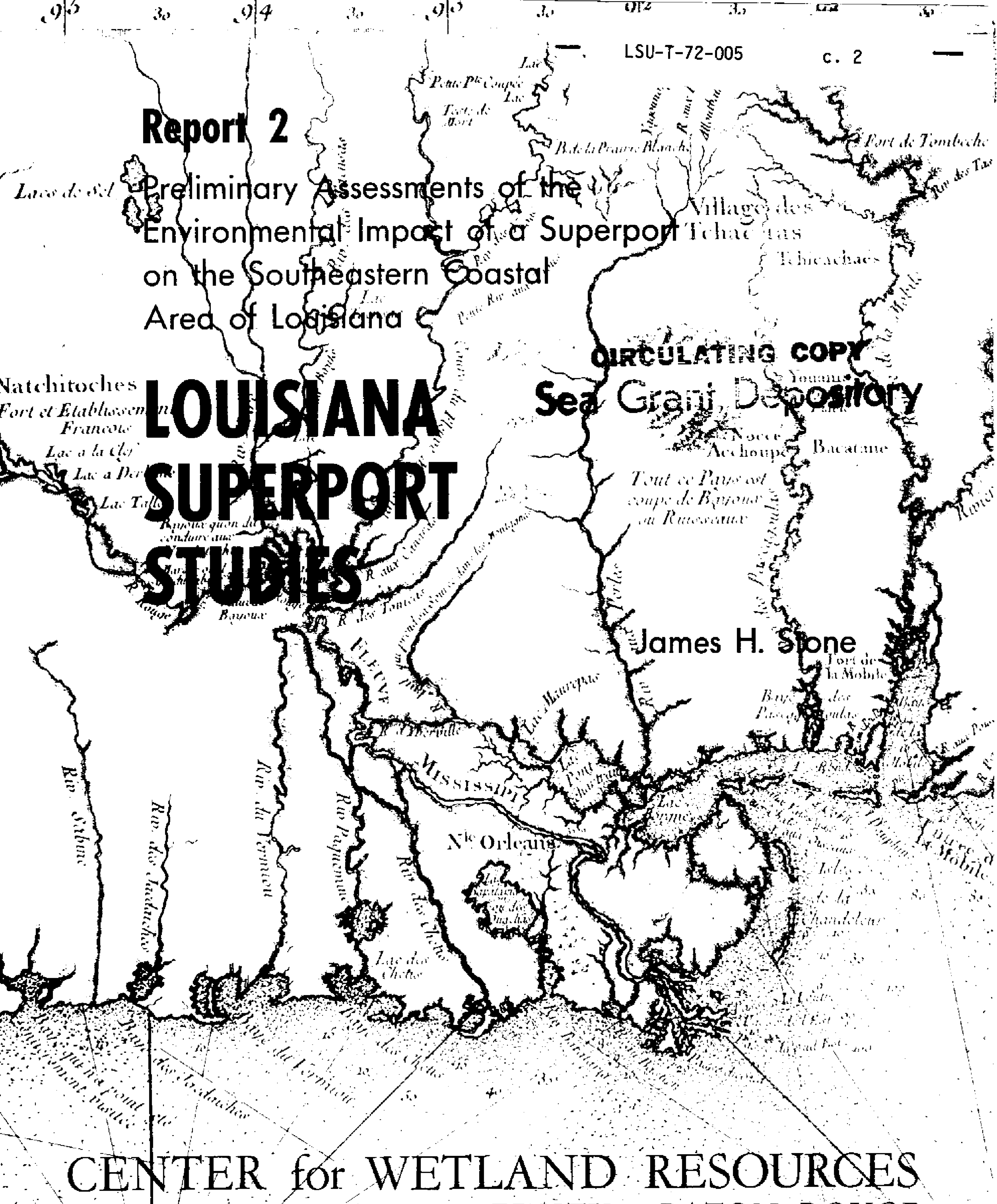


Report 2

Preliminary Assessments of the Environmental Impact of a Superport on the Southeastern Coastal Area of Louisiana

LOUISIANA SUPERPORT STUDIES

James H. Stone

CENTER for WETLAND RESOURCES
LOUISIANA STATE UNIVERSITY · BATON ROUGE
LSU-SG-72-05

REPORT 2

Preliminary Assessment of the Environmental Impact of a Superport on the Southeastern Coastal Area of Louisiana

LOUISIANA SUPERPORT STUDIES

Prepared by:

Dr. James H. Stone
Department of Marine Sciences
Center for Wetland Resources
Louisiana State University
Baton Rouge, Louisiana 70803

Prepared for:

Dr. Hugh J. McLellan
Associate Program Director
Institutional Support
National Sea Grant Program
National Oceanic and
Atmospheric Administration
Rockville, Maryland 20852

and

Mr. Steven D. Jellinek
Senior Staff Member
Council for Environmental
Quality
722 Jackson Place, N.W.
Washington, D.C. 20006

This work is a result of research sponsored by NOAA Office of Sea Grant, Department of Commerce, under Grant 2-35231. The U.S. Government is authorized to produce and distribute reprints for governmental purposes notwithstanding any copyright notation that may appear hereon.

I. ABSTRACT

Two offshore sites for a proposed Superport, off southeastern Louisiana, are evaluated for potential environmental impact on the coastal region. The most vulnerable areas along the coast are the estuaries. Oil drift projections indicate that the site more distant from shore would have less effect because a potential spill there would probably not reach the estuarine areas.

Louisiana's estuaries are flanked by levees and, on the Gulf side, usually by barrier islands. This configuration, coupled with a gentle slope, has produced a nutrient-rich environment that now supports over 4 million acres of estuarine marshlands--one of the world's most extensive coastal wetland areas. The climatic regime provides high solar insolation, abundant rainfall, and a wind system all of which interact with the physical setting in such a way that primary production supports the largest fishery in the United States. The principal fishery species are menhaden and shrimp, and they depend on the estuaries for a habitat and/or nursery area and for detrital food--the product of marsh grass disintegration.

Oil drift projections of hypothetical oil spills are based on a hydrodynamical numerical model using wind conditions, local tides, and bathymetry. At the closest site oil spills moved either northwest toward Timbalier Bay or northeast toward Barataria Bay. Oil spills at the farther site did not impinge on the shorelines nor into the estuaries. Oil spills at both sites usually assumed an east-west orientation and moved somewhat faster than drift projections based

solely on winds.

Potential adverse effects resulting from an oil spill would be most severe in the estuaries. Oil could damage or kill extensive areas of marsh grass, thereby reducing or eliminating the most important food source for the major consumers, which are fishery species. This damage could be by direct contact with the top of the plants, the root system, or the microbes which initiate the breakdown of grass into detritus. Most marsh fauna is located near the boundary between the grass and estuarine waters. If oil enters the estuaries, it is believed that it will concentrate in this boundary area and thereby possibly cause high mortalities of these forms and indirectly of the fishery species, inasmuch as detritus in the estuaries is used as a food source. The larval and juvenile stages of the fishery species use the tidal passes into and out of the estuaries as migratory routes, and if oil reached these areas mortalities could have severe effects on later fish harvests. Damage to the Gulf shoreline would probably be minimal unless the oil concentrated in the littoral currents, which are also used as a migratory aid. The most severe effect offshore would probably be damage to the spawning waters or grounds used by the fishery species. However, this damage would probably be low when compared with potential spill effects on estuaries because the size of the offshore shelf area and the large volume of water would tend to mitigate the damage.

Regardless of the final location of the Superport, research should be initiated on the detailed hydrography and meteorology of the proposed site, the toxic effects of various crude oils on planktonic stages of fishery species, and the effects of oil on marsh grasses and microbes.

TABLE OF CONTENTS

*Detailed listings are given on pages directly following.

LIST OF FIGURES

LIST OF TABLES

Table Page

II. INTRODUCTION

A. Objectives

The objectives of this project were (1) to conduct an overall environmental evaluation of a Superport operation at two hypothetical locations on the continental shelf off the southeast coast of Louisiana, (2) to establish within the limits of available data the existing environmental conditions at and around the proposed sites, and (3) to predict and/or document (a) the effects of an oil spill at or near the proposed sites and (b) the effects of operations.

Only a superficial assessment was made of the effects that a Superport would have on people and their activities. No research was done on the impact of ancillary developments, such as pipelines, tank farms, new refining and/or manufacturing complexes. The latter activities would probably have a more serious and adverse impact on the environment than the port itself.

B. Study Area and Conditions

Part of the coastal area of Louisiana and its continental shelf out to water depths of 200 meters is shown in Figure 1. Potential Superport site locations 1 and 2 are also indicated on Figure 1, and their geographic coordinates are as follows: Site 1 at 28°42'N and 90°14'W or about 27 miles south of Bayou Lafourche (43 kilometers) and Site 2 at 28°57'N and 89°56 1/2'W or about 17 miles (29 kilometers) southeast of Bayou Lafourche. Each site is located where water depths are approximately 100 feet (about 30 meters). Operational (chronic) spills were assumed to take place at the facility or site locations. Casualty spills were assumed to take place at those locations on Figure 1 marked by C_1 and C_2. The geographic coordinates for C_1 or Casualty Spill 1 are 28°47'N and 90°14'W and for C_2 or Casualty Spill 2 are 28°58 1/2'N and 90°01'W. On the basis of these locations we have roughly circumscribed a study area for this report indicated by the dark lines in Figure 1 and having approximately the following geographic coordinates:

North boundary	29°50' North latitude
South boundary	28°30' North latitude
West boundary	91°15' West longitude
East boundary	89°15' West longitude

The Mississippi River forms the boundary of the northeast corner of the study area. The study area roughly conforms to some geographic limits used by previous and ongoing studies, and where possible we have tried to confine our efforts to these limits in order to use existing data more easily. For example, Figure 2 illustrates the geographic boundaries for suggested hydrologic units along coastal Louisiana. Hydrologic units III (Mississippi Delta), IV (Barataria Bay complex), and V (Terrebonne Bay complex) are the areas that would most probably undergo environmental impact from a Superport and its operations. Offshore, the most likely impact areas correspond to commercial fishing grids 13 and 14. We have, therefore, confined our data procurement and analyses where possible to hydrologic units III, IV, and V and offshore fishing grids 13 and 14.

Large casualty oil spills were assumed to take place at C_1 and C_2 under the following conditions:

1. Release time: 2 hours
2. Size: (1) 500 tons
   (2) 30,000 tons
3. Frequency: (1) The immediate and cumulative effect of a 500-ton spill yearly for 20 years
   (2) The immediate and cumulative effect of a 30,000-ton spill midway through a 20-year period

For the periodic (chronic) operational spills we assumed the following conditions at S_1 and S_2:

Alternative #1: Assume that all crude is transshipped by tankship (40,000 DWT in 1980 and 50,000 DWT in 2000).

<u>Year 1980</u>

Amount: 840 bbl

Frequency: 2.3 bbl/day or 30 gal/supertanker operation (588 operations) and 4.8 gal/transshipment operation (3,673 operations).

<u>Year 2000</u>

Amount: 3,094 bbl

Frequency: 8.5 bbl/day or 30 gal/supertanker operation (2,165 operations) and 6.0 gal/transshipment operation (10,827 operations).

Location: At berth

Alternative #2: Consider that all oil is piped--no transshipment by tankship.

Year 1980

Amount: 420 bbl

Frequency: 1.2 bbl/day or 30 gal/supertanker visit (558 operations).

Year 2000

Amount: 1,546 bbl

Frequency: 4.2 bbl/day or 30 gal/supertanker visit (2,165 operations).

Location: At berth

We have also assumed that two types of crude oil arrive on the Gulf coast via supertanker from Africa or the Middle East. For both the large casualty spills and the periodic operational spills, these two crude oil types have the physical and chemical characteristics given in the following table.

Physical and Chemical Characteristics of Crude Oils
Considered for This Study

	A	B
Sulfur, percentage	0.14	1.30
Nitrogen, percentage	0.083	0.042
Color	brown-black	brown-green
Specific gravity	0.858	0.840
API gravity	33.4	37.0
Viscosity	122-69*	43-40**
Light gasoline	2.4	7.3
Total gasoline and naptha	15.1	30.3
Kerosene distillate	13.1	9.9
Gas oil	10.3	15.2
Nonviscous lubricating distillate	14.8	11.3
Medium lubricating distillate	4.3	6.8
Viscous lubricating distillate	---	3.5
Residuum	42.2	19.4
Distillation loss	0.2	3.6
3, 4 benzpyrene	1320 µg/kg crude	400 µg/kg crude

*Saybolt Universal at 100°F, 122 sec; at 130°F, 69 sec.
**Saybolt Universal at 77°F, 43 sec; at 100°F, 40 sec.

Crudes A and B would also contain compounds such as 1, 2 benzanthracene, 1, 2 benzphenanthrene, diphenylmethane, phenanthrene, and dibenzthiophene in the general proportions indicated by the benzpyrene content of each.

C. Data Sources and Acknowledgements

This report is based almost entirely on secondary data; no field investigations or new researches were carried out. As a result, data on the environmental background of the study area have been liberally extracted from published and unpublished sources. Many workers have, therefore, made this effort possible, and I gratefully acknowledge their data and/or aid. All tables and figures have their source indicated on them. Special thanks are tendered to Mrs. Nancy Roques, who did the programming for the Hansen's model. Personal acknowledgements are extended to Drs. John W. Day, Jr., James M. Coleman, Sherwood M. Gagliano, Robert H. Chabreck, A. N. Palmisano, S. P. Meyers, Stephen P. Murray, W. G. Smith, L. D. Wright, J. R. Van Lopik, W. P. James (Texas A&M), Don Mauer (Delaware), S. J. Moore (MIT), J. McHugh (New York), and H. J. McLellan (Sea Grant), and Mr. S. D. Jellinek (CEQ); also to Messrs. George Cry, Sidney Crow, Paul Wagner, and Robert Neuman and Louisiana Wild Life and Fisheries, the Environmental Protection Agency at the Mississippi Test Facility and W. N. Lindall (et al.) of the National Marine Fisheries Service, St. Petersburg Beach, Florida. Special acknowledgements are also due to the staff of Government Documents at the library of Louisiana State University, Baton Rouge. Use of the oceanographic data in the Glenn

(1972) report was made possible through the courtesy of Louisiana Offshore Oil Port, Inc. The extra efforts of the associates and office staff of the Center of Wetland Resources are especially appreciated.

III. SELECTED ENVIRONMENTAL INVENTORY OF STUDY AREA

A. Geological and Geographic Setting

1. Delta Formation

The study area as delineated in Figure 1 is part of the Mississippi River deltaic plain, which is a composite of many progradations of the Mississippi River (Fig. 3). There are at least three delta complexes in the study area: they are the Plaquemines-Modern, the St. Bernard, and part of the Lafourche complexes (Frazier, 1967). Figure 4 gives a "typical" diagrammatic development of a delta complex. Initial progradation begins when a stream discharges its sediment load into rather shallow and still waters and heavier sediments accumulate at the end of the delta. Additional channels usually develop, and they in turn discharge their sediment load; the common result is that the delta takes on a "bird-foot" shape. As further progradation occurs, the delta plain is enlarged and overflow deposition increases the sizes of the levees. Eventually, some of the distributary channels become too flat; the stream is abandoned, and a diversion takes place at another location where the slope is adequate for discharge. Often an old channel is reoccupied, and a repetition of the previous depositional phases can and often does follow (Frazier, 1967; Morgan, 1967).

2. Active Delta: Mississippi River

The distal end of the Mississippi River has at least four major distributaries which form the "bird-foot" shape (Fig. 5). The delta is active, fresh water and deposition dominating the immediate area. Unstable areas exist off the front of each major pass. The instability is characterized by mudlumps (see Fig. 5), which result from the accumulation of heavier sediments on lighter material, presumably causing the extrusion of the latter as mudlumps. More than a hundred mudlump sites have been found at the mouth of South Pass (Morgan et al., 1963; Coleman, 1972). Off South and Southwest passes a rather steep slope-off exists (Fig. 6), and this increases the general instability and foundation problems of the area.

The general morphology of the Mississippi Delta is the result of the interaction of wave attack with the subaqueous profile (Wright and Coleman, 1972). Compared to other active deltas (Table 1), the Mississippi has a high discharge rate, approximately 17.69×10^3 m^3/sec, and the shallow slope of its continental shelf (Fig. 7) apparently attentuates the offshore wave power sufficiently to allow a river-dominated configuration to develop.

3. Barrier Islands

At the distal end of the estuarine areas of Louisiana, barrier islands (such as Grand Isle; see Fig. 1) have been formed, presumably as a result of wave attack on abandoned sand bars at the mouths of abandoned distributaries. The sand is transported laterally and accumulates to form delta-margin or barrier islands. Russell (1967) suggested that these islands are commonly associated with low-coast estuaries, such as those of Louisiana and the study area.

4. Estuarine Areas

Between the major distributaries along the coast of Louisiana, the delta plain has established vast marshlands (Fig. 8). These marshlands originally were formed and maintained by annual flooding of water and sediments over the natural levees, but now rainfall and tidal exchange are the only means for water renewal. As a distributary system becomes less active, subsidence usually occurs at a greater rate in the areas of the old channels because of the heavier materials deposited there, and, as a result, open areas of brackish water are formed (Fig. 9).

Estimates of surface areas in all the hydrologic units along the Louisiana coast are given in Table 2. Hydrologic units III, IV, and V (Fig. 2) correspond roughly to the landward side of the study area and can be designated as the Mississippi Delta, Barataria Bay, and Terrebonne Bay. The total area of the Mississippi Delta complex is approximately 901 mi^2 (2,334 km^2), of which 243 mi^2 (629 km^2) is land surface and about 658 mi^2 (1,705 km^2) is water surface. The estimated water volume is 2,209,300 acre-feet. The total area of the Barataria Bay complex is approximately 2,509 mi^2 (6,500 km^2), of which 1,645 mi^2 (4,262 km^2) is land surface and about 864 mi^2 (2,238 km^2) is water surface. The estimated water volume of this area is 714,200 acre-feet. The total area of the Terrebonne Bay complex is approximately 3,692 mi^2 (9,565 km^2), of which 2,648 mi^2 (6,860 km^2) is land surface and about 1,044 mi^2 (2,705 km^2) is water surface. The estimated water volume of this area is 1,555,700 acre-feet.

Estimates of surface areas for various natural and man-made water bodies in each of the three hydrologic units under study are in Table 3. These data are given for the years 1931 to 1942, 1948 to 1967, and 1970. The surface area for all types of water bodies has increased over the years 1931 to 1970; presumably, this increase is at the expense of existing land.

5. Shoreline Features

The shoreline morphology of Louisiana is characterized by a highly developed and complex land-water interface area. The total land-water interface, estimated at 30,191 miles, is second among the states only to that of Alaska in extent. Approximately two-thirds of this total interface (18,188 miles) is in the study area. Table 4 gives a breakdown of types of interfaces; there are at least five categories, i.e., streams and bayous; bayous, lakes, and marshes; canals and cuts; major rivers; and the Gulf shoreline. Hydrologic units IV and V have 50% of the state's land-water interface. The Gulf shoreline, estimated to be 363 miles long, has the smallest land-water interface.

6. Offshore Areas

The continental shelf off Louisiana, out to depths of 200 meters, has an area of approximately 29,000 mi^2 (75,075 km^2). Approximately one-fifth (15,000 km^2) of the shelf is in the study area. Generally, the offshore subaqueous profile is not steep, and so there are extensive areas of shallow depths all along the Louisiana coast. However, off the delta of the Mississippi River the slope is greatly increased, and deeper waters are reached more rapidly. Figure 10 gives the 30-meter contour and bathymetry of the shelf per 29.6 km^2 (11.4 mi^2) grid in the study area. Table 5 gives estimates of surface water area and water volume per depth interval for all areas offshore of Louisiana. Separate estimates for hydrologic units III, IV, and V are not given, however. More than 50% of the surface area of the shelf waters is confined to shallow waters of $\leq$100 feet (30.5 meters) and 84% over depths of $\leq$300 feet (91.5 meters). Similarly, 54% of the volume of the shelf water is in water $\leq$300 feet (91.5 meters) in depth. The Mississippi River discharges an estimated 1 to 1.5 million tons of sediments per day along the continental shelf of Louisiana. A detailed characterization of the distribution of these sediments is given in Scruton (1956).

B. Characterization of Sediments and Waters

1. Selected Estuarine Areas

The mineral composition of the sediments of Barataria Bay is predominantly montmorillonite; there are lesser amounts of illite and kaolinite (Fig. 11). Under aerobic conditions, two layers are present in the sediments and are easily seen: a top layer that is quite thin (1 to 2 centimeters) and colored light gray, and a bottom layer that is usually very thick (up to >2 meters) and colored dark brown to black. The upper layer is oxidized mud and the lower layer is reduced mud. The upper layer develops and disappears in relation to the amount of dissolved oxygen, and its presence or absence has a significant impact on the types and amounts of substances that pass between the sediments and the water (Hutchinson, 1957). For example, under reduced or anaerobic conditions, soluble phosphorus (ionic) passes from the mud into the water. The seasonality of this phenomenon and its importance in Louisiana estuaries has not been researched.

Though detailed studies of circulation patterns of Louisiana estuaries have not been made, chemical data from Ho (1971) and from Barrett (1971) and Perret et al. (1971) suggest that non-conversative elements are being entrained and accumulated in sediments upstream along a north-south axis in Barataria Bay. The mechanism for estuarine entrainment, as outlined by Redfield et al. (1963), is one whereby the organic material is brought in by a countercurrent of seawater under the surface outflow. This organic material tends to sink differentially, and its concentration in the surface sediments increases upstream relative to the motion of the surface layer. Some of the organic entrainment in the northern sections of Louisiana estuaries may also represent incomplete flushing of the estuaries in that the more northerly sections presumably would not purge themselves of decaying organic material (such as dead marsh grass) as rapidly as the more southerly sections.

At a series of north and south stations (Fig. 12), Ho (ibid.) found that the sediments of the north stations contained an average of 24% organic carbon, whereas sediments of the south stations contained an average of <6% (Fig. 13A). The total nitrogen content of the sediments also exhibited entrainment upstream inasmuch as sediments of the north stations had an average of 1.23% total N, whereas the respective value for the south stations was 0.30 (Fig. 13B). Figure 14 shows the distribution of soil organic matter in all the Louisiana coastal marshes. Those marsh areas having soils with >50% organic matter are almost all located upstream or north of the mouth of the estuary and usually in the northernmost reaches of each estuary; this feature is especially well illustrated in the Mississippi Delta, in Barataria and Caminada bays, and in Timbalier and Terrebonne bays. In addition, Ho (ibid.) found that concentrations of sulfides were higher in the surface soils of the north stations than in those of the south (Fig. 15A). Total phosphorus (Fig. 15B) in the sediments did not show a south to north increase.

Average dissolved carbonates in water samples taken 6 inches (15 centimeters) above the sediment surface were slightly higher at the north stations than at the south, respective yearly averages being 149 and 141 milligrams as HCO_3^- per liter (Fig. 16). These values may reflect the availability of free oxygen in the water, greater concentrations presumably being present at the south stations. Inorganic nitrogen, nitrates, and nitrites have a high seasonal value during March and April; this high is followed by a sharp decrease in May and a general low through summer, which are presumably reflections of biological uptake during spring growth (Fig. 17A and B). Total phosphorus (Fig. 18) was generally higher at the north stations; the highest seasonal value for all stations occurred during fall (October), and a secondary peak is evident during summer (July). Both peaks of total phosphorus probably coincide with the sequence of the biological activities in the estuary.

2. Offshore Areas

Sediments offshore of Louisiana can be generally characterized into three types (Fig. 19), i.e., sands closest to the shoreline, alternating sands and muds, and finally muds. The origin and disposition of these are discussed by Curray (1960). Physical agents affecting sediment distributions from the source rivers are permanent currents, tidal currents, and hurricanes. The overall effect is a series of chenier-like bands, as shown in Figure 19. Fine sediments are generally carried farther to the west along the continental shelf of Louisiana toward the Texas coast. The heavier materials remain closer to the bays and near the shore.

Water chemistries offshore of Louisiana are greatly affected by freshwater runoff, particularly the discharge of the Mississippi River. Riley (1937), for example, found that surface salinities, phosphates, and chlorophyll distribution along the shelf were directly related to input by the Mississippi River (Fig. 20).

C. Climate

1. Average Conditions

At least two pressure ridges dominate weather conditions along coastal Louisiana. One ridge is the "Bermuda high" centered over the Bermuda-Azores area of the Atlantic, and the other is the "Mexican heat low" centered over Texas during the warm months. Pressure changes associated with these ridges set up winds that predominantly come out of the east (Table 6). For example, fall and winter winds have a strong component out of the east, 28% and 21% of all winds, respectively; but for these seasons the components from the northeast and north predominate over those from the southeast. In fall, 26% of all winds come from the northeast, but only 10% come from the southeast. During winter, 18% of all winds come from the northeast and 17% come out of the southeast; however, northwest winds increase 4% over fall season occurrences, so that overall the wind shift is still to the north. Spring and summer winds shift to the southeast. For example, 21% and 18% of all the spring and summer winds come from the southeast, whereas only 17% and 10%, respectively, come from the northeast.

Air temperatures usually reflect changes in wind direction. During fall and winter, mean air temperatures in southeast Louisiana are 69.4°F (20.9°C) and 56.7°F (13.8°C), respectively (Table 7). During spring and summer, mean air temperatures are 68.6°F (20.4°C) and 80.8°F (27.3°C), respectively (ibid.). Because the bulk of the surface waters of the Gulf of Mexico originate in tropical latitudes, coastal water temperatures are relatively higher than surface waters at similar latitudes, undoubtedly resulting in a great warming and increase of moisture content of the overlying air masses. Leipper (1954) gives the mean annual temperature of Gulf surface waters as 78°F (25.6°C), whereas in comparable areas at the same latitude the mean annual temperature is 74°F (23.3°C) in the western Atlantic, 73°F (22.8°C) in the eastern Atlantic, and 68°F (20.0°C) in the eastern Pacific.

Mean monthly rainfall in southeast Louisiana ranges from 3.2 inches/month (8.2 cm/mo) during October to 7.4 inches/month (18.7 cm/mo) during July. Generally, the winter and summer seasons are the rainiest, the monthly means being 5.2 inches (13.2 cm/mo) and 6.4 inches (16.3 cm/mo), respectively. Rainfall is slightly lower during the fall and spring, 4.5 inches/month (11.3 cm/mo) and 4.6 inches/month (11.6 cm/mo), respectively (Table 8).

Humidity along the southeast coast of Louisiana is high because of abundant rainfall and possibly because the prevailing winds have a long fetch over the warm surface waters of the Gulf. Table 9 gives the percent frequency of six classes of humidity on a seasonal basis for New Orleans. Humidity is generally high all year, but it is highest during summer.

Coastal fog (as indicated for New Orleans and Lake Charles) is 2 to 4 times more frequent during December and January (Table 10A and B). Generally, the duration of coastal heavy fog is only about 3 to 4 hours. Visibility offshore of Louisiana is reduced to less than 3 miles (4.8 kilometers) 4.3% of the time on a monthly basis. Poorest visibility occurs during winter and the spring months of March and April; visibility less than 3 miles occurs 7.9% of the time, during January and 9.6% and 8.0% of the time during March and April, respectively. The sky is obscured by cloud cover on the average from 4/10 to 6/10 of the time (Leipper, 1954).

The seasonal pattern of insolation in southeast Louisiana is given in Figure 21. During winter, solar radiation averages about

235 gr-cal/cm^2/day, and during spring months it increases to 435 gr-cal/cm^2/day. The rate reaches a maximum of 488 gr-cal/cm^2/day during summer and declines to 367 gr-cal/cm^2/day during the fall. This seasonal pattern of solar energy undoubtedly is one of the causal factors involved in biological productivity.

Cyclones, particularly the tropical species, generally affect the northwest Gulf area from late May to early November. Data on cyclones, including hurricanes, in coastal sections of Louisiana are given in Table 11. West of the Mississippi Delta, the probability of cyclone occurrence is slightly higher than to the east, occurrence values are 21% and 18%, respectively, for Barataria and Terrebonne and 15% west of the Mississippi Delta. The probability of hurricane and great hurricane occurrence is about the same on either side of the delta. Table 12A and B gives historical data on hurricanes within 180 miles (290 kilometers) of the Louisiana coast. During the entire hurricane season (163 days; May through early November), the average number of tropical storms is 0.76/year; the overall probability for any one day is 0.47%. Usually hurricanes occur at least once a year, and their overall probability is 0.61% for any one day. Comparative cyclone data are given in Figures 22 and 23 for the entire Atlantic and Gulf seaboards; it is apparent that the Gulf is more susceptible to cyclones (and hurricanes) than the Atlantic coast. Thus areas 5 and 6 (see Fig. 22 and Table 11), off Texas, for any one year have an overall tropical cyclone occurrence probability of 19% and a hurricane probability of 13%. For areas 11 and 12, off Louisiana, the probabilities are about the same, respective values being 18% and 11%. Similar probabilities for areas 46-47 (Delaware), 50-51 (New Jersey) and 58 (Maine) are 2.5% - 1.5%, 8.5% - 6.0%, and 13.0% - 5%, respectively.

2. Summer Conditions

Two pressure ridges dominate the summer weather of coastal Louisiana. One is the "Bermuda high," centered over the Bermuda-Azores area of the Atlantic, and the other is the "Mexican heat low," centered over Texas, resulting from solar heating over the land. During July, 67% of the coastal winds are out of the southeast, south and southwest; 98% of the wind speeds are $\leq$19 mph (8.5m/sec), and 50% of them are $\leq$9 mph (4 m/sec) (Table 13).

Average monthly air temperatures are high: 78.7°F (25.9°C) in June, 80.7°F (27.6°C) in July, and 82.2°F (27.9°C) in August (Table 7). Rainfall is also high during the summer; monthly averages are 5.3 inches (13.5 centimeters), 7.4 inches (18.8 centimeters), and 6.6 inches (16.8 centimeters), respectively, for June, July, and August (Table 8).

During active seasons for hurricanes the probability of a hurricane occuring on any one day is 0.56% between June and July; during inactive seasons it is 0.15%. During early August, in an active season, the hurricane probability increases sharply to 0.99%; but in an inactive mid-season, the first part of August is the calmest time of the year (Table 12A).

3. Fall Conditions

During fall, the "Bermuda high" pressure ridge starts to migrate toward the southeas- of the Gulf of Mexico. September winds (Table 14A) shift to a more northeasterly origin, 21% of winds coming out of the northeast compared to 3% for July. Wind speeds increase over those of July: 11.9 are >25 mpr (11.2 m/sec), compared to 1.7% during July. October winds (ibid.) continue the shift to northeast origin; almost 30% come from that direction. October wind speeds (Table 14B) also increase over those of September; 13.7% are >25 mph (11.2 m/sec).

Air temperatures begin to decrease during September (75.2°F or 24.0°C) and October (71.3°F or 21.8°C), but the sharpest drop occurs during November: down to 61.7°F (16.5°C). Rainfall is usually high during September (6.4 inches or 16.2 centimeters), but during October and November a drier period occurs: 3.2 inches (8.1 centimeters) and 3.7 inches (0.4 centimeters), respectively (Tables 7 and 8).

The first part of the fall is the most active period for tropical cyclones, the overall probability being 0.99% for any one day. Most hurricanes occur during this season; the average number is 0.7 per year (Table 12).

4. Winter Conditions

During winter, the "Bermuda high" is usually located in the southeast area of the Gulf of Mexico. In December winds out of the northeast, north, and northwest increase, the percentage of all winds from these directions being 24.7%, 16.6% and 8.6%, respectively (Table 15). Wind speeds increase over those of September and October: 23.1% are >25 mph (11.2 m/sec), as compared to 11.9% and 13.7% for the latter months, respectively.

Air temperatures are lowest during the winter season. During December, the mean air temperature is 56.8F (13.8°C); during January, 54.9°F (12.7°C); and during February, 58.5°F (14.7°C). Rainfall, however, increases over the fall season average, the average in December, January, and February being 5.0 (12.7 centimeters), 5.9 (15.0 centimeters), and 4.7 (11.9 centimeters) inches/month, respectively (Tables 7 and 8).

Tropical cyclones are rare during this season (Table 12).

5. Spring Conditions

The frequency and intensity of "northers" decrease during spring as the "Bermuda high" develops again over the northwest portion of the Gulf. During April, winds shift to an origin predominantly out of the southeast (Table 16): 32.6% are from the southeast compared to 15.2% during December (of Tables 15 and 16). Wind speeds are slightly reduced from those of December; 52.2% are $\leq$14 mph (6.3 m/sec) compared to 32.6% $\leq$14 mph (6.3 m/sec) for December.

Air temperatures begin to increase. The mean air temperatures during March, April, and May are 61.7°F (16.5°C), 68.9°F (20.5°C), and 75.2°F (24.0°C), respectively. The greatest increase in air temperature occurs during March (7.2°F or 4.0°C) and April (6.3°F or 3.5°C). Rainfall during the spring season is slightly less than that during the winter season, mean rainfall during March, April, and May being 4.9 (12.4 centimeters), 4.3 (10.9 centimeters), and 4.5 (11.4 centimeters) inches/month, respectively (Tables 7 and 8).

The probability of a tropical storm occurring during this season is slightly more than during winter, but the chances are still low, being 0.23%. The average number of hurricanes per year during this season is only 0.02%, the lowest of the year (Table 12).

D. Hydrographic Background

1. General Description

No systematic survey of the oceanography of the western shelf along Louisiana has yet been made. The generalized picture of the surface circulation system given in Figure 24 is a result of compiling data and extrapolating from a variety of sources. Just south of the Mississippi River delta the surface circulation has a northerly set, possibly as the result of intrusion of the Yucatan current. When this water reaches the delta it flows to the west and east. The eastern branch forms a clockwise gyral along the continental shelf of northern Florida; it is especially well defined during late winter and spring. The western current is not so well defined but is presumably a boundary current flowing northward; the overall net direction is probably to the northwest and west-northwest as a result of modifications by winds, bottom topography, and discharge waters of the Mississippi and other rivers.

A littoral drift, setting to the east, is present along the coast near Grand Isle and may be coupled with Mississippi River discharge, as suggested by satellite photographs and by the presence of high concentrations of _Escherichia_ _coli_ at times in the waters of Barataria Bay. The latter is presumed to be the result of Mississippi River input inasmuch as it contains sewage contaminants. In addition, cells of high-salinity waters are often present immediately off the mouth of the delta, probably as a result of the bifurcation to the east and west of the discharge waters of the river and the intrusion of oceanic waters between them. Hurricanes in the Louisiana area usually have a net drift toward the northwest. They can cause considerable modification to the shelf waters and generally push oceanic water onto the shore and into the estuaries.

2. Surface Circulation along Western Continental Shelf

The primary surface current of the Gulf of Mexico enters through the Yucatan Channel and eventually leaves through the Florida Straits. The extent of this intrusion into the Gulf varies with the season; it is just evident during February and March, but by August it becomes well defined, reaching approximately 760 kilometers across the Gulf or almost to the edge of the continental shelf off the delta of the Mississippi River (Nowlin and McLellan, 1967; Leipper, 1970). It is uncertain whether the shelf circulation off western Louisiana is coupled with the Yucatan Current (Nowlin, 1971), but it is generally known by mariners and from localized oceanographic surveys that the set of the shelf current is to the northwest and north-northwest.

Current data for a 1-year period, extracted from Scruton (1956), were taken within an area just west of Burrwood, Louisiana, in the Mississippi Delta (in a 1° square bound by 28°-29° north latitude and 90°-91° east longitude), and from an area just south of Grand Isle, Louisiana (in a 1° square bound by 28°-29° north latitude and 89°-90° west longitude). The mean current vector off Burrwood sets toward 348° at 10.8 cm/sec, and off Grand Isle it sets toward 318° at 14.9 cm/sec. The currents off the Burrwood area have more northerly and easterly components than those of the Grand Isle area. Monthly data (ibid.) confirm this difference inasmuch as each of the resultant currents off Burrwood usually sets more often to the north than those off Grand Isle; the fall season (September, October, and November) is an exception to this generalization. It is appropriate to note that during the summer months (June, July, and August) currents off Burrwood set due north and north-northeast. In the Grand Isle area, currents set with a north and west component, but during the summer months a more northerly set is evident. Wind data from Scruton (1956) for both areas are given in Tables 17 and 18. Scruton claims a significant correlation (at $p \leq 0.02$) between surface currents and winds. The correlation coefficients between the surface currents and winds are $r = 0.52$ and 0.41 for the Grand Isle and Burrwood areas, respectively.

Additional current data for the Grand Isle area are given in Table 19. These data were collected for a pipeline company just south of Grand Isle within an area delineated by geographic coordinates 28°55' to 28°57 1/2' north latitude and 89°56' to 89°58 1/2' west longitude. More than 55% of the surface currents flow to the west (NW + W + SW) at a median speed of approximately 1.2 ft/sec (42.7 cm/sec).

3. Littoral Currents

There is a littoral drift current along the shore of the Grand Isle area. Actual measurements of the direction and speed have not been made, but Conatser (1971) has inferred its presence and direction from sediment buildup on the sides of jetties and groins extending out along the ocean front of Grand Isle. Conatser states that waves moving out of the southeast and southwest arrive at Grand Isle at an angle just slightly from normal to the long axis of the beach and, as a result, they induce a littoral current to set toward the northeast. The end result is sand buildup on the southwestern sides of the jetties and groins. The jetty at the northeast end of Grand Isle particularly shows the effects of this buildup; it has increased by about 367 meters along its southwest side since 1958. This littoral transport is probably in response to prevailing southerly winds inasmuch as Conatser has observed a temporary reversal (i.e., on the northeast side) of sand buildup along the sides of jetties when strong easterly winds occur. In addition, he states that discharge out of Caminada Pass into the Gulf is, under normal circumstances, toward the northeast--another indication of the northeast littoral drift.

4. High-Salinity Cells off Delta of Mississippi River

There are cells of water off the Mississippi Delta which have high salinities (Walsh, 1969; Bouma et al., 1971). It has been suggested that oceanic waters which intrude near the delta split into an easterly and a westerly component. The result is probably a series of uneven convergence lines where mixing of oceanic and river waters is uneven and cells of high-salinity oceanic water are formed. Chew et al. (1962a), using drift bottles, found that bottle returns showed a consistent pattern of recovery from eastern and western locations on either side of the delta of the Mississippi River. These workers also found that stagnant or unmixed cells were often present off the delta of the river, and they took this to mean that there were unmixed areas of water, probably the result of the intersection of oceanic waters with river waters. Bouma (ibid.) found that these oceanic cells generally had higher salinities and temperatures but less detrital and sediment content than the surrounding waters.

5. Modification of Shelf Hydrography by Mississippi River

At the Head of Passes, the Mississippi River branches into three major distributaries (Fig. 5). Pass A Loutre carries 37% of the total river discharge, whereas South Pass accounts for 29% of the total and Southwest Pass accounts for about 15% of the total. Average river discharges by month over 21 years are given in Table 20. Figure 25 graphically illustrates the discharge volume per month of the Mississippi River. Highest discharge occurs during spring, especially during March and April. During summer there is a sharp decline in runoff, and by fall and early winter the river is generally at its lowest stage.

Studies near South Pass by Wright (1970) show that current vectors during flooding and ebb tides increase in velocity and change their direction from a southerly set to one toward the southwest (Fig. 26). Sediment distribution (Fig. 27) confirms this pattern inasmuch as the plumes generally bend toward the southwest. The isopleth of the 80 mg/l suspended concentration extends out approximately 6,000 meters. Vertical mixing and statification were found to be significant functions of the distance from the river's mouth, the river's stage, and winds (Table 21).

6. Effects of a Hurricane on Hydrography

Stevenson (1967) collected temperature and salinity data off the Louisiana coast before and after Hurricane Betsy in September 1965. Prior to the hurricane, the surface waters near the delta of the Mississippi River were usually brackish to fresh and spread parallel to the coast along the continental shelf (Fig. 28), extending seaward approximately 250 kilometers. Four to ten days after the hurricane, the same general transects were repeated along the coast and toward the shore at Terrebonne and Barataria bays (Figs. 29 and 30). The data indicate that water temperatures at depths as great as 75 meters increased as much as 6°C after the storm. It was estimated that the upper 30 meters of water was disturbed out to a distance of about 90 kilometers on either side of the hurricane eye.

7. Gross Circulation of Barataria Bay

Barataria Bay is considered to be a composite of three different hydrologic units, as shown in Figure 31. Its gross circulation patterns are outlined in Figures 32 and 33 (Pike and Hacker, 1972, unpublished data) in streamlines for each of the hydrologic units within Barataria Bay under conditions of an outgoing and an incoming tide. Estimates are given in Table 22 of the annual average flow of fresh water through each unit; the easternmost unit, through Quatre Bayou Pass, passes the most water per day at 1.0×10^6 ft^3/day. The average residence time that a particle of water spends in each of the units is 53, 48, and 50 years for units I, II, and III, respectively. Figure 34 presents residence times differently by dividing the areas into three subareas, running west to east. The total time for a water particle to move from north to south through all sections would be 3,000 days. Thereafter, transport out of the bay is assumed to be quite rapid and to be accomplished within a tidal cycle. These data imply that if a particle is located north of the boundary conditions shown in Figure 34, then its removal will be significantly slower.

8. Water Temperatures and Salinities

Median water temperatures for Barataria Bay are given in Table 23. Water temperatures during winter average 13.4°C and during spring increase to 21.4°C. The most significant increase in water temperature occurs during April and May; respective averages are 22.4°C and 25.4°C. Summer water temperatures average 28.4°C, and during fall they drop to 22.7°C. The most significant decrease usually occurring during December. It is probably significant to biological production (such as fishery harvest) that considerable variation in water temperatures occurs during the winter and spring months. The reader is especially directed to examine the monthly data for variations between them and the overall average.

Representative water salinities for Barataria Bay over a 1-year period are illustrated in Figure 35; they range from about 6 °/oo to a maximum of about 15 to 16 °/oo. Lowest salinities occur during April and May, and this condition appears to be directly correlated with the peak discharge of the Mississippi River. Figure 36 gives isohaline patterns for the entire Louisiana coast and for some offshore locations. The influence of freshwater influx is evident along the entire Mississippi Delta and in Barataria and Caminada bays. Timbalier and Terrebonne bays, however, appear to be comparatively more saline than the former two hydrologic units; the 20 °/oo isohaline is located farther north in these bays.

Table 24 gives water temperatures and salinities at a location 8 miles offshore from Grand Isle, Louisiana. Average water temperature during winter is 16.9°C (62.4°F), which is slightly warmer than in the estuaries. During spring, summer, and winter the mean water temperatures are 21.2°C, 29.0°C, and 24.9°C, respectively.

9. Sea Level and Tidal Effects

Sea level along the Louisiana coast has been rising since the 1940's (Fig. 37). Data from three recording stations reflect this gradual encroachment of seawater. Generally, however, the mean tidal range is small, from about 2 inches (5 centimeters) to 24 inches (60 centimeters). Table 25 gives monthly data on tides along the central Louisiana coast. Tides are diurnal, and maximum ranges recur about every 2 weeks, alternating with minimums. The highest mean water level occurs during September and October, and the lowest levels occur during December through March. Winds, however, modify the tides significantly by either pushing the water out of the shallow estuaries or pushing more in under either a north or a south wind. The marshes are rarely covered during winter as a result of strong north winds. Table 26 gives tide data for a location offshore of Grand Isle. The mean range is 1 foot (30 centimeters), and maximum range is 3.3 feet (1 meter).

10. Wave Characteristics

Approximately 92% of the waves along coastal Louisiana are 3 to 5 feet (1 to 1.5 meters) in height and have a period of 4.5 to 6 seconds when wind speeds are greater than 10 km/hr. Most of the waves (43%) come out of the southeast (Table 27). In water depths of 30 meters, maximum wave height is about 27 feet (8 meters) but, depending on the storm, it can be 34 feet (10 meters) every 5 years, 39 feet (12 meters) every 10 years, 46 feet (14 meters) every 25 years, 52 feet (16 meters) every 50 years, or up to 54 feet (16 meters) every 100 years (cf Tables 28, 29, 30, 31, 32, and 33). On an annual basis waves come out of the northeast, southeast, east, and south 70.9% of the time, and 71.9% of them are between 0 and 5.9 feet (1.8 meters) in height (Table 34). During April, 78% of the waves are from the northeast, east, southeast, and south. During July, the waves shift to a more southerly origin, 66.7% of them coming from the southeast, south, and southwest. During September and October, the waves shift to an origin more from the north, as 25% of the winds come from the northeast, compared to 3% during July. During December, the shift is slightly more to the north (cf Tables 35, 36, 37, 38, and 39).

The Louisiana coast is a low-energy coastline in terms of offshore waves. Data in Table 40 suggest that during spring and summer the intensity of offshore waves is at its lowest peak, but during fall and winter a 2X to 3X increase in intensity takes place. Figure 38 characterizes the Louisiana coast in terms of wave power and advance or retreat of a particular section of coast. The Mississippi and Atchafalaya (off Vermilion) deltas are, as would be expected, advancing. The Barataria and Terrebonne coastlines are, however, retreating. Along eastern and western Terrebonne this retreat amounts to >50 ft/yr (15 m/yr) and 25 to 50 ft/yr (7 to 15 m/yr), respectively. The coastline of Barataria Bay is retreating at a rate of 12 to 25 ft/yr (3 to 7 m/yr). It is noteworthy that the annual wave power at the 30-foot (9-meter) depth contour is greatest along the eastern side of Terrebonne Bay (i.e., Timbalier Bay). Figure 39 gives a plot of the orthogonals along the entire Louisiana coast. The density of orthogonals is greatest off and east of the Mississippi River delta which suggests that this is the area of greatest wave power.

E. Biological Units

1. Important Physical Parameters

Salt marshes such as the Barataria and Terrebonne systems are highly productive ecosystems, considered by some (Pomeroy, 1970) to be highly eutrophic and quite stable. Their stability is apparently enhanced by the presence of a large amount of nutrients, resulting in turn in high and continuous primary production by means of a diversity of species. Although the data are not complete, the most important parameters controlling the cycle of estuarine production appear to be weather-related or environmental phenomena. Guidelines as to which environmental factors are important in estuarine production exist in the research literature. For example, Riley (1937) demonstrated the significance of Mississippi River discharge in terms of nutrient input to the northern Gulf of Mexico. Schelske and Odum (1962) claimed that primary production in Georgia estuaries is directly related to high and continuous production by a diversity of species (i.e., marsh grass, benthic algae, and phytoplankton), to tidal flushing, to abundant nutrients, and to rapid turnover rates. Odum and de la Cruz (1967) demonstrated the role of tidal currents and temperature in the formation of estuarine detritus. Odum (1971) suggested that there is a good correlation between detritus production in an estuary and the production of coastal fisheries contiguous to the estuary.

With the above serving as a background, Stone (1972) regressed nineteen environmental variables on fishery harvest taken off the Louisiana coast on a monthly basis from 1962 through 1969. The variables are given in Table 41. The overall regression was significant at $p = 0.0001$ and accounted for 97% of the data variance (Table 42). Stepwise regressions (Table 43) revealed that water temperature significantly accounted for better than 80% of the data variance, and four other variables (i.e., tide range, sea level, air temperature, and Mississippi River discharge) and their interactions significantly accounted for an additional 6% of the data variance. Inasmuch as the major fishery species of Louisiana, i.e., menhaden and shrimp, are derived from estuaries, the assumption is that these five or six variables probably control a significant part of estuarine production. This does not mean that they are the only factors, and it should be emphasized that these variables are probably connected or mask the effects of temperature on growth and mortality and with the effects of the transportation of food (detritus) and nutrients.

2. Plant Communities

There are approximately 4 million acres (1.6 million hectares) of marshlands in the coastal zone of Louisiana (Table 44). Three general marsh zones are proposed by Chabreck (1972): (1) the chenier plain zone west of Lafayette, (2) the inactive delta zone east of Lafayette, and (3) the active delta zone or the delta area of the Mississippi River (see Fig. 40).

Within each zone, four general plant communities are recognized (Chabreck, 1970 and 1972). They are (1) the fresh community, which makes up about 30.8% of the total Louisiana marsh, (2) the brackish community, which accounts for 30.7% of the total, (3) the saline community, which accounts for 22.1% of the total, and (4) the intermediate community, accounting for 16.3% of the total (Fig. 41). These plant communities are based on vegetative types originally proposed by Penfound and Hathaway (1938), and this system refers to the relative salt tolerance of the major vascular species along the Louisiana coast. In saline communities, *Spartina alterniflora*, *Distichlis spicata*, *Juncus roemerianus*, and *Spartina patens* are the indicator species. In brackish and intermediate communities, the indicator species are *Spartina patens*, *Distichlis spicata*, *Phragmites communis*, and *Sagittaria falcata*. The indicator species for the fresh community are *Panicum hemitomon*, *Sagittaria falcata*, *Eleocharis* sp., and *Alternanthera philoxeroides*. At least one hundred eighteen species of vascular plants have been found within these communities (Table 45). *Spartina patens* makes up 25% of the total vegetation, and other major species (those >5% of total) are *S. alterniflora*, *Panicum hemitomon*, *Distichlis spicata*, and *Sagittaria falcata* (ibid.).

Tables 46 and 47 give the fourteen major plant species occurring in the active and inactive delta marsh zone. (These are the only two marsh zones pertinent to this report.)

The total acreage in terms of marshes, water bodies, swamp, and dry land for hydrologic units in the study area is given in Table 48, i.e., III (Mississippi Delta), IV (Barataria Bay), and V (Terrebonne Bay). Natural marsh makes up 22.9% of the total acreage in unit III, 36.4% in unit IV and 41.6% in unit V. Terrebonne Bay (V) has more marsh than any other estuary in Louisiana, and Barataria Bay is second in rank.

Table 49 gives total acreage of hydrologic unit III (Mississippi Delta) according to the four general types of marsh-plant communities. No saline marshes are present in the delta area, probably as the result of the freshwater input of the Mississippi River. Most of the delta marshes are of the fresh and intermediate types, i.e., 34.7% and 44.4%, respectively, though 20.8% is brackish.

Table 50 gives similar data on the Barataria Estuary, hydrologic unit IV. All four vegetative types are present in this estuary, but, in contrast to the delta estuary, 30.7% of the area is saline marsh. Fresh marsh accounts for most of the acreage, i.e., 38.3%, and brackish marsh accounts for 30.7% of the total acreage. Intermediate marsh is not so strongly developed in Barataria as in the delta (4.7% compared to 44.4% in the latter). Table 51 gives acreage estimates on vegetative types for the Terrebonne Estuary, hydrologic unit V; percentage composition is almost identical to that of Barataria Bay, i.e., 31.6% saline, 23.3% brackish, 6.5% intermediate, and 38.6% fresh.

The major plant species found in the natural marshes of the Delta, Barataria, and Terrebonne estuarine units are given in Tables 52, 53, and 54; no plant species were included in these listings that made up less than 1% of the total species composition. In the Delta estuary, the dominant species are _Phragmites communis_, _Myriphyllum spicatum_, _Panicum sepens_, _Bacopa monnieri_, and _Spartina alterniflora_.

In the Barataria Estuary, the dominant species are *Bacopa monnieri*, *Distichlis spicata*, *Eleocharis* sp., *Juncus roemerianus*, *Panicum hemitomon*, *Pluchea camphorata*, *Sagittaria falcata*, *Spartina alterniflora*, *Spartina patens*, and *Vigna repens*. In the Terrebonne Estuary the dominant species are *Bacopa monnieri*, *Cyperus odoratus*, *Distichlis spicata*, *Eleocharis* sp., *Leptochloa fascicularis*, *Panicum hemitomon*, *Sagittaria falcata*, *Scirpus olneyi*, *Spartina alterniflora*, *Spartina patens*, *Typha* spp., and *Vigna repens*.

3. Primary Production

Primary production in Louisiana coastal wetlands has been measured only in selected areas of the Barataria Bay estuary. A partial list of primary producers for those areas is given in Table 55. The significance of this listing is that primary production operates on at least four levels (benthos, phytoplankton, epiphytes, and marsh grass) and by means of a diversity of species.

Gross production for the benthos and phytoplankton is given in Figure 42. Phytoplankton production is at a maximum during July and at its lowest during the winter period. Benthic production peaks during late August and early September. Epiphytic production is shown in Figure 43; it has two seasonal peaks, one during spring and the other during late winter. The patterns of epiphytic and benthic production are quite similar in that they complement production by phytoplankton and marsh grass; their peak production generally occurs when the latter two groups are at low production.

Total net production for *Spartina alterniflora* at selected areas in Barataria Bay is given in Figure 44. Production is highest during April and May and remains relatively high through July. Streamside production is always greater than inland production. Live standing crop of S. alterniflora reaches its maximum value during September, whereas the dead standing crop reaches its maximum value during late winter and spring (April). The maximum loss rate of detritus occurs during April, and a secondary high peak occurs during September and October. S. alterniflora is an annual plant which flowers in October and dies back during December. Propagation of this species in the Barataria Estuary is thought to be primarily by means of the existing root system rather than by seeds (Gosselink, 1972, personal communication).

Summary data on primary production for the marsh and water community in the Barataria Bay area in terms of dry gram weight per square meter per year is given in Table 56. Net community production of the marsh grass is 764 g dry wt/m^2/yr for the water column. These data illustrate the prime importance of the marsh grass inasmuch as its net yield is some 12X to 40X greater than that of any of the other producers. For any one year, most of this net yield probably remains on the marsh as living plants until late winter, when the crop dies back. The dead plant material is then broken down into detritus and transported by high spring tides into the open bay areas offshore, where it supports an extensive marsh fauna and the major fishery species. Energy flow estimates for the Barataria Bay area are given in Figure 45. Approximately 58% of the total net production of the estuary is used by species within its geographic confines, and about 42% is estimated to be "exported" to the offshore area.

4. Marsh Consumer Species

Consumer species in three different habitats common to the marsh-estuarine system of the Barataria Bay area are listed in Table 57.

Population estimates of bacteria, on a seasonal basis, are given in Figure 46 for the Barataria Bay area. Bacteria associated with living marsh plants have a population peak of 10^7 cells per gram of wet substrate during August; however, high populations ($\gtrsim 10^6$ cells/g/wet substrate) generally prevail during the entire year. Bacteria populations in the sediments are approximately an order of magnitude lower than those associated with marsh grasses; they also appear to be relatively constant in numbers throughout the year. In the water, bacteria populations are about 2 to 4 orders of magnitude less than those of the sediments and marsh grass, but 2 peaks are evident, during spring and late summer. The difference in bacteria populations among these three habitats is probably a reflection of adequate surface area for growth. The available surface area on marsh grasses and sediments presumably would be greater than that of water. Table 58 gives additional population estimates for bacteria at various locations on the marsh grass *S. alterniflora*. The greatest populations occur at the mid and bottom portions of the plant; it is noteworthy that these areas have the greatest amount of moisture.

Seasonal biomass of zooplankton from a salt marsh area east of the Mississippi River is given in Figure 47. A population peak, about 3X that of the rest of the year, is reached during April.

Biomass estimates for various macrofauna common to the marsh grass habitat is given in Table 59. These organisms are polychaetes, *Neritina*, *Sesarma* sp., fiddler crabs, blue crabs, *Littorina* sp., *Melampus* sp., and *Modiolus* sp. Biomass estimates are given as a function of the distance the organisms are located from the edge of open water back into the marsh grass for 300 meters. Figure 48 graphically illustrates these data for two areas sampled in the Barataria Estuary. The bulk of the species biomass is located quite close to the water-marsh interface; indeed, the largest biomass usually occurs within the first 3 meters of the marsh away from the open water's edge, and probably greater than 80% of the biomass occurs within the first 50 meters.

Biomass estimates on a seasonal basis for benthic organisms common to the submerged sediments in the Bartaria Bay area are given in Figure 49. Nematodes and amphipods have a biomass peak during March, whereas foraminifera have their peak in April-May. It is noteworthy that the distribution of these benthic creatures is clumped near the shore or, equivalently, the water-marsh interface area (Fig. 50).

Fish species taken in Caminada Bay, part of the Barataria Estuary are listed in Table 60. One hundred and thirteen species of fish were collected during this study (Wagner, 1972). Number of fish per hectare x 1000 and their biomass in kilograms per hectare x 10 for the Barataria Bay area is given in Figure 51. The greatest number of fish occur during mid-march, and a secondary peak develops during August. Fish biomass reaches a peak during August. The 5 most dominant species of the sampled area are given in Table 61. Anchovy and menhaden are first and second ranked, respectively; they are followed by spot, croaker, and sea catfish. Generally, the other statistics, i.e., mean number per trip, percentage of total, total biomass per trip, and percentage of biomass, follow the ranking of the total numbers for each species; the only exception being for total biomass of the sea catfish. The population of the latter species was made up of larger individuals (Table 62). More detailed data on these 6 fish species in terms of numbers and biomass per sampling date are given in Tables 63 and 64. Anchovy and menhaden made up >70% of the total numbers and >19% of the total biomass. Sampling was done by means of a 6-foot otter trawl, hand seines, and trammel nets, and so some of the data undoubtedly reflect a sampling bias.

Seasonal biomass of fish species for other areas in the Barataria Estuary is given in Figure 52. A strong peak is evident during spring (March through May) and is followed by a decline through the fall season and a sharp decrease during the winter season. An abridged breakdown of the food used by the dominant fishery species of the Barataria Estuary is given in Table 65.

Biomass data for the brown and white shrimp (Penaeus aztecus and P. setiferus) in the Barataria Estuary is given in Figure 53. Brown shrimp have a peak biomass during March and early summer, whereas biomass of the white shrimp peaks during October and November.

Estimates of seasonal abundance of marsh birds common to the Barataria Estuary and some qualitative data on their feeding habits are given in Table 66. The birds are categorized into wading birds, waterfowl, shore birds, and birds of the marsh proper. Waterfowl (12 of the 13 species listed) are more abundant during the winter months; 6 of 9 wading species predominate during the warmer seasons. Species of shore birds do not show a pattern either way. About 6 species are abundant all year, and the other five are common during warm or cold months. Figure 54 graphically illustrates these data. Ducks (waterfowl) predominate during the winter, and waders have their largest biomass during summer. The other bird species have relatively constant populations during the year.

5. Fishery* Species

For the last 10 years Louisiana has been the leading fishery state in terms of volume, and in terms of economic value it usually ranks among the top five states. Table 67 gives the 1970 harvest data for Louisiana by volume and dollar value. Six species make up 99% of the harvest volume and 98% of the economic value. Menhaden and shrimp are the principal two species, accounting for 94% of the volume and 86% of the economic value. Other important species are the oyster, blue crab, freshwater catfish, and crawfish.

The production and value of the major estuarine-dependent fisheries as produced in Louisiana on a 5-year average (1963-67) by major species, by major species taken in adjacent states but produced

---

*Fish and shellfish

in Louisiana, and by major species produced in each of the hydrologic units along coastal Louisiana are given in Tables 68, 69, and 70. Units III, IV, and V are the Mississippi Delta, the Barataria Bay estuary, and the Terrebonne Bay estuary, which form the landward geographic limits of the area for this study. Commercial fishing grids 13 and 14 form the offshore geographic limit (see Figs. 1 and 2).

During 1963-67 the major fishery species were almost the same as those for 1970. Menhaden and shrimp constituted 93% of the volume and about 85% of the total economic value (Table 68). Harvest estimates in terms of volume and value for fish and shellfish landed in adjacent states but taken in Louisiana waters are given in Table 69. Fishery products totaling at least $5 million derived from the estuaries of Louisiana were harvested in adjacent states. A complete breakdown of similar data for harvest of major species for each of the nine hydrologic units along coastal Louisiana is given in Table 70.

The Barataria Bay estuary (unit IV) has the highest total production (1,183 pounds per acre) and value ($46 per acre) of any of the hydrologic units. Terrebonne Bay (unit V) is fourth- and third-ranked in terms of production and value, respectively. The Mississippi Delta (unit III) area ranks sixth in production and fifth in value.

The remainder of this section will deal with selected data on each of the principal fishery species in the following order: menhaden, shrimp, oyster, blue crab, and croaker.

Menhaden (*Brevoortia patronus*) - The life history of menhaden apparently follows the typical pattern of an estuarine-dependent species: the adults spawn offshore somewhere along the continental shelf and then the larvae enter the estuaries, where they undergo rapid growth and finally leave as near-adults. The individuals harvested off Louisiana are probably 1 to 2 years old.

The menhaden fishery of Louisiana started in 1948 and achieved mature status in the 1960's (Table 71). In the 1970's record harvests of $\overset{\sim}{>}1$ billion pounds have been achieved, suggesting to some that this species is now being exploited to its maximum.

Data on juvenile menhaden captured in each of the hydrologic units are given in Table 72. No data are given for the Mississippi Delta. The Barataria Bay area has the highest spring, summer, and winter abundances, and the Terrebonne area has the highest summer populations. The average abundances of juvenile menhaden per unit effort are one hundred thirty-one and thirty-four for Barataria and Terrebonne, respectively.

Production and harvest data on menhaden for each of the coastal hydrologic units and for each of the offshore grid areas are given in Tables 73 and 74. The largest harvest in the hydrologic units of Louisiana for this species occurs in the Barataria Bay estuary, production being 1,070 pounds per acre, almost 6X to 7X greater than the production in the Mississippi Delta and Terrebonne Estuary. Maximum offshore harvest occurs east of the study area in offshore grid 15, the 5-year average harvest being 174 million pounds.

Shrimp (Penaeus aztecus and P. setiferus) - Brown and white shrimp species that are most significant to Louisiana, and brown shrimp usually accounts for most of the harvest. These species are estuarine dependent in that they usually spawn offshore, the larvae migrate into the estuaries, and after 2 to 4 months the adults return to the Gulf. Presumably the Louisiana harvest is made up of individuals between 1 and 2 years old. The cycle of white shrimp is generally slightly later than that of the brown, and it is apparently slightly more resistant to environmental extremes such as low salinities.

Historical data on shrimp harvest for Louisiana are given in Table 75. The industry has been a mature fishery since the 1920's.

Seasonal distribution of brown and white shrimp per hydrologic unit along coastal Louisiana are given in Figures 55 and 56. During spring and summer juveniles of the brown are prevalent, and Barataria and Terrebonne bays have the greatest populations. Juveniles of the white shrimp prevail during the winter and fall seasons and appear to be more abundant in the Terrebonne Bay estuary and to the west.

Production data for harvested commercial shrimp per hydrologic unit along coastal Louisiana are given in Table 76. Terrebonne Bay and Barataria Bay estuaries are the first- and second-ranked areas for maximum harvest. In terms of production in pounds per acre, Barataria Bay was first-ranked at 63.7 pounds and Terrebonne Bay was second-ranked at 54.7 pounds. These are the prime shrimp production areas for Louisiana. Over a 5-year period the Terrebonne area yielded $4.5 million/yr, compared to $2.5 million/yr for Barataria.

Data for offshore harvest off Louisiana by offshore grid numbers are given in Table 77 (see Fig. 2 for code). Maximum offshore yield occurs in offshore grid 15, which is west of the study area. Grids 13 and 14 are offshore of Barataria and Terrebonne bays, respectively. Offshore Barataria (grid 13) is second-ranked in harvest and economic yield, and offshore Terrebonne Bay (grid 14) is third- and fourth-ranked in harvest and economic yield, respectively. This shift of maximum offshore harvest slightly to the west (i.e., offshore grid 15) may be a reflection of the prevailing westerly current.

Oyster (Crassostrea virginica) - Oysters generally flourish in brackish waters having a range of salinities from about 10 °/oo to 30 °/oo. They are found intertidally in waters with depths of about 30 centimeters above mean low water to about 12 meters below mean low water. Spawning occurs from early spring through October, and larvae appear in the water from April through October. The spatfall or larvae attachment occurs usually from 3 to 4 weeks after fertilization and is dependent on suitable substrate--in Louisiana, old oyster shells provide this requirement. The spatfall is best on the east side of the Mississippi Delta, but growth is best on the west side of the delta. As a result, oyster fishermen usually move the spatfall from the east side of the delta to the west. Both private and state-owned water bottoms are used in Louisiana for oyster harvest.

Historical data for oyster harvest in Louisiana are given in Table 78. The oyster industry has been well established in Louisiana since the early 1900's.

The total number of oyster grounds in Louisiana for 1969 by parish, seed ground reservations, "red line" areas, and public reef is given in Table 79. Over 800,000 acres are committed for oyster culture and harvest. More than three-quarters of this area lies east of the Mississippi Delta and hence is removed from the present study area.

Estimates of total oyster production by pounds of canned oyster meat per acre of leased land per hydrologic unit are given in Table 80. No oyster production occurs in the active Mississippi Delta, undoubtedly as a result of too much fresh water. However, the Barataria Bay estuary is the first-ranked production area and second only to Lake Borgne in terms of oyster pounds produced per acre leased (357 lbs/leased acre as compared to 539 lbs/leased acre for Lake Borgne and vicinity. Oyster harvest data by private and public grounds are given in Table 81. Maximum production in each occurs during the spring, and private grounds produce more oysters than public grounds.

Blue Crab (*Callinectes sapidus*) - Blue crabs are apparently common all year in all waters of Louisiana and can live in fresh water or oceanic waters. Spawning may occur in offshore waters throughout the year, and the larval forms migrate to the estuaries. After a residence time of about 4 to 6 months, the individuals are mature and the cycle is completed.

Historical data on blue crab harvest in Louisiana are given in Table 82. It has been a mature fishery for at least 30 years.

Juvenile blue crabs are apparently more abundant in hydrologic units I, II, IV, and V, but Barataria Bay estuary is first-ranked in terms of pounds of production per acre, i.e., 7.9 lbs/acre. This value is approximately 3 times greater than those of the other hydrologic units (Table 83).

Inshore harvest data on hardshell blue crabs per hydrologic unit are given in Table 84A. The Barataria Bay estuary and units east of the Mississippi have maximum harvest and dollar yield. Table 84B gives similar data for soft-shelled individuals. Terrebonne Bay estuary is the only unit with soft-shell harvest west of the Mississippi Delta.

Table 84C gives offshore harvest data on hard-shelled blue crabs. Offshore grid 15, just west of the study area, has maximum harvest and economic yield. This juxtapositioning of the best offshore harvest areas just west of the inshore best harvest areas may be a reflection of the prevailing westerly current along the continental shelf of Louisiana.

Croaker (*Micropogen undulatus*) - Historical harvest data for the croaker are given in Table 85. Though this species has been harvested since the early 1900's, some workers suggest that it is a fishery not being fully used and one which could be exploited approximately 6 times the volume of its present harvest.

Data on the distribution and abundances of juvenile croakers in Louisiana estuaries are given in Table 86. The largest populations occur from Barataria Bay to the west. Abundances are greatest during the spring and somewhat lower in the summer.

Harvest data on croakers per hydrologic unit along coastal Louisiana are given in Table 87A. Harvest production is greatest west of the present study area, in hydrologic unit VIII, along the chenier plains of the coast. Terrebonne and Barataria estuaries are second- and third-ranked among the hydrologic units in terms of croacker production per acre.

Inshore harvest data on croakers between 1963 and 1967 are given in Table 87B. Inshore harvest and economic yield are about the same among hydrologic units I, II, IV, and V. Table 87C gives data on harvest of croakers offshore of Louisiana. Maximum harvest and dollar yield occur in offshore grid 13, just off the Terrebonne Estuary.

6. Miscellaneous Consumer Species

Seasonal estimates are given in Table 88 on waterfowl common to southeast Louisiana. Winter and fall populations are the highest for all four types of waterfowl listed; the total estimated population for both seasons is 4,542,000 birds, and the total during spring and summer is 560,000 birds, or a difference by a factor of approximately 9X. An important feature implied by these data is that the marsh or coastal wetlands support a large population of migratory species, none of which, apparently, overlaps any other to a significant degree.

Data on the nutria and muskrat fur and meat industry of Louisiana are given in Table 89. Estimates are also given as to the density of muskrats per 100 acres in each of the hydrologic units considered in this study. Highest densities of 285 animals/100 acres are found in the brackish marsh area of Terrebonne Parish. The total dollar value of pelts and meat in the 1969-70 season was $\$6.8 \times 10^6$ and during the 1970-71 season was $\$5.2 \times 10^6$. Prior to the introduction of the nutria into Louisiana during the 1940's, the muskrat was the only species of animals found in the coastal wetlands involved in the fur and meat industry. In 1966, the peak production of nutria was 1.5 million animals, and muskrat production was dramatically reduced. Since then, it appears, the muskrat and nutria have been reestablishing a stable interspecific relationship, though the harvest data of Table 89 indicate that nutria accounted for about 48% of the fur market and 86% of the meat market.

Alligator populations are apparently on the comeback in Louisiana, though as a species they are still on the endangered list. Table 90 gives population estimates in the general marsh zones, i.e., subdelta and active delta, part of which make up the study area. The greatest populations are in the subdelta zone; about 42,000 alligators are estimated to be on private lands and about 7,000 on public lands. The total population of this animal in both marsh zones is estimated to be approximately 63,360. It is believed that an oil spill per se would not bother the alligator unless the oil were differentially absorbed by their eggs, causing high mortalities. However, because the alligator feeds mainly on blue crab, crawfish, muskrat, nutria, and raccoon (all of which are quite dependent on marsh grass), the spill might affect this species adversely in an indirect way by decimating its prey or the younger forms of its prey.

7. Offshore Communities

Population estimates of major fishery species harvested offshore of Louisiana have already been discussed. More work is needed on the benthic communities and on the distribution and abundance of larval and juvenile forms in the offshore areas. Parker and Curray (1956) classified three common macroorganisms of the central Gulf Coast in terms of the number of species found in a given gradient of salinity. His categories include gastropods, crustacea, and pelecypoda. The greatest number of species, i.e., twenty-three, occurs in more saline water (35 °/oo to 45 °/oo). There is a corresponding decrease in species as the salinity is decreased. Table 91 gives the estimated number of genera and species for five benthic forms common to the central Gulf Coast. Pelecypods and gastropods predominate the community species makeup (Table 91). More detailed data on various offshore communities are given in Table 92, but still this represents only a qualitative expression of part of the offshore communities.

The Gulf Coast Research Laboratory at Ocean Springs, Mississippi, recently published results of an extensive survey on nektonic and benthic forms carried out off Mississippi from 1967 through May 1969 (Franks et al., 1972). Fifty invertebrate species and one hundred twenty-three fish species made up the collection. *Renilla mulleri* was the most abundant invertebrate, and the brown shrimp (*P. aztecus*) was the second most abundant. The five most abundant fish were the croaker (*Micropogon undulatus*), the longspine porgy (*Stenotomus caprinus*), the butterfish (*Poronotus tricanthus*), the spot (*Leisotomus xanthurus*), and the seatrout (*Cynoscion nebulosus*). These species accounted for 81% of the numerical catch. Commercially important fish made up 93% of the total fish catch.

8. General Overview of Biological Units

Three major biological components of the Barataria Estuary of Louisiana are listed in Table 93. The first component is made up of the most important physical factors, such as insolation, air and water temperatures, rainfall, water level, and river input. The second component is made up of the primary producers, such as marsh grass, phytoplankton, and epiphytic and benthic algae. The third component is composed of the major consumer species, such as bacteria, fungi, meiofauna, zooplankton, menhaden, shrimp, and birds. Also given in Table 93, in an effort to summarize the previous sections on biological units as succinctly as possible, are the gross seasonal changes in each of these parameters or populations. This summary approach may result at times in circular reasoning, and the reader is forewarned to be cautious in this regard. These components operate primarily in the estuaries of Louisiana, such as Barataria Bay, but the offshore area is an integral part of the system and is separated only for convenience of presentation and because it has not been studied as extensively as the marsh area.

An important feature mentioned in the caption of Table 93 but not emphasized is the fact that these components operate within a unique geological and geographic context. Geological processes have established a nutrient-rich environment, and because of the resulting configuration these nutrients are probably continually being entrained into the estuaries. The geographic context is the location at approximately 30° N latitude, which provides the area with abundant rainfall, solar insolation, warm air and water temperatures, and a long growing season. Most of the variables have a seasonal pulse or high--see, for example, insolation, air and water temperatures, primary production, and all of the consumer species. Primary production is almost continuous throughout the year; this is accomplished not by one group but by production by one group followed by production by another group. Animal production is somewhat continuous throughout the year by alternation of groups of migratory species (i.e., shrimp, menhaden, birds, etc.).

The physical factors in Table 93 are primarily those influencing the weather. Before manmade levees were constructed, the rivers and bayous of Louisiana annually overflowed their banks, thereby adding water, nutrients, and sediments to the estuaries. The construction of levees, however, has eliminated this type of input, and now rainfall and estuarine exchange are the principal means of input. It is appropriate to note that the physical factors, particularly rainfall, mean water level, river input, and winds show a pattern of complementing and/or supplementing one another. For example, maximum rainfall occurs during the summer, when tidal action and winds are reduced and river input is on the decline. The end result is presumably sufficient water to "run" the system.

The important feature about the listing of the primary producers is that primary production operates on four levels and by means of a variety of species within each level. This type of system ensures high, continuous, and stable production. For example, marsh grass production is highest during spring, and phytoplankton production is highest during summer. In addition, production by benthic algae is high during fall and at a maximum during winter, the maximum occurring in conjunction with maximum production by epiphytic algae. Another important feature, though not evident on Table 93, is that marsh grass apparently provides the bulk of "surplus" production to the consumer species (see Table 56 and Fig. 45). Also, the impact of marsh grass production is not apparent until the following year, when the dead grass is converted into detritus.

The pattern for major consumer species as given in Table 93 is not so clear-cut because the data are not complete. Nonetheless, certain features seem important. First, there is always a high population of bacteria and fungi--probably essential for the initial conversion of the marsh grass to detritus. Second, the meiofauna associated with the marsh area are highly clumped in their distribution, most of them being located at the marsh edge-water interface. And, finally, a variety of species make full use of the estuary by means of their migratory habits. This presumably allows for maximum animal production of a particular species at one time and maximum production of another species at another. See, for example, the migratory patterns of shrimp, menhaden, and birds. One example of this sequential coupling is seen in menhaden production. During spring it is coupled with high zooplankton production. According to June and Carlson (1971), the early stages of menhaden show a preference for zooplankton; later (during summer) the larvae shift to a food preference of phytoplankton, and summer is the time of maximum phytoplankton production.

F. Selected Cultural Aspects

1. Archeological Sites

There are at least twenty-one known archeological sites in the study area, as shown in Figure 57. Sixteen of these are east of Bayou Lafourche and surround Caminada and Barataria bays. Most are beach deposits, shell mounds, and midden (Rangia sp.), as described in Table 94.

The impact of a Superport and its activities on these sites would be in terms of (1) ancillary developments of the Superport being located on or near them, such as tank farms and pipelines, and thus possibly damaging or destroying them and (2) possible cleanup activities associated with an oil spill that might also damage the sites.

2. People and Some of their Activities

The parishes (counties) of Louisiana are shown in Figure 58, and the readers are especially directed to the coastal parishes. Estimates on populations in parishes in and bordering the coastal wetlands of Louisiana are given in Table 95. Plaquemines, Jefferson, Lafourche, and Terrebonne parishes are especially pertinent for the requirements of this study. In 1960 the estimated population density in each of these was 22.9, 510.0, 47.9, and 43.7 per square mile, respectively. The estimate for Jefferson Parish is not representative of other coastal parishes because part of this parish is contiguous to the city of New Orleans. Nonetheless, the data illustrate that, even though coastal Louisiana is not densely populated, all parishes are showing a net increase in population. Additional data for projected population growth through 1985 in the parishes of Louisiana are given in Tables 96 and 97. Region 1, which includes the study area of this report, had the largest population increase in the entire state between 1960 and 1970, at 29.9%. Further, these data project that this area will also have the largest population growth through 1985 (Table 96). Table 97 gives the breakdown of these data by parishes within area 1.

This population increase undoubtedly means that additional recreational demands will be made on the study area. Twenty-four recreational activities enjoyed in the Louisiana area, especially region 1 of the study area for this report, are listed in Table 98. More than 39% of these activities are enjoyed outdoors, particularly in the coastal wetlands. Data on user-days for areas 1A and 1B projected from 1970 to 1980 are also given in Table 98. For all activities, except those marked with an asterisk, user-days in outdoor activities related to the coastal wetlands will increase by about 25% from 29 x 10^6 user-days in 1970 to 51 x 10^6 user-days in 1985.

G. Observed Effects of Previous Spills Off Louisiana

1. The Chevron and Shell Spills

Two major spills have occurred recently off the Louisiana coast. The first spill was at a platform owned by Chevron Oil Company; it started February 10 and lasted until March 31, 1970. The location of this spill was east of the Mississippi River in the Main Pass Oil Field and is shown on Figure 1 by CH. The second spill was at a platform owned by Shell Oil Company; it started December 1, 1970, and lasted until April 16, 1971. The location of this spill was approximately 7 miles (11 kilometers) south of Timbalier Bay and is shown on Figure 1 by SH.

The Chevron spill was monitored by a variety of federal, state, and private agencies. At least two reports on this spill were published. One was prepared by Alpine Geophysical Associates, Inc., Norwood, New Jersey, for the Environmental Protection Agency (EPA) in May 1971 under the title "Oil Pollution Incident; Platform Charlie, Main Pass 41 Field, Louisiana." The other report was published by Murray et al. (1970) under the title "Oceanographic Observations and Theoretical Analysis of Oil Slicks During the Chevron Spill, March 1970." The U. S. Geological Survey (personal communication from CEQ, 1972) estimates that the total volume of oil spilled at and about the Chevron platform was 30,500 barrels (about 4,200 metric tons).

The Shell spill was also monitored by a variety of federal, state, and private agencies. At least two reports were published on this spill. One was prepared by Resources Technology Corporation, Houston, Texas (for the EPA), under the title "Fate and Effect Studies of the Shell Oil Spill--December 1970." The other report was prepared by Texas Instruments, Inc., Dallas, Texas, under the title "Oceanographic and Remote-Sensing Survey" (a supplementary report was also included). Estimates of the total volume of oil spilled at and about the Shell platform range from 25,000 barrels, made by Shell Oil Company, to a 53,000-barrel estimate by the U. S. Geological Survey, and finally to a 90,000- to 119,000-barrel estimate by the EPA. These volume estimates are equivalent to 3,500, 7,420, 12,600, and 16,660 metric tons, respectively.

The reports on the Chevron spill mainly document the oceanographic observations made on the oil slicks as a function of winds, surface currents, and tidal currents. In general, Murray et al. (1970) found that the stress of the wind on the water's surface was the most important factor in determining the behavior of the oil slicks, especially when the winds were >15 mph (>6.7 m/sec). Tidal currents caused the oil slick to assume an L shape when the winds were <15 mph (<6.7 m/sec), and their diurnal rotation helped to keep the slick away from the shore. Freshwater input from the Mississippi River also served as a barrier between the shore and the oil slicks by the development of convergence lines between fresh and saline waters. The width/length ratios of the oil slicks were found to be independent of current speed. Murray (1972) developed a model for prediction of gross size and overall shape of the oil slick; it is based on Fickian diffusion equations. The geometry of the oil slick is defined as a function of current speed, horizontal eddy diffusion, the oil discharge rate, and a boundary concentration determined empirically.

Apparently no significant biological damage resulted from the Chevron Spill. No fish, bird, or other animal kills were reported. No data are given on various marine populations surrounding the platform. It is especially noteworthy that chemical dispersants were used (i.e., 1,000 barrels of "Corexit" and 500 barrels of "Cold Cream"), despite the fact that studies on oil spills elsewhere document the fact that dispersants are invariably more toxic than the oil itself and probably should not be used (see the article by Mills and Culley, 1970, as one example of the toxicity problem of dispersants).

The reports on the Shell spill are more detailed than those on the Chevron spill in terms of data on marine populations in and about the spill site. In general, slick orientation was best correlated with the near-surface current, the 10-foot (3-meter) depth, and wind vectors. When the winds were out of the east, southeast, and south the surface water and the oil slick showed a net movement and set toward the northeast and north (Figs. 59 and 60). Under these conditions, oil reached the beach just northeast of Bay Champagne. When the winds changed to a set toward the west and southwest, the surface movement and slick orientation were approximately 230° to 240°, or toward the southwest (Fig. 61).

Biological sampling, though not definitive, was somewhat more detailed and intensive for the Shell spill than the Chevron spill. Stations were occupied at approximately every mile, out to 7 miles, from the platform along at least three transects. These transects had sets of approximately south, north, and northwest. Within the limited sampling program, the overall conclusion was that benthic and fish populations about the platform had been stressed as a result of exposure to petroleum hydrocarbons, but some recovery was apparent. Data on hydrocarbon concentration in the sediments along each of the transects are given in Figure 62. It also gives the composite distribution of species in terms of simple diversity, mean diversity per sample, crab catch data, and composite meiofaunal mean along each transect out from the platform. The report states that a weak negative correlation generally existed between the presence of high concentrations of hydrocarbons in the sediments and low abundances of epifauna and infaunal species. This correlation should mean that areas having high concentrations of hydrocarbons have low abundances of species and individuals. Numerical data extracted from these figures are given in Table 99, and they confirm the above correlation; but it is not a strong relationship, probably because of considerable variance resulting from sampling problems. The north transects for simple diversity, mean diversity, crab data, and composite meiofaunal mean consistently showed a negative correlation with hydrocarbon contents at -0.63, -0.13, -0.46, and -0.36, respectively. The south transects had all positive relationships and had generally the lowest hydrocarbon concentrations. The northwest transect had positive and negative relationships. Limiting sampling to north, south, and northwest transects may have been unfortunate because the orientation of the slick near the platform, as shown in Figures 59, 60, and 61, appears to be, depending on the wind, either toward the northeast or the southwest. Inasmuch as wind data taken from the oceanographic report on the Shell spill (Table 100) show that January winds came mainly (65% of the time) from the north, northeast, south, and southeast, it may be logical to assume that transport would be predominant to the right of the wind direction and hence oil stress might predominate along an axis running northeast to southwest. Thus it is likely that the hydrocarbons would also take an overall distribution along a southwest-northeast axis. It is possible that the particular transects used for sampling may not have crossed or coincided as much as they could have with areas affected by oil.

In general, the Shell report concludes that the epifauna and infauna decreased in numbers as the platform was approached, particularly within the first 2 miles (Fig. 62). The average number of benthic creatures was about $13{,}000/m^2$ within a 1-mile radius, but beyond the 2-mile radius the density of organisms went as high as 32,000 and $48{,}000/m^2$. Grab samples also indicated a decrease in the number of organisms on approach to the platform (Fig. 62 and Table 99). A limited examination of the histology of fish gill filaments (only 6 species) showed that some epithelial cells were being sloughed off and that some gill filaments were swollen, presumably as a result of exposure to oil. The fish examined were collected along the north and northwest transects. The invertebrate form, stomatopods, was suggested to be an indicator of environmental or oil stress because no adult stages were taken within 4 miles of the platform. (The adults are burrowing benthic creatures and the larvae are planktonic.) The absence of adult stomatopods was taken as an indication that the oil had settled into sediments and then probably was being transported back and forth, recurrently, between the water surface and the sediments.

The Shell spill was also monitored, to a limited extent, by state officials (Adkins, 1972). Their report concluded that there were no differences in the plankton as a result of the spill; the baseline data for this conclusion extended back 4 years, but they were not included with the above report. No dead organisms were reported in the spill area, but some dead ducks were found in an oil slick on

Isle Dernieres, which is located on the extreme southwest corner of Terrebonne Bay, a considerable distance (about 30 miles or 48 kilometers due west) from the spill area. These conclusions need to be verified with more and better data than those attached to the report.

Yeast populations were monitored by Meyers (1971) during the Shell spill. The succession of yeast species and their populations in oil-free waters and in oil-stressed waters for 13 weeks after the spill is listed in Table 101. In oil-free waters, yeast populations are relatively sparse, at concentrations of 0-10 cells per 100 millileters, and are made up predominantly of the species complex *Rhodotorula*/*Rhodosporidium*, as well as *Debaryomyces hansenii* and *Candida parapsilosis*. Shortly after oil was introduced (about 2 weeks; see Table 101), the former group underwent a bloom and their populations increased to concentrations of >200 cells/100 ml. After 6 weeks, the concentrations of yeast populations increased to >500 cells/100 ml, but other species started to appear, e.g., *Candida* spp. and *Trichosporon cutanum*. After 13 weeks, the concentrations of yeast populations returned to the baseline level of >10 cells/100 ml, but species of the *Rhodotorula*/*Rhodosporidium* complex were absent. Meyers (ibid.) believes that the latter and other species known as oil-decomposing types disappeared despite oil-enrichment because nutrients (probably nitrogen and phosphate) became limiting. Oil decomposition presumably cannot occur at a rapid rate without an adequate N/P substrate.

2. Other Studies on the Impact of Oil on Louisiana Estuaries and Coastal Waters

Zobell and Prokop (1966) studied oil-oxidizing microbes in mud samples taken from Barataria Bay and found them in abundance (see Table 102), possibly because this area is under chronic hydrocarbon stress as a result of extensive development of the petroleum industry. Mackin studied the effect of crude oil on a variety of Louisiana marsh grasses (Table 103). The grass species included salt grass (Distichlis spica), saltwort (Bastis sp.), glass wort (Salicornia begeloii), cordgrass (Spartina alterniflora), and young mangroves (Avicennia sp.). The oil was retained in 16 ft^2 (1.7 m^2) pens (4 x 4 feet or 1.3 x 1.3 meters) with wooden bulkheads. Though estimates of absolute concentrations are not given, it can be assumed that there would be at least 4 inches (10 centimeters) of standing water surrounding the base of the plants; this assumption implies that the total volume of water in each pen would be approximately 25 gallons (114 liters). Thus for each dosing level given in Table 103 the equivalent absolute volume is estimated at 0.16%, 0.32%, 0.65%, and 1.31%, respectively. Plant damage is first indicated at the 0.65% concentration level. At the 1.31% level, 25% specimen mortality occurred after 2 months, and only 10% of the plant specimens survived after an exposure lasting 1 year. These data strongly imply that long-time exposure at relatively high concentrations is quite lethal and that immediate and rapid cleanup in a spill area is therefore very critical and essential.

Studies by Crow (1972) on yeast populations under oil stress in the marshes of Barataria Bay show the same general species succession as observed by Meyers (1971) offshore during the Shell spill.

A series of plots of *Spartina alterniflora* were given monthly doses of crude oil at approximately a 1% concentration. Yeast species from the genera *Pichia* and *Kenyveromyces* usually predominate in the untreated marsh plots. However, after treatment with crude oil, species with known capabilities for decomposing oils assume dominancy; these species were *Pichia ohmeri*, *Trichosporon* sp., and species from the *Rhodotorula*/*Rhodosporidium* complex (Table 104). It is significant that the concentrations of yeast cells in the oil-treated plots were considerably higher than those of the untreated plots (Fig. 63). For example, during June and July oil populations were about 8 times greater than in untreated plots. Thus yeasts of both water and sediments appear to respond similarly to oil treatment in that species and numbers of the *Rhodotorula*/*Rhodosporidium* complex increase. *Trichosporon* types did not develop in the treated water samples as well as they did in marshland sediments.

Extensive studies on Louisiana oysters in relation to the oil industry were made under Projects 9 and 23, starting in 1947 and continuing into the 1960's (Mackin and Hopkins, 1961). The general conclusion was that the oil operations were not responsible for widespread mortalities but that more likely the causal agent was a fungus called *Dermoceptidium marinum*. Lund (1957) studied the effect of crude oil on Louisiana oysters and found that there was no apparent effect on the oyster's ability to clear suspended material from the water it pumps through its system.

Toxicity studies (Mills and Culley, 1970) on four species marine shrimp, including both brown shrimp (Penaeus aztecus) and white shrimp (P. setiferus), were made. Static bioassays were employed using four types of crude oils (Table 105). Tests lasted over a 48-hour period, and mortalities were recorded as a function of time and concentration. The results are given in Table 106. It was found that the oil dispersants were more toxic than the crude oil. The oil type Q-4-D was the most toxic and had a gas-oil fraction of 40%, the highest value of all the four crudes used (see Table 105). Median lethal concentration at 48 hours (48 hr LC_{50}) for Penaeus shrimp ranged from 1 to 40 ppt (0.1% to 4%). Concentrations from 7.5 to 75 ppt (0.75% to 7.5%) caused 100% mortalities. Mixtures of crude oil and emulsifiers were considerably more toxic than either the crude oil or the dispersant by itself. No correlation was apparent between shrimp mortality and the sulfur content of the crude oils.

Qualitative toxicity data using the common guppy (Lebistes reticulatus), crude oils, oils innoculated with yeast, and dispersants were collected by Ahearn et al.(1971). Louisiana crude was lethal at a 4% concentration within 24 hours, whereas the high-asphalt Mississippi crude had no adverse effect at 4% V/V on guppies over a 30-day period. The dispersant (same type used in several oil spills on the coast) killed the guppies within 8 hours. The addition of fungal culture did not apparently affect the test fish.

Though not a research task of this report, it is pertinent to add that the oil industry has other environmental effects besides causing oil stress on various populations. A major stress is the disruption and changes in the natural drainage of the marshes a resulting from channels and pipelines dug expressly for oil exploration and production (see Fig. 64 as an example). Gagliano and Day (1972) estimate that approximately 35% (5.8 mi^2/yr or about 1,500 hectares) of all land losses in coastal Louisiana result from dredging activities--much of which are due to the petroleum industry. They further estimate that at least 10% (800,000 acres or 324,000 hectares) of the total coastal land of Louisiana will eventually be modified by petroleum-related activities.

IV. DRIFT PREDICTIONS FOR OIL SPILLS

A. Surface Circulation Based on Hansen's Model

1. Description of Hansen's Model

Reproduction of the surface currents in the study area was done by means of the Hansen model or the Hydrodynamical Numerical model (HN) (Laevastu and Rabe, 1972; Laevastu, 1972; Larsen and Laevastu, 1972), a single-layer model that can be used for describing the surface circulation of semienclosed bays, estuaries, or coastal areas having three open boundaries. The study area satisfies the third condition. Laevastu and Rabe (ibid.) provided the model with transport and diffusion equations so that the distribution of pollutants, such as oil, could be computed. The model is based on vertical integration of the equations for motion and for continuity. The input data were (1) tides typical of the Louisiana area of the Gulf (taken from Marmer, 1954), (2) bathymetry, as shown in Figure 10 (taken from Coast Guard maps for the Lousiana coast), (3) Coriolis parameters of 0.73×10^{-4}, (4) a smoothing parameter, alpha, of 0.980, (5) a wind vector per run typical for the study area and/or seasonal wind changes, and (6) a Austauche Coefficient of 0.25×10^{5}, as determined by the grid size and time steps used. The grid size and number used are shown in Figure 65; each grid is equivalent to an area of 29.6 km^2 (11.4 mi^2). The computer program for this model makes rather extensive demands for machine time because it must usually be run about 5 to 10 hours real time (5 to 10 minutes machine time) in order that equilibrium be established and correct outputs be obtained. All data outputs were taken after 5 hours real time. Equilibrium was verified by plotting water height for any particular grid as a function of time and checking to see if the tidal cycle showed any variations. Figure 66 gives water levels over a 30-hour period; variations appear to be very small from any one part of the tidal cycle to its counterpart at a later time.

The schedule of this project did not allow for testing beyond 30 hours real time; additional testing is needed for more adequate verification of the program's stability under the given Louisiana conditions. Also, the HN model was not modified so that permanent currents, simultaneous wind fields, and river input could be incorporated into the final surface current projections. We attempted this modification, but some of our output data became unrealistic, and on the advice of Laevastu (October 1972, personal communication) these changes were postponed.

2. Surface Circulation in Study Area Based on Hansen's Model

Current vectors in the study area for each of four times during one tidal cycle, i.e., low tide at 13 hours (46,800 seconds), at 17 hours (61,200 seconds), at 20 hours (72,000 seconds), and at 22 hours (79,200 seconds), and high tide at 26 hours (93,600 seconds) are given in Figure 67. The wind vector used during these analyses is toward 280° at 7 m/sec. This wind vector was taken from the data of Scruton, as given in Tables 17 and 18. The resultant wind direction for an area 1° square off Grand Isle, Louisiana, according to Scruton's data, is toward 280°. The speed 7 m/sec was derived from the data of

Glenn, given in Table 108, which shows that 48% of the winds on an annual basis are between 10 and 19 mph, and so 15 mph was chosen as a "mean" or representative wind speed. Table 107 gives numerical data for each current vector per grid in terms of direction (° north) and speed (cm/sec).

Current vectors at 13 hours (46,800 seconds) show a net movement to the north and north-northeast, toward the shore, as would be expected during low tide (Fig. 67A). Strong currents (50 to 60 cm/sec) are evident near the shore or near the landward boundary (Table 107A); this may be a boundary problem not adequately treated by the program, and so a certain amount of reserve is necessary in extrapolating from the grids next to the shoreline.

Current vectors at 17 hours (61,200 seconds) are mainly toward the east (Fig. 67B), and the resultant direction is approximately northeast (45°). Offshore currents are greater than those of low tide (cf Tables 107A and 107B). The currents in the grids near the shore are somewhat reduced but are still strong and still setting in the same general direction (to the east along the shore).

Current vectors at 20 hours (72,000 seconds) shift more to the east than those of 17 hours (Fig. 67C). This projection is approximately at mid-tide, between high and low tide, and the currents in the grids closest to the shore show a substantial decrease in speed (Table 107C), reduced to $\leq$20 cm/sec.

Current vectors at 22 hours (79,200 seconds) show a net movement more to the east (toward 90°) and some to the east by south (about 100°) when compared to 20 hours (cf Figs. 67C and 67D). Speeds are generally reduced, though currents close to the shore show a slight increase over those of 20 hours (Table 107C).

Current vectors at 26 hours (93,600 seconds) show a net movement away from shore to the south (180°); some move to the southwest (about 225°). Current directions near site 1 (grid 14, 17) are toward 218°; in the same general area some currents set toward the southwest (218° to 263°), and some set to west by south. Current speeds in the grids closest to shore are again well developed and strong (up to 75 cm/sec).

B. Casualty Oil Spills

1. Study Conditions

The Hansen model was used to predict the distribution of oil at the two casualty sites, i.e., C_1 and C_2 (Fig. 1). This model is briefly described in a previous section (IV A). The dispersion of oil units per grid per unit time; this means that the cumulative sum of oil units is more than the total of the original spill, and so the projections of distributions and abundances must be viewed with some caution until a more detailed computer program can be developed. However, it is believed that, as order of magnitude estimates, the projections are probably reasonable and valid.

Four wind conditions were used: (1) winds coming out of the northeast or blowing toward 225° at 7 m/sec, (2) winds coming out of the east or blowing toward 280° at 7 m/sec, (3) winds coming out of the southeast or blowing toward 315° at 7m/sec, and (4) winds coming out of the south or blowing toward 360° at 7 m/sec. It is assumed that these winds reflect average or prevailing conditions in the study area (see III C). Table 108 summarizes the study conditions for oil spills projections. No permanent currents or river inputs were used in these preliminary analyses. This should be done, at a later time, in order to reflect more accurately total drift conditions. Initial studies with permanent currents and river inputs provide the circulation with a more northerly set above or north of site 1 and a more westerly set near and about site 2. However, these additions cannot be used until the computer program is developed and refined for such inputs.

Two types of casualty spills were assumed (see II B), i.e., a 500-ton spill and a 30,000-ton spill, both with a release time of 2 hours. The oil was not spilled until the model had operated for 5 hours real time (5 minutes computer time) in order to satisfy the equilibrium requirement.

