Coast 2050 Region 4

EAST MUD LAKE MARSH MANAGEMENT (C/S-20)
C/S-20-MSPR-597-3
PROGRESS REPORT No. 3
for the period
May 1, 1996 to May 1, 1998

Project Status

The following data collection and analysis activities have been conducted since the previous progress report.

The 1-yr evaluation of the vegetative plantings was conducted in August 1997. Sediment Erosion Table (SET) measurements were taken and cryogenic coring of feldspar plots was conducted in July and December 1997 for the 12- and 18-mo monitoring periods. Fisheries monitoring was conducted in April and September 1997.

Project Description

The East Mud Lake Marsh Management project area consists of 8,054 acres (3,222 ha) located in the Calcasieu/Sabine Basin in Cameron Parish, Louisiana. The project is bounded by the southern FINA property line to the south, La. Hwy. 27 to the west, the Sabine National Wildlife Refuge north of Magnolia Road, and an existing step levee and property line near Oyster Bayou to the east (figure 1).

The Calcasieu/Sabine Basin suffers from human-induced hydrologic changes to the system (U.S. Department of Agriculture-Soil Conservation Service [USDA-SCS] 1993), which have led to the deterioration of the marsh since 1953. The Calcasieu Ship Channel (CSC), which is 1 mi (1.6 km) east of the project area, was first constructed in 1874 and redredged in 1951 and 1968 to a final width of 400 ft (122 m) and a depth of 40 ft (12 m) (USDA-SCS 1993). The CSC provides an avenue for extreme salinities (4–32 ppt) and rapid water movement into the East Mud Lake project area via West Cove, Oyster Bayou, and Mud Bayou (figure 1). These connections facilitate increases in turbidity and scouring within the project area. Analysis of aerial photos of the project area indicate a marsh loss rate of 76 ac/yr (30.8 ha) from 1953 to 1983 (USDA-SCS 1992). Excluding Mud Lake, the land to open water ratio had deteriorated from 99:1 in 1953 to 70:30 by 1983.

Another problem associated with the project area is excessive water levels over the surface of the marsh for prolonged time periods. The construction of La. Hwy. 27 to the west and La. Hwy. 82 to the south have decreased avenues for drainage from the western and southern areas of the project. This has lead to prolonged periods of sustained high water levels and "ponding," which has resulted in the deterioration of the vegetation (USDA-SCS 1994). The East Mud Lake project addresses these problems by increasing the total number of outlets for the area. Subsidence and sea level rise have also exacerbated the problem, resulting in a relative water level increase of 0.25 in./yr (0.64 cm/yr) from 1942 to 1988 (Penland et al. 1989).

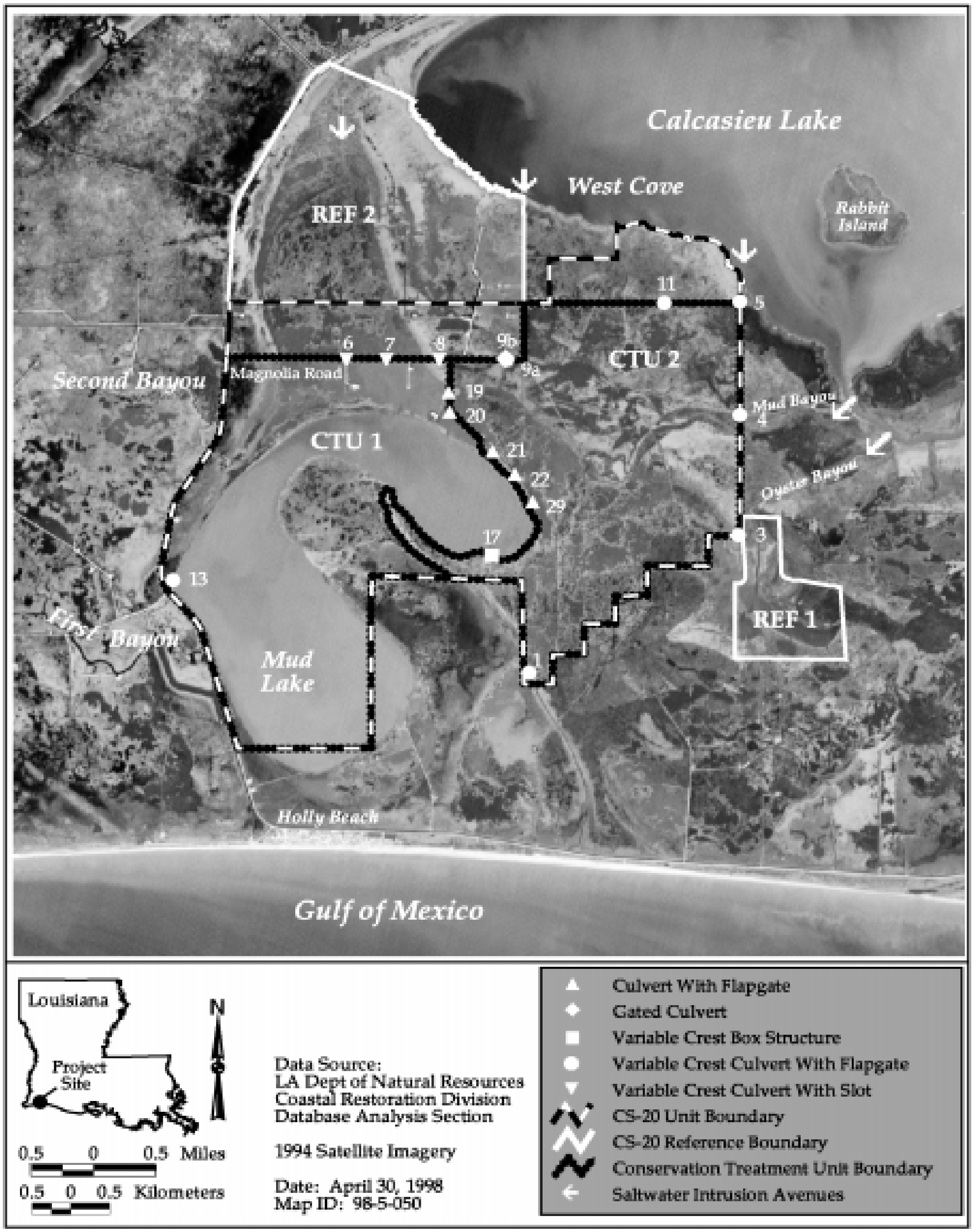


Figure 1. East Mud Lake (CS-20) project map depicting project boundaries, conservation treatment unit boundaries, reference area boundaries and project features.

The project area has been divided into two hydrologically separate Conservation Treatment Units (CTU) that will be managed independently (figure 1). CTU 1 contains Mud Lake and will be managed passively. Structures and features present in CTU 1 consist of vegetative plantings, earthen plugs, culverts with flapgates and variable-crest culverts. The variable-crest culverts at stations 6, 7, and 8 will be set at 6 in (15 cm) below marsh level with vertical slots open except when salinities exceed 15 ppt. The variable-crest culvert at station 13 will be set at 6 in (15 cm) below marsh level with flapgates locked open except when salinities exceed 7 ppt.

CTU 2 will be actively managed and will have drawdown capabilities in order to encourage shallow areas to revert to emergent vegetation. Two drawdown events area planned for the first five years of the project. Structures and features present in CTU 2 consist of vegetative plantings, variable crest culverts with flapgates, a gated culvert, and a variable-crest box structure (figure 1). Phase I emphasizes curtailing marsh erosion and reclaiming emergent marsh by implementing a partial drawdown from February 15-July 15. All flapgates at variable-crest culverts 1, 3, 4, 5, 9a, and 11 will be allowed to operate with all stoplogs removed. Stoplogs will be set at 12 in (30.5 cm) above marsh level (AML) on the variable crest box structure at station 17. The screwgate at station 9b will be opened and the flapgate allowed to operate.

Phase II, the maintenance phase, emphasizes stabilization of salinity and water levels while ensuring ingress and egress of fisheries species. During this phase of operation, flapgates at stations 3, 4, 5, 9a, 9b, and 11 will be locked open. Stoplogs will be set at 6 in (15 cm) below marsh level (BML) at stations 1, 3, 4, 9a, and 11 while at station 5, one bay will be set at 6 in (15 cm) BML and one bay at 12 in (30.5 cm) BML. The screwgate at station 9b will be opened and all stoplogs removed from station 17. To protect marsh vegetation during periods of high salinity, the ingress gates will be closed when salinity inside the project area exceeds 15 ppt at stations 3 or 5.

Construction was completed May 1, 1996. The project objectives are to prevent wetland degradation by reducing vegetative stress, thereby improving the abundance of emergent and submergent vegetation and to stabilize the shoreline of Mud Lake through vegetative plantings. Specific goals are to (1) decrease the rate of marsh loss, (2) increase vegetative cover along the shoreline of East Mud Lake, (3) increase percent cover of emergent vegetation in shallow open-water areas, (4) increase abundance of vegetation in presently vegetated portions of the project area, (5) reduce water-level and salinity fluctuations to within 6 in (15 cm) below marsh level to 2 in (5.08 cm) above marsh level and 15 ppt, respectively, (6) decrease the duration and frequency of flooding over emergent marsh, (7) decrease the mean salinity in CTU 2, and (8) increase sediment accretion in CTU 2. Maintaining fisheries abundance is not a specific goal as addressed in the project documentation. However, due to concerns regarding potential fishery impacts, it has been included in the monitoring plan.

