State of Louisiana

Coastal Protection and Restoration Authority of Louisiana (CPRA)

2015 Operations, Maintenance, and Monitoring Report

for

East Mud Lake Marsh Management (CS-20)

State Project Number CS-20
Priority Project List 2

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Cameron Parish

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Preface

The 2015 OM&M Report format combines the Operations and Maintenance annual project inspection information with the Monitoring data and analyses for the project. This report includes monitoring data collected through December 2014 and annual Maintenance Inspections through June 2014. The East Mud Lake Marsh Management Project (CS-20) is sponsored by the United Stated Department of Agriculture/National Resources Conservation Service (NRCS) under the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA, Public Law 101-646, Title III, Priority Project List 2).

The 2015 report is the 4^{th} and final in a series of OM&M reports. For additional information on lessons learned, recommendations, and project effectiveness refer to previous OM&M reports (2007, 2010, and 2013), annual O&M inspection reports (2005-2014), progress reports (four early monitoring, 1996-1999), and comprehensive monitoring reports (2000 and 2005) on the CPRA web site (http://lacoast.gov/new/Projects/Info.aspx?num=CS-20).

I. Introduction

The East Mud Lake Marsh Management Project (CS-20) area consists of 8,054 acres (3259 ha) located in the Calcasieu/Sabine Basin in Cameron Parish, Louisiana (Figure 1). The project is bounded by LA Hwy 27 to the west, Magnolia Road to the north, and an existing levee and property lines to the south and near Oyster Bayou to the east. The CS-20 project area has three wetland habitat types: Deep, Shallow, and Meadow Marsh (USDA-SCS 1951).

Tidal flow into and out of the project area has historically been from the north (LCWCRTF 2002) while Mud Pass and Oyster Bayou provide outlets from the area to the east. These tidal flows are hydrologically connected to the Lake Calcasieu. Fresh water historically entered the area from the west via sheet flow and input from First and Second Bayous; however, the installation of LA Hwy 27 and its associated borrow canals has restricted freshwater input from the west (Figure 1). Second Bayou has silted in since 1957 and now provides little or no freshwater flow. First Bayou remains the main source of freshwater introduction into the area; however, it is also silting in, and much of the remaining fresh water is diverted by the LA Hwy 27 borrow canal. Therefore, adjacent marshes to the west freshened to intermediate marsh over time (Chabreck et al. 1968, Chabreck and Linscombe 1988) while the project area had remained brackish prior to project construction.

Several human induced hydrologic changes have increased tidal fluctuations further into the coastal wetlands and led to the deterioration of the marsh over the years on a basin-wide scale, highlighted by the installations and channel bottom maintenance of the Calcasieu (permanently opened to the Gulf of Mexico in 1903, deepened to 30 ft and widened to 250 feet in 1941, deepened to 40 ft [12.2 m] and widened to 400 ft [122 m] over time to current dimensions by 1968) and Sabine-Neches (commissioned to 9 ft [2.7 m] deep and 100 ft [305 m] wide in 1908, deepened to 25 ft [7.6 m] in 1916, deepened to 40 ft [12.2 m] and widened to 400 ft [122 m] over time to current dimensions in 1972) Ship Channels and the Gulf Intracoastal Waterway between the Sabine and Calcasieu Rivers (5 ft [1.5 m] deep by 40 ft [12.2 m] wide channel installed 1913-1915, deepened to 30 ft [9.1 m] and widened to 125 ft [38 m] in 1927, depth maintained at 12 ft [3.7 m] since 1949) (see LCWCRTF 2002).

Specific to the project area, Mud Lake and its adjacent marshes suffer from increased flooding and salinity via the Calcasieu Ship Channel/Pass and isolation/fragmentation from adjacent marshes. The project area is connected to the Calcasieu Ship Channel (CSC) via Mud and Oyster Bayous to the east and the West Cove Canal to the north. Because the CSC/Pass has been maintained without obstruction since 1968, high tidal amplitudes and salt water from the Gulf of Mexico are drawn into the project area. In addition, high water levels are impounded over the marsh and are slow to recede in this area because of LA Highways 82 to the south and 27 to the west, the levees demarking property lines to north, east, and south, and several ring levees and roads within the project area. This combination of sustained high water levels and increased salinity stress has deteriorated the vegetation and led to "ponding" (USDA-SCS 1994). In addition, the subsidence rate and sea level rise has led to a 0.25 inch (0.64 cm) water level increase per year from 1942-1988 (Penland et al. 1989) which results in even less suitable conditions for vegetative production. The percent of land has deteriorated from 99% in 1953 to 57% by 1992 (USDA-SCS 1992).

The East Mud Lake Marsh Management Project (CS-20) is designed to reduce the extreme fluctuations in salinity and water levels while providing adequate water flow to create a hydrology conducive to the establishment of brackish vegetation to minimize marsh deterioration while not creating tidal scour problems (Louisiana Coastal Wetlands Conservation and Restoration Priority List, 1992). Vegetative plantings will help stabilize and protect eroding shorelines. CS-20 involves installing and maintaining water control structures, repairing and constructing levees, and planting vegetation, as components of a marsh management plan for the two, independently managed Conservation Treatment Units (CTU) that make up the project area. CTU #1 contains Mud Lake and is managed passively; Structures and features present in this unit consist of shoreline repair, vegetative plantings, earthen plugs, culverts with flapgates, and variable crest culverts. CTU #2 is actively managed for drawdown capabilities with flapgated, variable crest culverts and a variable crest box structure in order to encourage shallow areas to revert to emergent vegetation (Figure 1). This area also had levee repair and vegetative plantings. Construction in both CTUs was completed in June 1996.

The types and numbers of structures and features of the project are as follows:

1.	Variable Crest Culverts with Flapgates	6
2.	Variable Crest Culverts With Slots	3
3.	Gated Culvert	1
4.	Culverts with Flapgates	5
5.	Variable Crest Box Structure	1
6.	Earthen Plugs	2
7.	Shoreline Repair (Total = 25,153 cubic feet of dredged material)	2
8.	Levee Repair (66,461 cu yds of dredged material needed to shore up the step levee on the north, east, and southeast sides of CTU#2)	1

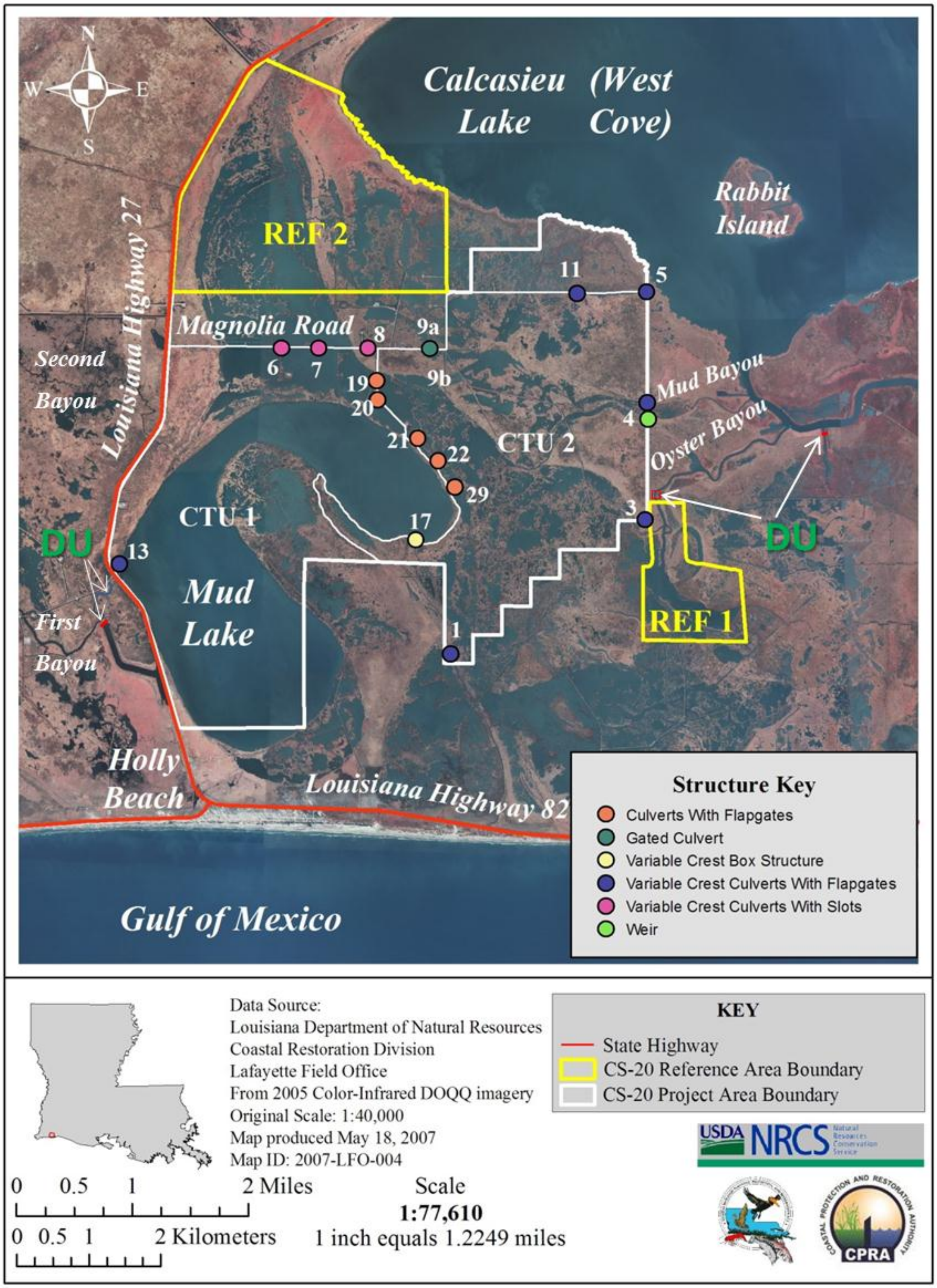


Figure 1. East Mud Lake (CS-20) project map depicting project boundaries, conservation treatment unit boundaries, reference area boundaries, and project features. Also included are Ducks Unlimited, Inc. (DU) projects to water inflows to the west and east of the project area.

II. Maintenance Activity

a. Project Feature Inspection Procedures

The purpose of the annual inspection of the East Mud Lake Marsh Management Project (CS-20) is to evaluate the constructed project features to identify any deficiencies and prepare a report detailing the condition of project features and recommended corrective actions needed. Should it be determined that corrective actions are needed, CPRA shall provide, in the report, a detailed cost estimate for engineering, design, supervision, inspection, and construction contingencies, and an assessment of the urgency of such repairs (O&M Plan, 2004). The annual inspection report also contains a summary of maintenance projects which were completed since completion of constructed project features and an estimated projected budget for the upcoming three (3) years for operation, maintenance and rehabilitation. The three (3) year projected operation and maintenance budget is shown in Appendix B. A summary of past operation and maintenance projects completed since completion of the Mud Lake Project are outlined in Section II.d below.

The last inspection of the East Mud Lake Marsh Management Project (CS-20) was held on June 11, 2014 under clear skies and hot temperatures. In attendance were Stan Aucoin, Darrell Pontiff and Tommy McGinnis from CPRA, Dustin Perron representing NRCS, and Scott Rosteet and Tim Allen representing Apache Corporation. The annual inspection began at approximately 10:35 a.m. at Structure # 6 and ended at Structure #13 at approximately 1:50 p.m.

The field inspection included a complete visual inspection of most of the project features. Conditions of features not inspected on this visit were verified by Mr. Scott Rosteet of Apache Louisiana Minerals, Inc. Staff gauge readings where available were used to determine approximate elevations of water, rock weirs, earthen embankments, steel bulkhead structures and other project features. Photographs were taken at each project feature (see Appendix A) and Field Inspection notes were completed in the field to record measurements and deficiencies (see Appendix C).

b. Inspection Results

<u>ES-6 –2-36" culverts with stop logs, and a 4” fish slot</u>

Structure No. 6 remains in very good condition. The timber piles, stop logs, grating, etc. are in good condition. (Photos: Appendix A, Photo 1).

<u>ES-7 – 2-36" culverts with stop logs, and a 4” fish slot</u>

Structure No. 7 is also in very good condition. The timber piles, stop logs, grating, etc. are in good condition. Water levels at this structure were +1.4 on the outside and +1.5 on the inside. (Photos: Appendix A, Photo 2).

ES-8 – 2-36" culverts with stop logs, and a 4" fish slot

Structure No. 8 is in very good condition. The timber piles, stop logs, grating, etc. are in good condition. (Photos: Appendix A, Photo 3).

ES-9a –1- 36" culvert w/ stop logs & flap gate

Structure No. 9a is in good condition and functioning as intended. (Photos: Appendix A, Photos 4 & 6).

ES-9b – 1- 48" culvert w/ sluice gate and flap gate

Structure No. 9b is in good condition. Vandals have broken the flapgate lifting arm. This will be one of the items addressed with the proposed maintenance event. Apache has filed a police report. The structure is still functional and all other components are in good shape. Water levels were ~+1.47 on the inside and ~ =1.49 on the outside however water was flowing out. These staff gauges will need to be verified. (Photos: Appendix A, Photos 5 & 6).

ES-11 – 1- 36" culvert w/ stop logs & flap gate

The structure is in good condition. Rock has stabilized the bank on both sides of the structure. The handle on the flap is bent to the point that it hangs up in the receiver when in the open position, however it is still functional. (Photos: Appendix A, Photos 7 & 8).

ES-5 –1- 36" culvert w/ stop logs & flap gate

The structure itself is in good condition. Rock placed here continues to work very well. (Photos: Appendix A, Photo 9 & 10).

ES-4 – 5- 48" culverts w/ stop logs & flap gates

This structure was completely replaced with a new 48 inch diameter five barrel drainage structure, including timber supports, and rock armoring. The pre-existing structure No. 4 was abandoned in place by driving steel sheet piles through the mid-section of the culverts. The dirt placed on top of the new structure has continued to settle. The sinkholes that developed on the stoplog side of the structure and have worsened, but the anti-seep collar is still in place and functioning. They will continue to be monitored. Two of the locks were missing from the stoplog locking devices but the stoplogs were still in place. The four large stoplogs that were stolen previously will need to be replaced. Timber is still missing from the boat barrier and will also need to be replaced. (Photos: Appendix A, Photos 11 - 14).

ES-3 – 1- 36" culvert w/ stop logs & flap gates

This is also a pre-existing structure that was incorporated into the CS-20 Project. Walkways are in excellent shape. Rock placed around the structure has stabilized the banks. (Photos: Appendix A, Photos 15 & 16).

ES-1 – 1- 36" culvert w/ stop logs & flap gates

This structure is in good condition. Walkways have been tacked into place. No vandalism at this structure. Rock has stabilized the banks. (Photo: Appendix A, Photos 17 & 18).

ES-17 – variable crest weir w/ boat bay

Erosion around both sides of this structure has continued. There is water exchange on both sides. The sheet pile cap rust is extensive. The hardware for lifting the stoplogs is still in place and in fairly good shape. In order to be able to perform any other drawdowns in the future, significant maintenance will be required on this structure. (Photo: Appendix A, Photos 19 & 20)

ES-13 – sheet pile bulkhead w/ 2 variable crested weirs & flap gates

The flaps are broken on both bays of this structure and were tied in place by Apache. The rest of the structure, sheet piles, caps, signs, etc. are in very good condition. Maintenance will be required to repair the flaps. (Photos: Appendix A, Photos 21 - 24).

ES-19, 20, 21, 22, & 29 – 24" culverts w/ flap gates

These structures were not directly inspected on this inspection as agreed jointly by CPRA and NRCS personnel. According to Mr. Rosteet, they are in working order and functioning as designed. CPRA and NRCS agree that no maintenance is required at this time.

ES-29a – earthen plug

Due to logistics, this plug also was not directly inspected on this trip. According to Mr. Rosteet, it is stable and functioning as designed. CPRA and NRCS agree that no maintenance is required at this time.

ES-14 - 15 – 5,000 linear feet of earthen embankment on E. Mud Lake

See ES-29a comments.

40,600 linear feet of Levee Refurbishment along the Step Canal

The inspection of the earthen levee consisted of a visual inspection of most of the levee along the Step Canal. Apache has made us aware of a few spots along the way that has settled somewhat, but the exact locations were not identified on this trip. These spots are slightly low or thin but still functional.

c. Maintenance Recommendations

i. Immediate/ Emergency Repairs

ii. Programmatic/ Routine Repairs

Minor maintenance will be performed on Structures No. 4, No. 9, and No. 13. Structure No. 17 will need to be removed and rebuilt.

d. Maintenance History

<u>General Maintenance:</u> Below is a summary of completed maintenance projects and operation tasks performed since April 1996, the construction completion date of the East Mud Lake Marsh Management Project (CS-20).

December-1999 LDNR: This maintenance project included the installation of approximately 600 tons of stone riprap around Structure #4, aluminum fabrication and installation of flap gate lifting devices and a stop log channel repair at Structure #4, approximately 950 linear feet of earthen levee repair, and placement of approximately 100 tons of stone riprap at Structures 6, 7, 8, 9a & 9b. Construction was completed in December 1999. The costs associated with the engineering, design and construction of the East Mud Lake Maintenance Project are as follows:

Construction:	$113,848.21
Engineering & Design:	$ In house
Construction Oversight/As built surveys:	<u>$ 11,902.28</u>
TOTAL CONSTRUCTION COST:	**$125,750.49**

(Does not include costs associated with in-house design.)

March 2010 M&M Electric: This maintenance project included complete replacement of Structure No.4 (five barrel 48 inch diameter structure, 2,300 tons of 30# class rock) and general repairs with 30# class rock installation at Structure Nos. 1, 3, 5, 6, 7, 8, and 11. Total rock placement at all of these structures was approximately 1,500 tons. Other maintenance included repairs to structure 9a & 9b (gear box, flap gate) and 175 LF of pile cap replacement at structure No.13. Construction was completed in February 2011. The costs associated with the engineering, design and construction of the 2010 East Mud Lake Maintenance Project are as follows:

Engineering & Design:	$ 116,307.00
Construction:	$1,415,327.00
Construction Oversight/As built surveys:	<u>$ 121,890.00</u>
TOTAL CONSTRUCTION COST:	**$1,653,524.00**

December, 2011 Simon & Delany, LLC: This event was a PO issued to Simon & Delany for the replacement of stoplogs that were stolen from Structure 4.

TOTAL COST	**$2,600.00**

III. Operation Activity

a. Operation Plan

The project area is divided into Conservation Treatment Unit (CTU) #1 and CTU #2. Operational plans and procedures for CTU #1 are designed to stabilize salinity and water levels. Operational plans and procedures for CTU #2 are designed to expose mud flats for seed germination and planting (Phase I, 1996-1997). Once vegetative plantings are established, operations and procedures for CTU #2 are designed to gradually increase water levels to maintain and enhance vegetative growth for optimum waterfowl and furbearer utilization and to stabilize salinity (Phase II, 1998-present).

CTU #1 – Water Management Scheme – January 1, 1996 to present

1. Structures ES-#6, ES-#7, and ES-#8 – The stop logs will be set no higher than 6-inches below marsh level. The vertical slots in the structures will remain open except to protect marsh vegetation during the periods of high salinity. These slots will be closed when salinity inside the marsh exceeds 15 ppt, 100 feet south of structure ES-#7.

2. Structures at ES-#13 (First Bayou) – Set stop logs 6-inches below marsh level. Lock flap gates open except when salinity exceeds 7 ppt in the road ditch on the west side of LA Highway 27 at the Drainage District's Structure.

CTU #2 – Water Management Scheme Phase I – Revegetation Phase 1a
February 15 – May 31 (or to July 15), 1996 and 1997

1. Remove all stop logs and allow flap gates to operate at structures ES-#1, ES-#3, ES-#4, ES-#5, ES-#9a, and ES-#11.

2. Screw gate open and allow flap gate to operate at structure ES-#9b.

3. Allow flap gates to operate at structures ES-#19, ES-#20, ES-#21, ES-#22 and ES-#29.

4. Set stop logs at 12-inches above marsh level at structure ES-#17.

CTU #2 – Water Management Scheme Phase I – Revegetation Phase 1b
May 31 (or July 15) – February 14 +/- 2 weeks, 1996 and 1997

1. Set stop logs 6-inches below marsh level and lock flap gates open at structures ES-#1, ES-#3, ES-#4, ES-#9a and ES-#11.

2. Set the weir crest of one 5-foot wide bay at 12-inches below marsh level and the crest of the other 5-foot wide bay at 6-inches below marsh level and lock flap gate open at ES-#5.

3. Screw gate open and lock flap gate open at structure ES-#9b.

4. Lock flap gates open at ES-#19, ES-#20, ES-#21, ES-#22 and ES-#29.

5. Remove all stop logs at structure ES-#17.

CTU #2 – Water Management Scheme Phase II – Maintenance Phase
January 1, 1998 to present

1. Set stop logs 6-inches below marsh level and lock flap gates open at structures ES-#1, ES-#3, ES-#4, ES-#9a and ES-#11.

2. Set the weir crest of one 5-foot wide bay at 12-inches below marsh level and the weir crest of the other 5-foot wide bay at 6-inches below marsh level and lock flap gates open at structure ES-#5.

3. Screw gate open and lock flap gate open at structure ES-#9b.

4. Lock flap gates open at structures ES-#19, ES-#20, ES-#21, ES-#22 and ES-#29.

5. Remove all stoplogs at structure ES-#17.

Safety Provisions

1. Storms: Immediately following heavy rain storms or tidal surges, all gates and weirs shall be opened as needed, to provide normal gravity drainage for the area as well as to protect the integrity of the levee system.

2. Water Salinity: Water salinity will be managed to maintain the area as brackish marsh. To protect marsh vegetation during periods of high salinity, the ingress gates will be closed when salinity inside CTU #2 exceeds 15 ppt at ES-#3 or ES-#5. The water salinity provision is adaptable to long-term weather conditions such as drought; at which time, the structures will be adaptively managed as agreed upon by the landowner (Apache Louisiana Minerals, Inc.) and CPRA.

b. Actual Operations

Effective January 1, 2013, a Cooperative Endeavor Agreement was established between CPRA and Apache Louisiana Minerals, Inc. for the operation of the structures at a cost of $6,500/year for the remaining life of the project. In accordance with the operation schedule outlined in the Operation and Maintenance Plan and USACE Permit, structures were manipulated as required by Apache Louisiana Minerals, Inc. personnel who are under contract with CPRA (Table 1). Copies of the quarterly reports that are provided as well as a copy of the operations contract between CPRA and Apache Louisiana Minerals, Inc. are attached in the “Structure Operations” section of the CS-20 East Mud Lake Marsh Management Operation & Maintenance Plan.

Table 1. Summary structure operations since 2005 compiled from reports delivered by the land owner of CS-20, Apache Louisiana Minerals, Inc. Stoplogs are typically set at 0.5’ below marsh level (BML).

Date	CTU 1 Structure (ES 6, 7, 8, 13)	CTU 2 Structures (ES 1, 3[a], 4[b], 5, 9, 11)	Remarks
7/15/2005	Stoplogs at 0.5’ BML	Flaps Closed	
9/25/2005	Hurricane Rita - Not able to lock flaps after Hurricane Rita		
10/10/2005	Removed all stop logs to drain storm surge except ES3 & 4 b/c debris		
4/3/2006	Stoplogs replaced to 0.5’ BML after storm drainage. ES 3 & 4 still damaged.		
9/29/2006	Hurricane Rita debris removed from ES 6, 7, 8, and 9.		
1/30/2007	Stoplogs at 0.5’ BML	Flaps Locked Open	Flush CTU 2 with low salinity water
3/20/2007	Stoplogs at 0.5’ BML	Stoplogs removed	
5/16/2007	Stoplogs at 0.5’ BML	Stoplogs returned and Flaps Closed	
3/4/2008	Stoplogs at 0.5’ BML	Flaps Locked Open	Flush CTU 2
3/12/2008	Stoplogs at 0.5’ BML	ES3 Closed; All Others Open	
Thru 4/7/2009	No operation changes during Hurricane Ike. Flaps have remained open to encourage water exchange (flushing) despite salinity > 15 ppt.		
4/8/2009	Stoplogs at 0.5’ BML	ES3 Opened; All Others Remained Open	
6/3/2011	ES7A Fish Slot Closed; ES13 Remains Open	ES4 Open; All Others Were Closed	High salinity
6/27/2012	ES13 Closed	No Change	Sustained high salinity (>15 ppt)
1/25/2013	ES13 Opened	No Change	Sustained low salinity (<15 ppt)
9/26/2014	No Change	No Change	End of Record

[a]Structure 3 was damaged during Hurricane Rita; the flap gate was ajar with low water flow. Structure 3 was repaired in February 2011.

[b]Structure 4 was partially sunken prior to Hurricane Rita, partially functioning, and vandalized to keep flaps open for shrimping. Structure 4 was replaced in February 2011.

IV. Monitoring Activity

Pursuant to a CWPPRA Task Force decision on August 14, 2003 to adopt the Coastwide Reference Monitoring System-*Wetlands* (CRMS) for CWPPRA, updates were made to the CS-20 Monitoring Plan to merge it with CRMS-*Wetlands* and provide more useful information for modeling efforts and future project planning while maintaining the monitoring mandates of the Breaux Act. There are two CRMS sites in the CS-20 project area (CRMS0672 and CRMS0655) and references are made to basin-marsh type (Cal/Sab-brackish marsh) scale averages of CRMS sites. Given the age and rigorous monitoring design for CS-20, CRMS data (which only begins in 2006) will be used to provide a regional scale context where applicable.

