Coastal Protection and Restoration Authority of Louisiana

2020 Operations, Maintenance, and Monitoring Report

for

Jonathan Davis Wetland Restoration (BA-20)

State Project Number BA-20
Priority Project List 2

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Jefferson Parish

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Preface

The Jonathan Davis Wetland Restoration (BA-20) project was funded through the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA) on the 2nd Project Priority List with the Natural Resources Conservation Service (NRCS) as the federal sponsor. The 2020 Operations, Maintenance, & Monitoring (OM&M) report for BA-20 is the fourth in a series of reports to summarize monitoring and O&M activities conducted during the life of the project. This report includes monitoring data collected through December 2019 and Annual Maintenance Inspections through March 2019. Additional documents pertaining to the BA-20 project may be accessed on the CPRA website at https://cims.coastal.louisiana.gov/outreach/Projects/ProjectView?projID=BA- 0020 or on the CWPPRA website at https://www.lacoast.gov/new/Projects/Info.aspx?num=BA-20.

I. Introduction

The Jonathan Davis Wetland Restoration (BA-20) project is located in Jefferson Parish within the Barataria Basin. The 7,462-acre (3,020 ha) project area is bounded on the north by the Pailet Canal, on the east by LA Hwy 301, on the south by Bayou Perot and Bayou Rigolettes, and on the west by the Gulf Intracoastal Waterway (GIWW) (Figure 1). Overall, 1,393 ac (557 ha) of land were converted to open water between 1945 and 1989 (Coastal Environments Inc. 1991). The average rate of change from marsh to non-marsh (including loss to both open water and commercial development) has increased since the 1940s. Marsh loss rates were 0.56 %/yr between 1939 and 1956, 0.60 %/yr between 1956 and 1974, and 0.73 %/yr between 1983 and 1990 (Dunbar et al. 1992). In the National Biological Survey (NBS) Geographic Information System (GIS) habitat data from 1956, the majority of the area was characterized as fresh marsh (NBS 1994a). However, the 1978 and 1990 data indicated that the area had become more saline. In 1978, 1988, and 1990, the area was classified as primarily intermediate marsh (NBS 1994b; NBS 1994c; Chabreck and Linscombe 1988).

Large-scale factors influencing degradation in the Barataria Basin included subsidence, lack of sedimentation, and reduced freshwater influx due to the levee system on the Mississippi River and its major distributaries. The subsidence rate based on the U.S. Army Corps of Engineers (USACE) tide gauge readings (1947–78) at Bayou Rigaud, Grand Isle, Louisiana, was 0.80 cm/yr (Penland et al. 1989). Although some sediment entered via the GIWW, there were no substantial sources allowing inorganic sediment into the project area. In addition, the increase in oil field canals led to the exportation of indigenous inorganic and organic sediment during storm surges (U.S. Department of Agriculture, Soil Conservation Service 1994).

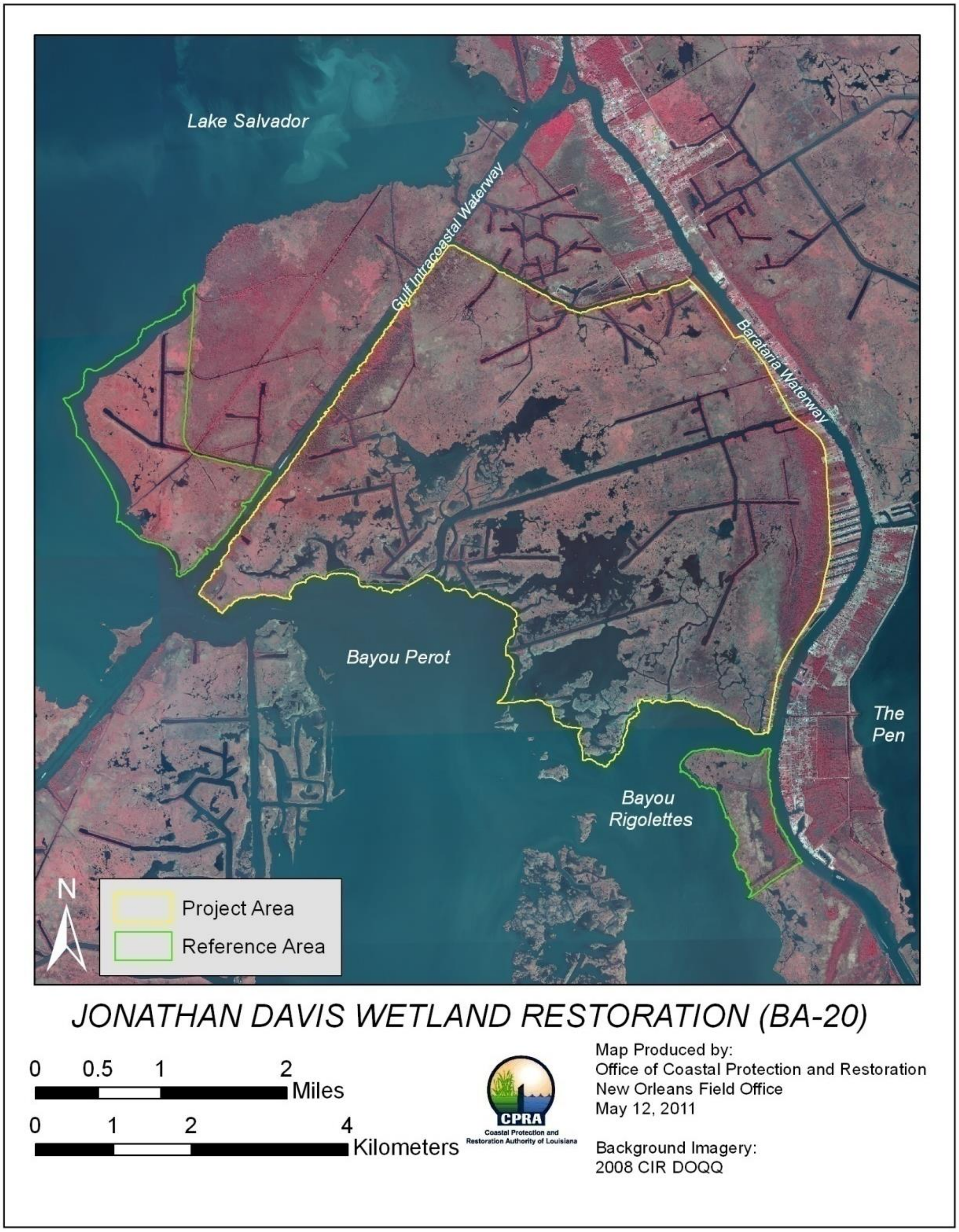

Figure 1: Jonathan Davis Wetland Restoration (BA-20) project and reference areas.

Additional factors that influenced wetland loss within the project area were increased water exchange, saltwater intrusion, tidal scour, and shoreline erosion along Bayous Perot and Rigolettes (U.S. Department of Agriculture, Soil Conservation Service 1994). Shoreline erosion from 1945 to 1989, caused primarily by wave action along Bayou Perot, was measured at 20 ft/yr (6.1 m/yr) (Coastal Environments Inc. 1991). Saltwater intrusion and tidal scour were enhanced during the construction of oil field canals dredged in the 1940s. At the time, oil companies were not responsible for maintaining a continuous spoil bank along canals. The resulting breaches were not repaired and the interior marsh was exposed to increased salinity and tidal flows during storm surges (U.S. Department of Agriculture, Soil Conservation Service 1993).

The objectives of the BA-20 project were to: 1) use structural measures to restore hydrologic conditions that reduce water level and salinity fluctuations (variability) and allow freshwater retention to increase the quantity and quality of emergent vegetation, and 2) reduce wetland loss through hydrologic restoration and reduce erosion through shoreline protection. Constructed project features consist of shoreline protection, rock armored plugs, rock weirs, and sheetpile weirs with boat bays (Figure 2). Construction Unit 1 (CU1), which consists of structures 12, 13, 14, 15, 16, 17, 19, 20, and 21, was completed in September 1998. Construction Unit 2 (CU2), which consists of a weir at site 22 and 3,967 linear feet of rock riprap shoreline protection from structures 20 to 22, was completed in May 2001. Construction Unit 3 (CU3), which consists of 13,088 linear feet of rock riprap shoreline protection from structure 12 extending west to the Gulf Intracoastal Waterway and a smaller portion extending west from CU2, was completed on July 7, 2003. Construction Unit 4 (CU4), which consists of 18,703 linear feet of concrete panel and rock riprap shoreline protection connecting the eastern and western portions of CU3, was completed in 2011. Construction of additional breach armor and rock weir features in the northern project area has been deferred because: 1) the Davis Pond diversion may have transformed these sites into avenues for freshwater (including fine-grain sediments and nutrients) to enter the project area marshes from the north; 2) early attempts to secure land rights were unsuccessful; and 3) these sites did not appear to be causing any significant marsh erosion as a result of water exchange.

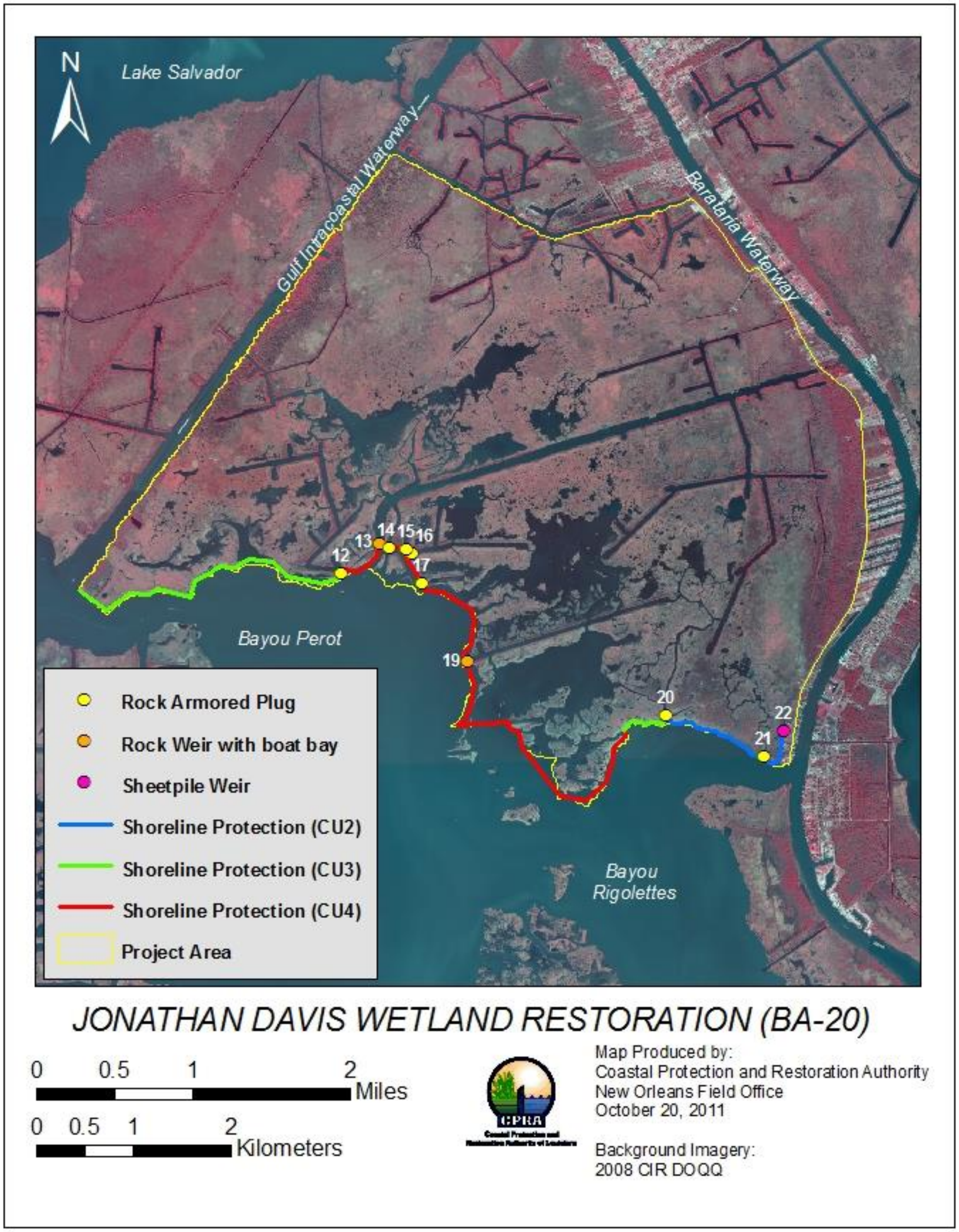

Figure 2: Constructed project features of the Jonathan Davis Wetland Restoration (BA-20) project.

