Monitoring Series No. PO-17-MSPR-0499-5

PROGRESS REPORT 5

BAYOU LA BRANCHE WETLAND RESTORATION PROJECT PO-17 (PPO-10)

First Priority List Beneficial Use of Dredged Material Project of the Coastal Wetlands Planning, Protection, and Restoration Act (Public Law 101-646)

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BAYOU LA BRANCHE WETLAND RESTORATION PROJECT (PO-17)
PO-17-MSPR-0499-5
PROGRESS REPORT NO. 5
for the period
April 7, 1998 to April 6, 1999

Introduction

The Bayou La Branche Wetland Restoration Project (PO-17) encompasses 436 ac (176.4 ha) and is located in St. Charles Parish, Louisiana, on the southwestern shore of Lake Pontchartrain (figure 1). The project area is bounded by Lake Pontchartrain (north), the Illinois Central Gulf Railroad (south), an unnamed pipeline canal (east) and Bayou LaBranche (west).

Historically the La Branche wetlands have been classified as brackish marsh (O'Neil 1949; Chabreck and Linscombe 1968, 1988), as the hydrology is significantly influenced by Lake Pontchartrain. The wetlands receive tide waters from the lake through two openings in the shoreline and are flooded during normal high tides. Water circulation in the area is also greatly influenced by winds. Consequently, the wetlands experience flooding at times other than high tides and may also be drained at times other than low tide.

A combination of events, dating back to the 1800's, has contributed to an almost complete loss of marsh in the area and subsequent conversion into open water (Pierce et al. 1985). The construction of the Illinois Central Railroad in 1830 significantly altered the hydrology of the area by creating a barrier to drainage and sheet flow across the marsh from upland areas. In the early 1900's, an attempt to reclaim the area for agriculture failed, after which open water areas began to appear. During the construction of Interstate 10 in the 1960's, access canals were dug through the area, which further altered hydrology and provided a conduit for saltwater intrusion from Lake Pontchartrain into the interior marsh. Two natural events that have received blame for land loss in the area were Hurricane Betsy in 1965 and Hurricane Camille in 1969. The tidal surge generated from these storms most likely created prolonged flooding of the Bayou La Branche wetlands with higher saline water from Lake Pontchartrain. Because of the altered hydrology of this area, flood waters may have taken several weeks to drain from the wetlands, thereby stressing vegetation and contributing to the loss of marsh acreage (Montz and Cherubini 1973).

In addition to these seemingly major events that have impacted the La Branche wetlands, subsidence and shoreline erosion have also contributed to land loss in the area. Pierce et al. (1985) determined that subsidence was estimated as 0.39 in (1 cm) per year in the La Branche wetland, and erosion of the Lake Pontchartrain shoreline was estimated to be 9.5 ft/yr (2.9 m/yr) between 1955 and 1972 (Coastal Environments, Inc. 1984).

A method that has been used to combat land loss in many states, including Louisiana, is to create or restore wetlands through the beneficial use of dredged materials (Broome 1988, Patrick et al. 1984, USACE and LSU 1995). When creating a wetland with dredged materials, the most important

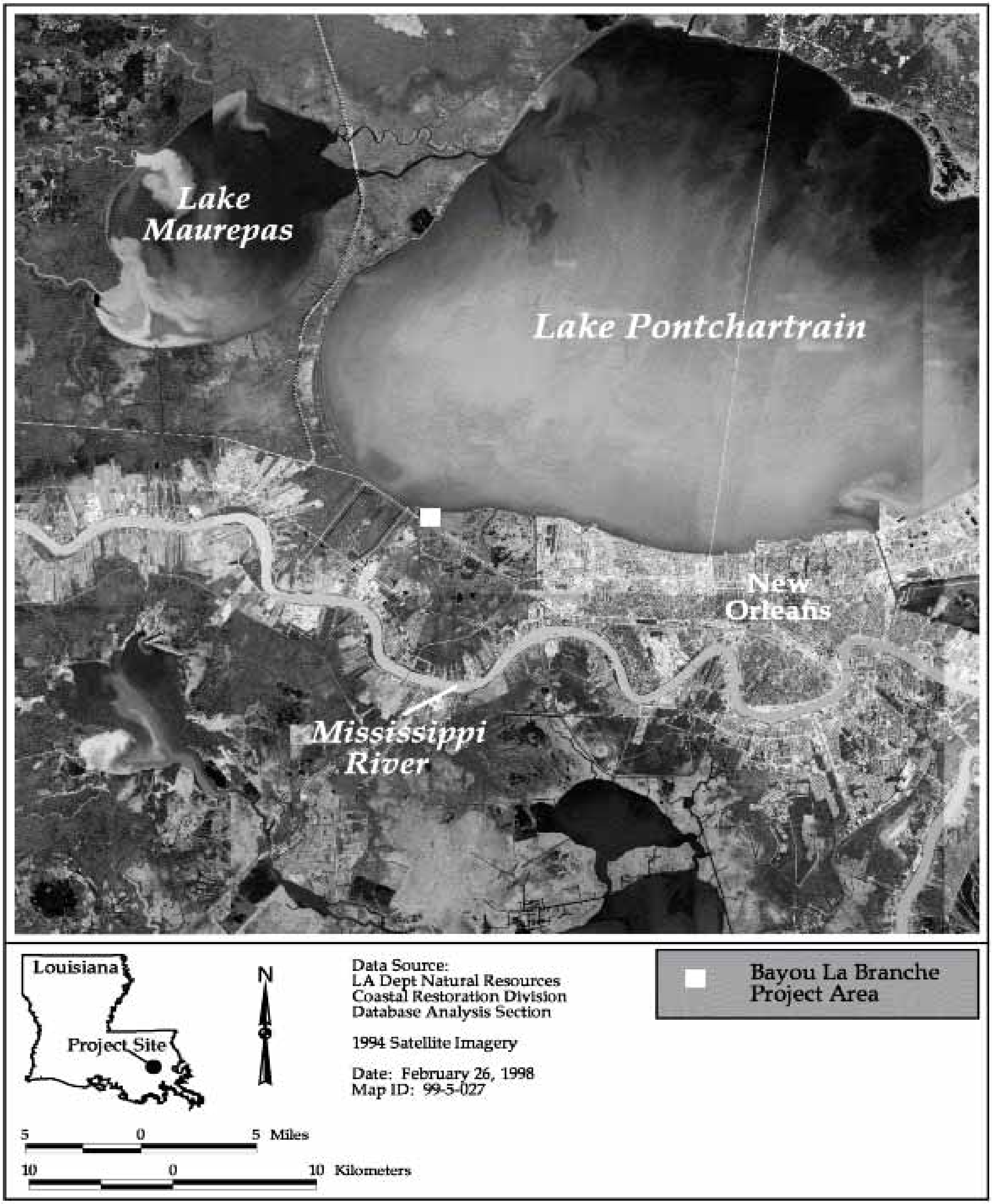


Figure 1. Location of the Bayou La Branche project area.

factor to consider is the elevation of the deposited sediments in relation to the hydrologic regime of which the vegetation of interest is adapted (Broome 1988). Sediment elevation affects the frequency and duration of flooding, which in turn affects the species of vegetation that become established within the wetland and the distribution of those species throughout the area.

The purpose of this project was to create new emergent marsh in the open water area of the Bayou La Branche wetlands utilizing dredged sediment from Lake Pontchartrain. Project construction was completed April 1, 1994. The project features consist of an earthen berm that was constructed to confine the 2.7 million yds^3 (2.1 million m^3) of dredged sediment that were pumped into the project area. The area is divided by a spoil ridge that contains a sheet pile z-wall closure and a concrete weir (weir 1, figure 2). The removal of several segments of the z-wall and the opening of the weir allows the exchange of water between these two areas. Two weirs and four box culverts located in the containment berm allow water to flow in and out of the project area, and provide for ingress and egress of marine species during periods of high water (figure 2). The measurable project goals were to create approximately 305 ac (123.5 ha) of shallow-water habitat conducive to the natural establishment of emergent wetland vegetation and to produce a ratio of 70% emergent marsh to 30% open water within 5 years following project completion.

Methods

To create a habitat that will sustain emergent wetland vegetation, the proper sediment elevation must be attained in the project area. Therefore, staff gauges (set to the North American Vertical Datum 1988, NAVD) were installed in the project area to monitor elevation of the dredged sediments. After project construction in 1994, the deposited sediments were too unconsolidated to allow access to interior portions of the project area; therefore, eight temporary staff gauges were set up around the perimeter of the area. Five gauges were installed in Pond A, and three were installed in Pond B. Elevation data collected from these staff gauges were used to obtain an approximate estimate of sediment consolidation and settlement in the area. However, these data were not used in statistical analyses, because they were located mostly around the perimeter and did not afford adequate coverage of the entire area.

In 1996, the sediments had consolidated enough to allow access to the entire area, so 19 permanent staff gauges were installed along north-south transects (figure 3), as outlined in the project monitoring plan (Steller 1994). Only sediment elevations measured from these permanent staff gauges (1996 through 1999 data) were used in the analysis in this report. An analysis of covariance (ANCOVA; Littell et al. 1996) was used determine if differences ($\alpha = 0.05$) in elevation existed among stations and if time (covariate) had an effect on sediment elevation. Least squared means (Littell et al. 1996) were used to compare factor levels (stations) when ANCOVA indicated significant differences were present.

In addition to proper sediment elevation, soil composition is also important to the establishment of emergent wetland vegetation. To characterize soil composition in the project area, duplicate 10-cm soil samples were collected at the 19 staff gauge stations with a Swenson corer (Swenson 1982).