The area east of the project area CTU 2, between the Calcasieu Ship Channel and Oyster Lake and Mud Bayou (reference area 1) was selected as the best reference area for the evaluation of the water level, salinity, and fisheries monitoring elements. Both the project area and this reference area are classified as brackish marsh (Chabreck and Linscombe 1988) and contain mainly the organic

Bancker and Creole soils (USDA-NRCS 1995). Both the project and the reference areas are directly influenced hydrologically by the CSC and are dominated by *Spartina patens* (marshhay cordgrass). The area north of Magnolia Road (reference area 2) is a suitable reference area for the evaluation of the vegetative, accretion, water-level, salinity, fisheries, and soil monitoring elements. Both the project area and this reference area are classified as brackish marsh (Chabreck and Linscombe 1988) and both contain mainly the organic Bancker and Creole soils (USDA-NRCS 1995). Both areas are influenced hydrologically by the CSC and Calcasieu Lake through West Cove Canal.

Methods

A detailed description of the monitoring design over the entire project life can be found in Holbrook (1995).

Habitat mapping: Near-vertical color-infrared, aerial photography (1:12,000 scale) was obtained December 26, 1994. The photography was 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 was 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 processing and geographic information system software, the photography is mosaicked and used for basemap production. Global positioning system (GPS) points were collected in the field to georeference the basemap to a Universal Transverse Mercator (UTM) coordinate system.

Vegetative plantings: Vegetative plantings were conducted by the Department of Natural Resources (DNR) vegetative planting program June 5 through July 8, 1995. A total of 7200 *Spartina alterniflora* (smooth cordgrass) plugs were planted along the step levee in CTU 2. Due to the cut bank configuration of most of the Mud Lake shoreline, only areas adjacent to structures 17, 13, and the earthen plug west of structure 17 were planted for a total of 480 plants. To document vegetative planting success, 5% of the plants along the step levee and 5% of the plants along the East Mud Lake shoreline were sampled. Thirty-six plots along the step levee and 4 plots along the shoreline, consisting of 10 plants spaced 5 ft (1.5 m) apart, were randomly selected and sampled for percent survival of planted vegetation, species composition of encroaching vegetation, and percent cover for each species present. Monitoring stations were placed every 1,000 ft. The 1-mo, 6-mo, and 1-yr postplanting sampling was conducted in July 1996, December 1996, and August 1997, respectively. The plantings were divided into three land types due to different stress factors from boat wakes, wave energy, and herbivory. The canal plantings, located on a long, straight canal in CTU 2 (figure 1) are subject to herbivory from cattle year-round. The step levee plantings are located in CTU 2 on short canals where plants were installed at a farther distance from the shoreline. Lakeshore plantings are located on the shoreline of East Mud Lake in CTU 1 and subject to a high wave energy due to the long north-south fetch across the lake.

Planting survival was evaluated in terms of four variables (Harper 1977), which are defined and calculated as follows:

survival frequency = number of live plants inside plot at timepoint x

mortality (d_x) = probability (at planting time) of dying during age interval x, $x+1 = l_x - l_{x+1}$

survivorship (l_x) = probability (at planting time) of surviving until age $x = \frac{\text{no. live plants inside plot at timepoint } x}{\text{original no. plants inside plot}}$

mortality rate (q_x) = probability of a planting at age x dying before the age of $x+1 = \frac{l_x - l_{x+1}}{l} = \frac{d_x}{l}$

Plant survival and percent cover were compared among the land types with the Kruskal-Wallis test, a nonparametric test.

Existing vegetation: Sites to monitor existing vegetation were selected using a systematic transect pattern in which five transect lines were drawn in a northwest to southeast configuration from the Calcasieu Lake/West Cove shoreline in the project area and reference area 2. Five stations were chosen uniformly across each transect line, for a total of 25 stations in the project area and 20 stations in reference area 2, to obtain an even distribution of stations throughout the marsh (figure 2). Percent cover, height of dominant plants, and species composition were monitored in 1.0-m^2 vegetative plots. Emergent vegetation data were collected in July 1995 and July 1997 at the pre-construction and 1-yr post-construction sampling periods, respectively. Total cover and cover of *S. patens* were compared over time (pre- and post-construction) with the Kruskal-Wallis test. A three-way analysis of variance (ANOVA) was performed to compare species richness and height among areas (project and reference), by station according to soil type, and over time (pre- and post-construction). Species richness was log transformed; height did not required transformation. Abundances of other species were not analyzed because of few observations and limited distributions.

Soils: Soils were sampled in the plots used for vegetation monitoring and analyzed for percent organic matter, and field moist bulk density. Cores were 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 100^o C for 24-48 hours. Preconstruction soil samples were collected in July 1996. Means and standard deviation for percent organic matter and field bulk density in the project and reference areas were calculated. Field moist bulk density is calculated as (weight of oven dry sample - weight of empty tube) divided by the volume of the field moist sample.

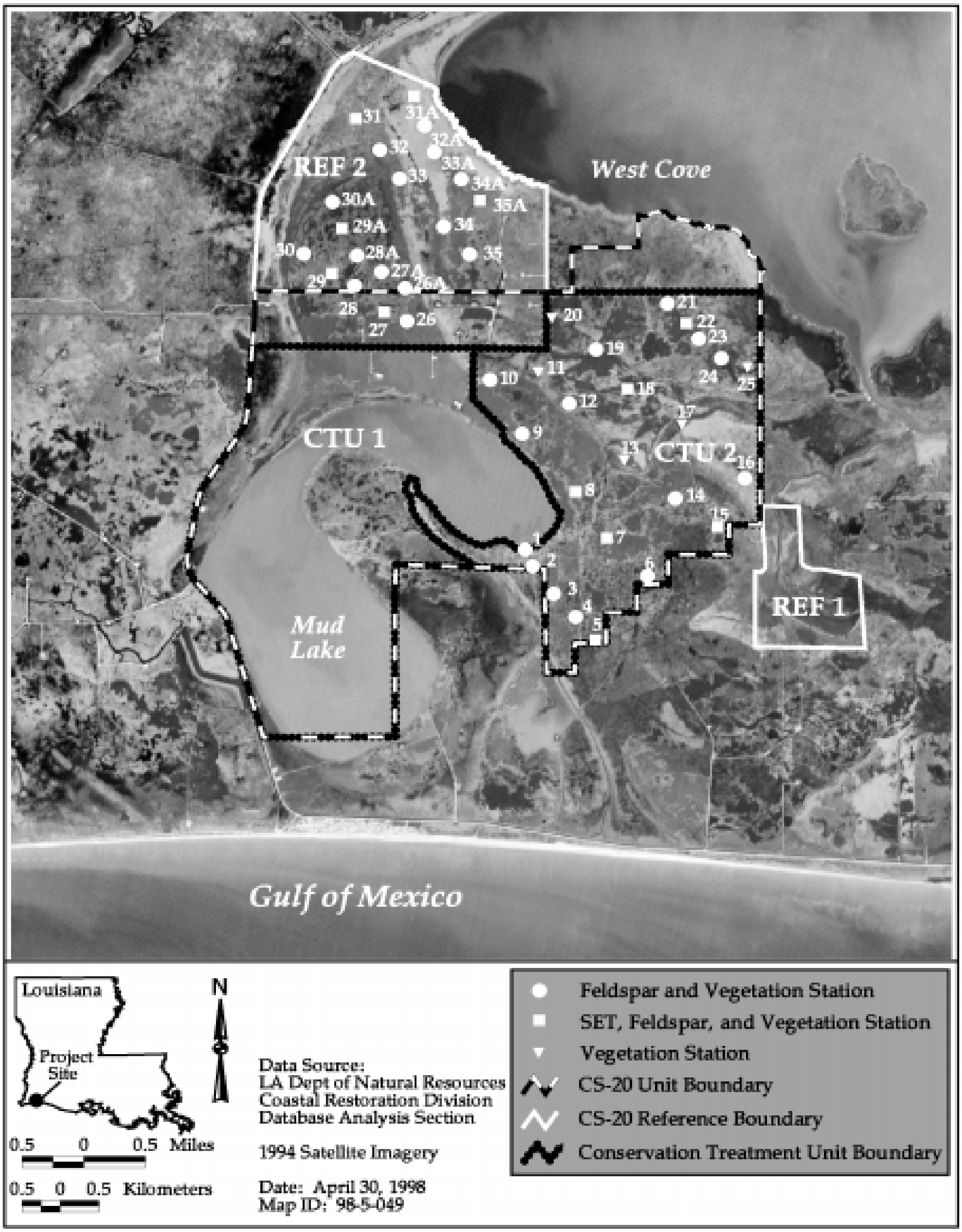


Figure 2. East Mud Lake (CS-20) project map depicting feldspar stations, vegetation stations, and SET stations.

Water quality: Water quality data was collected using seven (7) YSI 6000 continuous recorders at five stations inside the project area and 2 stations in the reference areas (figure 3). Water level, salinity, temperature, and specific conductance were recorded hourly at these stations. All continuous recorder data were shifted when necessary due to biofouling. Discrete monthly samples were taken at 25 stations, 13 located inside the project area, and 12 in the reference areas (figure 4). Monthly staff gage readings were taken at 11 stations located inside the project area, and 10 in the reference areas (figure 4). Water level data presented was collected from July 1996 to December 1997. Water level data was used to document frequency and duration of inundation inside and outside CTU 2 and compared with the Kolmogorov-Smirnov critical value. Water level and salinity means were calculated for continuous recorder data.

Discrete salinity data was collected from October 1994 to December 1997. Continuous water salinity data collected from June 1996 to December 1997 were analyzed to determine if the project and reference areas differed in variability of water salinity during nondrawdown periods. The coefficient of variability (defined as the standard deviation/mean) was used as a measure of water salinity variability. The coefficient of variability was chosen over the standard deviation because it was expected that the standard deviation would be larger when salinity was higher. A coefficient of variability was calculated for each week, for stations 3, 9, and 17 in CTU 2, station 14R in reference 1 and 15R in reference 2. These data were log transformed to improve normality and analyzed as a repeated measures to determine if salinity variability differed among the project area (CTU 2) and the two reference areas. Data from all stations were used, but observations during drawdowns were deleted. Statistical comparisons among areas were performed.

