ECOLOGICAL CHARACTERIZATION OF JEAN LAFITTE NATIONAL HISTORICAL PARK, LOUISIANA: BASIS FOR A MANAGEMENT PLAN

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Abstract

A management plan for Jean Lafitte National Park based on surface hydrology, salinity regime, soil characteristics, and historical changes in vegetative community patterns is presented. Results indicate that portions of the interior part of the park and areas affected by spoil banks are converting to a floating ecosystem. The park has experienced both a sediment deficit and a slight salinity increase accompanied by encroachment of Spartina patens. Vegetative health and soil characteristics indicate that saltwater intrusion has not been a problem. Management strategies for the park include reestablishment of natural hydrology and enhancement of sediment input to the area. Suggested management actions for Jean Lafitte National Park include a shoreline erosion control and revegetation experiment, breaching or elimination of spoil banks along some major waterways, introduction of resuspended lake sediments into flotant marshes, rollover weirs, and freshwater and sediment diversions. Managed succession is proposed as a management tool for some coastal wetlands. The environmental data collected and synthesized from this study provide needed information for park management; however, management strategies should be carried out in phases, so that monitoring and modification, if needed, can be implemented.

1.0 INTRODUCTION

This paper describes an active management plan for the JLNHP which was developed based on an ecological characterization. The area requires an active management approach because of the dynamic nature of the natural system and because it has been heavily influenced by human activity, especially the construction of canals for, wetland reclamation for urban expansion, and upland runoff of sewage effluent and surface drainage. The plan was designed to achieve the goal of the Park Service to reestablish, insofar as possible, the natural environment as it existed before human interference. The objectives include preserving the original vegetation and productivity of the area, hydrology, and limiting the encroachment of nuisance or introduced species, such as Chinese Tallow (Sapium sebiferum) and wax myrtle (Myrica cerifera).

In order to accomplish this we developed an ecosystem-based management approach, founded on a sound data base and a conceptual framework which incorporated the principles of natural resource management. Despite the recognition by environmental managers of a need for more pre-wetland management environmental data collection and analysis, Louisiana coastal management plans often lack a sufficient scientific baseline characterization of the area in question. Hence, information is needed to determine whether wetland management strategies actually achieve the goals for which they were designed.

Much coastal wetland management in Louisiana has recently become synonymous with semi-impoundment (Templet and Meyer-Arendt 1987), and much of Louisiana's coastal wetlands are currently impounded or semi-impounded (Day et al. 1986) and nearly all plans include structural techniques designed to control water levels and flow in order to slow land loss and increase productivity in managed areas. There is, however, a lack of evidence and much controversy about the effectiveness of such marsh management and there is evidence that impoundment of wetlands may in some cases be exacerbating the geologic problems currently associated with Louisiana's subsiding coastline (Day et al. 1986). Thus we attempted to develop an ecological characterization which would lead to an adequate data base for management as well as a monitory plan to test the effectiveness of the management.

The general objective of this work was to establish an ecological data base for a management plan. The specific objectives included:
(1) establishment of wetland management units within the area based on local hydrology, natural biological and physical features, and previous studies, (2) Conducting an intensive year-long environmental data collection program to characterize the surface hydrology, salinity patterns, sedimentation rates, soil characteristics, gross water movements, water budget, and emergent plant species distributions to determine if saltwater intrusion, sediment starvation, and altered hydrology are problems in the park, and (3) Using this ecological characterization for the development of a management plan aimed at preventing continued wetland degradation.

2.0 DESCRIPTION OF STUDY AREA

Jean Lafitte National Park is a 5160 ha area located in the central Barataria Basin (see Figure 1). Elevations in the park grade from greater than 1 meter above sea level on a bottomland ridge and to fresh and intermediate marshes near sea level. The soils include highly organic Holocene soil series such as Allemand, Kenner, Lafitte, and Larose (SCS 1985). Vegetation includes various types of lowland deciduous hardwoods and cypress-tupelo communities (White et al. 1983). Young disturbed canal spoil banks support Salix nigra, Myrica cerifera, Iva frutescens, and Phragmites australis (communis), in addition to an introduced species Sapium sebiferum. Older spoil bank (>50 years old) support species resembling those found on cheniers of coastal Louisiana (White et al.1983). Common trees are Taxodium distichum, Celtis laevigata, Quercus virginiana, Liquidambar stryaciflua, Acer rubrum, Quercus nigra, and Salix nigra (White et al.1983). The intermendiate marsh is characterized by Spartina patens, Phragmites australis and a mix of freshwater plants. The freshwater marsh is dominated by Sagittaria lancifolia, Panicum hemitonum, Polygonum punctatumn, and Alternanthera philoxeroides.

2.1 Hydrology of the area

Rainfall, evapotranspiration, tides and wind are the primary forcing functions responsible for the hydrologic patterns in the central Barataria Basin freshwater swamps and marshes (Conner and Day 1987). The natural hydrology of the area included both overland flow from the natural levee through the forests and marshes into Lake Salvadore and Cataouatche, and stream flow through Bayou des Familles and Bayou Coquille. Prior to the completion of the artificial Mississippi River levee system, riverine sediments were deposited in the Barataria basin by overbank flow and crevasse formation. At present, the major external sediment input to marsh and swamp areas is resuspended bay bottom sediments (Baumann et al. 1984).

Water flow through Jean Lafitte National Park has been drastically transformed. A combination of agricultural, urban, industrial, and drainage activities have created an altered ecosystem dissected by modified bayous and dredged canals. Surplus water flows into channelized bayous or dredged canals and is diverted into open water.

Canal systems short-circuit many of the natural water flows. Much runoff now bypasses wetlands within the park. When nutrient-laden waters enter water bodies directly, nutrient uptake and removal processes are insufficient to reduce nutrient loads, and thus eutrophication often results (Day et al. 1977, Craig and Day 1987). Spoilbanks retard water and material exchange and cause prolonged flooding and stagnation leading to decreased productivity and species changes (Conner and Day 1976, Hopkinson and Day 1980 b).

2.2 Habitat changes

There were significant habitat changes between 1956 and 1983 (Figures 2 and 3 and Table 1,U.S. Fish and Wildlife Service 1983). In 1956, there were 2,385 ha of fresh marsh, 470 ha of bottomland hardwood forest, 614 ha of forested swamp, and 98 ha of forested and developed upland. The emergence of large stands of *Myrica cerifera* by 1983 indicates that park drainage patterns had been altered. A study by Michot (1984) showed that the scrub/shrub areas experienced the shallowest fall water levels (3.83 cm) reflecting either higher elevations or floating conditions. The conversion of 1322 ha of fresh marsh to intermediate marsh and the emergence of a small number of inland open water areas are probably a result of subsidence and salinity increase.

Table 1. Historical land use changes in Jean Lafitte National Park.

Land Use	1956 ha	1983 ha	Hectare /	Percent Change
Fresh marsh	2413	1073	-1340	-56%
Intermediate marsh	0	1109	+1109	+100%

Bottomland hardwood	476	441	-35	-7%
Forested swamp	622	537	-85	-14%
Scrub/shrub	0	120	+120	+100%
Forested upland	11	94	+83	+750%
Developed upland	88.6	54	-35	-40%
Open water	94.7	280	+185	+195%

2.3 Floating wetland terminology

Because much of Jean Lafitte National park is a floating wetland, it is important to define terminology referring to floating wetlands carefully. Flotant or floating marsh is defined as a fresh marsh mat which oscillates freely with the water layer beneath it (O'Neil 1949). Tremblant is defined as a floating brackish marsh (O'Neil 1949). Quaking marsh is a form of marsh intermediate between a stable marsh and floating marsh. Quaking marsh experiences some mat movement, yet because of vegetative connections with the substrate beneath it, does not oscillate freely with water levels.

4.0 METHODS

4.1 Establishment of study plots

Sixteen study plots were established throughout the park in an effort to encompass the range of habitat conditions which exist (canal, firm marsh, floating marsh, swamp, and areas affected by spoil banks; site locations and characteristics are in Figure 4). In establishing these plots, we used aerial imagery, Soil Conservation Service CTU's (Figure 5), discussions with park representatives, and field observations. Sites 4, 5, 6, 10, and 15 were selected to study the affect of the spoil banks on the inland marsh characteristics. Marsh and swamp hydrologic stations were placed 50 m inland, to characterize typical habitat both in the absence of spoil and behind a continuum of spoil bank widths. All sites were monitored monthly for hydrology, salinity, and soil substrate characteristics, while sites 5, 6, 9, 12, 17, and 18 were also examined for sedimentation rates.

4.2 Marsh elevation and marsh water depth

Vertical movements of the marsh surface and water depth over the marsh were measured monthly. Between mid-May 1986 and early April 1987, wetland elevation and surface water depth were measured to the nearest cm on tide staffs secured in the clay layer beneath the marsh or swamp surface. (If the marsh surface was dry, the water level was assumed to be at the marsh surface. If the marsh was flooded, the water level was read directly from the tide staff, and the marsh elevation was inferred by subtracting the water depth above the marsh from the reading on the tide staff.) Since marsh elevations could not be leveled to a common datum, all marsh and water elevation changes are discussed in terms of yearly ranges about their relative means.

4.3 Salinity

Marsh and canal salinity readings were obtained monthly. Interstitial soil salinity was obtained at a depth of 15 cm below marsh surface, and when the marsh was flooded surface water salinity was also measured. Monthly mean and maximum salinities at Bayou Barataria at Lafitte were obtained from the COE for the years 1956 to 1981.

4.4 Soil characteristics

Sedimentation was measured as accumulation over marker horizons established at 9 locations in 3 different environments: (1) streamside marsh or behind spoil banks, (2) inland marsh (both behind spoil banks and in areas without spoil about 50 m from the water edge), and (3) inland swamp. Marker horizons of feldspar chalk were established in June, 1986 as described in Baumann (1980), Baumann et al. (1984), and Swenson (1982) and sediment accumulation was measured in August 1986. The marsh and swamp substrate was sampled for bulk density, percent organic matter, mineral content, and percent water. Details of procedures for all field methods and analytical and statistical analyses are described in Taylor (1988).

5.0 RESULTS

5.1 Soil characteristics

The soil results indicate that the sites near to sources of mineral sediment generally experienced greater vertical accretion rates, and had higher bulk densities, lower organic content, and lower water content than sites in the interior of the park or behind spoil banks.

5.1.1 Vertical accretion and over marker horizons

Vertical accretion results illustrated that (1) sediment accretion rates in Jean Lafitte National Park were relatively low compared with apparent water level rise,

(2) sites with free communication with natural waterways experienced significantly greater accumulation rates than sites behind spoil, and (3) streamside sites generally experienced greater sedimentation accumulation rates than inland sites (Tables 2). Vertical accretion rates during the nine-month study ranged from 1.0 to 5.9 mm. The rates were extrapolated to 1.3 to 7.9 mm/yr. These accretion rates were lower than the average subsidence rates (1.0 cm) measured elsewhere in the Barataria Basin. Sites with open access to natural waterways (5I, 9S, and 12I) experienced significantly greater accretion rates than sites distant from a sediment source or behind spoil banks (5S, 6S, 6I).

Table 2. Mean sediment accretion rates and significance for groups of stations with sediment sources (sites 5I, 12I, 9S), behind spoil (6S, 6I, and 5S), or inland (sites 6I and 9I). Note that groups are listed in order of decreasing accretion rates.

Group	Mean Sediment Accretion Rate	Significance[1]
Sediment Source	5.42 mm/9 mo.	A
Inland	2.12 mm/ 9 mo.	B
Behind Spoil	1.41 mm/ 9 mo.	C

1 as determined by Tukey's Studentized Range with a=0.05. Groups with different letters are significantly different.

5.1.2 Bulk density, organic content, and water content

Bulk density, water content, organic content, and mineral content are highly interrelated soil characteristics. Organic content (on a dry weight basis) determines the amount of water in a given volume of saturated soils (Rainey 1979) because highly organic materials are porous and hold large amounts of water when saturated (Boelter 1974).

