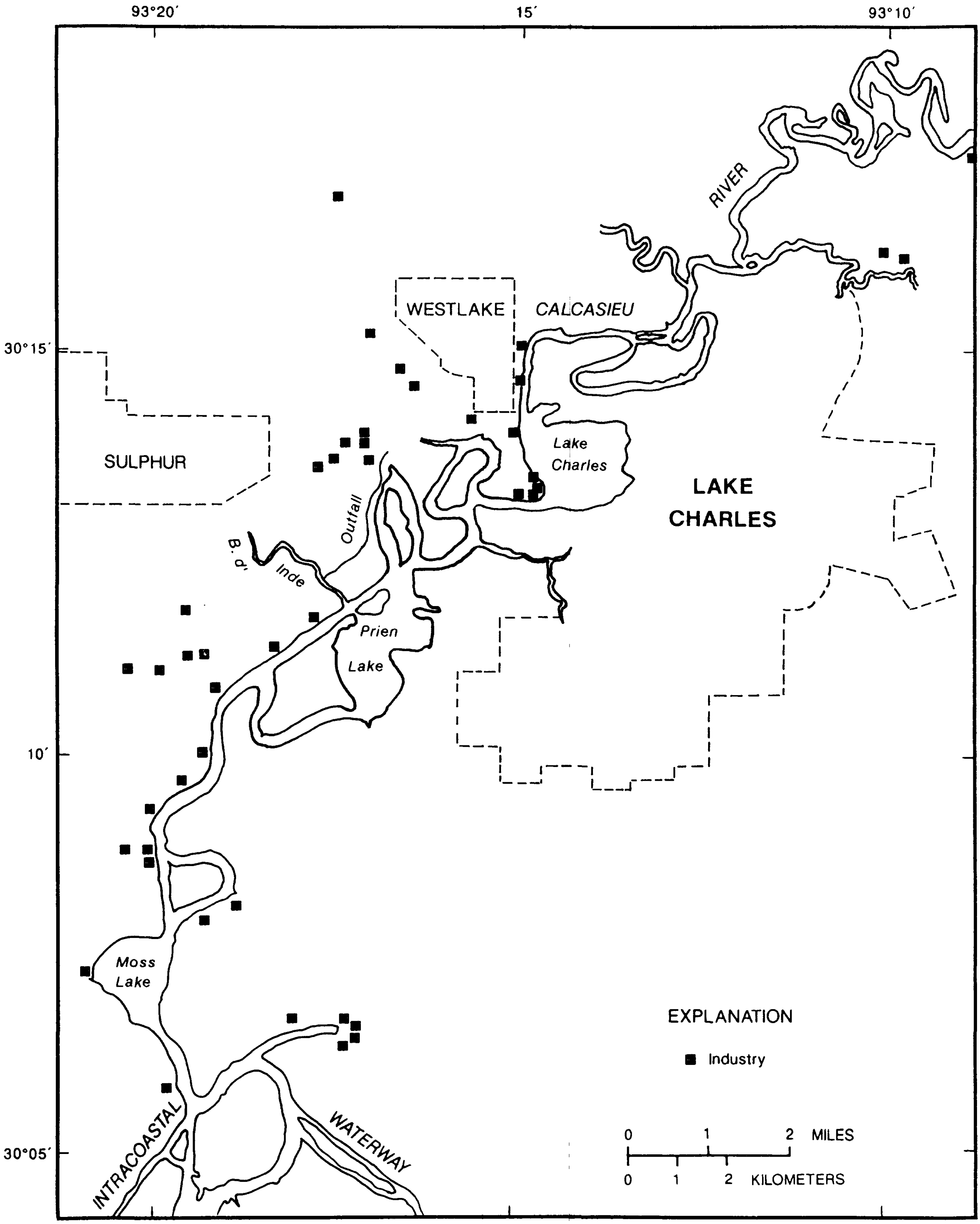

Figure 3.--Industrial development along the lower Calcasieu River, Louisiana.

Table 1.--Major industrial categories of the Greater Lake Charles area, Louisiana, and wastewater characteristics monitored

[T, temperature; TSS, total suspended solids; O&G, oil and grease; BOD, biochemical oxygen demand; TOX, total organic halides; TOC, total organic carbon; NH_3, ammonia; NO_3, nitrate; COD, chemical oxygen demand; Cr, chromium; hex. Cr, hexavalent chromium; N, nitrogen; FC, fecal coliform; Cl, chloride; P, phosphorus; Zn, zinc; Cu, copper; Ni, nickel; Hg, mercury; Pb, lead; H_2S, hydrogen sulfide]

Industrial category	Number of plants present	Principal products	Wastewater characteristics monitored
Chemical manufacturing plants	5	Chemicals	pH, T, TSS, O&G, BOD, TOX, total P, TOC, NH_3, total Kjeldahl N, NO_3, total Cr
		Polypropylene, high density polyethylene, and polyolefins	T, BOD, pH, COD, TSS, O&G, NH_3, TOC
		Chemicals	T, pH, TSS, BOD, COD, NH_3, chlorinated hydrocarbons
		Chemicals	Hg, Pb, Cr, TSS, BOD, total chlorinated hydrocarbons
		Polymers and polyvinyl chloride	BOD, TSS, FC
Speciality chemical manufacturing plants	1	Speciality chemicals-olefins	TSS, Cu, Ni, lime, dichlorobromomethane, bromoform, chloroform, TOC, chlorodibromomethane, sodium aluminate
Synthetic rubber plant	1	Synthetic rubber and latex	T, BOD, COD, Cr, pH, TSS, O&G, NH_3
Paint plant	1	Paint	TOC, O&G, pH
Oil refineries and related industries		Oil refinery; produces naphtha, distillate and residual oil, and liquified propane gas	NH_3, H_2S, Cl, O&G, phenols, P
		Products of petroleum cracking catalysts	T, BOD, pH, TSS, NH_3
		Oil products	BOD, COD, TSS, O&G, phenols, NH_3, H_2S, total Cr, hex. Cr, pH, flow
		Petrochemicals	BOD, TSS, TOC, phenols, H_2S, O&G, NH_3, Zn
		Regasification of liquified natural gas	T, TSS, BOD, O&G
Fertilizer	1	Ammonia	NH_3, O&G, Cr
Domestic sewage treatment plants	1	Municipal sewage	NH_3, BOD, FC, pH, TSS
Oil and gas drilling	1	Grinding and distribution of barite	Treated sanitary wastewater
Others	1	Cryogenic air separation	O&G, Cr, pH
	3	Cement Calcium chloride	T, pH Rainwater runoff

Water quality has been monitored by the Survey intermittently at several sites in the upper Calcasieu River basin since 1944. Water-quality data have been collected monthly or quarterly at upper Calcasieu River sites since October 1975. Because of tidal effects that make streamflow measurements difficult, the lower Calcasieu River is not monitored routinely. The Survey also has collected and published data in cooperation with the U.S. Army Corps of Engineers, which is responsible for dredging the Calcasieu River from the Gulf of Mexico to the Port of Lake Charles to maintain the depth at 40 ft. Cooperative studies between the Survey and the U.S. Army Corps of Engineers were conducted in 1975 through 1977 and in 1980 during and after dredging operations on the Calcasieu River. Water and bottom-material samples from sites extending from Lake Charles southward into the Gulf of Mexico were analyzed for inorganic constituents, nutrients, minor elements, and pesticides (Demas, 1976; Lurry, 1983).

