Coast 2050 Region 4

CAMERON-CREOLE WATERSHED BORROW CANAL PLUG PROJECT (C/S-17)
C/S-17-MSPR-0298-1
PROGRESS REPORT No. 1
for the period
February 1, 1997 to February 1, 1998

Project Status

This is the first in a series of progress reports describing the Department of Natural Resources Coastal Restoration Division monitoring for the Cameron-Creole Watershed Borrow Canal Plug project. This report, and all subsequent Progress Reports for this project, will identify the monitoring data being collected and will briefly discuss the preliminary results from project monitoring files.

Project Description

The Cameron-Creole Watershed consists of 64,000 acres (25,900 ha) of brackish, intermediate, and fresh marsh located in the Calcasieu/Sabine Basin in Cameron Parish, Louisiana (figure 1). This area is part of the Sabine National Wildlife Refuge. Since the original 30 ft (9.15 m) deep dredging of the Calcasieu Ship Channel in the 1940's, salt water intrusion from the Gulf of Mexico into the interior marshes via Calcasieu Lake has caused high rates of marsh loss. As a result, approximately 63,000 acres (25,496 ha) of brackish, intermediate, and fresh marsh on the east side of Calcasieu Lake were lost between 1950 and 1970, and replaced by brackish and saline marsh (Delany 1991). In 1989, a levee and five (5) water control structures (three variable-crest and two fixed crest) with vertical slots were constructed by the United States Fish and Wildlife Service (USFWS) and the Soil Conservation Service (SCS) along the east shore of Calcasieu Lake to reduce the movement of salt water into the watershed. A borrow canal was also constructed along the wetland side of the levee. Management of the five water control structures is controlled by the USFWS and is designed to retard the introduction of saltwater into the Cameron-Creole Watershed.

The five water control structures along Calcasieu Lake are scheduled for operation in two phases. Phase I emphasizes curtailing marsh erosion and reclaiming emergent marsh by implementing a partial drawdown of 0.5 ft (0.15 m) below marsh elevation from February 15-July 15. At least one of the vertical slots in each structure remains open during this time. Phase II, or the maintenance phase, primarily emphasizes curtailing marsh erosion with secondary emphasis on improving fisheries habitat, maintaining and improving wildlife habitat, and increasing species diversity in emergent marsh plants. The crests of all structures are set at 0.5 ft (0.15 m) below marsh level with all slots and the boat bay at Grand Bayou open. Temporary closures of the boat bay and slots are dependent on maintaining salinities below the 5 ppt limit at the east end of East Prong.

Changes in the water movement patterns on the Cameron-Creole Watershed since the water control structures were installed and the management plan was implemented in 1989 have not occurred as anticipated. Saline water continues to move through the structures, and through the borrow canal, resulting in excessive pooling of saline water in the southern end of the watershed (Delany 1991).