Analysis of the soil characteristics in Jean Lafitte National Park revealed the following conclusions: (1) bulk density values were generally low, ranging from 0.04 to 0.10 g/cm3 at 14 of the 17 sites, (2) soil water content throughout the park was high and fell in the range of 78-94% for all sites, and (3) organic content was high and ranged from 43.7 to 87.1% (Table 3) These low bulk densities, high water contents, and high organic content concentrations are consistent with values for fresh and intermediate marsh (Swarzenski 1987, Hatton et al. 1983, Baumann 1980). These soil characteristics are a result of peat soils composed almost entirely of living and dead plant material (Odum et al 1984, Leet et al. 1982).

Cluster analysis of the bulk density, organic content, and water content data revealed three distinct clusters: (1) a group with high bulk density, low organic content, and low percent water, characteristic of sites with open access to mineral sediments, (2) a group with low bulk density, high organic content, and high percent water, characteristic of floating marsh sites and inland sites affected by spoil, (3) and a group with intermediate bulk density, organic content, and percent water values, characteristic of interior, quaking marsh sites (see Figure 6). There was an 87% correlation between water content and bulk density.

5.2 Water and marsh level changes

5.2.3 Annual water level changes

Ranges of annual vertical water level changes revealed the following results: (1) there were no significant differences in monthly water level ranges between canal sites and water over marsh sites, (2) canal sites had water level changes grouped at the upper end of the range of yearly water level changes, (3) marsh sites exhibited yearly water level changes with a range of 24-36 cm, (4) the lakeside station (site 5) and the impounded swamp (site 18) exhibited the lowest yearly water level ranges, indicating hydrologic flow inhibition, and (5) sites along Pipeline canal (2,13, 13C, 16) experienced water level changes in the upper range of water level changes.

The range of water level fluctuation at marsh sites was 24 to 36 cm, while canal sites experienced water level changes of 45-67 cm. Since surface water response to climatic and tidal factors was on the order of hours to days and our measurements of water levels were only once a month, it was impossible to detect any significant difference between canal and marsh surface water level changes. Swenson and Turner (1987) reported that partially impounded marsh sites in Louisiana were characterized by both longer flooding events and reduced water exchange both above and below ground.

5.2.4 Degree of vertical marsh movement

Vertical movement of the marsh revealed several interesting trends: (1) the lakeside site 5 station experienced a range of vertical marsh movement (1.5 cm) that was an order of magnitude less than all other sites, (2) sites with open access to waterways (sites 2, 9, 12, 13, 7, and 1), regardless of exact location within the park, experienced vertical movement ranges clustered at the low end of the range, (3) most of the park experienced slight vertical movement through time (and could thus be called quaking marsh), (4) sites affected by spoil (sites 4, 5, and 10) and several swamp sites experienced the greatest ranges of vertical movement through time, (5) floating marsh (sites 10 and 15) and semi-impounded (site 17) and impounded swamps (site 18) were clustered at the high end of the vertical movement range, and (6) the "truest" floating marsh (site 10) experienced significantly more movement than all other sites (see Figure 7). These results suggest that ranges in vertical marsh/swamp movement through time may be a good indicator of vertical marsh stability or lack thereof.

5.3 Salinity

Seasonally adjusted monthly average salinity means at Bayou Barataria at Lafitte revealed an increase of 1.5 ppt for the record from 1956 to 1981 (Figure 18). Mean salinity increased from about 1.1 ppt to 2.6 ppt. The yearly increase, 0.06 ppt, was highly significant (Pr>F=0.0001). The model accounted for 13% of the total variation in data. Seasonally adjusted maximum salinity means at Bayou Barataria at Lafitte revealed an increase of 2.95 ppt/30 years and and increase of 0.1 ppt/yr. There was no statistically significant differences between mean surface (1.7 ±1.1 ppt) and subsurface park salinities (1.5 ±1.4 ppt). The data in figure 16 suggest that average salinities cet Lafitte increases in the early 1960's. We believe that this may be due to the enlargement of the Barataria waterway which was completed during this period.

5.3.3 Station salinities

Clustering of monthly station salinity results revealed three significant groups (p/>F=0.0001): (1) a lakeside quaking marsh group (sites 1, 2, 4, 5, 7, 9, 13) with intermediate range salinities which peaked during October or November, (2) floating marsh (sites 10 and 15) and swamp sites (12, 17, and 18) which were fresh salinities the year, and (3) canal sites (13C,14,16, 20) which experienced highly variable and erratic yearly salinity patterns (see Figures 9 and 10). The extreme variability in salinity at the canal sites emphasized the fact that these areas show quick hydrologic responses to outside environmental factors such as tides and rains. Sites along Segnette Waterway (1, 5, 7, 9, and 20) had mean salinities significantly greater than both the floating marsh (10 and 15) and swamp sites (12, 17, and 18). Water salinity at the swamp and floating marsh sites ranged between 0.3 to 2.2 ppt (mean =1.11± 0.54). These low station salinities appeared to be buffered from the salinity effects of outside environmental factors such as tides. In addition, the salinities of these sites were more heavily influenced by upland runoff than by tidal effects.

6.0 DISCUSSION

6.1 Environmental conditions in the park

The results of the ecological study indicate the following trends: (1) there was a slight salinity increase over the past 30 years accompanied by an encroachment of more salt-tolerant plant species, (2) this encroachment of salt-tolerant species occurred without resulting in marsh breakup, (3) accretion rates were lower than regional subsidence, (4) sediment accretion rates were significantly lower in areas inland behind spoil compared with areas with access to direct sediment sources, (5) soil characteristics were the firmest and accretion rates were the highest along areas with access to mineral sediment sources compared with floating and inland locations, (6) the hydrology of the park has been drastically altered over time beginning in the 1700s, (7) some areas of the park were impounded and covered by approximately 0.6 meters of water year- round, (8) most of the park is a quaking marsh, and (9) the park has been experiencing a sediment accretion deficit and has been evolving into floating marsh as a response to this deficit, and large areas of scrub-shrub have invaded the floating marsh. Each of these points will be addressed in the following sections.

6.2 Effects of saltwater intrusion in Jean Lafitte national park

Over the past 30 years, mean salinity at Bayou Barataria at Lafitte increased by 1.2 ppt. This salinity increase is reflected in vegetation changes. The western (lake side) portion of the park, which was characterized as fresh marsh in 1956 (U.S. Fish and Wildlife Service 1983), is now intermediate marsh, as indicated by soil salinity and vegetation dominated by *Spartina patens*.

Saltwater intrusion does not seem to be a serious problem in the park for the following reasons: (1) significant wetland loss has not occurred, 2) vegetation composition is changing to reflect a successional adjustment to salinity changes in the area, (3) marsh soils with the highest bulk density, highest mineral content, and lowest water content occur in the areas where the increase in salinity has been highest, and (4) the healthiest and firmest marsh occur in the areas where salinity increase has been highest. Few open water areas have developed and the lakeside soil characteristics (where salinity is highest) have the highest bulk density, lowest organic content levels, highest mineral content levels, and highest accretion rates. In addition, the mean salinity tolerances ranges of the dominant vegetation (Myrica cerifera, Sagittaria lancifolia, and Spartina patens) indicate that these species are occurring within tolerable salinity ranges, relative to the conditions that exist in the park. For example, while salinity levels in the western portion of the park usually fall below 3 ppt, laboratory studies show that Myrica cerifera and Spartina patens do not experience stunted growth below 8 and 10 ppt, respectfully (Williamson et al. 1984, Odum et al. 1983).

6.3 Soil characteristics

Sediment input plays an essential role in maintaining both nutrient input and vertical accretion which allow wetlands in the Louisiana coastal zone to offset the current rate of apparent water level rise (AWLR). Results from this study indicate that vertical accretion in wetlands of the Park are significantly less than the AWLR of about 1.0 cm/yr. Vertical accretion rates and soil characteristics showed three important trends: (1) vertical accretion rates were highest near sediment sources (lakes and Millaudon Canal), (2) vertical accretion rates were significantly lower behind spoil banks, and (3) only sediment accretion sites near the lake had >60% mineral content. Thus, although vertical accretion rates in the park were low compared with the AWLR, the healthiest marshes with the highest accretion rates and best soil characteristics were close to new sediment sources.

6.4 Hydrology

The hydrology of Jean Lafitte National Park has been drastically altered by the construction of canals through the wetlands during the past 280 years. (see Figure 11). Under natural conditions, water flowed across the wetlands, the rate depending on the freshwater runoff, tidal exchange, and winds. Currently, however, altered hydrology in the park includes: (1) upland runoff which quickly flows into the canals and is shunted out of the park, (2) regional water level fluctuation, especially during frontal passages, which lead to both rapid water level changes and water flowing quickly into and out of the park, and (3) semi-impoundment of wetlands caused by spoil banks. Most upland runoff and tidal exchange are primarily shunted directly in canals, thereby influencing relatively small areas of wetlands in the park. For example, during flood tide, water piles up at the intersection of Kenta and Pipeline canals and leaves quickly the park during ebb tide. Semi-impoundment also causes relatively low net flows through the park. Overland sheet flow through the wetlands is minimal.

In addition to the gross hydrologic flows which have been altered, spoil placement along the canals has impounded some areas of the park. The impounded cypress swamp, (site 18) was flooded by at least 0.6 m of water during the entire study because spoil placement altered the natural hydrologic gradient of flow from the swamp into the marshes. Impoundment of this swamp undoubtedly has led to altered nutrient export and lowered productivity and seedling regeneration (Conner et al. 1981). Brown and Lugo (1982) report that cypress tupelo communities show severely reduced growth and productivity if the mean depth of flooding exceeds 60 cm. The impounded site in Jean Lafitte

National Park is currently experiencing this critical water depth and thus may be experiencing stress.

Altered hydrology such as channelization and impoundment can lead to both increased and decreased retention times of water in wetlands. The channels themselves may lead to more rapid drainage of some areas while spoil banks may retard drainage from other areas. For example, Swenson and Turner (1987) reported that partially impounded marsh sites in Louisiana were characterized by both longer flooding events and reduced water exchange both above and below ground. In addition, wetland ecosystems with altered hydrology, which include deeper water levels, longer retention times, and slow flushing rates, ie. impoundments or semi-impoundments often have lower productivity and symptoms of stress. Conner et al. (1981) showed that a permanently flooded impounded swamp had fewer number of trees, lower basal areas, reduced recruitment, and lower productivity compared to a healthy control swamp. Prolonged periods of deep inundation often reduce vegetative productivity and regeneration (Conner et al. 1981).

6.5 Floating marsh formation hypothesis

Floating marshes are widespread in coastal Louisiana, yet the process of formation is uncertain. Two different theories have emerged: (1) Russell (1942) concluded that flotant resulted from the encroachment and expansion of emergent vascular aquatics into previously open water area, and (2) O'Neil (1949) proposed that floating marshes were formed by buoyant detachment of marsh from the subsiding soil substrate as a response to marsh flooding and an absence of mineral sediment. Swarzenski (1987) studied floating marshes in coastal Louisiana and determined that buoyant detachment was probably the most important mode of formation.

Aerial imagery of Jean Lafitte National Park indicates that 322 ha of wax myrtle stands emerged in the area during the past 30 years. Field observations, soil characteristics, and sediment accretion rates all suggest that this area has undergone an accelerated rate of flotant formation catalyzed by both a sediment accretion deficit and spoil bank placement. Although no documentation exists for stable marsh in the park more than 30 years ago, Williamson et al. (1984) reported that fresh marsh north of Lake Salvador converted from stable marsh to flotant during the last three decades. The flotant formation characteristics in Jean Lafitte National Park are consistent with other observed flotant patterns: a sediment deficit, hydrologic alteration, prolonged flooding and mat detachment, and successional stages developing into shrub-scrub species.