Elevation and accretion: Feldspar platforms were constructed August 1995 at 20 stations in the project area and 20 stations in reference area 2 along the same transect lines as the vegetation stations to detect changes in sediment accretion (figure 2). Feldspar was placed in 0.5 x 0.5 m plots marked with 2 PVC poles at opposite corners to enable locating the feldspar over time (Knauss and Cahoon 1990). Pre-construction feldspar measurements were sampled by cryogenic corer in December1996. Post-construction data was collected July 1997 and December 1997. Additional feldspar will be placed as needed.

Sediment erosion tables (SET) were established in August 1995 at 12 of the 40 feldspar stations to detect changes in elevation due to subsidence and accretion/erosion combined (figure 2). Three SET stations were located in each of the Bancker and Creole soil types for a total of 6 stations each in CTU 2 of the project area and in reference area 2. Nine pin measurements were taken in four directions at each of the stations. Detailed procedures for the SET are documented in Steyer et al. (1995). Pre-construction SET measurements were taken December 1995. Post-construction data was collected in July 1996, December 1996, July 1997, and December 1997, every six months. Due to low water levels, only 10 of the 12 SET stations were accessible for the first two measurements. Sampling was initiated at the two remaining stations in December 1996, when water levels allowed access.

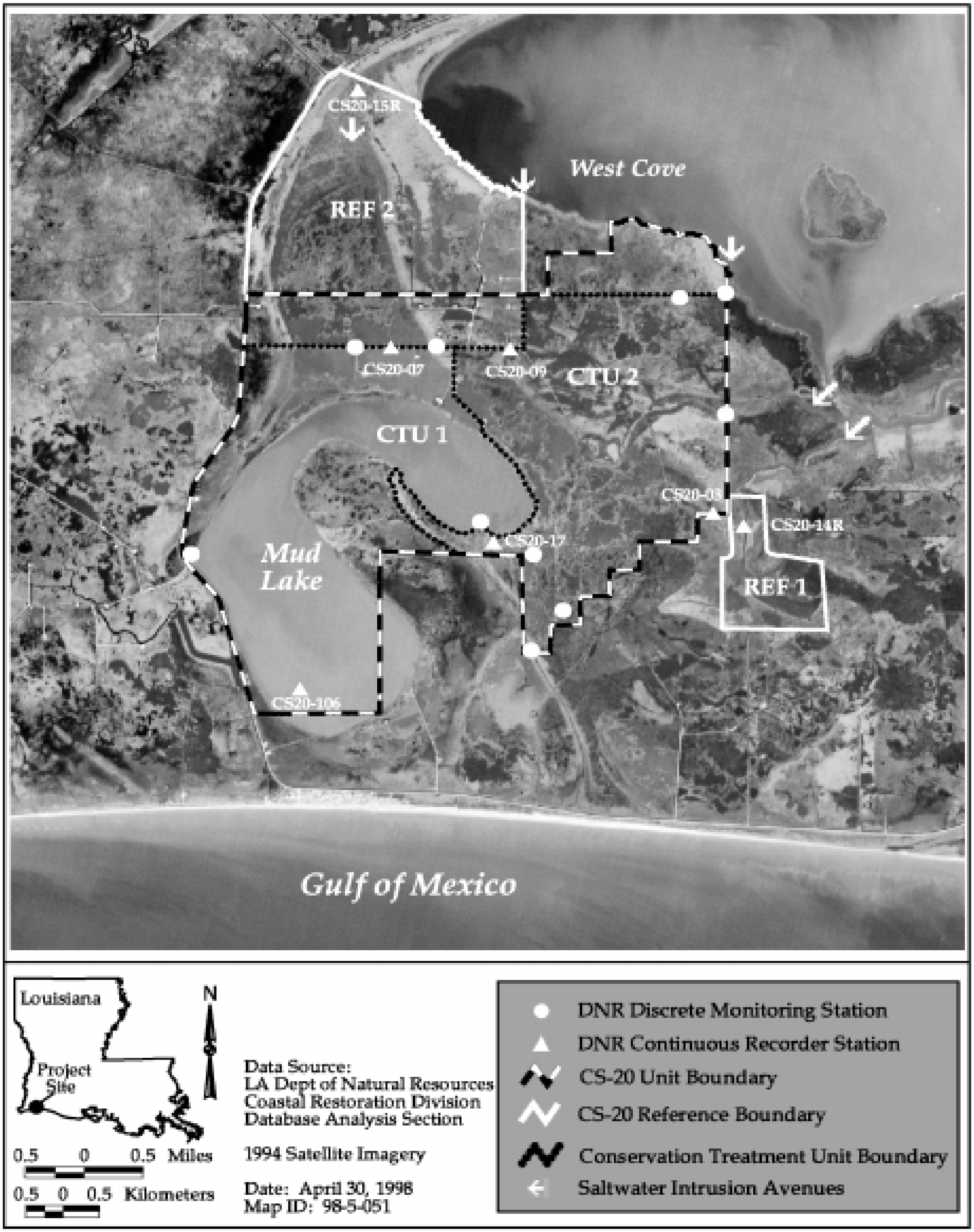


Figure 3. East Mud Lake (CS-20) project map depicting discrete monitoring stations, continuous recorder stations, and saltwater intrusion avenues.

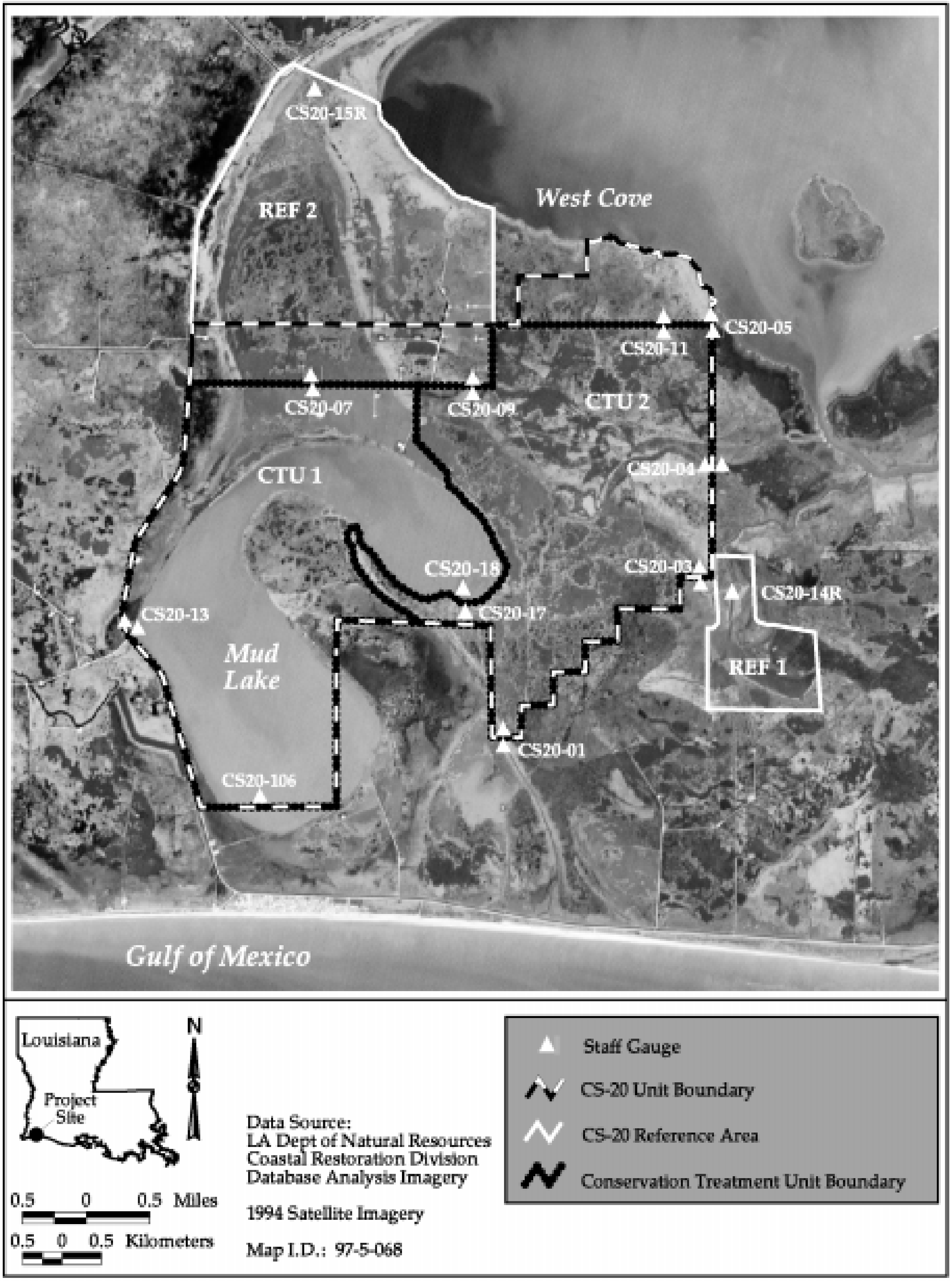


Figure 4. East Mud Lake (CS-20) project map depicting locations of staff gauges.