II. Maintenance Activity

a. Project Feature Inspection Procedures

An inspection of the Jonathan Davis Wetland Restoration (BA-20) project was held on March 8, 2019 by Barry Richard and Zachary Collier of CPRA, along with Quin Kinler of NRCS. Photographs and field notes taken during the inspection are included in Appendices A and B.

The purpose of the annual inspection of the Jonathan Davis Wetland Restoration (BA-20) project is to evaluate the constructed project features, to identify any deficiencies, and to prepare a report detailing the condition of project features and recommended corrective actions needed. Should it be determined that corrective actions are needed, the 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: Babin 2002). The annual inspection report also contains a summary of past maintenance projects and an estimated projected budget for the upcoming three (3) years for operations, maintenance and rehabilitation. The three (3) year projected operations and maintenance budget is shown in Appendix C.

b. Inspection Results

With the exception of a few locations where individual structures or the rock dike bank stabilization has experienced more rapid settlement, the structures have proven to be very stable. No significant structure maintenance is warranted at this time. Minor sign repair may be needed at a few isolated locations; if this is deemed necessary, CPRA and NRCS will discuss the timing and manner in which these repairs may be accomplished. If more settlement is noticed on a future inspection, then an assessment of needed maintenance will occur at that time.

<u>Construction Unit 1</u>

<u>Structure 12 – Rock rip-rap armored plug</u>

The structure was in good condition; some minor settlement was observed. All of the signs and supports were generally in good condition. No maintenance needs were identified for this location at this time.

<u>Structure 13 – Rock rip-rap armored weir w/ boat bay</u>

Due to the water level and structure settlement, the structure was not visible, preventing a detailed inspection. Signs and timber supports were generally in good condition. No maintenance will be required at this time. (Photo #1)

Structure 14 – Rock rip-rap armored plug

The rock plug was in good shape with some minor settlement; however, the overall condition was good. There is currently no need for maintenance on this structure.

Structure 15 – Rock rip-rap weir w/ boat bay

The original weir was converted to a rock plug structure as part of the work effort for Construction Unit 4. No defects were noted during the inspection. (Photo #2)

Structure 16 – Rock rip-rap channel plug

Rip-rap and warning signs appeared to be in good condition. No maintenance work is recommended at this time. (Photo #3)

Structure 17 – Rock rip-rap channel plug

The plug appeared to be in good condition; no maintenance needs were identified here during the inspection.

Structure 19 – Rock rip-rap weir w/ boat bay

The weir has experienced some settlement, but is performing as designed. Signs and timber supports were generally in good condition. No maintenance will be required at this time. (Photo #4)

Structure 20 – Rock rip-rap armored plug

The rock plug was heavily vegetated at the time of inspection, but appeared to be in good condition. No maintenance needs were identified at this location.

Structure No. 21 – Rock rip-rap armored plug

No significant defects were noted. The structure is generally in good condition and does not require any maintenance at this time.

Construction Unit 2

Structure 22 A – Canal bank stabilization

No significant defects were noted. No immediate maintenance concerns were noted at this site.

Structure 22 – Steel sheet pile weir w/ boat bay

No significant defects were noted on the visible portion of the structure. The warning signs and supports were in good condition. No maintenance is required at this time.

Bayou Rigolettes Bank Stabilization

The shoreline protection function is performing adequately in spite of previous settlement. The area should be monitored on future inspections, but no immediate maintenance is required.

Construction Unit 3

Bayou Perot Bank Stabilization

No significant changes were noted since the last inspection. The rock shoreline protection appeared to be in good condition, with minor settlement in some areas. The areas of lower elevation requires continued observation on future inspections, but no maintenance needs were identified at this time. (Photo #5)

Construction Unit 4

Concrete Panel Wall Shoreline Protection

No defects in the concrete panel wall sections were noted; the structure appeared to be in good condition. Minor damage/vandalism to some warning signs are noted, as in previous inspections, and one sign was missing, but all other signs and timber supports are in place and performing as designed. No immediate maintenance needs were identified at this construction unit. (Photo #6)

c. Maintenance Recommendation

All project features were serving their intended purpose. Continued monitoring of signs along the concrete panel wall for any additional vandalism or missing signs is needed. Continue to inspect and assess project conditions annually.

i. **Immediate/ Emergency Repairs**
None at this time.

ii. **Programmatic/ Routine Repairs**
Continue to monitor the condition of all structures.

d. Maintenance History

On January 30, 2002, Stone Energy Corporation was issued a Coastal Use Permit to plug and abandon existing wells within the Jonathan Davis Wetland Restoration project. This work was completed on 7/18/02 and consisted of removing and replacing structures 13 & 19 and to plug and abandon several existing wells located behind these structures. The cost associated with removing and replacing these structures was incurred entirely by Stone Energy Corporation. However, at the request of NRCS, CPRA was required to provide inspection services for this project. CPRA obtained the services of GSE Associates, Inc. to inspect construction activities and prepare a project completion report and as-built drawings. These services were performed for a total cost of $9,394.13.

As part of the construction documents prepared by NRCS for this project, Stone Energy Corporation was required to reconstruct structure 13, increasing the boat bay crest from 50' to 100' in width and raising the crest elevation from -5.0' NGVD to -2.5' NGVD.

As part of work for Construction Unit 4, maintenance was performed on structures 14, 15, and 17. Due to the location and activity of a pipeline in the vicinity of Structure 16, no work was performed there. However, due to the location and infilling in front of Structure 16, no work was required.

III. Operation Activity

There are no operations activities associated with the BA-20 project.

IV. Monitoring Activity

a. Monitoring Goals

The following measurable goals were established to evaluate the effectiveness of the project:

1. Reduce rate of emergent marsh loss.

2. Decrease variability in salinity within the project area.

3. Decrease variability in water level within the project area.

4. Stabilize or increase relative abundance of intermediate-to-fresh marsh plant species.

5. Reduce marsh edge erosion rate along southern project boundary.

b. Monitoring Elements

The following monitoring elements will provide the information necessary to evaluate the goals listed above. A timeline of data collection events associated with these monitoring elements is shown in Figure 3 along with completion dates of the four construction units (CU's).

Aerial Photography

To determine changes in land to water ratios over the project life, color-infrared aerial photography was obtained of the project area and reference areas in 1994, 1997, 2002, 2012, and 2018 (Appendix D1-D5). The 1994, 1997, and 2002 photography was 1:12,000 scale, color infrared (CIR) imagery acquired through BA-20 monitoring funds (Appendix D1-D3). The 2012 and 2018 photography was 1-meter resolution, CIR digital ortho-imagery acquired through the Coast-wide Reference Monitoring System (CRMS) program. All acquired photography was geo-rectified, photo-interpreted, and analyzed by the USGS Wetland and Aquatic Research Center to determine habitat classifications (1994, 1997, 2002) or land to water ratios (2012 and 2018) using standard operating procedures documented in Steyer et al. (1995, revised 2000). Although the original monitoring plan (Barmore 2003) stated that habitat analyses would be conducted throughout the project life, the remaining analyses were changed to land/water analyses upon the implementation of the CRMS program in 2003. To compare the earlier habitat classification datasets with the land/water classification datasets, the 'Open Water' and 'Beach/Bar/Flat' categories were combined to determine the total 'Water' Acreage and the remaining land categories were combined to determine the total 'Land' Acreage.

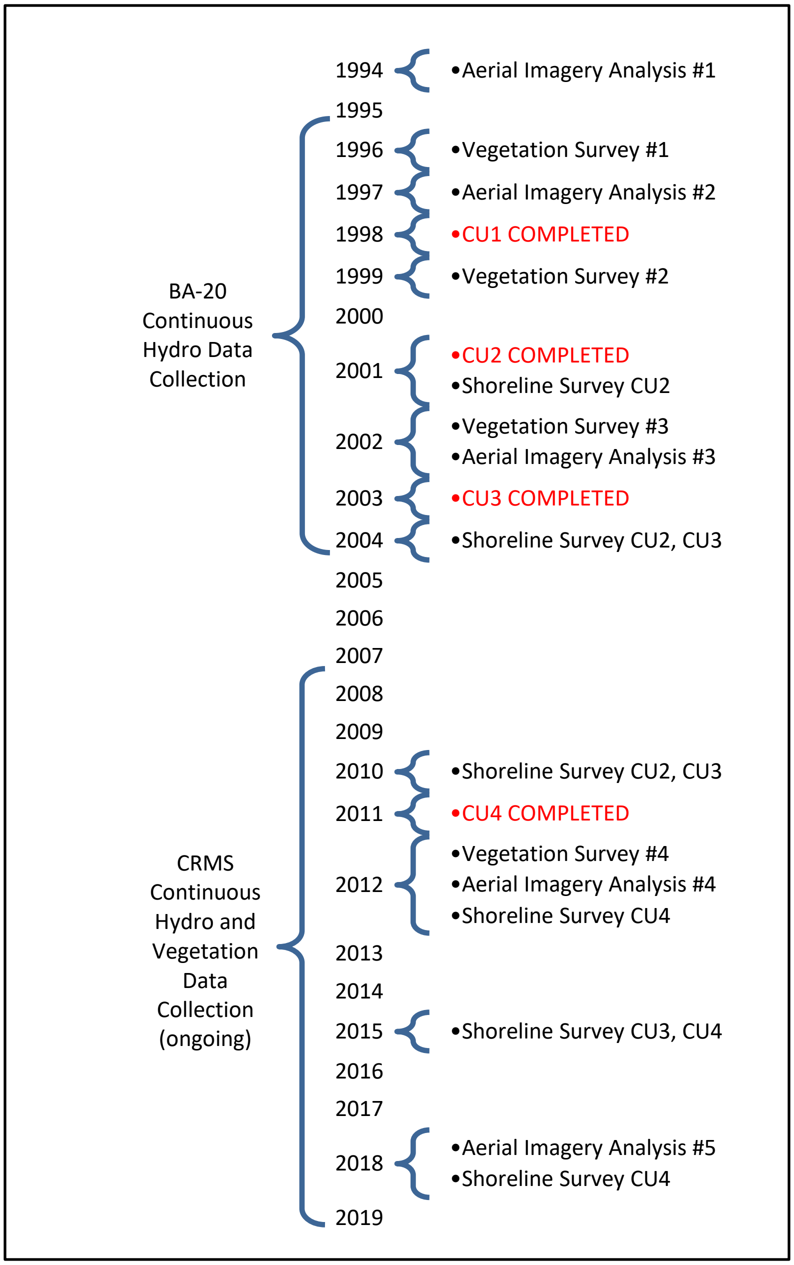

Figure 3: Timeline of monitoring and construction events associated with the Jonathan Davis Wetland Restoration (BA-20) project from 1994 to 2019.

Land/water classifications were also conducted by the USGS Wetland and Aquatic Research Center for a 1-km^2 area encompassing CRMS3985 and CRMS4245 in years 2005, 2008, 2012, and 2016 (Appendix D6 and D7). These classifications were obtained from digital imagery with 1-meter resolution, acquired during the fall months (October to November). All areas characterized by emergent vegetation, upland, wetland forest, or scrub-shrub were classified as land, while open water, aquatic beds, and mudflats were classified as water.