2. Northeast Winds

Oil spill distribution under northeast winds blowing toward 225° at 7 m/sec. is given in Figures 68, 69, and 70. The distribution of a 30,000-ton spill at C_1 through 20 hours real time is given in Figure 68. Figure 68A shows the distribution of the oil at 7 hours (2 hours after the start of spill). The oil spill has developed a strong east-west axis. Figure 68B shows the distribution of the oil at 15 hours (10 hours after the start of the spill). The east-west axis is still evident, though some discontinuities are present, and the oil is shifting more to the east and to the south. The general drift of the oil is to the south and along an east-west axis. Also, a small amount of oil has moved to the north.

Figure 69 shows the distribution of a 500-ton spill at C_2 through 10 hours of real time. Winds are, as before, blowing toward 225° at 7 m/sec. After 10 hours (5 hours after the start of the spill) the oil has taken an east-west orientation, and some drift is evident to the south. Oil drift is slightly more to the west than to the east.

Figure 70 shows the distribution of a 30,000-ton spill at C_1 through 10 hours real time (5 hours after the start of the spill). Figure 70A shows the oil distribution after 7 hours. The spill is oriented west to east and slightly more to the west than to the east. After 10 hours (Fig. 70B), the spill still has a west to east orientation, but some drift to the south has occurred. The grids due west of C_1, just off Timbalier Bay, show some presence of oil. It is likely that some oil would enter this estuary if further projections were made.

On the basis of northeast winds, C_1 and/or S_1 appear to be "better" locations because the general surface drift does not carry the oil near the estuaries. All the oil spills at C_1 and C_2 have an axis in an east-west direction and some general drift toward the south.

3. <u>East Winds</u>

Figures 71, 72, and 73 show oil spill distribution under easterly winds blowing toward 280° at 7 m/sec. Figure 71 shows the distribution of a 30,000-ton spill at C_1 through a 20-hour time period. Figure 71A shows the oil spill after 7 hours (2 hours after the start of the spill). The orientation of the spill is along an east-west axis and slightly to the west, and some drift is evident toward the north. Figure 71B shows the oil after 10 hours; the east-west axis is still evident, but the drift is no longer to the north. Figure 71C, showing the oil distribution after 15 hours (10 hours after the start of the spill), indicates that the general orientation of the spill is still along an east-west axis, but there is some extension toward the east. The northward movement evident during the initial stages is no longer apparent. Figure 71D shows the oil after 20 hours (15 hours after the start of the spill). The oil distribution is now more to the east than before, but the east-west orientation is still strongly developed.

Figure 72 shows the distribution of a 500-ton spill through a 30-hour (real time) period. Figure 72A shows the distribution after 10 hours (5 hours after the start of the spill). The general orientation of the spill is along an east-west axis, and there is some drift toward the northeast. Figure 72B shows that the oil distribution after 15 hours is still along an east-west axis. Figure 72C indicates the oil distribution after 25 hours. The oil has now shifted more to the east, and some drift is evident toward the north. Figure 72D shows the oil distribution after 30 hours (25 hours after the start of the spill). The net drift is now predominantly to the east and northeast.

Figure 73 shows the distribution of a 30,000-ton spill at C_2 under easterly winds through 30 hours. Figure 73A shows the oil distribution after 10 hours. An east-west axis has developed, and there is shift more to the west than to the east. Figure 73B shows the oil distribution after 15 hours. A strong east-west axis has developed and there is some drift toward the northwest. Figure 73C, which shows the oil distribution after 25 hours, indicates that a shift to the east and northeast has occurred, but the east-west axis is still present. After 30 hours (Fig. 71D) the entire area north of C_2 is covered by oil. It is highly probably the oil would enter all estuaries under these conditions.

Under easterly winds C_1 and/or S_1 appear to be the "better" location. The oil spills have a general orientation along an east-west axis and a slightly stronger easterly component.

4. Southeast Winds

Figures 74, 75, 76, and 77 show oil distribution under southeast winds blowing toward 315° at 7 m/sec. Figure 74 shows the oil distribution of a 500-ton spill at C_1 through a 20-hour period. Figure 74A shows the oil distribution after 7 hours (2 hours after the start of the spill). An east-west axis has developed, slightly stronger to the west, but some movement toward the southwest is also evident. After 10 hours (Fig. 74B) a westerly to southwesterly movement is indicated. Figure 74C shows that after 15 hours the same pattern is evident, i.e., to the west and southwest. Figure 74D shows the oil distribution after 20 hours (15 hours after the start of the spill). Generally the east-west axis is still evident, and there is some drift toward the southwest but also some to the northeast.

Figure 75 shows the oil distribution of a 30,000-ton spill at C_1 through a 20-hour period. The general pattern is the same as for the previous 500-ton spill. However, after 20 hours (Fig. 75D) a drift toward the east is more evident with this larger spill. Figure 75A shows the oil distribution after 7 hours. The oil is oriented along an east-west axis but more to the west. Some drift is evident to the southwest. Figure 75B shows that after 10 hours the westerly and southwesterly drift is more strongly evident. Figure 75C shows the oil distribution after 15 hours. An east-west axis is still developed, and there is some drift to the southwest. Figure 75D shows the oil distribution after 20 hours (15 hours after the start of the spill). The most apparent change is from a west to southwest drift to one toward more to the east.

Figure 76 shows oil distribution of a 500-ton spill at C_2 through 20 hours. After 7 hours (Fig. 76A) an east-west axis begins to develop, and net movement is stronger to the west. Figure 76B shows the oil distribution after 10 hours. Movement is toward the west, and there is some drift toward the south and southwest. Figure 76C shows the oil distribution after 15 hours. Movement is toward the west and to the southwest. Some oil is evident north toward the shore in grids (6, 13 and 7, 14), just off the mouth of Bayou Lafourche. The oil distribution after 20 hours (15 hours after the start of the spill) (Fig. 76D) is still along an east-west axis, but there is some drift to the south. The westerly end of the spill is now close to the Timbalier Bay area.

Figure 77 shows the oil distribution of a 30,000-ton spill at C_2 through a 20-hour period. Figure 77A shows the oil distribution after 7 hours. Net movement is toward the west and northwest. Figure 77B shows the oil distribution after 10 hours. Drift is toward the west and southwest. After 15 hours (Fig. 77C) the westerly movement is more strongly developed and some grids close to the shore are accumulating oil. Figure 77D, showing the oil distribution after 20 hours, indicates general movement still to the west and southwest. The more northerly grids now have oil, suggesting that some oil will intrude into the Timbalier Bay estuary. An easterly movement is also now apparent.

Under southeast winds C_1 and/or S_1 is the "better" location inasmuch as the net movement of oil spills is sufficiently removed so as not to intrude into the estuaries.

5. South Winds

Figures 78A and 78B show oil spill distribution under south winds blowing toward 360° at 7 m/sec. Figure 78A shows the oil distribution of a 30,000-ton spill at C_1 after 20 hours (15 hours after the start of the spill). The spill has an east-west orientation, and some oil is moving slightly to the northwest. Figure 78B shows the oil distribution of a 30,000-ton spill at C_2 after 20 hours. The spill has an east-west orientation but is situated slightly more to the west. Some oil movement is indicated to the northwest, and the grids closest to Timbalier Bay have some oil present.

Under south winds, locations C_1 and/or S_1 appear to be more favorable than C_2 and/or S_2.

6. Summary of Oil Drift Studies

Under the four wind conditions, i.e., out of the northeast, east, southeast, and south, the oil spill is at the two sites roughly assumes, in all cases, an east-west orientation. C_1 and/or S_1 appears to be the "best" location since the prevailing currents, winds, and bathymetry apparently keep the oil away from the shore and hence Louisiana estuaries. The circulation pattern at C_2 and/or S_2 appears to have a net movement toward the northeast and east. The resulting oil spill distributions in this area suggest that the oil is entrained there. This may be an expression of a combination of factors, such as the bathymetry, tidal currents, and land topography. The latter is suggested by the fact that a small crescent area or embayment exists between Timbalier Bay and Southwest Pass.

Table 109 gives monthly wind vectors offshore of Grand Isle, Louisiana. Also given are time estimates for an oil spill to reach shore assuming transport at 3.7% of the wind speed and that transport would be in the direction of the wind. Projections of oil spill by means of Hansen's model, given in Figures 69 through 77, were carried out for ≤ 30 hours (real time). The reason for this limitation was because this program demands a fair amount of computer time and because of the overall schedule limitations of the project itself. Nonetheless, there is one major discrepancy between Table 109 and Figures 69 through 77: the amount of time for the oil to reach the shore. Crude wind data in Table 109 suggest that during 6 months of the year winds come from a beaching direction and hence would provide a more favorable condition if an oil spill were to occur. However, the amount of time required for beaching, using wind drift and direction, ranges from 3 to 20 days. Figures 69 through 70 are based on grids having an area of 29.5 km^2 (11.4 mi^2)--a large area, and so the presence of oil in the grids closest to the shore does not necessarily mean oil will hit the beach or that it will intrude into the estuaries. Nonetheless, oil does reach some of the grids closest to shore in $\leq$30 hours, and so it is probable that with the model beaching time is reached sooner than with wind drift projection only, as given in Table 109. Because the Hansen model has projected offshore currents that roughly duplicate the hydrography of the area, it is assumed that its oil drift projections will be more accurate than those based on wind drift.

C. Chronic Oil Spills

Section II B gives the hypothetical operational spills that might be expected to occur at a Superport. We did not analyze any of these spills with the Hansen model. However, Table 110 (from Ichiye, 1972) gives estimates on the area visible for spills ranging from 1.2 bbl/day to 8.5 bbl/day. The resulting plumes vary from 600 meters wide and 0.5 kilometer long at 1.2 bbl/day to 4,000 meters wide and 24 kilometers long at 8.5 bbl/day.

V. PREDICTED EFFECTS OF OIL SPILLS

A. Estuarine Effects

1. Marsh Grass

The most significant effect that an oil spill could have in the Louisiana area is damage to or alteration of marsh grass production. Though it has been established that there are at least four levels of primary production in the Louisiana marshes, by and large the most significant producer is the marsh grass (Table 48). Marsh grass produces at least 16 times more than any of the other producers; about 50% of the net yield (in the form of detritus) is used by consumers within the estuaries, and about 50% is exported to the offshore area (Fig. 45) and presumably consumed there by the major fishery species (i.e., menhaden and shrimp).

The effects of oil on marsh grass can vary from no damage to extensive damage to the root system and hence death of the plant. The most serious effect would, of course, be the death of the root system. Patrick (1972, unpublished data) has found, for example, that the root system of *Spartina alterniflora* is quite extensive, its root:top dry weight ratio being approximately 12:1. In addition, Crow (1972, unpublished data) has found that regrowth of *S. alterniflora* does not occur when the plant is dosed monthly with a 1% concentration of crude oil. Death of the root system would also undoubtedly accelerate land loss inasmuch as the above data on the root:top ratio suggest that the landholding capacity of this marsh plant is large and important. Oil exposure could damage the top of the marsh grasses by direct exposure or by killing the flowering parts, but this type of damage is considered less serious than if the entire plant were killed because propagation can and does occur from the root system.

2. Microbial Populations

Meyers (1971) and Crow (1972) have shown that yeast populations change in species composition and in absolute numbers when exposed to oil. They also found that the initial population "explosion" becomes significantly reduced after several weeks, presumably because of nutrient (nitrogen and/or phosphorus) depletion. It is unknown whether the alteration of species and numbers would have a significant impact on the initial formation of detritus from the dead marsh grass. In view of this uncertainty, the wisest course is to assume that the effect would be adverse. And, indeed, the effect would be adverse if sufficient detritus were not formed inasmuch as fishery production (i.e., menhaden and shrimp) would undoubtedly show a reduction during the following year.

Oil would tend to be entrained into the back sections of the dendritic or branching flow channels through the marsh grass (see Fig. 79) and also into the more northerly sections of the estuary. Because production of detritus is initiated in this area from the dead marsh grass, the effect could be significant during the next year's fishery harvest.

3. Other Primary Producers

Epiphytic algae are highly clumped about the bottom portions of the stems of marsh grasses, and it is therefore likely that their populations would be severely reduced by exposure to oil. Similarily, benthic algae would be reduced by sinking oil. It is impossible to predict where and when this effect would be manifested, but again the conservative approach would be prudent--that is, assume damage would occur and that its effects would pass throughout the food web.

4. Marsh Edge-Water Interface

Figure 79 shows the general features of the Louisiana estuarine and offshore systems. The marsh edge-water interface is illustrated in detail by means of a "blow-up" picture. Day et al. (1972) and Bennett (1972) have shown that at least 80% of the marsh fauna biomass is located within 50 meters of this interface, and probably most of this is almost directly contiguous to the interface area. The reader is also directed to the marsh picture between the two levees of Figure 79. The important feature in this illustration is that the marsh has a dendritic or branch-like flow pattern, and any intruding oil would extend first into this main series of distributaries and hence suffocation and toxic effects would likely be imposed on the fauna of the interface area.

5. Nutrient Cycle

Estuarine sediments in Louisiana have two major zones: the top, thin, aerobic layer and the bottom, thick, anaerobic (reducing) layer. The presence and/or absence of the aerobic layer is apparently a seasonal phenomenon and important in the nutrient cycling of the marsh (Hutchinson, 1957). If oil were to intrude on extensive mud areas of the marsh, it is likely that it would create a high biological oxygen demand and would cause anaerobic conditions to persist for some time. This may mean that phosphate, an essential nutrient, would be leached and lost from the estuarine system, thereby causing aberrations to the primary production cycle during later seasons or years. Of the two types of crude oils described in Section II B, type A may have a more severe effects on the nutrient cycles because it has a higher proportion of heavier distillates and residuum and hence more of it is likely to sink to the bottom.

6. Fishery Species

The effect of oil on fishery species within the estuaries could be either indirect, by the elimination of their food sources (detritus and/or marsh fauna), or direct, as a result of suffocation and toxic effects. It is likely that, of the two crude oils described in Section II B, type B would be more toxic, at least initially (for about the first 24 hours), because it has a higher proportion of lighter fractions such as gasolines.

The impact of an oil spill on fishery species might be more severe in the open bays and tidal passes because fish are mobile and would likely move away from the marsh edge-water interface if oil intruded. Because the tidal passes (see Fig. 79) are important migratory routes for various aquatic larval forms, they are also areas of considerable vulnerability.

B. Shoreline Effects

The shoreline communities of Louisiana have not been studied adequately. It is assumed, because of the small amount of Gulf shoreline present in Louisiana, that the impact of oil on the shores would be negligible compared to potential estuarine damage. Perhaps the most dangerous potential effect is that oil might tend to move parallel to the shore in response to the littoral currents. Truesdale (1972, unpublished data) believes that the larval forms of the major fishery species also move along with the littoral currents (see Fig. 79) in an effort to find tidal passes into the estuaries. Planktonic forms such as these would be especially susceptible to suffocation and toxic effects from intruding oil.

C. Offshore Effects

Figure 79 shows the major components of the offshore water column. Phytoplankters and zooplankters in the immediate area of the oil plume (casualty or chronic) would undoubtedly be destroyed or greatly reduced. It is possible to assume that the net effect is not significant because these species have a short generation time.

The impact of oil, however, could be more severe on suspended materials (such as detritus) which would tend to accumulate oil and possibly sink. If this effect were on a sufficiently large scale, the impact would be immediate to the fishery species inasmuch as detritus is produced mainly during the spring of the year and its origin and formation are quite different from that of phytoplankton and zooplankton.

Benthic creatures directly below the oil plume would undoubtedly be destroyed or greatly reduced. If this effect were persistent (such as with chronic spills), it could result in extensive areas of reduced benthos. In addition, the sediments might act as a reservoir for the hydrocarbons and thereby release them periodically and reenforce the persistence of chronic or operational spills.

Nekton species offshore would be affected as in the estuarine bays, either by suffocation or toxicicity. Because many of the fishery species are of a schooling type (such as menhaden), this effect could be significant, but it is believed that the size of the offshore area is sufficiently large to mitigate this damage. However, the detailed locations of spawning grounds and/or waters of the major fishery species offshore of Louisiana are unknown, and if the Superport and its operation were located in a prime area for spawning the overall effect could be quite significant.

D. Summary of Predicted Effects

Figure 79 illustrates the important features of Louisiana. The estuaries are considered to be most vulnerable to Superport operations. The major reason for this is because they are the most productive per unit and because they serve as habitats or nurseries for various stages of the major fishery species.

In addition, any oil spill intruding into an estuarine area would tend to accumulate in (1) the marsh edge-water interface, the exact location of the majority of the marsh fauna, and (2) the upper areas of the marsh grass, or toward the "ends" of the dendrite flow channels, where the dead marsh grass (future detritus) also tends to accumulate. Movement of the oil through the tidal passes would also tend to concentrate it in the prime migratory routes of the major fishery species.

Shoreline effects would probably be minimal unless the oil tended to accumulate in those areas having a littoral current. The littoral currents are apparently used by migratory species to find an entrance into the estuaries.

Potential adverse effects to the offshore are considered to be less important than those to the estuarine areas. However, the locations of spawning and/or feeding grounds need to be known in order to keep the effects minimal. Chronic or operational spills will tend to create permanently stressed areas. The extent of these areas needs to be quantified so that compensational techniques can be designed.

VI. RECOMMENDATIONS

1. Tentatively, locations C_1 and/or S_1, farther from the shore, will have less environmental impact on the estuaries of Louisiana than the closer sites C_2 and/or S_2. Other likely areas may exist between S_1 and S_2, but detailed analyses on oil drift projections must be done to verify this. The basis for this recommendation is that the surface currents near and about C_1 and/or S_1 set up surface drift conditions away from the estuaries.
2. If a Superport is established along the Louisiana coast, then only one such port operation should be allowed in order to ensure that adequate environmental controls are meaningfully financed and established.
3. Cleanup procedures analogous to those used by civil defense or hurricane protection should be established. The important features to incorporate in these procedures are immediate containment and rapid cleanup.
4. Protective measures should be taken along all the tidal passes of the port area. Such measures should be designed so as to prevent oil from entering the estuaries but yet not disrupt these migratory areas by construction or during nonemergency times.
5. Strict and meaningful navigational controls should be established for <u>all</u> vessels using the facility and for operation of the facility.
6. Shore development ancillary to Superport operations should be carefully monitored and controlled so as to minimize the impact to the estuaries.

7. Immediate research is needed in the following areas:
    a. Field investigations on the detailed hydrography and meteorology of the Superport area.
    b. Toxicity studies on the effects of various crude oils and their concentrations on planktonic forms of the major fishery species.
    c. Establishment and detailing of the location of the primary spawning waters and/or grounds for the major fishery species.
    d. Formulation and refinement of oil drift models so that effective and accurate projections under all types of conditions can be made.
    e. Additional studies on the effects of oil on marsh grass and microbes.

VII. REFERENCES

Adkins, Gerald. 1972. A Biological Summary of the Shell Oil Company's Fire, Platform B, Gulf of Mexico. La. Wild Life and Fisheries Comm., Bourg. Unpubl. rept., 19 pp.

Ahearn, D. G., W. L. Cook, N. L. Berner and S. P. Meyers. 1971. Degradation of Hydrocarbons by Fungi. Amer. Chem. Soc. Symposium on Oil Biodegradation, Wash., D.C., 9 pp.

Alpine Geophysical Associates, Inc. 1971. Oil Pollution Incident; Platform Charlie, Main Pass Block 41 Field, Louisiana. Proj. No. 15080 FTU, Contr. 14-12-860. U.S. Gov't. Print. Off., Stock No. 5501-0130.

Austin, G. B., Jr. 1955. Some Recent Oceanographic Surveys of the Gulf of Mexico. Trans. Amer. Geophys. Union, 36(5):855-892.

Barrett, B. B. 1971. Cooperative Gulf of Mexico Estuarine Inventory and Study, Louisiana. Phase II, Hydrology and Phase III, Sedimentology. La. Wild Life and Fisheries Comm.

Bates, C. C. 1953a. Rational Theory of Delta Formation. Bull. Amer. Assoc. Petrol. Geol., 37(9):2219-2162.

Bates, C. C. 1953b. Physical and Geological Process of Delta Formation. Texas A&M Univ., Bryan, Ph.D. dissertation.

Becker, R. E. 1972. Wave Energy Studies along the Louisiana Coast. Rept. No. 12, Hydrologic and Geologic Studies of Coastal Louisiana, La. State Univ., Baton Rouge, Center for Wetland Resources, 22 pp.

Bouma, A. H., F. B. Chmelik and R. Rezak. 1971. East Bay, Mississippi River Delta. Trans. Gulf Coast Assoc. Geol. Soc., pp. 273-289.

Bretschneider, C. L. and R. D. Gaul. 1956. Wave Statistics for the Gulf of Mexico off Burrwood, Louisiana. U.S. Corps of Engrs., Beach Erosion Board, Tech. Memo 87, 25 pp., plus appendices A, B, and C.

Brower, W. A., D. D. Sisk and R. G. Quayle. 1972. Environmental Guide for Seven U.S. Ports and Harbor Approaches. NOAA, Natl. Climatic Center, Asheville, N.C.

Chabreck, R. H. 1970a. Marsh Zones and Vegetative Types in the Louisiana Coastal Marshes. La. State Univ., Baton Rouge, Ph.D. dissertation, 113 pp.

Chabreck, R. H. 1970b. Vegetation and Size of Hydrologic Units along the Louisiana Coast. Rept. by La. Co-op Wildlife Unit to U.S. Corps of Engrs. and La. Wild Life and Fisheries Comm., New Orleans.

Chabreck, R. H. 1971. Soil and Water Chemical Data for the Louisiana Coastal Marshes. Rept. by La. Co-op Wildlife Unit to U.S. Corps of Engrs. and La. Wild Life and Fisheries Comm., New Orleans.

Chew, Frank, K. L. Drennan and W. J. Demoran. 1962a. Some Results of Drift Bottle Studies off the Mississippi Delta. Limnol. and Oceanog., 7(2):252-257.

Chew, Frank, K. L. Drennan and W. J. Demoran. 1962b. On the Temperature Field East of the Mississippi Delta. J. Geophys. Res., 67(1):271-279.

Coleman, J. M. 1972. Foundation Characteristics off Louisiana Coast. La. State Univ., Baton Rouge, Coastal Studies Inst., unpubl. ms., 14 pp.

Coleman, J. M. and S. M. Gagliano. 1965. Sedimentary Structures: Mississippi River Deltaic Plain. La. State Univ., Baton Rouge, Coastal Studies Inst., Tech. Rept. No. 16(H):133-148.

Conatser, W. E. 1971. Grand Isle: A Barrier Island in the Gulf of Mexico. Geol. Soc. Amer. Bull. 82:3049-3068.

Court, Arnold and R. D. Gerston. 1966. Fog Frequency in the United States. Geog. Rev., 56:543-550.

Cronin, E. L. 1971. Preliminary Analysis of the Ecological Aspects of Deep Port Creation and Supership Operation. Rept. to U.S. Corps of Engrs., Alexandria, Va. by Natural Res. Inst., Univ. of Maryland.

Crow, S. A., Jr. 1972. The Effect of Louisiana Crude Oil on Estuarine Yeast Populations. La. State Univ., Baton Rouge, Master's thesis, 79 pp.

Curray, J. R. 1960. Sediments and History of Holocene Transgression, Continental Shelf, Northwest Gulf of Mexico. In Recent Sediments, Northwest Gulf of Mexico, F. P. Shepard et al. (eds.), Amer. Assoc. Petrol. Geol., Tulsa, Okla., pp. 221-264.

Cuzon du Rest, R. P. 1963. Distribution of the Zooplankton in the Salt Marshes of Southeastern Louisiana. Univ. of Texas, Port Aransas, Inst. of Mar. Sci., 9(12):132-155.

Duxbury, A. C. 1962. Averaged Dynamic Topographies of the Gulf of Mexico. Limnol. and Oceanog., 7(3):428-431.

Fisk, H. N., E. McFarlan, Jr., C. R. Kolb and L. J. Wilbert, Jr. 1954. Sedimentary Framework of the Modern Mississippi Delta. J. Sed. Petrology, 24(2):76-99.

Franks, J. S., J. Y. Christmas, W. L. Siler, R. Combs, R. Waller and C. Burns. 1972. A study of nektonic and benthic faunas of shallow Gulf of Mexico - Mississippi. Gulf Coast Res. Lab, Ocean Springs, 148 pp.

Frazier, D. E. 1967. Recent Deltaic Deposits of the Mississippi River: Their Development and Chronology. Trans. Gulf Coast Assoc. Geol. Soc., 17:287-315.

Gagliano, S. M., H. J. Kwon, P. Light, J. S. Peake and J. L. van Beek. 1970. Selected Environmental Parameters of Coastal Louisiana, 1945, 1946, 1959-1965. Rept. No. 10, La. State Univ., Baton Rouge, Center for Wetland Resources, Hydrologic and Geologic Studies of Coastal Louisiana.

Gagliano, S. M. and J. W. Day, Jr. 1972. Environmental Aspects of a Superport off the Louisiana Coast. Rept. No. 1, Preliminary Recommendations and Data Analyses, Louisiana Superport Studies. La. State Univ., Baton Rouge, Center for Wetland Resources, Publ. No. LSU-SG-72-03, pp. 281-317.

Gagliano, S. M., P. L. Light and R. E. Pecker. 1972. Controlled Diversions in the Mississippi Delta System: An Approach to Environmental Management. La. State Univ., Baton Rouge, Center for Wetland Resources, Hydrologic and Geologic Studies of Coastal Louisiana, Rept. No. 8.

Galtsoff, Paul S. (ed.) 1954. Gulf of Mexico: Its Origin, Waters, and Marine Life. U.S. Fish and Wildlife Service, Vol. 55, Fish. Bull. No. 89, 580 pp.

Geyer, R. A. 1970. The Multi-User Zone of the Gulf of Mexico - Its Promise and Problems. Water Resources Bull., 6(4):429-436.

Glenn, A. H. 1972. Meteorological-Oceanographic Conditions Affecting Tanker Terminal Design and Operations: Grand Isle Block 46, 110 Foot Mean Low Water Depth, Offshore Louisiana. Private rept. to Marathon Pipeline Co., Houston, Texas.

Hacker, Simon, R. W. Pike and Bert Wilkins, Jr. 1971. Analysis of the Energy, Mass, and Momentum Transfer in the Louisiana Coastal Marsh Region. La. State Univ., Baton Rouge, Coastal Studies Inst. Bull. No. 6 (Special Sea Grant Issue), pp. 109-153.

Ho, C. L. 1971. Seasonal Changes in Sediment and Water Chemistry in Barataria Bay. La. State Univ., Baton Rouge, Coastal Studies Inst. Bull. No. 6 (Special Sea Grant Issue), pp. 67-84.

Hood, M. A. 1970. A Bacterial Study of an Estuarine Environment: Barataria Bay, 1970. La. State Univ., Baton Rouge, Master's thesis.

Hope, J. R. and C. J. Neumann. 1969. Climatology of Atlantic Tropical Cyclones by Two and One-Half Degree Latitude-Longitude Boxes. U.S. Dept. of Commerce, ESSA, Tech. Memo WBTM SR-44.

Howcott, H. B. 1972. Observations, Notes, Correlations: South Pass, Louisiana Fishing. New Orleans Big Game Fishing Club Information, unpubl. ms.

Hutchinson, G. E. 1957. A Treatise on Limnology: Volume I, Geography, Physics, and Chemistry. John Wiley & Sons, Inc., New York, pp. 701-704.

Ichiye, Takashi. 1972. Hydrodynamic Problems Concerning Oil Spillage in the Ocean. Texas A&M Univ., Dept. of Oceanog., prelim. rept.

June, F. C. and F. T. Carlson. 1971. Food of Young Atlantic Menhaden, Brevortia tyrannus, in Relation to Metamorphosis. U.S. Fish and Wildlife Service, Fishery Bull. 68(3):493-512.

Laevastu, T. 1972. Reproduction of Currents and Water Exchange in the Strait of Gibraltar with Hydrodynamical Numerical (HN) Model of Walter Hansen. Studies in Physical Oceanography, Vol. 1, Gordon & Breach, N.Y., paper No. 24.

Laevastu, T. and K. Rabe. 1972. A Description of the EPRF Hydrodynamical-Numerical Model. Naval Postgraduate School, Monterey, Cal., Environmental Prediction Research Facility.

Larsen, S. and T. Laevastu. 1972. Numerical Analysis of Ocean Surface Currents. Instituto Universitario Navale di Napoli (Naples, Italy), Inst. di Meteorologia e Oceanographia, pp. 55-74.

Leipper, D. F. 1954. Marine Meteorology of the Gulf of Mexico, a Brief Review. In Gulf of Mexico: Its Origin, Waters, and Marine Life. U.S. Fish and Wildlife Service, Vol. 55, Fishery Bull. 89: 89-98.

Leipper, D. F. 1970. A Sequence of Current Patterns in the Gulf of Mexico. J. Geophys. Res., 75(3):637-657.

Lindall, Jr., W. N., J. R. Hall, J. E. Sykes and E. L. Arnold, Jr. 1972. Louisiana Coastal Zone: Analyses of Resources and Resource Development Needs in Connection with Estuarine Ecology. Sections 10 and 13, Fishery Resources and Their Needs. Rept. to U.S. Corps of Engrs., New Orleans, Contr. No. 14-17-002-430, unpubl. rept., 323 pp.

Louisiana State Parks and Recreation Commission. 1971. State of Louisiana Outdoor Recreation Plan, Baton Rouge.

Louisiana State University in New Orleans. 1971. Statistical Abstract of Louisiana. Div. of Business and Econ. Res., Coll. of Business Admin.

Louisiana Wild Life and Fisheries Commission. 1968-69. 13th Biennial Report.

Louisiana Wild Life and Fisheries Commission. 1970-71. 14th Biennial Report.

Lund, E. J. 1957. Effect of Bleedwater, 'Soluble Fraction' and Crude Oil on the Oyster. Univ. of Texas, Inst. Mar. Sci., 4(2):328-341.

Mackin, J. G. and S. H. Hopkins. 1961. Studies on Oysters in Relation to the Oil Industry. Univ. of Texas, Inst. of Mar. Sci., Vol. 7.

Marmer, H. A. 1954. Tides and Sea Level in the Gulf of Mexico. In Gulf of Mexico: Its Origin, Waters and Marine Life, U.S. Fish and Wildlife Service, Vol. 55, Fishery Bull. 89:101-118.

McLellan, H. J. and W. D. Nowlin. 1963. Some Features of the Deep Water in the Gulf of Mexico. J. Mar. Res., 21(3):233-245.

Meyers, S. P. 1971. The Impact of Microorganisms on Oil. Federal Quality Control Admin. Proj. 18080 CDJ, Environmental Protection Agency Progress Rept. for Sept. 1970 through August 1971.

Mills, E. R. and D. D. Culley, Jr. 1970. Toxicity of Various Offshore Crude Oils to Marine and Estuarine Shrimp. La. State Univ., Baton Rouge, Forestry and Wildlife Management School, Fisheries Section, unpubl. ms.

Moore, G. T. 1970. Role of Salt Wedge in Bar-Finger Sand and Delta Development. Amer. Assoc. Petrol. Geol. Bull. 54(2):326-333.

Moore, S. F. 1972. A Simple Model for Estimating the Weathering of Oil. A draft, not for publication.

Morgan, J. P. 1967. Ephemeral Estuaries of the Deltaic Environment. In Estuaries, G. H. Lauff (ed.). Amer. Assoc. Adv. Sci., Publ. No. 83:115-120.

Morgan, J. P. 1972. Impact of Subsidence and Erosion on Louisiana Coastal Marshes and Estuaries. Preprint for Coastal Marsh and Estuary Symposium, La. State Univ., Baton Rouge, July 1972.

Morgan, J. P., J. M. Coleman and S. M. Gagliano. 1963. Mudlumps at the Mouth of South Pass, Mississippi River; Sedimentology, Paleontology, Structure, Origin, and Relation to Deltaic Processes. La. State Univ., Baton Rouge, Coastal Studies Inst. Series No. 10, 190 pp.

Morgan, J. P., J. M. Coleman and S. M. Gagliano. 1968. Mudlumps: Diapiric Structures in Mississippi Delta Sediments. In Diapirism and Diapirs, Amer. Assoc. Petrol. Geol., Memoir No. 8, pp. 145-161.

Murray, S. P. 1972. Turbulent Diffusion of Oil in the Ocean. Limnol. and Oceanog. 17(5):651-660.

Murray, S. P., W. G. Smith and C. J. Sonu. 1970. Oceanographic Observations and Theoretical Analysis of Oil Slicks During the Chevron Spill, March 1970. La. State Univ., Baton Rouge, Coastal Studies Inst., Tech. Rept. No. 87.

Nathan, Robert R. 1972. U.S. Deepwater Port Study. Annex I-B, Crude Petroleum and Petroleum Products; Annex IV, The Environmental and Ecological Aspects of Deepwater Ports. Prepared for U.S. Corps of Engrs., Inst. for Water Resources, unpubl. repts.

Nowlin, W. D. 1971. Water Masses and General Circulation of the Gulf of Mexico. Oceanol. Intern., 6(2):28-33.

Nowlin, W. D., J. M. Hubertz and R. O. Reid. 1968. A Detached Eddy in the Gulf of Mexico. J. Mar. Res., 26(2):117-118.

Nowlin, W. D. and H. J. McLellan. 1967. A Characterization of the Gulf of Mexico Waters in Winter. J. Mar. Res., 25(1):25-59.

Odum, W. E. 1971. Pathways of Energy Flow in a South Florida Estuary. Univ. of Miami, Sea Grant Tech. Bull. No. 7.

Odum, W. E. and A. A. de la Cruz. 1967. Particulate Organic Detritus in a Georgia Salt Marsh-Estuarine Ecosystem. In Estuaries, G. H. Lauff (ed.). Amer. Assoc. Adv. Sci., Publ. No. 83:383-388.

Odum, W. E., J. C. Zieman and E. J. Heild. 1972. The Importance of Vascular Plant Detritus to Estuaries. Paper read at Coastal Marsh and Estuary Symposium, La. State Univ., Baton Rouge, July 1972.

Orton, Robert B. 1964. The Climate of Texas and the Adjacent Gulf Waters. U.S. Dept. of Commerce, Weather Bureau, Wash., D.C.

Parker, R. H. 1956. Macro-Invertebrate Assemblages as Indicators of Sedimentary Environments in East Mississippi Delta Region. Bull. Amer. Assoc. Petrol. Geol., 40(2):295-376.

Parker, R. H. and J. R. Curray. 1956. Fauna and Bathmetry of Banks on Continental Shelf, Northwest Gulf of Mexico. Bull. Amer. Assoc. Petrol. Geol., 40(1):2428-2439.

Paulus, W. C. 1972. Physical Processes of the Marine Environment (Oil Movement Forecasting). U.S. Naval Oceanographic Office, unpubl. rept.

Peake, J. S. and R. A. Muller. 1971. Fog in Louisiana. La. State Univ., Baton Rouge, Dept. of Geography and Anthropology, unpubl. rept.

Penfound, W. T. and E. S. Hathaway. 1938. Plant Communities in the Marshland of Southeastern Louisiana. Ecol. Monogr. 8:1-56.

Perret, W. S., B. B. Barrett, W. R. Latapie, J. F. Pollard, W. R. Mock, G. B. Adkins, W. J. Gaidry and C. J. White. 1971. Cooperative Gulf of Mexico Estuarine Inventory and Study, Louisiana. Phase I, Area Description and Phase IV, Biology. La. Wild Life and Fisheries Comm.

Pomeroy, L. R. 1970. The Strategy of Mineral Cycling. In Annual Review of Ecology and Systematics, R. F. Johnston, P. W. Frank and C. D. Michener (eds.), Annual Reviews, Inc., Palo Alto, Cal., Vol. 1:171-190.

Redfield, A. C. 1958. The Biological Control of Chemical Factors in the Environment. Amer. Scientist, 46(3):205-221.

Redfield, A. C., B. H. Ketchum and F. A. Richards. 1963. The Influence of Organisms on the Composition of Sea-Water. In The Sea, M. N. Hill (ed.). Interscience Publishers, John Wiley and Sons, N.Y., Vol. 2:26-77.

Resources Technology Corporation. 1972. Studies and Investigations of the Fate and Effect of the Shell Oil Spill, Platform B, Block 26, South Timbalier Bay, December 1, 1970 through November 30, 1971. Final Rept., Contr. 68-01-0051, prepared for Environmental Protection Agency.

Riley, G. E. 1937. The Significance of the Mississippi River Drainage for Biological Conditions in the Northern Gulf of Mexico. J. Mar. Res., 1(1):60-74.

Rivas, L. R. 1968. Fishermen's Atlas of Monthly Sea Surface Temperatures for the Gulf of Mexico. U.S. Fish and Wildlife Service, Circ. 300; Univ. of Miami Contr. No. 58.

Rounsefell, G. A. 1972. Ecological Effects of Offshore Construction. Mar. Sci. Inst., Bayou LaBatre, Ala., J. Mar. Sci., 2(1).

Russell, R. J. 1967. Origins of Estuaries. In Estuaries, G. H. Lauff (ed.). Amer. Assoc. Adv. Sci., Publ. No. 83:93-99.

Schelske, C. L. and E. P. Odum. 1962. Mechanisms Maintaining High Productivity in Georgia Estuaries. Proc. Gulf Carib. Fish. Inst., 14:75-80.

Scruton, P. C. 1956. Oceanography of Mississippi Delta Sedimentary Environments. Bull. Amer. Assoc. Petrol. Geol., 40(12):2864-2952.

Shepard, F. P. 1960. Mississippi Delta: Marginal Environments, Sediments and Growth. In Recent Sediments, Northwest Gulf of Mexico, 1951-1958. Amer. Assoc. Petrol. Geol., Tulsa, Okla., pp. 56-81.

Simpson, R. H. and M. B. Lawrence. 1971. Atlantic Hurricane Frequencies along the U.S. Coastline. NOAA Tech. Memo, NWS SR-58, Southern Region, Ft. Worth, Texas.

Sonu, C. J., S. P. Murray and W. G. Smith. 1971. Environmental Factors Controlling the Spread of Oil: An Investigation of the Chevron Oil Spill, March 1970. Naval Res. Rev. 24(8):11-19.

Soros Associates, Inc. 1971a. Evaluation of Offshore Terminal System. Rept. to U.S. Maritime Admin. Study.

Soros Associates, Inc. 1971b. Evaluation of Offshore Terminal System Concepts. Statement of Work, RFP No. 1-35409.

Stacy, Gus. 1972. State of Louisiana Comprehensive Outdoor Recreation Plan, 1970-75. Rept. by La. State Parks and Recreation Comm.

St. Amant, L. S. 1972. The Petroleum Industry as it Affects Marine and Estuarine Ecology. J. Petrol. Tech., April, pp. 385-492.

Stevenson, R. E. 1967. Gulf Oceanography Program. U.S. Fish and Wildlife Service, Bur. Comm. Fisheries, Circ. No. 268:33-43.

Stone, J. H. 1972. Predictive Variables for Fishery Harvest off the Louisiana Coast. La. State Univ., Center for Wetland Resources, Sea Grant Proj., unpubl. ms.

Texas Instruments. 1971a. Oceanographic and Remote-Sensing Survey in the Vicinity of the Shell Oil Spill, Gulf of Mexico. Rept. prepared for Environmental Protection Agency, Contr. No. 68-01-0017.

Texas Instruments. 1971b. Supplement of Oceanographic and Remote-Sensing Survey in the Vicinity of the Shell Spill, Gulf of Mexico. Rept. prepared for Environmental Protection Agency, April 1971.

Thomas, Jim and Harold Loesch. 1970. Some Notes on Fish Collected in the Barataria Bay, Louisiana Region. La. State Univ., Baton Rouge, Coastal Studies Inst. Bull. No. 5 (Special Sea Grant Issue), pp. 83-87.

Trivedi, H. K. 1972. Transport Phenomena in Barataria Bay. La. State Univ., Baton Rouge, Reacting Fluids Lab., Dept. of Chem. Engrs. Research Proposal, May 1972.

Van Andel, T. H. and D. Poole. 1969. Sources of Recent Sediment in the Northern Gulf of Mexico. J. Sed. Petrology, 30(1):91-122.

Wagner, P. R. 1973. Seasonal Biomass, Abundance, and Distribution of Estuarine Dependent Fishes in the Caminada Bay System of Louisiana. La. State Univ., Baton Rouge, Dept. of Mar. Sci., Ph.D. dissertation (in preparation).

Walsh, Don. 1969. Characteristic Patterns of River Outflow in the Mississippi Delta. Texas A&M Univ., Dept. of Oceanography, Ref. No. 69-8-T, 222 pp.

Wright, L. D. 1970. Circulation, Effluent, Diffusion, and Sediment Transport, Mouth of South Pass, Mississippi River Delta. La. State Univ., Baton Rouge, Coastal Studies Inst. Tech. Rept. No. 84, 56 pp.

Wright, L. D. and J. M. Coleman. 1971. River Delta Morphology: Wave Climate and the Role of the Subaqueous Profile. Science, 176(4032): 282-284.

ZoBell, C. E. and J. H. Prokop. 1966. Microbial Oxidation of Mineral Oils in Barataria Bay Bottom Deposits. Zeitschrift für Allgemein Mikrobiologie, 6(3):143-162.

U.S. Army Corps of Engineers. 1950-1970. Stages and discharges, Mississippi River and its outlets and tributaries. U.S. Army Engineers Dist., New Orleans, La.

U.S. Department of Commerce. 1931-1971. Climatological data - Louisiana.

U.S. Department of Commerce. Surface water temperature and density, Atlantic coast, north and south America. Publ. 31-1: 1st edition, 1960; 2nd edition, 1965; and 3rd edition, 1968.

U.S. Department of Commerce. 1970. Louisiana Landings. Natl. Mar. Fisheries Serv., and La. Wild Life and Fisheries Comm.

U.S. Naval Weather. 1970. Summary of synoptic meteorological observations, North American coastal marine areas, Vol. 6, Area 17 (New Orleans).

U.S. Weather Bureau. 1971. National Climatic Summary.

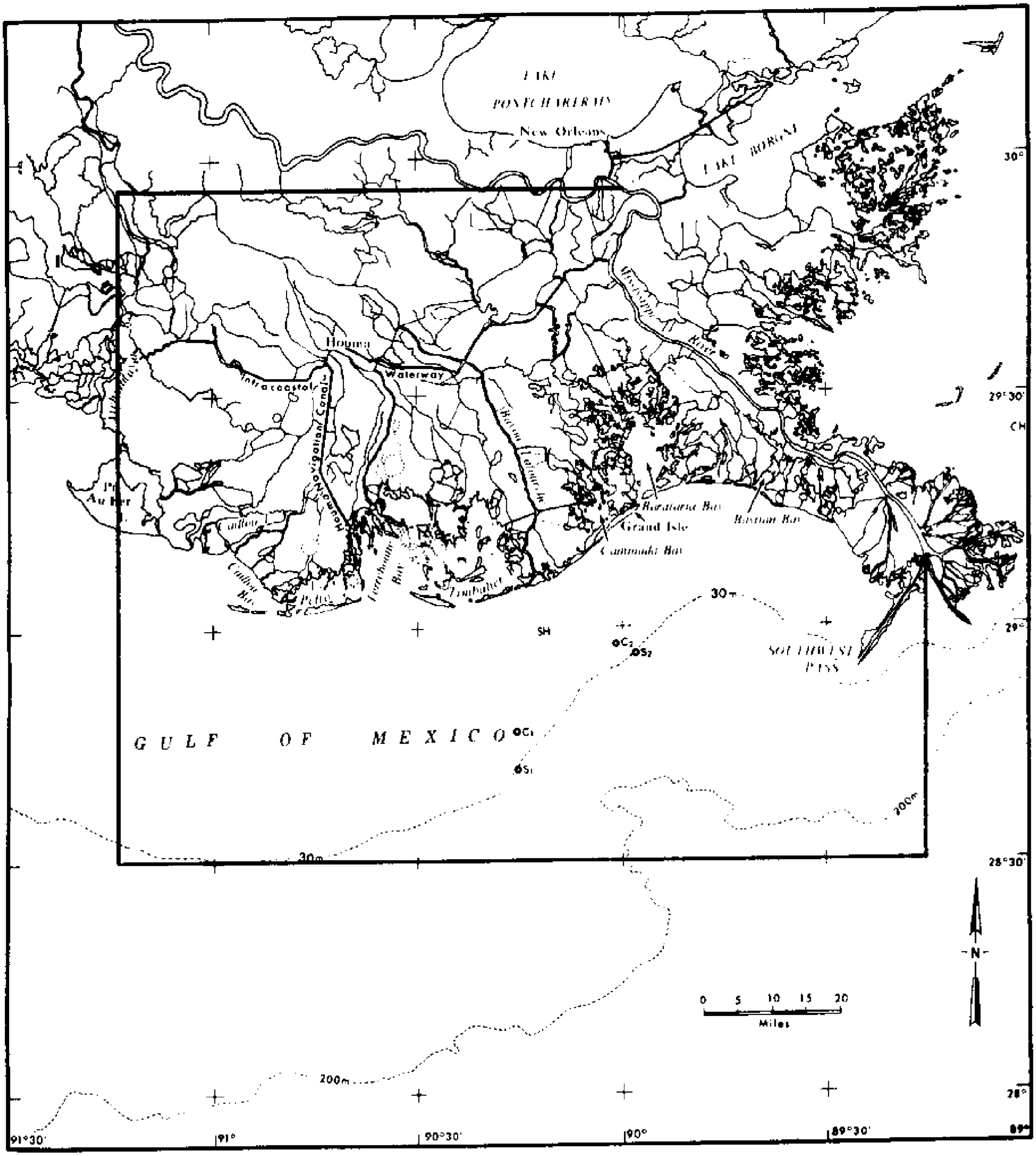


Figure 1. Geographic context of study area in Louisiana. S_1 and S_2 are the locations of a hypothetical Superport facility, and C_1 and C_2 are the locations of hypothetical casualty spills. CH is the location of the Chevron Platform spill in 1970, and SH is the location of the Shell platform spill in 1971.

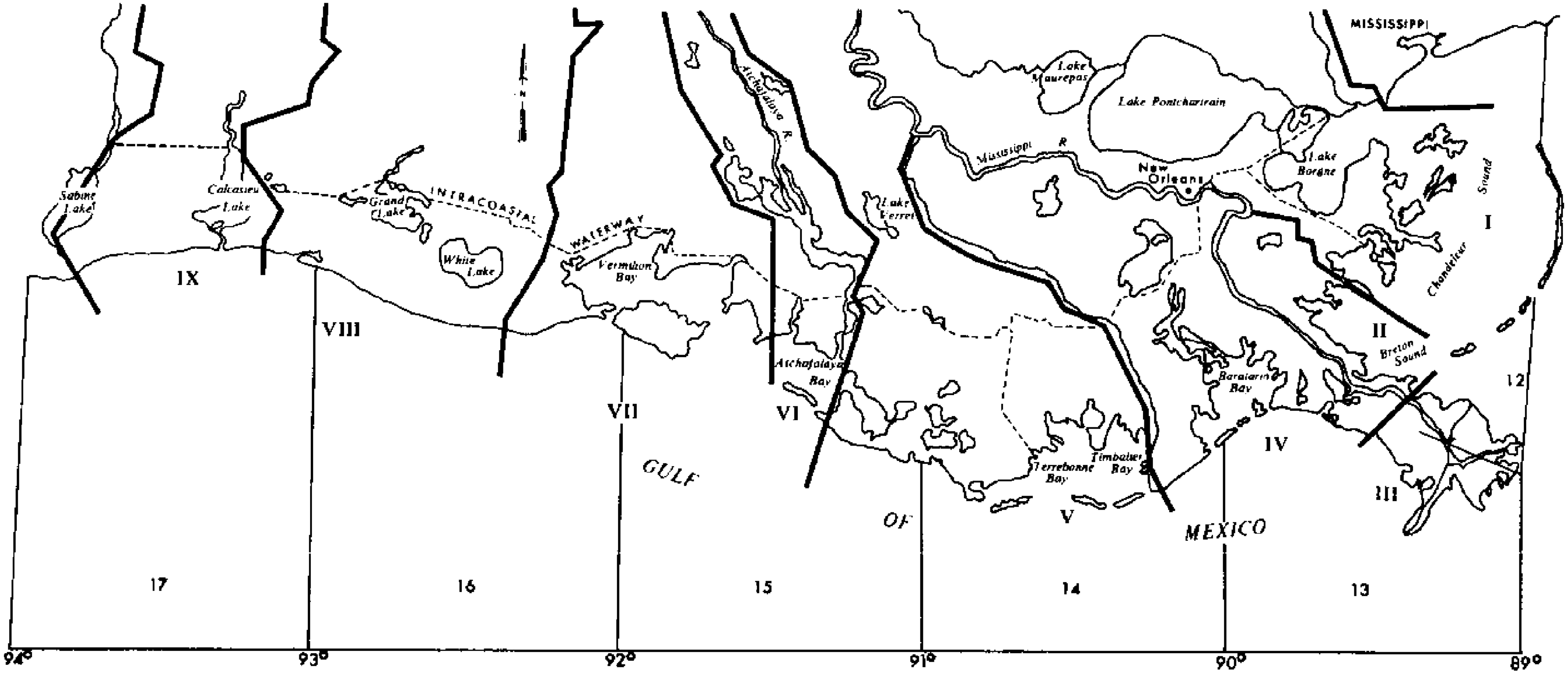


Figure 2. Coastal zone of Louisiana showing natural catchment basins (hydrologic units I-IX) offshore commercial fishing grids (12-17) and major bays, lakes, and rivers (adapted from Lindall et al., 1972).

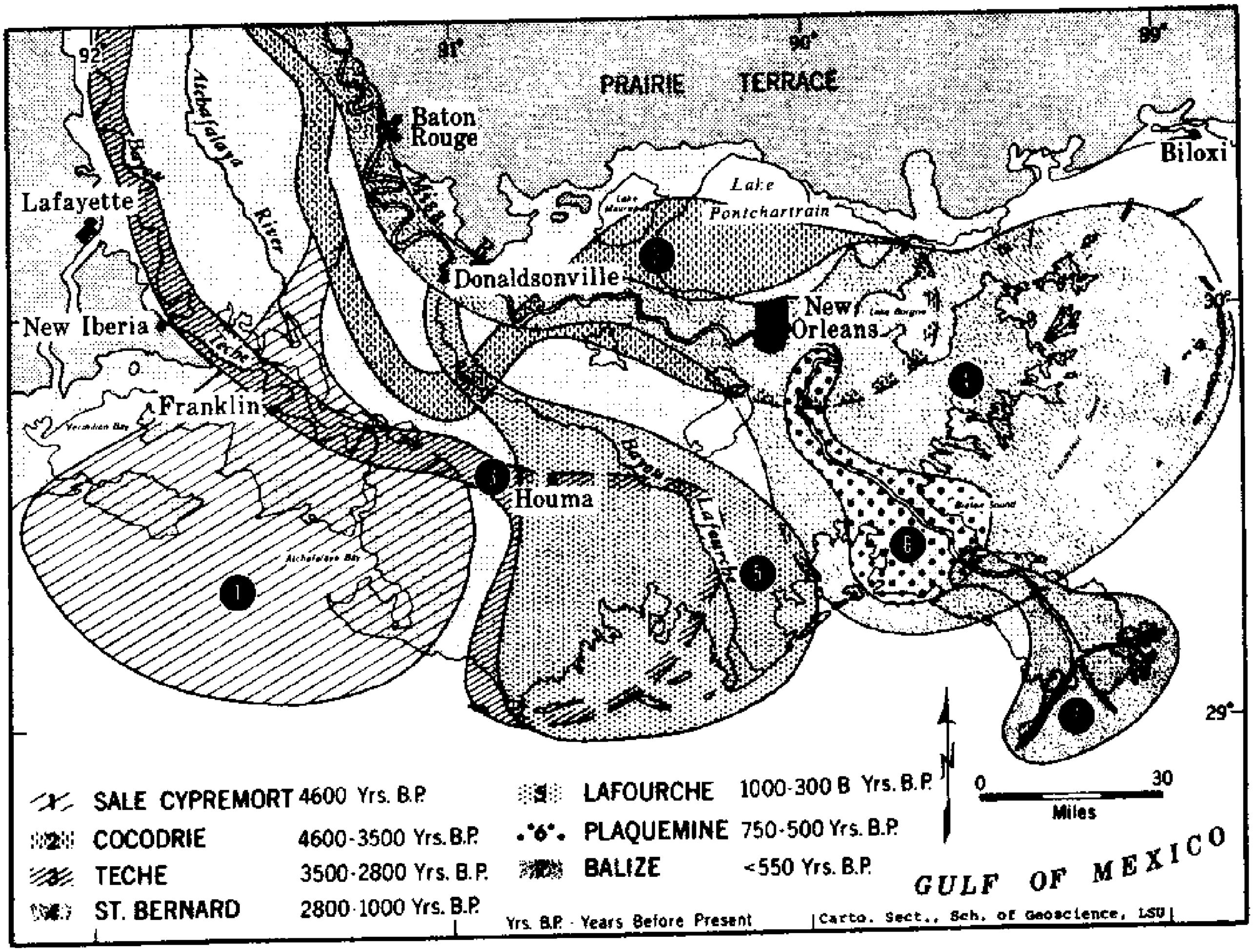


Figure 3. Chronology of the deltas that comprise the Mississippi River deltaic plain (from Kolb and Van Lopik, 1958).

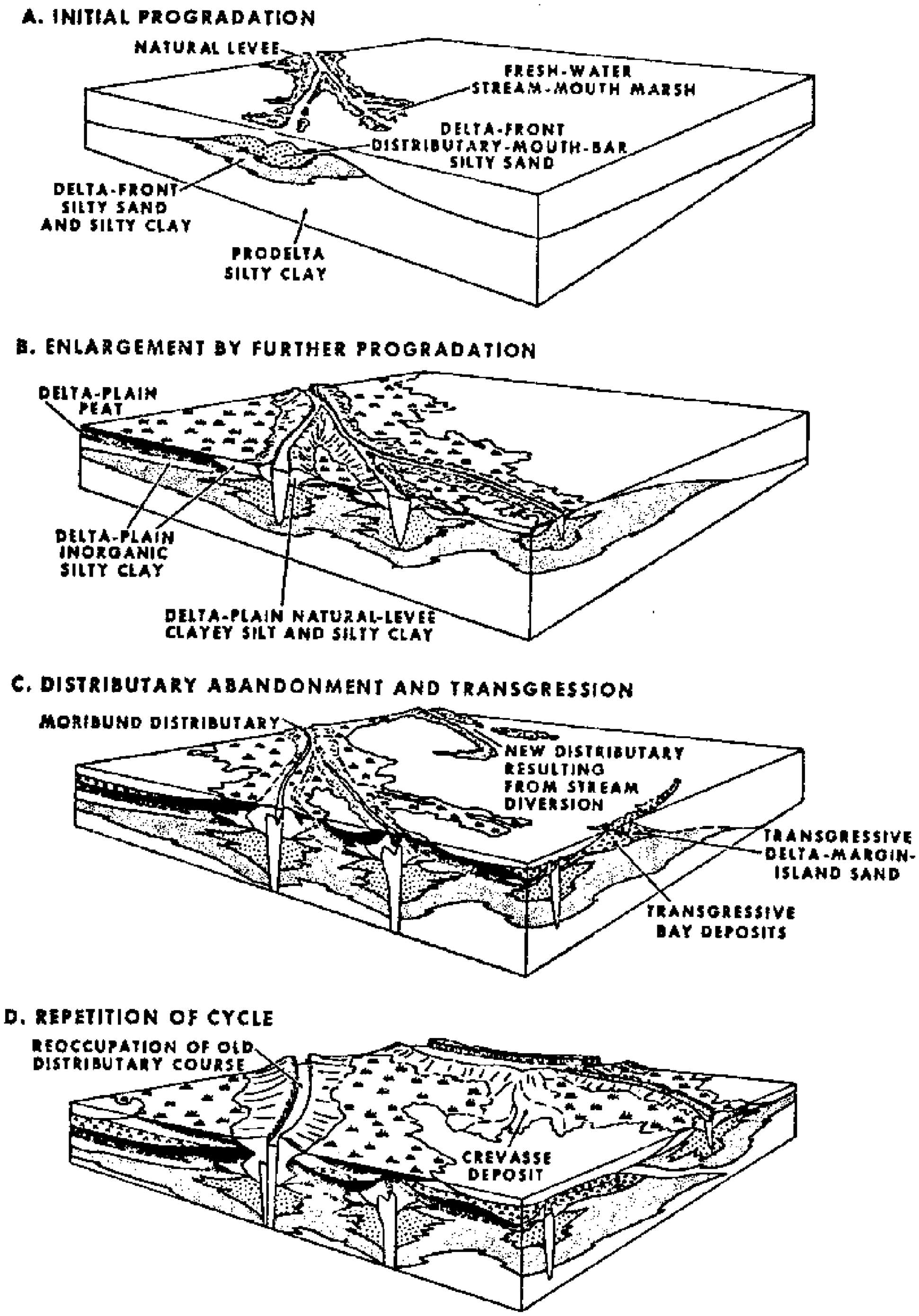


Figure 4. Sequence of development of deltaic facies (from Frasier, 1967).

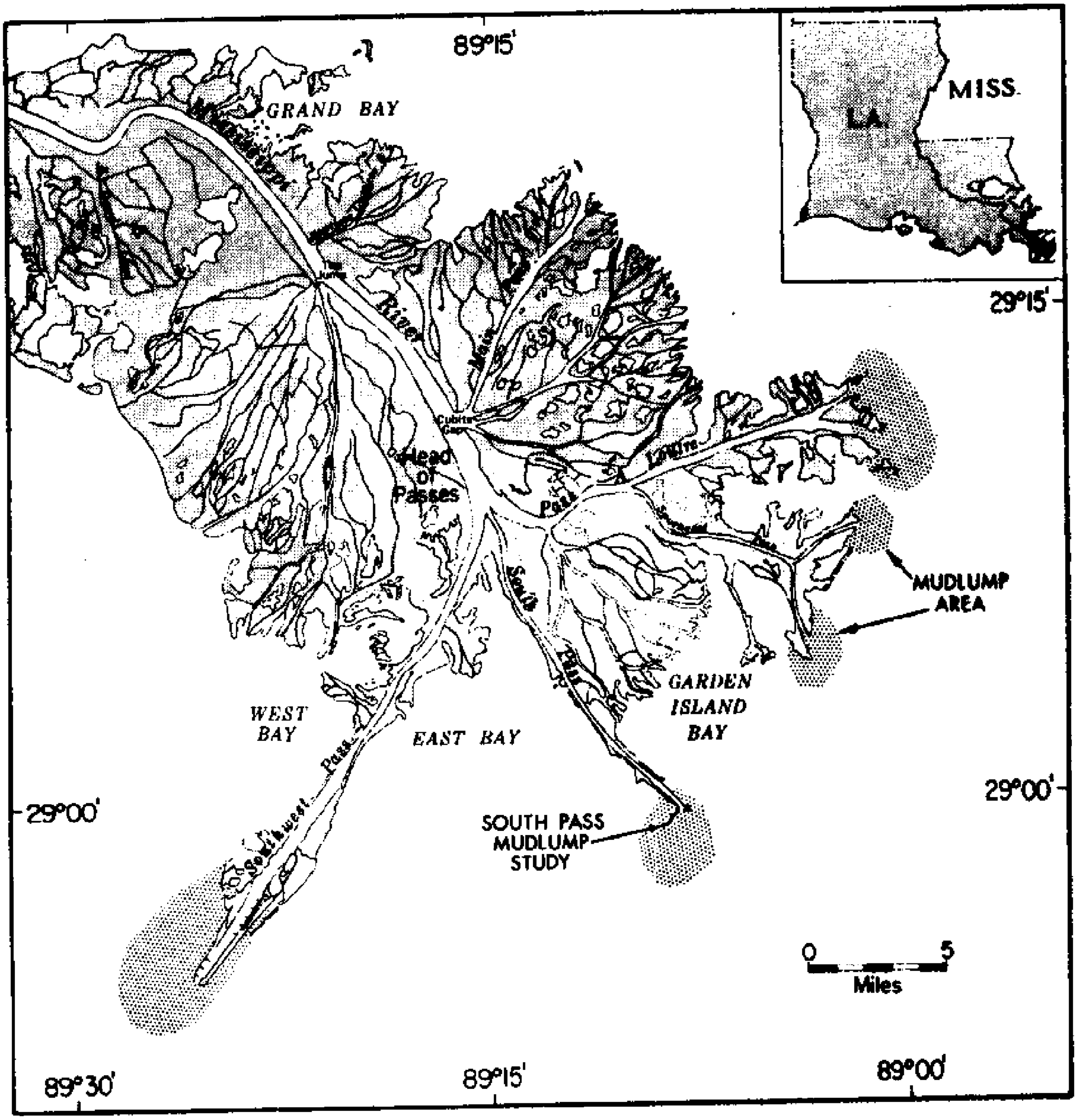


Figure 5. Areas of mudlump development at distributary mouths of Mississippi River delta (from Morgan, Coleman, and Gagliano, 1968).

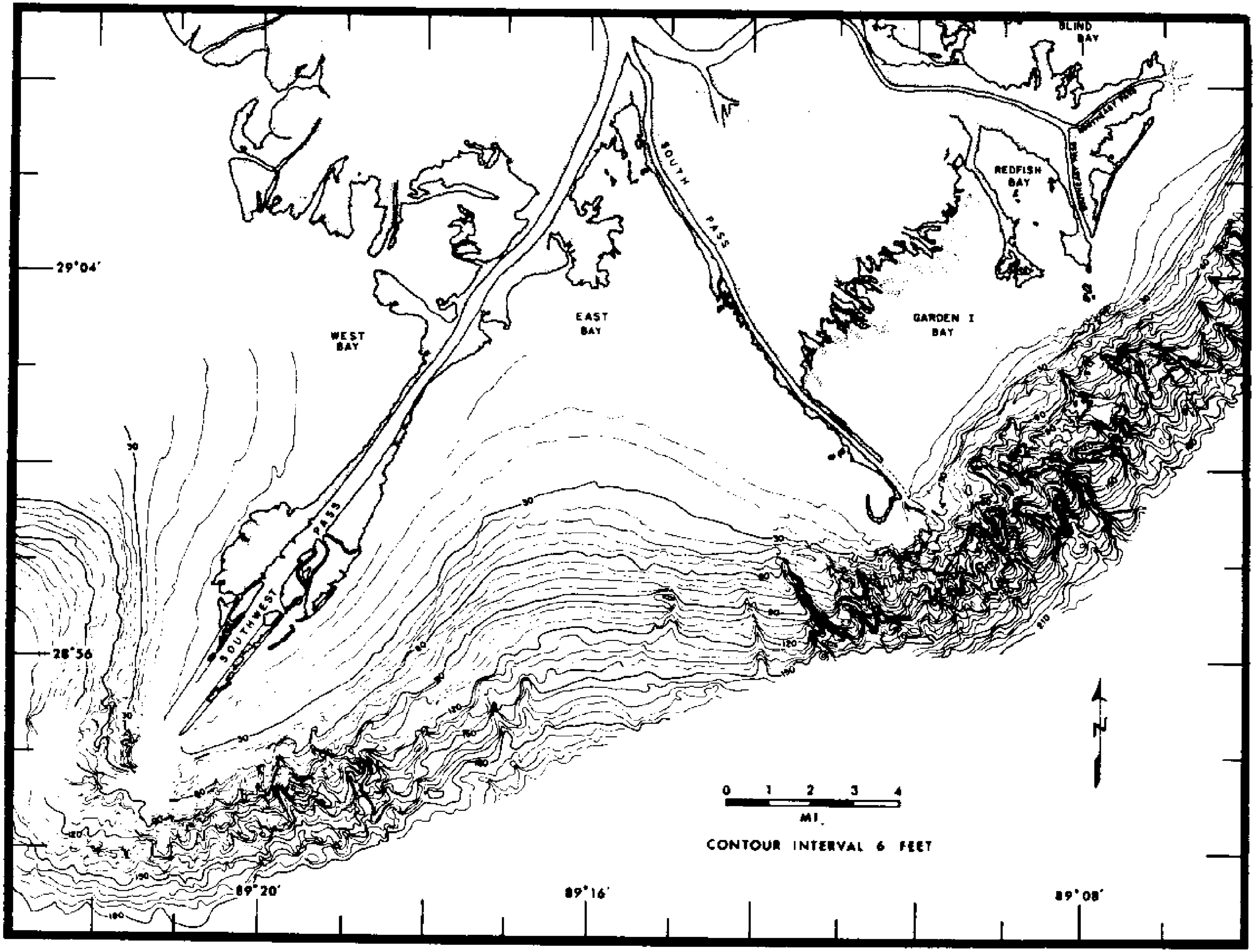


Figure 6. Submarine topography of the upper slope of the Mississippi Delta platform (from Gagliano and Day, 1972).

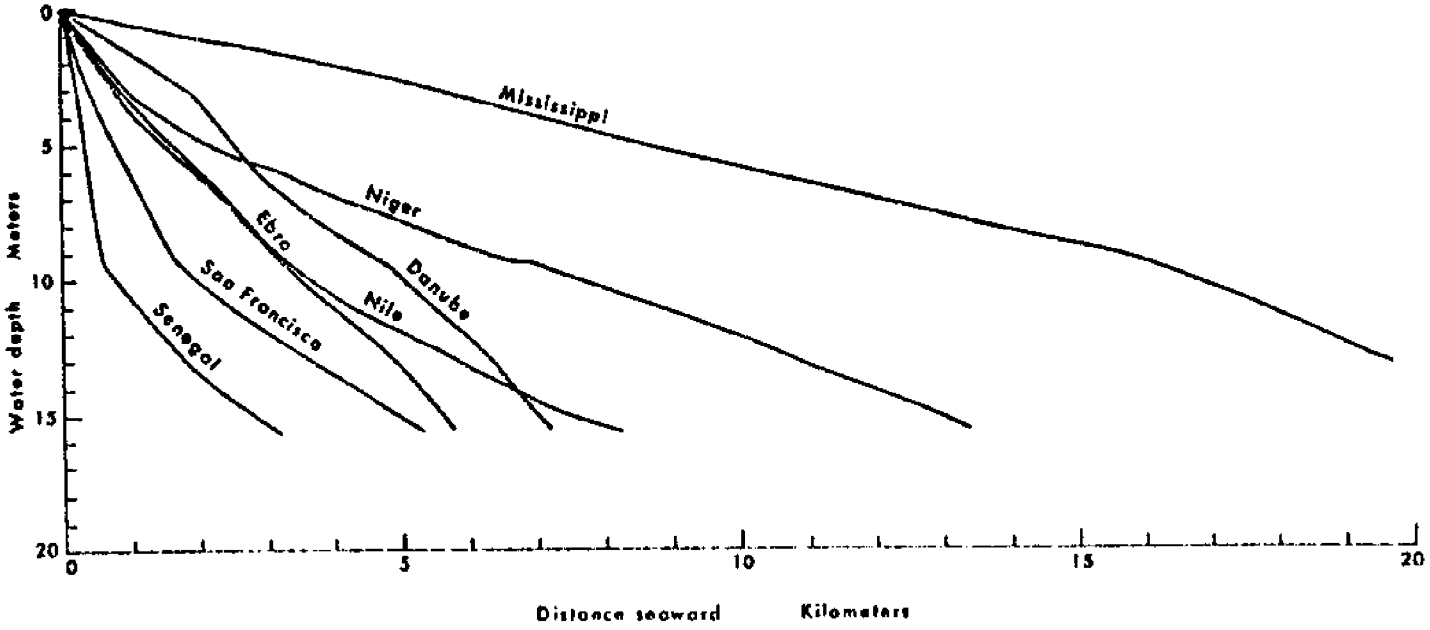


Figure 7. Average subaqueous profiles of seven deltas (from Wright and Coleman, 1972).

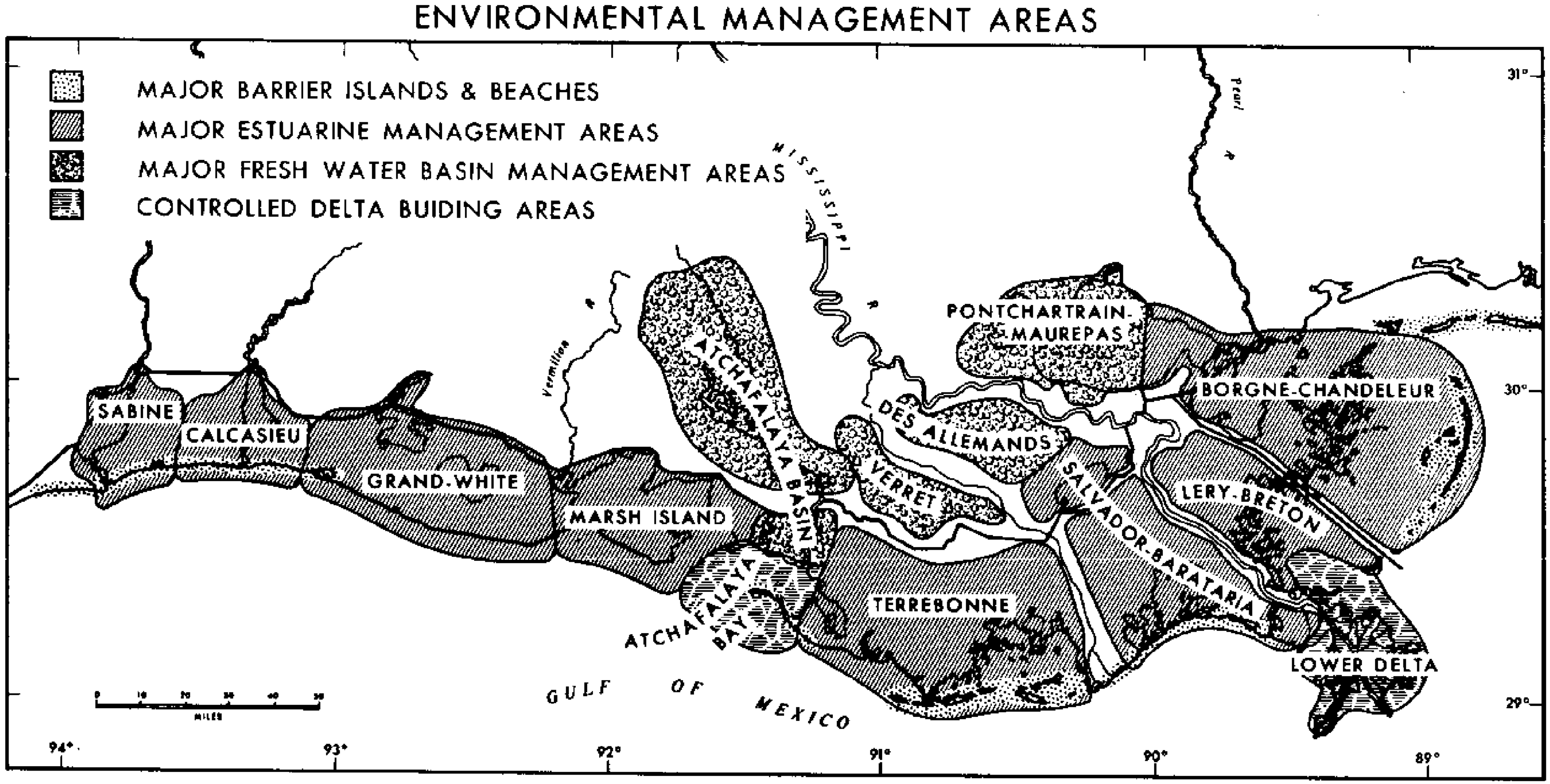


Figure 8. Environmental management areas of the Louisiana coastal zone (from Gagliano and Day, 1972).

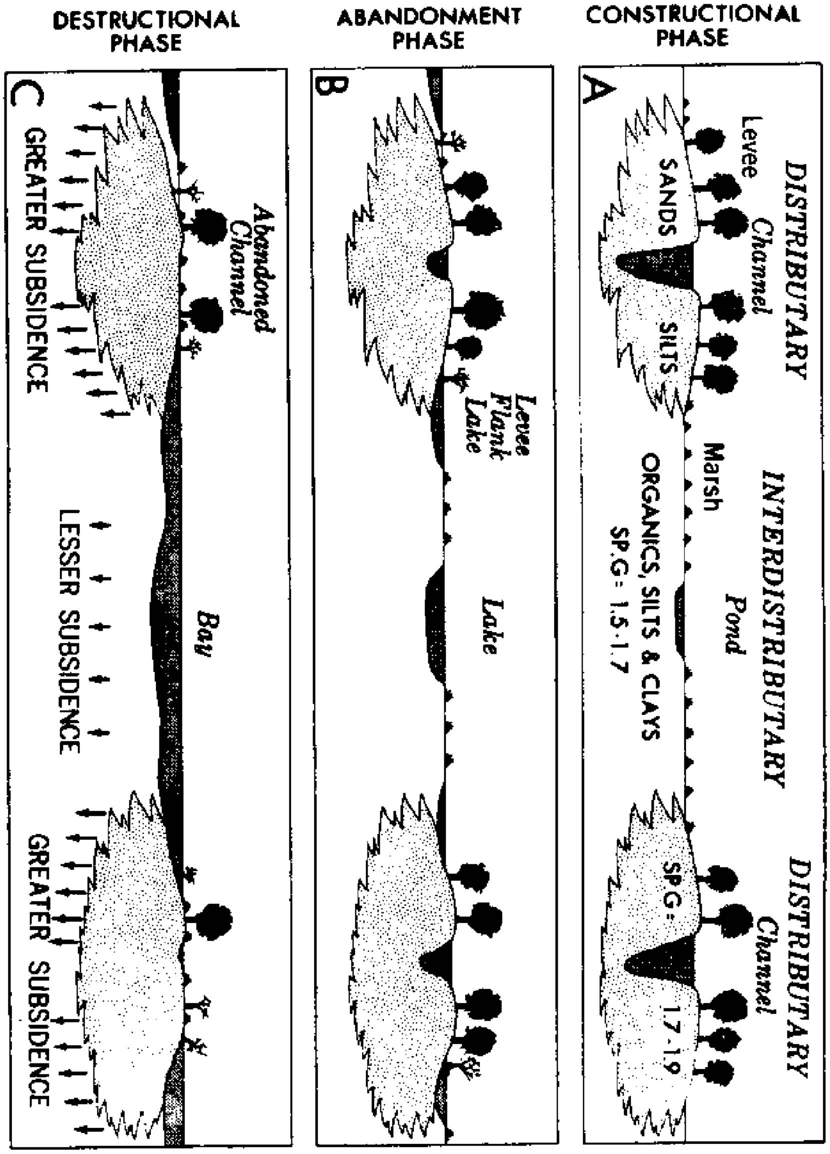


Figure 9. Influence of subsidence on delta deterioration (from Morgan, 1972).

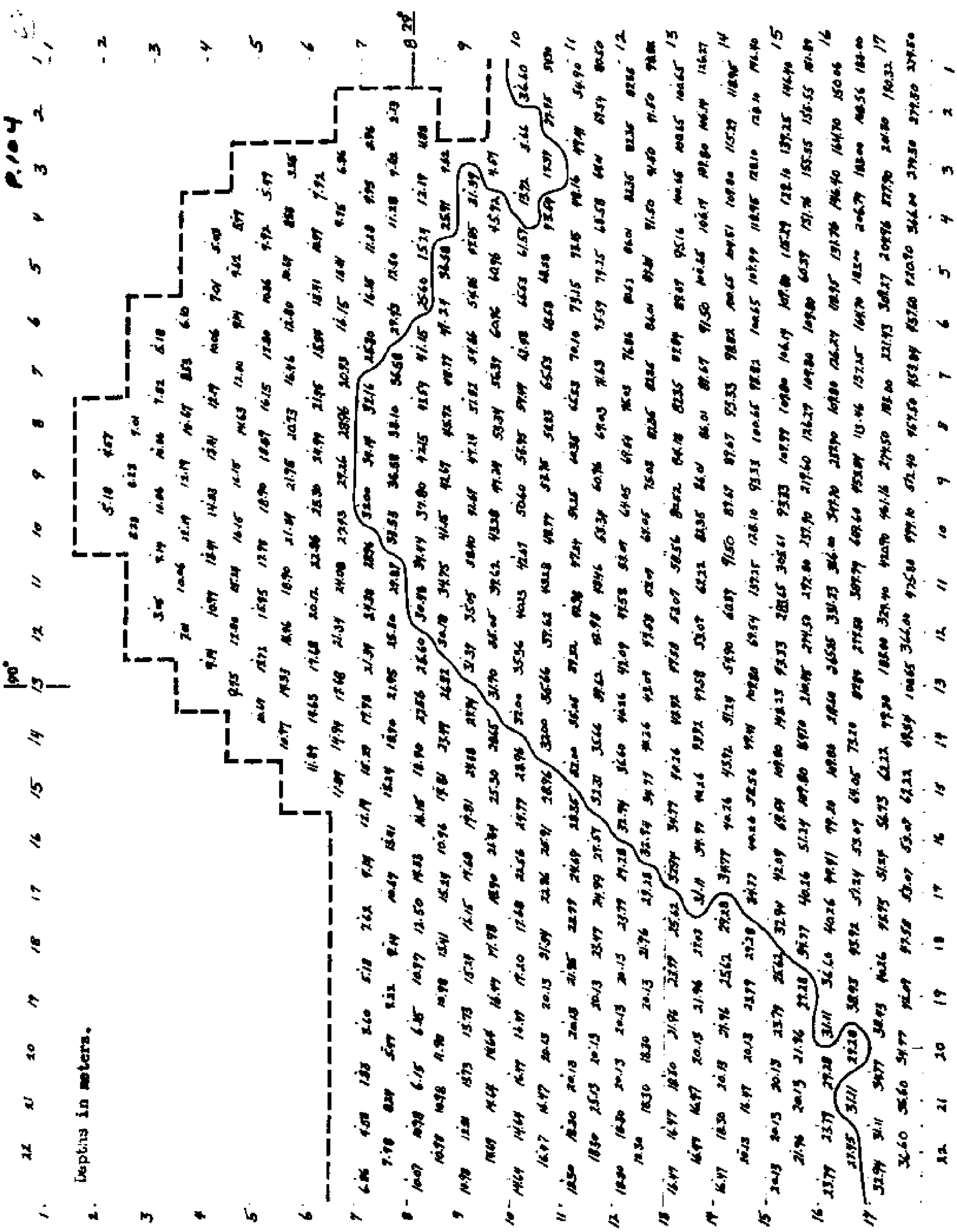


Figure 10. Bathymetry of offshore region in study area. Grid pattern coincides with Figure 65. Shoreline represented by dotted line and 30-meter isobath represented by solid line.

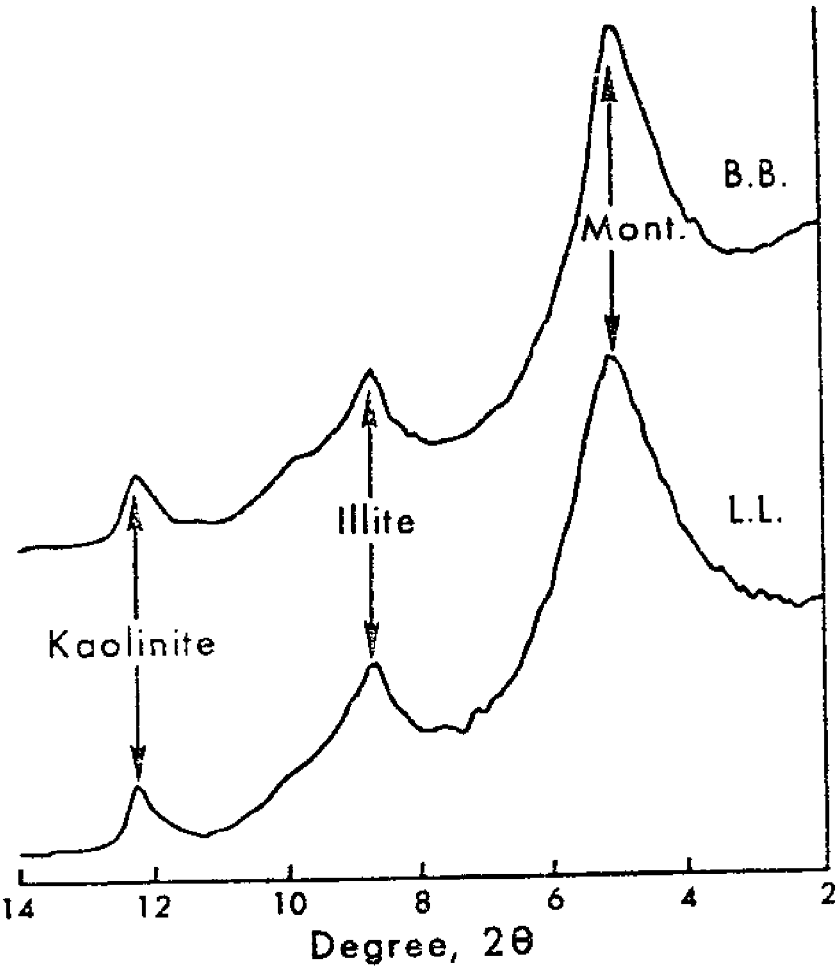


Figure 11. X-ray diffraction diagrams for clay minerals separated from Barataria Bay (B.B.) and Lake Laurier (L.L.) sediments (from Ho, 1971).

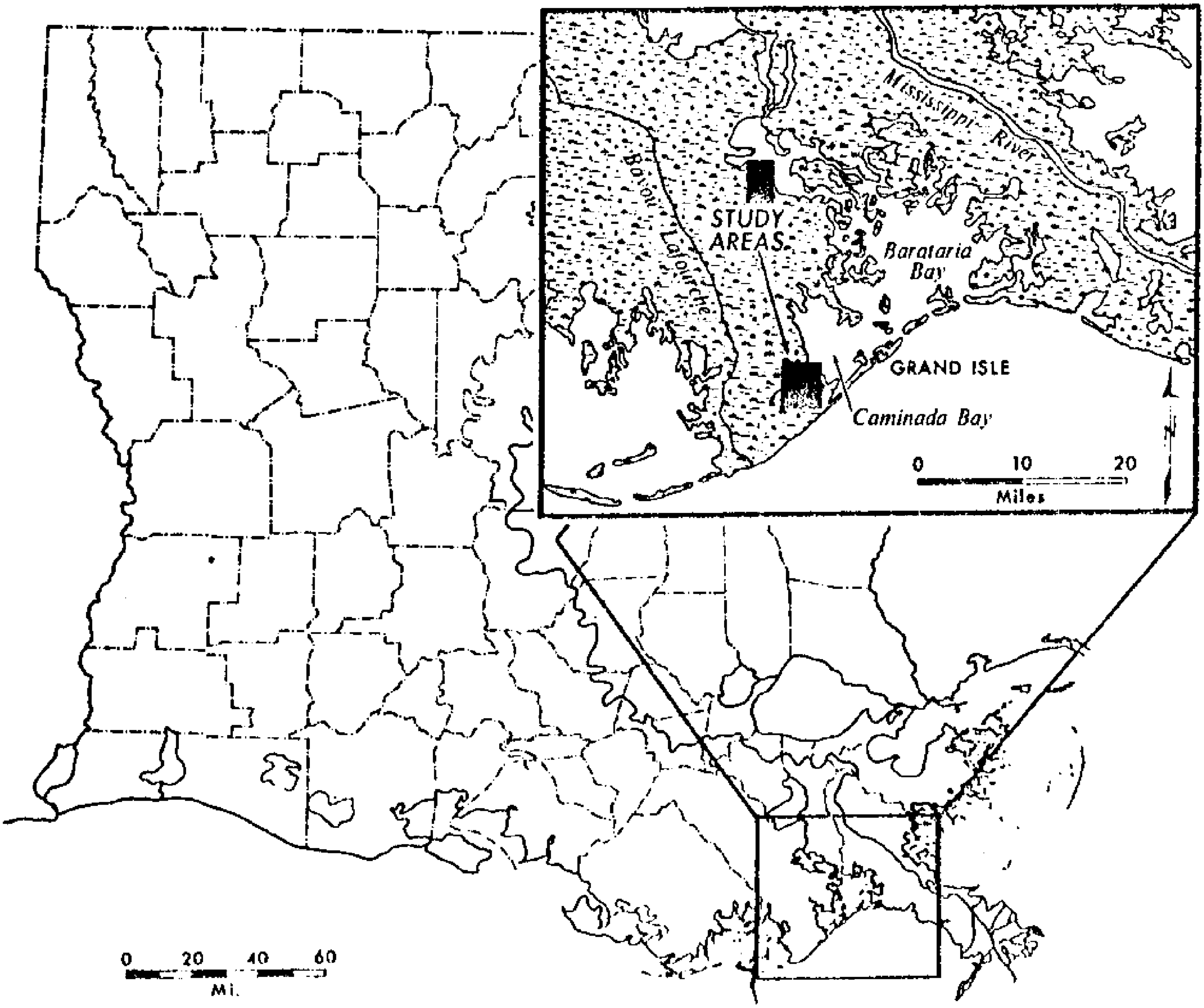


Figure 12. Location map for north and south sampling areas. North stations are listed as John The Fool Bayou and south stations are listed as Airplane Lake and Lake Palourde in Figures 13, 15, 16, 17, and 18.

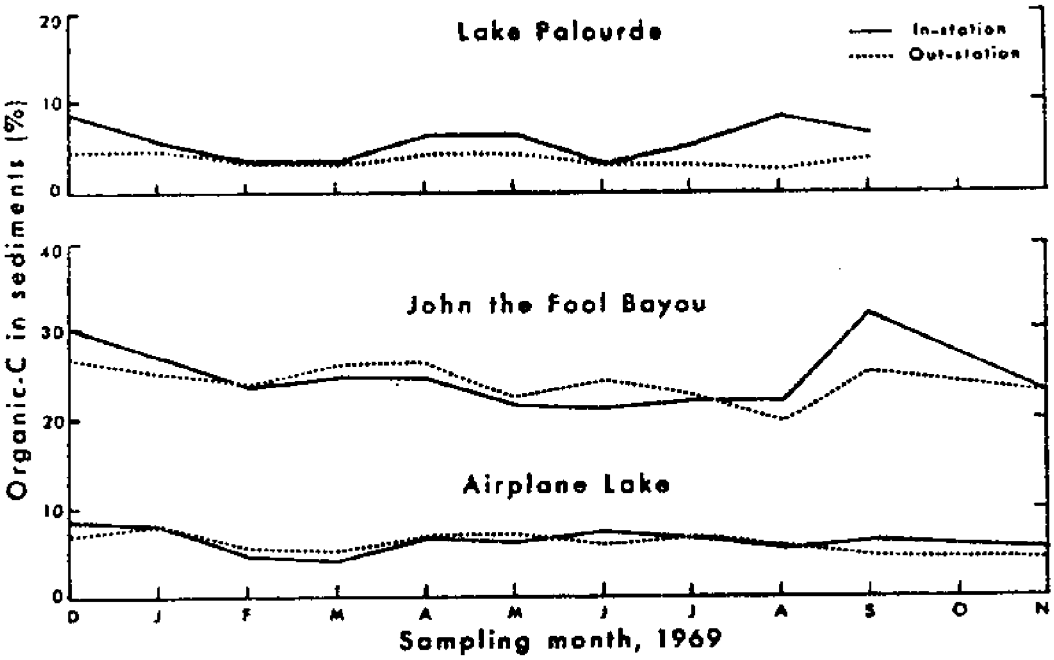


Figure 13A. Seasonal changes in organic-C content in sediments (from Ho, 1971). See Figure 12 for geographic locations of stations.

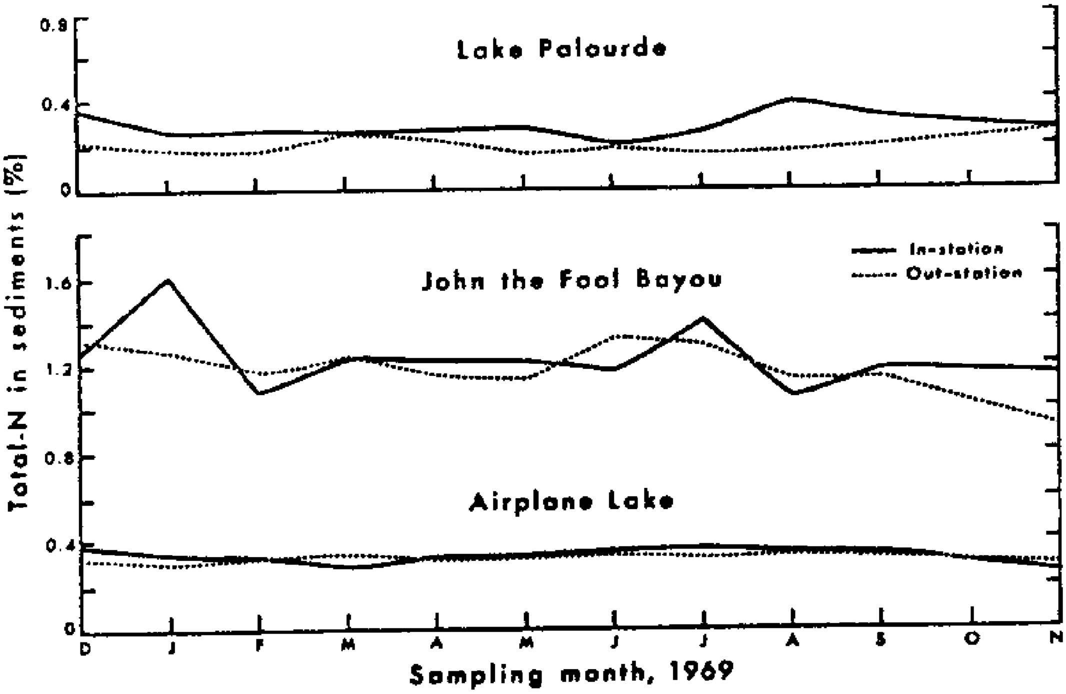


Figure 13B. Seasonal changes in total-N content in sediments (from Ho, 1971). See Figure 12 for geographic locations of stations.

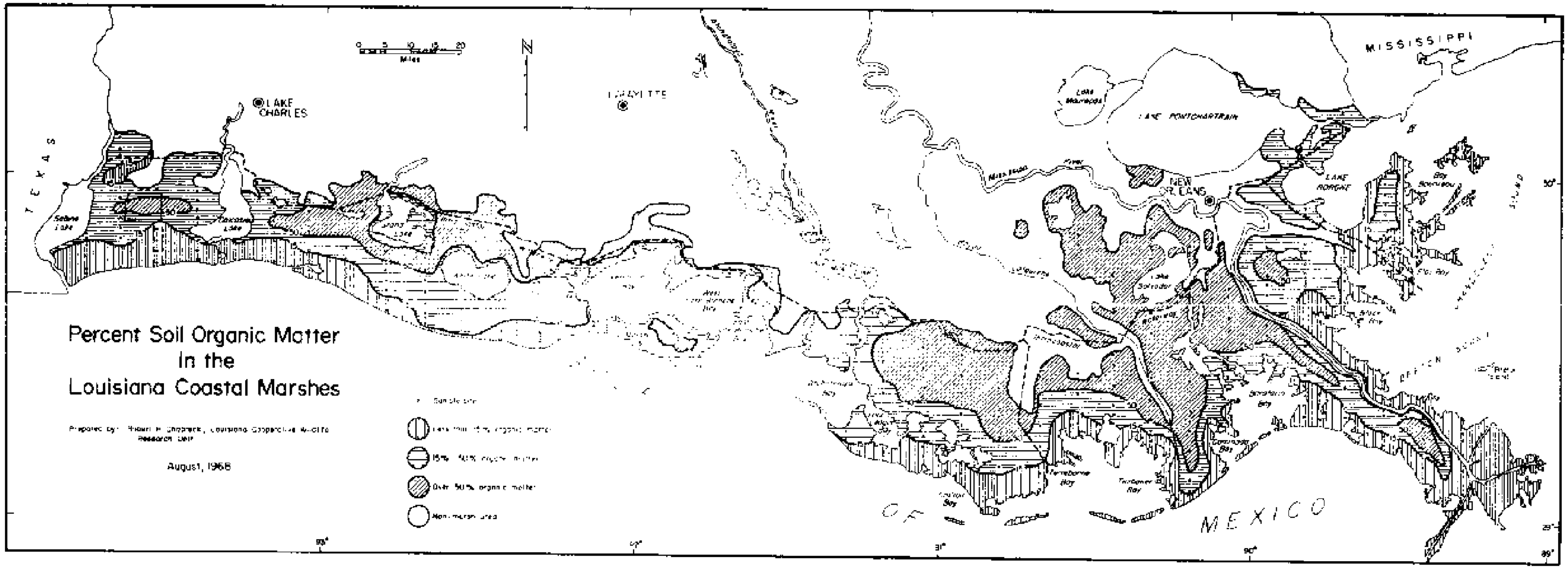


Figure 14. Percent soil organic matter in the Louisiana coastal marshes (Chabreck, 1972).

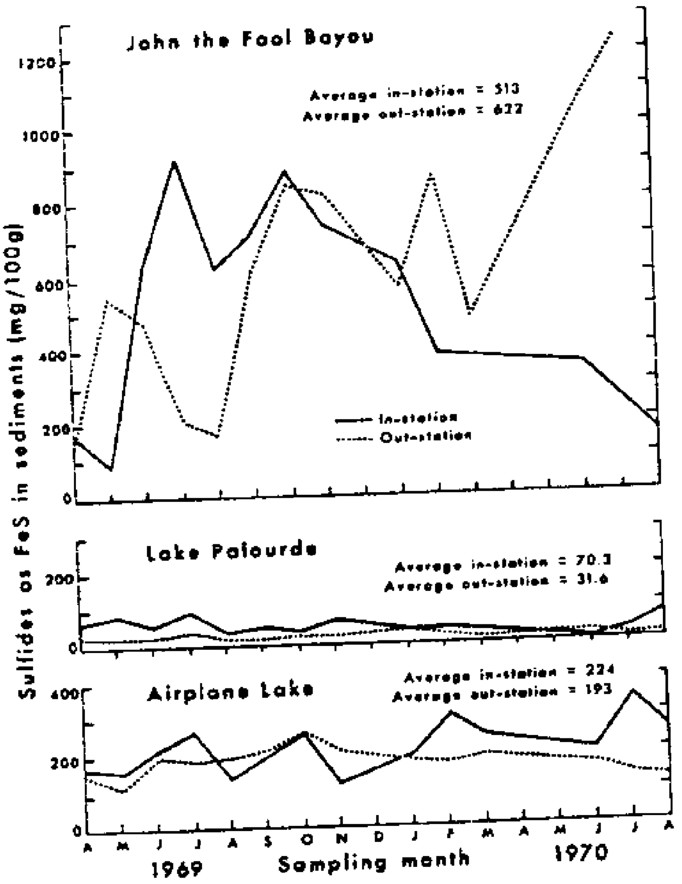


Figure 15A. Seasonal changes in 6N HCl decomposable sulfides in sediments (from Ho, 1971). See Figure 12 for geographic locations of stations.

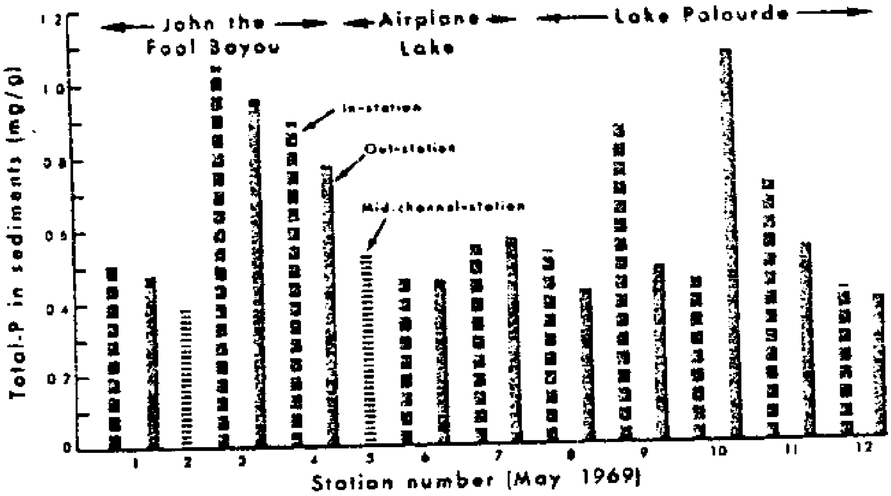


Figure 15B. Total-P content in sediments from various stations (from (Ho, 1971). See Figure 12 for geographic locations of stations.