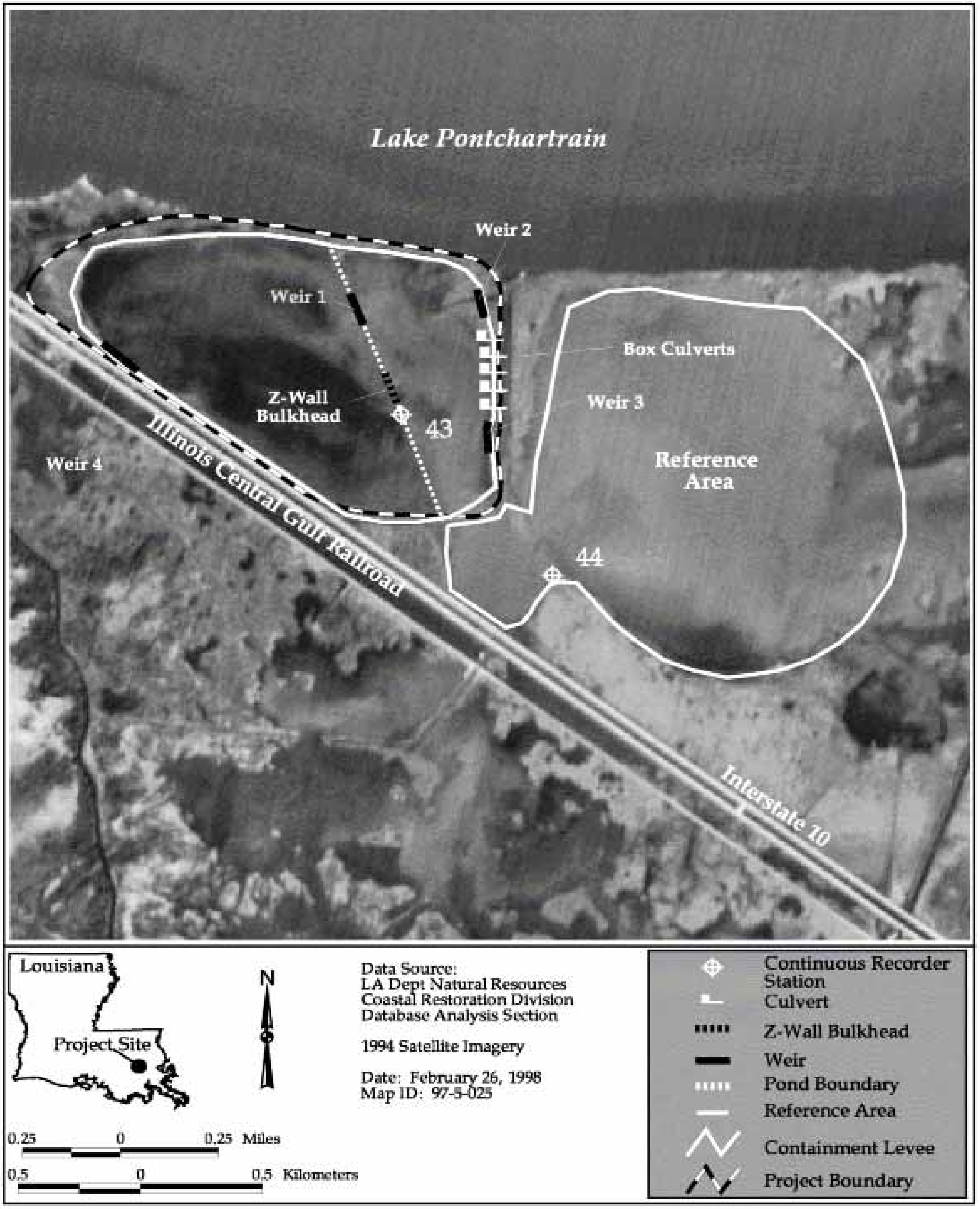


Figure 2. Bayou La Branche Wetland Restoration project features.

Figure 3. Bayou La Branche Wetland Restoration project vegetation, soil sample, and sediment staff gauge locations.

Soil samples were taken to coincide with vegetation surveys, once during preconstruction and at years two (1996), three (1997), and four (1998) postconstruction. The soil cores were analyzed to determine percent organic matter, bulk density (g/cc), and percent moisture. Because different soils were sampled pre- and postconstruction (natural marsh soils vs. dredged sediments from Lake Pontchartrain), no statistical comparison was made between pre- and postconstruction samples. An ANOVA was used to compare ($\alpha = 0.05$) mean percent organic matter, bulk density and percent moisture among stations, years and their interaction. Factor level means were compared (MEANS/ option=Tukey, SAS Institute Inc. 1989) when ANOVA indicated significant differences were present.

The establishment of emergent wetland vegetation in a marsh is greatly influenced by hydrology in the area. Thus, water level was recorded hourly at two continuous recorders (YSI Model 6000 or 6920 Water Quality Analyzers), one located in the project area (station 43) and one in the reference area (station 44; figure 2). Staff gauges were established at each continuous recorder station in August 1997 so that staff gauge data could be used to convert water level data from the recorders to a known vertical datum (NAVD). Water level data, in conjunction with marsh elevation, was used to calculate frequency and duration of flooding in the project and reference areas.
Emergent vegetation was surveyed with the Braun-Blanquet sampling method to quantify species composition and relative abundance in the project area (Mueller-Dombois and Ellenberg 1974). A total of 42 stations were surveyed during preconstruction and at years two (1996) and three (1997) postconstruction; however due to budget cuts, the number of stations were reduced to 19 for the year three (1998) survey and all future surveys. Vegetation stations were distributed at 440-ft (134.2 m) intervals along six north-south transects (same transects as sediment staff gauges) in the project area (figure 3). The frequency of occurrence each species and mean percent cover of the most common species was calculated. Additionally, the "wetland status" of the project area was calculated for each survey year (Steyer et al. 1995). This was done by first determining the wetland indicator status of the vegetation species (Reed 1988) at each station, then assigning a prevalence index number to each species based on its status (1 = obligate wetland, 2 = facultative wetland, 3 = facultative, 4 = facultative upland, 5 = upland). An average prevalence index was calculated for the project area and compared among years using ANOVA ($\alpha = 0.05$). A prevalence index of three or less represents a wetland plant community.

At the U.S. Geological Survey's National Wetlands Research Center (NWRC), 1:12,000 scale color infrared aerial photography was classified and photointerpreted to measure land to open water ratios and map habitat types in the project and reference areas. Preconstruction photography was obtained November 7, 1993, and postconstruction photography was obtained December 19, 1994, and November 17, 1997 (figures 4 & 5). The GIS analysis for this report only pertains to the 1993 and 1997 photography. The 1994 photography was not included in the project monitoring plan, thus no funds were available to conduct a complete habitat analysis. However, the land to open water ratio was calculated for the project area from the 1994 photos.

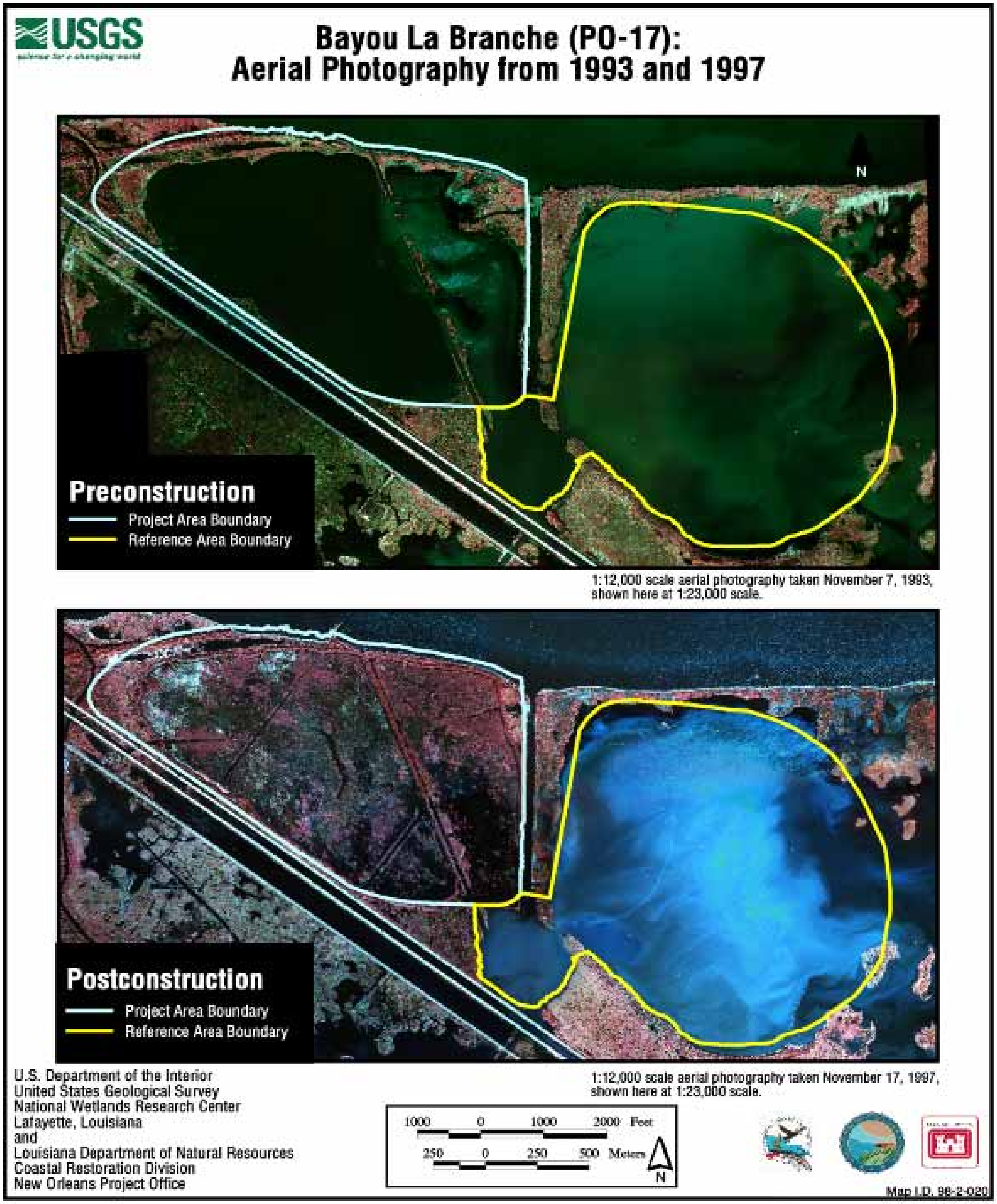


Figure 4. Preconstruction and postconstruction aerial photography for the Bayou La Branche project and reference areas.