Trends in land change between 1985 and 2016 have also been evaluated using Landsat 5 Thematic Mapper (TM) and Landsat Operational Land Imager (OLI) satellite imagery (Couvillion et al. 2011 and 2016) within the BA-20 project boundary and within all of the 1-km^2 CRMS sites, including those within the BA-20 project area, CRMS3985 and CRMS4245.

Salinity

Between December 1995 and January 2005, salinity was sampled hourly at three continuous recorder stations within the project area (BA20-08, BA20-11, BA20-20) and at three reference stations (BA20-90R, BA20-91R, BA20-98R) using methods described in Folse et al. 2008, revised 2018 (Figure 4). The continuous recorder at each site was mounted on a wooden post in open water with sufficient water depths to inundate the recorder year round. Each continuous recorder station was serviced approximately once a month to clean and calibrate the recorder and to download the data. During processing, the data were examined for accuracy and loaded to the CPRA database, and are available for download from the CRMS website (http://www.lacoast.gov/crms2). Data collection ended prematurely at two of the reference stations, BA20-91R and BA20-90R. A decision was made in September 2002 not to rebuild the northern reference station, BA20-91R, after it was damaged, because the northern project features were not being constructed. Salinity monitoring at BA20-90R ended in November 2003 because the station was destroyed. Discrete salinity readings were also collected monthly at 17 stations from December 1994 to December 2003 using a handheld salinometer (Figure 4). Discrete data were used in concert with continuous salinity data to characterize the spatial variation of salinity throughout the project and reference areas.

Hourly salinity data has since been collected at two CRMS stations within the project area, CRMS3985 and CRMS4245, from May 2008 to present (Figure 4). CRMS3985 is located in the northern project area approximately 0.6 miles northwest from the former location of BA20-11. CRMS4245 is located in the southern project area approximately 0.9 miles southwest from the former location of BA20-20.

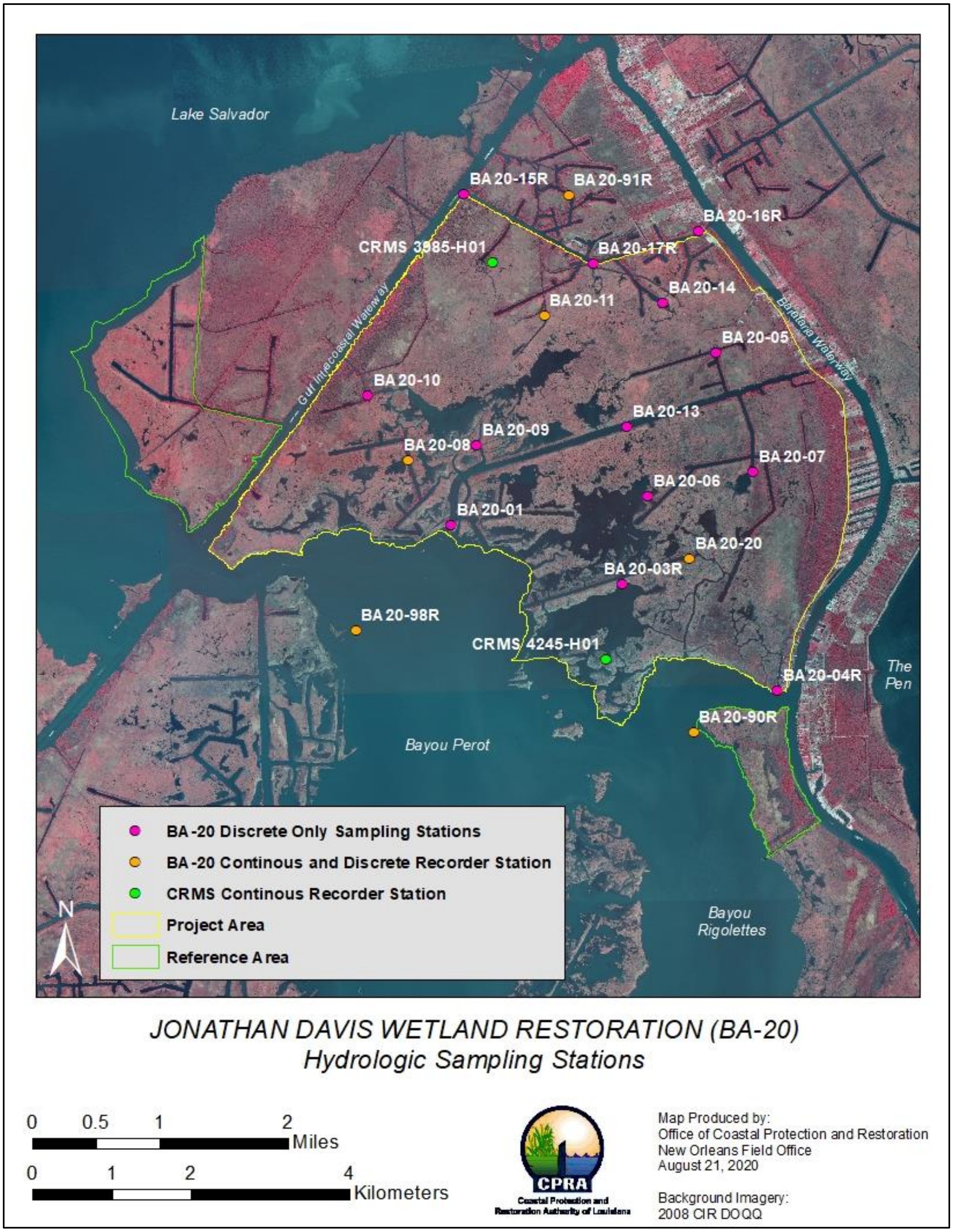

Figure 4: Hydrologic sampling stations associated with the Jonathan Davis Wetland Restoration (BA-20) project.

Water Level

Water levels were also measured hourly at the continuous recorder stations using methods described in Folse et al. 2008, revised 2018 (Figure 4). A staff gauge was installed next to each continuous recorder to compare recorded water levels to a known datum (ft NAVD88, Geoid99). Water level data are available from November 1997 to January 2005 at the three sites within the project area, but are not available past 2003 at BA20-90R and BA20-98R due to station damage and survey issues, which shortened the length of post-construction analysis period.

Hourly water level data (ft NAVD88, Geoid 12A) have since been recorded at the two CRMS sites within the project area, CRMS3985 and CRMS4245, from May 2008 to the present (Figure 4). Additionally, these water level data are used to calculate marsh inundation at CRMS3985 relative to the average marsh elevation surveyed in 2014. CRMS4245 is located in an area of floating marsh; therefore, the elevation of the marsh surface is variable. At this site, marsh inundation is measured directly by a separate continuous recorder attached to the floating mat at a fixed distance below the mat surface.

Shoreline Change

To evaluate shoreline change, a sub-meter Differential Global Positional Satellite (DGPS) system was used to document the position of the vegetated marsh edge in 2001, 2004, 2010, 2012, 2015 and 2018. Three shoreline surveys were conducted along each of the three shoreline protection segments associated with Construction Units 2, 3, and 4 (Figure 2, Table 1). The eastern reference area was only surveyed twice (2001 and 2004), because it is now part of the Barataria Landbridge Shoreline Protection Project, Phase 4 (BA-27d) and has been protected with rock revetment since 2006. Shoreline position was documented by manually taking a DGPS point every 5 to 10 feet along the vegetated edge in 2001 and 2004. Subsequently, shoreline position has been documented by continuously logging points every 1 second along the vegetated edge in 2010, 2012, 2015, and 2018. GPS receiver settings were configured to use real time correction, and data were post-processed in order to achieve sub-meter accuracy. Shoreline change in the western reference area was not surveyed in the field but was estimated by comparing the shoreline from three National Agriculture Imagery Program (NAIP) images from 2004, 2010, and 2015 and Digital Orthophoto Quarter Quads (DOQQ) from 2018. Lastly, shoreline data were used to calculate an estimate of "land saved", or land that would have been lost if the shoreline protection features were not installed. This analysis was conducted by digitizing the pre-construction CU4 shoreline from 1998 DOQQ imagery and comparing it to the 2012 CU4 shoreline survey (immediately after construction) in order to obtain an annual shoreline retreat rate prior to construction. This rate was then applied to all sections over the life of the project so far (through 2020) and projected for the life of the project (through 2032), to gain a rough estimate of land area saved thus far, and how much may be saved during the entire project life.

Table 1: Schedule of shoreline surveys conducted for the Jonathan Davis Wetland Restoration (BA-20) project from 2001 to 2018.

Construction Unit	Construction Completed	Survey #1	Survey #2	Survey #3
2	2001	Jul-2001	Jul-2004	Nov-2010
3	2003	Jul-2004	Nov-2010	Oct-2015
4	2011	May-2012	Oct-2015	Oct-2018
Reference Area	N/A	Jul-2001	Jul-2004	

Vegetation

Emergent marsh vegetation sampling stations were established in the project area along five transects running parallel to the Gulf Intracoastal Waterway (GIWW) (Figure 5). Stations were located along these transects at 0.8-km increments for a total of 27 stations within the project area. Four transects were established in the two reference areas yielding ten reference stations. Species composition, percent cover, and relative abundance were evaluated within 2-m x 2-m plots using a modified Braun-Blanquet sampling method (Mueller-Dombois and Ellenberg 1974, Folse et al. 2008, revised 2018) in 1996, 1999, 2002, and 2012. Emergent marsh vegetation has also been sampled annually at the two CRMS sites (CRMS3985 and CRMS4245) within the project area from 2008 to present. At each CRMS site, ten 2-m x 2-m sampling plots were randomly located along a 288-m transect and were sampled using the same method described above.

Percent coverage data from the BA-20 stations and CRMS stations were summarized according to the Floristic Quality Index (FQI) method utilized by CRMS (Cretini et al. 2011), where cover is qualified by scoring species according to their tolerance to disturbance and stability within specific habitat types.