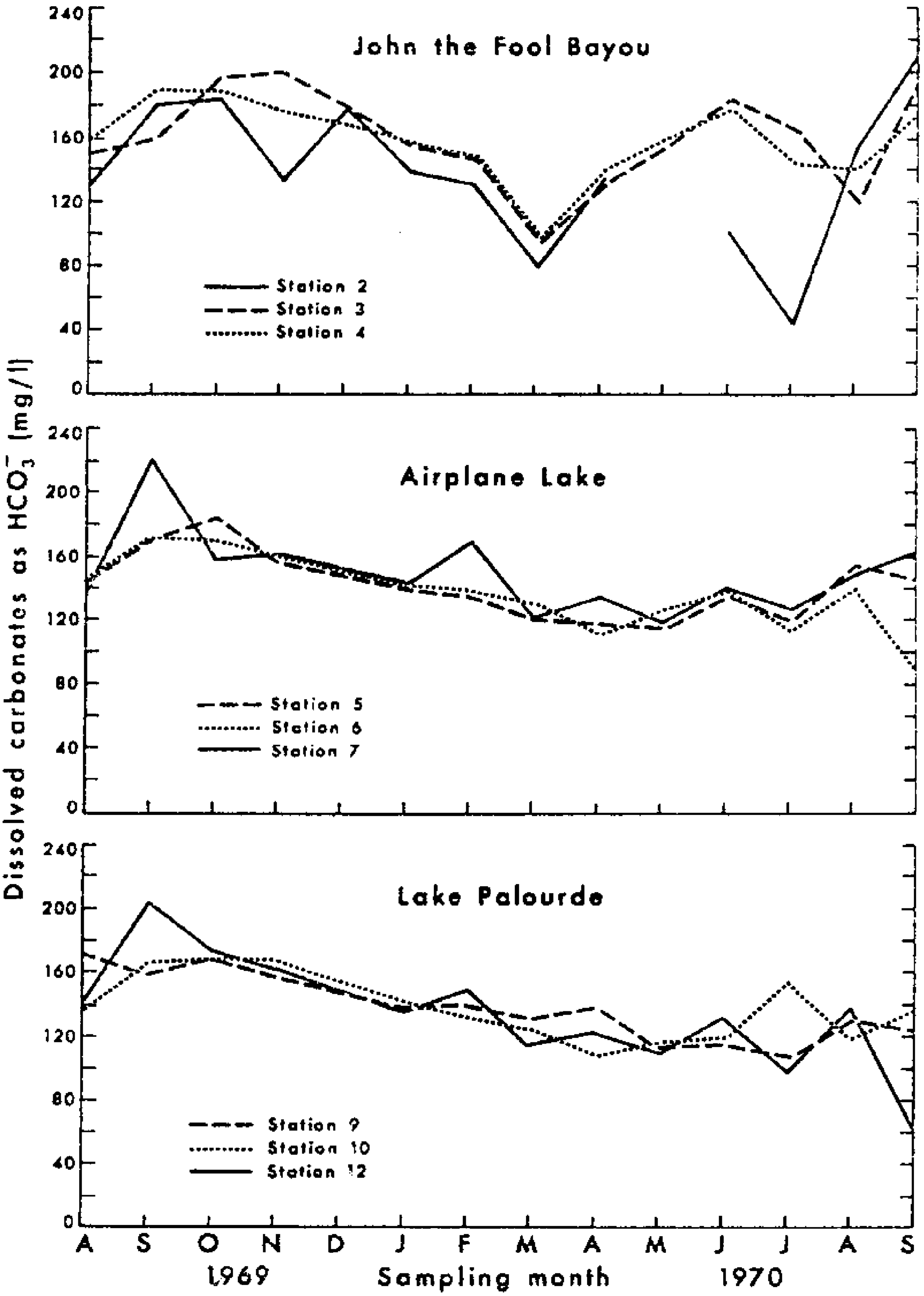


Figure 16. Seasonal changes in dissolved carbonates in waters (from Ho, 1971). See Figure 12 for geographic location of stations.

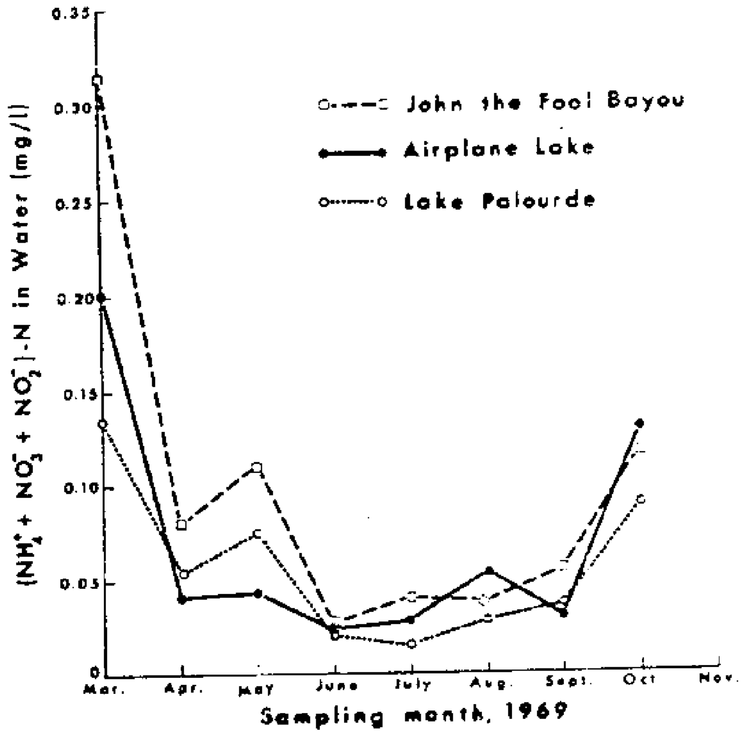


Figure 17A. Seasonal changes in inorganic forms of nitrogen in Barataria Bay subarea waters (from Ho, 1971). See Figure 12 for geographic locations of stations.

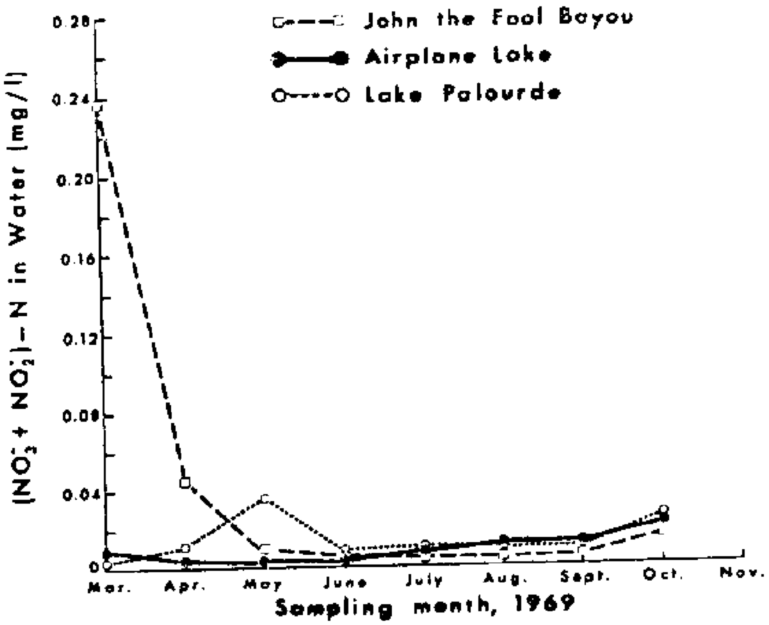


Figure 17B. Seasonal changes in nitrate and nitrite forms of nitrogen in Barataria Bay subarea waters (from Ho, 1971). See Figure 12 for geographic locations of stations.

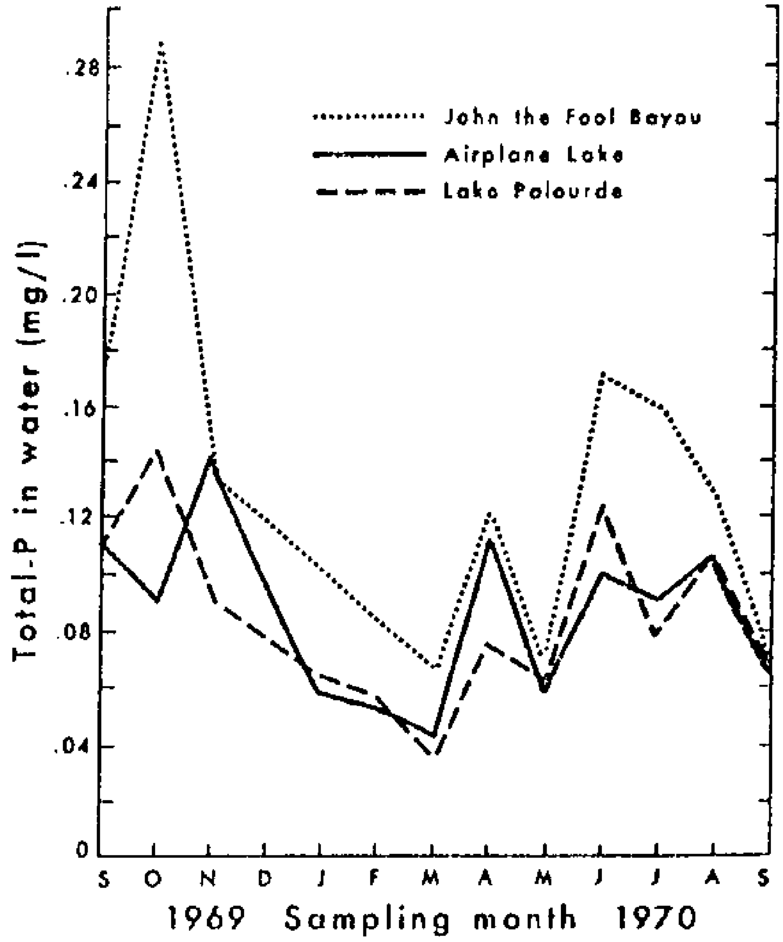


Figure 18. Seasonal changes in total-P in Barataria Bay subarea waters (from Ho, 1971). See Figure 12 for geographic locations of stations.

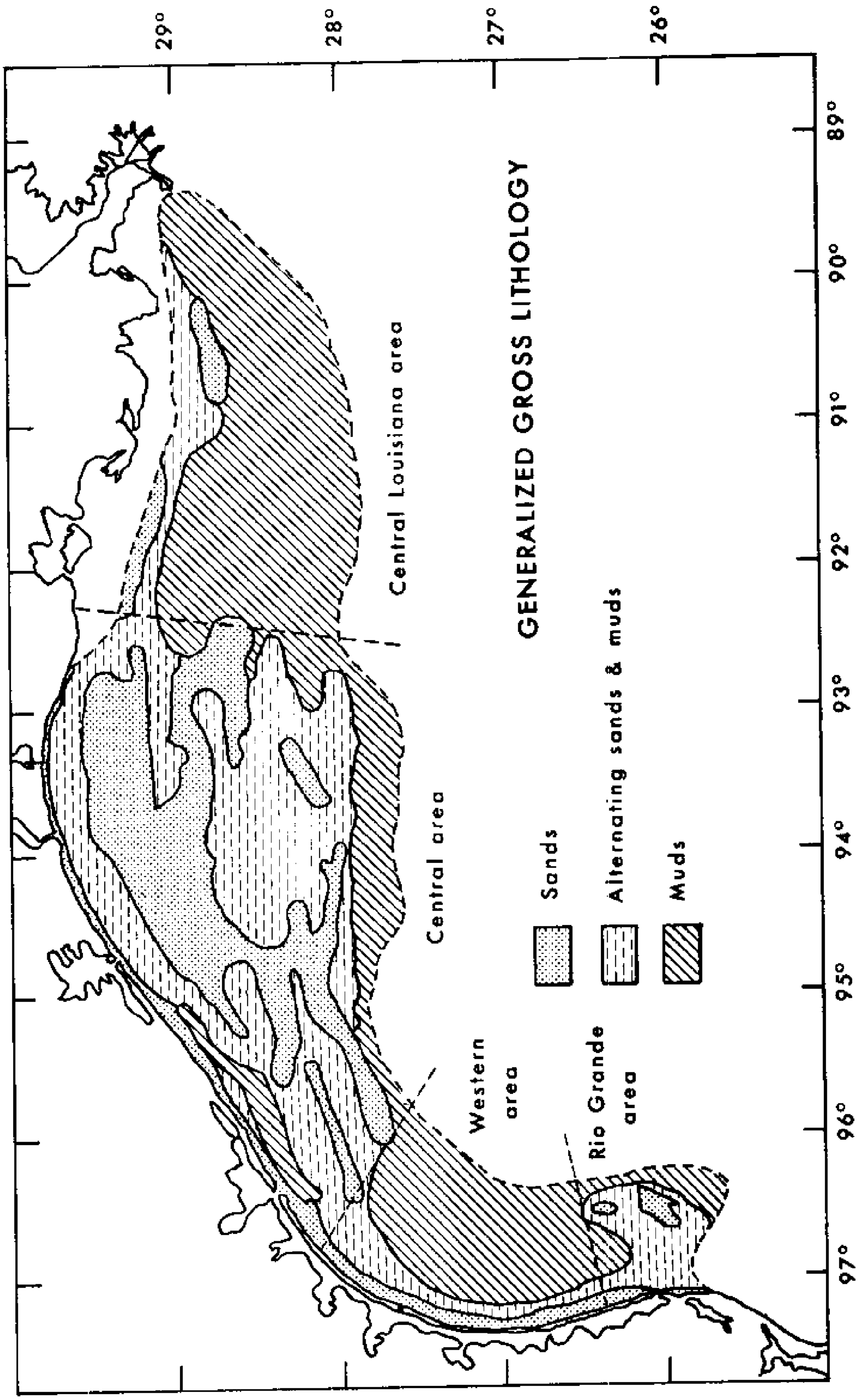


Figure 19. Generalized gross lithology of sediments on the shelf and upper continental slope. Mud is used here as the unconsolidated equivalent of shale (from Curray, 1970).

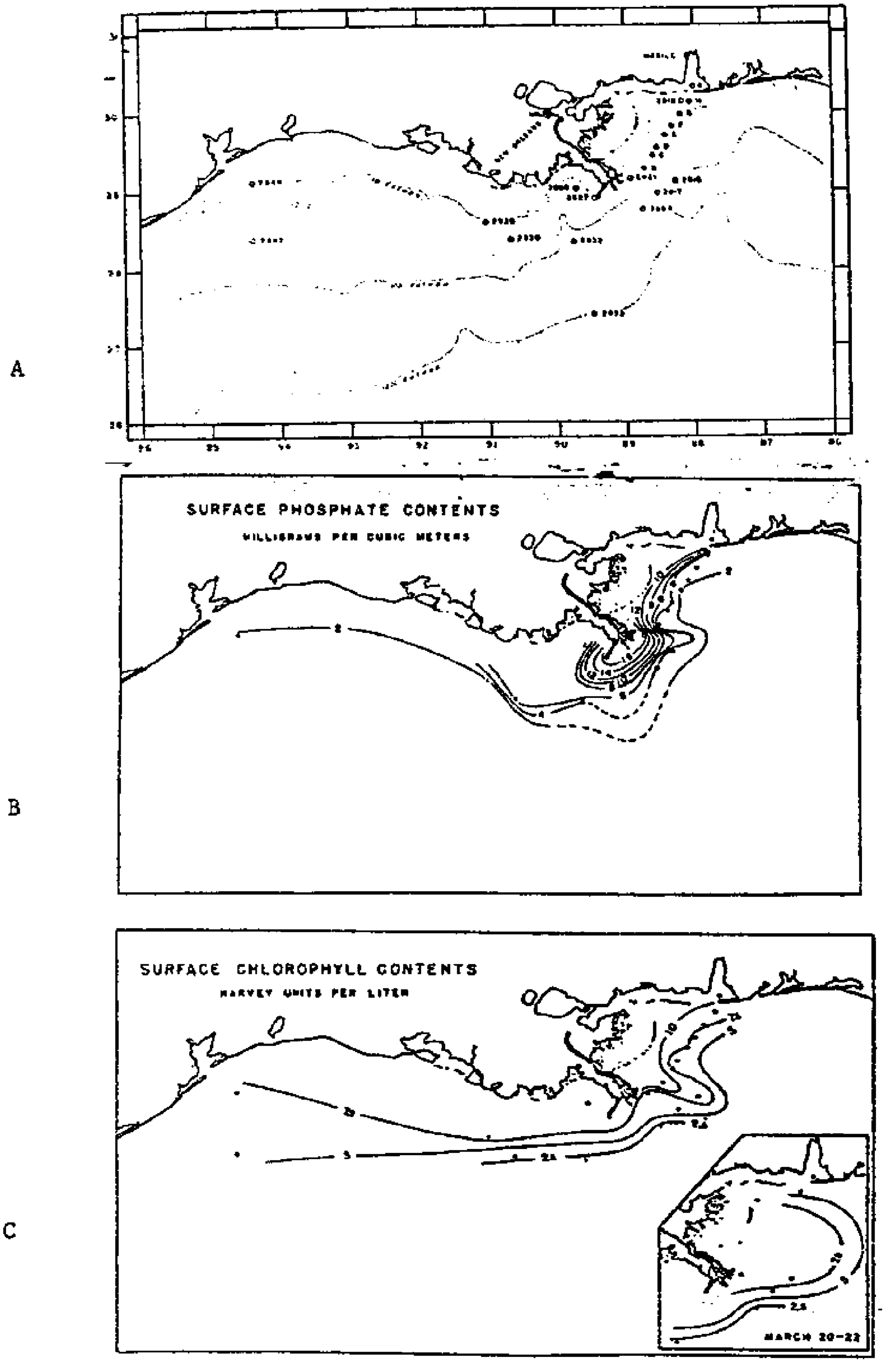


Figure 20. A. Station locations. B. Surface distribution of phosphates. C. Surface distribution of chlorophyll (from Riley, 1937).

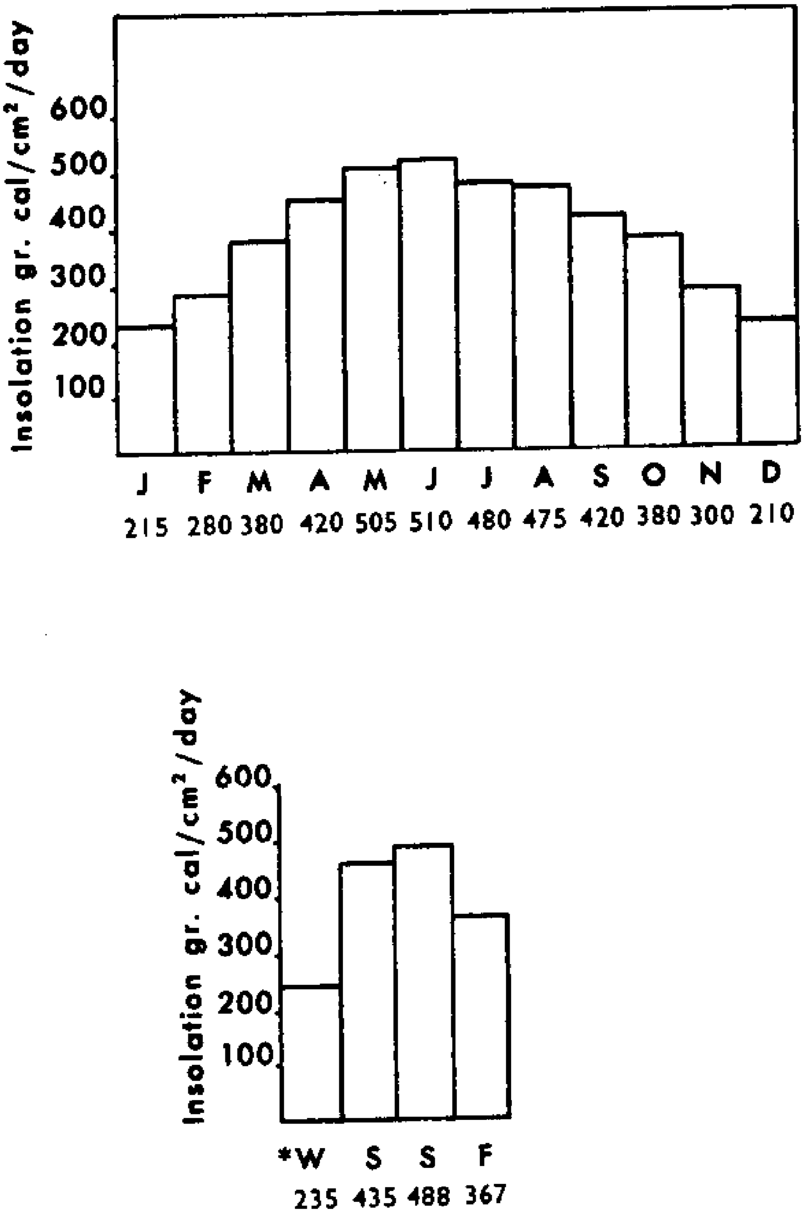


Figure 21. Annual variation in insolation along the Louisiana coast (adapted from Day et al., 1972). Winter is December, January, and February. Spring is March, April, and May. Summer is June, July, and August. Fall is September, October, and November.

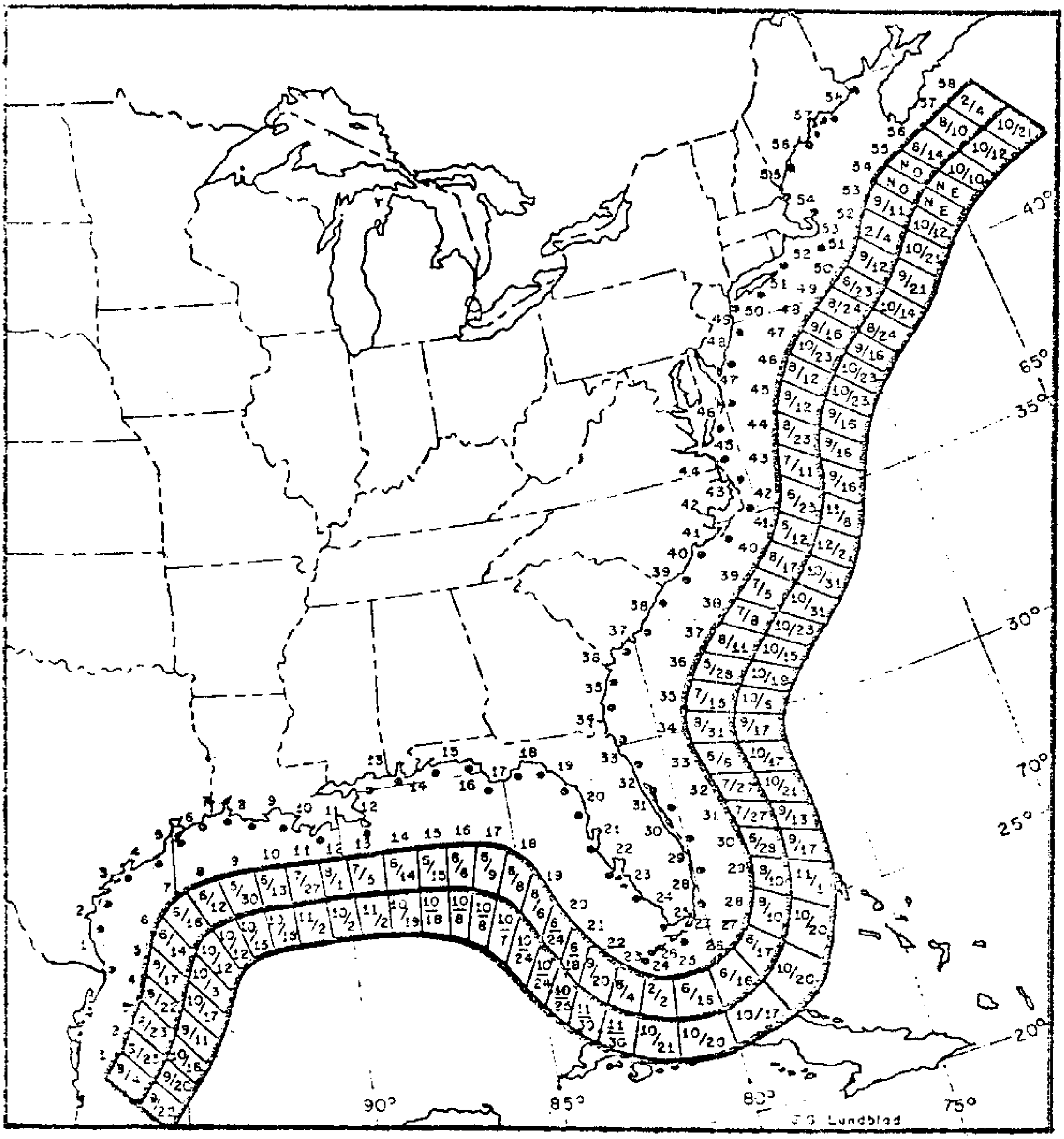
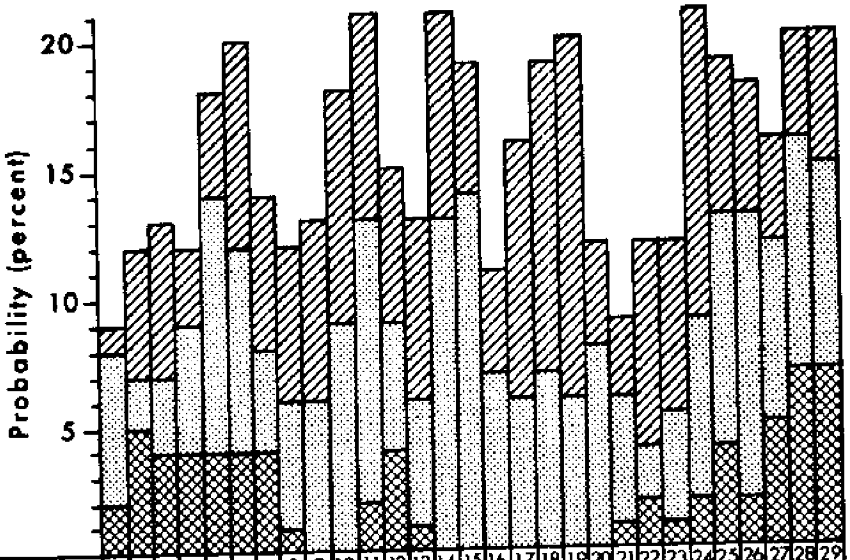


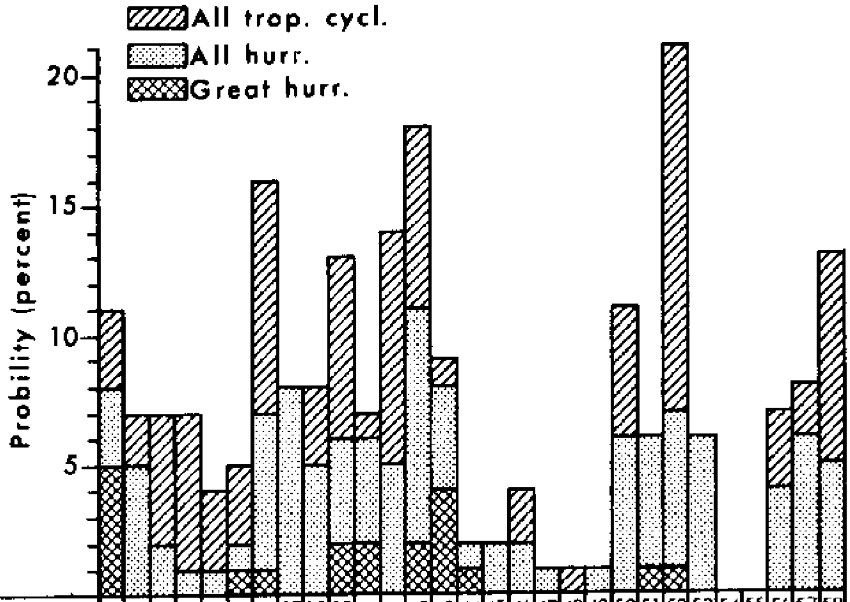
Figure 22. Earliest and latest tropical cyclone occurrences for the period 1886-1970. Numbers within boxes are the month and date of earliest and latest landfalls for the indicated coastal segment (from Simpson and Lawrence, 1971). Texas areas, 5-6; Louisiana areas, 11-12; Delaware areas, 46-47; New Jersey areas, 50-51; and Maine areas, 58.

This histogram and table shows the probability (percentage) that a <u>tropical storm</u>, <u>hurricane</u>, or <u>great hurricane</u> will occur in any one year in a 50 mile segment of the coast line.



Coastal sector	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
All tropical cyclones	9	12	13	12	18	20	14	12	13	18	21	15	13	21	19	11	16	19	20	12	9	12	12	21	19	18	16	20	20
All hurricanes	8	7	7	9	14	12	8	6	6	9	13	9	6	13	14	7	6	7	8	8	6	4	5	9	13	13	12	16	15
Great hurricanes	2	5	4	4	4	4	4	1	-	-	2	4	1	-	-	-	-	-	-	-	1	2	1	2	4	2	5	7	7

Figure 23A. Cyclone probabilities for coastal sector along Gulf and Atlantic Seaboard (from Simpson and Lawrence, 1971). See Figure 22 for geographic locations of each coastal sector.



Coastal sector	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
All tropical cyclones	11	7	7	7	4	5	16	8	8	13	7	14	18	9	2
All hurricanes	8	5	2	1	1	2	7	8	5	6	6	5	11	8	2
Great hurricanes	5	-	-	-	-	1	1	-	-	2	2	-	2	4	1

Coastal sector	45	46	47	48	49	50	51	52	53	54	55	56	57	58
All tropical cyclones	2	4	1	1	1	11	6	21	6	-	-	7	8	13
All hurricanes	2	2	1	-	1	6	6	7	6	-	-	4	6	5
Great hurricanes	-	-	-	-	-	-	1	1	-	-	-	-	-	-

Figure 23B. Cyclone probabilities for coastal sector along Gulf and Atlantic Seaboard (from Simpson and Lawrence, 1971). See Figure 22 for geographic locations of each coastal sector.

APPENDIX

Coastline Segment Locations

The following latitude/longitude combinations comprise a list of the left endpoints of the coastline segments as referenced from an off-shore viewing position and as illustrated in Fig. 1a. The right endpoint of any segment is the left endpoint of the next higher-numbered segment. There are two exceptions: segment no. 25 in extreme southern Florida; and segment no. 58, the northernmost segment. The right endpoints for the exceptions are indicated in the listings below.

Also, the cities identified below are only for the reader's convenience as points of reference.

Coastline Segment Locations

Coastline Segment No.	Left Endpoint		
	Lat.	Long.	
1	25.95	97.15	(Brownsville)
2	26.75	97.35	
3	27.57	97.22	
4	28.23	96.62	
5	28.67	95.80	
6	29.13	95.02	(Galveston)
7	29.60	94.25	
8	29.77	93.30	
9	29.52	92.37	
10	29.32	91.43	
11	29.07	90.52	(New Orleans)
12	28.98	89.15	
13	30.20	88.93	
14	30.22	87.97	
15	30.35	87.02	

Figure 23C. Appendix of location for Figures 23A and 23B.

APPENDIX (con't)

Coastline Segment No.	Left Endpoint		
	Lat.	Long.	
16	30.28	86.05	(Panama City)
17	29.68	85.38	
18	29.88	84.43	
19	29.70	83.50	
20	29.08	82.88	
21	27.23	82.87	
22	27.42	82.68	
23	26.67	82.25	
24	25.97	81.77	
25	25.12	81.13	...Rt. Endpoint: Lat. 25.32, Long. 80.25
26	24.53	81.82	(Key West)
27	24.77	80.93	
28	25.32	80.25	
29	26.13	80.03	
30	27.00	80.05	
31	27.73	80.38	
32	28.55	80.55	
33	29.27	81.02	
34	30.05	81.33	(Jacksonville)
35	30.90	81.42	
36	31.68	81.12	(Savannah)
37	32.33	80.48	
38	32.83	79.70	
39	33.48	79.08	
40	33.77	78.15	(Wilmington)
41	34.43	77.53	
42	34.60	76.53	
43	35.23	75.53	
44	36.05	75.67	(Norfolk)
45	36.85	75.97	
46	37.63	75.60	
47	38.35	75.07	
48	39.15	74.70	
49	39.83	74.08	
50	40.58	73.63	
51	40.80	72.57	
52	41.15	71.55	(Nantucket)
53	41.25	69.95	
54	42.08	69.90	
55	42.72	70.62	
56	43.52	70.32	(Portland)
57	43.91	69.32	
58	44.25	68.25	...Rt. Endpoint: Lat. 44.80, Long. 66.90

Figure 23D. Appendix of locations for Figures 23A and 23B.

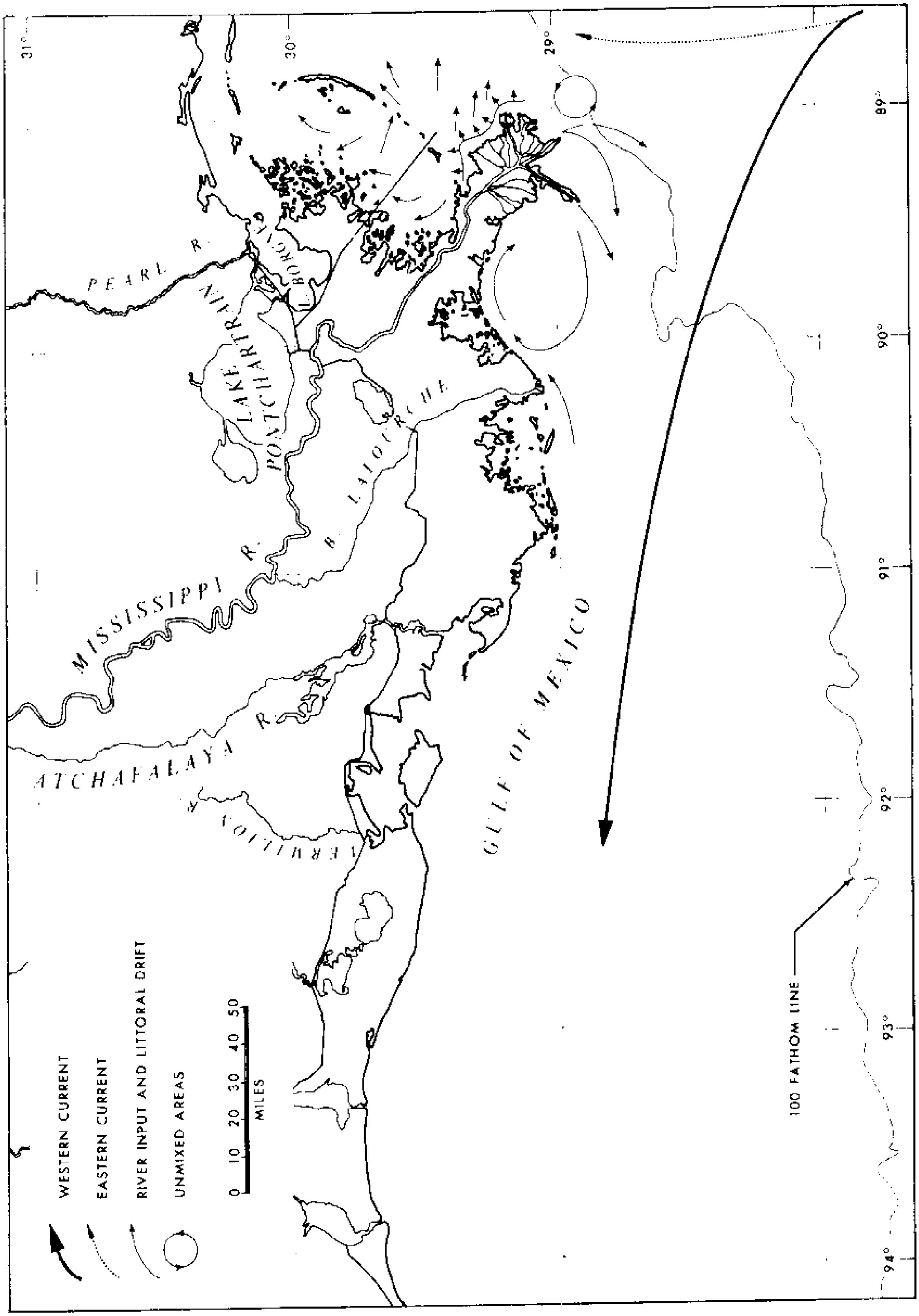


Figure 24. Generalized surface circulation along Louisiana continental shelf. Compiled from various sources.

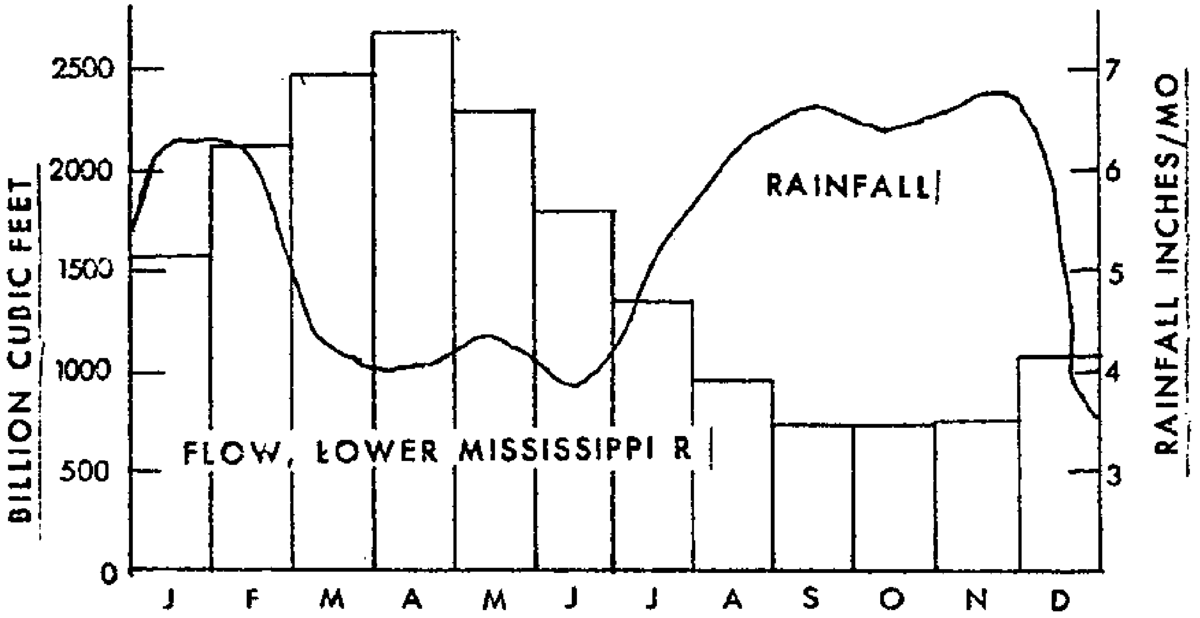


Figure 25. Annual variations of Mississippi River discharge and rainfall along Louisiana coast (adapted from Day et al., 1972).

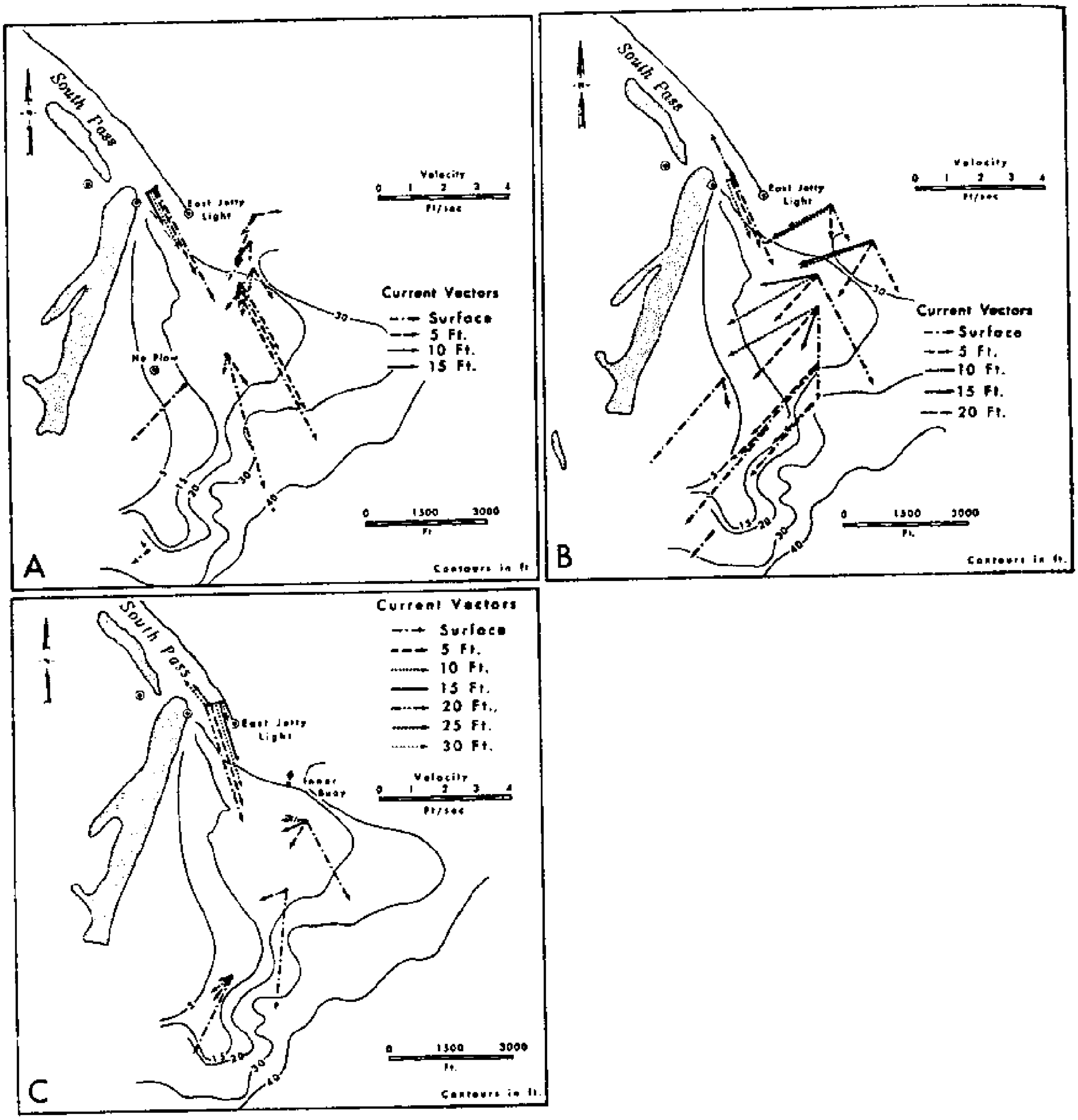


Figure 26. Current vectors transverse to the effluent and along the distributary mouth bar of South Pass in Mississippi River delta. A. Ebb tide. B. Flooding tide. C. Flooding tide (from Wright, 1970).

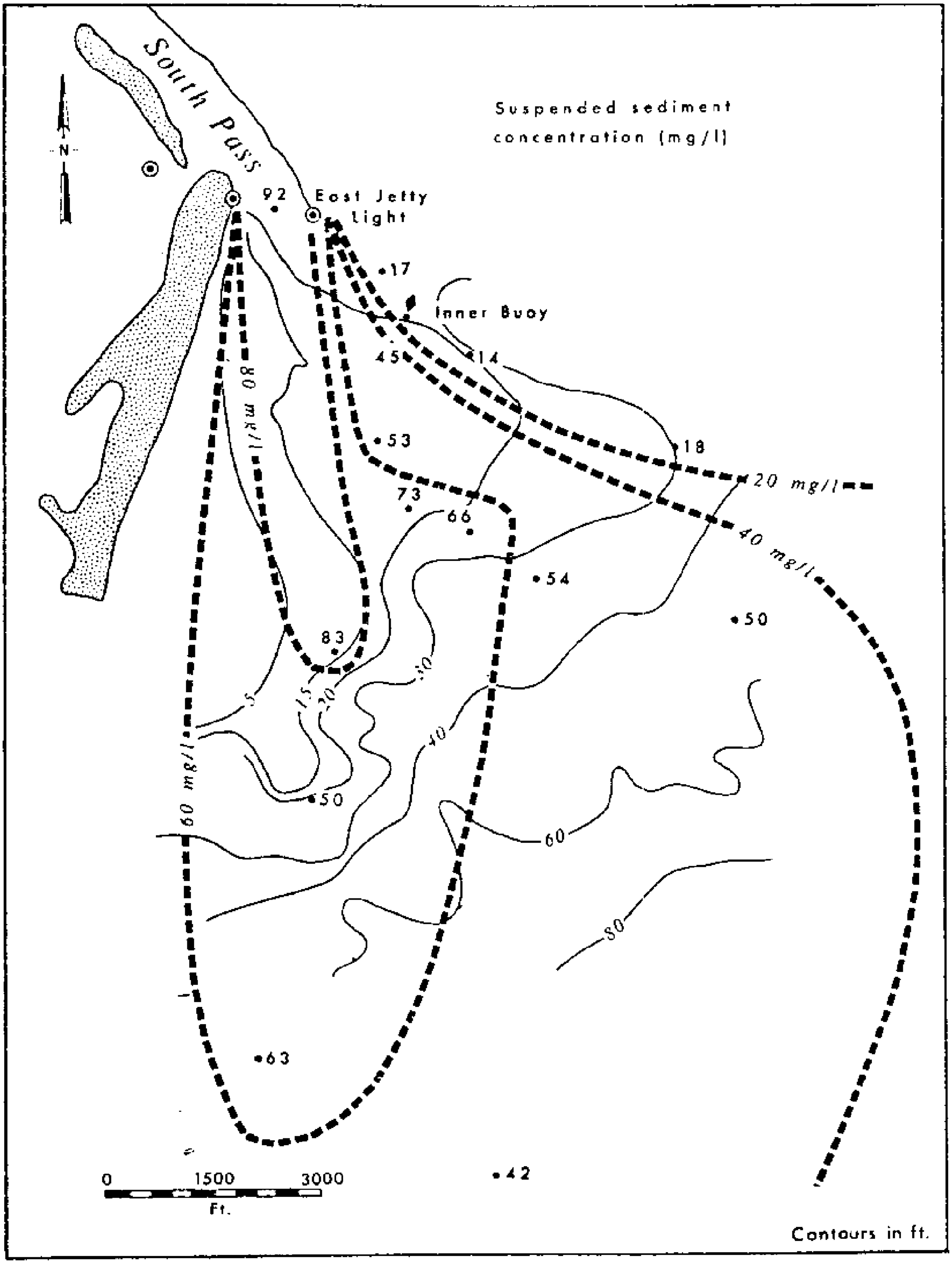


Figure 27. Surface distribution of suspended-concentration at high river stage of South Pass in Mississippi River delta on April 12, 1969. The plume boundary lies approximately between the 60 mg/l and 40 mg/l isolines (from Wright, 1970).

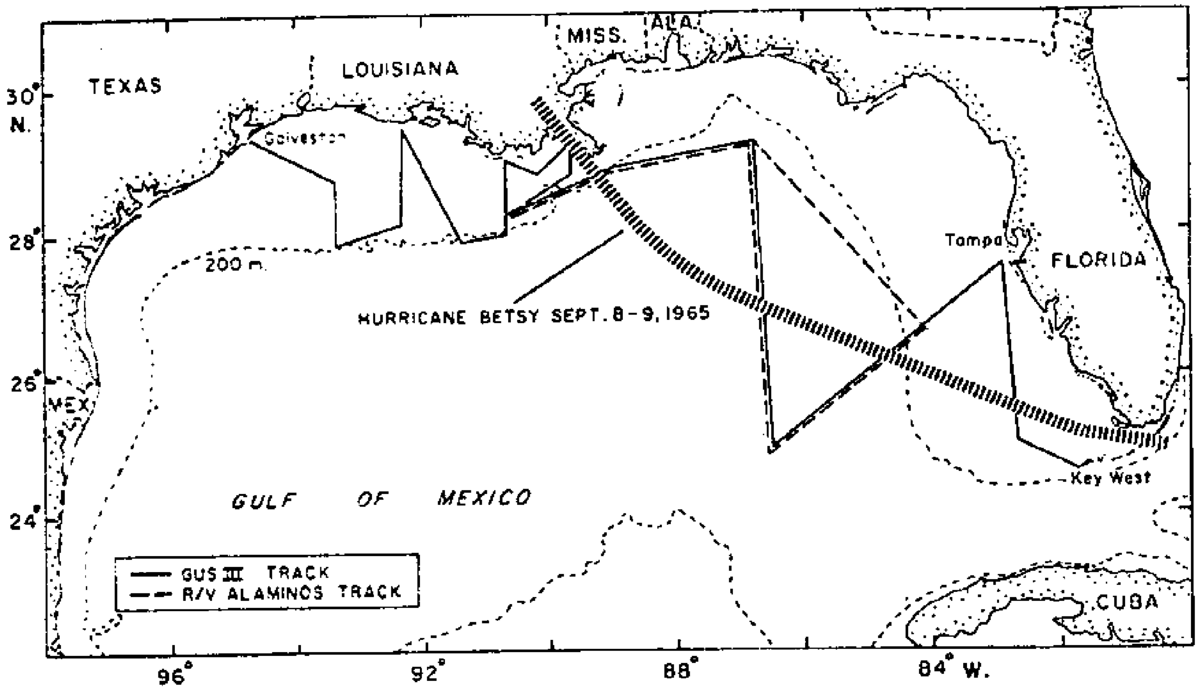


Figure 28A. Track of the M/V Gus III of the Bureau of Commercial Fisheries, Galveston, and the R/V Alaminos of Texas A&M University on cruises after Hurricane Betsy, in September 1965 (from Stevenson, 1967).

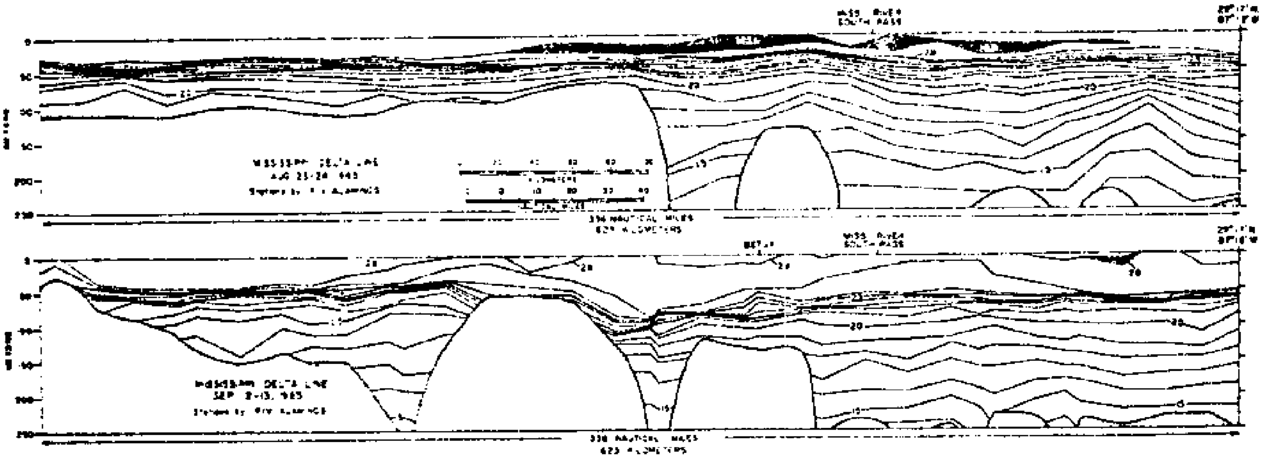


Figure 28B. Temperature profiles along the east-west line seaward from the Mississippi Delta. The "blacked-in" portions indicate strong temperature inversions and represent surface layers of brackish water from the Mississippi River. Hurricane Betsy crossed these waters on September 9, 1967 (from Stevenson, 1967).

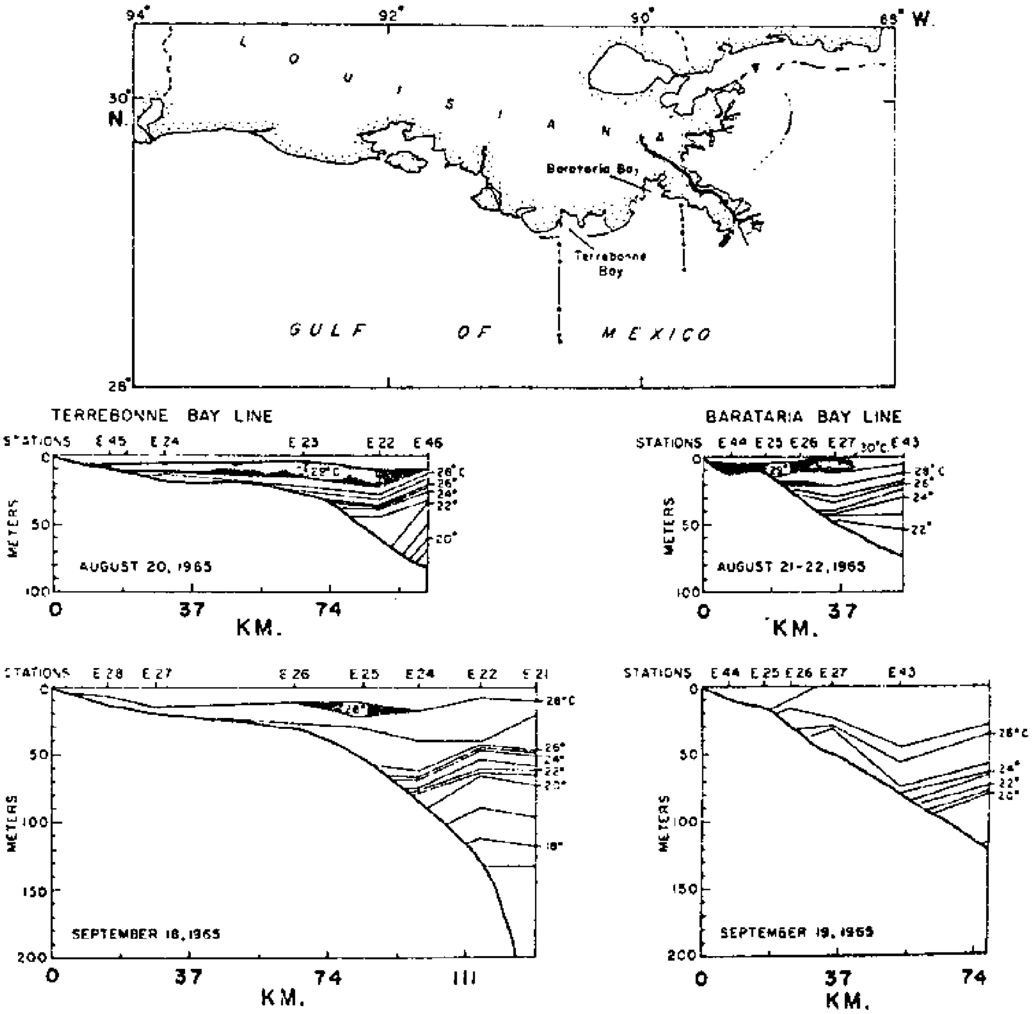


Figure 29. Station lines occupied aboard the M/V Gus III before and after Hurricane Betsy. The hurricane eye crossed the coast over Barataria Bay. Note the subsidence of the thermocline after the hurricane and the wedge of warm water against the shore (from Stevenson, 1967).

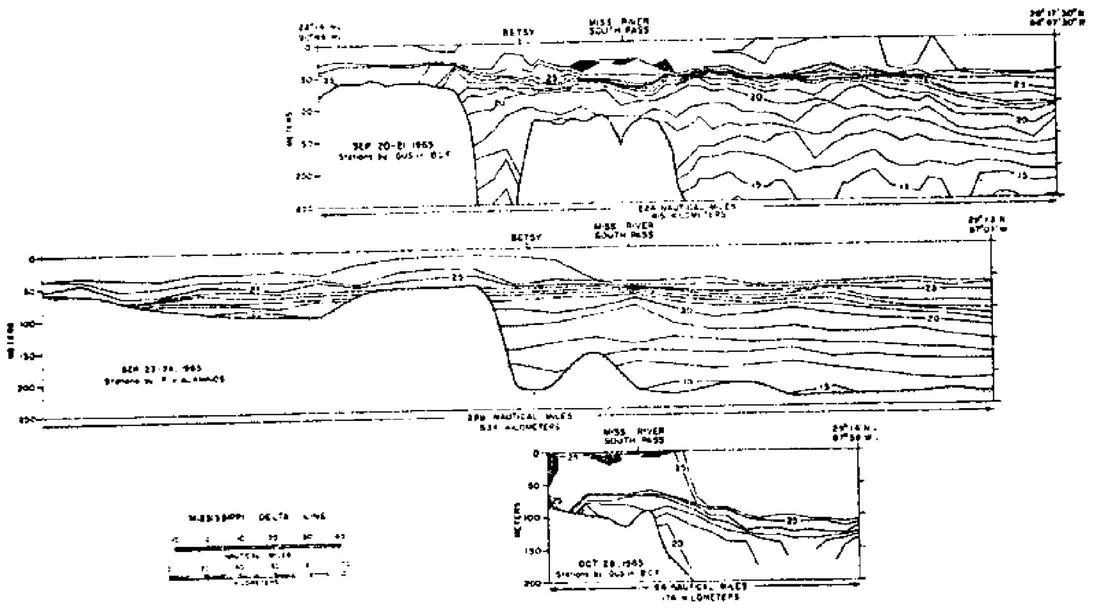


Figure 30A. Temperature profiles seaward from the Mississippi Delta from the data gathered from the M/V Gus III and R/V Alaminos (from Stevenson, 1967).

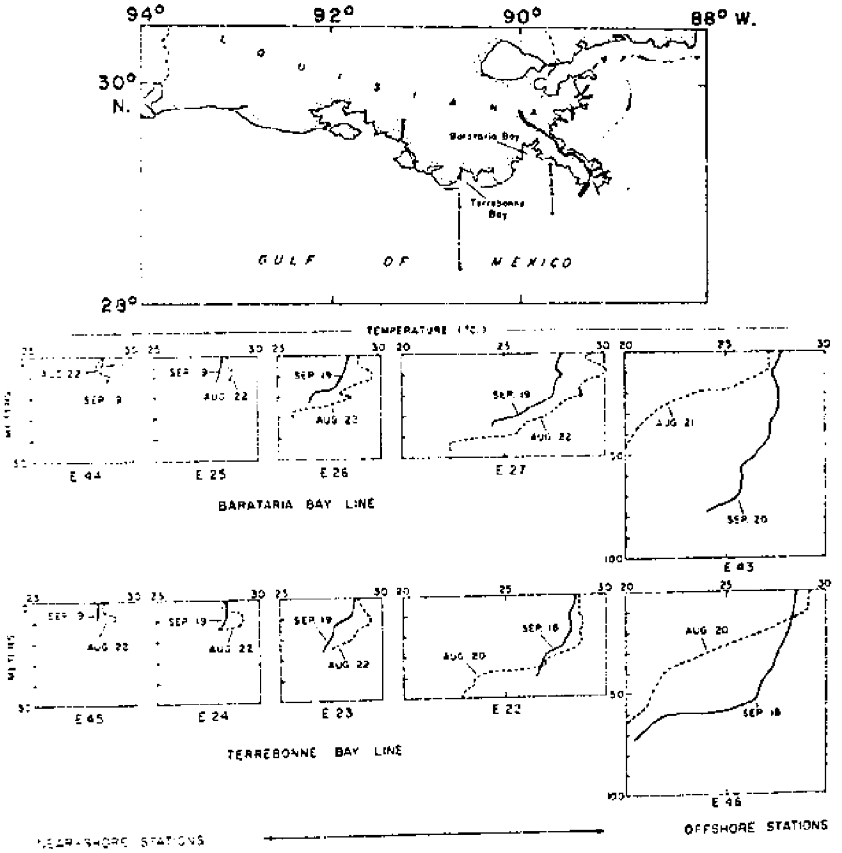


Figure 30B. Temperature traces of the waters off the Mississippi Delta before and after Hurricane Betsy. The "downwelling" of warm surface waters is noted in depths greater than 50 meters (from Stevenson, 1967).

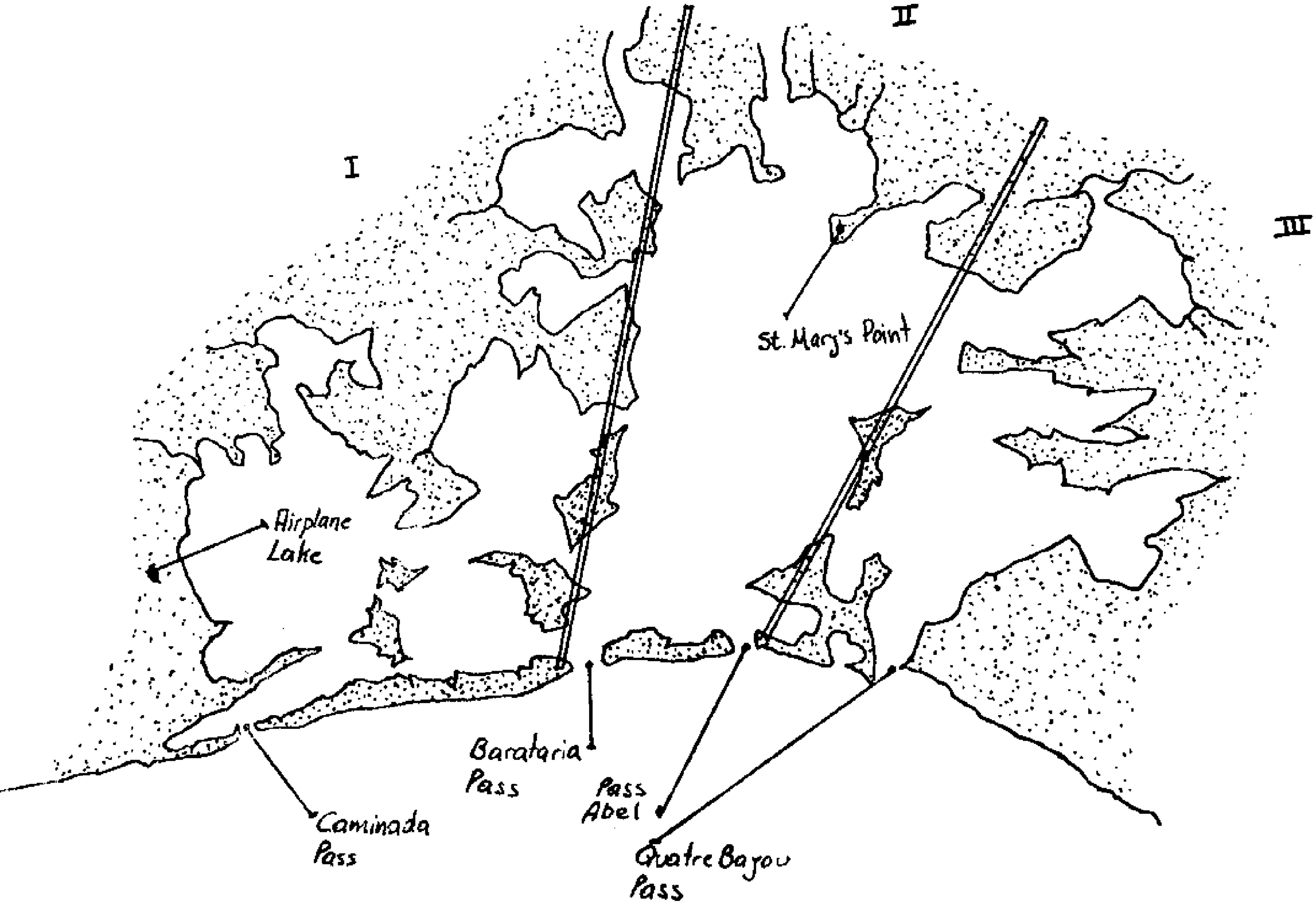


Figure 31. The three hydrologic units of Barataria and Caminada Bays, Louisiana (Pike and Hacker, 1972, unpublished data).

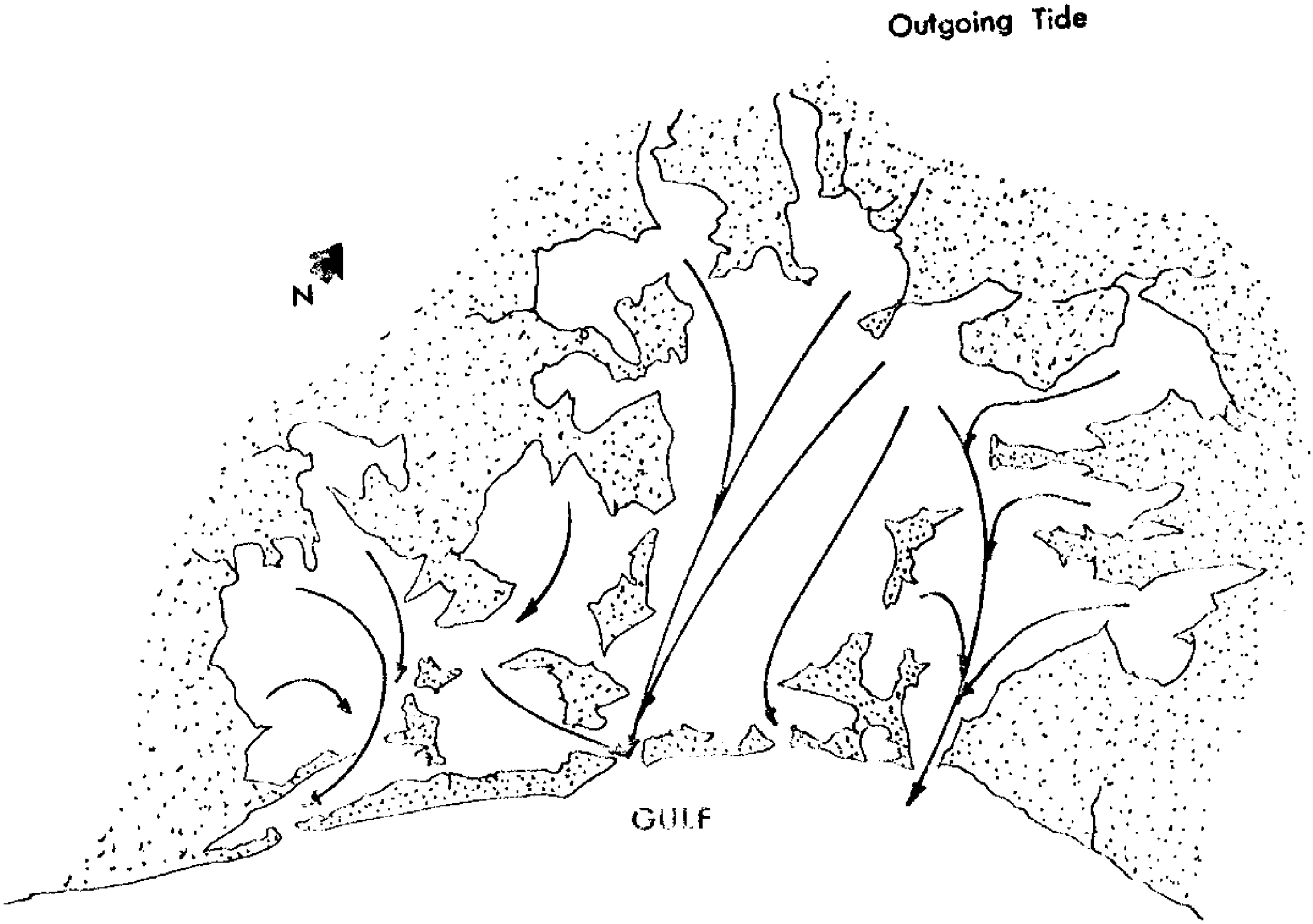


Figure 32. Gross estuarine circulation in Barataria and Caminada Bays, Louisiana, at ebb tide (Pike and Hacker, 1972, unpublished data).

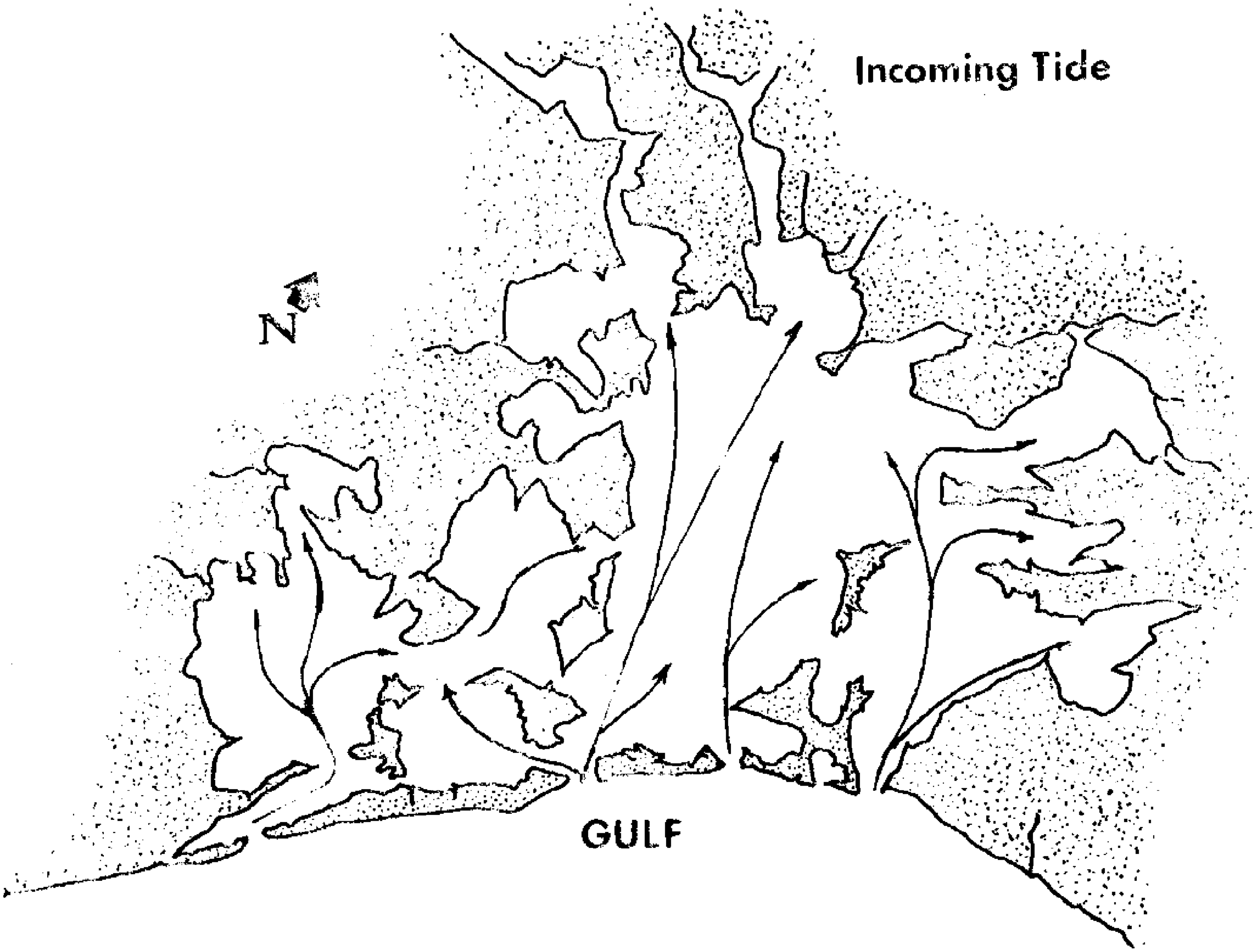


Figure 33. Gross estuarine circulation in Barataria and Caminada Bays, Louisiana, at flood tide (Pike and Hacker, 1972, unpublished data).

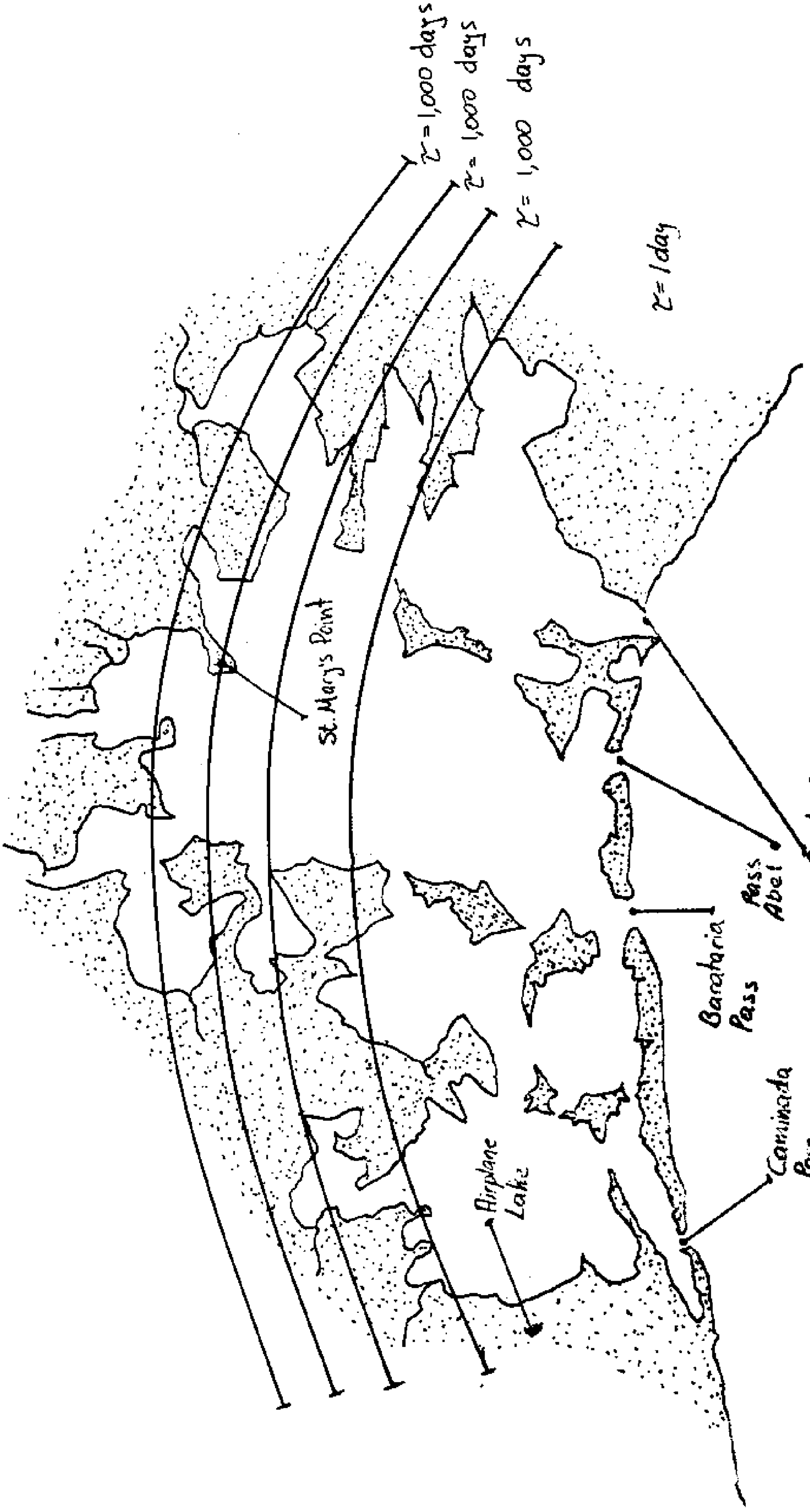


Figure 34. West to east water envelopes having equivalent residence times (Pike and Hacker, 1972, unpublished data).

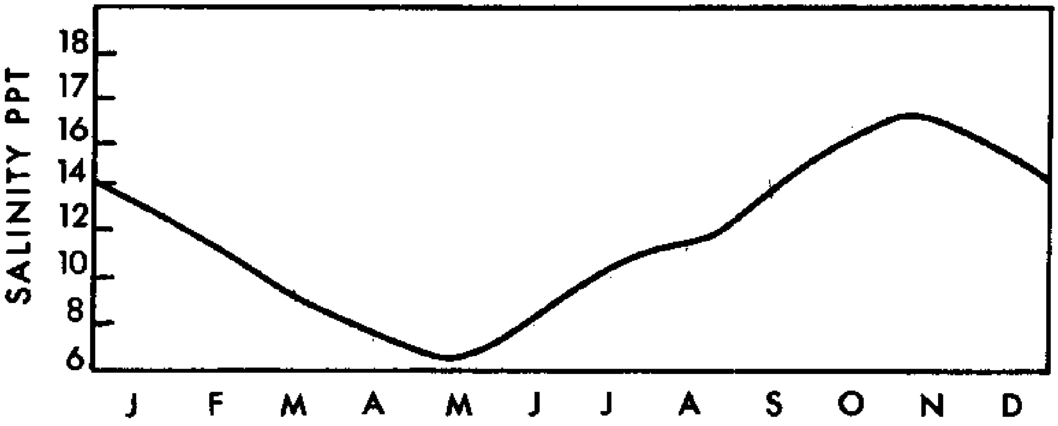


Figure 35. Annual variations in salinities in Barataria Bay, Louisiana (adapted from Day et al., 1972).

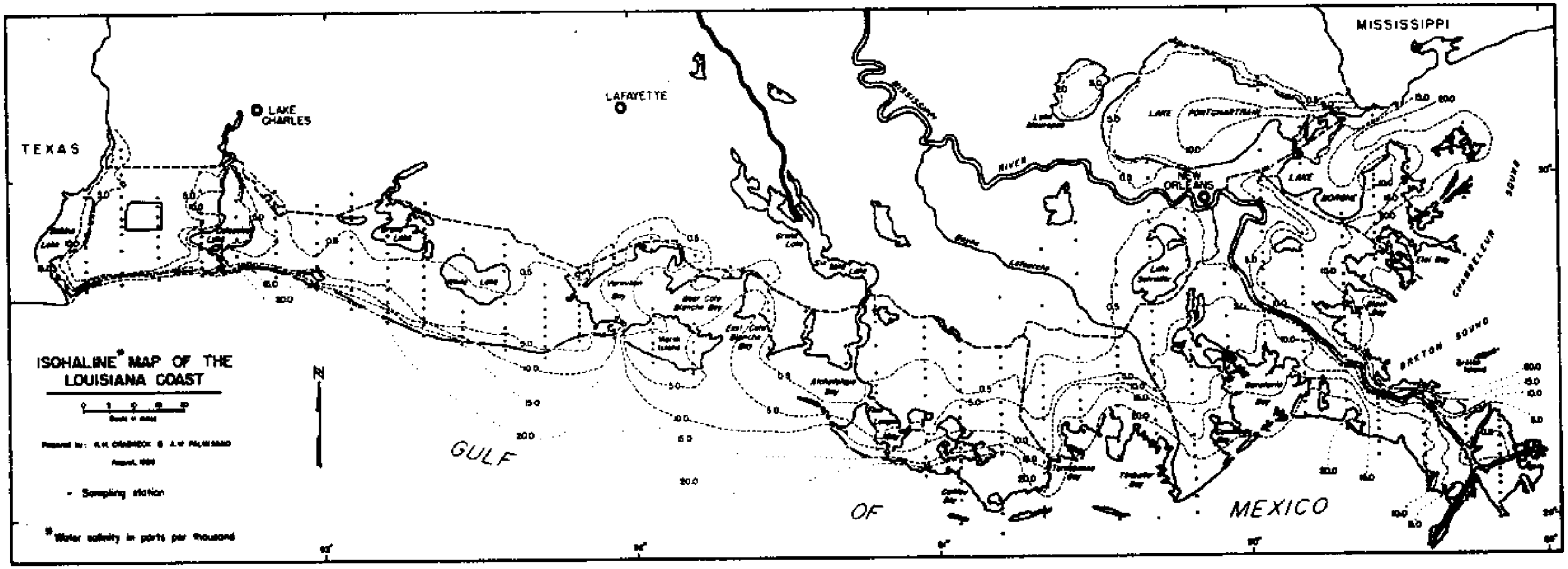


Figure 36. Isohaline areas along coastal zone of Louiaiana (from Chabreck, 1972).

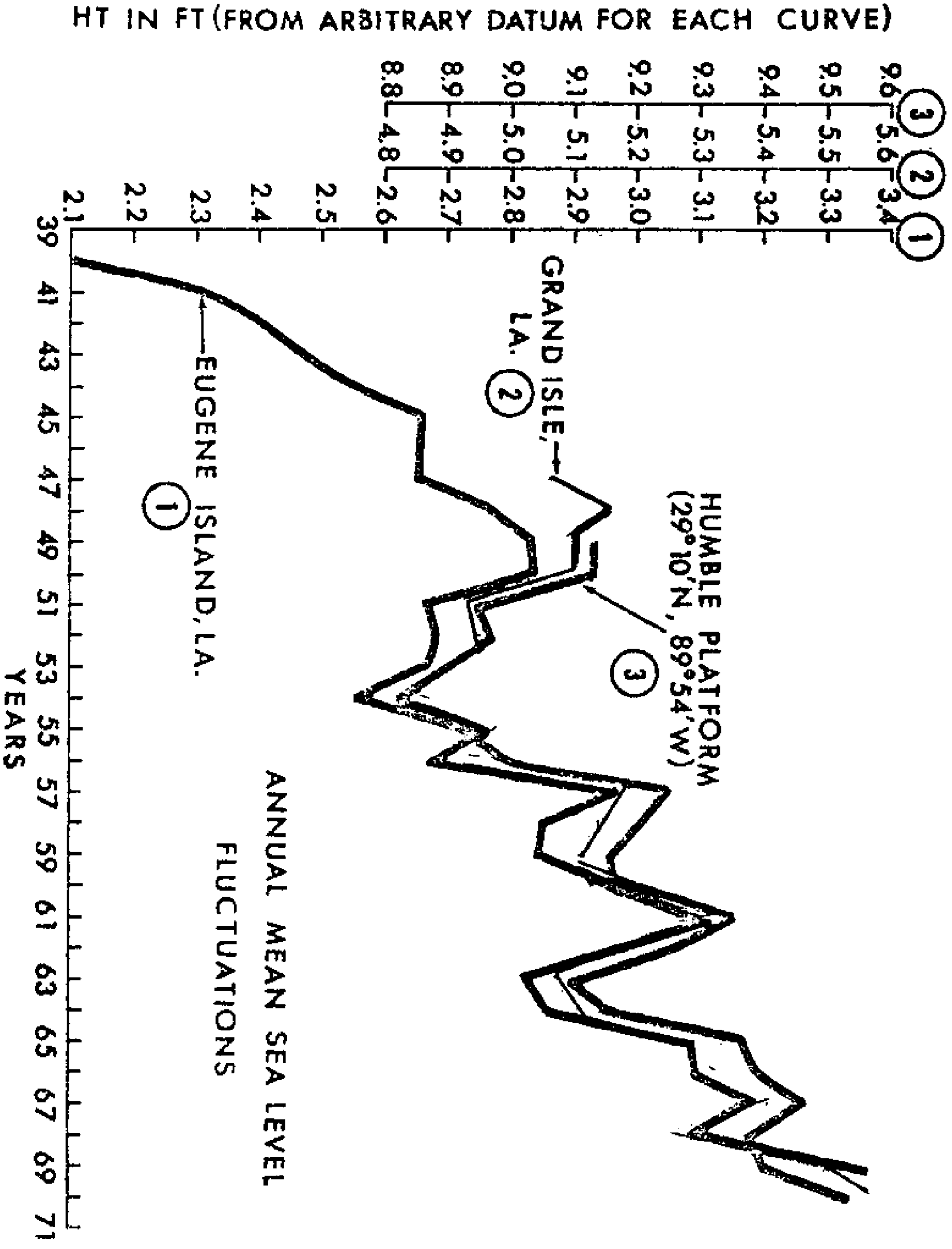


Figure 37. Record of rise in mean sea level from three stations along the Louisiana coast (from Day et al., 1972).

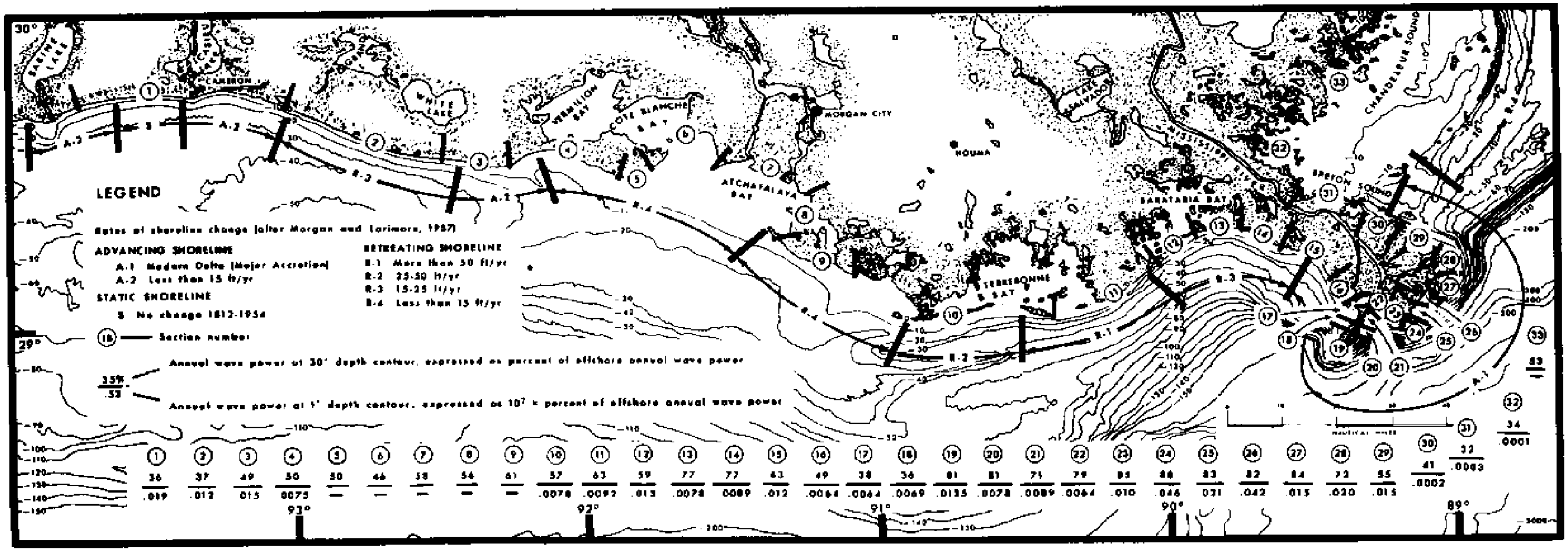


Figure 38. Wave power levels and shoreline change along Louisiana coast (from Becker, 1971).

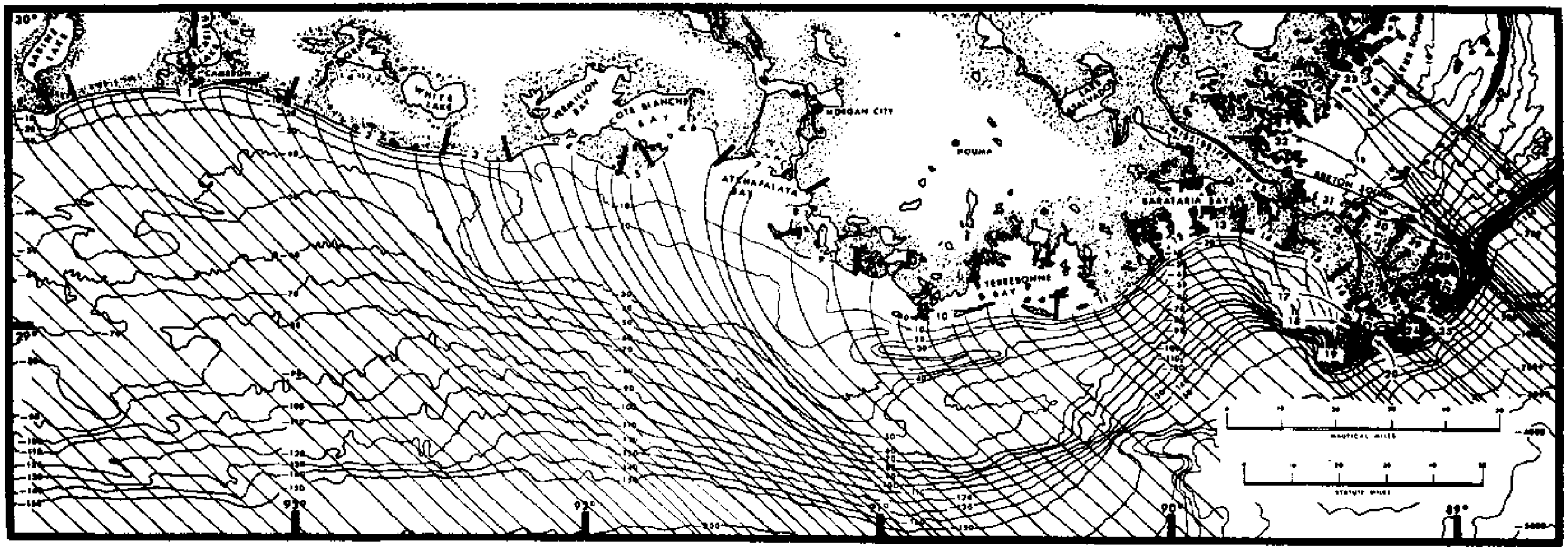


Figure 39. Wave refraction diagram for the Louisiana coast (southeastern wave: height = 5 feet, period = 6 seconds; from Becker, 1971).

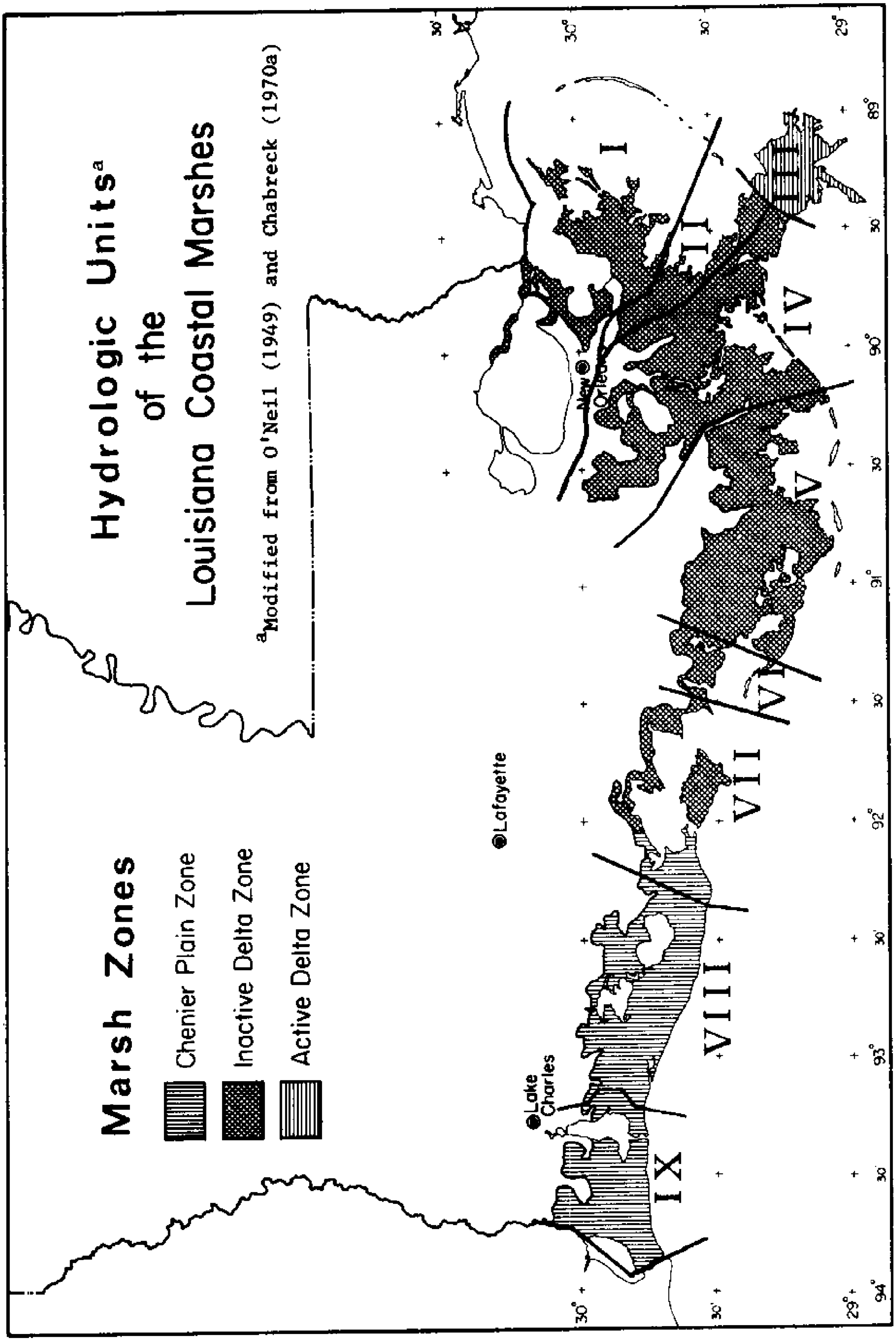


Figure 40. Hydrologic units and marsh zones along Louisiana coast (from Chabreck, 1972).