The Louisiana Department of Environmental Quality recently sponsored several studies to determine the occurrence of synthetic chemicals in bottom-material and biota samples collected from Louisiana estuaries. Research Triangle Institute (Dugan Sabin, Louisiana Department of Environmental Quality, written commun., 1985) studied the occurrence of trace metals and organic compounds in bottom sediment and biota at 14 sites on the Calcasieu River system. A study by the University of New Orleans, Center for Bio-Organic Studies (Dugan Sabin, Louisiana Department of Environmental Quality, written commun., 1984), examined volatile and semivolatile organic compounds in bottom-material cores and biota from seven sites in Calcasieu Lake. Although results differed widely between the two studies and among sites, volatile and semivolatile organic compounds commonly were detected at low concentrations in bottom material and biota.

Other unpublished Louisiana Department of Environmental Quality-sponsored studies on the lower Calcasieu River have identified fish populations (two studies), by Louisiana State University, Center for Wetland Resources; and ammonium nitrogen transformations (one study), by Dugan Sabin, Louisiana Department of Environmental Quality (written commun., 1985). Nonpoint source nutrient and minor element loading effects on the Calcasieu River basin also were investigated by Alan Plummer and Associates (Michael Schurtz, Louisiana Department of Environmental Quality, written commun., 1984).

Two studies by the U.S. Environmental Protection Agency (EPA) examined sediment oxygen demand rates along the Calcasieu River for use in a water-quality model for waste-load allocation studies (Michael Schurtz, Louisiana Department of Environmental Quality, written commun., 1984; 1985). Concern about the water quality of the Calcasieu River led the EPA in August 1985 to sample the water column at seven sites for minor elements, volatile and semivolatile organic compounds, pesticides, nutrients, and inorganic constituents. Concentrations of organic compounds generally were below detection limits, although volatile organic compounds were detected at Bayou d'Inde at Highway 108 (Michael Bastian, U.S. Environmental Protection Agency, written commun., 1985). Concentrations of minor elements were below detection limits or well within the EPA recommended levels for domestic water supply (U.S. Environmental Protection Agency, 1977). Also, Science Applications International Corporation investigated the toxicity of Calcasieu River water to sea urchin sperm, and Environed Laboratories conducted 24-hour Daphnia toxicity tests (Michael Bastian, U.S. Environmental Protection Agency, written commun., 1985).

The Louisiana Department of Agriculture (Spicer, 1984) prepared a report on pesticide use in the Calcasieu River basin. A National Oceanic and Atmospheric Administration study for Louisiana Department of Environmental Quality summarized municipal- and industrial-contaminant loading in the lower Calcasieu River and estimated annual mean concentrations for 33 priority pollutants in Calcasieu Lake source waters (Michael Schurtz, Louisiana Department of Environmental Quality, written commun., 1984).

Comparison and interpretation of data from previous studies can be difficult. Analyses of inorganic constituents, nutrients, minor elements, and organic compounds in the water column for the various studies tend to be fairly comparable. However, organic analyses of bottom material commonly are highly variable because: (1) Sample collection techniques are not consistent; (2) the high cost of organic analysis limits the number of samples that can be collected during a survey; (3) organic compounds are not distributed uniformly in bottom material; and (4) extraction methods for separating the organic compounds from the sediments differ in their efficiencies and are still under development.

The variability of organic compounds in bottom material can be partly overcome by: (1) Standardizing collection techniques among agencies, (2) sending replicate quality-control samples to the laboratory, and (3) collecting multiple samples within a localized area. Standardized collection techniques among agencies allow for more valid comparisons of results. Results from replicate quality-control analyses can indicate the precision and accuracy of the laboratory results. When precision and accuracy are well defined, the number of samples can be limited to the minimum number required to address the specific water-quality problem. Samples collected within a short distance of each other can indicate the nonuniform distribution of organic compounds within a localized area and also can be useful to determine movement of the heavier organic compounds present in the system.

HYDROLOGIC SETTING

The study area is in the Coastal Plain where the terrain is nearly flat; land-surface altitudes range from sea level to 25 ft above sea level near Lake Charles. The Calcasieu River and associated waterways provide considerable open-water surfaces throughout the study area.

Physical Characteristics

The lower Calcasieu River system is dominated by the ship channel from the city of Lake Charles to the Gulf of Mexico. This ship channel was completed in 1968. The channel is maintained at a depth of 40 ft and a width of 400 ft.

The Calcasieu River saltwater barrier is located just north of Lake Charles (fig. 2). The barrier, which consists of flood and navigation control structures, was designed to minimize saltwater intrusion upstream from this point. The barrier is operated to maintain a gage height of 2.5 ft (about 1 ft above sea level) on the upstream side of the structure.

Cross sections of the Calcasieu River were developed from detailed channel surveys made with a fathometer. The areas of these cross sections increase moderately in a downstream direction. Cross-sectional areas are about 15,000 to 30,000 ft^2 in the ship channel and higher in the lakes. Therefore, even at low velocity, large amounts of water can circulate through the channel.

A longitudinal depth profile of the Calcasieu River main channel also was defined from Interstate Highway 10 bridge to the Intracoastal Waterway. Water depths ranged from 33.0 to 46.5 ft. The average depth was 42.8 ft. The bottom slope was computed as 3.00×10^{-6} ft/ft. Grain-size analyses of the bottom material indicate a sandy substrate upstream near Kinder that becomes increasingly silty downstream to Lake Charles. The bottom material is predominantly fine silt and clay at and downstream from Lake Charles.

Tidal Fluctuations and Flow Characteristics

Stages of the lower Calcasieu River are influenced by the tidal fluctuations in the Gulf of Mexico. Stage data show tidal fluctuations are a mixture of diurnal and semidiurnal components, although a diurnal tide pattern predominates.

The last detailed harmonic analysis of the tidal stages for Calcasieu Pass near the mouth of the river was completed by National Oceanic and Atmospheric Administration in 1933 and 1934. A tidal range of 1.95 ft occurs at that location. Considerable channel-modification and alignment projects have been constructed since 1934, and the harmonic constants now may be different. A harmonic analysis is planned as part of this Calcasieu River project.

A series of discharge measurements made by the Survey in 1984 at the Southern Pacific Railroad bridge at Lake Charles about 600 ft upstream from the buoy 130 site (fig. 2) using directional-velocity flowmeters. The measurements show that bidirectional flow and relatively low velocities, usually less than 0.5 ft/s, are typical of the lower Calcasieu River (fig. 4). This illustrates the incomplete mixing that commonly occurs in the river. Although tidal action is a dominant factor in mixing and circulation in the lower Calcasieu River, meteorological conditions, especially wind action, can substantially affect mixing and circulation. The National Weather Service has collected data on wind speed and direction at the Lake Charles Municipal Airport since 1937.

Water-Quality Characteristics

Water in the upper Calcasieu River has a relatively low specific conductance, ranging from 13 to 187 µS/cm (microsiemens per centimeter at 25 °C) at Kinder, with a mean value of 51 µS/cm (Carlson and others, 1984, p. 413).