The following steps constitute our hypothesis for the development of floating marsh in Jean Lafitte National Park:

(1) JLNP experiences a sediment accretion deficit and levee (spoil) inhibits sheet flow. Because local sedimentation is less than apparent water level rise, there is an increasing sediment accretion deficit, especially in the interior parts of the park distant from sediment sources.

(2) Low bulk density substrate roots, combined with anaerobic conditions and methane gas formation beneath the marsh mat cause it to detach from the bottom and float (O'Neil 1949, Cypert 1972, Hogg and Wein 1987).

(3) Succession of Sagittaria lancifolia -> Panicum spp. -> Myrica cerifa in fresh areas.

(4) Small salinity increase accompanied by encroachment of _Spartina patens._

Jean Lafitte National Park is located in an interdistributary basin which no longer receives direct sediments from the Mississippi River due to flood control levees. Input of resuspended sediments is reduced due to spoil banks and altered hydrology. The area is experiencing a sediment accretion deficit with respect to local apparent water level rise. Soil characteristics and field observations indicate that sites with little or no sediment input and hydrologic alterations have low bulk density, high organic content, and high water content. These are characteristics of floating marshes.

Canal spoil banks in the park inhibit sheet flow and cause water to flood the marsh for longer periods of time. These conditions tend to accelerate the process of floating marsh formation. Prolonged flooding of fresh marsh results in anaerobic conditions which enhance methane gas formation beneath the vegetative mat. Upward gaseous pressure beneath the mat, in combination with the low bulk density of vegetation roots, causes the mat to detach from the bottom and float up like a cork (O'Neil 1949, Cypert 1972, Hogg and Wein 1987). After detachment from the solid substrate, the top of the vegetation mat floats a few cm above the water level and thus no longer floods. The floating mat oscillates freely up and down in phase with the water layer beneath it (Swarzenski 1987). Field observations of several wax myrtle stands in the central area of the park, (stations 10 and 15) indicate that these sites are freely floating. The response of this system to the conditions discussed above has been to succeed to a floating wetland ecosystem.

Hydrological alteration has led to the formation of floating marsh in several regions. In northern Wisconsin, floating bog formed behind a sand sill adjacent to the lake (R. P. Novitski, pers. comm., U. S. Geological Survey, Ithaca, NY 14850). A Canadian floating Typha spp. marsh emerged in a diked freshwater impoundment (Hogg and Wein 1977). In Louisiana, Bahr et al. (1983) noted that 4,000 ha of scrub-shrub developed in the Barataria and Verret basins since the 1950s as a result of human modifications to basin hydrology. Much of this newly emerged shrub-scrub in Louisiana is floating (R. Chabreck, pers. comm., School of Wildlife, Forestry, and Fisheries, Louisiana State University, Baton Rouge, LA, 70803). The emergence of the floating scrub-shrub in Jean Lafitte National Park and areas of the Verret and Barataria basins occurred both during the same time frames and under the same circumstances: post 1950s canal construction activities.

6.6 Management implications of these results

The management implications of saltwater intrusion, sediment budgets and dynamics, and floating marsh formation will be sequentially discussed in the following section. The interpretation of these results forms the basis for management suggestions for Jean Lafitte National Park discussed in section 7.0.

6.6.1 SALTWATER INTRUSION

Saltwater intrusion has historically been identified as one of the principal causes of wetland loss, and control of saltwater intrusion has been one of the principal goals of wetland management in Louisiana and structures have been used in an effort to control saltwater intrusion. Yet considerable literature suggests that increased submergence and sediment deficits may be as important in causing vegetation diebacks in the coastal zone.

Submergence results in poorer drainage and increased waterlogging of wetland soils (Day et al. 1987). The deleterious effects of waterlogging on plants has been amply reported in the literature. For example, responses of plant shoots to water logging may include reduced stem elongation, chlorosis, senescence, abscission of lower leaves, wilting, hypertrophy, epinasty, leaf curling, and a decline in relative growth rate (Drew 1983, Jackson and Drew 1984). Apparent water level rise leads to submergence and waterlogging stress.

Williamson et al. (1984) determined that inundation, not salinity, was the principal cause of the decline of floating wax myrtle stands in the Lake Salvador management area. In addition, Mendelssohn and McKee (1987) reported that in a laboratory study sudden submergence of 10 cm had a significant negative effect on the biomass productivity of salt, brackish, and fresh marsh species. Increased salinity had a negative effect on fresh and brackish marshes, the extent of which was dependent on salinity level and duration and abruptness of the stress. Analysis of freshwater and brackish species tolerances to salinity and inundation reveal that many of these species have rather wide ranges of salinity tolerance and only limited inundation tolerances with respect to environmental conditions experienced in the park. Future research is needed on the relative importance of submergence and salinity as the cause of vegetation die-offs in the coastal zone.

There are two alternate approaches which could be used to deal with problems of salinity intrusion. The first approach is site specific, in which intrusion of saltwater to a specific area is limited with a combination of structural devices such as levees and weirs. There is evidence that this method has had limited success in the Louisiana coastal zone (Cowan et al 1986). An alternate approach is basin wide management of freshwater resources and hydrology. The rate of saltwater input to the southern coastal region, via canals such as the Barataria Waterway, could be slowed by locks or gates and canals closures. Long term salinity records (see Figure 8) strongly suggest that the enlargement of the Barataria Bay waterway resulted in an abrupt increase in salinity in the mid basin. In the upper basin, diversion of Mississippi River waters and management for retention of fresh water could be used used to both increase sediment sources to wetlands and buffer and dilute saltwater flow within the wetlands. Since most of the upper Barataria Basin is channelized, freshwater runoff through the coastal zone proceeds very quickly. Therefore the goals would be to slow both freshwater runoff and saltwater input to the wetlands.

The rate of saltwater intrusion into a healthy fresh marsh is very important. If saltwater intrusion into a fresh area is rapid, sudden, and includes a significant salinity increase, then salinity can be a problem. But this is not the case in Jean Lafitte National Park; salinity increase has been slow enough that the plants and soils have been able to adapt to the changes.

The Soil Conservation Service proposed a management plan for the Park which advocated the use of plugs along all the oil slips intersecting the Segnette Waterway (see Figure 3, SCS 1985). In light of the results of this study, which show small salinity increases and healthy robust vegetative communities where the salinity increase has occurred, it seems more important to practice management which enhances open access to the sediment sources derived from the lake and surrounding bayous and canals, than to deter water flows with weirs, plugs, etc. at the current salinity levels. Plugs and weirs could lead to further waterlogging and more rapid flotant formation. It is impossible to optimize both sediment input and salinity in the park. The implementation of the Davis Pond diversion and changes to restore natural hydrology will be very beneficial in dealing with any salt water problems.

6.6.2 Sediment dynamics

The importance of mineral sediment input for wetland health has been highlighted during the last two decades (Delaune et al. 1978, Hatton et al. 1983, Bauman 1980, Bauman et al. 1984). Mineral sediment input both increases wetland elevation and enhances primary productivity and thus organic accretion in wetlands. Both of these accretionary processes are often necessary to offset inundation occurring in subsiding areas. Studies of sediment accretion in Barataria Basin wetlands show that this area is experiencing a sediment accretion deficit (Bauman 1980, Bauman et al. 1984, Hatton et al. 1983). Jean Lafitte National Park is also experiencing a sediment deficit, especially in those inland areas and areas behind spoil banks. Thus, new sediment and mineral input must be enhanced in this area to encourage healthier vegetation and firmer substrate.

Management of the park should include plans to enhance sediment input during frontal passages when southerly winds pile water up in the basin, and marshes are flooded with water with high suspended sediments concentrations, often >100mg/l. These sediments settle and accrete in the marshes. Weirs in Pipeline and Tarpaper canals would decrease the rapidity of the water exchanges and allow the sediments to settle both within the canal and in the marshes.

The proposed SCS management plan for Jean Lafitte National Park included plug and weir placement along the Segnette Waterway, which would have resulted in semi-impoundment and sediment exclusion from the park. Based on results of this study, open access of park wetlands to both resuspended and diverted sediment sources is of high priority to the health and maintenance of the area.

6.6.3 Management implications of altered hydrology

Disturbance of natural sheet flow through the wetlands and impoundment of cypress swamps are two of the major hydrologic alterations which have occurred in the park. Considerable research shows that impoundment, as a management practice for cypress swamps, results in lowered productivity and regeneration (Conner et al. 1981). The swamp in Jean Lafitte National Park will dissappear if management practices are not changed. Overland sheet flow from the bottomland hardwood forests to the cypress swamps and into fresh and intermediate marshes should be encouraged (see Figure 11). Structures in pipeline and canals will moderate rapid water level fluctuations. Canal spoil impounding cypress swamps and marshes should be breached and perhaps eliminated.

6.6.4 Resilience and management implications of floating marshes

There is relatively little information about floating marsh productivity and resilience in Louisiana. The productivity of floating Panicum marshes, ranges from 1700g/m2/yr to 1960 g/m2/yr (Sasser et al. 1981 and Sasser and Gosselink 1984) as compared to 1501-2310 g/m2/yr for freshwater Saggitaria lancifolia marshes (Hopkinson, Gosselink, and Parrondo 1978 and Hopkinson et al. 1978). Secondary production of fish and other aquatic organisms is probably less in floating marshes than that in stable marshes, due to low O_2, high CO_2, and low pH below the mat (Howard-Williams and Gaudet 1985). Alligators, deer, and mammals do, however, use elevated floating marshes and wax myrtle stands as habitat.

Whether floating marshes are ephemeral or resilient ecosystems, within a management time frame, is important for decisions concerning wetland management. In some cases, floating marshes have persisted for long periods. Sasser (opers. comm., Center for Wetland Resources, Louisiana State University, Baton Rouge, LA 70803), notes that floating marshes in Lake Boeuf have remained stable ecosystems for more than 46 years. Similarly, Hogg and Wein (1987) state that Canadian "floating Typha spp. mats develop to become very resilient systems and it appears doubtful that mat buoyancy and the current trend toward bog-like conditions will be disrupted, either by natural or anthropogenic perturbations at the mat surface." Conversely, several researchers reported that floating marshes may be ephemeral. Williamson et al. (1984) determined that as "floating wax myrtle stands increase in size, they develop tilt and add instability to an already tenuous system because the weight of the tree forces the surface roots under water causing the shrubs to slowly die." The question is, do these areas surrounding the dead

Myrica cerifera stump convert to open water, or fill in with herbaceous floating vegetation? Huffman and Lonard (1977) reported that sinking floating mats are actually a successional phase to swamp forests with cypress. But this is probably not the case in a subsiding environment such as coastal Louisiana.

Management of these floating marshes, whether they are ephemeral or not, must take into account the long-term productivity and health of the environment. Within coastal wetlands, new mineral sediment and nutrient input leads to healthier vegetation and firmer substrate (Kadlec 1987, Kadlec and Bevis 1987, and Gosselink and Gosselink 1985). Therefore, we suggest that resuspended and diverted sediment and nutrient sources be diverted into these floating areas to possibly convert them into stable marshes and to enhance their productivity.

7.0 MANAGEMENT OF JEAN LAFITTE NATIONAL PARK

In developing a management plan for the park, there should be three primary objectives: retardation of lakeside erosion, improved hydrology, and enhancement of sediment input to the area. If these three objectives are accomplished, there will be a number of beneficial effects, including enhanced vegetation health and productivity, more rapid soil formation, and stronger connections among different wetland habitats.

Improvement of hydrology of the area should reestablish, insofar as possible, overland flow which follows the east to west elevational gradient from the bottomland hardwoods to the cypress swamp, fresh marsh, intermediate marsh, and finally into the open water bodies. To facilitate overland flow through the park subbasins, canal spoil banks should be breached, lowered, or eliminated in some cases. The extreme fluctuation and dominance of the water flows into and out of Pipeline and Kenta canals should be moderated. The flow in natural channels (Bayou Boeuf, Bayou Des Familles, and Bayou Coquille) should be encouraged where possible. The degree and speed of water level fluctuations both within the wetlands and the canals should be dampened to what would occur naturally.