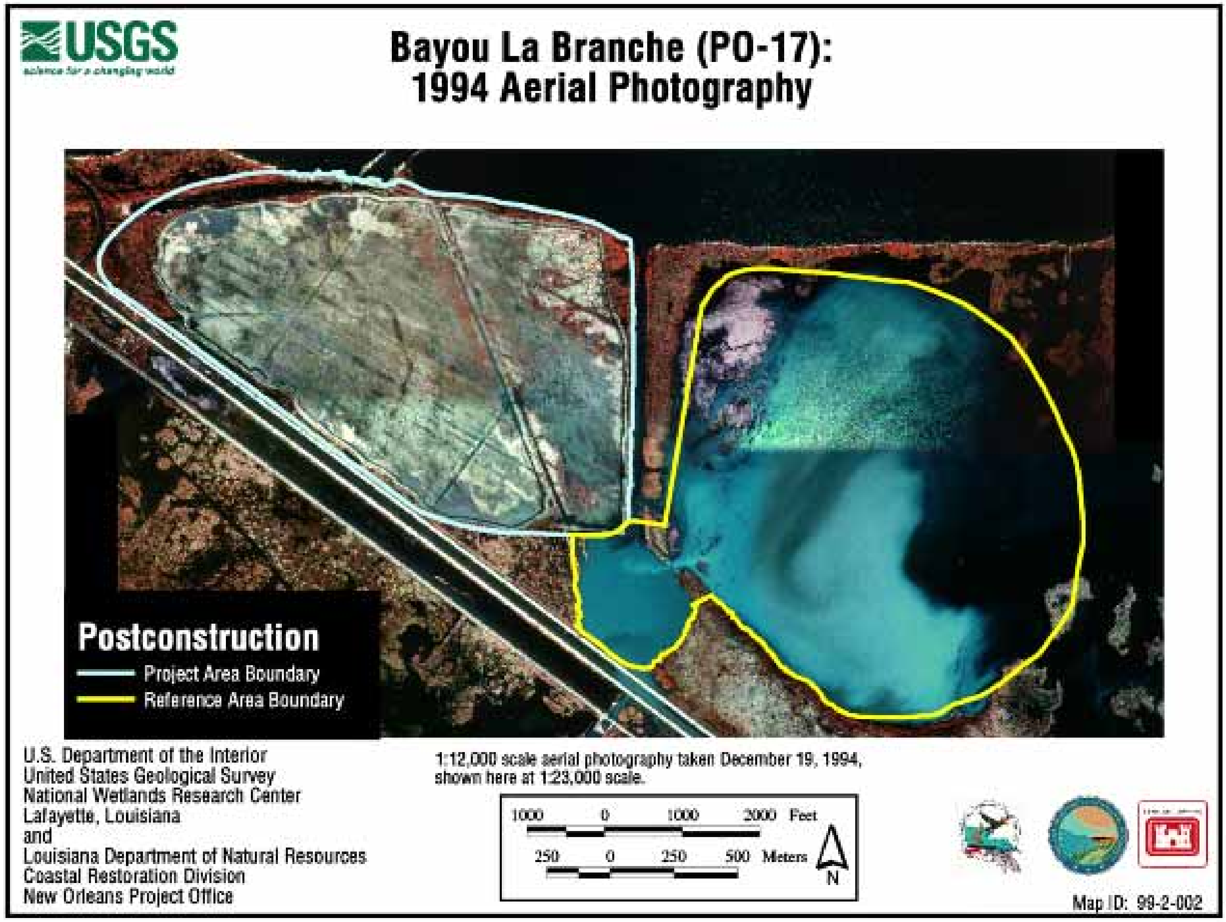


Figure 5. Postconstruction aerial photography of the Bayou La Branche project area in 1994.

To determine land to water ratios, the aerial photographs were scanned at 300 pixels per inch and georectified using ground control data collected with a differentially correctable global positioning system capable of sub-meter accuracy. These individually georectified frames were then mosaicked together to produce a single image of the project and reference areas. Using geographic information systems (GIS) technology, the photomosaic was classified according to pixel value and analyzed to determine land to water ratios in the project and reference areas. All areas characterized by emergent vegetation were classified as land, while open water, aquatic beds, and mud flats were classified as water. An accuracy assessment comparing the GIS land-water classification of 100 randomly chosen pixels to aerial photography determined an overall classification accuracy of 99%.

Using the National Wetlands Inventory (NWI) Classification System, the photography was photointerpreted by NWRC personnel and classified to the subclass level. The habitat delineations were transferred to 1:6,000 scale Mylar base maps, digitized, and checked for quality and accuracy. The resulting digital data were subsequently aggregated and analyzed using GIS to determine habitat change over time in the project and reference areas. Classification of photography to the NWI subclass level yielded 32 distinct habitat types in the project and reference areas. These habitat types were aggregated into fourteen habitat classes for the purpose of mapping change (table 1).

Habitats in the Bayou La Branche Wetland project and reference areas represent three NWI habitat systems: the estuarine system, the palustrine system, and the riverine system. The estuarine system includes all tidal habitats in which waters consist of at least 0.5% ocean-derived salt and are diluted at least occasionally by freshwater runoff from the land. Palustrine habitats are nontidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens, and all wetlands that occur in tidal areas where ocean-derived salinities are less than 0.5%. The riverine system includes those wetlands and deepwater habitats contained within a channel that are not dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens and that are freshwater (salinity less than 0.5%) (Cowardin et al. 1992). Additionally, three upland habitats were identified in the project and reference areas. Upland barren habitats are those whose areal coverage consists of less than 30% vegetation or other cover. Upland scrub-shrub and upland forested habitats consist of at least 30% scrub-shrub or forest, respectively (Anderson et al. 1976).

When describing both upland and wetland habitats, the term "scrub-shrub" refers to woody vegetation less than twenty feet (six meters) in height. The term "forested" refers to woody vegetation taller than twenty feet. Where more than one class of vegetation exists, the uppermost layer of vegetation with areal coverage greater than 30% determines the NWI habitat type. For example, a habitat whose areal cover consists of 60% emergent marsh and 40% scrub-shrub would be classified as scrub-shrub. The terms "unconsolidated bottom" and "unconsolidated shore" both refer to habitats with less than 30% vegetative cover which are flooded at least part of the time. The class "unconsolidated bottom" is applied to subtidal, permanently flooded, intermittently exposed, and semipermanently flooded habitats, while "unconsolidated shore" refers to habitats flooded less frequently. The bottom of a small pond is an example of an unconsolidated bottom, while a beach or a mudflat is an example of an unconsolidated shore.

Results

Sediment elevation that was measured from the temporary staff gauges in October 1994, just after project construction, ranged from 3.28 to 1.81 ft (1.01 to 0.56 m) NAVD, and had a mean of 2.44 ± 0.19 ft (0.75 ± 0.06 m) NAVD. In June 1995, sediment elevation ranged from 2.10 to 1.30 ft (0.64 to 0.40 m) NAVD, with a mean of 1.65 ± 0.09 ft (0.51 ± 0.03 m) NAVD. The analysis of sediment elevation data (table 2) that was measured from the permanent staff gauges (1996 - 1999) showed a significant (df = 1, F = 105.12, p = 0.0001) time effect, which accounted for 94% of the variation in sediment elevation in the project area. A plot of mean sediment elevation by year (figure 6) displays a negative trend in sediment elevation, with the exception of the 1999 datum. The remaining variation in sediment elevation was accounted for by stations, among which significant differences (df = 18, F=7.02, p=0.0001) were also present. In general, stations located in the northern section of the project area had higher elevations than those in the southern project area (table 2). In addition, the greatest changes in elevation have occurred at several of the northern stations (2, 7, 9, 12, 14).

Analysis of the preconstruction soil samples indicated that mean bulk density was 0.9 g/cc, mean organic matter was 5.6%, and mean soil moisture was 52.9%. As stated earlier, these samples were taken in the project area before dredged sediments were deposited and thus were not compared to postconstruction samples. Analysis of the postconstruction data showed that mean percent organic matter, bulk density and percent moisture all differed significantly among years (figure 7). Percent organic matter and bulk density decreased over time, whereas percent moisture varied by year. For bulk density, marginally significant differences (df = 18, F = 1.97, p = 0.0419) were found among stations. Stations 21 and 34 had significantly lower mean bulk densities than any other station. Percent moisture also differed significantly (df = 18, F = 4.02, p = 0.0002) among stations. Stations located along the northern transects (2, 4, 7, 9, 12, 14, 28, 30, 36) had a lower moisture content than those along the southern transects. No significant differences were found among stations for percent organic matter. In addition, no significant interactions were found among years and stations for either of the three soil properties.

Water level in the project and reference areas followed moderately similar patterns for both years (figures 8 & 9). However, some differences in frequency and duration of flooding were noted. The reference area was inundated more frequently than the project area each year; however, the average duration of floods was greater in the project area (table 3). The maximum duration of a single flood event in the project area was 67.4 days, whereas the maximum duration in the reference area was 41.5 days. Both of these extended floods occurred in the early fall of 1998 and were associated with two consecutive hurricanes to the region. Although Lake Pontchartrain and New Orleans were not directly hit by either of these hurricanes, storm surge from the Gulf of Mexico caused a temporary increase in water levels of three to four feet above normal. Conversely, the minimum duration of a single flood event in the project area was three hours, whereas the minimum in the reference area was a single hour.

Table 1. Habitat classes used in GIS analyses of the Bayou La Branche project area.

Explanations of Classes Used for

Habitat Mapping and Change Analysis

	Class	**NWI Code**	**Description**
1.	Estuarine Open Water	E1UB	Estuarine, Subtidal, Unconsolidated Bottom
		E1UBx	Estuarine, Subtidal, Unconsolidated Bottom (excavated)
		E2US	Estuarine, Intertidal, Unconsolidated Shore
		E2US5	Estuarine, Intertidal, Unconsolidated Shore (vegetated)
2.	Estuarine Aquatic Bed	E1AB3	Estuarine, Subtidal, Aquatic Bed, Rooted Vascular
		E1AB4	Estuarine, Subtidal, Aquatic Bed, Floating Vascular
		E1AB4x	Estuarine, Subtidal, Aquatic Bed, Floating Vascular (excavated)
3.	Estuarine Emergent Marsh	E2EM	Estuarine, Intertidal, Emergent
		E2EMs	Estuarine, Intertidal, Emergent (spoil)
4.	Estuarine Scrub-shrub	E2SS1	Estuarine, Intertidal, Scrub-shrub, Broad-leaved Deciduous
		E2SS3	Estuarine Intertidal Scrub-shrub, Broad-leaved Evergreen
		E2SS3s	Estuarine, Intertidal, Scrub-shrub, Broad leaved Evergreen (spoil)
5.	Palustrine Open Water	PUB	Palustrine, Unconsolidated Bottom
		PUBx	Palustrine, Unconsolidated Bottom (excavated)
		PUS	Palustrine, Unconsolidated Shore
		PUSx	Palustrine, Unconsolidated Shore (excavated)
6.	Palustrine Aquatic Bed	PAB3	Palustrine, Aquatic Bed, Rooted Vascular
		PAB4	Palustrine, Aquatic Bed, Floating Vascular
		PAB4x	Palustrine, Aquatic Bed, Floating Vascular (excavated)
7.	Palustrine Emergent Marsh	PEM	Palustrine, Emergent
		PEMs	Palustrine, Emergent (spoil)
8.	Palustrine Scrub-shrub	PSS1	Palustrine, Scrub-shrub, Broad-leaved Deciduous
		PSS3	Palustrine, Scrub-shrub, Broad-leaved Evergreen
		PSS3s	Palustrine, Scrub-shrub, Broad-leaved Evergreen (spoil)
9.	Palustrine Forested	PFO1	Palustrine, Forested, Broad-leaved Deciduous
		PFO1s	Palustrine, Forested, Broad-leaved Deciduous (spoil)
10.	Riverine Open Water	R2UBx	Riverine, Lower Perennial, Unconsolidated Bottom (excavated)
11.	Riverine Aquatic Bed	R2AB4x	Riverine, Lower Perennial, Aquatic Bed, Floating Vascular (excavated)
12.	Upland Barren	UBs	Upland, Barren (spoil)
13.	Upland Scrub-shrub	USS8s	Upland, Scrub-shrub, Mixed Evergreen and Deciduous (spoil)

Table 2. Bayou LaBranche sediment staff gauge elevations from May 1996 through January 1999.