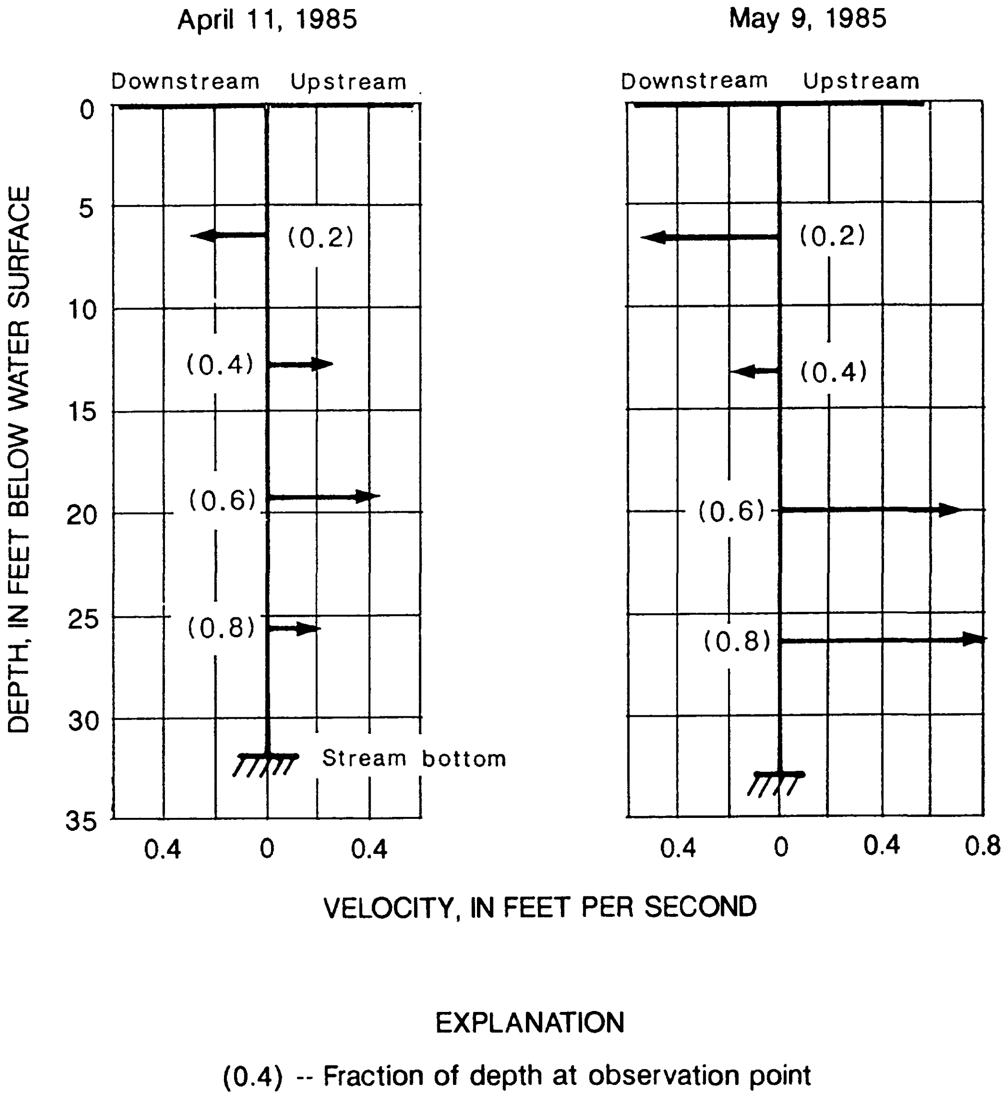

Figure 4.--Flow direction and velocity at various depths in the Calcasieu River at Southern Pacific Railroad bridge, Lake Charles, Louisiana. (Modified from Forbes, 1988, fig. 25.)

The lower Calcasieu River may be classified under most flow conditions as a partially mixed estuary. Partially mixed estuaries are characterized by sufficient turbulence to prevent formation of a distinct salt wedge or tongue, yet there remains a definite salinity gradient with depth. Typical variations in specific conductance are shown in figure 5. Density differences between freshwater and saltwater account for the gradient. The density differences also are responsible for upstream density currents that may occur along the ship channel. These currents are readily apparent in measurements of dissolved oxygen, temperature, pH, and salinity. Also, water entering the river from industrial effluent canals frequently is as much as 10 °C above the average river temperature. These temperature and salinity-related density differences can cause even dissolved contaminants to become entrained in differing layers and be transported upstream or downstream. The occurrence of contaminants at one depth in the water column, while possibly being absent at

