ASSESSMENT OF EXTENT AND IMPACT OF SALTWATER INTRUSION INTO THE WETLANDS OF TANGIPAHOA PARISH, LOUISIANA

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FINAL REPORT

Prepared for
Tangipahoa Parish Police Jury

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CHAPTER I: INTRODUCTION

Statement of Problem

It has been reported that the salinity of water bodies in the wetlands of southern Tangipahoa Parish has increased gradually over the last 20 to 30 years. Local trappers and fishermen report a decline in harvests of freshwater species as a result of the change in salinity values. A comparison of photographs taken in 1955/56 and 1976/78 shows that large expanses of cut-over cypress forest near Pass Manchac have not experienced successful natural regeneration. In many cases, the cypress appear stressed or dead, and marsh vegetation has replaced the cypress forest in many areas. There is speculation that these changes are a result of rising, year-round levels of salinity that have penetrated into the extensive cypress forest through unblocked logging canals.

Before this study, there had been no analysis of existing data to substantiate the increase in salinity values in Tangipahoa Parish. There was no documentation of the extent and severity of the impact of saltwater intrusion on fish and furbearer harvests in the area. No studies had been conducted to establish the relationships between vegetative composition and vigor in the wetlands and increasing water and soil salinities. Furthermore, no baseline data had been compiled for the area which could be used to evaluate environmental changes and to predict future trends in renewable resource use and development. Such studies are essential to formulate plans for prudent utilization of the abundant natural resources in southern Tangipahoa Parish.

Objectives

The purpose of this study is to determine the extent and severity of saltwater intrusion into the wetlands in the southern portion of Tangipahoa Parish. The primary objective is to collect baseline environmental data so that recommendations to alleviate present environmental problems can be made. A secondary objective is to conduct a basic scientific investigation of salinity-induced mortality in freshwater swamps, which has not been attempted in Louisiana.

Scope-of-Work

The study consisted of two major tasks which were carried out concurrently. Task I involved the gathering of published data on past environmental conditions in the Tangipahoa Parish coastal region. These data were used as the base of comparison from which to assess the extent and severity of recent environmental changes. Task II examined present environmental conditions through a field study consisting of water, soil, and vegetation sampling. Recently published data and aerial photographs provided additional data for the interpretation of present environmental conditions.

In Task I, daily chlorinity (salinity) values for Pass Manchac at the La. 51 bridge for 1951-1979 were obtained from the New Orleans District, U.S. Army Corps of Engineers (USACE). The USACE also furnished daily A.M. and P.M. stage readings for Pass Manchac for 1961-1977. Mean monthly discharge records were retrieved for the Tickfaw River (1941-1980) and the Tangipahoa River (1939-1980) from the U.S. Geological Survey (USGS), Water Resources Division. Wind speed and direction were obtained from the National Oceanic and Atmospheric Administration (NOAA) Monthly Climatological Summaries for New Orleans International Airport (1971-1977).

After reconnaissance of the study area from boat, a single, low-elevation fly-over from fixed-wing aircraft, and careful study of aerial photographs, three general vegetative zones were delineated based on degree of coverage of emergent and woody vegetation (trees and shrubs) and apparent age of the stand. Change in vegetative cover was documented by mapping vegetative zones for 1955/56 and 1976/78, measuring the habitat area for each year, and comparing the measurements to determine areal change. One zone was predominantly marsh vegetation with little tree cover; the second zone consisted of herbaceous marsh plants interspersed with a sparse cover of shrubs and young trees; and the third zone was a fairly closed canopy baldcypress (*Taxodium distichum*) forest. There are intergradations of these zones at the ecotones where they meet.

During Task II, selected water quality parameters were monitored once a month at 20 sites within the study area (June 1980-May 1981). Temperature, dissolved oxygen (DO), specific conductance (salinity), pH, secchi depth (water clarity), water level, and current speed and direction were measured at each station.

Vegetative sampling was conducted during 1980 along transects located in each of the zones identified in Task I. Circular plots were established every 100 ft, and diameters of all trees and shrubs were measured in 14 plots along each transect. Percentage cover of herbaceous species was also estimated at each sampling site. In addition, at every fifth sampling site along a transect, a soil core approximately 15 in in length was taken along with a sample of free soil water from the resulting soil cavity. Soil analysis included testing for soil salinities and percentage organic content.

The final element of Task II was to synthesize and evaluate the data on hydrology and vegetation in order to establish a relationship between changes in hydrologic conditions and vegetation composition. Once this was done, general recommendations were made to retard and/or prevent undesirable changes in the distribution of vegetation, especially the displacement of cypress swamps by marsh and marsh/shrub communities.

CHAPTER II: DESCRIPTION OF STUDY AREA

Location and Physical Setting

The study area is located within the Pontchartrain Basin of east central Louisiana and contains all the wetlands in the southern extremity (about 20%) of Tangipahoa Parish (Figure 2-1). The area is situated north of Lakes Maurepas and Pontchartrain and Pass Manchac and south of the Pleistocene Prairie Terrace. The site is bounded on the west by the Natalbany and Tickfaw Rivers and on the east by the Tangipahoa-St. Tammany Parish border (Plate 1).

The major physiographic feature of the area is the low-lying, low-relief, wetland habitat that grades from cypress-tupelogum (Nyssa spp.) swamps south of the terrace through a swamp-marsh ecotone of scrub-shrubs to the fresh-to-intermediate marshes of the southern and eastern portions of the parish. This swamp-marsh environment is rarely more than 1 ft above mean Gulf level (MGL), but it does reach 2 to 3 ft near the terrace, and the local relief seldom exceeds 1 ft (Saucier 1963). The southernmost portion of the Tangipahoa wetlands consists of a low-lying island separated from the rest of the parish by North Pass. The perimeter of the island is a fresh-to-intermediate marsh, while the interior consists of a marsh-shrub habitat.

Natural levees, while present, are not exceedingly prominent features in the Tangipahoa wetlands. Some of the smaller bayous, which experience occasional flooding, have levees 6 to 12 in high, while larger rivers, such as the Tangipahoa, have levees 2 to 4 ft high, and 200 to 300 ft wide (Saucier 1963). These higher levees, especially along the lower Tangipahoa River near its junction with Lake Pontchartrain, support linear recreation developments. There are sand-shell beaches along portions of the Lake Pontchartrain shoreline at the eastern side of the study area, but they are relatively narrow, low, and discontinuous.

The area is largely undeveloped. Camps are located on the higher levees along many of the larger channels, such as the Tangipahoa, Tickfaw, and Natalbany Rivers, and along Stinking Bayou, North Pass, and Pass Manchac. A linear settlement has developed between the Illinois Central Railroad and U.S. 51 at Strader, north of North Pass, and at Manchac near Pass Manchac. The railroad and U.S. 51 were constructed on grade and served to segment the study area into two units, the eastern portion

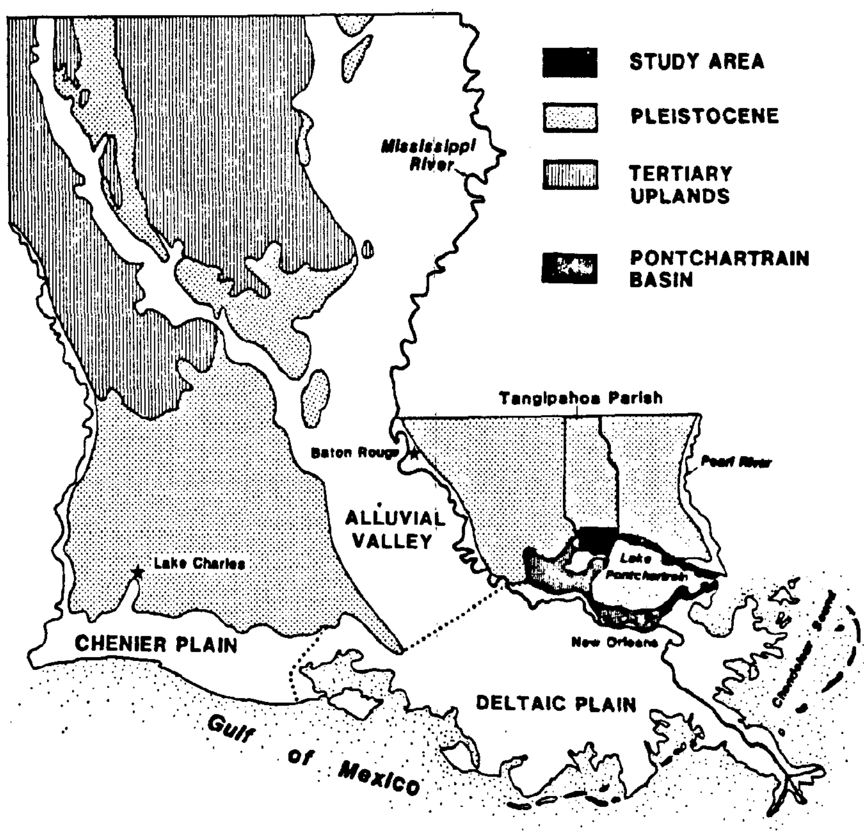

Figure 2-1. Location of study area - Tangipahoa Parish Wetlands.

being about twice as large as the western section. The dredging of a major borrow pit canal during construction of the elevated Interstate 55 (I-55) in the late 1970s, and dredging of smaller canals perpendicular to it, have resulted in a recent proliferation of camp sites on the excavated spoil in the vicinity of Strader and Manchac. The Port of Tangipahoa Parish is located south of Strader on the north bank of North Pass, east of the railroad. The median strip separating U.S. 51 and I-55, between Manchac and Strader, is being improved for parking, and boat ramps have been built near the highway at Pass Manchac and North Pass. Another boat launch exists at Lee's landing, south of the terrace on the east bank of the Tangipahoa River.

West of I-55, water drains from the terrace to Lake Maurepas through waterways such as the Pontchatoula, Natalbany, and Tickfaw Rivers or the Anderson Canal, the I-55 borrow canal, and Owl Bayou (Plate 1). The slightly elevated, continuous beach ridge along the north shore of Lake Maurepas prohibits excessive drainage directly into the lake from the swamp environments. East of I-55, Bedico Creek and the Tangipahoa River convey runoff from the terrace and wetlands to Lake Pontchartrain. Stinking Bayou, Middle Bayou, and the Marlin Canal drain the lower portion of the wetlands into North Pass and Pass Manchac. The swamp and marsh environment is also extensively dissected by various types of logging canals and scars that permit ingress and egress of waters from the lakes and channels into the wetland interior.

Geology and Soils

Geologic Forms and Processes

The wetlands of Tangipahoa Parish are located along the north central portion of the Pontchartrain Basin, just south of the Pleistocene Prairie Terrace (Plate 2). The Pleistocene Terrace consists of the Prairie Deltaic Plain which reached its maximum development about 60,000 years before present (B.P.) (Saucier 1963). Around 55,000 to 60,000 years B.P., during the Wisconsin glacial stage, sea level began to fall and the Prairie formation was subjected to downwarping and faulting (Saucier 1963). During this period of lowering sea level, which, at its lowest level reached - 450 ft below the present stage, streams became entrenched on the Pleistocene Prairie Terrace and the surface was subjected to erosion, oxidation, and consolidation (Saucier 1963).

As the Wisconsin glacial stage waned, sea level rose, gradually covering the previously exposed Prairie formation (Figure 2-2) until it reached a still-stand near the present level about 5000 years B.P. (Saucier 1963). During the last 40 ft of sea level rise, two major barrier spit beaches (Miltons Island Trend and Pine Island Trend) accreted westward into the embayment from the mouth of the Pearl River. This period also marked the maximum extent of the Pontchartrain embayment (Figure 2-3) (Saucier 1963). As sea level neared its present level, the Mississippi River alluviated its formerly entrenched river valley and extended its course seaward via delta progradation. Between 4600 and 3500 years B.P., the Mississippi River-Cocodrie delta complex introduced sediment into the embayment, separating it from the Gulf of Mexico (Figure 2-4). At this stage, the water body that eventually became Lake Pontchartrain began to evolve from a marine to a lacustrine environment (Saucier 1963). At this time, Lake Maurepas was not formed, and rivers drained through the Pontchartrain Basin to the Gulf via channels in the vicinity of the presently existing Rigolets. Pass Manchac, now the southern boundary of Tangipahoa Parish, is believed to have been a former channel of the Amite River. North Pass, separating Jones Island from the northern part of the parish, was an eastern portion of the Tickfaw-Natalbany channel, and the Tangipahoa River connected with the Amite near the present Pass Manchac-North Pass juncture (Saucier 1963) (Figure 2-4). When the Mississippi River shifted its course and began building the Teche delta complex about 3500 years B.P., the Cocodrie delta lobe began deteriorating (Kolb and Van Lopik 1958). During this time, Lake Maurepas developed either as a trapped depression between the delta and the Pleistocene Terrace, or as an unfilled remnant of the Pontchartrain embayment (Saucier 1963).

Between 2800 and 1000 years B.P., the Mississippi River shifted its course eastward, creating the St. Bernard delta lobe south-southeast of the Pontchartrain embayment (Kolb and Van Lopik 1958). At the time of the St. Bernard Delta abandonment, all the major landforms (wetlands, lakes, creeks, rivers, and terrace-swamp escarpment) were established, and the succeeding years have seen a gradual lowering of the land surface and enlargement of water bodies due to shoreline erosion (Saucier 1963).

While there has been no delta progradation into the Pontchartrain Basin since the abandonment of the St. Bernard Delta, natural Mississippi River crevasses as late as the turn of the twentieth century introduced freshwater and limited amounts of sediment into the basin. Crevassing, groundwater seepage, and surface runoff from

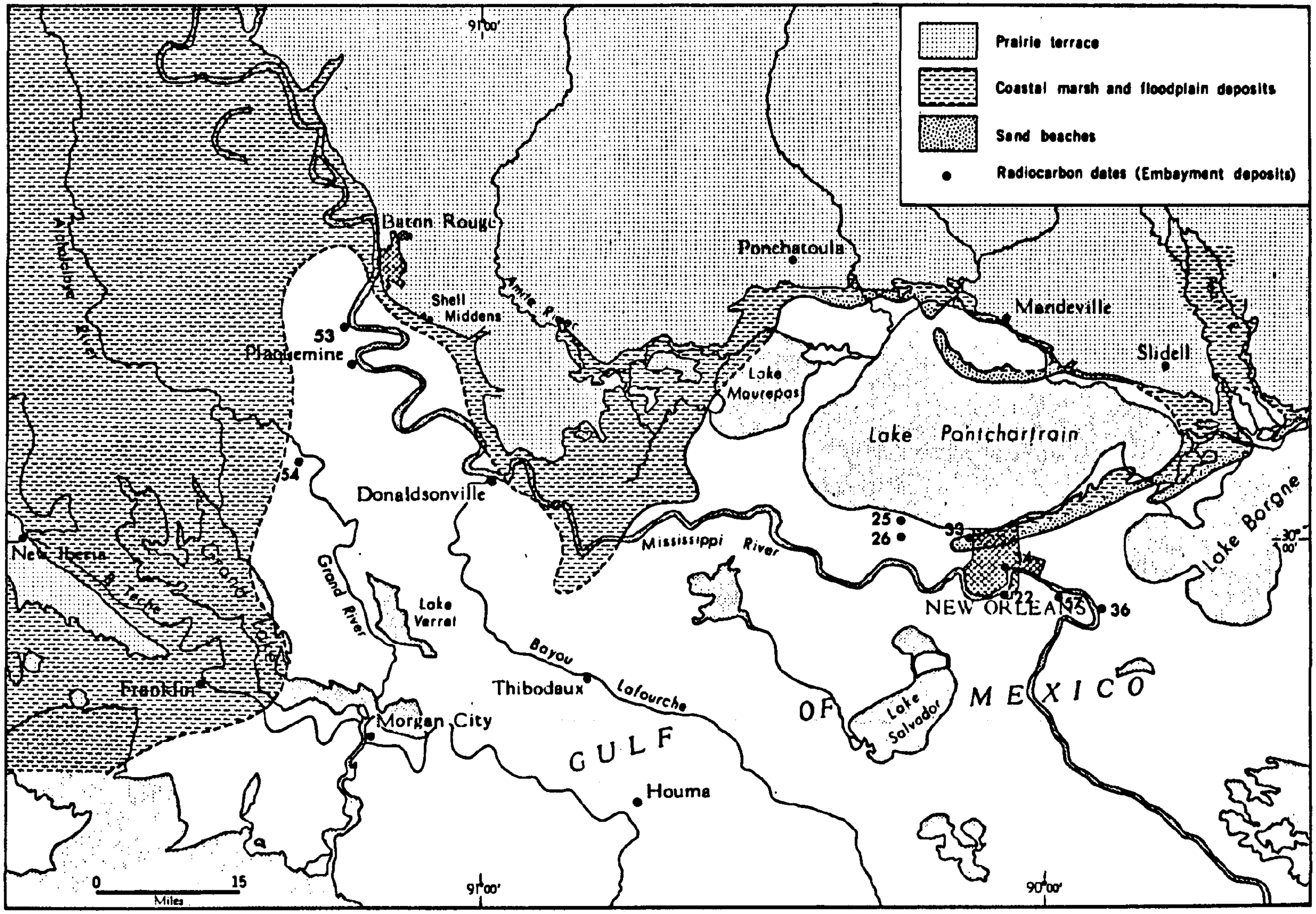

Figure 2-2. **Postulated maximum extent and shoreline features of the Pontchartrain Embayment (after Saucier 1963:45).**

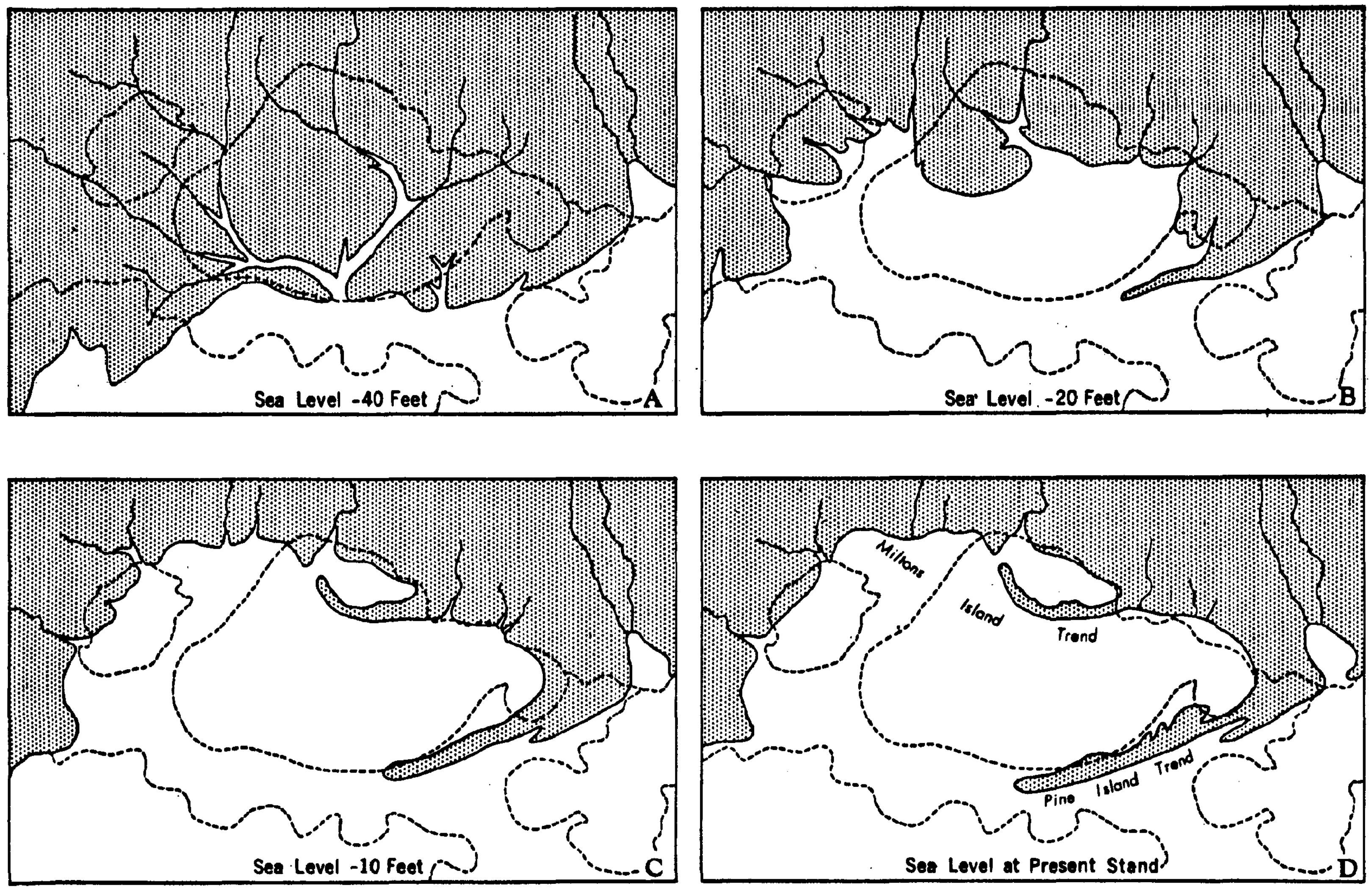

Figure 2-3. Origin of the Miltons Island and Pine Island beach trends (after Saucier 1963:53).