Monitoring funds for CS-20 expired ahead of schedule causing monitoring activities to be discontinued in February 2010. Critical project structure repairs and hydrologic modifications in bayous connected to the project (First Bayou to the west and Oyster Bayou to the east) were completed in 2010 which validated continued and extended monitoring. Debris was removed from Structure 3, and Structure 4 was replaced with a much larger structure. Ducks Unlimited, Inc. (DU) cleaned First Bayou and plugged its connection to a canal which will allow more, and typically less saline, water to drain into East Mud Lake from the west. To the east, DU restricted the channel in Oyster Bayou and plugged a location canal to restrict tidal flow from the Calcasieu Ship Channel (Figure 1). Pursuant to conditions for receiving additional funds through the CWPPRA Technical Committee Task Force on October 13, 2010, the Coastal Protection and Restoration Authority of Louisiana (CPRA, formerly LDNR) and the NRCS agreed to alter the terms of previous monitoring plans in accordance with the Cost Sharing Agreement No. 25085-94-05 Amendment No. 6 dated August 08, 2011. The Monitoring Plan was revised on April 29, 2011 to reduce costs for the remaining monitoring elements, mainly hydrology (Water Level and Salinity), while extending the sampling effort through 2014; revisions are detailed in the Monitoring Elements (IV.b.).

a. Monitoring Goals

The goals of the East Mud Lake Management Project are:

1. Prevent wetland degradation in the project area by reducing vegetative stress, thereby improving the abundance of emergent and submergent vegetation. This will be achieved through hydrologic structural management to reduce water levels and salinities.

2. Stabilize shoreline of Mud Lake through vegetative plantings.

The following objectives will contribute to the evaluation of the above objectives:

1. Decrease rate of marsh loss.

2. Increase vegetative cover along shoreline of East Mud Lake.

3. Increase coverage of emergent vegetation in shallow open water areas.

4. Increase abundance of vegetation in presently vegetated portions of project area.

5. Reduce water level and salinity fluctuations to within target ranges for brackish vegetation. Target range for salinities is less than or equal to 15 ppt and 6" below marsh level to 2" above marsh level for water levels.

6. Decrease duration and frequency of flooding over marsh.

7. Decrease mean salinity in Conservation Treatment Unit #2.

8. Increase accretion in Conservation Treatment Unit #2.

9. Maintain fisheries abundance.

b. Monitoring Elements

Habitat Mapping and Land to Water Change

Color infrared aerial photography (1;12,000 scale) obtained in December 1994, November 2000, November 2006, and October 2014 was classified photo-interpreted, and georectified to measure areas of and map habitat types in the project (CTU 1 and CTU 2) and reference (REF 1 and REF 2) areas pre-(1994) and post-(2000, 2006, 2014) construction by the United States Geologic Survey – National Wetlands Research Center (USGS-NWRC). An accuracy assessment comparing the GIS classification of 100 randomly chosen pixels to aerial photography determined an overall classification accuracy of 96%. In addition, USGS-NWRC produced habitat analysis maps of the project and reference areas from the classic habitat analyses of 1956, 1978, and 1988 (Appendix D). Twenty-seven habitat classifications were collated from habitat analyses for 1956-2014 and grouped into five functional and consistent classes for each area over time. Open Water included all open water classifications, mudflats, and aquatic vegetation. Marsh included all marsh classifications. Marshes were typically delineated into "Fresh", which never exceeded 1 acre, and "Non-Fresh" or "Salt" marsh; only in 1978 were marshes delineated to intermediate, brackish, and saline marsh. Wetland Scrub-Shrub is associated with higher elevations within marsh and was not delineated during 1956-1988 classifications. Upland Scrub-Shrub/Forest is typically associated with unmaintained oilfield infrastructure such as spoil banks, roads, and pads. Developed land is typically the result of active oilfield infrastructure and included Urban, Inert, Upland Barren, and Agriculture/Pasture (expanses of short grass in along roads and within oil pads) classifications.

Habitat classifications were combined into larger land and water categories. Unvegetated mudflats and aquatic vegetation were considered water and all else was grouped as land. For each time period, land area was calculated into percent land for the project and reference areas. Regressions of percent land over time were plotted and land change rates were calculated for each area. The regressions and rates were divided into historical pre-construction (1956-1994) and post-construction (1994-2014). The 1994-2000 and 2000-2006 Land-Water Change Analysis Maps, produced by NWRC, displays where change had occurred.

Vegetative Plantings

The *Spartina alterniflora* 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 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 high wave energy due to the long north-south fetch across the lake. To document planting success, 5% of the plants along the step levee and canal, and 5% of the plants along the East Mud Lake shoreline were sampled. Nineteen plots along the step levee, seventeen plots along the canal, and four plots along the shoreline, consisting of 10 plants spaced 5 ft (1.5 m) apart, were selected and sampled. Parameters measured included, 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 (305 m). The 1-mo, 6-mo, 1-year, and 4-year postplanting sampling was conducted in July 1996, December 1996, August 1997, and June 2000, respectively. A Kruskal – Wallis test was used to compare percent survival and percent cover of *S. alterniflora* among the three planting locations (step levee, canal, and lake shoreline) for each sampling time. Chi – Square tests were considered significant at $p< 0.05$.

Existing Vegetation

Stations 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 at equally spaced points along each transect line, for a total of 25 stations in CTU 2 (project area) and 20 stations in REF 2 (reference area), to obtain an even distribution of stations throughout the marsh (Figure 2). The number of stations decreased over time as a result of accidental damage (2 stations in CTU 2) and the revised monitoring plan (5 stations in CTU 2 where only vegetation had been collected in the past). Percent cover, height of dominant species, and species composition were monitored in 1.0 m^2 vegetation plots in 1995 and 1997, and in 4 m^2 plots in 1999 – 2012. Emergent vegetation data were collected in July 1995 (preconstruction) and after construction in July 1997, June 1999, July 2003, December 2005 (special post Hurricane Rita sample), June 2006, September 2007, September 2008, August 2009, and August 2012. Floristic Quality Index (FQI), a grading index based on the quality of species composition for a vegetation type and percent coverage of species, was calculated for each station during each sampling period (Cretini et al. 2009).

Water Level and Salinity

Prior to exhaustion of monitoring funds, hydrologic data were collected using continuous recording sondes at five stations inside the project area (two in CTU 1 and three in CTU 2) and two stations in the reference areas (1 in each REF 1 and REF 2) from 1996 - 2009 (Figure 2). In addition, two CRMS sites located in the project area, both in CTU 2, have been collecting surface water data since August 2007 (CRMS0655) and June 2010 (CRMS0672). Water level (ft, NAVD), salinity (ppt), water temperature (^{o}C), and specific conductance (µ☞S/cm) were recorded hourly at these stations. All continuous recorder data were shifted

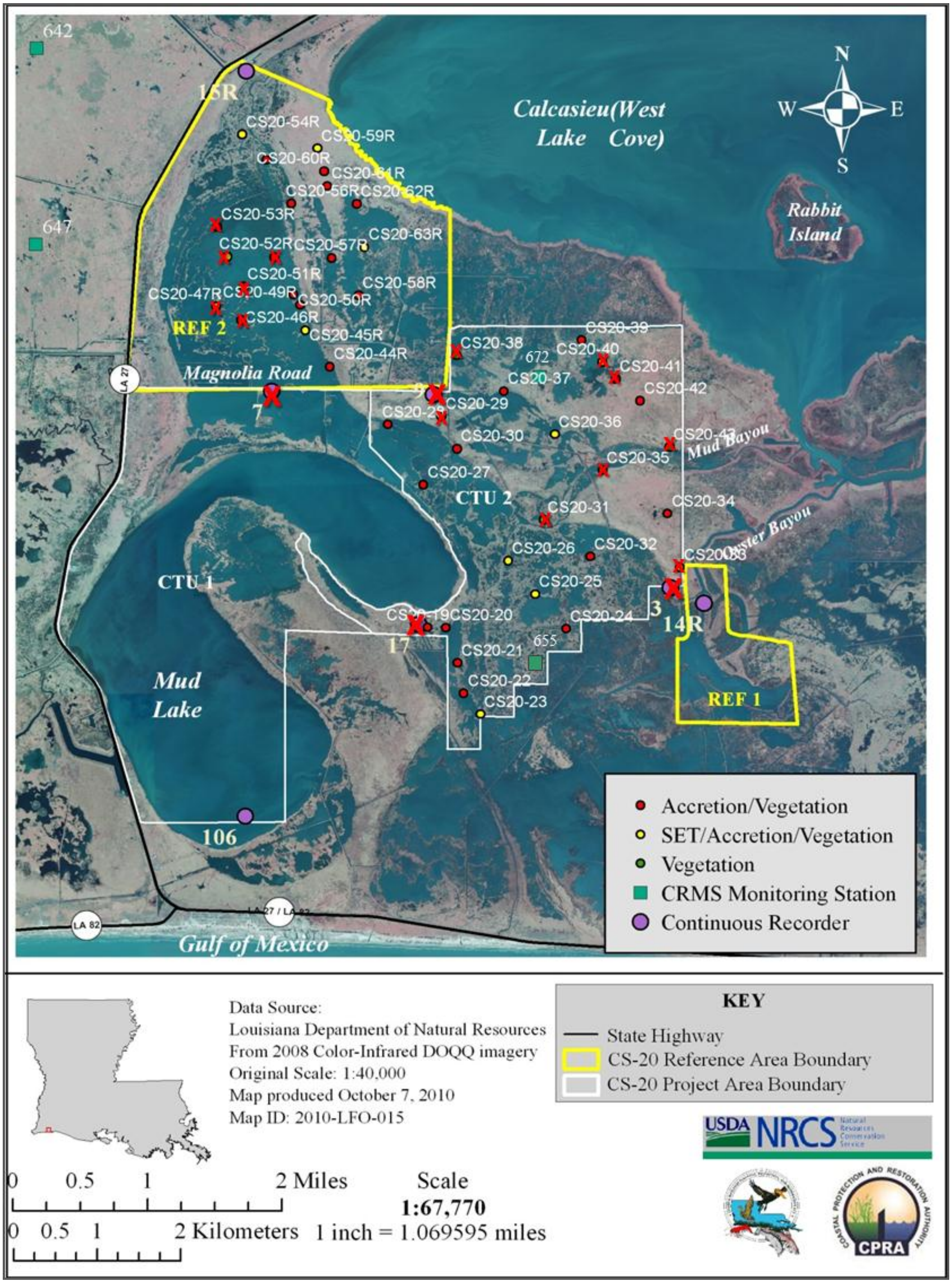


Figure 2. East Mud Lake Marsh Management Project (CS-20) site map depicting monitoring stations. "**X**" represents original continuous hydrologic (**X**) and field stations (**x**) that have been lost due to hurricanes, accidental damage, and the revised monitoring plan.

when necessary due to biofouling when error at time of retrieval exceeded 5%. Percent error caused by biofouling was calculated at the time of retrieval by comparing dirty and clean discrete readings to those taken with a calibrated instrument. Some data are missing due to inaccessibility to sites at some sampling times.

As per the revised monitoring plan, hourly hydrologic data was collected at three stations inside the project area and two stations in the reference area since 2011 using a combination of project specific and CRMS stations (Figure 2; Table 2). Unfortunately, water-level data from CS20-07 (CTU 1) and CS20-14R (REF 1) were corrupt following Hurricane Rita until 2007, and sufficient data was not collected in 2010 to assess water level and salinity.

Representative stations of comparable project/reference areas for 1996-2009 and 2011-2014 (Table 1) were used to assess the project goal of reduce water level and salinity fluctuations to within target ranges for brackish vegetation. Water-level data relative to marsh surface (1.01 ft NAVD88) are presented on a yearly basis. The percent of hourly water level measurements lower, higher, or within the target zone of 2 inches above average marsh level (1.18 ft NAVD88) and 6 inches below marsh level (0.50 ft NAVD88) were calculated for all available years. Yearly mean salinity data are presented to evaluate the goal of decreasing mean salinity in CTU 2. The percent of hourly salinity measurements per year relative to the target salinity of < 15 ppt is presented to determine if the project was effective at maintaining salinities less than or equal to 15 ppt.

Table 2. Hydrologic stations in the CTUs and Reference areas over time used of statistical analysis of for hourly water level and salinity data East Mud Lake Marsh Management Project (CS-20).

Time Period	CTU 1	REF 2	CTU 2	REF 1
1996-2009	CS20-07	CS20-15R	CS20-03	CS20-14R
2011-2014	CS20-106	CS20-15R	CRMS0655, 0672	CS20-14R

Marsh Elevation Change

Surface elevation measured from surface elevation tables (SET) and vertical accretion (VA) data was collected in the project (CTU 2) and reference (REF 2) areas in July 1996 (baseline SET measurements using DNR-CRD and original establishment of VA horizon layers), December 1996, July 1997, December 1997, June 1998, June 2000, July 2003, December 2005 (post hurricane Rita subset), June 2006, August 2009, August 2012, and October 2014 (Figure 2, details of installation and data collection are below). Marsh surface elevation was originally measured preconstruction in December 1995; however, only 10 of the 12 SET station sites were accessible for the first two measurements, and a different SET was used to start the post construction period. Therefore, only post construction data, starting in July 1996, are used in this report. Initially, 12 SET sites (6 in each area) and 40 VA sites (20 in each area) were established; however, the number of sites decreased over time as a result of physical loss during Hurricanes Rita in 2005 and Ike in 2008 and accidental damage. In 2012 and 2014, the SET was measured at 4 stations in CTU 2 and 4 stations in REF 2 while VA was measured at 17 stations in CTU 2 and 13 stations in REF 2. Multiple VA sites were matched to the SET sites to create functional elevation change units based on wetland habitat/soil types (Deep Marsh/Banker Muck, Shallow Marsh/Creole Mucky Clay, and

Meadow Marsh/Mermentau Clay) (Table 3). Surface elevation change (SEC) is determined from measurements from the SETs over time. Cumulative elevation change of vertical accretion from the units was averaged by area for each time interval to present the pattern of change over time. Distinct differences over time resulted from Hurricane Rita in 2005; therefore, change rates (slopes from VA and SEC over time) were calculated for the overall life of the project (1996-2014), before the hurricanes (1996-2003), and after Hurricane Rita (2006-2014) for each site. Shallow marsh subsidence (SS) rate, the change from the bottom of the SET pipe to the feldspar marker, was then calculated by subtracting surface elevation change (SEC) from vertical accretion (VA) rates:

SS (cm/y) = VA (cm/y) – SEC (cm/y). (1)

Area (project, reference) × time period (overall, pre hurricane, post hurricane) full factorial ANOVAs with Student's t-test to describe differences within the interaction effects are used for comparisons within each of the marsh elevation change rates (SEC, VA, and SS).

Table 3. Distribution of Surface Elevation Table (SET) and Vertical Accretion (VA) sites within CS-20 areas and wetland habitat/soil types.

Area	SET Site	VA Sites	Wetland Habitat/Soil Types
Project	CS20-23	CS20-20,21,22,23	Deep Marsh/Banker Muck
(CTU 2)	CS20-25	CS20-19,24,25,32	Deep Marsh/Banker Muck
	CS20-26	CS20-26,27,28	Deep Marsh/Banker Muck
	CS20-36	CS20-30,36,37	Shallow Marsh/Creole Mucky Clay
	CS20-40[1]	CS20-39,40	Shallow Marsh/Creole Mucky Clay
	CS20-33[1]	CS20-33,34,42,43	Meadow Marsh/Mermentau Clay
Reference	CS20-45R	CS20-44R,45R,49R	Deep Marsh/Banker Muck
(REF 2)	CS20-47R	CS20-46R,47R,51R	Deep Marsh/Banker Muck
	CS20-52R[2]	CS20-48R,52R,53R	Deep Marsh/Banker Muck
	CS20-54R[2]	CS20-54R,55R,56R	Shallow Marsh/Creole Mucky Clay
	CS20-63R	CS20-57R,58R,63R	Shallow Marsh/Creole Mucky Clay
	CS20-59R	CS20-59R,60R,61R,62R	Meadow Marsh/Mermentau Clay

[1]SET pipe was damaged prior to August 2009 sampling; only pre-hurricane data is analyzed.
[2]Site was converted to open water by Hurricane Rita; only pre-hurricane data is available.

Surface elevation - Surface elevation table (SET) sites were established in August 1995 at 12 (6 in CTU 2; 6 in REF 2) of the 40 feldspar and vegetation sites to detect changes in marsh surface elevation due to subsidence and accretion/erosion combined (Figure 2). Detailed procedures for the SET installation and data collection are documented in Steyer et al. (1995). During each sample date, nine pin height measurements were taken in four directions at each SET. For graphical display, the cumulative elevation change for a sample date (CEC_i) was calculated for each pin by subtracting the previous pin height (t_p) from the current pin height (t_i) to determine the interval elevation change (IEC) and adding the cumulative elevation change from the previous interval (CEC_p):

$CEC_i = (t_i - t_p) + CEC_p$ (2)

For each SET site, pin CEC_i for each direction was averaged, then directions were averaged. Sites were then averaged by area for each time period to calculate values for the graph. For statistical analysis, rate of change over time (cm/y) for each pin was calculated using a linear regression to determine the slope (mm/d) of pin height (mm) over time (d) which was converted to the more commonly used cm/y. Surface elevation change (SEC) rates were divided into three time periods because of overarching hurricane effects beginning with Hurricane Rita in 2005: overall project life (1996-2014), pre hurricane Rita (1996-2003), and post Hurricane Rita (2006-2014). To determine the SEC rate for each SET, slopes for each pin were averaged, then the directions were averaged. Surface elevation change rates grouped by area and time period were used to statistically compare area × time period interactions. Surface elevation change rates are also compared to relative sea-level rate of 0.54 cm/y at Sabine Pass, the nearest long-term staff gage.

Vertical accretion – We used the marker horizon technique to measure soil accumulation over time. A marker horizon that contrasts with the marsh soil (Feldspar clay) was placed in 0.5 x 0.5 m plots marked with 2 PVC poles at opposing corners to enable location of the feldspar over time, and cores from randomly selected locations within each plot were taken with a cryogenic corer (Knauss and Cahoon 1990). Vertical accretion (soil depth above the feldspar) was measured to the nearest millimeter at 1-4 locations on each core. A maximum of 3 cores per plot were taken at each sampling period when feldspar was not always clearly visible on the cores. Feldspar stations (2 plots per site) were established at 20 sites in both the project area (CTU 2) and the reference area (REF 2) (Figure 2). In July 1996, 14 sites in CTU 2 and 16 stations in REF 2 were originally established while sites that were inaccessible in July were established in December 1996 (CTU 2 – 6 sites; REF 2 – 3 sites). New feldspar plots were systematically reestablished at all sites in December 1997, and the original plots were abandoned; thereafter, sites were reestablished on an as-needed basis (could not find stations or feldspar layer). Some sites were not visited during sampling periods due to inaccessibility.

For each sample date, the core measurements from each station were averaged per site. To keep the data "cumulative" over uneven time periods, the data was manipulated to have a common establishment date (July or December 1996) by adding the last measurement of the previous establishment period to measurements from following reestablishment periods. Vertical accretion sites were then grouped with corresponding SET sites (as described above, Table 2); grouping VA sites per SET site compensated for missing data at individual VA sites during a given sample date.

Fisheries

Fisheries monitoring was conducted to estimate abundance and species composition in the project and reference areas to determine whether the project affected fish abundance. Thirty samples each were collected from CTU 2 in the project area and Ref 2, concurrently, in the spring and fall of 1995, 1996, 1997, and 2001 with 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. 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 potential deficiency of the throw traps for determining 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. Mean density, relative abundance, and total biomass (dry weight in grams) of each species were recorded. A water sample was collected at each site and measurements taken for water temperature (^oC), salinity (ppt), dissolved oxygen (mg/l), water depth (cm) and distance to the marsh edge (m). At each site, presence or absence of SAV was noted. Sampling locations were randomly chosen from a grid pattern for each sampling trip. Personnel from LDNR/CRD conducted sampling in June 1995, October 1995, April 1996 (during drawdown), October 1996, and March 1997. National Marine Fisheries Service (NMFS) personnel and the LDNR/CRD monitoring manager conducted sampling in April 1997 (during drawdown), September 1997, April 2001, and November 2001. NMFS analyzed data from June and October 1995 and April 1996 and determined that throw trap sampling depicted species composition of the area at least as well as seine sampling, and seine sampling was discontinued.

Density and biomass means and standard errors for each fish and crustacean species were calculated for the project and reference area for each sampling period. Means and standard errors for all environmental variables collected were calculated for the project and reference area per sampling period. Although construction was not completed until after the April 1996 sampling time, access to the project area was disturbed by the ongoing construction and April 1996 was thus considered post construction. Two factor ANOVAs with interaction were used to compare mean animal densities and environmental variables between the project and reference areas for preconstruction sampling times to estimate the suitability of the reference area. The specific environmental variables tested were salinity, temperature, dissolved oxygen, depth, and distance to edge and the animal variables were total fishes, total crustaceans, transient fishes, transient crustaceans, resident fishes, and resident crustaceans. The same set of environmental and animal variables were then compared between preconstruction and post construction sampling times with a one-way ANOVA for each area separately (Appendix A). Prior to statistical analyses, Hartley's F-max test was used to determine if variances in the treatment cells were equal (Milliken and Johnson 1992). We performed a ln(x+1) transformation on the density, species richness, and biomass data, because cell means were positively related to standard deviations. In cases where cell means were positively related to variances (i.e., salinity, water temperature, dissolved oxygen concentration, water depth, distance to edge), a square root transformation was used prior to analyses. These transformations generally reduced the relationships between means and standard deviations or variances. However, F-max tests still indicated heterogeneity for some variables. Despite this failure to meet the assumption of homogeneity of variances in all cases, ANOVA tests were conducted on transformed data because the test is considered robust, and failure to correct heterogeneity does not preclude its use (Green 1979, Underwood 1981). An alpha level of 0.05 was used to determine statistical significance for all ANOVA tests.

c. Monitoring Results and Discussion

i. Habitat Mapping and Land to Water Change

No less than 95% of the acreage was classified as Marsh or Open Water for all time periods and areas (Figure 3). Wetland Scrub-Shrub increased in the Reference areas from 1994 to 2014 where as it decreased in the CTUs from 2006 to 2014 (Figure 3 and Appendix D); these patterns are consistent with higher water levels in the CTUs than the reference areas during this time period (see Water Level and Salinity section below). Wetland scrub-shrub converted from or to marsh and did not result in a land loss.

Before the hydrologic modifications made by the CS-20 project, historical land-loss rates (1956-1994) were similarly high in CTU 2 and REF 2, twice as low in REF 1, and three times lower in CTU 1; a pattern which reflected the percent of land in each area in 1956 (Figure 4A). By the time CS-20 was constructed in 1996, CTU 2, REF 1, and REF 2 were ~60% land; whereas, CTU 1 was ~30% land. Following construction, land-loss rates reduced substantially in CTU 2 (actually gained land, overall) and reduced moderately in CTU 1 and REFs 1 and 2 1994-2014 (Figure 4B). Land area dynamics in the three time intervals within the post construction period were defined by different weather conditions; 1994-2000 included three significant droughts along with managed water-level drawdowns in 1996 and 1997, 2000-2006 was dominated by Hurricane Rita effects, and 2006-2014 started with Hurricane Ike in 2008 and was followed by droughts in 2010-2011 then alternating periods of wet and dry through 2014. Land loss in CTU 1, REF 1, and REF 2 significantly slowed to ~ -0.1 %/y from 1994-2000 while CTU 2 went from the area losing the most land preconstruction to reversing land-loss as it gained land from 1994-2000 (0.70 %/y). The low water levels and more oxygenated soils allow vegetation to expand from shorelines and into broken marsh (Figure 5A). Land loss increased across all areas from 2000-2006 resulting from the scour energy and prolonged flooding from Hurricane Rita. REF 2 and CTU 1 experienced the greatest loss rates while REF 1 and CTU 2 had lower loss rates from 2000-2006 (Figures 4B and 5B).

Much of the land loss from 2000-2006 occurred in large swaths in REF 2 and on the East Mud Lake peninsula shared by CTU 1 and CTU 2 (Figure 5B); whereas, gains occurred primarily in the headwaters from the West Cove Canal in REF 2 and sparsely throughout broken marsh into shallow water (Figure 5 A and B). Much of large scale areas of land loss occurred in areas with Bancker Muck which is described as poorly drained, typically low-elevation soil; whereas, the stable land areas are typically coincidental with Mermentau Clay which are associated with higher elevation ridges. Another soil type, Creole Muck, found throughout the CS-20 project areas is intermediate in elevation and is often dynamic in terms of land change. These soil types are distributed evenly among CTU 1, CTU 2, and REF 2, while REF 1 does not have Bancker Muck.