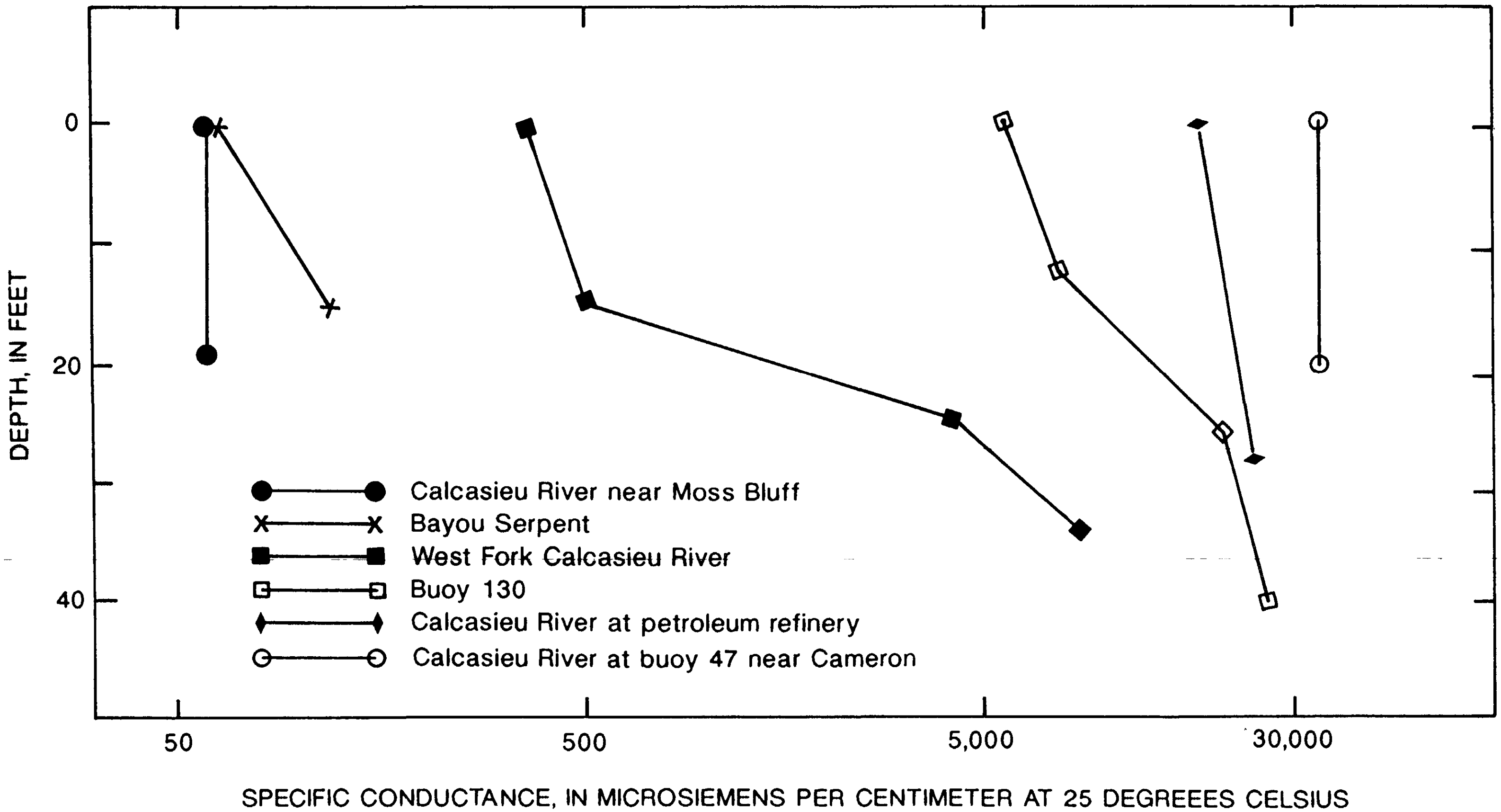

Figure 5.--Specific-conductance profile in the Calcasieu River system, May 29-30, 1985.

another depth at the same location, necessitate a more thorough understanding of the flow conditions of the river than can be obtained by conventional measurements of stage and discharge. Thus, an integration of surface-water flow characteristics and water-quality studies is required for meaningful results.

The dissolved-oxygen profiles also have shown that anoxic conditions frequently exist at or near the bottom. Limited measurements of oxidation-reduction potential conditions during the May and August 1985 sampling surveys reveal that reducing conditions sometimes occur in and just above the bottom material, although the duration and magnitude remain unclear. Knowledge of the oxidation state of the water and bed sediments is important, as oxidation-reduction potential conditions are a controlling factor in the speciation and toxicity of minor elements, such as chromium (Nancy Simon, U.S. Geological Survey, oral commun., 1985). The persistence or breakdown of organic compounds also is significantly affected by oxidation-reduction potential conditions.

RECONNAISSANCE WATER-QUALITY SURVEY, MAY AND AUGUST 1985

Water-quality reconnaissance surveys were conducted in May and August 1985 to verify and supplement the data collected during previous studies. A basic question the reconnaissance surveys were designed to answer is which substances, particularly synthetic organic substances, are to be selected for further study. The careful use of reconnaissance data can be helpful in reducing the number of analyses required in the final study. Reconnaissance data also can define the scope of an investigation more accurately by enabling the investigators to concentrate their work efforts in the most productive areas.

Techniques and Equipment

Instrumentation has been placed at the upstream boundary (Interstate Highway 10 bridge at Lake Charles) and downstream boundary (Burton Landing) of the intensive study area to develop a data base of river stage, directional-velocity of flows in the river, and specific conductance and temperature of water in the river. The data, in conjunction with instantaneous discharge measurements, will be used to verify a flow model of the river.

Instrumentation at the upstream boundary monitors directional velocity of flow, specific conductance, and temperature of water at two depths (approximately 20 and 80 percent of total depth). These depths were chosen as a result of preliminary multiple-point (0.2, 0.4, 0.6, and 0.8 of total depth) discharge measurements. Stage also is monitored. Specific conductance and temperature are measured and recorded hourly with a water-quality minimonitor. Real-time stage and directional-velocity data can be displayed through the use of a satellite data acquisition system at the Survey.

The Survey has two minimonitors at the downstream boundary. One minimonitor senses river stage, wind direction, and wind speed. These data are necessary for determining the volatilization and transport of organic compounds. The other minimonitor senses specific conductance and temperature at one depth. All data are punched and stored on digital input and output 16-channel paper-tape recorders.

Physical characteristics of the river will determine what type of sampler to use. Although velocities can exceed 2 ft/s, the sampling equipment and techniques used are usually determined by low-velocity (less than 1 ft/s) conditions. The distribution of salinity, dissolved oxygen, and pH throughout the water column can be highly variable in this estuarine system. These physical properties are measured immediately before sampling by the use of a directional-velocity flowmeter and a water-quality monitor.

Minor elements in the water column can be sampled using either depth-integrating or point samplers. At velocities greater than 1.5 ft/s an integrating sampler (D-77) or point sampler (P-61) is used. At velocities less than 1.5 ft/s a wire-basket sampler, fitted with a narrow-mouthed glass bottle, can be used; alternatively, a lake sampler can be used. The lake sampler is constructed of hard plastic and has no interior metal fittings. Organic compounds in the water column can similarly be sampled with either depth-integrating or point samplers. These include the P-61, wire-basket, and sewage sampler equipped for point sampling. All samples are collected in glassware that has been previously baked at 350 °C to burn off residual organic compounds that would otherwise contaminate the sample.

The low suspended-sediment concentrations in the river require a means of collecting and concentrating enough suspended sediment for laboratory analysis which can be as much as 25 g for selected organic compounds. In this study a tangential-flow filtration instrument, which enables more than 400 L of river water to be filtered through 0.00045 mm pore-size filters, will be used.

Bottom material can be sampled for trace metals and organic compounds with stainless-steel or Teflon[1]-coated grab samplers. Corers, either hand-held or gravity-driven, are equipped with stainless-steel liners for organic-compound sampling or with plastic liners for minor-element sampling.

Methods of collection were tailored to the particular characteristics of the river. Volatile organic compounds (VOC's) in the water column were sampled by using a stainless-steel plated sewage sampler modified for point sampling. Inside the sampler was a baked 40-mL (milliliter) glass vial. Semivolatile organic compounds in the water column were collected by depth-integrating 1-L glass bottles in a weighted wire basket, as the low velocities (less than 1 ft/s) in the Calcasieu River precluded the use of point samplers. Bottom material was collected using a stainless-steel grab sampler. Bottom-material cores were collected using two types of corers: A hand corer (2 X 20 in.) with stainless-steel liners for water depths of less than 10 ft or a 200 lb (4 X 48 in.) oceanographic corer with plastic liners for water depths of greater than 10 ft. All water and bottom-material samples were chilled to 4 °C immediately upon collection and shipped for analysis to the Survey's National Water Quality Central Laboratory in Arvada, Colorado.

Techniques and samplers for gathering biota must be tailored to the species desired. Monofilament gill nets, oyster dredges, crab traps, and hook and line are used for sampling. A scientific collector's permit, issued by the appropriate State agency, may be required.

---

[1] The use of brand, trade, or company names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

Nutrients

The various forms of nitrogen and phosphorus needed for plant growth were sampled during the May and August 1985 sampling surveys. Six species of nitrogen and two species of phosphorus were analyzed in unfiltered and filtered water samples. Three nitrogen species and one phosphorus specie were analyzed for bottom material. The results were used to develop a list of candidate compounds from which several would be selected for further study. A relatively high concentration of total ammonia, 1.3 mg/L (milligrams per liter), was detected in the water sample collected from the Calcasieu River at the petroleum refinery site (table 2).

Minor Elements

Minor elements occur naturally in streams at very low concentrations. However, these elements also can be associated with industrial wastes. High concentrations of minor elements can have harmful physiological effects on aquatic organisms and man. The Calcasieu River was sampled for 13 minor elements in the water column and 10 minor elements in the bottom material to develop a list of candidate compounds. All water samples were within the EPA (1977) recommended limits for concentrations of minor elements in the water column. Highest concentrations of minor elements in the bottom material generally were found at the Bayou d'Inde and the petroleum refinery sites (table 3).