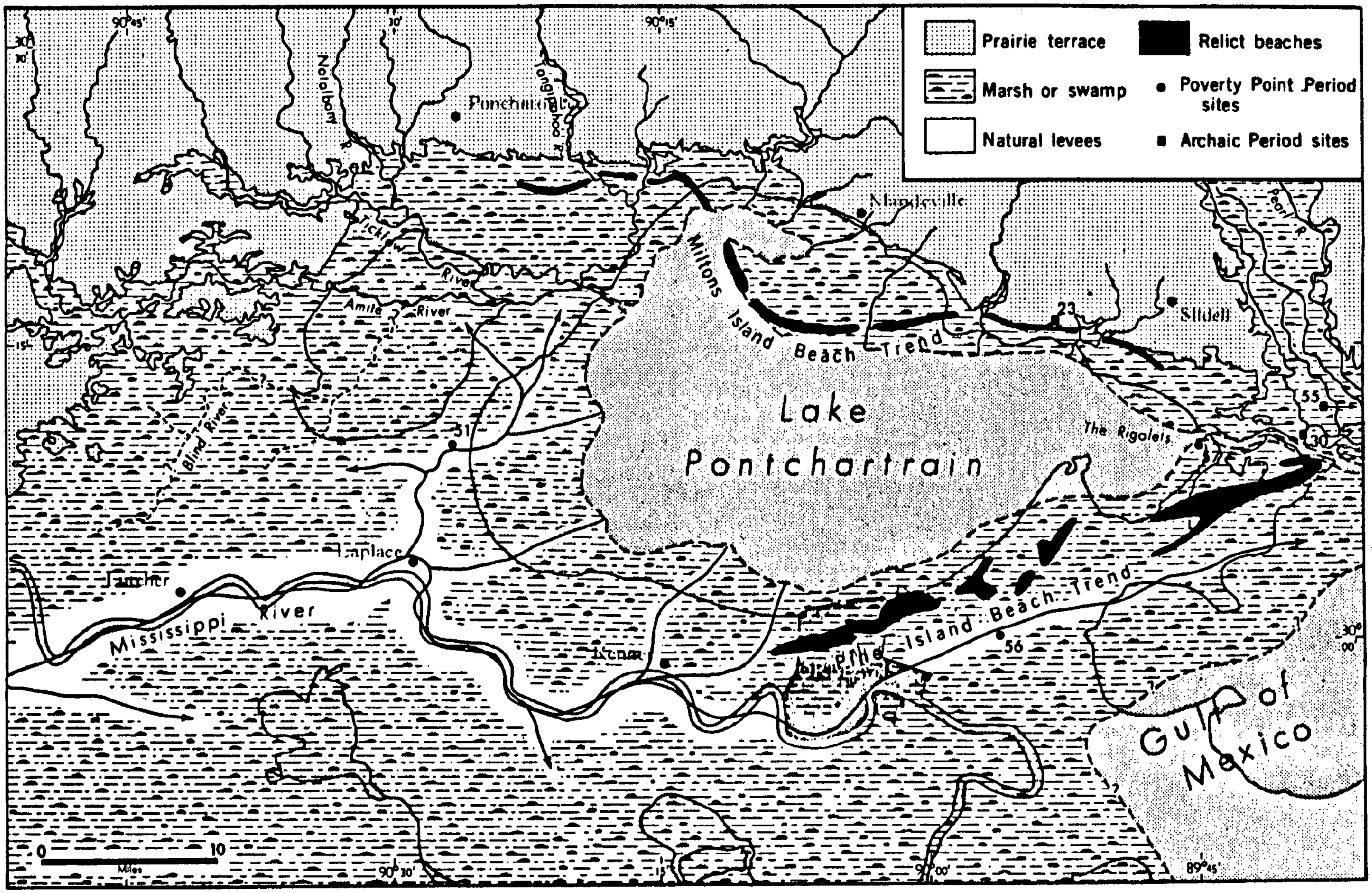

Figure 2-4. Paleogeography of the Pontchartrain Basin, about 3500 to 4000 years B.P., showing maximum extent of the Cocodrie Delta and locations of Poverty Point and Archaic period sites (after Saucier 1963:58).

the terrace and swamps maintained a low-salinity environment in the basin (Figure 2-5). However, during the latter half of the twentieth century, natural crevassing along the Mississippi River has been prevented through successful leveeing of the Mississippi River. This, along with erosion of the marshlands to the east and construction of major navigation and petroleum canals, has increased salinities in the basin to the extent that Lakes Maurepas and Pontchartrain are reverting to a more saline environment.

The present physiography of southern Tangipahoa Parish is the result of previous and ongoing geologic processes, including subsidence ("the relative lowering of the land surface with respect to sea level" [Kolb and Van Lopik 1958]), faulting, and sea level fluctuations. While these three processes may result in rising water levels and a possible detrimental impact on the swamp vegetation, extensive, detailed studies quantifying these parameters do not exist. However, the location and nature of major and minor faults have been documented (Plate 2) (Fisk 1944; Saucier 1963), and the average subsidence rate for the Pontchartrain Basin (obtained from radiocarbon datings of peat deposits) has been calculated to be 0.39 ft per century (Saucier 1963).

The amount of wetland loss due to shoreline erosion along Lakes Maurepas and Pontchartrain varies with location (Plate 3). The largest loss (an average of 41 ft/yr between 1955 and 1976) occurred in the vicinity of the Pass Manchac lighthouse, and the smallest amount (14.3 ft/yr between 1955 and 1976) was in Lake Maurepas along the northwest shore of Jones Island. Earlier measurements of shoreline retreat between Pass Manchac and the Tangipahoa River over a 17 year period prior to 1954 (Plate 2) indicated an average loss of 5.9 ft/yr.

Soils

The majority of the Tangipahoa Parish wetland soils consist of swamp deposits containing organic to highly organic clays with scattered lenses of silt and peat layers. The swamp soils have been differentiated and mapped into two types: Hydraquents in the northwestern half of the study area and Medasaprists (Maurepas) in the southeastern half (Plate 2). Hydraquent soils are semi-fluid, frequently flooded, and constantly under water. They are gray, nonorganic, mineral soils, low in soil strength and receive no oxygen (Slusher 1972; U.S. Department of Agriculture, Soil Conservation Service [USDA, SCS] 1978). Medasaprists are dominantly organic soils

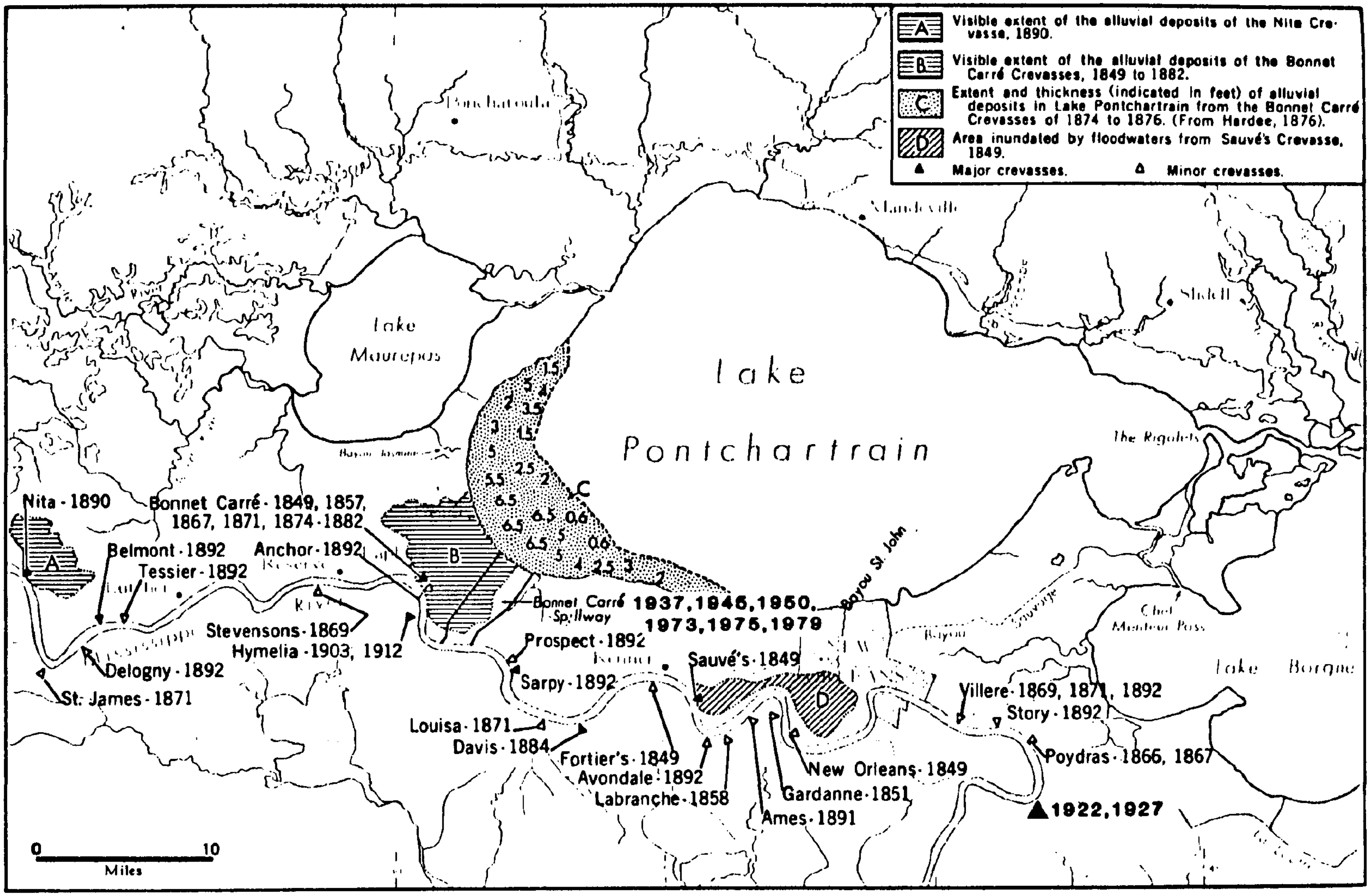

Figure 2-5. Locations of crevasses along the Mississippi River from 1849 to 1927, including areas affected by three major crevasses (after Saucier, 1963:89).

located in frequently flooded freshwater environments, i.e., fresh marsh and swamp. The term Maurepas describes the type of organic material (usually logs and stumps) present in the soil. Medasaprists have a subsidence potential of 1 to 12 ft, and because of their high organic content, they are susceptible to deep burns during drought conditions (Slusher 1972; USDA, SCS 1978).

Soil borings taken by the Louisiana Department of Highways (LDOH) (1973) prior to construction of I-55 further document the locations of silty clay with organics south of the terrace (within the Hydraquents type) and in the vicinity of the now subsided levees of North Pass and Pass Manchac (Plate 2). The soils along I-55 in the Medasaprist zone were described as organic and clay (Plate 2) (LDOH 1973).

The lower natural levees along small bayous consist of firm, slightly oxidized clays with a high organic content. The larger natural levees are well oxidized, very silty to sandy clay.

Beaches along Lakes Maurepas and Pontchartrain, in the southern portion of the study area, are very limited in extent. The Lake Maurepas beach between Pass Manchac and the Tickfaw River corresponds to the type Saucier (1963:25) described as being a "small, discontinuous, and irregular strip of fine to very fine sand, silt, and shell...most frequently associated with a cypress swamp shoreline." It is less than 25 feet wide, seldom over 2 ft in elevation, cuspate in form, and has cypress stumps and living cypress trees situated in the shallow waters up to 100 ft offshore (Saucier 1963). The shore stretching from the eastern mouth of Pass Manchac north for about 2.5 mi is also of this type. The shore stretching about a mile north and south of the Tangipahoa River corresponds to the shell beach type described by Saucier (1963) as being composed almost entirely of Rangia cuneata shells. This beach has steep slopes, is about 25 ft wide, and reaches between 4 and 6 ft high. The shell beach is formed naturally by waves which rework Indian shell middens and deposit shells on the beach from the lake bottoms (Saucier 1963). Within the last 25 years, a shell island has also developed northeast of the mouth of the Tangipahoa River approximately 1000 yds offshore.

Cypress Swamps and the Logging Industry

Over 60,000 ac of southern Tangipahoa Parish were historically composed of low-lying baldcypress-tupelogum swamps. The logging activities which occurred in this area from the late nineteenth to mid-twentieth centuries altered both the vegetative composition and the landscape (Plate 3).

As early as 1723, settlers in the swamps of Louisiana were producing cypress timber for trade. Float roads were cleared through the swamps at the time of the tree girdling to facilitate the transport of floating logs out of the swamp. Usually manpower, often supplemented by mules and oxen, was used to transport the logs to the mill. These pre-industrial logging activites left few permanent, physical scars upon the swamps of Tangipahoa Parish.

By the late nineteenth century, logging methods had been industrialized to improve the scope and efficiency of timber extraction. Railroad expansion reached its maximum mileage during the industrial logging era around the turn of the twentieth century. The first railroad through the Tangipahoa wetlands was the Illinois Central (Plate 3), laid in 1870 to connect Jackson, Mississippi, and New Orleans. By 1873, the commercial railroad network was completed between New Orleans and Chicago, and in 1883, New Orleans was linked by rail to California. Cypress logged in southern Louisiana could be shipped throughout the continental United States, providing lumber for construction in areas that had been previously lumbered out. This encouraged the lumbering industry because it expanded the market and facilitated the harvesting and delivery of timber.

In 1891, the age of industrial cypress logging began. The railroad skidder, in addition to two other industrial logging methods, the overhead cableway skidder, and the pullboat, altered the physical landscape of Tangipahoa Parish between 1889 and 1925.

Railroad logging involved the clearing of a right-of-way through the swamp (Figure 2-6). If the ground were solid enough, a dirt roadbed was thrown up for the main rail line and spurs (secondary lines that connected at right angles to the main line). Swampy conditions required construction on pilings or a cribwork of logs. Some spur lines were constructed of dunnage, which is waste material such as bark, shavings, sawdust, and slabs. Under very soft conditions, spur lines were constructed on pilings

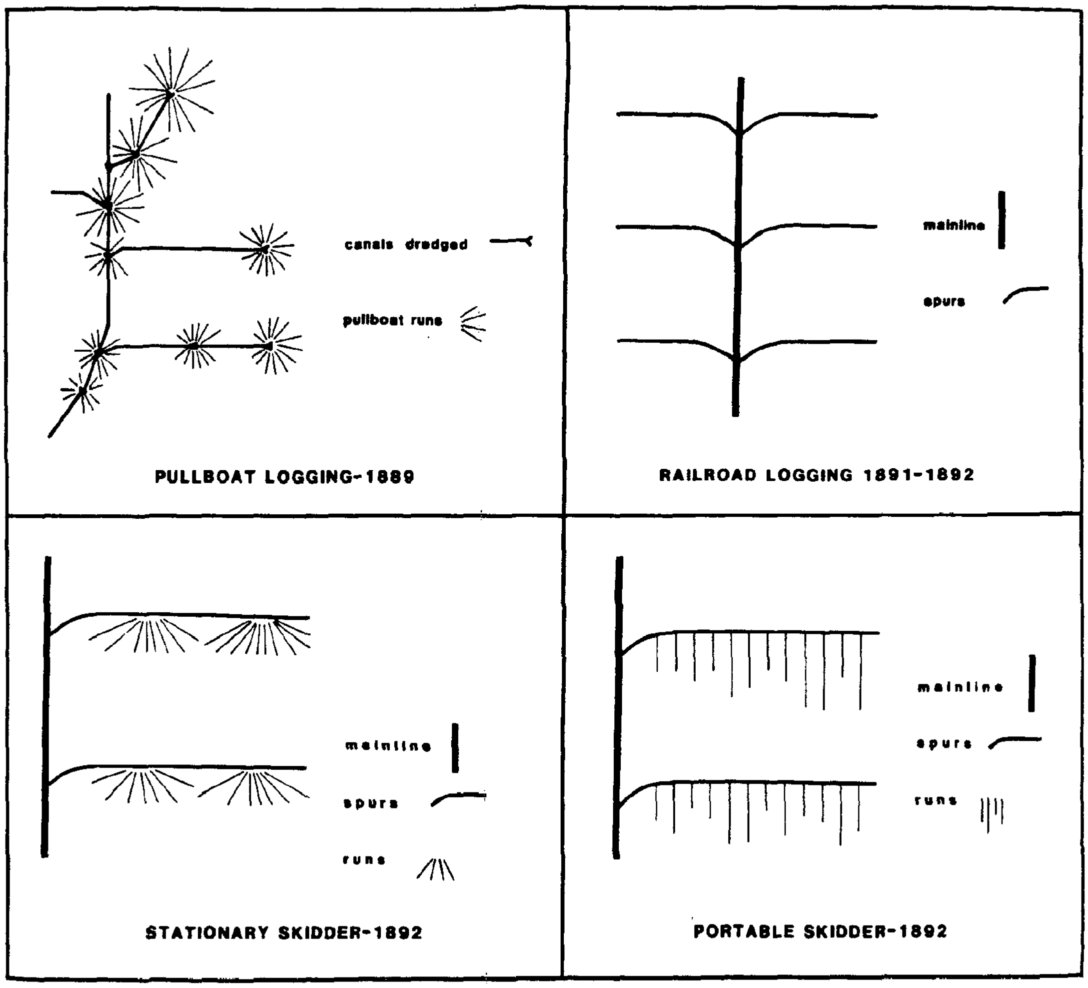

Figure 2-6. Typical logging scars found in Louisiana swamps.

or cribwork. Some main lines were also constructed of dunnage. The laying of these railroad beds in the swamps blocked drainage. This may have caused an increase in flooding of some swamps to the extent that the cypress was unable to regenerate. Railroad logging was an aerial operation which caused additional damage to young trees in the paths of the skidders.