Based on regional scale analysis of satellite imagery (Thematic Mapper, 30 m^2 resolution) starting in 1985, the Calcasieu/Sabine (CS) Basin as a whole was experiencing slight gains in land area prior to construction of CS-20 (1985-1995) while the project area was losing land (Figure 6). Including time since construction (1985-2010), land area change shifted from land gain to land loss with a -0.3 %/y change CS basin-wide; conversely, the land loss was reduced by a similar amount within the CS-20 project area. Land area change has been similar at both scales spatial since the Hurricane Rita in 2005 as the CS Basin and CS-20 project area lost land, averaging -0.8 %/y change (Figure 6).

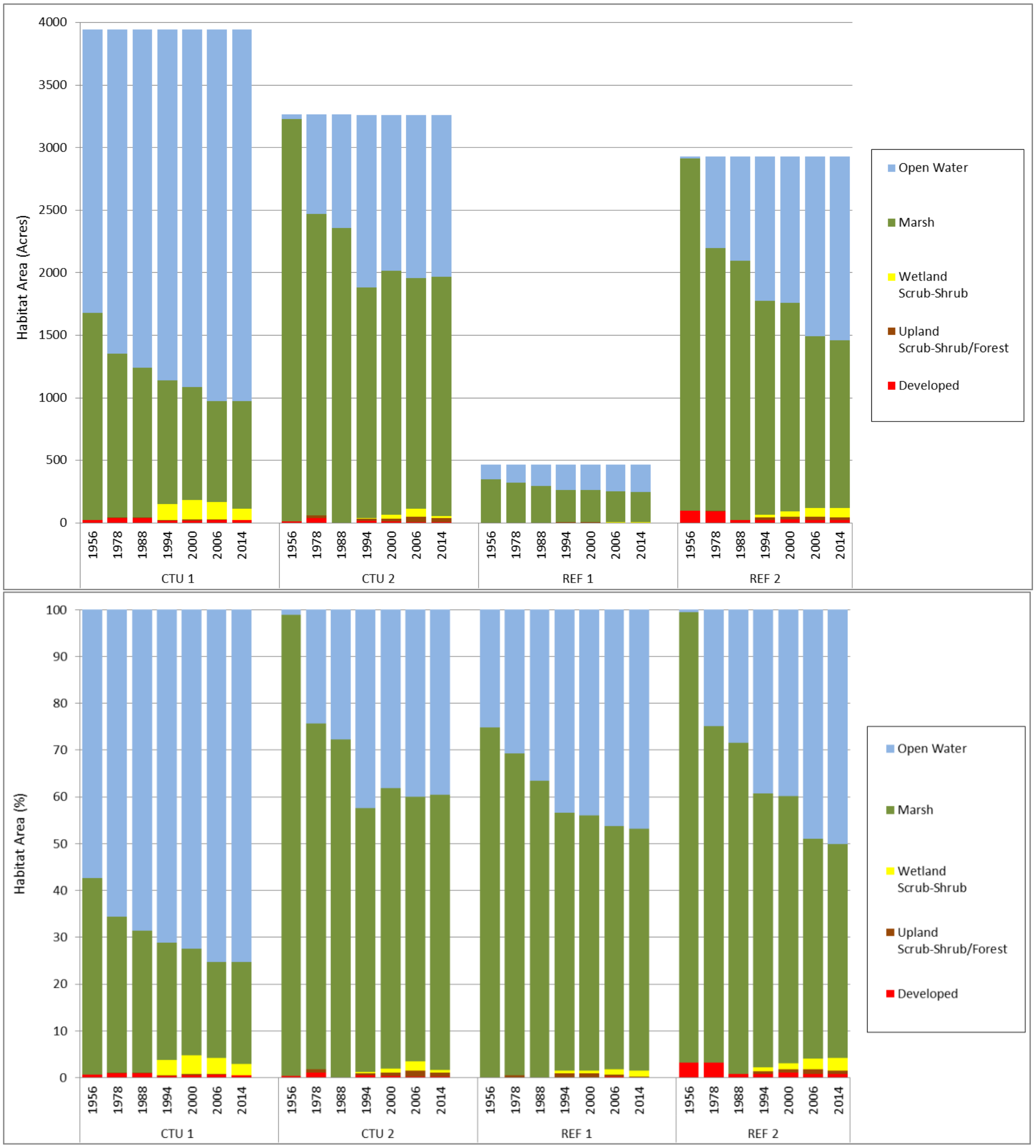


Figure 3. Habitat areas (acres and percent) were compiled from CS-20 habitat maps conducted by the USGS National Wetlands Research Center (Appendix D) and grouped into five habitat classifications.

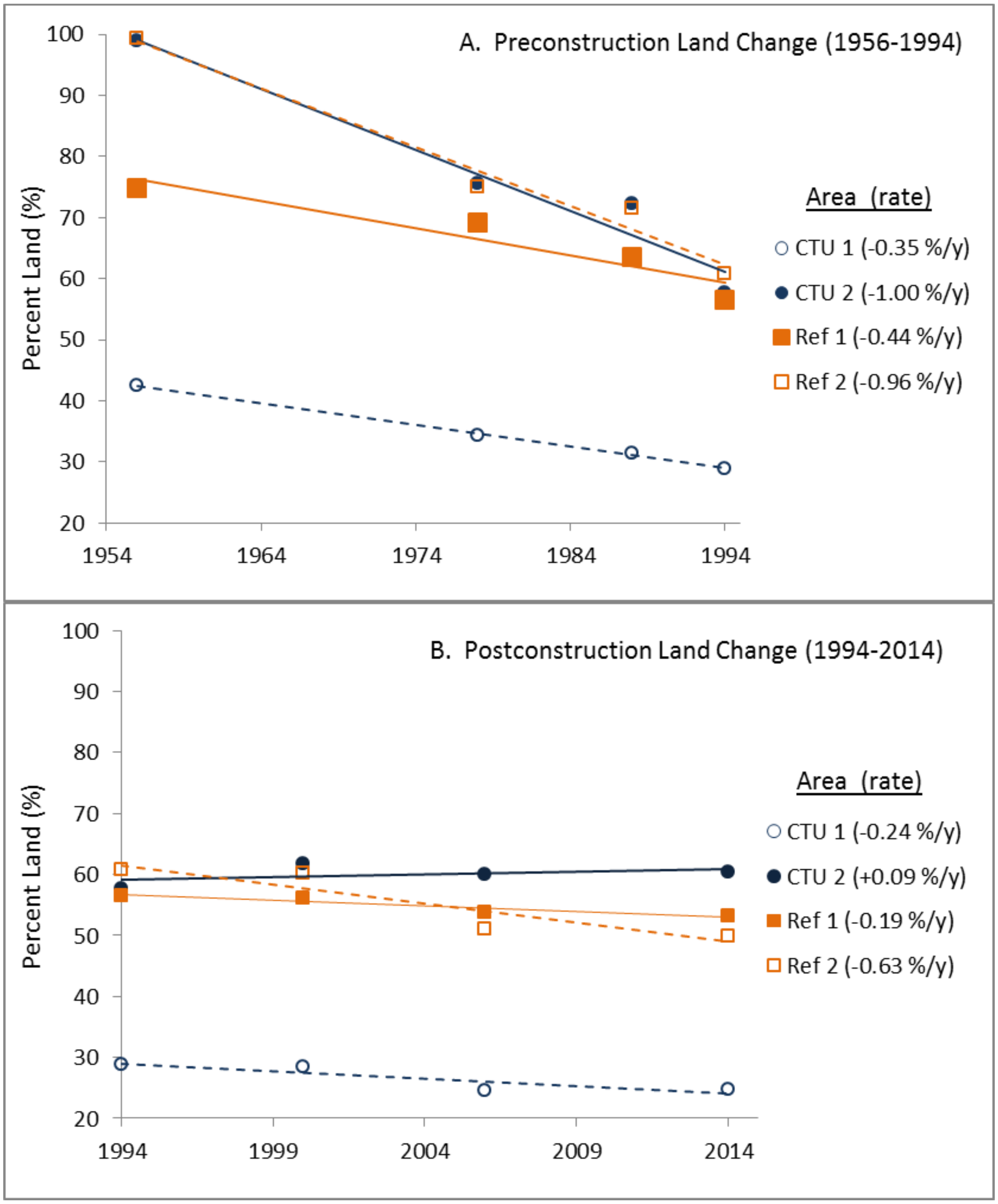


Figure 4. Percent vegetated land coverage of each CS-20 area with trend lines and rates over preconstruction (**A**) and postconstruction (**B**) time periods compiled from USGS-NWRC habitat analyses maps.

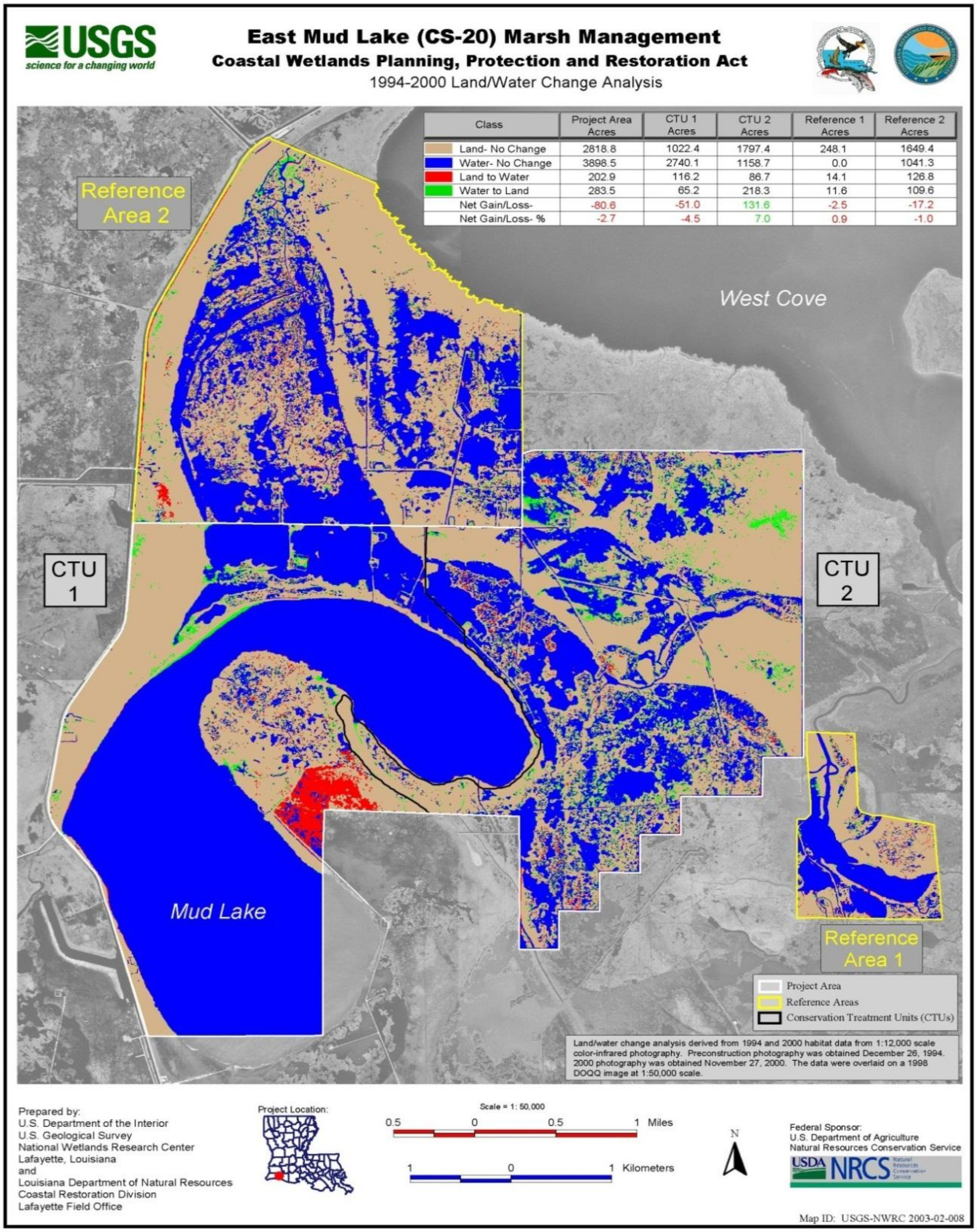


Figure 5A. Land to water change analysis from 1994-2000 at CS-20. Note marsh gains (green) within broken marsh and along larger ponds in CTU 2. The large swath of marsh loss (red) in CTU 1 was caused by a marsh fire that mostly recovered by 2006.

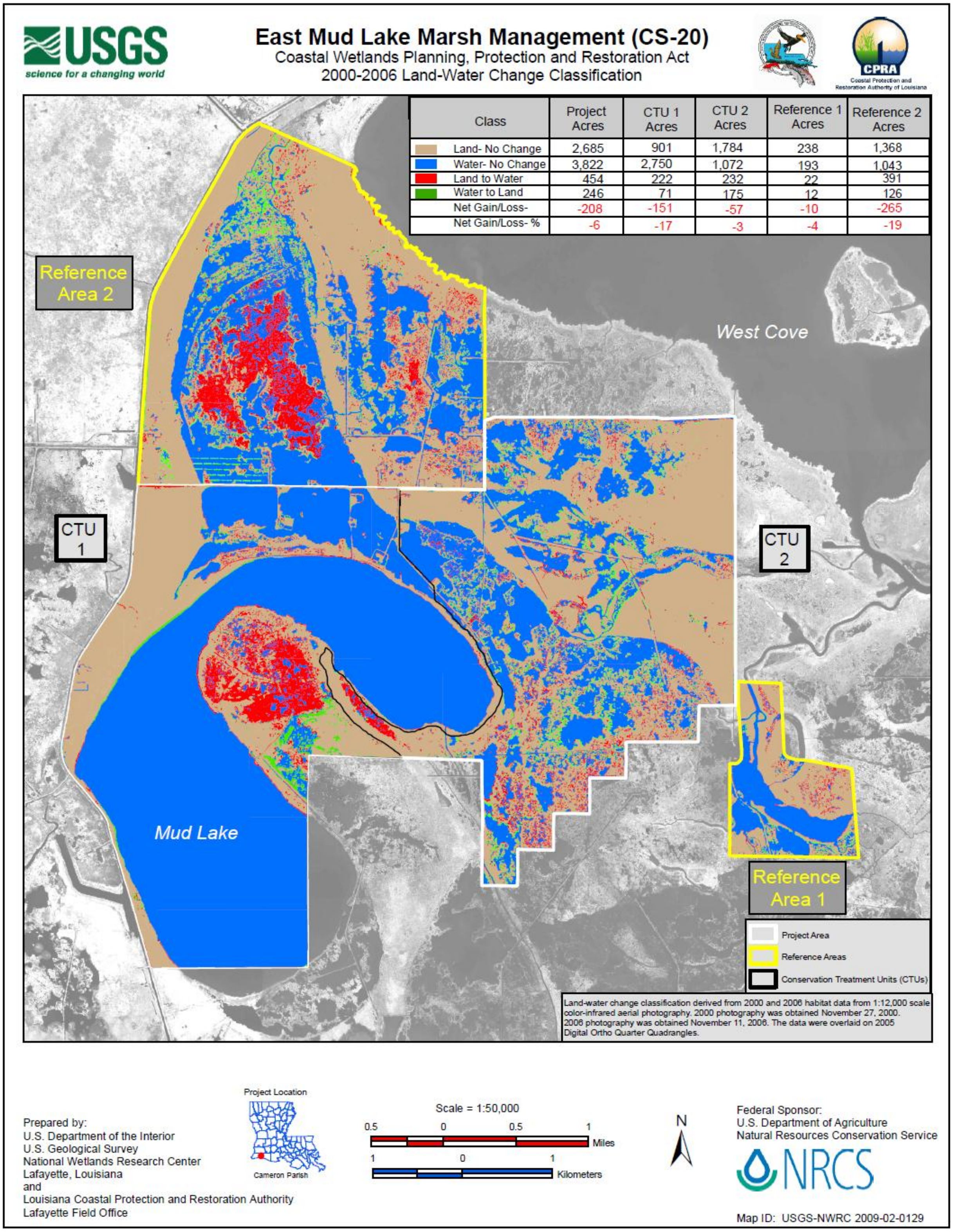


Figure 5B. Land to water change analysis at CS-20 from 2000-2006. Note marsh gains (green) within broken marsh and along larger ponds in CTU 2. The large swaths of marsh loss (red) were the result of Hurricane Rita in 2005.

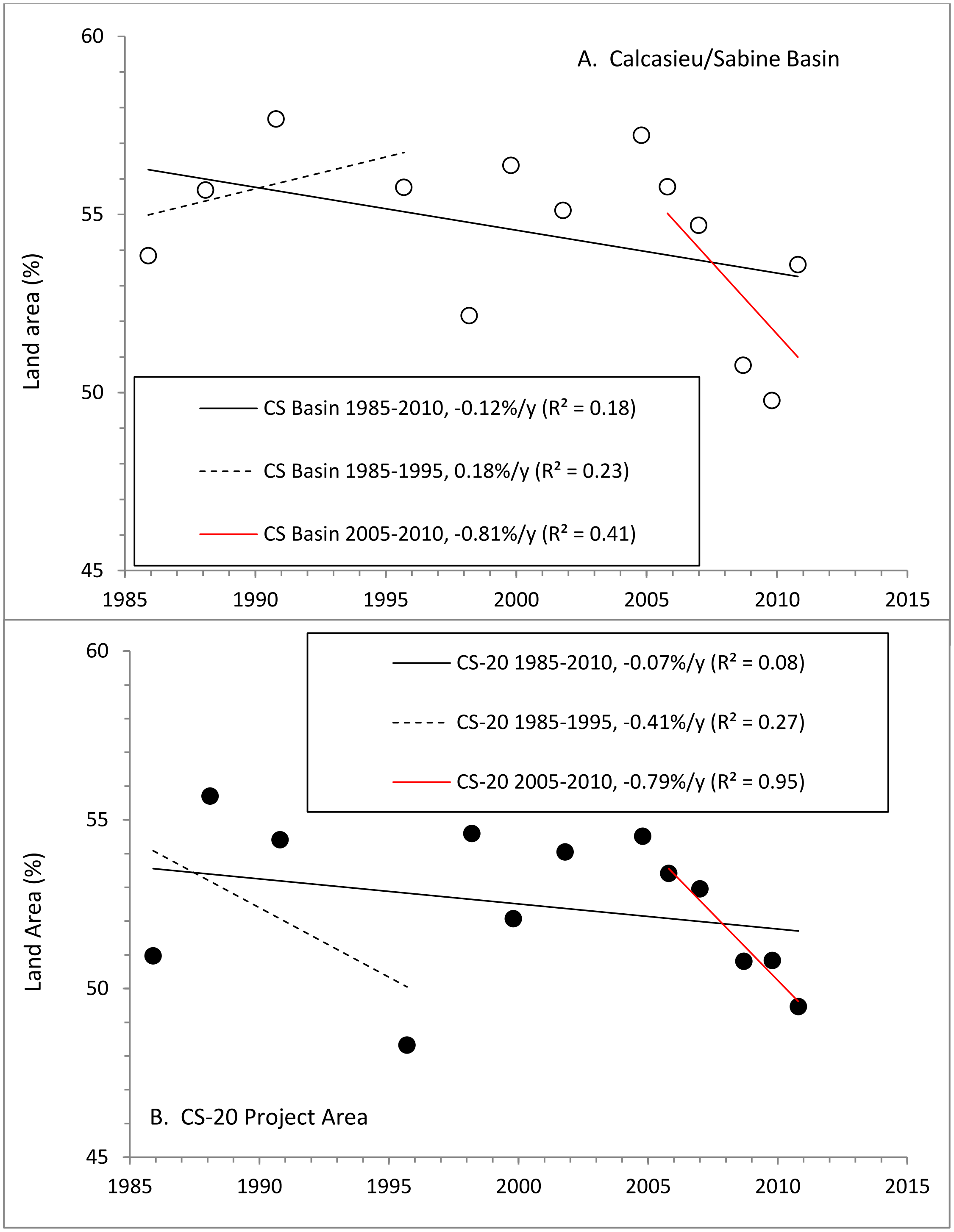


Figure 6. Land area (%) was analyzed over 25 years (1985-2010) from satellite imagery for the Calcasieu/Sabine (CS) basin (**A**) and the CS-20 project area (**B**). The trend lines represent the linear rate of land change (% land/y) for time periods including the CS-20 project life (solid black line, 1985-2010), prior to CS-20 construction (dashed lines, 1985-1995), and since hurricanes (2005-2010, red lines). Positive land change rates indicate land gain whereas negative rates indicate land loss. The CS basin data was modified with permission from Couvillion et al. 2011.

ii. Vegetative Plantings

The following is a summary of percent cover change and marked plant survival detailed in the CS-20 Three Year Comprehensive Report; no additional data has been collected. Vegetative cover along the shoreline of East Mud Lake (CTU 1) was not increased by vegetative plantings; however, about 50% of plantings along the canal (east border of CTU 2) and step levee (southeast border of CTU 2) areas remained four years after planting, and maintained over 20% cover. The original plan to install all plantings on the lakeshore was modified because of unexpected difficulty securing suitable planting substrate. A small portion of the plantings on the lake shoreline survived well for six months but did not increased in cover; however, no plants survived by our last sampling in 2000. Land gains along the lake could be due to protection of the shoreline made possible by the short fetch in that narrow part of the lake allowing for deposition of suspended sediment that existing vegetation could have colonized (Figure 5 A and B). The new land could also be the result of the expansion of existing vegetation into previously unvegetated mudflat that had not been detected by earlier aerial photography. Native species colonizing the shoreline and step levee were indicative of drier/saltier conditions and included *Distichlis spicata* (salt grass), *S. patens*, *Heliotropium currassivicum* (seaside heliotrope), *Lycium carolinianum* (salt matrimony-vine), and *Salicornia bigelovii* (glasswort). Marked individuals of *Spartina alterniflora* from plantings survived longer along the canal and step levee than the shoreline of East Mud Lake over a four year period (July 1996 – June 2000). Plant survival was greater than 90% after 6 mos across all land types. Along the canal plant survival was greater than 90% thru 12 mos and then decreased to 55% after 48 mos. Along the step levee survival decreased to 45-50% after 12 mos and maintained thru 48 mos. Along the East Mud Lake Shoreline, plant survival sharply declined to 15% from 6 to 12 months, and no marked plants from the plantings survived to 48 months. Typical plant turnover or stress caused plant survival decreases along the Canal and Step Levee; whereas, planting were physically removed by wave energy along East Mud Lake.

iii. Existing Vegetation

The goal to increase coverage of emergent vegetation in shallow, unvegetated, open water areas was achieved, but the amount is difficult to quantify. The drawdown phase of the project was intended to allow germination of marsh vegetation seeds and expansive tillering. Because our emergent vegetation sampling only incorporated existing vegetated areas, the only way to attempt to evaluate this goal was through analysis of aerial photography and through observations during field trips. CTU 2 gained land from 1994-2000 due mainly to vegetative expansion at the marsh/water interface in broken marsh and shallow open-water areas (Figure 5A). Evidence of this new vegetation first became apparent during vegetation sampling after the drawdown and drought in 1996. Subsequently, land-loss rates from 2000-2006, which included Hurricane Rita in 2005, were the lowest in CTU 2 with a combination of marsh loss and gain within broken marsh areas and along pond edges (Figure 5B).