Organic Compounds

The identification and quantification of organic compounds in the natural environment is complex and difficult. A primary distinction is made between organic substances occurring naturally through the decomposition of plant or animal matter and synthetic organic compounds. Naturally occurring organic substances can be roughly quantified by analyzing for dissolved organic carbon (DOC). This can be further investigated by separating the DOC into hydrophilic and hydrophobic fractions. This is an area of active research; investigators of the Survey's National Research Program are pursuing the further identification of naturally occurring organic compounds in the Calcasieu River.

The analysis of synthetic organic compounds is made difficult by the tens of thousands of organic compounds produced by industry. In a court settlement dated June 7, 1978 (commonly known as the "EPA Consent Decree"), the EPA was directed to identify and publish a list of toxic pollutants for which effluent limitations and guidelines would be required (Keith and Telliard, 1979). The main technical problem continues to be that there are little data on toxic chemicals present in water or their effects. The original EPA list of toxic pollutants included 129 substances, of which 113 are organic (Keith and Telliard, 1979).

The organic substances in the water column detected in the Calcasieu River system during the two reconnaissance trips are listed in table 4. The majority of the 84 volatile or semivolatile compounds analyzed were below limits of detection at all sites and are not listed. Most of the compounds

Table 2.--Concentrations of selected nutrients in the water column and bottom material in the Calcasieu River, Louisiana, May 29-30 and August 28-30, 1985

[mg/L, milligrams per liter; mg/kg, milligrams per kilogram; ---, sample ruined during analysis]

Site	Ammonium ion			Nitrite plus nitrate (as N)		
	Total recov-erable in water (mg/L)	Dis-solved in water (mg/L)	Total recov-erable in bottom material (mg/kg)	Total recov-erable in water (mg/L)	Dis-solved in water (mg/L)	Total recov-erable in bottom material (mg/kg)
May 29-30, 1985						
Calcasieu River near Moss Bluff.	0.08	0.07	1.9	<0.1	<0.10	<2
Bayou Serpent.	.11	.10	58	<.1	<.10	<2
West Fork Calcasieu River.	.16	.16	12	.2	.14	<2
Calcasieu River at buoy 130.	.17	.20	23	.2	.17	<2
Calcasieu River at Bayou d'Inde.	.29	---	4.7	<.1	---	2
Calcasieu River at petroleum refinery.	1.3	1.2	2.4	.2	.18	<2
Calcasieu River at Burton Landing.	.17	.17	4.9	<.1	<.10	<2
Calcasieu Lake.	.16	.15	7.6	<.1	<.10	<2
Calcasieu River at buoy 47.	.43	.34	7.4	<.1	<.10	<2
August 28-30, 1985						
Calcasieu River at buoy 130.	0.13	0.14	1,800	<0.1	<0.10	47
Calcasieu River at Bayou d'Inde.	---	.12	100	<.1	<.10	14
Calcasieu River at petroleum refinery.	.20	.11	570	.1	<.10	12
Calcasieu River at Burton Landing.	.26	.25	670	<.1	<.10	<10
Calcasieu Lake.	.10	.13	190	<.1	<.10	16

Table 3.--Concentrations of selected minor elements in the water column and bottom material in the Calcasieu River, Louisiana, May 29-30 and August 28-30, 1985

[mg/L, milligrams per liter; mg/kg, milligrams per kilogram; ---, not analyzed]

Site	Chromium			Iron			Mercury		
	Total recov-erable in water (mg/L)	Dis-solved in water (mg/L)	Total recov-erable in bottom material (mg/kg)	Total recov-erable in water (mg/L)	Dis-solved in water (mg/L)	Total recov-erable in bottom material (mg/kg)	Total recov-erable in water (mg/L)	Dis-solved in water (mg/L)	Total recov-erable in bottom material (mg/kg)
May 29-30, 1985									
Calcasieu River near Moss Bluff.	<10	<10	70	1,000	200	5,400	<0.1	---	0.01
Bayou Serpent.	<10	<10	20	1,500	170	1,900	<.1	---	.06
West Fork Calcasieu River.	<10	<10	30	1,100	250	2,200	<.1	---	.03
Calcasieu River at buoy 130.	10	<10	80	330	40	6,400	.2	---	.09
Calcasieu River at Bayou d'Inde.	10	<10	200	150	40	4,900	.1	---	.80
Calcasieu River at petroleum refinery.	10	<10	330	180	60	14,000	.1	---	.50
Calcasieu River at Burton Landing.	20	10	70	270	40	5,300	.1	---	.09
Calcasieu Lake.	20	10	70	1,700	90	6,700	.1	---	.05
Calcasieu River at buoy 47.	30	20	40	1,300	80	3,300	.2	---	.05
August 28-30, 1985									
Calcasieu River at buoy 130.	80	10	100	400	40	3,500	<0.1	<0.1	.08
Calcasieu River at Bayou d'Inde.	10	10	450	190	30	9,500	<.1	<.1	2.0
Bayou d'Inde at industrial outfall.	---	---	220	---	---	2,500	---	---	.10
Calcasieu River at petroleum refinery.	20	20	490	150	50	9,600	<.1	<.1	.60
Calcasieu River at Burton Landing.	420	20	70	250	60	2,800	<.1	<.1	.08
Calcasieu Lake.	30	30	130	350	80	8,900	<.1	<.1	1.7

Table 4.--Concentrations of organic compounds in the water column in the Calcasieu River, Louisiana, May 29-30 and August 28-30, 1985

[Total organic compounds in micrograms per liter; dissolved organic carbon (DOC) and fractions in milligrams per liter; ---, not analyzed]

Site	Bromoform	Chloroform	Methylene chloride	1,2-dichloroethane	Tetrachloroethylene	Trichloroethylene	Chlorodibromomethane	Dissolved organic carbon (DOC)	Hydrophobic DOC fraction	Hydrophilic DOC fraction
May 29-30, 1985										
Calcasieu River at Bayou d'Inde.	2.1	3.3	<3.0	<3.0	<3.0	<3.0	<3.0	7.4	---	---
Calcasieu River at petroleum refinery.	19	3.2	<3.0	4.0	<3.0	<3.0	3.1	7.9	---	---
August 28-30, 1985										
Calcasieu River at buoy 130.	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	7.5	3.6	3.9
Calcasieu River at Bayou d'Inde.	100	7.8	9.8	7.0	4.3	<3.0	7.5	5.2	2.1	3.1
Bayou d'Inde near industrial outfall.	530	34	25	21	36	30	45	---	---	---
Calcasieu River at petroleum refinery.	15	6.2	3.0	3.0	3.0	3.0	<3.0	6.0	2.8	3.2
Calcasieu River at Burton Landing.	5.4	3.0	<3.0	<3.0	<3.0	<3.0	<3.0	4.9	1.8	3.1
Calcasieu Lake.	<3.0	6.4	<3.0	<3.0	<3.0	3.0	<3.0	4.7	1.5	3.2

detected were in the industrial area, from Lake Charles to Moss Lake. The DOC and its hydrophilic-hydrophobic fraction also are presented. Semivolatile compounds were not detected in the water column. Analyses for 54 priority pollutants in bottom material by the Survey's National Water Quality Laboratory were all below limits of detection; however, W.E. Pereira (U.S. Geological Survey, written commun., 1985) detected hexachlorobenzene, hexachlorobutadiene, benzopyrene, benzoperylene, naphthalene, and octachloronaphthalene in the Bayou d'Inde area.