Elevation was compared pre- and post-construction, and over time by month and site (project and reference). There were 2,160 observations made with the SET. A repeated measures design was originally planned but that analysis required more computer memory than was available at DNR, NWRC, or USL. Therefore, the difference in elevation between the first observation taken December 1995 and the four subsequent observations taken July 1996, December 1996, July 1997, and December 1997, was determined for each of the 36 pins at each SET monitoring station. There were 396 observations for each time period except the first, for which only 360 were available. These observations were analyzed to determine if elevation change during any period differed between project and reference area using a completely random design with nesting of pin within direction within station within area. The alpha level (0.05) was not adjusted to account for the multiple comparison because we judged it would be better to incorrectly conclude that differences existed when none did, than to fail to detect real differences.

For accretion analysis, an ANOVA was performed. A Duncan's multiple range test was used to compare means when differences were detected.

Fisheries: Fisheries monitoring was conducted to estimate abundance and species composition in the project and reference areas to determine whether the project affects fish abundance. Thirty samples each were collected from the project and reference area 2 during each sampling period using a 1-m^2 throw trap with 1-m high walls constructed of 1.6 mm mesh nylon netting (Kushlan 1981). A 0.25 in (0.64-cm) diameter steel bar, bent into a square was attached to the bottom of the net to make it sink rapidly in the water while a floating collar of plastic pipe 0.75 in (1.91-cm) diameter was attached to the top of the net to keep the throw trap vertical in the water column after deployment. Additional samples were collected randomly using a 20-ft (6.1 m) minnow seine with 3/16 in (0.48 cm) mesh to compensate for the deficiency of the throw traps for species composition. A minimum of three seine pulls were conducted in the project area and both reference areas at each sampling event to determine whether throw traps adequately depict species composition. The throw trap samples were collected from the project and reference area 2 to quantify biomass and abundance. Mean density, relative abundance, and total biomass (dry weight in grams) of each species were recorded. Sampling locations were randomly chosen from a grid pattern for each sampling trip.

Personnel from DNR conducted sampling pre-construction in June 1995, October 1995, and April 1996, and post-construction in May 1996, October 1996, and March 1997. National Marine Fisheries Service (NMFS) personnel and the DNR monitoring manager conducted post-construction sampling in April 1997 and October 1997. NMFS analyzed data from the three preconstruction sampling periods and determined that throw trap sampling adequately depicted species composition of the area and seines were discontinued prior to post-construction sampling. Sampling was conducted prior to the closing of the gates for the drawdown, late spring, and in the fall at times when the water level is at or below marsh elevation, to determine whether fisheries access is limited by the project features. Statistical comparison among areas, pre- and post-construction, by season, and by management phase (drawdown or maintenance) were performed. Hartely's F-max test will be used to determine if variances in the treatment cells are equal. To compare mean animal density, biomass, species richness, and environmental parameters between the project and reference areas, t-test for either equal or unequal variances will be used.

Results

Structure Operations: Operational changes were carried out by FINA personnel according to permit specifications (table 1). The permit for the project allows a drawdown twice in the first 5 years following end of construction. The most severe drought in 20 years (Louisiana Office of State Climatology [LOSC] 1996) occurred in 1996, optimizing conditions for drawdown (table 2). The parish experienced mild to moderate drought conditions from February through July 1996. Cumulative statewide precipitation totaled less than two-thirds of the normal level from January to May 1996, ranking as the fifth driest January to May total in the last century (LOSC 1996). Upon completion of construction the first Phase I drawdown was initiated on May 5, 1996. The drawdown was terminated July 17, 1996 as stop logs were set in place and flaps were opened, however, water levels did not return to normal until October 1996 due to extended drought conditions.

A second drawdown was initiated March 3, 1997, when weather conditions favorable to lower water levels predominated. This drawdown was terminated July 15, 1997.

Habitat mapping: Color-infrared aerial photography for the pre-construction phase of the project was flown on December 16, 1994. 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 complete 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 post-construction photography is obtained.

Vegetative Plantings: Overall survivorship was 100% at 1 mo, decreasing slightly to 96% between 1 mo and 6 mo with mortality increasing from 0.0 to 0.04 at this time (table 3). Between 6 mo and 12 mo, survivorship decreased to 62% with mortality increasing to 0.35. There were no differences among land types during the 1-mo and 6-mo periods, but survivorship (χ^2_{df2}= 17.15, P= 0.0002) and mortality (χ^2_{df2} =18.33, P= 0.0001) differed among the land types at 12 mo. Percent survival remained above 90% in the canal plantings, but declined to 45.6% in the step levee and to 15% in the lake at 1-yr postplanting (figure 5).

Percent cover differed among the land types at 1–mo (χ^2_{df2} = 6.09, P= 0.047), at 6-mo (χ^2_{df2} =7.47, P= 0.02), and at 1-yr (χ^2_{df2} =16.83, P=0.0002). Cover continually increased over time in the canal and the step levee but not in the lakeshore plantings (figure 6 and table 4). Native species colonizing the step levee and shoreline included *Distichlis spicata* (saltgrass), *S. patens* (marshhay cordgrass), *Heliotropium currassivicum* (seaside heliotrope), *Lycium carolinianum* (salt matrimony-vine) and *Salicornia bigelovii* (glasswort).

Table 1. Operational changes for each of the structures at East Mud Lake.

Structure number	**Date and Operation Performed**				
	5/2/96 (Phase I)	6/11/96	6/18/96	7/18/96(Phase II)	7/26/96
17	stoplogs 12" AML			stoplogs removed	
1	stoplogs removed			stoplogs 6" BML flapgates locked open	
3	stoplogs removed flapgates operating			stoplogs 6" BML flapgates locked open	
4	stoplogs removed flapgates operating			stoplogs 6" BML flapgates locked open	
5	stoplogs removed flapgates operating			stoplogs1 bay 6" BML, 1 bay 12" BML flapgates locked open	
9a	stoplogs removed flapgates operating			stoplogs 6" BML flapgates locked open	
11	stoplogs removed flapgates operating	flapgates locked open 24 hrs (planting access)	flapgates locked open 24 hrs (planting access)	stoplogs removed flapgates operating	stoplogs 6" BML flapgates locked open
13	stoplogs 6" BML flapgates locked open			stoplogs 6" BML flapgates operating	
6	stoplogs 6" BML			stoplogs 6" BML	
7	stoplogs 6" BML			stoplogs 6" AML	stoplogs1 bay 6" BML, 1 bay 12" BML
8	stoplogs 6" BML			stoplogs 6" BML	
9b	flapgates operating screwgate open			flapgates locked open screwgate open	

Table 1, continued. Operational changes for each of the structures at East Mud Lake.

Structure number	Date and Operation Performed				
	8/3/96	3/12/97 (Phase I)	6/10/97	7/15/97 (Phase II)	8/26/97*
17		stoplogs 12" AML		stoplogs removed	
1		stoplogs removed		stoplogs 6" BML	
3	flapgates operating 24 hrs (vandalism)	stoplogs stuck 6" BML flapgates operating		stoplogs 6" BML flapgates locked open	stoplogs 6" BML flapgates operating
4			12 stoplogs removed 48 hrs (vandalism)	stoplogs 6" BML boards bolted (vandalism) flapgates locked open	
5		stoplogs removed flapgates operating		stoplogs1 bay 6" BML, 1 bay 12" BML flapgates locked open	stoplogs1 bay 6" BML, 1 bay 12" BML flapgates operating
9a		stoplogs removed flapgates operating		stoplogs 6" BML flapgates locked open	stoplogs 6" BML flapgates locked open
11		stoplogs removed flapgates operating		stoplogs 6" BML flapgates locked open	stoplogs 6" BML flapgates operating
13		stoplogs 6" BML flapgates locked open		stoplogs 6" BML flapgates operating	
6		stoplogs 6" BML		stoplogs 6" BML	
7		stoplogs 6" BML		stoplogs1 bay 6" BML, 1 bay 12" BML	
8		stoplogs 6" BML		stoplogs 6" BML	
9b		flapgates operating screwgate open		flapgates operating screwgate open	

Table 1, continued. Operational changes for each of the structures at East Mud Lake.

Structure number_	Date and Operation Performed		
	9/5/97	10/12/97	10/20/97
17			
1			
3	flapgates operating 24 hrs (vandalism)		
4		2' hole dug in levee adjacent to structure (vandalism)	1 flapgate permanently removed from culvert (vandalism)
5			
9a			
11			
13			
6	stoplogs 6" AML**		
7			
8	stoplogs 6" AML**		
9b			

* Salinities exceeded 15 ppt in CTU 2.
** Salinities exceeded 15 ppt in CTU 1.

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.

Table 3. Partial life table of *Spartina alterniflora* plantings in the East Mud Lake (C/S-20) project area, based on means of data collected from forty 10-plant sampling plots, from July 1996 to December 1996, at 1-mo, 6-mo, and 1-yr postplanting.

Age (mo)	**Survival Frequency (n)**	**Survivorship** (l_x)	**Mortality** (d_x)	**Mortality Rate** (q_x)
0	10	1.0	0.0	0.0
1	10	1.0	0.04	0.04
6	9.6	0.96	0.34	0.35
12	6.2	0.62		

n=mean number of live plants per plot

Table 4. Percent cover (standard deviation) of *Spartina alterniflora* plantings in the East Mud Lake (C/S-20) project area at 1-mo, 6-mo, and 1-yr.