Patterns in the percent cover of species (% cover) and Floristic Quality Index (FQI) responded differently to climatic events in the project (CTU 2) and reference (REF 2) areas (Figure 7). Just prior to construction in 1995, both CTU 2 and REF 2 had high % cover, FQI, and were

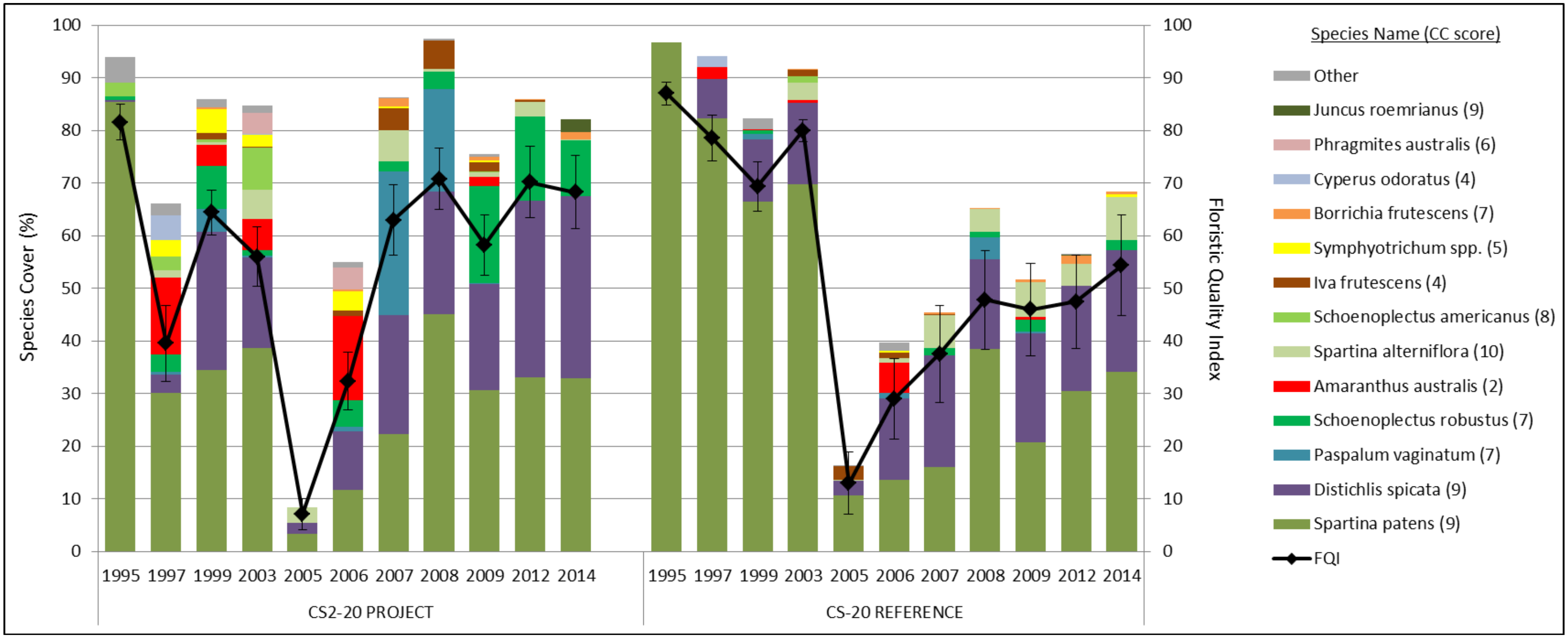


Figure 7. Species cover (%) and Floristic Quality Index (FQI) was collected over the life of CS-20 in project (CTU 2) and reference (REF 2) areas. The stacked columns represent % cover of species listed in the legend (primary y-axis). The overlaid line graph represents the FQI score (secondary y-axis) which is calculated from the cumulative Conservation Coefficient (CC) scores in the legend weighted by % cover of each species. Values are means of vegetation stations within areas for each sampling date. 2005, 2007, and 2008 values are based on a subsample of stations for post hurricane vegetation monitoring.

dominated by *Spartina patens* while the project area had higher species richness. Just following construction in spring 1996, the region was struck by severe drought (1996-1997) followed by prolonged flooding following Hurricane Francis (1998). Vegetation in REF 2 responded to these conditions with slight, but consistent, declines in % cover and FQI through 1999 as % cover fell ~15% and FQI dipped ~20%. Both % cover and FQI rebounded prior to Hurricane Rita in REF 2. In addition to the regional weather conditions, CTU 2 also had managed drawdowns in 1996 and 1997 which intensified the drought effect, and existing vegetation responded with sharp declines in % cover (~30%) and FQI (~40%) in 1997 as *S. patens* declined by about ~50% while lower quality, disturbance species became established. By 1999, % cover rebounded ~20% and FQI increased 40% as *S. patens* remained repressed and other more salt tolerant species encroached. Both areas were heavily impacted by Hurricane Rita (September 2005) as both lost about 75% of their vegetative cover and FQI scores dropped ~85%. Salty storm surge scoured away several stations and converted them to open water REF 1 while prolonged flooding caused severe vegetation die-off in CTU 2 which was apparently protected from scour by the ring levee. While standing vegetation recovered in both areas by September 2008 just before Hurricane Ike, stations scoured and converted to open water slowed recovery in REF 2. Based on sampling in August 2009, both areas had small set-backs following Hurricane Ike. From 2009 to 2012, the time interval that included both replacement of Structure 4 and installation Ducks Unlimited, Inc. projects to improve the hydrology flowing into the project area, CTU 2 had more improvement in both % cover and FQI than the REF 2. As of 2014, both % cover and FQI have continued to improve in REF 1 whereas they have declined in CTU 2; % cover and FQI are greater in CTU 1 as a result of 30% of REF 2 stations converting to open water.

On a regional scale, CRMS sites within the CS-20 project area, CRMS0655 and CRMS0672, have consistently had higher FQI scores than the CRMS sites averaged overall for the Calcasieu/Sabine basin since 2007; 2006 sampling followed Hurricane Rita (Figure8).

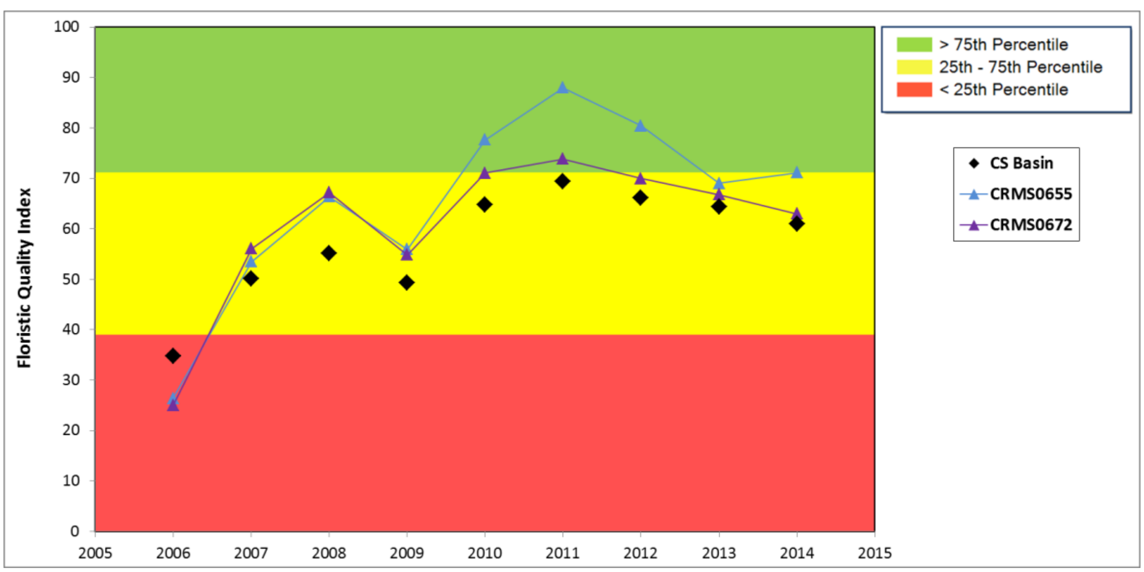


Figure 8. Floristic Quality Index (FQI) scores collected from Coastwide Reference Monitoring System (CRMS) sites in the Calcasieu/Sabine (CS) hydrologic basin and CRMS sites within CS-20 since 2006. Values for the CS Basin are a mean of all CRMS sites per year; values for the CS-20 CRMS sites are a mean of the stations per year. The background represents the coast-wide distribution of FQI scores from CRMS sites collected 2006-2014.

Over time, both the CS-20 project and reference areas have experienced a community shift towards more salt tolerant species such as *Distichlis spicata*, *Spartina alterniflora*, and *Schoenoplectus robustus* since project construction (Figure 7) resulting in saltier vegetation communities (Figure 9).

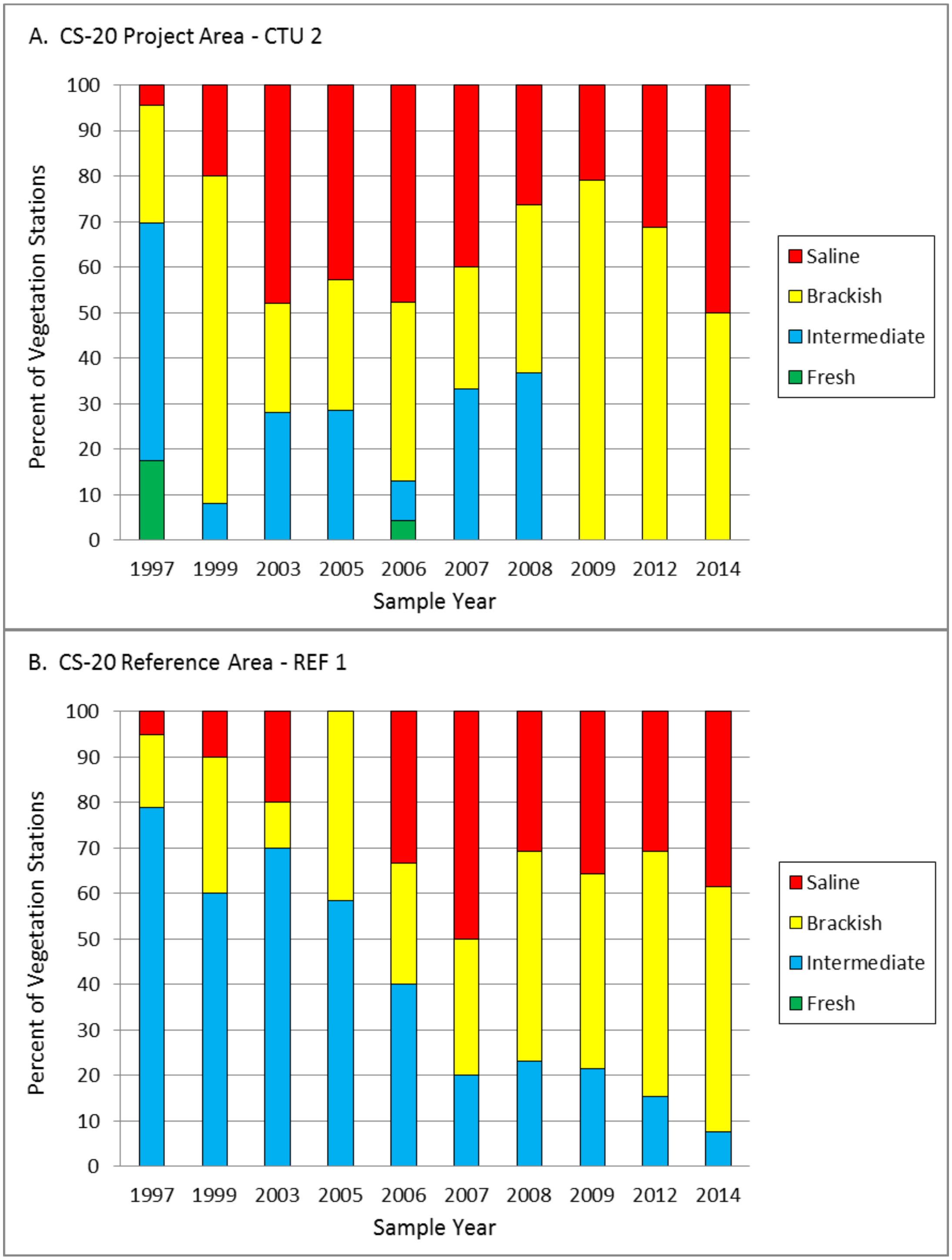


Figure 9. Marsh vegetation of vegetation stations from the CS-20 Project (CTU 2) and Reference (REF 2) areas have shifted to more salt tolerant communities over time.

iv. **Water Level and Salinity**

CS-20 has been meeting its water-level goal to reduce fluctuations; water-level ranges have been greater in the reference than project areas (Figure 10). Water levels in the project areas (CTUs) are more often within the target range of 6" below to 2" above marsh level than their respective reference areas (Figure 11); CTU/REF pairings are CTU 2/REF 1 (Figures 12) and CTU 1/REF 2 (Figure 13). Aside from the drawdown in 1996 and 1997 in CTU 2 (Figure 11 and 12A), water levels followed similar trends in all areas with the CTUs maintaining water levels within the target range more consistently than the REFs until Hurricane Rita in September 2005. Water levels in CTU 2 remained within target level for more than 60% of 2006 (Figures 11 and 12A). From 2007-2009 water levels stabilized at a higher level than typical as all areas averaged > 2" above marsh elevation (Figure 10) and both CTUs were flooded ~50% of the time and dipped below the water-level target less than the REFs (Figures 12 and 13). Effects of Hurricane Ike in 2008 were not as evident as Hurricane Rita as water levels returned to "normal" after about 3 weeks. When data collection resumed, southwest Louisiana was in a drought. In 2011, water levels in all areas averaged close to marsh elevation (Figure 11) while the CTUs spent less time below the target elevation of 6" below marsh elevation than the REFs (Figures 12B and 13B). As the drought broke in 2012 water levels increased in all areas with the CTUs holding more water on average than the REFs (Figure 11); water levels in the CTUs did not fall less than the target elevation of 6" below marsh elevation. This trend continued through 2014 as water levels averaged 0.17 ft higher in the CTUs than REFs.

CS-20 has been meeting its goals in the actively managed CTU 2 of decreasing mean salinity and reducing salinity fluctuations to within the target range for brackish vegetation of < 15 ppt relative to its reference area, REF 1. Salinity in CTU 2 has been less than in REF 1 every year except 2011 (Figure 14); annual salinity in CTU 2 has been 20% (3.6 ppt) less than salinity in REF 1, overall. CTU 2 has had a greater percentage of days within the target range than REF 1 for 15 of 16 years (Figure 15) as CTU 2 has spent 25 % more time under 15 ppt than REF 1. Salinity in the more passively managed CTU 1 has been similar to its reference, REF 2, over the life of the project. CTU 1 has been less than 1 ppt saltier than REF 2 (Figure 14), overall. CTU 1 had a greater percentage of days within the target range than REF 2 for half of the years (Figure 16) but spent 0.2% less time per year < 15 ppt than REF 2, overall. Climatic conditions are the major factor influencing salinity in CS-20. During "normal" conditions (2001-2004) the CTUs were above 15 ppt less than 25% of the time and less than their paired reference areas (Figure 14). Salinity increased sharply from 2004 to 2006 in all areas, as a result of Hurricane Rita, approaching concentrations existing during the drought of 1999-2000 (Figure 14). All stations, including CTUs, spent over 75% of the days above the 15 ppt target in 2000 (Figures 15A and 16A) and 50% in 2005-2006 (Figures 15B and 16B). Salinity receded in 2007, though not to pre-Rita concentrations, then increased through 2009 as a result of Hurricane Ike; CTU 1 increased the most while REF 1 remained the saltiest area, overall (Figure 14). Salinity reached the greatest concentrations over the project life in 2011 (Figure 14) resulting from a regional drought (2009-2011); all the areas spent more than 90% of the year above 15 ppt (Figures 15B and 16B). Salinity sharply decreased in 2012 after heavy rainfall relieved drought conditions; however, salinity averaged just above 15 ppt in both CTUs (Figure 14), and the CTUs diverged in terms of days within the target as CTU 2 spent 30% (Figure 15) and CTU 1 spent 56% (Figure 16) of the year < 15 ppt. From 2012-2014, the actively managed CTU 2 was less salty than REF 1, but averaged over just over 15 ppt; whereas, the passively managed CTU 1 averaged just below 15 ppt but was a little saltier than REF 2. Salinity is more variable in the passively managed CTU 1 than the actively managed CTU 2. CTU 1 spends the most time below 15 ppt during "calm" periods but holds higher salinities following regional climatic events (1999/2000 drought, post hurricanes in 2006 and 2008, and 2009-2011 drought) as structure 13 prevents water from draining west into fresher areas across La. Hwy 27.

Operation of water control structures coupled with the previous impoundment of the area moderates water levels and attenuates the high salinities that occur outside the project area during normal weather conditions. But, even when operated correctly, strong weather/climate patterns dominate control of water level and salinities inside and outside of project area as demonstrated by the high salinity during the 1999-2000 drought that was not controlled by the structures. Unfortunately, it is extreme weather/climate patterns, rather than normal conditions, that impact coastal marshes the most. The ability to determine project effects on water level and salinity are confounded by the operational status of the water control structures (storm damage, vandalism, and length of time for maintenance) and the decision to keep the structures open since March 2008 in order to keep high salinity water flowing through the project area rather than trapping it in the project area. Maintenance of ES 3 and replacement of ES 4 in February 2011 facilitated improved control of CTU 2, and a project to reduce the cross section of Oyster Bayou by Ducks Unlimited, Inc. in August 2010 should reduce tidal fluctuations entering the SE portion of CTU 2. Unfortunately, siltation had been a chronic problem at ES 13, which regulates the flow of water from the west into CTU 1, because of low flow rates from First Bayou. Removal of silt and hurricane debris from ES 13 in February 2011 and improvements to restore flow to First Bayou by Ducks Unlimited, Inc. (DU) completed in February 2012 may have improved water exchange into CTU 1 from the west. In fact, as documented during the 2011 and 2012 O&M Annual Inspections, flow was again possible through the ES13 structure and a noticeable change had occurred. Southwest Louisiana, including the CS-20 area, endured an extensive drought from 2009 through 2011 resulting in very high annual salinity concentrations throughout all CS-20 areas (22-27 ppt) with the highest concentration in the passively managed CTU 1; water levels were typically within the target zone with the reference areas able to spend more time below the target zone. 2012 was a high rainfall year resulting in decreases in salinity in both project and reference areas. CTU 1 seemed to be receiving more flow from the First Bayou as it had the sharpest decrease in salinity in terms of annual salt concentration and % time > 15 ppt. The time period following replacement of ES 4 and surrounding hydrologic projects by DU, 2012 – 2014, showed some improvement for salinity as the CTUs had a larger percentage of days < 15 ppt than the REFs, although the CTUs held slightly higher water levels than the REFs.

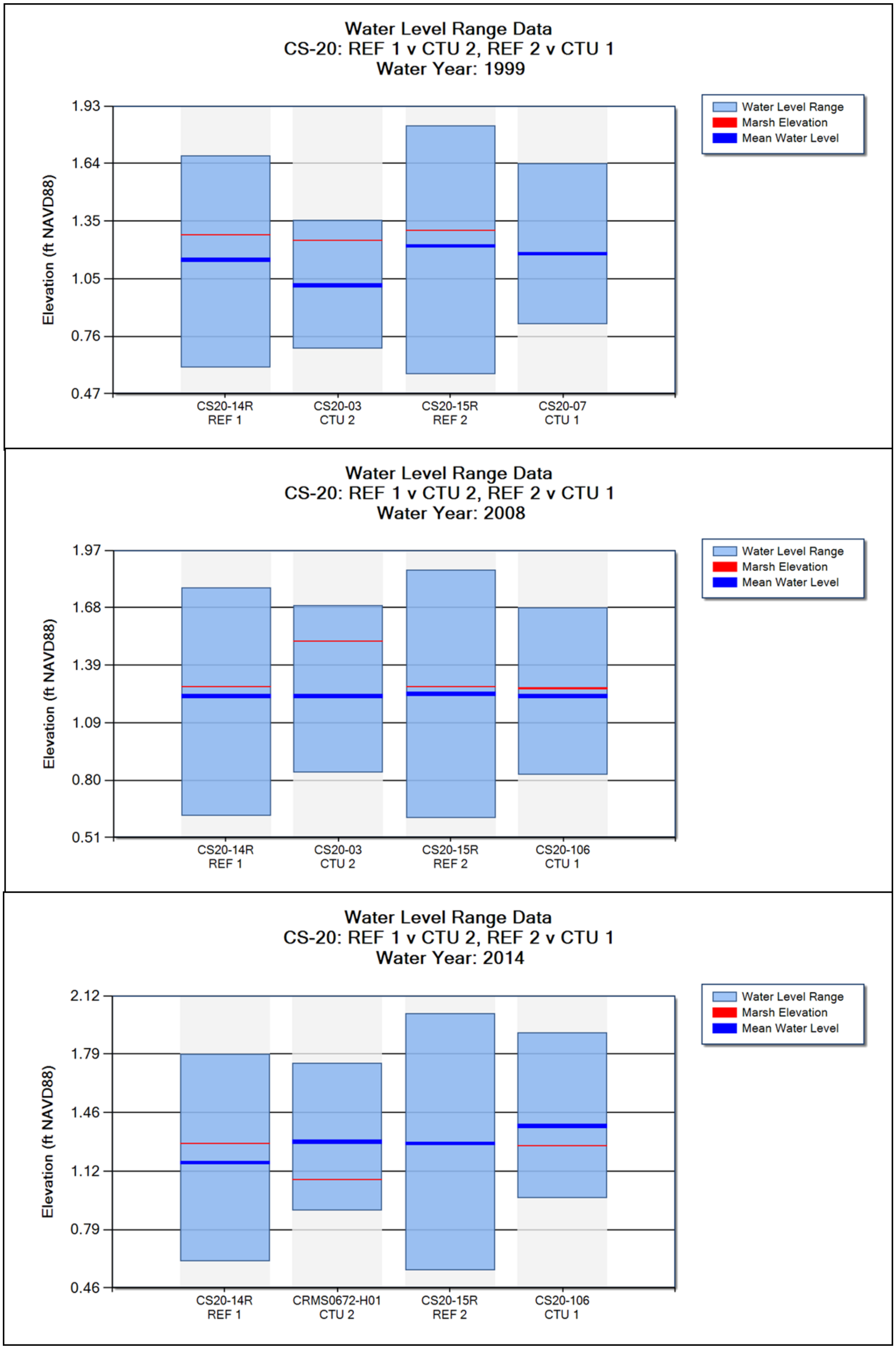


Figure 10. Water-level range depicts reduced fluctuation in CS-20 project areas (CTUs) compared to reference areas (REFs) during different years through the project life. Figure adapted from the CRMS website (http://lacoast.gov/chart2/Charting.aspx?laf=crms).

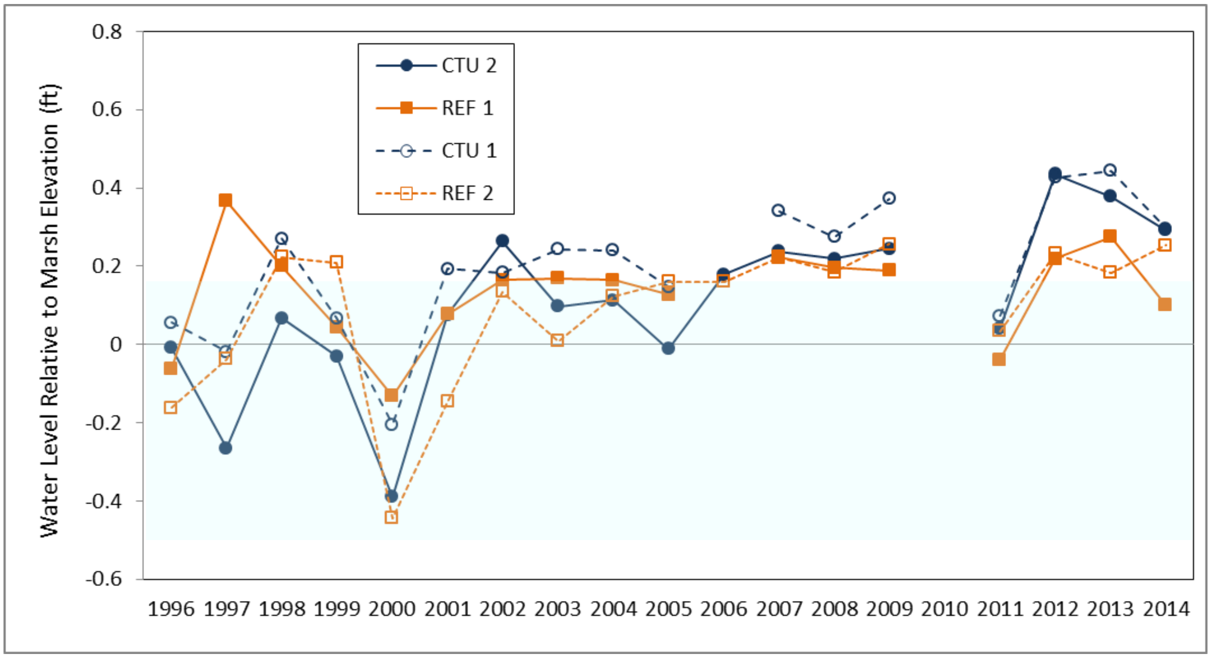


Figure 11. Mean water level relative to marsh elevation (1.01 ft NAVD88) per year collected by continuous water level recorders within the project (blue circles) and reference (orange squares) areas. The targeted water-level range for the project areas is <2" (0.167 ft) above and <6" (0.5 ft) below marsh surface elevation (shaded). The paired comparisons are CTU 2 (1996-2009: CS20-03; 2011-2014: average of CRMS0672 and 0655) v REF 1 (CS20-14R throughout the years) (solid markers and lines) and CTU 1 (1996-2009: CS20-07; 2011-2014: CS20-106) v REF 2 (CS20-15R throughout the years) (open markers and dashed lines).