PLAN OF STUDY

The preliminary plan of study was developed by: (1) Formulating the overall objectives and approach; (2) reviewing literature of previous studies of the basin and pertinent toxic substances; (3) documenting the hydrologic setting of the basin; and (4) designing and conducting a preliminary reconnaissance sampling program that would provide a basis for a modified plan of study.

Results of discussions with the Louisiana Department of Environmental Quality and personnel of the Survey's National Research Program, as well as results from the literature review, led to the definition of the following study program. Although toxic substances are present in the Calcasieu River, their distribution and the processes that control their fate are unknown. This led to the generation of project objectives:

1. Define the flow characteristics in the lower Calcasieu River system, such as rate and direction of movement, routing through the numerous loops within the system, and circulation patterns within the lakes bordering the channel.

2. Determine the biological and chemical fates of selected organic compounds, nutrients, and minor elements in the industrial reach and in the transition zones between brackish and freshwater areas and the processes involved.

3. Identify the physical characteristics, such as specific conductance, temperature, and dissolved-oxygen concentrations, that affect the chemical and biological processes in the lower Calcasieu River.

Approach

After the project proposal was approved, project personnel prepared a schedule of work elements (table 5) and decided on the extent of the study area. Duration of this study is estimated to be 3.5 years starting in fiscal year 1985 and continuing through fiscal year 1988.

Attempts will be made to closely adhere to the work elements although the work plan is flexible. Too much deviation will indicate that either the project is losing its direction or that project objectives need to be reevaluated. The work elements were formulated for the Calcasieu River project during the literature review, but before any actual sampling was initiated.

Table 5.--Schedule of major work elements

[1, January-March; 2, April-June; 3, July-September; 4, October-December; X, date of task; Z, due date of first draft of planned report]

Task	Water year 1985		1986				1987				1988			
	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Compilation of previous studies, project planning and organization.	X	X	X	X	X	X	X	Z	X	X	X	X	X	X
Transport mechanisms:														
a. Particle-size distribution.		X	X	X	X	X								
b. Suspended-sediment concentrations during differing flows.		X	X	X	X	X								
c. Core sampling to determine sedimentation rates.			X	X	X	X								
d. Sediment-water exchange rates using Radon-222 as a tracer.				X						X	X		Z	
Water-quality studies:														
a. Reconnaissance sampling.	X	X							Z					
b. Define biotic communities.	X	X												
c. Selection and collection of targeted organic compounds.			X	X	X	X	X	X	X	X	X	X	X	
d. Tissue analyses of selected biota.			X	X	X	X					X	X	Z	
e. Chemical analyses in relation to differing sediment particle sizes.					X	X								
f. Biological uptake of targeted compounds using a clam.							X	X	X	X	X	X	X	Z
g. Microbial degradation of organic compounds.							X	X	X					
h. Remobilization of selected organic compounds from bottom material into the water column.							X	X	X	X	X	Z		
Streamflow-related studies:														
a. Installationn and maintenance of instrumentation to define the flow.	X	X	X	X	X	X	X	X	X	X	X	X		Z
b. Measurements of instantaneous discharge to calibrate flow model.	X	X	X	X	X	X	X	X	X	X				
c. Dye studies to determine water routing and re-aeration.							X	X	X	X			Z	
d. Application of flow models to collected hydrologic data.							X	X	X	X	X	X	X	X

Selected organic compounds and minor elements in water, bottom material, and biota and the processes governing their movement will be studied in the lower Calcasieu River from the saltwater barrier to Burton Landing, a distance of 14 mi. Areas near Cameron, Louisiana, and between Kinder and the saltwater barrier also will be studied to improve understanding of inflows and outflows of selected toxic substances from the main study area.

Purpose and Scope of the Study

This study will attempt to define processes that determine the fate and movement of toxic substances in low-lying coastal streams. This study will afford researchers many opportunities to conduct allied studies in surface-water toxics, such as establishing the rates of sorption and desorption for the sediment fractions and the presence of toxic constituents in coastal streams. Results will be transferable to other southern coastal states. Data collected as part of this study will provide a systematic and objective data set for use by research interests and a data base for future trend studies that would evaluate changes in toxic substances in time. Results of this study will be of particular interest to Louisiana Department of Environmental Quality, which has been delegated responsibility for developing a waste-load allocation plan for the lower Calcasieu River as required by the EPA.

Specific objectives of the study include the following:

1. Document quantitatively the presence of toxic substances in water (dissolved and suspended), in bottom material, and in biologic matter (both plant and animal) from the lower Calcasieu River system. This will be accomplished by:

    1.1 Summarizing data from studies conducted by the Louisiana Department of Environmental Quality and the Louisiana Department of Wildlife and Fisheries, National Oceanic and Atmospheric Administration, Louisiana Department of Agriculture, McNeese State University, and from permit discharge information of Louisiana Department of Environmental Quality.

    1.2 Reconnaissance sampling of water (whole and dissolved), bottom material, and biologic matter from several areas for analysis of minor elements, semivolatile organic compounds, and pesticides to verify and supplement the data collected during previous studies. Also, water and bottom material will be analyzed for standard inorganic compounds, total and dissolved organic carbon, chemical oxygen demand, oil and grease, humic and fulvic acids, and phenolic compounds.

2. Determine the hydraulic and transport characteristics of the riverine system.

    2.1 Flow characteristics will be defined using unsteady flow modeling. Data necessary to drive the model will be collected by project personnel and personnel assigned to a cooperatively funded Survey hydrologic study.

2.2 Sediment movement and routing will be determined from transport modeling and of dye studies.

3. Define processes which are important in determining the movement and fate of selected toxic substances in the lower Calcasieu River.

3.1 Several organic compounds and/or minor elements will be selected and analyzed in water (dissolved and suspended phases), bottom material, and biologic matter at several sites based on Lagrangian sampling methodology determined by effluent discharge characteristics. Sampling will be conducted over several tidal cycles. Organic compounds and/or minor elements studied will be selected on the basis of information gathered as specified in item 1.

3.2 Settling and resuspension rates of the selected toxic compounds will be determined within the study area on the basis of results of work specified in item 3.1. Knowledge of settling and resuspension rates will help to define movement of these toxic compounds within the system.

3.3 Analyze sediments by size fraction and composition (that is, biologic matter, such as plant material, and inorganic matter, such as sand) for selected toxic compounds to determine size and compositional-toxic substance relations. Sampling in the saltwater-freshwater interaction zones will be imperative to improve understanding of the processes mentioned in 3.2 and 3.3.

3.4 Define the benthic invertebrate, fish, and plant communities within the study area and select specific organisms, such as the blue crab (Callinectes sapidus), fiddler crab (Uca spp), and oysters (Crassostrea virginica) for tissue analysis to determine where and in what quantities toxic substances are being concentrated in those organisms as they move through the ecosystem. Information on species present in the above communities is available from McNeese State University (DeRouen and Stevenson, 1987) and the Department of Wildlife and Fisheries.