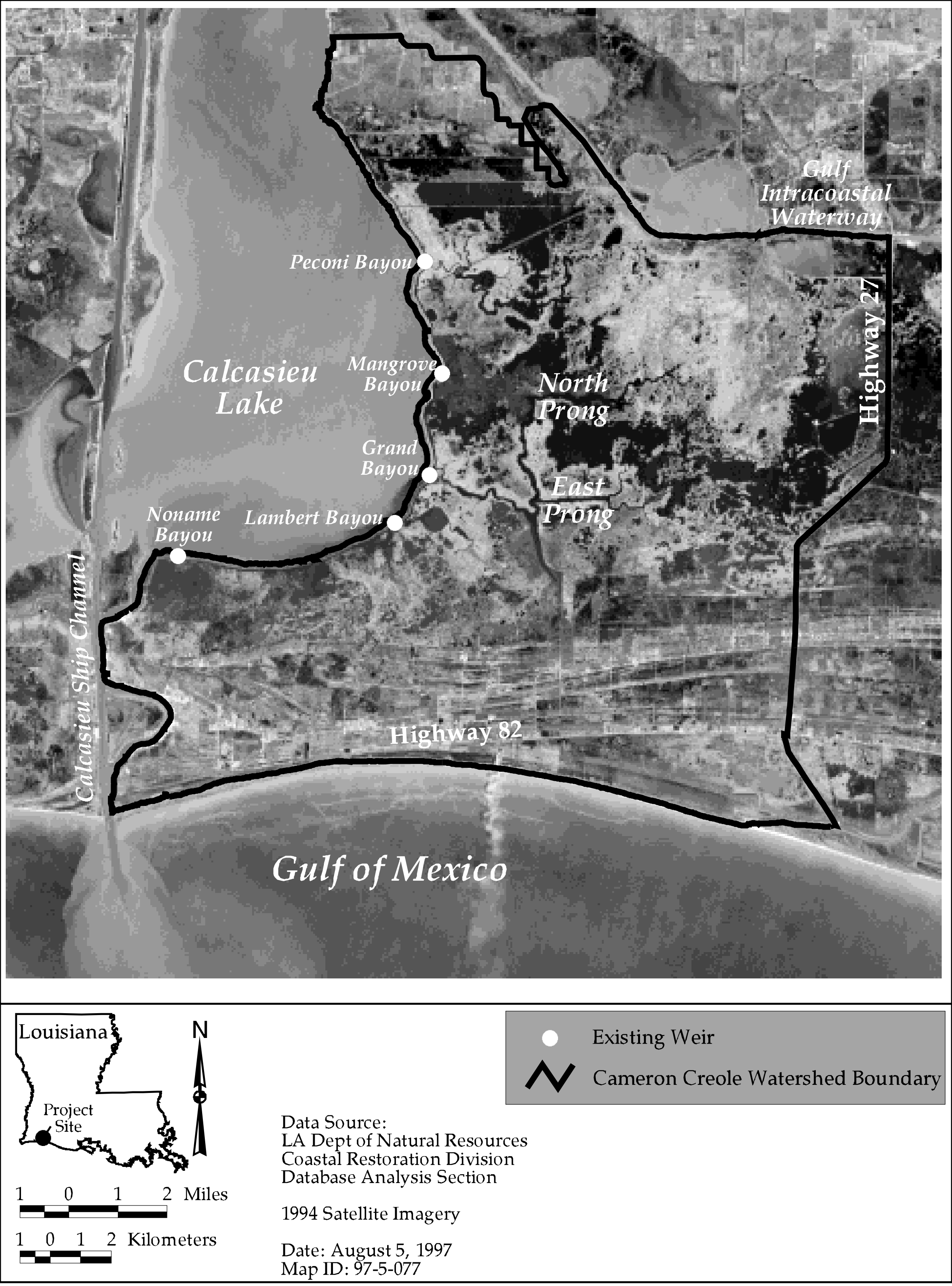

Figure 1. Cameron Creole Watershed boundary and existing water control structures.

In the northern project area, water moves rapidly in a counter-clockwise circulation pattern through the Peconi (Bois Connine) Bayou system.

The Cameron-Creole Watershed Borrow Canal Plug project (C/S-17) will install two sheetmetal plugs in the lakeshore borrow canal, one south of Grand Bayou and one south of Mangrove Bayou (figure 2) to isolate management areas and improve hydrologic control. The two C/S-17 plugs require no operations, and will remain at their as-built elevations. The plug south of Mangrove Bayou, set at 1.5 ft (0.46 m) National Geodetic Vertical Datum (NGVD), will affect 2,500 acres (1,012 ha) in the northern project area. The vegetated marsh in this area is composed of *Spartina patens* (marshhay cordgrass), *Scirpus americanus* (Olney's three-cornered grass), *Paspalum vaginatum* (joint grass), *Typha* spp. (cattail), and *Phragmites australis* (roseau cane). Soils over the majority of the northern project area are comprised of Bancker and Clovelly soil types, except in the northern project area, where a small percentage of Gentilly Muck is present (USDA 1995).

The plug south of Mangrove Bayou will also affect 1,750 acres (708 ha) of broken marsh and shallow open water ponds from 0.5 ft to 2 ft (0.15-0.61 m) deep vegetated by *Ruppia maritima* (widgeon grass), *Myriophyllum spicatum* (Eurasian watermilfoil), and *Ceratophyllum demersum* (coontail). The broken emergent marsh, composed of *S. patens*, is subject to shoreline erosion caused by wind driven wave action across long fetches of open water.

The plug south of Grand Bayou, set at 1.0 ft (0.3 m) NGVD, will allow separate operation of the Grand Bayou and Lambert Bayou structures, affecting 8,000 acres (3,238 ha) of brackish marsh in the southern project area. The vegetated marsh in this area is composed of *S. patens*, *Distichlis spicata* (saltgrass), and *Spartina alterniflora* (smooth cordgrass).

Construction was completed on February 1, 1997. The project objectives are to enhance and improve marsh condition in the northern, southern, and eastern project areas, and to improve present structural management capabilities. The specific project goals are to reduce duration of flooding in the southern project area, reduce water flow in the borrow canal in the northern project area, increase coverage of emergent marsh plants in both the northern and southern project areas, and to increase the relative frequency of occurrence of SAV in the eastern project area.

Methods

Habitat mapping: Near-vertical color-infrared aerial photography (1:24,000 scale) was taken in November 1993 (preconstruction), and will be taken once post-construction in 2010. The photography will be photointerpreted, scanned, mosaicked, georectified, and analyzed by National Wetlands Research Center (NWRC) personnel according to the standard operating procedures described in Steyer et al. (1995). The photography will be used to determine changes in land-to-water ratios and acreages, marsh loss rates, and shoreline movement within the project and reference areas over the project life. A digital file with 300 pixels-per-inch resolution was created from photography for geographic information system (GIS) analysis. Using ERDAS Imagine, an image