Logging by overhead cableway skidder, whether stationary or portable (Figure 2-6), was similar to railroad logging in that both were aerial operations. The overhead skidder, partially suspended from an overhead cable, would pull the logs out of the swamp. The standing trees in the path of the rapidly moving logs were partially destroyed or killed. By this method, trees in the entire area being logged were either removed or badly damaged, leaving few cypress to re-seed the area.

Pullboat logging, introduced in 1889, left distinctive, long term scars on the landscape which are characterized by canals with numerous sets of radial or fantail "runs" or trails radiating from log collection sites along the canal (Figure 2-6). This logging method had numerous impacts on the swamp environment. Spoil deposited during the canal dredging affected drainage by impounding water on the upslope side of the spoil and accelerating drainage on the downslope or "unspoiled" side of the canal. In areas where the hydroperiod (length of flooding) was increased, the natural regeneration of cypress was inhibited. In the better drained areas, more competitive species, such as cottonwood (Populus deltoides), sycamore (Platanus occidentalis) and willow (Salix nigra), were able to establish themselves and this new forest association displaced the cutover cypress-tupelogum climax forest (Mancil 1972). The pulling of logs toward and along the radial paths to the collection site destroyed non-harvestable vegetation. The action also created soft-bottomed swamps with lower elevation and increased hydroperiod and inhibited cypress regeneration (Mancil 1972).

Between 1880 and 1925, the cypress lumbering industry in Louisiana thrived. In 1907, Louisiana ranked second in the United States in lumber production, but by then 50% of all the virgin forests in Louisiana had been cut. Within the study area, the mill at the Louisiana Cypress Lumber Company, Inc., Ponchatoula, began sawing logs on 15 July 1947 from the last stand of virgin tidewater "red" cypress timber in Louisiana. The last cypress logs were processed in 1956 at Ponchatoula. By 1970, the Louisiana Cypress Lumber Company, Inc., now called the Fremont Lumber Company, was the only former cypress mill site still in operation in Louisiana. The majority of the lumber now being processed consists of pine (Pinus spp.) and hardwoods.

After the last stands of virgin cypress were cut in 1947, water tupelo and red maple (Acer rubrum var. drummondii) replaced the cypress in the timber industry. The rotting baldcypress stumps and fallen logs provided seeding places for the germination of maple seeds, in an environment with reduced competition for growing space and sunlight (Conner and Day 1976). The history of the cypress logging industry in Tangipahoa Parish was destructive in that the entire southern Tangipahoa swamp was altered to some extent by the railroad and pullboat logging methods.

However, it should be noted that despite the relatively recent and thorough cypress clear-cutting, some cut-over areas in the study area were experiencing cypress regeneration. The clear-cutting characteristic of the industrial logging era was not totally responsible for the sparcity of second-growth cypress in the southern portions of the Tangipahoa wetlands. The extensive stands of even-height cypress trunks indicate that cypress was regenerating in portions of formerly logged swamps until other environmental factors destroyed them.

CHAPTER III: METHODOLOGY

Hydrology

Analysis of Historic Data

As one of the first steps in the analysis of hydrologic conditions, all existing data pertaining to salinity, tidal stage, and river discharge for long-term stations in the study area were retrieved from the USACE and the USGS Water Resources Division. Daily chlorinity readings for Pass Manchac at the U.S. 51 bridge were obtained in printed form for 1951-1963 and in magnetic tape form for 1963-1979 from the USACE. Mean monthly discharges for the Tickfaw River at Holden (1941-1980), the Natalbany River at Baptist (1943-1980), and the Tangipahoa River at Robert (1939-1980) were furnished by the USGS. These discharge values were extrapolated to the mouth of the Tickfaw River at Lake Maurepas and the mouth of the Tangipahoa River at Lake Pontchartrain by adding the inputs of drainage basins downstream from the gauging stations (USGS 1963). An equal contribution to discharge per unit of drainage area was assumed in both cases.

In order to gain an understanding of the general processes and patterns in hydrology over the annual cycle, mean monthly discharges, chlorinities (salinity), and stages were calculated for the period of record. The effects of wind were summarized by calculating average monthly resultant wind direction and velocity (NOAA 1971-1977) and comparing this with the other data.

Analysis of Existing Conditions

Selected water quality parameters and current patterns were monitored once a month at 20 sites within the study area from June 1980 through May 1981 (Plate 1). Specific conductance (salinity), DO, pH, and temperature (T°C) measurements were taken with a portable Martek Mark V Water Quality Analyzer. Water clarity (turbidity) was measured with a secchi disk, and current direction and speed were estimated using a current cross. Stage of the tide was read from staff gauges (notched PVC pipe) at each station. This survey was designed to accomplish four major objectives:

1) to determine the differences in salinity as a function of distance from the source (Lake Pontchartrain),

2) to identify the major pathways for salinity intrusion,

3) to characterize the salinity regimes of different zones of wetland vegetation in the study area, and

4) to determine statistical relationships between salinity at more distant sites and salinity in Pass Manchac where a long-term record is available.

All data collected in the field were cataloged and appear as Appendix A in this report.

Defining Trends in Salinity Conditions

Computer analysis was performed on the salinity data for Pass Manchac from 1951 to 1979 to determine if salinity has increased significantly since 1951 and if salinity is continuing to increase through the present.

The daily values were first converted to annual means for the period of record. Wide variations in these annual means were expected due to alternating flood, normal, and drought years. To exclude some of the annual variations in regional climate, a "smoothing" technique was performed on the annual means. Observation of the data revealed that "wet" and "dry" periods operated on about a five-year cycle, so the data were smoothed using a five-year "running" mean. For example, the annual means for 1951-1955 were averaged to give a value for 1953, for 1952-1956 to give a value for 1954, etc. The resulting 24 pairs of values were used as data points in trend-line linear regression to identify any rate of salinity increase through time.

Because obvious changes in vegetation have occurred in the study area, apparently due to an increase in salinity, attempts were made to recreate past salinity regimes for each existing zone of vegetation for the period of record. Salinity measured in Pass Manchac at the U.S. 51 bridge during each monthly monitoring trip was used as the independent variable in linear regression analysis along with the salinity measured at a representative station for the same trip (dependent variable). The resulting equation was used to transform the long-term daily salinity data at Pass Manchac to values for the particular site in question, within the probability dictated by the correlation coefficient of the regression analysis and the number of observations involved. Using these relationships, a data set containing daily salinity was created for each of four representative vegetation zones described later in the report. Ground elevation transects were taken in each vegetation zone, and the average between the highest and lowest points was calculated. Knowing the average elevation in each zone, a computer was used to document all instances of inundation for the period of record. Finally, for the times of inundation in each zone, frequencies of exposure were produced for salinities from 0 to 10 ppt. From this, one is able to see the percentage of time that each zone has been flooded with water of a particular salinity.

Vegetation

Analysis of Historic Data

Detailed vegetation analyses of the Tangipahoa wetlands prior to this study have not been published. Early topographic maps of the area (USGS 1935) indicate that a swamp vegetation association covered all of the wetlands of southern Tangiphoa Parish. Later USGS maps (1951) depict four separate patches of marsh south of the Pleistocene Terrace trending in a northwest-southwest direction southeast of Ponchatoula. The literature indicates that the study area consisted of virgin cypress-tupelogum swamps that were clear-cut during the industrial logging era and up to 1955 (Plate 3) (Grace 1910; Mancil 1972, Norgress 1947). While cypress did regenerate in some areas, much of the second-growth vegetation consisted of willow and maple (Mancil 1972).

In order to assess changes in vegetation, two sets of habitat maps were compiled for the study area at a scale of 1:62,500 for 1955/56 and 1976/78 (Plates 4 and 5). The 1955/56 interpretations were made from quad-centered, controlled, black-and-white air photo mosaics at a scale of 1:24,000 (Petroleum Information Corporation 1955/56). Data for the 1976/78 habitat map came from color infrared transparancies at a scale of approximately 1:123,000 (NASA 1976/78). While field checking verified the species composition on the 1978 transparencies, lack of information regarding specific composition on the 1955/56 photographs limited habitat interpretation to three general vegetation zones: forest trees, marsh-shrub, and marsh.

Analysis of Existing Conditions

Vegetative Sampling

After reconnaissance of the study area from boat, a single fly-over at low elevation in a small plane, and careful study of aerial photographs, three general vegetative zones were delineated based on degree of coverage of emergent and woody vegetation (trees and shrubs) and apparent age of the stand. One zone (marsh) consisted predominantly of herbaceous marsh vegetation with little or no trees and shrubs, the second zone (marsh-shrub) consisted of marsh plants interspersed with a sparse cover of shrubs and young trees, and the third zone (forest) was a fairly closed canopy baldcypress forest. Intergradations of these zones occurred at the ecotones where they overlapped.

Transects for vegetative sampling were located such that areas were sampled in each of the three zones. Transects A and B, run off the northern rim of Lake Maurepas and off Pass Manchac, respectively, were located in the marsh zone (Plate 5). Transects C and F, located near water quality station 3 and off Marlin Canal, respectively, occurred in the marsh-shrub zone (Plate 5). Transect D was located off Pontchatoula Creek near water quality station 6 in a baldcypress-tupelo forest (Plate 5).

Transects were generally run perpendicular to the stream or canal with the first vegetative plot located near the stream bank. Plots were taken every 100 ft with a total of 14 plots for each transect. Thus, each vegetative transect was approximately 0.25 mi in length. At each sample plot along a transect, all stems (i.e., tree boles) 1 in diameter or greater at breast height (dbh) of all woody shrubs and trees were measured within a 0.02-ac circular plot. In addition, percentage ground cover of each herbaceous species present was estimated in a square plot of approximately 25 sq ft at each sampling site along a transect. Data from all 14 plots along a transect were compiled and tabularized. For trees and shrubs, basal area in square feet per acre was computed for each species from measurements of dbh. Number of stems per acre and average dbh were also calculated for each woody species. Average percentage cover and frequency were calculated from the data for herbaceous ground cover.

Soil Sampling

At every fifth sample plot along a transect (i.e., 400-ft intervals), a soil core approximately 15 in in length was taken and a sample of free soil water was obtained from the resulting soil core cavity. Soil samples were analyzed in the laboratory for total chlorides which were converted to soil pore (i.e., interstitial) salinities. A measurement was also made of total organic carbon (TOC) as a percentage of dry weight. The free soil water samples were measured for conductivity in milliohms per centimeter using a Mark V Martek Water Quality Analyzer. Conductivities were then converted to total salt by multiplying the electrical conductance at 77°F by the standard conversion factor 0.64, then by 1000 to give the salinity in parts per thousand (ppt) (Richards 1954).

CHAPTER IV: RESULTS AND ANALYSIS

Introduction

The properties of the water, its timely movement, and the energy this movement expends upon the landforms within a basin largely dictate the nature and extent of the wetland plant communities which can exist there (Gosselink and Turner 1978). The relationship between hydrology and wetlands is such that a change in hydrologic processes will induce a change in vegetation. The change will progress until the wetlands equilibrate to the new hydrologic regime. In a short time frame, wetlands can be seen to reach equilibrium with changes, such as clearing of upland watersheds, channelization of rivers, leveeing for flood protection, or major channel excavations, such as the Mississippi River-Gulf Outlet (MRGO). In reality, however, over a long time frame, a wetland "steady state" is never achieved due to cyclic swings in climate, eustatic sea level rise, subsidence, and changes in the course of the Mississippi River.

The changes which are evident in the recent history of the study area appear to be adjustments to both short-term and long-term alterations in the hydrologic regime. The following results and analysis strive to discover and explain some of the mechanics involved in this "evolution" of the wetland system.

Hydrology

Hydrologic Processes

Lake Pontchartrain is the largest hydrologic entity in the study area. Although its expanse tends to buffer changes in salinity, it serves as the only source of salt to the Tangipahoa wetlands. Therefore, the movement of Lake Pontchartrain waters into and out of the study area is a primary determinant of the salinity regime.

There are three main forces which cause movement of water masses in the study area: astronomical tides, winds, and river discharges. Tides are the least important mechanism of water movement. The normal tidal range is only 3.5 in at the mouth of Pass Manchac, and the phase of the tide lags 7 hours behind tides in the Rigolets (Outlaw 1979). Water levels over all of Lake Pontchartrain tend to rise and fall as a unit due to the tidal signal (Swenson 1980a). Mean monthly water levels in the lake show two peaks over the annual cycle, one in the spring and another in the fall. These correspond to peaks in the level of the Gulf of Mexico and also to periods of predominant easterly winds (Swenson 1980a). It appears that water levels in Lake Pontchartrain and the study area are primarily controlled by the forcing of the winds.

The predominance of winds from the eastern quadrant can be seen in Figure 4-1, insert C. The axes represent the main compass coordinates; the direction of the arrows indicates the average resultant wind direction each month; and the length of the arrows shows the average wind velocity relative to the highest month (October). Generally, the strongest winds come from the northeast in September, October, and November and from the southeast in March and April. In both cases, water is pushed into Lake Pontchartrain from Mississippi Sound via Lake Borgne and from Breton Sound via the MRGO. Water "piles up" against the northwestern shore, causing prolonged flood tides in Pass Manchac and elevated water levels in the study area. This effect can be seen in the graph of mean monthly stage at Pass Manchac (Figure 4-1, insert D). The fall peak in mean monthly stage corresponds to the maximum mean monthly salinity at Pass Manchac (Figure 4-1, insert D). However, there is no salinity peak corresponding to the April peak in water level due to the annual cycle of river discharge.

Inserts A and B (Figure 4-1) illustrate the average monthly discharges of the Tickfaw River at Lake Maurepas and the Tangipahoa River at Lake Pontchartrain (USGS 1939-1980). The two rivers have approximately equal drainage basins (about 750 mi^2), and the trends in discharge are almost identical in an average year. The vertical lines show the range in discharge that can be expected (standard error of the mean). December through April are the months of highest discharge. Strong southeast winds in March and April tend to prevent rapid drainage of river waters, resulting in high stage and depressed salinity throughout the study area. The impounding effect of wind "set up" is one of the major factors causing chronic flooding on the Tangipahoa, Tickfaw, and Amite River systems. Despite these adverse effects, overbank flooding in the spring saturates the swamps with freshwater, introducing sediments and essential nutrients and leaching out salts which may have accumulated during the year. During dry years, however, the river discharges are not sufficient to repel the incoming "wind tides," and the study area receives a spring dosage of salt on top of the normal fall exposure.

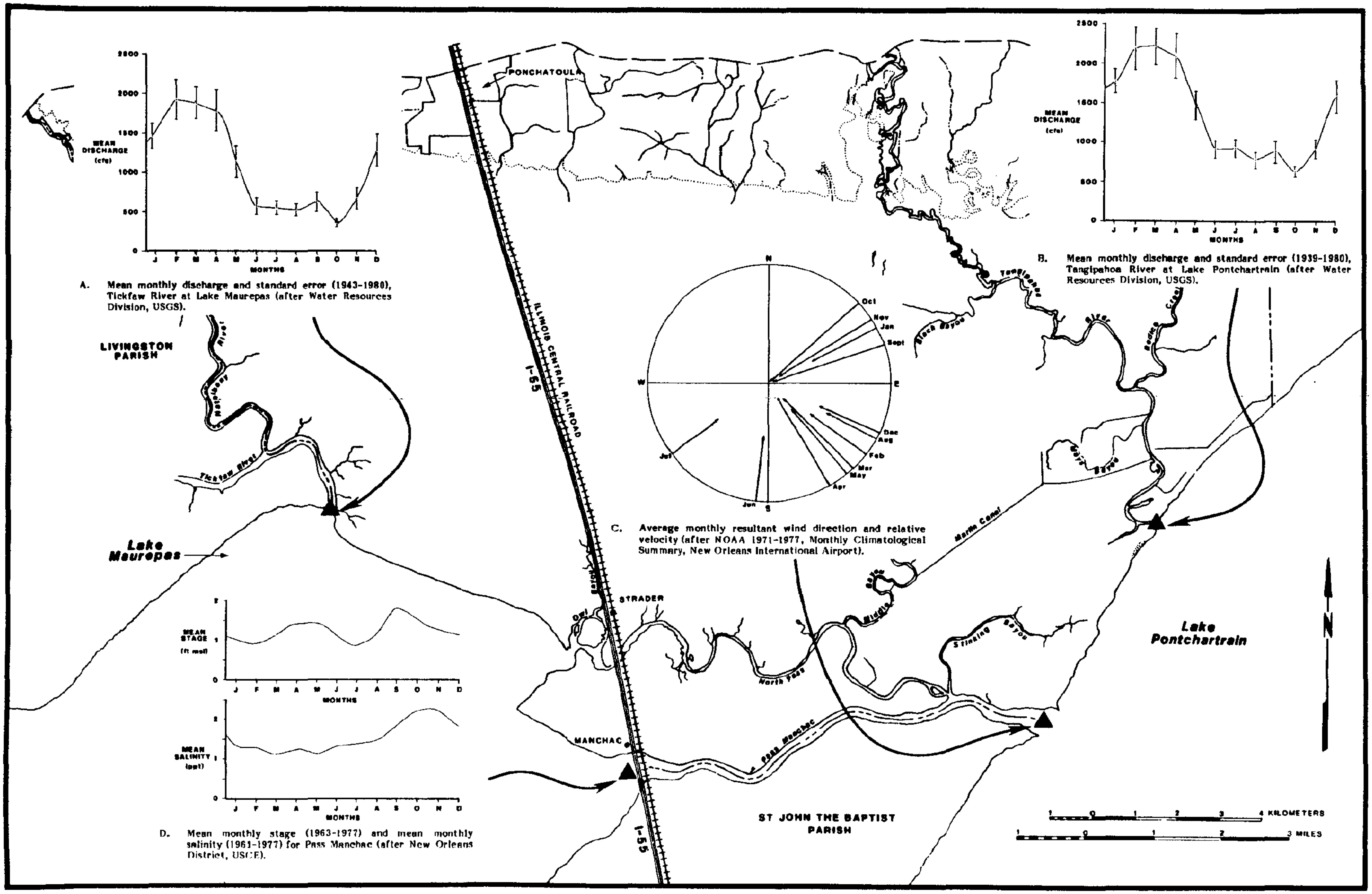

Figure 4-1. Hydrological summary: mean monthly values of salinity, stage, wind, and river discharge for selected sites in the study area.