Sediment input to the park should be increased by encouraging input and trapping of resuspended sediments from Lakes Salvador and Cataouatche and local canals (Millaudon Canal and the Intercoastal Waterway). Resuspended sediments and nutrients from local canals and lakes would serve to partially offset the process of subsidence. But the only sediment diversion option which could truly overcome the subsidence problem occurring in the central Barataria Basin, would be diversion of sediment-laden water from the Mississippi River. The implementation of the Davis Pond diversion will thus be beneficial to the Park.

The pattern of vegetation adjustment to gradually increasing salinity suggests that an important conceptual tool for the management of some Louisiana coastal wetlands may be the idea of managed succession. A number of management plans have as their objective the maintenance of fresh and intermediate marshes in areas which are converting to brackish marshes or open water. This is done for preservation of a particular habitat type or for the preservation of any type of vegetationed wetlands. Senic impoundment may pressure a certain habitat type for a while , but as we have discussed earlier, problems of waterlogging, sediment starvation, and poor drainage after tropical storms may make managed succession a viable alternative.

By managed succession, we mean management actions employed to facilitate wetland succession which is already taking place while minimizing net wetland loss. In the Lafitte Park, for example there has been a succession of fresh to intermediate and brackish marshes. Given the environmental setting of the Park (gradual salinity increase and altered hydrology), we believe that actions can be taken to minimize wetland loss. These include a variety of actions described above and in the next section designed to improve hydrology and increase sediment input to the park. In general, we suggest that the ideas of managed succession be investigated more thoroughly to determine its utility as a general management tool in coastal Louisiana.

7.1 Suggested management pilot studies

The results of this research and experiences in wetland management from other areas suggest that a coordinated management plan is necessary for the Jean Lafitte National Park. A plan for the park is outlined below. The plan includes a number of measures designed to reduce wetland erosion, restore a more natural hydrologic regime, increase sediment input to the park, and enhance productivity (Figure 12). The plan also identifies areas of further research necessary to address critical information needs.

(1) Shore Line Protection Along Lake Salvador

Lakeside erosion is one of the most critical problems facing the park. To arrest further erosion some type of shore protection must be implemented. Shore protection could be coupled with wetland formation such as used by the Dutch in the Wadden Sea (DeGlopper 1965, Kamps 1962, Boumans et al. 1987).

(2) Small Scale Lakeside Flotant Conversion Experiment

We suggest choosing a floating marsh site with potential access to lake suspended sediments (Figure 12). The objectives of this experiment are to determine the feasibility of increasing bulk density of soils of a floating marsh, increasing the overall health and productivity of the area, and ,ultimately, promotion of succession of floating marsh in the direction of stable marsh.

The design of this pilot project is as follows. A break would created in a spoil bank adjacent to an area of lakeside floating marsh to allow direct input of resuspended lake sediments to the marsh surface. A low level sill structure should be installed at the spoil break, to ensure that the incoming lake water does not cut a crevasse and lead to erosion of the flotant and a wire mesh screen should be stretched across the break to insure that the mat does not float out of the area. Vegetation, soil characteristics, and accretion rates should be monitored periodically (every six months) for several years to determine the success of the experiment, and thus its practical application to other sites in the park.

(3) Structural Suggestions

Several structural measures are necessary to achieve the objectives of the management plan. These include breaching or elimination of some spoil banks along major waterways and installation of weirs. Rollover weirs would allow small boat access to the park while dampening water level fluctuations. A slotted weir could be used if park goals included allowing the marshes and canals to draw down, while preventing rapid water level fluctuations. Slotted weirs would allow access to migratory marine organisms. Other possible weir types include rock weirs and those with flapgates. Rock weirs allow water to flow around and through the rocks, but at a much slower rate. Flapgates allow more control of water movement. Structural alternatives should be carried out in phases, so that monitoring and modification, if needed, can be implemented.

We suggest that the spoil impounding the cypress swamp (site 18) be removed to promote flushing and dry downs, and therefore aid regeneration, establishment of seedlings, and enhanced productivity (Figure 12). Water levels and forest species composition and productivity should be monitored to determine the ecological consequences of this action.

To both slow rapid water level fluctuations in the wetlands and encourage over bank flow, three structures should be installed: (1) in the Pipeline Canal, just north of its intersection with the Segnette Waterway; (2) just west of the intersection of Tarpaper and the perpendicular canal flowing north of it; and (3) at the intersection of Kenta Canal and the Intercoastal Waterway. Placement of the structure in Pipeline Canal would slow the flow of water out of the park and therefore enhance overland flow in both CTU 6 and 8, which currently show signs of hydrologic alteration. Overland flow through CTU 2, 4, and 6 would be encouraged by the structure placed in Tarpaper Canal. Removal of the spoil at the end of the northernmost oil cut on Segnette Waterway would enhance water flow out into Segnette and into Lake Salvador. These alterations would encourage water flow out of the park following both the natural wetland elevation gradient and the dampened canal courses.

Establishment of these structural changes would establish and promote four types of flow through the park: (1) upland runoff from the ridge into the park, (2) overland net flow through the interior CTU, (3) enhanced exchange between the lake water and the wetlands, and (4) diminished water level fluctuations in the canals. These changes are depicted in Figure 13.

(4) Fresh Water and Sediment Diversions

Freshwater and sediment diversions have been suggested as a means of nourishing wetlands (Templet and Meyer-Arendt 1987, Gosselink and Gosselink 1985, Conner and Day 1987). Wetlands act as a buffer and filter for sediments and nutrients (Kennedy 1983, Howard-Williams 1985). Studies on effluent application to wetlands have shown that (1) long-term nutrient accumulation occurs in some cases (Gupta 1977, Dixon and Kadlec 1975), 2) increased organic matter and accumulation rates occur, and 3) that these nutrient and mineral sources are incorporated into long lived plant and animal matter (Howard-Williams 1985, Gaudet 1977, Dolan et al. 1981, and Verhoeven et al. 1983). Fresh marsh biomass increases significantly with nutrient input (Dolan et al. 1981, Verhoeven et al. 1983).

These are three potential sources for freshwater and sediment diversion into the park: (1) resuspended sediments from Lake Salvador and local canals including the Intercoastal Waterway, (2) nutrient and sediment sources from Millaudon Canal, and (3) Mississippi River water. The first two sources would help offset the effects of subsidence and increase vegetation growth. Mineral sediment inputs increase wetland elevation and enhance primary productivity and thus organic accretion in wetlands.

Diversion has never been attempted into floating areas, and the consequences and methods are yet to be determined. For example, would sediment accretion and productivity changes be more substantial if sediment-laden waters were introduced above or below the floating mat? In order to answer this question, a three-part experiment is suggested. Water should be pumped or diverted into three separate regions, a control (where no water is pumped at all), an area where water is introduced above the mat, and an area where the water is introduced below the mat. For the experiment, it might not be absolutely necessary to pump water. It could be either be diverted at higher levels and allowed to flow by gravity or sprayed.

A diversion at Davis is scheduled to begin operation by 1992. This diversion is designed mainly for salinity management and will freshen the area of the park. It may also result in some sediment input to the park. The Algiers Lock can also be used to divert small amount of freshwater (on the order of 2000 cfs) into the Barataria Basin during high flow. Since this diversion is via the GIWW, some of this water and sediments could be used for the Park. In the future, perhaps a small scale diversion could be implemented especially for the park area.

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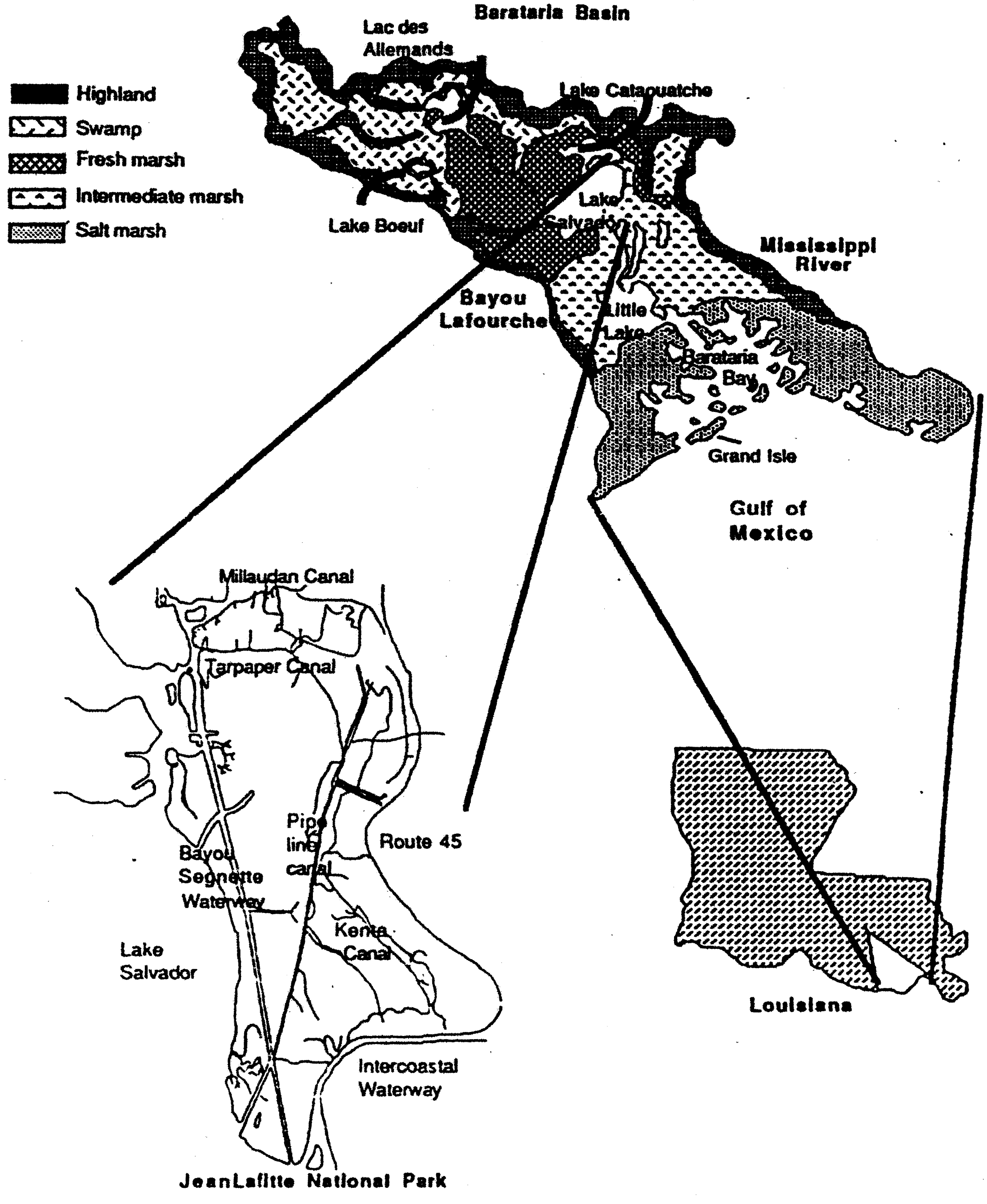


Figure 1. Location map of study site.