Station	Location	Elevation May '96	Elevation May '97	Elevation July '98	Elevation January '99	Elevation Change May '96 thru Jan '99
2	North/East	1.60	1.30	1.05	1.05	0.55
4	North/East	1.10	1.10	0.80	1.00	0.10
7	North/East	1.80	1.50	1.00	1.20	0.60
9	North/East	1.60	1.40	1.00	1.05	0.55
12	North/East	1.80	1.50	1.15	1.25	0.55
14	North/East	1.55	1.40	0.90	0.95	0.60
19	North/West	1.50	1.30	0.95	1.10	0.40
21	North/West	1.30	1.15	0.90	0.90	0.40
28	North/West	1.90	1.80	1.40	1.50	0.40
30	North/West	1.25	1.20	1.05	1.10	0.15
36	North/West	1.50	1.40	1.15	1.20	0.30
38	North/West	1.50	1.40	1.10	1.10	0.40
16	South/East	1.45	1.35	1.05	1.05	0.40
23	South/West	1.30	1.15	0.80	0.80	0.50
25	South/West	1.10	1.15	0.95	1.00	0.10
32	South/West	1.20	1.10	1.00	0.95	0.25
34	South/West	1.40	1.30	1.10	1.10	0.30
40	South/West	1.10	1.15	0.85	1.10	0.00
42	South/West	1.00	1.15	0.80	0.85	0.15
Mean		**1.42**	**1.31**	**1.00**	**1.07**	**0.35**

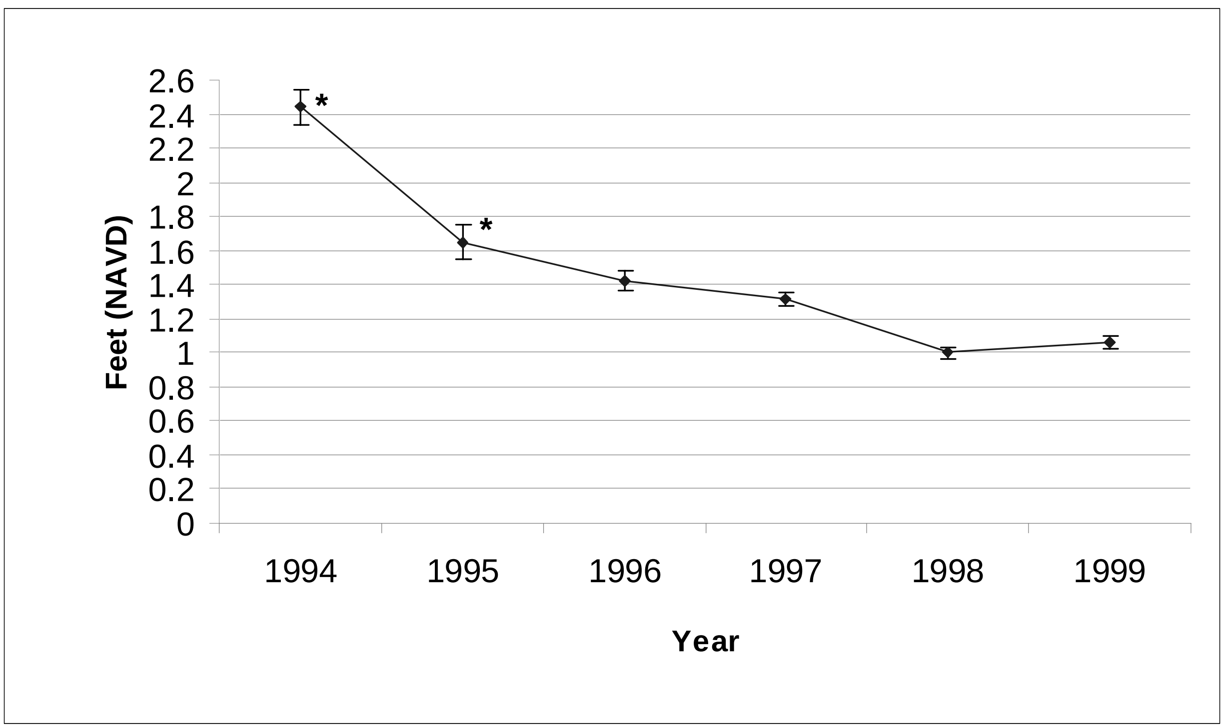
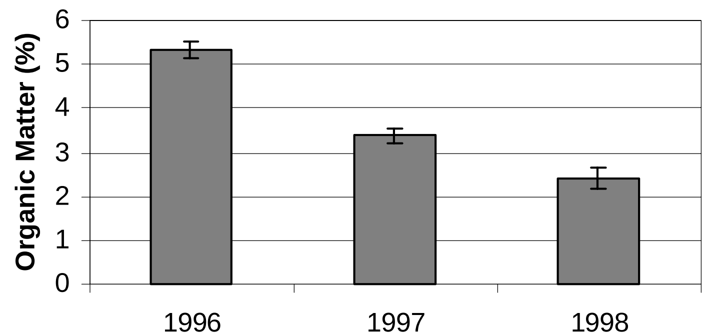
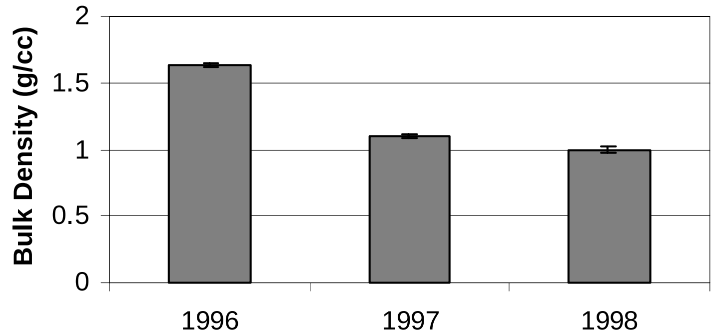


Figure 6. Mean (standard error) sediment elevation by year for the Bayou La Branche Wetland Restoration Project. Data from years 1994 and 1995 (*) were measured from eight temporary staff gagues and were not used in statistical analyses.

(A)



(B)



(C)

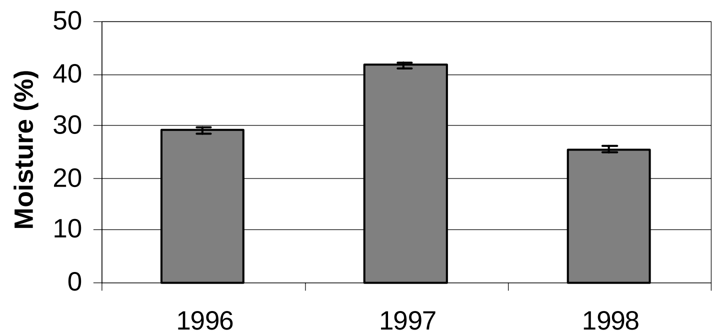
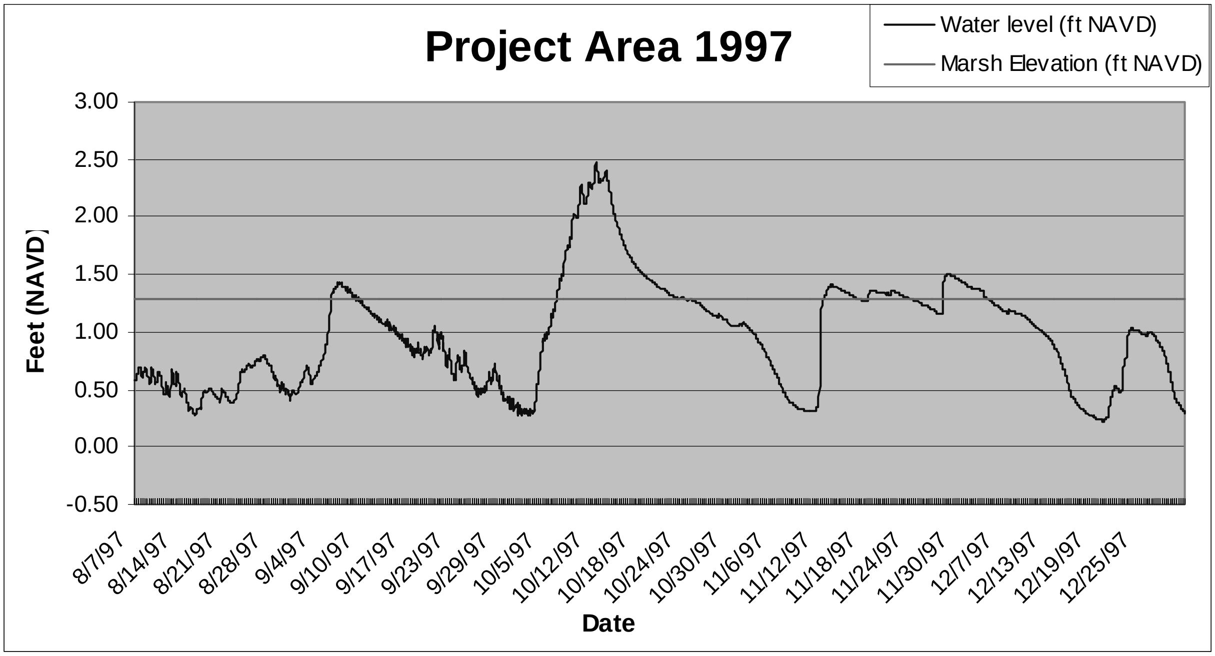


Figure 7. Mean percent organic matter (A), bulk density (B), and percent moisture (C) for dredged sediments for 1996, 1997, and 1998. Standard error bars are given for each mean.