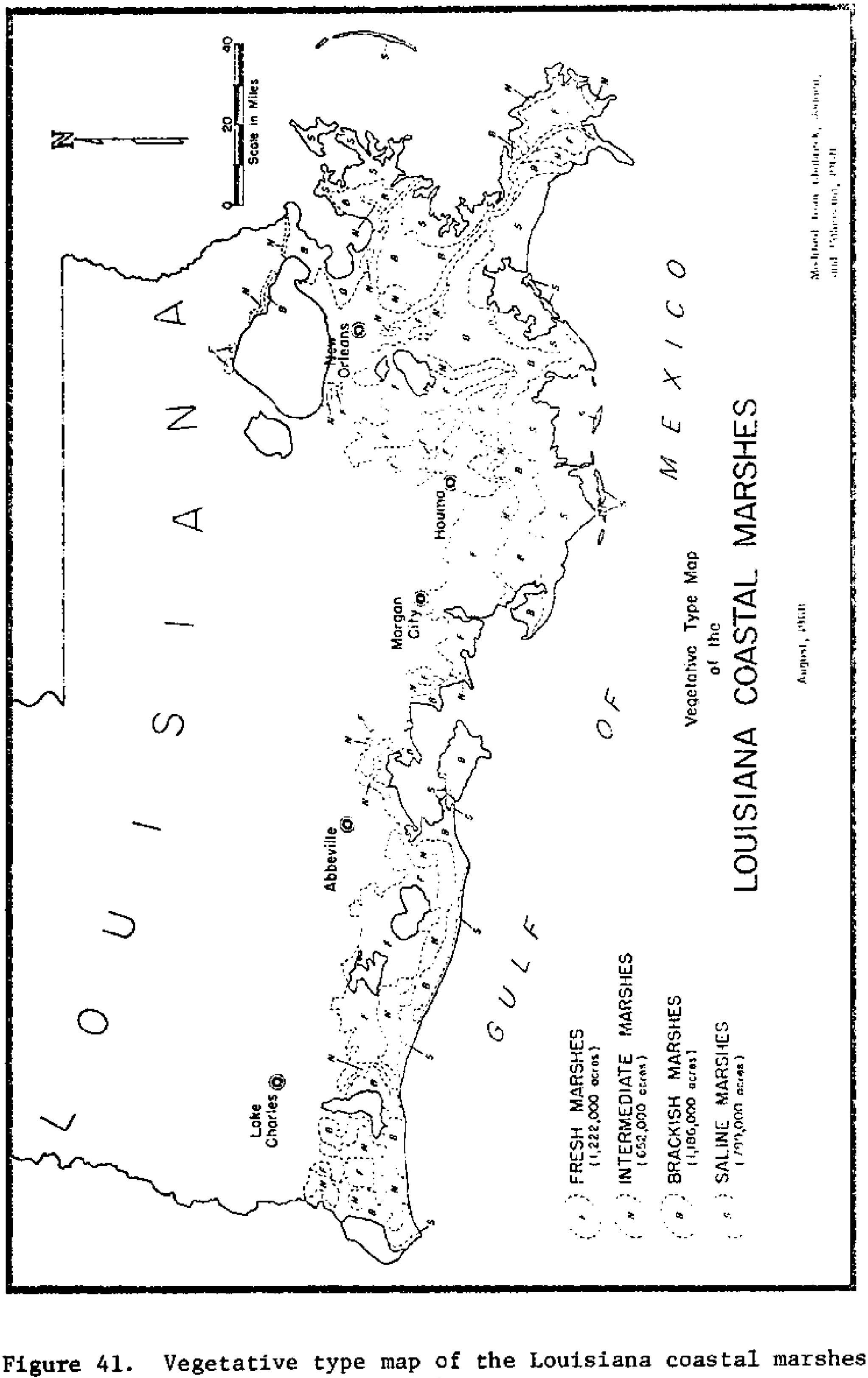


Figure 41. Vegetative type map of the Louisiana coastal marshes (from Chabreck, 1972).

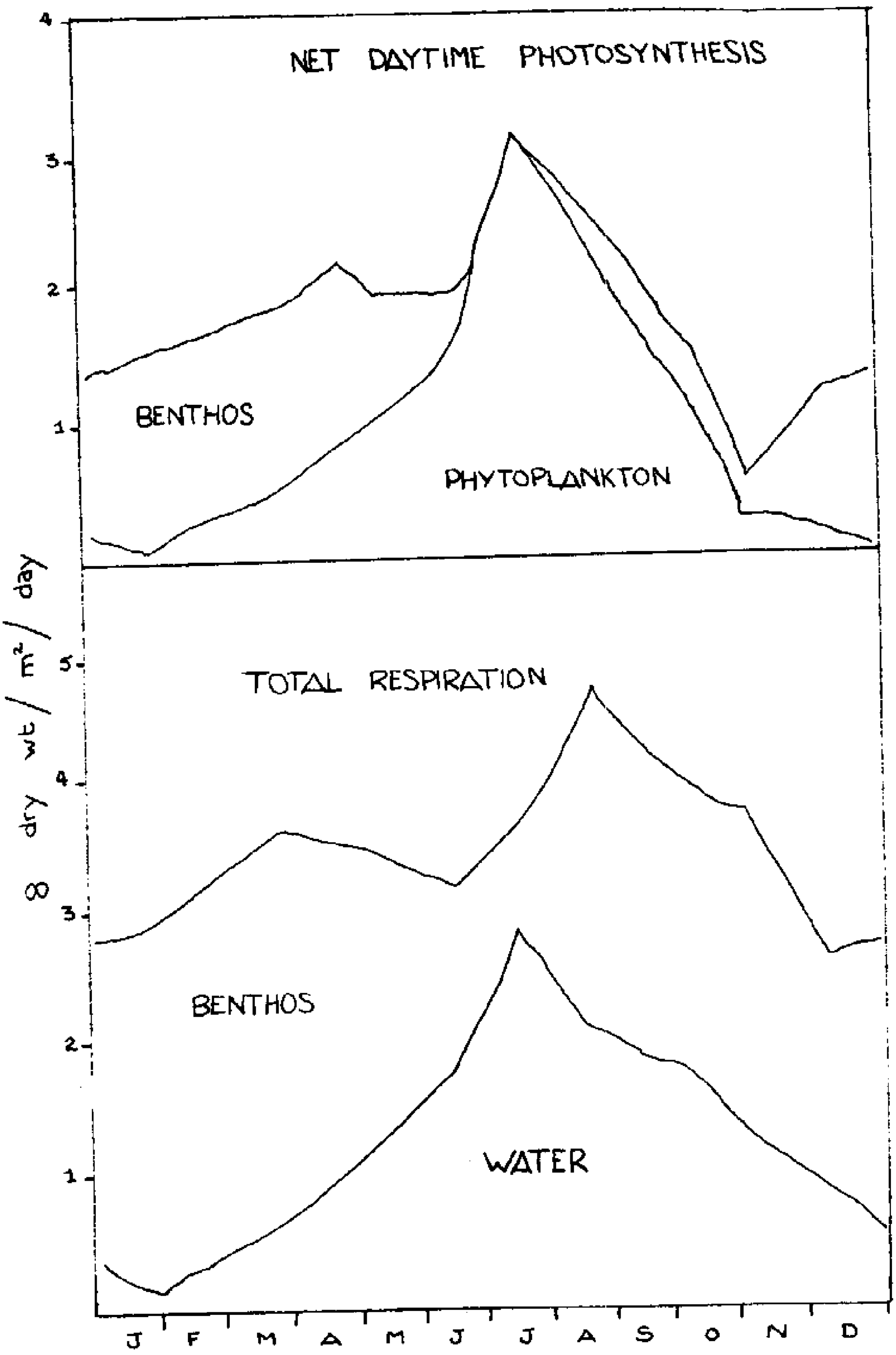


Figure 42. Top: Net daytime production of benthic algae and phytoplankton. Bottom: Total respiration of benthos and water column. Both taken in Barataria Bay, Louisiana (from Day et al., 1972).

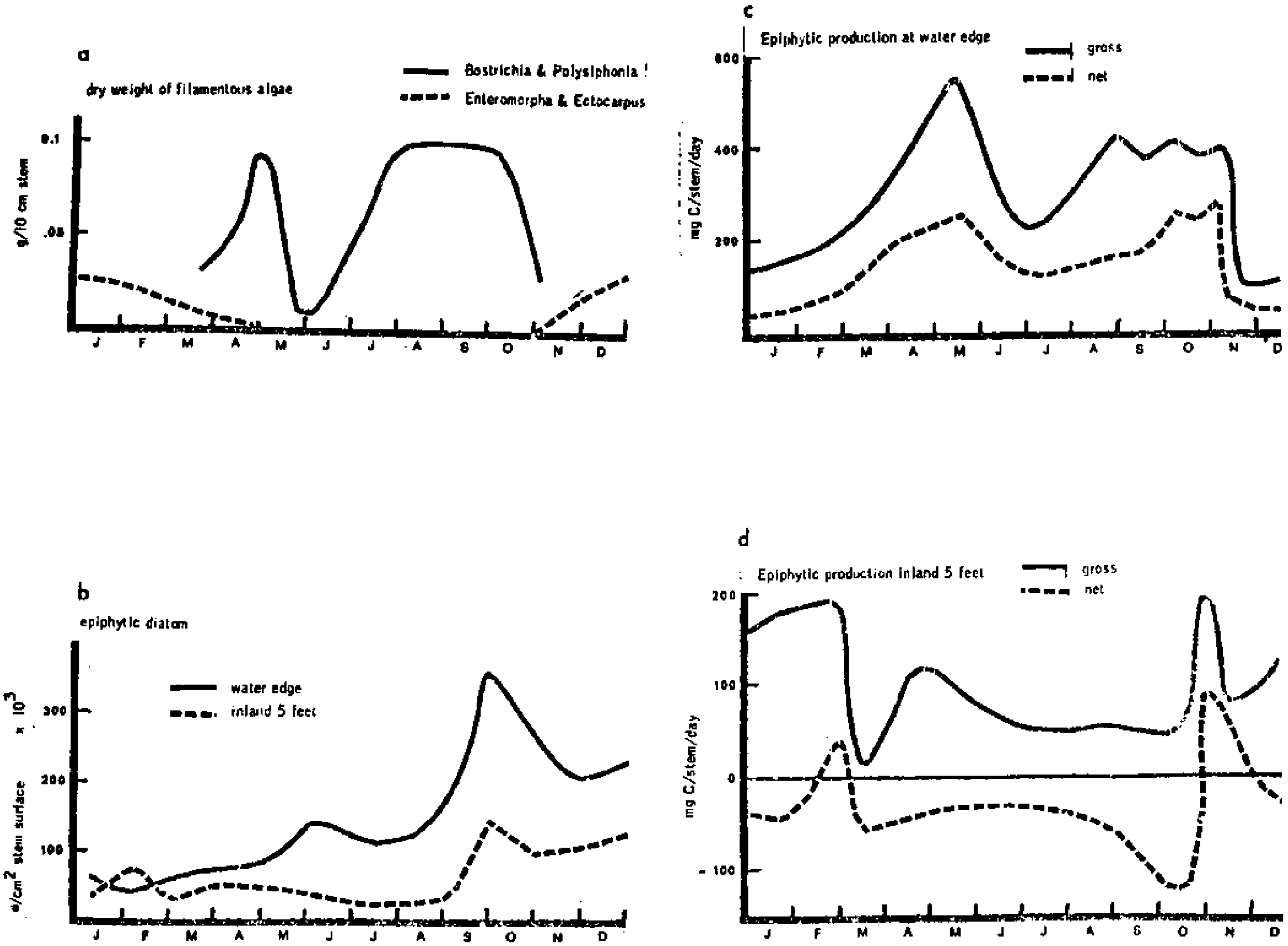


Figure 43. Productivity of the epiphytic community and standing crop of filamentous algae and epiphytic diatoms (from Day et al., 1972).

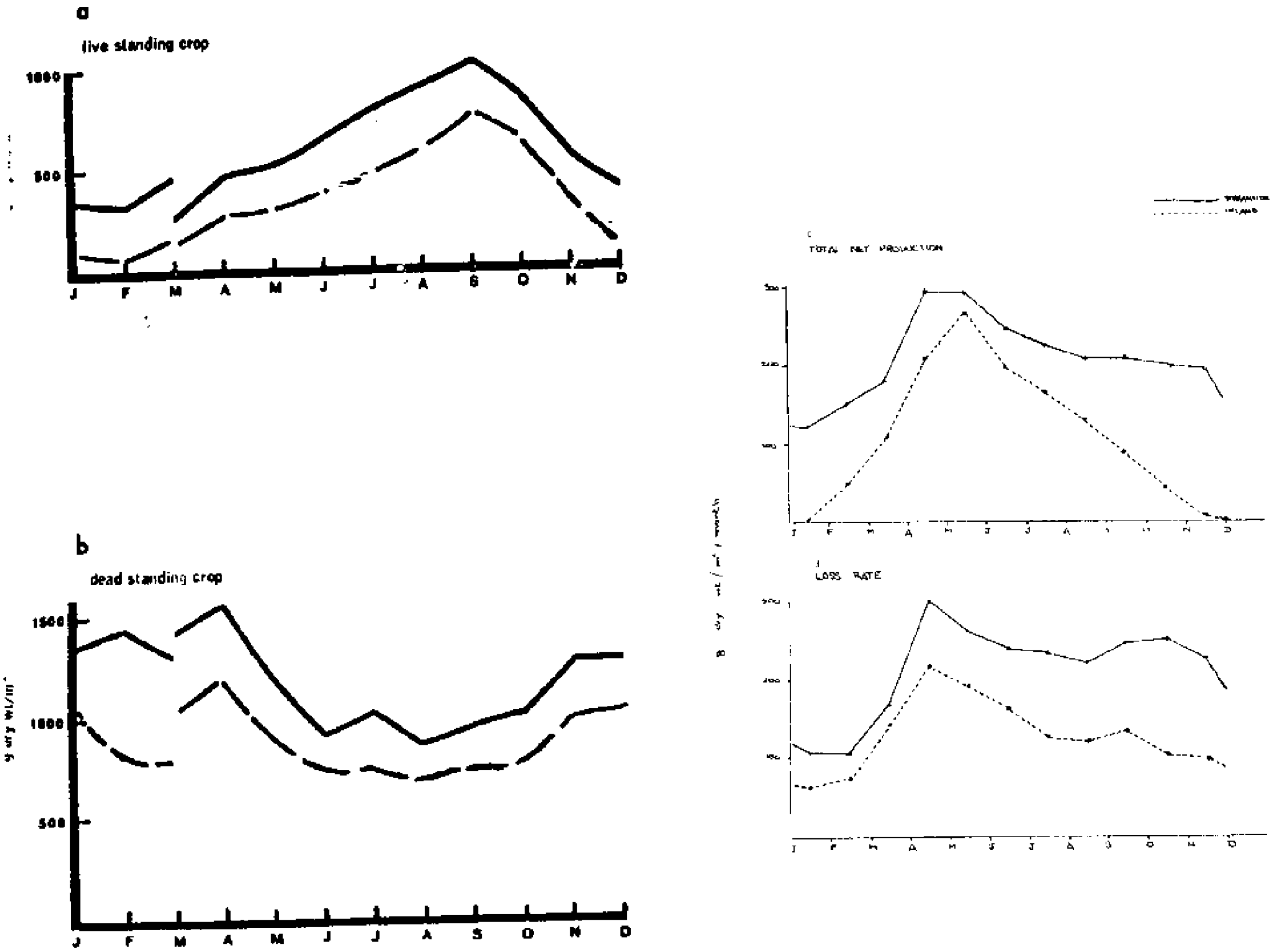


Figure 44. Yearly variations in biomass and productivity of _Spartina alterniflora_ in the vicinity of Airplane Lake (from Day et al., 1972).

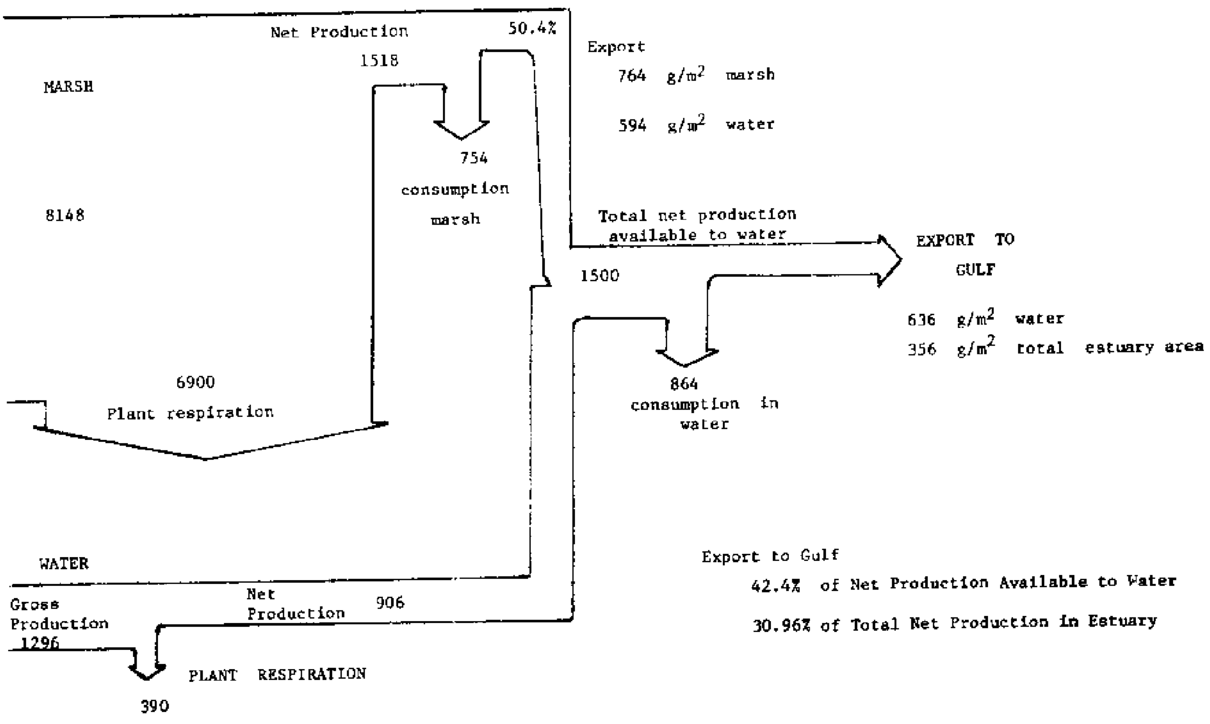


Figure 45. Production and flow of organic matter in Barataria Bay. Numbers for marsh are g dry wt/m^2 marsh/yr and g dry wt/m^2 water/yr for water areas (from Day et al., 1972).

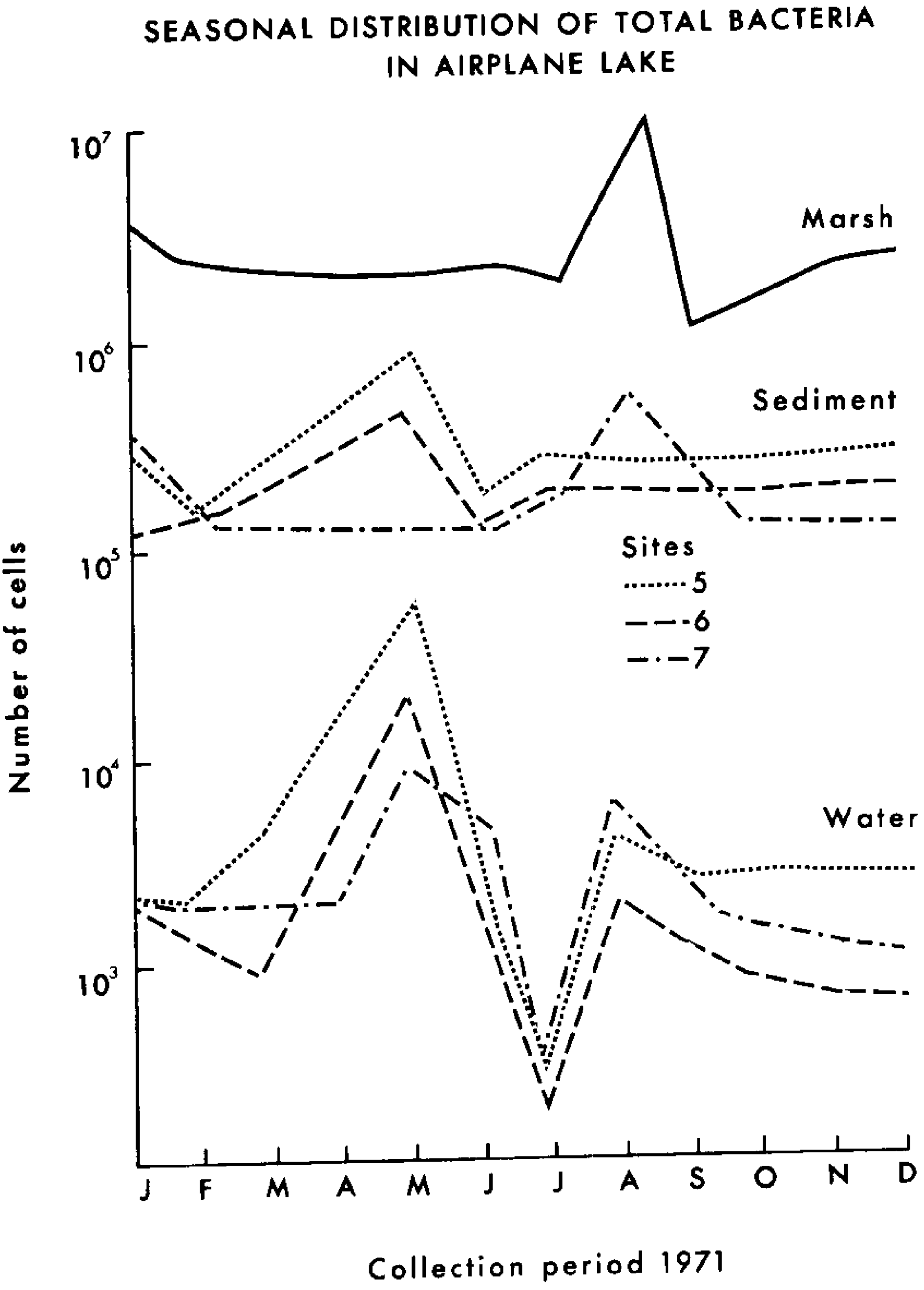


Figure 46. Seasonal distribution of total bacteria in three habitats of Barataria Bay (from Hood, 1970, and unpublished data of Hood, 1970).

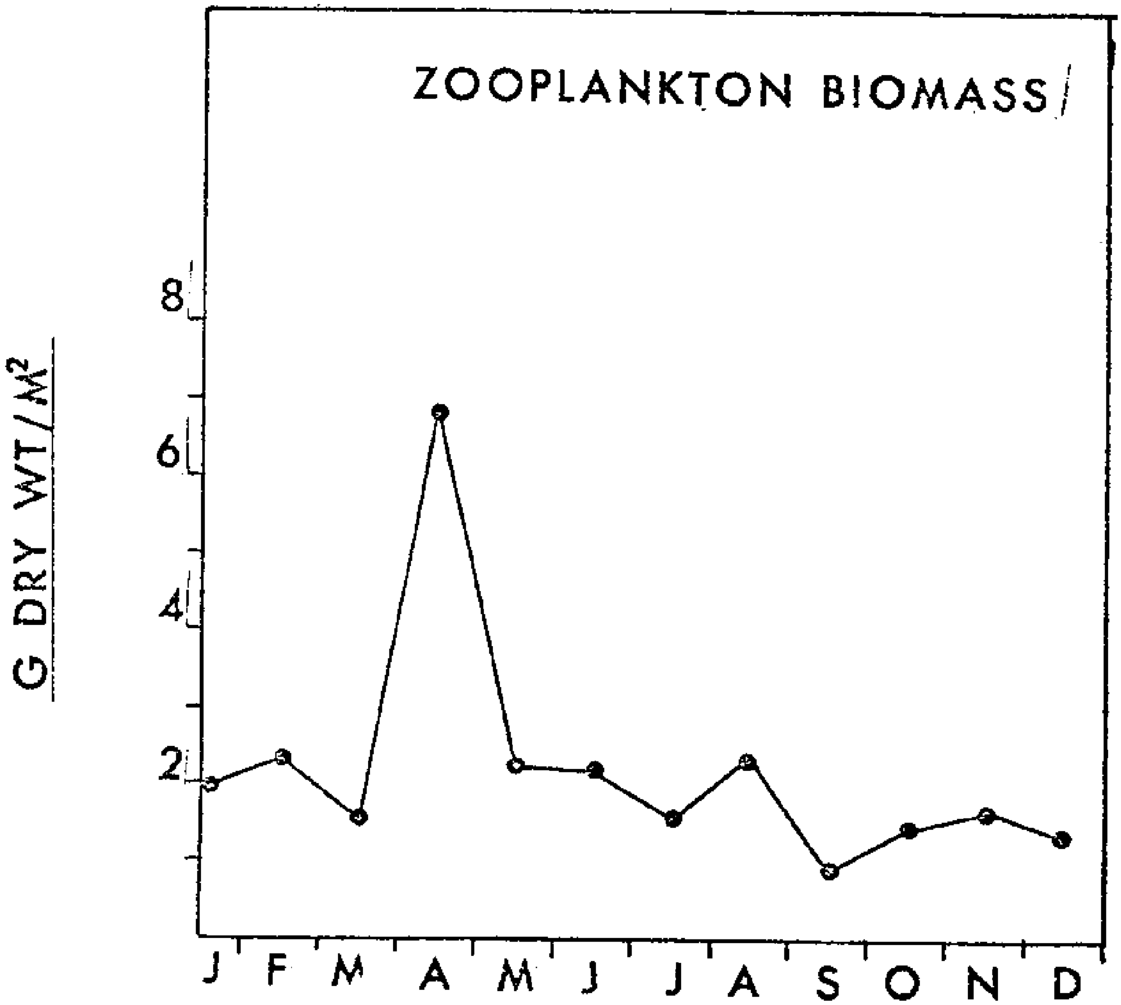


Figure 47. Annual cycle of zooplankton from salt marshes east of the Mississippi River (from Cuzon du Rest, 1963).

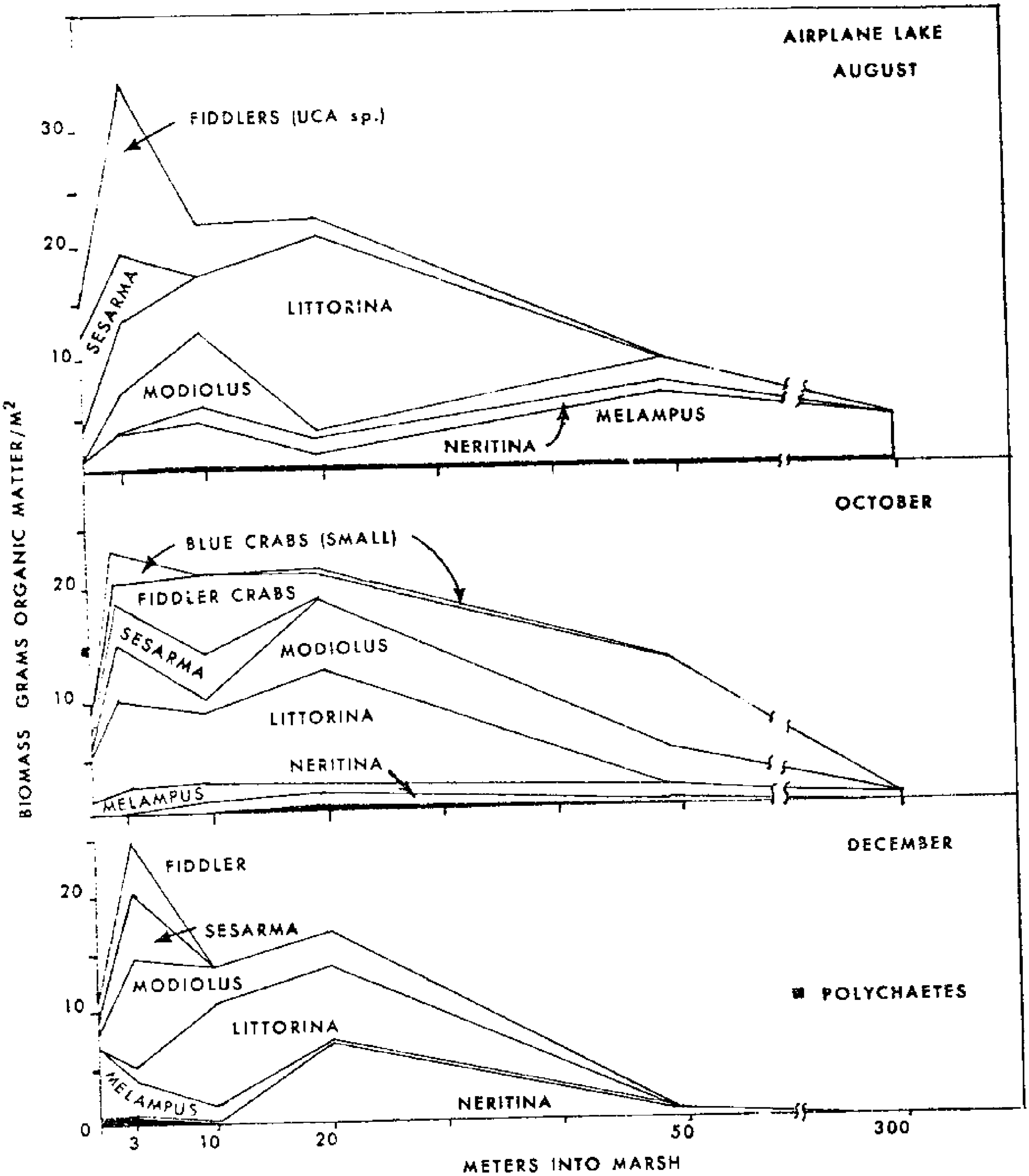


Figure 48A. Distribution of macrofauna in Spartina alterniflora marsh at Airplane Lake (from Day et al., 1972).

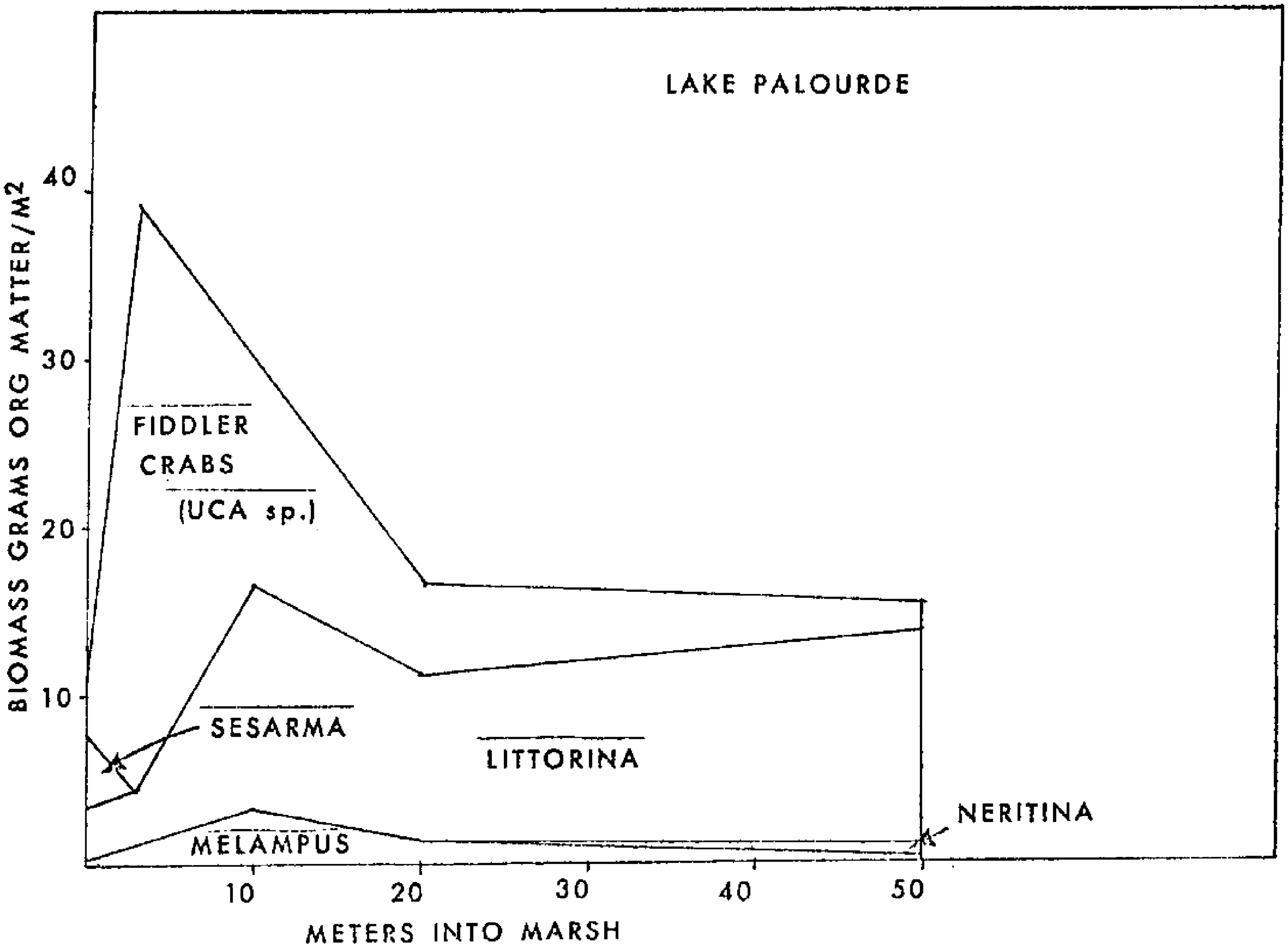


Figure 48B. Distribution of macrofauna in *Spartina alterniflora* marsh at Airplane Lake (from Day et al., 1972).

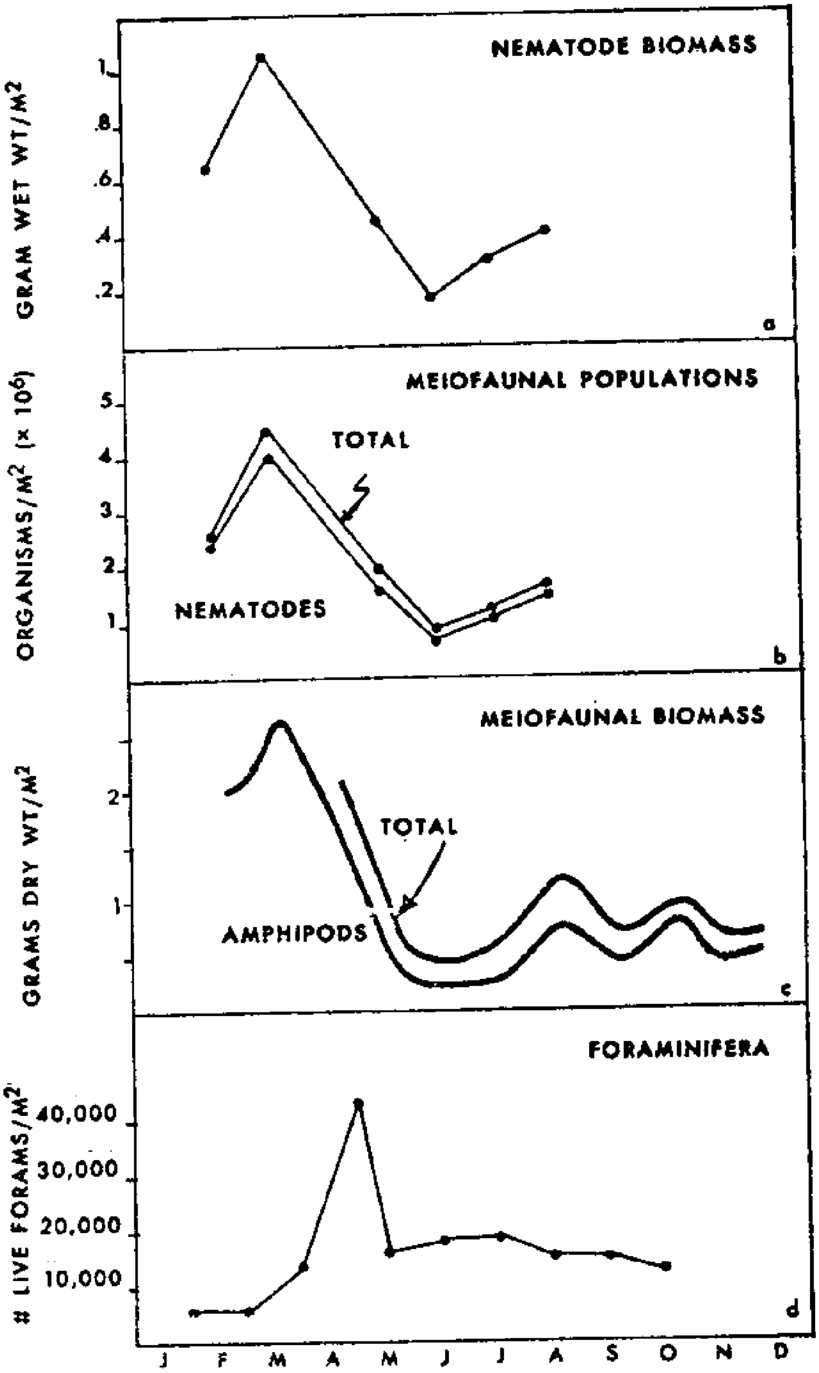


Figure 49. Annual variations of biomass and population levels of meiobenthic organisms of the submerged sediments in Airplane Lake (Bennett, 1972, unpublished data).

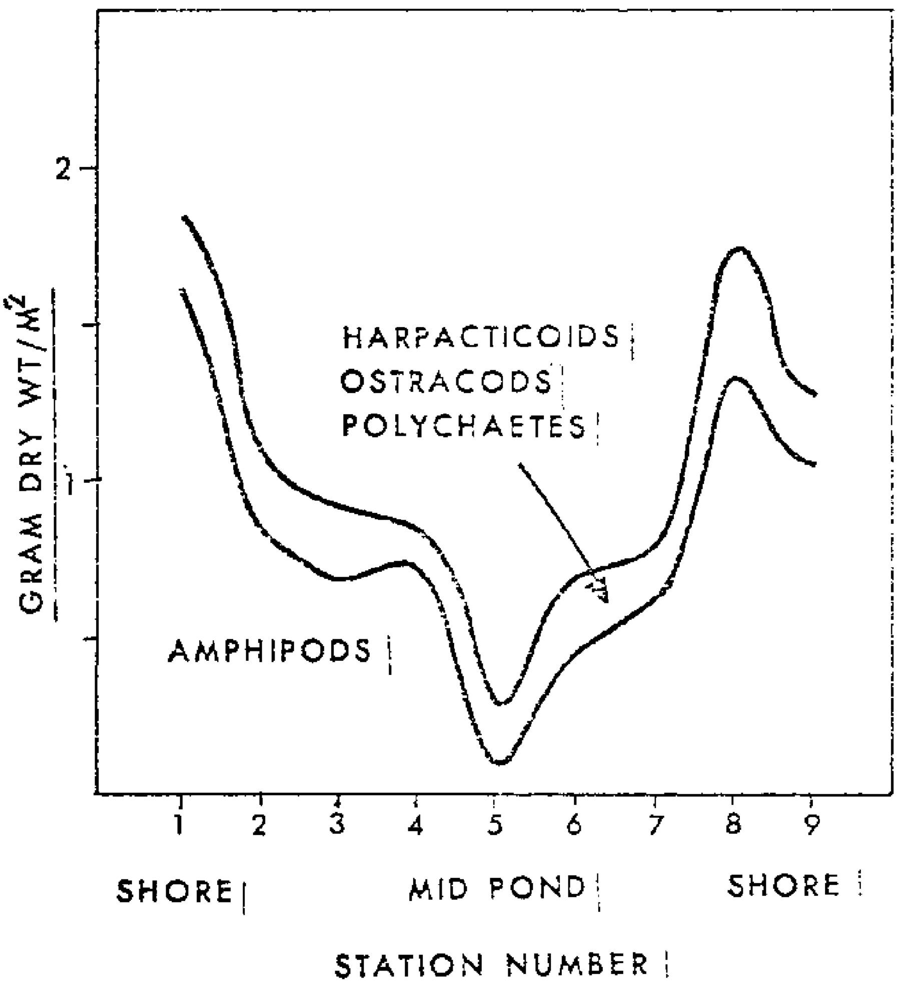


Figure 50. Variation of biomass of meiobenthic organisms on a transect across Airplane Lake. Note that biomass is higher near shore (Bennett, 1972, unpublished data).

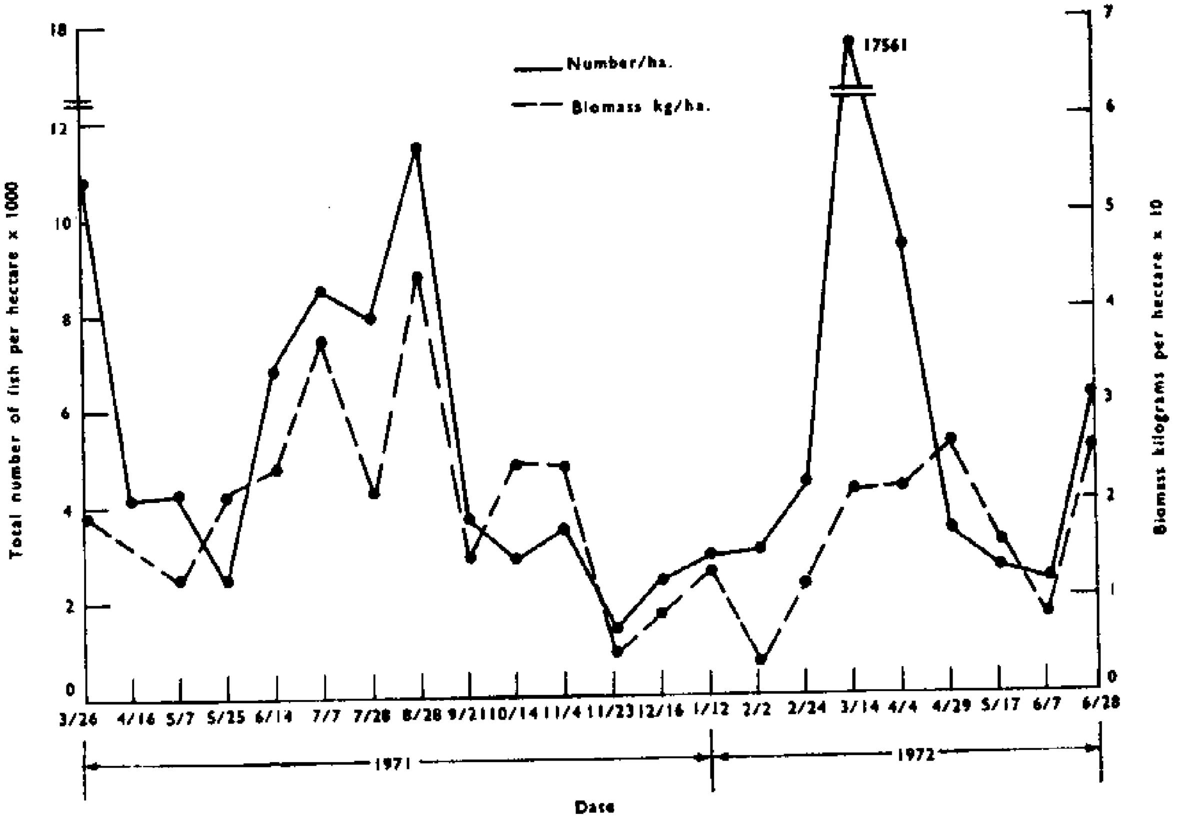


Figure 51. Total biomass and number of fish taken with combined gear at all stations March 1971 - June 1972 (from Wagner, 1972).

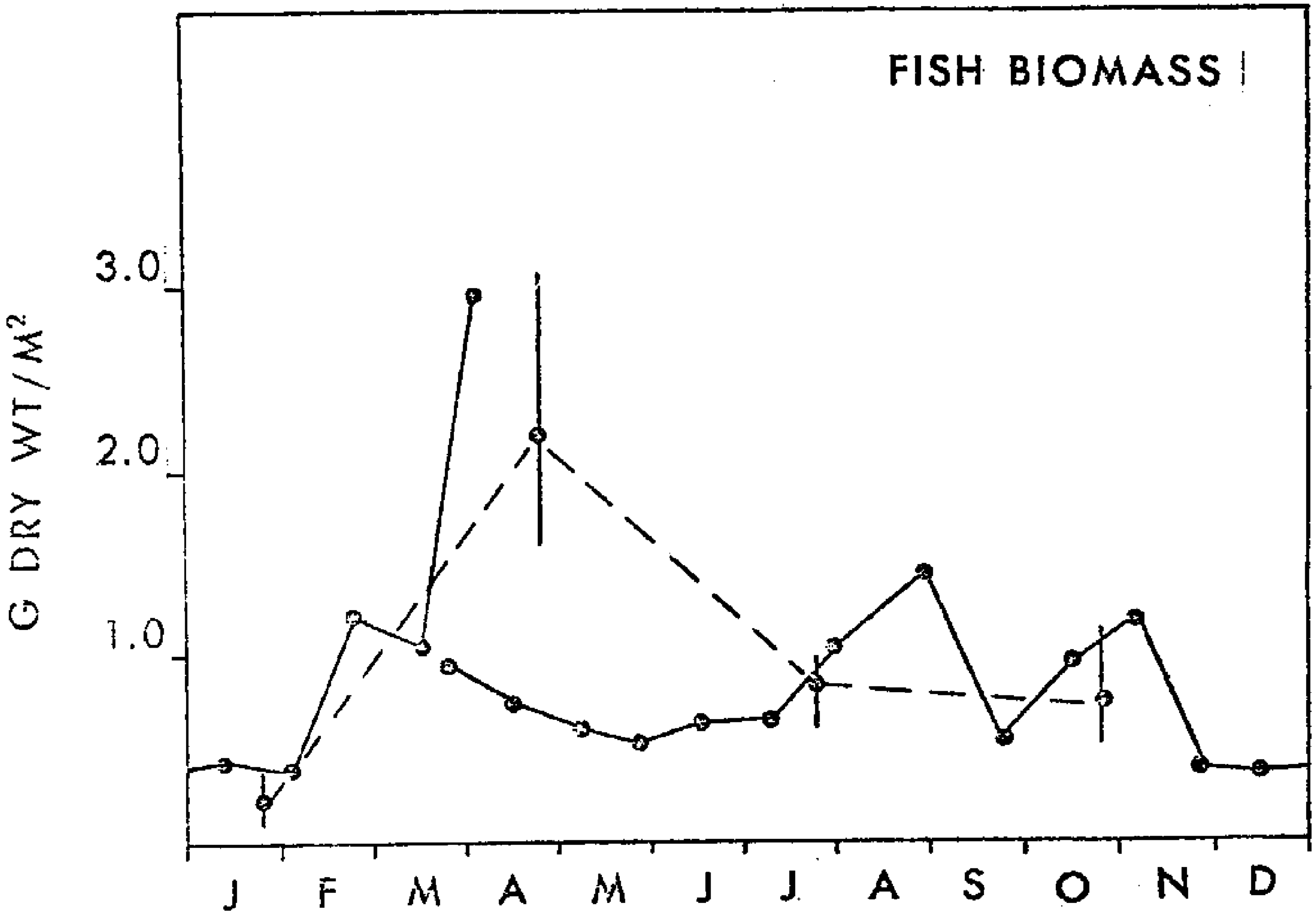


Figure 52. Annual patterns of biomass of fishes. Solid line is average of seven sites in western Barataria Bay (see Figure 3) for 1971-72. Dashed line is average of 3 years (1968-1971) at three stations in Lake Grade Ecaille (see Figure 3). Vertical lines are range over 3 years (from Day et al., 1972).

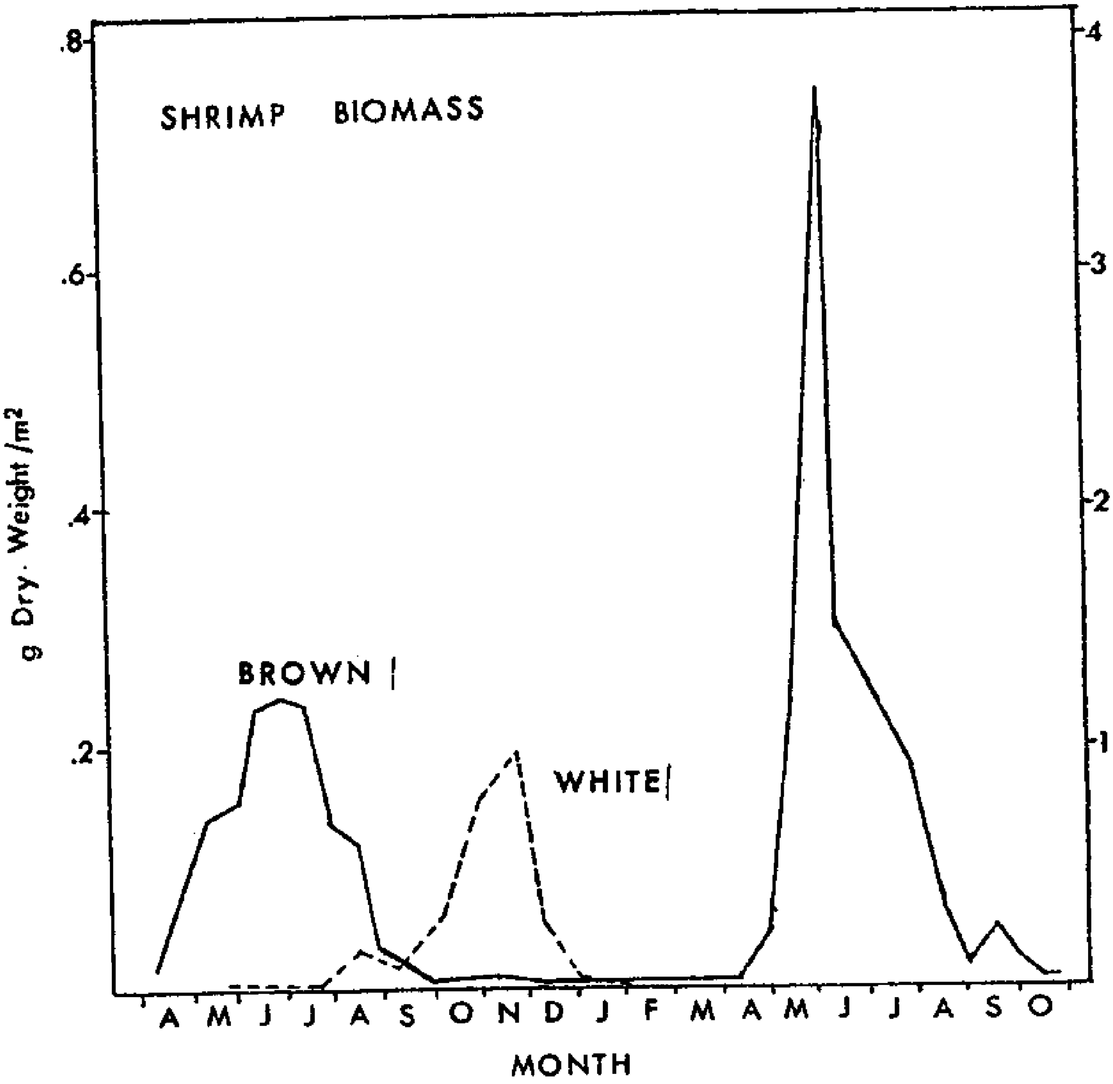


Figure 53. Annual biomass variation for brown and white shrimp in Barataria Bay. The two years of data for brown shrimp are 1969 and 1970. The data for white shrimp are for 1971 (from Day et al., 1972).

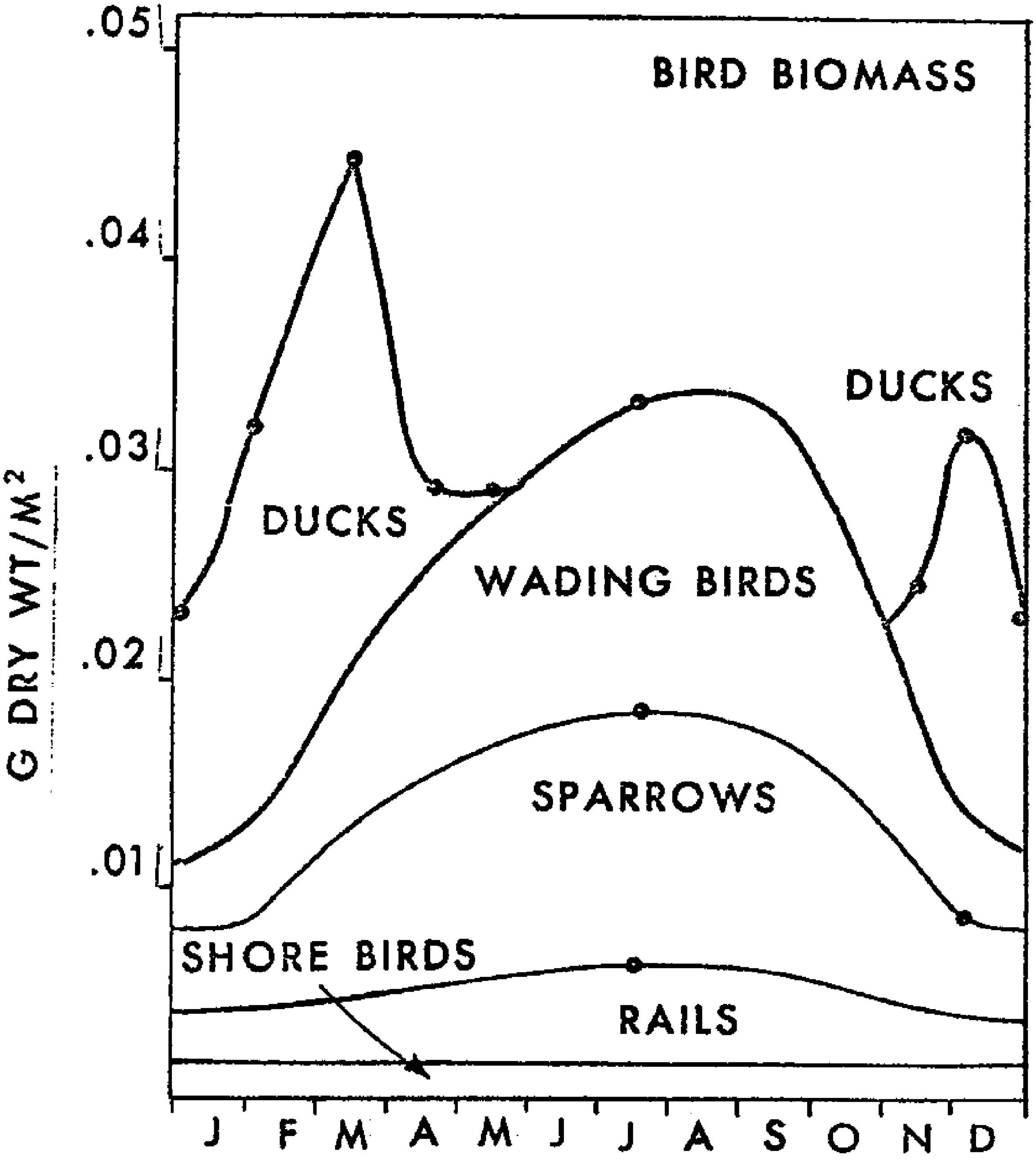


Figure 54. Pattern of population composition and biomass of birds in the salt marsh (from Day et al., 1972).

Average number of shrimp per unit effort of combined seines and trawls.

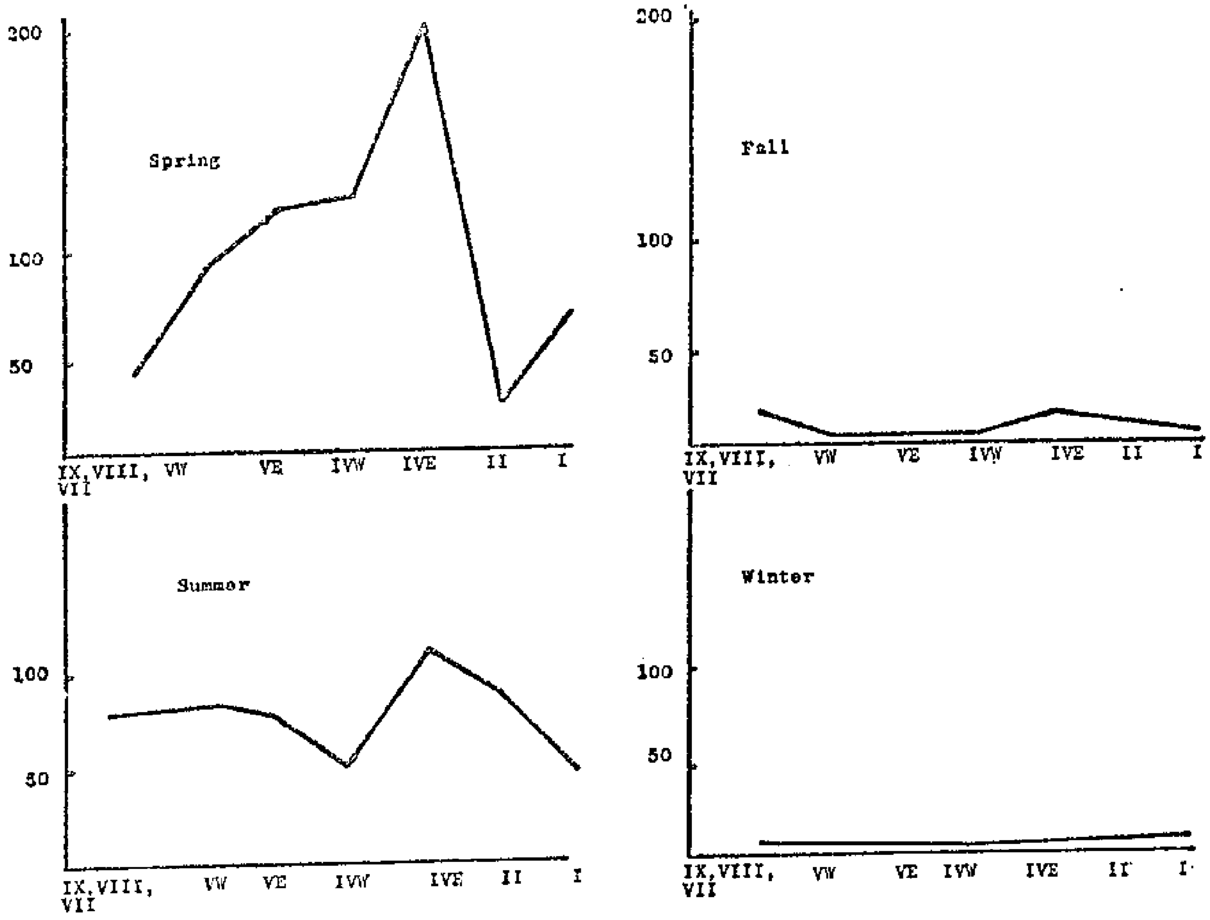


Figure 55. Seasonal abundance and distribution of juvenile brown shrimp (*Penaeus aztecus*) by hydrologic unit (1968-69). Sampling by Louisiana Wild Life and Fisheries Commission, Cooperative Gulf of Mexico Estuarine Inventory. Geographical overlap of catches resulted in division of some hydrologic units into E (east) and W (west) (from Lindall et al., 1972).

Average number of shrimp per unit effort of combined seines and trawls.

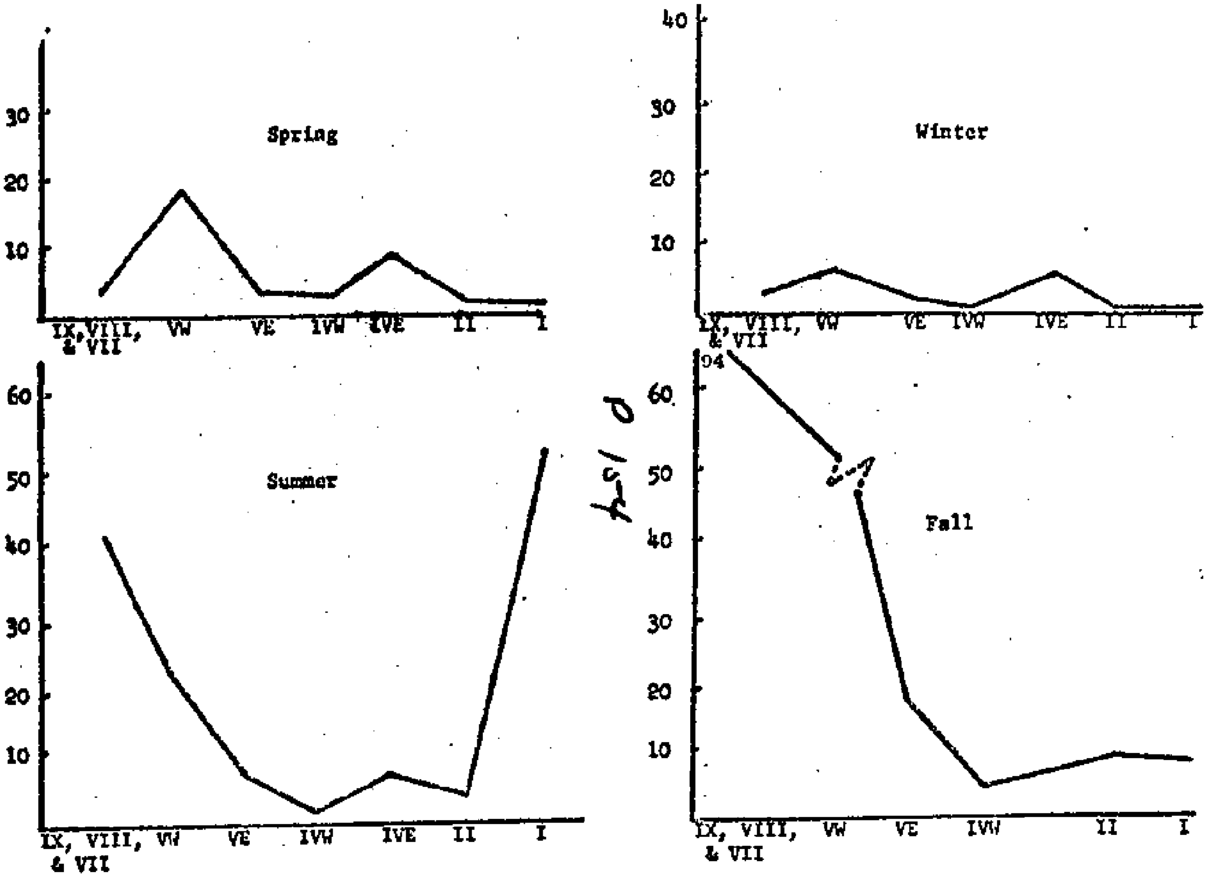


Figure 56. Seasonal abundance and distribution of juvenile white shrimp (*Penaeus setiferus*) by hydrologic unit. Sampling by Louisiana Wild Life and Fisheries Commission, Cooperative Gulf of Mexico Estuarine Inventory. Geographical overlap of catches resulted in division of some hydrologic units into E (east) and W (west) (from Lindall et al., 1972).

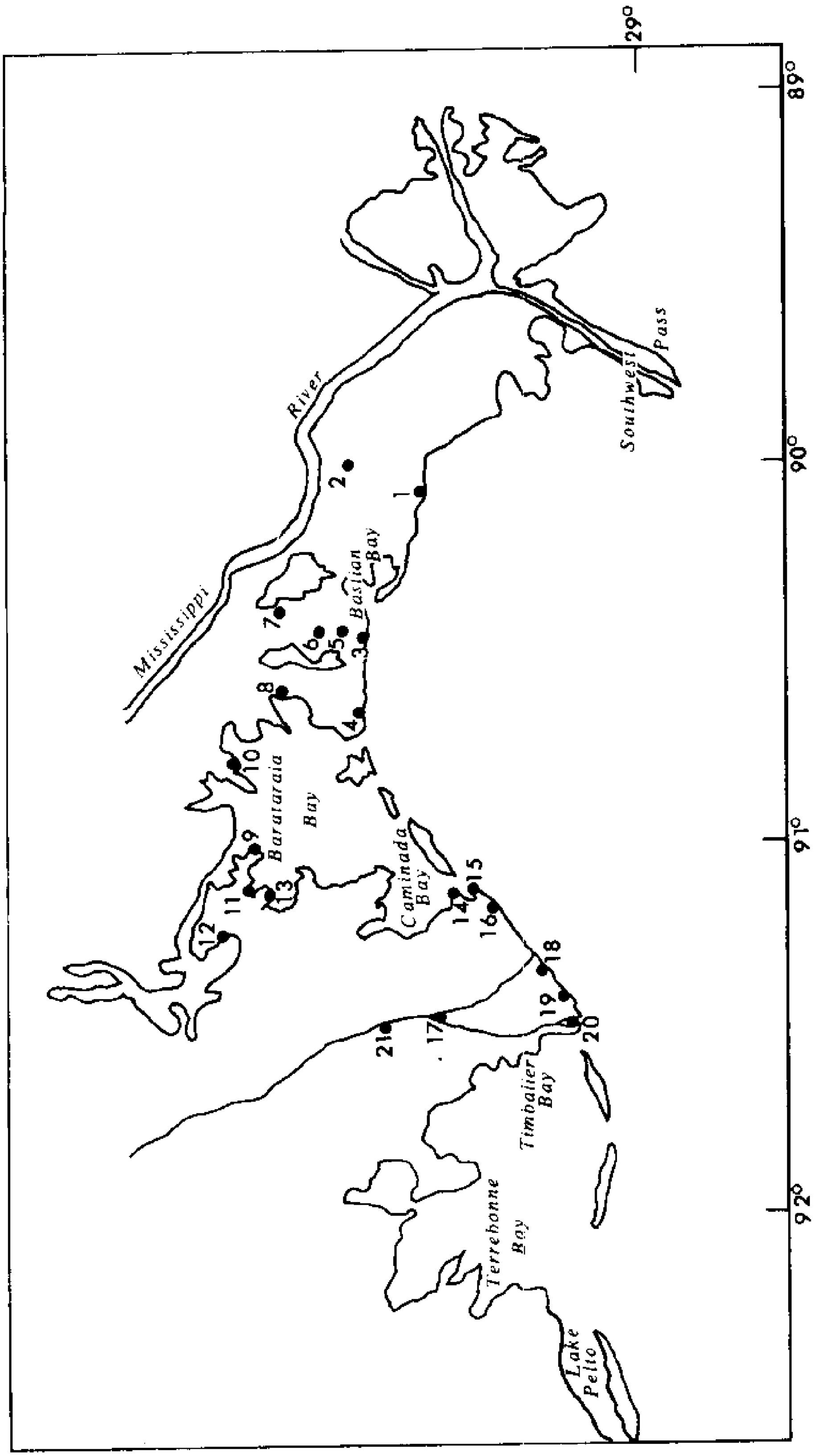


Figure 57. Known archeological sites in study area (unpublished data of Neuman, 1972, and Gagliano, 1972).

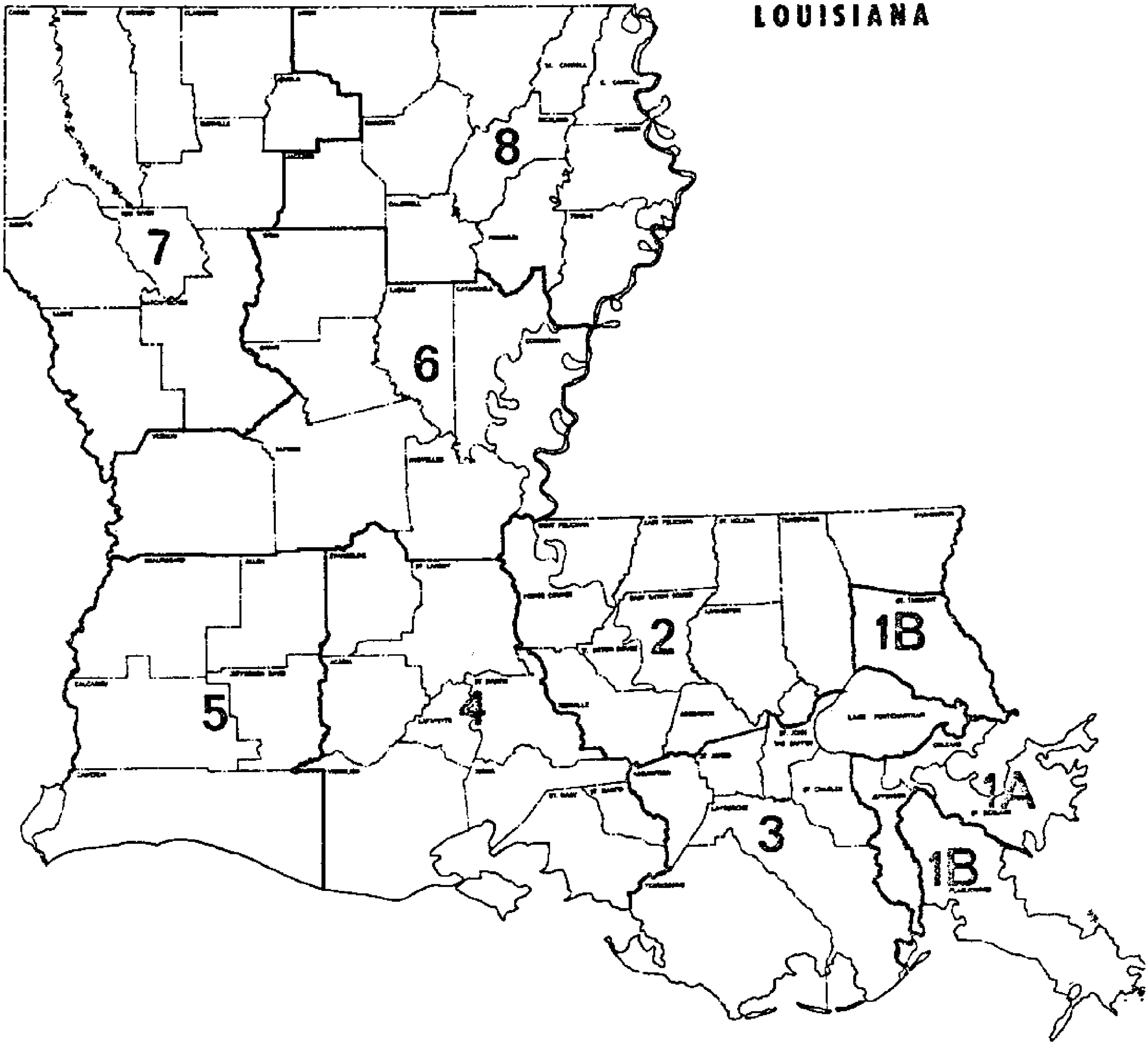


Figure 58. Areas in Louisiana for population estimates (from Louisiana State Parks and Recreation Commission, June 1971. Comprehensive Outdoor Recreation Plan, 1970-75).

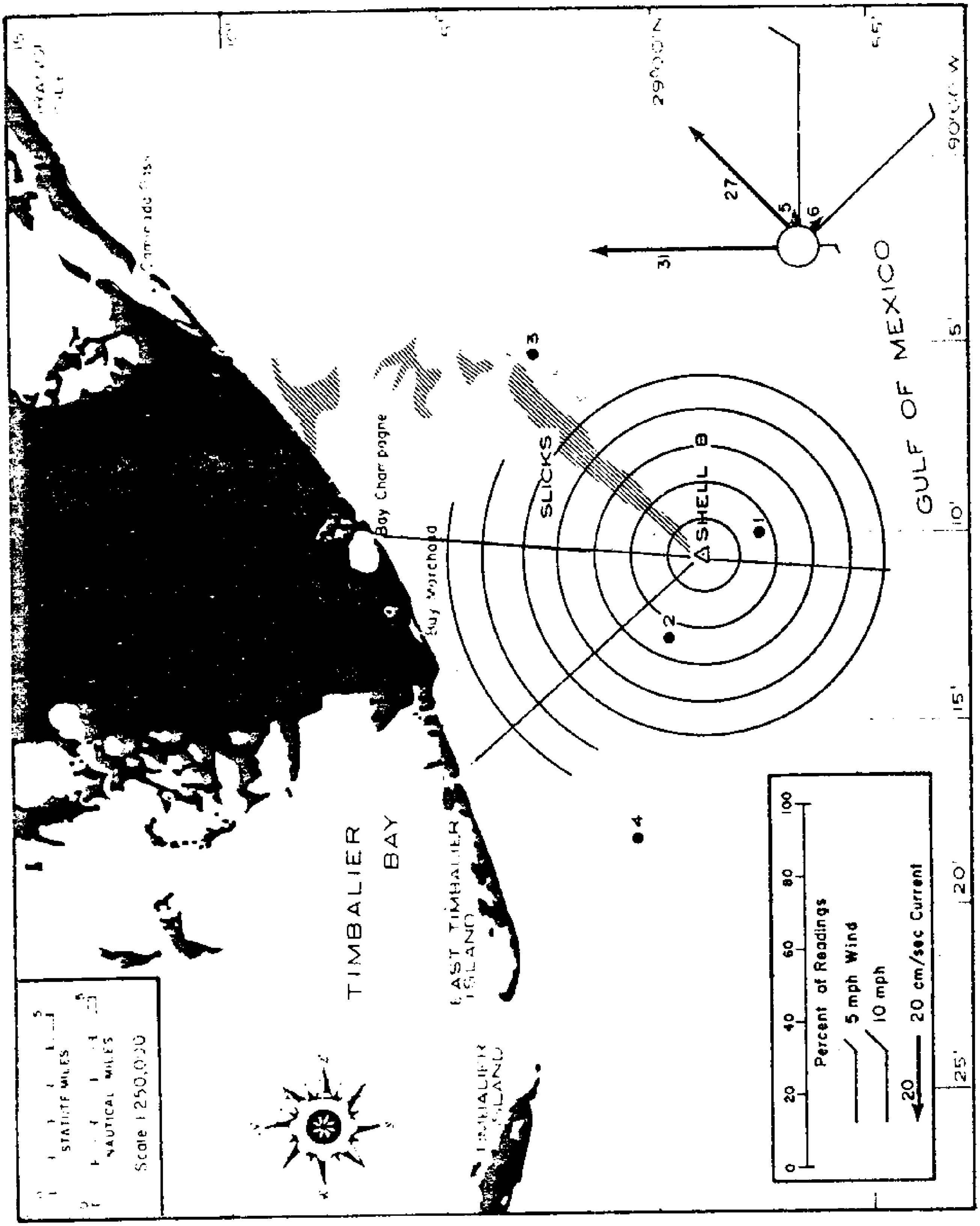


Figure 59. Current and wind data and oil-slick orientation, 13 January 1971, Texas Instruments surveillance (from Resources Technology Corporation, 1972).

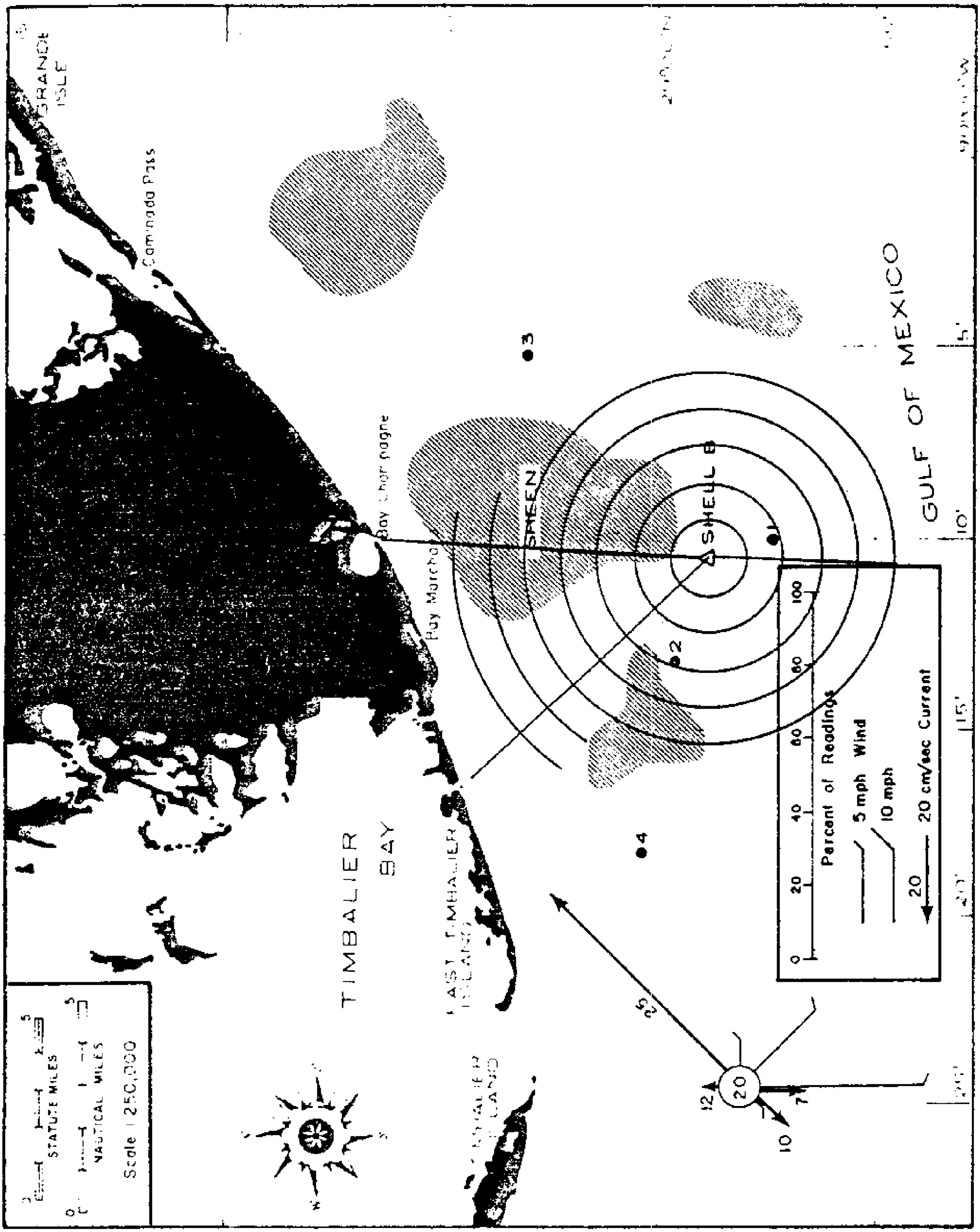


Figure 60. Current and wind data and oil-slick orientation, 14 January 1971, EPA spill surveillance (from Resources Technology Corporation, 1972).

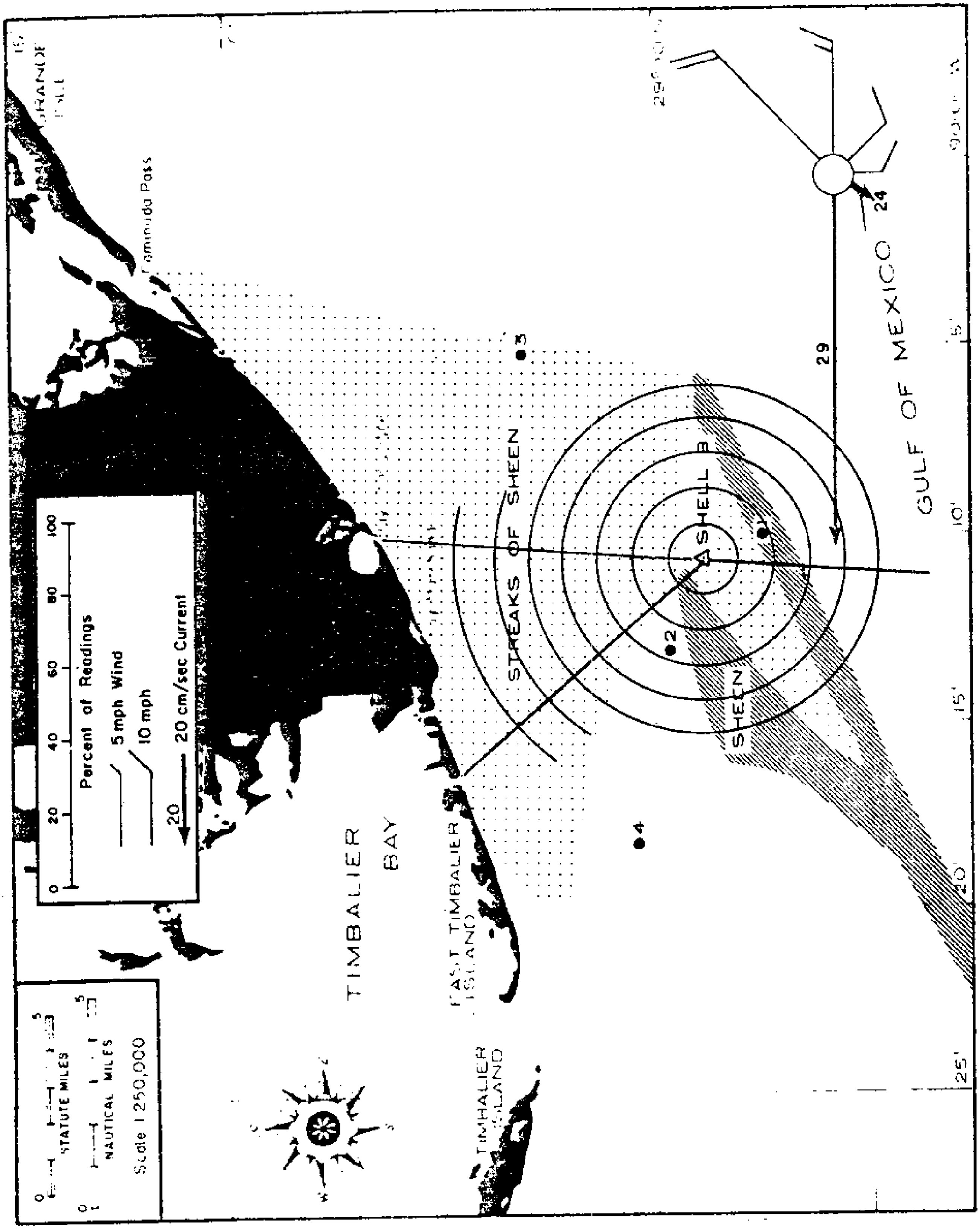


Figure 61. Current and wind data and oil-slick orientation, 16 January 1971, EPA spill surveillance (from Resources Technology Corporation, 1972).

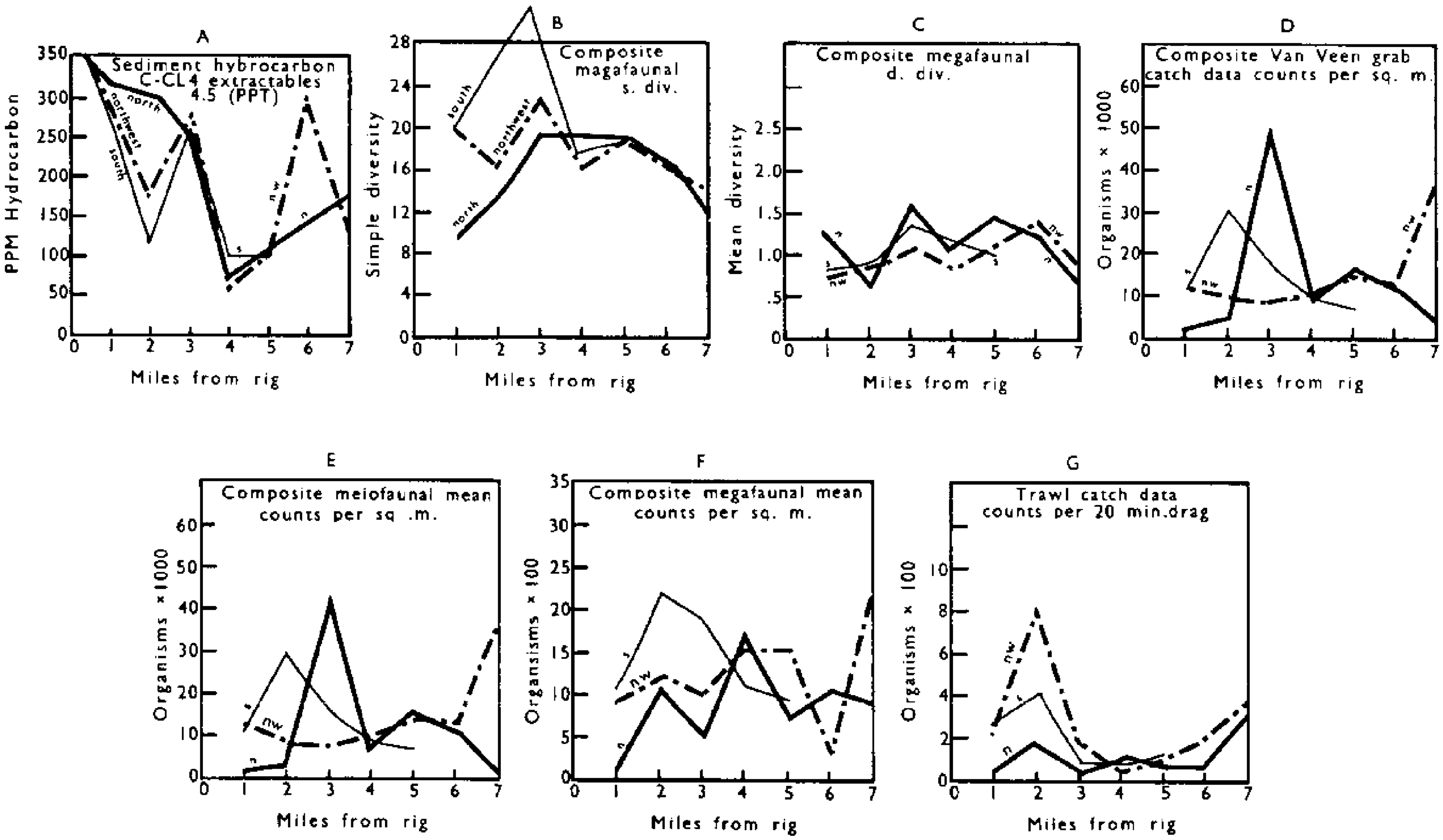


Figure 62. Sediment distribution of hydrocarbons (A), species diversity (B), mean species diversity (C), composite grab data (D), composite meiofauna data (E), composite megafauna data (F), and trawl data (G) (adapted from Resources Technology Corporation, 1972).

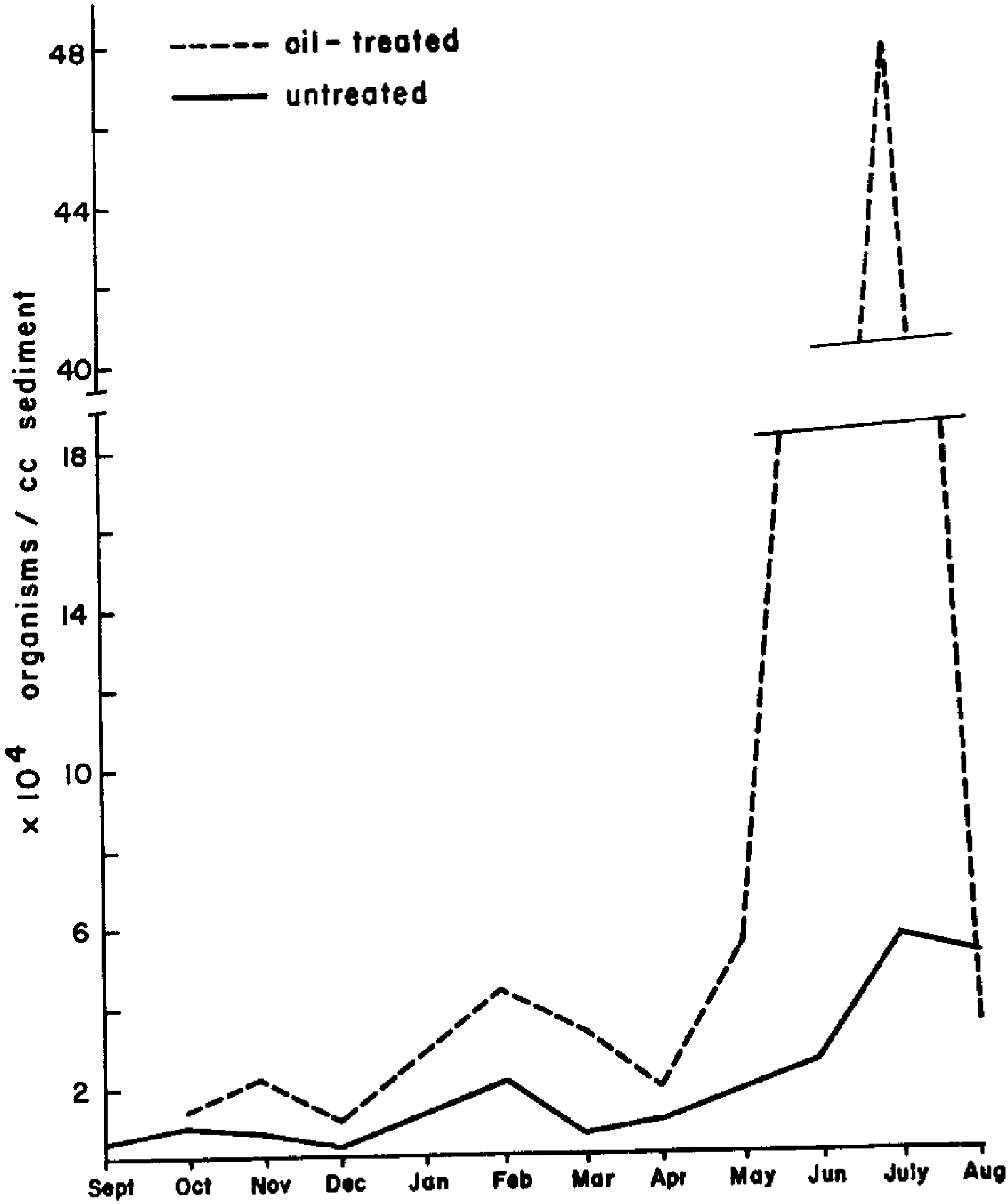


Figure 63. Comparison of yeast concentrations in oil-treated sediment and sediment not exposed to oil (from Crow, 1972).

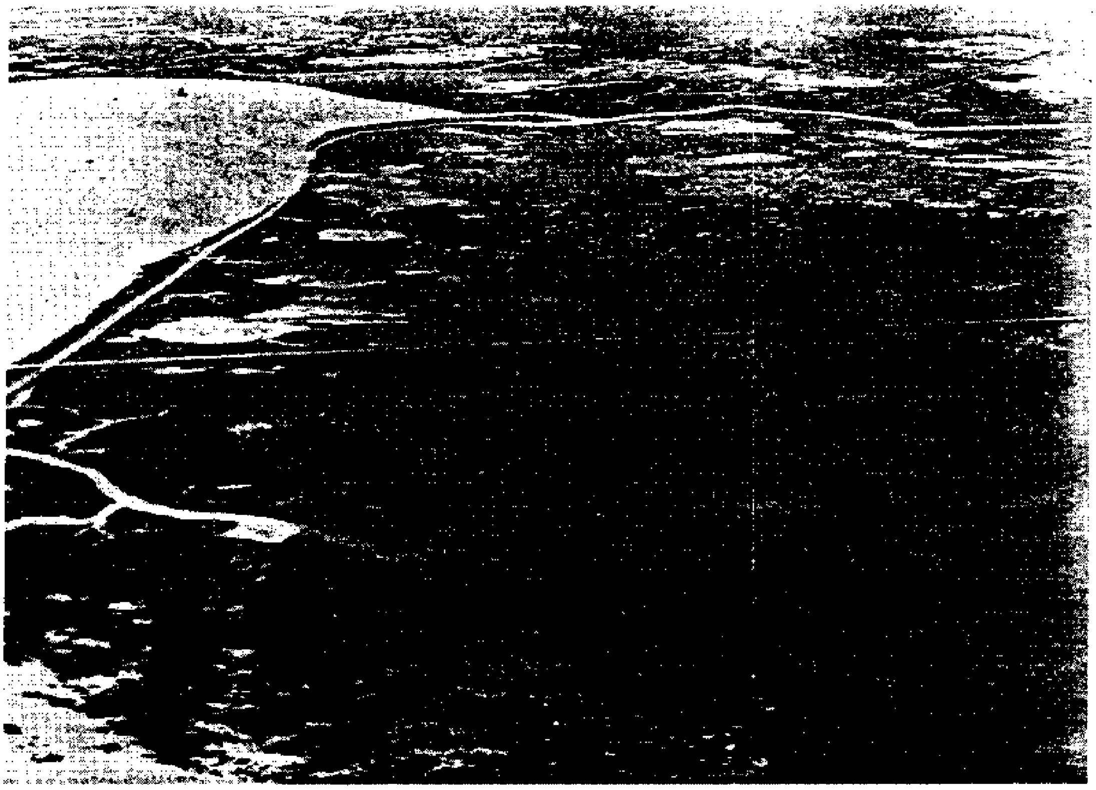


Figure 64A. Aerial view of relatively undisturbed marsh, indicating tortuous water courses and ponding associated with active nursery (from St. Amant, 1972).

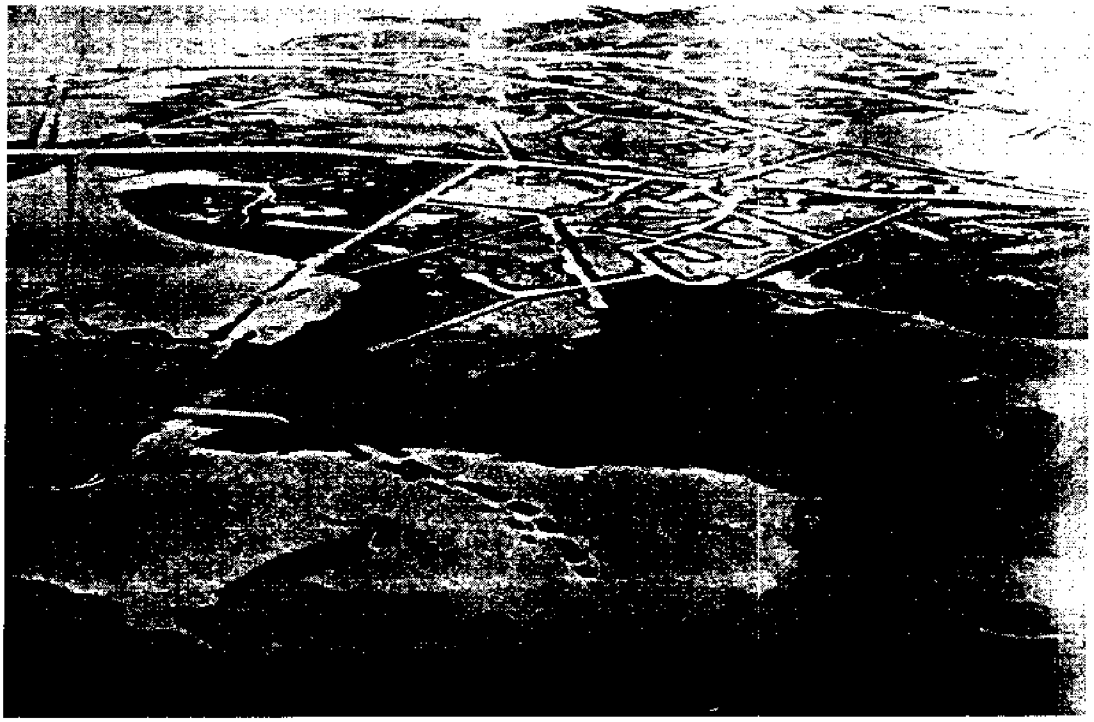


Figure 64B. Extreme disruption of marshes attendant with intensive oil production--compare with Figure 64A (from St. Amant, 1972).