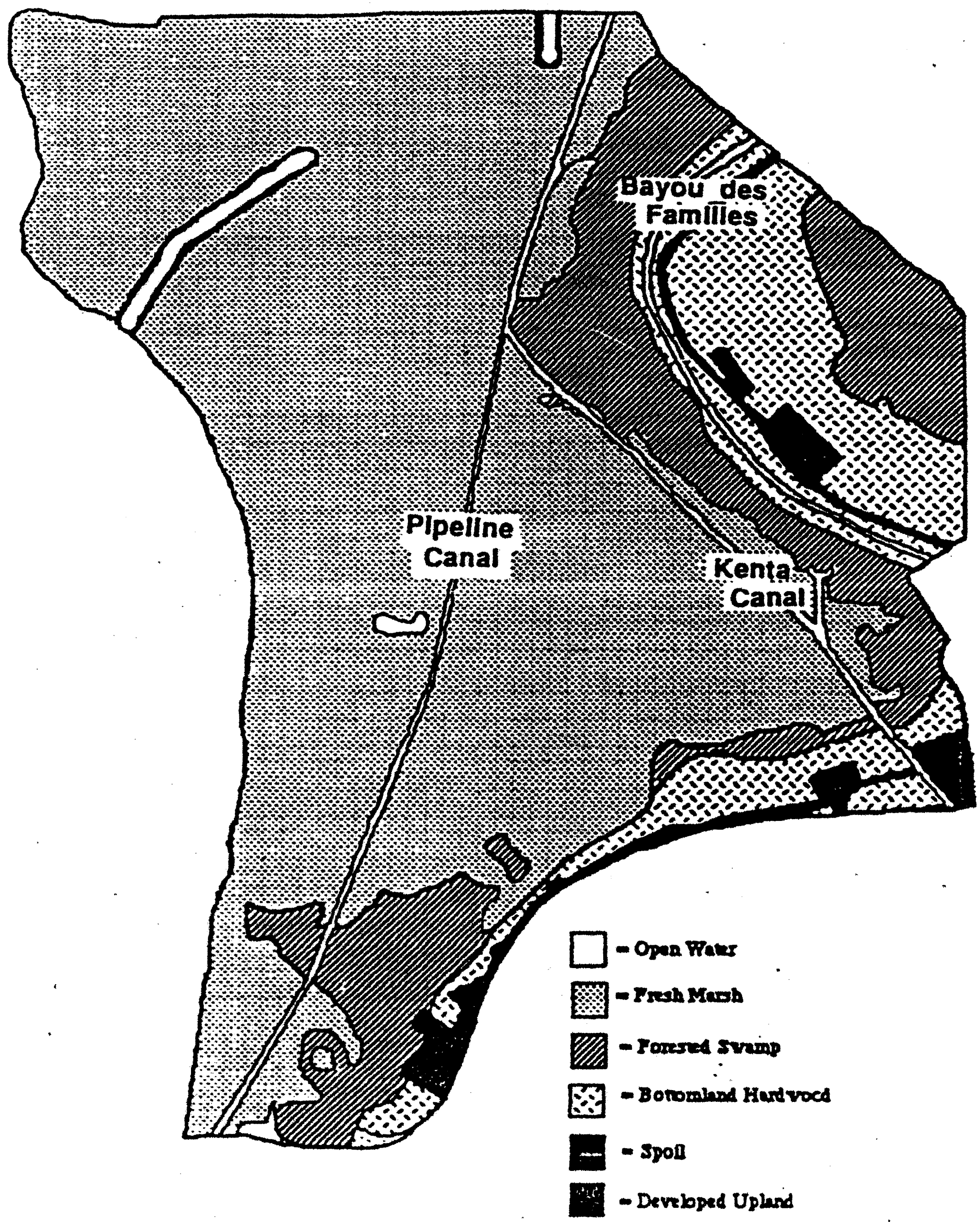


Figure 2. 1956 habitat map for Jean Lafitte National Park (from U. S. Fish ar
Wildlife Service map 1983).

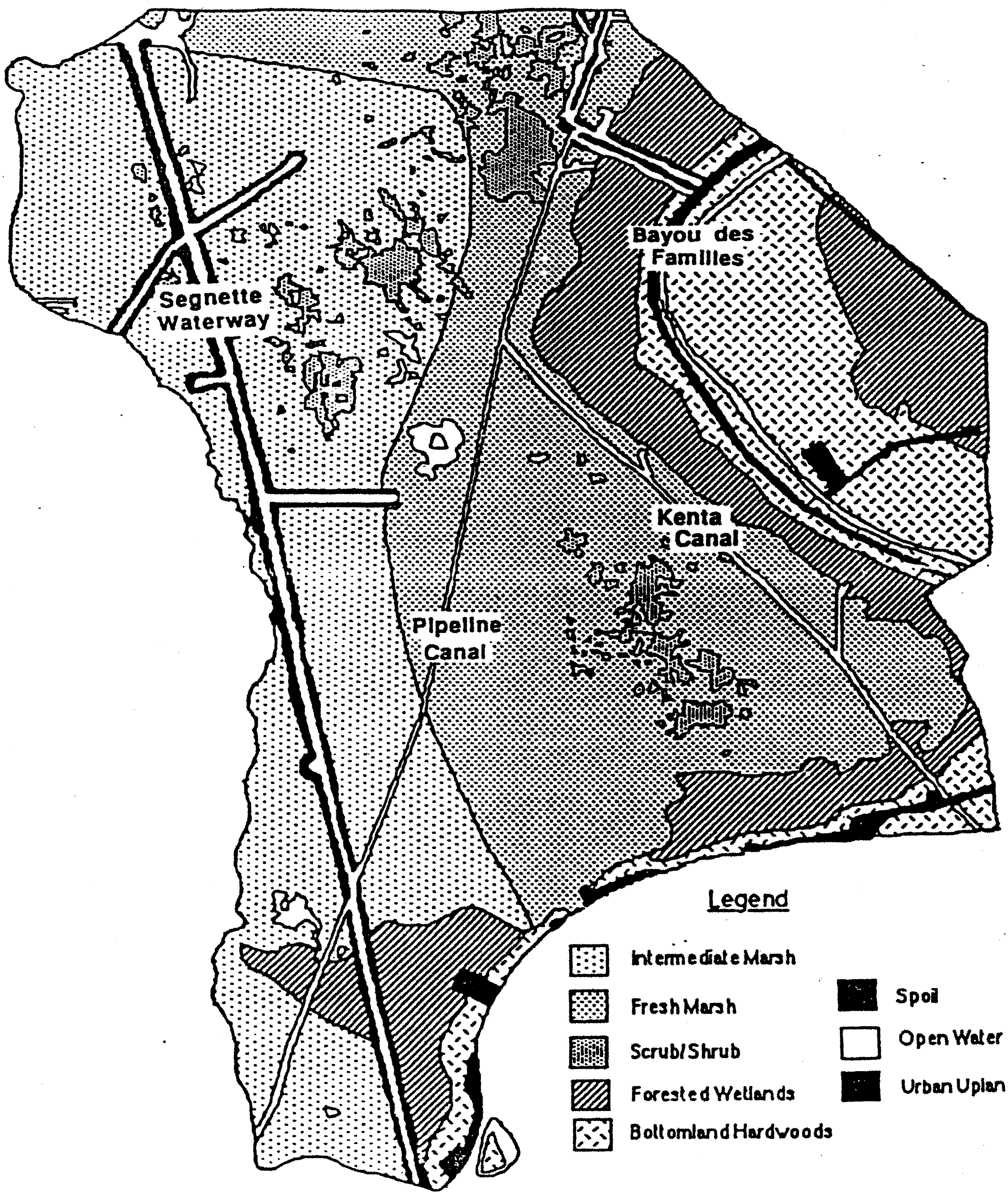


Figure 3. 1983 habitat map for Jean Lafitte National Park (from U. S. Fish and Wildlife Service map 1983).

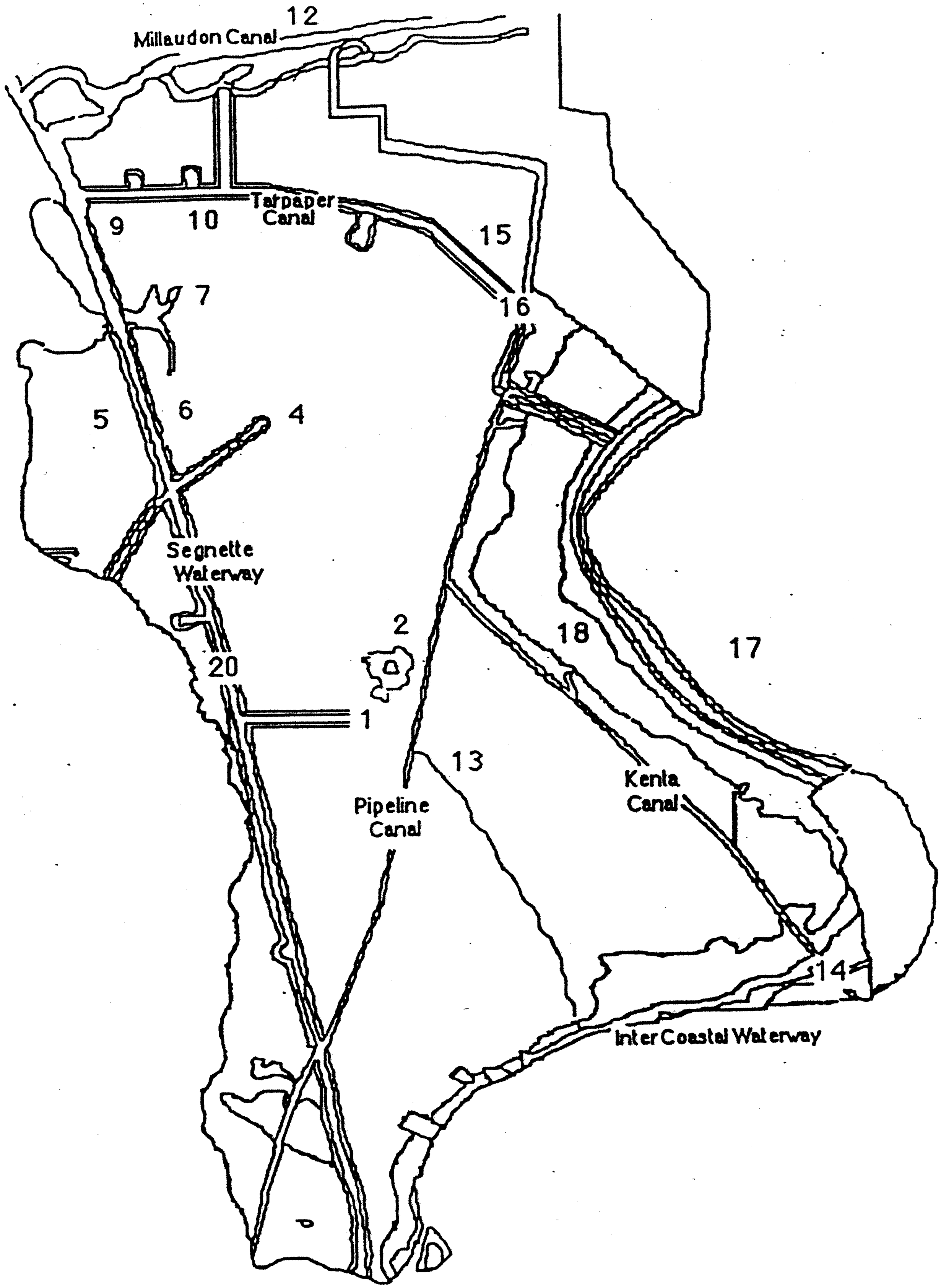


Figure 4. Station locations in Jean Lafitte National Historical Park.