Hydrologic Trends

The variations in climate over North America which result in periods of flood and drought are abundantly evident in the salinity record for Pass Manchac. Warm, dry, winters produce little snowmelt to feed the main stem of the Mississippi River. This makes operation of the Bonnet Carré Spillway unnecessary. Conversely, when the spillway is opened, it depresses salinity for six to nine months afterwards in the study area. Smaller scale variations in regional climate and precipitation are also evident in the salinity record. Because of these differences in annual freshwater input, it is difficult to isolate a trend of increasing salinity due to other causes. The five-year "running mean" of mean annual salinities does show a measurable trend of increasing salinity at Pass Manchac (Figure 4-2). Trend line analysis indicates an increase of 0.031 ppt per year between 1951 and 1979, with a correlation coefficient of 0.365. However, this correlation coefficient is only significant at the 0.1 level of probability (90% chance of being correct), which is below the level generally acceptable to the scientific community. The actual mean annual salinities, also plotted on Figure 4-2, display the reason for the low correlation coefficient. Possible causes for the apparent salinity increase, other than climatic variations, include:

1. Construction of the MRGO. In a recent study of the tidal passes of Lake Pontchartrain (Swenson 1980b), it was reported that the Inner Harbor Navigation Canal (IHNC) (which is directly connected to the MRGO) supplies 20% of the total salt entering the lake, but only carries about 7% of the tidal flow. This canal was the only one of the three passes to exhibit vertical stratification (a salt wedge) during the study. It is likely that these figures represent an increase in the salinity of the lake since the MRGO construction in 1963.

2. Increase in the tidal prism due to marsh loss and subsidence. As marshes break up and disappear south of Lake Pontchartrain, water area increases. The effect of the tides then becomes more pronounced because there is less friction with land to dampen the energy. This tends to increase the rate of water exchange and decrease the residence time of freshwater, resulting in higher salinities. The continuing progression of marsh loss between Chandeleur Sound and Lake Borgne has probably resulted in a gradual rise in salinity in Lake Borgne, the "source waters" of Lake Pontchartrain.

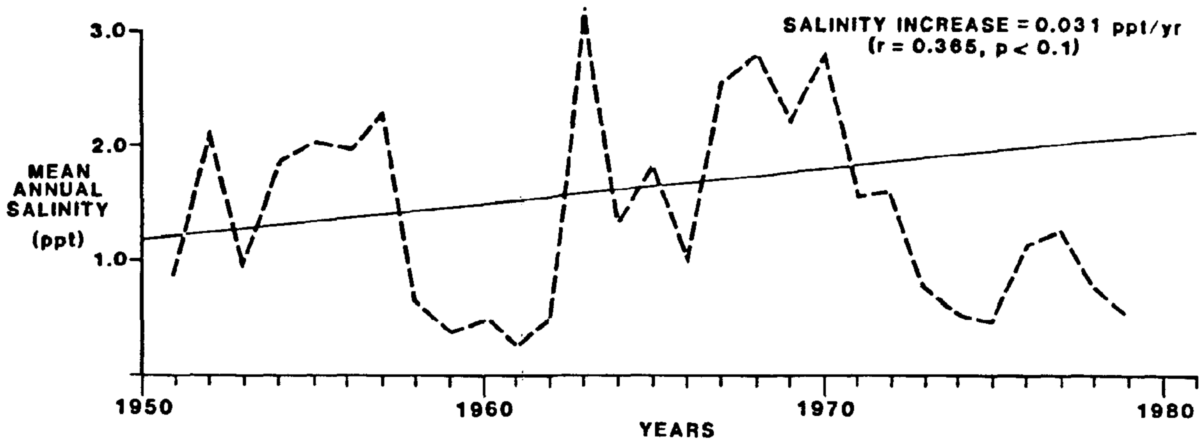

Figure 4-2. Trend line analysis of mean annual salinities in parts per thousand (ppt) at Pass Manchac from 1951-1979.

3. Modification of hydrologic regime due to canal excavation. Canals, in general, are a major factor in promoting saltwater intrusion over all of coastal Louisiana. However, the study area has not been subject to as much canal excavation as other areas in the coastal zone where oil and gas activities have been concentrated. The Marlin Canal and the smaller canals which branch out from it between Middle Bayou and the Tangipahoa River have certainly provided greater access for brackish waters into the former freshwater swamp. In addition, there are numerous radial scars where cypress logs were dragged from the swamp to a central point. These also allow intrusion of brackish waters.

4. Reduction of freshwater inputs because of drainage projects. There are at least two instances where drainage canals below the +5-ft contour have decreased the amount of freshwater entering the swamps. South Slough intercepts the flows of Big Branch and Selsers Creek and shunts this water into the borrow canal along I-55 (Plate 1). Flow from the small drainage basins west of Ponchatoula and east of Ponchatoula Creek is intercepted by the Anderson Canal and conducted to the borrow canal. Synthesis of geologic theory and photo interpretation indicates that each of these small branches and creeks historically emptied into the peculiar series of fresh marsh

pockets in the northern part of the study area. These marshes follow the trend of a major fault through the area (Saucier 1963), falling consistently south of it on the down-thrown block (Plates 2, 4, and 5). They were probably once shallow ponds formed in the subduction zone between the up-thrown and down-thrown blocks of the fault. The creeks and branches flowed into these ponds after rainfall events, filling them to overflowing, and the excess water flowed as a sheet across the swamp. Over time, the shallow ponds filled with silt and organic debris to the point where fresh marsh vegetation became established. Today, with little water flow entering the marshes, water levels have become low enough to allow germination of cypress seeds, and small hummocks of young trees have appeared. However, the freshwater which once overflowed into the mature swamp is no longer available. In this case, a re-evaluation of drainage and flood control projects in the parish may be warranted in view of the freshwater needs of the stressed cypress swamps.

Vegetation

Changes in Vegetation Distribution

Comparison of two vegetation maps made from 1955/56 and 1976/78 aerial photographs indicates that major shifts in vegetation associations or zones have occurred during the past 23 years. In 1955/56, the marsh habitat, with the exception of four large patches south of the Pleistocene Terrace, was confined to small strips of land along North Pass, Stinking Bayou, and south of the center portion of the Marlin Canal. The marsh-shrub zone covered all of Jones Island, except for the interior which contained cypress, and stretched north from North Pass in a narrow band which widened towards Lake Pontchartrain to include most of the area between Pass Manchac and the Marlin Canal. The present stands of dead cypress indicate that many of the shrubs in this zone were young, second-growth cypress growing in a scattered stand formation. Two large patches of marsh-shrub habitat also existed west of U.S. 51 in an area which appeared to have been recently clear-cut. The remainder of the area, with the exception of narrow natural levee vegetation (live oak [*Quercus virginiana*] association) along the Tangipahoa River and the Pleistocene Terrace outliers (pine [*Pinus* spp.] association) east of the Ponchatoula River, was covered by second-growth cypress probably intermixed with willow, red maple, and possibly waxmyrtle (*Myrica cerifera*) (Mancil 1972). On aerial photographs, this second growth swamp appeared to have a very dense tree canopy.

By 1976/78, the vegetation zones shifted to the extent that the cypress association in the interior of Jones Island had been replaced by a marsh-shrub association, primarily bulltongue (Sagittaria lancifolia), alligatorweed (Alternanthera philoxeroides), waxmyrtle, and red maple (marsh-shrub association), and the perimeter of Jones Island had shifted from a marsh-shrub to a marsh association, of bulltongue and alligatorweed. In contrast, the older marshes south of the Pleistocene Terrace were predominantly maidencane (Panicum hemitomon).

The former marsh-shrub zone north of North Pass had lengthened and moved inland as a narrow band stretching northeast from the mouth of the Tickfaw River to the Tangipahoa-St. Tammany Parish line. A marsh devoid of virtually all shrubs replaced the former marsh-shrub zone along North Pass and expanded to cover a broad band of land from about 1.5 mi east of the Tickfaw River to about 1 mi west of the Tangipahoa-St. Tammany Parish line. The natural levee forest remained along the banks of the Tangipahoa River, and narrow stands of cypress remained along the slightly elevated levees and beach rim of the eastern end of Pass Manchac, the western shore of Lake Pontchartrain, and the northern shore of Lake Maurepas between the Tickfaw River and Owl Bayou. The marsh zone appears to be advancing in area away from the major water bodies along old logging scars, primarily canals left from pullboat and skidder operations.

The areal change in these major vegetation zones was documented by planimetering each zone on the two vegetation maps at a scale of 1:62,500 (Plates 4 and 5; Table 4-1). The results indicate that the swamp forest zone decreased by approximately 17,100 ac, the marsh zone increased by 16,718 ac, and the marsh-shrub zone, despite its major locational shift, increased in area by only 50 ac. Whereas the swamp zone constituted 78% of the wetlands in 1955, it covered only 52% of the area by 1976/78. In contrast, the marsh zone increased from 5.5% of the area in 1955 to 31.6% of the area in 1976/78. The marsh-shrub zone maintained its areal coverage at 16% for both years.

Spoil habitat increased very slightly (about 8 ac) because of construction of the I-55 borrow canal. There was no measurable change in area for either the natural levee or Pleistocene Terrace outlier vegetation associations. The study area decreased in size by approximately 324 ac, primarily due to shoreline erosion along Lakes Maurepas and Pontchartrain and construction of the I-55 borrow pit.

Table 4-1. Areal Changes in Vegetation Categories between 1955/56 and 1976/78 (area in acres)[1].

VEGETATION CATEGORIES	AREA 1955/56	AREA 1976/78	CHANGE IN AREA
MARSH	3,582	20,300	+16,718
MARSH-SHRUB	10,342	10,392	+50
SWAMP	50,382	33,282	-17,100
NATURAL LEVEE HARDWOODS	22	22	0
TERRACE PINE AND HARDWOODS	82	82	0
SPOIL	85	94	+9
TOTAL ACRES	**64,495**	**64,172**	**-323**[2]

1 The study area was defined on the south, east, and west by the parish boundaries and on the north by the terrace escarpment (see Plates 4 and 5).

2 Land loss primarily due to shoreline erosion and canal dredging.

Comparison of Vegetation and Soil Conditions by Site

Sampling of mid-story and overstory vegetation permitted the construction of stand composition tables for each transect showing basal area (ft^2/ac), number of stems per acre (density), frequency of occurrence, average dbh, relative dominance, and relative density for each species. Relative density and relative dominance were calculated using the following formulas:

$$\textbf{Relative density} = \frac{\text{Number of individuals of species}}{\text{Number of individuals of all species}}$$

$$\textbf{Relative dominance} = \frac{\text{Total basal area of species}}{\text{Total basal area of all species}}$$

Herbaceous understory was tabulated showing average percentage cover, frequency of occurrence, and relative abundance. Frequency of occurrence is simply the percentage of plots on the transect in which the species occurs. The relative abundance is the product of average cover and frequency. The tables in the following sections contain mid-story and overstory stand composition and herbaceous cover compilations for each transect (see Plate 5 for location of transects).

Marsh

Scrutiny of the stand composition tables reveals obvious differences between sites in the amount of baldcypress measured in terms of basal area and number of stems per acre present. Transects A and B, located on the north shore of Lake Maurepas and off Pass Manchac, respectively, were designated as marsh sites. Transect B contained almost no overstory, although baldcypress was dominant in terms of basal area (Table 4-2). Waxmyrtle, an evergreen shrub, made up an important component of the woody composition, especially in terms of relative density of stems. Smartweed (Polygonum sp.) and alligatorweed were the most abundant species in the herbaceous cover (Table 4-3). This transect site, characterized also by the presence of numerous dead, standing cypress, was a former baldcypress swamp that had been transformed to a fresh-intermediate marsh.

In contrast, the stand composition of transect A was dominated by tupelogum and contained a greater basal area of baldcypress and fewer shrubs than transect B (Table 4-4). This was due in part to the healthy stand of trees occurring on the

Table 4-2. Stand Composition of Midstory and Overstory Woody Species along Transect B, Tangipahoa Parish, August 1980.

Species	Number Stems/Ac	Basal Area (ft^2/ac)	Relative Dominance	Relative Density	Frequency (%)	Average dbh (in)
Baldcypress (Taxodium distichum)	7.1	3.90	.6210	.0343	7.1	10.0
Waxmyrtle (Myrica cerifera)	157.1	2.01	.3201	.7593	42.8	1.4
Live Oak (Quercus virginiana)	7.1	0.16	.0255	.0343	7.1	2.0
Groundsel Bush (Baccharis halimifolia)	21.4	0.13	.0207	.1034	21.4	1.0
Buttonbush (Cephalanthus occidentalis)	7.1	0.04	.0064	.0343	7.1	1.0
Green Ash (Fraxinus pennsylvanica)	7.1	0.04	.0064	.0343	7.1	1.0
TOTALS	**206.9**	**6.28**	**1.0001**	**.9999**		

Table 4-3. Average Plant Cover and Relative Abundance of Herbaceous Understory Species, Transect B, Tangipahoa Parish, August 1980.

Species	Average Cover (%)	Frequency (%)	Relative Abundance
Smartweed (Polygonum sp.)	35.7	100.0	3570.0
Alligatorweed (Alternanthera philoxeroides)	25.8	85.7	2211.1
Morning Glory (Ipomea sagittata)	22.1	50.0	1105.0
Cowpea (Vigna luteola)	23.0	35.7	821.1
Saltmarsh Aster (Aster subulatus)	14.3	42.8	612.0
Bulltongue (Sagittaria lancifolia)	25.0	21.4	535.0
Giant Cutgrass (Zizaniopsis miliacea)	20.0	14.3	286.0
Flatsedge (Cyperus sp.)	25.0	7.1	177.5
Palmetto (Sabal minor)	4.0	42.8	171.2
Arrowhead (Sagittaria latifolia)	5.0	14.3	71.5
Panic grass (Panicum sp.)	3.0	14.3	42.9
Groundsel Bush (Baccharis halimifolia)	5.0	7.1	35.5
Marshmallow (Hibiscus lasiocarpus)	5.0	7.1	35.5
Buttonbush (Cephalanthus occidentalis)	5.0	7.1	35.5
Marsh Elder (Iva frutescens)	5.0	7.1	35.5
Coffeeweed (Sesbania macrocarpa)	1.0	7.1	7.1

Table 4-4. Stand Composition of Midstory and Overstory Woody Species along Transect A, Tangipahoa Parish, August 1980.

Species	Number Stems/Ac	Basal Area (ft^2/ac)	Relative Dominance	Relative Density	Frequency (%)	Average dbh (in)
Tupelogum (Nyssa aquatica)	157.1	58.6	.7390	.6110	42.8	8.0
Baldcypress (Taxodium distichum)	57.1	11.1	.1400	.2221	42.8	5.5
Swamp Blackgum (Nyssa sylvatica var. biflora)	14.3	9.4	.1185	.0556	14.3	11.0
Boxelder (Acer negundo)	14.3	0.1	.0013	.0556	14.3	1.0
Drummond Red Maple (Acer rubrum var. drummondii)	14.3	0.1	.0013	.0556	14.3	1.0
TOTALS	**257.1**	**79.3**	**1.0001**	**.9999**		

elevated lake rim. The lake rim here contained the common bottomland-swamp species such as swamp blackgum (Nyssa sylvatica var. biflora), boxelder (Acer negundo), and Drummond red maple. The forest opened up quickly north along the transect as the elevation dropped and changed to an open marsh with no canopy. The dominant herbaceous species along this transect was water primrose (Ludwigia bonariensis), which occured in dense, 6-ft-high stands in the open marsh (Table 4-5). Thus, although this "marsh" transect contained a greater amount of overstory species, they were largely restricted to the narrow lake rim.

Soil pore salinities along transect B were greatest at the Pass Manchac streambank (1.51 ppt) and decreased somewhat toward the interior marsh (Table 4-6). Similar values were obtained for free soil water salinities. Correspondingly, total organic carbon increased away from the streambank. Higher soil salinities near the streambank are probably indicative of more frequent inundation by brackish water from Pass Manchac. The low percentage of carbon at the stream bank (5.48%) is due to the mineral soils associated with natural levee formation. During inundation, the larger, coarse sand particles drop out of suspension more quickly than the smaller clay particles. This results in an enrichment of the inorganic mineral components and relatively low percentages of organics in the soils near the streambank. Because of the decrease in the amount of mineral particles available and less energetic water movement, greater percentages of organic matter make up the interior marsh soils, which are classified usually as peats and mucks.

Soil pore salinities along transect A increased dramatically from 0.43 ppt on the elevated lake rim to 2.04 ppt in the interior marsh. Because the lake rim is higher than the interior marsh, it is inundated infrequently by brackish water from Lake Maurepas and is also well drained. Conversely, the interior marsh area is poorly drained and subject to more frequent inundation. Evapotranspiration during dry summer and fall months facilitates the build-up of the soil salt content. It is significant that no overstory canopy species occurred at the plot with the high 2.04 ppt soil salinity, while a healthy stand did occur on the well-drained lake rim with a soil pore salinity of only 0.43 ppt. Free soil water salinities along transect A were not so variable, but for inexplicable reasons were slightly higher on the lake rim (1.12 ppt) (Table 4-6). Along transect B where soil salinity decreased slightly toward the interior but remained above 1 ppt, the overstory remained sparse. Again, organic carbon content increased from the lake rim (3.06 %) to the interior (45.04 %) (Table 4-6). No

Table 4-5. Average Plant Cover and Relative Abundance of Herbaceous Understory Species, Transect A, Tangipahoa Parish, August 1980.