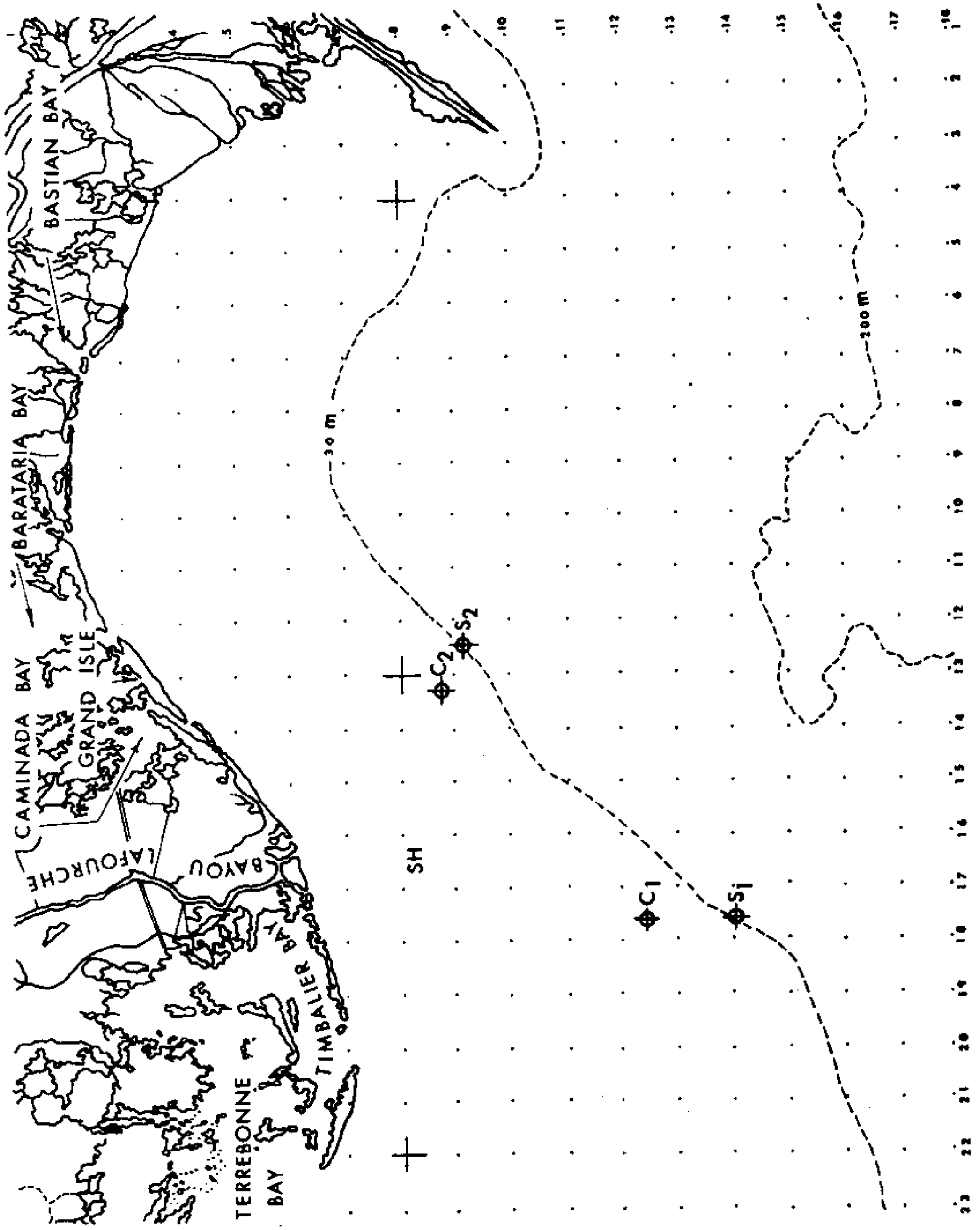


Figure 65. Grid system used for projection of surface circulation offshore Louisiana. Each grid approximately 29.6 km^2. Letters identified in Figure 1. Numbering system corresponds to graphic and numerical current vectors.

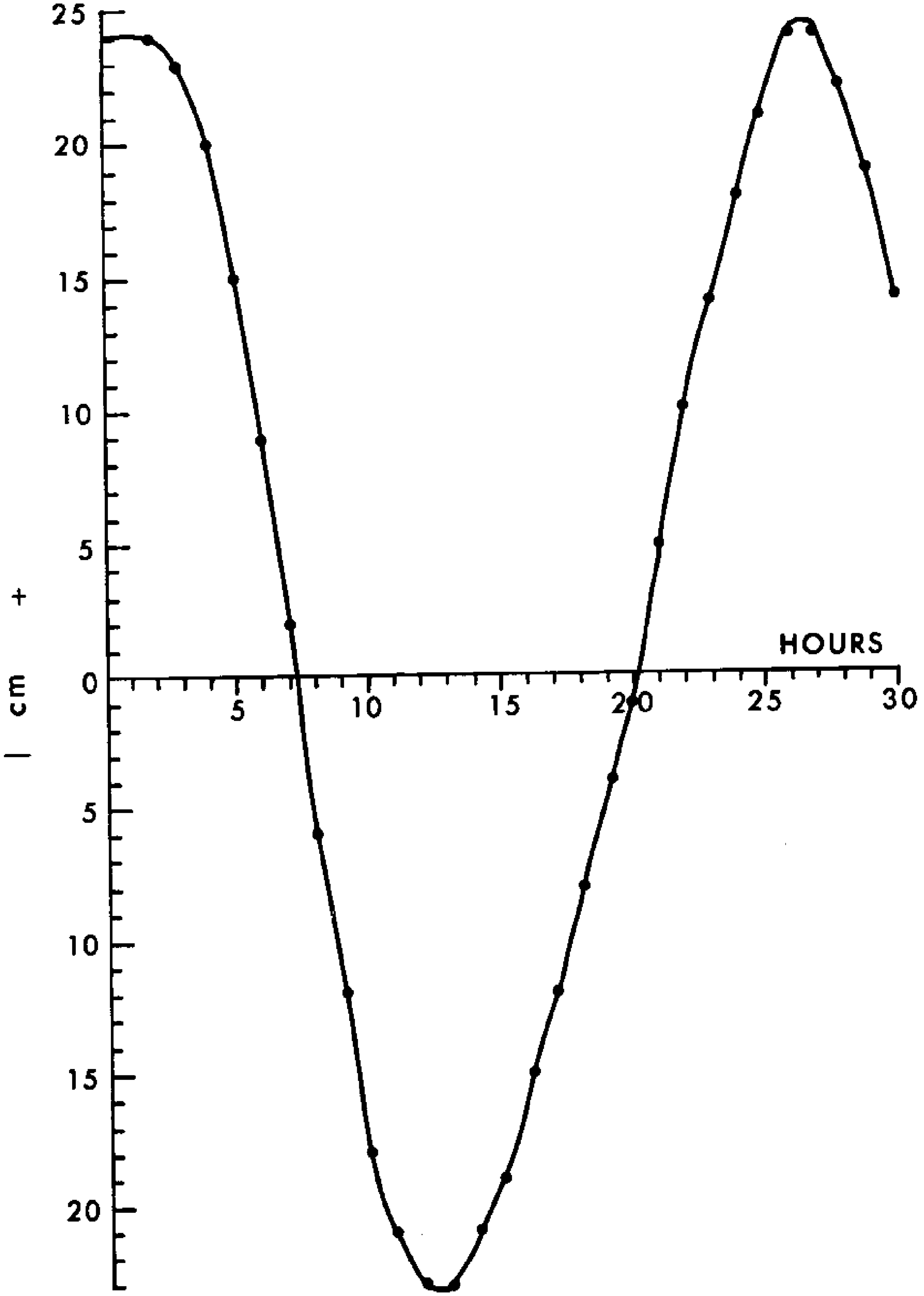


Figure 66. Stability test for Hansen's model by means of water height, in centimeters, at grid location 5,5 as indicated in Figure 65. Total time is a 30-hour run.

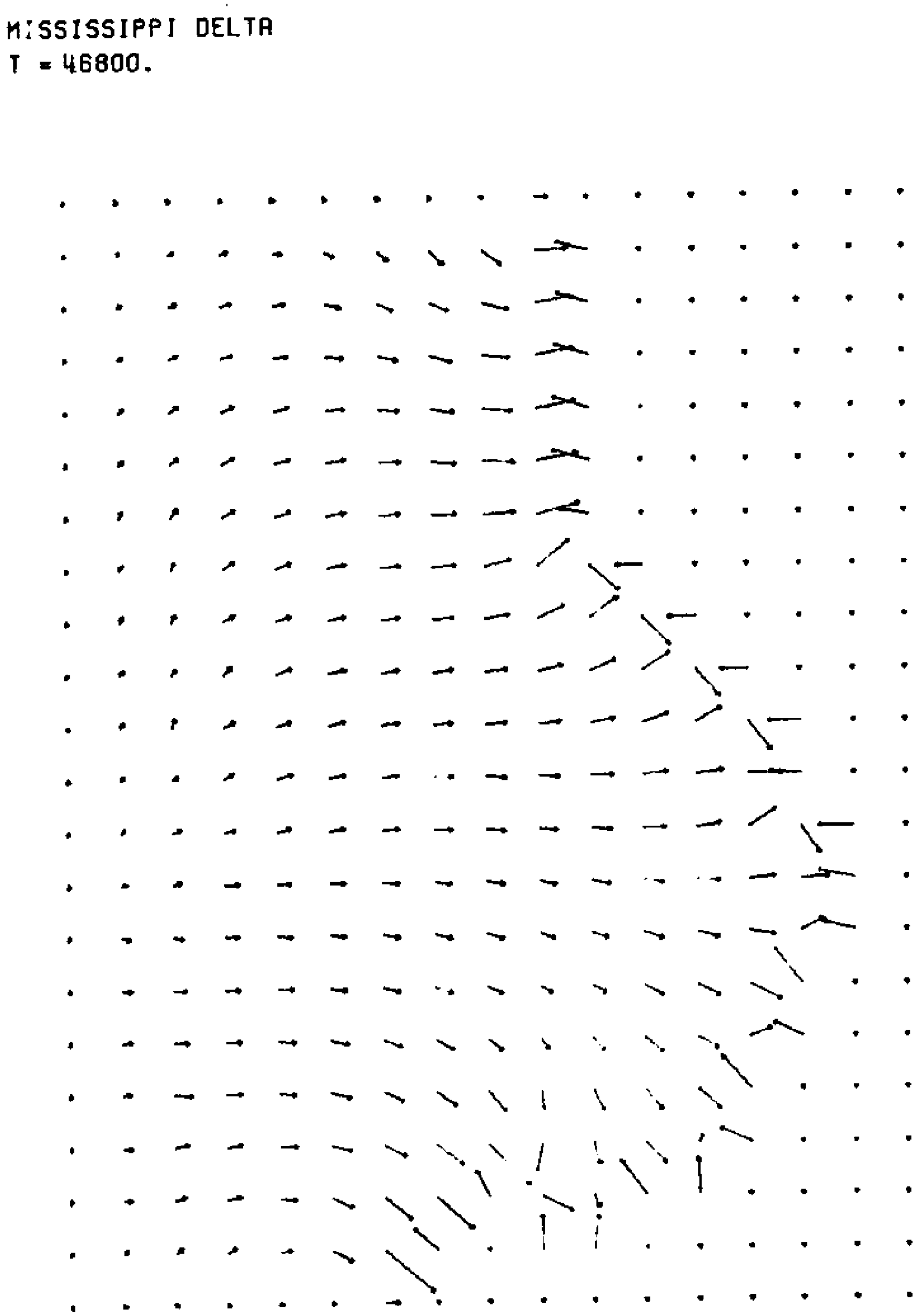


Figure 67A. Current vectors at 13 hrs (46,800 sec) based on Hansen's model (Laevastu and Rabe, 1972) using winds toward 280° at 7 m/sec. Grid pattern as indicated on Figure 65.

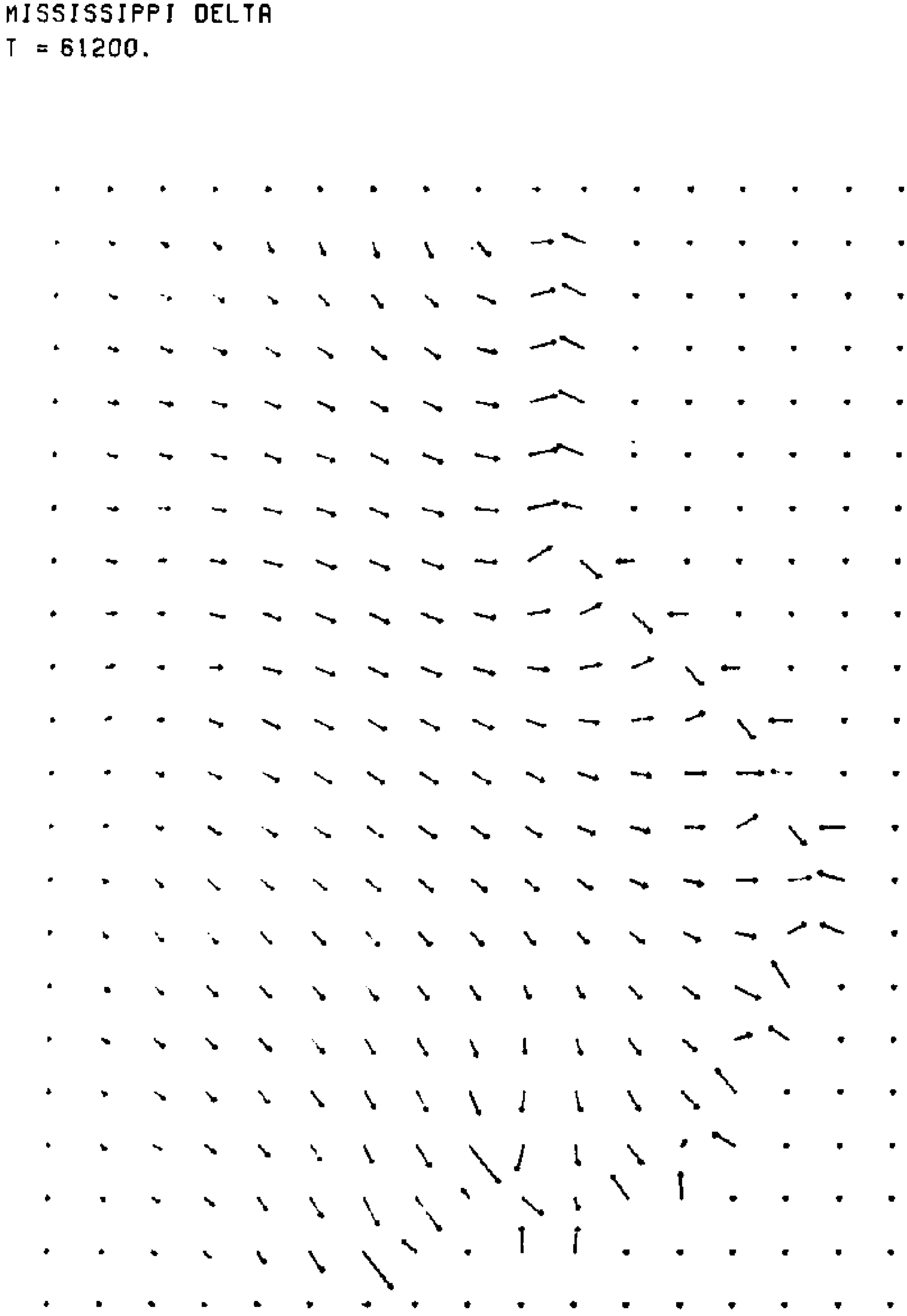


Figure 67B. Current vectors at 17 hrs (61,200 sec) based on Hansen's model (Laevastu and Rabe, 1972) using winds toward 280° at 7 m/sec. Grid pattern as indicated on Figure 65.

MISSISSIPPI DELTA
T = 72000.

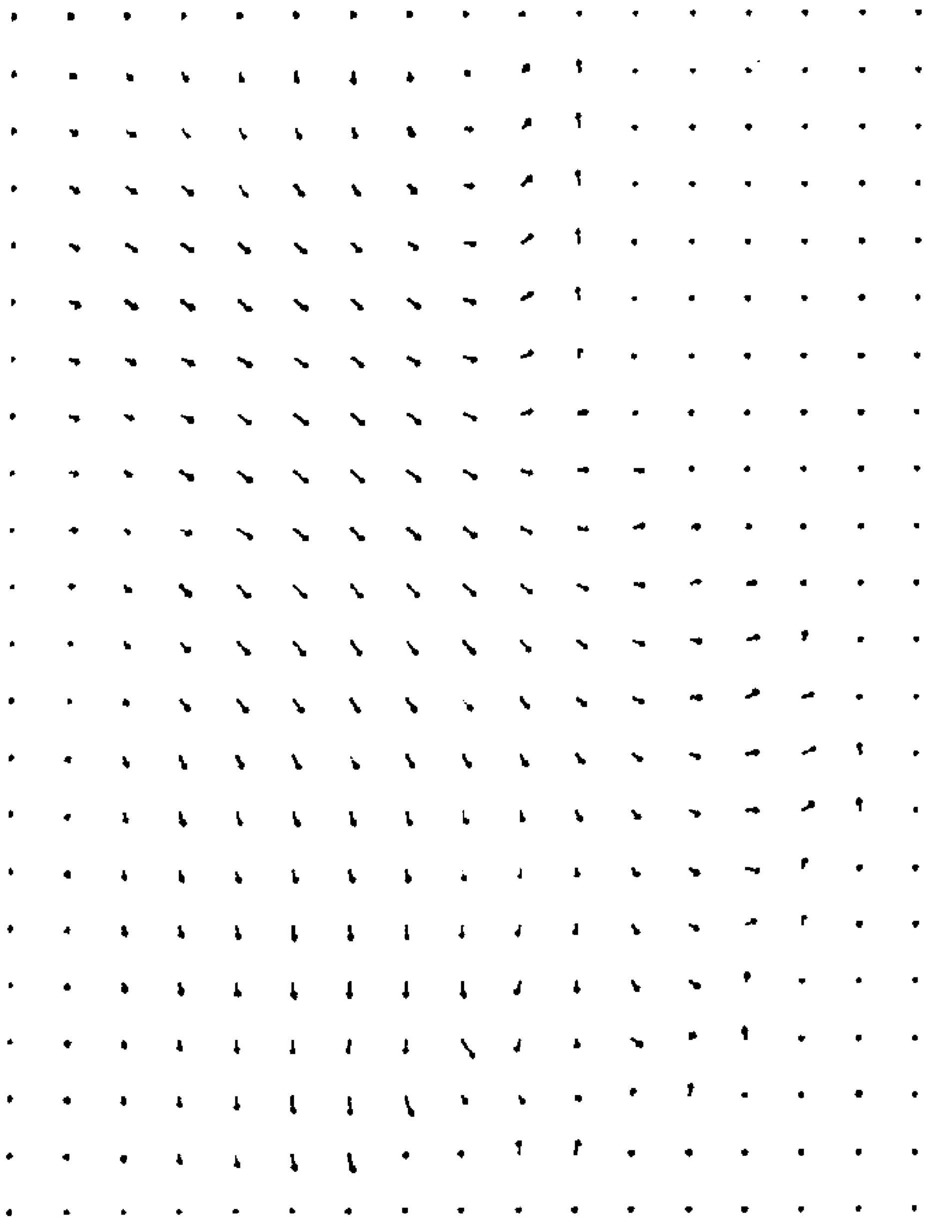


Figure 67C. Current vectors at 20 hrs (72,000 sec) based on Hansen's model (Laevastu and Rabe, 1972) using winds toward 280° at 7 m/sec. Grid pattern as indicated on Figure 65.

MISSISSIPPI DELTA
T = 79200.

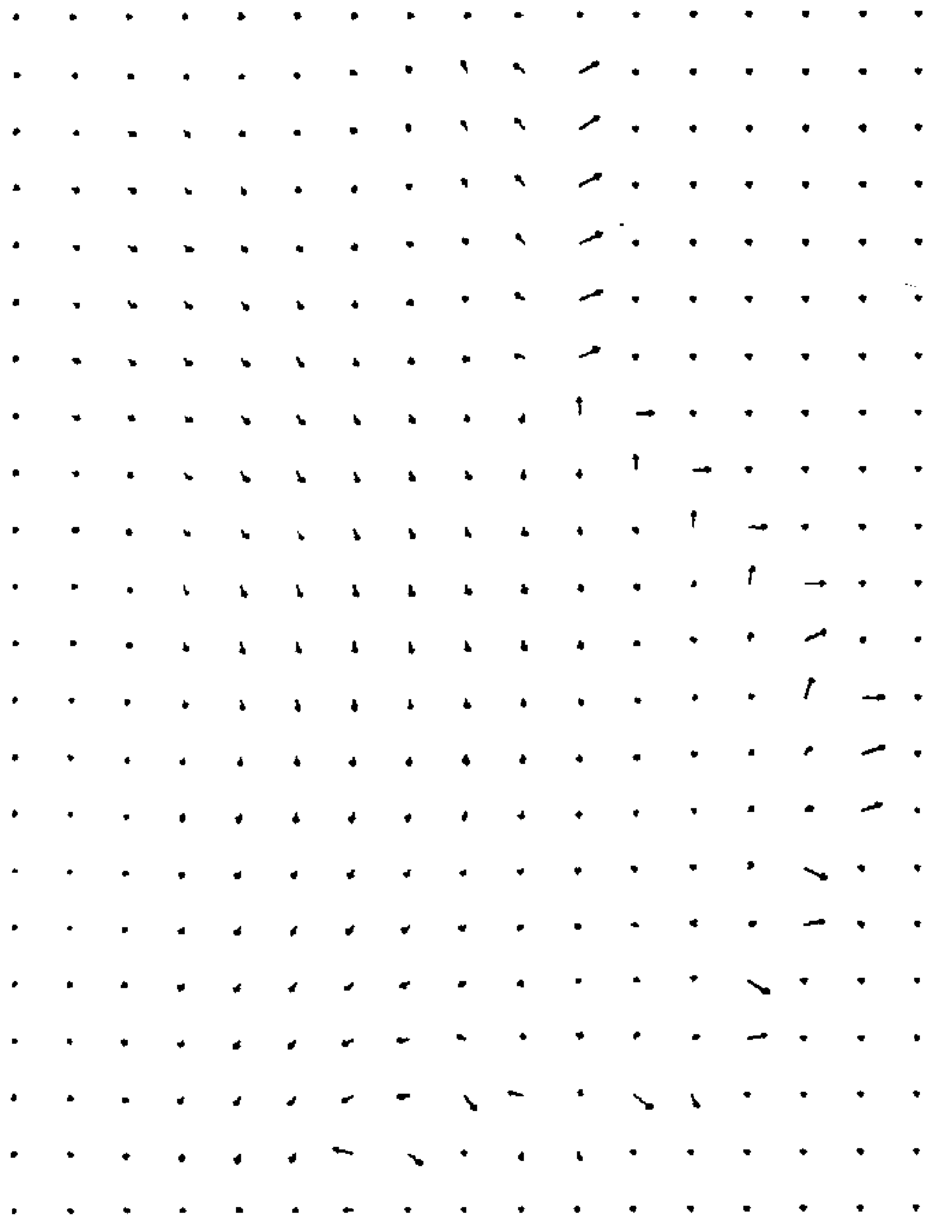


Figure 67D. Current vectors at 22 hrs (79,200 sec) based on Hansen's model (Laevastu and Rabe, 1972) using winds toward 280° at 7 m/sec. Grid pattern as indicated on Figure 65.

MISSISSIPPI DELTA
T = 93600.

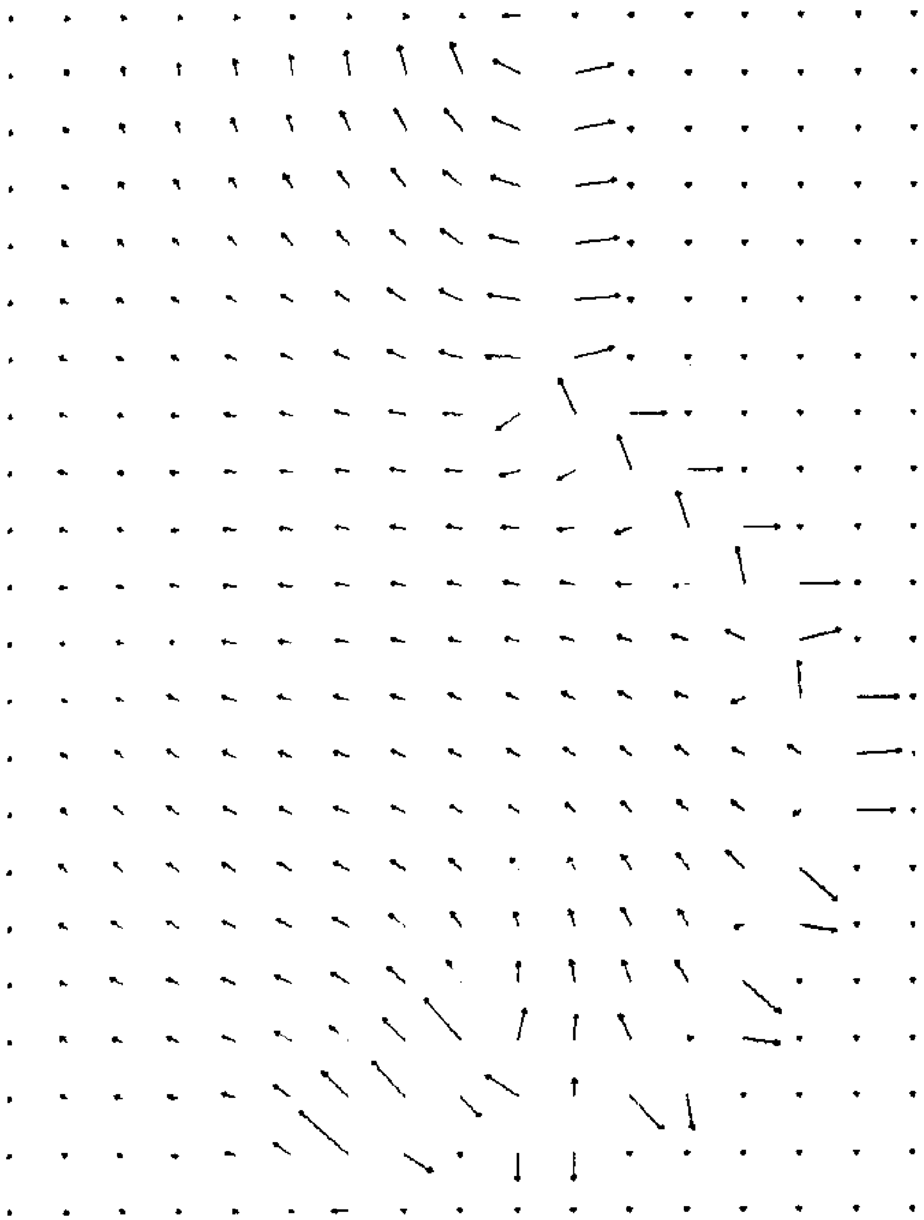


Figure 67E. Current vectors at 26 hrs (93,000 sec) based on Hansen's model (Laevastu and Rabe, 1972) using winds toward 280° at 7 m/sec. Grid pattern as indicated on Figure 65.

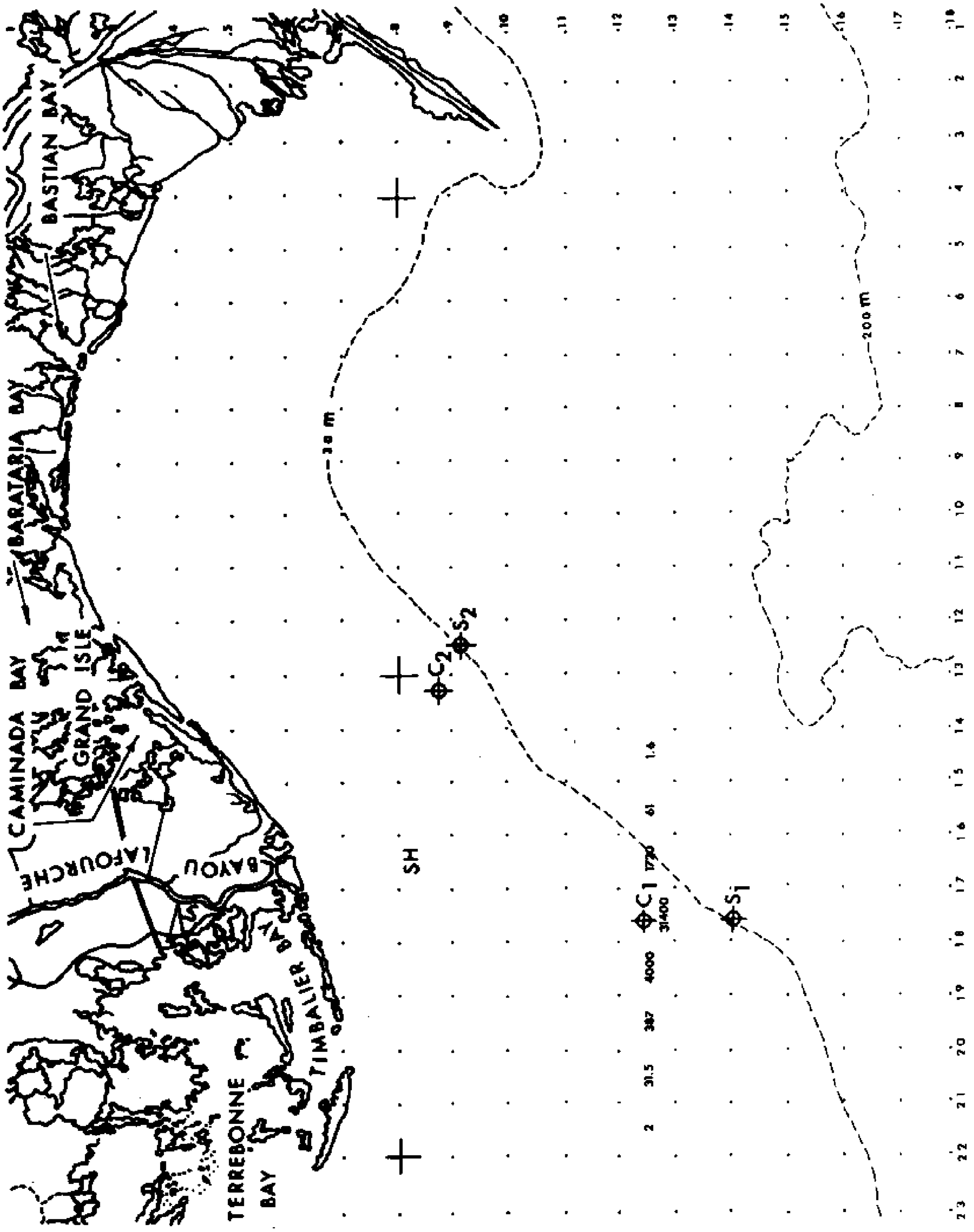


Figure 68A. Distribution of a 30,000 ton spill at C_1 after 7 hrs with winds toward 225° at 7 m/sec. Based on Hansen's model. Oil released at 5 hrs and completed in 2 hrs.

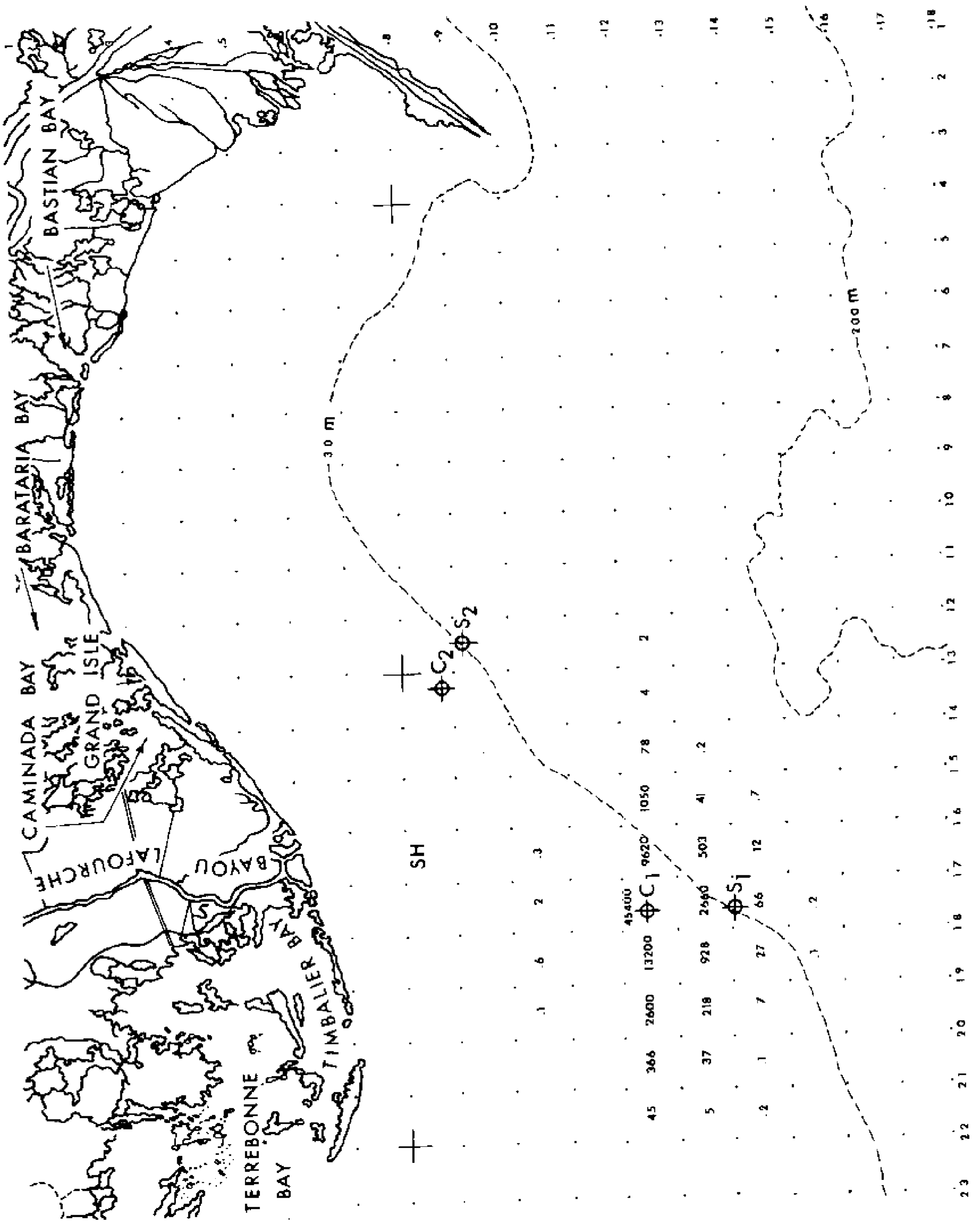


Figure 68B. Distribution of a 30,000 ton spill at C_1 after 10 hrs with winds toward 225° at 7 m/sec. Based on Hansen's model. Oil released at 5 hrs and completed in 2 hrs.

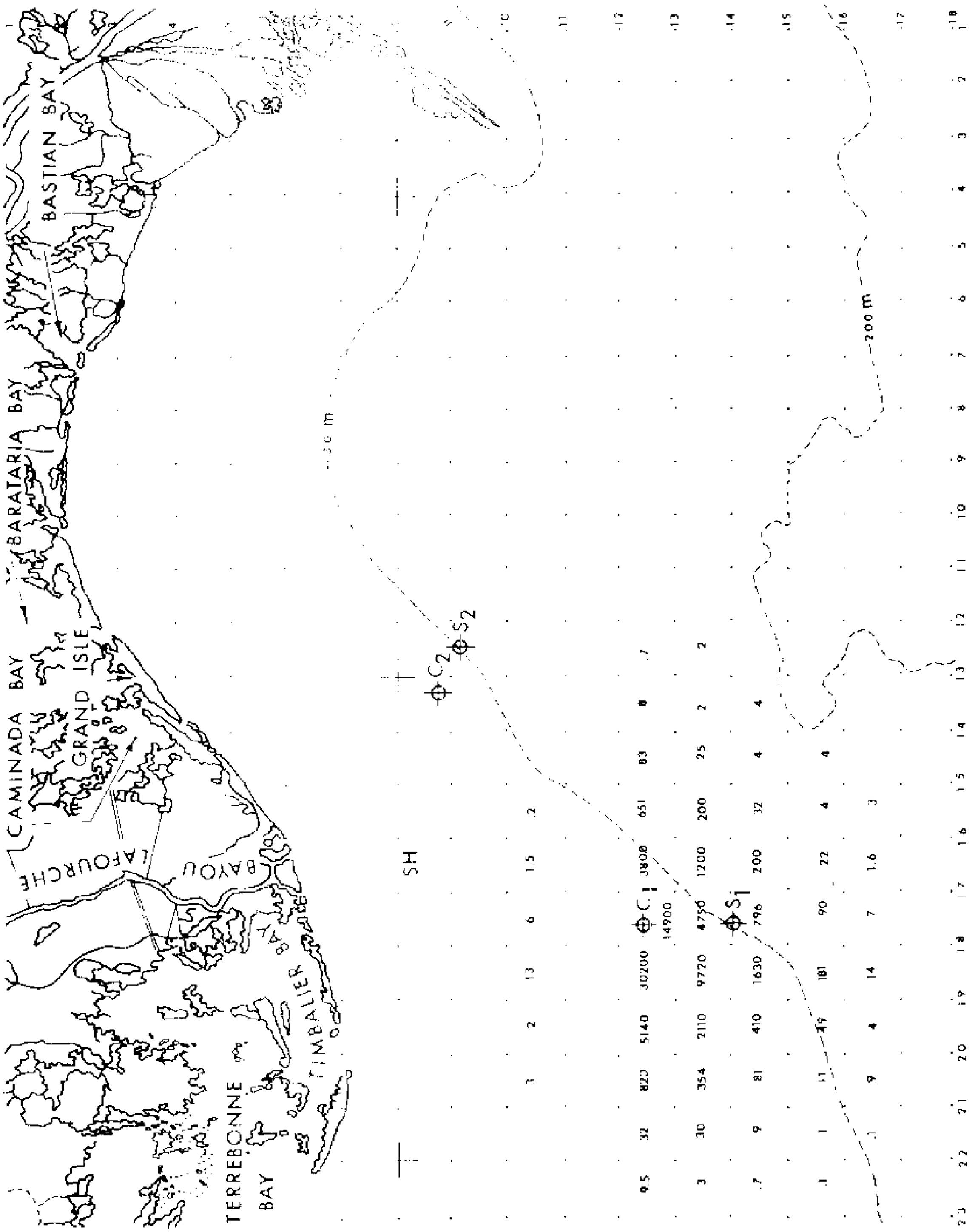


Figure 68C. Distribution of a 30,000 ton spill at C_1 after 15 hrs with winds toward 225° at 7 m/sec. Based on Hansen's model. Oil released at 5 hrs and completed in 2 hrs.

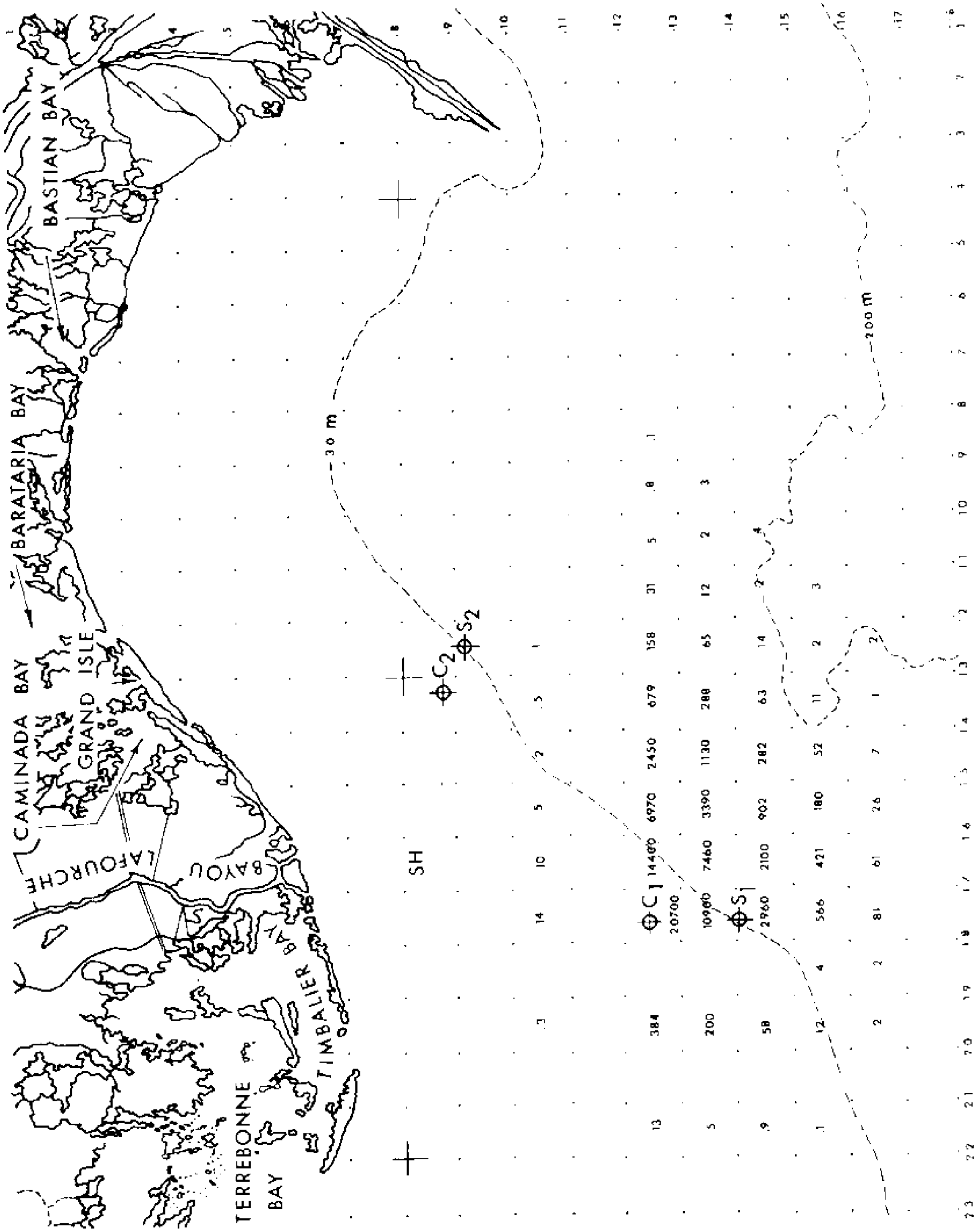


Figure 68D. Distribution of a 30,000 ton spill at C_1 after 20 hrs with winds toward 225° at 7 m/sec. Based on Hansen's model. Oil released at 5 hrs and completed in 2 hrs.

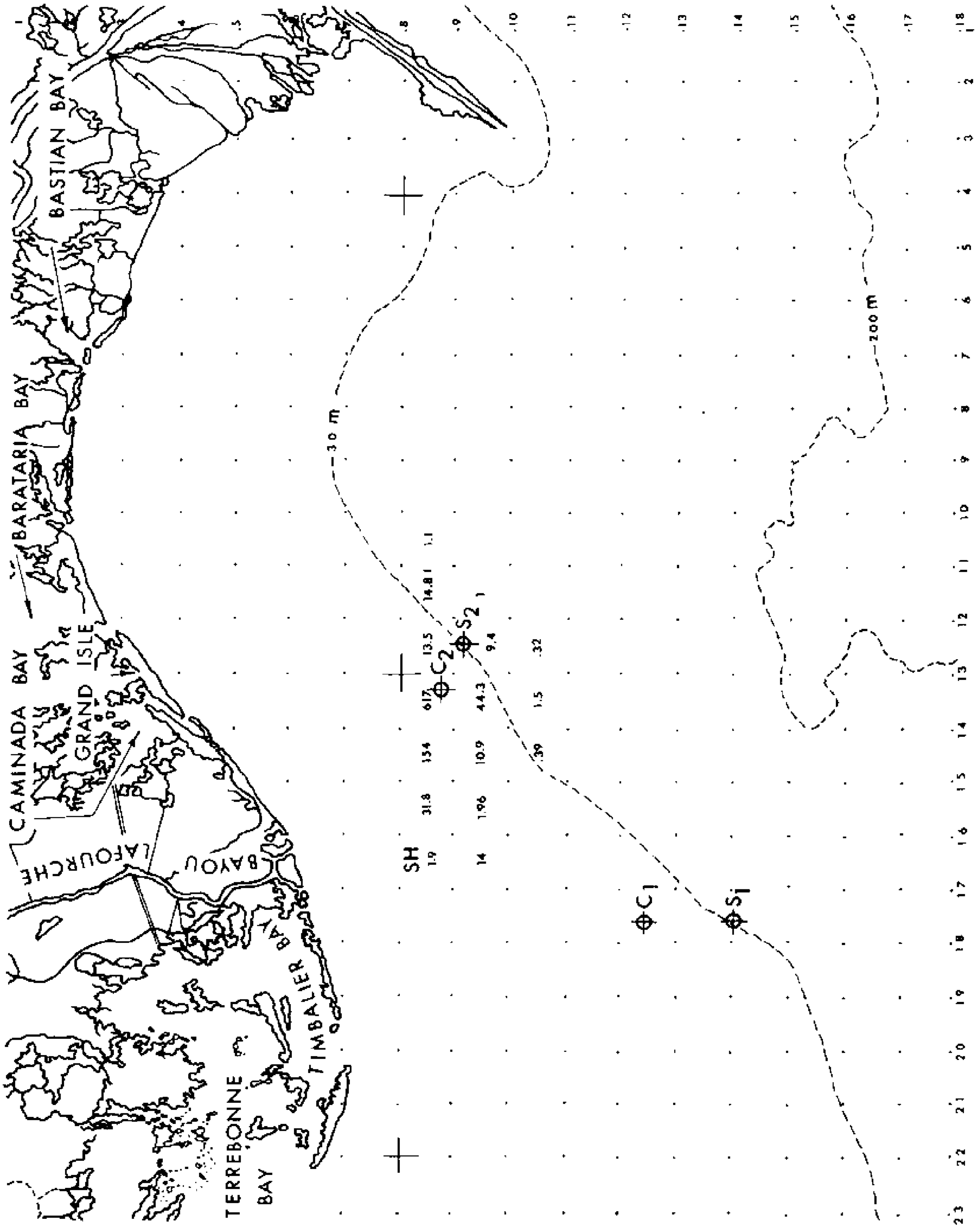


Figure 69. Distribution of a 500 ton spill at C_2 after 10 hrs with winds toward 225° at 7 m/sec. Based on Hansen's model. Oil released at 5 hrs and completed in 2 hrs.

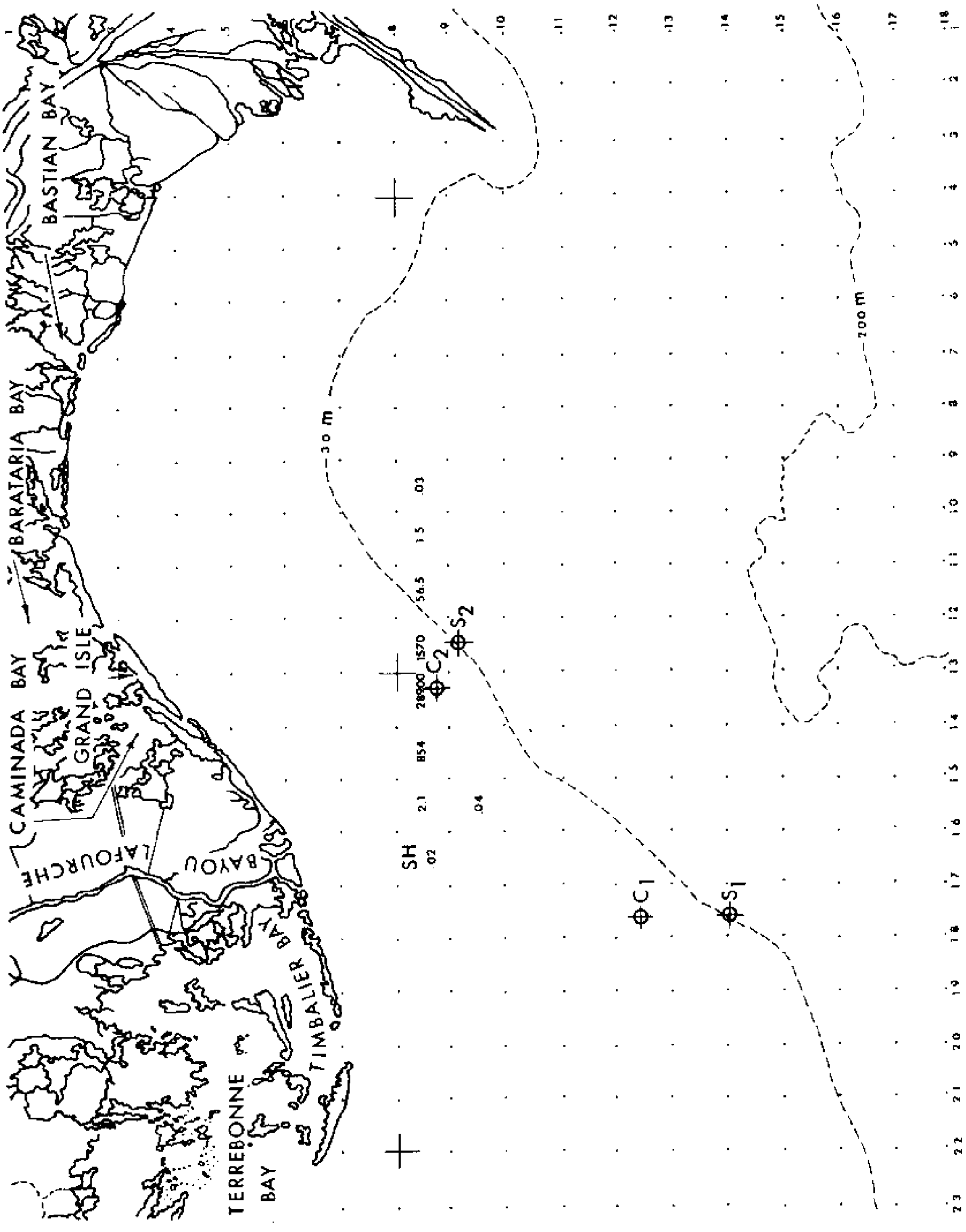


Figure 70A. Distribution of a 30,000 ton spill at C_2 after 7 hrs with winds toward 225° at 7 m/sec. Based on Hansen's model. Oil released at 5 hrs and completed in 2 hrs.

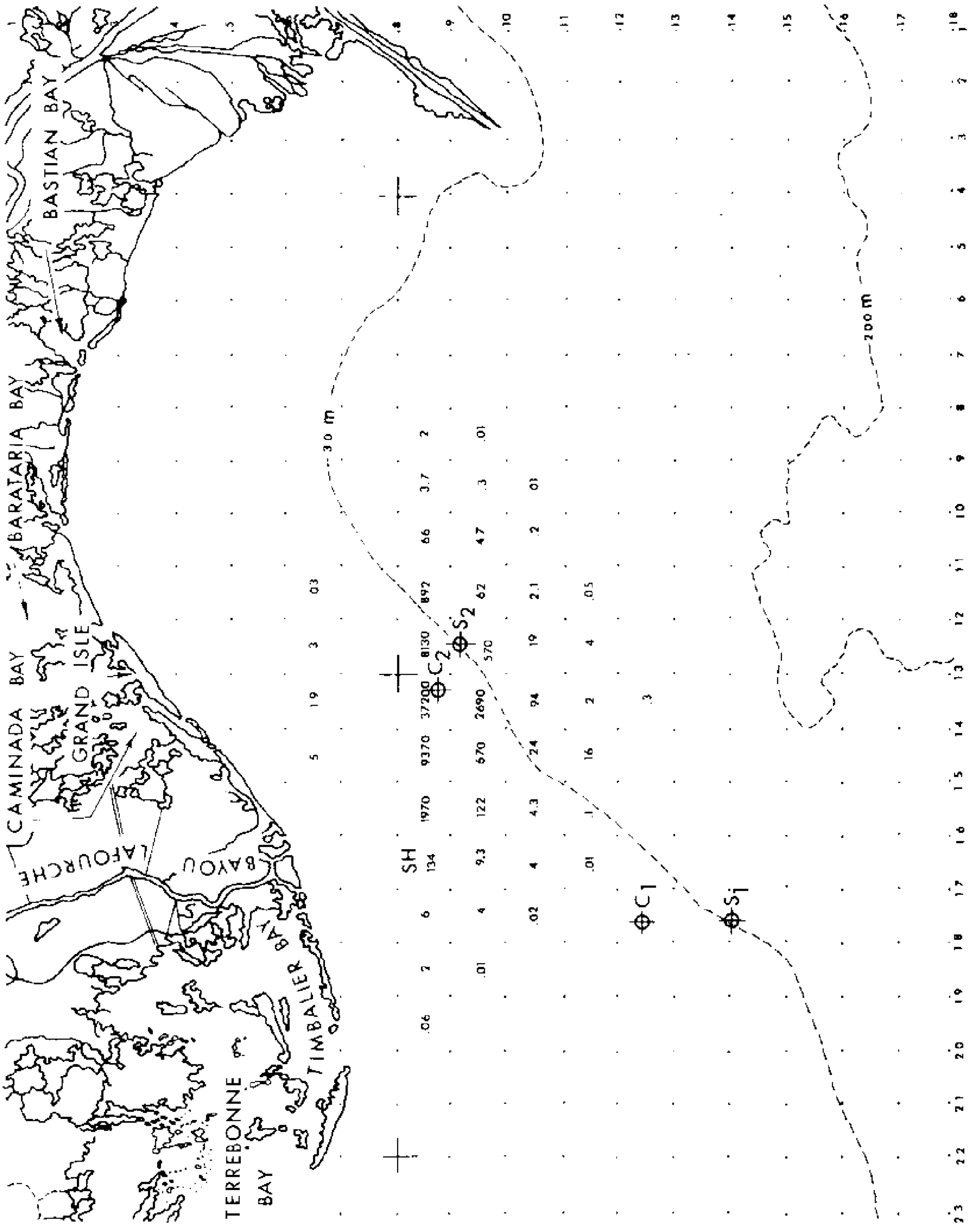


Figure 70B. Distribution of a 30,000 ton spill at C_2 after 10 hrs with winds toward 280° at 7 m/sec. Based on Hansen's model. Oil released at 5 hrs and completed in 2 hrs.

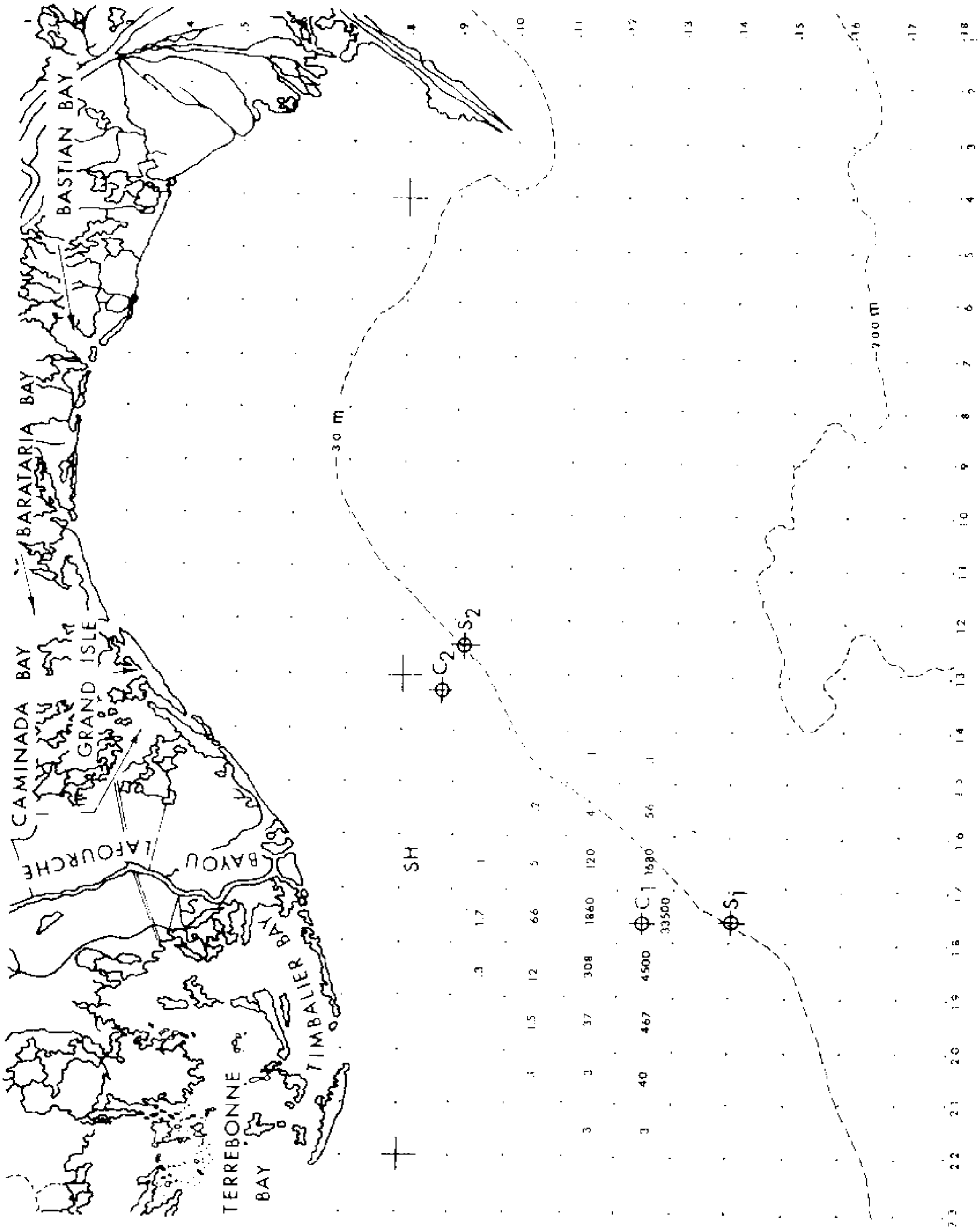


Figure 71A. Distribution of a 30,000 ton spill at C_1 after 7 hrs with winds toward 280° at 7 m/sec. Based on Hansen's model. Oil released at 5 hrs and completed in 2 hrs.

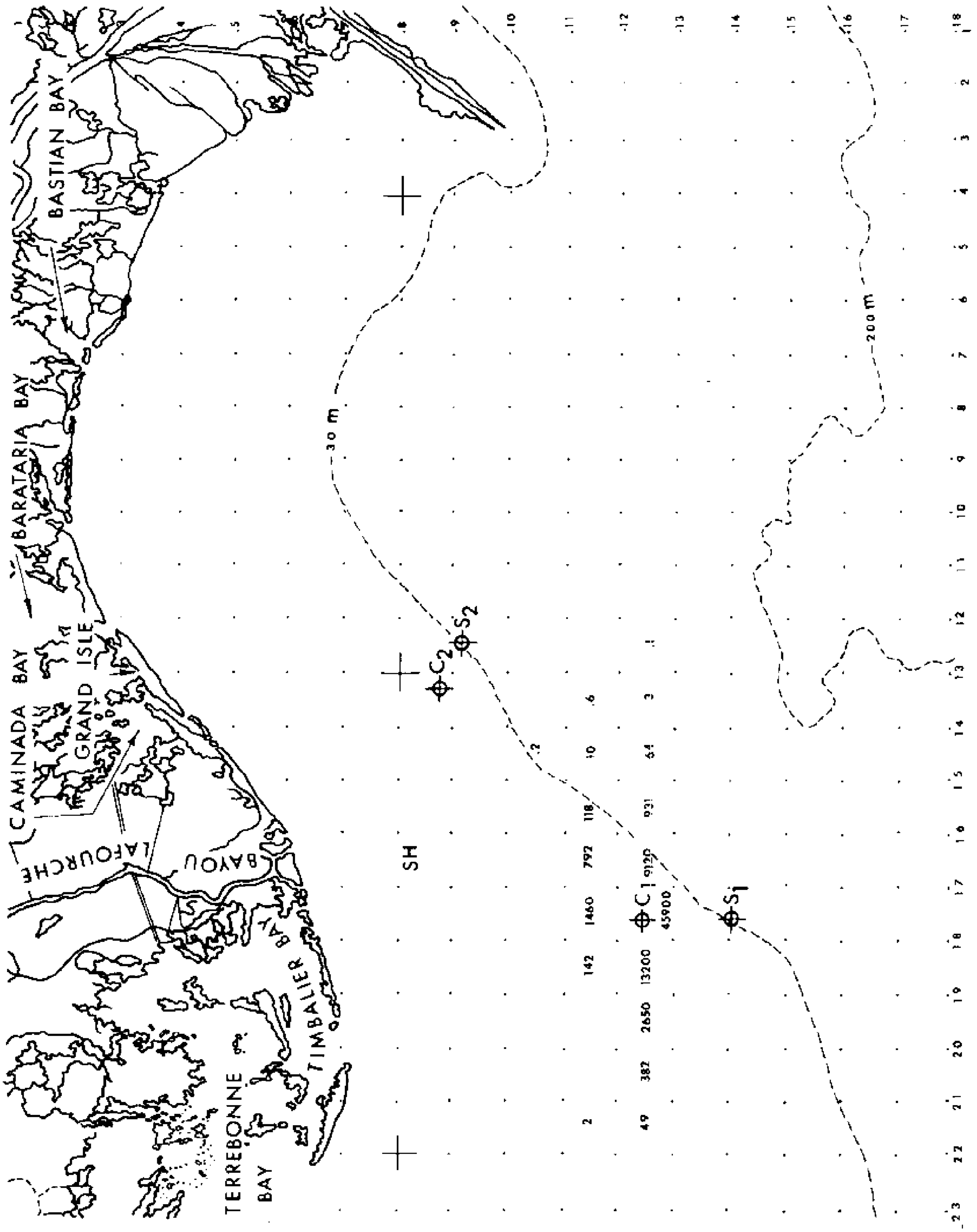


Figure 71B. Distribution of a 30,000 ton spill at C_1 after 10 hrs with winds toward 280° at 7 m/sec. Based on Hansen's model. Oil released at 5 hrs and completed in 2 hrs.

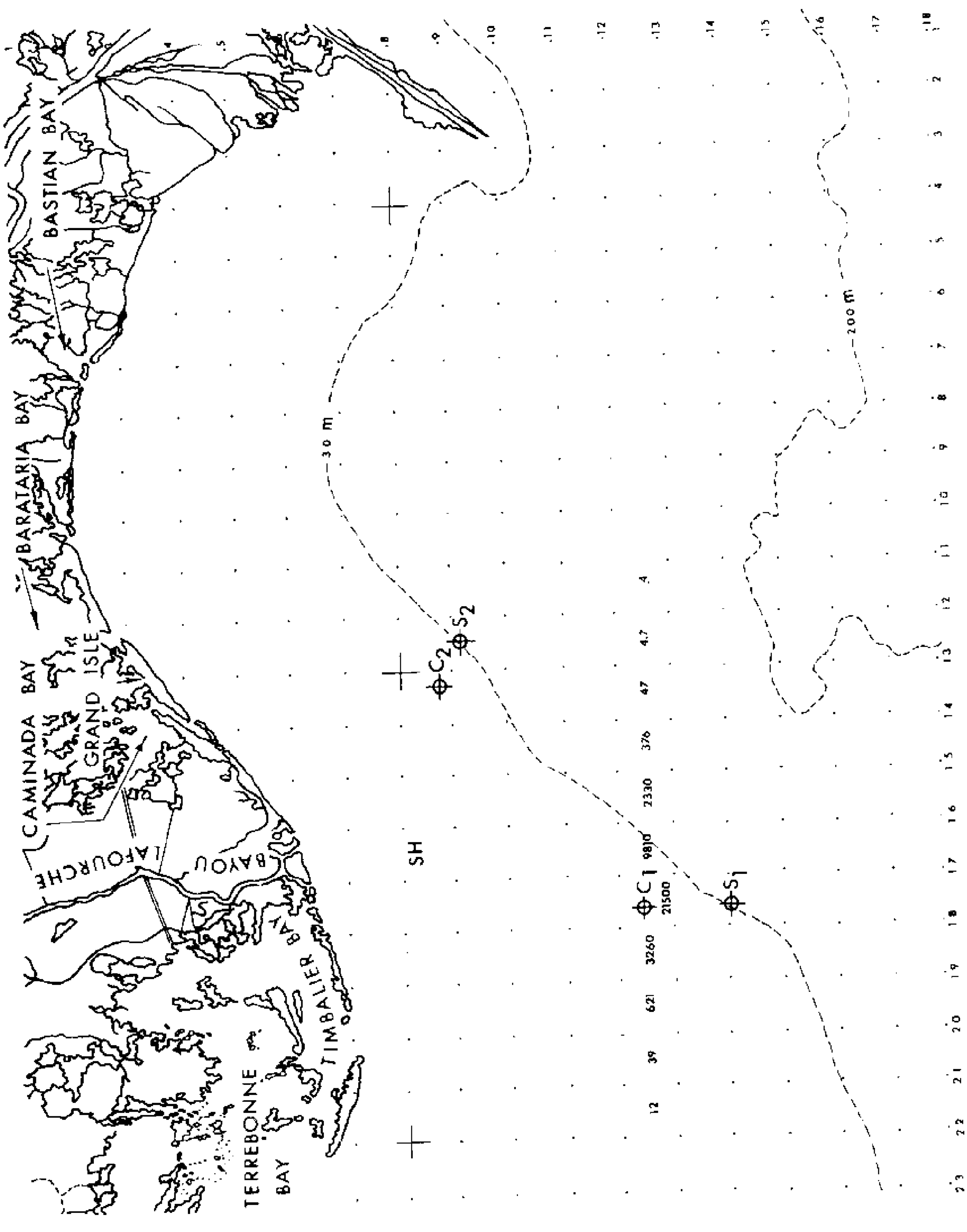


Figure 71C. Distribution of a 30,000 ton spill at C_1 after 15 hrs with winds toward 280° at 7 m/sec. Based on Hansen's model. Oil released at 5 hrs and completed in 2 hrs.

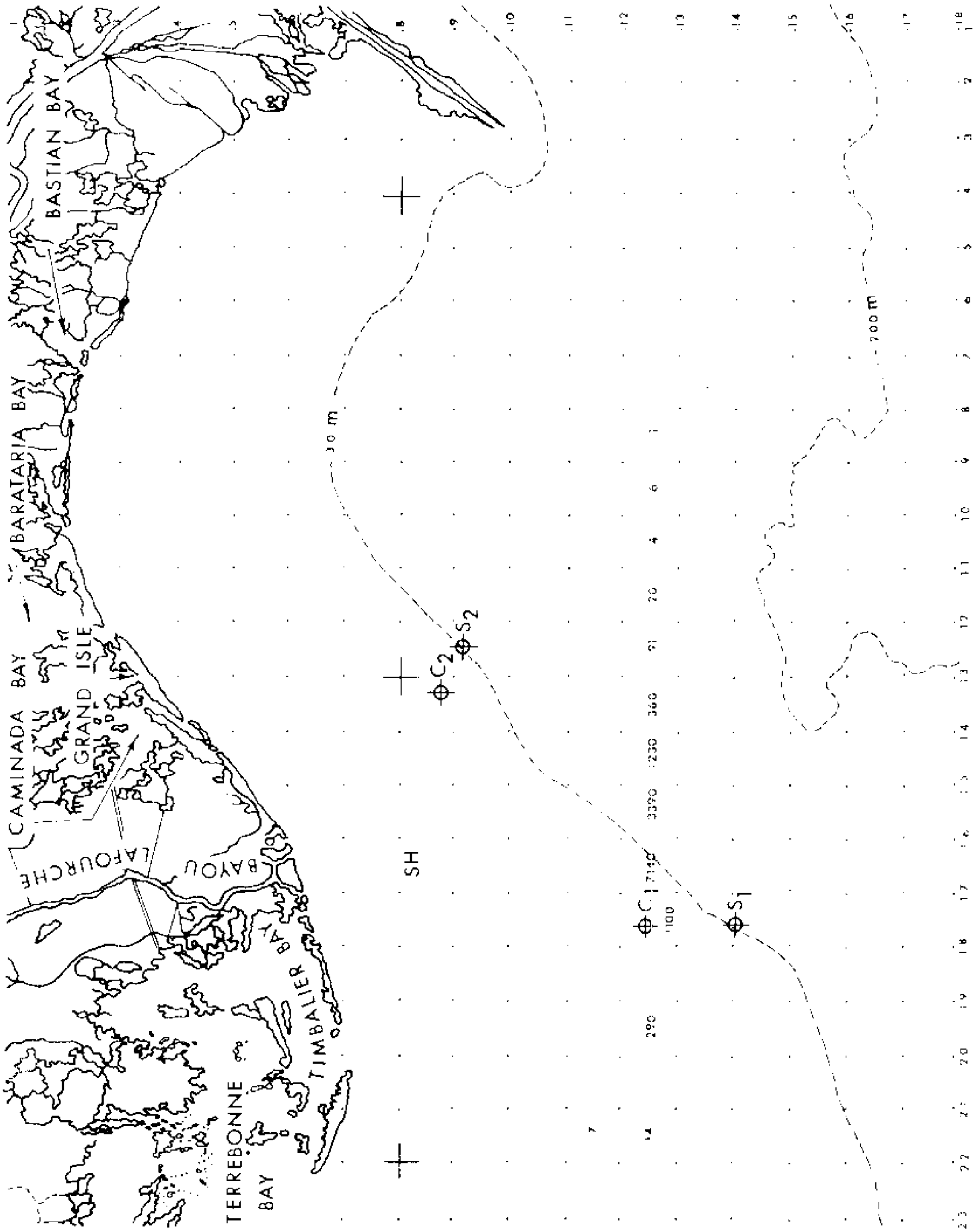


Figure 71D. Distribution of a 30,000 ton spill at C_1 after 20 hrs with winds toward 280° at 7 m/sec. Based on Hansen's model. Oil released at 5 hrs and completed in 2 hrs.

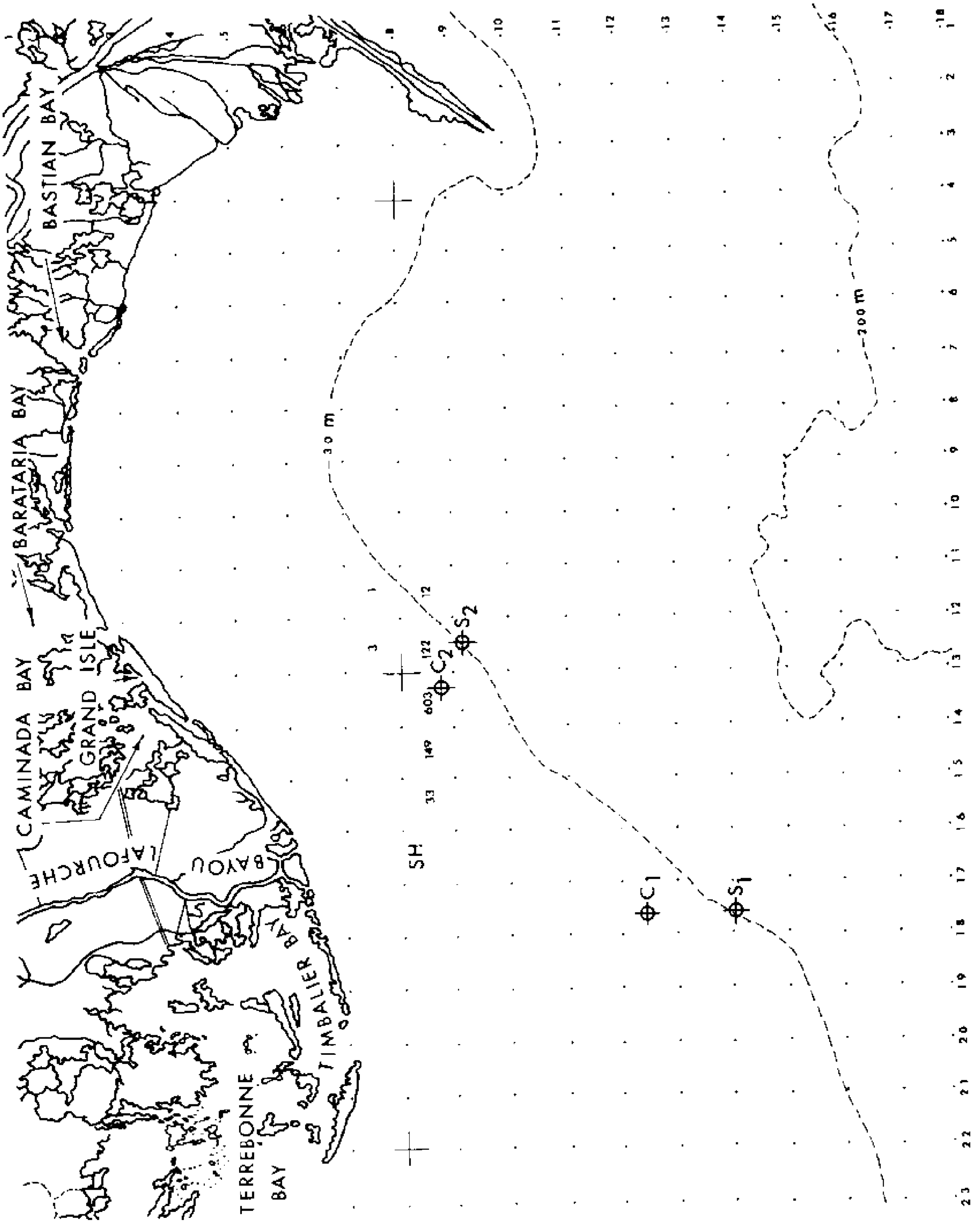


Figure 72A. Distribution of a 500 ton spill at C_2 after 10 hrs with winds toward 280° at 7 m/sec. Based on Hansen's model. Oil released at 5 hrs and completed in 2 hrs.

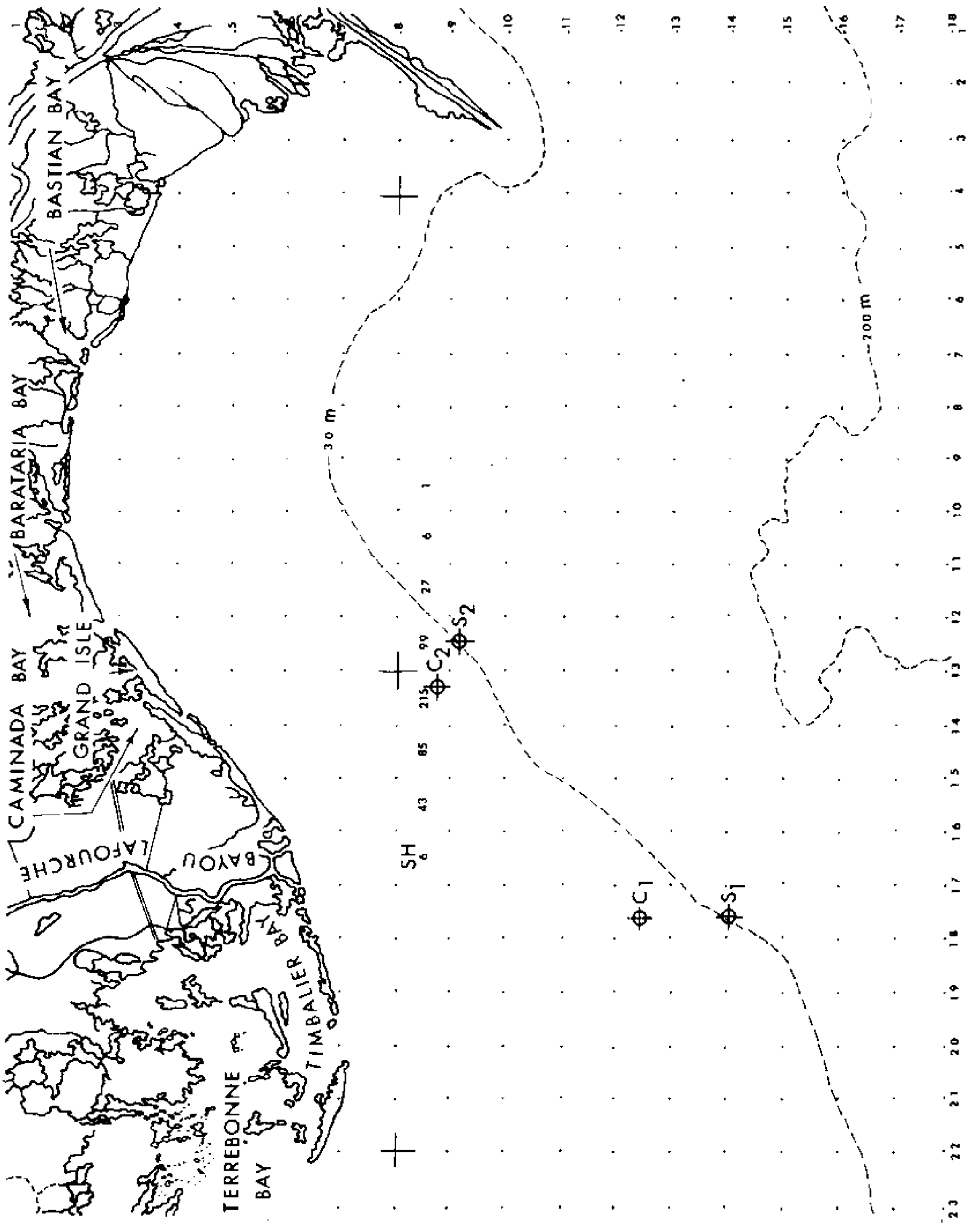


Figure 72B. Distribution of a 500 ton spill at C_2 after 15 hrs with winds toward 280° at 7 m/sec. Based on Hansen's model. Oil released at 5 hrs and completed in 2 hrs.

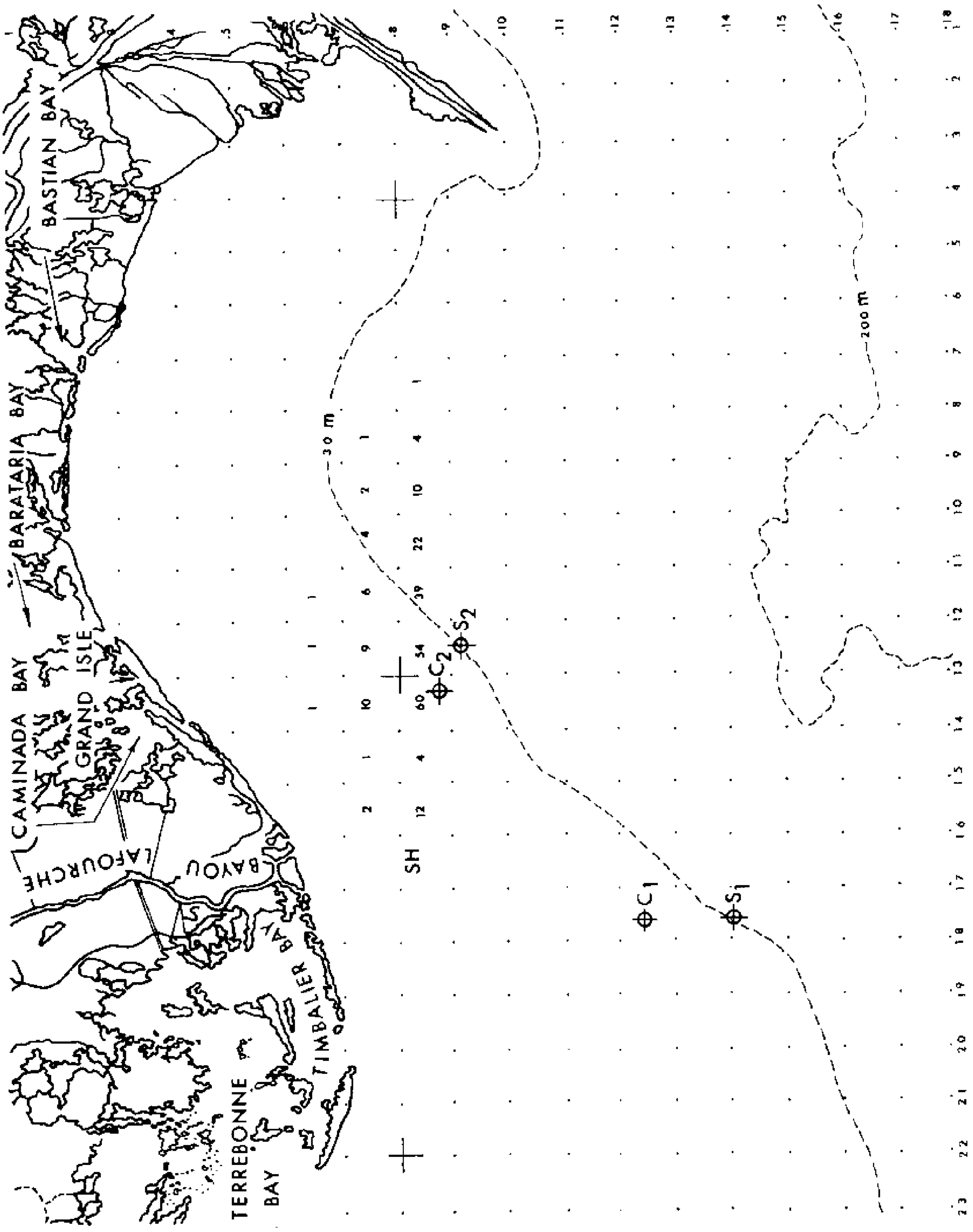


Figure 72C. Distribution of a 500 ton spill at C_2 after 25 hrs with winds toward 280° at 7 m/sec. Based on Hansen's model. Oil released at 5 hrs and completed in 2 hrs.

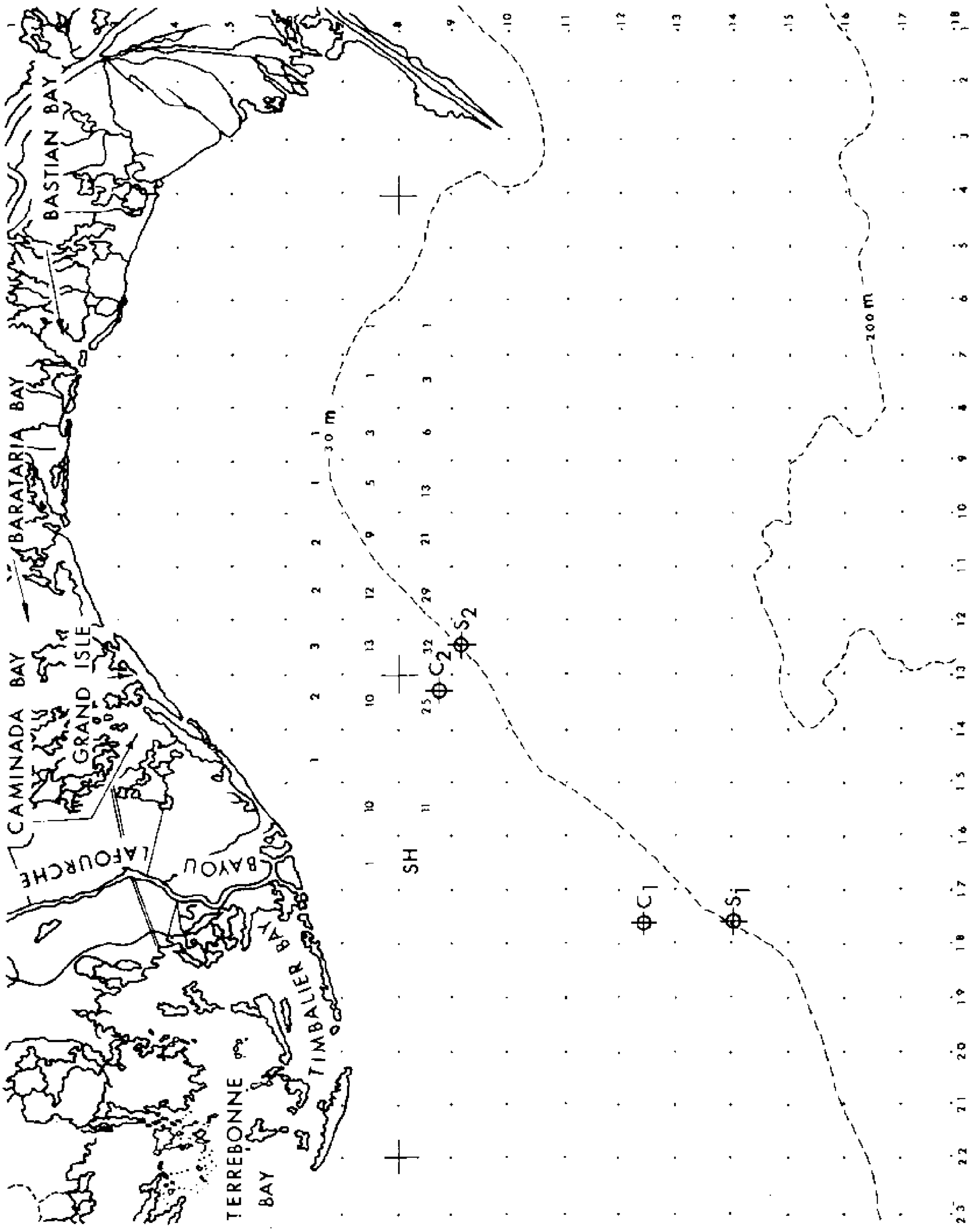


Figure 72D. Distribution of a 500 ton spill at C_2 after 30 hrs with winds toward 280° at 7 m/sec. Based on Hansen's model. Oil released at 5 hrs and completed in 2 hrs.

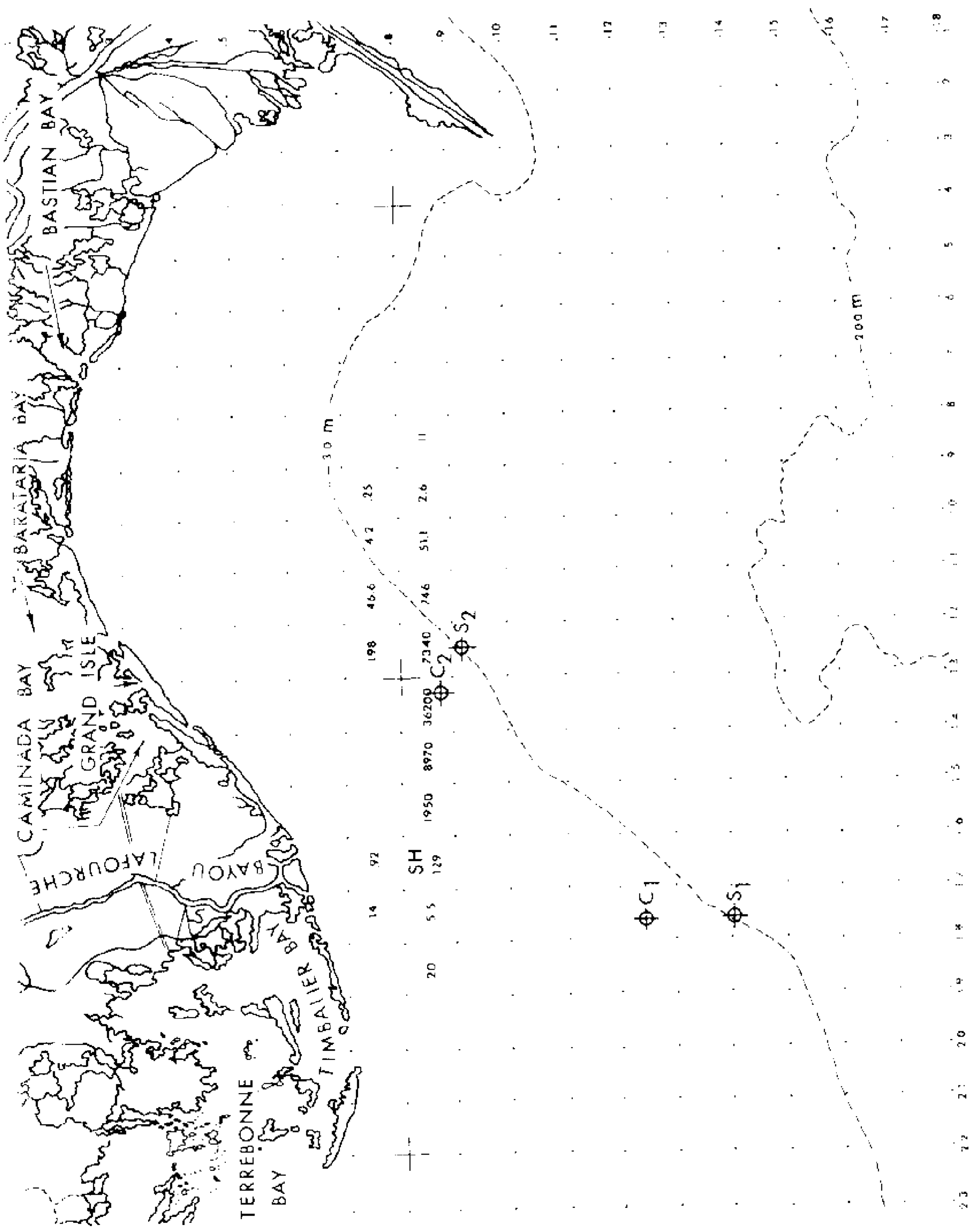


Figure 73A. Distribution of a 30,000 ton spill at C_2 after 10 hrs with winds toward 280° at 7 m/sec. Based on Hansen's model. Oil released at 5 hrs and completed in 2 hrs.

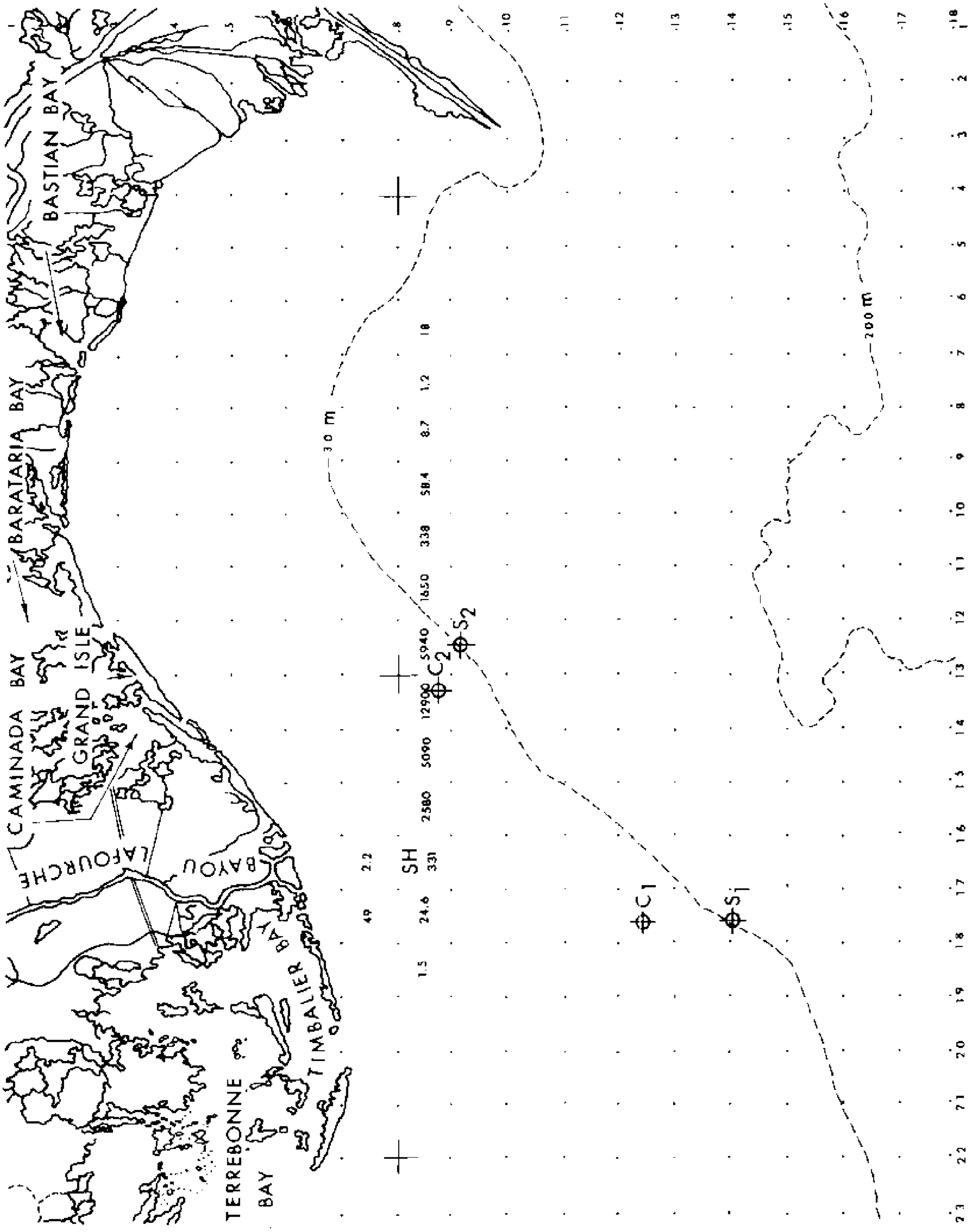


Figure 73B. Distribution of a 30,000 ton spill at C_2 after 15 hrs with winds toward 280° at 7 m/sec. Based on Hansen's model. Oil released at 5 hrs and completed in 2 hrs.

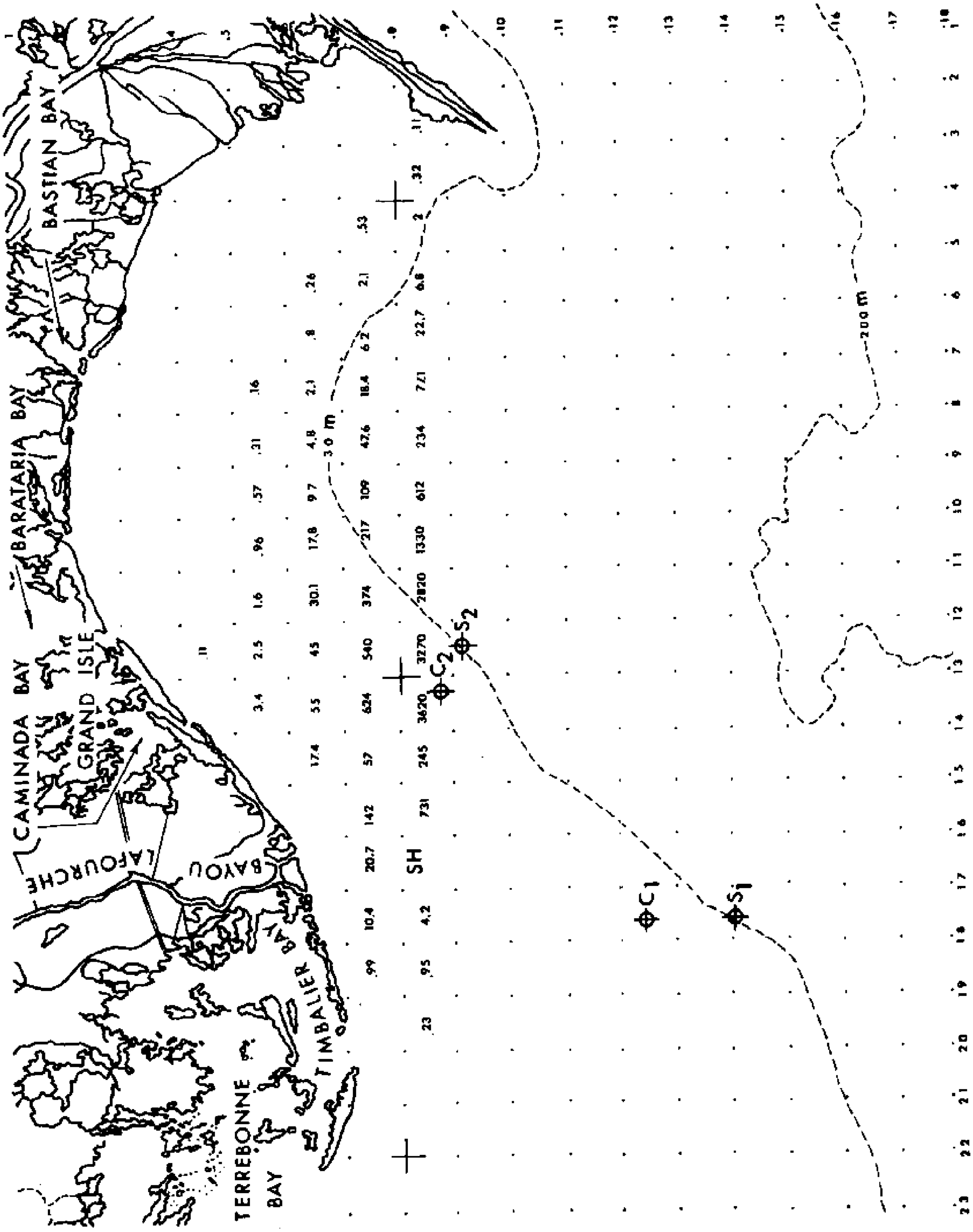


Figure 73C. Distribution of a 30,000 ton spill at C_2 after 25 hrs with winds toward 280° at 7 m/sec. Based on Hansen's model. Oil released at 5 hrs and completed in 2 hrs.