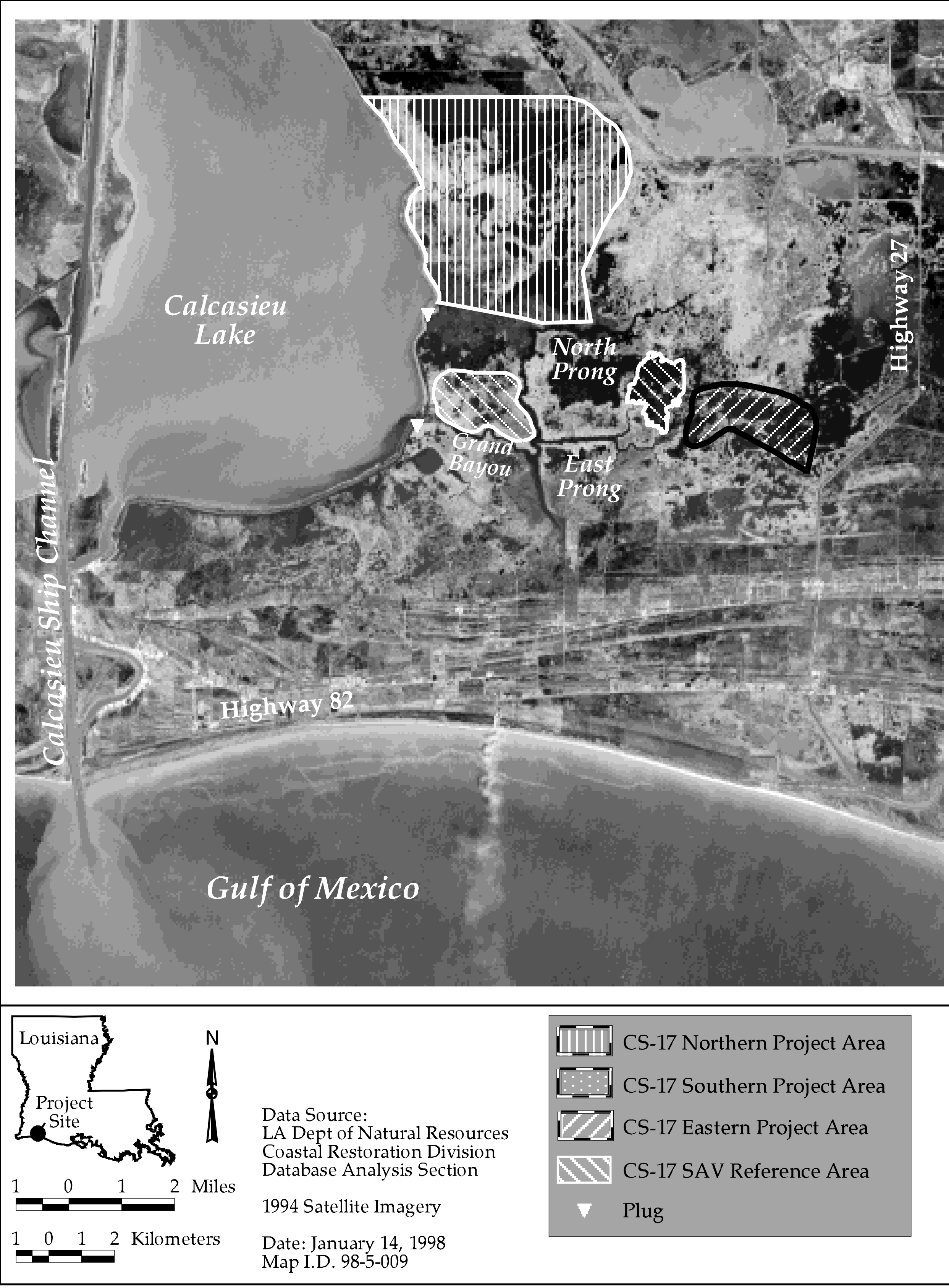

Figure 2. Cameron Creole Watershed borrow canal plugs, project areas, and reference areas.

processing and geographic information system software, the photography is mosaicked and used for basemap production. Global positioning system (GPS) points will be collected in the field to georeference the basemap to a Universal Transverse Mercator (UTM) coordinate system.

Water Quality: Water quality data will be collected using four (4) YSI 6000 continuous recorders at stations 1, 2, 11, and 12 (figure 3). Water level, salinity, temperature, and specific conductance will be recorded hourly at these stations. All continuous recorder data will be shifted to compensate for biofouling. Discrete bi-weekly samples will be taken by refuge personnel at 16 existing USFWS monitoring stations, 8 located inside the project area, and 8 located outside the project area. Six staff gages surveyed to NGVD (three located within the project area and three located outside the project area) will be monitored bi-weekly by USFWS personnel (figure 3). Four of the staff gages are located at continuous recorder stations. Elevations of continuous recorder staff gages have been surveyed relative to the marsh surface. Water level data will be used to document frequency and duration of marsh inundation. Monthly means during the growing and non-growing season will be calculated for discrete and continuous water quality data. Statistical comparisons among areas will be performed.

Water flow: Water flow will be measured at four sites in the northern project area (figure 3) denoted by the letters A-D. Channel A is a shallow, manmade pipeline canal approximately 3 ft deep x 80 ft wide x 2.5 mi long (0.9 m x 24.4 m x 4 km) running northeast to southwest. Channel B is a deep borrow canal approximately 9.1 ft deep x 165 ft wide x 10 mi long (2.8 m x 50.3 m x 16 km) running north/south at the sampling point. Channel B was constructed when the levees were built along Calcasieu Lake in 1990. Channel C is a natural trenasse running north/south approximately 5.6 ft deep x 73 ft wide x 600 ft long (1.7 m x 22.3 m x 183 m) connecting North Prong to upper marshes. Channel D is a short natural cut 4.3 ft deep x 42 ft wide x 300 ft long (1.3 m x 12.8 m x 91.5 m) running north/south connecting two large bodies of shallow open water.

Cross channel transect sampling will be conducted using Marsh-McBirney Model 2000 portable hand-held flow meters to characterize the vertical and horizontal flow structure (Boon 1978; Kjerfve et al. 1981). According to the manufacturer's specifications, the sensor has an accuracy of ± 2% with a threshold of 19.99 ft/sec (6.1 m/s). The instantaneous volume flux through the channel will be calculated by multiplying the velocity times the channel cross-sectional area. The cross channel transects will be profiled every 2 hours from 7:30 am to 4:30 pm for a 72 hour period. Weather during the sampling period will be characterized from data provided by the Louisiana Office of State Climatology (LOSC). Monitoring will be performed in 1996 (preconstruction) and once post-construction under similar conditions (i.e. drawdown). Means will be calculated for each station.