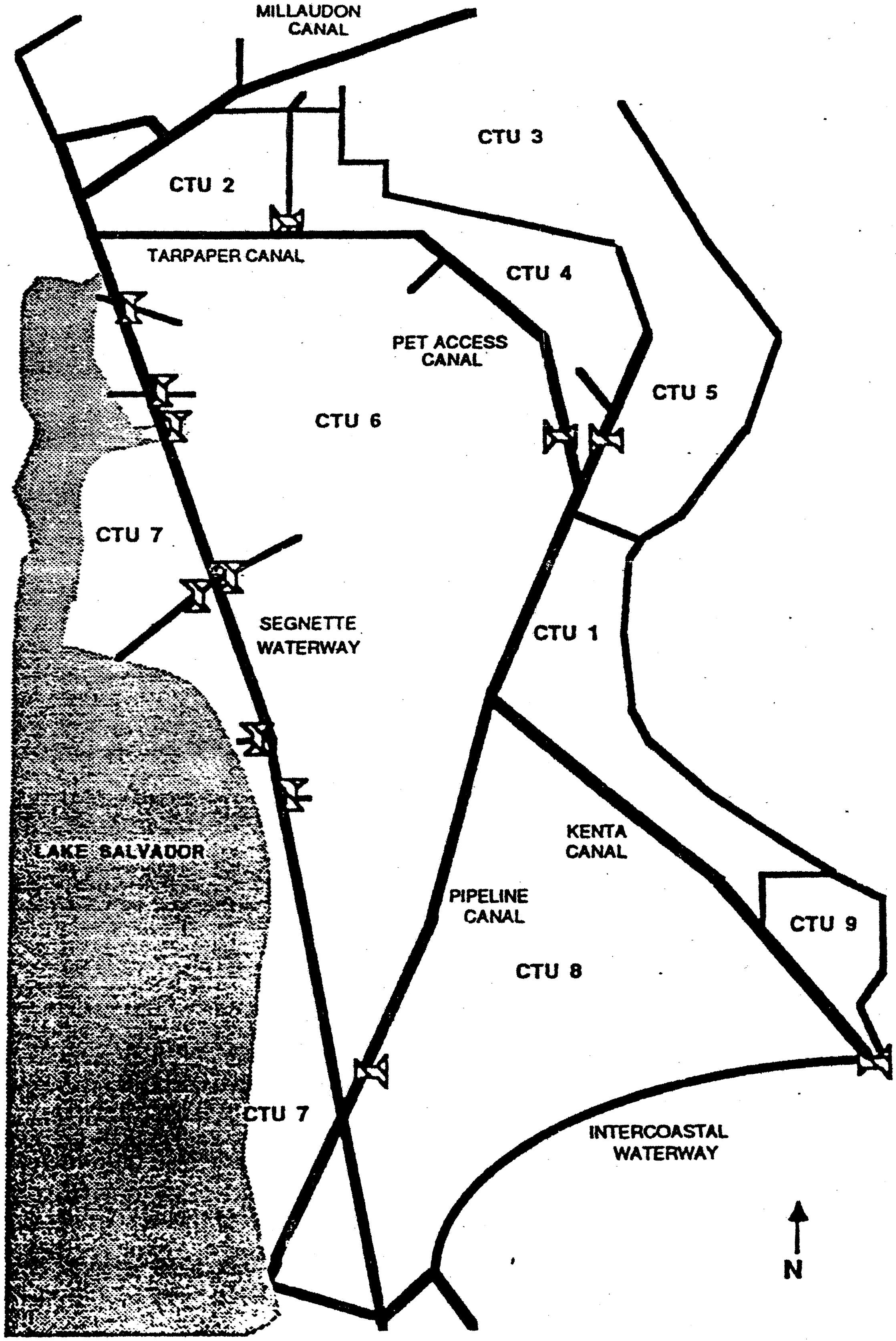


Figure 5. Map of Jean Lafitte National Park showing proposed structure placement and Conservation Treatment Units (CTUs) from (SCS 1985).

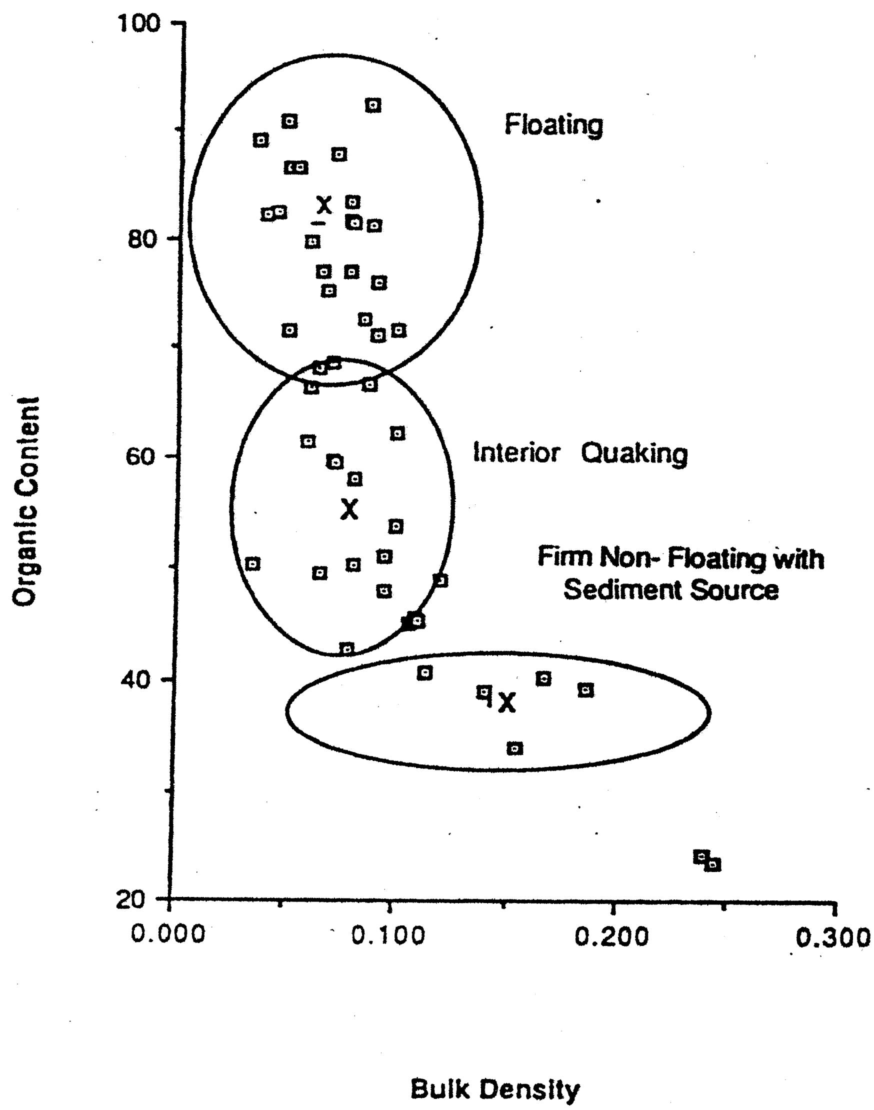


Figure . 6. Cluster analysis of bulk density and percent organic for stations in Jean Lafitte National Park. (x) represents cluster means and ellipses represent two standard deviations around the means.

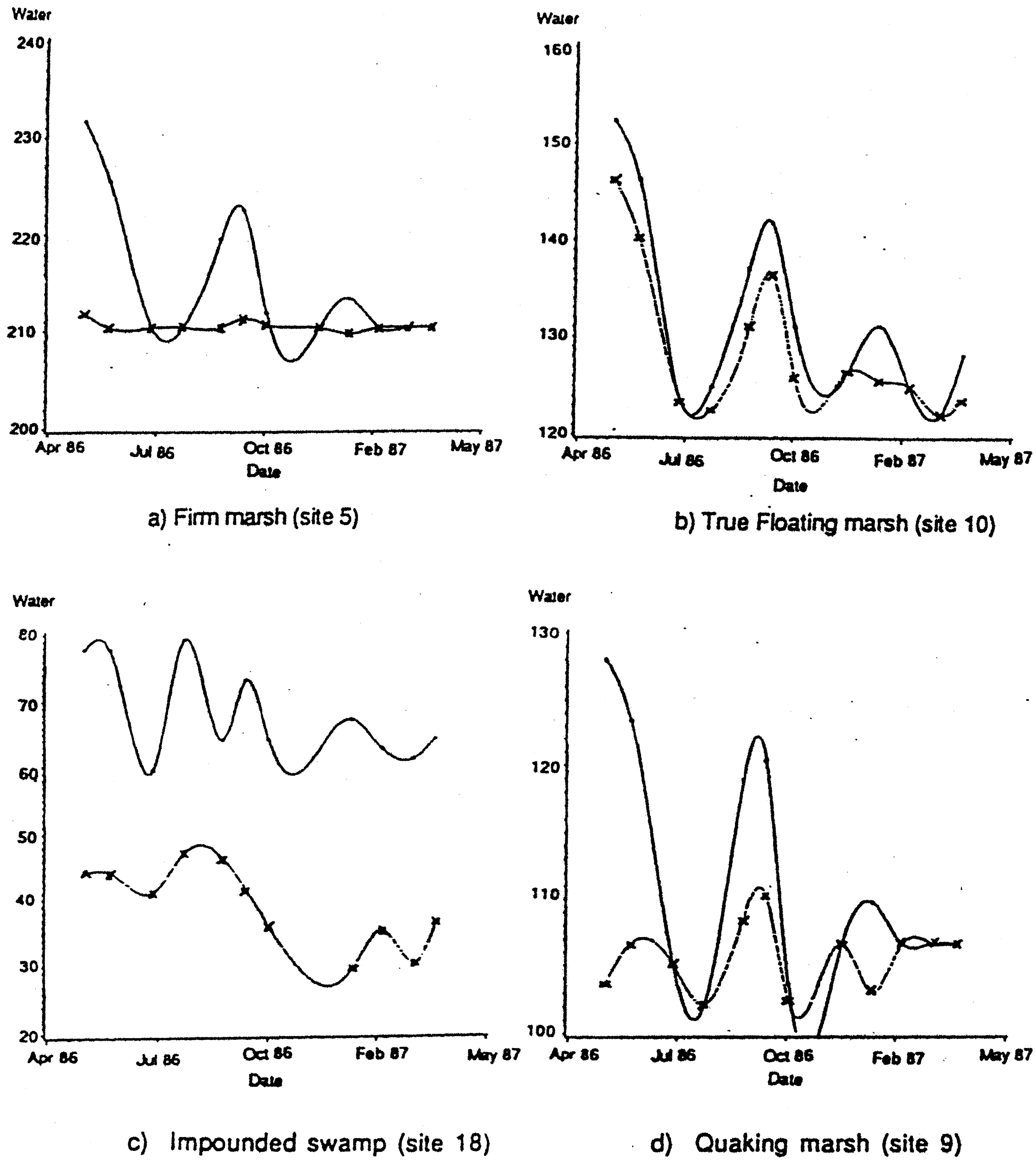


Figure 7. Monthly water and marsh level variation at selected stations in Jean Lafitte National Park from April 1986 to May 1987 illustrating different degrees of floating. Water levels are denoted by a (*) and marsh levels are denoted by an (x). Note that the two curves on the same plot are absolute to each other, and that the vertical scales between plots are different.

$$Meansal = 1.09 + 0.036 X_1 - 0.79 \sin X_2 + 0.08 \cos X_2$$
$$X_1 = 12 * (Year - 1938) + Month$$
$$X_2 = (4 * Arsin(1) * Month) / 12$$