	Percent Cover		
	1 month	6 months	1 year
canal	10.2 (7.23)	26.1 (18.0)	72.8 (28.6)
step levee	9.2 (6.2)	15.2 (11.8)	33.2 (34.9)
lakeshore	4.7 (0.5)	7.6 (2.9)	0.8 (1.4)

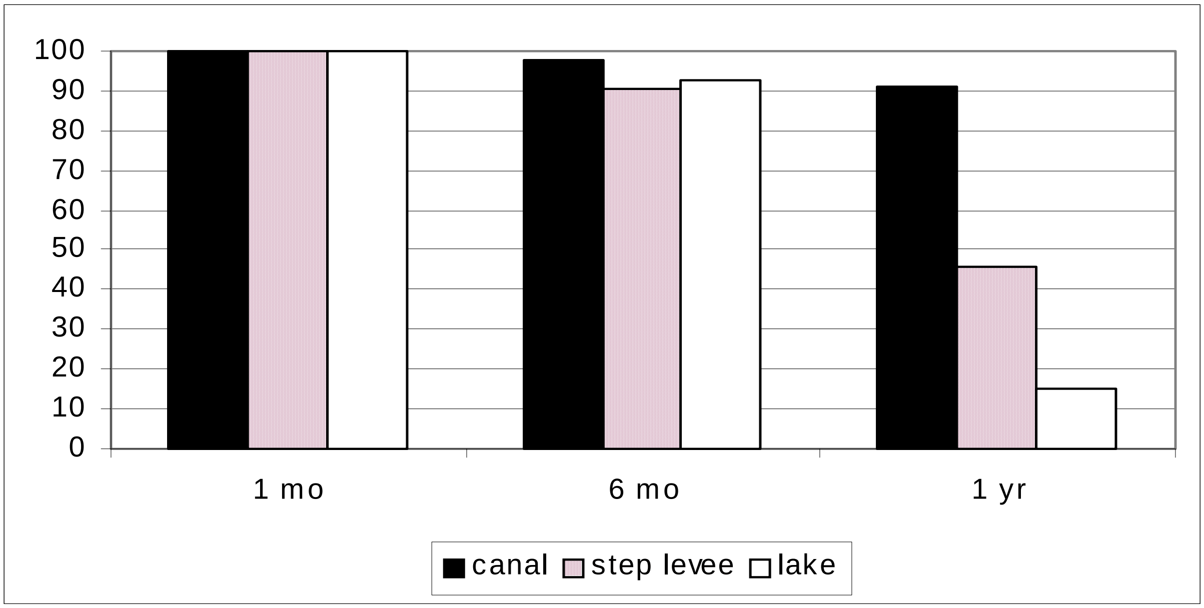


Figure 5. Percent survival of *Spartina alterniflora* plantings in the East Mud Lake (C/S-20) project area based on means collected at 1-mo, 6-mo, and 1-yr postplanting.

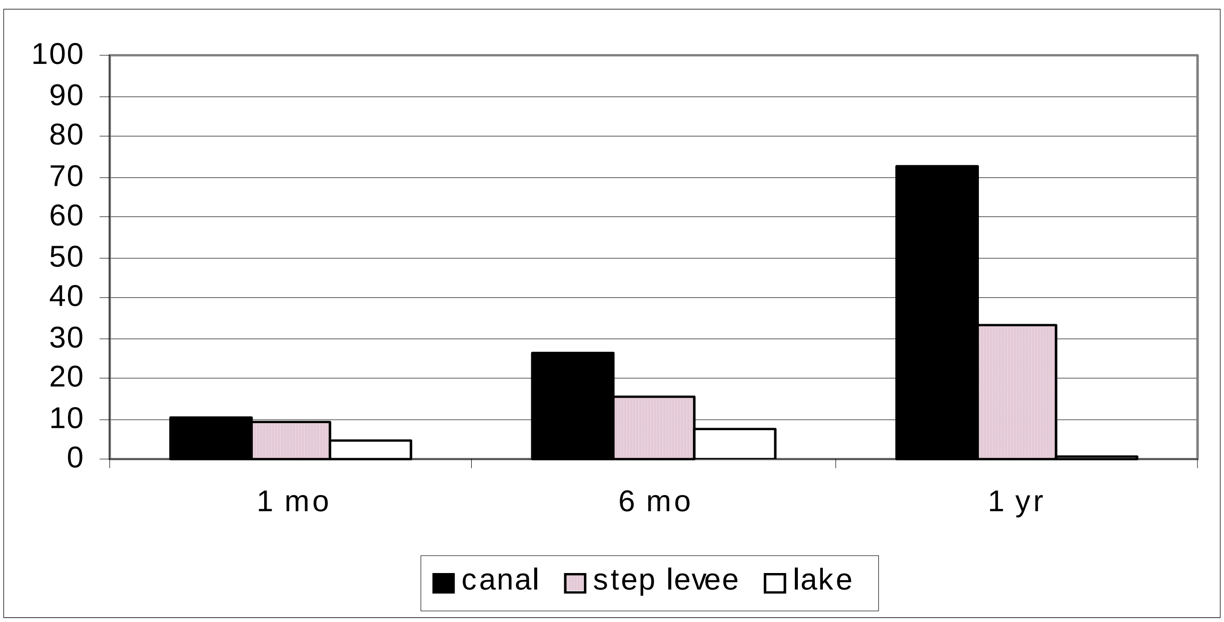


Figure 6. Percent cover of *Spartina alterniflora* plantings in the East Mud Lake (C/S-20) project area based on means of data collected at 1-mo, 6-mo, and 1-yr postplanting.

Existing Vegetation: Total cover did not differ significantly among areas. Total cover did not differ in the reference area between 1995 and 1997, nor was there a difference in total coverage or coverage of *S. patens* between high and low soils. Significant differences were detected in total cover (χ^2_{df1} =7.81, P= 0.0005) and coverage of *S. patens* (χ^2_{df1} =18.30, P= 0.0001) within the project area between 1995 and 1997. Within the low soil type in the project area, significant differences were found in both total cover (χ^2_{df1} = 4.50, P= 0.034) and coverage of *S. patens* (χ^2_{df1} =11.63, P= 0.0006). Coverage of *S. patens* on the high ground in the project area was significantly different between 1995 and 1997 (χ^2_{df1} = 6.75, P= 0.009).

Total cover decreased in the project area from 88.52% in 1995 to 64.5% in 1997, but remained stable in the reference area with 86.6% in 1995 and 86.9% in 1997 (table 5). A shift in species was noted in both the project and reference areas. Cover of *S. patens* decreased in the project area from 84% in 1995 to 26.9% in 1997, while cover of *S. alterniflora*, *Paspalum vaginatum* (seashore paspalum), and *Aster subulatus* (saltmarsh aster) increased from 7.96%, 0.2%, and 0% in 1995 to 27.83%, 6.25%, and 14.06%, respectively in 1997. In the reference area, cover of *S. patens* and *S. alterniflora* decreased from 86.6% and 16.5% to 71.0% and 1.6%, respectively, over time. However, *P. vaginatum,* and *A. subulatus* increased from 0% to 12.4% and 4.2%, respectively, from 1995 to 1997.

Species richness did not differ between the project and reference areas in July 1995, ($F_{1,33}$ = 1.80, P = 0.1894). This supports the assumption that the areas were similar before construction. Analysis of the combined data from1995 and 1997 indicated that the project and reference areas changed differently over time ($F_{1,32}$ = 5.72, P = 0.0228), with richness increasing in the project area, but declining in the reference area after construction.

Plant height inside the vegetation sample plots was not different between the project and reference areas in July 1995, ($F_{1,33}$ =2.82, P = 0.1028). Analysis of 1995 and 1997 data combined indicated no interaction between plant height among the areas over time ($F_{1,32}$ =1.39, P = 0.2476). Mean height decreased slightly in the project area, from 4.37 ft (1.33 m) in 1995 to 4.11 ft (1.25 m) in 1997 while in the reference area, mean height decreased from 4.89 ft (1.91 m) in 1995 to 3.83 ft (1.17 m) in 1997.

<u>Soils:</u> Means and standard deviation for percent organic matter and field bulk density in the project and reference areas are presented in table 6.

<u>Water Level:</u> In CTU 2, mean marsh elevation is 1.51 ft National Geodetic Vertical Datum (NGVD) at station 3 and 1.25 ft NGVD at station 9. Mean marsh elevation is 1.28 ft (0.39 m) NGVD at station 14R in reference area 1, and 1.3 ft (0.40 m) NGVD at station 15R in reference area 2. Water level in CTU 2 was at or below mean marsh elevation for 65.1% of the time from June 10 to December 31, 1996, and 91.8% of the time from January 1 to December 31, 1997, at station 3. Water level in CTU 2 was at or below mean marsh elevation for 61.2 % of 1996 and 65.0 % of 1997 at station 17 during the same time period. Water level in reference area 1 (station 14R) was at or below mean marsh elevation for 72.7 % of 1996 and 77.6 % of 1997. Water level in reference

Table 5. Mean (standard deviation) of emergent vegetation percent cover, species richness, and height values for data collected July 1995 and July 1997 at 25 monitoring sites in the project area and 20 in the reference area at East Mud Lake (C/S-20).

	Project Area		Reference Area	
	1995	1997	1995	1997
Height (ft)	4.37 (0.81)	4.11 (1.77)	4.89 (0.86)	3.83 (0.63)
Height (m)	1.33 (0.25)	1.25 (0.54)	1.49 (0.26)	1.17 (0.19)
Richness	1.7 (0.1)	2.4 (0.1)	2.0 (0.2)	1.8 (0.2)
% Total cover	88.52 (17.13)	64.5 (33.09)	86.6 (15.67)	86.9 (19.19)
% cover *Spartina patens*	84.00 (21.99)	31.35 (39.15)	86.6 (15.66)	71.0 (32.95)
S. alterniflora	7.96 (23.82)	27.83 (42.76)	16.5 (22.49)	1.6 (4.72)
Paspalum vaginatum	0.2 (1.0)	6.25 (20.44)	0	12.4 (31.07)
Aster subulatus	0	14.06 (20.78)	0	4.2 (12.59)

Table 6. Mean (standard deviation) of soil variables for data collected July 1996, at 25 monitoring sites in the project area and 20 in the reference area at East Mud Lake (C/S-20).