Emergent vegetation: Species composition, species cover, percent cover, and height of dominant plants in vegetation plots 2.0 m^2 (1.4 m x 1.4 m) will be determined at sixty sampling points (25 in the northern portion, 25 in the southern portion, and 10 in the reference area [figure 4]), using the Braun-Blanquet method outlined in Steyer et al. (1995). Species growing within approximately 30 m of the sampling plots will be recorded and ranked to determine adequacy of the plot size. Surface and pore water salinity will be recorded. Vegetation will be monitored in 1996 (preconstruction), nd in 1997, 2000, 2002, 2005, 2010, and 2015 post-construction. Statistical comparisons of height

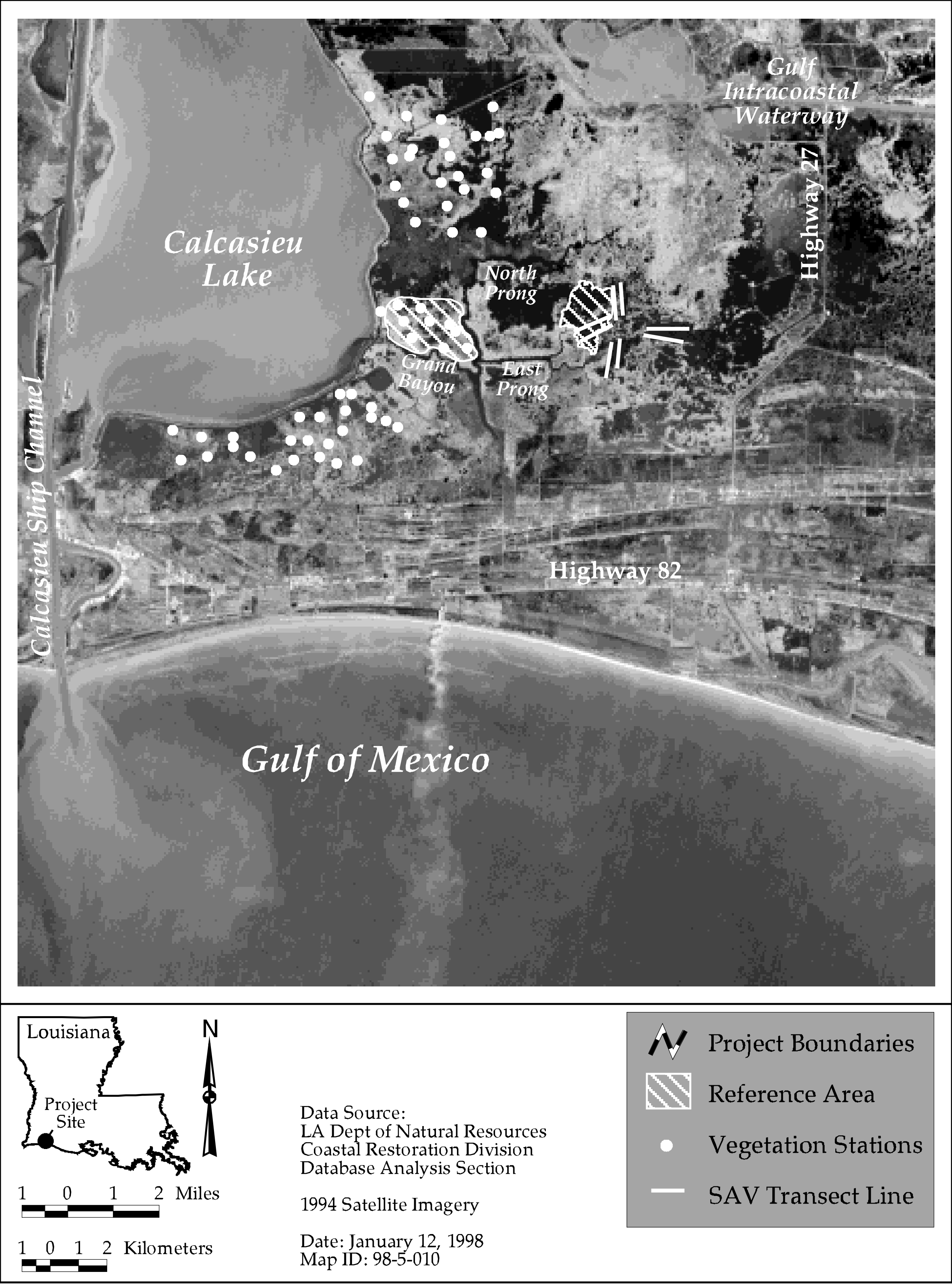

Figure 3. Cameron Creole Watershed (C/S-17) vegetative stations and transects for submersed aquatic vegetation.