Species	Average Cover (%)	Frequency (%)	Relative Abundance
Water Primrose (Ludwigia bonariensis)	65.0	85.7	5570.5
Smartweed (Polygonum sp.)	50.0	28.6	1430.0
Duckweed (Lemna minor)	65.0	14.3	929.5
Flatsedge (Cyperus sp.)	10.0	57.1	571.0
Alligatorweed (Alternanthera philoxeroides)	25.0	14.3	357.5
Water Hyacinth (Eicchornia crassipes)	15.0	28.6	429.0
Cowpea (Vigna luteola)	10.0	14.3	143.0
Baldcypress (Taxodium distichum)	10.0	14.3	143.0
Waterhyssop (Bacopa monnieri)	10.0	14.3	143.0
Arrowhead (Sagittaria latifolia)	1.0	14.3	14.3
Cattail (Typha sp.)	1.0	14.3	14.3

Table 4-6. Soil Pore Salinity, Free Soil Water Salinity, and Total Organic Carbon for Each Sample Site along Each Transect.

Transect-Sample Plot	Soil Pore Salinity (ppt)	Free Soil Water Salinity (ppt)	Total Organic Carbon (%C)
A-1	0.43	1.12	3.06
A-5	0.97	0.80	29.24
A-7	2.04	0.83	45.04
B-1	1.51	1.45	4.41
B-5	1.24	1.25	13.89
B-9	1.24	1.10	25.60
B-13	1.15	1.02	26.91
C-1	0.72	0.44	11.85
C-5	0.37	0.52	34.84
C-9	0.39	0.42	29.32
C-13	0.61	0.54	32.27
D-1	0.41	0.19	4.14
D-5	0.43	0.17	8.79
D-9	0.55	0.18	24.02
D-13	0.59	0.17	16.27
F-1	1.40	2.09	23.41
F-5	2.04	Missing	31.98
F-9	1.60	1.89	28.54
F-13	1.76	2.24	25.04

obvious relationship could be detected between soil salinity and total organic carbon on these two transects.

Marsh-Shrub

Transect C near water quality station 3 and transect F off Marlin Canal were samples of the designated marsh-shrub zone. However, transect C contained a fair amount of baldcypress (41.66 ft^2/ac) and tupelogum (38.16 ft^2/ac), as well as several other overstory species, such as swamp blackgum and green ash (Fraxinus pennsylvanica) (Table 4-7). This area was characterized by finger-like projections of swamp forest interspersed with open canopy, herbaceous marsh. Smartweed was the dominant herbaceous plant and occurred in almost every plot (Table 4-8). Young cypress seedlings were noted thriving at or near some plots. This site was difficult to categorize in that, although open marsh areas were conspicuous, baldcypress occurred here at the rate of 150 trees per acre (Table 4-7). Transect C, therefore, represents a stressed swamp zone rather than a marsh-shrub zone. Transect F, on the other hand, contained considerably fewer and smaller baldcypress and was dominated by numerous, young red maples and waxmyrtle shrubs (Table 4-9). This site was truly a marsh-shrub-association with an open canopy allowing proliferation of many marsh species. The most abundant marsh plants were smartweed, which occurred in every plot, Walter's millet (Echinochloa walteri), bulltongue, and palmetto (Sabal minor) (Table 4-10). The preponderance of red maple at this site may indicate a successional trend toward reforestation here. Long-term salinity records for Pass Manchac indicated a general trend of lower salinities during the 1970s compared with the mid-1960s, possibly allowing the regeneration of the maples from seed sources along the spoil of Marlin Canal. However, the trees appeared stressed and may not withstand high soil salinities found along transect F.

Soil pore salinities along transect C were variable and ranged from 0.39 ppt to 0.72 ppt (Table 4-6). The occurrence of two sample plots along this transect with soil salinities below 0.5 ppt is probably a major reason why this site contained a fairly extensive stand of baldcypress and tupelogum. Free soil water salinities were also relatively low and ranged from 0.42 ppt to 0.54 ppt (Table 4-6). The percentage of organic carbon increased slightly toward the interior swamp.

Table 4-7. Stand Composition of Midstory and Overstory Woody Species along Transect C, Tangipahoa Parish, August 1980.

Species	Number Stems/Ac	Basal Area (ft^2/ac)	Relative Dominance	Relative Density	Frequency (%)	Average dbh (in)
Baldcypress (Taxodium distichum)	150.00	41.66	.4634	.2625	85.7	6.6
Tupelogum (Nyssa aquatica)	257.14	38.16	.4245	.4500	92.8	4.9
Swamp Blackgum (Nyssa sylvatica var. biflora)	85.71	9.38	.1043	.1500	28.6	4.1
Waxmyrtle (Myrica cerifera)	28.57	0.28	.0031	.0500	21.4	1.2
Drummond Red Maple (Acer rubrum var. drummondii)	7.14	0.16	.0018	.0125	7.1	2.0
Green Ash (Fraxinus pennsylvanica)	21.43	0.13	.0014	.0375	7.1	1.0
Black Willow (Salix nigra)	7.14	0.04	.0004	.0125	7.1	1.0
Buttonbush (Cephalanthus occidentalis)	7.14	0.04	.0004	.0125	7.1	1.0
Groundsel Bush (Baccharis halimifolia)	7.14	0.04	.0004	.0125	7.1	1.0
TOTALS	**571.41**	**89.89**	**.9997**	**1.0000**		

Table 4-8. Average Plant Cover and Relative Abundance of Herbaceous Understory Species, Transect C, Tangipahoa Parish, August 1980.

Species	Average Cover (%)	Frequency (%)	Relative Abundance
Smartweed (Polygonum sp.)	53.5	92.8	4964.8
Alligatorweed (Alternanthera philoxeroides)	22.0	71.4	1570.8
Bulltongue (Sagittaria lancifolia)	26.7	42.8	1142.8
Pickerelweed (Pontederia cordata)	13.8	50.0	690.0
Water Primrose (Ludwigia bonariensis)	9.3	50.0	465.0
Flatsedge (Cyperus sp.)	21.7	21.4	464.4
Waterhyssop (Bacopa monnieri)	45.0	7.1	319.5
Walter's Millet (Echinocloa walteri)	8.0	28.6	228.8
Bulrush (Scirpus californicus)	5.0	14.3	71.5
Paille Fine (Panicum hemitomum)	5.0	14.3	71.5
Baldcypress (Taxodium distichum)	1.8	35.7	64.3
False Nettle (Boehmeria cylindrica)	5.0	7.1	35.5
Pennywort (Hydrocotyle ranunculoides)	5.0	7.1	35.5
Burhead (Echinodorus cordifolius)	5.0	7.1	35.5
Aster (Aster sp.)	5.0	7.1	35.5
Soft Rush (Juncus effusus)	2.0	14.3	28.6

Table 4-9. Stand Composition of Midstory and Overstory Woody Species along Transect F, Tangipahoa Parish, August 1980.

Species	Number Stems/Ac	Basal Area (ft^2/ac)	Relative Dominance	Relative Density	Frequency (%)	Average dbh (in)
Drummond Red Maple (Acer rubrum var. drummondii)	196.4	5.92	.3571	.4104	100.0	1.9
Baldcypress (Taxodium distichum)	21.4	5.49	.3311	.0447	28.6	5.3
Waxmyrtle (Myrica cerifera)	164.3	2.77	.1671	.3434	92.8	1.5
Black Willow (Salix nigra)	42.8	1.93	.1164	.0894	28.6	2.6
Groundsel Bush (Baccharis halimifolia)	35.7	0.21	.0127	.0746	50.0	1.0
Diamond Leaf Oak (Quercus obtusa)	3.6	0.18	.0108	.0075	7.1	3.0
Dahoon (Ilex cassine)	7.1	0.04	.0024	.0148	14.3	1.0
Buttonbush (Cephalanthus occidentalis)	3.6	0.02	.0012	.0075	7.1	1.0
Red Bay (Persea borbonia)	3.6	0.02	.0012	.0075	7.1	1.0
TOTALS	**478.5**	**16.58**	**1.0000**	**.9998**		

Table 4-10. Average Plant Cover and Relative Abundance of Herbaceous Understory Species, Transect F, Tangipahoa Parish, August 1980.

Species	Average Cover (%)	Frequency (%)	Relative Abundance
Smartweed (Polygonum sp.)	44.3	100.0	4430.0
Walter's Millet (Echinocloa walteri)	13.2	78.6	1037.5
Bulltongue (Sagittaria lancifolia)	9.3	100.0	930.0
Palmetto (Sabal minor)	13.0	71.4	928.2
Cowpea (Vigna luteola)	5.9	78.6	463.7
Alligatorweed (Alternanthera philoxeroides)	5.0	21.4	107.0
Flatsedge (Cyperus sp.)	3.7	21.4	79.2
Pickerelweed (Pontederia cordata)	5.0	14.3	71.5
Buttonbush (Cephalanthus occidentalis)	5.0	7.1	35.5
Beak Rush (Rhynchospora corniculata)	5.0	7.1	35.5
Drummond Red Maple (Acer rubrum var. drummondii)	5.0	7.1	35.5
Saltmarsh Aster (Aster subulatus)	5.0	7.1	35.5
Baldcypress (Taxodium distichum)	1.0	7.1	7.1

Transect F, off Marlin Canal, exhibited the highest soil pore and free soil water salinities of any site. With soil salinities ranging over 2 ppt, it is surprising that the shrubs and red maple could have established themselves so well here. When soil samples and free soil water samples were obtained on this site in November 1980, tropical storm Jeanne was moving through the Gulf of Mexico southwest of New Orleans. Easterly winds had pushed waters from Lake Pontchartrain into the study area, resulting in water levels several inches above the swamp surface. Water salinities at several of the water quality stations at this time were at or just above 3 ppt. Free soil water salinities were certainly influenced by these conditions at the time of sampling, and the soil pore salinities may have been influenced as well.

Baldcypress-Tupelogum Forest

A baldcypress-tupelogum forest association was sampled near water quality station 6 off Ponchatoula Creek. Transect D represented the healthiest stand that was sampled in terms of overstory. Baldcypress and swamp blackgum were almost codominant with basal areas of 85.74 ft^2/ac and 80.30 ft^2/ac, respectively (Table 4-11). Swamp blackgum is a common constituent of cypress forests in the Pontchartrain Basin (Brown 1945). Green ash, tupelogum, and red maple were also abundant species along transect D. The numerous, young green ash, with an average dbh of 2.3 in, indicate a continuing diversification of the young swamp stand, particularly near the stream bank where overflow sediment deposits have created slightly higher elevations and higher mineral content of the soil (Table 4-6). The high density of baldcypress (164 trees per acre), swamp blackgum (282 trees per acre), tupelogum (107 trees per acre), and green ash (285 trees per acre) along this transect (Table 4-11) is indicative of a young stand regenerating on cut-over cypress swamps. Mattoon (1915) cites a figure of 340 cypress trees per acre 20 to 30 years old, occurring on a cut-over cypress tract. Density of cypress on more mature stands often ranges from 40 to 60 cypress per acre (Mattoon 1915). Smartweed and water primrose were the most abundant herbaceous species present (Table 4-12). Marsh plants generally increased toward the interior where the tree canopy was not as closed and where more light penetrated to the swamp surface.

Soil pore salinities ranging from 0.41 to 0.59 ppt increased toward the interior, which may account for the slight reduction in tree canopy closure. Free soil water salinities were quite low (Table 4-6). Again, on this transect, total organic carbon increased slightly toward the swamp interior.

Table 4-11. Stand Composition of Midstory and Overstory Woody Species along Transect D, Tangipahoa Parish, August 1980.

Species	Number Stems/Ac	Basal Area (ft^2/ac)	Relative Dominance	Relative Density	Frequency (%)	Average dbh (in)
Baldcypress (Taxodium distichum)	164.3	85.74	.4081	.1804	71.4	9.1
Swamp Blackgum (Nyssa sylvatica var. biflora)	282.1	80.30	.3822	.3098	78.6	6.6
Tupelogum (Nyssa aquatica)	107.1	29.70	.1414	.1176	42.8	6.3
Green Ash (Fraxinus pennsylvanica)	285.7	11.68	.0556	.3137	92.8	2.3
Drummond Red Maple (Acer rubrum var. drummondii)	53.6	2.20	.0105	.0588	64.3	1.9
Waxmyrtle (Myrica cerifera)	10.7	0.43	.0020	.0117	21.4	2.7
Roughleaf Dogwood (Cornus drummondii)	3.6	0.02	.0001	.0040	7.1	1.0
Buttonbush (Cephalanthus occidentalis)	3.6	0.02	.0001	.0040	7.1	1.0
TOTALS	**910.7**	**210.09**	**1.0000**	**1.0000**		

Table 4-12. Average Plant Cover and Relative Abundance of Herbaceous Understory Species, Transect D, Tangipahoa Parish, August 1980.

Species	Average Cover (%)	Frequency (%)	Relative Abundance
Smartweed (Polygonum sp.)	24.3	100.0	2430.0
Water Primrose (Ludwigia sp.)	21.9	92.8	2032.3
Arrowhead (Sagittaria latifolia)	11.4	78.6	896.0
Pickerelweed (Pontederia cordata)	11.6	50.0	580.0
Bulltongue (Sagittaria lancifolia)	8.3	42.8	355.2
Lizard Tail (Saururus cernuus)	11.7	21.4	250.4
Panic Grass (Panicum sp.)	5.0	28.6	143.0
Alligatorweed (Alternanthera philoxeroides)	15.0	7.1	106.5
Greenbriar (Smilax sp.)	5.0	14.3	71.5
Burhead (Echinodorus cordifolius)	5.0	14.3	71.5
Gulfcoast Waterhemp (Acnida cuspidata)	3.0	14.3	42.9
Soft Rush (Juncus effusus)	5.0	7.1	35.5
Pennywort (Hydrocotyle ranunculoides)	5.0	7.1	35.5
Duckweed (Lemna minor)	5.0	7.1	35.5
Marsh Fern (Thelypteris palustris)	5.0	7.1	35.5
Palmetto (Sabal minor)	1.0	7.1	7.1

Baldcypress abundance versus soil salinities

Substantial variation was noted between transects in basal area of baldcypress and total basal area of all woody species combined (Figure 4-3). To a large extent, this report involves the investigation and possible explanations for the transition of some areas, such as along transect B, from historically baldcypress swamp to its present marsh status with little forest canopy. If saltwater intrusion has been an important factor in this change, a relationship may exist between soil salinities and cypress abundance. To explore this possibility, basal area of baldcypress versus average soil pore salinities for each transect was graphed (Figure 4-4). Linear regression performed on this data implied a definite relationship with a correlation coefficient of -0.846. However, this relationship was statistically significant only at the $P<0.1$ level. This means that, statistically, the relationship shown could result purely from chance and not be an actual expression of environmental processes less than 10% of the time.

In scientific fields, a significance level of $P<0.1$ is marginal and caution must be observed. Therefore, the authors graphed the number of stems per acre of baldcypress versus soil pore salinities (Figure 4-5). Linear regression on this data resulted in a correlation coefficient of -0.9387 which was significant at the $P<0.05$ level. The reason basal area did not provide as high a correlation is probably due to the differences in age of the cypress in different transects. Whereas the average dbh of baldcypress on transect D was 9 in, it was only 5.5 in along transect A and 5.3 in along transect F. The smaller the dbh the less the basal area, so that different-aged stands do not correlate well even with similar salinities. On the other hand, no such anomalies occur when number of stems per acre is used as the parameter. The authors believe the data show a definite relationship between baldcypress abundance and soil salinities, indicating that major impacts occur when soil pore salinities reach about 1.0 ppt.

Relationship of Vegetative Composition to Hydrologic Conditions

The inter-relationships between hydrologic processes, soil characteristics, and wetland vegetation are not easily separated in a search for simple causes and effects. For the case in point, both natural and man-induced changes are the causes for the increase in marsh and shrub vegetation at the expense of cypress-tupelo swamp. The initial cutting of the virgin cypress in the area could have caused a disappearance of the

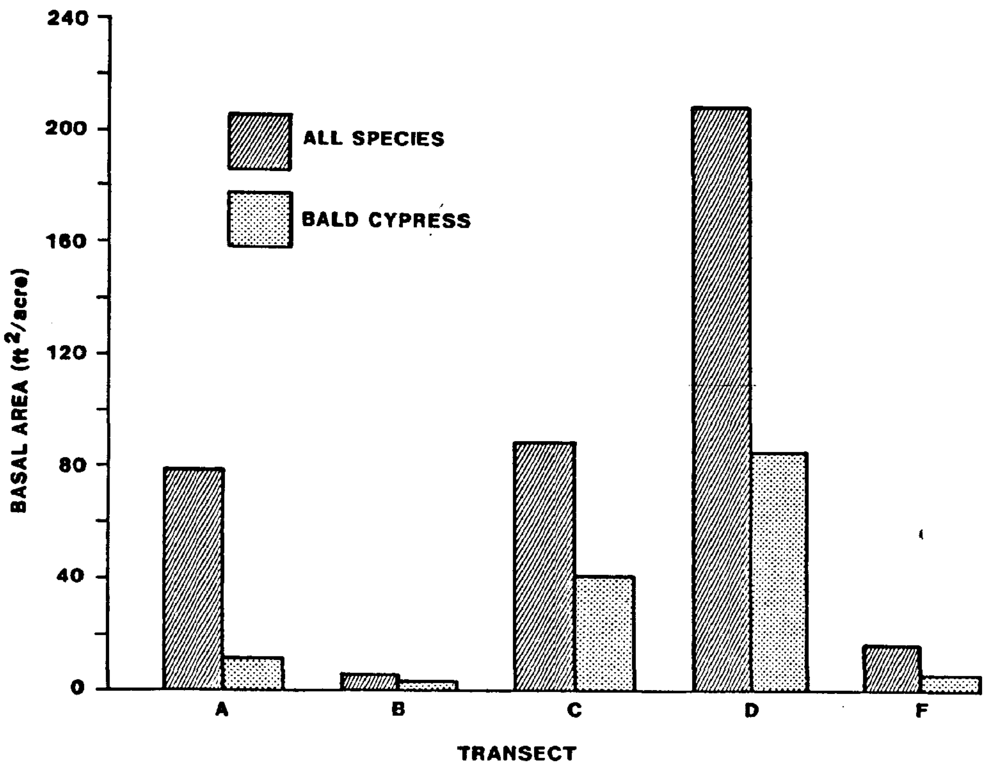

Figure 4-3. Basal area estimates for all species combined and for baldcypress along each transect.