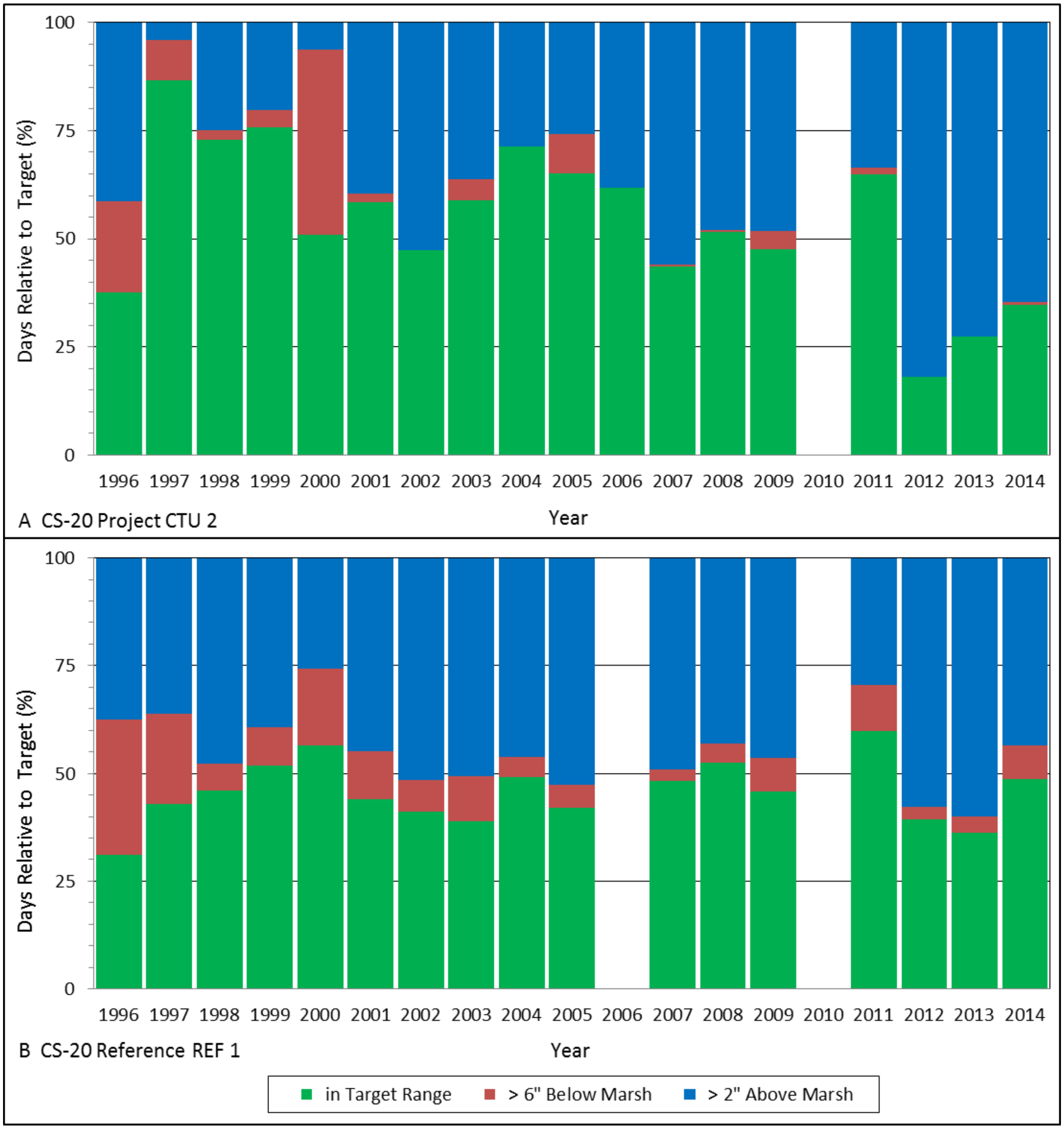


Figure 12. Percent days per year of water levels relative to target range (2” above to 6” below averaged marsh elevation of 1.01 ft NAVD88) for actively managed CTU 2 (A) and its reference, REF 1 (B), since construction in 1996 through 2014. CTU 2 is represented by station CS20-03 for 1996-2009 and an average of CRMS0672 and 0655 for 2011-2014; REF 1 is represented by CS20-14R throughout the years.

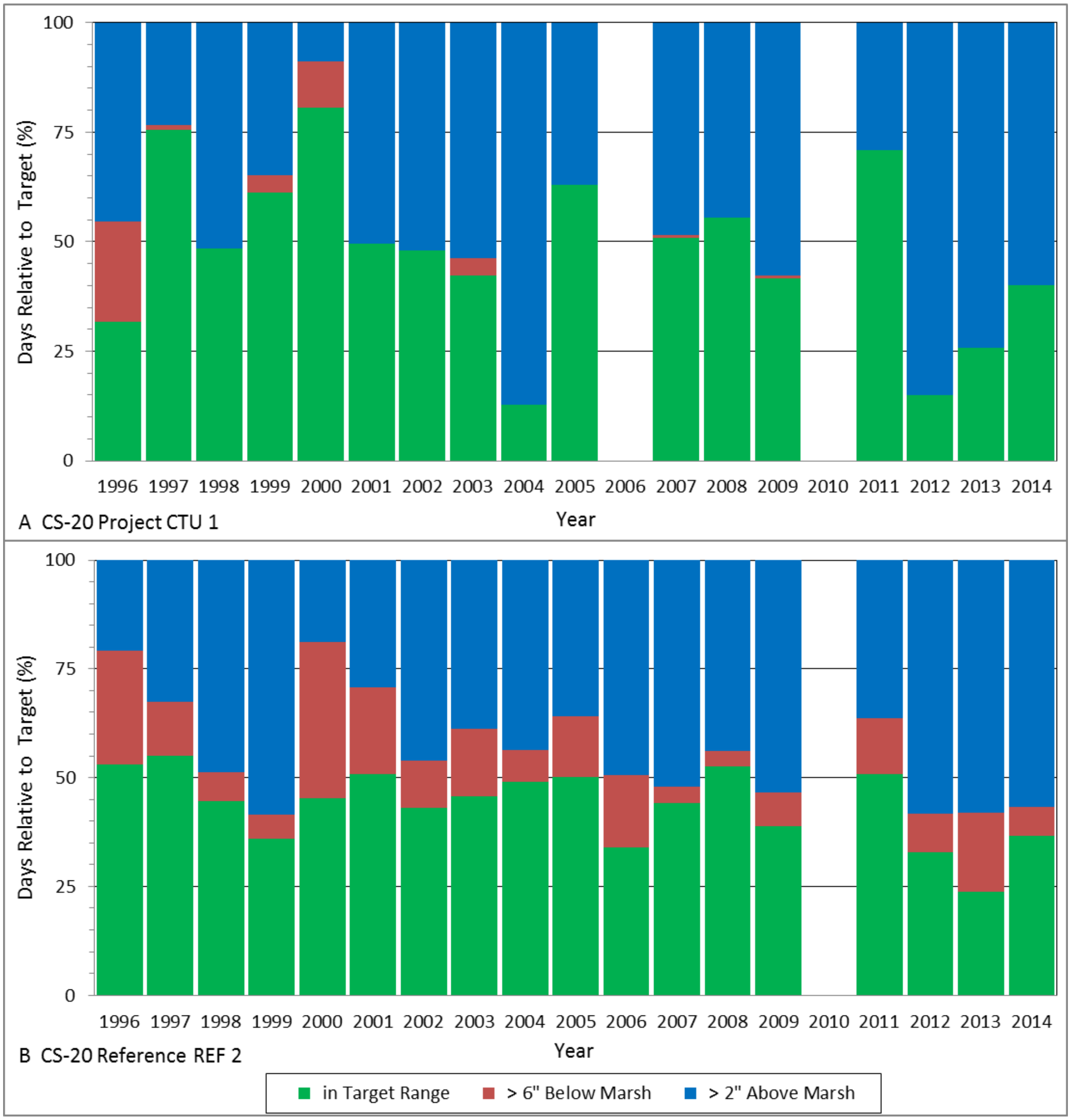


Figure 13. Percent days per year of water levels relative to target range (2" above to 6" below averaged marsh elevation of 1.01 ft NAVD88) for passively managed CTU 1 (A) and its reference, REF 2 (B), since construction in 1996 through 2014. CTU 1 is represented by station CS20-07 for 1996-2009 and CS20-106 for 2011-2014; REF 2 is represented by CS20-15R throughout the years.

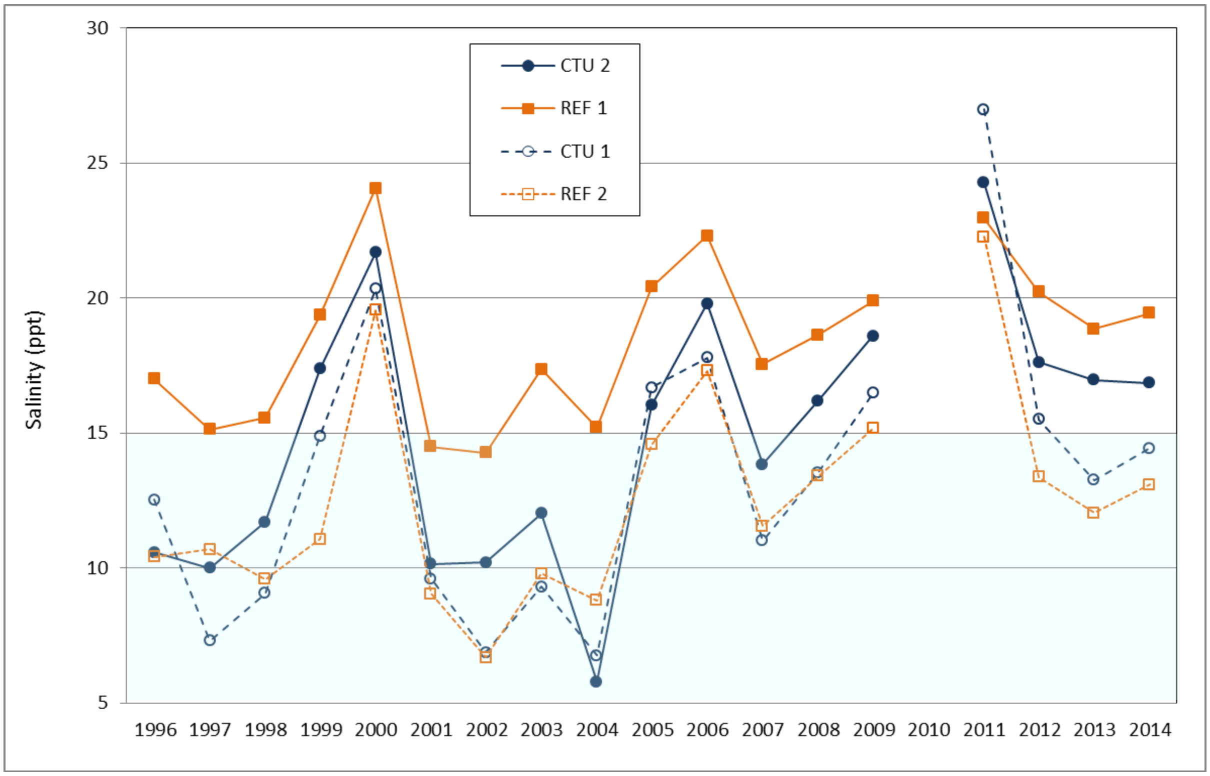


Figure 14. Annual water salinity was averaged from salinity data collected by continuous water-level recorders within the managed CTU (circles) and reference (squares) areas. The targeted salinity for the CTUs is below 15 ppt (shaded area). Paired comparisons are CTU 2 (1996-2009: CS20-03; 2011-2014: average of CRMS0672 and 0655) v REF 1 (CS20-14R throughout the years) (solid markers and lines) and CTU 1 (1996-2009: CS20-07; 2011-2014: CS20-106) v REF 2 (CS20-15R throughout the years) (open markers and dashed lines).

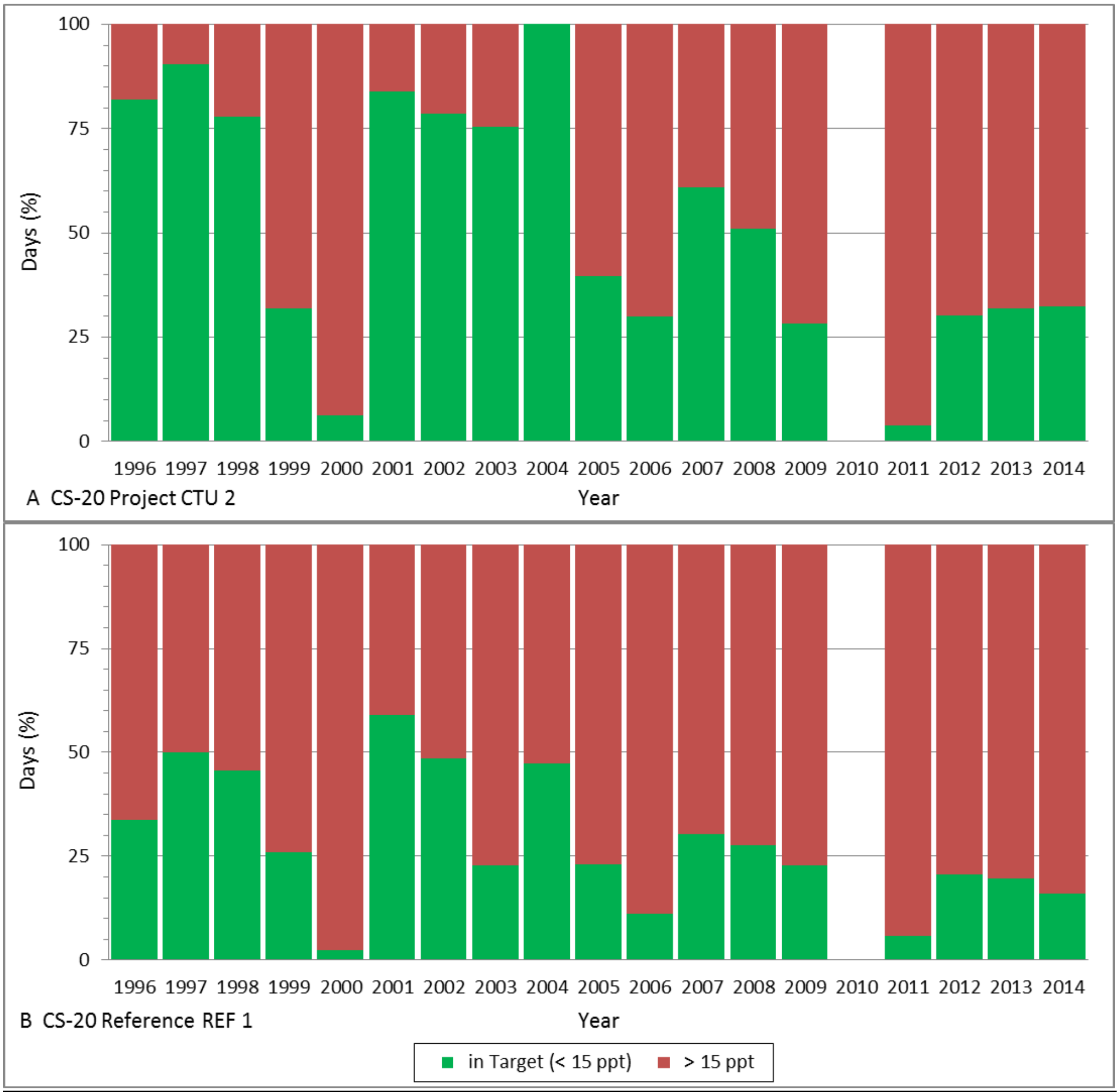


Figure 15. Percent days per year of water salinity relative to target range (< 15 ppt) for actively managed CTU 2 (A) and its reference, REF 1 (B), since construction in 1996 through 2014. CTU 2 is represented by station CS20-03 for 1996-2009 and an average of CRMS0672 and 0655 for 2011-2014; REF 1 is represented by CS20-14R throughout the years.

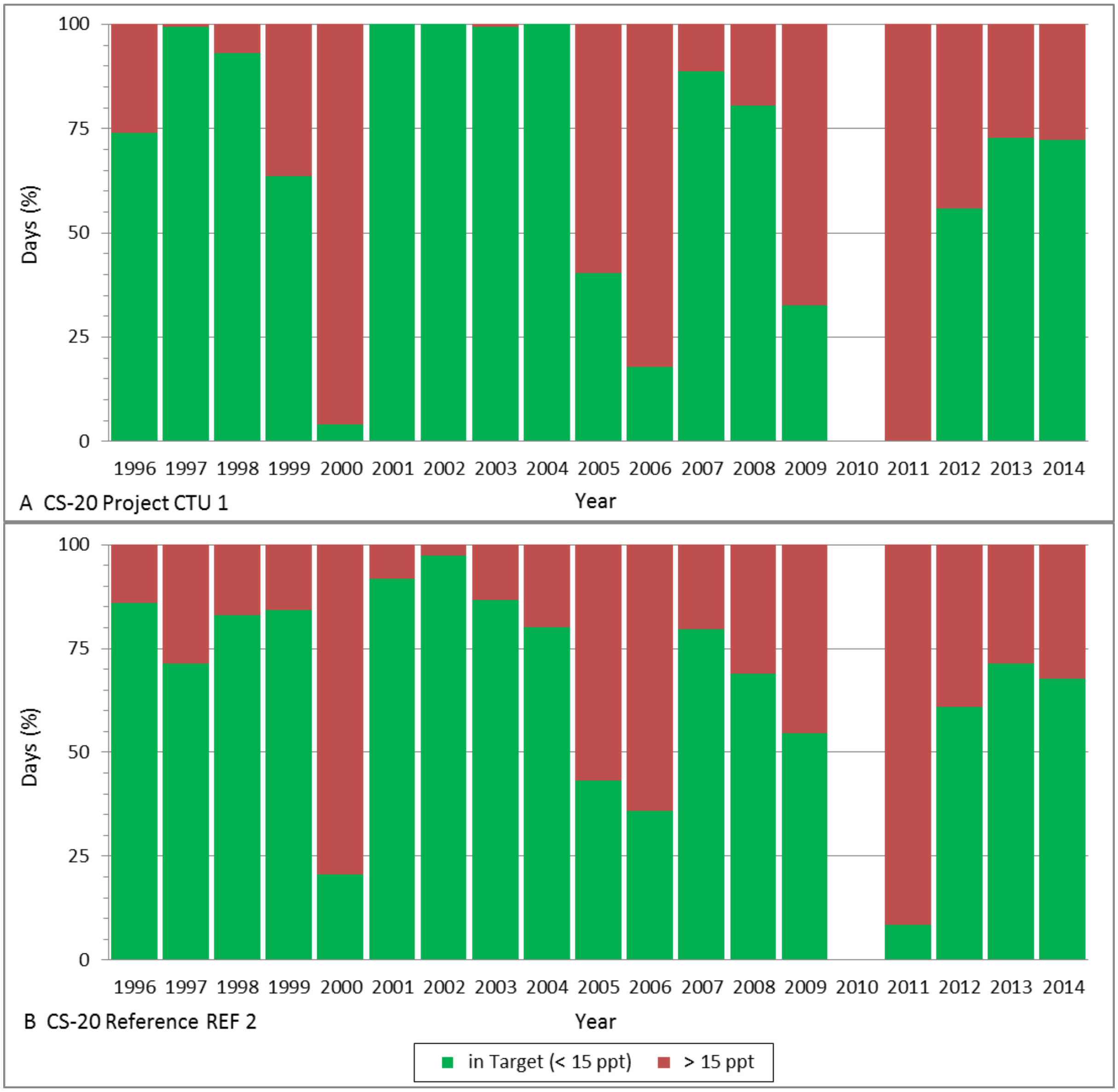


Figure 16. Percent days per year of water salinity relative to target range (< 15 ppt) for passively managed CTU 1 (A) and its reference, REF 2 (B), since construction in 1996 through 2014. CTU 1 is represented by station CS20-07 for 1996-2009 and CS20-106 for 2011-2014; REF 2 is represented by CS20-15R throughout the years.

v. **Marsh Elevation Change**

CS-20 has been achieving the surface elevation goal as accretion in CTU 2 has increased since the beginning of the project. Distinct differences over time in CS-20 resulted from Hurricane Rita in 2005 (Rita); therefore, elevation change rates were calculated from the time periods for the overall life of the project (1996-2014), before the hurricanes (1996-2003), after the hurricane (2006-2014) and for each SET unit (Table 4 and figure 17). Six of the VA stations and two SET sites were converted to open water during the hurricanes in the Deep Marsh/Banker Muck of the reference area (picture 1), and two SET stations were damaged in CTU 2 before the 2009 sampling; therefore, analyses were conducted with 6 units per area for the pre-hurricane time period and 4 units per area for the overall and post-hurricane time periods. Elevation losses at the sites removed by hurricanes, estimated to be at least 1 ft (30.5 cm), were not included in the elevation change analyses for the overall or post-hurricane time period.

Surface elevation change (SEC) rates measured from the SET pipes were statistically greater during the overall and post-hurricane time periods than pre-hurricane time period. Although there were no statistical differences between the areas within time periods, the project area improved 20% more than the reference area as its rate more than quadrupled from the lowest pre-hurricane rate to among the highest overall rate (Table 3). Vertical accretion rates were similar for the pre and post hurricane periods and statistically greater for the overall time period (Table 4), demonstrating the sediment input from Hurricane Rita (Figure 17). Shallow subsidence was greatest in the Reference area in the overall time period and least in the Project area during the post-hurricane time period; such differences are typically caused by (1) increased reworking/ displacement of surface sediment inflating vertical accretion which may account for greater shallow subsidence in the reference area and/or (2) root production adding to the soil volume which may account for the lesser shallow subsidence in the project area. Relative sea-level rise (RSLR) based on observations from NOAA's long-term water level station in Sabine Pass, Texas is estimated to be 0.54 ± 0.08 cm/y from 1958-2014 (http://tidesandcurrents.noaa.gov/sltrends/sltrends_update.shtml?stnid=8770570). Over the life of the project (1996-2014), surface elevation change in CTU 2 has outpaced RSLR by 0.09 cm/y while surface elevation change in REF 2 is 0.07 cm/y less than RSLR.

Increasing vegetative area will only last if the marsh elevation is maintained or increased. Overall, components of elevation change are less variable in the project than the reference areas; this is attributable to the water control structures and the pre-existing ring levees around CTU 2. The project area receives less allochthonous input than the reference area because of the pre-existing ring levees; recently, however, it appears that the accretion rates of the two areas are similar so it is doubtful that the lack of suspended material input is the only factor influencing marsh elevation change. Prior to and following the hurricanes, elevation change was slightly greater in the reference area; however, elevation change was ~35% greater in the project area over the whole project life than the reference area. Much of the difference in elevation change between the areas is accounted for by greater shallow subsidence in the reference area. Sedimentation from the Hurricane Rita was relatively large, greater than years or even decades of normal deposition. The newly introduced sediments were very unconsolidated and settled over time; compaction or other loss of hurricane sediments has been greater in the reference area. Sediments are more likely to be held in place and integrated into the soil and roots in the project area than the reference area.

Table 4. Vertical accretion, surface elevation, and shallow subsidence change rates collected in CS-20 project (CTU 2) and reference (REF 2) areas over the life of the project and pre- and post- Hurricane Rita in September 2005. A separate Area (project, reference) × Time Period (overall, pre hurricane, post hurricane) full-factorial ANOVA was used for each rate type; different letters within each rate type indicate statistical differences between areas over time based on Student's t post-test.