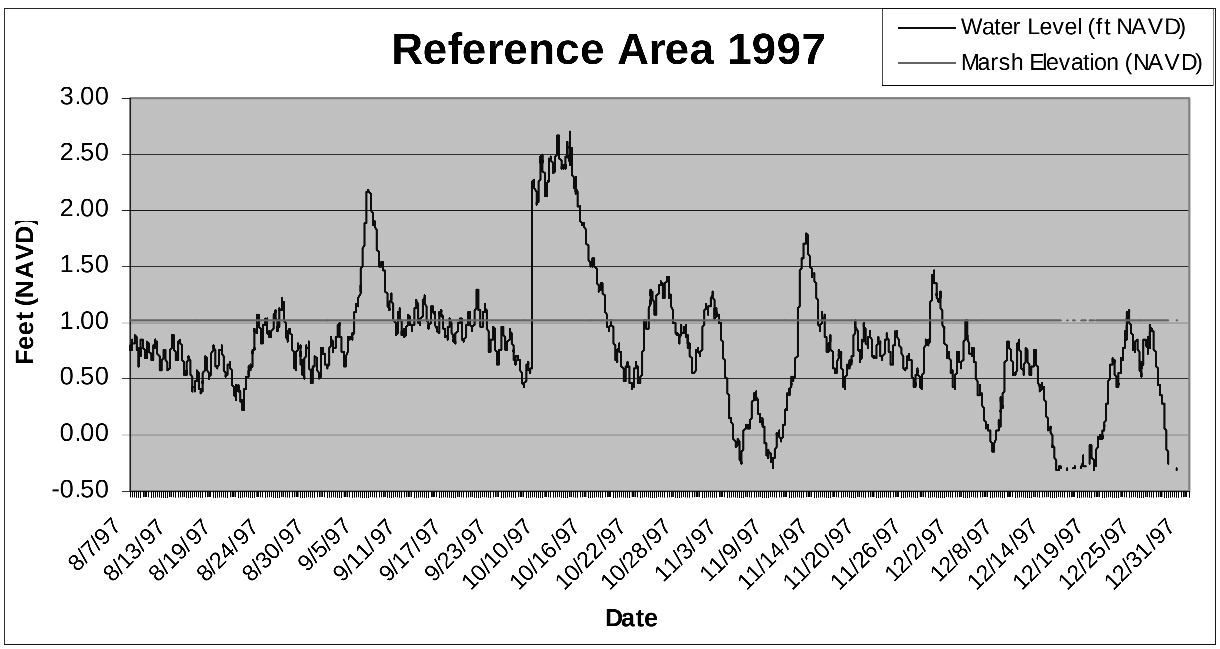
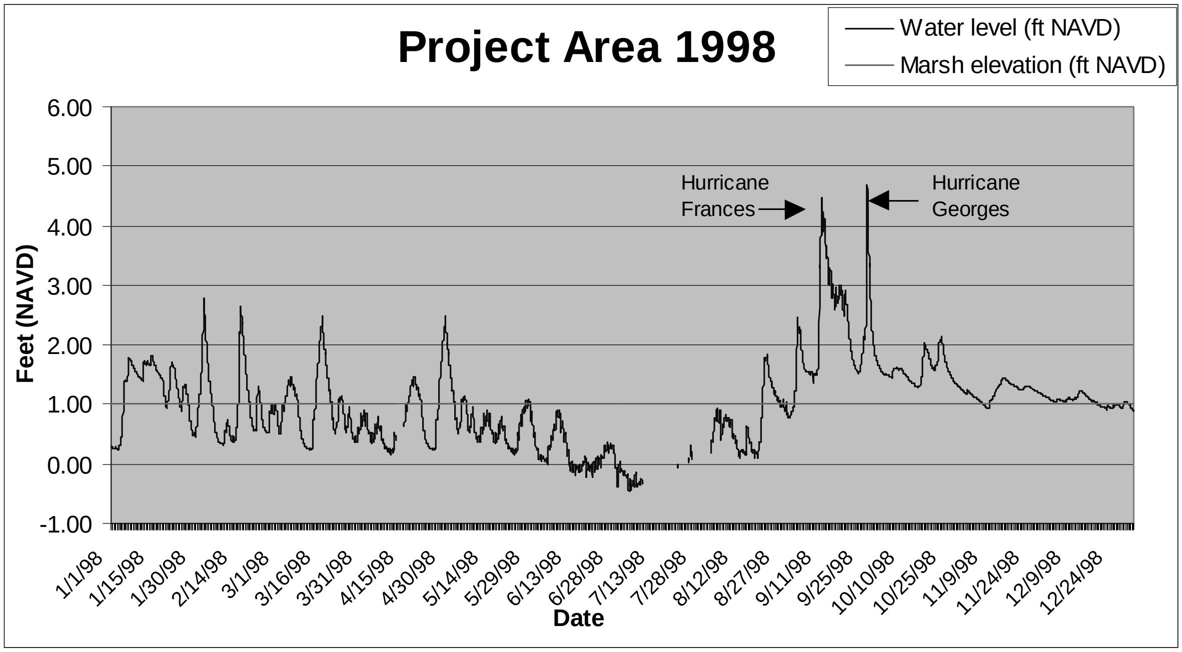


Figure 8. Hydrographs of the Bayou La Branche project and reference areas for 1997.



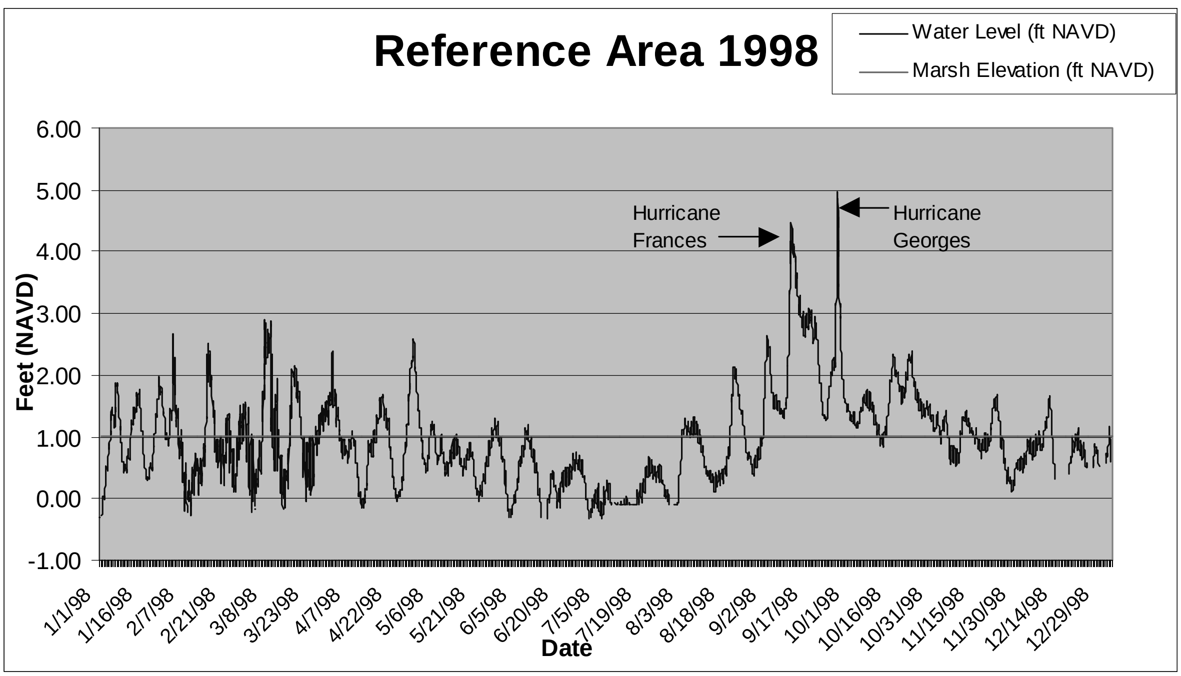


Figure 9. Hydrographs of the Bayou La Branche project and reference areas for 1998.

Table 3. Frequency and duration of flooding in the Bayou La Branche project and reference areas for 1997 and 1998 .

	Project		Reference	
	1997 (5 mo.)	1998 (1 year)	1997 (5 mo.)	1998 (1 year)
# Flood Events	6	21	26	51
Average Length (days)	7.6	8.13	1.16	2.9
Total Days Flooded	45.6	171.42	30.2	149.5
% Time Flooded	31.00%	46.96%	20.61%	40.36%

Table 4. Presence-absence and frequency (% of stations where present) of vegetation species from the Bayou LaBranche project area for 1996, 1997, and 1998.

Species	Common Name	1996	1997	1998
Amaranthus australis	Southern water-hemp	7.14%	.	4.55%
Aster tenuifolius	Saltmarsh aster	14.29%	1.00%	31.82%
Baccharis halimifolia	Groundselbush, Saltbush	38.10%	21.43%	13.64%
Bacopa monnieri	Carolina waterhyssop	30.95%	64.29%	54.55%
Cyperus ordoratus	Fragrant flatsedge	7.14%	.	.
Distichlis spicata	Saltgrass	.	.	4.55%
Echinochloa walteri	Walter's millet, Coast cockspur	9.52%	.	9.09%
Eleocharis parvula	Dwarf spikerush	42.86%	45.24%	.
Iva frutescens	Marsh elder	.	.	4.55%
Panicum virgatum	Switchgrass, Feather grass	7.14%	9.52%	9.09%
Paspalum repens	Water paspalum	2.38%	.	4.55%
Paspalum virgatum	Seashore paspalum, Jointgrass	2.38%	.	4.55%
Pluchea camphorata	Camphorweed	19.05%	.	63.64%
Polygonum pensylvanicum	Pink smartweed	7.14%	.	.
Ranunculus spp.	Buttercup	83.33%	.	.
Scirpus americanus	Common three-square bullrush	2.38%	9.52%	4.55%
Senecio glabellus	Butterweed	7.14%	.	.
Sesbania drumondi	Rattlebox	7.14%	11.90%	40.91%
Solidago sempervirens	Seaside goldenrod	83.33%	42.86%	4.55%
Spartina patens	Wiregrass, Marshay cordgrass	.	2.38%	4.55%
Spartina alterniflora	Smooth cordgrass, Oyster grass	.	2.38%	.

At the time of the preconstruction vegetation survey, the project area was mostly an open water pond and was dominated by *Myriophyllum spicatum* (Eurasian watermilfoil) and *Ceratophyllum demersum* (coontail grass). The only emergent vegetation that was present was *Eleocharis parvula* (dwarf spikerush), which occurred around the edges of the pond. During the initial postconstruction vegetation survey (table 4), conducted in May 1996, the project area was dominated by *Solidago sempervirens* (seaside goldenrod) and *Ranunculus* spp. (buttercup), which were both present at 83.33% of the survey stations. Other frequently encountered species included *E. parvula*, *Baccharis halimifolia* (groundsel bush) and *Bacopa monnieri* (coastal water-hyssop), which were found at 42.86%, 38.10%, and 30.95% of the stations, respectively. Twelve additional species were found, but at much lower frequencies (table 4). In addition to being the most frequently encountered species in this survey, *S. sempervirens* and *Ranunculus* spp. also had the highest mean percent cover values (figure 10).

The June 1997 survey revealed moderate changes in species composition with a decrease in species richness from 17 to nine species. The most appreciable changes in frequency involved *Ranunculus* spp. This plant was encountered most frequently in 1996, but was not observed at any station in 1997. Moreover, *B. halimifolia* was found at fewer stations and was observed to be either dead or dying in much of the project area. *S. sempervirens* decreased in frequency, whereas *B. monneri* doubled in frequency (table 4). In this survey, *E. parvula* and *B.halimifolia* had the highest percent cover within the survey plots, followed by *S. sempervirens* and *B. monneri* (figure 10).