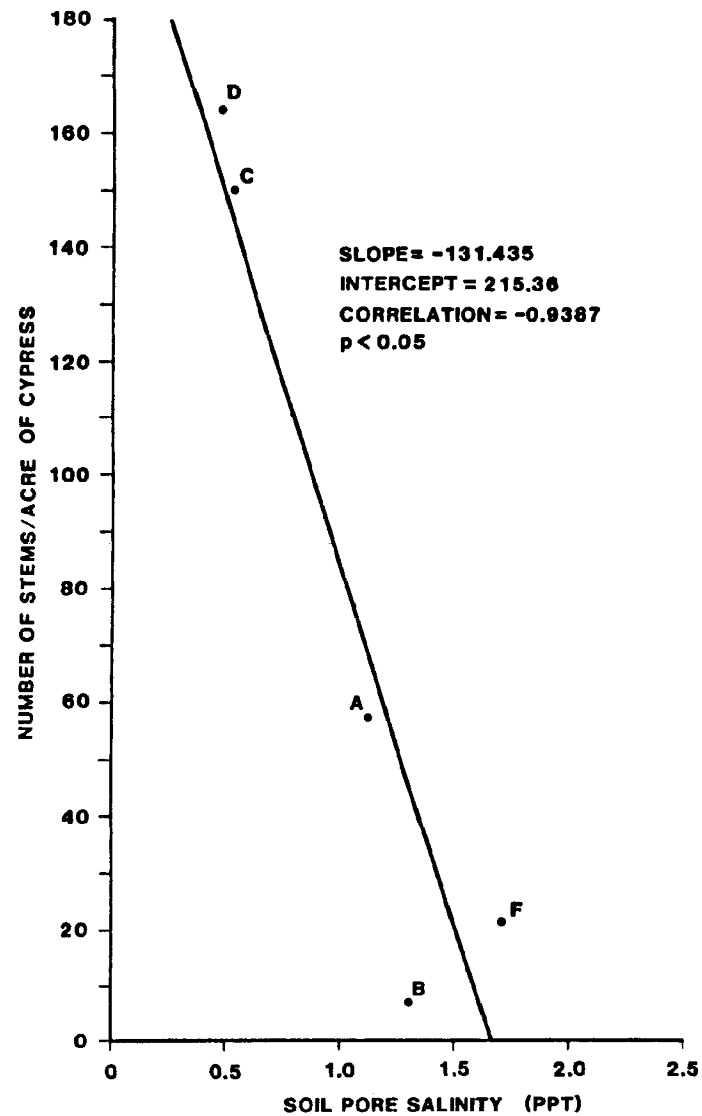

Figure 4-4. Number of stems per acre of baldcypress versus soil pore salinities for each transect.

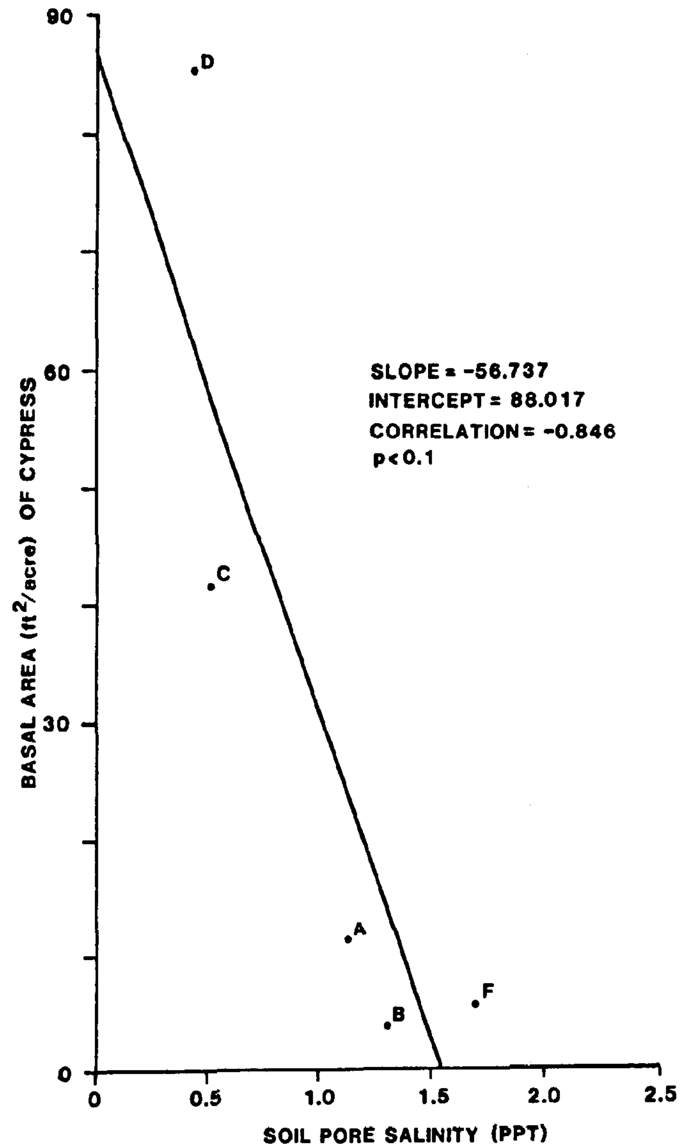

Figure 4-5. Basal area of baldcypress versus soil pore salinities for each transect.

swamp "hardpan" of interlocking roots, thereby changing the consistency of the soil. Logging, especially clear-cutting of the virgin cypress forest, may possibly have caused changes in the nutrient stores of the swamp. Bormann et al. (1968) reported that clear-cutting of a New Hampshire forest tended to deplete nutrients of the forest ecosystem not only by removal of nutrients in the trees themselves but also by increasing runoff and the amounts of dissolved nutrients, especially nitrates, in leaching waters. Losses of cations were 3 to 20 times greater than in a comparable, undisturbed system (Bormann et al. 1968). Also, Schlesinger (1978) found that very little nutrient circulation occurred in the closed-basin cypress forest of Okefenokee Swamp, Georgia. Most nutrients were contained in the cypress boles, with little annual nutrient uptake. The peat accumulations in this swamp were represented as large, permanent nutrient losses from the community. If similar conditions are approximated in the Tangipahoa swamps, clear-cutting could have reduced available nutrient supplies and possibly could have affected successful cypress regeneration and rate of growth.

At the same time, logging scars, especially canals, altered the hydrology, allowing greater access of brackish water. With logging came an opening of the forest canopy and a consequent generation of fresh marsh vegetation to compete with seedling cypress. Each of these events could have been detrimental to regeneration of the swamps. There is also a possibility that subsidence of the swamp surface due to natural processes and logging activities has increased the frequency of inundation and deterred germination of cypress seeds. Both Mattoon (1915) and Demaree (1932) report failure of cypress seeds to germinate while submerged. The presence of lowered water levels but retention of moist soils is needed for successful germination. However, cypress seeds will evidently remain viable for several months while submerged. Baldcypress seeds lose viability within about one year (Applequist 1959) so that continuous flooding throughout a spring and summer could reduce prospects for regeneration.

The limitations of this investigation do not allow evaluation of all of the possible causes of vegetation change. However, the authors feel that this analysis of the effects of salinity on the cypress-tupelo swamps is well founded and surpasses any existing research on this subject.

Salt "poisoning" of the cypress-tupelo swamps is a function of both the level of exposure (concentration) and duration of exposure. Because the level and duration of exposure are closely related in the study area, the question as to which exerts the most influence cannot be answered. In other words, it is not known whether the effects of 2 ppt for 5 days and 5 ppt for 2 days are different. This same type of study needs to be done in another area perhaps in the vicinity of Lake Salvadore in the Barataria Basin with a slightly different hydrologic regime to provide more data.

For salts to cause stress to cypress and other overstory vegetation, they must first enter the soil to cause an increase in the soil salinity. Soil salinity is not only influenced by the level and duration of exposure, but also by other factors such as:

1) The composition of the soil. Soils containing high percentages of clay minerals and organics absorb and retain salts more readily than silty or sandy soils.

2) The rate of evapotranspiration at the time of exposure. During the growing season when temperatures are high, salts may accumulate more rapidly as freshwater is evapotranspired by the vegetation.

3) The amount of flushing with freshwater between exposures. Accumulated salts can be leached from the soil by water with salinity less than the soil pore water salinity. For example, the passage of winter cold fronts usually results in some rainfall followed by very low tides. Waters flowing out of the swamps are usually more saline than those in the canals and bayous, indicating that leaching of salts is occurring. This has been observed five times at station 3 during the monthly monitoring. Overbank flooding of the rivers also leaches salts, but this phenomenon has not been recorded during the study because of abnormally low rainfall during the year.

To document the past salinity regimes of the marsh, marsh-shrub, stressed swamp, and non-stressed swamp zones, the frequencies of exposure to salinities from 0-10 ppt were derived for four stations. The frequency of inundation of each zone appears in Figure 4-6, and the salinity regimes are shown in Figures 4-7 and 4-8. The marsh zone is represented by vegetation transect B and water quality station 10, the marsh-shrub zone by transect F and station 14, the stressed swamp by transect C and station 3; and the non-stressed swamp, by transect D and station 6 (Plates 1 and 5).

The water level regime in Figure 4-6 is based on daily stage readings at Pass Manchac from 1961-1977 and average elevations for each zone. This represents the minimum degree of flooding for each zone. Measurements of ground elevation in each case decreased steadily from the streambank, inland, to the end of each elevation transect which was 85 ft long. Therefore, it must be assumed that the elevation continues to

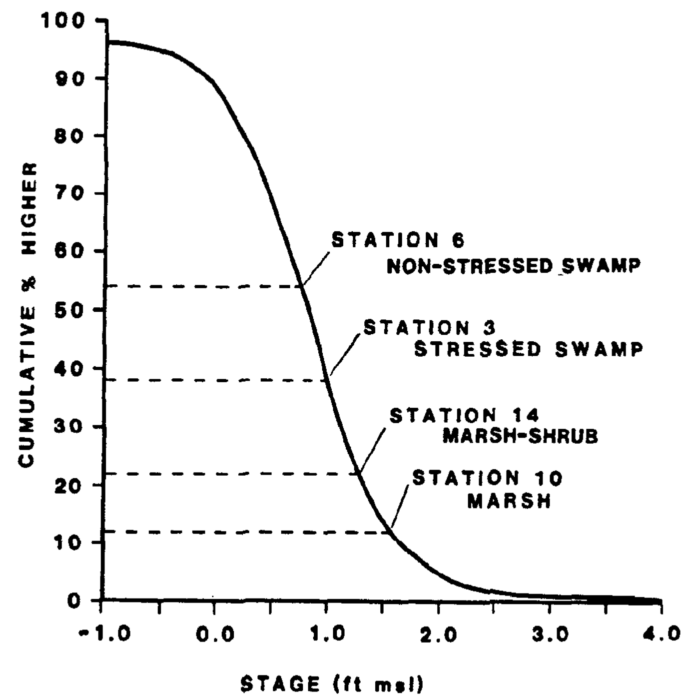

Figure 4-6. Water level regime for the study area based on daily stage readings at Pass Manchac, 1961-1977. Minimum amount of flooding is shown for the four characteristic vegetative zones.

decrease inland, toward the swamp interior which would increase the frequency of inundation. It is perhaps significant that the non-stressed swamp is flooded 54% of the time as compared to the marsh zone which is flooded only 12% of the time. The difference is attributable either to increased subsidence in the swamp because of proximity to the major fault line (Plate 2) or greater overbank input of sediments to the marsh zone from Lake Pontchartrain, or both.

It was calculated that the marsh zone has been flooded with water of salinity 2 ppt or greater, 30% of the time and with 3 ppt or greater, 10% of the time (Figure 4-7). In contrast the marsh-shrub zone has been flooded with water of 2 ppt salinity or greater, 20% of the time and with 3 ppt or greater just 5% of the time (Figure 4-8). This difference in salinity exposure is probably a factor producing the differences in stand composition shown in Tables 4-2 and 4-9. Transect F, in the marsh-shrub zone, contained a greater number of stems per acre and basal area for baldcypress, as well

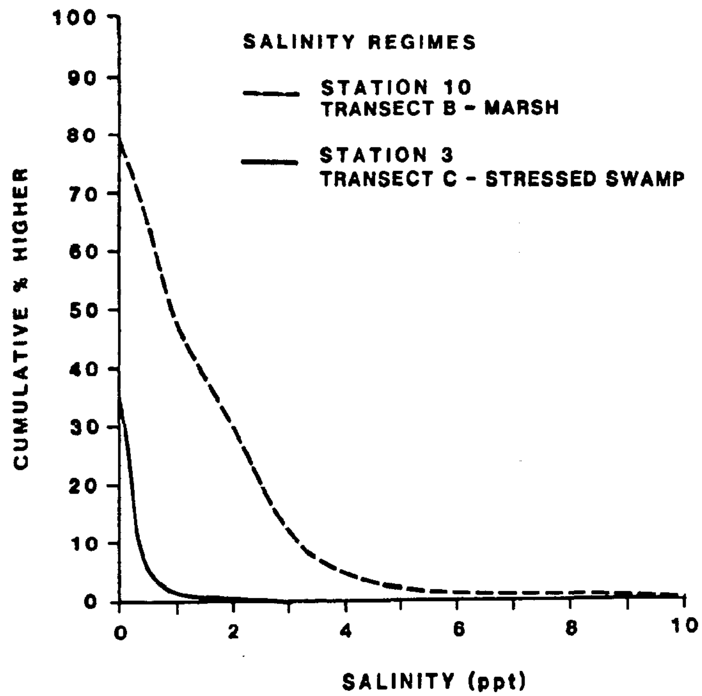

Figure 4-7. Salinity regimes of the marsh zone and the stressed swamp zone.

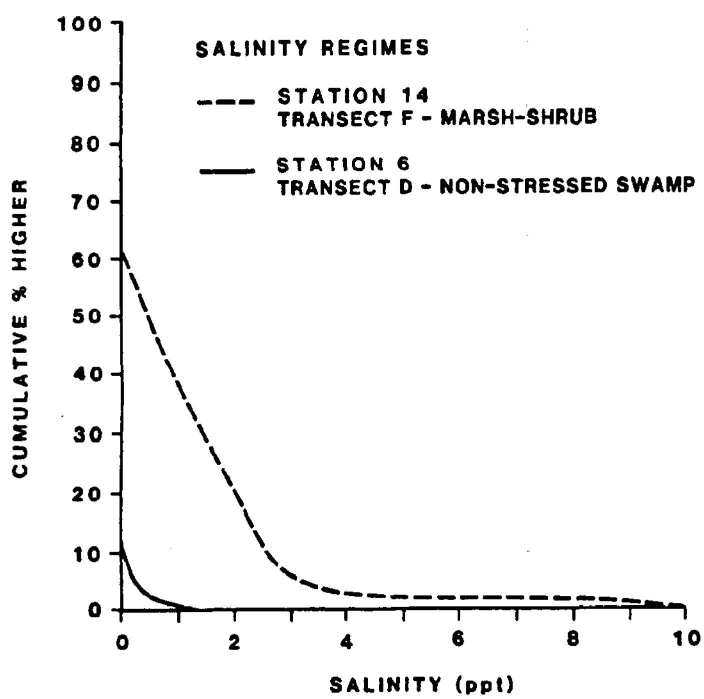

Figure 4-8. Salinity regimes of the marsh-shrub zone and the non-stressed swamp zone.

as for most other species, than transect B in the marsh zone. Another conspicuous difference was the preponderance of small red maples in the marsh-shrub zone as a result of either the lower level salinity exposure or the tendency of this species to regenerate by sprouting on decaying baldcypress stumps.

In comparing the marsh-shrub zone with the stressed swamp zone, the marsh-shrub zone has experienced water salinities of 1 ppt or greater 38% of the time, while the stressed swamp has been flooded with water salinities of 1 ppt or greater less than 2% of the time. This substantial difference in frequency of exposure is reflected in great differences in the abundance and size of baldcypress on the two sites (Tables 4-7 and 4-9), as well as the greater abundance and diversity of overstory swamp species in the stressed swamp. This seems to indicate that Lake Maurepas acts as a fairly effective buffer to salinity encroachment.

Vegetative composition in the stressed swamp and non-stressed swamp zones was somewhat similar in species composition and densities (Tables 4-7 and 4-11). In reality, the non-stressed swamp should be called a "less stressed swamp" because it is not totally healthy and viable. However, basal area in the non-stressed swamp was much greater (Figure 4-3), with larger average dbh measurements. This is probably a function of the forest flanking Ponchatoula Creek being an older stand having been less impacted in the past. In this regard, the stressed swamp was flooded with water of salinity greater than 0 ppt 35% of the time while the non-stressed swamp was flooded with water of salinity greater than 0 ppt 11% of the time. Note that both zones were flooded with water of salinity greater than 1 ppt less than 1% of the time (Figures 4-7 and 4-8). This lower level of exposure contributed to their better health when compared to the marsh and marsh-shrub zones.

A basic hypothesis in this study has been that increasing water salinities encroaching into the Tangipahoa Parish wetlands have been the major factor contributing to the mortality of the baldcypress swamps. In this regard, a search of the literature was conducted to determine the extent of published information relative to the salinity tolerance of baldcypress. Surprisingly, very little information was available.

Penfound and Hathway (1938), in their study of the marshes of southeastern Louisiana, reported an upper range of salinity of 0.89% salt for baldcypress. This figure was derived hydrometrically from water samples taken on vegetative transects. However, there is some question as to the exact methodology used and the actual meaning of the percentage salt figure used in the Penfound and Hathaway paper. Normally percentage salt on a weight basis can be easily converted to ppt by multiplying by 10 because percent is actually parts per 100. In this case, it would mean the tolerance of cypress would be 8.9 ppt using the Penfound and Hathaway (1938) report. This rather high salinity range, as well as the tolerance of other wetland species reported in terms of percent salt, has been viewed skeptically by others (Montz 1980, personal communication).

When Chabreck (1972) published results of his Louisiana marsh sampling, baldcypress occurred in a few of the plots. He reported a mean water salinity of 1.90 $\pm$ 0.7 ppt for these five plots which may give a good indication of tolerance because these plots probably were located at the interface of swamp and marsh, i.e., the seaward limit of baldcypress. In a manual of marsh and aquatic plants of North Carolina (Beal 1977), the upper range of chlorinity reported for baldcypress was about 0.1 ppt, which is virtually fresh, and was not meant to represent a tolerance limit but only the range observed in the particular sites sampled.

No other data were found relative to the salinity tolerance of baldcypress. Thus, it seems logical that this report should be a valuable addition to this scant body of knowledge if some type of critical salinity for baldcypress can be estimated.