	% Organic Matter	field Bulk Density
	Mean	Mean, gm/cm^3
Project area	39.69 (13.94)	0.40 (0.07)
Reference area	42.70 (14.31)	0.43 (0.18)

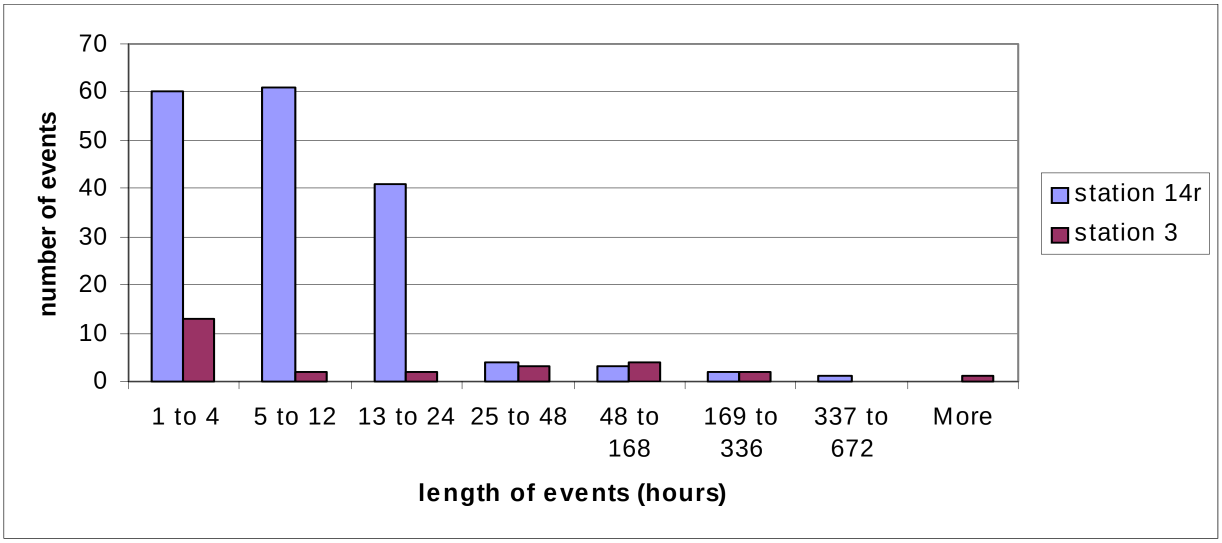
area 2 (station15R) was at or below mean marsh elevation for 82.8 % of 1996 and 72.4 % of 1997.

Distribution of the duration of flooding events was significantly different between inside and outside CTU 2 at stations 9 and 15R (Kolmogorov-Smirnov critical value of 0.31), but was not significantly different between stations 3 and 14R (Kolmogorov-Smirnov critical value of 0.268) (figure 7). Daily tidal influences apparently accounted for 94.7% and 94.2% of the flooding events less than 24 hrs long in reference areas 1 and 2 (stations 15R and 14R), respectively, and for 81.8% and 63.0% of the flooding in CTU 2 at stations 9 and 3, respectively. Flooding events of 25 to 336 hrs (2 to 14 days) represented 5.3% and 5.2% of the flooding in reference areas 1 and 2 respectively, and for 13.6% and 33.3% of the flooding in CTU 2 at stations 9 and 3, respectively. Flooding events of 337 to 672 hrs (15 to 28 days) represented 0% and 1.0% of the flooding in reference areas 1 and 2 respectively, and for 0% and 7.4% of the flooding in CTU 2 at stations 9 and 3, respectively. CTU 2 experienced flooding lasting more that 672 hrs (28 days) for 4.6% of the total flooding events at station 9 and 3.7% at station 3, while neither reference area experienced a flooding event of this duration. This prolonged flooding event occurred October 3 through November 27, 1996 as water overtopped Magnolia Road and the northern levee of CTU 2.

Salinity: Discrete salinity values represent means from 4 stations in reference area 1, 4 stations in reference area 2, and 9 stations in CTU 2. Both reference areas experience higher salinity values than the project area (CTU 2) due to tidal exchange from the Gulf of Mexico via the CSC (figure 8). Salinity trends in the project area follow those in the reference areas to a lesser magnitude. Typically, all three areas experience highest salinities from August to October. However, the drought of 1996 caused salinities to elevate due to persistent strong southerly winds and tides. Evaporation of the high saline water may have caused soil salinity to increase, further stressing emergent vegetation already under drought stress.

Daily means of continuous salinity values in the project and reference areas are presented in figures 9 and 10. Continuous water salinity data were analyzed to determine if the project and reference areas differed in variability of water salinity during nondrawdown periods. Significant differences occurred among the areas over time ($F_{25,183}$=2.66 , P= 0.0001). Graphical examination of these data indicate that salinity was less variable in the project area than the reference areas during seven of the fifteen months that data were collected (figure 11). Salinity was more variable in the project area than in the reference areas during only one month, August 1997.

Elevation and Accretion: Vertical accretion was at least twice as great in the reference area as in the project area during each sampling period (table 7). Significant differences were detected between the project and reference areas during all three sampling periods, December 1996 (T_{147} = -5.8461, P = 0.0001), July 1997 (T_{379} = 11.7894, P = 0.0001), and December 1997 (T_{248} = -13.2260, P = 0.0001). Accretion increased from December 1996 to July 1997 in both the project and reference areas, although significant differences were detected only in the reference area (T_{281} = -5.7670, P = 0.0001). Accretion also decreased in both the project and reference areas from July 1997 to December 1997, but significant changes were occurred only in the project area (T_{321} = 3.301, P = 0.0011).



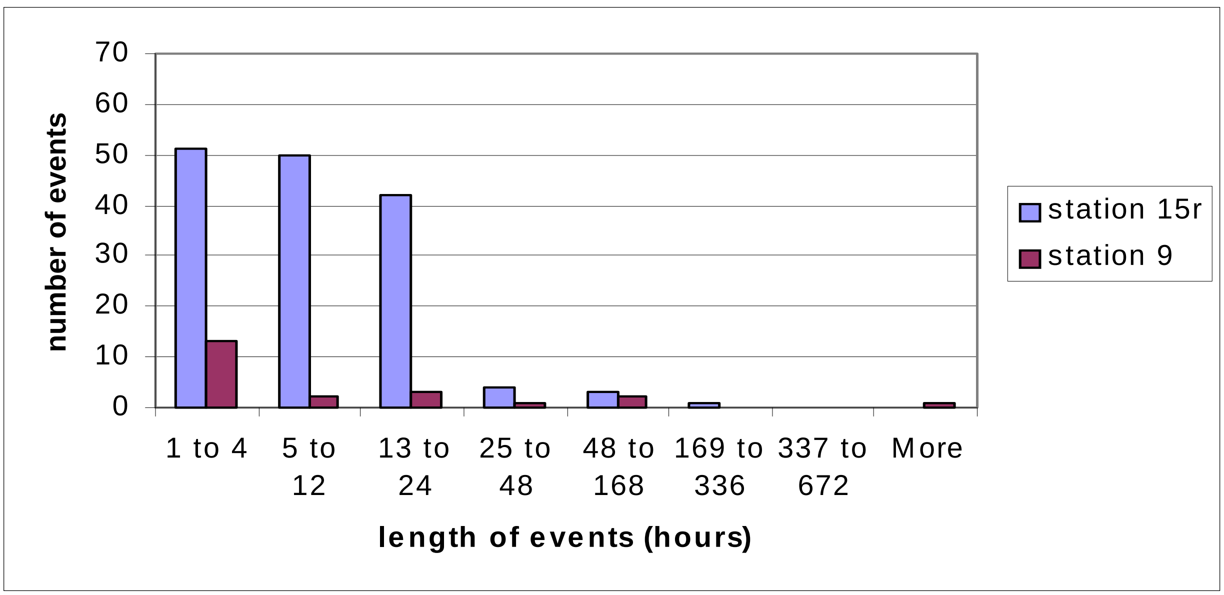


Figure 7. Duration of flooding events in the southern portion of CTU 2 (station 3) and reference 2 (station 14R) and the northern portion of CTU 2 (station 9) and reference 1 (station 15R).