Many of the species that were found in survey plots in 1996, but were absent from the plots in 1997, were again present in 1998 (table 4). Two of these plants, *Pluchea camphorata* (camphorweed) and *Aster tenifolius* (saltmarsh aster), occurred at a much higher percentage of stations in the 1998 survey. Of the species that were present in all three surveys, *B. halimifolia* and *S. sempervirens* decreased in frequency over time, *Sesbania drummondii* (rattlebox) increased in frequency, and the others varied from one year to the next. For the 1998 survey, *P. camphorata* and *B. monneri* were not only the most frequently encountered species, but they were also dominant in percent cover (figure 10).

The mean wetland status or prevalence index for the project area in 1996 was 1.75 ± 0.08 SE. In 1997 the index decreased to 1.42 ± 0.13 SE, but increased to 1.61 ± 0.10 SE in 1998. Analysis of variance indicated that no significant differences (df = 2, F = 2.21, p = 0.1137) were found in these index values among years. Although no differences were found among years, the index indicates that the project area was classified as wetland (a prevalence index less than three) for all three years. GIS land-water analysis of aerial photography revealed that the land to open water ratio in the project area increased between 1993 and 1997 but remained unchanged in the reference area during the same time period (figure 11). In the project area, proportions of land to water increased from 18.5% land and 81.5% water in 1993 to 81.7% land and 18.3% water in 1997. In the reference area, the land to open water ratio remained constant at 2.2% land and 97.8% water in both 1993 and 1997 (figure 11).

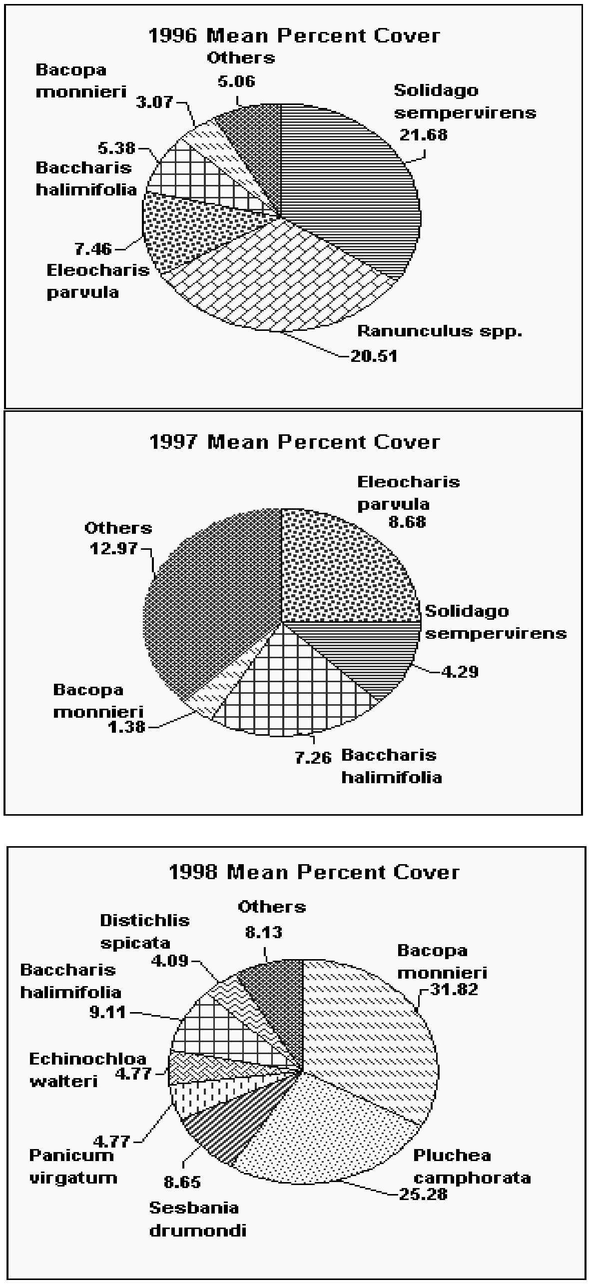


Figure 10. Mean percent cover of vegetation species from the Bayou LaBranche project area for 1996, 1997, and 1998

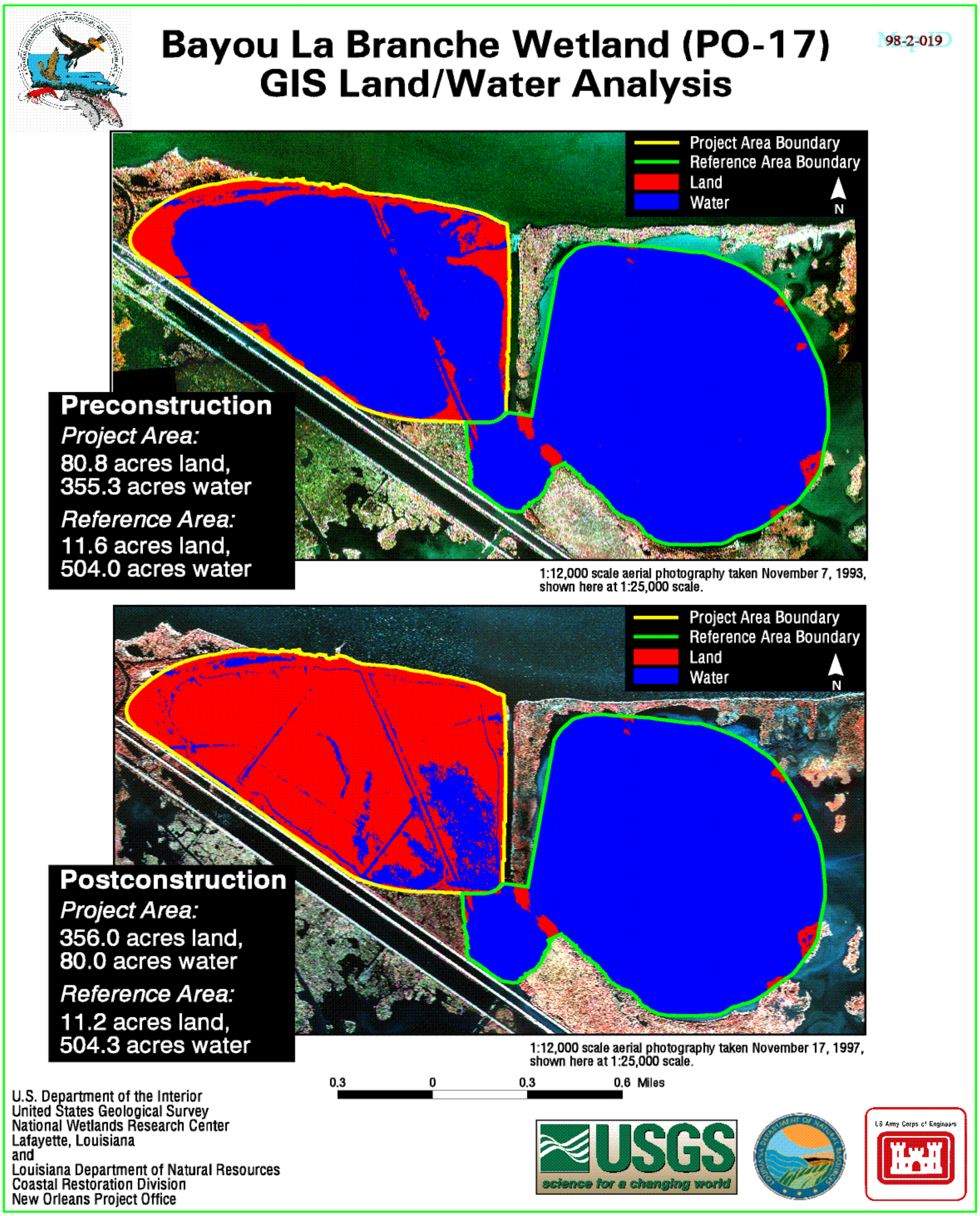


Figure 11. GIS land-water analysis of Bayou LaBranche before (top) and after (bottom) project construction.

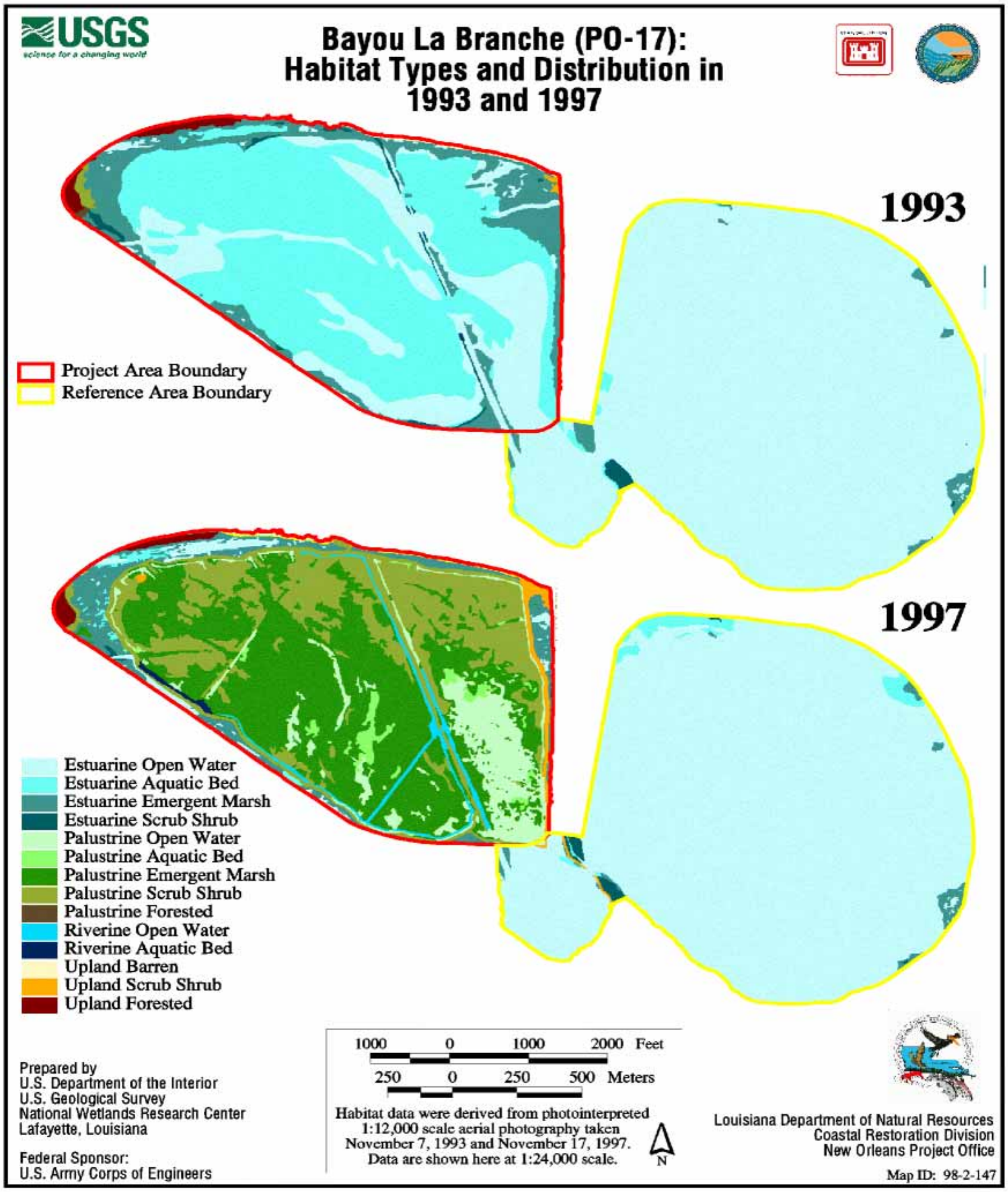


Figure 12. Habitat distribution in the Bayou La Branche project area for 1993 (preconstruction) and 1997 (postconstruction).