Definition of Flow Characteristics

The river, tidal, and meteorological-driven flows of the Calcasieu River are the unifying mechanisms controlling circulation, mixing, material transport (chemical and sediment), and residence time for the riverine system. Knowledge and understanding of circulation and dispersion are necessary to interpret properly the biological, chemical, and sediment characteristics of the lower Calcasieu River system. The specific objective of the flow-system studies is to estimate the relative importance of the various mechanisms. This objective will be accomplished by hydrographic field studies, dye-tracer studies, and numerical modeling.

The initial, intensive effort will focus on a hydrographic survey of the Calcasieu River system. Detailed cross-sectional and longitudinal profiles of the system will be constructed to aid in determining hydraulic properties of the main channel, loops, and lakes.

A study of the movement and dispersion of a dye tracer will be undertaken to determine the routing of water through the main channel, loops, and lakes of the Calcasieu River system. In addition to the upstream-downstream movement of the dye due to tidal flows, there will be a net downstream movement of the dye due to freshwater inflow.

As part of the ongoing research into the physical processes that control the fate and transport of synthetic organic compounds, a numerical model of the hydrodynamics of the lower Calcasieu River system will be developed. The model that will represent the combined effects of wind forcing, freshwater inflow, stratification, density variations, and gravitational circulation of water in the river will be an aid in understanding the roles of the individual effects and also will be useful for planning sampling strategies and future research.

Determination of Water-Quality Characteristics and Biota

On the basis of results of the reconnaissance sampling program, the project was modified in the following ways: (1) The scope was narrowed to place greater emphasis on organic compound contamination of the Bayou d'Inde area. (2) Sampling for VOC's was increased, because VOC's also were found in high concentrations in the Bayou d'Inde area. (3) Studies were designed to investigate more closely the interactions among bottom material, water column, and biota. (4) Substances were selected from a group of candidate substances for further study. Criteria for selection were that the substances be detected in substantial concentrations in the study area and that they could be associated with specific industries and human activities, or that the substance be typical of certain chemical or biological processes.

Nutrients

Ammonium (NH_4^+) and nitrite plus nitrate ($NO_2^- + NO_3^-$) ions have been selected for further study, and concentrations will be determined in the water column and bottom material. The concentrations of ammonium and nitrite plus nitrate will indicate the oxidation-reduction conditions in the river, because transformation of organic nitrogen from its most reduced (NH_4^+) state to its most oxidized (NO_3^-) state is reversible and contingent on the current oxidation state of the water or bottom material. The presence of ammonium has been documented by the reconnaissance surveys and appears to be associated with certain reaches of the river (table 2).

Minor Elements

Minor elements selected for study are iron (Fe), chromium (Cr), and mercury (Hg). They will be monitored in the water column and bottom material. Iron was selected to study the chemical process commonly referred to as salting out in the water column, which occurs when freshwater containing dissolved iron contacts saltwater. The ability of iron to complex with organic substances also makes it important to monitor in a project concerned with organic substances.

Chromium was selected because it is extensively discharged by industry in the area. Chromium, although a nutrient in low levels in its trivalent (Cr^{+3}) state, is toxic in its hexavalent (Cr^{+6}) state (U.S. Environmental Protection Agency, 1977). Thus, as with organic nitrogen, the prevailing oxidation state is important in understanding the form and activity of compounds in the natural environment. Mercury was selected because of widespread knowledge of, and concern with, its toxicity in the environment.

Organic Compounds

Three volatile and six semivolatile organic compounds have been selected to study the processes that control their distribution in the Bayou d'Inde area. The VOC's, selected on the basis of results from the Louisiana District reconnaissance samples, are bromoform, chloroform, and 1,2-dichloroethane. They were chosen because they were present in concentrations high enough to be tracked downstream to investigate volatilization processes. The semivolatile organic compounds, based on results from the Survey's National Research Program analyses of bottom material, are hexachlorobutadiene, hexachlorobenzene, benzopyrene, benzoperylene, naphthalene, and octachloronaphthalene.

Remobilization Studies

Results from the reconnaissance samples indicate that semivolatile organic compounds are strongly attached to bottom material in the lower Calcasieu River in the presence of saltwater. Little information is available on whether these compounds will remobilize into the water column during periods of high flow or when dredged bottom material in spoil banks is exposed to rain water. Therefore, semivolatile organic compounds in bottom material will be studied to determine how strongly they are attached to bottom material and whether, upon exposure to waters with varying concentrations of dissolved solids, they dissolve in the water column. A modified elutriate test (Keeley and Engler, 1974) using bottom material from Bayou d'Inde and water from: (1) The Calcasieu River at Bayou d'Inde (specific conductance 12,800 µS/cm); (2) Calcasieu River near Kinder (specific conductance 57 µS/cm); and (3) de-ionized water (specific conductance 3 µS/cm) will be performed. Low specific conductance waters will be used to simulate: (1) The river during periods of freshwater input and (2) spoil bank exposure to rain water. Bottom material, to be mixed with the bottom material, and the elutriate water after mixing with bottom material will be analyzed for semivolatile organic compounds. Unfiltered and filtered water will be analyzed to determine whether the organic compounds remain attached to resuspended bottom material or dissolve into the water column.

Microbial-Degradation Studies

A study will be initiated to determine if microbial degradation of selected synthetic organic compounds is a significant factor in determining the fate of these compounds in Calcasieu River sediments. Bottom-sediment samples will be collected and divided into two groups. One group will be taken to the Louisiana State University, Nuclear Science Department and exposed to 1 megarad of ionizing radiation from a cobalt-60 source. This technique will kill almost all bacteria present, while minimizing alterations of the organic compounds present in the sediment; alternative sterilization methods, such as autoclaving or use of antibiotics or formaldehyde, may alter or mask the synthetic organic compounds present in the sediment. The other group will be incubated to provide a productive growth environment for bacteria.

Control samples, irradiated and nonirradiated, will be shipped immediately for analysis. Other irradiated and nonirradiated samples will be incubated at 20 °C for 60 days. Significant differences in synthetic organic-compound concentrations between the two incubated samples will be attributed to bacterial degradation.

Biological Studies

Finfish and shellfish will be collected at five water-quality sites along the Calcasieu River for tissue analyses. Blue crabs will be captured in commercial crab traps and clams will be collected by using a small oyster dredge. Finfish (catfish, spotted seatrout, redfish, croakers, flounder, mullet, and other species) will be collected by use of either a monofilament gill net or rod and reel. Scientific collector's permits will be obtained from Department of Wildlife and Fisheries before sampling begins.

Biologic sampling has two major difficulties: (1) Variability in analytical results will be a problem unless a large number of individual organisms are collected and analyzed, which is both costly and time consuming; and (2) representativeness of water-quality conditions because it is almost impossible to determine if samples from a site truly represent water-quality conditions at that site, because the organisms (other than clams) captured may have spent relatively little of their lifespan at that site. Therefore, biota should be considered long-term integrators of the prevailing water quality of a general area, rather than representing the water quality at the specific site at the time of sampling.

The investigators have developed a procedure for processing biologic samples. Initially, the biota are weighed and measured. Whole organisms are then homogenized by using commercial blenders or grinders. Organisms are composited whenever possible to obtain an average concentration for the species. For fish, a composite of 3-5 individual specimens is usually the practical limit, whereas for smaller organisms such as clams, 20-40 individual specimens are composited. Finally, the composited-species samples are frozen and shipped for analysis.