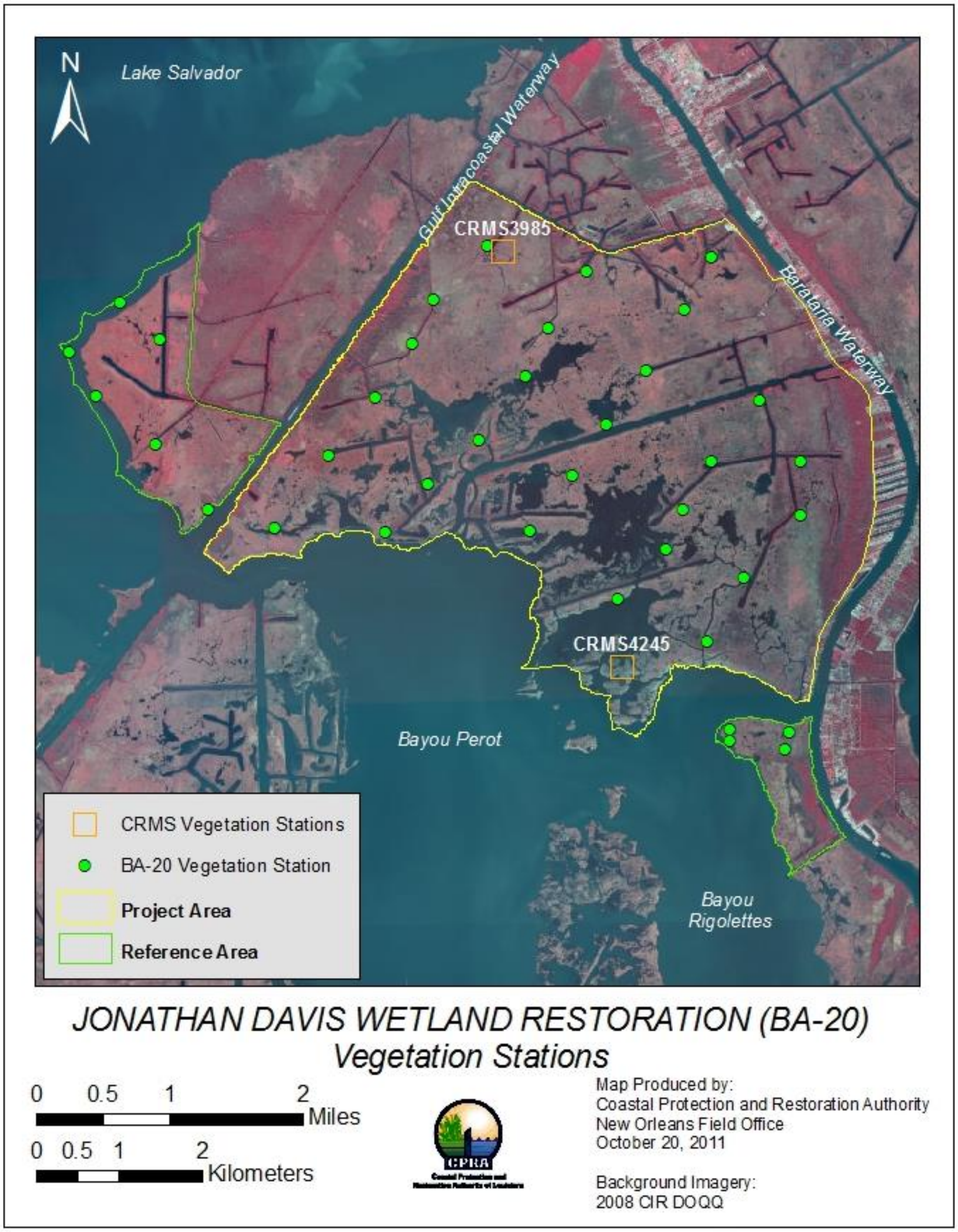

Figure 5: Vegetation stations within the Jonathan Davis Wetland Restoration (BA-20) project and reference areas.

Soils

This report will include soil information for the two CRMS stations in the project area (CRMS3985 and CRMS4245). At each site, three cores were collected in each year. Soil bulk density (BD) and organic matter (OM) were analyzed by year and depth interval (6 depth intervals) using ANOVA in RStudio (RStudio Team 2019). Pairwise comparisons were made using Tukey's Honestly Significant Difference test. Bulk density is the measure of the mass of dry soil per unit volume. It can vary with soil texture and organic matter content. Bulk density tends to be higher for mineral soils (1-2 g/cm^3) and lower for highly organic soils (0.05 – 0.4 g/cm^3) (Richardson and Vepraskas 2001, Chapin et al. 2002). Lower BD, in general, increases soil porosity and infiltration (Richardson and Vepraskas 2001). Organic matter (OM) often follows an inverse pattern to BD, where cores with higher BD have low OM and vice versa. Organic matter is important in wetland habitats by aiding aeration, infiltration, and water holding capacity, and is a major source of plant nutrients (Richardson and Vepraskas 2001). In addition to the soil cores, accretion measurements are collected annually using feldspar and elevation is measured annually using Surface Elevation Tables (SETs) (Folse et al. 2008, revised 2018). The accretion and elevation data can then be used to estimate rates of subsidence at the CRMS stations. While there are no specific project goals in relation to soil properties, these data can indicate a trajectory of stability or change at these sites, which would inform the goals of marsh type and shoreline stability.

c. Monitoring Results and Discussion

i. Aerial Photography

Habitat analyses of photography obtained in 1994, 1997, 2002, and a land/water analysis from 2012 and 2018 are presented in Appendix D with the caveat that the analyses should be used only for predicting trends. Recent and ongoing work by the U.S. Geological Survey (USGS) (John Barras and others) has revealed considerable variability in habitat and land:water classifications due to 1) clarity of image; 2) water level at time image was taken; 3) seasonality; 4) difficulty in distinguishing submerged, floating, and emergent vegetation; and 5) in the case of floating marshes, variable mat buoyancy and frequent vegetative changes. Photography was always acquired in fall to early winter which adjusts for some seasonality differences. However, floating marsh has been confirmed to exist in the BA-20 project area, particularly in the southern project area around CRMS4245, which may introduce additional error in acreage calculations.

One of the specific monitoring goals of the project was to reduce the rate of emergent marsh loss within the project area. The 1994 and 1997 analyses both occurred during the pre-construction period and the only construction unit which may have impacted the 2002 habitat analysis was CU1, which was constructed in

September 1998 (Figure 3). All construction units were completed by the time of the 2012 land/water analysis; however, CU4 was completed only one year before. Trends were compared between the project and reference areas from 1997 to 2018 (Figure 6, Table 1). Land change for each sample year was expressed as a percent of the total acreage to account for the difference in size between project and reference areas. The 1994 analysis was excluded from the project/reference comparison because the 1994 photography did not cover the entire boundary of the reference areas.

Proportionally, the greatest land loss occurred in Reference Area 1 during all time periods (Figure 6, Table 2). Overall, from 1997 to 2018 the project area gained 0.6% of its total acreage (2 acres/yr), while Reference Area 1 lost 23.9% (10 acres/yr). Greater land loss occurred in Reference Area 1 from 2002 to 2012 (13.4%), a period in which the area was impacted by several high energy storms. During some of this period (2002-2012) the project area was receiving protective effects from shoreline protection structures associated with CU's 2 and 3. It is visually evident in the 2012 land/water analysis (Appendix D3) that much of the loss in Reference Area 1 between 2002 and 2012 was due to shoreline erosion and less to interior loss. Although the land loss rate in the project area was higher from 2002 to 2012 than during the earlier period, the significant loss within Reference Area 1 from 2002 to 2012 implies that the project area loss may have been greater if the shoreline protection structures had not been in place. Reference Area 2, which was protected with rock riprap shoreline protection in 2006 through the Barataria Landbridge Shoreline Protection project (BA-27) shows a similar, but slightly lower, land loss trend than the project area, and by 2018 had a net land change of zero (Table 2). From 2012 to 2018, the project area gained land (5.0%, 46 acres/year) which offset the loss in the project area from 1997 through 2012. Some of this gain was in interior marsh behind the shoreline protection feature (see Shoreline Change Section) and some was due to infilling behind the shoreline protection feature. Overall, the project area and Reference Area 2 demonstrated land change stability over time and recovery from losses, especially those attributable to Hurricane Katrina. Alternatively, Reference Area 1, which is not protected by any features, continues to lose land over time. Land/water analysis at CRMS 3985 (Appendix D6) within the project area demonstrates consistent but little gain over time with a net gain from 2005 to 2018 of 10 acres or 4.4% gain in land. CRMS 4245 (Appendix D7) lost land between 2005 and 2008 but gained from 2008 through 2016, with a net gain of 9.7 acres or 12% gain in land. Both sites gained an average of 0.9 acres per year from 2005 to 2016. In summary, it appears that the goal of reducing the rate of land loss in the project area was achieved primarily due to the installation of the shoreline protection structures.

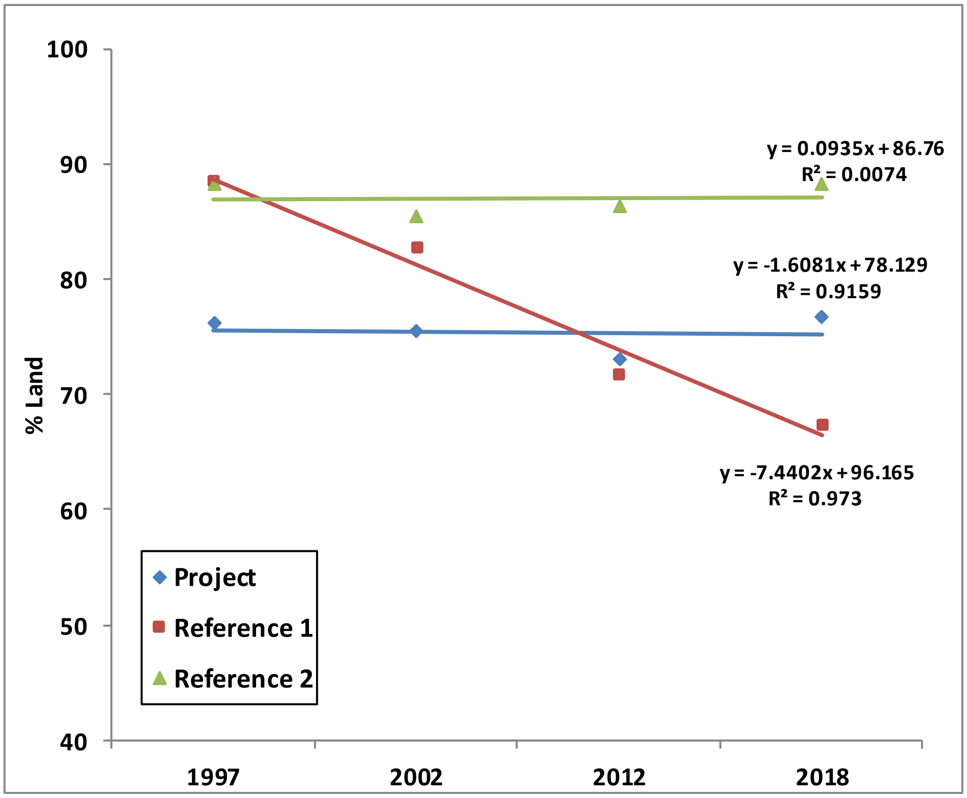

Figure 6: Trends in % land change within the Jonathan Davis Wetland Restoration project and reference areas from 1997 to 2018.

Table 2: Land acreage changes within the Jonathan Davis Wetland Restoration (BA-20) project and reference areas from 1994 to 2018.

Year Range	Project			Reference Area 1			Reference Area 2		
	Land Change (acres)	% Change in Land Acreage	Loss/Gain Rate (acres/yr)	Land Change (acres)	% Change in Land Acreage	Loss/Gain Rate (acres/yr)	Land Change (acres)	% Change in Land Acreage	Loss/Gain Rate (acres/yr)
1994-1997 (Pre-construction)	+151	2.7%	+50	--	--	--	--	--	--
1997-2002 (Post CU1/CU2)	-57	-1.0%	-11	-57	-6.4%	-11	-9	-3.2%	-2
2002-2012 (During CU3/CU4)	-183	-3.2%	-18	-111	-13.4%	-11	+3	1.1%	+0.3
2012-2018 (Post-construction)	+275	5.0%	+46	-44	-6.1%	-7	+6	2.2%	+1
Overall (1997-2018)	**+35**	**0.6%**	**+2**	**-212**	**-23.9%**	**-10**	**0**	**0.0%**	**0**

ii. <u>Salinity</u>

Hourly salinity data was collected at the BA-20 continuous recorder stations (Figure 4) from December 1995 to January 2005, and has been collected at CRMS3985 and CRMS4245 from May 2008 to present (Figure 7). Monthly mean salinity at the different recorder stations displayed similar responses to seasonal influences and storm events. Salinity at BA20-90R was generally higher than salinity at the other project and reference stations. Salinity spikes resulted from several tropical events including Tropical Storm Frances/Hurricane George in 1998, and Hurricanes Gustave and Ike in 2008, but were generally not prolonged. A prolonged drought occurred from late 1999 through late 2000 with all stations experiencing elevated salinities during most of this period. Salinity at the two CRMS stations followed similar patterns throughout the period of record but CRMS 4245 (southern station) appears to consistently have slightly, but statistically significant ($p<0.001$), higher salinity than CRMS 3985 (1.17 ± 1.25 ppt and 0.99 ± 0.98 ppt, respectively). A slight negative trend in daily mean salinity over time was observed in the project area using an average of stations BA20-11, BA20-20, CRMS3985 and CRMS4245 after removing the extreme drought period and Hurricanes Gustav, Ike and Isaac (Figure 8).