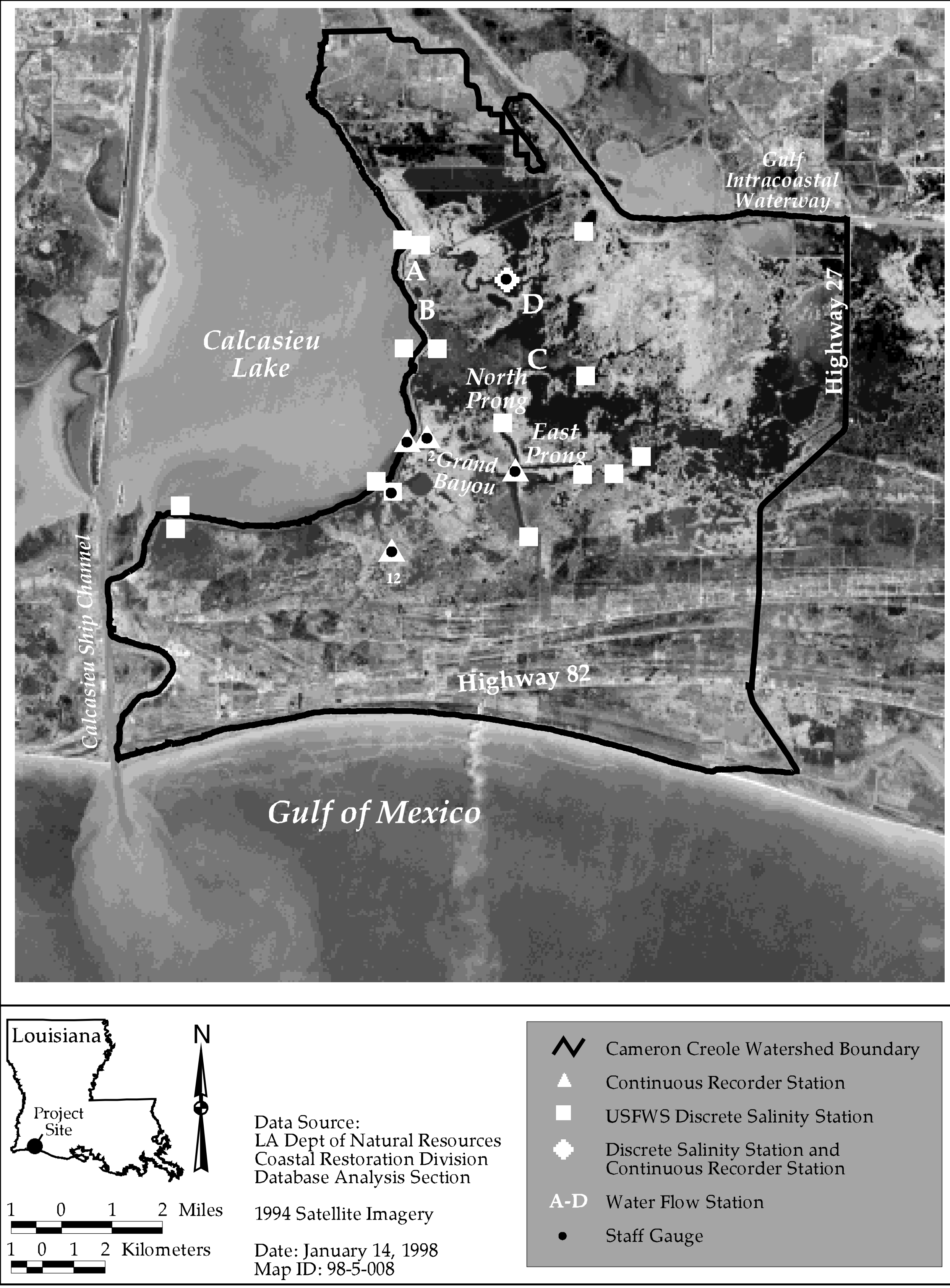

Figure 4. Cameron Creole Watershed salinity and water flow stations.

and percent cover of important species, species richness, and salinity among areas will be performed. Species richness is defined as the number of species occurring in one sampling plot at a given time.

Soils: Soil will be sampled in the plots used for vegetation monitoring and analyzed for field moist bulk density, percent organic matter, and soil salinity. Cores will be taken with a Swensen corer, refrigerated and analyzed by personnel at the Louisiana State University (LSU) Agronomy Department where samples are first air dried and then oven dried at approximately 100º C for 24-48 hours. Soil condition will be monitored in 1996 (preconstruction) coinciding with vegetative monitoring. Field moist bulk density is calculated as (weight of oven dry- weight of empty tube) divided by volume of field moist.

Submersed aquatic vegetation: Species composition and relative frequency of occurrence will be determined for SAV in two ponds in the eastern project area and two ponds in a reference area (figure 4). Presence or absence of SAV will be recorded at 25 random points along two transects in each pond, using the rake method (Chabreck and Hoffpauir 1962, Nyman and Chabreck 1996). SAV will be monitored in 1996 (preconstruction) and 1997, 2000, 2002, 2005, 2010, and 2015 (post-construction) coinciding with vegetation sampling. Project and reference area means will be calculated. Statistical comparisons of relative frequency of occurrence of each species, species richness, depth and salinity among areas over time will be performed. Species richness is defined as the number of species occurring in one sampling plot at a given time.

Results/Discussion

Structure Operations: The most severe drought in 20 years (LOSC 1996) occurred in 1996, optimizing conditions for drawdown (table 1). All five water control structure were closed on February 22, 1996. The flapgates on the Grand Bayou structure remained open to allow the marsh to drain until June 26, 1996, when drawdown was achieved, and drought conditions persisted (table 2). Fisheries slots on all structures were closed April 12, 1996, due to high salinities, and remained closed until August 17, 1996, when salinities decreased enough to allow one slot on each structure to be opened. The boat bay at Grand Bayou was opened August 30, 1996, while the other structures were opened gradually from September through October to conclude the drawdown. Structure closures were extended past the scheduled July 15, 1996 opening date due to prolonged high salinities in Calcasieu Lake coupled with extremely low water levels in the marsh.