In view of the lack of published information on the tolerance of cypress-tupelo swamps to salt, the following analysis was made. Using the frequency curves of salinity exposure in Figures 4-7 and 4-8, the logarithms of stems per acre of baldcypress were plotted against the frequency of inundation by waters greater than 0 ppt, 1 ppt, 2 ppt, and 3 ppt for each transect. Four regression equations were calculated, one for each level of salinity exceedance. The results (Figure 4-9) indicate that the best relationship between decrease in baldcypress and salinity corresponds to the frequency of inundation with waters having salinities greater than 2 ppt (Figure 4-9). A drastic decrease in the abundance of baldcypress with increasing salinity, is represented by the slopes of the four lines. The four slopes have been plotted in Figure 4-10 along with the salinity mean and standard error reported by Chabreck (1972) for baldcypress trees at the marsh-swamp ecotone. It is significant that the mean salinity of 1.9 ppt from Chabreck's (1972) study corresponds very closely with the "break point" in the rate of decrease curve. Stated simply, the agreement between these two independent

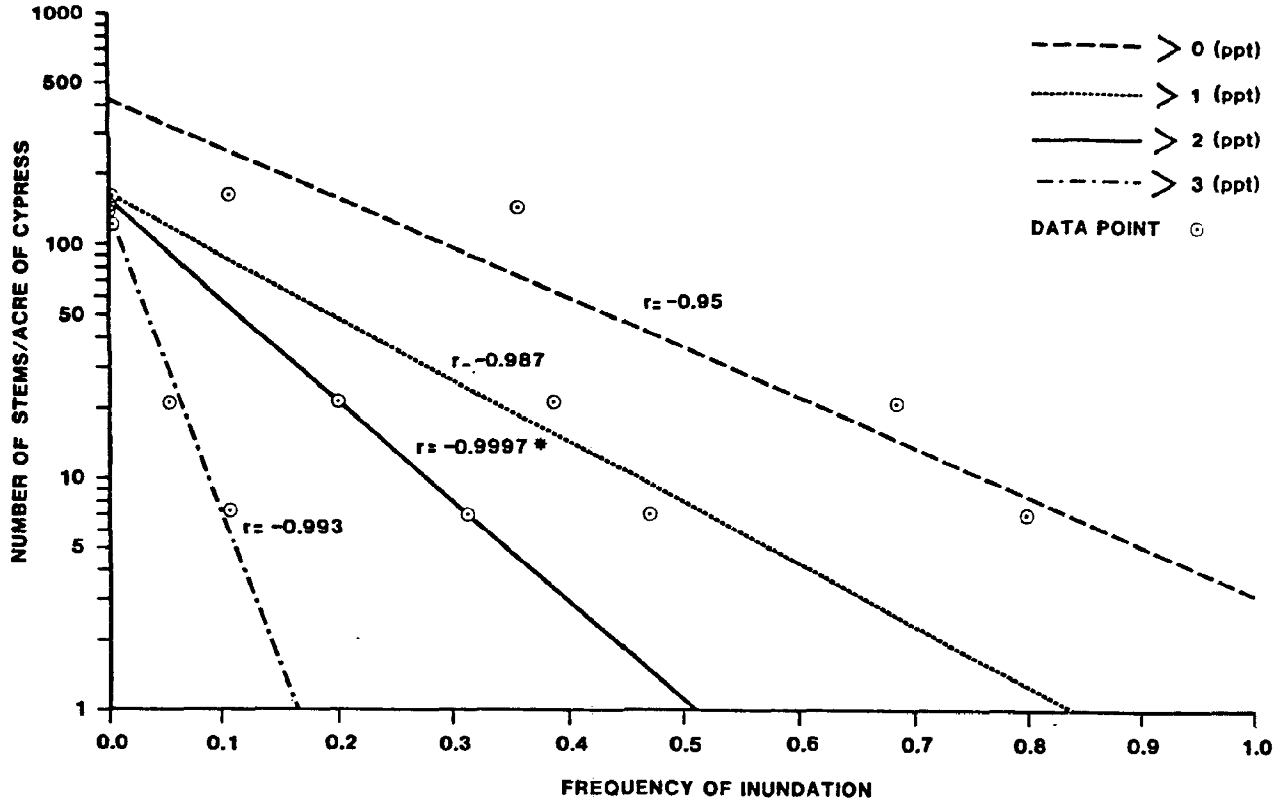

Figure 4-9. Relationships between frequency of inundation with waters greater than 0, 1, 2, and 3 ppt salinity and the number of stems per acre of cypress. All regressions are significant at the 0.05 level. An asterisk (*) indicates significance at the 0.001 level.

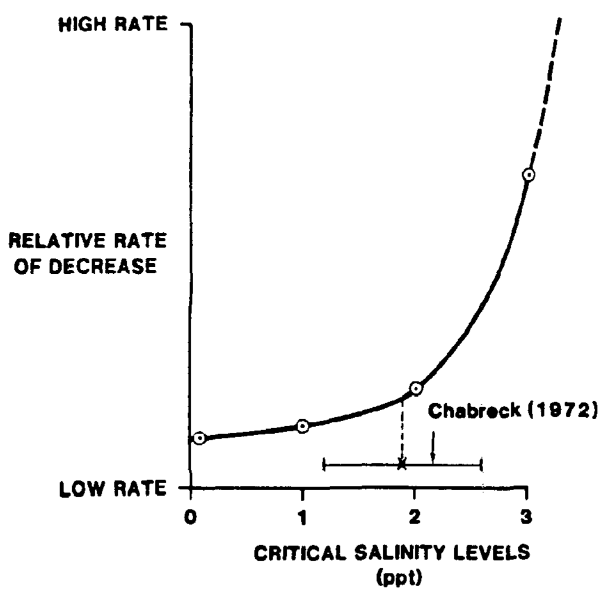

Figure 4-10. Relative rates of decrease in stems per acre of cypress per unit of exposure to salinities greater than 0, 1, 2, and 3 ppt and the salinity mean and standard error reported by Chabreck (1972) for cypress at the swamp-marsh ecotone.

studies strongly suggests that the upper tolerance limit of baldcypress swamps to salinity is between 1.8 and 2.1 ppt. The mean annual salinity for Pass Manchac for 1953-1979 is 1.54 ± 0.12 ppt, below the critical range. However, mean monthly salinities are within the critical range during the months of September, October, November, and December at Pass Manchac. Almost every year during the fall and early winter, salinities exceed the tolerance for baldcypress and have at times surpassed 10 ppt under extreme conditions.

CHAPTER V: CONCLUSIONS AND RECOMMENDATIONS

The data show conclusively that salinity intrusion is the primary cause of the changes in the vegetation composition of the study area, regardless of the inter-related mechanisms involved. Baldcypress trees are generally limited in distribution to areas where salinity does not exceed 2 ppt for more than 50% of the time the trees are inundated (Figures 4-9 and 4-10). This distribution is not only a function of salinity regime, but also of ground elevation, with trees at lower elevations being more susceptible to flooding by higher salinity waters. Therefore, subsidence can be an important factor.

Using the rate of salinity increase (0.031 ppt/yr) in Figure 4-2, the critical salinity (2 ppt) for cypress, and the mean salinity (0.15 ppt) at station 6 in Ponchatoula Creek from the current monitoring year, the following calculation was made: (2.0 - 0.15) ppt divided by 0.031 ppt/yr = 59.7 years. These numbers indicate that in 60 years the baldcypress-tupelogum forest association flanking Ponchatoula Creek may be transformed to a marsh association similar to that presently occurring on Jones Island, if the apparent trends are accurate. This equates to the loss of some 33,000 acres of swamp forest. Even though the rate of increase is not statistically significant in itself, the possibility of recurrent droughts and hurricanes in the next 60 years is great enough to fulfill this projection unless remedial management measures are taken to prevent the decline in baldcypress vegetation. In addition, the salinities measured during monitoring at Pass Manchac in this study are relatively low compared to the long term record, making 60 years a conservative estimate. Substantial loss of the remaining swamp forest can be expected within the next 25 years.

A direct and feasible solution to the salinity intrusion problems in the Tangipahoa wetlands is the diversion of freshwater from the Mississippi River into the Maurepas-Pontchartrain Basin. CEI is presently investigating the feasibility of and preparing a plan for such diversions for the Coastal Management Section, Louisiana Department of Natural Resources. At present, it appears that the potential for man-made diversions of freshwater into Lake Maurepas is severely restricted by two major factors: 1) it would require displacement of existing development in some locations; and 2) much of the area has flooding problems due to poor drainage. The Bonnet Carre Spillway, however, is an excellent site for Mississippi River water diversion because it can be modified to deliver annually a small portion of its full flood control capacity to Lake

Pontchartrain. Because the spillway is part of a Federally funded flood control program, the modifications must be authorized by Congress. The authors feel that it is in the best interest of Tangipahoa Parish to support a plan for freshwater diversion via the Bonnet Carré Spillway.

An action that could be implemented at the parish level to improve conditions would be to re-establish freshwater drainage from north to south through the swamps. As mentioned earlier in the report, South Slough and Anderson Canal intercept runoff from the terrace lands and shunt it into the borrow canal adjacent to I-55. If this discharge did not by-pass the swamps on its way to Lake Pontchartrain, it would surely help mitigate the effects of salinity intrusion and at least help protect the swamp areas near the terrace which have not yet been severely impacted. It is recommended that an analysis of the situation be made to devise a plan to introduce this terrace runoff directly into the wetlands without adversely affecting drainage on the terrace. This same analysis could also be aimed at improving drainage in and around Pontchatoula. Furthermore, the quality of the runoff would be improved by circulating the waters through the swamp. Such a measure could retard eutrophication while providing essential nutrients to the swamps.

Another approach to deterring salinity intrusion is to structurally exclude the inflow of brackish waters. Innovative technology for regulating water flow has recently been developed for application to marsh management in St. Bernard Parish (CEI 1981), including such things as variable weirs, flap-gate weirs, gated pipes, and shell or earthern dams and dikes. Such structural measures could be implemented in the study area at Middle Bayou, north of the camps on the I-55 borrow canal, and other small logging canals which allow inflow of higher salinity waters to the backswamp. "Boat ladders" would have to be included in the designs to allow continued access to the interior wetlands. The construction of low dikes could be beneficial in areas with little or no natural bank crest, such as the northern bank of Owl Bayou. Any future plans for canal construction in the wetlands, such as dredging in relation to oil and gas exploration, should be critically evaluated in terms of potentially increasing saltwater intrusion into interior swamps and marshes.

To be most effective, all of the measures mentioned here, plus other economic and social considerations, must be viewed in the context of an overall management plan for the Tangipahoa wetlands. It is imperative that the parish evaluate its wetland habitat in terms of present and future environmental viability and the beneficial services it provides for the parish. It is highly desirable that the parish formulate a set of guidelines for utilization and management of these wetlands in order to maximize their beneficial functions as a naturally renewable timber, fur, and fisheries resource; a recreation area; an aesthetically pleasing habitat type; and a potentially valuable water treatment area. The cypress swamps are being destroyed slowly, apparently by an almost imperceptible rise in salinity. If this process continues unabated, the parish stands to lose an enormous expanse of cypress swamp to marsh or even to open water. A long term increase in salinity levels in areas with normally high water levels will result in much of this area becoming open water because brackish-water marsh species cannot colonize deep water sites.

This study has identified and documented a crucial problem pertaining to the Tangipahoa wetlands. It is strongly recommended that these findings be used to initiate action, especially along management lines, to offset this particular problem and to initiate effective management of the Tangipahoa wetlands to maximize their major functions.

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APPENDIX A:

MONTHLY WATER QUALITY MONITORING DATA
(JUNE 1980 - MAY 1981)

**Location of monitoring stations is shown on Plate 1. A dash (--) denotes missing value due to equipment failure or hazardous weather conditions.

1. Parameter: Dissolved Oxygen (in ppm).

DATE:	1980							1981				
STATION*	JUN 11,12	JUL 15,16	AUG 13,14	SEP 31,1	OCT 28	NOV 13,14	DEC 16,17	JAN 26,27	FEB 25	MAR 24	APR 30	MAY 28
1	6.1	6.7	10.8	7.2	6.4	7.6	7.7	9.5	8.6	6.8	5.0	2.8
1A	6.8	6.0	6.8	8.6	7.8	7.7	8.6	10.2	8.5	8.7	8.6	6.6
2	7.1	6.2	4.8	5.2	6.6	8.4	--	10.9	7.4	7.4	7.1	3.3
3	4.6	4.8	3.1	3.0	7.7	8.0	--	6.7	2.6	3.9	2.6	1.2
4	9.0	7.3	3.1	4.4	4.6	7.8	--	10.1	3.2	7.5	5.8	1.5
5	9.9	5.7	2.6	2.7	4.7	7.2	--	11.3	3.0	5.2	6.3	5.5
6	10.6	7.3	7.8	5.3	2.9	7.5	--	11.5	5.4	6.3	5.2	4.5
7	7.6	9.0	4.6	6.9	7.5	8.6	8.4	11.2	4.3	7.8	7.2	6.4
8	6.9	9.0	5.8	5.7	6.2	7.5	4.7	8.7	3.4	6.4	4.8	4.0
9	5.4	8.8	7.8	4.1	3.3	3.8	6.5	5.9	5.4	6.4	6.6	4.6
10	6.1	8.0	6.4	8.8	8.0	8.1	8.5	10.0	8.5	8.1	8.2	6.7
11	6.4	7.1	5.8	8.5	--	8.3	--	--	8.5	8.1	7.5	7.6
12	5.8	5.2	1.4	4.6	--	8.2	--	--	7.2	6.6	7.6	2.9
13	7.0	3.4	2.2	7.6	--	8.3	5.7	9.9	7.0	4.6	8.1	7.5
14	5.2	4.2	2.0	6.3	--	7.5	6.5	7.2	3.9	8.6	2.5	3.6
15	8.2	5.4	3.4	5.7	--	8.4	8.0	9.4	6.7	8.4	6.6	5.8
16	7.5	6.5	4.8	7.4	--	8.1	8.2	8.9	7.2	8.7	7.3	5.4
17	8.1	6.0	1.5	7.9	--	8.2	4.4	9.5	6.5	9.4	4.0	4.3
18	5.8	3.6	1.7	3.0	--	7.9	4.3	7.3	2.3	13.8	3.0	3.8
19	8.1	6.8	5.4	6.4	--	8.0	8.4	10.2	6.1	9.6	7.7	7.6

2. Parameter: Salinity (in ppt).

DATE:	1980							1981				
STATION*	JUN 11,12	JUL 15,16	AUG 13,14	SEP 31,1	OCT 28	NOV 13,14	DEC 16,17	JAN 26,27	FEB 25	MAR 24	APR 30	MAY 28
1	0.21	0.24	1.29	1.32	1.11	2.48	0.95	2.40	1.26	1.40	1.97	1.95
1A	0.22	0.09	0.87	1.33	1.39	2.58	0.91	2.74	0.64	1.23	1.37	2.04
2	0.00	0.03	0.66	0.22	0.63	0.64	0.10	0.49	0.09	0.11	0.31	0.95
3	0.00	0.21	0.63	0.51	0.57	0.64	0.28	0.30	0.24	0.39	0.62	0.70
4	0.00	0.04	0.41	0.14	0.11	0.62	0.04	0.16	0.03	0.04	0.33	0.14
5	0.02	0.02	0.22	0.12	0.04	0.62	0.06	0.11	0.03	0.04	0.09	0.01
6	0.02	0.06	0.30	0.12	0.05	0.62	0.06	0.11	0.05	0.07	0.12	0.00
7	0.02	0.26	1.12	0.96	1.19	1.88	0.78	0.99	0.09	0.66	1.02	1.32
8	0.02	0.09	0.91	0.26	0.67	1.09	0.27	0.45	0.00	0.20	0.30	0.12
9	0.01	0.10	0.37	0.17	0.07	0.29	0.13	0.13	0.05	0.10	0.11	0.00
10	0.45	0.79	0.89	1.95	--	2.96	0.81	2.68	0.59	1.33	1.32	1.89
11	0.65	0.90	0.87	1.32	--	1.96	1.21	--	1.83	1.70	1.44	2.24
12	0.23	0.61	1.16	1.44	--	3.06	1.03	--	1.00	1.20	2.35	1.94
13	0.40	0.21	1.01	1.06	--	2.88	0.55	2.06	0.23	0.49	1.59	0.60
14	0.05	0.16	1.06	1.02	--	2.89	0.53	1.28	0.20	0.29	1.36	0.62
15	0.00	0.01	0.24	0.20	--	2.26	0.04	0.04	0.03	0.00	0.17	0.00
16	0.00	0.00	0.01	0.04	--	2.17	0.03	0.02	0.01	0.00	0.01	0.00
17	0.00	0.01	0.46	0.08	--	2.30	0.23	0.02	0.04	0.00	0.09	0.01
18	0.01	0.05	0.36	0.05	--	2.16	0.25	0.04	0.09	0.21	0.11	0.37
19	0.32	0.29	0.75	1.10	--	2.83	0.80	2.35	0.37	0.66	1.12	1.24

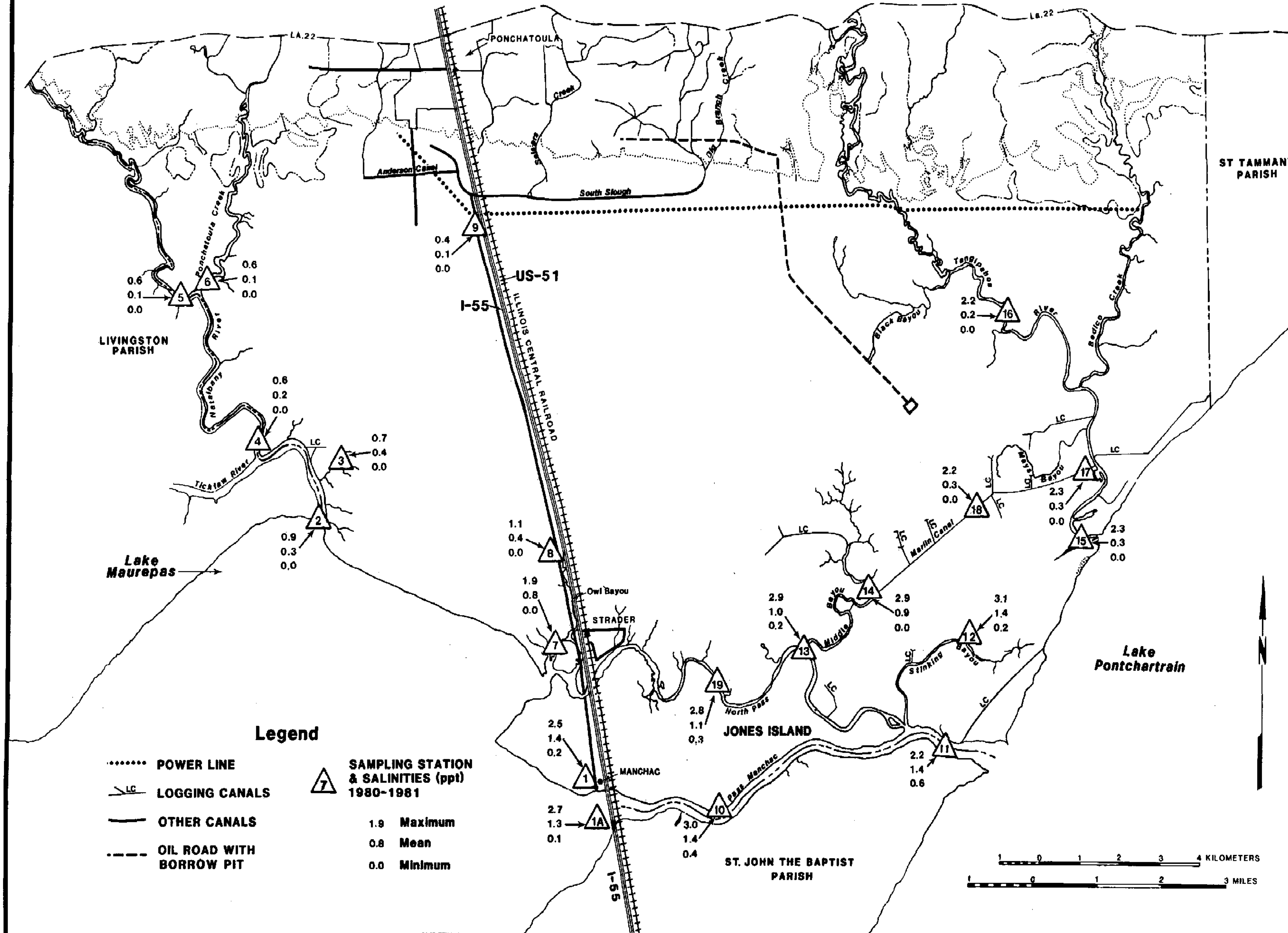
3. Parameter: Secchi Disc (in inches of visibility).