Delayed and staggered construction of the project features led to challenges in testing for project impacts on salinity levels. Construction of CU1, consisting of several rock weirs and plugs in the southwestern region of the project area (Figure 2), was finished in September 1998, while construction of CU2, consisting of a sheetpile weir and shoreline protection in the southeastern region of the project area, was completed in May 2001. For this reason, separate tests were conducted on the eastern (BA20-20 vs BA20-90R) and western (BA20-08 vs BA20-98R) regions of the project area, each with separate, relative pre/post-construction units as well as with CRMS beginning in 2008. CU3 was not completed until July 2003 and there was a data gap from 2005 to 2008; therefore, CU3 was not included in this analysis. Data from both CRMS sites (CRMS3985 and CRMS4245) from 2008 through 2019 were used to analyze pre-construction of CU4 (completed in 2011) and post-construction of all features.

The analysis of the western region (CU1: BA20-08 vs BA20-98R) had a pre-construction period from December 1995 to September 1998 and a post-construction period from October 1998 to January 2005. The analysis of the eastern region (CU2: BA20-20 vs BA20-90R) had a pre-construction period from December 1995 to May 2001 and a post-construction period from June 2001 to November 2003 (due to the loss of BA20-90R). A third analysis tested the southern project area as a whole by comparing three stages of construction: pre-construction (December 1995 – September 1998), during-construction (October 1998 – May 2001), and post-construction (June 2001 – January 2005). It should be noted that the drought period occurred during the 'during-construction' period and it would

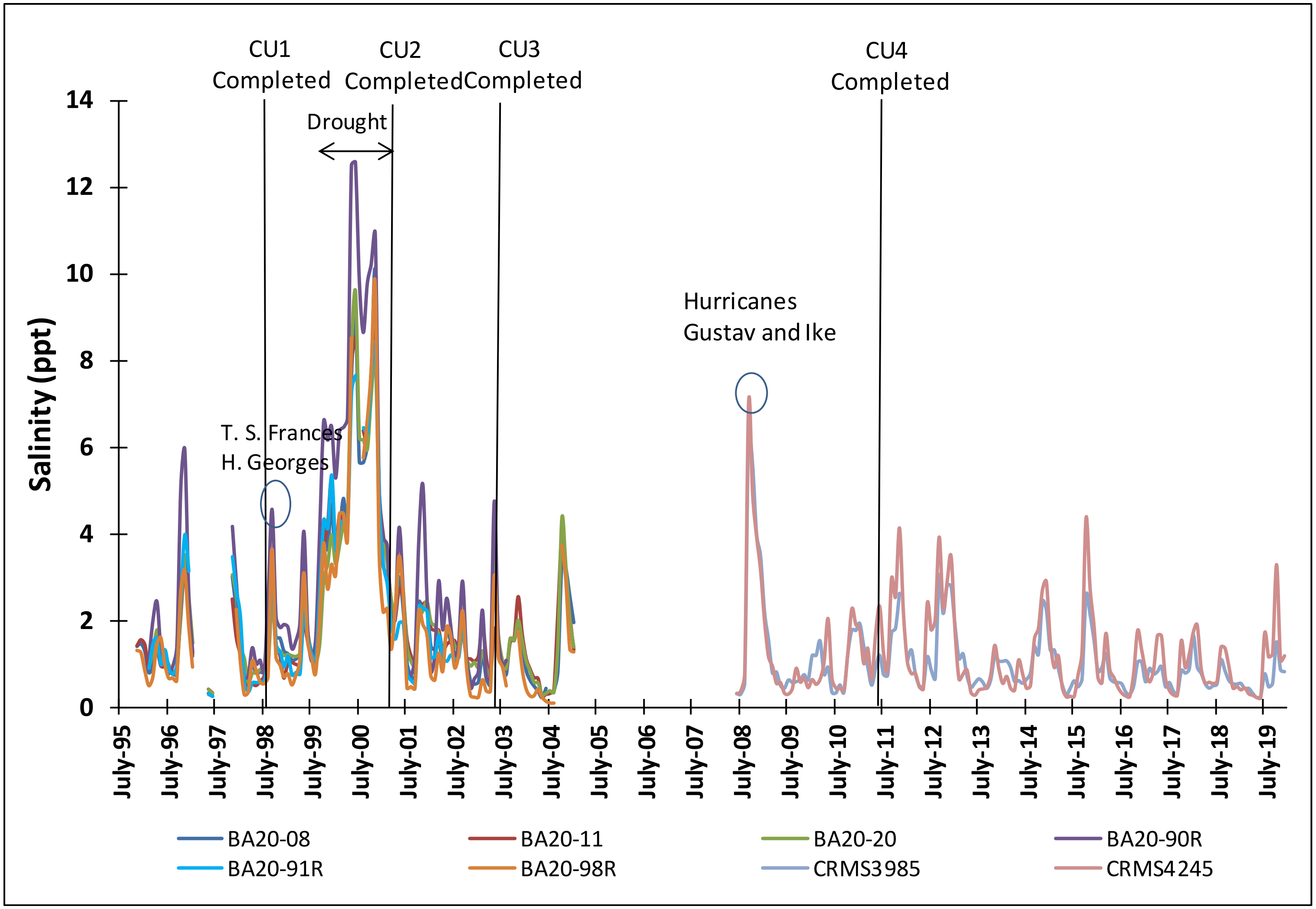

Figure 7: Monthly mean salinity data for all BA-20 and CRMS continuous recorder stations from 1995 through 2019.

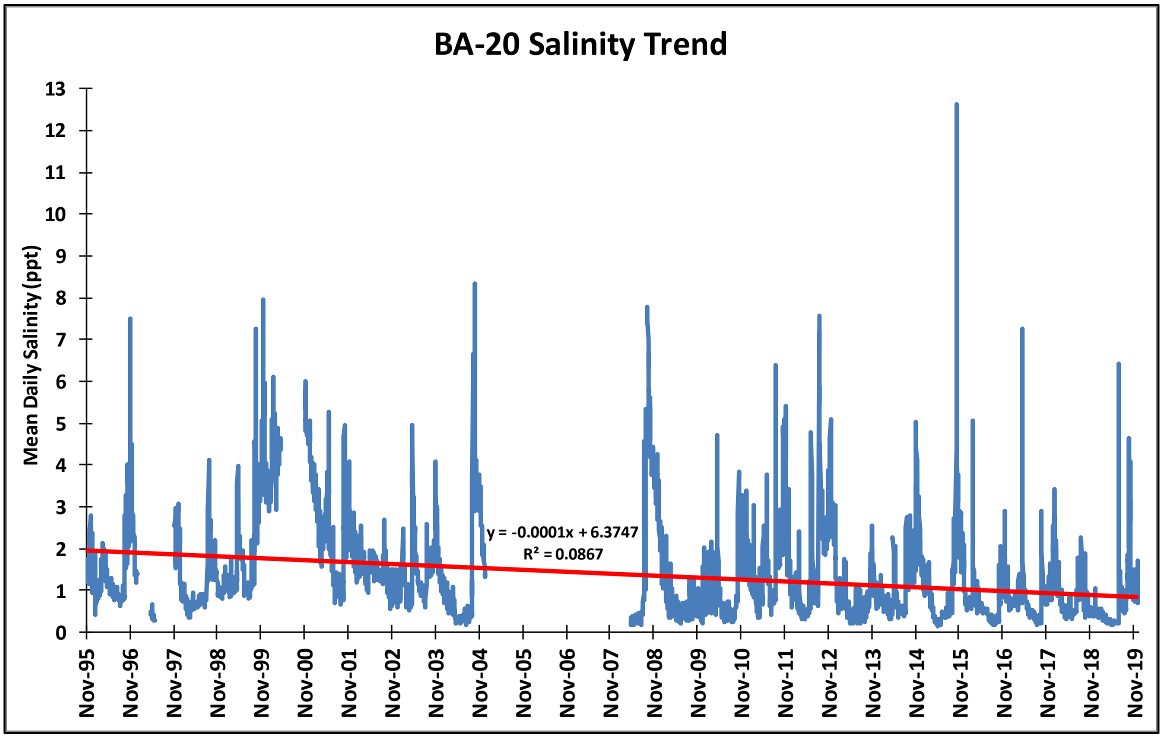

Figure 8: Trend in daily mean salinity within the BA-20 project area using BA20-11/BA20-20 (1995 to 2005) and CRMS3985/CRMS4245 (2008 to 2019). The extreme drought period in mid to late 2000 was removed, as well as Hurricanes Gustav, Ike, and Isaac.

be expected that mean salinities would be highest during that time (Figure 9). However, one of the statistical assumptions would be that the drought is affecting all stations equally. A fourth analysis investigated salinity before construction of CU4 and after (all construction features in place) using only the two CRMS stations.

A special note must be made about BA20-11 and BA20-91R, which were located in the northern portion of the project area (Figure 4). The original project specifications included plans for eight weir/breach armor structures in the northern area; however these structures were never built in order to allow sufficient ingress of water from the Davis Pond Diversion to the north. Because there are no structures between the project station (BA20-11) and the reference area station (BA20-91R), there is no reason to expect an environmental effect as a result of the project. Therefore, these stations were excluded from the salinity analyses.

The east and west analyses compared salinity between the pre- and post-construction periods using paired project and reference stations. The statistical model followed a 2X2 BACI factorial analysis of variance (ANOVA) in which a statistically significant interaction between the main effects (*period* and *location*) provides evidence for a project impact (Stewart-Oaten et al. (1986), Underwood (1994), and

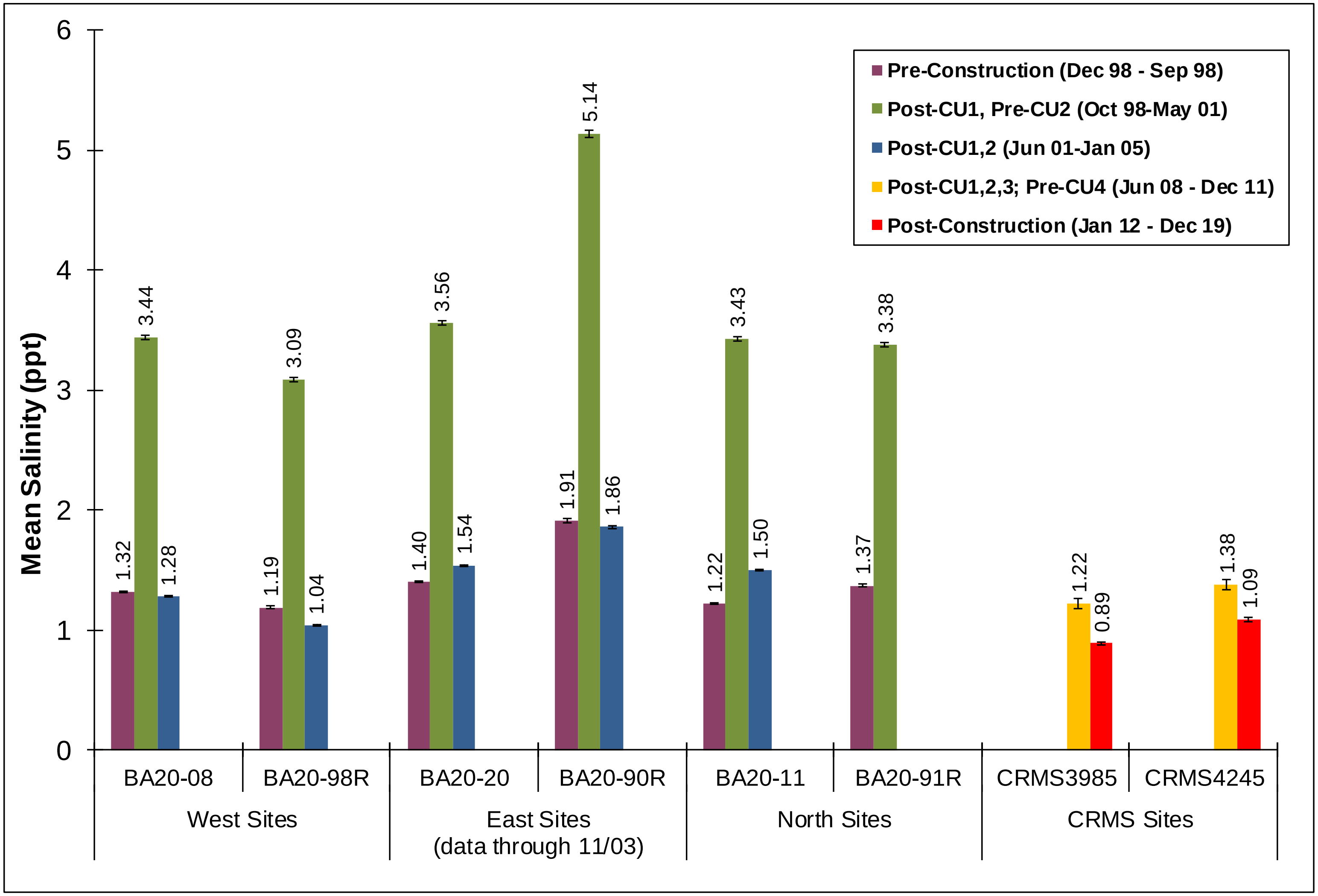

Figure 9: Weekly mean salinity at each BA-20 and CRMS continuous recorder stations during different periods of construction.