			Rates of Change (cm/yr ± 1 SE)		
Time Period	Area	n	Surface Elevation	Vertical Accretion	Shallow Subsidence
Overall (Jul 1996–Oct 2014)	Project	4	0.63 ± 0.12 [A]	0.92 ± 0.09 [GH]	0.28 ± 0.17 [MN]
	Reference	4	0.47 ± 0.18 [ABC]	0.95 ± 0.08 [I]	0.52 ± 0.24 [M]
Pre Hurricane Rita (Jul 1996–Jul 2003)	Project	6	0.12 ± 0.12 [C]	0.42 ± 0.05 [I]	0.30 ± 0.10 [MN]
	Reference	6	0.18 ± 0.09 [BC]	0.59 ± 0.07 [I]	0.41 ± 0.08 [M]
Post Hurricane Rita (Jun 2006-Oct 2014)	Project	4	0.56 ± 0.15 [AB]	0.43 ± 0.13 [I]	-0.13 ± 0.19 [N]
	Reference	4	0.47 ± 0.16 [ABC]	0.64 ± 0.16 [HI]	0.17 ± 0.24 [MN]

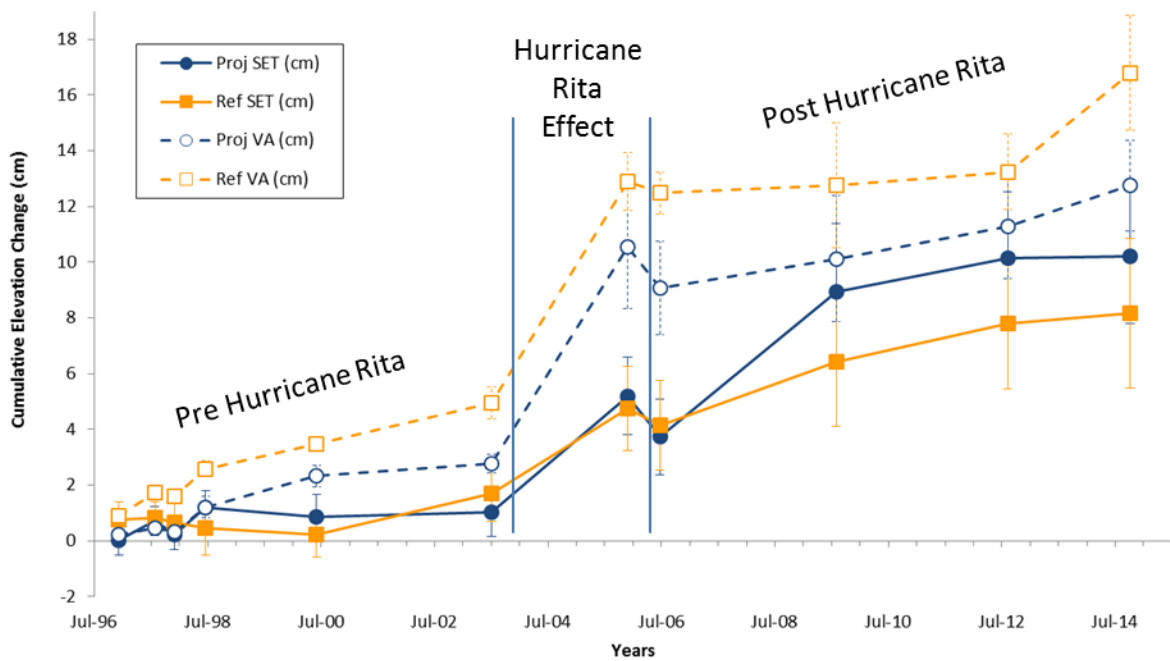
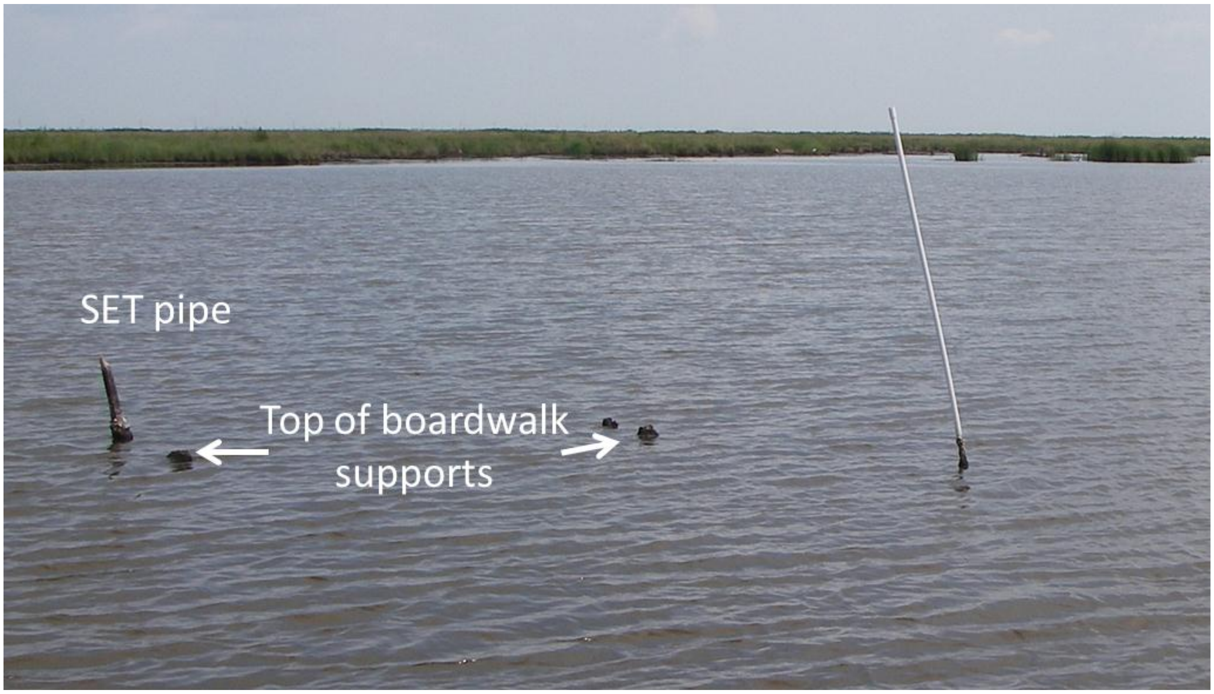


Figure 17. Cumulative elevation change was calculated from surface elevation measurements collected at Surface Elevation Tables (SET) and vertical accretion measurements collected from horizon markers (VA) collected at CS-20 project (Proj – CTU 2) and reference (Ref – REF 2) areas over time (Jul 1996 – Oct 2014). Values are means and standard errors of each time interval grouped by SET units for each area. Change rates were calculated for statistical analysis of pre- and post-Hurricane Rita time periods and the overall time period which included the direct Hurricane Rita effects.



Picture 1. Picture of Station CS20-52R taken in Aug 2009 following Hurricanes Rita (2005) and Ike (2008). Most of the open water was marsh prior to the hurricane storm-surge scour (see figure 5B for extent of damage in Reference Area 1).

vi. Fisheries

Fisheries aspects were collected in the CTU 2 (project area) and REF 2 (reference area). In order to accurately describe the most important differences in fisheries species abundances, resident and transient species are treated separately. Resident species spend most of their life cycle within the estuary, whereas transient species spawn in nearshore or offshore waters and use shallow estuarine habitats as nursery areas.

The most abundant resident fish species included *Poecilia latipinna* (sailfin molly), *Gambusia affinis* (western mosquitofish), *Menidia beryllina* (inland silversides), and *Cyprinodon ariegates* (sheepshead minnow), while *Brevoortia patronus* (gulf menhaden) and *Anchoa mitchilli* (bay anchovy) were two of the most abundant transient fish species. The most abundant resident decapod taxa include *Palaemonetes intermedius* (brackish grass shrimp), *P. pugio (*daggerblade grass shrimp), and *Palaemonetes* sp., while *Penaeus setiferus* (white shrimp), *P. aztecus* (brown shrimp), and *Callinectes sapidus* (blue crab) represent most abundant transient decapod species.

Before and after project construction, transient fishes and crustaceans were generally more abundant in the reference area (REF 2) than the project area (CTU 2) (Figures 18 and 19) while resident fishes and crustaceans were generally more abundant in the project area than the reference area (Figures 20 and 21). This likely indicates a previous and present access restriction for transient species to the project area caused by ring levees which is more suitable habitat for resident species. Fisheries species densities were temporally variable in both areas, and despite a trend toward higher crustacean densities after project construction in both areas, the project did not have a significant effect on total fisheries species densities. Although transient crustacean densities did increase significantly post construction in the project area, there was a much greater significant post construction increase in the reference area in total, transient, and resident crustacean densities, which means that even if the project effects contributed to an increase in animal numbers it was overshadowed by other (likely natural) causes.

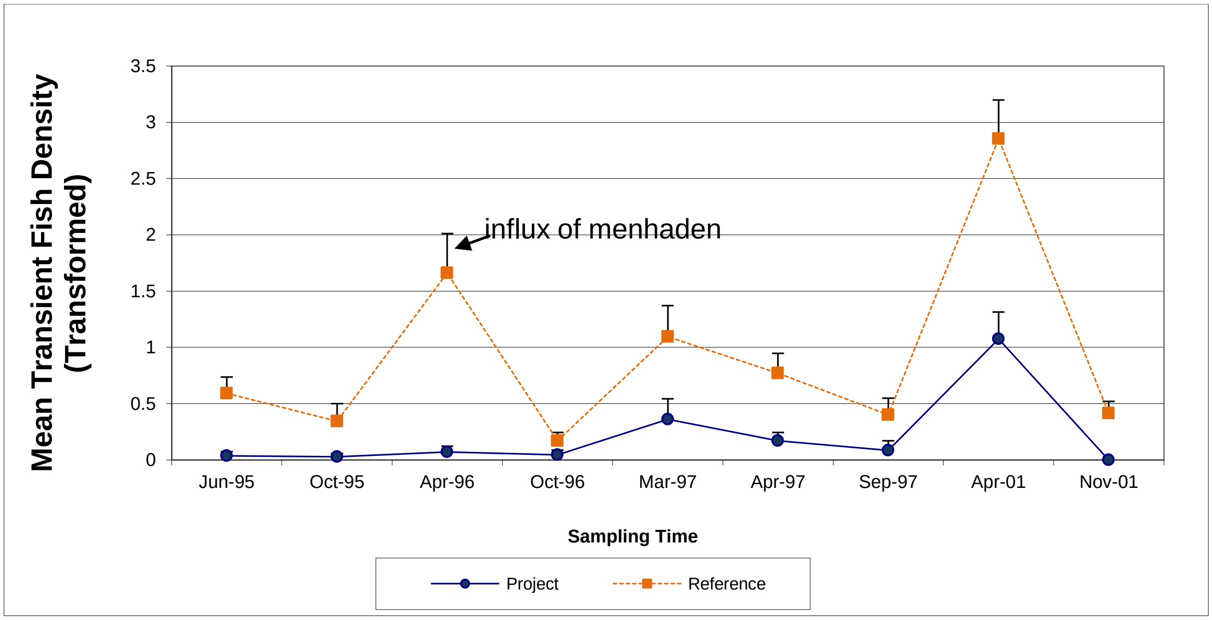


Figure 18. Transformed mean density per square meter of transient fish species collected in the East Mud Lake (CS-20) project and reference areas at sampling dates between June 1995 and November 2001**.**

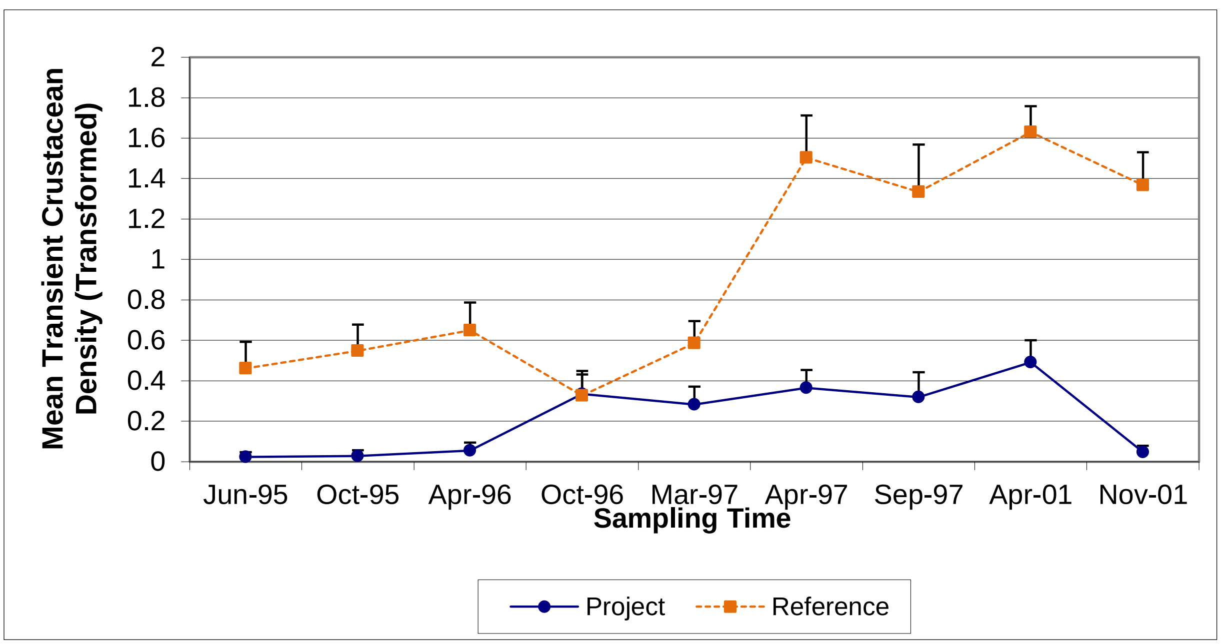


Figure 19. Transformed mean density per square meter of transient crustacean species collected in the East Mud Lake (CS-20) project and reference areas at sampling dates between June 1995 and November 2001.

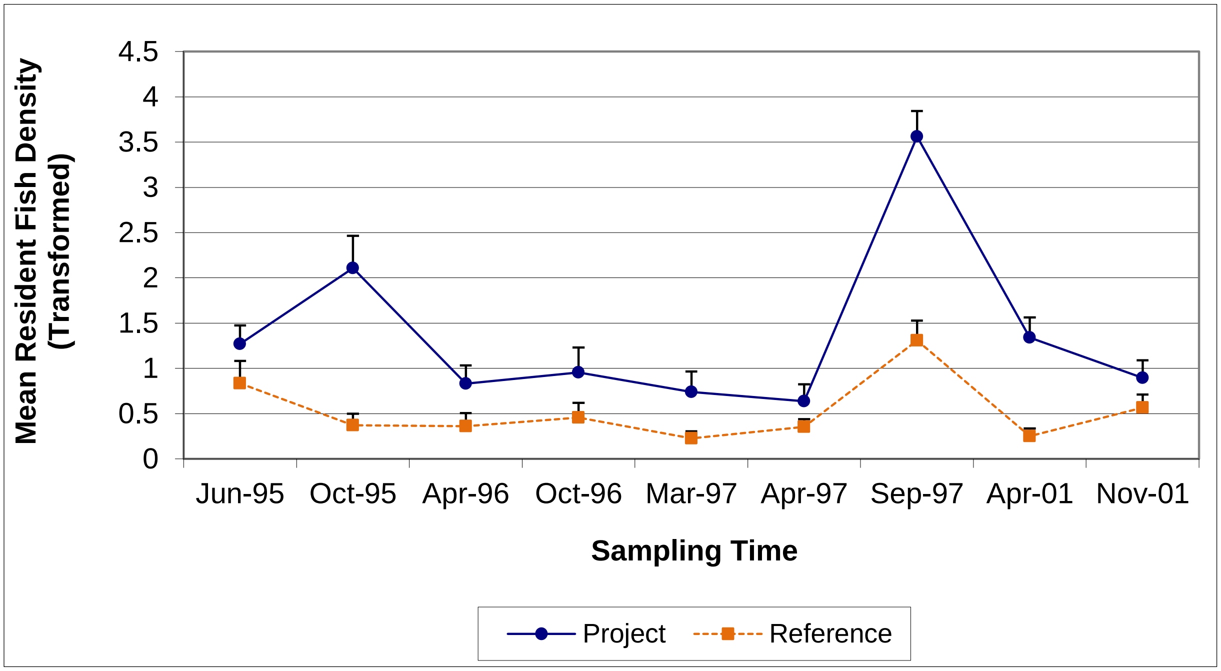


Figure 20. Transformed mean density per square meter of resident fish species collected in the East Mud Lake (CS-20) project and reference areas at sampling dates between June 1995 and November 2001**.**

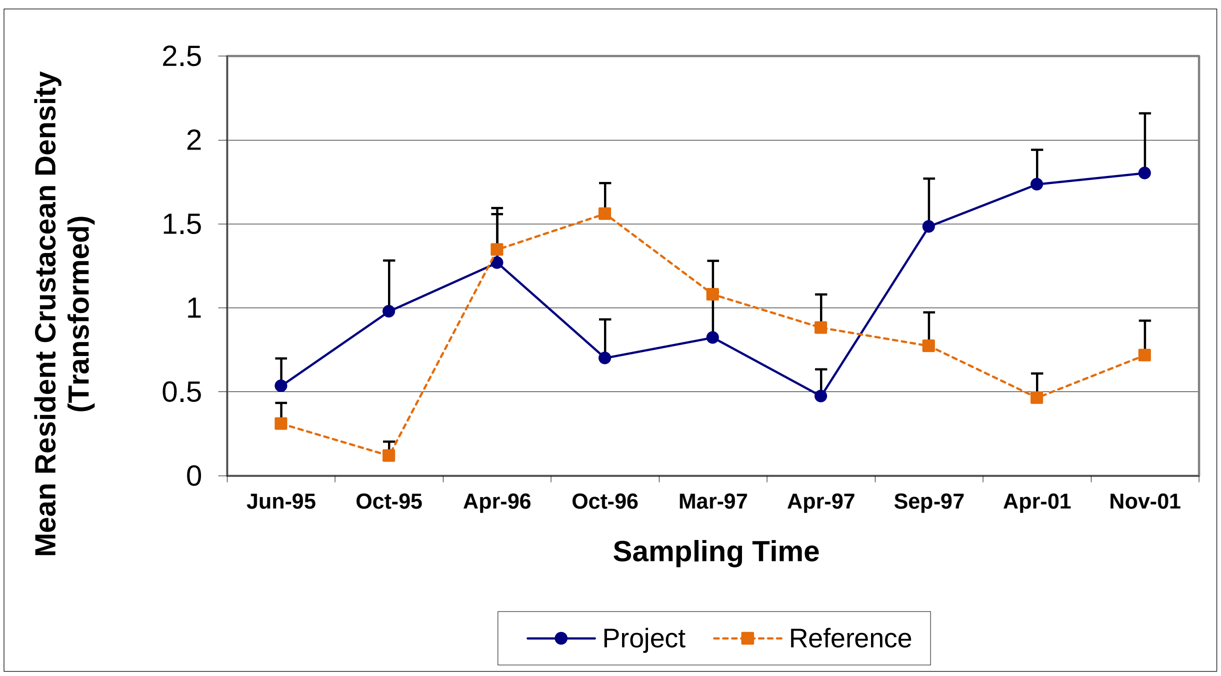


Figure 21. Transformed mean density per square meter of resident crustacean species collected in the East Mud Lake (CS-20) project and reference areas at sampling dates between June 1995 and November 2001**.**

V. Conclusions

a. Project Effectiveness

The CS-20 project has been achieving the first goal to prevent wetland degradation in the project area by reducing vegetative stress, thereby improving the abundance of emergent and submerged vegetation. This has been achieved through hydrologic structural management to reduce water levels and salinities, and adaptive management to allow for hydrologic flushing after major climatic events such as droughts and storm surge despite salinities being > 15 ppt.

The shoreline of Mud Lake has been stable stabile throughout the project life.

CS-20 has been effective at decreasing the rate of marsh loss. Land loss rates decreased substantially after construction in CTU 2 which actually gained land and had the lowest percentage of marsh loss resulting from Hurricane Rita.

CS-20 has been meeting its hydrologic objective of reducing water level and salinity within target ranges for brackish vegetation comparing CTUs to their reference areas. This has led to more consistent conditions for vegetative growth and surface accretion.

CS-20 met the objective of decreasing duration and frequency of flooding over marsh from 1996 -2007 but has not from 2007 - 2014 relative to the reference areas.

CS-20 has been meeting its objective of decreasing mean salinity in the actively managed CTU 2 relative to its reference area, REF 1.

Overall, the CS-20 project has been effective at increasing emergent vegetation into shallow open-water areas in CTU 2.

Increasing the land to water ratio by encouraging vegetation growth will only last if the marsh elevation is maintained or increased. CS-20 has been achieving the objective of increasing surface accretion in CTU 2. Also, surface elevation change in CTU 2 has outpaced relative sea-level rise (RSLR) while surface elevation change in REF 2 is less than RSLR.

The project had maintained fisheries abundance as resident fishes and crustaceans were generally more abundant in the project area, and transient fishes and crustaceans were generally more abundant in the reference area prior to and 5 years after project construction. This indicates the pre-existing ring levee has restricted access of transient species to the project area and provides a more suitable habitat for resident species in the project area.

b. Recommended Improvements

Continue adaptation to operations plan to allow for water exchange on a limited basis in CTU 2 to reduce vegetative stress. The vegetative community shift to more salt tolerant plants should make salinity > 15 ppt less of a stress to the vegetation.

Periodic elevation surveys should be conducted to ensure that marsh elevation and structure operation elevations remain complementary to avoid excessive flooding or drying of the marsh vegetation.

c. Lessons Learned

Large ecological changes over time are driven by climatic conditions (droughts, flooding, hurricanes) occurring on a regional scale rather than project effects. During "calmer times" between regional scale events, differences among project and reference areas are more distinctive as the project areas typically have more moderate (less fluctuations) water levels and lower salinity thereby providing conditions to reduce vegetative stress. Operations and Management work on hydrologic structures completed in 2011 in addition to hydrologic projects adjacent to the project area in 2010 and 2012 improved the overall performance and effectiveness of CS-20 as the area recovered well by 2012 from drought conditions and has continued through 2014.

Adaptive management of the operations plan to allow for structure openings despite salinity > 15 ppt allowed the project area to flush following the hurricanes. Adaptive management continued after the installation of ES-#4 in 2011. Despite salinities reaching 25+ ppt during an extensive drought, the flap gates at ES-#4 were left open with stoplogs set at 6" below marsh elevation while other CTU 2 structures were closed. As a result of adaptive management to allow for some limited hydrologic exchange, wide spread stagnation of CTU 2 was not observed during monitoring events in 2009 and 2012 nor by the landowner as a result of a severe drought from 2009-2011. This is in contrast to the drought of the late 1990s that lead to loss of vegetative cover, floristic quality, and surface elevation. CPRA-Operations Division-Lafayette Regional Office crafted a Special Provision for CTU 2 Maintenance Phase for Drought Conditions (Appendix E).

Hydrologic structures are vandalized when fisheries resources are perceived to be held within the project area.

d. End of Project Life Recommendations

The CS-20 project will reach its end of project life in 2016. CWPPRA awarded a 5 year project extension and funding increase in spring 2015 to CPRA and NRCS to conduct a final Maintenance event to repair ES-#4 and ES-#13 and replace ES-#17 for future hydrologic operations. CPRA and NRCS will then cede ownership and operations of the structural project features to the landowner, Apache Louisiana Minerals, Inc. A Revised Drawdown Guidance and special provision for operations during a drought was given to Apache Louisiana Minerals, Inc. in 2011 (Appendix E).

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Appendix A
(Inspection Photographs)

Photo No.1 Structure No. 6

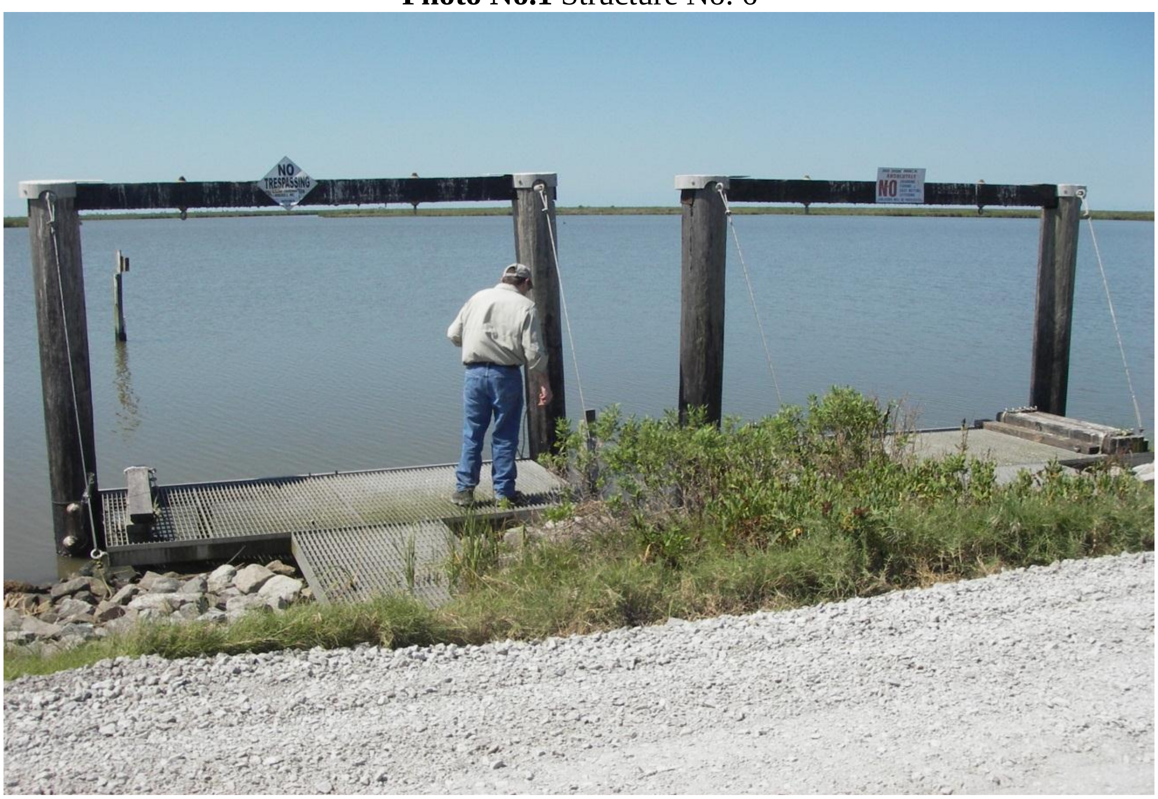


Photo No. 2 Structure No. 7

Photo No. 3, Structure No. 8

Photo No. 4, Structure No. 9a

Photo No. 5, sluice gate gear box on Structure 9b

Photo No. 6, flapgates on Structures 9a & 9b

Photo No. 7, flap stuck open, Structure No. 11

Photo No. 8, Structure No. 11

Photo No. 9, Structure No. 5

Photo No. 10, flap side, Structure No. 5

Photo No. 11, flap side, Structure No.4

Photo No. 12, Structure No. 4

Photo No. 13, boat barrier, Structure No. 4

Photo 14, sinkholes developing behind Structure 4 stoplog bays

Photo 15, Structure 3

Photo 16, flap side, Structure 3

Photo 17, Structure 1

Photo 18, flap side, Structure 1

Photo 19, Structure 17

Photo 20, sheet pile, cap and lifting hardware at Structure 17

Photo 21—Structure 13

Photo 22—sheet pile wall and cap at Structure 13

Photo 23—disconnected flap on Structure 13

Photo 24—broken pivot point on Structure 13 flap

Appendix B
(Three Year Budget Projection)

E. MUD LAKE/ CS-20 / PPL 2

Three-Year Operations & Maintenance Budgets 07/01/2015 - 06/30/2018

Project Manager	O & M Manager	Federal Sponsor	Prepared By
Pat Landry	*Stan Aucoin*	*NRCS*	*Stan Aucoin*