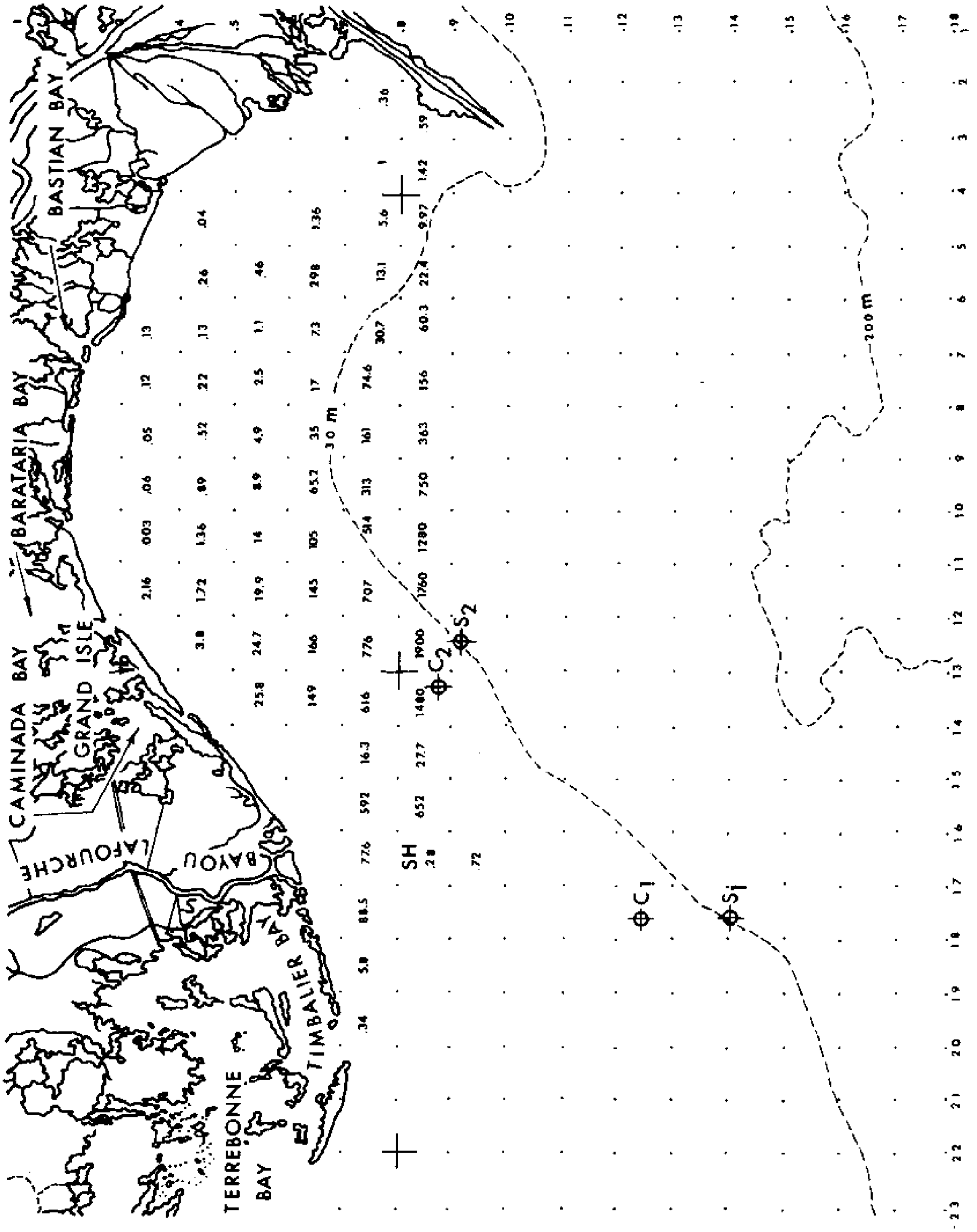


Figure 73D. Distribution of a 30,000 ton spill at C_2 after 30 hrs with winds toward 280° at 7 m/sec. Based on Hansen's model. Oil released at 5 hrs and completed in 2 hrs.

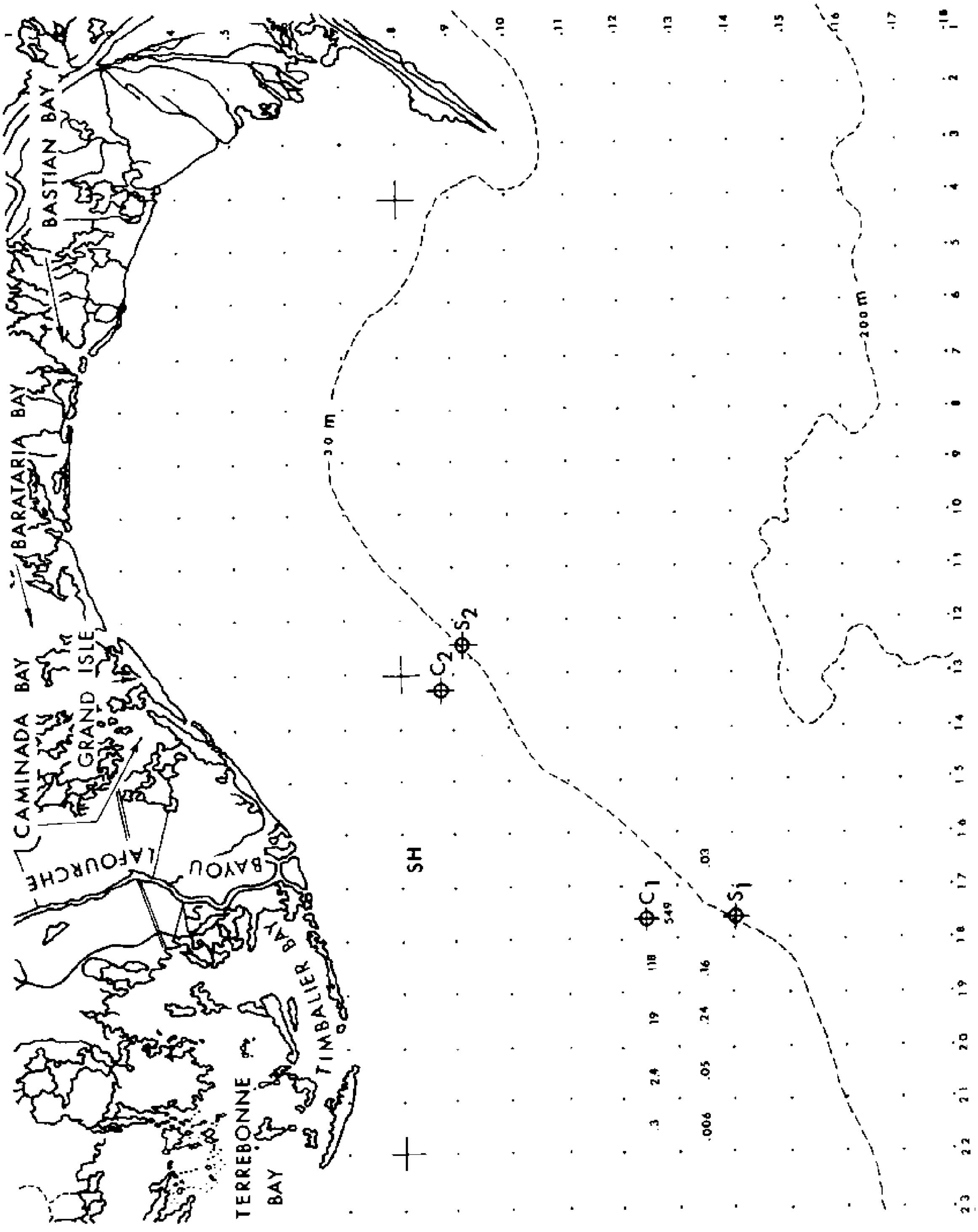


Figure 74A. Distribution of a 500 ton spill at C_1 after 7 hrs with winds toward 315° at 7 m/sec. Based on Hansen's model. Oil released at 5 hrs and completed in 2 hrs.

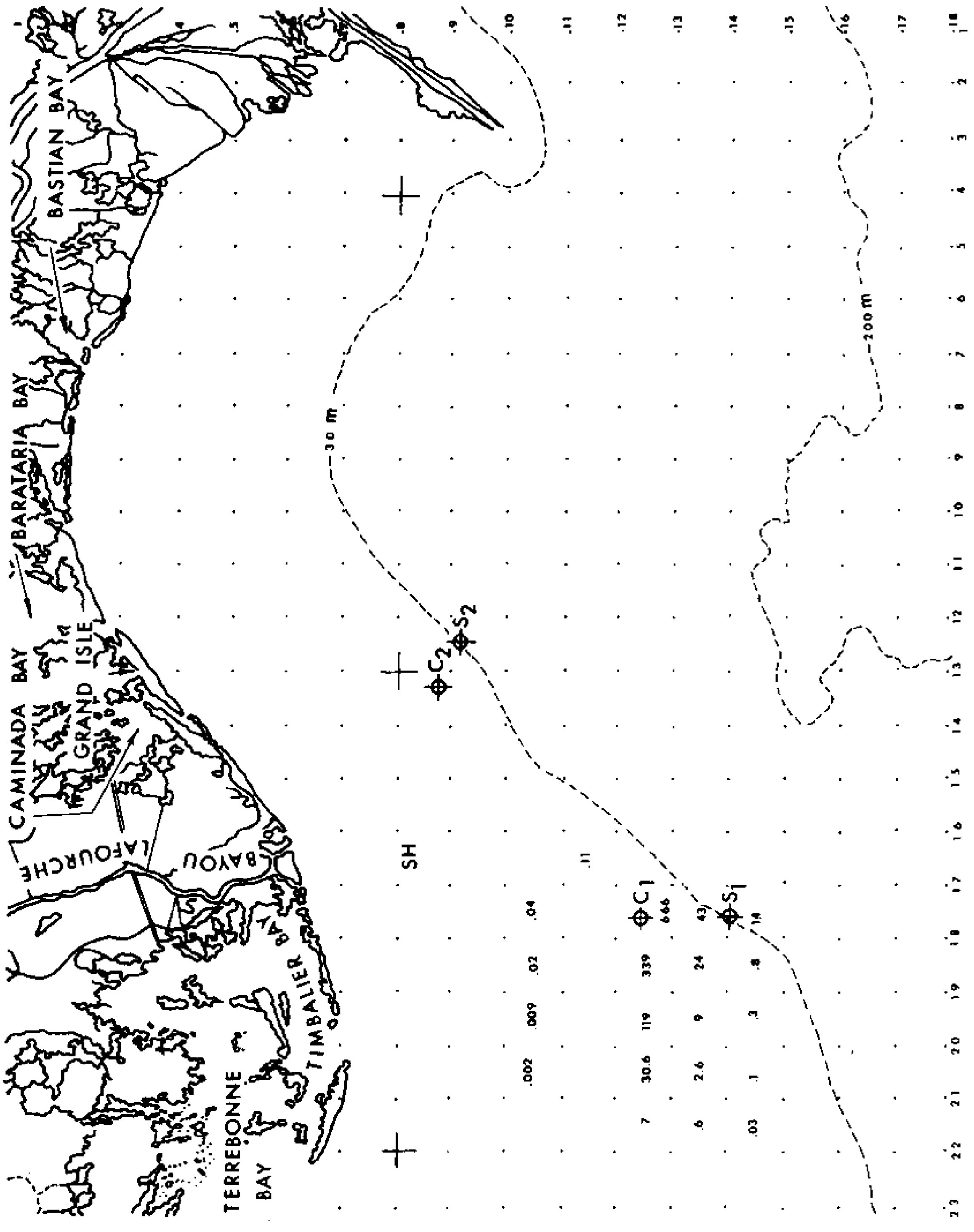


Figure 74B. Distribution of a 500 ton spill at C_1 after 10 hrs with winds toward 315° at 7 m/sec. Based on Hansen's model. Oil released at 5 hrs and completed in 2 hrs.

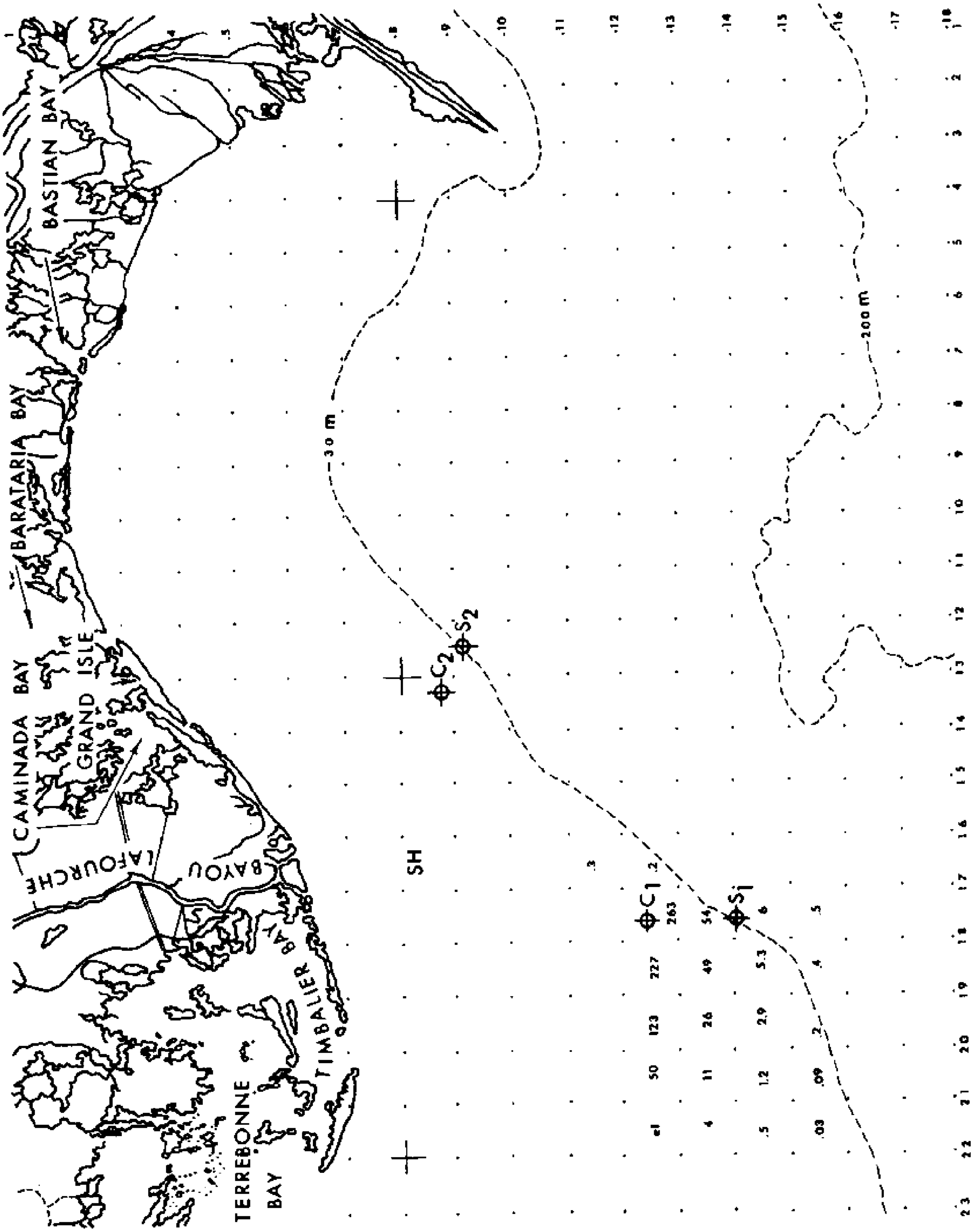


Figure 74C. Distribution of a 500 ton spill at C_1 after 15 hrs with winds toward 315° at 7 m/sec. Based on Hansen's model. Oil released at 5 hrs and completed in 2 hrs.

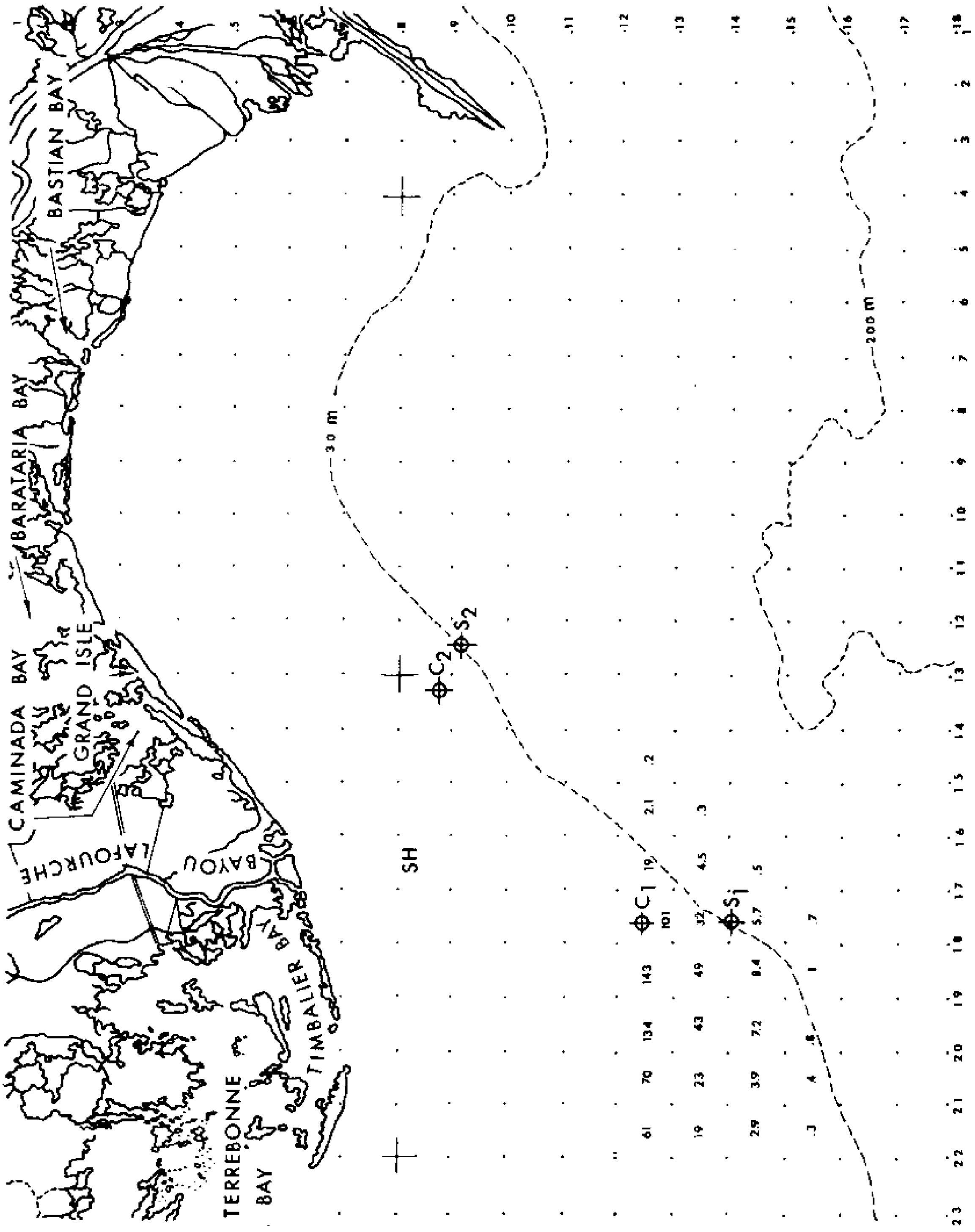


Figure 74D. Distribution of a 500 ton spill at C_1 after 20 hrs with winds toward 315° at 7 m/sec. Based on Hansen's model. Oil released at 5 hrs and completed in 2 hrs.

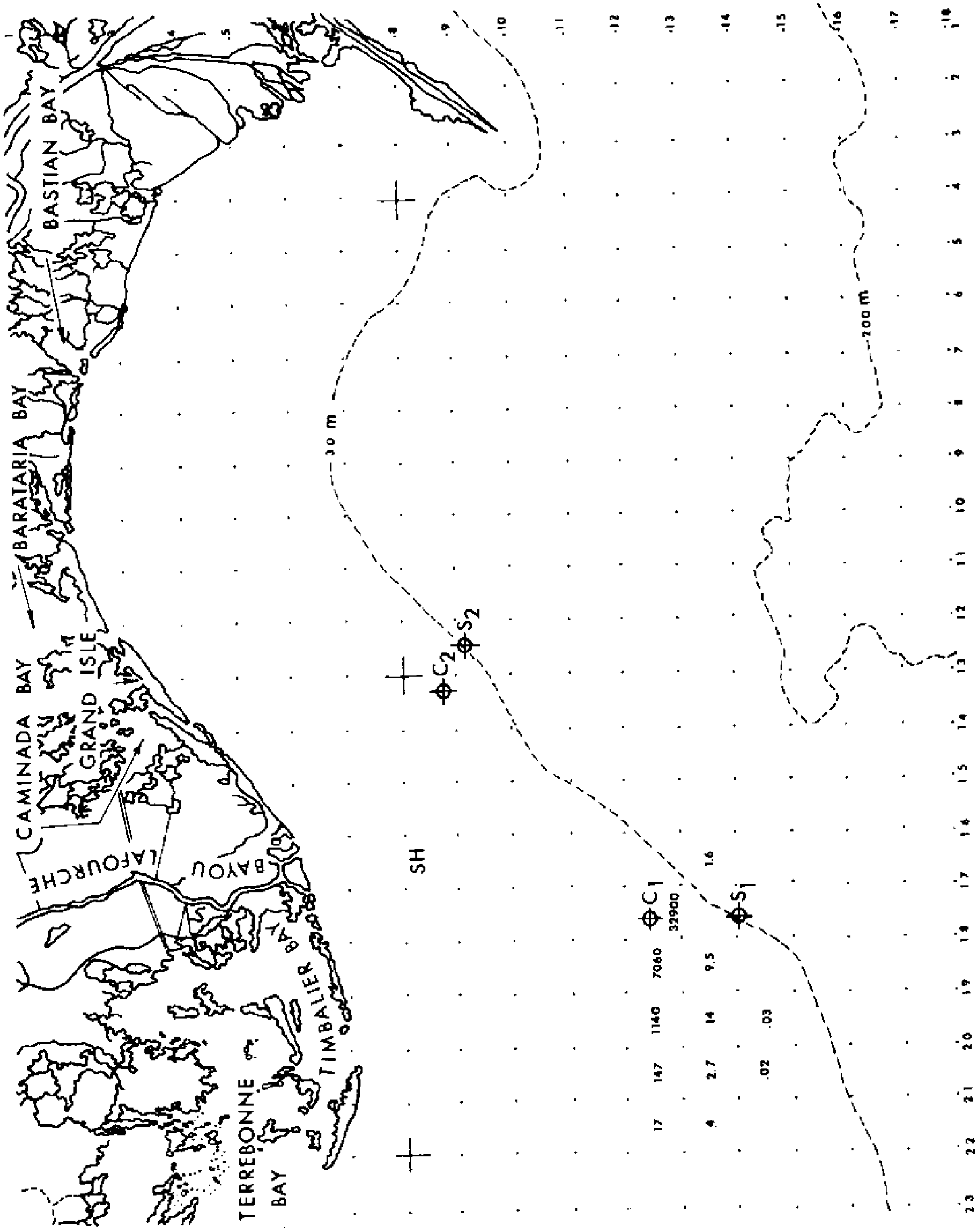


Figure 75A. Distribution of a 30,000 ton spill at C_1 after 7 hrs with winds toward 315° at 7 m/sec. Based on Hansen's model. Oil released at 5 hrs and completed in 2 hrs.

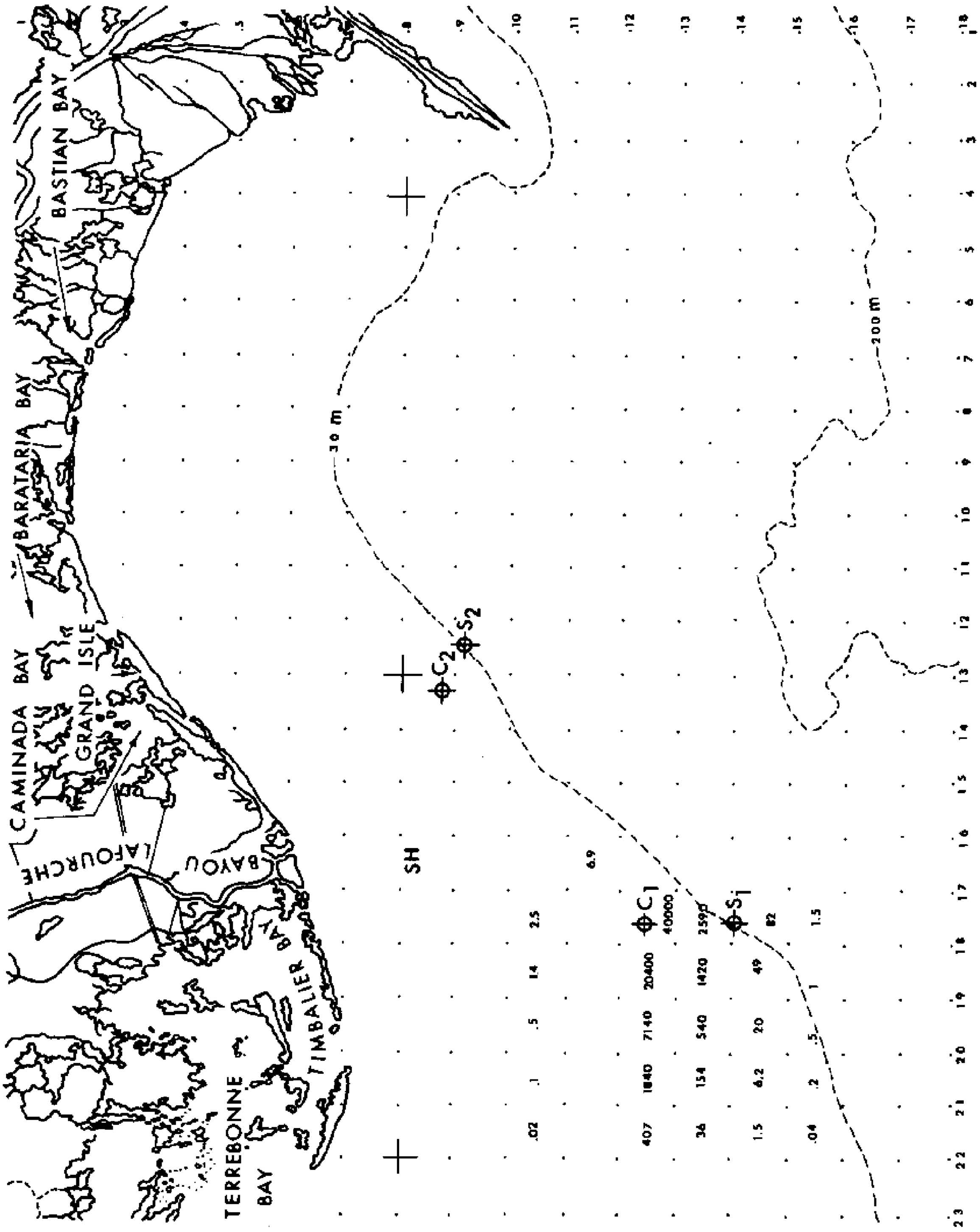


Figure 75B. Distribution of a 30,000 ton spill at C_1 after 10 hrs with winds toward 315° at 7 m/sec. Based on Hansen's model. Oil released at 5 hrs and completed in 2 hrs.

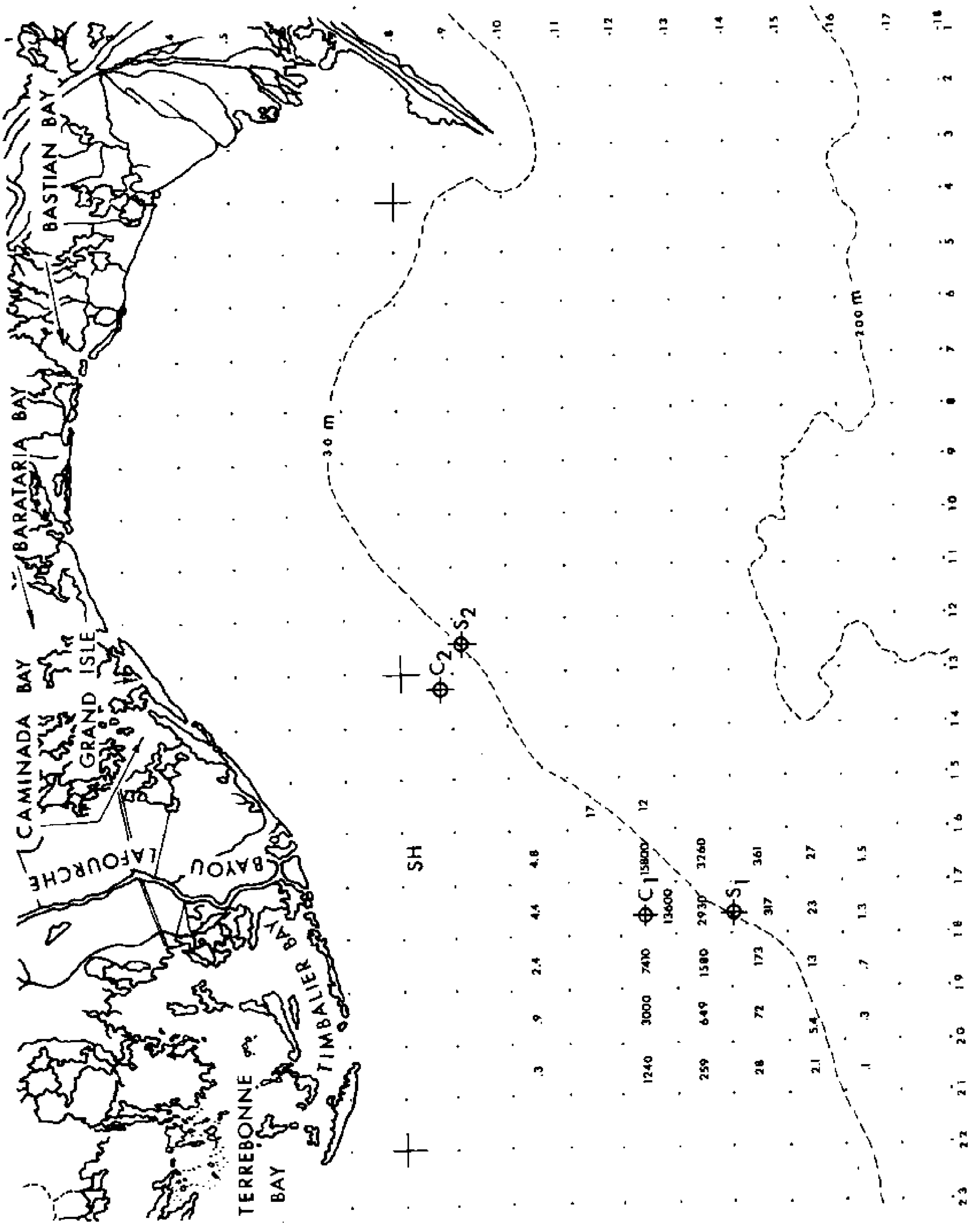


Figure 75C. Distribution of a 30,000 ton spill at C_1 after 15 hrs with winds toward 315° at 7 m/sec. Based on Hansen's model. Oil released at 5 hrs and completed in 2 hrs.

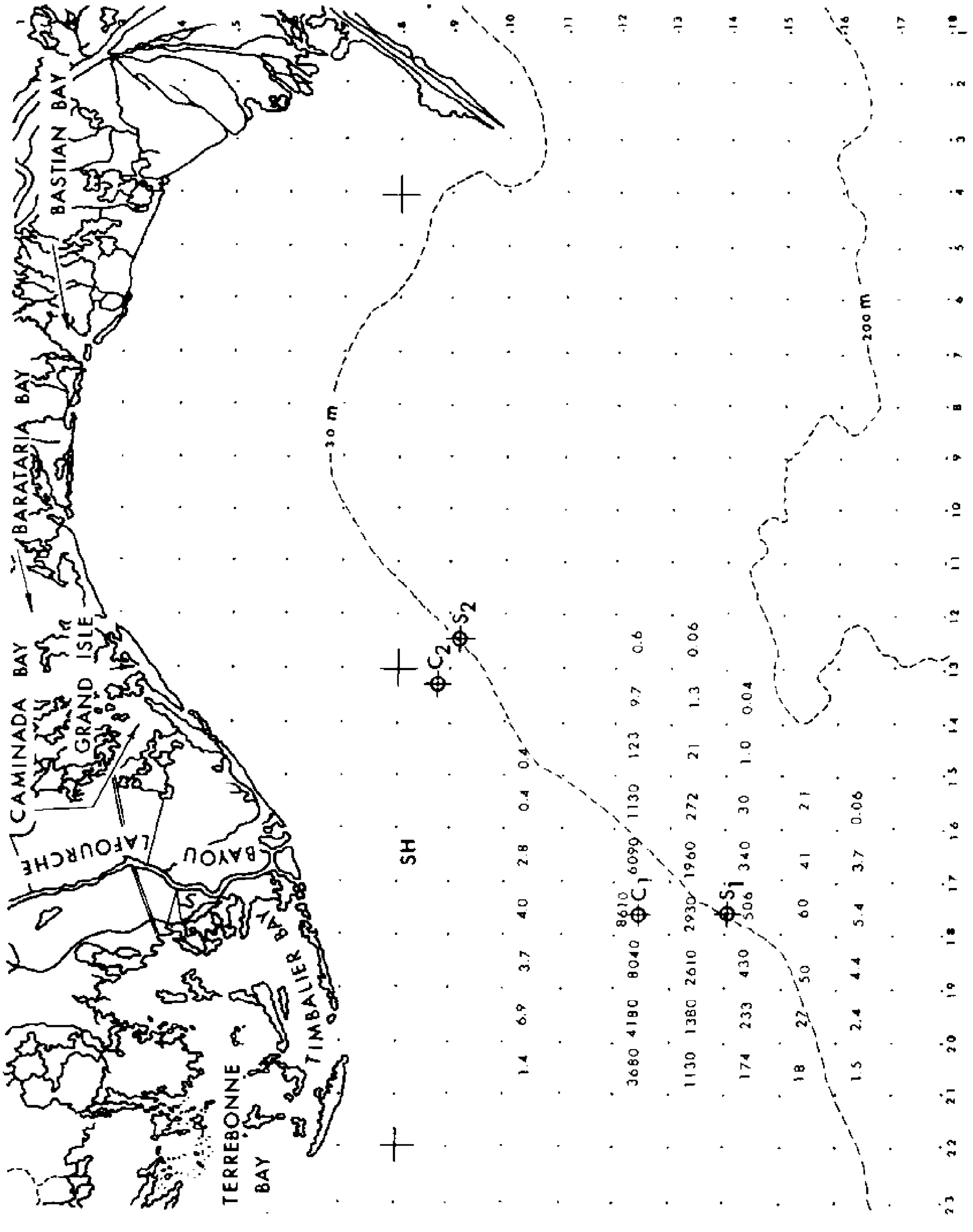


Figure 75D. Distribution of a 30,000 ton spill at C_1 after 20 hrs with winds toward 315° at 7 m/sec. Based on Hansen's model. Oil released at 5 hrs and completed in 2 hrs.

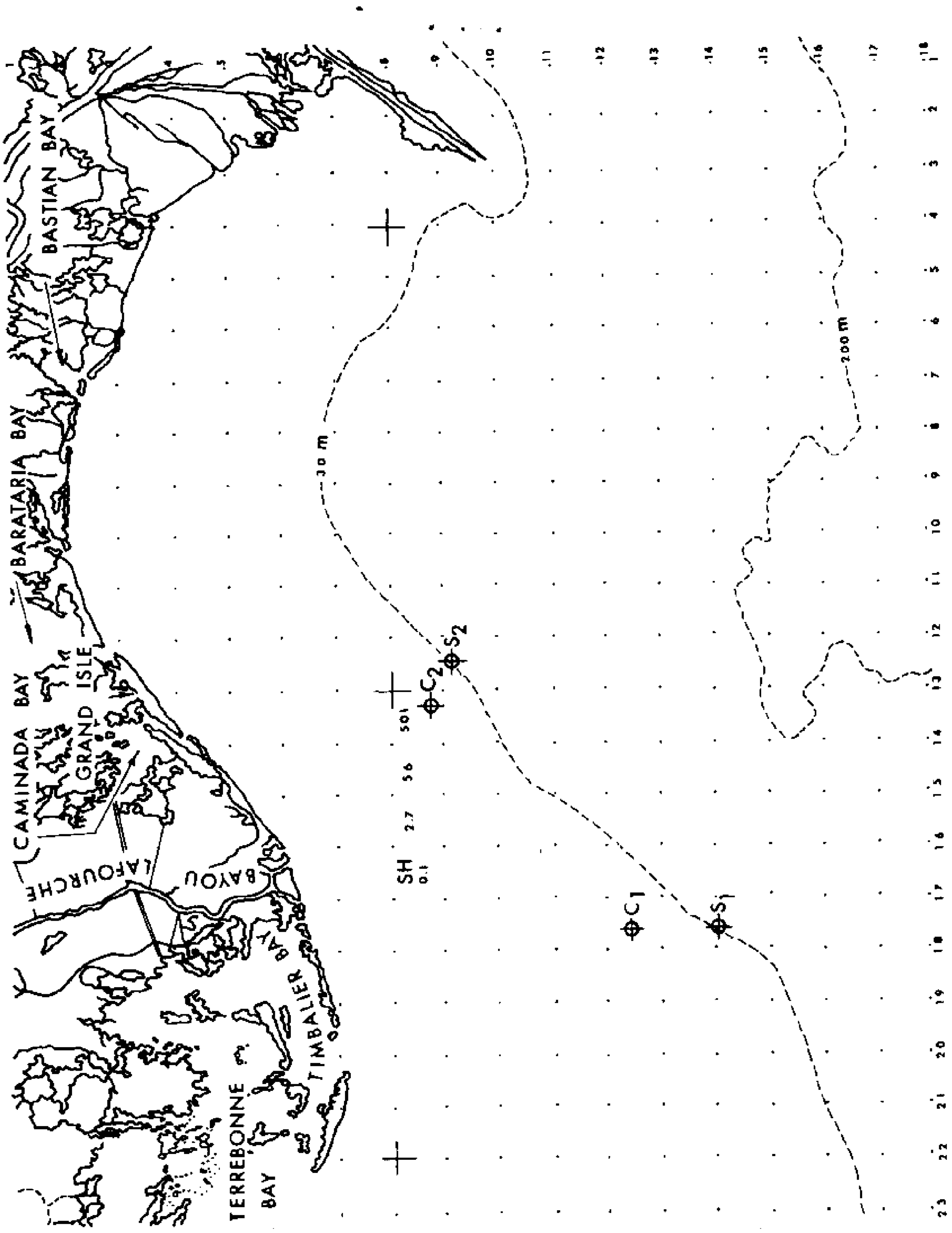


Figure 76A. Distribution of a 500 ton spill at C_2 after 7 hrs with winds toward 315° at 7 m/sec. Based on Hansen's model. Oil released at 5 hrs and completed in 2 hrs.

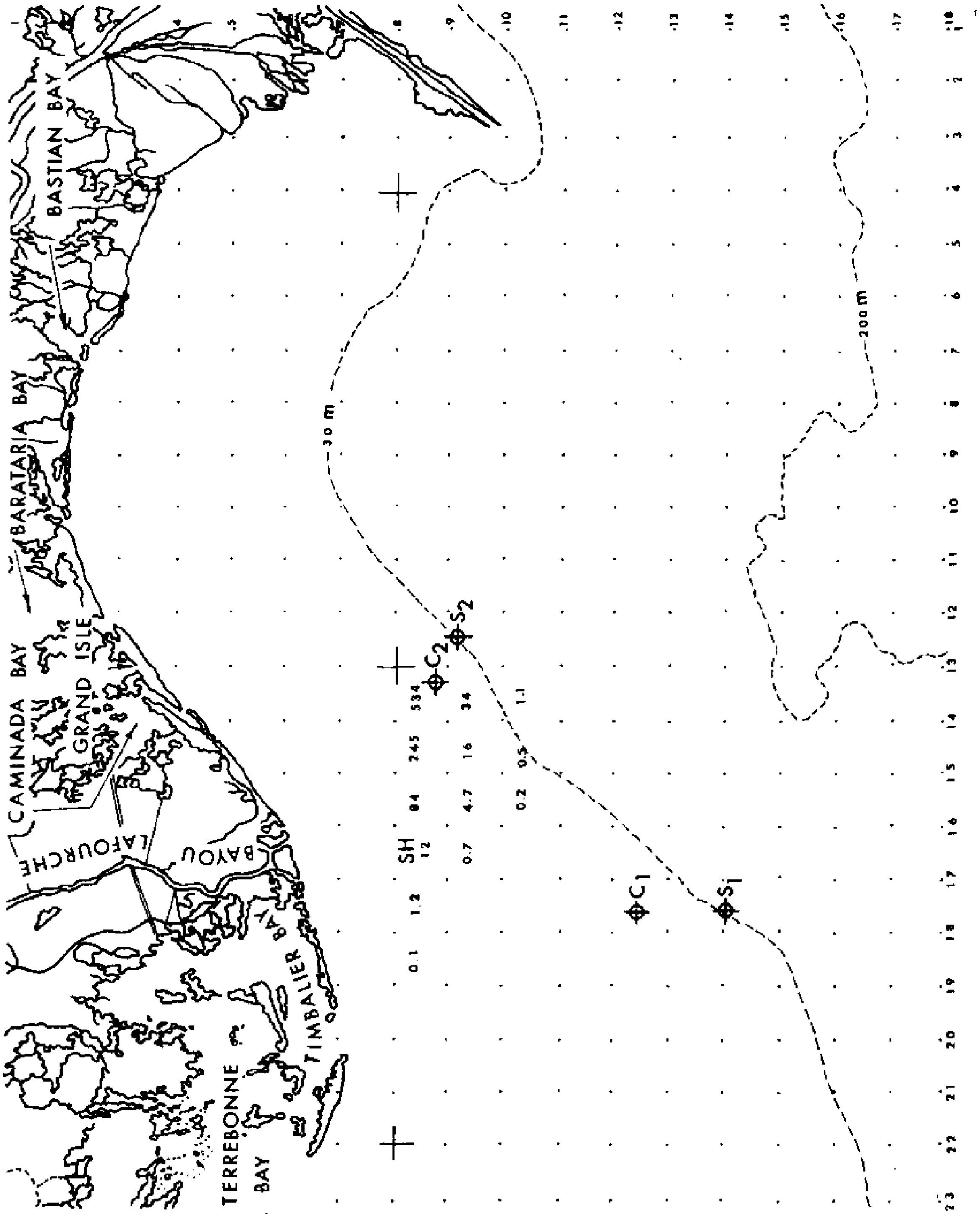


Figure 76B. Distribution of a 500 ton spill at C_2 after 10 hrs with winds toward 315° at 7 m/sec. Based on Hansen's model. Oil released at 5 hrs and completed in 2 hrs.

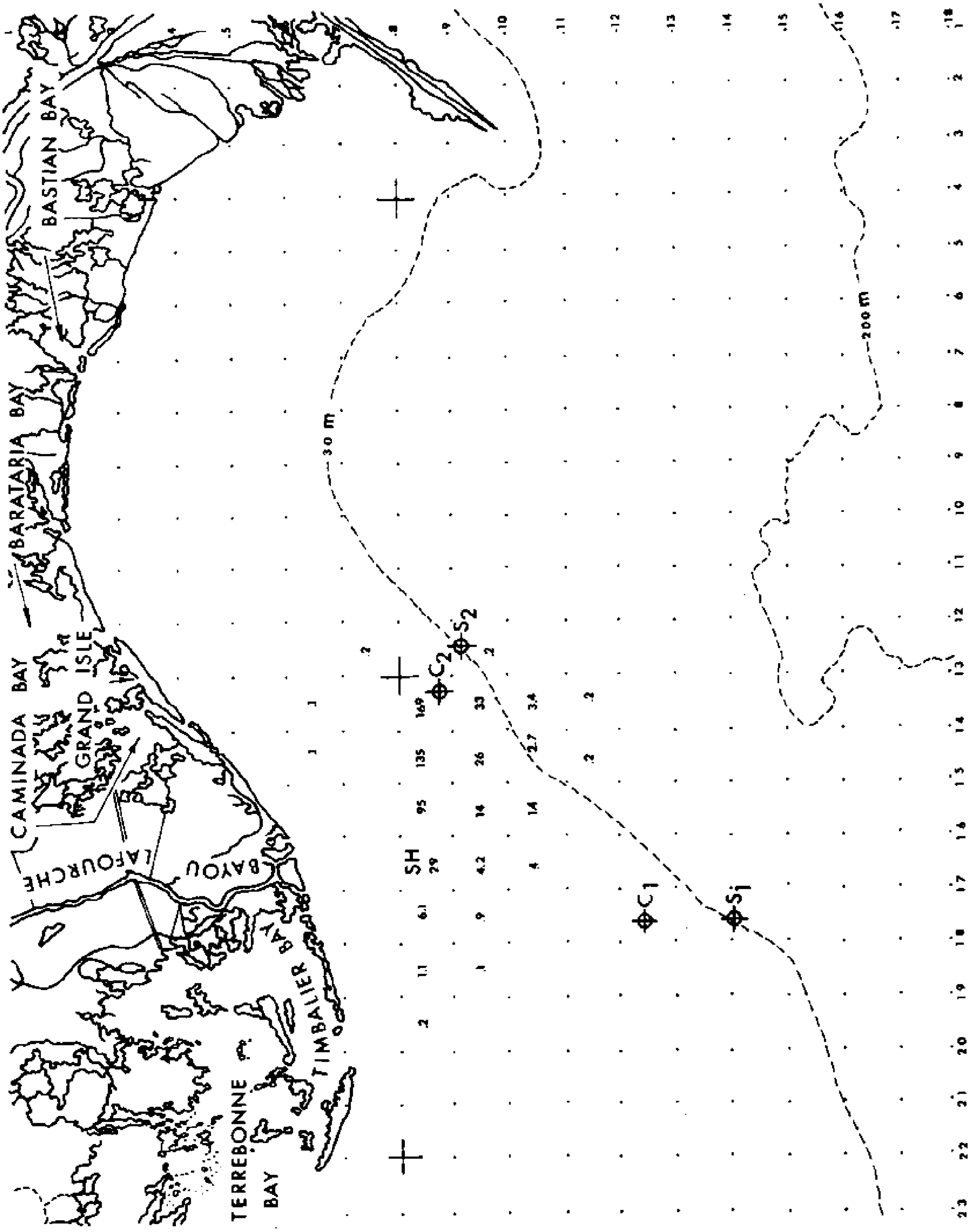


Figure 76C. Distribution of a 500 ton spill at C_2 after 15 hrs with winds toward 315° at 7 m/sec. Based on Hansen's model. Oil released at 5 hrs and completed in 2 hrs.

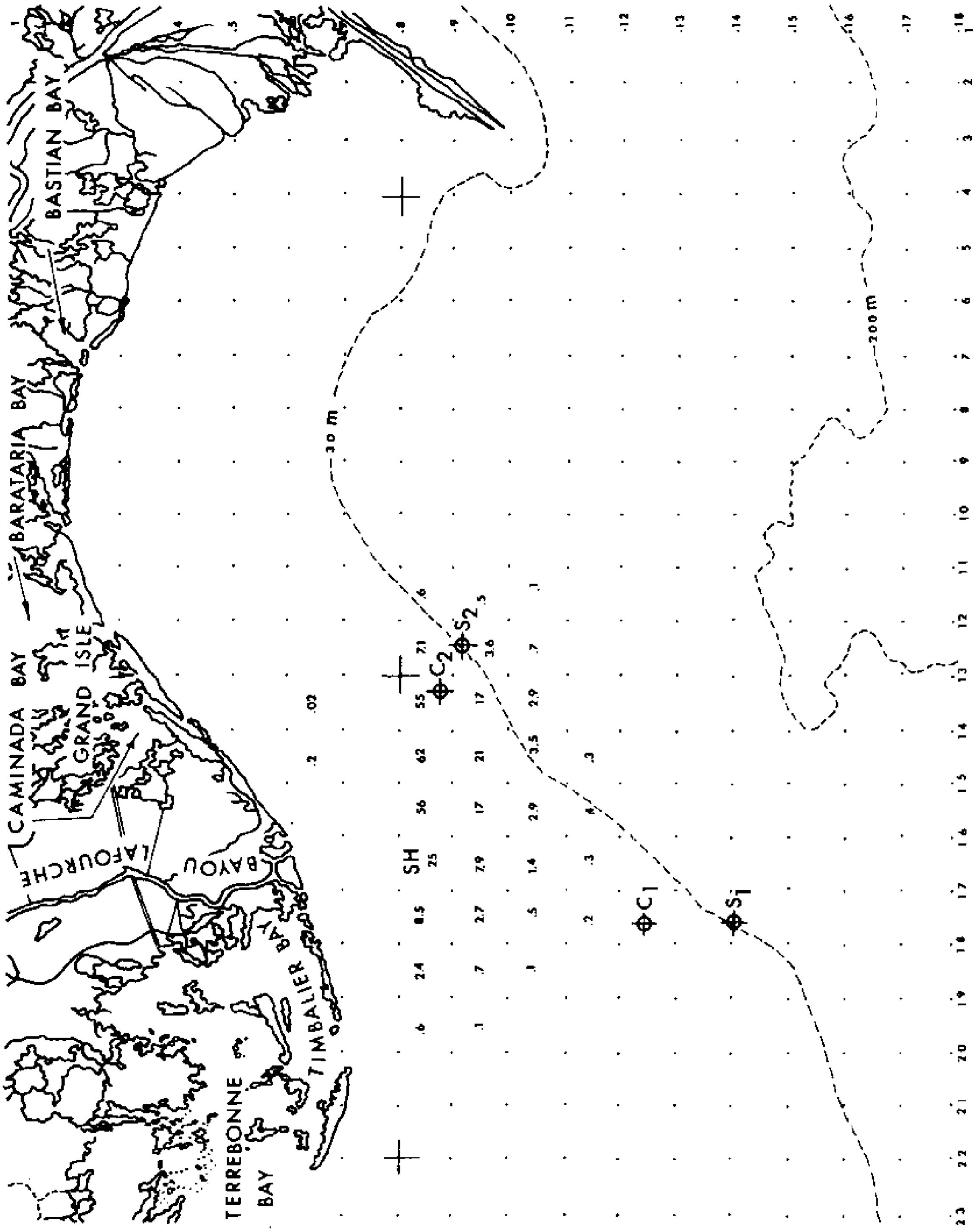


Figure 76D. Distribution of a 500 ton spill at C_2 after 20 hrs with winds toward 315° at 7 m/sec. Based on Hansen's model. Oil released at 5 hrs and completed in 2 hrs.

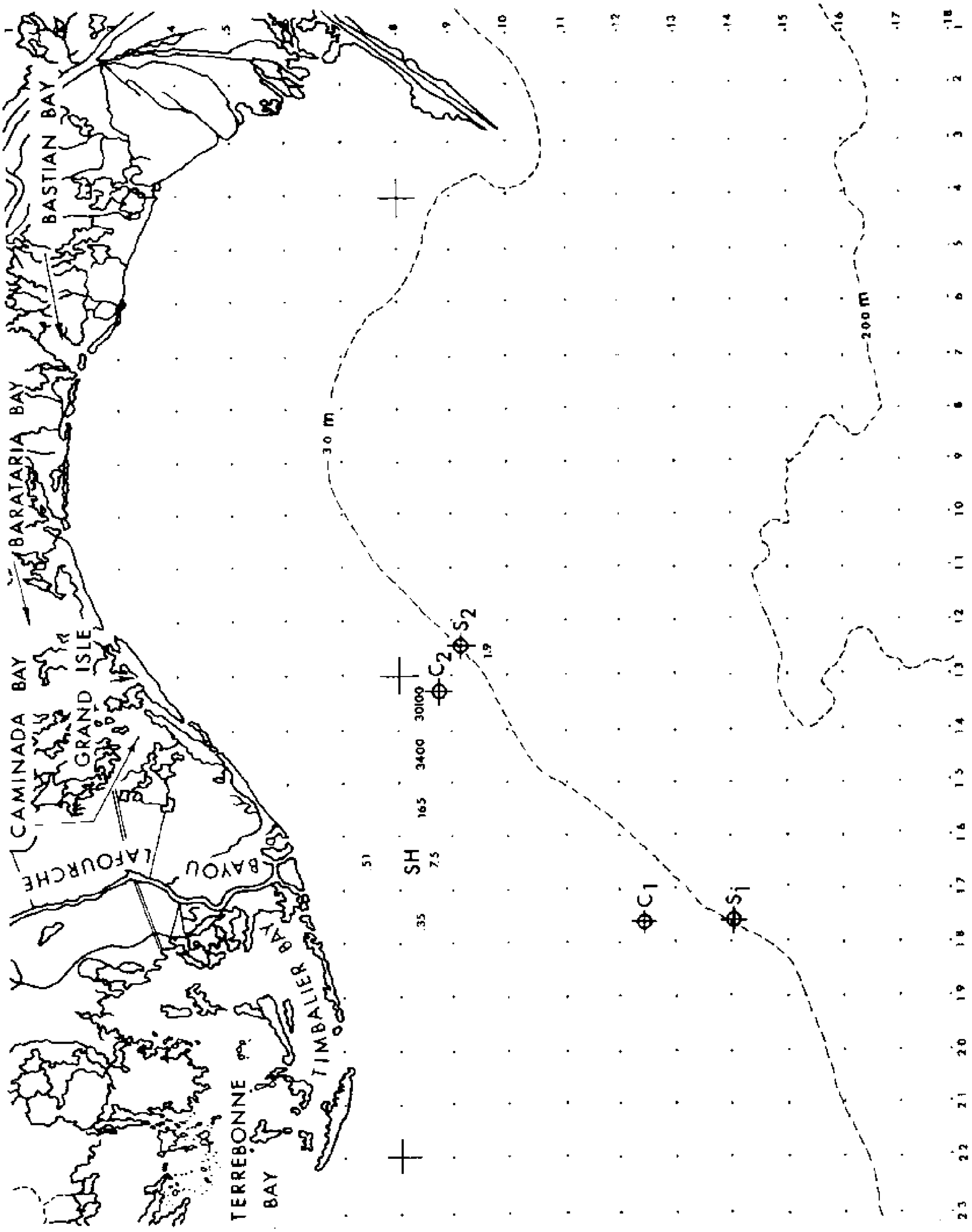


Figure 77A. Distribution of a 30,000 ton spill at C_2 after 7 hrs with winds toward 315° at 7 m/sec. Based on Hansen's model. Oil released at 5 hrs and completed in 2 hrs.

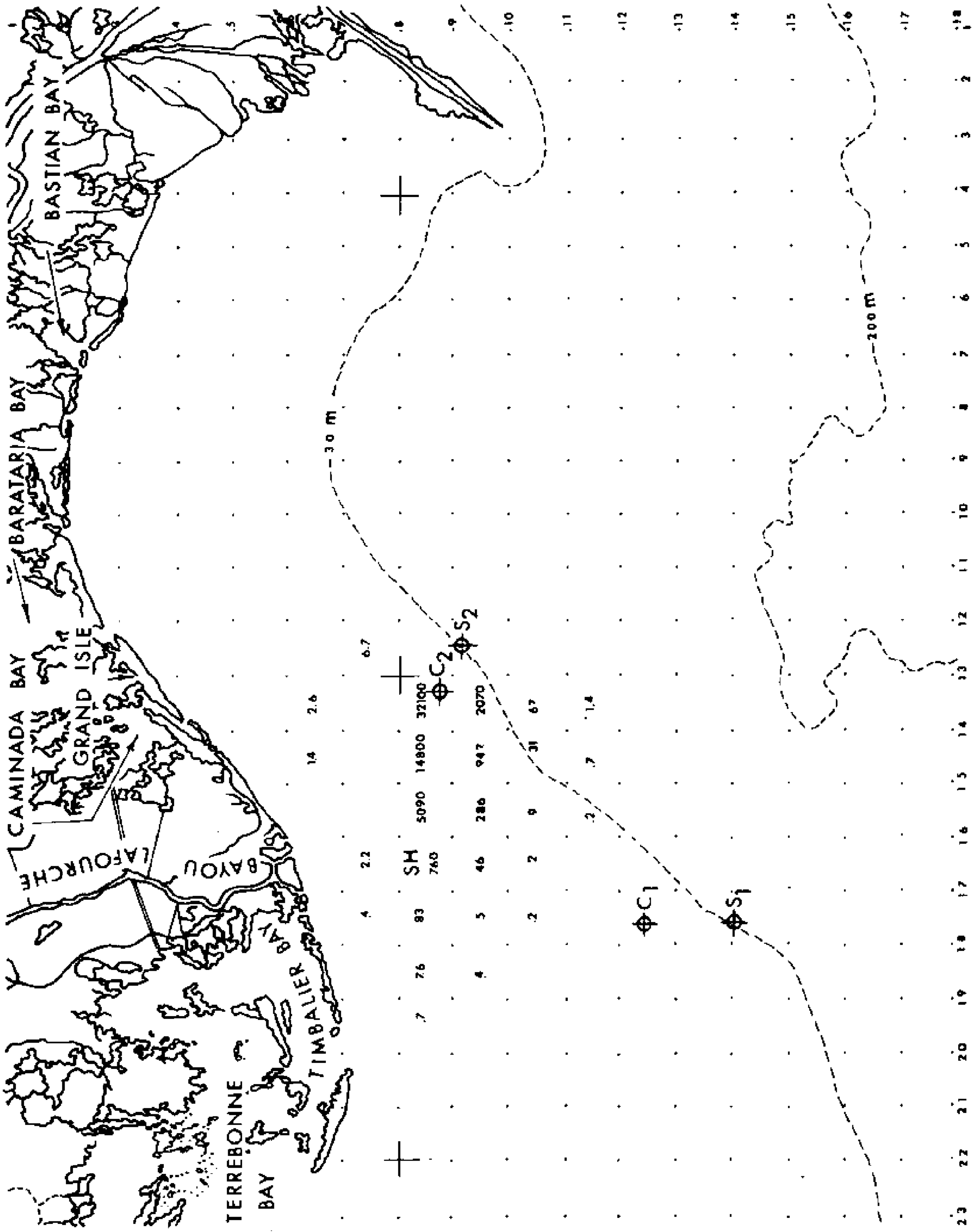


Figure 77B. Distribution of a 30,000 ton spill at C_2 after 10 hrs with winds toward 315° at 7 m/sec. Based on Hansen's model. Oil released at 5 hrs and completed in 2 hrs.

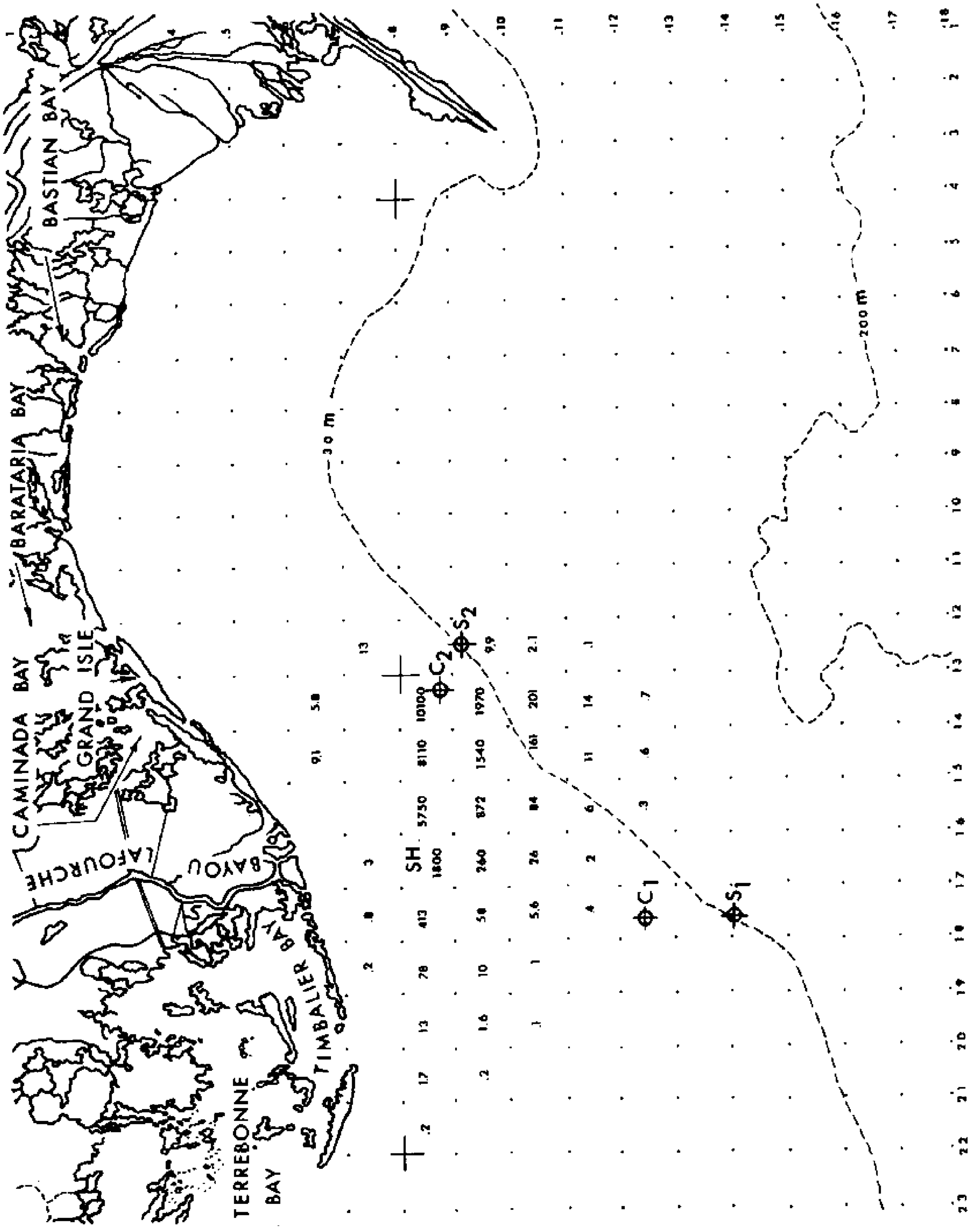


Figure 77C. Distribution of a 30,000 ton spill at C_2 after 15 hrs with winds toward 315° at 7 m/sec. Based on Hansen's model. Oil released at 5 hrs and completed in 2 hrs.

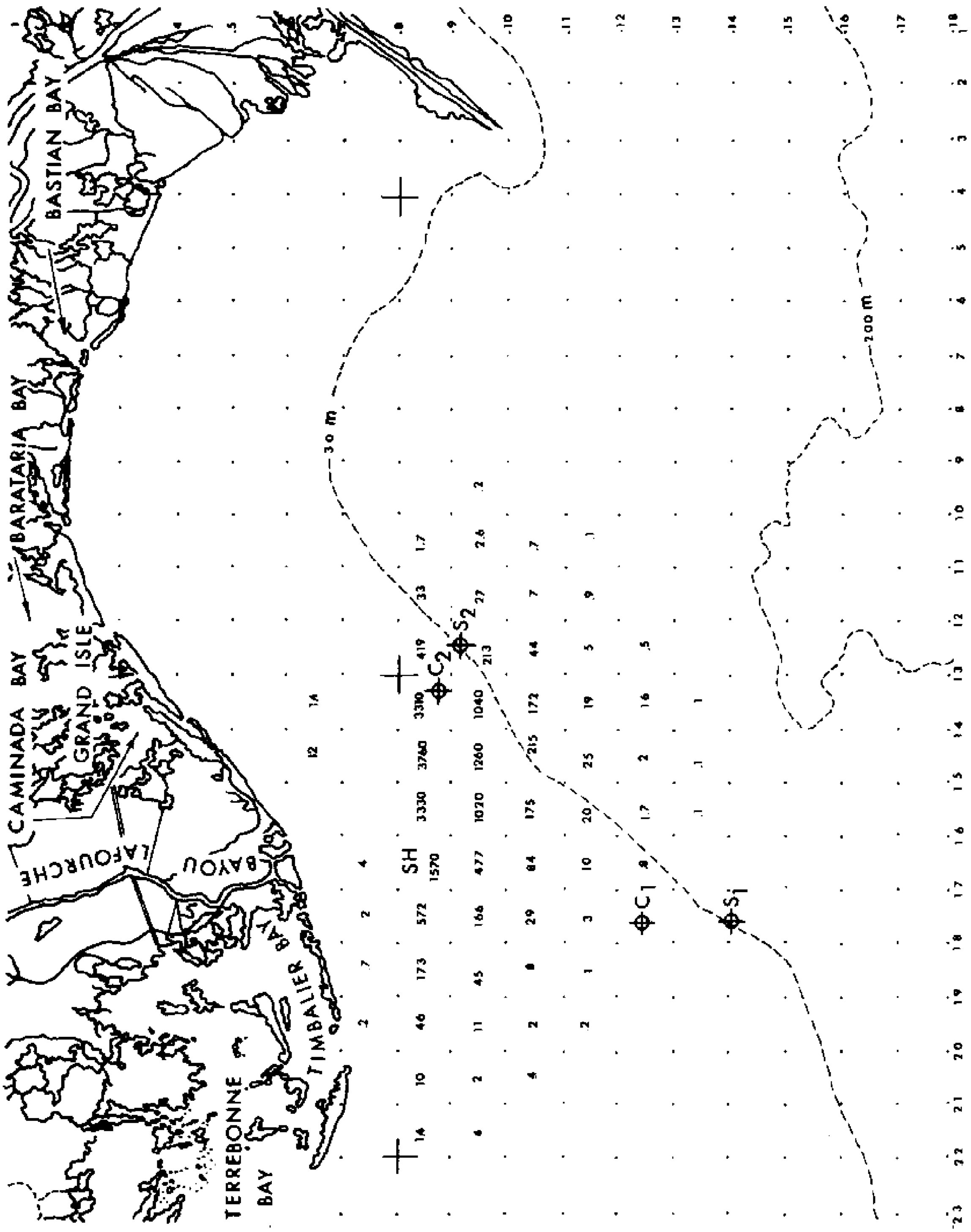


Figure 77D. Distribution of a 30,000 ton spill at C_2 after 20 hrs with winds toward 315° at 7 m/sec. Based on Hansen's model. Oil released at 5 hrs and completed in 2 hrs.

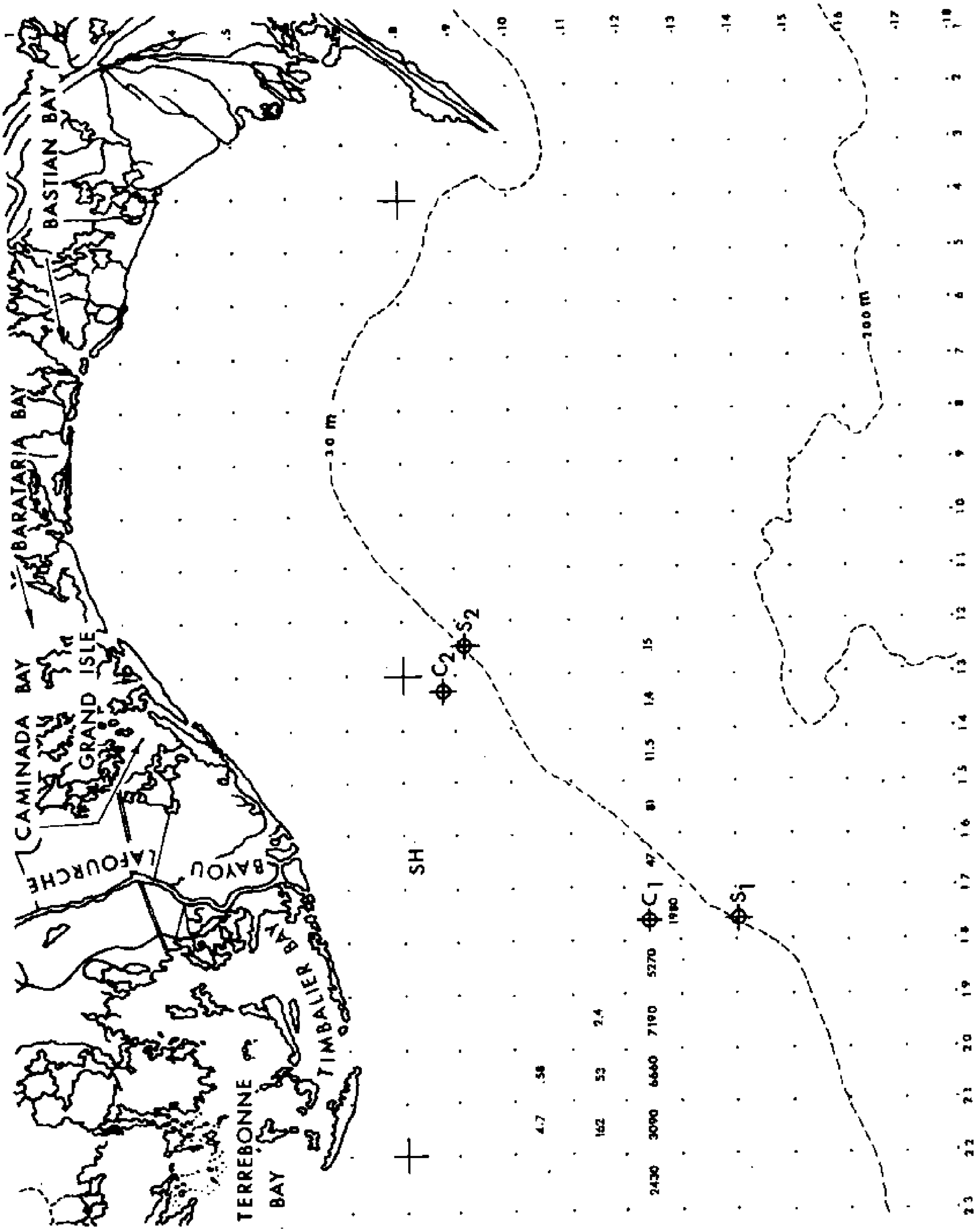


Figure 78A. Distribution of a 30,000 ton spill at C_1 after 20 hrs with winds toward 360° at 7 m/sec. Based on Hausen's model. Oil released at 5 hrs and completed in 2 hrs.

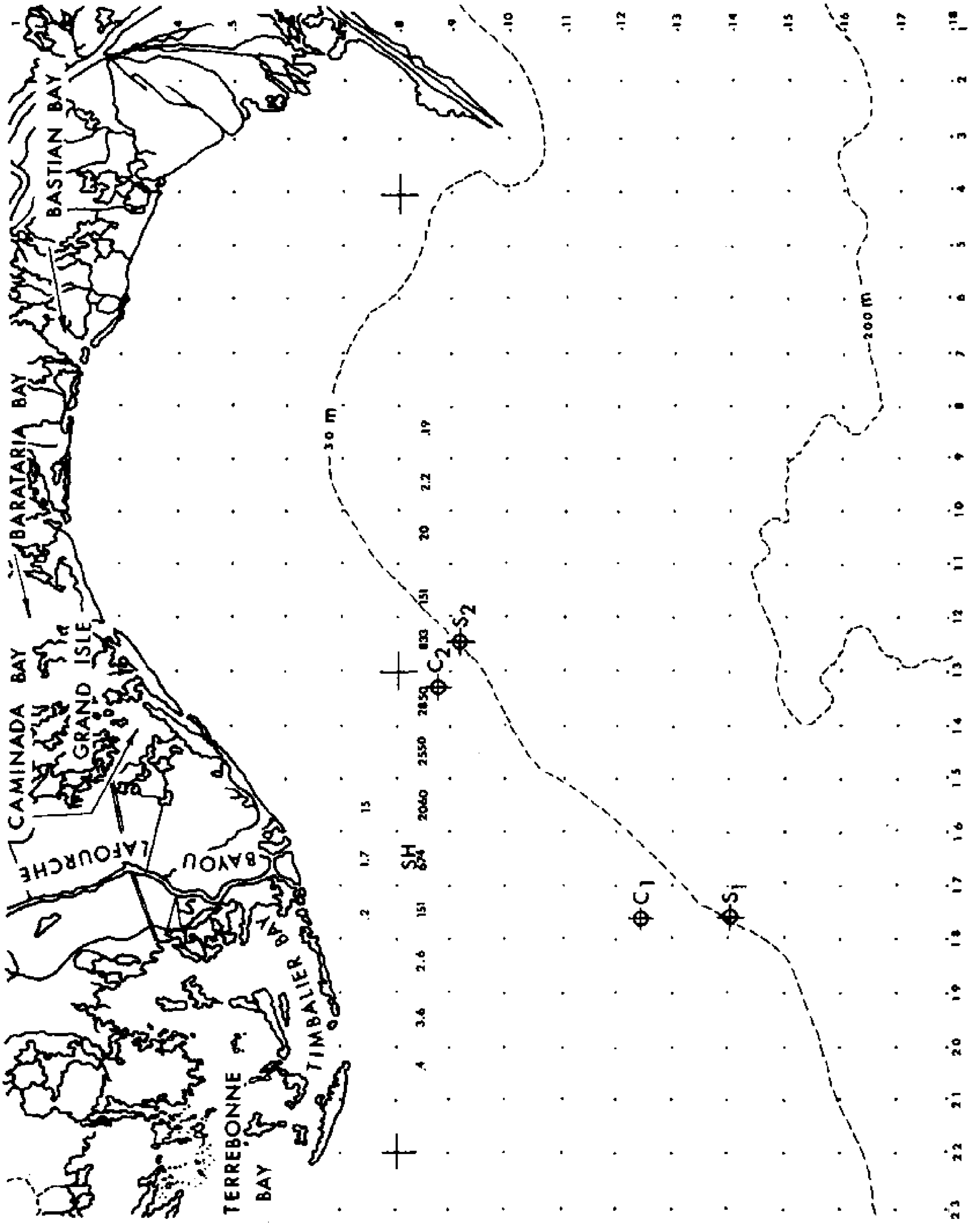


Figure 78B. Distribution of a 30,000 ton spill at C_2 after 20 hrs with winds toward 360° at 7 m/sec. Based on Hansen's model. Oil released at 5 hrs and completed in 2 hrs.

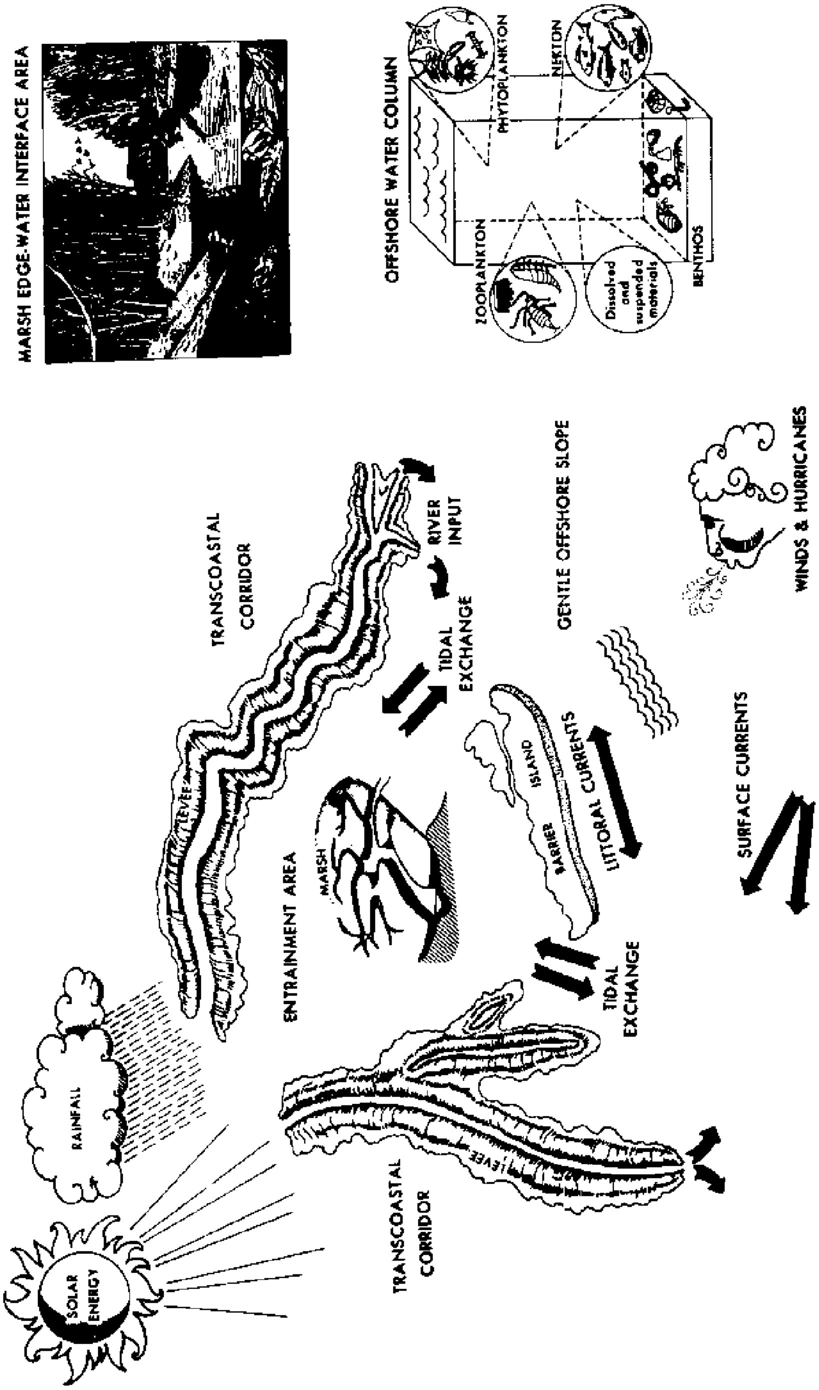


Figure 79. Schematic diagram of the major features of the coastal zone area of Louisiana. Those features especially appropriate in regard to an oil spill are discussed in the text.

Table 1. Mean annual discharge and wave-power climate indices (Wright and Coleman, 1972).

River	Mean Annual Deep Water Wave Power Ergs/sec/cm crest	Mean Annual Nearshore Wave Power Ergs/sec/cm crest	Mean Annual Discharge Rate (Entire River) $(m^3/sec) \times 10^3$	Mean Annual Discharge Effectiveness Index (Normalized to Maximum)	Mean Annual Attenuation Ratio
Mississippi	1.06×10^8	1.34×10^4	17.69	1.00	7913.3
Danube	2.30×10^7	1.40×10^4	6.29	2.14×10^{-1}	2585.0
Ebro	7.28×10^7	5.09×10^4	0.55	4.87×10^{-2}	1299.5
Niger	6.76×10^7	6.59×10^5	10.90	8.03×10^{-4}	102.8
Nile	1.36×10^8	3.21×10^6	1.47	5.86×10^{-4}	42.46
São Francisco	3.71×10^8	9.97×10^6	3.12	2.37×10^{-4}	37.2
Senegal	1.56×10^8	3.77×10^7	.77	4.75×10^{-5}	4.16

Table 2. Dimensions of estuarine study areas, Louisiana, and surface water acres in coastal Louisiana by area and depth interval. Areas 4, 5, 6 and 7 roughly correspond to the study areas in this report, i.e., Mississippi Delta, Barataria Estuary and (6 and 7) Terrebonne Estuary (adapted from Perret et al., 1971).

Surface Water Acres in Coastal Louisiana by Area and Depth Interval
(Barrett, 1970)

	Depth (feet)				
Area	0-3	3-6	6-9	>9	Total Acres per acre
1	12,903	22,868	59,690	357,625	453,086
2	169,907	182,726	280,335	331,331	964,299
3	157,586	39,685	51,418	84,776	333,465
4	107,333	12,530	8,945	69,279	198,087
5	145,941	75,876	6,955	6,824	235,596
6	87,166	115,500	29,393	5,903	237,962
7	106,669	57,817	9,523	6,814	180,823
8	80,337	214,229	159,569	15,155	469,290
9	137,741	90,434	69,335	8,806	306,316
Total Acres per Depth Interval	1,005,583	811,665	675,163	886,513	3,378,924

Dimensions of Estuarine Study Areas, Louisiana

Study Areas[1]	Surf.[2] Water Area (Acres)	Water[3] Vol. (Acre-Feet)
AREA 1	453,083	5,098,490
Maj. w. bodies		
L. Maurepas	58,191	533,741
L. Pontchartrain	394,127	4,537,974
AREA 2	964,299	7,637,034
Maj. w. bodies		
Chandeleur Sound	578,003	5,371,632
L. Borgne	171,380	1,128,568
AREA 3	333,465	2,074,416
Maj. w. bodies		
Breton Sound	195,330	1,650,716
AREA 4	198,087	2,209,381
Maj. w. bodies		
East Bay	48,195	425,878
Garden Is. Bay	13,504	44,732
Miss. River	34,982	1,399,280
West Bay	17,646	63,343
AREA 5	235,596	200,917
Maj. w. bodies		
Barataria Bay	43,551	200,917
Caminada Bay	14,158	24,085
Little Lake	12,888	51,552

Study Areas[1]	Surf.[2] Water Area (Acres)	Water[3] Vol. (Acre-Feet)
AREA 6	237,962	939,437
Maj. w. bodies		
L. Barre	21,247	84,613
L. Raccourci	19,278	63,495
Terrebonne Bay	50,388	313,039
Timbalier Bay	79,713	297,662
AREA 7	180,823	616,304
Maj. w. bodies		
Caillou Bay	27,085	113,132
Caillou Lake	7,752	14,382
Four League Bay	20,402	63,851
L. Mechant	8,395	28,292
L. Pelto	24,633	101,516
AREA 8	469,290	2,533,202
Maj. w. bodies		
Atchafalaya Bay	134,679	616,014
E. Cote Bl. Bay	82,314	405,757
Vermilion Bay	121,604	825,067
W. Cote Bl. Bay	89,902	507,192
AREA 9	306,319	1,317,987
Maj. w. bodies		
Calcasieu Lake	42,792	210,482
Grand Lake	31,733	147,194
Sabine Lake	55,858	300,776
White Lake	51,649	234,182
TOTAL (9 areas)	3,378,921	23,140,497

Table 3. Surface area of natural and manmade water bodies, 1931-1942, 1948-1967, and 1970 (from Gagliano et al., 1972).

	Unit	Total Water Area	Natural Water Bodies	Manmade Water Bodies	%	Canals	%	Ponds	%
1931-1942	3	611.48	611.01	0.47	0.07	0.47	0.07	-	-
	4	747.27	730.06	17.21	2.30	6.66	0.89	10.55	1.41
	5	962.30	953.60	8.70	0.90	7.78	0.80	0.92	0.10
1948-1967	3	658.58	644.49	13.89	2.11	12.63	1.92	1.62	0.19
	4	863.35	792.15	71.20	8.25	54.71	6.34	16.49	1.91
	5	1044.27	997.21	47.06	4.51	44.41	4.26	2.65	0.25
1970	3	680.98	660.27	20.71	3.04	18.79	2.76	1.92	0.28
	4	907.79	818.48	89.31	9.83	71.18	7.84	18.13	1.99
	5	1078.75	1022.48	56.27	5.21	53.25	4.93	3.02	0.28

Table 4. Shoreline inventory by hydrologic unit for coastal Louisiana (from Becker, 1972).

Unit	Streams and Bayous	Bays, Lakes and Marshes	Canals and Dredged Cuts	Major Rivers	Gulf Shore-line	Totals
I	970.6	3,410.3	350.8	43.1	30.2	4,805.0
II	697.5	1,389.0	560.5	77.7	13.9	2,738.6
III	769.9	1.232.0	764.8	149.3	64.7	2,980.7
IV	1,478.2	3,488.3	1,556.5	58.5	43.9	6,625.4
V	2,089.9	4,914.7	1,499.7	9.4	68.7	8,582.4
VI	292.6	87.4	103.0	32.2	-	515.2
VII	460.2	1,156.1	243.7	9.4	45.3	1.914.7
VIII	184.0	522.3	315.6	37.4	52.1	1,111.4
IX	251.6	437.4	156.0	28.2	44.2	917.4
Totals	7,194.5	16,637.5	5,550.6	445.2	363.0	30,190.8

Table 5. Surface water area and water volume estimates for the study area, as indicated in Figure 1, part of the continental shelf of Louisiana (Barrett, 1969, unpublished data).

Depths Feet	Surface Water Acres	%	Volume Acre - feet	%
0-100	4,167,442	51	6,251,000	.6
100-200	1,654,900	20	248,235,000	25.0
200-300	1,085,400	13	271,350,000	28.0
300-400	696,800	8	209,386,000	22.0
400-500	336,675	5	135,838,000	14.0
500-600	202,675	2	101,439,000	10.0
	8,143,892		972,501,000	

Totals for entire Louisiana continental shelf:

18,737,841 acres	2,486,611,612 acre-feet

Table 6. Frequency in percent of winds from various direction in Gulf of Mexico (extracted from U.S. Naval Weather, 1970). A. Monthly data. B. Seasonal data.

A. Monthly data.

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
N	19	13	12	10	10	4	4	4	6	13	18	12
NE	16	20	13	18	16	10	10	11	22	34	23	18
E	21	21	20	32	28	30	28	22	33	28	24	22
SE	17	17	27	19	17	23	18	13	13	7	11	16
S	7	10	12	7	6	6	10	8	5	2	6	8
SW	5	3	3	2	3	4	5	7	2	2	2	3
W	5	6	4	4	4	2	4	6	3	2	3	5
NW	10	10	7	7	5	4	4	5	4	4	7	7

B. Seasonal data.

	Fall	Winter	Spring	Summer
NE	26	18	16	10
E	28	21	27	27
SE	10	17	21	18
NW	5	9	6	4

Table 7. Average air temperatures in °F (Celsius equivalent given) for southeast division of Louisiana, 1931-1971 (Climatological data, Louisiana).

Year	J	F	M	A	M	J	J	A	S	O	N	D	Annual Average °F
1931	52.4	58.0	56.6	64.7	71.6	79.5	83.0	79.7	79.7	74.0	67.8	62.7	69.2
1932	60.8	65.9	58.4	68.3	73.1	81.3	84.1	84.1	82.2	69.2	56.4	58.6	69.7
1933	59.2	58.6	63.3	69.2	79.0	79.2	82.1	82.5	82.9	72.8	63.5	64.8	71.4
1934	57.2	56.7	61.0	68.5	73.9	81.0	82.0	82.0	78.4	73.7	65.0	55.8	69.6
1935	56.5	57.9	66.7	69.4	76.6	80.2	82.3	83.1	78.7	73.5	62.1	51.8	69.9
1936	55.5	54.2	63.7	66.6	74.4	82.0	82.3	82.0	81.5	72.9	60.6	57.3	69.4
1937	66.1	56.8	58.2	68.1	75.9	81.4	82.5	82.6	79.0	70.1	58.8	54.9	69.5
1938	55.7	60.7	68.9	67.6	75.1	80.8	81.6	82.8	78.2	71.0	61.9	55.7	70.0
1939	58.8	59.9	64.4	68.0	73.4	80.7	82.3	81.7	80.1	72.5	60.1	58.5	70.1
1940	43.9	54.3	62.1	67.6	73.1	79.5	81.5	81.8	77.2	71.2	62.6	59.7	67.9
1941	55.8	53.3	57.5	70.2	75.0	80.3	82.5	84.1	81.1	77.9	60.0	58.9	69.7
1942	51.0	53.3	60.2	67.9	74.5	80.4	82.4	81.7	77.2	71.9	64.1	57.4	68.5
1943	54.9	57.6	60.8	69.3	77.8	82.0	82.8	83.3	76.9	67.8	58.5	55.1	68.9
1944	54.1	63.8	63.5	68.5	75.3	82.9	82.8	82.7	80.5	69.1	63.7	55.3	70.2
1945	54.5	61.3	68.8	71.1	73.6	81.7	81.2	82.6	80.3	70.0	64.9	52.4	70.2
1946	54.6	57.4	64.6	70.5	75.2	78.7	81.7	82.6	78.0	72.7	66.3	59.2	70.1
1947	56.8	50.4	57.2	70.5	75.7	81.8	80.9	82.4	80.3	75.5	61.2	55.9	69.1
1948	47.6	58.6	64.9	72.0	76.7	81.9	82.9	81.9	76.5	69.6	63.8	60.6	69.8
1949	60.2	62.1	62.3	67.4	76.5	81.3	81.9	81.9	78.6	74.8	60.3	59.9	70.6
1950	67.5	61.5	60.1	65.3	76.5	81.0	80.6	81.7	78.9	71.7	58.4	53.1	59.7
1951	55.9	56.7	63.1	66.0	74.6	81.1	82.8	85.2	80.2	73.1	57.3	60.0	69.7
1952	63.0	59.4	61.2	65.9	75.3	82.8	82.5	82.8	77.0	64.3	59.8	55.7	69.1
1953	57.3	57.3	66.8	68.8	77.5	82.8	81.9	81.8	78.7	71.5	61.1	54.4	70.0
1954	57.5	60.4	60.8	72.1	72.0	80.9	82.6	83.4	80.7	71.9	59.3	56.0	69.8
1955	54.5	58.7	65.5	71.0	77.6	78.5	81.4	82.2	80.6	70.5	61.4	56.8	69.9
1956	52.6	61.8	62.9	67.7	77.0	78.8	81.9	82.0	78.0	72.7	61.5	62.2	69.9
1957	61.2	64.1	61.6	69.8	77.0	81.1	84.0	82.1	77.7	67.4	62.7	56.0	70.4
1958	49.3	48.4	58.6	68.9	75.5	81.7	81.9	81.8	80.5	70.5	64.6	53.2	67.9
1959	51.1	38.2	59.8	67.2	76.6	80.5	81.5	82.5	79.9	73.4	59.6	55.7	68.8
1960	53.0	51.2	57.3	69.2	72.8	81.3	84.4	81.5	78.8	72.2	64.2	53.3	68.3
1961	48.8	59.4	65.7	65.5	73.6	78.6	81.1	80.4	79.1	69.9	62.6	58.0	68.5
1962	51.6	63.8	58.6	66.9	77.2	80.7	84.5	83.7	80.2	73.9	59.6	53.4	70.2
1963	49.6	50.7	65.1	72.4	76.8	80.6	82.3	82.8	79.2	72.8	62.3	47.7	68.5
1964	51.3	51.7	61.5	70.7	76.0	80.3	81.2	83.2	79.9	67.1	65.2	57.7	68.8
1965	56.6	55.2	59.5	72.3	75.8	80.1	81.9	80.6	78.5	78.7	66.4	56.7	69.3
1966	49.5	54.1	60.1	69.0	75.3	78.4	82.7	81.1	78.2	68.7	63.7	54.2	67.9
1967	53.6	54.4	64.3	73.2	74.2	80.5	80.5	79.9	75.8	67.8	61.4	59.3	68.7
1968	52.5	48.7	57.9	70.3	74.9	81.0	81.3	81.8	77.6	71.7	58.9	53.8	67.5
1969	54.8	55.4	55.1	69.0	74.3	81.4	83.1	81.2	77.4	70.8	59.4	55.2	68.1
1970	48.0	52.3	60.2	71.0	74.1	79.2	81.4	81.9	80.5	69.4	57.1	59.4	67.8
1971	55.4	55.3	60.0	67.4	73.5	80.3	81.2	81.2	79.1	72.8	61.7	64.2	69.3
Monthly Average °F:	54.9	48.4	61.7	68.9	75.2	78.7	80.7	82.2	75.2	71.3	61.7	56.8	20.7
Monthly Average °C:	12.7	14.7	16.5	20.5	24.0	25.9	27.0	27.9	23.9	21.8	16.5	13.8	69.3

	Winter	Spring	Summer	Fall	Annual
Seasonal Average °F	56.7	68.6	80.8	69.4	68.9
Seasonal Average °C	13.7	20.3	27.1	20.8	20.5

Table 8. Monthly precipitation in inches (metric equivalents given), southeast division, 1931-1970. Extracted and derived from National Climatic Summary (courtesy G. Cry).