Smith (2002)). The third, overall analysis tested for impact using a 3X2 BACI ANOVA in which the variable *period* had three levels: pre- construction, during-construction, and post-construction. The statistical models depend on simultaneity of measurements among the various stations. For this reason, hourly salinity measurements were aggregated into weekly means, one week being enough time to average out temporal lags among the stations during tidal and meteorological events. Another advantage to using weekly means (versus hourly means) is that they exhibit less serial correlation, i.e., greater sample independence, which is an important underlying assumption of the statistical model. The hourly salinity measurements were first transformed into common logarithms in order to meet assumptions of normal distribution and uniform variance, and then aggregated into weekly means on which the statistics are based. The analyses were run using Proc GLM in SAS© Version 9 with *period* and *location* as fixed effects. A BACI analysis was not conducted for CU4 since there is not an associated control or reference site for this construction feature. The analysis of CU4 was conducted using an ANOVA in RStudio (RStudio Team 2019), which compared daily salinity means from 2008-2011 (before construction of CU4) to daily salinity means from 2012 -2019 (after all construction features installed) collected at CRMS4249 and CRMS3985. These analysis are subject to bias because the post-construction data set is a much longer record (8 years) than the pre-construction data (4 years).

In the eastern project area, the '*period x location'* interaction showed a statistically significant impact (p=.0035) of the project on mean weekly salinity levels. This shows up graphically as lines out of parallel in Figure 10, which shows that salinity decreased slightly more at the reference station, BA20-90R, in the post-CU2 period than it did inside the project, a 51% and 42% reduction, respectively. The statistical significance reflects the size of the data set, not the size of the impact, which was modest, amounting to a difference of about one part per thousand from what would be expected if there were no impact. Although this was not the desired outcome, it should be noted that pre-construction salinity was already lower in the project area, and in order to see the same reduction as observed in the reference area, the salinity would have had to decrease to almost 0.5 ppt. In terms of percent reduction, the salinity would only have needed to decrease to 1.3 ppt in the project area to experience the same percent reduction as the reference area. The actual post-CU2 salinity in the project area was near that target at 1.5 ppt.

The western project area also experienced a slightly significant impact (p=.0355) of the project on mean weekly salinity levels at BA20-08. This shows up graphically as lines out of parallel in Figure 11, which shows that salinity increased slightly more in the project area in the post-CU1 period. Salinity increased by 71% and 60% in the project and reference areas, respectively. Again, the statistical significance corresponds to an impact with only modest biological significance, a departure of less than one part per thousand from what would be expected had there been no impact. It should be noted that the drought occurred during the pre-construction period for the eastern analysis and during the post-construction for the

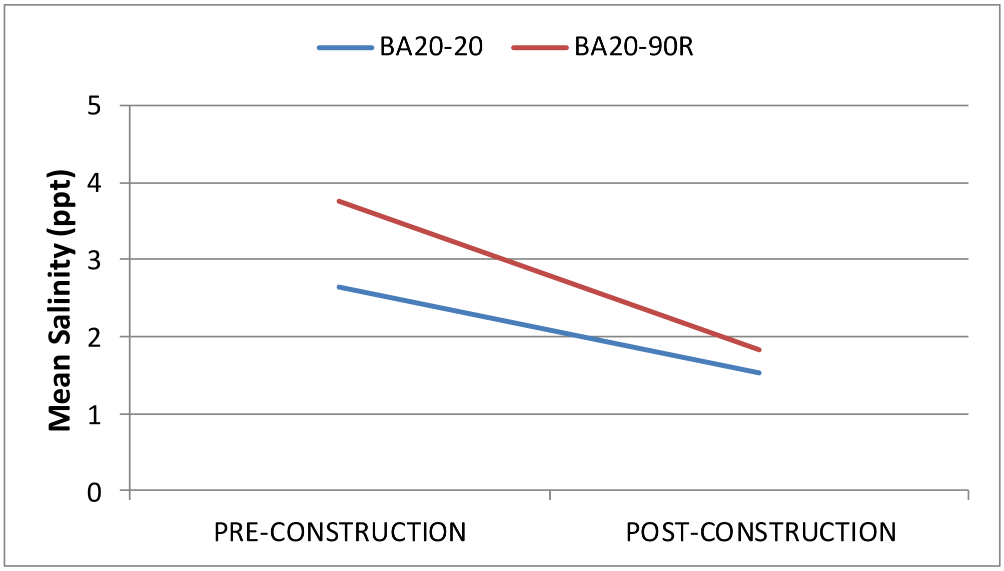

Figure 10: Comparison of mean weekly salinity of eastern sondes (BA20-20 and BA20-90R) during the pre- and post-CU2 periods.

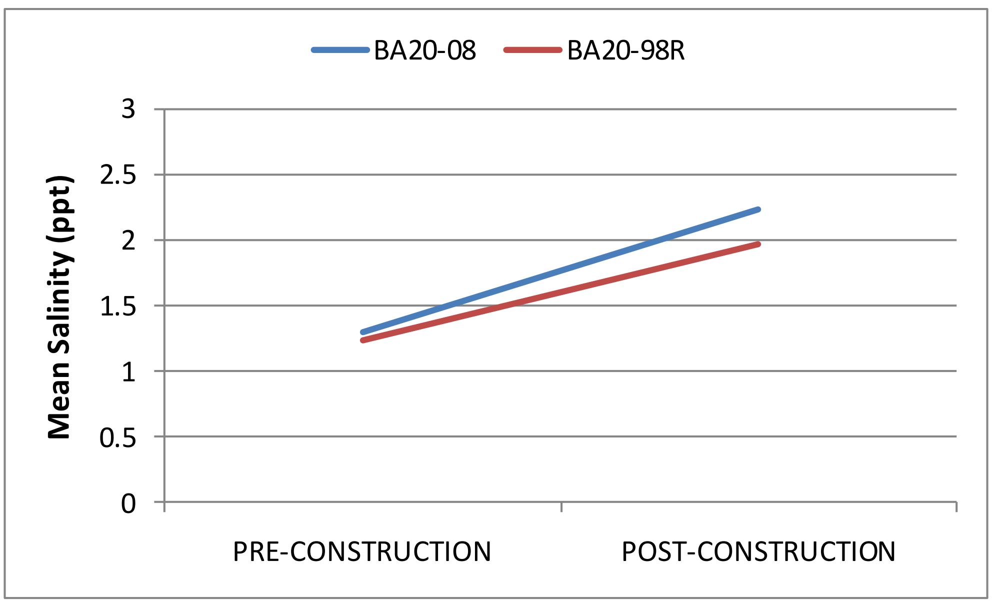

Figure 11: Comparison of mean weekly salinity of western sondes (BA20-08 and BA20-98R) during the pre- and post-CU1 periods.

western analysis. The effects of the drought on salinity were extreme (Figures 7 and 9) and it may be possible that some stations could have been more adversely affected due to specific differences in geographic location. One of the assumptions of the analysis is that factors such as the drought would affect all stations equally.

The 3X2 BACI analysis of the complete southern project area (comprising sondes 08, 20, 90R, and 98R) also registered a statistically significant project impact ($p < .0001$) on mean weekly salinity levels. This shows up graphically in Figure 12 as lines out of parallel between the during-construction and post-construction periods. As in the other tests, the size of the impact was modest, representing a departure of less than one part per thousand from what would be expected had there been no impact. There was a greater decrease in reference mean salinity (67% vs 61%) between the during- and post-construction time periods, with the resulting project and reference mean salinities being nearly identical in the post-construction period.

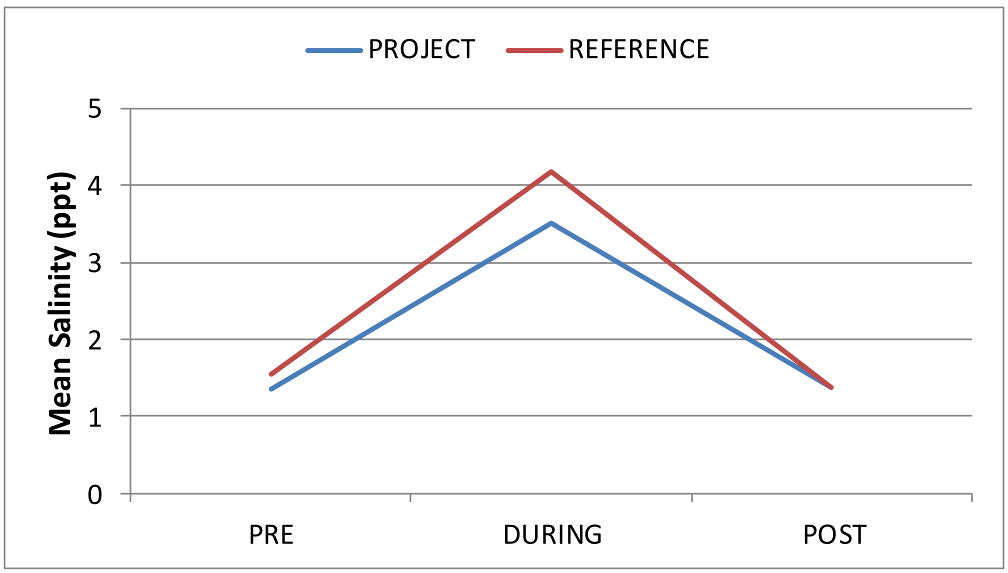

Figure 12: Comparison of mean weekly salinity of project stations (BA20-08 and BA20-20) vs reference stations (BA20-90R and BA20-98R) during three stages of project construction.

Analyses of mean daily salinity pre- and post- construction of CU4 at CRMS3985 and CRMS4245 revealed that there was a significant difference in salinity at both stations between the two time periods ($p<0.001$ for both stations). As seen in Figure 9, both stations had a mean salinity between 1.0 and 1.5 ppt before CU4 construction, but became even fresher (<1 ppt) after CU4 construction. Since there is no reference station, the same analysis was conducted for the nearest CRMS stations north and south of the Jonathan Davis Wetlands which were CRMS0261 (5.3 miles south of CRMS4245) and CRMS0188 (5.4 miles north of CRMS3985).

The same pattern of significant difference in salinity during the two time periods was detected at those stations as well, indicating that the decrease in salinity during the post-construction period is most likely a regional phenomenon and not attributable to the completion of CU4.