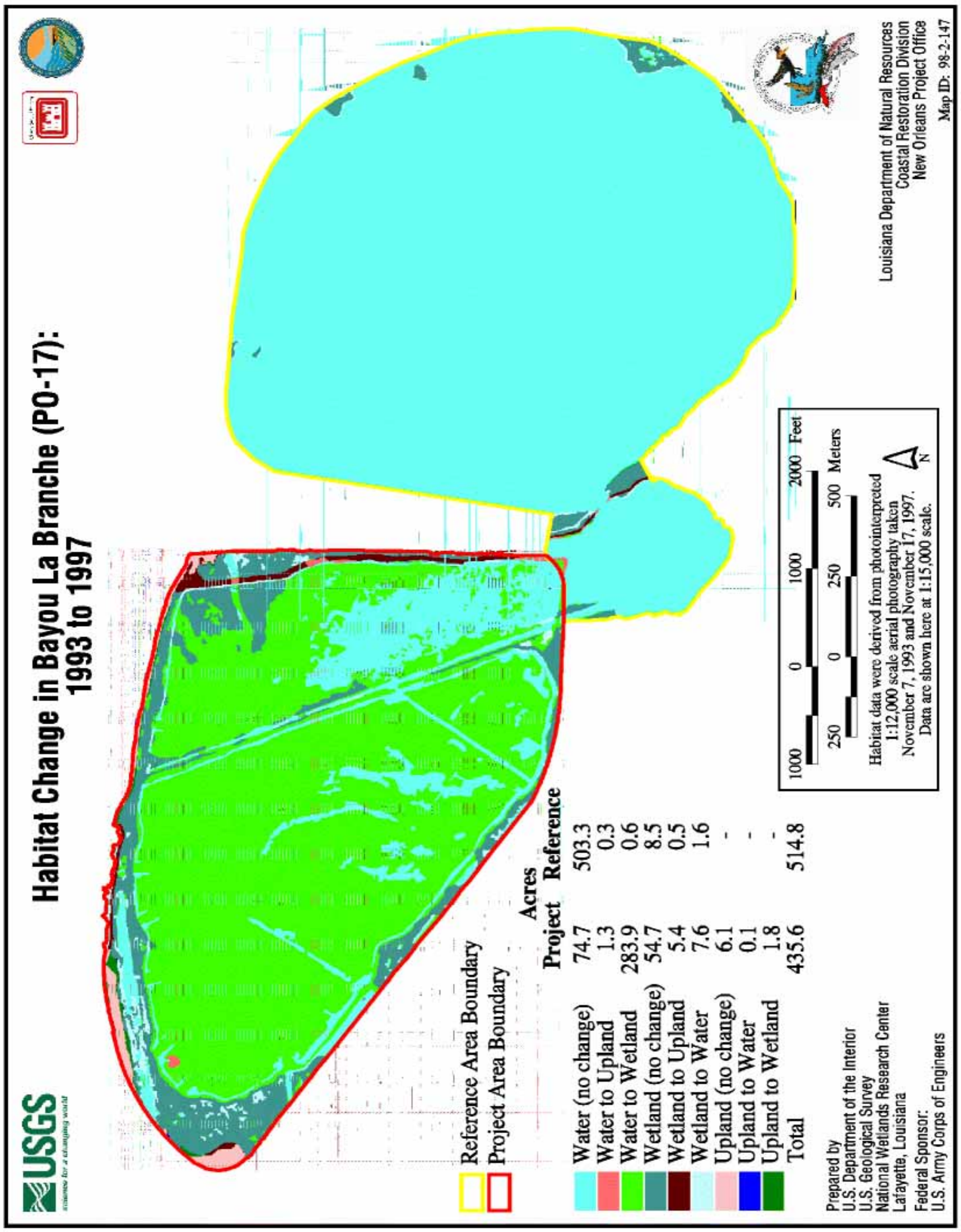


Figure 13. Habitat change in the Bayou La Branche project area between 1993 (preconstruction) and 1997 (postconstruction).

Table 5. Habitat distributions for the Bayou LaBranche project area for 1993 and 1997.

Habitat Mapping Results

Habitat Types: 1993

	Project Area (acres)	Project Area (hectares)	Percentage of Total Area	Reference Area (acres)	Reference Area (hectares)	Percentage of Total Area
Estuarine Open Water	108.0	43.7	24.8%	500.4	202.5	97.2%
Estuarine Aquatic Bed	248.9	100.7	57.2%	3.9	1.6	0.7%
Estuarine Emergent Marsh	63.7	25.8	14.6%	8.4	3.4	1.6%
Estuarine Scrub-shrub	4.8	1.9	1.1%	2.2	0.9	0.4%
Palustrine Open Water	0.0	0.0	0.0%	0.0	0.0	0.0%
Palustrine Aquatic Bed	0.0	0.0	0.0%	0.0	0.0	0.0%
Palustrine Emergent Marsh	0.0	0.0	0.0%	0.0	0.0	0.0%
Palustrine Scrub-shrub	1.7	0.7	0.4%	0.0	0.0	0.0%
Palustrine Forested	0.4	0.2	0.1%	0.0	0.0	0.0%
Riverine Open Water	0.0	0.0	0.0%	0.0	0.0	0.0%
Riverine Aquatic Bed	0.0	0.0	0.0%	0.0	0.0	0.0%
Upland Barren	2.1	0.8	0.5%	0.0	0.0	0.0%
Upland Scrub-shrub	0.6	0.2	0.1%	0.0	0.0	0.0%
Upland Forested	5.3	2.1	1.2%	0.0	0.0	0.0%
Total	435.5	176.1	100.0%	514.9	208.4	100.0%

Habitat Types: 1997

	Project Area (acres)	Project Area (hectares)	Percentage of Total Area	Reference Area (acres)	Reference Area (hectares)	Percentage of Total Area
Estuarine Open Water	10.8	4.4	2.5%	495.0	200.3	96.1%
Estuarine Aquatic Bed	3.2	1.3	0.7%	9.9	4.0	1.9%
Estuarine Emergent Marsh	34.2	13.8	7.8%	6.1	2.5	1.2%
Estuarine Scrub-shrub	0.6	0.2	0.1%	2.8	1.1	0.5%
Palustrine Open Water	48.3	19.6	11.1%	0.2	0.1	0.0%
Palustrine Aquatic Bed	8.4	3.4	1.9%	0.0	0.0	0.0%
Palustrine Emergent Marsh	187.8	76.0	43.1%	0.0	0.0	0.0%
Palustrine Scrub-shrub	117.9	47.7	27.1%	0.0	0.0	0.0%
Palustrine Forested	0.0	0.0	0.0%	0.0	0.0	0.0%
Riverine Open Water	10.2	4.1	2.3%	0.0	0.0	0.0%
Riverine Aquatic Bed	1.5	0.6	0.3%	0.0	0.0	0.0%
Upland Barren	2.3	0.9	0.5%	0.0	0.0	0.0%
Upland Scrub-shrub	5.9	2.4	1.4%	0.9	0.4	0.2%
Upland Forested	4.4	1.8	1.0%	0.0	0.0	0.0%
Total	435.5	176.2	100.0%	514.9	208.4	100.0%

Table 6. Habitat change in the Bayou LaBranche project area between 1993 (preconstruction) and 1997 (postconstruction).

Upland/Wetland Change: 1993 to 1997						
	Project Area		**Percentage of**	**Reference Area**		**Percentage of**
	(acres)	**(hectares)**	**Total Area**	**(acres)**	**(hectares)**	**Total Area**
Upland	6.1	2.5	1.4%	0.0	0.0	0.0%
Upland to Water	0.1	0.0	0.0%	0.0	0.0	0.0%
Upland to Wetland	1.8	0.7	0.4%	0.0	0.0	0.0%
Water	74.7	30.2	17.2%	503.3	203.7	97.8%
Water to Upland	1.3	0.5	0.3%	0.3	0.1	0.1%
Water to Wetland	283.9	114.9	65.2%	0.6	0.2	0.1%
Wetland	54.7	22.1	12.6%	8.5	3.4	1.6%
Wetland to Upland	5.4	2.2	1.2%	0.5	0.2	0.1%
Wetland to Water	7.6	3.1	1.7%	1.6	0.7	0.3%
Total	435.6	176.2	100.0%	514.8	208.3	100.0%

The most notable habitat changes in the project area were the increase in palustrine emergent marsh and scrub-shrub from 1.7 ac in 1993 to 305.6 ac (123.7 ha) in 1997 and the corresponding decrease in estuarine open water and aquatic beds from 356.9 ac (144.4 ha) in 1993 to 14.0 ac (5.7 ha) in 1997 (figures 12 & 13; tables 5 & 6). Upland habitats in the project area increased from 8.0 ac (3.2 ha) in 1993 to 12.6 ac (5.1 ha) in 1997. In the reference area, only small changes in habitat distribution were evident. Total open water increased from 504.3 ac (204.1 ha) in 1993 to 505.1 ac (204.4 ha) in 1997. Also, estuarine emergent wetland decreased from 8.4 ac (3.4 ha) in 1993 to 6.1 ac (2.5 ha) in 1997, whereas upland habitats increased from none in 1993 to 0.9 ac (0.4 ha) in 1997.

Discussion

One of the most important factors to consider when creating a wetland is elevation of the deposited sediments in relation to tidal regime (Broome 1988). Elevation affects frequency and duration of flooding, which determines the zonation of vegetation. The target range of sediment elevation for this project, after five years of consolidation, was estimated at 0.65 to 1.62 ft (0.20 - 0.49 m) NAVD (personal communication, Cottone 1996). As of January 1999, elevation at all staff gauge stations was within this target range. However, some elevations were in the high end of this range, and it is apparent from the vegetation surveys and habitat analyses that the upper limit of the target range may not be suitable for the establishment of emergent wetland vegetation. For instance, the project area contained an abundance of scrub-shrub vegetation in the northern areas that had elevations in the upper bounds of the target range.