Habitat Mapping: Color-infrared aerial photography for the preconstruction phase of the project was flown on November 1, 1993. The photography was checked for flight accuracy, color correctness, and clarity. The duplicate photography was prepared for photointerpretation and GIS analysis and the original film archived. Photointerpretation was completed for project and reference areas and will be checked for accuracy. The linework will be transferred onto basemaps for digitizing. Wetland gain/loss rates within the project area will be determined once the first set of postconstruction photography is obtained.

Table 1. Operational changes for each of the five lakeshore structures at the Cameron Creole Watershed.

			Structure		
Date	**Peconi**	**Mangrove**	**Grand Bayou**	**Lambert**	**No Name**
8-3-1995	open 4 crest gates	open 4 crest gates	open boat bay	open 4 crest gates	open 4 crest gates
8-10-95		close 4 crest gates			close 4 crest gates
8-18-95			close boat bay		
8-25-95			open boat bay		
9-19-95					open 4 crest gates
10-27-95	open 1 crest gate	open 1 crest gate	close flaps	open 1 crest gate	open 1 crest gate
11-1-95	close 1 crest gate	close 1 crest gate	close boat bay open flaps	close 1 crest gate	close 1 crest gate
11-3-95	open 1 crest gate		open boat bay	open 1 crest gate	
11-7-95	close 1 crest gate		close boat bay	close 1 crest gate	
12-4-95			open boat bay close flaps		
12-14-95			close boat bay		
12-19-95			open flaps		
12-21-95	open 2 crest gates			open 3 crest gates	
12-30-95	close 2 crest gates			close 3 crest gates	
1-9-96			close flaps		
2-14-96	open 1 crest gate open 3 slots	open 3 slots	open boat bay 4 flaps raised open 3 slots	open 1 crest gate open 3 slots	open 3 slots
2-22-96	close crest gates			close crest gates	
3-1-96			close boat bay		

Table 1 (continued). Operational changes for each of the five lakeshore structures at the Cameron Creole Watershed.

Date	Structure				
	Peconi	**Mangrove**	**Grand Bayou**	**Lambert**	**No Name**
6-26-96			close 4 flaps		
8-17-96	open 1 slot	open 1 slot	open 1 slot	open 1 slot	open 1 slot
8-30-96			open boat bay		
9-13-96	open 1 crest gate				
9-19-96	open 1 crest gate open 2 slots			open 2 crest gates open 2 slots	
9-28-96			raise 4 flaps		
9-30-96	2 deep gates open			2 deep gates open	
10-10-96	open 2 crest gates			open 2 crest gates	
10-12-96	close 4 deep gates			close 4 deep gates	
10-18-96	open deep gates			open deep gates	
10-25-96	close deep gates			close deep gates	
10-26-96	open deep gates			open deep gates	
11-9-96			close boat bay		
11-19-96		open 2 crest gates			open 2 crest gates
12-1-96			open boat bay		
12-9-96	close crest gates close deep gates	close crest gates		close crest gates close deep gates	close crest gates
12-18-96				open 1 deep gate	
12-20-96			close boat bay		
1-3-97				close deep gate	
1-17-97			open boat bay		

Table 1 (continued). Operational changes for each of the five lakeshore structures at the Cameron Creole Watershed.

	Structure				
Date	**Peconi**	**Mangrove**	**Grand Bayou**	**Lambert**	**No Name**
1-21-97			close flaps		
1-30-97	open 4 crest gates				
2-5-97		open 2 slots			open 1 slot
2-13-97	open 4 deep gates		open flaps		
3-4-97		open 4 crest gates		open 4 deep gates	open 4 crest gates
3-24-97	close 4 deep gates	open 4 crest gates		close 4 deep gates	close 4 deep gates
4-29-97	open 4 deep gates			open 4 deep gates	
5-2-97	close 4 deep gates			close 4 deep gates	
6-12-97					close 4 crest gates
7-1-97	open 4 deep gates		close flaps		

Table 2. Monthly and cumulative climate data from January through December 1996 for the southwestern Louisiana division (Allen, Beauregard, Calcasieu, Cameron, and Jefferson Davis parishes). Compiled with data from the Louisiana Office of State Climatology (1996).

Month	Monthly Mean Precipitation (inches)	Cumulative Departure From Normal (inches)	Monthly Palmer Drought Severity Index
Jan	3.33	-1.75	±Normal
Feb	1.51	-4.41	Mild
Mar	1.58	-6.97	Mild
Apr	3.22	-7.54	Mild
May	1.38	-11.52*	Moderate
Jun	6.01	-10.75	Mild
Jul	4.98	-11.81	Moderate
Aug	8.77	-8.89	±Normal
Sep	7.33	-6.77	Moist Spell
Oct	8.79	-1.92	Very Moist
Nov	4.13	-2.15	Very Moist
Dec	4.20	-4.03	Unusually Moist

* Indicates highest May departure on record for the southwestern Louisiana division.

Water Quality: Water quality data were collected as described above, but have not been analyzed at this time. These data will be presented in the next report.