One of the project objectives was to reduce salinity fluctuations, with the specific goal of decreasing salinity variability within the project area. Salinity variability was expressed in terms of daily range for each station by subtracting the minimum from the maximum hourly salinity reading within each 24 hour period. While the overall salinity range during the entire sampling period was around 20 ppt, the mean daily salinity range was less than 1 ppt at all sites except for BA20-90R (Table 3). To test for the effects of CU1 and CU2 on salinity variability, mean daily salinity range at BA20-08 and BA20-98R was calculated for the pre- and post-CU1 periods and at BA20-20 and BA20-90R for the pre- and post-CU2 periods. An analysis of variance (ANOVA) was then conducted separately for the western (BA20-08 vs BA20-98R) and eastern (BA20-20 vs BA20-90R) areas using *period* (pre- vs post-construction) and *station* as the dependent variables. Tukey-Kramer's post-hoc test was used to examine various station/period comparisons. In the western project area, the mean daily salinity range at both project and reference sites was significantly higher in the post-CU1 period ($F=38$, $p<.0001$), although this was only equivalent to a 0.1 ppt increase (Figure 13). The increase at the project and reference sites was nearly identical, which was confirmed by an insignificant '*station x period*' interaction ($F=0.24$, $p=0.6261$). Therefore, the changes appear to be a reflection of widespread conditions, and CU1 did not significantly affect mean daily salinity range within the project area at BA20-08.

Table 3: Mean, minimum, and maximum salinity (ppt) over the entire sampling period, as well as the mean daily range in salinity, for all BA-20 project and reference sites.

	Time Period	Mean Salinity (ppt)	Minimum Salinity (ppt)	Maximum Salinity (ppt)	Mean Daily Salinity Range (ppt)
BA20-08	12/95-1/05	1.98	0.10	19.58*	0.30
BA20-20	12/95-11/03	2.27	0.13	17.83*	0.46
BA20-90R	12/95-11/03	3.08	0.20	24.61*	1.20
BA20-98R	12/95-1/05	1.74	0.10	22.7*	0.38
CRMS3985	5/08-12/19	0.99	0.12	14.58**	0.21
CRMS4245	5/08-12/19	1.40	0.11	18.75***	0.96

*occurred during drought in November 2000
**occurred 9/13/2008 during Hurricane Ike; CRMS4245 was not recording due to malfunction
***occurred 8/29/2012 during Hurricane Isaac

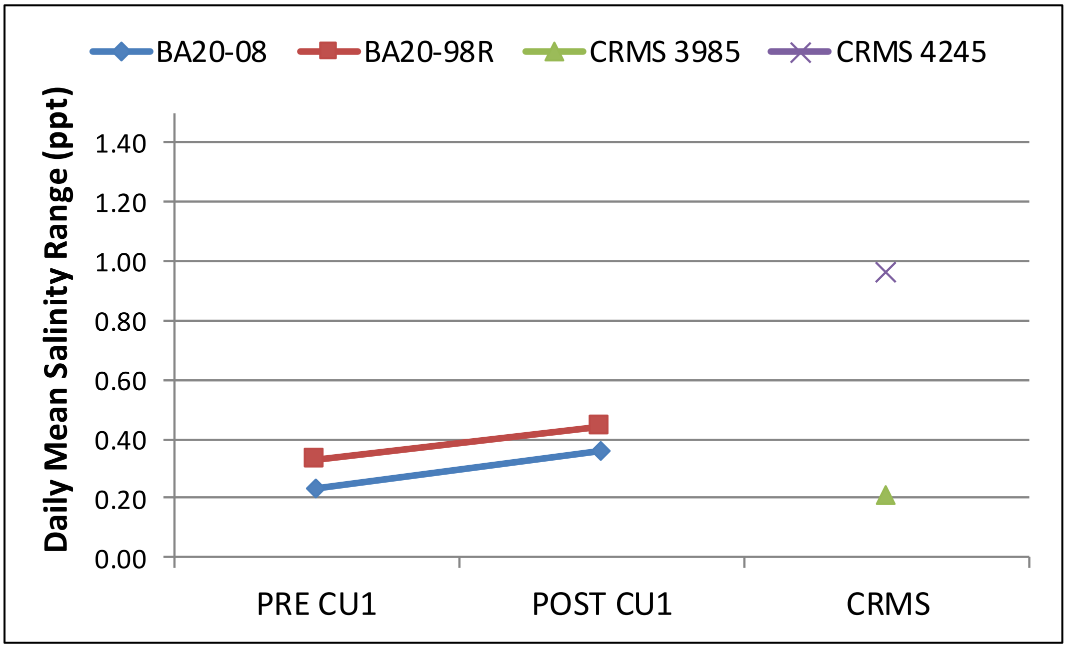

Figure 13: Daily mean salinity range (ppt) at the western project and reference sites (BA20-08, BA20-98R) before and after construction of CU1 and at the CRMS sites (3985, 4245) from 2008 through 2019.

In the eastern project area, there was a significant difference in mean daily salinity range between the pre- and post-CU2 periods (F=33, p<.0001); however, post-hoc comparisons reveal that this is only true for the reference site, which showed a significant decrease of 0.35 ppt (p<.0001) (Figure 14). The difference between the pre- and post-CU2 periods at BA20-20 was not significant (p=.7187), although a small decrease was observed. A significant '*station x period*' interaction (F=26, p<.0001) is likely due to the difference in magnitude of salinity range between the two sites rather than to any negative project effect. It would have been impossible to see a similar decrease in the project area because the mean daily salinity range at the project site was already much lower than the reference site. Therefore, CU2 did not appear to have a positive or negative affect on the mean daily salinity range within the project area at BA20-20.

Mean daily salinity range from 2008 to 2019 was also calculated for the two CRMS sites within the project area (Figure 15). Mean daily salinity range was significantly higher in the southern project area at CRMS4245 (mean=0.96 ppt, S.E.=0.016) than at CRMS3985 (mean=0.21 ppt, S.E.=0.006) (F=1,899, p<.0001). Although the immediate goal of CU4 was to reduce shoreline loss, an ANOVA was conducted to determine if CU4 construction had a buffering effect on salinity range at the CRMS sites. CU4 construction did not appear to buffer salinity range at CRMS4245 but did at CRMS3985 in the post-construction period (1/1/12-12/31/19) (Figure

15). Mean daily salinity range at CRMS4245 was significantly higher in the post-CU4 period at 1.07 ppt (F=116.1, p<0.001) than in the pre-CU4 period (0.7 ppt). At CRMS3985, salinity range was significantly lower post-CU4 construction (0.17 ppt) than pre-CU4 construction (0.29 ppt) (F=90.2, p<0.001). However, as indicated above, there appears to be a regional freshening in the post-construction period that could also decrease salinity variability. Additionally, CRMS3985 is located at the northern end of the Jonathan Davis Wetland, where it is far from project features and closer to the Davis Pond Diversion. While this diversion was constructed in 2002, consistent operation did not begin until 2006 and higher discharges didn't occur until 2008. Therefore, the decreased in salinity variability at CRMS3985 in the post-construction period could be due to the operation of Davis Pond decreasing salinity overall, as well as salinity variability at the northern end of the Jonathan Davis Wetland.

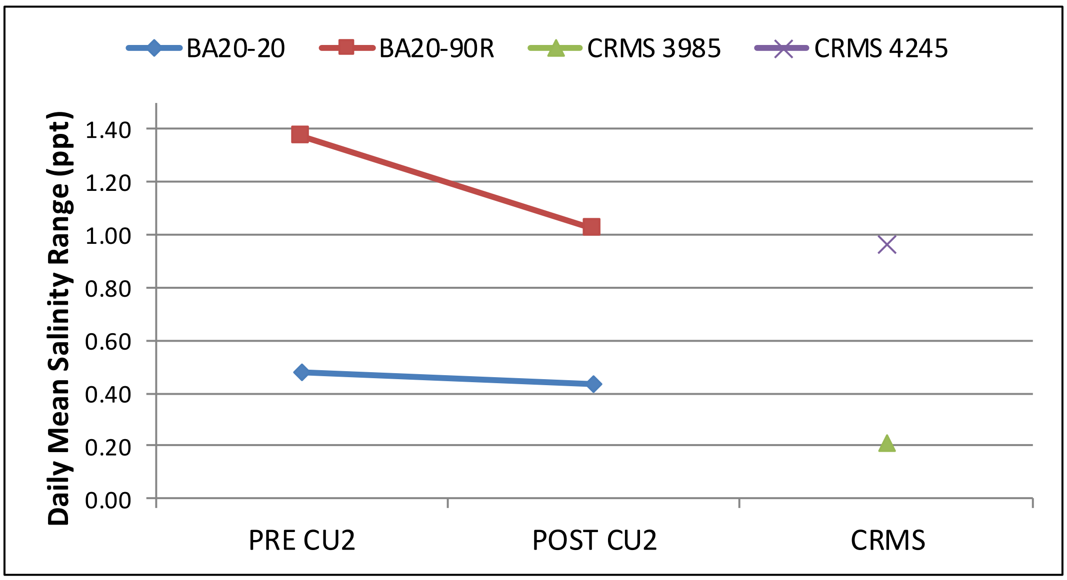

Figure 14: Daily mean salinity range (ppt) at the eastern project and reference sites (BA20-20, BA20-90R) before and after construction of CU2 and at the CRMS sites (3985, 4245) from 2008 through 2019.

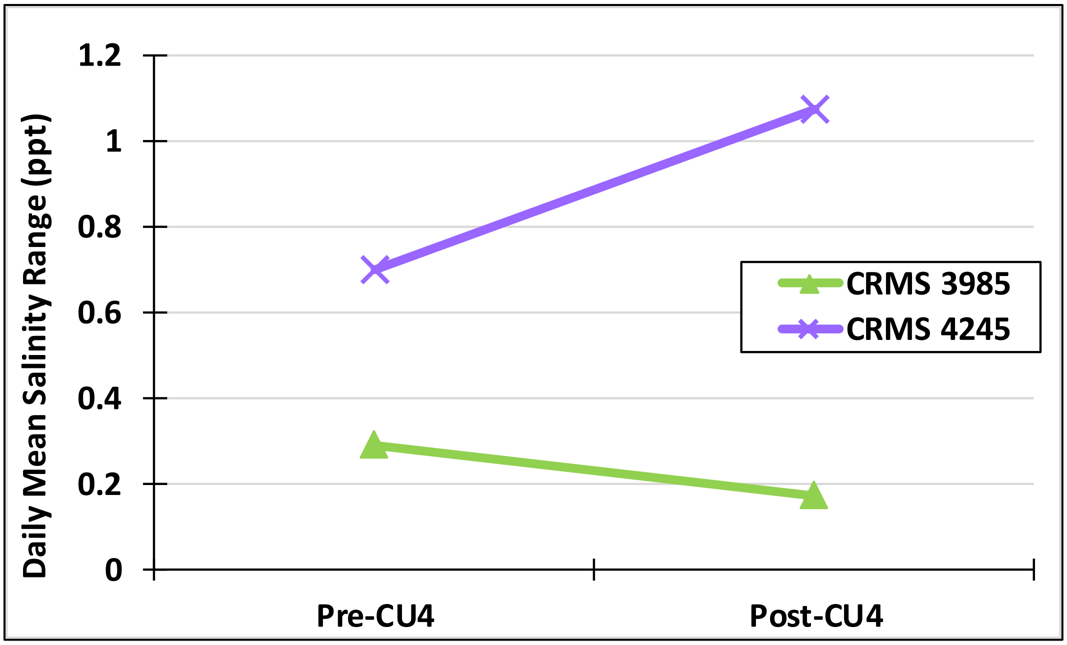

Figure 15: Daily mean salinity range pre- (2008-2011) and post - (2012-2019) construction of CU4 at CRMS3895 and CRMS4245.

iii. <u>Water Level</u>

Hourly water level data (ft NAVD88, Geoid99) was collected at the BA-20 continuous recorder stations (Figure 4) from November 1997 to January 2005, and has been collected at CRMS3985 and CRMS4245 from May 2008 to present (Figure 16). Water level at the different recorder stations displayed similar responses to seasonal influences and storm events. Water elevations were higher in spring, early summer, and fall, while lower levels occurred in late summer and winter. Two tropical storm events in September 1998 produced different effects on water levels in the project and reference areas. Tropical Storm Frances, which made landfall to the west of the project area, caused a sharp increase in water levels, while Hurricane Georges, which made landfall to the east, caused a decrease in water levels. Water level increases were also observed during Hurricanes Isidore and Lili in 2002 and during Hurricanes Gustav and Ike in 2008. Since approximately 2011, at the CRMS sites, there appears to be a slight increase in water levels over time (Figure 16).