	2015/2016 (-20)	2016/2017	2017/2018
Maintenance Inspection	$ 6,851.00		
Structure Operation	$ 6,500.00		
State Administration	$ 5,000.00		$ -
Federal Administration	$ 5,000.00		$ -
Maintenance/Rehabilitation			

15/16 Description: Repairs to Structures 4, 13 and replacement of Structure 17

	2015/2016 (-20)	
E&D		
Construction	$ 518,250.00	(Incl. 25% Contingency)
Construction Oversight		
Sub Total - Maint. And Rehab.	$ 518,250.00	

16/17 Description:

	2016/2017
E&D	
Construction	
Construction Oversight	
Sub Total - Maint. And Rehab.	$ -

17/18 Description:

	2017/2018
E&D	$ -
Construction	$ -
Construction Oversight	$ -
Sub Total - Maint. And Rehab.	$ -

	2015/2016 (-20)	2016/2017	2017/2018
Total O&M Budgets	**$ 541,601.00**	**$ -**	**$ -**

O &M Budget (3 yr Total)	**$ 541,601.00**
Unexpended O & M Budget	**$ 140,240.00**
Remaining O & M Budget (Projected)	**$ (401,361.00)**

OPERATION AND MAINTENANCE BUDGET WORKSHEET

E. MUD LAKE / PROJECT NO. CS-20 / PPL NO. 2 / 2015-2016 (-20)

DESCRIPTION	UNIT	EST. QTY.	UNIT PRICE	ESTIMATED TOTAL
O&M Inspection and Report	EACH	1	$6,851.00	**$6,851.00**
General Structure Maintenance	LUMP	0	$0.00	**$0.00**
Engineering and Design	LUMP	0	$0.00	**$0.00**
Operations Contract	LUMP	1	$6,500.00	**$6,500.00**
Construction Oversight	LUMP	0	$0.00	**$0.00**

ADMINISTRATION

STATE Admin.	LUMP	1	$5,000.00	$5,000.00
FEDERAL SPONSOR Admin.	LUMP	1	$5,000.00	$5,000.00
SURVEY Admin.	LUMP	0	$0.00	$0.00
OTHER Land Rights	LUMP	0	$0.00	$0.00
			TOTAL ADMINISTRATION COSTS:	**$10,000.00**

MAINTENANCE / CONSTRUCTION

SURVEY

SURVEY DESCRIPTION:

Secondary Monument	EACH	0	$0.00	$0.00
Staff Gauge / Recorders	EACH	0	$0.00	$0.00
Marsh Elevation / Topography	LUMP	0	$0.00	$0.00
TBM Installation	EACH	0	$0.00	$0.00
OTHER				$0.00
			TOTAL SURVEY COSTS:	**$0.00**

GEOTECHNICAL

GEOTECH DESCRIPTION:

Borings	EACH	0	$0.00	$0.00
OTHER				$0.00
			TOTAL GEOTECHNICAL COSTS:	**$0.00**

CONSTRUCTION

CONSTRUCTION DESCRIPTION: Repairs to Structures 4, 13 and replacement of Structure 17

Rip Rap	LIN FT	TON / FT	TONS	UNIT PRICE	
2# Rip Rap (Str. No. 4)	0	0.0	75	$100.00	$7,500.00
30# Rip Rap (Str. No. 17)	0	0.0	150	$100.00	$15,000.00
	0	0.0	0	$0.00	$0.00

Filter Cloth / Geogrid Fabric	SQ YD	0	$12.00	$0.00
Navigation Aid	EACH	0	$0.00	$0.00
Signage	EACH	0	$0.00	$0.00
General Excavation / Fill	CU YD	330	$20.00	$6,600.00
Dredging	CU YD	0	$0.00	$0.00
Sheet Piles (Lin Ft or Sq Yds)		0	$0.00	$0.00
Timber Piles (each or lump sum)		0	$0.00	$0.00
Timber Members (each or lump sum)		0	$0.00	$0.00
Hardware	LUMP	0	$0.00	$0.00
Materials	LUMP	0	$0.00	$0.00
Mob / Demob	LUMP	1	$85,000.00	$85,000.00
Contingency (25 %)	LUMP	1	$103,650.00	$103,650.00
General Structure Maintenance (Str. No. 4)	LUMP	1	$500.00	$500.00
General Structure Maintenance (Str. No. 13)	LUMP	1	$30,000.00	$30,000.00
New Structure (Str. No. 17)	LIN FT	100	$2,500.00	$250,000.00
Structure Removal (Str. No. 17)	LUMP	1	$20,000.00	$20,000.00
			TOTAL CONSTRUCTION COSTS:	**$518,250.00**

TOTAL OPERATIONS AND MAINTENANCE BUDGET: $541,601.00

Appendix C
(Field Inspection Form)

MAINTENANCE INSPECTION REPORT CHECK SHEET

Date of Inspection: June 11, 2014 Time:

Project No. / Name: CS-20 E. Mud Lake

Inspector(s):Stan Aucoin, Tommy McGinis, Darrell Pontiff (CPRA)
Dustin Perron (NRCS), Tim Allen, Scott Rosteet (Apache)

Structure No. 1

Structure Description: Culvert w/stop logs and Flap

Water Level Inside: Outside:
Weather Conditions: Sunny and hot

Type of Inspection: Annual

Item	Condition	Physical Damage	Corrosion	Photo #	Observations and Remarks
Steel Bulkhead / Caps	N/A				
Steel Grating	Good				
Stop Logs	Good				
Hardware	Good				
Timber Piles Timber Walkway	Good Good				
Timber Wales	Good				
Galv. Pile Caps	Good				
Cables	Good				
Signage /Supports Staff Gages	Good Good				
Rip Rap (fill)	Good			17-18	
Earthen Embankment	Good				

What are the conditions of the existing levees?
Are there any noticeable breaches?
Settlement of rock plugs and rock weirs?
Position of stoplogs at the time of the inspection?
Are there any signs of vandalism? Yes

MAINTENANCE INSPECTION REPORT CHECK SHEET

Date of Inspection: June 11, 2014 Time:

Project No. / Name: CS-20 E. Mud Lake

Inspector(s):Stan Aucoin, Tommy McGinis, Darrell Pontiff (CPRA)
Dustin Perron (NRCS), Tim Allen, Scott Rosteet (Apache)

Structure No. 3

Structure Description: Culvert w/stop logs and Flap

Water Level Inside: Outside:
Weather Conditions: Sunny and hot

Type of Inspection: Annual

Item	Condition	Physical Damage	Corrosion	Photo #	Observations and Remarks
Steel Bulkhead / Caps	N/A				
Steel Grating	Good				
Stop Logs	Good				
Hardware	Good				
Timber Piles Timber Walkway	Good Good				
Timber Wales	Good				
Galv. Pile Caps	Good				
Cables	Good				
Signage /Supports Staff Gages	Good Good				
Rip Rap (fill)	Good			15-16	
Earthen Embankment	Good				

What are the conditions of the existing levees?
Are there any noticeable breaches?
Settlement of rock plugs and rock weirs?
Position of stoplogs at the time of the inspection?
Are there any signs of vandalism? Yes

MAINTENANCE INSPECTION REPORT CHECK SHEET

Date of Inspection: June 11, 2014 Time:

Project No. / Name: CS-20 E. Mud Lake

Inspector(s):Stan Aucoin, Tommy McGinis, Darrell Pontiff (CPRA)
Dustin Perron (NRCS), Tim Allen, Scott Rosteet (Apache)

Structure No. 4

Structure Description: Culvert w/stop logs and Flap

Water Level Inside: Outside:
Weather Conditions: Sunny and hot

Type of Inspection: Annual

Item	Condition	Physical Damage	Corrosion	Photo #	Observations and Remarks
Steel Bulkhead / Caps	Good			11	
Steel Grating	Good				
Stop Logs	Good				some stoplogs have been stolen
Hardware	Good				some locks have been stolen
Timber Piles Timber Walkway	Good Good				
Timber Wales	Good			13	
Galv. Pile Caps	Good				
Cables	Good				
Signage /Supports Staff Gages	Good Good				
Rip Rap (fill)	Good				
Earthen Embankment	Fair			12,14	sinkholes forming on stoplog side of structure

What are the conditions of the existing levees?
Are there any noticeable breaches?
Settlement of rock plugs and rock weirs?
Position of stoplogs at the time of the inspection?
Are there any signs of vandalism? Yes

MAINTENANCE INSPECTION REPORT CHECK SHEET

Date of Inspection: June 11, 2014 Time:

Project No. / Name: CS-20 E. Mud Lake

Inspector(s):Stan Aucoin, Tommy McGinis, Darrell Pontiff (CPRA)
Dustin Perron (NRCS), Tim Allen, Scott Rosteet (Apache)

Structure No. 5

Structure Description: Culvert w/stop logs and Flap

Water Level Inside: Outside:
Weather Conditions: Sunny and hot

Type of Inspection: Annual

Item	Condition	Physical Damage	Corrosion	Photo #	Observations and Remarks
Steel Bulkhead / Caps	N/A				
Steel Grating	Good				
Stop Logs	Good				
Hardware	Good				
Timber Piles Timber Walkway	Good Good			9,10	
Timber Wales	Good				
Galv. Pile Caps	Good				
Cables	Good				
Signage /Supports Staff Gages	Good Good				
Rip Rap (fill)	Good			9,10	
Earthen Embankment	Good				

What are the conditions of the existing levees?
Are there any noticeable breaches?
Settlement of rock plugs and rock weirs?
Position of stoplogs at the time of the inspection?
Are there any signs of vandalism? Yes

MAINTENANCE INSPECTION REPORT CHECK SHEET

Project No. / Name: CS-20 E. Mud Lake

Structure No. 13

Structure Description: bulkhead w/stop logs and Flaps

Type of Inspection: Annual

Date of Inspection: June 11, 2014 Time:

Inspector(s):Stan Aucoin, Tommy McGinis, Darrell Pontiff (CPRA)
Dustin Perron (NRCS), Tim Allen, Scott Rosteet (Apache)

Water Level Inside: Outside:
Weather Conditions: Sunny and hot

Item	Condition	Physical Damage	Corrosion	Photo #	Observations and Remarks
Steel Bulkhead / Caps	Fair			21-24	
Steel Grating	Good				
Stop Logs	Good				
Hardware Flap Gates	Good Poor			21-24	
Timber Piles Timber Walkway	Good Good				
Timber Wales	Good				
Galv. Pile Caps	Good				
Cables	Good				
Signage /Supports Staff Gages	Good Good				
Rip Rap (fill)	Good				
Earthen Embankment	Good				

What are the conditions of the existing levees?
Are there any noticeable breaches?
Settlement of rock plugs and rock weirs?
Position of stoplogs at the time of the inspection?
Are there any signs of vandalism? Yes

MAINTENANCE INSPECTION REPORT CHECK SHEET

Date of Inspection: June 11, 2014 Time:

Project No. / Name: CS-20 E. Mud Lake

Inspector(s):Stan Aucoin, Tommy McGinis, Darrell Pontiff (CPRA)
Dustin Perron (NRCS), Tim Allen, Scott Rosteet (Apache)

Structure No. 17

Structure Description: Culvert w/stop logs and Flap

Water Level Inside: Outside:
Weather Conditions: Sunny and hot

Type of Inspection: Annual

Item	Condition	Physical Damage	Corrosion	Photo #	Observations and Remarks
Steel Bulkhead / Caps	Poor			19,20	
Steel Grating	Good				
Stop Logs	Good				
Hardware	Good				
Timber Piles Timber Walkway	Good Good				
Timber Wales	Good				
Galv. Pile Caps	Good				
Cables	Good				
Signage /Supports Staff Gages	Good Good				
Rip Rap (fill)	Good				
Earthen Embankment	Good				

What are the conditions of the existing levees?
Are there any noticeable breaches?
Settlement of rock plugs and rock weirs?
Position of stoplogs at the time of the inspection?
Are there any signs of vandalism? Yes

MAINTENANCE INSPECTION REPORT CHECK SHEET

Date of Inspection: June 11, 2014 Time:

Project No. / Name: CS-20 E. Mud Lake

Inspector(s):Stan Aucoin, Tommy McGinis, Darrell Pontiff (CPRA)
Dustin Perron (NRCS), Tim Allen, Scott Rosteet (Apache)

Structure No.

Structure Description: Step Canal levee

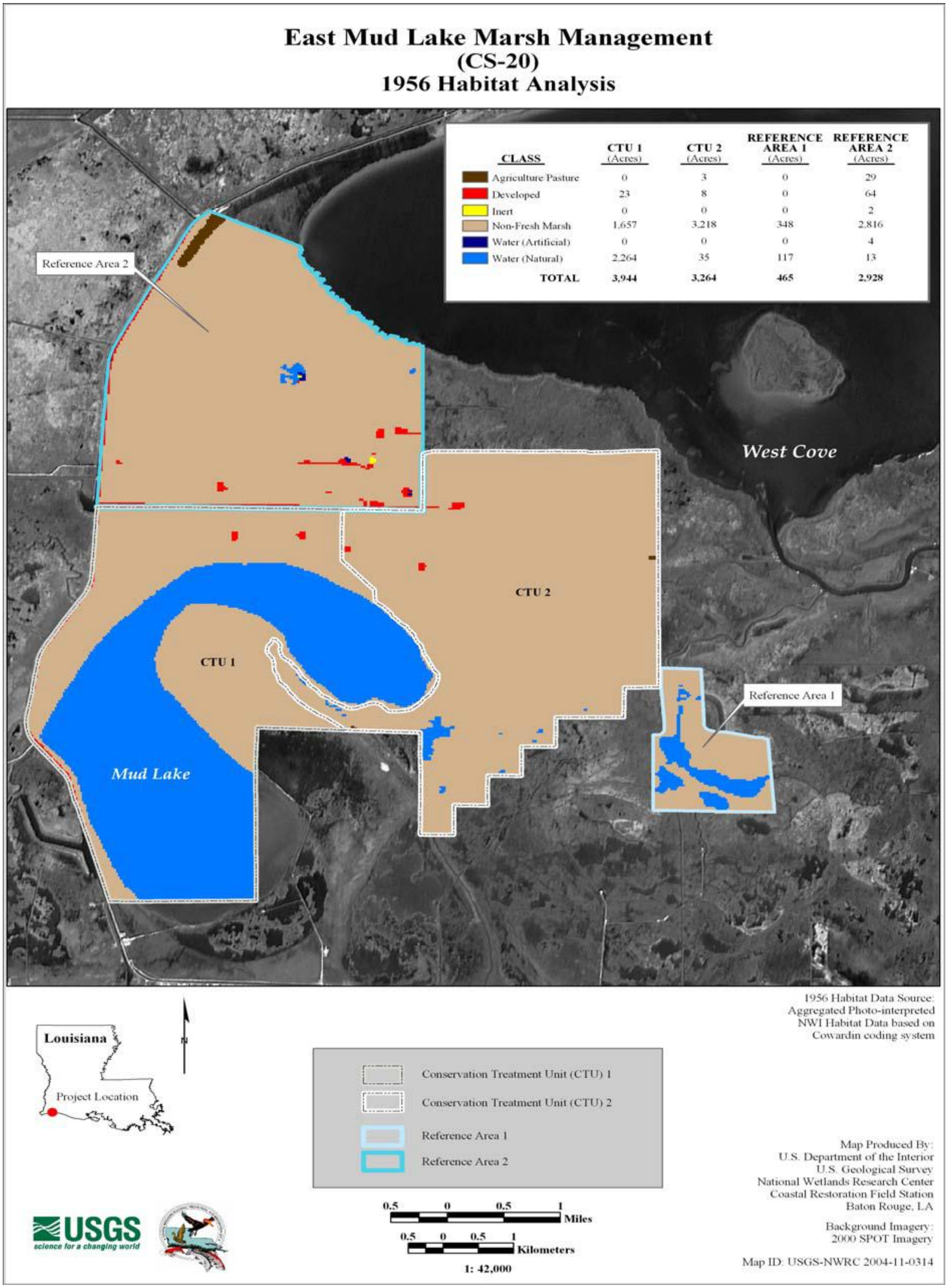
Water Level Inside: Outside:
Weather Conditions: Sunny and hot

Type of Inspection: Annual

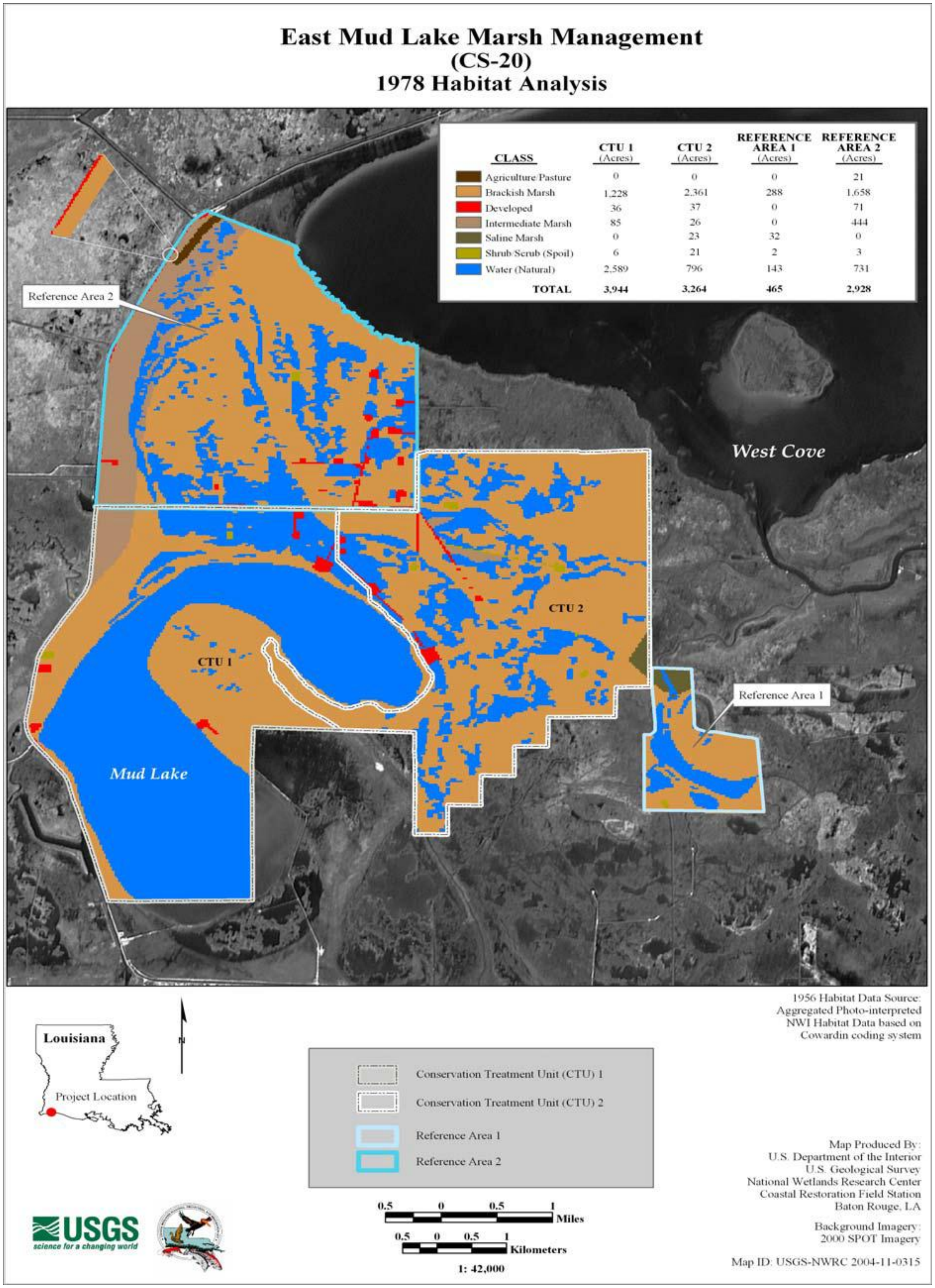
Item	Condition	Physical Damage	Corrosion	Photo #	Observations and Remarks
Steel Bulkhead / Caps	N/A				
Steel Grating	N/A				
Stop Logs	N/A				
Hardware	N/A				
Timber Piles	N/A				
Timber Walkway	N/A				
Timber Wales	N/A				
Galv. Pile Caps	N/A				
Cables	N/A				
Signage /Supports	N/A				
Staff Gages	N/A				
Rip Rap (fill)	N/A				
Earthen Embankment	Good				

What are the conditions of the existing levees?
Are there any noticeable breaches?
Settlement of rock plugs and rock weirs?
Position of stoplogs at the time of the inspection?
Are there any signs of vandalism? Yes

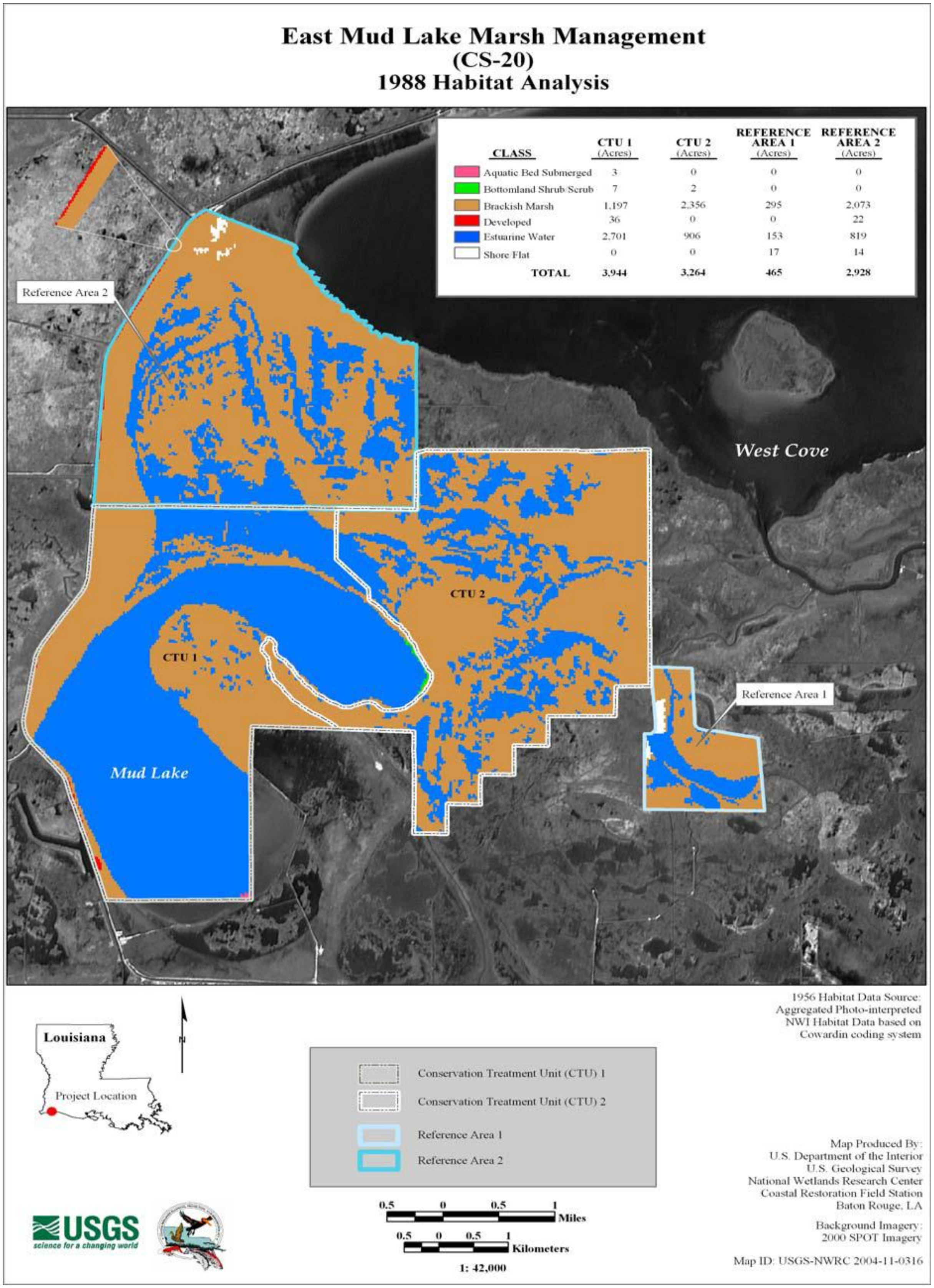
Appendix D
(USGS Habitat Maps)



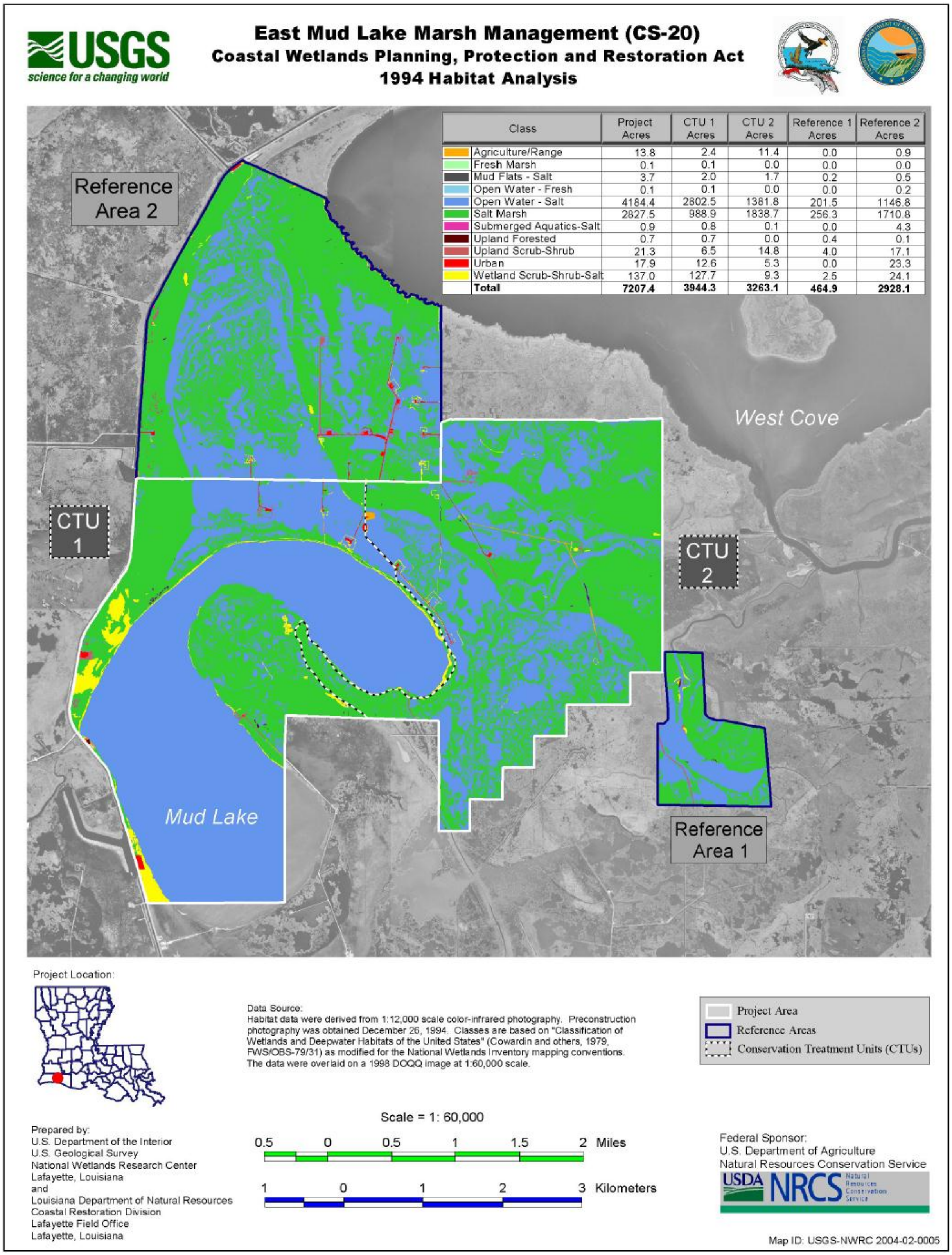
East Mud Lake Hydrologic Restoration (CS-20) project Habitat Map for 1956 conducted by USGS – National Wetlands Research Center.