Water Flow: Preconstruction water flow data were collected April 14-16, 1996. No precipitation occurred during sampling, air temperature remained around 83º F (25º C) and south winds averaged 10.5 mph April 14-15, and 8.6 mph April 16. A high tide of 2.0 ft NGVD occurred at approximately 1:00 PM each day during sampling; however, since structures were closed at that time, flow from tides was minimal. Flow was determined to be predominantly wind driven in one direction except at Channel B, the deepest, widest canal where flow was minimal, but bidirectional. Average flow at Channels A, B, C, and D was 17.26 cfs, 81.44 cfs, 126.9 cfs, and 60.96 cfs, respectively, with direction and average velocities of 0.11 ft/sec (0.03 m/sec) southwest to northeast, 0.06 ft/sec (0.02 m/sec) predominantly south to north, 0.38 ft/sec (0.12 m/sec) south to north, and 0.45 ft/sec (0.14 m/sec) south to north.

Emergent Vegetation: Emergent vegetation data were collected in September 1996 and October 1997 at the pre-construction and 1-yr post-construction sampling periods, respectively (table 3). A three-way analysis of variance (ANOVA) was performed to measure changes among areas (project and reference), by station, and over time (pre- and post-construction). Variables include cover, species richness inside and outside of the sample plot, and height of the dominant species.

Dominant species in the northern project area include *Spartina patens, Scirpus americanus, Scirpus robustus* (salt marsh bulrush), and *Vigna luteola* (deerpea). In the southern project area, *S. patens, Spartina alterniflora, S. americanus,* and *Distichlis spicata* were dominant. In the reference area, *S. patens* and *S. americanus* were dominant.

Total cover was highest in the northern project area and reference area at 94.24% and 95.9%, respectively, in 1996, and 95.72% and 98.1% in 1997, indicating slight increases in cover over time. In the southern project area, a slight decrease in cover was detected over time, at 83.48% in 1996 and 79.8% in 1997 (table 3). Cover values were not used for statistical analysis due to difficulty in transforming the data, which is neither continuous nor normal. Of 120 observations over the two sampling periods, 95 have cover values of 90% or above. Analysis of this variable is ongoing.

Species richness inside the vegetation sample plots was not significantly different between the project and reference areas in September 1996, ($F = 0.54$, $df_{2, 57}$, $P = 0.5866$). This supports the assumption that the areas were similar before construction of the plugs. Examination of mean richness also supports this assumption (table 3). Analysis of the combined data from1996 and 1997 did not detect a difference in the way the project and reference areas changed over time ($F=0.41$, $df_{2, 57}$, $P = 0.6651$), or between years either ($F = 0.28$, $df_{1, 57}$, $P = 0.5994$).

Species richness outside the sample plots was included in the analysis when changes observed in the field over time were not detected using inside the sample plots only. Species richness outside the sample plots (which includes inside species) indicates that the project and reference areas differed among years and areas ($F = 6.04$, $df_{2, 57}$, $P = 0.0042$). Post- ANOVA comparisons with least square means indicates that the areas did not differ among each other in 1996, but richness declined more in the northern and reference areas than in the southern area from 1996 to 1997. The greater inside richness than outside richness, and the lack of statistical differences obtained using inside richness, suggests that the plot size may be too small to reflect richness in this marsh.

Analysis of data from 1996 indicates that plant height differed among the areas ($F = 3.50$,$df_{2, 57}$, $P = 0.0369$). Post-ANOVA comparisons with least square means indicate that height was similar in the northern and southern areas, but was lower in the reference area. This was corroborated by the mean plant height data listed in table 3. Analysis of 1996 and 1997 data combined indicated no interaction between plant height among the areas over time ($F=2.15$, $df_{2, 57}$, $P = 0.1254$). There was, however, a large increase in height from 96 to 97 ($F=49.18$, $df_{1, 57}$, $P = 0.0001$). The increase in height appeared less in the southern area than in the other areas, however the year*area term was non-significant. The increase in height observed in 1997 may have resulted from the removal of combined drought and drawdown stress, as both were present in 1996.

Table 3. Mean (standard deviation) of emergent vegetation percent cover, species richness, and height values for data collected October 1996 and October 1997 at 25 monitoring sites in the northern project area, 25 in the southern project area, and 10 in the reference area in the Cameron Creole Watershed.

	% Cover		Richness		Height (cm)	
	1996	1997	1996	1997	1996	1997
Northern project area	94.24 (8.86)	95.72 (9.98)	1.76 (1.01)	1.84 (0.90)	33.48 (6.98)	44.84 (11.99)
Southern project area	83.48 (20.93)	79.8 (30.76)	2.0 (0.96)	2.24 (0.97)	31.64 (5.51)	40.16 (12.96)
Reference area	95.9 (5.89)	98.1 (2.85)	2.1 (1.2)	2.0 (0.47)	27.2 (6.65)	45.8 (5.57)

Soils: Soil salinities were collected in September 1996 and October 1997. In September 1996, the soil samples could not be collected due to the fluidity of the soil. Soil samples were, however, collected in October 1997. These samples will represent the conditions during the preconstruction period. Means and standard error for percent organic matter, bulk density, and soil salinity in the northern and southern project areas, as well as the reference area were calculated (table 4).

Analysis of data from 1996 indicates that soil salinity differed among the project and reference areas at that time ($F = 5.41$, $df_{2, 57}$, $P = 0.0071$). Post-ANOVA comparisons with least square means indicates that soil salinity was similar in the northern and southern areas, but was lower in the reference area. Analysis of the combined 1996 and 1997 data indicate that soil salinity changed differently among the areas over time ($F = 10.72$, $df_{2, 57}$, $P = 0.0001$). Post-ANOVA comparisons with least square means indicates that soil salinity increased in the southern area over time, but did not change in the other two areas. Mean soil salinities are reported in table 4.