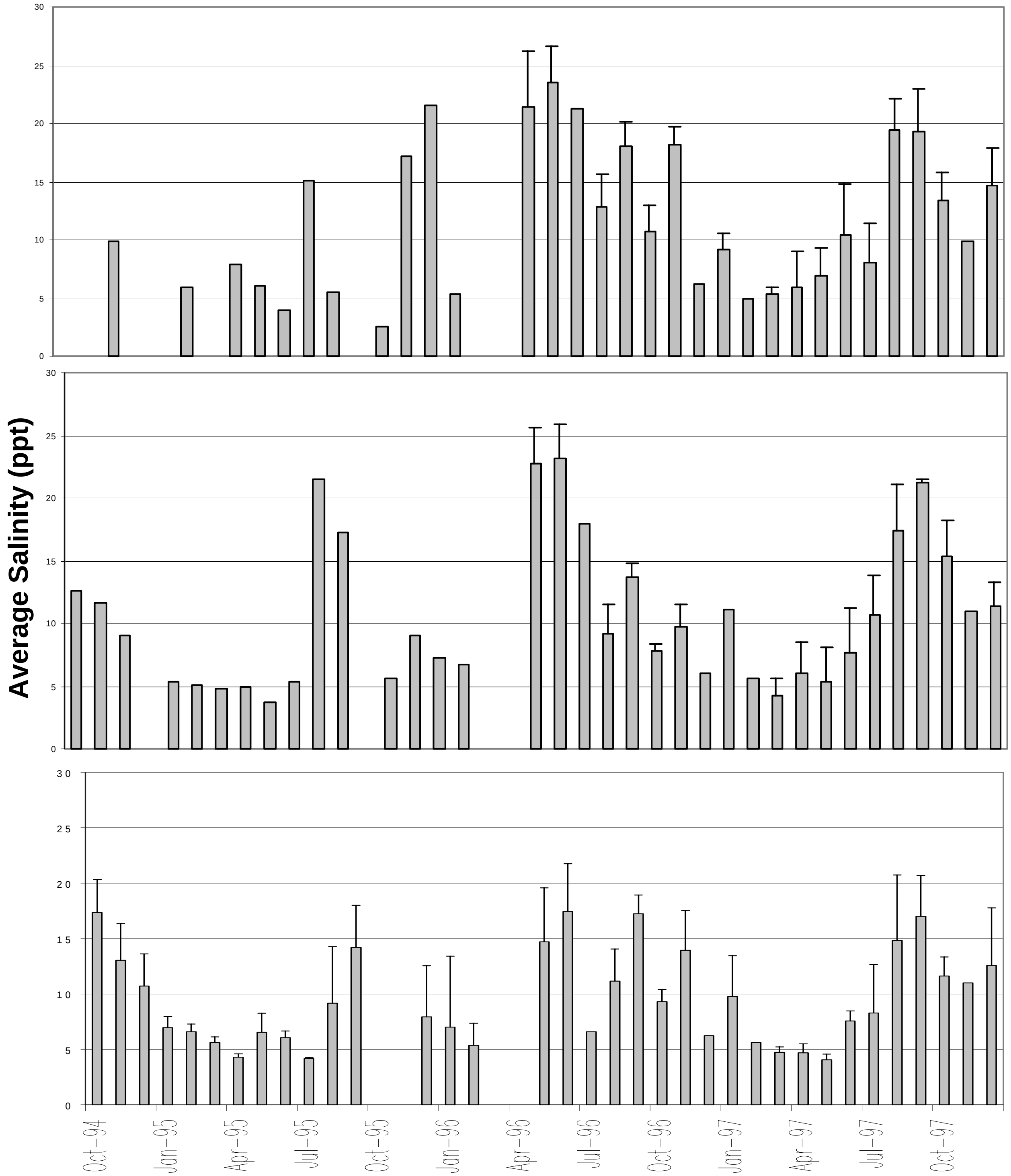


Figure 8. Mean salinity values from monthly discrete data collected October 1994 to December 1997 for reference 1, reference 2 and CTU 2, from top to bottom at East Mud Lake.

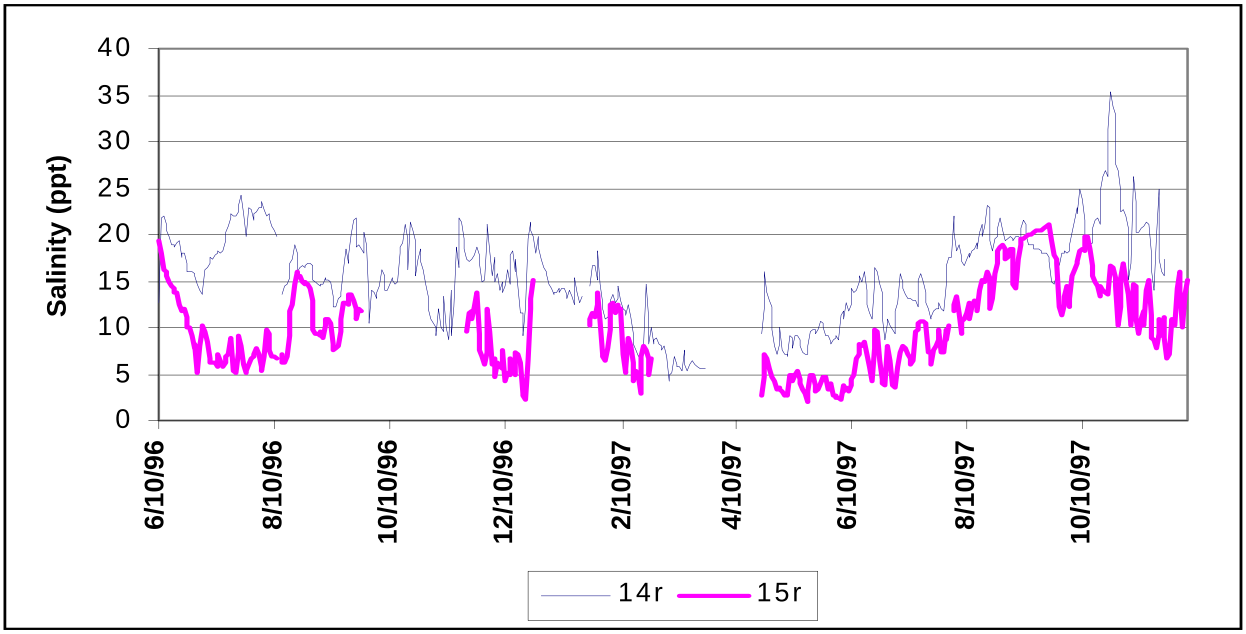


Figure 9. Mean daily salinity in reference areas 1 (14R) and 2 (15R), at East Mud Lake.

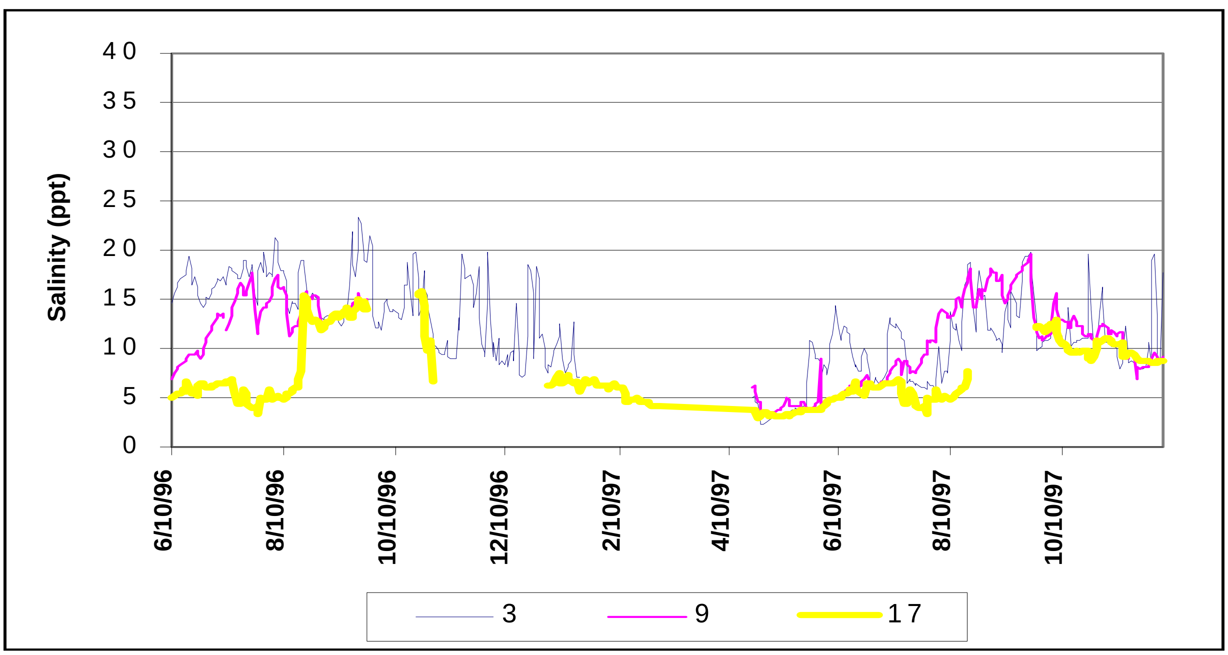


Figure 10. Mean daily salinity values at stations 3, 9, and 17 inside CTU 2 at East Mud Lake.