East Mud Lake Hydrologic Restoration (CS-20) project Habitat Map for 1978 conducted by USGS – National Wetlands Research Center.

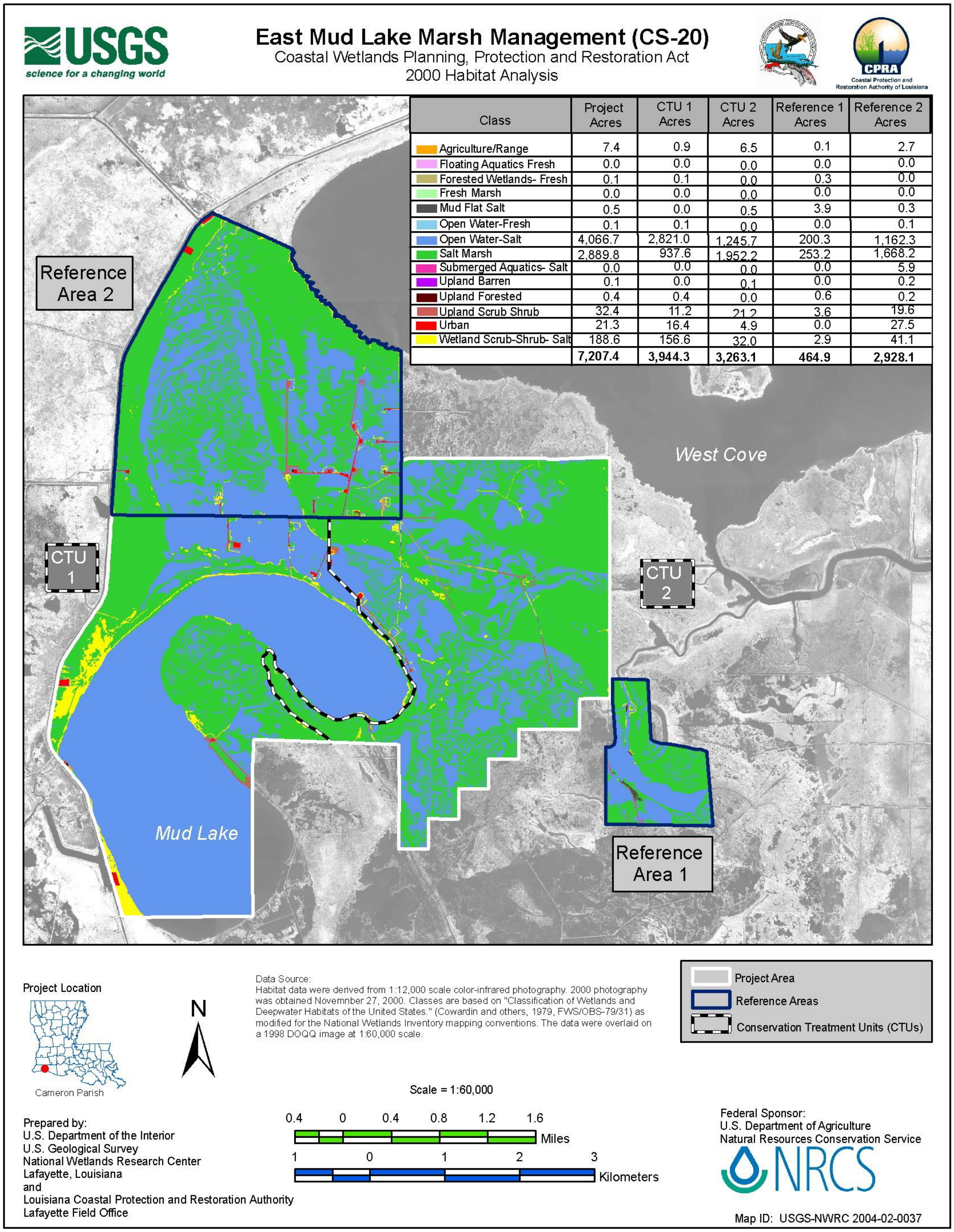


East Mud Lake Hydrologic Restoration (CS-20) project Habitat Map for 1988 conducted by USGS – National Wetlands Research Center.



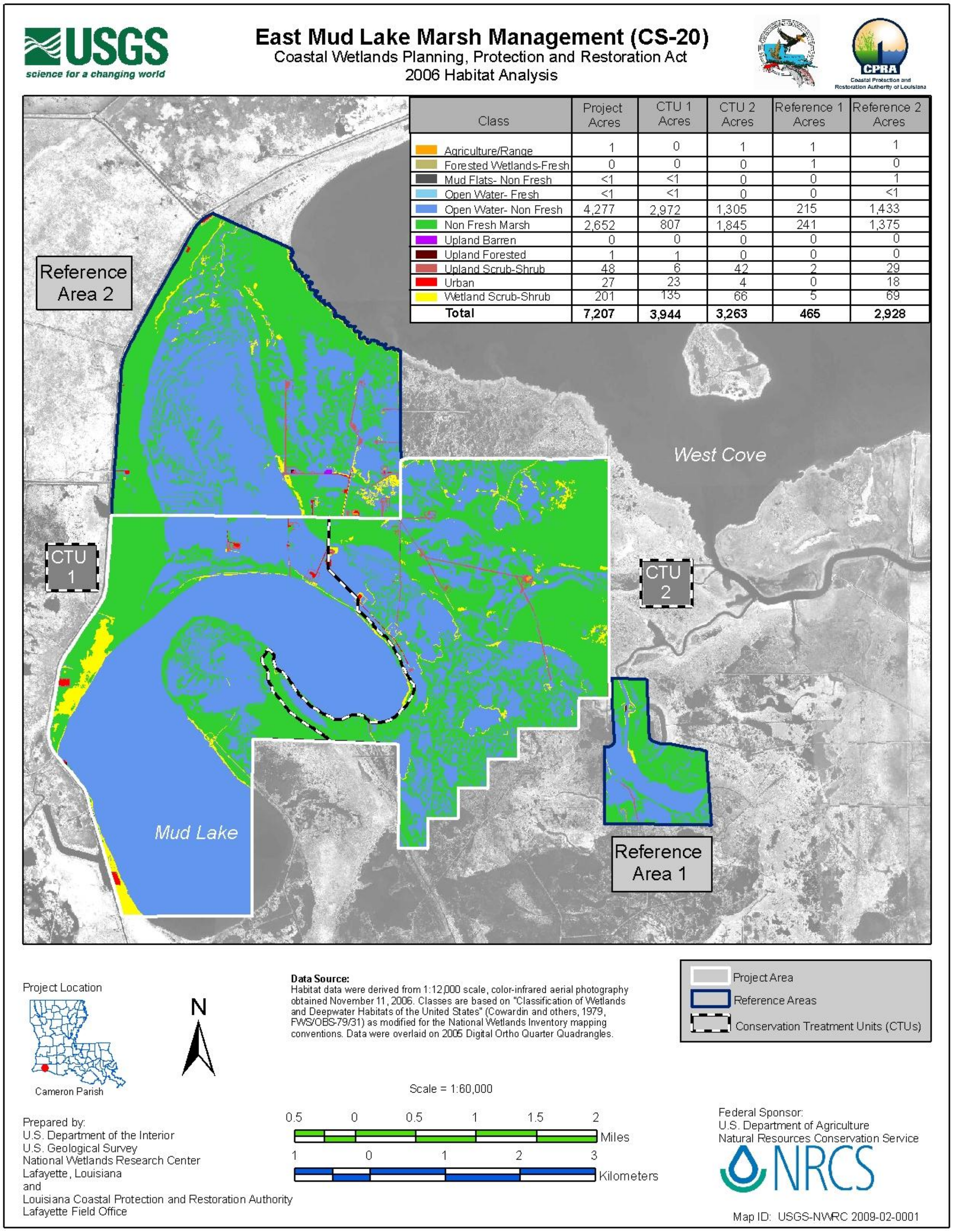
Class	Project Acres	CTU 1 Acres	CTU 2 Acres	Reference 1 Acres	Reference 2 Acres
Agriculture/Range	13.8	2.4	11.4	0.0	0.9
Fresh Marsh	0.1	0.1	0.0	0.0	0.0
Mud Flats - Salt	3.7	2.0	1.7	0.2	0.5
Open Water - Fresh	0.1	0.1	0.0	0.0	0.2
Open Water - Salt	4184.4	2802.5	1381.8	201.5	1146.8
Salt Marsh	2827.5	988.9	1838.7	256.3	1710.8
Submerged Aquatics-Salt	0.9	0.8	0.1	0.0	4.3
Upland Forested	0.7	0.7	0.0	0.4	0.1
Upland Scrub-Shrub	21.3	6.5	14.8	4.0	17.1
Urban	17.9	12.6	5.3	0.0	23.3
Wetland Scrub-Shrub-Salt	137.0	127.7	9.3	2.5	24.1
Total	**7207.4**	**3944.3**	**3263.1**	**464.9**	**2928.1**

East Mud Lake Hydrologic Restoration (CS-20) project Habitat Map for 1994 conducted by USGS – National Wetlands Research Center.



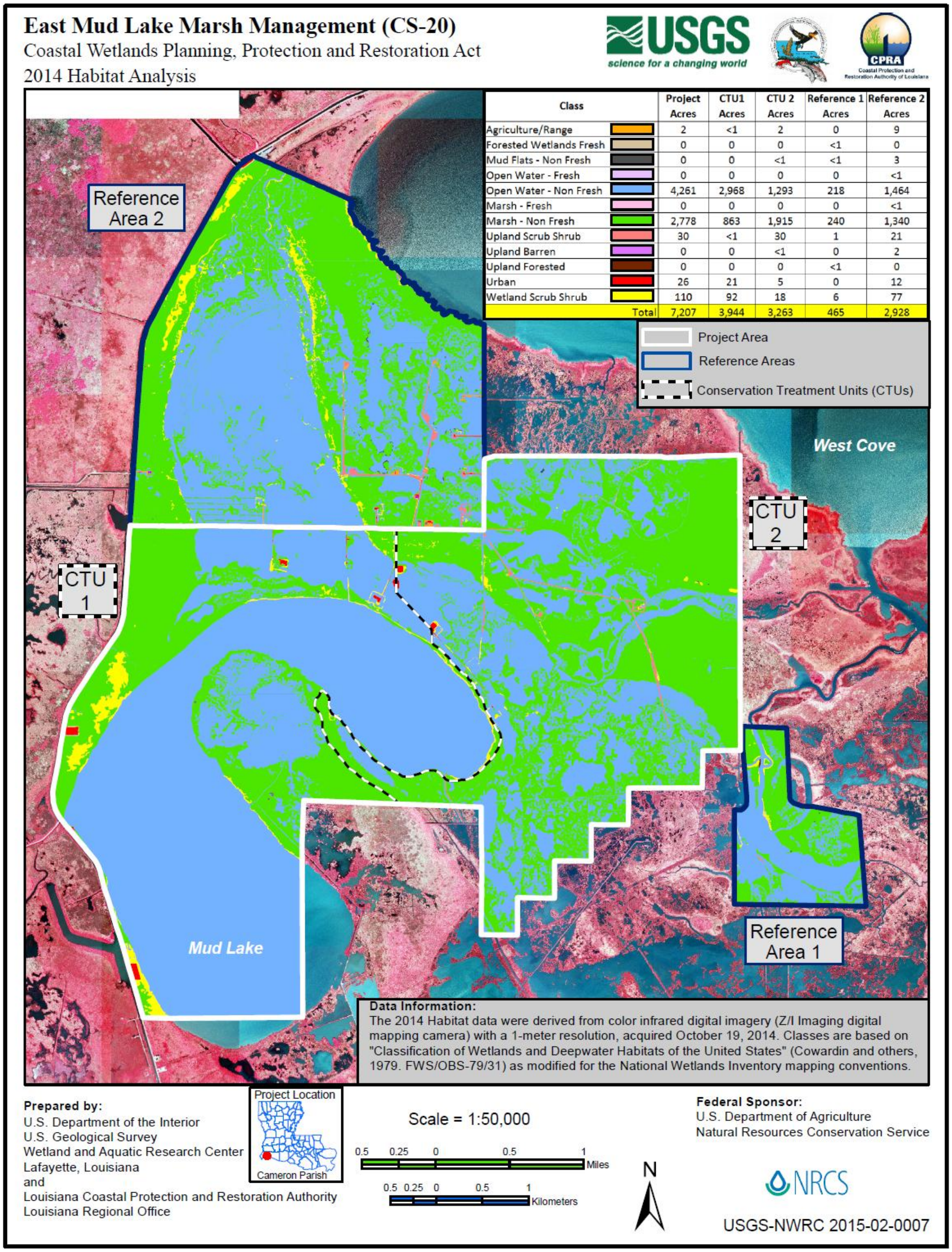
Class	Project Acres	CTU 1 Acres	CTU 2 Acres	Reference 1 Acres	Reference 2 Acres
Agriculture/Range	7.4	0.9	6.5	0.1	2.7
Floating Aquatics Fresh	0.0	0.0	0.0	0.0	0.0
Forested Wetlands- Fresh	0.1	0.1	0.0	0.3	0.0
Fresh Marsh	0.0	0.0	0.0	0.0	0.0
Mud Flat Salt	0.5	0.0	0.5	3.9	0.3
Open Water-Fresh	0.1	0.1	0.0	0.0	0.1
Open Water-Salt	4,066.7	2,821.0	1,245.7	200.3	1,162.3
Salt Marsh	2,889.8	937.6	1,952.2	253.2	1,668.2
Submerged Aquatics- Salt	0.0	0.0	0.0	0.0	5.9
Upland Barren	0.1	0.0	0.1	0.0	0.2
Upland Forested	0.4	0.4	0.0	0.6	0.2
Upland Scrub Shrub	32.4	11.2	21.2	3.6	19.6
Urban	21.3	16.4	4.9	0.0	27.5
Wetland Scrub-Shrub- Salt	188.6	156.6	32.0	2.9	41.1
	7,207.4	**3,944.3**	**3,263.1**	**464.9**	**2,928.1**

East Mud Lake Hydrologic Restoration (CS-20) project Habitat Map for 2000 conducted by USGS – National Wetlands Research Center.



Class	Project Acres	CTU 1 Acres	CTU 2 Acres	Reference 1 Acres	Reference 2 Acres
Agriculture/Range	1	0	1	1	1
Forested Wetlands-Fresh	0	0	0	1	0
Mud Flats- Non Fresh	<1	<1	0	0	1
Open Water- Fresh	<1	<1	0	0	<1
Open Water- Non Fresh	4,277	2,972	1,305	215	1,433
Non Fresh Marsh	2,652	807	1,845	241	1,375
Upland Barren	0	0	0	0	0
Upland Forested	1	1	0	0	0
Upland Scrub-Shrub	48	6	42	2	29
Urban	27	23	4	0	18
Wetland Scrub-Shrub	201	135	66	5	69
Total	**7,207**	**3,944**	**3,263**	**465**	**2,928**

East Mud Lake Hydrologic Restoration (CS-20) project Habitat Map for 2006 conducted by USGS – National Wetlands Research Center.



East Mud Lake Hydrologic Restoration (CS-20) project Habitat Map for 2014 conducted by USGS – National Wetlands Research Center.

Appendix E
(Special Provisions for Operations)

East Mud Lake Marsh Management Project (CS-20)

June 15, 2011

Special Provision to CTU #2 – Water Management Scheme Phase II – Maintenance Phase for Drought Conditions

Rationale:

Plants in a drought experience stress due to high salinity water in the root zone. Drying of the marsh surface further increases plant stress by concentrating salinity, limiting water supply to the root zone, preventing plant toxins from being flushed, and acidifying the soil (pH decreases as the soil oxidizes). Aquatic organisms are also stressed or killed during drought conditions if water circulation is poor and oxygen level decreases while biological oxygen demand (BOD) increases. This special provision is designed to prevent damage to plants brought on by drought stress and to prevent fish kills from stagnant water conditions.

Conditions:

The National Weather Service in Lake Charles has declared moderate drought conditions (D1 – Drought Moderate) in Cameron Parish (U.S. Drought Monitor South - http://www.drought.unl.edu/dm/DM_south.htm).

Salinities have exceeded target levels (15 ppt) inside and outside CTU #2 or when salinities are greater inside than outside CTU 2.

Sufficient rain to break the moderate drought condition is not forecasted (NOAA Drought Termination and Amelioration web site - http://www.ncdc.noaa.gov/temp-and-precip/drought/recovery.php).

Actions:

Structure operation is at the discretion of the project manager (OCPR) and land owner/structure operator (Apache Louisiana Minerals, LLC). Lock flaps open on Structures 1 and 4 (the natural bayous) to allow flow into CTU2 preventing the marsh from excessive drying. Collect additional discrete salinity measurement at interior sites in CTU 2. If salinities increase or stagnant water conditions appear, lock open additional structures (3, 5, 9, and/or 11) to increase flow as needed.

Operation plan for CTU #2 – Water Management Scheme Phase II – Maintenance Phase shall resume when moderate drought conditions are ameliorated, salinities inside the project area are less than or equal to outside the project area, salinity in the project area is less than 15 ppt, water levels are greater than average marsh elevation in CTU #2 (1.0 ft NAVD88).

East Mud Lake Marsh Management Project (CS-20)

Revised Drawdown Guidance

OCPR-LFO August 02, 2011

I. Introduction

The landowners and contracted operators of the CS-20 project area, Apache Louisiana Minerals Inc., have requested to conduct two more controlled drawdowns before the end of the CS-20 project life in 2016 in order to stimulate vegetative expansion into shallow open areas. This drawdown activity is condoned by the Operations division of the Office of Coastal Protection and Restoration (OCPR-Ops) provided and the operation plan alterations are followed and the conditions below are met (Sect III).

II. Original Operations Plan

Operational plans and procedures for CTU #2 are designed to expose mud flats for seed germination and planting (Phase I, 1996-1997). Once vegetative plantings are established, operations and procedures for CTU #2 are designed to gradually increase water levels to maintain and enhance vegetative growth for optimum waterfowl and furbearer utilization and to stabilize salinity (Phase II, 1998-present).

CTU #2 – Water Management Scheme Phase I – Revegetation Phase 1a

February 15 – May 31 (or to July 15), 1996 and 1997

1. Remove all stop logs and allow flap gates to operate at structures ES-#1, ES-#3, ES-#4, ES-#5, ES-#9a, and ES-#11.
2. Screw gate open and allow flap gate to operate at structure ES-#9b.
3. Allow flap gates to operate at structures ES-#19, ES-#20, ES-#21, ES-#22 and ES-#29.
4. Set stop logs at 12-inches above marsh level at structure ES-#17.

III. Alterations to drawdown operations based on lessons learned from past experiences

In 1996 and 1997, drawdowns were conducted in CTU #2 based on the above operating plan; unfortunately, the drawdowns were concurrent with an extensive drought at the beginning of the drawdown (winter - summer 1996) and prolonged flooding (fall 1996 – spring 1997) caused by a tropical storm surge. Initially, the vegetation cover and marsh elevation at previously established sampling stations decreased within CTU #2 relative to stations outside of CTU #2. Vegetation had rebounded in CTU #2 by 2003; whereas, elevation change remained a bit lower in CTU #2 until Hurricane Rita. However, based on land change analyses of aerial photography, CTU #2 was the only area within the CS-20 project range to gain land from the 1996-2000 which was attributed to vegetation expansion along the edges of pond and into broken marsh (locations not represented by marsh sampling stations) (McGinnis and Pontiff 2010). To avoid excessive stress to existing vegetation and losses in marsh elevation, the management practice of a "partial" drawdown has become a common practice (Chabreck and Nyman 2005). During a partial drawdown, water levels are lowered to expose pond edges and shallow open water areas within broken marsh while avoiding the drying of pond bottoms. This practice allows for vegetative expansion and deeper root penetration while preventing soil desiccation and pond deepening. To accomplish a partial drawdown the operation plan has been revised:

<u>Revisions to operations plan</u>

CTU #2 – Water Management Scheme Phase I – Drawdown Phase 1a

March 1 – June 30

1. Set stop logs to 6" below marsh elevation (0.5 ft NAVD 88) and allow flap gates to operate at structures ES-#1, ES-#3, ES-#4, ES-#5, ES-#9a, and ES-#11.
2. Screw gate open and allow flap gate to operate at structure ES-#9b.
3. Allow flap gates to operate at structures ES-#19, ES-#20, ES-#21, ES-#22 and ES-#29.
4. Set stop logs at 12-inches above marsh level at structure ES-#17.
5. Maintain water levels between 12"-6" below average marsh surface by allowing water into CTU #2 by first utilizing structures with lower salinity. For example, open flaps on the west side of the project area along border between CTU #1 and #2 and/or ES 9 before eastern structures (3, 4, 5, and 11) that are more connected to Lake Calcasieu and the Calcasieu Ship Channel if the west side structures have lower salinity.

Based on lessons learned from the previous drawdowns at CS-20, the following conditions should be met before proceeding with future drawdowns:

1. Non drought conditions for 6 months prior to initiation of drawdown.

2. Ideally a wet winter leading up to the drawdown with normal to above normal water levels (> 1.1 NAVD88, ft) and salinity < 10 ppt.

3. The drawdown will be terminated if the salinity inside CTU #2 (1) averages greater than 15 ppt AND (2) is greater than salinity concentration outside of CTU #2 for 1 month based on discrete measurements collected for operations.

Although not a condition for conducting the drawdown, check the prevailing weather conditions that will affect weather patterns during the time of the drawdown such as Southern Oscillations (El Niño/La Niña; La Niña was associated with droughts of 1995-1996 and 2000). The National Weather Service in Lake Charles, LA is a good source for such information.

References

Chabreck, R.H., and J.A. Nyman. 2005. Management of coastal wetlands. Pages 839-860 in C.E. Braun (editor), Techniques for wildlife investigations and management. Sixth Edition. The Wildlife Society, Bethesda, Maryland, USA.

McGinnis, T. and Pontiff, D. 2010. 2010 Operations, Maintenance, and Monitoring Report for East Mud Lake Marsh Management (CS-20), Office of Coastal Protection and Restoration/Operations – Lafayette Field Office. Lafayette, Louisiana.