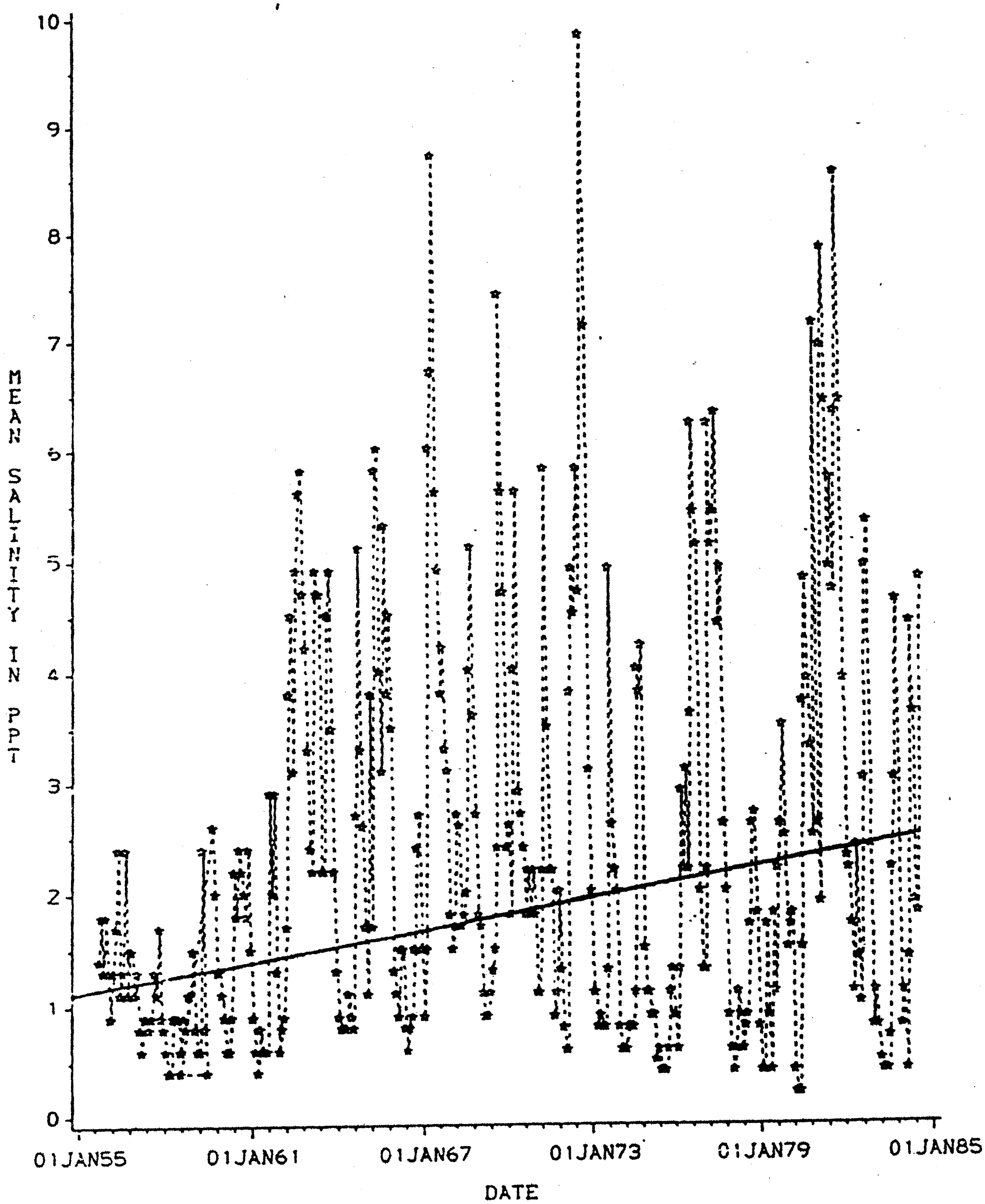


Figure 8. Long term monthly mean salinities at Bayou Barataria at Lafitte, Louisiana.

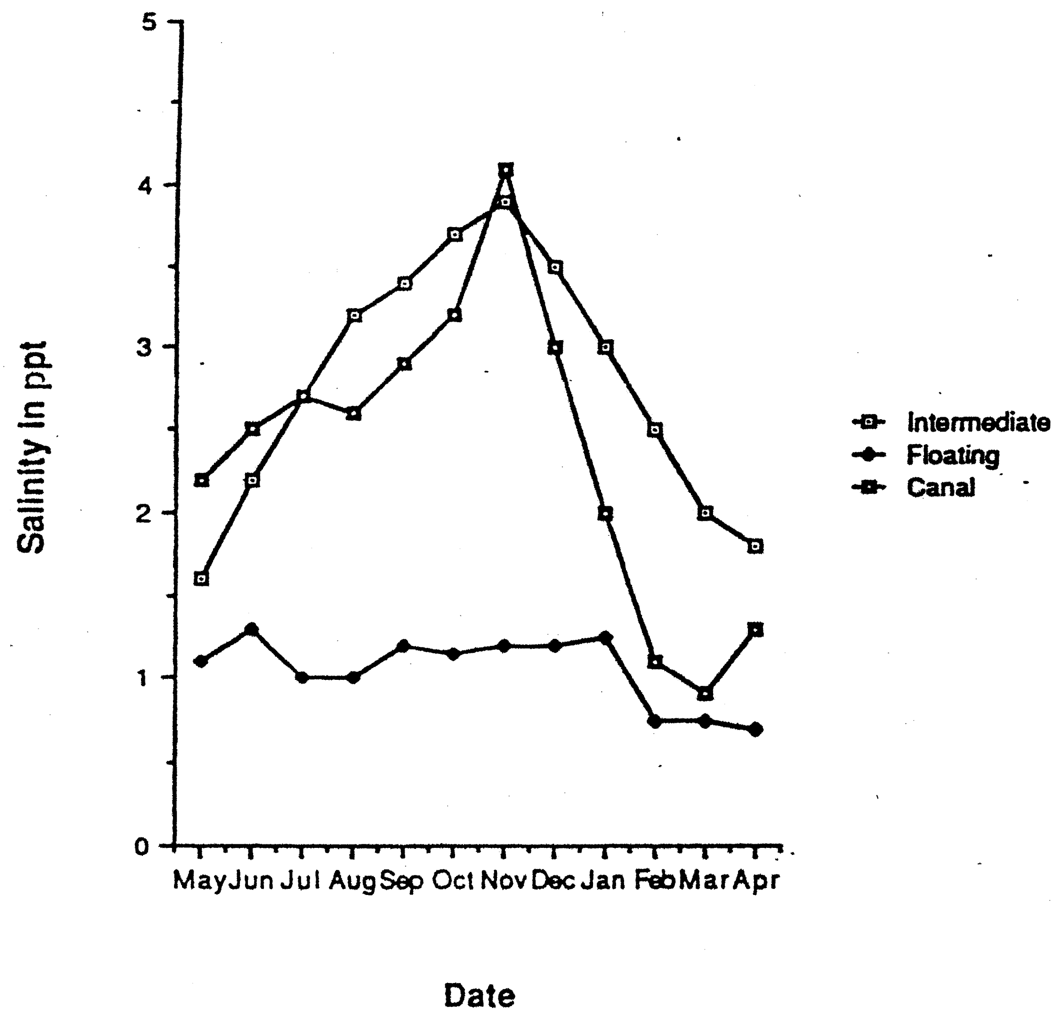
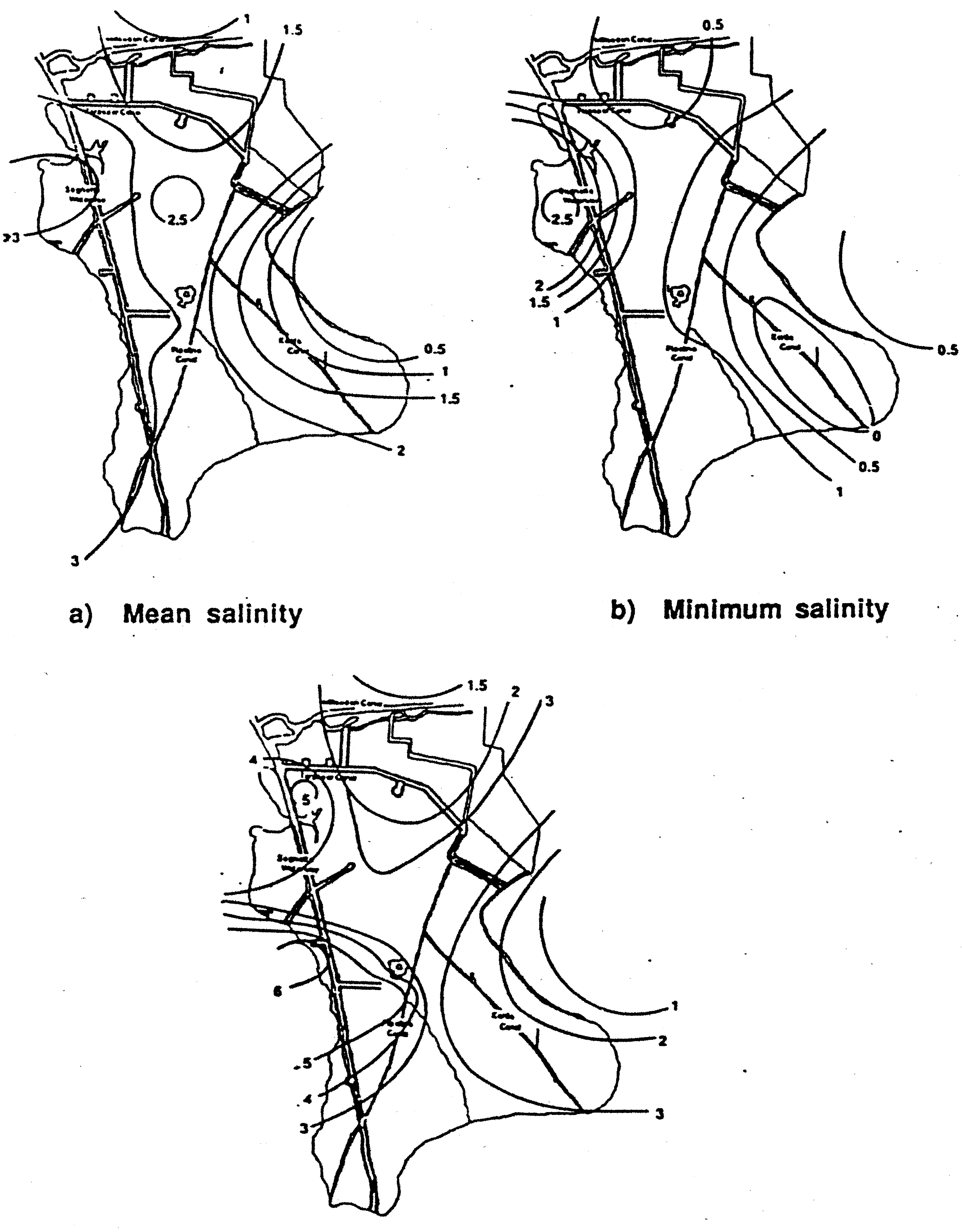


Figure 9 . Mean monthly salinities of freely floating marsh, intermediate marsh, and canal stations from April 1986 to May 1987, in Jean Lafitte National Park, Louisiana.



a) Mean salinity

b) Minimum salinity

c) Maximum salinity

Figure 10. Isohaline maps of mean, minimum, and maximum salinities in Jean Lafitte National Park during May 1986 to April 1987.