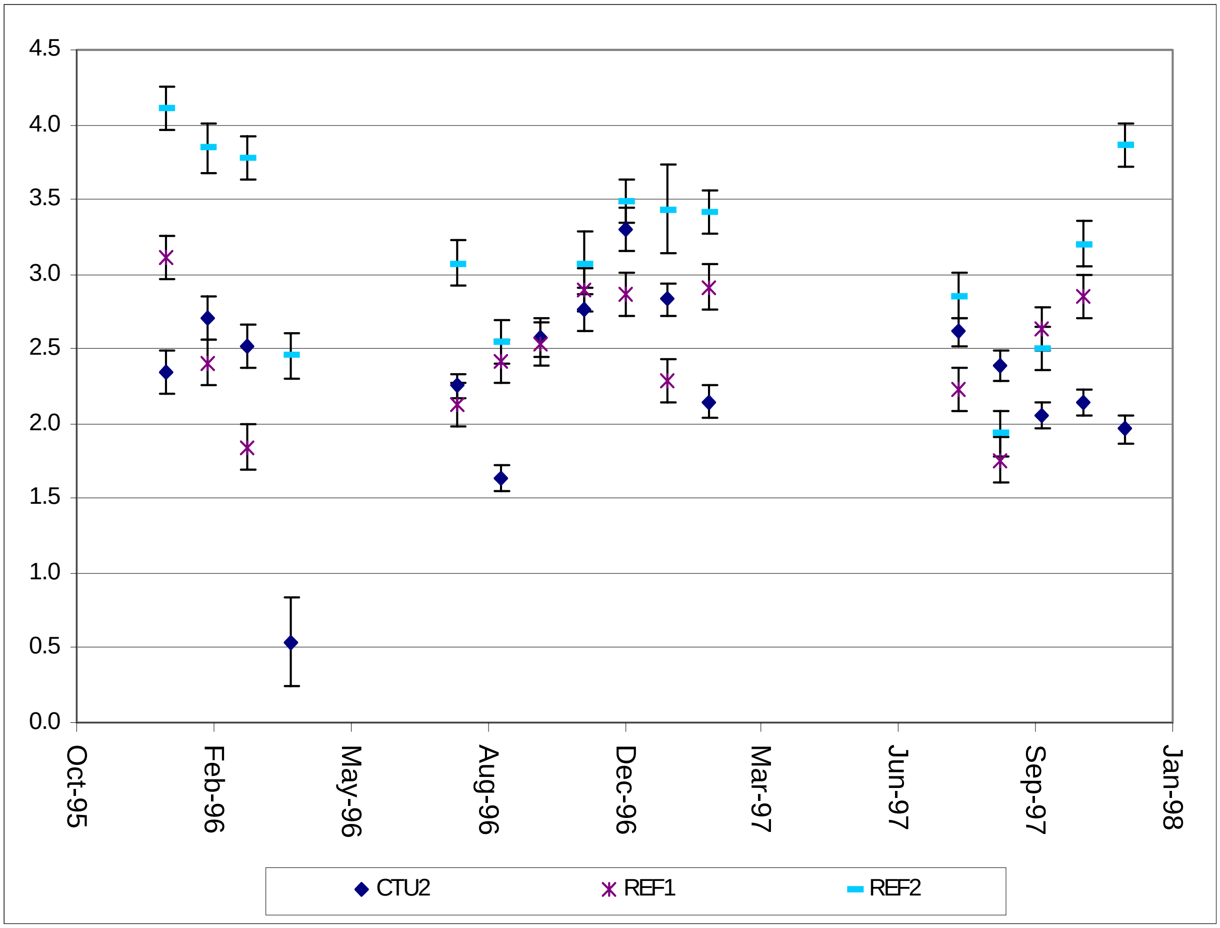


Figure 11. Salinity variability of the project and reference areas from the log transformation of the coefficient of variability of weekly salinity data at East Mud Lake.

Table 7. Mean (standard error) of accretion in mm measured at 20 sites in the project area and 20 in the reference area at East Mud Lake (C/S-20).

	Project Area		Reference Area	
December 1996	n = 18	11.19 (3.14)	n = 30	30.6 (5.32)
July 1997	n = 68	17.07 (3.13)	n = 76	52.12 (5.33)
December 1997	n = 65	12.30 (1.33)	n = 59	56.77 (6.48)

Table 8. Elevation change (cm) in project and reference area marshes as determined with Sediment Erosion Tables (SET's) at East Mud Lake (C/S-20). Each value is the least square mean (least square standard error) of 36 pins from 5 SET stations, except for December 1995 when only 4 SET stations in each area were used.

	Project Area	Reference Area
change from December 1995 to July 1996	-1.7 (1.0)	-1.6 (1.0)
change from December 1995 to December 1996	-1.9 (0.6)	-1.0 (0.6)
change from December 1995 to July 1997	-1.4 (0.5)	-0.8 (0.5)
change from December 1995 to December 1997	-1.9 (0.7)	-0.9 (0.7)

Data collected with SET's indicated that elevation in the project and reference areas declined during the drought of 1996 and has yet to completely recover (table 8). No difference was detected between the project and reference area in elevation change during the entire 22 month observation period, except for a temporary difference between December 1996 and July 1997 ($F_{1,9} = 8.45$, $P = 0.0174$). Fisheries: Animals are grouped as fish and decapod, transient and resident species (tables 9 and 10). Transients are species that spawn in nearshore or offshore waters and use shallow estuarine habitats as nursery areas. Resident species spend most of their life cycle within the estuary. The most abundant resident fisheries species include *Poecilia latipinna* (sailfin molly), *Gambusia affinis* (western mosquitofish), and *Cyprinodon variegatus* (sheepshead minnow), while *Brebortia patronus* (gulf menhaden), *Menidia beryllina* (inland silversides), and *Anchoa mitchilli* (bay anchovy) represent the most abundant transient fisheries species. The most abundant resident decapod species include *Palaemonetes intermedius* (brackish grass shrimp), and *P. pugio* (daggerblade grass shrimp), while *Penaeus setiferus* (white shrimp), *P. aztecus* (brown shrimp), and *Callinectes sapidus* (blue crab) represent most abundant transient decapod species. Data have been partially analyzed and will be presented in the comprehensive report on May 1, 1999.

Table 9. Fisheries totals of resident and transient fish species for all sampling periods in the project and reference areas at East Mud Lake.

	Fish					
	Resident			Transient		
	Project	Reference	Total	Project	Reference	Total
Preconstruction						
June 1995	8	11	14	1	8	8
October 1995	5	3	5	1	3	3
April 1996	5	3	8	1	1	8
Postconstruction						
October 1996	8	6	9	1	1	1
March 1997	3	2	6	3	1	4
April 1997	3	5	9	1	6	8
September 1997	9	9	12	1	3	5

Table 10. Fisheries totals of resident and transient decapod species for all sampling periods in the project and reference areas at East Mud Lake

	Decapod					
	Resident			Transient		
	Project	Reference	Total	Project	Reference	Total
Preconstruction						
June 1995	1	1	1	1	1	1
October 1995	1	1	1	1	2	2
April 1996	1	1	1	1	1	1
Postconstruction						
October 1996	1	1	1	2	2	2
March 1997	3	1	4	2	1	2
April 1997	2	2	4	2	2	2
September 1997	3	4	4	2	3	3

Discussion

Vegetative Plantings: High survival rates (90%) were detected in the canal plantings despite heavy herbivory from cattle along the eastern levee. Lower survival rates (45.6%) were detected in plantings along the newly refurbished step levee. The surviving plants appear to be10-15 ft from the shoreline of the levee, which may have settled over time. At this distance, water levels are high and plants remain inundated except in the lowest water conditions. Low survival (15%) in the East Mud Lake lakeshore plantings most likely resulted from high wave energy from the long fetch across the lake.

Existing Vegetation: Lower cover values of dominant species such as *S. patens* and *S. alterniflora*, and an increase in opportunistic species such as *A. subulatus* and *P. vaginatum* in both areas probably resulted from the drought. *Spartina patens* does not tolerate waterlogging and is replaced by *D. spicata* in poorly drained soils. *Paspalum vaginatum*, a perennial edge species, benefitted from the low water conditions and spread along pond edges ranging from 2-15 ft (0.6 - 4.6 m) into the interior of many ponds in CTU 2 of the project area and in the reference area (personal observation). The data from vegetation plots did not adequately reflect the increase in abundance of this species since plots are generally not located on pond edges. If increased coverage by *P. vaginatum* persists, then future analyses of aerial photography may detect decreases in water area.

Water quality: Flooding stress followed the drought event in the project area in the fall of 1996, when a flooding event lasting from October 3 to November 27 resulted from prolonged rains and high tides. Analysis of water level and salinity data from this time indicated that water levels averaged 1.4 ft (0.4 m) over the marsh surface and salinity averaged 13.6 ppt in the project area, while water levels and salinity averaged 0.8 ft (0.2 m) above the marsh surface and 10.4 ppt in reference area 2. This event may have further aggravated damaged root systems, causing anoxic conditions in the soil, when coupled with high salinities, results in root oxygen deficiencies, decreased nutrient uptake and a buildup of sulfides in the soil (Mendelssohn and McKee 1989). Water levels during this time were lower outside the project area, although they were above marsh level more than 50% of the time, impeding drainage as indicated by water levels averaging 0.3 ft above the marsh surface in reference area 1, where salinity averaged 15.6 ppt.

Elevation and Accretion: The decrease in elevation from July and December 1996 may be the result of soil compaction coupled with decreased sediment load through the marsh resulting from the drought of April through July 1996. Reabsorption of water to soil particles may have been achieved by July 1997, when elevation increased in both the project and reference areas. The project area experienced a greater loss in elevation during the drought than the reference area because soils in the reference area did not dry out completely as did soils in the project area. A prolonged flooding event of October 3 through November 27, 1996, occurred as water overtopped Magnolia Road and the northern levee of CTU 2. When Magnolia Road was overtopped again in April 1997, additional sediment may have been introduced into the project area offsetting the loss of sediment input due to drawdown.

Conclusions

Extreme weather conditions in the form of a six month drought and a month long period of heavy rain and high water levels were prevalent in Cameron Parish during the first year after construction of the project. The drought caused drying, cracking, and compaction of the soil surface in the project area at periods when water salinity was high, increasing soil salinities. Following the drought, high water levels of 1.4 ft AML with average salinity of 13.6 ppt inside the project area may have further damaged emergent vegetation as well as recent plantings of *S. alterniflora*. Emergent vegetation of the broken marsh on the low, fluid Bancker soils in the southern portion of the project area experienced a dramatic decrease in cover values due to these stressors. As *S. patens* cover decreased, opportunistic species such as *P. vaginatum* and *Aster* spp. increased. These sudden environmental changes leading to loss of marsh vegetation may reduce the potential for the marsh accretion rate to keep pace with subsidence and sea level rise since vertical accretion in marshes is dependent upon the accumulation of organic matter (Mendelssohn and McKee 1989).

Water levels were low a large percentage of the post-construction period due to two consecutive drawdown years. However, water levels appear to remain higher, and flooding events remain longer in the project area compared to both reference areas. The drought may have lowered marsh elevation, especially in the low soils, causing ponding to occur. A change in structure operations may be necessary to exit water from CTU 2 to prevent further damage to vegetation.

Although no statistical difference in elevation change existed as of the most recent sampling, it is possible that an ecological difference exists. This possibility that the project area has lost one more centimeter of elevation than the reference area suggests that additional drawdowns should perhaps be postponed until estimates of elevation change indicate complete recovery from the drought of 1996 and the subsequent drawdown.

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Construction Start:	January 1, 1996
Construction End:	May 1, 1996