Year	J	F	M	A	M	J	J	A	S	O	N	D	Annual Total	Annual Mean (In.)	Annual Mean (cm)
1931	4.37	3.79	4.43	2.88	2.35	2.76	8.88	7.52	2.75	6.62	3.31	8.02	57.68	4.81	12.21
1932	5.40	2.64	3.16	5.57	11.26	2.89	5.33	10.65	6.71	8.50	3.21	4.90	70.22	5.85	14.18
1933	4.27	6.27	7.21	6.41	2.45	1.65	6.40	4.18	2.36	2.10	3.74	2.88	49.92	4.16	10.57
1934	6.84	2.91	4.60	2.83	7.98	6.36	4.72	10.77	2.90	4.91	6.00	2.56	63.38	5.28	13.41
1935	1.70	4.97	5.28	6.77	2.68	4.63	7.95	6.66	4.65	.80	1.57	5.92	53.58	4.46	11.33
1936	7.04	5.07	2.71	4.08	5.83	.95	5.98	7.49	4.02	1.75	2.91	3.70	51.53	4.29	10.90
1937	3.96	3.29	6.00	3.78	2.93	6.56	4.53	7.50	5.55	13.89	2.00	3.70	63.69	5.31	13.49
1938	4.82	2.40	1.33	3.79	4.14	5.03	8.21	4.89	4.31	2.13	3.22	3.82	48.09	4.01	10.19
1939	2.09	4.36	.96	2.72	9.46	5.05	7.43	6.79	6.93	.98	6.86	2.74	56.37	4.70	11.94
1940	3.55	8.54	3.53	8.80	1.40	8.50	9.43	10.08	5.81	.47	3.01	8.33	71.45	5.95	15.11
1941	3.56	3.84	4.57	2.10	3.73	8.12	8.10	4.53	7.07	4.63	2.57	4.60	57.42	4.78	12.14
1942	1.87	9.71	6.66	1.93	5.50	11.51	7.74	8.78	7.12	6.25	1.46	4.75	73.28	6.11	15.52
1943	2.72	1.78	7.43	1.71	3.98	5.45	6.85	4.48	14.82	.93	2.81	4.20	57.16	4.76	12.10
1944	9.22	4.42	4.60	8.14	4.71	3.22	5.64	7.11	6.21	1.00	10.64	2.54	67.45	5.62	14.27
1945	4.73	4.91	2.40	3.50	3.26	3.53	11.37	8.31	7.00	3.27	1.81	7.12	61.21	5.10	12.10
1946	5.40	3.50	12.24	2.86	10.79	9.86	7.89	4.26	11.55	.56	4.47	3.41	76.79	6.40	16.26
1947	8.37	3.38	7.35	7.52	4.75	4.47	2.88	5.86	4.51	2.11	12.43	7.96	71.59	5.97	15.17
1948	4.95	1.54	13.96	2.30	3.45	2.73	7.19	6.15	14.59	1.21	12.49	4.89	75.45	6.29	15.98
1949	2.17	3.49	9.11	8.93	1.35	5.44	8.47	6.67	8.73	4.29	.39	5.52	64.56	5.38	13.67
1950	2.39	3.15	6.25	6.94	2.74	5.86	8.36	2.95	2.72	2.26	1.00	6.79	51.41	4.26	10.82
1951	3.60	2.20	6.85	6.30	2.70	2.79	6.66	3.65	7.39	1.38	3.43	3.17	50.12	4.18	10.62
1952	2.58	8.98	2.96	5.72	5.42	1.75	7.31	5.96	4.37	.10	2.41	4.98	52.54	4.38	11.13
1953	2.23	6.26	3.78	6.32	1.82	8.03	9.03	7.77	2.07	.53	8.63	11.11	67.58	5.63	14.30
1954	4.36	1.16	1.76	2.14	4.14	3.82	11.24	2.92	7.26	4.22	2.50	5.59	51.11	4.26	10.82
1955	5.35	3.56	.25	4.34	4.08	3.29	9.69	9.60	5.82	2.19	4.08	3.26	55.51	4.63	11.76
1956	3.67	7.17	3.06	3.61	4.32	9.06	7.02	4.80	11.33	2.65	1.50	5.59	63.78	5.31	13.49
1957	1.31	3.34	7.78	7.29	2.96	7.79	5.21	6.58	11.55	2.62	5.83	2.63	64.89	5.41	13.74
1958	7.49	4.64	7.02	2.81	7.65	5.24	9.00	7.73	8.69	2.39	1.44	1.57	65.67	5.47	13.89
1959	3.40	8.80	3.63	4.22	9.17	9.59	11.71	6.52	4.49	9.14	1.44	2.06	74.17	6.18	15.70
1960	4.29	5.20	3.19	5.28	3.77	1.77	5.26	8.77	5.66	5.19	.32	4.29	52.99	4.42	11.23
1961	6.32	7.14	7.35	3.49	4.76	9.49	7.08	8.08	7.32	1.72	7.11	6.42	77.28	6.44	16.36
1962	4.30	1.14	2.07	2.24	.67	6.87	3.99	5.00	4.23	3.03	2.84	3.24	39.62	3.30	8.38
1963	4.17	5.12	.91	.88	2.12	7.59	6.34	3.38	7.08	.04	8.72	5.24	51.59	4.30	11.92
1964	7.73	7.25	5.71	5.06	3.18	4.03	9.96	5.56	3.78	5.78	3.51	2.19	63.74	5.31	13.49
1965	4.97	6.01	3.69	1.01	2.96	4.06	6.58	7.47	9.64	1.18	1.79	7.19	56.55	4.71	11.96
1966	11.22	11.07	1.96	5.97	4.05	7.59	9.14	6.93	6.67	3.28	1.57	6.59	76.04	6.34	16.10
1967	4.31	5.56	2.23	1.77	3.86	4.56	6.71	9.36	5.93	6.06	.28	10.13	60.76	5.06	12.85
1968	1.70	3.24	2.67	3.41	4.73	3.57	5.30	5.02	2.96	1.67	4.26	6.42	44.95	3.75	9.53
1969	3.63	4.13	6.74	6.86	6.99	1.47	8.25	6.22	2.75	1.08	1.02	5.28	53.62	4.47	11.35
1970	3.38	2.22	7.49	.81	5.78	4.06	6.27	8.26	6.66	6.23	1.05	3.02	55.23	4.60	11.68
Monthly Average:	5.89	4.70	4.90	4.31	4.50	5.27	7.37	6.63	6.40	3.23	3.74	4.96			
Monthly Average (cm):	14.96	11.84	12.45	10.95	11.43	13.39	18.72	16.84	16.26	8.20	9.50	12.59			

	Winter (DJF)	Spring (MAM)	Summer (JJA)	Fall (SON)	Annual
Seasonal Average:	5.18	4.57	6.42	4.46	5.16
" " (cm):	13.16	11.61	16.31	11.33	13.10

Table 9. Percent frequency of specific relative humidity at selected hours for midseasonal months (U.S. Weather Bureau, National Climatic Summary, 1971).

(New Orleans records: 1949-1954)

		< 30	< 40	< 50	≥ 50	≥ 70	≥ 90
Jan	6 am	0	1	2	98	93	61
	3 pm	3	15	23	77	37	7
Apr	5 am	0	1	2	98	83	53
	3 pm	8	26	43	57	19	7
Jul	4 am	0	0	0	100	98	77
	3 pm	1	2	17	83	41	6
Oct	5 am	0	0	3	97	90	52
	3 pm	11	33	47	53	13	4

Table 10. Percent frequency of fog occurrence at specific locations in Louisiana. A. Monthly occurrence at Lake Charles and intensity for Grand Isle, Block 46, offshore Louisiana (Glenn, 1972).

MONTHLY OCCURRENCE OF FOG - 1964

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Lake Charles	8	2	5	4	3			1	3	5		11	42
New Orleans	10	2	3	1	1				1	1		8	27

Note: Numbers cited are number of days that heavy fog occurred at each station for the month noted.

Month	Less Than 3 Miles	Less Than 1 Mile	Less Than 1/2 Mile	Less Than 1/4 Mile	Less Than 1/8 Mile
Jan	7.9	3.3	2.2	1.6	1.4
Feb	9.0	3.9	2.7	2.0	1.7
Mar	9.6	4.2	2.9	2.2	1.9
Apr	8.0	3.4	2.3	1.7	1.5
May	2.9	1.2	0.8	0.6	0.4
Jun	1.0	0.5	0.3	0.2	0.1
Jul	0.7	0.2	0.1	0.1	0.0
Aug	0.8	0.2	0.1	0.1	0.0
Sep	1.0	0.5	0.3	0.2	0.1
Oct.	2.0	1.0	0.6	0.4	0.2
Nov	3.3	1.5	1.0	0.7	0.5
Dec	5.7	2.3	1.6	1.2	1.0
Annual	4.3	1.9	1.2	0.9	0.7

[1] Visibility reductions are caused primarily by fog.

Table 11. Cyclone data for selected Louisiana areas (extracted from Simpson and Lawrence, 1971). See Figure 22 for location of area designation numbers.

	Coastal Section		
	Terrebonne	Barataria	M. Delta
	10	11	12
Earliest tropical cyclone occurrence*	June	July	August
Latest tropical cyclone occurrence	October	November	October
Probability (%) of occurence in any one year:			
Tropical cyclones	18%	21%	15%
Hurricanes	9%	13%	9%
Great hurricanes	---	2%	4%

Cyclone Probability percentage (data extracted and derived from Simpson & Lawrence, 1971)

	Trop. Cyclone	Hurricanes	Great Hurricanes	Cyclone
Texas (5-6)	19	13	4	6
Louisiana (11-12)	18	11	3	7
Delaware (46-47)	2.5	1.5	0	1
New Jersey (50-51)	8.5	6	0.5	2.5
Maine (58)	13	5	0	8

*All tropical cyclones means winds 40 mph or higher
All hurricanes means winds 74 mph or higher
All great hurricanes means winds 125 mph or higher

Table 12A. Data on occurrence of tropical storms and hurricanes within 180 nautical miles of Louisiana coast (Glenn, 1972).

Period of Hurricane Season	Tropical Storms: Average Number Per Year	Tropical Storms: Average Interval Between Storms, Years	Tropical Storms: Occurrence Probability On Any Day In Period	Hurricanes: Average Number Per Year	Hurricanes: Average Interval Between Hurricanes, Years	Hurricanes: Occurrence Probability On Any Day In Period
May 29 - June 10 (13 Days) (Inactive Early Season)	0.03	33.3	0.23%	0.02	50.0	0.15%
June 11 - July 5 (25 Days) (Active Early Season)	0.13	7.7	0.52%	0.14	7.1	0.56%
June 6 - August 10 (36 Days) (Inactive Mid-Season)	0.14	7.1	0.39%	0.12	8.3	0.33%
Aug. 11 - Oct. 20 (71 Days) (Active Mid-Season)	0.43	2.3	0.61%	0.70	1.4	0.99%
Oct. 21 - Nov. 7 (18 Days) (Inactive Late Season)	0.03	33.3	0.17%	0.20	50.0	0.11%
Entire Season (163 Days)	0.76	1.31	0.47%	1.00	1.00	0.61%

Maximum Number of Hurricanes and Tropical Storms in Any Year: 6, 1886

Minimum number of Hurricanes and Tropical Storms in Any Year: 0, (Occurred in several years).

Table 12B. Occurrence of hurricane and tropical storm centers within 180 nautical miles of the Louisiana coast, 1871-1971 (Glenn, 1972).

Year	Date	Tropical Cyclone* Intensity	Year	Date	Tropical Cyclone* Intensity	Year	Date	Tropical Cyclone* Intensity	Year	Date	Tropical Cyclone* Intensity	Year	Date	Tropical Cyclone* Intensity
1871	Jun 3	H	1891	Jul 5	H	1911	Aug 11	H	1935	Nov 7	T	1953	Jun 6	T
1871	Jun 9	H	1892	Sep 11	T	1912	Jun 12	T	1936	Jul 27	T	1953	Sep 18	T
1871	Sep 5	H	1893	Jun 14	H	1912	Sep 12	H	1936	Jul 31	H	1953	Sep 25	H
1871	Oct 3	H	1893	Sep 6	H	1914	Sep 18	T	1936	Aug 8	T	1954	Jul 27	T
1872	Jul 10	H	1893	Oct 1	H	1915	Aug 16	H	1937	Sep 18	T	1955	Aug 1	T
1873	Sep 10	H	1894	Aug 5	T	1915	Sep 29	H	1937	Oct 3	T	1955	Aug 26	T
1874	Jul 2	H	1894	Oct 7	H	1916	Jul 5	H	1938	Aug 14	H	1956	Jun 13	T
1875	Sep 15	H	1895	Aug 14	T	1916	Oct 18	H	1938	Oct 16	T	1956	Sep 24	H
1875	Sep 25	H	1895	Oct 6	T	1917	Sep 27	H	1938	Oct 23	T	1957	Jun 8	T
1877	Sep 17	H	1896	Jul 6	H	1918	Aug 6	H	1939	Jun 14	T	1957	Jun 27	H
1877	Oct 2	H	1897	Sep 12	H	1919	Jul 3	T	1939	Aug 13	H	1957	Aug 9	T
1877	Oct 25	H	1898	Sep 19	T	1919	Sep 12	H	1939	Sep 26	T	1957	Sep 7	T
1878	Oct 10	H	1898	Sep 27	T	1920	Sep 21	H	1940	Aug 6	H	1957	Sep 18	T
1879	Aug 22	H	1900	Sep 8	H	1920	Sep 29	H	1940	Sep 23	T	1958	Sep 5	T
1879	Sep 1	H	1900	Sep 12	T	1921	Jun 22	H	1941	Sep 11	T	1959	May 29	T
1879	Oct 6	H	1900	Oct 11	T	1922	Oct 16	T	1941	Sep 23	H	1959	Jul 24	H
1879	Oct 15	H	1901	Jun 13	T	1923	Oct 15	H	1942	Aug 19	H	1959	Oct 8	T
1880	Jun 22	H	1901	Jul 10	T	1923	Oct 17	T	1942	Aug 29	H	1960	Sep 14	H
1881	Aug 2	H	1901	Aug 13	H	1924	Sep 14	H	1943	Jul 26	H	1960	Sep 25	T
1881	Aug 12	H	1901	Sep 16	T	1924	Oct 12	T	1943	Sep 18	H	1961	Sep 10	H
1882	Sep 9	H	1902	Jun 26	H	1926	Aug 24	H	1944	Sep 10	T	1963	Sep 17	H
1885	Aug 29	H	1902	Oct 6	H	1926	Sep 20	H	1945	Jul 20	T	1964	Aug 7	T
1885	Sep 20	H	1903	Sep 13	H	1929	Jun 28	H	1945	Aug 27	H	1964	Oct 2	H
1885	Sep 25	H	1904	Nov 1	T	1931	Jul 15	T	1945	Sep 5	T	1965	Jun 14	T
1886	Jun 14	T	1905	Sep 27	T	1932	Aug 13	H	1946	Jun 14	T	1965	Sep 9	H
1886	Jun 20	H	1905	Oct 8	T	1932	Aug 31	H	1947	Aug 22	H	1965	Sep 28	T
1886	Jun [illegible]	H	1906	Jun 12	T	1932	Sep 13	T	1947	Sep 8	T	1969	Aug 17	H
1886	Jul 16	H	1906	Sep 26	H	1932	Sep 19	T	1947	Sep 19	H	1969	Oct 5	T
1886	Aug 19	H	1907	Sep 27	T	1932	Oct 15	T	1948	Jul 8	T	1969	Oct 21	H
1886	Oct 11	H	1907	Sep 20	T	1933	Jul 5	H	1948	Sep 3	H	1970	Jul 21	T
1887	Jul 26	H	1907	Sep 28	T	1933	Jul 22	T	1949	Sep 4	T	1970	Sep 15	T
1887	Oct 18	H	1908	Sep 17	T	1933	Aug 2	T	1949	Sep 21	T	1971	Sep 9	H
1888	Jun 16	H	1909	Jun 27	T	1934	Jun 16	H	1949	Oct 3	H	1971	Sep 16	H
1888	Jul 5	T	1909	Jun 30	T	1934	Jul 25	H	1950	Aug 30	H			
1888	Aug 19	H	1909	Jul 20	H	1934	Aug 27	H	1950	Oct 2	T			
1889	Sep 22	H	1909	Sep 20	H	1934	Oct 5	T	1950	Oct 18	H			

* H(Hurricane)
T(Tropical Storm)

Table 13. Average percentage frequency of occurrence of wind speed - direction groups: Grand Isle, Block 46: Offshore Louisiana: July (Glenn, 1972).

	Wind Speed Groups (mph)									
Direction	0-4	5-9	10-14	15-19	20-24	25-29	30-34	35-40	40 Plus	Total
N	0.3	0.8	0.7	0.2	0.0	0.0	0.0	0.0	0.0	2.0
NE	0.5	1.0	1.0	0.4	0.1	0.0	0.0	0.0	0.0	3.0
E	1.1	2.3	2.4	0.9	0.3	0.1	0.1	0.0	0.0	7.2
SE	2.6	6.0	6.3	2.2	0.4	0.3	0.2	0.1	0.0	18.1
S	3.2	7.5	7.8	2.8	0.5	0.3	0.2	0.1	0.0	22.4
SW	4.3	9.9	8.2	3.2	0.5	0.1	0.0	0.0	0.0	26.2
W	2.3	5.8	5.0	1.9	0.3	0.1	0.0	0.0	0.0	15.4
NW	0.8	2.0	1.9	0.7	0.2	0.1	0.0	0.0	0.0	5.7
Total	15.1	35.3	33.3	12.3	2.3	1.0	0.5	0.2	0.0	100.0

Table 14A. Average percentage frequency of occurrence of wind speed - direction groups: Grand Isle, Block 46: Offshore Louisiana: September (Glenn, 1972).

	Wind Speed Groups (mph)									
Direction	0-4	5-9	10-14	15-19	20-24	25-29	30-34	35-40	40 Plus	Total
N	0.4	1.3	1.7	1.3	0.8	0.3	0.2	0.1	0.2	6.3
NE	1.5	3.8	5.7	4.8	2.5	0.9	0.8	0.3	0.7	21.0
E	1.6	4.6	7.6	6.3	3.3	1.3	1.0	0.4	0.7	26.8
SE	1.6	4.1	6.5	5.4	2.8	1.1	0.8	0.4	0.8	23.5
S	0.8	2.1	2.9	2.3	1.3	0.5	0.3	0.1	0.3	10.6
SW	0.6	1.2	1.0	0.7	0.5	0.2	0.1	0.1	0.1	4.5
W	0.5	1.4	1.2	0.6	0.3	0.1	0.0	0.0	0.0	4.1
NW	0.3	0.7	0.9	0.8	0.4	0.1	0.0	0.0	0.0	3.2
Total	7.3	19.2	27.5	22.2	11.9	4.5	3.2	1.4	2.8	100.0

Table 14B. Average percentage frequency of occurrence of wind speed - direction groups: Grand Isle, Block 46: Offshore Louisiana: October (Glenn, 1972).

	Wind Speed Groups (mph)									
Direction	0-4	5-9	10-14	15-19	20-24	25-29	30-34	35-40	40 Plus	Total
N	0.4	1.3	2.6	2.8	2.0	1.3	0.8	0.3	0.5	12.0
NE	1.1	4.5	7.9	7.5	4.6	1.8	1.2	0.3	0.6	29.5
E	0.8	3.5	6.6	6.0	3.8	1.5	1.1	0.3	0.6	24.2
SE	0.8	2.3	4.4	4.1	2.4	1.0	0.6	0.2	0.4	16.2
S	0.5	1.7	2.6	1.8	0.8	0.3	0.1	0.0	0.0	7.8
SW	0.5	0.8	0.6	0.4	0.2	0.1	0.0	0.0	0.0	2.6
W	0.5	0.8	0.6	0.4	0.2	0.1	0.0	0.0	0.0	2.6
NW	0.3	0.8	1.3	1.4	0.7	0.3	0.2	0.1	0.0	5.1
Total	4.9	15.7	26.6	24.4	14.7	6.4	4.0	1.2	2.1	100.0

Table 15. Average percentage frequency of occurrence of wind speed - direction groups: Grand Isle, Block 46: Offshore Louisiana: December (Glenn, 1972).

	Wind Speed Groups (mph)									
Direction	0-4	5-9	10-14	15-19	20-24	25-29	30-34	35-40	40 Plus	Total
N	0.3	1.0	2.3	3.1	2.7	2.3	1.8	1.2	1.9	16.6
NE	0.4	2.1	4.6	6.7	5.1	2.1	1.6	0.8	1.3	24.7
E	0.4	1.6	3.5	4.7	2.8	1.0	0.7	0.3	0.5	15.5
SE	0.4	1.7	3.4	4.6	2.8	1.0	0.7	0.2	0.4	15.2
S	0.4	1.1	2.6	3.1	2.2	0.7	0.3	0.1	0.2	10.7
SW	0.3	1.2	1.6	1.3	0.8	0.1	0.0	0.0	0.0	5.3
W	0.3	0.5	0.7	0.7	0.5	0.3	0.2	0.1	0.1	3.4
NW	0.3	0.6	1.3	1.8	1.4	1.2	0.8	0.5	0.7	8.6
Total	2.8	9.9	19.9	26.0	18.3	8.7	6.1	3.2	5.1	100.0

Table 16. Average percentage frequency of occurrence of wind speed - direction groups: Grand Isle, Block 46: Offshore Louisiana: April (Glenn, 1972).

Direction	Wind Speed Groups (mph) 0-4	5-9	10-14	15-19	20-24	25-29	30-34	35-40	40 Plus	Total
N	0.3	0.7	1.3	1.2	1.1	0.8	0.4	0.3	0.4	6.5
NE	0.6	1.5	2.9	2.7	2.2	0.9	0.4	0.3	0.3	11.8
E	0.7	2.1	3.6	3.1	2.2	0.6	0.3	0.1	0.1	12.8
SE	2.1	5.6	9.7	9.5	4.0	0.9	0.4	0.2	0.2	32.6
S	1.3	4.7	6.5	4.8	2.5	0.7	0.3	0.1	0.1	21.0
SW	0.6	1.7	1.5	1.3	0.6	0.1	0.0	0.0	0.0	5.8
W	0.5	1.1	1.1	0.8	0.4	0.2	0.1	0.0	0.0	4.2
NW	0.2	0.7	1.2	1.2	0.8	0.5	0.3	0.2	0.2	5.3
Total	6.3	18.1	27.8	24.6	13.8	4.7	2.2	1.2	1.3	100.0

Table 17. Current and wind vectors for area near and around Burrwood, Louisiana, which is located on Mississippi River delta (extracted from Scruton, 1956).

Burrwood - Resultant Currents and Winds

	J	F	M	A	M	J	J	A	S	O	N	D	All
Resultant Currents													
Direction (°)	360°	329°	340°	328°	339°	360°	21°	357°	307°	305°	302°	325°	348°
Speed (nt.mi/da)	2	2	3	9+	6	4	5	2	2	3	2	5	5
Speed (knots)	.08	.08	.125	.375	.25	.17	.21	.08	.08	.125	.08	.21	.21
Speed, ft/sec	.135	.135	.21	.63	.42	.29	.35	.135	.135	.21	.135	.35	.35
Speed, cm/sec	4.12	4.12	6.43	19.29	12.86	8.75	10.80	4.12	4.12	6.43	4.12	10.80	10.80
Resultant Winds													
Direction (°)	206°	228°	261°	283°	322°	352°	24°	322°	254°	221°	226°	204°	254°
Speed (nt.mi/da)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Speed (knots)	3 1/2	1 3/4	4	3 1/3	4 1/2	3	2 1/2	1 3/4	5 1/3	4 3/4	5 1/2	3 3/4	2 1/4
Speed, ft/sec	5.9	2.95	6.75	5.62	7.59	5.06	4.22	2.95	8.99	8.02	9.28	6.33	3.80
Speed, cm/sec	180	90	206	171	231	154	129	90	274	244	283	193	116

Table 18. Current and wind vectors for area near and around Grand Isle, Louisiana (extracted from Scruton, 1956).

Table 18. Current and Wind Vectors for Area Near and About Grand Isle, Louisiana (Scruton, 1956).

Grand Isle - Resultant Currents and Winds

29° 13' N - 90° W

Resultant Currents	J	F	M	A	M	J	J	A	S	O	N	D	All
Direction (°)	275°	320°	300°	312°	313°	330°	1°	344°	318°	314°	312°	313°	318°
Speed (nt.mi/da)	5	7	8	8	9	5	2	3	6	10	7	6+	7
Speed (knots)	.21	.29	.33	.33	.375	.21	.08	.125	.25	.42	.29	.25	.29
Speed, ft/sec	.35	.49	.56	.56	.63	.35	.135	.21	.42	.71	.49	.42	.49
Speed, cm/sec	10.80	14.92	16.98	16.98	19.29	10.80	4.12	6.43	12.86	21.60	14.92	12.86	14.92

Resultant Winds	J	F	M	A	M	J	J	A	S	O	N	D	All
Direction (°)	202°	241°	287°	301°	326°	355°	10°	320°	270°	236°	254°	203°	280°
Speed (nt.mi/da)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Speed (knots)	3 1/3	1 3/4	2 1/4	4 3/4	3 3/4	3 1/4	1 1/3	2 1/4	3	3 1/2	1 1/4	3	2
Speed, ft/sec	5.62	2.95	3.80	8.02	6.33	5.49	2.24	3.80	5.06	5.9	2.11	5.06	3.38
Speed, cm/sec	171	90	116	244	193	167	68	116	154	180	64	154	103

Table 19. **Average annual total surface ocean current[2] speed - direction groups: Grand Isle, Block 46: Offshore Louisiana: 110 foot mean low water depth (Glenn, 1972).**

	Current Speed - Feet/Second								
Direction[1]	0.0-0.4	0.5-0.9	1.0-1.4	1.5-1.9	2.0-2.4	2.5-2.9	3.0-3.4	3.5 Plus	Total
N	1.1	2.4	2.4	1.7	0.9	0.5	0.3	0.0	9.3
NE	0.6	1.2	1.2	0.9	0.5	0.3	0.1	0.0	4.8
E	1.8	3.7	3.8	2.7	1.3	0.8	0.4	0.1	14.6
SE	1.3	2.7	2.7	1.9	0.9	0.6	0.3	0.1	10.5
S	0.6	1.3	1.4	1.0	0.5	0.3	0.1	0.0	5.2
SW	1.3	2.6	2.7	1.9	0.9	0.5	0.3	0.1	10.3
W	3.0	6.4	6.4	4.6	2.3	1.4	0.7	0.1	24.9
NW	2.5	5.3	5.3	3.7	1.9	1.1	0.5	0.1	20.4
Total	12.2	25.6	25.9	18.4	9.2	5.5	2.7	0.5	100.0

NOTES [1] Direction toward which current flows.

[2] Total surface ocean current is the vector sum of the tidal, wind drift, and density currents.

Table 20. Mississippi River discharge in cfs x 1000 at Darberta Landing, Louisiana. Extracted from stages and discharges, Mississippi River and its outlets and tributaries (from data of U.S. Army Corps of Engineers).

	J	F	M	A	M	J	J	A	S	O	N	D
1950	1402.2	1805.2	1475.7	1070.5	979.0	798.5	613.0	596.6	540.0	420.0	380.3	721.8
1951	771.4	1027.3	1294.0	1220.0	1020.7	674.7	1022.6	626.4	493.3	344.4	437.5	871.4
1952	995.8	1173.8	1018.7	1285.8	987.0	574.7	389.4	285.2	234.4	158.3	148.5	277.8
1953	366.7	556.8	837.5	763.8	940.4	599.1	376.6	297.5	194.0	143.6	142.0	174.8
1954	339.3	447.0	372.6	385.0	659.4	409.3	303.2	205.8	214.3	235.0	285.0	221.0
1955	543.7	495.3	1023.4	1162.6	567.6	433.4	362.0	256.8	182.0	247.0	221.3	236.8
1956	156.3	823.5	1038.7	770.5	568.0	428.3	344.8	318.7	221.8	155.2	164.0	254.8
1957	405.6	1115.8	647.0	852.0	946.1	1149.5	774.5	436.5	254.3	279.0	526.3	842.4
1958	768.4	652.3	668.3	829.3	1149.8	602.2	690.4	982.2	410.2	322.6	240.2	381.5
1959	298.2	856.2	837.0	715.3	560.7	476.7	323.6	315.3	249.8	459.4	369.8	484.4
1960	721.8	740.0	698.0	980.8	802.6	620.5	622.8	316.0	272.0	219.6	253.4	276.8
1961	334.0	353.0	1159.2	1296.0	1174.2	1056.3	405.8	433.0	335.5	404.7	474.8	713.7
1962	805.3	961.4	1223.0	1486.8	890.3	482.0	341.4	254.2	277.0	304.4	300.4	279.6
1963	332.1	275.0	598.0	774.0	344.6	306.6	215.1	190.6	152.8	128.0	133.9	162.5
1964	182.0		613.0	839.0	804.0	337.0	299.0	170.0	169.0	195.0	171.0	362.0
1965	460.8	478.7	569.2	855.2	638.4	383.7	310.9	216.6	267.4	374.9	212.1	220.1
1966	389.7	628.3	657.6	365.4	754.0	380.6	202.2	182.1	172.7	167.6	187.8	291.3
1967	293.0	280.0	468.4	503.6	613.2	497.3	520.6	282.5	199.0	215.7	292.7	476.7
1968	620.2	572.0	360.0	781.9	542.2	714.9	297.7	271.7	181.0	198.8	237.8	372.2
1969	414.8	954.1	499.2	703.5	714.6	385.7	506.2	290.3	222.4	281.8	245.8	277.0
1970	511.8	416.7	529.3	651.0	875.9	533.6	260.7	233.0	216.3	345.6	375.7	360.2
21 Year Average	529.19	707.97	789.89	871.20	787.27	563.93	437.26	340.96	267.3	266.7	638.57	8058.8
Seasonal Average	Winter (DJF) 513.6			Spring (MAM) 816.1			Summer (JJA) 447.4			Fall (SON) 312.5		

Table 21. Results of analysis of variance for mixing and stratification seaward of the mouth of South Pass of the Mississippi River delta (Wright, 1970).

	Source of Variation	d.f.	F-Ratios $(\bar{C})$	Density Ratio	Depth of Interface	$\Delta\sigma_t/\Delta z$
Primary Factors	River Stage	1	41.208**	7.344**	7.794**	5.222*
	Tide (Flood or Ebb)	1	0.138 NS	14.671**	0.031 NS	3.253 NS
	Seas (Rough or Calm)	1	5.509*	0.940 NS	1.204 NS	6.482*
	Line Number	3	0.387 NS	5.422**	1.449 NS	0.694 NS
	Shoreward or Seaward of Bar Crest (Bar Pos.)	1	0.122 NS	14.561**	3.433 NS	8.140*
2-Factor Interactions	River Stage - Tide	1	3.726 NS	31.547**	5.399*	6.743*
	River Stage - Sea State	1	0.011 NS	5.039*	1.232 NS	3.606 NS
	River Stage - Line Number	3	0.979 NS	0.872 NS	1.405 NS	0.162 NS
	River Stage - Bar Position	1	0.939 NS	21.568**	5.367*	0.202 NS
	Tide - Sea State	1	0.668 NS	0.959 NS	0.859 NS	0.611 NS
	Tide - Line Number	3	0.066 NS	0.716 NS	0.888 NS	2.787*
	Tide - Bar Position	1	0.983 NS	3.459 NS	0.008 NS	0.050 NS
	Sea State - Line Number	3	1.982 NS	5.139*	1.533 NS	3.830*
	Sea State - Bar Position	1	0.675 NS	1.383 NS	3.014 NS	3.580 NS
	Line Number - Bar Position	3	0.317 NS	0.217 NS	0.139 NS	0.561 NS
	# Distance Seaward of Mouth (Linear)	1	25.714**	2.859 NS	7.963**	0.398 NS
	Error	111				
	Total (Uncorrected)	138				

** Significant at .01 level

* Significant at .05 level

NS Not significant

\# Continuous variable

Table 22. Flow rates and average residence times per hydrologic unit of Barataria Bay, Louisiana, as shown in Figure 31 (Pike and Hacker, 1972, unpublished data).

Hydrologic Unit	Area (mi^2)	Annual Average Flow of Fresh Water through the Hydrologic Unit (ft^3/day)	Average Residence Time in the Hydrologic Unit (years)
I	92	0.4×10^6	53
II	120	0.6×10^6	48
III	219	1.0×10^6	50
Total	431	2.0×10^6	

Table 23. Median water temperature in °C at station 3017:PM, Barataria Bay, Louisiana (extracted from unpublished data, courtesy of B. Barrett of Louisiana Wild Life and Fisheries Commission, 1972).

	1962	1963	1964	1965	1966	1967	1968	1969	Average
Jan	12.1	11.1	12.3	16.3	11.9	13.6	12.3	12.8	12.8
Feb	16.1	10.5	13.6	14.3	13.2	14.0	10.6	14.0	13.3
Mar	15.6	18.5	17.1	16.1	16.6	17.4	15.4	14.0	16.4
Apr	21.3	23.5	20.8	24.1	20.2	25.1	22.4	21.8	22.4
May	26.4	25.1	24.9	24.8	25.3	25.9	25.9	24.6	25.4
Jun	27.1	25.5	29.1	27.4	27.6	29.6	29.1	29.0	28.0
Jul	28.7	27.1	28.1	27.5	29.2	28.5	29.4	29.9	28.5
Aug	28.5	28.3	27.9	27.6	28.9	28.5	30.5	29.4	28.7
Sep	27.2	26.1	27.5	26.6	27.6	26.6	27.9	27.9	27.2
Oct	24.6	22.2	20.7	22.4	22.5	21.1	25.2	22.7	22.7
Nov	15.1	15.8	20.8	20.5	20.3	17.9	16.7	17.8	18.1
Dec	11.9	8.2	16.8	14.0	14.5	16.4	13.5	16.4	14.0

Winter (DJF) - 13.4
Spring (MAM) - 21.4
Summer (JJA) - 28.4
Fall (SON) - 22.7

Table 24. Surface water temperature (°C) and salinities (°/₀₀) 8 miles southeast of Grand Isle, Louisiana on drilling platform, and Eugene Island, Louisiana (C&GS publ. 31-1, 2nd edition, 1965 and 3rd edition, 1968).

Years	January		February		March		April		May		June		July		August		September		October		November		December		Means		Maximum		Minimum	
	Temp. °C	Dens. σ_{15}	Temp. °C	Dens. σ_{15}	Temp. °C	Dens. σ_{15}	Temp. °C	Dens. σ_{15}	Temp. °C	Dens. σ_{15}	Temp. °C	Dens. σ_{15}	Temp. °C	Dens. σ_{15}	Temp. °C	Dens. σ_{15}	Temp. °C	Dens. σ_{15}	Temp. °C	Dens. σ_{15}	Temp. °C	Dens. σ_{15}	Temp. °C	Dens. σ_{15}	Temp. °C	Dens. σ_{15}	Temp. °C	Dens. σ_{15}	Temp. °C	Dens. σ_{15}
GRAND ISLE (Drilling platform 8 miles SE. of), LA.																														
1949	--	--	--	--	--	--	--	--	25.7	17.0	28.3	17.8	28.9	18.5	29.0	20.4	28.1	20.3	26.6	20.8	21.9	23.2	19.7	23.8	--	--	30	25.5*	17*	12.1*
1950-1954	16.3	20.7	16.9	19.1	18.1	19.1	20.7	19.1	24.7	17.2	28.8	19.3	29.3	21.1	29.6	21.1	27.9	20.9	24.4	22.6	20.7	24.9	17.3	24.0	22.9	20.8	32	28.9	11	-1.6
1955-1959	16.6	21.0	16.6	20.7	13.0	21.1	20.8	18.3	25.4	17.1	27.9	18.0	28.9	19.8	29.3	20.9	28.2	20.9	25.3	22.5	21.3	24.1	18.2	23.5	23.0	20.9	32	27.0	11	3.7
1960	15.3	20.7	14.2	22.6	15.2	20.5	21.0	17.9	23.9	18.0	28.2	18.2	30.6	20.0	29.1	19.5	28.1	20.4	25.6	21.5	21.7	23.2	18.1	24.9	22.6	20.6	33	25.7	11	10.7
1961	15.3	24.0	16.6	23.6	19.2	17.6	20.3	18.8	24.3	13.1	28.3	9.6	30.1	14.0	29.3	17.1	28.0	20.0	24.4	21.0	20.4	22.6	19.3	20.6	23.0	18.5	32	25.7	11	2.3
1962	14.8	21.6	16.5	16.4	17.6	18.3	19.9	15.0	26.0	12.4	28.7	15.3	30.4	20.7	30.8	21.1	29.6	21.6	26.2	22.1	20.7	24.2	18.1	24.4	23.3	19.4	32	26.0	12	3.5
1963	15.4	24.3	14.9	24.5	17.5	20.3	23.1	17.1	26.7	22.0	28.4	21.5	29.7	23.2	30.5	23.7	29.8	22.9	25.6	24.7	21.7	25.3	16.9	25.4	23.4	23.0	32	27.6	12	11.2
1964	14.6	25.7	15.9	25.1	17.3	21.7	20.3	14.5	25.3	12.6	28.6	13.7	28.9	20.5	29.6	21.5	28.9	22.8	22.9	25.0	21.9	23.7	18.2	23.8	22.7	20.9	31	27.2	11	5.5
1965	17.3	22.0	16.4	23.0	16.8	19.9	20.1	13.0	25.2	15.4	28.2	17.1	28.7	20.7	28.7	21.5	--	--	24.3	22.0	22.4	22.6	19.6	24.8	--	--	30*	26.2*	14	11.7*
1966	16.4	23.4	15.0	22.0	--	--	--	--	25.7	17.3	27.5	18.3	29.6	20.9	29.4	21.8	28.7	22.4	25.1	24.2	21.6	24.2	18.4	24.4	--	--	31	25.9*	12*	13.7*
Mean	16.2	22.7	16.3	20.9	17.7	20.0	20.8	17.6	25.2	16.5	28.2	17.5	29.3	20.1	29.5	20.9	28.4	21.2	25.0	22.6	21.2	24.1	18.1	23.8	23.0	20.7				
Maximum	22	23.2	24	27.0	23	27.0	26	26.0	30	25.6	32	28.4	33	27.6	32	28.9	31	25.9	30	27.2	26	27.3	23	27.1			33	28.9		
Mean Max.	15.4	25.4	18.8	26.7	20.6	24.4	24.0	22.6	28.1	22.5	30.2	22.2	30.9	23.8	30.9	23.9	30.0	23.6	27.8	24.7	23.9	25.7	20.7	25.9						
Mean Min.	13.4	13.7	13.9	13.3	15.3	13.6	17.9	12.2	22.7	10.9	25.9	13.0	27.8	15.0	27.9	17.5	26.4	18.2	21.9	19.9	17.9	21.1	15.0	19.0						
Minimum	11	3.1	11	-1.6	11	1.2	16	9.9	20	2.5	23	3.3	26	2.1	26	8.9	24	14.2	18	13.5	14	15.6	11	12.1					11	-1.6
EUGENE ISLAND, LA.																														
1944	--	--	--	--	--	--	20.0	4.0	22.8	0.1	28.9	-0.2	29.9	1.0	29.9	5.5	28.8	7.9	22.9	6.2	18.8	7.3	11.9	3.4	--	--	32	22.1*	7*	-0.5*
1945-1949	10.9	1.3	11.6	0.5	15.9	0.7	20.9	0.6	24.7	0.4	28.0	0.8	28.9	0.6	29.3	2.4	27.6	6.0	23.9	5.8	18.5	5.0	13.6	3.2	21.2	2.3	33	22.1	3	-1.4*
1950-1954	13.3	3.1	14.0	1.7	16.4	1.6	19.1	0.6	24.4	1.0	28.8	0.5	29.4	1.4	29.9	3.1	27.6	5.0	23.2	6.8	16.1	4.3	12.2	3.5	21.2	2.7	32	23.7	4	-2.7
1955-1959	11.9	3.9	12.3	0.6	15.7	1.3	20.1	1.0	25.6	1.3	28.2	0.9	29.7	1.3	29.7	2.0	28.2	6.2	23.0	5.9	16.6	4.4	12.4	3.6	21.2	2.7	33	21.4	4	-2.0
1960	[illegible]	[illegible]	8.8	-0.4	11.6	[illegible]	19.4	0.0	23.5	0.2	28.7	1.0	30.2	-0.1	28.3	0.6	--	--	24.8	3.6	18.0	2.1	11.4	5.0	--	--	33*	21.1*	7	-1.5*
1961	[illegible]	[illegible]	13.3	[illegible]	[illegible]	[illegible]	[illegible]	0.2	23.6	-0.2	--	--	29.0	0.7	28.6	0.9	28.6	1.1	23.1	0.9	17.5	0.6	13.2	0.0	--	--	32*	8.5*	6	-2.0*
1962	[illegible]	-0.5	13.7	-0.3	13.7	-0.5	15.5	-0.3	26.2	-0.3	29.2	0.1	31.7	0.2	31.5	2.4	29.6	5.0	24.8	4.8	17.0	2.6	11.9	2.1	21.4	1.3	34	17.0	3	-1.5
1963	[illegible]	1.6	9.9	[illegible]	16.6	4.0	21.4	-0.3	26.1	0.2	28.4	0.1	29.9	0.7	30.3	2.5	28.3	8.8	24.9	11.1	18.2	11.5	9.7	5.1	21.0	4.1	33	22.7	3	-2.1
1964	9.5	3.6	11.7	3.0	16.5	4.2	20.4	-0.6	27.1	0.5	29.5	4.2	29.6	2.8	30.3	3.6	28.4	7.3	20.9	4.8	19.9	10.9	12.6	3.4	21.4	4.0	33	25.6	4	-1.3
1965	12.6	[illegible]	11.4	1.7	[illegible]	-0.5	20.1	0.0	24.3	-0.1	28.9	0.9	29.5	1.1	29.6	2.6	27.9	4.8	21.9	3.6	20.7	8.1	14.4	7.8	21.2	2.7	32	23.9	3	-1.4
1966	10.0	3.1	11.7	2.3	15.3	2.1	20.6	2.5	23.7	-0.2	26.8	0.1	29.5	0.5	29.5	3.2	27.6	3.7	21.7	4.3	18.4	7.5	13.4	4.7	20.7	2.9	33	20.0	3	-1.8
Mean	11.4	2.2	12.4	1.2	15.7	1.3	20.1	0.7	24.8	0.6	28.4	0.8	29.6	1.0	29.7	2.5	28.0	5.7	23.3	5.7	17.7	5.3	12.6	3.6	21.1	2.6				
Maximum	21	22.1	23	23.9	24	25.6	26	22.0	30	19.8	32	14.7	33	18.6	34	22.1	33	22.1	30	23.7	26	22.4	21	23.1			34	25.6		
Mean Max.	16.6	11.4	17.2	10.0	20.6	11.0	23.8	8.2	27.9	6.7	30.6	6.6	31.4	6.8	31.7	11.2	30.8	16.2	27.4	15.8	22.8	16.1	18.1	14.8						
Mean Min.	6.5	-0.3	7.9	-1.0	11.3	-0.9	15.6	-0.9	21.1	-0.8	25.6	-0.6	27.3	-0.7	27.3	-0.4	24.4	0.1	18.0	-0.3	11.9	-0.5	7.9	-0.6						
Minimum	3	-1.5	3	-2.7	7	-1.7	10	-1.9	17	-2.1	23	-1.8	26	-1.5	26	-1.7	21	-1.7	12	-2.0	9	-2.0	3	-2.3					3	-2.7

Table 25. Monthly tide levels along the central Louisiana coast, 1958-59[a] (Chabreck, 1972).

Month	Mean High Tide	Mean Low Tide	Mean Water Level	Highest Individual Tide	Lowest Individual Tide
	- - - - - - - - - - - - - Feet	- - - - - - - - - - - - -			
January	.39	-.35	.02	1.5	-2.0
February	.56	-.26	.15	1.6	-1.8
March	.60	-.18	.21	1.3	-1.5
April	.78	.09	.43	1.2	- .7
May	1.13	.40	.76	2.4	- .7
June	1.19	.18	.69	1.7	- .7
July	.83	-.06	.39	1.5	-1.0
August	.83	.11	.47	1.6	- .8
September	1.26	.69	.97	2.6	- .2
October	1.06	.39	.72	1.8	- .5
November	.85	.07	.46	1.5	-2.1
December	.37	-.62	-.12	1.4	-2.2
Annual	.82	.04	.43	2.6	-2.2

[a] From Chabreck and Hoffpauir, 1962.

Table 26. Normal astronomical tide characteristics: Grand Isle, Block 46: Offshore Louisiana: 110 foot mean low water depth (Glenn, 1972).

Maximum Astronomical Tide	2.5 Feet
Mean High Water	1.2 Feet
Mean Tide Level	0.8 Feet
Mean Low Water	0.2 Feet
Lowest Astronomical Tide	-0.8 Feet
Maximum Range	3.3 Feet
Mean Range	1.0 Feet

Table 27. Annual wave climate summary for coastal Louisiana (from Becker, 1972).

Wave		Direction From Which Wave is Coming				
H, ft	T, sec	E	SE	S	SW	Subtotals
3.0	4.5	13.4%	20.9%	7.5%	5.0%	46.8%
5.0	6.0	8.9%	20.6%	8.7%	7.6%	45.8%
7.0	7.0	1.2%	1.2%	0.8%	0	3.2%
8.5	8.0	1.4%	0.5%	1.5%	0.8%	4.2%
Subtotals		24.9%	43.2%	18.5%	13.4%	100.0%

*The percentages cited are relative to portion of time during the year when wind velocities exceed 10 km/hr. Winds >10 km/hr prevail during 43.3 percent of the year on the average.

Table 28. 1-year storm tide and wave characteristics: Grand Isle, Block 46: Offshore Louisiana: 110 foot mean low water depth (Glenn, 1972).

Mean Low Water Depth	110.0 Ft.
Maximum Astronomical Tide	2.5 Ft.
Storm Tide	0.8 Ft.
Total Tide	3.3 Ft.
Still Water Depth	113.3 Ft.
Height of Maximum Wave	26.6 Ft.
Period of Maximum Wave	9.3 Sec.
Length of Maximum Wave	431.2 Ft.
Crest Elevation of Maximum Wave Above Bottom	128.3 Ft.
Trough Elevation of Maximum Wave Above Bottom	101.7 Ft.

Table 29. 5-year storm tide and wave characteristics: Grand Isle, Flock 46: Offshore Louisiana: 110 foot mean low water depth (Glenn, 1972).

Mean Low Water Depth	110.0 Ft.
Maximum Astronomical Tide	2.5 Ft.
Storm Tide	1.1 Ft.
Total Tide	3.6 Ft.
Still Water Depth	113.6 Ft.
Height of Maximum Wave	34.5 Ft.
Period of Maximum Wave	10.8 Sec.
Length of Maximum Wave	548.7 Ft.
Crest Elevation of Maximum Wave Above Bottom	133.7 Ft.
Trough Elevation of Maximum Wave Above Bottom	99.2 Ft.

Table 30. 10-year storm tide and wave characteristics: Grand Isle, Block 46: Offshore Louisiana: 110 foot mean low water depth (Glenn, 1972).

Mean Low Water Depth	110.0 Ft.
Maximum Astronomical Tide	2.5 Ft.
Storm Tide	1.4 Ft.
Total Tide	3.9 Ft.
Still Water Depth	113.9 Ft.
Height of Maximum Wave	38.8 Ft.
Period of Maximum Wave	12.4 Sec.
Length of Maximum Wave	668.3 Ft.
Crest Elevation of Maximum Wave Above Bottom	137.2 Ft.
Trough Elevation of Maximum Wave Above Bottom	98.4 Ft.

Table 31. 25-year storm tide and wave characteristics: Grand Isle, Block 46: Offshore Louisiana: 110 foot mean low water depth (Glenn, 1972).

Mean Low Water Depth	110.0 Ft.
Maximum Astronomical Tide	2,5 Ft.
Storm Tide	2.2 Ft.
Total Tide	4.7 Ft.
Still Water Depth	114.7 Ft.
Height of Maximum Wave	45.6 Ft.
Period of Maximum Wave	13.4 Sec
Length of Maximum Wave	769.5 Ft.
Crest Elevation of Maximum Wave Above Bottom	143.2 Ft.
Trough Elevation of Maximum Wave Above Bottom	97.6 Ft.

Table 32. 50-year storm tide and wave characteristics: Grand Isle, Block 46: Offshore Louisiana: 110 foot mean low water depth (Glenn, 1972).

Mean Low Water Depth	110.0 Ft.
Maximum Astronomical Tide	2.5 Ft.
Storm Tide	3.0 Ft.
Total Tide	5.5 Ft.
Still Water Depth	115.5 Ft.
Height of Maximum Wave	51.6 Ft.
Period of Maximum Wave	15.3 Sec.
Length of Maximum Wave	906.9 Ft.
Crest Elevation of Maximum Wave Above Bottom	150.2 Ft.
Trough Elevation of Maximum Wave Above Bottom	98.6 Ft.

Table 33. 100-year storm tide and wave characteristics: Grand Isle, Block 46: Offshore Louisiana: 110 foot mean low water depth (Glenn, 1972).

Mean Low Water Depth	110.0 Ft.
Maximum Astronomical Tide	2,5 Ft.
Storm Tide	3.6 Ft.
Total Tide	6.1 Ft.
Still Water Depth	116.1 Ft.
Height of Maximum Wave	54.3 Ft.
Period of Maximum Wave	16.0 Sec.
Length of Maximum Wave	967.0 Ft.
Crest Elevation of Maximum Wave Above Bottom	153.6 Ft.
Trough Elevation of Maximum Wave Above Bottom	99.3 Ft.

Table 34. Average percentage frequency of occurrence of significant wave height - direction groups: Grand Isle, Block 46: Offshore Louisiana: 110 foot mean low water depth: Annual (Glenn, 1972).

	Significant Wave Height Groups (Ft.)							
Direction	0-1.9	2-3.9	4-5.9	6-7.9	8-9.9	10-15	15 Plus	Total
N	1.5	2.7	2.1	1.5	0.7	0.2	0.0	8.7
NE	2.9	5.8	4.6	2.9	1.2	0.5	0.1	18.0
E	2.5	5.2	4.1	2.7	1.4	1.1	0.3	17.3
SE	2.5	5.3	5.4	3.9	2.0	1.7	0.3	21.1
S	2.1	4.5	3.6	2.3	1.1	0.7	0.2	14.5
SW	1.9	3.5	1.8	1.0	0.5	0.2	0.0	8.9
W	1.6	2.3	1.1	0.6	0.2	0.1	0.0	5.9
NW	1.7	2.1	1.1	0.5	0.2	0.0	0.0	5.6
Total	16.7	31.4	23.8	15.4	7.3	4.5	0.9	100.0

Table 35. Average percentage frequency of occurrence of significant wave height - direction groups: Grand Isle, Block 46: Offshore Louisiana: 110 foot mean low water depth: April (Glenn, 1972).

	Significant Wave Height Groups (Ft.)							
Direction	0-1.9	2-3.9	4-5.9	6-7.9	8-9.9	10-15	15 Plus	Total
N	1.0	2.0	1.8	1.2	0.4	0.1	0.0	6.5
NE	1.6	4.7	3.3	1.7	0.4	0.1	0.0	11.8
E	1.9	3.8	3.6	2.3	0.8	0.3	0.1	12.8
SE	3.3	6.3	10.6	6.7	3.6	1.9	0.2	32.6
S	2.0	4.8	6.5	4.4	2.1	1.1	0.1	21.0
SW	0.8	1.5	1.7	1.2	0.4	0.2	0.0	5.8
W	0.7	1.4	1.1	0.7	0.2	0.1	0.0	4.2
NW	1.3	2.4	1.1	0.4	0.1	0.0	0.0	5.3
Total	12.6	26.9	29.7	18.6	8.0	3.8	0.4	100.0

Table 36. Average percentage frequency of occurrence of significant wave height - direction groups: Grand Isle, Block 46: Offshore Louisiana: 110 foot mean low water depth: July (Glenn, 1972).

	Significant Wave Height Groups (Ft.)							
Direction	0-1.9	2-3.9	4-5.9	6-7.9	8-9.9	10-15	15 Plus	Total
N	1.1	0.7	0.2	0.0	0.0	0.0	0.0	2.0
NE	1.2	1.3	0.4	0.1	0.0	0.0	0.0	3.0
E	2.8	2.9	1.1	0.3	0.1	0.0	0.0	7.2
SE	4.9	8.9	2.9	1.0	0.3	0.1	0.0	18.1
S	5.9	10.9	3.7	1.2	0.6	0.1	0.0	22.4
SW	7.0	12.9	4.3	1.4	0.5	0.1	0.0	26.2
W	5.3	7.4	2.0	0.6	0.1	0.0	0.0	15.4
NW	2.9	2.1	0.6	0.1	0.0	0.0	0.0	5.7
Total	31.1	47.1	15.2	4.7	1.6	0.3	0.0	100.0

Table 37. Average percentage frequency of occurrence of significant wave height - direction groups: Grand Isle, Block 46: Offshore, Louisiana: 110 foot mean low water depth: September (Glenn, 1972).

	Significant Wave Height Groups (Ft.)							
Direction	0-1.9	2-3.9	4-5.9	6-7.9	8-9.9	10-15	15 Plus	Total
N	1.5	2.2	1.3	0.8	0.4	0.1	0.0	6.3
NE	4.1	6.5	5.3	3.2	1.3	0.5	0.1	21.0
E	4.4	7.9	6.1	4.5	1.8	1.6	0.5	26.8
SE	2.4	5.4	6.1	4.7	2.0	2.1	0.8	23.5
S	1.1	2.5	2.7	2.1	1.0	0.9	0.3	10.6
SW	0.9	1.2	1.1	0.8	0.4	0.1	0.0	4.5
W	1.1	1.1	1.0	0.7	0.2	0.0	0.0	4.1
NW	1.2	1.4	0.5	0.1	0.0	0.0	0.0	3.2
Total	16.7	28.2	24.1	16.9	7.1	5.3	1.7	100.0

Table 38. Average percentage frequency of occurrence of significant wave height - direction groups: Grand Isle, Block 46: Offshore Louisiana: 110 foot mean low water depth: October (Glenn, 1972).

	Significant Wave Height Groups (Ft.)							
Direction	0-1.9	2-3.9	4-5.9	6-7.9	8-9.9	10-15	15 Plus	Total
N	2.3	4.0	3.0	1.9	0.7	0.1	0.0	12.0
NE	4.8	10.0	7.8	4.3	1.7	0.8	0.1	29.5
E	2.5	7.0	5.8	4.0	2.5	1.9	0.5	24.2
SE	1.2	3.2	4.0	3.4	1.9	2.1	0.4	16.2
S	1.0	2.1	2.3	1.4	0.6	0.3	0.1	7.8
SW	0.5	0.7	0.7	0.4	0.2	0.1	0.0	2.6
W	0.6	0.8	0.7	0.4	0.1	0.0	0.0	2.6
NW	1.2	2.5	0.9	0.4	0.1	0.0	0.0	5.1
Total	14.1	30.3	25.2	16.2	7.8	5.3	1.1	100.0

Table 39. Average percentage frequency of occurrence of significant wave height - direction groups: Grand Isle, Block 46: Offshore, Louisiana: 110 foot mean low water depth: December (Glenn, 1972).

	Significant Wave Height Groups (Ft.)							
Direction	0-1.9	2-3.9	4-5.9	6-7.9	8-9.9	10-15	15 Plus	Total
N	1.5	4.5	4.1	3.6	2.1	0.7	0.1	16.6
NE	2.6	6.7	6.2	5.4	2.7	1.0	0.1	24.7
E	1.2	4.4	3.7	2.6	1.7	1.6	0.3	15.5
SE	0.7	2.6	3.6	3.1	2.2	2.6	0.4	15.2
S	0.6	2.1	2.7	2.3	1.6	1.1	0.3	10.7
SW	0.4	1.1	1.3	1.1	0.8	0.5	0.1	5.3
W	0.4	0.8	0.9	0.6	0.4	0.2	0.1	3.4
NW	1.7	2.1	2.3	1.7	0.7	0.1	0.0	8.6
Total	9.1	24.3	24.8	20.4	12.2	7.8	1.4	100.0

Table 40. Intensity of offshore waves for coastal Louisiana (from Becker, 1972).

Month	Deep-Water Power	Month	Deep-Water Power
January	358	July	134
February	298	August	64
March	477	September	305
April	191	October	190
May	167	November	329
June	24	December	269

Table 41. A. Variables selected for study of Louisiana coastal fisheries for 1962 through 1969. B. Treatment of variables by category of relationships (Stone, 1972).

A.

	VARIABLE	UNIT AS A MONTHLY MEAN	SOURCE*
No.	Name		
1	Mississippi River Discharge	cubic feet/second	Army Corps
2	Tide Range, Mobile, Ala., Predicted	feet	Tide Tables
3	Tide Range, Eugene Island, La.	feet	NOAA
4	Tide Range, Humble Oil Platform, La.	feet	NOAA
5	Tide Range, Bayou Rigaud, La.	feet	NOAA
6	Tide Currents, Mobile, Ala., Predicted	feet/second (ebb & flood)	Tide Currents
7	Sea Level, Eugene Island, La.	feet	NOAA
8	Sea Level, Humble Oil Platform, La.	feet	NOAA
9	Sea Level, Bayou Rigaud, La.	feet	NOAA
10	Wind Direction, South Central La.	10° increments	Clim.
11	Wind Speed, South Central La.	mph	Clim.
12	Air Temperature, Mean °F, South Central La.	°F	Clim.
13	Air Temperature, °F, Departure from Mean, South Central La.	Coded scale	Clim.
14	Air Degree Hours > 65°F, Negative Departure	No. degree hours	Clim.
15	Rainfall, Mean Inches, South Central La.	inches	Clim.
16	Rainfall, Departure from Mean, South Central La.	inches	Clim.
17	Water Temperature Median, °C at 3017 PM:11	°C	LWLF
18	Number of Hours Water Temperature ≥ 20°C at 3017 PM:11	No. hours	LWLF
19	Wind Direction & Speed, Grand Isle, La.	Between 135° to 225°	LWLF
y	Fish Harvest Off Louisiana	No. pounds harvested	La. Landings

B.

No. 1 through No. 19 are defined as independent variables and y is defined as the dependent variable.
Linear Relationships: X_1 through X_{19}
Curvilinear Relationships: X_{12}, X_{13}, X_{14}, X_{15}, X_{16}, X_{17}, and X_{18} (numbered No. 20 through No. 26)
Interactions: X_2 through X_5 respectively with X_6, X_7, X_8, X_9, X_{10}, X_{11}, and X_{19} (numbered No. 27 through No. 54)
X_{10}, X_{11} and X_{19} respectively with X_{12}, X_{13}, X_{14}, and X_{17} (numbered No. 55 through No. 66)
X_{15} and X_{16} respectively with X_{10}, X_{11}, and X_{19} (numbered No. 67 through No. 72)

---

* Army Corps: U.S. Army Corps of Engineers. "Stages and Discharges, Mississippi River and Its Outlets and Tributaries." U.S. Army Engineer District, New Orleans, La., 1962 through 1969.

Tide Tables: U.S. Coast and Geodetic Survey. "Tide Tables, High and Low Water Predictions." U.S. Government Printing Office, Washington, D.C., 1962 through 1969.

NOAA: Data furnished by U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Survey. Rockville, Maryland 20852

Tide Currents: U.S. Coast and Geodetic Survey. "Tidal Current Tables." U.S. Government Printing Office, Washington, D.C. 1962 through 1969.

Clim.: "Climatological Data." U.S. Department of Commerce, Environmental Science Service Administration, Environmental Data Service, Louisiana, 1962-1969, Ashville, N. Carolina.

LWLF: Louisiana Wild Life and Fisheries Data, X_{17} derived from X_{18} from station in Barataria Bay, La.

La. Landings: National Marine Fisheries Service, in conjunction with the Louisiana Wild Life and Fisheries Commission. Louisiana Landings. Washington, D.C. 1962-1969.

Table 42. Analyses of variance for Louisiana's coastal fishery, 1962-1969, using 72 variables for straight forward regression and correlations between observed and predicted data (Stone, 1972).

Source	Degrees of Freedom	Sums of Squares	Mean Square
Regression	72	396,489,101,160	5,506,793,072
Error	22	13,648,769,024	620,398,592
Corrected Total	94	410,137,870,185	

F Value	Probability, F	R-Square
8.9	0.0001	0.97

Correlation Coefficients	(Between observed and predicted fishery harvest at p = 0.0001)
All Data	0.95
May through September	0.93
April through September	0.96
April through October	0.96
October through March	0.54
October through April	0.57

Table 43. Significant variables* and their R-square values for fisheries harvest off Louisiana, 1962 through 1969, as identified by stepwise regression using (A) General Foods (GF) and (B) Statistical Analysis System (SAS) programs (Stone, 1972).

VARIABLE		CUMULATIVE R-SQUARE**
A. GF Program		
No.	Name	
25	(Water Temperature, Median °C at 3017 PM:11)^2	0.75
18	Number of Hours Water Temperature $\geq$ 20°C at 3017 PM:11	0.81
3	Tide Range, Eugene Island, La.	0.83
1	Mississippi River Discharge	0.85
21	(Air Temperature, °F, Departure from Mean, South Central La.)^2	0.86
8	Sea Level, Humble Oil Platform, La.	0.87
B. SAS Program		
No.	Name	
25	(Water Temperature, Median °C at 3017 PM:11)^2	0.75
17	Water Temperature, Median °C at 3017 PM:11	0.81
20	(Air Temperature, Mean °F, South Central La.)^2	0.83
21	(Air Temperature, °F, Departure from Mean, South Central La.)^2	0.84
7	Sea Level, Eugene Island, La.	0.86
29	Tide Range, Mobile, Ala., Predicted x Sea Level, Humble Oil Platform, La.	0.87

---

*For A, $p \lesssim 0.05$ and for B, $p = 0.0001$.

**Each cumulative R-square value implies a summation of the effect of each of the previous variable. Under part A, for example, variable No. 25 and variable No. 18 account for 81% of the data variance, etc.

Table 44. The acreage of marsh zones and vegetative types in the Louisiana coastal marshes, August, 1968 (Chabreck, 1970).

Marsh Zones	Vegetative Types				
	Saline	Brackish	Intermediate	Fresh	Total
	- - - - - - - - - Thousands of Acres - - - - - - - - -				
Chenier Plain	47.3	364.9	354.6	425.1	1,191.9
Sub-delta	868.5	907.0	224.9	744.9	2,745.3
Active Delta	15.6	23.1	106.8	129.4	274.9
Total	931.4	1,295.0	686.3	1,299.4	4,212.1

Table 45A. Plant species composition of vegetative types in the Louisiana coastal marshes (Chabreck, 1972).

Species	Vegetative Type			
	Saline	Brackish	Intermediate	Fresh
	---------- Percent	----------	----------	----------
Acnida alabamensis	- -	.10	.30	.02
Aeschynomene virginica	- -	- -	- -	.07
Alternanthera philoxeroides	- -	- -	2.47	5.34
Aster sp.	- -	.08	.44	.13
Avicennia nitida	.60	- -	- -	- -
Azolla caroliniana	- -	- -	- -	.13
Baccharis halimifolia	- -	.10	.56	.02
Bacopa caroliniana	- -	- -	.28	.34
Bacopa monnieri	- -	.92	4.75	1.14
Bacopa rotundifolia	- -	.11	.32	- -
Batis maritima	4.41	- -	- -	- -
Bidens laevis	- -	- -	- -	.08
Borrichia frutescens	.67	.11	- -	- -
Brasenia schreberi	- -	- -	- -	.57
Cabomba caroliniana	- -	- -	- -	.71
Carex sp.	- -	- -	- -	.02
Centella erecta	- -	- -	.16	.12
Cephalanthus occidentalis	- -	- -	- -	.21
Ceratophyllum demersum	- -	- -	- -	1.50
Cladium jamaicense	- -	- -	- -	.84
Colocasia antiquorum	- -	- -	- -	.39
Cuscuta indecora	- -	.02	- -	- -
Cynodon dactylon	- -	- -	- -	.10
Cyperus compressus	- -	- -	- -	.02
Cyperus odoratus	- -	.84	2.18	1.56
Daubentonia texana	- -	- -	.04	.17
Decodon verticillatus	- -	- -	- -	.51
Dichromena colorata	- -	- -	- -	.03
Distichlis spicata	14.27	13.32	.36	.13
Dryopteris thelypteris var. haliana	- -	- -	- -	.44
Echinochloa walteri	- -	.36	2.72	.77
Eichornia crassipes	- -	- -	- -	1.43
Eleocharis parvula	- -	2.46	.49	.54
Eleocharis sp.	- -	.62	3.28	10.74
Eupatorium capillifolium	- -	- -	- -	.05
Eupatorium sp.	- -	- -	.08	.03
Fimbristylis castanea	.04	.11	.12	- -
Gerardia maritima	.01	.08	- -	- -
Heliotropium curassavicum	- -	.02	- -	- -
Hibiscus lasiocarpus	- -	- -	.10	.05
Hydrocotyle bonariensis	- -	- -	- -	.02
Hydrocotyle ranunculoides	- -	- -	- -	.11
Hydrocotyle umbellata	- -	- -	- -	1.93
Hymenocallis occidentalis	- -	- -	.04	.14
Hypericum virginicum	- -	- -	- -	.07
Ipomoea stolonifera	- -	- -	- -	.03

Table 45B. Plant species composition of vegetative types in the Louisiana coastal marshes (Chabreck, 1972).

Species	Vegetative Type			
	Saline	Brackish	Intermediate	Fresh
	Percent			
Ipomoea sagittata	- -	.13	.84	.19
Iva frutescens	.03	.10	- -	- -
Juncus effusus	- -	- -	- -	.11
Juncus roemerianus	10.10	3.93	.72	.60
Jussiaea diffusa	- -	- -	- -	.24
Jussiaea sp.	- -	- -	- -	.84
Kosteletzkya virginica	- -	.02	.18	.07
Lemna minor	- -	.02	.16	2.31
Leptochloa fascicularis	- -	.32	2.17	.49
Leptochloa filiformis	- -	- -	.04	- -
Limnobium spongia	- -	- -	- -	.16
Lippia nodiflora	- -	- -	- -	.06
Lycium carolinianum	.07	- -	- -	- -
Lythrum lineare	.01	.16	.18	.07
Myrica cerifera	- -	- -	- -	.16
Myriophyllum spicatum	- -	.15	.44	1.56
Myriophyllum heterophyllum	- -	- -	- -	.19
Najas quadalupensis	- -	- -	1.03	1.07
Nelumbo lutea	- -	- -	- -	.54
Nymphaea odorata/tuberosa	- -	- -	- -	1.15
Nymphoides aquaticum	- -	- -	- -	.11
Osmunda regalis	- -	- -	.16	.43
Ottelia alismoides	- -	- -	- -	.03
Panicum hemitomon	- -	- -	.76	25.62
Panicum repens	- -	- -	.92	.24
Panicum virgatum	- -	.14	2.51	.45
Panicum sp.	- -	- -	- -	.10
Paspalum dissectum	- -	- -	.40	.42
Paspalum vaginatum	- -	1.38	4.46	.35
Philoxerus vermicularis	- -	- -	.08	.01
Phragmites communis	- -	.31	6.63	2.54
Pluchea foetida	- -	- -	- -	.02
Pluchea camphorata	- -	.87	2.26	.36
Polygonum sp.	- -	- -	- -	.56
Pontederia cordata	- -	- -	- -	.07
Potamogeton nodosus	- -	- -	.28	.03
Potamogeton pusillus	- -	- -	.24	.62
Ruppia maritima	- -	3.83	.64	- -
Sacciolepis striata	- -	- -	- -	.06
Sagittaria falcata	- -	- -	6.47	15.15
Sagittaria latifolia	- -	- -	- -	.21
Sagittaria platyphylla	- -	- -	- -	.23
Sagittaria sp.	- -	- -	.08	- -
Salicornia bigelovii	.13	- -	- -	- -
Salicornia virginica	.63	- -	- -	- -
Salix nigra	- -	- -	- -	.06
Saururus cernuus	- -	- -	- -	.16
Scirpus americanus	- -	- -	1.27	.13
Scirpus californicus	- -	- -	1.83	.42
Scirpus olneyi	- -	4.97	3.26	.45
Scirpus robustus	.66	1.78	.68	- -

Table 45C. Plant species composition of vegetative types in the Louisiana coastal marshes (Chabreck, 1972).

Species	Vegetative Type			
	Saline	Brackish	Intermediate	Fresh
	Percent			
Scirpus validus	- -	.08	- -	- -
Sesbania exaltata	- -	.06	.20	- -
Sesuvium portulacastrum	- -	.04	- -	- -
Setaria glauca	- -	.06	- -	- -
Setaria magna	- -	- -	- -	.03
Solidago sp.	- -	- -	.04	.08
Spartina alterniflora	62.14	4.77	.86	- -
Spartina cynosuroides	- -	.89	1.19	.02
Spartina patens	5.99	55.22	34.01	3.74
Spartina spartinae	.01	.04	1.48	- -
Spirodela polyrhiza	- -	- -	- -	.20
Suaeda linearis	.23	- -	- -	- -
Taraxacum officinale	- -	- -	.02	- -
Taxodium distichum	- -	- -	- -	.02
Typha spp.	- -	- -	.93	1.57
Utricularia cornuta	- -	- -	- -	1.68
Utricularia subulata	- -	- -	- -	.21
Vallisneria americana	- -	.08	- -	- -
Vigna repens	- -	1.20	3.84	1.43
Woodwardia virginica	- -	- -	- -	.28
Zizaniopsis miliacea	- -	- -	- -	1.20

Table 46. Published reports of major plant species of vegetative types within the active delta marsh zone (chabreck, 1970).

Species	Vegetative Types		
	Brackish	Intermediate	Fresh
Alternanthera philoxeroides			a,c,d
Bacopa monnieri		a	
Ceratophyllum demersum			d
Distichlis spicata	a,c,d		
Eichornia crassipes			a,d
Juncus roemerianus	d		
Lemna minor			a,c
Myriophyllum spicatum			a
Panicum repens		a	
Phragmites communis	a,d	a,b,c,d	a,b,c,d
Scirpus americanus		c,d	
Scirpus robustus	a		
Spartina alterniflora	a,c,d	a,c,d	
Typha latifolia		c	c,d

Reported by:

(a) This report (Tables 12, 13, and 14).
(b) Brown (1936)
(c) Lloyd and Tracy (1901)
(d) O'Neil (1949)

Table 47. Published reports of major plant species of vegetative types within the inactive delta marsh zone (Chabreck, 1970).

Species	Vegetative Types			
	Saline	Brackish	Intermediate	Fresh
Alternanthera philoxeroides				d,h
Avicennia nitida	b,g,j			
Cladium jamaicense			h,j	d,h
Distichlis spicata	a,b,g,h,j	a,f,i,j		
Juncus roemerianus	a,b,d,g,h,j	a,c,i,j		
Panicum hemitomon				a,d,h
Sagittaria falcata			a	a,j
Scirpus californicus			j	h,j
Scirpus olneyi		c,e,f,g,h,i		
Spartina alterniflora	a,d,g,h,j			
Spartina cynosuroides		f,i,j	a	
Spartina patens	a,b,d,h	a,c,e,f,g,h,i,j		
Typha latifolia				d,h,j
Vigna repens		g	a	

Sources of information:

- (a) This report (Tables 11, 12, 13, and 14)
- (b) Brown (1936)
- (c) Chabreck and Hoffpauir (1962)
- (d) Eggler (1961)
- (e) Harris and Chabreck (1958)
- (f) Harris and Webert (1962)
- (g) Lemaire (1961)
- (h) O'Neil (1949)
- (i) Orton (1959)
- (j) Penfound and Hathaway (1938)

Table 48. Acreages of the subdivision of hydrologic units of the Louisiana coastal marshes, August, 1968 (Chabreck, 1970).

Type of Area	Hydrologic Unit				
	I	II	III	IV	V
	Acres				
Marshes:					
Natural marsh	261,198	143,850	81,738	469,311	583,101
De-watered marsh	18,300	2,373	---	27,748	18,226
Water Bodies:					
Ponds and Lakes	603,306	49,517	95,391	292,056	228,390
Bays and Sounds	1,019,066	212,260	122,625	108,841	320,082
Bayous and Rivers	26,040	5,888	17,004	43,795	16,965
Canals and Ditches	9,234	7,075	12,476	5,198	9,365
Swamp	---	---	---	15,419	22,853
Dry Land[a]	263,835	27,108	27,234	327,428	202,172
Total	2,200,979	448,071	356,468	1,289,796	1,401,154

Type of Area	Hydrologic Unit				
	VI	VII	VIII	IX	Total
	Acres				
Marshes:					
Natural marsh	40,554	271,087	396,353	212,362	2,459,554
De-watered marsh	---	4,511	54,773	39,858	165,789
Water Bodies:					
Ponds and Lakes	20,825	33,904	230,747	228,552	1,782,688
Bays and Sounds	64,668	332,127	---	---	2,179,669
Bayous and Rivers	3,288	4,781	4,174	3,262	125,197
Canals and Ditches	1,095	5,328	3,849	3,855	57,475
Swamp	21,920	8,256	---	---	68,448
Dry Land[a]	4,383	54,204	26,456	51,746	984,566
Total	156,733	714,198	716,352	539,635	7,823,38

---

[a] includes active beaches, cheniers, spoil deposits, ridges and elevated bayou and lake banks.

Table 49. Acreages of subdivisions of vegetative types in hydrologic unit III of the Louisiana coastal marshes, August, 1968 (from Chabreck, 1970).

Type of Area	Vegetative Type Saline	 Brackish	 Intermediate	 Fresh	 Non-marsh
	- - - - - - -	- - - - - - -	- Acres -	- - - - - - -	- - - - - - -
Marshes:					
Natural marsh	- -	17,039	36,324	28,375	- -
De-watered marsh	- -	- -	- -	- -	- -
Water Bodies:					
Ponds and lakes	- -	10,231	10,231	74,929	- -
Bays and sounds	11,336	85,160	18,180	7,949	- -
Bayous and rivers	- -	1,141	4,427	11,336	- -
Canals and ditches	- -	4,527	4,527	3,422	- -
Swamp	- -	- -	- -	- -	- -
Dry Land[a]	- -	- -	- -	- -	27,234
TOTAL	11,336	118,098	73,789	126,011	27,234

[a] Includes active beaches, cheniers, spoil deposits, ridges and elevated bayou and lake banks.

Table 50. Acreage of subdivisions of vegetative types in hydrologic unit IV of the Louisiana coastal marshes, August, 1968 (Chabreck, 1970).

	Vegetative Type				
Type of Area	Saline	Brackish	Intermediate	Fresh	Non-marsh
	- - - - - - - - - - Acres	- - - - - -	- - - - - -	- - - - - -	- - - - - -
Marshes:					
Natural marsh	144,214	125,296	20,084	179,717	- -
De-watered marsh	- -	- -	- -	- -	27,748
Water Bodies:					
Ponds and lakes	61,547	96,920	3,498	130,091	- -
Bays and sounds	108,841	- -	- -	- -	- -
Bayous and rivers	14,253	11,791	3,498	14,253	- -
Canals and ditches	2,332	1,166	200	1,500	- -
Swamp	- -	- -	- -	- -	15,419
Dry Land[a]	- -	- -	- -	- -	327,428
TOTAL	331,187	235,173	27,280	325,561	370,595

[a] Includes active beaches, cheniers, spoil deposits, ridges and elevated bayou and lake banks.

Table 51. Acreage of subdivisions of vegetative types in hydrologic unit V of the Louisiana coastal marshes, August, 1968 (Chabreck, 1970).

Type of Area	Vegetative Type				
	Saline	Brackish	Intermediate	Fresh	Non-marsh
	Acres				
Marshes:					
Natural marsh	184,086	135,996	37,714	225,305	- -
De-watered marsh	- -	- -	- -	- -	18,226
Water Bodies:					
Ponds and lakes	99,403	68,559	4,487	55,941	- -
Bays and sounds	268,768	39,958	11,356	- -	- -
Bayous and rivers	7,992	5,608	1,122	2,243	- -
Canals and ditches	1,122	2,243	1,200	4,800	- -
Swamp	- -	- -	- -	- -	22,853
Dry Land[a]	- -	- -	- -	- -	202,172
TOTAL	561,371	252,364	55,879	288,289	243,251

[a] Includes active beaches, cheniers, spoil deposits, ridges and elevated bayou and lake banks.

Table 52. Plant species composition of vegetative types in hydrologic unit III of the Louisiana coastal marshes, August, 1968[a] (Chabreck, 1970).

Species	Vegetative Types			
	Saline	Brackish	Intermediate	Fresh
	- - - - - - - - - -	-Percent-	- - - - - - - - - -	
Alternanthera philoxeroides	- -	- -	2.60	8.69
Bacopa monnieri	- -	- -	10.41	- -
Cyperus odoratus	- -	- -	- -	- -
Distichlis spicata	- -	8.54	- -	- -
Echinochloa walteri	- -	- -	1.49	- -
Eichornia crassipes	- -	- -	- -	5.53
Eleocharis parvula	- -	2.85	- -	- -
Eleocharis sp.	- -	- -	3.12	- -
Lemna minor	- -	- -	- -	7.85
Myriophyllum spicatum	- -	- -	4.09	25.29
Panicum hemitomon	- -	- -	2.97	- -
Panicum repens	- -	- -	8.55	3.95
Phragmites communis	- -	10.82	43.64	37.30
Pluchea camphorata	- -	- -	2.16	- -
Potamogeton pusillus	- -	- -	1.49	2.90
Ruppia maritima	- -	- -	1.49	- -
Sagittaria falcata	- -	- -	4.09	- -
Sagittaria platyphylla	- -	- -	- -	3.69
Saururus cernuus	- -	- -	- -	2.11
Scirpus americanus	- -	-	3.72	- -
Scirpus robustus	- -	7.59	- -	- -
Scirpus validus	- -	3.79	- -	- -

Table 52. (con't)

Species	Vegetative Types			
	Saline	Brackish	Intermediate	Fresh
	- - - - - - - - - -Percent- - - - - - - - - -			
Spartina alterniflora	- -	58.44	6.17	- -
Spartina patens	- -	6.64	1.49	- -
Spirodela polyrhiza	- -	- -	- -	2.69
Other Species[b]	- -	1.33	2.52	- -

[a] Includes only natural marshes

[b] Includes only plants making up less than 1.00 percent of the species composition

Table 53. Plant species composition of vegetative types in hydrologic unit IV of the Louisiana coastal marshes, August, 1968[a] (Chabreck, 1970).

Species	Vegetative Types			
	Saline	Brackish	Intermediate	Fresh
	- - - - - - - - Percent - - - - - - - - - -			
Alternanthera philoxeroides	- -	- -	- -	3.43
Bacopa monnieri	- -	- -	23.97	1.82
Batis maritima	3.08	- -	- -	- -
Cyperus odoratus	- -	- -	5.34	3.21
Decodon verticillatus	- -	- -	- -	1.16
Distichlis spicata	10.05	28.96	3.05	- -
Echinochloa walteri	- -	- -	- -	2.15
Eichornia crassipes	- -	- -	- -	1.99
Eleocharis parvula	- -	5.49	- -	- -
Eleocharis sp.	- -	1.40	2.29	12.31
Ipomoea sagittata	- -	- -	1.53	- -
Juncus roemerianus	14.90	3.26	- -	- -
Panicum hemitomon	- -	- -	- -	41.35
Pluchea camphorata	- -	- -	16.79	- -
Polygonum sp.	- -	- -	- -	1.60
Sagittaria falcata	- -	- -	3.82	17.42
Salicornia virginica	1.19	- -	- -	- -
Scirpus olneyi	- -	2.26	- -	1.48
Spartina alterniflora	62.79	9.03	- -	- -
Spartina patens	7.77	45.84	41.99	- -
Typha spp.	- -	- -	- -	2.59
Vigna repens	- -	- -	- -	1.16
Zizaniopsis miliaceae	- -	- -	- -	1.36

Table 53. (con't)

Species	Vegetative Types			
	Saline	Brackish	Intermediate	Fresh
	- - - - - - - - - - Percent - - - - - - - - -			
Other Species[b]	.22	3.76	1.22	6.97

[a] Includes only natural marshes

[b] Includes only plants making up less than 1.00 percent of the species composition

Table 54. Plant species composition of vegetative types in hydrologic unit V of the Louisiana coastal marshes, August 1968[a] (Chabreck, 1970).

Species	Vegetative Types			
	Saline	Brackish	Intermediate	Fresh
	- - - - - - - - -	- Percent -	- - - - - - - - -	
Alternanthera philoxeroides	- -	- -	- -	2.42
Aster sp.	- -	- -	1.12	- -
Avicennia nitida	1.52	- -	- -	- -
Bacopa monnieri	- -	- -	3.72	2.73
Batis maritima	6.58	- -	- -	- -
Cyperus odoratus	- -	2.31	2.98	1.92
Decodon verticillatus	- -	- -	- -	1.10
Distichlis spicata	11.66	13.09	1.86	- -
Dryopteris thelypteris	- -	- -	- -	1.43
Echinochloa walteri	- -	- -	2.60	- -
Eleocharis sp.	- -	1.93	1.27	18.03
Hydrocotyle umbellata	- -	- -	- -	4.32
Ipomoea sagittata	- -	- -	1.12	- -
Juncus roemerianus	3.69	- -	- -	- -
Leptochloa fascicularis	- -	- -	9.23	- -
Najas quadalupensis	- -	- -	3.35	- -
Osmunda regalis	- -	- -	1.49	- -
Panicum hemitomon	- -	- -	4.09	42.17
Paspalum vaginatum	- -	- -	2.98	- -
Phragmites communis	- -	- -	1.49	- -
Pluchea camphorata	- -	- -	3.12	1.19
Sagittaria falcata	- -	- -	2.45	7.67
Scirpus olneyi	- -	6.57	7.07	- -
Scirpus validus	- -	1.50	- -	- -

Table 54. (con't)

Species	Vegetative Types			
	Saline	Brackish	Intermediate	Fresh
	- - - - - - - - - Percent - - - - - - - - -			
Spartina alterniflora	67.73	2.08	- -	- -
Spartina cynosuroides	- -	1.13	- -	- -
Spartina patens	6.81	63.39	34.23	1.22
Typha spp.	- -	- -	5.95	1.58
Vigna repens	- -	4.08	7.07	1.04
Zizaniopsis miliaceae	- -	- -	- -	3.18
Other species[b]	2.01	3.92	2.81	10.00

[a] Includes only natural marshes

[b] Includes only plants making up less than 1.00 percent of the species composition

Table 55. Partial list of the major primary producers in the Barataria Bay, Louisiana (Day et al., 1972).

Angiosperms

Spartina alterniflora
S. patens
Avicennia germina
Distichlis spicata
Juncus roemerianus
Batis maritima
Salicornia

Benthic macrophytes

Enteromorpha flexuosa
E. intestinalis
Ectocarpus
Bostrychia rivularis
Polysiphonia havanensis
Ulva lactuca
Gracilaria foliifera
Cladophora repens or
Cladophora gracilis

Benthic cyanophyta

Oscillatoria
Lyngbya
Spirulina
Chroococcus
Merismopedia
Anacystis

Epiphytic diatoms

Amphiprora
Amphora
A. angusta
Camphylodiscus
Cocconeis
C. disculoides
C. disculus
C. placentula
Cylindrotheca fusiforma
Denticula
Diploneis bombus
Gyrosigma terryanum
Hantzschia
Navicula
Nitzschia
N. paradoxa
Pleurosigma
Rhopalodia gibberula
Surirella amoricana
Grammatophora marina
Melosira distans
Isthmia nervosa
Cylindrotheca closterium

Benthic diatoms

Amphora
Denticula
Diploneis
D. interrupta
Gyrosigma
Navicula directa
Nitzschia
Opephora
Paralia
Amphiprora
Caloneis
Mastogloia
Pleurosigma
Surirella
Cylindrotheca closterium

Phytoplankton

Merismopedia
Actinoptychus
Biddulphia
Chaetoceros
Coscinodiscus
Ceratium fusus
C. hircus
C. trichoceros
C. tripos
C. vultur
Dinophysis caudata
Gonyaulax monilata
Peridinium
Prorocentrum gracile or micans
Prorocentrum maximum
Skeletonema
Ditylum brightwellii
Thalassionema
Cylindrotheca closterium
Nitzschia pungens
Rhizosolenia

Table 56. Primary production in the Barataria Bay, Louisiana, in g dry wt/m^2/year (Day et al., 1972).

	Production		Consumer	Community Net
MARSH	Gross	Net*	Respiration	Production
Grass:				
Streamside	14,000	2,960	--	--
Inland (50 m)	9,750	1,484	--	--
Average over marsh	8,418**	1,518**	754**	764**
Epiphytes:				
Streamside	103.9	--	--	60
Inland (2 m)	27.3	--	--	-18.4
Average (to 2 m)	32.2	25.8	--	--
Total:				764

	Production			Community Net
WATER	Gross	Net*	Respiration	Production
Phytoplankton	598	418	--	--
Benthic Plants	698	488	--	--
Water Column#	--	--	450	--
Benthos and Nekton	--	--	798	--
Total:	1296	906	1248	48

*Net production is less respiration of plants
**Takes into consideration bare areas on marsh
#Phytoplankton, zooplankton, and bacteria

Table 57. Components considered in the marsh-estuarine system (Day et al., 1972).

PRODUCERS		Angiosperms
		Epiphytic diatoms
		Benthic Macrophytes
		Benthic diatoms
		Phytoplankton
CONSUMERS	Marsh	Bacteria, Fungae
		Meiofauna
		Snails
		Crabs
		Polychaetes
		Modiolus
		Insects
		Birds and mammals
	Submerged Sediments	Microbiota
		Meiobenthos
	Water	Bacteria
		Zooplankton
		Blue crabs
		Brown and white shrimp
		Oysters
		Fish
		Birds

Table 58. Bacterial populations in various habitats of the marsh-estuarine system in Barataria Bay. Numbers are average over the year. From standard dilution and plate techniques (Day et al., 1972).

	% Moisture	# Cells/g dry wt or ml H_2O
Spartina - top	35	15.7×10^8
Spartina - mid portion	66	30.0×10^8
Spartina - bottom portion	94	30.0×10^9
Marshland soil	66	6.6×10^8
Submerged sediment	73	4.8×10^6
Water	---	9.5×10^4

Table 59. Distribution of marsh fauna in Airplane Lake, Louisiana (Day et al., 1972).

Organism	Distance into Marsh from Waters Edge						average biomass
	shore	3m	10m	20m	50m	300m	to 50 m
Polychaetes							
Aug.	0	0	.1/22	.2/8	.4/36	.3/16	.4691
Oct.	.2/8	.22/20	0	.29/10	.36/20	0	.3364
Dec.	.69/40	.47/12	.07/4	0	0	0	.1250
							$\bar{x} = .31$
Neritina							
Aug.	0	0	1.2/36	1.3/200	.8/20	0	.9743
Oct.	.07/4	0	1.4/28	1.6/52	.25/4	0	.9411
Dec.	0	.08/4	0	6.9/136	.4/8	0	2.8857
							$\bar{x} = 1.6$
Sesarma							
Aug.	7.9/4	5.8/8	0	0	0	0	.8764
Oct.	0	3.6/8	4.2/8	.03/4	0	0	1.1251
Dec.	1.1/4	5.5/8	0	0	0	0	.4688
							$\bar{x} = .8234$
Fiddler							
Aug.	3.0/8	14.8/20	4.7/8	1.8/4	0	0,	3.0107
Oct.	0	1.7/4	6.7/8	2.1/2	7.5/12	0	4.4743
Dec.	0	4.7/8	0	0	0	0	.6407
							$\bar{x} = 2.71$
Blue Crab							
Aug.	0	0	0	0	0	0	0
Oct.	0	2.75/8	0	.02/2	.016/4	0	.5783
Dec.	.0188/4	0	0	0	0	0	.005
							$\bar{x} = .1927$

Table 59. (con't)

Organism	Distance into Marsh from Waters Edge						average biomass to 50 m
	shore	3m	10m	20m	50m	300m	
Littorina							
Aug.	2.8/28	6.3/52	4.9/36	16.9/112	0	0	8.4394
Oct.	3.6/32	7.6/76	6.3/52	10.0/76	0	0	5.9991
Dec.	0	1.1/8	8.9/56	6.7/40	0	0	4.4067
							$\bar{x}$ = 6.2817
Melampus							
Aug.	1.2/316	3.6/688	4.1/444	1.3/208	6.1/1088	4.3/680	3.5675
Oct.	1.1/112	2.4/497	1.6/216	0.4/108	1.4/284	.7/52	1.1724
Dec.	6.2/68	3.3/600	1.6/176	.14/16	.07/28	0	.8751
							$\bar{x}$ = 1.8716
Modiolus							
Aug.	0	3.6/64	6.6/148	0.6/24	2.0/80	0	2.3457
Oct.	.5/4	4.8/44	.9/12	6.3/64	3.4/72	0	4.3587
Dec.	1.4/36	9.5/40	3.3/16	3.0/20	0	0	2.8076
							$\bar{x}$ = 3.1706

Table 59. (con't)

Organism	Distance into Marsh from Waters Edge						average biomass
	shore	3m	10m	20m	50m	300m	to 50 m
<u>Neritina</u>	0	0	0	0	.2/16		.3129
<u>Sesarma</u>	3.2/4	0	0	0	0		.1251
<u>Fiddler</u>	3.2/20	34.9/80	11.7/20	5.6/16	1.3/4		8.5122
<u>Littorina</u>	3.6/40	2.9/40	13.3/148	9.8/80	13.5/88		10.3587
<u>Melampus</u>	.2/28	1.4/392	3.1/672	1.3/260	0.2/20		1.2100

Table 60. Check list of fishes of the Caminada Bay, Louisiana (Wagner, 1972).

- Class Chondrichthyes
  - Order Squaliformes
    - Carcharhinidae-Requiem Sharks
      - *Rhizoprionodon terraenovae*-Atlantic Sharpnose Shark
      - *Carcharhinus leucas*-Bull Shark
  - Order Rajiformes
    - Dasyatidae-Stingrays
      - *Dasyatis sabina*-Atlantic Stingray
- Class Osteichthyes
  - Order Semionotiformes
    - Lepisosteidae-Gars
      - *Lepisosteus oculatus*-Spotted Gar
      - *Lepisosteus platystomus*-Shortnose Gar
      - *Lepisosteus spatula*-Alligator Gar
  - Order Elopiformes
    - Elopidae-Tarpons
      - *Elops saurus*-Ladyfish
  - Order Anguilliformes
    - Congridae-Conger Eels
      - *Congrina flava*-Yellow Conger
    - Ophichthidae-Snake-Eels
      - *Ophichthus gomesi*-Shrimp Eel
  - Order Clupeiformes
    - Clupeidae-Herrings
      - *Alosa chrysochloris*-Skipjack Herring
      - *Brevoortia patronus*-Gulf Menhaden
      - *Dorosoma cepedianum*-Gizzard Shad
      - *Dorosoma petenense*-Threadfin Shad
      - *Harengula pensacolae*-Scaled Sardine
      - *Opisthonema oglinum*-Atlantic Thread Herring
      - *Sardinella anchovia*-Spanish Sardine
    - Engraulidae-Anchovies
      - *Anchoa hepsetus*-Striped Anchovy
      - *Anchoa lyolepis*-Dusky Anchovy
      - *Anchoa mitchilli*-Bay Anchovy

Table 60. (con't)

- Order Myctophiformes
  - Synodontidae-Lizardfishes
    - *Synodus foetens*-Inshore Lizardfish

- Order Siluriformes
  - Ariidae-Sea Catfishes
    - *Bagre marinus*-Gafftopsail Catfish
    - *Arius felis*-Sea Catfish
  - Ictaluridae-Freshwater Catfishes
    - *Ictalurus catus*-White Catfish

- Order Batrachoidiformes
  - Batrachoididae-Toadfishes
    - *Opsanus beta*-Gulf Toadfish
    - *Porichthys porosissimus*-Atlantic Midshipman

- Order Gobiesociformes
  - Gobiesocidae-Clingfishes
  - *Gobiesox strumosus*-Skilletfish

- Order Lophiiformes
  - Antennariidae-Frogfishes
    - *Histrio histrio*-Sargassumfish

- Order Gadiformes
  - Gadidae-Codfishes
    - *Urophycis floridanus*-Southern Hake
  - Ophidiidae-Cusk-Eels + Brotulas
    - *Lepophidium graellsi*-Blackedge Cusk-eel
    - *Gunterichthys longipenis*-Gold Brotula

- Order Atheriniformes
  - Exocoetidae-Halfbeaks and Flyingfishes
    - *Hyporhampus unifasciatus*-Halfbeak
    - *Hirundichthys rondeleti*-Blackwing Flyingfish
  - Belonidae-Needlefishes
    - *Strongylura marina*-Atlantic Needlefish
  - Cyprinodontidae-Killifishes
    - *Adenia xenica*-Diamond Killifish
    - *Cyprinodon variegatus*-Sheepshead Minnow
    - *Fundulus confluentus*-Marsh Killifish
    - *Fundulus grandis*-Gulf Killifish
    - *Fundulus similis*-Longnose Killifish
    - *Lucania parva*-Rainwater Killifish
  - Poeciliidae-Livebearers
    - *Gambusia affinis*-Mosquitofish
    - *Poecilia latipinna*-Sailfin Molly

Table 60. (con't)

- Atherinidae-Silversides
    - *Membras martinica*-Rough Silverside
    - *Menidia beryllina*-Tidewater Silverside

- Order Gasterosteiformes
    - Syngnathidae-Pipefishes + Seahorses
        - *Syngnathus floridae*-Dusky Pipefish
        - *Syngnathus louisianae*-Chain Pipefish
        - *Syngnathus scovelli*-Gulf Pipefish

- Order Perciformes
    - Serranidae-Sea Basses
        - *Centropristes philadelphicas*-Rock Sea Bass

    - Pomatomidae-Bluefishes
        - *Pomatomus saltatrix*-Bluefish

    - Carangidae-Jacks and Pompanos
        - *Caranx hippos*-Crevalle Jack
        - *Caranx latus*-Horse-eye Jack
        - *Chloroscombrus chrysurus*-Atlantic Bumper
        - *Oligoplites saurus*-Leatherjacket
        - *Selene vomer*-Lookdown
        - *Trachinotus carolinus*-Florida Pompano
        - *Trachinotus falcatus*-Permit
        - *Vomer setipinnis*-Atlantic Moonfish

    - Coryphaenidae-Dolphins
        - *Coryphaena equisetis*-Pompano Dolphin

    - Lutjanidae-Snappers
        - *Lutjanus griseus*-Gray Snapper
        - *Lutjanus synagris*-Lane Snapper

    - Lobotidae-Tripletails
        - *Lobotes surinamensis*-Tripletail

    - Gerreidae-Mojarras
        - *Eucinostomus argenteus*-Spotfin Mojarra
        - *Eucinostomus gula*-Silver Jenny

    - Rachycentridae-Cobias
        - *Rachycentron canadum*-Cobia
    - Pomadasyidae-Grunts
        - *Orthopristis chrysoptera*-Pigfish

Table 60. (con't)

Sparidae-Porgies
Archosargus probatocephalus-Sheepshead
Lagodon rhomboides-Pinfish

Sciaenidae-Drums
Bairdiella chrysura-Silver Perch
Cynoscion arenarius-Sand Seatrout
Cynoscion nebulosus-Spotted Seatrout
Larimus fasciatus-Banded Drum
Leiostomus xanthurus-Spot
Menticirrhus americanus-Southern Kingfish
Micropogon undulatus-Atlantic Croaker
Pogonias cromis-Black Drum
Scianops ocellata-Red Drum
Menticirrhus littoralis

Ephippidae-Spadefishes
Chaetodipterus faber-Atlantic Spadefish

Mugilidae-Mullets
Mugil cephalus-Striped Mullet
Mugil curema-White Mullet

Sphyraenidae-Barracudas
Sphyraena guachancho-Guaguanche

Polynemidae-Threadfins
Polydactylus octonemus-Atlantic Threadfin

Uranoscopidae-Stargazers
Astroscopus y-graecum-Southern Stargazer

Blenniidae-Combtooth Blennies
Hypsoblennius ionthas-Freckled Blenny

Eleotridae-Sleepers
Dormitator maculatus-Fat Sleeper
Eleotris pisonis-Spinycheek Sleeper
Erotelis smaragdus civitatum-Emerald Sleeper

Gobiidae-Gobies
Gobioides broussonetii-Violet Goby
Gobionellus boleosoma-Darter Goby
Gobionellus hastatus-Sharptail Goby
Gobiosoma bosci-Naked Goby
Gobiosoma robustum-Code Goby
Microgobius gulosus-Clown Goby?
Microgobius thalassinus-Green Goby
Gobionellus shufeldti-Freshwater Goby
Evorthodus lyricus-Lyre Goby

Trichiuridae-Cutlassfishes
Trichiurus lepturus-Atlantic Cutlassfish

Table 60. (con't)

Scombridae-Mackerels and Tunas
Scomberomorus cavalla-King mackerel
Scomberomorus maculatus-Spanish Mackerel

Stromateidae-Butterfishes
Peprilus alepidotus-Harvestfish
Peprilus burti-Gulf Butterfish

Triglidae-Searobins
Prionotus tribulus-Bighead Searobin
Prionotus roseus-Bluespotted Searobin
Prionotus rubio-Blackfin Searobin

Order Pleuronectiformes
Bothidae-Lefteye Flounders
Ancylopsetta quadrocellata-Ocellated Flounder
Citharichthys spilopterus-Bay Whiff
Etropus crossotus-Fringed Flounder
Paralichthys albigutta-Gulf Flounder
Paralichthys lethostigma-Southern Flounder

Soleidae-Soles
Achirus lineatus-Lined Sole
Trinectes maculatus-Hogchoker

Cynoglossidae-Tonguefishes
Symphurus plagiusa-Blackcheek Tonguefish

Order Tetraodontiformes
Balistidae-Triggerfishes and Filefishes
Aluterus schoepfi-Orange Filefish

Tetraodontidae-Puffers
Sphoeroides nephelus-Southern Puffer (also *Sphoeroides parvus*)

Table 61. Dominant fishes in Caminada Bay, Louisiana (Wagner, 1972).

Species	Total Number	Avg. No. per Trip	% Total Number	Total Biomass	Area Biomass per Trip	% Total Biomass
Anchova mitchilli	52,633	2392	65.1	34201.4	.27	11.4
Brevoortia patronus	14,782	672	15.4	23012.9	.14	7.7
Leiostomus xanthurus	5,786	263	6.0	20404.7	.13	6.8
Micropogon undulatus	5,300	241	5.5	22949.2	.13	7.1
Aries felis	2,166	98	2.2	52539.2	.34	17.6

Table 62. Total length range in millimeters for 6 most abundant fishes per trip in Caminada Bay, Louisiana (Wagner, 1972).