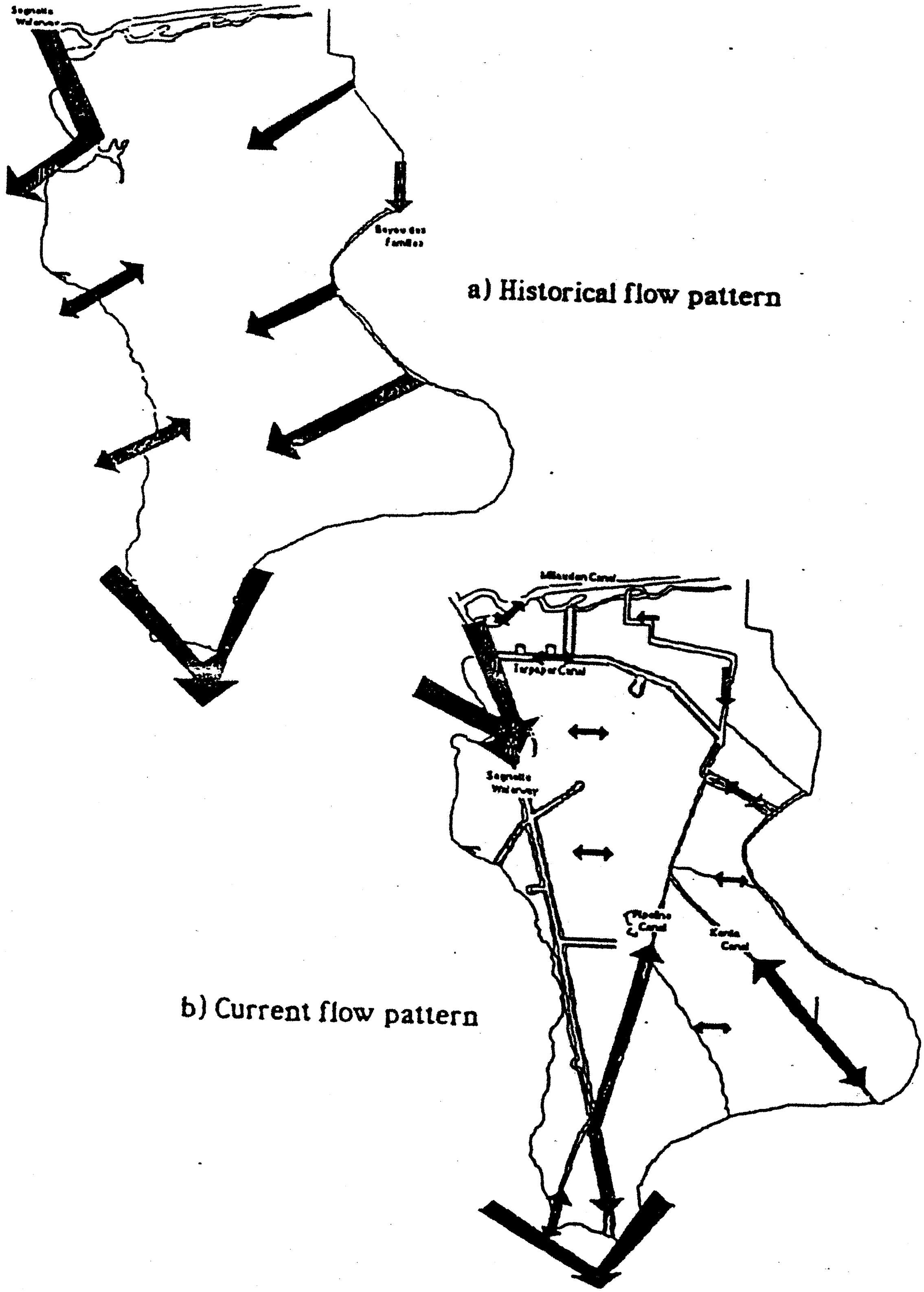


Figure 11. Historical and present hydrologic flow patterns in Jean Lafitte National Park. The relative size of the arrows denotes the relative water flow.

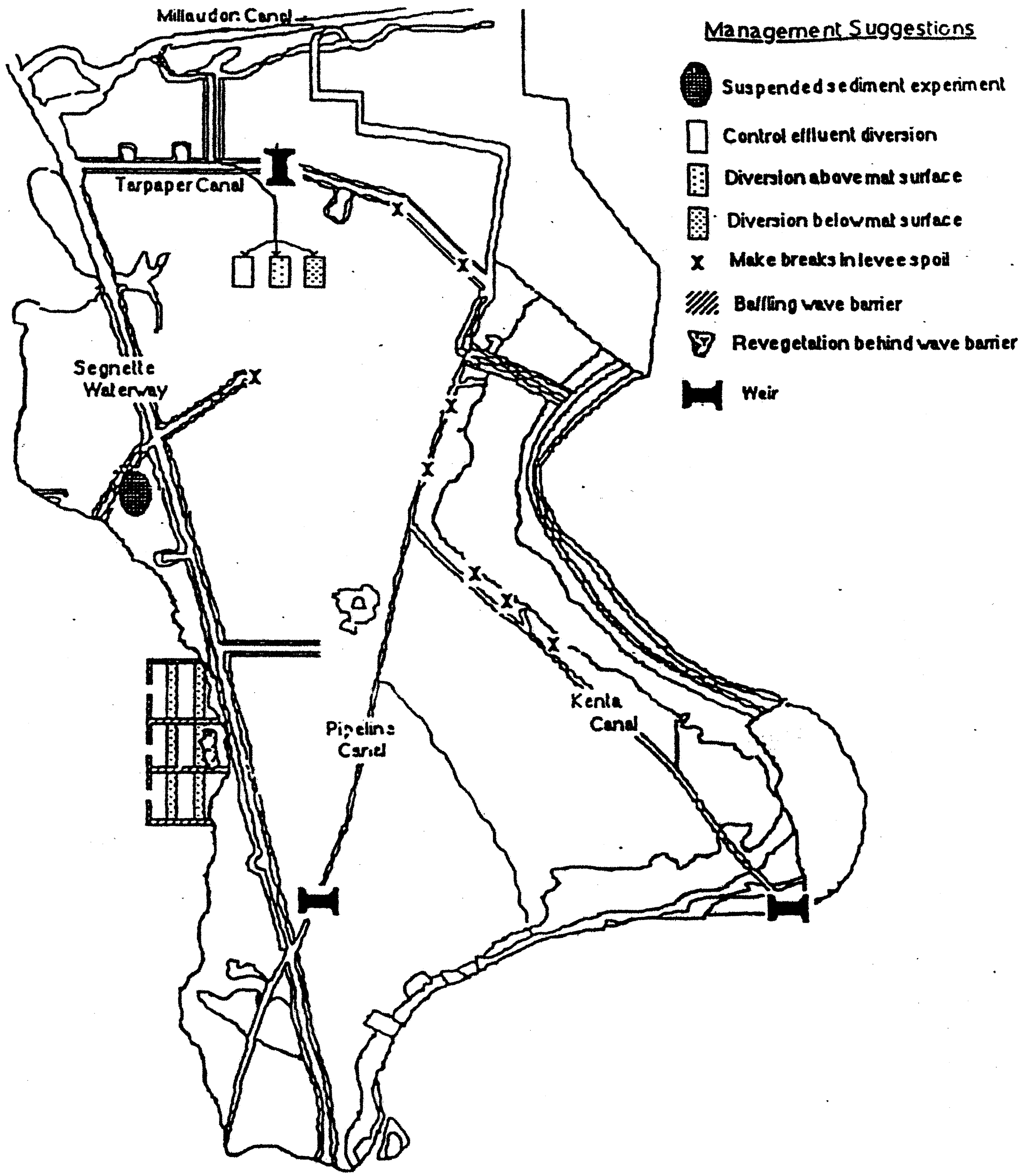


Figure 12. Management suggestions for Jean Lafitte National Park.

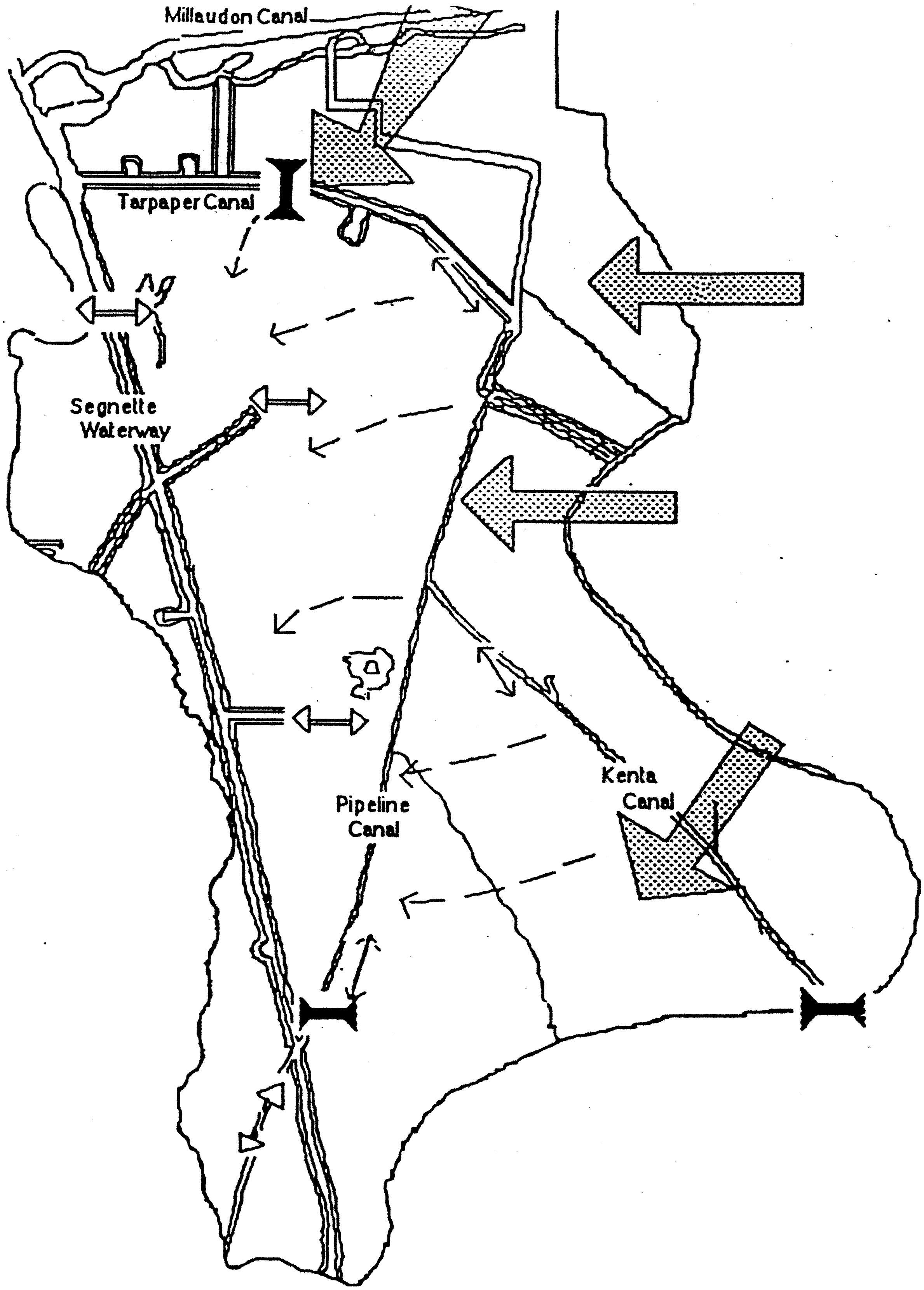


Figure 13. Proposed water control structures and resulting generalized flow patterns. Note that relative size of arrows indicates relative discharge.

Table 3. Soil characteristics in Jean Lafitte National Park. Note that sites are listed in order of decreasing bulk density. (Bulk density and water content are denoted by both site and location since both were statistically significant. Organic content, however was only significant between sites.)

Site	Mean Bulk Density dry g/cm3	Mean Water Content % wet weight
5S b	0.210 ± 0.056	77.8 ± 3.34
7S	0.160 ± 0.023	84.8 ± 1.73
9S	0.130 ± 0.033	86.9 ± 2.17
9 I	0.100 ± 0.026	88.4 ± 2.00
1 I	0.089 ± 0.024	90.6 ± 2.36
2S	0.085 ± 0.015	90.4 ± 1.88
4I b	0.084 ± 0.016	91.4 ± 0.82
13I	0.083 ± 0.021	90.4 ± 1.99
[illegible]I	0.077 ± 0.013	91.1 ± 0.62
[illegible] b	0.076 ± 0.014	92.2 ± 1.23
[illegible]	0.075 ± 0.009	89.9 ± 0.74
[illegible]	0.072 ± 0.024	91.2 ± 1.35
[illegible]	0.069 ± 0.019	92.0 ± 1.10
[illegible]	0.066 ± 0.027	88.0 ± 1.07
[illegible]	0.066 ± 0.012	92.5 ± 0.80
15I b	0.059 ± 0.021	92.6 ± 1.58
10S b	0.044 ± 0.004	93.6 ± 0.95

Site	Organic Content (at 10-15 cm depth) % dry weight
10 b	87.11 ± 4.20
15 b	82.84 ± 3.30
5 b	80.17 ± 5.61
2	70.59 ± 7.09
4 b	67.46 ± 8.58
1	60.86 ± 13.80
13	53.47 ± 7.16
12	52.13 ± 3.14
9	46.64 ± 7.05
7	43.74 ± 8.73

I signifies inland location

S signifies stream side location

b Signifies sites behind spoil banks.