Volatilization Studies

The VOC's in the water column will be sampled at fixed sites under several different wind conditions to determine the occurrence and the fate of these compounds in the lower Calcasieu River system. Both depth-integrating and point sampling techniques will be used to compare sampling techniques.

In addition to the fixed-site sampling described above, Lagrangian sampling of VOC's will be attempted in Bayou d'Inde. In this study a dye tracer will be slug injected into the bayou and followed downstream, thereby marking a specific parcel of water. Volatile organic water samples will be collected as the dye passes various locations downstream. By sampling in this manner, convective concentration gradients will be factored out and dispersive concentration gradients will be quantified by the dye samples; this leaves volatilization as the only physical process that influences or changes compound concentrations in the marked parcel of water.

Sediment-Water Interfacial Flux Studies

The distribution of synthetic organic chemicals in estuarine waters and sediments is strongly influenced by physical processes, including turbulent mixing and exchange across the sediment-water and air-water interfaces. Unfortunately, the rates of mass transfer are difficult to measure directly. One solution is to measure and model the distribution of naturally occurring tracers in terms of these physical processes.

Naturally occurring radon-222 will be used to estimate the rate of exchange of dissolved constituents in interstitial water across the sediment-water interface. Radon is a noble gas with a 4-day half-life. It is generated within the sediment by the decay of dissolved radium-226. A fraction of the radon that is produced in the sediment near the sediment-water interface escapes to the overlying water and leaves a deficiency in the sediment, so that the activity ratio of radon to radium is less than one. This deficiency is a measure of the rate of exchange across the sediment-water interface.

Reports and Availability of Data

Because of the toxic nature of the compounds being studied, it is important that research plans and analytical results of the study be available to Federal, State, and local agencies, and the general public on a timely basis. Project personnel have met for project status discussions with the following groups since the beginning of the project: U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, Louisiana Department of Environmental Quality, Department of Wildlife and Fisheries, Louisiana Department of Health and Human Resources, and interested public citizens. Interagency communication has resulted in improved understanding of the problems present in the lower Calcasieu River system, helped to prevent duplication of effort, and promoted the efficient use of the resource.

An important element of this project will be the formal presentation of the results of the study. The principal product will be published in a formal Survey report. In addition to this report, a basic-data report will be published, containing all of the results of analyses and describing sampling techniques used. Short technical papers and journal articles also will be used to communicate details of study elements to the scientific community.

All data collected during this study will be entered into the Survey's National Water Information System (NWIS), which includes three hydrologic data files that will be used to store, retrieve, and statistically and graphically process data collected during the project:

1. The Daily Values File accommodates daily data, such as mean stream discharge.

2. The Unit Values File stores data collected at uniform short-time intervals (as many as 2,880 observations per day per variable, such as stage, velocity, or specific conductance).

3. The Water-Quality File stores water-quality data and associated field measurements. Each value is referenced to sampling site, date, and time of sampling, and other pertinent information. Data stored in this file are transferred automatically to the Storage and Retrieval System (STORET) of the EPA for parallel storage.

ORGANIZATION AND STAFFING

The processes that control the distribution and fate of selected substances will be studied cooperatively by personnel from the Louisiana District Office and National Research Program, the U.S. Geological Survey. The flow system will be analyzed by District personnel, which will include three hydrologists and one technician.

District project personnel will need background experience in all aspects of water quality, including sediment chemistry, biology, modeling, and surface-water hydraulics. Throughout the project the assigned personnel will collaborate with other researchers from the Survey's National Research Program on the chemistry of metals, naturally-occurring organic compounds, and synthetic organic compounds. In those instances where the researchers are unable to make repeated visits to the study area, District project personnel will collect and ship the required sample to the researchers. Collaboration with other agencies, such as the EPA will be encouraged.

District manpower needs are detailed as follows:

Manpower	First Year
1 GS 12/13	3 months (Project leader)
1 GS 11/12	3 months (Assistant project leader)
1 GS 9/11	6 months (Assistant)
1 GS 6/7	3 months (Technician assistant, boat operator)
	Second Year
1 GS 12/13	9 months (Project leader)
1 GS 11/12	9 months (Assistant project leader)
1 GS 9/11	12 months (Assistant)
1 GS 6/7	6 months (Technician assistant, boat operator)

Third Year

1 GS 12/13	9 months (Project leader)
1 GS 11/12	9 months (Assistant project leader)
1 GS 9/11	12 months (Assistant)
1 GS 6/7	6 months (Technician assistant, boat operator)

Fourth Year

1 GS 12/13	12 months (Project leader)
1 GS 11/12	12 months (Assistant project leader)
1 GS 9/11	12 months (Assistant)

REFERENCES CITED

Carlson, D.D., Stallworth, G.R., Dantin, L.J., and Stuart, C.G., 1984, Water resources - data for Louisiana, water year 1984: U.S. Geological Survey Water-Data Report LA-84-1, 608 p.

Demas, C.R., 1976, Analyses of native water, bed material, and elutriate samples of major Louisiana waterways, 1975: U.S. Geological Survey Open-File Report 76-853, 304 p.

DeRouen, L.R., and Stevenson, L.H., eds., 1987, Ecosystem analysis of the Calcasieu River/Lake complex, final report: McNeese State University, v. 1-4, 1779 p.

Forbes, M.J., Jr., 1988, Hydrologic investigations of the lower Calcasieu River, Louisiana: U.S. Geological Survey Water-Resources Investigations Report 87-4173, 61 p.

Keeley, J.W., and Engler, R.M., 1974, Discussion of regulatory criteria for ocean disposal of dredged materials: Elutriate test rationale and implementation guidelines: U.S. Army Corps of Engineers, Waterways Experiment Station, Office of Dredged Material Research, Vicksburg, Miss., Miscellaneous Paper D-74-14.

Keith, L.H., and Telliard, W.A., 1979, Priority pollutants I - a perspective view: Environmental Science and Technology, v. 13, no. 4, p. 416-423.

Lurry, D.L., 1983, Analyses of native water, bottom material, elutriate samples, and dredged material from selected southern Louisiana waterways and selected areas in the Gulf of Mexico, 1979-81: U.S. Geological Survey Open-File Report 82-690, 105 p.

Schaffranek, R.W., Baltzer, R.A., and Goldberg, D.E., 1981, A model for simulation of flow in singular and interconnected channels: U.S. Geological Survey Techniques of Water-Resources Investigations, book 7, chap. C3, 110 p.

Spicer, B.E., 1984, Louisiana agricultural pesticide use patterns for use in identifying potential low level toxic material problem levels: Louisiana Department of Agriculture and the Louisiana Department of Transportation and Development, State Soil and Water Conservation Committee, November 1984, 124 p.

Steinheimer, T.R., Pereira, W.E., and Johnson, S.M., 1981, Application of capillary gas chromatography mass spectrometry/computer techniques to synoptic surveys of organic material in bed sediment: Analytica Chemica Acta, v. 129, p. 57-67.

U.S. Environmental Protection Agency, 1977 [1978], Quality criteria for water, 1976: U.S. Environmental Protection Agency, Washington, D.C., 256 p.

*U.S. GOVERNMENT PRINTING OFFICE: 1990-766-820 Region 4.