Trip	Date	Bay Anchovy	Menhaden	Sea Catfish	Atlantic Croaker	Spot	White Trout
1	3/26/71				46-85		
2	4/16-17/71				28-120		
3-4	5/1&7/71				31-145		
5	5/25-26/71	29-76	40-247	74-385	51-132	75-171	60-87
6	6/14-16/71	19-74	38-204	102-377	61-225	85-202	33-120
7	7/7-8/71	28-71	42-137	116-298	76-210	97-123	26-128
8	7/28-29/71	22-75	76-218	61-373	96-185	107-202	46-109
9	8/28-29/71	19-68	90-130	61-350	146-210	157-228	55-164
10	9/21-22/71	21-74	69-185	52-104	116-185	---	25-115
11	10/14-15/71	20-75	149-179	75-335	141-150	139-210	51-132
12	11/4-5/71	19-80	69-161	78-323	11-195	143-185	62-156
13	11/23/71	16-72	---	77-153	11-50	140-194	95-100
14	12/16/71	26-79	---	82-420	11-65	145	---
15	1/12-13/72	24-75	22-261		16-90	36-51	---
16	2/2/72	21-75	25-108	---	11-105	43-173	---
17	2/24/72	34-80	29-190	75-362	16-125	18-163	---
18	3/14-15/72	27-79	28-216	219-359	16-113	27-95	---
19	4/4/72	31-80	25-51	30-452	16-135	35-105	27-33
20	4/29-30/72	17-92	35-210	99-320	29-170	50-180	31-59
21	5/17-18/72	18-80	60-235	113-370	41-150	65-149	63-82
22	6/7-8/72	17-79	35-65	102-150	50-228	75-124	67-134
23	6/28-29/72	17-79	37-97	113-385	71-216	81-157	40-132

Table 63. Total number of 6 most abundant fishes per trip (all gear) in Caminada Bay, Louisiana (Wagner, 1972).

Trip	Date	Bay Anchovy	Menhaden	Sea Catfish	Atlantic Croaker	Spot	White Trout	% Total Number
1	3/26/71	4559	95	20	259	425	0	99.03
2	4/16-17/71	2199	28	4	78	277	0	97.75
3-4	5/1-7/71	1872	192	5	298	189	68	94.83
5	5/25-26/71	1248	12	64	305	45	75	88.78
6	6/14-16/71	1065	4438	32	56	27	63	91.94
7	7/7-8/71	835	247	20	47	8	61	19.82
8	7/28-29/71	5568	10	43	28	11	69	93.53
9	8/28-29/71	7493	14	1288	10	10	9	84.38
10	9/21-22/71	927	31	98	8	0	45	40.50
11	10/14-16/71	1646	6	129	2	16	18	81.22
12	11/4-5/71	2589	56	218	46	43	18	92.12
13	11/23/71	558	0	2	164	8	3	72.84
14	12/16/71	1116	0	5	673	1	0	96.58
15	1/12-13/72	1240	207	4	255	48	0	66.32
16	2/2/72	1245	65	0	210	28	0	70.91
17	2/24/72	1931	175	36	540	571	0	95.36
18	3/14-15/72	5079	7946*	3	476	2454	0	99.10
19	4/4/72	4555	861	48	608	535	2	97.50
20	4/29-30/72	1081	57	9	705	533	7	89.10
21	5/17-18/72	1300	31	48	397	451	14	93.2
22	6/7-8/72	972	308	53	108	48	31	86.7
23	6/28-29/72	3555	3	37	27	58	10	77.1
$\bar{x}$		2392	672	98	241	263	22	
Total all trips		52,633	14,782	2,166	5,300	5,736	493	
% Total Number		55.1	15.4	2.2	5.5	6.0	0.5	
$\bar{x}/m^2$		.37	.09	.01	.03	.03	.003	

*Hit one large school in Airplane Lake seine

Table 64. Total biomass in grams (wet weight) of 6 most abundant fishes per trip in Caminada Bay, Louisiana (Wagner, 1972).

Trip	Date	Bay Anchovy	Menhaden	Sea Catfish	Atlantic Croaker	Spot	White Trout
1	3/26/71				802.2 0.16		
2	3/16-17/71	1489.1 0.30			447.4 0.09		
3-4	5/1-7/71				822.4 0.13		
5	5/25-26/71	891.2 0.15	258.9 0.04	5404.4 .76	2453.9 0.31	454.9 0.09	213.6 .04
6	6/14-16/71	843.1 0.13	8782.5 .96	2660.4 .29	907.1 .10	492.5 .05	366.0 .06
7	7/7-8/71	603.3 0.09	1647.3 .25	1805.7 .28	936.0 .14	85.8 .01	98.9 .02
8	7/28-29/71	5414.3 .83	218.0 .03	3995.9 .51	761.0 .10	426.9 .05	241.5 .04
9	8/28-29/71	4586.4 .70	180.2 .03	7280.6 .79	729.8 .08	1090.7 .12	98.5 .02
10	9/21-22/71	557.8 .09	315.0 .05	429.1 .07	268.1 .04	--	138.5 .02
11	10/14-15/71	1320.5 .20	254.3 .03	4117.5 .53	58.1 .01	1387.7 .18	81.8 .01
12	11/4-5/71	1237.7 .19	409.7 .06	2412.7 .26	91.9 .01	2688.3 .29	175.0 .03
13	11/23/71	444.8 .07	--	30.1 .004	27.6 .004	463.8 .06	18.6 .003
14	12/16/71	821.7 .13	--	906.7 .12	145.4 .02	44.4 .006	--
15	1/12-13/72	747.5 .11	1390.2 .15	1580.3 .17	121.5 .02	33.9 .005	--
16	2/2/72	1017.1 .14	32.1 .004	--	196.8 .03	255.9 .235	--
17	2/24/72	2287.9 .35	224.9 .028	3046.9 .39	502.0 .08	316.7 .04	--
18	3/14-15/72	4285.8 .66	6401.6 .70	672.0 .07	477.6 .07	3165.6 .35	--
19	4/4/72	2890.8 .44	271.7 .04	5671.3 .78	2352.9 .32	1970.9 .27	.5 .00006
20	4/29-30/72	1456.9 .22	1479.7 .19	1223.3 .16	5208.8 .66	3430.8 .44	7.0 .001
21	5/17-18/72	836.2 .13	721.1 .08	5378.2 .59	3528.6 .38	2873.9 .31	46.0 .007
22	6/7-8/72	563.4 .08	413.2 .06	659.4 .09	1364.8 .19	405.4 .06	190.5 .03
23	6/28-29/72 ←	1885.9 .29	12.5 .001	5264.7 .67	748.3 .10	816.6 .10	103.2 .02
Total:		34201.4	23012.9	52539.2	22949.2	20404.7	1779.6
$\bar{x}$ g/m²		.27	.14	.34	.13	.13	.02
% Total (T5-23)		11.4	7.7	17.6	7.1	6.8	0.5

Sampling done with:

6 trawls, 3 seine	7275m²
6 trawls, 2 seine, 1 trammel	7842m²
6 trawls, 2 seine	6515m²
6 trawls, 1 seine	5755m²
6 trawls, 1 seine, 1 trammel	7082m²
6 trawls, 2 seine, 2 trammel	9169m²

Table 65. Stomach contents of 6 dominant fish species of Caminada Bay, Louisiana (extracted from Day et al., 1972).

Anchoa mitchilli: (anchovy)	crab megalops, zooplankton *Other studies*: copepods, detritus, small fishes and microbenthos
Brevoortia patronus (menhaden)	phytoplankton, detritus *Other studies*: phytoplankton, zooplankton and detritus
Leiostomus xanthurus: (spot)	amphipods, copepods, detritus *Other studies*: pelecypods, copepods, detritus, annelids, microbenthos
Micropogon undulatus: (croaker)	amphipods, annelids, copepods, detritus, fish, insect larvae *Other Studies*: shrimp, annelids, fish, crabs, mollusks, diatom, decapods, mysids, microbenthos, zooplankton
Aries felis: (sea cat)	crab megalops, fish, detritus *Other studies*: macrobenthos, zooplankton, small crabs, amphipods, mysids

Table 66. Seasonal abundance and food habits of principal marsh birds (Day et al., 1972).

Species		Food Habits
Wading Birds		
Great Blue Heron	(3)	minnows, 67%; shrimp & crabs, 10; small mammal, 5%
Little Blue Heron	(2)	fish, 27%; crustaceans, 45%; insects, 16%
Louisiana Heron	(2)	
American Egret	(2)	
Snowy Egret	(2)	small fishes, crustaceans, snails, insects
Cattle Egret	(3)	mostly insects
White Ibis	(2)	crustaceans, 60%; fish, 13%; snails, 13%; insects, 13%
Wood Ibis	(2)	crustaceans, insects
White-faced Ibis	(3)	
Water Fowl		
Puddle Ducks	(1)	plants, 68%
Shoveler	(1)	animal, 31.5%; mollusc, 29%
Cadwall	(1)	crabs, 3%
Pintail	(1)	
Mallard	(1)	
Mottled Duck	(3)	plant, 75.2%
Blue-winged Teal	(1)	animal, 24.8%; snails, 11%
Green-winged Teal	(1)	insects, 4%
Diving Duck	(1)	fish, 2%
Lesser Scaup	(1)	
American Merganser	(1)	
Wooded Merganser	(1)	
Coots	(1)	
Shore Birds		
Herring Gulls	(1)	
Laughing Gulls	(3)	
Ring-billed Gulls	(1)	minnows & open water fish
Forster's Tern	(3)	
Royal Tern	(3)	
Least Tern	(2)	shrimp
Caspian Tern	(3)	
Gull-billed Tern	(2)	
Plovers, willets	(3)	
Sandpipers	(3)	
White Pelicans	(1)	fish
Marsh Proper		
Rails	(2)	crabs, snails, insects
Sea Side Sparrow	(2)	insects, 70%, plant material, 20%, small snails, 10%

---

(1) more abundant in cold months
(2) more abundant in warm months
(3) equal abundance all year

Table 67. Louisiana fisheries landings in 1970. Given in terms of volume and value for principal species (extracted from Current Fisheries Statistics No. 5794, Louisiana Landings, Annual Summary 1970).

POUNDAGE

	Species	Pounds	%	cummulative
1.	Menhaden	959,809,800	86.05	86.05
2.	Shrimp	90,938,900	8.15	94.20
3.	Crab	10,254,200	.92	95.12
4.	Oyster	8,638,900	.77	95.89
5.	Catfish	5,547,000	.50	96.39
6.	Crawfish	3,173,300	.28	96.67
7.	Unclassified	27,286,100	2.45	99.12

VALUE

1.	Shrimp	34,611,931	55.36	55.36
2.	Menhaden	18,930,641	30.28	85.64
3.	Oyster	3,630,560	5.80	91.44
4.	Catfish	1,594,292	2.55	93.99
5.	Crabs	1,007,538	1.61	95.60
6.	Crawfish	945,463	1.51	97.11
7.	Unclassified	1,186,648	1.89	99.00

Table 68. Average annual harvest (1963-67) of the major commercial fish and shellfish produced in Louisiana waters (Lindall et al., 1972).

Species	Pounds (Million)	Percent of Total	Value[3] (Million)	Percent of Total
Menhaden	713.06	84.6	10.12	23.5
Shrimp	73.51[1]	8.7	26.68	61.4
Croaker	23.71[2]	2.8	0.42	0.9
Oyster	9.97	1.2	4.39	10.1
Blue Crab	8.27	1.0	0.73	1.7
Catfish and Bullheads	4.59	0.5	0.78	1.8
Spot	4.62[2]	0.6	0.08	0.2
Seatrout (Spotted and White)	4.11[2]	0.5	0.19	0.4
Red Drum	0.53	0.1	0.09	0.2
Total	842.37	100.0	43.48	100.0

---

[1] Live weight (computed by NMFS Statistical Office, New Orleans). The general conversions of heads-off to live weight are: 161 for brown, 1.54 for white, and 1.60 for pink.

[2] Includes industrial bottom fish

[3] 1967 exvessel prices ($)

Table 69. Average annual landings of major commercial fish and shellfish taken from Louisiana waters and landed in adjacent states (1963-67) (Lindall et al., 1972).

Species	Pounds[1] (Million)	Value[2] (Million Dollars)
Menhaden	142.09	2.00
Shrimp	7.70	2.50
Croaker	12.80[3]	0.23
Oyster	1.18	0.51
Blue Crab	0.34	0.03
Spot	2.50[3]	0.04
Seatrout (Spotted and White)	1.94[3]	0.06
Red Drum	.04	0.01
Total	168.59	5.28

[1] Live weight

[2] 1967 exvessel price

[3] Includes industrial bottomfish

Table 70. Production and value of major commercial estuarine-dependent fisheries by hydrologic unit. Data based on five-year (1963-67) average annual harvests and 1967 exvessel prices (Lindall, et al., 1972).

Species	Hydrologic Unit								
	I and II[1]	III	IV	V	VI	VII	VIII	IX	Total
Menhaden									
Production[2]	159.33	30.20	335.83	64.80	28.30	41.10	12.40	41.10	713.06
Value[3]	2.26	0.43	4.77	0.92	0.40	0.58	0.18	0.58	10.12
Shrimp									
Production	18.30	3.70	20.00	22.91	2.00	3.20	0.50	2.90	73.51
Value	6.64	1.34	7.25	8.31	0.73	1.17	0.19	1.05	26.68
Croaker									
Production	4.33	1.20	4.93	7.63	1.10	2.11	0.30	2.11	23.71
Value	0.07	0.02	0.08	0.14	0.02	0.04	0.01	0.04	0.42
Oyster									
Production	4.68	0.00	4.14	0.85	0.00	0.01	0.00	0.29	9.97
Value	2.06	0.00	1.82	0.37	0.00	0.005	0.00	0.13	4.39
Blue Crab									
Production	3.66	0.03	2.46	1.12	0.28	0.06	0.04	0.62	8.27
Value	0.32	0.003	0.22	0.10	0.03	0.005	0.004	0.05	0.73
Spot									
Production	0.57	0.23	0.85	1.58	0.22	0.53	0.11	0.53	4.62
Value	0.01	0.004	0.01	0.03	0.004	0.01	0.002	0.01	0.08
Catfish and Bullheads									
Production	0.16	0.00	1.94	0.41	1.79	0.07	0.22	0.003	4.59
Value	0.03	0.00	0.33	0.07	0.30	0.01	0.04	0.001	0.78
Seatrout									
Production	1.41	0.21	1.08	0.31	0.18	0.42	0.08	0.42	4.11
Value	0.07	0.01	0.05	0.01	0.01	0.02	0.003	0.02	0.19
Red Drum									
Production	0.23	0.02	0.12	0.13	0.005	0.00	0.00	0.02	0.53
Value	0.04	0.003	0.02	0.02	0.001	0.00	0.00	0.003	0.09
Total									
Production[2]	192.68	35.59	371.35	99.74	33.87	47.50	13.65	47.99	842.37
Value[3]	11.50	1.81	14.55	9.97	1.50	1.84	0.43	1.88	43.48
Estuarine water[4]	1,764	163	314	419	153	323	13	134	3,283
Production, pounds/acre	109.2	218.3	1,182.6	238.0	221.4	147.1	1,050.0	358.1	256.6
Value dollars/acre	6.5	11.1	46.3	23.8	9.8	5.7	33.1	14.0	13.2

[1] Hydrologic Units I and II were grouped because of overlap of Breton and Chandeleur Sounds and probable overlap of catch designations therein

[2] Millions of pounds

[3] Millions of dollars

[4] Thousands of acres

Table 71. Louisiana historical commercial landings of menhaden, 1880-1967 (Lindall et al., 1972).

Year	Thousands of Pounds	Year	Thousands of Pounds	Year	Thousands of Pounds
1880	-	1932	-	1954	270,094
1887	-	1934	-	1955	298,309
1888	-	1935	-	1956	320,521
1889	-	1937	-	1957	162,817
1890	-	1938	-	1958	241,813
1897	-	1939	-	1959	442,740
1902	-	1940	-	1960	470,108
1908	-	1945	-	1961	581,682
1918	-	1948	88,110	1962	689,157
1923	-	1949	165,914	1963	633,484
1927	-	1950	207,755	1964	599,538
1928	-	1951	209,574	1965	682,435
1929	-	1952	283,373	1966	555,900
1930	-	1953	307,492	1967	510,414
1931	-				

Landings years 1880-1965 from Lyles (1967a). Landings 1966 and 1967 from Lyles (1968 and 1969).

Table 72. Seasonal abundance and distribution of menhaden juveniles in Louisiana estuaries. Results are based on catch per unit effort of combined seines and trawls taken by Louisiana Wild Life and Fisheries Commission from April 1968 through March 1969. Temperature, salinity ranges, and seasonal catches are monthly averages (Lindall et al., 1972).

Hydrologic Unit	I	II	IV E Bay Adam Area	IV W Barataria Area	V E Pelto to Timbalier	V W Caillou Area	West of V
SEASON							
Spring (Mar.-May)							
Temp. Range (C°)	13.8-24.4	23.1-31.1	14.4-26.7	9.2-24.9	12.1-27.3	12.7-25.4	13.2-25.3
Sal. Range (0/00)	7.8-12.9	12.8-18.0	11.6-17.3	5.3-18.1	17.9-23.0	6.8-12.3	1.9-11.1
Summer (June-Aug.)							
Temp. Range	30.0-31.6	29.5-32.2	29.5-30.5	28.2-31.4	29.3-31.2	25.4-31.0	28.6-34.5
Sal. Range	11.2-17.2	13.2-17.6	9.4-15.0	13.4-16.2	19.7-24.4	10.0-18.4	1.5-14.4
Fall (Sep.-Nov.)							
Temp. Range	14.8-27.9	11.5-27.2	12.5-30.0	11.1-23.8	12.2-27.8	12.7-27.7	13.5-27.0
Sal. Range	11.4-19.9	16.4-23.9	18.6-28,0	18.3-26.2	21.0-25.5	5.8-15.7	3.8-23.5
Winter (Dec.-Feb.)							
Temp. Range	12.7-13.6	12.1-14.9	11.8-15.6	10.9-16.3	10.6-15.8	10.4-15.2	10.9-15.7
Sal. Range	8.3-13.3	10.9-16.3	18.9-27.6	14.4-18.4	18.7-24.7	9.8-23.5	3.8-6.8
Brevoortia patronus							
Spring	10.9	10.9	241.2	28.5	12.4	49.6	93.1
Summer	38.9	1.7	375.3	150.8	27.2	64.4	131.4
Fall	10.5	0.6	9.8	19.8	96.2	21.1	11.6
Winter	24.3	11.1	14.7	110.3	1.7	6.7	14.1
Yearly Average	18.0	6.0	186.0	77.0	34.0	35.0	66.0

Table 73. Production of harvested menhaden per hydrologic unit based on 5-year average (1963-67) (Lindall et al., 1972)

MENHADEN

Hydrologic Unit	Nursery Areas (Acres)	Million Pounds	Pounds per Acre
I and II	1,764,000	159.33	90.3
III	163,000	30.20	185.3
IV	314,000	335.83	1,069.6
V	419,000	64.81	154.7
VI	153,000	28.30	185.0
VII	323,000	41.10	127.2
VIII	13,000	12.40	953.8
IX	134,000	41.10	306.7
TOTAL	3,283,000	713.07	217.2

Table 74. Harvest of menhaden from offshore Louisiana including landings by other states (1963-67) (Lindall et al., 1972).

	Offshore Grid						Year Total
	12	13	14	15	16	17	
Five-year Total	107,036,800	537,520,700	288,470,400	872,856,000	530,305,000	695,707,400	3,031,896,300
Five-year Average	21,407,360	107,504,140	57,694,080	174,571,200	106,061,000	139,141,480	606,379,260
Value ($)	369,157	1,506,084	883,753	2,301,635	1,484,099	2,058,520	8,603,248

Table 75. Louisiana shrimp landings and number of trawls and/or seines (1913-1968) (Lindall et al., 1972).

Calendar Year	Barrels Shrimp (210 lbs.)	No. of Seines	No. of Trawls	Calendar Year	Barrels Shrimp (210 lbs.)	No. of Seines	No. of Trawls
1913	50,000	131	-	1941	554,354	5	3,028
1914	52,381	131	-	1942	489,173	4	2,380
1915	57,143	268	-	1943	441,445	4	2,101
1916	85,714	-	-	1944	544,378	4	1,866
1917	57,143	-	-	1945	495,994	4	2,373
1918	71,429	300	17	1946	464,981	4	3,030
1919	76,190	-	-	1947	365,617	4	3,408
1920	152,381	97	499	1948	376,695	4	3,200
1921	163,012	135	983	1949	376,040	4	3,310
1922	109,050	111	699	1950	361,365	3	2,819
1923	153,749	128	1,021	1951	396,980	-	2,248
1924	150,624	143	905	1952	398,952	-	2,277
1925	154,722	180	1,010	1953	437,340	10	3,543
1926	123,967	143	692	1954	451,647	4	3,442
1927	150,896	120	913	1955	365,542	5	3,276
1928	195,303	261	1,494	1956	318,130	7	3,072
1929	210,033	125	1,486	1957	181,061	9	2,419
930	197,550	172	1,176	1958	208,586	9	4,400
1931	178,815	126	1,131	1959	254,438	8	4,154
1932	152,373	66	699	1960	306,774	7	4,896
1933	166,058	67	1,045	1961	148,423	8	4,577
1934	226,576	107	1,441	1962	208,920	-	5,453
1935	252,981	125	1,433	1963	384,828	-	7,025
1936	286,749	30	1,920	1964	282,852	-	7,397
1937	362,942	35	2,313	1965	297,993	8	7,296
1938	363,656	13	1,662	1966	296,520	21	7,215
1939	395,050	26	1,621	1967	358,571	29	9,089
1940	397,189	5	3,016	1968	322,702	37	8,996

Source: Louisiana Wildlife and Fisheries Commission, 13th Biennial Report, 1968-69

Table 76. Production of harvested commercial shrimp per hydrologic unit. Figures based on 5-year (1963-67) average harvests and proportion of juveniles determined by samplings by the Gulf of Mexico Estuarine Inventory, Louisiana Wild Life and Fisheries Commission (Lindall et al., 1972).

Hydrologic Unit	I and II	III	IV	V	VI	VII	VIII	IX	Total
Estuarine Waters (Thousand acres)	1,764	163	314	419	153	323	13	134	3,283
Shrimp harvest (Millions of pounds)	18.3	3.7	20.0	22.9	2.0	3.2	0.5	2.9	73.5
Pounds per acre	10.4	22.7	63.7	54.7	13.1	9.9	38.5	21.6	22.4

Table 77. Harvest of shrimp (live weight) from offshore Louisiana including landings by other states (1963-67) Lindall et al., 1972).

Five-year Total	4,305,500	43,852,100	35,324,000	62,557,400	34,353,000	34,017,900	214,329,900
Five-year Average	861,100	8,770,420	7,064,800	12,511,480	6,870,600	6,803,580	42,865,980
Value ($)	239,467	3,200,864	2,812,116	4,667,973	3,013,788	2,640,298	16,574,506

Harvest of shrimp (liveweight) from inshore Louisiana including landings by other states (1963-67).

	I	II	III	IV	V	VI	VII	VIII	IX	Year Total
Five-year Total	9,264,100	14,428,900	8,173,000	38,286,100	68,469,100	47,900	8,000,060	1,400	6,544,100	153,214,660
Five-year Average	1,852,800	2,885,780	1,634,600	7,657,220	13,693,820	9,580	1,600,012	280	1,308,020	30,642,932
Value ($)	611,430	952,307	539,418	2,526,882	4,518,960	3,161	528,003	92	431,910	10,112,163

Table 78. Louisiana historical commercial landings of oysters, 1880-1967 (thousands of pounds of meat) (Lindall et al, 1972).

Year	Landings	Year	Landings	Year	Landings
1880	1,189	1932	2,978	1954	8,361
1887	2,733	1934	5,591	1955	9,396
1888	2,902	1935	5,743	1956	10,056
1889	3,367	1937	8,048	1957	10,490
1890	3,392	1938	10,222	1958	8,265
1897	3,866	1939	13,586	1959	9,667
1902	4,830	1940	12,412	1960	8,311
1908	11,953	1945	9,884	1961	10,139
1918	4,522	1948	9,016	1962	10,160
1923	4,119	1949	9,688	1963	11,563
1927	6,640	1950	8,716	1964	11,401
1928	6,246	1951	8,164	1965	8,343
1929	4,549	1952	11,402	1966	4,800
1930	4,846	1953	9,435	1967	7,742
1931	3,590				

Landings years 1880-1965 from Lyles (1967a). Landings 1966 and 1967 from Lyles (1968 and 1969).

Figure 79. Oyster grounds in Louisiana (1969). Number of acres leased by parish, in seed ground reservations, in the "red line" area, and in public reefs. Information furnished by Louisiana Wild Life and Fisheries Commission (Lindall et al., 1972).

PARISH		ACRES
Iberia		701
Jefferson		10,758
Lafourche		7,955
Orleans		333
Plaquemines		37,654
St. Bernard		36,939
St. Mary		713
St. Tammany		208
Terrebonne		20,347
Vermilion		709
	Total	116,318
SEED GROUND RESERVATIONS		
Sister Lake		7,356
(productive reef only)		(600)
Bay Junop		2,416
Bay du Cheine (Hackberry Bay)		4,015
Bay Gardene		2,666
	Total	16,453
"RED LINE" AREA		
Mississippi Sound		219,158
Breton and Chandeleur Sounds		445,233
	Total	664,491
PUBLIC REEF		
Calcasieu Lake		6,737
(productive reef only)		(581)
	Total	6,737
Total Oyster Grounds (Committed)		803,999

Table 80. Estimated production of cannery oyster meats in pounds per acre of lease by hydrologic unit (1963-67) (Lindall et al., 1972).

Hydrologic Unit	I	II	III	IV	V	VI	VII	VIII	IX	Total
Acres of private leases (1963-67 average)	30,531	10,401	0	35,517	16,574	578	1,157	0	0	94,758
Estimated acres in production	9,159	3,120	0	10,655	4,972	173	348	0	0	28,427
Annual private lease harvest (1963-67 average in pounds of meat)	1,438,280	1,682,780	0	3,800,120	853,460	0	11,500	0	0	7,786,140
Approximate annual production per acre leased	157	539	0	357	172	0	33	0	0	274

Table 81. Harvest of oysters from Louisiana waters including landings by other states (1963-67). Statistics include cannery oysters only (Lindall et al., 1972).

Hydrologic Unit	Year	State	Private Grounds a/ Spring	Private Grounds a/ Fall	Public Grounds b/ Spring	Public Grounds b/ Fall	Total Pounds of Meat	Total Value ($)
		Five-year Total - All Units	29,609,600	9,321,100	8,119,600	2,788,100	49,838,400	16,280,699
		Five-Year Average - All Units	5,921,920	1,864,220	1,623,920	557,620	9,967,680	3,256,140
		Annual Harvest - All Units		1963	1964	1965	1966	1967
				12,624,200	13,891,700	9,620,800	5,236,200	8,465,400

a/ harvests from leased grounds

b/ harvests from public reefs and seed ground areas

Table 82. Louisiana historical commercial landings of blue crab, 1880-1967 (thousands of pounds) (Lindall et al., 1972).

Year	Blue Crab	Year	Blue Crab	Year	Blue Crab
1880	288	1931	5,106	1953	8,619
1887	971	1932	5,977	1954	7,540
1888	994	1934	12,328	1955	11,392
1889	989	1935	12,941	1956	10,002
1890	981	1937	15,046	1957	9,110
1897	1,459	1938	10,781	1958	9,913
1902	1,312	1939	11,443	1959	10,175
1908	322	1940	14,314	1960	10,564
1918	282	1945	33,650	1961	12,530
1923	316	1948	22,018	1962	9,867
1927	1,227	1949	18,329	1963	8,311
1928	2,503	1950	13,470	1964	5,892
1929	2,755	1951	9,060	1965	9,488
1930	4,332	1952	7,782	1966	8,000
				1967	8,705

Landings years 1880-1965 from Lyles (1967a). Landings 1966 and 1967 from Lyles (1968 and 1969).

Table 83. Production of harvested blue crab per hydrologic unit based on average annual catched (1963-67) and distribution of juveniles (Lindall et al., 1972).

Hydrologic Unit	I and II	III	IV	V	VI	VII	VIII	IX	Total
Estuarine Water (acres)	1,764,000	163,000	314,000	419,000	153,000	323,000	13,000	134,000	3,283,000
Million Pounds	3.66	0.03	2.46	1.12	0.28	0.06	0.04	0.62	8.27
Pounds/acre	2.1	0.2	7.9	2.7	1.9	0.2	3.8	4.7	2.5

Table 84A. Harvest of hard-shelled blue crabs from inshore Louisiana including landings by other states (1963-67) (Lindall et al., 1972).

Year	I	II	III	IV	V	VI	VII	VIII	IX	Year Total (Pounds)
year Total	12,171,200	4,670,900	-	11,744,100	4,853,300	1,339,900	219,600	-	2,990,300	37,642,000
year Average	2,434,240	934,180	-	2,348,820	970,660	267,980	43,920	-	598,060	7,528,400
($)	170,396	65,392	-	164,417	67,946	18,758	3.074	-		

Table 84B. Harvest of blue crabs (soft) from inshore Louisiana (1963-67). There were no landings by other states in this period (Lindall et al., 1972).

State	Year	Hydrologic Unit									Year Total (Pounds)
		I	II	III	IV	V	VI	VII	VIII	IX	
Louisiana	1963	177,200	99,500	-	51,600	-	-	-	-	-	328,300
Louisiana	1964	108,700	75,100	-	24,100	-	-	-	-	-	207,900
Louisiana	1965	92,900	70,100	-	39,800	-	-	-	-	-	202,800
Louisiana	1966	47,000	27,900	-	38,000	-	-	-	-	-	112,900
Louisiana	1967	68,700	26,100	-	51,500	-	-	-	-	-	146,300
Five-Year Total		494,500	298,700	-	205,000	-	-	-	-	-	998,200
Five-Year Average		98,900	59,740	-	41,000	-	-	-	-	-	199,640
Value ($)		82,087	49,584	-	34,030	-	-	-	-	-	165,701

Table 84C. Harvest of hard-shelled blue crabs from offshore Louisiana including landings by other states (1963-67) (Lindall et al., 1972).

Year	Offshore Grid						Year Total
	12	13	14	15	16	17	(Pounds)
Five-Year Total	-	143,300	100,000	1,550,800	403,500	360,000	2,557,600
Five-Year Average	-	28,600	20,000	310,160	80,700	72,000	511,520
Value ($)	-	1,514	1,200	16,763	4,794	4,865	29,136

Table 85. Historical commercial landings of croaker in Louisiana (1880-1967) (Lindall et al., 1972).

Year	Thousands of Pounds	Year	Thousands of Pounds
1880	[1]	1945	146
1887	52[2]	1948	44
1888	55[2]	1949	63
1889	150	1950	59
1890	158	1951	27
1897	329	1952	25
1902	155	1953	36
1908	369	1954	27
1918	383	1955	12
1923	219	1956	30
1927	186	1957	32
1928	169	1958	4,983
1929	81	1959	57
1930	60	1960	35
1931	59	1961	18
1932	44	1962	7
1934	301	1963	25
1935	408	1964	20
1937	137	1965	15
1938	78	1966	20
1939	113	1967	56
1940	33		

---

[1] Not available.

[2] Includes Spot.

Landings years 1880-1965 from Lyles (1967a). Landings 1966 and 1967 from Lyles (1968 and 1969).

Table 86. Seasonal abundance and distribution of juvenile croaker in Louisiana estuaries. Results are based on average number of fish per unit effort of combined seines and trawls taken by Louisiana Wild Life and Fisheries Commission from April 1968 through March 1969. Temperature and salinity ranges are monthly averages (Lindall et al., 1972).

Hydrologic Area	I	II	IV Bay Adam Area	IV W Barataria Bay Area	V E Lake Pelto to Timbalier Bay	V W Caillou Bay Area	West of V
SPECIES							
Micropogon undulatus (Croaker)							
Spring	70.4	124.7	306.2	159.0	360.5	335.8	350.5
Summer	24.6	25.7	74.7	14.5	52.8	125.2	175.1
Fall	1.4	1.7	4.9	0.8	2.0	19.1	29.1
Winter	10.7	9.8	26.0	20.6	22.8	46.7	128.1
Yearly Average	36.0	47.0	113.0	47.0	109.0	132.0	174.0

Table 87A. Production of harvested croaker per hydrologic unit based on five-year average (1963-67) (Lindall et al., 1972).

Hydrologic Unit	Nursery Areas (Acres)	Million Pounds	Pounds Per Acre
I and II	1,764,000	4.33	2.5
III	163,000	1.20	7.4
IV	314,000	4.93	15.7
V	419,000	7.63	18.2
VI	153,000	1.10	7.2
VII	323,000	2.11	6.5
VIII	13,000	0.30	23.1
IX	134,000	2.11	15.7
Total	3,283,000	23.71	7.2

Table 87B. Harvest of croakers from inshore Louisiana waters including landings by other states (1963-67) (Lindall et al., 1972).

Year	Hydrologic Unit									Year Total (Pounds)
	I	II	III	IV	V	VI	VII	VIII	IX	
Total per unit	14,400	12,100	13,700	8,900	--	--	--	--	--	49,100
Five-year Average	5,560	5,740	--	5,740	5,760	--	--	--	40	22,840
Value ($)	389	401	--	401	403	--	--	--	3	1,597

Table 87C. Harvest of croakers from offshore Louisiana including landings by other states (1963-67) (Lindall et al., 1972).

	Offshore Grid						Year Total (Pounds)
	12	13	14	15	16	17	
Total per Grid	2,200	379,300	--	4,300	--	--	385,800
Five-year Average	440	89,760	440	2,000	--	--	92,640
Value ($)	22	7,370	24	123	--	--	7,539

Table 88. Seasonal waterfowl population estimates[1] for Southeast Louisiana below intracoastal canal in the parishes of Terrebonne, Lafourche, Jefferson, and Plaquemines (unpublished data from H. Bateman, Wild Life and Fisheries Comm., LA, 1971).

	- - - - - - - - - - September 1970 through August 1971 - - -				
	Puddle Ducks	Diving Ducks	Geese	Coots	Total
Fall	905,000	184,000	75,000	566,000	1,730,000
Winter	400,000	445,000	75,000	892,000	2,812,000
Spring	309,000	77,000	0	133,000	519,000
Summer	41,000[2]	0	0	0	41,000

[1] Figures based on 90% of total puddle ducks and 60% of total diving duck estimates for southeast Louisiana. Louisiana Wild Life and Fisheries Commission, 1970-1971.

[2] Mottled duck and blue-winged teal only.

Table 89. Nutria and muskrat fur and meat statistics in Louisiana (unpublished data courtesy of State of Louisiana, 1972).

			Year 1969-1970	
Muskrat fur	1,232,052	41%	$1,512,052	25%
Muskrat meat	550,000	5%	44,000	5%
Nutria fur	1,604,175	53%	3,826,680	64%
Nutria meat	9,500,000	90%	760,000	85%
Total all species fur	3,002,043		$5,965,700	
Total all species meat	10,480,000		890,000	
Total pelts and meat			$6,855,700.25	

			Year 1970-1971	
Muskrat fur	777,960	37%	$1,230,246	27%
Muskrat meat	400,000	3%	32,000	4%
Nutria fur	726,739	35%	2,180,217	48%
Nutria meat	8,000,000	65%	640,000	86%
Total all species fur	2,090,761		$4,512,968.50	
Total all species meat	12,370,000		746,000	
Total pelts and meat			$5,258,968.50	

Highest production 1945.....8 million muskrats
lowest production 1964.....unknown

Nutria: increased from 0 in 1942 to 1.5 million in 1966

MUSKRATS*	Saline	Brackish	Intermediate	Fresh
Unit III	--	--	18.5	4.0
Unit IV	73.0	81.5	93.0	15.0
Unit V	82.5	266.0	98.8	12.0

*Figures given are numbers of muskrats per 100 acres

Table 90. Population estimates on alligator in inactive and active areas of coastal Louisiana. See Figure 40 for locations. (Palmisano, 1972).

	Sub-delta	Active-delta
Private	16,740 brackish	1,200
	9,720 intermediate	4,200
	15,680 fresh	2,800
Public (gm mgmt and refuges)	3,400 fresh (Salvador)	2,160 fresh
	2,820 fresh	1,320
	240 intermediate	1,320
	640 Biloxi brackish	920 intermediate

Table 91. Benthic organisms of the Central Gulf Coast per salinity class and per taxon (extracted from Resources Technology Corporation, 1972).

	Salinity					
	0-5	1-10	5-30	10-30	20-40	35-45
Gastropoda	2*	1	2	2	5	12
Crustacea	2	2	0	3	0	2
Pelecypoda	0	4	5	7	12	9

*Number of species occuring in given gradient of salinity

	Total Genera	Total Species
Crustacea	13	14
Pelecypoda	53	67
Gastropoda	25	33
Echinodermata	6	6
Coelenterata	1	1
Scaphoda	1	1

Resources Technology Corporation
"Fate and Effect Studies of Shell Oil Spill, Dec. 1970"
Final Report, pp. 3-6 to 3-12

Table 92A. Sequential macro-organismal faunal successions for the Central Gulf Coast (taken from Resources Technology Corporation, 1972).

Freshwater/Brackish Water Assemblages (0 - 5 ^{o}/oo)

Gastropoda

Littorina irrorata	A
Neritina reclivata	A

Crustacea

Uca pugilitor	C
Cambarus sp.	A

Low-salinity Assemblages (0 - 10 ^{o}/oo)

Pelecypoda

Rangia cuneta	C
Rangia flexuosa	O
Rangia carolinesis	O
Macoma mitchelli	C

Gastropoda

Littoridina sphinctostoma	O-C

Crustacea

Callinectes sapidus	C
Macrobrachium sp.	O

Intermittent Variable-salinity Assemblages (5 - 30 ^{o}/oo)

Pelecypoda

Rangia cuneata	O-C
Rangia flexuosa	O-C
Macoma mitchelli	R
Crassostrea virginica	A
Petricola pholadiformis	C

Gastropoda

Littordina sp.	O
Amnicola sp.	O

Variable-salinity Oyster Reef Assemblages (10 - 30 ^{o}/oo)

Pelecypoda

Crassostrea virginica	A
Brachidontes recurvus	C-A

Table 92B. Sequential macro-organismal faunal successions for the Central Gulf Coast (taken from Resources Technology Corporation, 1972).

Variable-salinity Oyster Reef Assemblages (continued)

Gastropoda

Crepidula plana	O-C

Crustacea

Balanus eburneus	C
Balanus amphitrite	O-C

Variable-salinity Non-reef Assemblages (10 - 30 °/oo)

Pelecypoda

Nuculana acuta	R-O
Nuculana concentrica	C
Mulina lateralis	A
Tagelus plebius	C
Ensis minor	C

Gastropoda

Retusa canaliculata	R-O

Echinodermata

Amphiodia limbata	C

Intermediate-salinity Inshore Coastal Assemblages (20 - 40 °/oo)

Pelecypoda

Aequipectern irradians	A
Trachycardium muricatum	A
Mercenaria mercenaria	A
Chione cancellata	C-A
Tagelus divisus	A

Gastropoda

Nassarius vibex	C
Neritina virginea	R-O
Melampus bidentatus	C

Intermediate-salinity Inshore Shallow Water Assemblages (20 - 40 °/oo)

Pelecypoda

Abra aequalis	A
Corbula contracta	C
Diplodonta punctata	R-O
Mulina lateralis	A
Nuculana concentrica	C
Pandora trilineata	R-O
Periploma fragile	R-O

Table 92C. Sequential macro-organismal faunal successions for the Central Gulf Coast (taken from Resources Technology Corporation, 1972).

Intermediate-salinity Inshore Shallow Water Assemblages (continued)

Gastropoda	
Nassarius acutus	C
Retusa canaliculata	O-C

High-salinity Oyster Reef Assemblages (34 - 45 °/oo)

Pelecypoda	
Anomia simplex	C
Brachidontes exustus	C
Diplothyra smithi	O
Ostrea equestris	A

Gastropoda	
Anachis avara	C
Anachis obesa	C
Mitrella lunata	C
Thais haemostoma floridana	O-C

Crustacea	
Crangon heterochelis	C
Menippe mercenaria	O

High-salinity Non-reef Assemblages (34 - 45 °/oo)

Pelecypoda	
Amygdalum papyria	C
Anomalocardia cuneimeris	A
Laevicardium mortoni	C
Phacoides pectinatus	R-O
Pseudocyrena floridana	C

Gastropoda	
Bittium varium	A
Caecum pulchellum	C
Cerithidea pliculosa	C
Cerithium variabile	C
Haminoea succinea	R-O
Modulus modulus	R
Tegula fasciata	R-O
Vermicularia fargoi	C

Table 92D. Sequential macro-organismal faunal successions for the Central Gulf Coast (taken from Resources Technology Corporation, 1972).

Inshore/nearshore Inlet and Pass Assemblages

Pelecypoda	
Atrina seminuda	R-O
Crassinella lunulata	C
Lucina amiantus	C
Lucina crenella	C
Tellidora cristata	C
Gastropoda	
Anachis avara	R-O
Polinices duplicatus	C
Sinum perspectivum	R-O
Scaphoda	
Dentalium texasianum	O-C
Echinodermata	
Arbacia punctulata	O
Hemipholis elongata	R-O
Luidia clathrata	O
Mellita quinquiesperforata	C
Ophiolepis elegans	C
Coelenterata	
Astrangia astreiformis	C
Crustacea	
Dromidia antillensis	R-O
Heterocrypta granulata	R-O

Table 92E. Sequential macro-organismal faunal succession for the Central Gulf Coast (taken from Resources Technology Corporation, 1972).

Nearshore and Offshore Facies

Intertidal Surf Zone

Pelecypoda

Donax variabilis variabilis	A
Donax variabilis texasiana	A
Donax tumida	C

Gastropoda

Olivella mutica	C
Terebra cinerea	A

Crustacea

Emerita talpoida	A
Octpode albicans	C

Constant-salinity Littoral Zone

Pelecypoda

Atrina serrata	C
Chione intapurpurea	C
Dinocardium robustum	C
Dosinia discus	C
Dosinia elegans	R
Labiosa plicatella	R-O
Solen viridis	C
Spisula solidissima	C
Tellina tayloriana	A

Gastropoda

Architectonica nobilis	C
Busycon plagiosum	C
Oliva sayana	C
Phalium granulatum	C
Terebra dislocata	A

Echinodermata

Luidia clathrata	C
Mellita quinquiesperforata	A

Variable-salinity Littoral Zone (15 -36 ^{o}/oo

Pelecypoda

Abra lioica	A
Macoma tageliformis	C
Mulina lateralis	C-A
Nuculana concentrica	C

Table 92F. Sequential macro-organismal faunal succession for the Central Gulf Coast (taken from Resources Technology Corporation, 1972).

Variable-salinity Littoral Zone (continued

Gastropoda

Anachis avara	C
Nassarius acutus	C
Polinices duplicatus	C

Crustacea

Portunus gibbesi	O-C
Squilla empusa	C-A

Offshore Littoral Zone - Soil or Mud Bottom

Pelecypoda

Nucula proxima	C
Nuculana concentrica	C
Pandora bushiana	C
Pitor cordara	C
Varicorbula operculata	A

Gastropoda

Anachis saintpairiana	A
Nassarina glypta	C
Nassarius ambiguus	C

Offshore Littoral Zone - Sandy Bottom

Pelecypoda

Aequipecten gibbus	C
Aequipecten mucosus	C
Chione clenchi	A
Chione grus	C
Gouldia cerina	A
Laevicardium laevigatum	R-O
Lucina sombrerensis	C
Pecten raveneli	R
Phylloda squamifera	C
Quadrans lintea	C
Semele purpurescens	C
Solecurtus cumingianus	R-O
Tellina georgiana	C

Gastropoda

Antilliphos candei	C
Distorsio clathrata	C
Murex fulvescens	C
Murex pomum	C
Strombus alatus	R-O
Tonna galea	R-O

Table 93. The major components of the estuarine system of Louisiana especially Barataria Bay (Stone, 1972).

			SPRING (MAM)	SUMMER (JJAS)	FALL (ON)	WINTER (DJF)
PHYSICAL FACTORS	1.	Insolation	Increase	Maximum	Decline	Lowest
	2.	Air Temperatures	Increase	Maximum	Decline	Lowest
	3.	Water Temperatures	Increase	Maximum	Decline	Lowest
	4.	Rainfall	Moderate	Maximum	Lowest	Increase
	5.	Mean Water Level	Increase	Decline then Increase	Maximum	Lowest
	6.	River Input	Maximum	Decline	Lowest	Increase
	7.	Wind	Decrease (SE)	Calmest then Increase (SE, (NE	Increase (NE)	Windiest (NE)
PRIMARY PRODUCTION	1.	Marsh Grass	Maximum Production	High Production	Maximum Standing Crop	Annual Die Back
		Dead Grass	High	Low	Lowest	Highest Standing Crop
		Detritus	Peak Loss Rates	Moderate	Secondary Peak Loss Rate	Low
	2.	Phytoplankton	Increasing	Maximum Production	Decline	Low
	3.	Epiphytes	Maximum	Low	Low	Maximum
	4.	Benthos	Decreasing	Lowest	High	Maximum
MAJOR CONSUMER SPECIES	1.	Bacteria				
		Marsh	High	High	Highest	High
		Sediment	Highest	Minimum	Minimum	Secondary Peak
		Water	Highest	Minimum	Minimum	Secondary Peak
	2.	Fungi	Increase	Secondary Peak	Maximum	Decline
	3.	Meiofauna	Maximum	Low	Lowest	Low
	4.	Zooplankton	Maximum	Low	Low	Low (secondary peak)
	5.	Menhaden	Maximum	Decrease (adults out)	Lowest	Increase (post larvae in)
	6.	Shrimp	Maximum {brown shrimp in	Maximum then Decrease	Low {brown shrimp out white shrimp in	Increase (white shrimp out)

Table 94. Archaeological sites and brief description in study area. See Figure 57 for locations (unpublished data of Neuman, 1972 and Gagliano, 1972).

Marine Science #	Museum of Archaeology #	Description
1	16PL24	Pelican Isle, beach deposit
2	16PL13	Earth mound
3	16PL30	Beach deposit, marine shell more abundant than chenier material
4	16PL3]	Beach deposit, few rangia
5	16PL7	Oyster midden - few rangia
6	16PL5	Rangia and few oyster mounds, 100 yds x 25 yds x 21/2 / deep
7	16PL8	(1) 65' x 30' x 5 1/2' above marsh level 89' x 54' (bottom of the pit) (2) irregular 30' x 21' (3) irregular 30' x 21' Site area 300' x 200', including 5 smaller heaps of shell, three mainly oyster and two mainly rangia, some pottery from mound
8	16PL26	Beach deposit, rangia and pottery
9	16PL19	Island, shell midden
10	16PL10	200' x 15' x 1' deep (eroded and disappearing,1936) Rangia midden
11	16PL9	Rangia and soil midden
12	16JF3	Shell Midden
13	16JF47	The Graveyard (no information)
14	16JF12	Very large shell midden, rangia, 3' above water level, Several trappers shacks
15	16JF11	Well Preserved shell midden, bore holes 2' below marsh
16	16JF10	Well Preserved,beach deposit
17	16JF34	Beach deposit
18	16JF9	Beach deposit
19	16JF8	Beach Deposit
20	16JF7	Beach Deposit
21	16JF37	Shell mounds and middens, 400 yds long

Table 95. Statistics of parishes and cities bordering estuarine study areas in Louisiana (Perret et al., 1971).

Name of Parish	*Population* 1960¹	*Population* 1969²	*Area (sq. mi.)*	*Pop. Density (no. per sq. mi.)* 1960	*Pop. Density (no. per sq. mi.)* 1969
Assumption	17,991	20,918	357	50.4	58.6
Name of City or Town					
Napoleonville	1,148				
Calcasieu	145,476	167,437	1,104	131.8	151.7
Name of City or Town					
DeQuincy	3,928				
Goosport	16,778				
Hollywood	1,740				
Iowa	1,857				
Lake Charles	63,393	72,900			
Maplewood	2,432				
Sulphur	11,429	13,348			
Sulphur South	1,351				
Vinton	2,987				
Westlake	3,311				
Cameron	6,909	7,926	1,444	4.8	5.5
Name of City or Town					
Iberia	51,657	61,721	588	87.9	105.1
Name of City or Town					
Jeanerette	5,568				
Loreauville	655				
New Iberia	29,062	34,522			
Weeks Island	1,138				
Jefferson	208,769	252,815	409	510.0	618.1
Name of City or Town					
Grand Isle	2,074				
Gretna	21,967	25,343			
Harahan	9,275				
Jefferson Heights	19,353				
Kenner	17,037	28,000			
Westwego	9,815				
Jefferson Davis	29,825	33,851	658	45.3	51.5
Name of City or Town					
Elton	1,595				
Jennings	11,887	13,380			
Lake Arthur	3,541				
Welsh	3,332				
Fenton	429				
Lafourche	55,381	67,110	1,157	47.9	58.0
Name of City or Town					
Golden Meadow	3,097				
Larose	2,796				
Lockport	2,221				
Raceland	3,666				
Thibodaux	13,403	16,097			
Orleans	627,525	650,521	199	3,153.4	[illegible]
Name of City or Town					
New Orleans	627,525	650,521			
Plaquemines	22,545	27,215	964	23.4	27.7
Name of City or Town					
Port Sulphur	2,868				
Buras-Triumph	4,908				
St. Bernard	32,186	38,142	510	63.1	74.5
Name of City or Town					
St. Charles	21,219	25,648	304	69.8	84.4
Name of City or Town					
Allemands	1,167				
Hahnville	1,297				
Luling	2,122				
New Sarpy	1,259				
Norco	4,682				
Saint Rose	1,099				
St. Mary	48,833	59,006	605	80.7	97.5
Name of City or Town					
Baldwin	1,548				
Berwick	3,880				
Franklin	8,673				
Morgan City	13,540	16,744			
Patterson	2,923				
St. Tammany	38,643	44,834	908	42.6	49.54
Name of City or Town					
Abita Springs	456				
Covington	6,754				
Folsom	325				
Madisonville	860				
Mandeville	1,740				
Pearl River	964				
Slidell	6,356				
Sun	284				
Tangipahoa	59,434	67,817	803	74.0	84.6
Name of City or Town					
Amite City	3,316				
Hammond	10,563	12,228			
Hammond East	1,462				
Independence	1,941				
Kentwood	2,607				
Ponchatoula	4,727				
Roseland	1,254				
Tangipahoa	455				
Tickfaw	317				
Terrebonne	60,771	75,612	1,391	43.7	54.4
Name of City or Town					
Bayou Cane	3,173				
Daigleville	3,906				
Houma	22,561	29,166			
Vermilion	38,855	44,150	1,204	31.7	36.1
Name of City or Town					
Abbeville	10,414	12,141			
Delcambre	1,857				
Erath	2,019				
Gueydan	2,156				
Kaplan	5,267				
Maurice	411				

Source:

¹U. S. Census of Population: 1960. Final Report PC (1)-20A.

²Louisiana State Department of Health, Division of Tabulation and Analysis, 1970.

Table 96. Population predictions for State of Louisiana (Comprehensive Outdoor Recreation Plan - 1970-75, Louisiana State Parks and Recreation Commission, June, 1971).

Region	Population 1960	% of State	% Change 1950-1960	Population 1970	% of State	% Change 1960-1970	Population 1975	% of State	% Change 1960-1975	Population 1980	% of State	% Change 1960-1980	Population 1985	% of State	% Change 1960-1985
1	1,225,287	37.6	27.0	1,591,446	40.9	29.9	1,871,147	42.3	52.7	2,237,983	43.8	82.6	2,714,761	45.5	121.5
2	393,937	12.1	31.6	510,844	13.1	29.7	600,058	13.5	52.3	714,227	14.0	81.3	853,849	14.3	116.7
3	416,127	12.8	17.5	491,696	12.6	18.1	540,797	12.2	29.9	599,520	11.7	44.0	669,871	11.2	60.9
4	221,264	6.8	39.4	271,820	7.0	22.8	323,116	7.3	46.0	387,509	7.6	75.1	466,442	7.8	110.8
5	277,174	8.5	8.4	305,156	7.8	10.1	323,712	7.3	16.7	346,205	6.8	24.9	372,742	6.2	34.4
6	410,105	12.6	4.3	450,891	11.6	9.9	482,259	10.9	17.5	516,552	10.0	25.9	551,907	9.3	34.5
7	313,125	9.6	4.1	274,440	7.0	-12.4	288,196	6.5	-7.9	309,897	6.1	-1.0	341,372	5.7	9.0
State	3,257,022	100.0	21.1	3,896,293	100.0	19.6	4,429,285	100.0	35.9	5,111,893	100.0	56.9	5,970,944	100.0	83.3
1 A	868,480	26.7	26.7	1,149,771	29.5	32,4	1,373,290	31.0	58.1	1,673,866	32.8	92.7	2,072,831	34.7	138.6
1 B	356,807	10.9	27.8	441,675	11.4	23.8	497,857	11.3	39.5	564,117	11.0	58.1	641,930	10.8	79.9

*Source: Bobo, Etheridge and Weed, (1968); The Population of Louisiana

Table 97. Projected population changes for 6 years of age and over in State of Louisiana (Comprehensive Outdoor Recreation Plan - 1970-75, Louisiana State Parks and Recreation Commission, June, 1971).

Section 1A	1970	1975	1980	1985
Jefferson	332,308	467,779	646,864	907,867
Orleans	602,326	643,080	692,854	735,523
St. Bernard	39,896	48,943	60,569	75,029
TOTAL	974,530	1,153,802	1,400,287	1,736,419
Section 1B				
Assumption	15,605	15,837	16,157	16,523
Lafourche	55,745	61,617	68,309	75,769
Plaquemines	26,713	32,470	39,309	49,285
St. Charles	18,696	21,710	25,434	29,926
St. James	18,575	20,776	23,497	26,769
St. John	17,868	19,530	21,533	23,846
St. Tammany	46,874	56,117	67,592	81,823
Tangipahoa	56,397	59,666	63,168	66,756
Terrebonne	65,739	73,931	88,299	102,577
Washington	42,053	44,557	47,485	50,904
TOTAL	364,265	406,211	461,280	524,178

Table 98A. Participation activity of persons six years and older, Region 1A, part of coastal Louisiana (Comprehensive Outdoor Recreation Plan - 1970-75, Louisiana State Parks and Recreation Commission, July, 1971).

		REGION 1A			
ACTIVITY		1970 User Days	1975 User Days	1980 User Days	1985 User Days
Swimming - Pool	Summer 1/	4,872,650	5,769,010	7,001,435	8,682,095
	Summer Sunday	140,332	166,147	201,641	250,044
Beach	Summer	2,757,919	3,265,259	3,962,812	4,914,065
	Summer Sunday	79,428	94,039	114,125	141,525
Bicycling	Summer	6,012,850	7,118,958	8,639,770	10,713,705
	Summer Sunday	173,170	205,025	248,825	303,554
Driving for Pleasure	Summer	4,044,299	4,788,278	5,811,191	7,205,138
	Summer Sunday	116,475	137,902	167,362	207,536
Playing Outdoor Games	Summer	3,800,667	4,499,827	5,461,119	6,772,034
	Summer Sunday	109,459	129,595	157,250	195,074
Fishing	Summer	3,050,278	3,611,400	4,382,898	5,434,991
	Summer Sunday	87,848	104,008	126,227	156,527
Walking for Pleasure	Summer	2,718,938	3,219,107	3,906,800	4,844,609
	Summer Sunday	78,305	92,710	112,515	139,524
Sightseeing	Summer	2,358,362	2,792,200	3,388,694	4,202,133
	Summer Sunday	67,920	80,415	97,594	121,021
Attending Outdoor Sports Events	Summer	2,046,513	2,422,984	2,940,602	3,646,479
	Summer Sunday	58,939	69,781	84,689	105,018
Picnicking	Summer	1,744,408	2,065,305	2,506,513	3,108,190
	Summer Sunday	50,238	59,480	72,187	89,515
Motor Boating	Summer	1,676,191	1,984,539	2,408,493	2,986,640
	Summer Sunday	48,274	57,154	69,364	85,727
Hunting	Fall/winter	1,617,720	1,915,311	2,324,476	2,882,456
	Fall/winter Sunday	85,739	101,511	123,197	152,770
Camping - Trailer	Summer	760,153	899,765	1,092,223	1,354,406
	Summer Sunday	21,901	25,919	31,456	39,006
Camping - Tent	Summer	545,736	646,129	784,160	972,394
	Summer Sunday	15,717	18,608	22,583	28,004
Crabbing	Summer	799,114	946,117	1,148,235	1,423,863
	Summer Sunday	23,014	27,248	33,069	41,007
Horseback Riding	Summer	701,651	830,737	1,008,206	1,250,221
	Summer Sunday	20,207	23,925	29,036	36,006
Bird Watching	Summer	652,935	773,047	938,192	1,163,400
	Summer Sunday	18,804	22,263	27,019	33,505
Water Skiing	Summer	584,718	692,281	840,172	1,041,851
	Summer Sunday	16,839	19,937	24,196	30,005
Crawfishing	Summer	477,519	565,362	686,140	850,845
	Summer Sunday	13,752	16,282	19,760	24,504
Playing Golf	Summer	438,538	519,210	630,129	781,388
	Summer Sunday	12,629	14,953	18,147	22,503
Nature Walks	Summer	399,557	473,058	574,117	711,931
	Summer Sunday	11,507	13,624	16,534	20,503
Hiking	Summer	321,594	380,754	462,094	573,018
	Summer Sunday	9,261	10,965	13,308	16,502
Attending Outdoor Concerts, Plays	Summer	146,179	173,070	210,043	260,462
	Summer Sunday	4,209	4,984	6,049	7,501
Canoeing	Summer	136,434	161,532	196,040	243,098
	Summer Sunday	3,929	4,652	5,645	7,001
Sailing	Summer	68,217	80,766	98,020	121,549
	Summer Sunday	1,964	2,326	2,822	3,500

Table 98B. Participation activity of persons 6 years and older, Region 1B, part of coastal Louisiana (Comprehensive Outdoor Recreation Plan - 1970-75, Louisiana State Parks and Recreation Commission, July, 1971).

REGION 1B

ACTIVITY		1970 User Days	1975 User Days	1980 User Days	1985 User Days
Swimming - Pool	Summer	1,821,325	2,031,055	2,306,400	2,620,890
	Summer Sunday	52,454	58,494	66,424	75,481
Beach	Summer	1,030,869	1,149,577	1,305,422	1,483,423
	Summer Sunday	29,689	33,107	37,596	42,722
Bicycling	Summer	2,247,515	2,506,321	2,846,097	3,234,178
	Summer Sunday	64,728	72,182	81,967	93,144
Driving for Pleasure	Summer	1,511,699	1,685,775	1,914,312	2,175,338
	Summer Sunday	43,536	48,550	55,132	62,649
Playing Outdoor Games	Summer	1,420,633	1,584,222	1,798,992	2,044,294
	Summer Sunday	40,914	45,625	51,810	58,875
Fishing	Summer	1,140,149	1,271,440	1,443,806	1,640,677
	Summer Sunday	32,836	36,617	41,581	47,251
Walking for Pleasure	Summer	1,016,299	1,133,328	1,286,971	1,462,456
	Summer Sunday	29,269	32,639	37,064	42,118
Sightseeing	Summer	881,521	983,030	1,116,297	1,268,510
	Summer Sunday	25,387	28,311	32,149	36,533
Attending Outdoor Sports Events	Summer	764,956	853,043	968,688	1,100,773
	Summer Sunday	22,030	24,567	27,898	31,702
Picnicking	Summer	652,034	727,117	825,691	938,278
	Summer Sunday	18,778	20,940	23,779	27,022
Motor Boating	Summer	626,535	698,682	793,401	901,586
	Summer Sunday	18,044	20,122	22,849	25,965
Hunting	Fall/Winter	604,680	674,310	765,725	870,135
	Fall/Winter Sunday	32,048	35,738	40,583	46,117
Camping - Trailer	Summer	284,126	316,844	359,798	408,858
	Summer Sunday	8,182	9,125	10,362	11,775
Camping - Tent	Summer	203,988	227,478	258,316	293,539
	Summer Sunday	5,874	6,551	7,439	8,453
Crabbing	Summer	298,397	333,093	378,249	429,825
	Summer Sunday	8,602	9,593	10,893	12,378
Horseback Riding	Summer	262,270	292,471	332,121	377,408
	Summer Sunday	7,553	8,518	9,565	10,869
Bird Watching	Summer	244,057	272,161	309,057	351,199
	Summer Sunday	7,028	7,838	8,900	10,114
Water Skiing	Summer	218,559	243,726	276,768	314,506
	Summer Sunday	6,294	7,019	7,970	9,057
Crawfishing	Summer	178,489	199,043	226,027	256,847
	Summer Sunday	5,140	5,732	6,509	7,397
Playing Golf	Summer	163,919	182,794	207,576	235,880
	Summer Sunday	4,720	5,264	5,978	6,793
Nature Walks	Summer	149,348	166,546	189,124	214,912
	Summer Sunday	4,301	4,796	5,446	6,189
Hiking	Summer	120,207	134,049	152,222	172,978
	Summer Sunday	3,461	3,860	4,383	4,981
Attending Outdoor Concerts, Plays	Summer	54,639	60,931	69,192	78,626
	Summer Sunday	1,573	1,754	1,992	2,264
Canoeing	Summer	50,997	56,869	64,579	73,384
	Summer Sunday	1,468	1,637	1,859	2,113
Sailing	Summer	25,498	28,434	32,289	36,692
	Summer Sunday	734	818	929	1,056

Table 99. Rankings by hydrocarbon sediments and catches (extracted from Resources Technology Corporation, 1972).

	Miles From Rig	Sediment Hydrocarbon CCl_4 Extractable		
		N	NW	S
Sediment Distribution	1	3.20	2.80	2.75
	2	3.05	1.80	1.25
	3	2.50	2.75	2.60
	4	.70	.60	1.00
	5	1.10	1.00	1.00
	6	1.40	3.00	--
	7	1.70	1.25	--

		Simple Diversity			Mean Diversity		
		N	NW	W	N	NW	S
Composite Megafauna Diversity	1	10	20	20	1.25	.80	.75
	2	14	17	27	.65	.80	.80
	3	19	23	31	1.60	1.40	1.10
	4	19	16	18	1.15	1.20	.80
	5	18	18	18	1.45	1.00	1.15
	6	17	16	--	1.35	1.25	--
	7	12	14	--	.65	.80	--

		Composite Van Veen Crab Catch Data Count Per m^2		
		N	NW	S
Composite Crab Catch Data	1	2	12	11
	2	5	9	31
	3	48	9	18
	4	10	11	10
	5	16	15	8
	6	12	14	--
	7	4	39	--

		Counts Per m^2		
		N	NW	S
Composite Meiofaunal Mean	1	2	12	11
	2	4	9	28
	3	42	8	16
	4	8	10	9
	5	14	13	8
	6	11	12	--
	7	1	36	--

	Hydrocarbon Sediments Ranked With:			
	Simple Diversity	Mean Diversity	Crab	Composite Meiofauna
North Transect	-.6339	-.1339	-.4642	-.3571
Northwest Transect	+.2947	+.1786	-.1160	-.1517
South Transect	+.8929	+.4331	+.7679	+.7679

Table 100. Prevailing winds for January offshore Louisiana. See Figures 59, 60 and 61 for location (Texas Instruments, 1971a and b).

Direction (from)	Speed (knots)	Percent
North	10-16	23
Northeast	10-16	11
East	6-10	11
Southeast	6-10	16
South	6-10	15
Southwest	6-10	4
West	17-21	6
Northwest	10-16	14

Table 101. Yeast populations in Gulf of Mexico area following oil rig fire and spill[a] (Meyers, 1971).

TIME OF COLLECTION AFTER INITIAL EXPLOSION	CONCENTRATION OF YEASTS (CELL/100 ML)	IDENTIFICATION
2 WEEKS	66 - > 200	_RHODOTORULA/RHODOSPORIDIUM_
6 WEEKS	2 - > 500	_RHODOTORULA/RHODOSPORIDIUM_ _CANDIDA_ _TRICHOSPORON_
13 WEEKS	0 - 2	_TRICHOSPORON_ _CANDIDA_

---

[a] CONCENTRATIONS CALCULATED FROM APPROXIMATELY 30-40 SAMPLES OVER "CONTROL" AND OIL-CONTAMINATED REGION

Table 102. Results from employing minimum dilution method to estimate the relative abundance of aerobic oil-oxidizing bacteria in mud collected from oil-polluted areas of Barataria Bay and adjacent regions (Zobell and Prokop, 1966).

Results from employing minimum dilution method to estimate the relative abundance of aerobic oil-oxidizing bacteria in mud collected from oil-polluted areas of Barataria Bay and adjacent regions.

Total number of samples examined	84
Number in which oil-oxidizing bacteria were present	82
Number of samples having at least 10^2 oil oxidizers per gram	47
Number of samples having at least 10^3 oil oxidizers per gram	31
Number of samples having at least 10^4 oil oxidizers per gram	25
Number of samples having at least 10^5 oil oxidizers per gram	11
Number of samples having at least 10^6 oil oxidizers per gram	8

Results from employing the minimum dilution method to estimate the relative abundance of bacteria in mud samples from the Barataria Bay region which oxidized oil under strictly anaerobic conditions as indicated by sulfate reduction.

Total number of samples tested	100
Number of samples positive with 1.0 gram of wet mud	78
Number of samples positive with 0.1 gram of wet mud	36
Number of samples positive with 0.01 gram of wet mud	12

Table 103. Effect of crude oil on marsh plants and its persistence under natural field conditions on coast of Louisiana. The oil was retained in 16 ft^2 pens by 4 x 4 ft wooden bulkheads (Zobell, 1962).

	Amount of oil applied per pen				
	none	187 ml	375 ml	750 ml	1500 ml
Calculated amount of oil per acre (U.S. gallons)	0	134	269	539	1078
Time oil remained visible on water surface (days)	-	30	30	60	60
Time oil persisted in bottom mud (days)	-	60	60	100	180
Plants surviving in pen after 2 months (percent)	100	100	90	85	75
Plants surviving in pen after 1-year (percent)	100	100	100	50	10

Table 104. Yeast populations in marshland sediments before and after saturation with oil (Meyers, 1971).

Species	Per cent of total population[a]	
	Before	After
Pichia spartina	20-30	<10
P. saitoi	20-30	<10
Kluyveromyces drosophilarum	10-25	<10
P. ohmeri	<10	25-30 ←
Trichosporon sp.	<10	15-30 ←
Rhodotorula/ *Rhodosporidium*	<10	25-30 ←
Cryptococcus sp.	<15	<10
Sporobolomyces sp.	<15	<10
Mean Population	9000[b]	18300[b]

[a] based on colony differences and use of selective agar (Meyers et al., 1971).

[b] colony forming units per cc of sediment.

Table 105. Results of physical and chemical analysis performed by the E. W. Saybolt Company, Inc., on the test crude oils (Mills and Culley, 1972).

Property	Oil Number			
	Q-30	W-30	Q-4-D	W-4-D
Gravity, API at 60 F	33.5°	29.3°	32.3°	22.4°
Viscosity, S.U. at 100 F	45.4 sec	63.5 sec	50.4 sec	188.1 sec
Asphaltenes	NIL	NIL	NIL	NIL
Naphtha	23%	26%	14%	15%
Gas Oil 390-620 F	36%	24%	40%	22%
Heavy Distillate 620-760 F	27%	36%	36%	13%
Residuum	14%	14%	10%	50%
Sulfur ASTM D1551	0.22%	0.33%	0.30%	0.83%

Table 106A. Approximate 48-hour LC_0, LC_{50} and LC_{100} values for *Penaeus* shrimp and crude oil (ppt) (Mills and Culley, 1972).

Oil Number	LC_0	LC_{50}	LC_{100}
Q-30	<1.0	7.5	15.0
W-30	2.5	5.0-7.5	>10.0
W-4-D	10.0	40.0	50.0-75.0
Q-4-D	<1.0	1.0-2.5	7.5

Table 106B. Approximate 48-hour LC_0, LC_{50} and LC_{100} values for *Penaeus* shrimp and oil spill removers (ppm) (Mills and Culley, 1972).

Oil Spill Remover	LC_0	LC_{50}	LC_{100}
Corexit	500.0	5,000.0	>7,500.0
Ameroid	<0.5	2.5	5.0

Table 107A. Data on resultant current vectors in terms of speeds (cm/sec) and direction (degrees) for each grid of Figure 65 at 46,800 sec (13 hrs). Winds toward 280° at 7 m/sec.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0., 90.	23., 1.	0.,113.	0.,135.	0.,135.	0.,135.	0.,135.	0.,135.
2	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	59.,276.	59.,270.	0.,999.	57.,222.	118., 41.	39., 29.	19.,358.	14.,334.	11.,324.	7.,320.	0.,135.
3	0.,999.	0.,999.	0.,999.	0.,999.	66.,268.	78.,233.	22., 66.	62., 27.	53.,242.	87., 41.	62., 39.	40., 24.	28., 4.	23.,349.	18.,343.	11.,355.	0.,135.
4	0.,999.	0.,999.	0.,599.	61.,203.	13.,305.	51., 47.	39., 73.	51.,102.	106., 45.	59., 37.	42., 27.	35., 14.	30., 2.	26.,352.	24.,347.	13., 6.	0.,135.
5	0.,999.	0.,999.	0.,999.	80.,229.	53., 40.	45., 49.	40., 60.	31., 79.	47., 48.	44., 35.	38., 23.	34., 13.	29., 2.	24.,359.	30., 3.	13.,347.	0.,135.
6	0.,999.	0.,999.	59.,205.	39.,340.	40., 30.	40., 39.	29., 47.	22., 52.	31., 38.	35., 28.	34., 19.	31., 11.	28., 3.	25.,360.	24., 0.	15.,354.	0.,135.
7	0.,999.	0.,999.	81.,231.	62., 27.	44., 28.	36., 29.	25., 29.	23., 29.	28., 25.	37., 20.	30., 14.	28., 8.	26., 2.	23., 0.	20., 2.	15.,359.	0.,134.
8	0.,999.	59.,197.	42.,330.	45., 8.	40., 15.	33., 18.	28., 18.	27., 18.	28., 16.	29., 13.	29., 6.	25., 4.	24., 1.	21.,359.	16., 8.	13., 9.	0.,134.
9	0.,999.	68.,192.	50.,357.	47.,355.	41., 3.	35., 9.	31., 11.	30., 12.	30., 9.	29., 7.	29., 3.	25.,359.	23.,358.	22.,357.	14.,338.	9.,347.	0.,135.
10	0.,999.	63.,180.	61., 56.	58.,327.	45.,352.	39., 1.	35., 5.	32., 6.	32., 6.	30., 3.	29.,359.	27.,353.	23.,350.	16.,350.	13.,340.	8.,319.	0.,135.
11	0.,999.	0.,999.	57.,182.	60.,359.	49.,351.	43.,354.	38.,358.	35., 1.	33., 2.	32., 9.	30.,355.	28.,351.	27.,345.	17.,326.	9.,322.	9.,313.	0.,135.
12	0.,999.	0.,999.	59.,180.	67., 52.	53.,331.	47.,341.	43.,350.	39.,355.	36.,358.	33.,357.	31.,354.	29.,348.	26.,343.	20.,334.	16.,284.	10.,298.	0.,135.
13	0.,999.	0.,999.	0.,999.	49.,180.	67., 48.	57.,326.	50.,338.	44.,347.	39.,354.	35.,356.	32.,353.	30.,349.	28.,341.	19.,315.	11.,306.	9.,310.	0.,134.
14	0.,999.	0.,999.	0.,999.	0.,999.	49.,180.	70., 45.	62.,324.	54.,336.	43.,350.	38.,356.	34.,354.	30.,348.	27.,342.	21.,330.	14.,294.	10.,299.	0.,135.
15	0.,999.	0.,999.	0.,599.	0.,999.	0.,999.	48.,180.	69., 41.	76.,320.	49.,346.	41.,357.	35.,356.	32.,350.	29.,340.	23.,326.	15.,296.	10.,306.	0.,134.
16	0.,999.	0.,999.	0.,599.	0.,999.	0.,999.	0.,999.	54.,187.	81.,347.	55.,356.	43.,360.	36.,357.	32.,352.	29.,344.	24.,330.	17.,305.	11.,303.	0.,135.
17	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	69.,196.	77.,349.	55., 3.	43., 4.	37.,360.	32.,350.	28.,346.	23.,333.	17.,317.	11.,315.	0.,135.
18	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	69.,197.	73.,350.	52., 5.	41., 8.	35., 3.	33.,357.	26.,346.	23.,337.	17.,324.	11.,324.	0.,135.
19	0.,999.	0.,999.	0.,599.	0.,999.	0.,999.	0.,999.	65.,198.	70.,349.	48., 4.	38., 14.	33., 11.	30., 2.	25.,352.	21.,340.	16.,330.	10.,329.	0.,135.
20	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	60.,196.	68.,351.	48., 14.	34., 21.	29., 22.	26., 11.	20.,356.	17.,346.	13.,336.	8.,333.	0.,135.
21	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	59.,194.	60.,357.	42., 37.	31., 44.	22., 41.	17., 27.	14., 7.	11.,347.	9.,332.	5.,321.	0.,135.
22	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	6., 90.	23., 1.	0.,105.	0.,132.	0.,133.	0.,134.	0.,134.	0.,134.	0.,135.	0.,135.	0.,135.

Table 107B. Data on resultant current vectors in terms of speeds (cm/sec) and direction (degrees) for each grid of Figure 65 at 61,200 sec (17 hrs). Winds toward 280° at 7 m/sec.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0., 90.	12., 1.	0.,125.	0.,135.	0.,135.	0.,135.	0.,135.	0.,135.
2	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	42.,277.	42.,270.	0.,999.	30.,219.	85., 51.	40., 56.	22., 56.	13., 50.	8., 39.	4., 23.	0.,135.
3	0.,999.	0.,999.	0.,999.	0.,999.	46.,269.	49.,234.	19., 71.	44., 37.	18.,233.	71., 53.	55., 61.	38., 58.	25., 51.	17., 42.	11., 33.	7., 32.	0.,135.
4	0.,999.	0.,999.	0.,999.	41.,210.	10.,313.	39., 50.	33., 81.	45.,104.	86., 51.	43., 58.	34., 62.	30., 55.	25., 47.	19., 39.	15., 26.	10., 39.	0.,135.
5	0.,999.	0.,999.	0.,999.	51.,231.	39., 43.	35., 57.	33., 75.	32., 92.	42., 65.	37., 61.	33., 57.	30., 51.	25., 46.	21., 43.	22., 33.	9., 28.	0.,135.
6	0.,999.	0.,999.	39.,213.	29.,343.	30., 38.	32., 52.	25., 71.	23., 84.	30., 67.	32., 59.	31., 53.	29., 49.	26., 44.	22., 42.	19., 37.	11., 30.	0.,135.
7	0.,999.	0.,999.	52.,235.	46., 27.	33., 36.	28., 45.	22., 58.	22., 63.	27., 57.	29., 52.	30., 48.	28., 47.	26., 45.	23., 44.	18., 44.	12., 40.	0.,135.
8	0.,999.	39.,205.	33.,329.	34., 11.	30., 25.	26., 35.	24., 43.	25., 47.	27., 46.	29., 45.	30., 43.	28., 43.	26., 43.	23., 44.	19., 49.	10., 44.	0.,135.
9	0.,999.	44.,198.	37.,354.	34.,359.	31., 13.	28., 25.	27., 33.	28., 38.	29., 38.	30., 38.	31., 37.	29., 38.	27., 39.	25., 42.	15., 46.	7., 35.	0.,135.
10	0.,999.	40.,180.	39., 49.	40.,331.	33., 1.	30., 16.	30., 25.	30., 31.	32., 34.	32., 35.	32., 34.	31., 33.	30., 32.	23., 33.	10., 25.	6.,354.	0.,135.
11	0.,999.	0.,999.	34.,188.	42.,359.	35.,359.	32., 8.	32., 17.	32., 24.	33., 29.	33., 31.	33., 31.	33., 29.	31., 25.	19., 23.	10., 19.	8.,348.	0.,135.
12	0.,999.	0.,999.	37.,180.	43., 49.	35.,338.	33.,353.	33., 8.	34., 18.	34., 24.	35., 28.	35., 28.	34., 27.	31., 24.	23., 25.	9.,359.	11.,340.	0.,135.
13	0.,999.	0.,999.	0.,999.	29.,180.	43., 46.	37.,336.	35.,353.	35., 7.	35., 19.	36., 24.	35., 26.	35., 24.	33., 17.	18., 6.	9., 7.	14.,353.	0.,134.
14	0.,999.	0.,999.	0.,999.	0.,999.	29.,180.	44., 44.	39.,334.	37.,351.	36., 12.	37., 21.	36., 23.	34., 22.	31., 18.	24., 13.	9.,354.	15.,358.	0.,134.
15	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	28.,180.	43., 40.	48.,329.	37., 4.	37., 20.	36., 23.	34., 21.	31., 15.	23., 7.	12.,358.	16., 7.	0.,134.
16	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	32.,192.	53.,348.	40., 7.	36., 19.	35., 23.	33., 22.	30., 17.	24., 12.	16., 7.	16., 9.	0.,134.
17	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	46.,202.	50.,349.	39., 11.	35., 22.	33., 25.	31., 22.	29., 22.	24., 16.	19., 14.	16., 13.	0.,134.
18	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	47.,205.	48.,348.	36., 12.	32., 25.	30., 29.	31., 27.	26., 24.	24., 20.	20., 17.	15., 14.	0.,134.
19	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	44.,207.	46.,345.	32., 12.	30., 32.	30., 37.	27., 33.	24., 29.	22., 23.	18., 18.	14., 16.	0.,134.
20	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	41.,207.	44.,348.	32., 23.	27., 42.	27., 49.	24., 45.	21., 38.	18., 31.	16., 26.	12., 20.	0.,134.
21	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	39.,201.	36.,356.	29., 49.	28., 64.	25., 69.	22., 66.	17., 58.	14., 48.	10., 36.	7., 27.	0.,135.
22	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0., 90.	12., 1.	0.,121.	0.,132.	0.,133.	0.,133.	0.,134.	0.,134.	0.,134.	0.,135.	0.,135.

Table 107C. Data on resultant current vectors in terms of speeds (cm/sec) and direction (degrees) for each grid of Figure 65 at 72,000 sec (20 hrs). Winds toward 280° at 7 m/sec.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0., 90.	1.,162.	0.,135.	0.,135.	0.,135.	0.,135.	0.,135.	0.,135.
2	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	18.,287.	17.,270.	0.,999.	3., 70.	28., 74.	24., 77.	18., 80.	12., 80.	7., 76.	3., 68.	0.,135.
3	0.,999.	0.,999.	0.,999.	0.,999.	17.,284.	9.,281.	7., 39.	12., 54.	11., 52.	31., 68.	28., 84.	24., 84.	18., 84.	12., 83.	7., 80.	3., 76.	0.,135.
4	0.,999.	0.,999.	0.,999.	14.,262.	10.,320.	16., 38.	13., 74.	18.,103.	34., 58.	19., 87.	20., 94.	20., 87.	17., 82.	13., 80.	8., 75.	4., 75.	0.,135.
5	0.,999.	0.,999.	0.,999.	11.,280.	15., 29.	14., 54.	14., 82.	17.,102.	20., 83.	20., 88.	20., 88.	20., 83.	17., 79.	14., 78.	10., 71.	4., 73.	0.,135.
6	0.,999.	0.,999.	14.,272.	17.,339.	13., 30.	14., 58.	13., 87.	14.,102.	18., 89.	19., 85.	20., 81.	19., 78.	17., 76.	14., 75.	10., 72.	5., 71.	0.,135.
7	0.,999.	0.,999.	14.,289.	20., 15.	15., 34.	13., 56.	12., 79.	14., 86.	17., 80.	19., 77.	20., 74.	19., 74.	18., 73.	15., 72.	11., 75.	6., 75.	0.,135.
8	0.,999.	15.,267.	20.,325.	17., 1.	14., 26.	13., 48.	14., 63.	15., 69.	18., 69.	20., 67.	20., 66.	20., 67.	19., 68.	17., 69.	12., 70.	5., 80.	0.,135.
9	0.,999.	14.,262.	21.,336.	17.,352.	15., 17.	15., 38.	16., 51.	18., 57.	19., 58.	21., 59.	22., 59.	21., 66.	20., 60.	19., 64.	13., 72.	4., 69.	0.,135.
10	0.,999.	3.,180.	16.,345.	19.,332.	15., 6.	16., 29.	17., 42.	19., 50.	21., 53.	23., 55.	24., 55.	24., 54.	24., 51.	18., 51.	7., 60.	3., 24.	0.,136.
11	0.,999.	0.,999.	12.,282.	19.,344.	16., 2.	16., 22.	18., 35.	20., 43.	22., 48.	24., 50.	25., 51.	25., 49.	24., 45.	17., 46.	8., 43.	5., 5.	0.,135.
12	0.,999.	0.,999.	2.,180.	13., 2.	15.,345.	15., 10.	18., 28.	21., 38.	23., 44.	25., 46.	26., 47.	26., 46.	25., 43.	19., 47.	9., 41.	8.,357.	0.,135.
13	0.,999.	0.,999.	0.,999.	2., 0.	12., 5.	14.,353.	16., 16.	19., 30.	23., 39.	25., 43.	27., 43.	27., 41.	26., 34.	15., 31.	8., 39.	11., 4.	0.,134.
14	0.,999.	0.,999.	0.,999.	0.,999.	1., 0.	12., 9.	14.,355.	18., 17.	21., 33.	25., 39.	26., 41.	26., 39.	25., 35.	20., 32.	8., 32.	14., 11.	0.,134.
15	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	1., 0.	12.,356.	16.,351.	19., 26.	23., 37.	25., 39.	26., 37.	25., 32.	18., 28.	11., 28.	15., 19.	0.,134.
16	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	11.,280.	18.,342.	18., 19.	21., 35.	23., 39.	24., 37.	23., 34.	19., 32.	15., 31.	10., 24.	0.,134.
17	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	17.,263.	18.,332.	16., 15.	19., 36.	21., 41.	22., 39.	23., 39.	20., 35.	18., 33.	15., 27.	0.,134.
18	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	20.,263.	19.,325.	14., 9.	16., 36.	18., 45.	21., 42.	20., 41.	19., 37.	18., 34.	14., 27.	0.,135.
19	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	21.,265.	20.,318.	11., 3.	14., 44.	17., 51.	18., 49.	17., 45.	17., 38.	15., 33.	13., 27.	0.,135.
20	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	21.,266.	17.,315.	9., 12.	12., 56.	15., 64.	15., 62.	15., 54.	15., 46.	14., 38.	10., 29.	0.,135.
21	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	15.,263.	10.,318.	6., 49.	12., 78.	15., 82.	15., 79.	13., 71.	12., 60.	9., 51.	7., 37.	0.,135.
22	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0., 90.	1.,162.	0.,135.	0.,134.	0.,134.	0.,134.	0.,134.	0.,134.	0.,135.	0.,135.	0.,135.

Table 107D. Data on resultant current vectors in terms of speeds (cm/sec) and direction (degrees) for each grid of Figure 65 at 79,200 (22 hrs). Winds toward 280° at 7 m/sec.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0., 90.	9.,179.	0.,141.	0.,135.	0.,135.	0.,135.	0.,135.	0.,135.
2	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	11., 67.	10., 90.	0.,999.	25., 43.	27.,193.	14.,120.	13.,103.	13.,109.	6., 99.	2.,102.	0.,135.
3	0.,999.	0.,999.	0.,999.	0.,999.	19., 63.	33., 38.	8.,339.	20.,197.	26., 51.	14.,175.	16.,152.	15.,129.	14.,120.	12.,119.	6.,123.	2.,150.	0.,135.
4	0.,999.	0.,999.	0.,999.	29.,352.	10.,346.	8.,293.	7.,301.	5.,290.	11.,201.	14.,169.	16.,146.	15.,130.	13.,123.	10.,124.	7.,132.	3.,163.	0.,135.
5	0.,999.	0.,999.	0.,999.	35., 30.	8.,301.	5.,290.	2.,248.	3.,161.	8.,158.	12.,149.	14.,136.	14.,126.	12.,127.	9.,122.	7.,146.	3.,144.	0.,135.
6	0.,999.	0.,999.	30.,353.	8.,351.	5.,317.	1.,286.	4.,145.	7.,138.	9.,136.	12.,132.	13.,125.	13.,118.	12.,117.	9.,120.	7.,135.	4.,151.	0.,135.
7	0.,999.	0.,999.	36., 28.	8.,302.	3.,322.	2., 94.	5.,120.	8.,121.	10.,120.	11.,116.	12.,112.	13.,109.	12.,109.	9.,113.	6.,126.	4.,146.	0.,135.
8	0.,999.	32.,342.	10.,337.	8.,322.	3.,349.	3., 75.	6., 98.	8.,103.	10.,102.	12.,101.	13., 99.	13., 97.	12.,100.	10.,103.	6.,111.	3.,157.	0.,135.
9	0.,999.	37.,343.	13.,305.	7.,323.	4., 1.	5., 62.	7., 81.	9., 86.	11., 88.	12., 89.	13., 87.	13., 86.	12., 87.	11., 94.	8., 97.	2.,124.	0.,135.
10	0.,999.	32., 0.	31.,289.	5.,345.	4., 7.	5., 55.	8., 70.	11., 77.	13., 79.	14., 80.	15., 80.	15., 78.	15., 73.	11., 73.	4.,101.	1., 86.	0.,135.
11	0.,999.	0.,999.	36.,336.	9.,279.	3.,338.	5., 55.	9., 66.	11., 70.	14., 73.	15., 74.	16., 74.	17., 71.	15., 68.	12., 66.	5., 64.	2., 18.	0.,135.
12	0.,999.	0.,999.	30., 0.	26.,280.	2., 22.	5., 65.	8., 69.	12., 69.	14., 70.	16., 69.	17., 69.	18., 66.	16., 63.	13., 66.	8., 60.	4., 8.	0.,135.
13	0.,999.	0.,999.	0.,999.	27., 0.	24.,272.	5., 87.	8., 77.	11., 72.	13., 69.	16., 67.	17., 64.	18., 62.	17., 53.	11., 52.	6., 59.	6., 10.	0.,135.
14	0.,999.	0.,999.	0.,999.	0.,999.	26., 0.	22.,266.	8., 95.	10., 82.	12., 71.	15., 66.	16., 61.	17., 57.	16., 52.	13., 48.	6., 51.	8., 18.	0.,135.
15	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	25., 0.	24.,264.	12.,102.	9., 80.	12., 67.	15., 61.	16., 55.	16., 49.	12., 45.	8., 44.	10., 26.	0.,135.
16	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	32.,338.	10.,194.	3.,121.	8., 70.	12., 61.	14., 54.	14., 49.	13., 47.	11., 44.	11., 31.	0.,135.
17	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	36.,339.	12.,219.	4.,212.	5., 73.	9., 65.	12., 57.	14., 52.	13., 48.	12., 43.	11., 33.	0.,135.
18	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	37.,335.	14.,230.	7.,236.	2.,107.	7., 71.	10., 59.	11., 54.	12., 47.	12., 41.	10., 32.	0.,135.
19	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	37.,332.	17.,235.	9.,239.	2.,209.	5., 80.	8., 67.	9., 56.	11., 45.	10., 38.	9., 30.	0.,135.
20	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	36.,329.	18.,232.	13.,237.	4.,222.	3.,115.	5., 83.	7., 63.	8., 49.	9., 39.	7., 29.	0.,135.
21	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	31.,332.	18.,221.	16.,244.	7.,234.	2.,147.	4., 99.	5., 78.	6., 60.	6., 48.	5., 33.	0.,135.
22	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0., 90.	9.,179.	0.,143.	0.,136.	0.,135.	0.,135.	0.,135.	0.,135.	0.,135.	0.,135.	0.,135.

Table 107E. Data on resultant current vectors in terms of speeds (cm/sec) and direction (degrees) for each grid of Figure 65 at 93,600 (26 hrs). Winds toward 280° at 7 m/sec.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0., 90.	23.,180.	0.,148.	0.,135.	0.,135.	0.,135.	0.,135.	0.,135.
2	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	44., 90.	44., 90.	0.,999.	54., 33.	111.,222.	33.,214.	13.,194.	7.,187.	4.,188.	2.,211.	0.,135.
3	0.,999.	0.,999.	0.,999.	0.,999.	56., 80.	77., 46.	26.,271.	62.,284.	45., 45.	80.,228.	58.,226.	34.,215.	2.,202.	14.,196.	9.,201.	7.,219.	0.,135.
4	0.,999.	0.,999.	0.,999.	61., 9.	6.,352.	42.,245.	40.,272.	51.,285.	92.,229.	49.,226.	35.,219.	28.,210.	22.,204.	17.,202.	14.,201.	10.,225.	0.,135.
5	0.,999.	0.,999.	0.,999.	80., 40.	38.,247.	37.,250.	35.,262.	33.,271.	42.,237.	37.,226.	32.,217.	28.,210	23.,208.	18.,217.	21.,212.	9.,218.	0.,135.
6	0.,999.	0.,999.	62., 10.	14.,169.	27.,240.	31.,244.	24.,253.	20.,257.	27.,234.	29.,222.	28.,215.	25.,211.	23.,210.	20.,214.	19.,217.	11.,219.	0.,135.
7	0.,999.	0.,999.	82., 41.	38.,225.	29.,234.	24.,237.	18.,240.	18.,235.	22.,224.	24.,216.	25.,212.	23.,211.	22.,212.	21.,218.	18.,225.	14.,229.	0.,136.
8	0.,999.	63.,358.	12.,150.	23.,219.	23.,227.	20.,228.	18.,226.	18.,221.	20.,215.	22.,211.	23.,207.	21.,209.	21.,211.	20.,218.	19.,228.	10.,234.	0.,135.
9	0.,999.	74.,357.	23.,214.	20.,207.	21.,215.	19.,217.	18.,215.	19.,213.	20.,207.	21.,204.	21.,202.	20.,203.	21.,208.	21.,215.	14.,227.	7.,231.	0.,135.
10	0.,999.	69., 0.	60.,266.	21.,156.	21.,199.	20.,207.	20.,207.	19.,205.	20.,203.	20.,200.	21.,198.	20.,197.	21.,199.	18.,205.	9.,208.	5.,206.	0.,135.
11	0.,999.	0.,999.	69.,346.	33.,209.	24.,200.	22.,199.	21.,199.	20.,199.	20.,198.	20.,195.	20.,193.	20.,192.	2.,191.	13.,192.	8.,204.	6.,195.	0.,136.
12	0.,999.	0.,999.	64., 0.	61.,258.	21.,172.	22.,182.	23.,189.	22.,192.	21.,193.	20.,192.	19.,191.	19.,189.	18.,190.	14.,197.	6.,194.	7.,184.	0.,136.
13	0.,999.	0.,999.	0.,999.	58., 0.	61.,253.	26.,159.	25.,173.	24.,182.	22.,189.	21.,190.	19.,190.	19.,188.	18.,185.	10.,177.	5.,198.	9.,190.	0.,136.
14	0.,999.	0.,999.	0.,999.	0.,999.	57., 0.	62.,248.	31.,153.	30.,166.	25.,185.	23.,192.	20.,192.	17.,190.	15.,188.	11.,188.	4.,194.	10.,196.	0.,136.
15	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	57., 0.	64.,245.	45.,144.	29.,182.	25.,197.	21.,198.	18.,196.	15.,191.	10.,189.	6.,197.	10.,201.	0.,136.
16	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	66.,347.	53.,182.	36.,196.	28.,205.	22.,207.	18.,205.	14.,201.	10.,201.	8.,207.	9.,206.	0.,136.
17	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	75.,355.	50.,191.	39.,208.	32.,216.	24.,217.	19.,215.	15.,217.	11.,215.	9.,216.	8.,212.	0.,136.
18	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	74.,354.	48.,196.	39.,214.	32.,223.	26.,227.	23.,227.	16.,228.	12.,227.	10.,226.	7.,219.	0.,136.
19	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	70.,351.	47.,201.	39.,221.	36.,234.	30.,238.	24.,239.	18.,240.	14.,239.	10.,238.	7.,230.	0.,136.
20	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	65.,349.	48.,205.	44.,231.	38.,244.	33.,249.	26.,252.	2.,251.	15.,252.	11.,250.	6.,242.	0.,135.
21	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	64.,348.	45.,207.	53.,249.	46.,257.	37.,262.	29.,263.	23.,262.	16.,262.	11.,262.	6.,254.	0.,135.
22	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0.,999.	0., 99.	23.,180.	0.,151.	0.,139.	0.,138.	0.,137.	0.,137.	0.,136.	0.,136.	0.,135.	0.,135.

Table 108. Summary of wind conditions and types of oil spills used at C_1 and C_2 (see Figure 1) used with Hansen's model for projecting the distribution and abundances of hypothetical spills. See Figures 68 to 78.

Wind toward (at 7 m/sec)	Spilled at C_1		Spilled at C_2	
	500 ton	30,000 ton	500 ton	30,000 ton
225°		thru 20 hrs Fig. 68	thru 10 hrs Fig. 69	thru 10 hrs Fig. 70
280°		thru 20 hrs Fig. 71	thru 30 hrs Fig. 72	thru 30 hrs Fig. 73
315°	thru 20 hrs Fig. 74	thru 20 hrs Fig. 75	thru 20 hrs Fig. 76	thru 20 hrs Fig. 77
360°		thru 20 hrs Fig. 78A		thru 20 hrs Fig. 78B

Table 109. Monthly wind vectors offshore of Grand Isle, Louisiana, and beaching times based on 3.7% of wind drift (wind data extracted from Scruton, 1956).

Month	Dir.*	Knots Speed	3.7% of Speeds	Knots	Site #1			C #1			Site #2			C #2		
					NM	Hrs	Days	NM	Hrs	Days	NM	Hrs	Days	NM	Hrs	Days
Jan	200	3.3	0.12													
Feb	240	2.1	0.08													
Mar	285	2.2	0.08								22.6	283	11.8	18.7	234	9.8
April	300	4.7	0.17		42.5	250	10.4	30.0	176	7.3	16.1	95	4.0	14.3	84	3.5
May	325	3.9	0.14		28.2	201	8.4	20.0	143	6.0	14.0	100	4.2	11.5	82	3.4
June	355	3.1	0.12		22.9	190	7.9	17.5	146	6.1	17.1	143	6.0	14.5	121	5.0
July	10	1.3	0.05		25.0	500	20.8	19.2	384	16.0	20.3	406	16.9	18.5	370	15.4
Aug	318	2.2	0.08		30.0	375	15.6	24.0	300	12.5	14.0	175	7.3	11.4	143	6.0
Sept	270	2.9	0.11													
Oct	235	3.4	0.12													
Nov	255	1.4	0.05													
Dec	205	3.0	0.11													
Annual	280	1.9	0.07								35.5	507	21.1	32.6	466	19.4

*wind blowing towards

Table 110. Area of visible influence of various levels of a continuous oil spill (Ichiye, 1972).

Barrels Per Day	Initial Plume Width		Final(1) Plume Width		Time Required in Hrs(2)			Length km	Area (km)^2
	ft	m	ft	m	D_y=50	D_y=100	D_y=200		
1.2	200	60	2,000	600	1	0.5	0.2	0.5	0.2
2.3	400	120	4,000	1,200	4	2.0	1.0	2.2	1.4
4.2	600	180	6,000	1,800	9	4.0	2.0	5.0	5.0
8.5	1,300	400	13,000	4,000	44	21.0	11.0	24.0	53.0