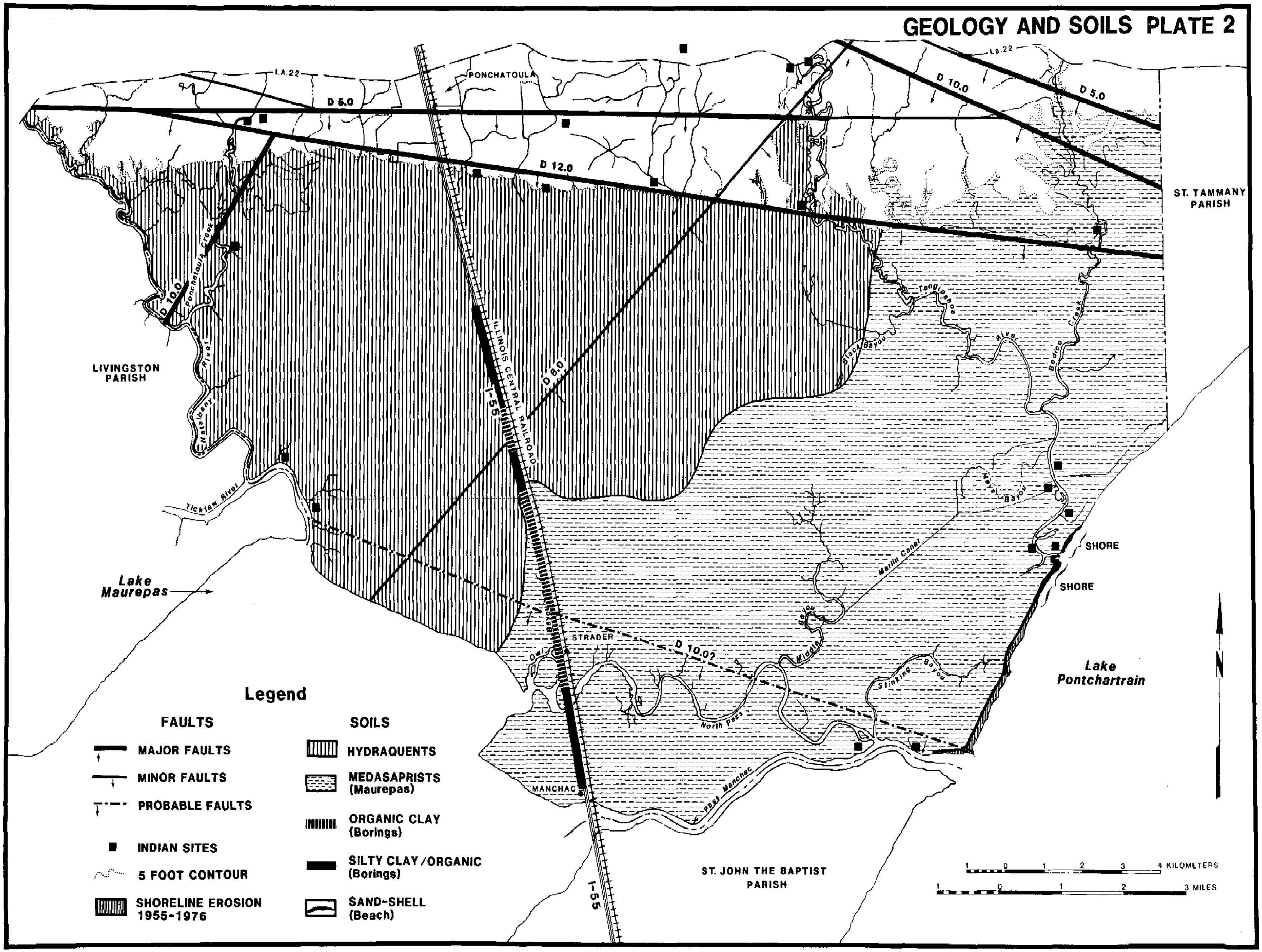
DATE:	1980							1981				
STATION*	JUN 11,12	JUL 15,16	AUG 13,14	SEP 31,1	OCT 28	NOV 13,14	DEC 16,17	JAN 26,27	FEB 25	MAR 24	APR 30	MAY 28
1	25	9	29	36	28	26	15	33	29	16	23	46
1A	23	6	8	58	23	12	14	35	12	15	41	48
2	32	28	12	39	24	65	29	14	18	20	37	37
3	24	18	22	30	29	58	21	24	27	21	31	39
4	25	29	8	39	14	65	24	30	14	21	34	22
5	22	28	21	31	15	28	20	16	14	18	21	15
6	17	18	12	12	9	31	15	16	12	10	22	14
7	17	14	24	22	24	--	14	20	14	13	33	24
8	21	28	19	27	31	28	30	28	22	17	30	--
9	28	34	24	6	20	25	21	21	14	--	31	24
10	25	12	9	40	--	12	14	31	12	8	39	--
11	16	13	4	--	--	7	36	--	17	23	25	45
12	29	24	13	27	--	10	23	--	14	26	33	33
13	30	8	29	36	--	11	24	28	20	26	--	39
14	30	27	32	34	--	13	48	26	31	34	28	55
15	33	34	29	45	--	16	22	37	28	23	37	14
16	28	34	36	22	--	26	22	37	28	28	36	21
17	35	31	17	39	--	14	16	33	24	24	25	18
18	33	32	18	25	--	13	9	30	26	16	28	38
19	27	15	21	28	--	27	20	35	8	14	--	25

4. Parameter: Temperature (in °C).

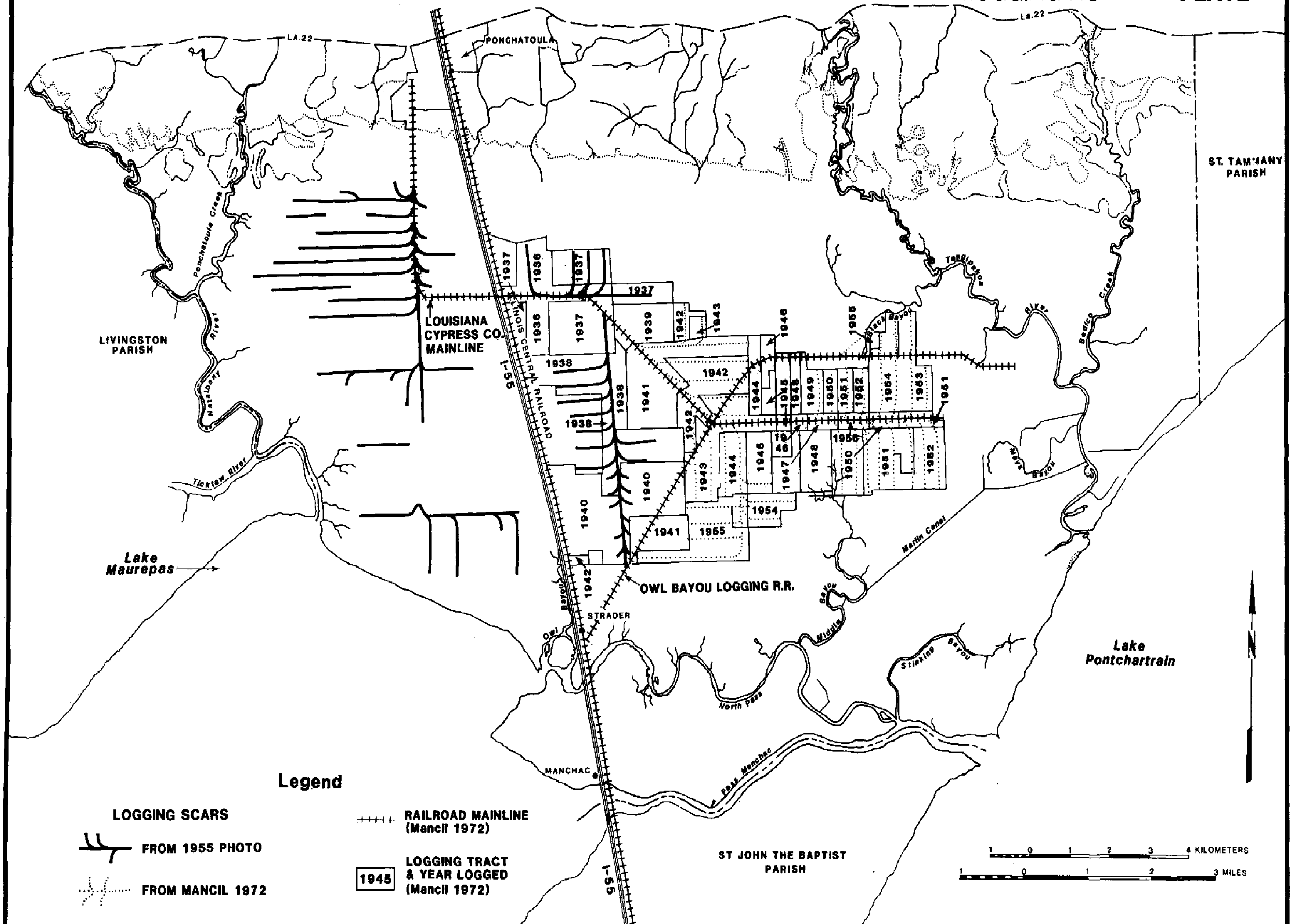
DATE:	1980							1981				
STATION*	JUN 11,12	JUL 15,16	AUG 13,14	SEP 31,1	OCT 28	NOV 13,14	DEC 16,17	JAN 26,27	FEB 25	MAR 24	APR 30	MAY 28
1	28.4	31.4	29.7	24.8	20.0	17.0	12.8	8.6	13.2	14.7	26.3	24.9
1A	27.5	31.0	30.0	25.1	19.4	16.5	13.0	8.5	13.2	14.4	27.1	25.7
2	30.6	32.5	30.5	25.3	19.7	17.3	12.5	10.4	13.2	15.0	25.0	24.8
3	27.7	32.3	29.2	21.0	19.6	17.2	8.0	10.2	14.3	14.7	25.0	26.1
4	30.9	33.0	29.4	25.6	19.4	17.4	12.5	9.8	12.1	16.0	25.0	24.7
5	31.7	32.1	28.4	24.2	19.0	18.0	12.0	9.5	12.6	15.7	24.7	24.5
6	31.8	32.7	29.3	24.7	18.7	18.0	12.5	10.0	15.9	16.3	24.3	24.8
7	32.0	32.8	34.0	26.8	19.7	18.1	13.5	12.8	16.3	14.5	25.3	26.0
8	32.0	34.4	31.6	26.6	19.9	18.1	12.5	9.6	17.8	15.6	24.7	25.8
9	27.1	34.9	29.6	23.2	19.3	16.8	11.9	9.3	15.2	15.4	25.1	23.6
10	27.0	31.4	29.8	25.8	18.5	17.0	12.5	9.1	13.6	15.3	25.3	30.0
11	28.5	31.3	29.9	26.1	--	16.8	14.0	--	13.1	18.3	25.5	29.7
12	28.6	32.4	29.2	24.1	--	17.2	12.5	--	14.2	17.2	27.2	27.3
13	28.8	33.8	30.4	26.3	--	17.3	11.9	9.3	14.2	17.4	26.8	29.8
14	30.8	34.0	31.0	25.8	--	17.4	11.6	10.5	16.5	16.8	23.6	28.1
15	30.2	31.5	29.4	25.4	--	18.7	11.4	10.3	13.0	16.1	23.8	26.4
16	27.7	31.9	29.0	24.7	--	18.0	11.6	11.0	15.3	16.7	23.9	23.8
17	29.6	32.4	29.1	25.2	--	18.0	11.5	10.2	16.0	15.6	24.5	24.8
18	28.4	33.3	29.8	29.6	--	18.0	12.1	9.5	16.2	20.1	25.4	26.8
19	30.8	33.7	31.3	26.0	--	18.0	13.2	9.3	16.0	15.7	26.3	27.9

HYDROLOGY PLATE 1

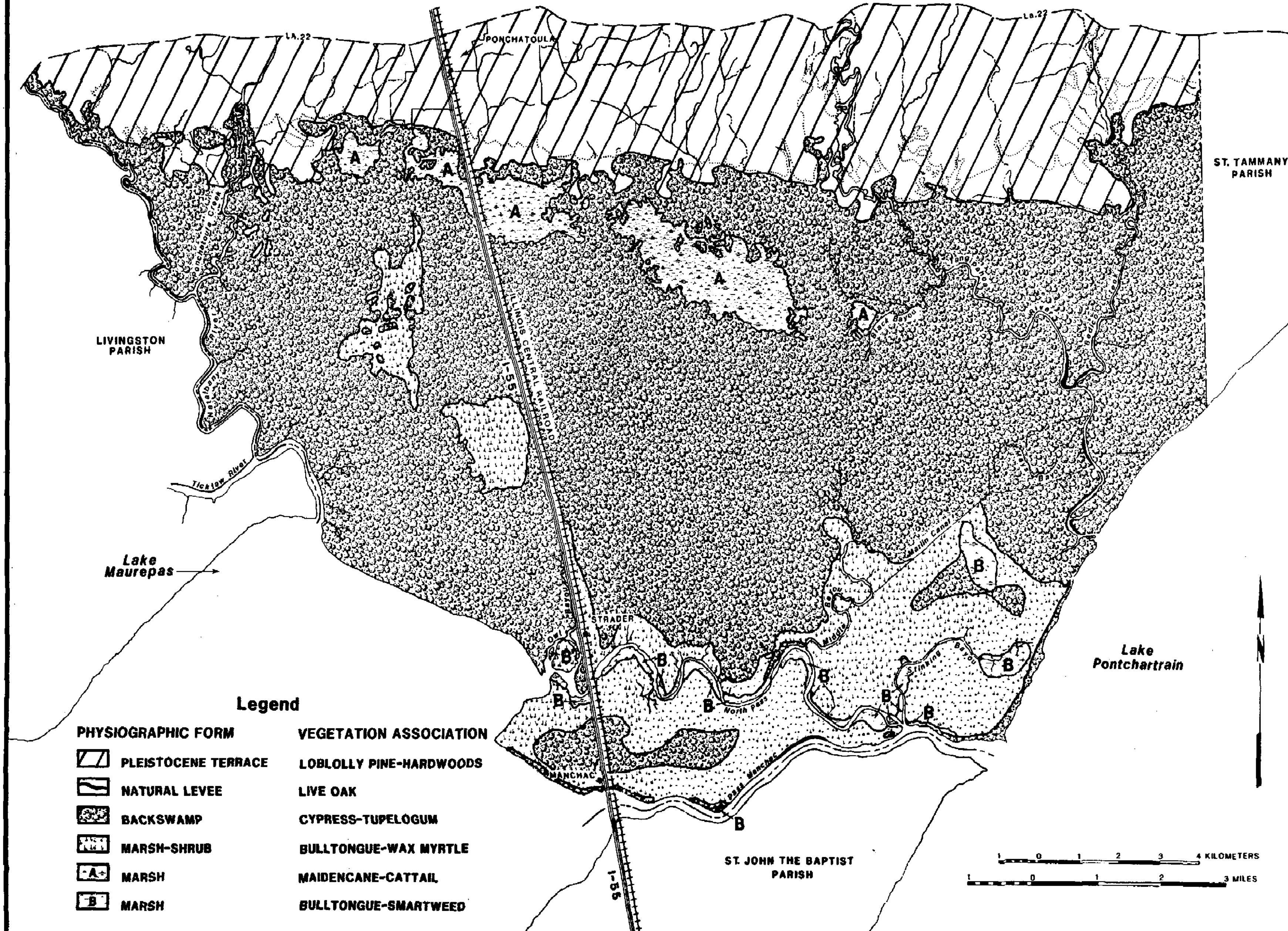



GEOLOGY AND SOILS PLATE 2
LA.22
PONCHATOULA
D 5.0
D 12.0
D 10.0
D 8.0
D 10.0?
ST. TAMMANY PARISH
LIVINGSTON PARISH
Ponchatoula Creek
Natalbany River
Tickfaw River
ILLINOIS CENTRAL RAILROAD
I-55
Lake Maurepas
STRADER
MANCHAC
North Pass
Pass Manchac
Middle Bayou
Black Bayou
Tangipahoa River
Bedico Creek
Marlin Canal
Stinking Bayou
SHORE
SHORE
Lake Pontchartrain
ST. JOHN THE BAPTIST PARISH
N
1 0 1 2 3 4 KILOMETERS
1 0 1 2 3 MILES
Legend
FAULTS
MAJOR FAULTS
MINOR FAULTS
PROBABLE FAULTS
INDIAN SITES
5 FOOT CONTOUR
SHORELINE EROSION 1955-1976
SOILS
HYDRAQUENTS
MEDASAPRISTS (Maurepas)
ORGANIC CLAY (Borings)
SILTY CLAY/ORGANIC (Borings)
SAND-SHELL (Beach)

LOGGING ACTIVITY PLATE 3



1955-56 VEGETATION PLATE 4



1976-78 VEGETATION PLATE 5