Submersed Aquatic Vegetation: Submersed aquatic vegetation data were collected in September 1996 and October 1997 at the preconstruction and 1-yr postconstruction sampling periods, respectively. A two-way ANOVA was performed to measure changes among areas (project and reference) and over time (pre- and postconstruction). Variables include relative frequency of occurrence of species, percent cover, species richness, depth, and salinity (table 5).

The project and the reference areas did not differ statistically for any of the variables tested before project implementation. However, changes in percent cover of SAV were detected between 1996 and 1997 in both the project and reference areas (year*area $p = 0.89$ for cover) indicating that both project and reference areas reacted similarly from 1996 to 1997. While no overall significant

Table 4. Mean (standard error) of soil variables for data collected October, 1997, at 25 monitoring sites in the northern project area, 25 in the southern project area, and 10 in the reference area in the Cameron Creole Watershed.

	Soil Salinity (ppt)	% Organic Matter	field Bulk Density
	Mean	Mean	Mean, gm/cm^3
Northern project area	4.95 (0.72)	48.26 (3.69)	0.13 (0.01)
Southern project area	8.34 (0.56)	59.28 (4.09)	0.11 (0.01)
Reference area	2.76 (0.43)	62.55 (4.72)	0.11 (0.01)

Table 5. Mean (standard deviation) relative frequency of occurrence, percent cover, and species richness of submersed aquatic species, along with depth and salinity in the Cameron Creole Watershed from data collected October 1996 and October 1997.

	Project Area 1996		Project Area 1997		Reference Area 1996		Reference Area 1997	
Species or variable	Mean		Mean		Mean		Mean	
Ruppia maritima	44.0	(19.13)	1.5	(1.91)	45.75	(17.75)	0	(0)
Vallisneria americana	14.75	(14.72)	23.25	(17.46)	23.0	(100.98)	69.5	(5.0)
Najas guadalupensis	18.75	(17.5)	41.75	(33.51)	42.25	(22.81)	32.5	(14.64)
Myriophyllum spicatum	2.5	(3.0)	1.0	(2.0)	0	(0)	1.5	(3.0)
Algae	36.5	(5.74)	53.5	(54.0)	63.25	(20.77)	28.5	(27.05)
% Cover	69.75	(9.03)	69.5	(36.78)	86.25	(9.87)	79.5	(9.57)
Species Richness	4.25	(0.95)	3.5	(0.58)	4	(0)	3.0	(0.81)
Depth (ft)	2.43	(0.1)	1.77	(0.2)	2.35	(0.12)	1.71	(0.24)
Salinity (ppt)	1.65	(0.06)	6.85	(0.53)	1.65	(0.06)	6.30	(0.24)

differences were detected in depth, salinity, and relative frequency of occurrence of each species, there was a change in species composition. Reduction in the occurrence of *R. maritima* from 44% to 1.5% was detected in the project area and from 45.75% to 0% in the reference area between 1996 to 1997 (table 5). Occurrence of *Vallisneria americana* (water-celery) increased from 14.75% to

23.25% in the project area and from 23% to 69.5% in the reference area. Occurrence of *Najas guadalupensis* (common waternymph) increased in the project area from 18.75% to 41.75%, but decreased in the reference area from 42.25% to 32.5% over time.

These changes possibly resulted from the drought and drawdown conditions, which caused water levels to reach record lows from April to July 1996. During this time, ponds that normally held water from 0.5 ft to 2 ft (0.15-0.61 m) deep were completely dry with surfaces exposed. Continued drying over time caused deep fissures in the exposed mud. *Ruppia maritima* can have an annual or perennial life cycle depending upon environmental stresses (Koch and Seeliger 1988). Although the plant may withstand prescribed drawdowns, excessive or irregular water level fluctuations that expose bottom soils for long durations may eliminate existing stands or cause great difficulty in establishing new stands (Joanen 1964; Joanen and Glasgow 1966). Drought conditions are efficient in causing seed coat breakage of *R. maritima* (Richardson 1980), favoring germination by increasing the seed permeability to water. The prolonged drought may have caused an increase in germination of *R. maritima* seeds when the marsh was flooded in late summer, perhaps depleting the seed bank in the soil. In addition, water and soil salinities were high at this time, favoring *R. maritima* over *V. americana*. R. maritima tolerates a wider range of salinity than any other group of SAV (Brock 1979). This would account for high percentages of *R. maritima* recorded in October 1996.

Although *V. americana* is capable of both asexual and sexual reproduction it lives in a habitat where vegetative reproduction is apparently favored (Titus and Stone 1982). It reproduces vegetatively by producing winter buds, called turions, at the end of the growing season. Buds may have sprouted in early spring when water was available, only to die back in late spring when soil surfaces were exposed, preventing new winter bud formation. In late summer, when water flooded the marsh surface, soil salinities were high while energy in the buds was low, perhaps causing low sprouting percentages. In 1997, there was adequate fresh water on the marsh all year, reducing salinities in the soil, providing optimal conditions for germination and growth of *V. americana*.

The changes documented in this report in the Cameron-Creole Watershed since construction of the borrow canal plugs in November 1996 cannot be attributed to the project at this time. Extreme drought conditions occurring from February through August 1996 are likely responsible for shifts in species composition in the aquatic plant community as well as richness and height responses in the emergent plant community.

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Prepared on January 24, 1998, by Dona Weifenbach.

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Monitoring Implementation	October 1, 1994	
Construction Start:	August 1, 1996	
Construction End:	November 1, 1996	

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