The north-south elevation gradient in the project area may be explained by the manner in which the area was filled with dredged sediments. During construction, discharge pipes from the dredge were placed in several locations along the northern (lake) shore of the project area and the dredged sediments were allowed to flow south into the area. During this process, sediment would have been stacked more in the northern areas around each discharge location, and areas furthest from the discharge pipes would have received less sediment. Another aspect of construction was that no direct sediment discharge was allowed within 1,000 ft (305 m) of the Interstate-10 bridge because of concerns that the deposited dredged sediments would displace the underlying peat foundation in the project area, possibly affecting the interstate's infrastructure (Wilde 1997). Thus, the southern section of the project area, much of which borders the interstate, received less sediment than the northern section during filling.

Although the greatest amount of sediment consolidation seems to have occurred during the first two years after project construction, the data indicate that sediment elevation is still decreasing in the project area. For example, a perceptible decrease in elevation was noted after an extended dry period (May - August) in 1998, during which water level remained well below marsh elevation. During this period, large cracks in the sediment were observed throughout the project area (figure 14), and most of the deep channels in the area were void of standing water. Continued settlement of the dredged sediment and subsidence in the area should result in lower sediment elevations, which will further benefit the establishment of wetland vegetation.

Figure 14. Dry conditions in the Bayou La Branche project area during an extended dry period (May-August) during 1998.

Soils of newly created wetlands are composed largely of mineral material and have low organic matter content (Odum 1988). For example, percent organic matter of a created marsh in Galveston, Texas was less than 2%, which was 2 to 4 times lower than organic matter concentration in surrounding natural marshes (Lindau and Hossner 1981). It was not surprising, therefore, to see low values for percent organic matter in the Bayou La Branche project area relative to the surrounding wetlands, which have been shown to contain soils with greater than 50% organic matter (Palmisano and Chabreck 1972). It was surprising, however, to see a decrease in percent organic matter over time in the project area. In the Galveston study mentioned above, organic matter content steadily increased from zero to approximately 2% over two years. The Bayou La Branche project is still young, and as this marsh matures, there should be a gradual build up of organic matter through the input of vegetative materials. The decrease in bulk density in this project area was also unexpected; with further compaction of the sediments and a decrease in percent organic matter, bulk density would be expected to have increased. The changes in percent moisture may be explained by water level in the marsh at the time that the soil samples were taken. Much of the project area was inundated when soil samples were taken in 1997, whereas the area was dry for the 1996 and 1998 sample dates. The changes in these soil characteristics are important to the development of the marsh in the project area, as soils can influence the distribution of vegetation in coastal areas (Palmisano and Chabreck 1972).

Differences in the frequency and duration of flooding between the project and reference areas were likely due to the semi-impoundment of the project area. During construction a small levee was built around the project area to contain the dredged sediments, and box culverts were installed to allow water to drain from the project area as the dredged sediments de-watered. Over the project's life, the containment levee has breeched three times (once by USACE, twice naturally), but these breeches were closed with weirs or sandbags. In addition, the drainage culverts in the eastern levee were blocked with lumber (2x4's) during the fall and winter months. All of these structures, and modifications to them, affect water flow into and out of the project area. Members of a local duck hunting club were responsible for closing two of the breeches and for blocking the culverts (personal communication, Ensminger 1996). It is presumed that they made these modifications to hold more water in the project area in order to create a more desirable habitat for wintering waterfowl.

The variability of water levels in the project area is important, because water-level variability can affect the establishment of vegetation in a marsh (Chabreck and Hoffpauir 1965). Weirs prevent impounded areas from dewatering during low tides, and stabilize water levels by reducing tidal exchange (Cowan et al. 1988). In turn, stabilization of water levels reduces environmental stress on certain species of vegetation, which can increase species diversity (Larrick and Chabreck 1976), and may increase the production of certain aquatic vegetation species (Davidson and Chabreck 1983). Conversely, other species of aquatic vegetation may become stressed or even excluded if high water levels are maintained (Conner et al. 1981).

Of the 21 species encountered in the vegetation surveys, all but *Ranunculus* spp. and *B. halimifolia* are good vegetative indicators of wetlands (Reed 1988; Tiner 1993). Both are normally considered upland or scrub-shrub species, but are occasionally found in marshes subject to frequent drying (Chabreck and Condrey 1979; Cowardin et al. 1992). Thus, it was not surprising to see that *Ranunculus* spp. and *B. halimifolia* were dominant at the vegetation stations in northern section of the project area where higher sediment elevations existed. Although *Ranunculus* spp. was not present in the vegetation plots during the 1997 or 1998 surveys, *B. halimifolia* was still present in the plots during the other surveys, but it was found at fewer stations over time.

Differences in the vegetation community among years were indicative of the changes in sediment elevation and water levels in the project area. With the wetter conditions caused by the decrease in sediment elevation and the longer duration of flooding in the area, obligate wetland species (*Spartina patens*, *B. monneri*, *Scirpus americanus*) generally increased in frequency, whereas the facultative species (*Ranunculus* spp*., B. halimifolia, S. sempervirens*) generally decreased in frequency (figure 15). These results agree with Dell (1990), who found that higher water levels were the major force driving shifts in the vegetative community in a created marsh at Savage Island in the Delta National Wildlife Refuge, Louisiana.

The establishment of wetland vegetation in the project area is meaningful to the success of this project. Therefore, it is important to note that although the GIS land/water analysis indicated that approximately 82% of the project area was land in 1997, only 51% of the project area was emergent marsh. The remaining 31% of the area was a combination of scrub-shrub habitat, which mostly consisted of *B. halimifolia,* and upland habitats. The majority of the scrub-shrub habitat was confined to the northern section of the project area and along the canal banks. If elevation continues to decrease in these areas, the habitat should change from scrub-shrub to the desired emergent marsh habitat.

The GIS habitat change analysis identified areas of open water or aquatic vegetation within the project area as "water (no change)," indicating that water was present in those areas on both the 1993 photography and the 1997 photography. However, this part of the analysis was misleading, because it doesn’t consider data from the 1994 aerial photography, which showed that, immediately postconstruction, these areas were actually unvegetated mudflats. The presence of these mudflats indicated that project construction filled the impoundment with dredged sediments, but these areas subsequently subsided, forming the ponds which were classified as "water (no change)" in 1997.

It was not surprising that this land loss mostly occurred in the southeastern section of the project area. As mentioned earlier, the southern reaches of the project area may have received less sediment than areas closer to the lake. Thus, the southern area started out with lower elevations, and has subsided relatively quickly to an elevation that cannot support wetland vegetation. Another possible reason that the southeastern section of the project area has lost more land may be that most of the water exchange for the project area occurs in the southeastern corner of the area. Tidal scour during normal high tides, and especially storm events, may be responsible for the localized land loss.

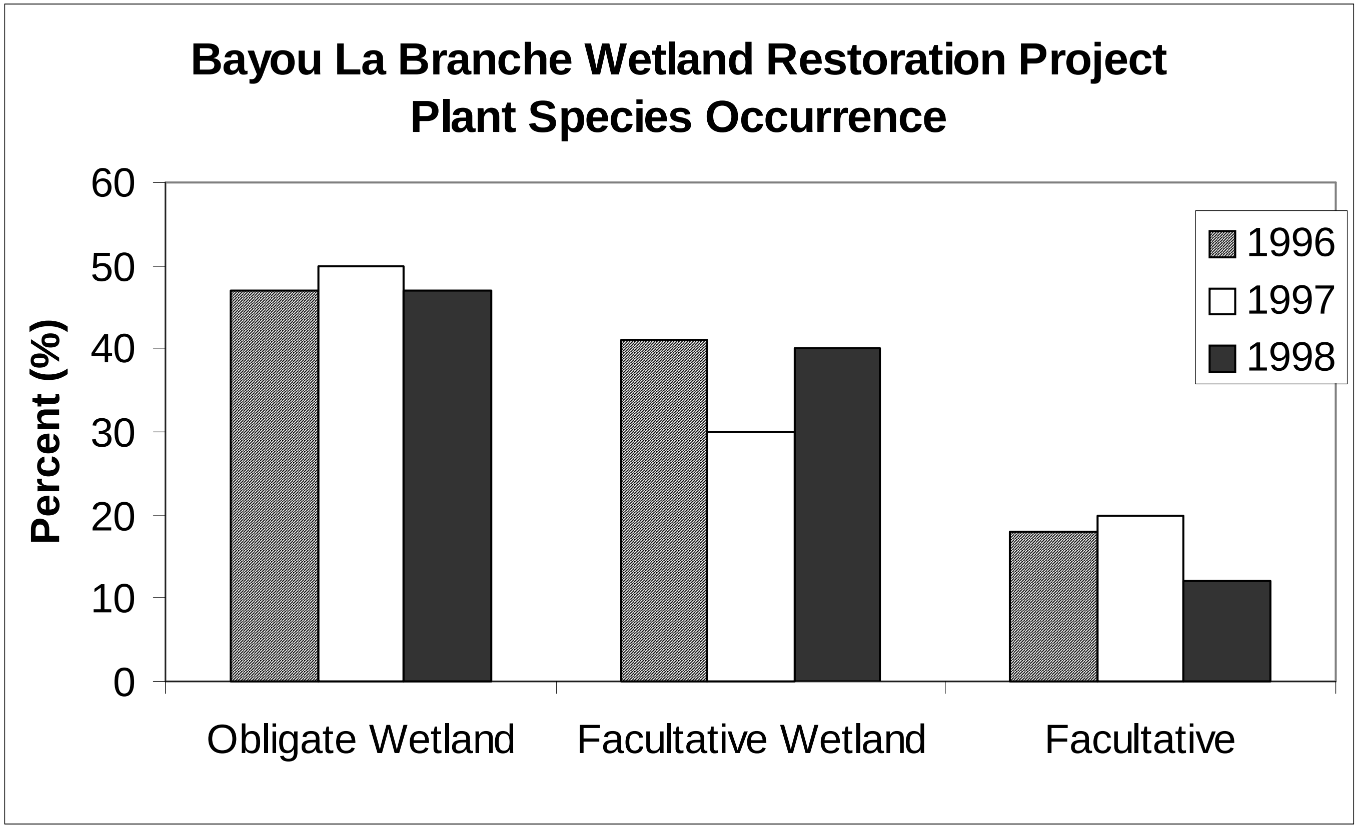


Figure 15. Occurrence (% of stations) of vegetation classes in the Bayou La Branche project area for 1996, 1997, and 1998.

Conclusions

For the Bayou La Branche Wetland Restoration Project, the goal of creating a shallow water habitat conducive to the natural establishment of wetland vegetation has not been fully met. Although most of the project area is classified as emergent wetlands, approximately one third of the area is classified scrub-shrub and upland habitat. Moreover, the goal of creating a ratio of 70% marsh to 30% open water in the project area has not been attained. As sediment elevation continues to decrease in the project area, the remaining scrub-shrub vegetation species (e.g., B. halimifolia) are expected to be supplanted by more wetland-specific species, and the desired marsh to water ratio should be achieved.

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