Mean water levels were lowest at all stations except BA20-98R in the period between construction of CU1 and CU2, which was most likely a result of the drought that occurred during this period (Figure 17). This was probably also the case for BA20-98R, however high water data during the 1998 storm season was lost at this site due to sonde malfunction. Water levels were the highest at all BA-20 project and reference sites during the post-CU2 period compared to the pre-CU1/CU2 periods. Mean water levels at the two CRMS sites since 2008 are also higher than mean water levels at the BA-20 stations for all construction periods. However, possible differences in elevation surveys between the BA-20 sites and CRMS sites, such as the reference benchmark used, may cause some error when comparing the NAVD water level between these two groups of stations.

Mean water levels at both CRMS sites increased after the installation of CU4. However, when water levels were examined for the nearest CRMS stations north and south of the project area, which were CRMS0261 (5.3 miles south of CRMS4245) and CRMS0188 (5.4 miles north of CRMS3985), they showed an increase in water level over time as well. Therefore, the increase in water levels after the installation of CU4 is most likely a regional occurrence and not attributable to the project features.

One of the stated goals of the project was to reduce water level variability within the project area. In order to test for the effects of the project on water level variability, a tidal analysis was conducted. A program was written using R Statistical Software which identified the maximum (high tide) and minimum (low tide) water elevations for each tidal period. Figure 18 shows an example of the tidal periods at BA20-08 from November 25, 1997 to January 6, 1998. High tide (red) and low tide (blue) for each period were identified and any tidal period longer than 15 hours in length was excluded. Abnormally long tidal periods were excluded because these were presumably influenced by weather events. Tidal range was calculated by subtracting each minimum elevation from the preceding maximum elevation for each tidal period. Mean tidal range was then subjected to an analysis of variance (ANOVA) with construction period (pre- vs post-construction) and station as the dependent variables.

To test for the impacts of CU1 on water level variability, BA20-08 and BA20-98R (western project area) were compared using a pre-construction period from November 1997 to September 1998 and a post-construction period from October 1998 to November 2003. Mean tidal range in the western project area was significantly lower in the post-construction (CU1) period ($F=38$, $p<8.16\text{x}10^{-10}$), and the reduction of tidal range at reference station BA20-98R was significantly greater than the reduction in the project area (‘*period x station*’: $F=9.5$, $p<0.002$) (Figure 19). The reduction in tidal range appears to be a regional occurrence, and not a result of CU1 construction. The smaller reduction of tidal range in the project area is likely due to the fact that the pre-construction tidal range was comparatively lower in the project area, allowing more ‘room’ for reduction at the reference station. In order to experience the same reduction in tidal range as the reference area, post-CU1 mean tidal range in the project area would have needed to approach 0.18 ft, which may be an unrealistic expectation for the natural tidal range in the project area. Therefore, the smaller reduction in the project area is not due to any negative project affect.

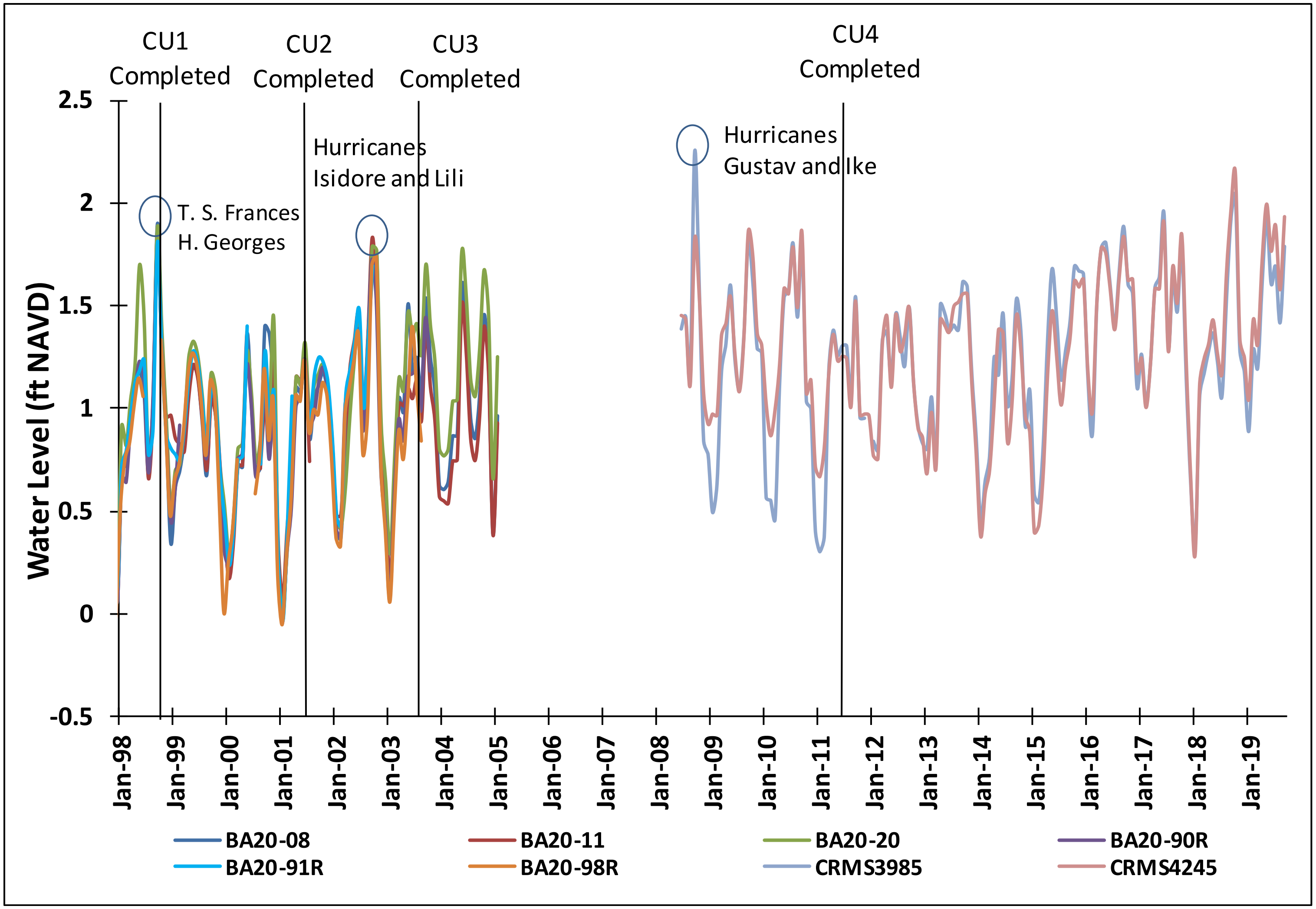

Figure 16: Monthly mean water level data (ft NAVD88) for all BA-20 and CRMS continuous recorder stations from 1995 to 2019.

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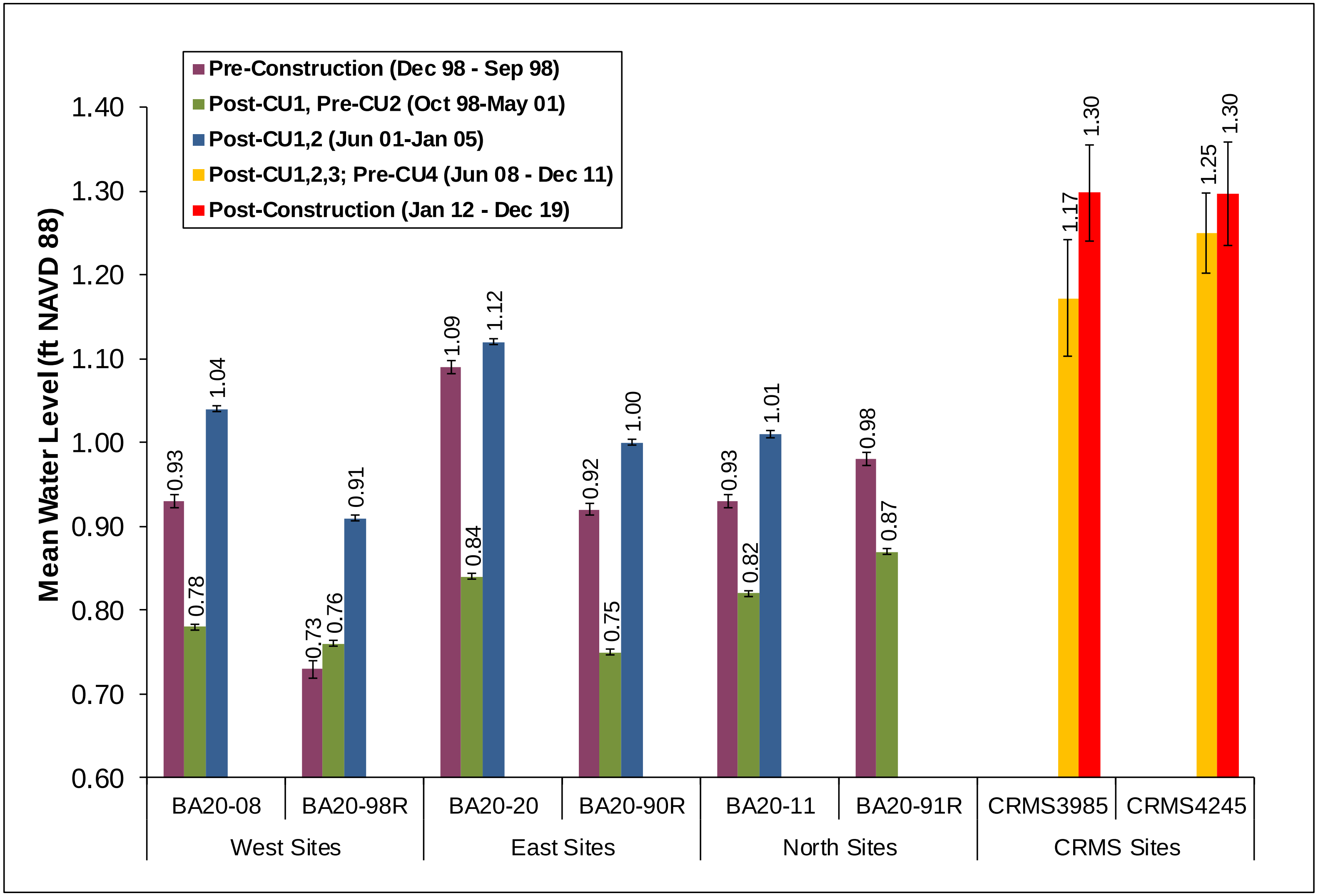

Figure 17: Mean water level at each BA-20 and CRMS continuous recorder station during four different periods of construction based on hourly water level readings.

To test for the impacts of CU2 on water variability, BA20-20 and BA20-90R (eastern project area) were compared using a pre-construction period from November 1997 to May 2001 and a post-construction period from June 2001 to November 2003. Mean tidal range in the eastern project area was significantly higher in the post-construction (CU2) period (F=45, $p<2.58\times10^{-11}$) (Figure 20). In this case, the '*period x station*' interaction was not significant (F=1.9, $p<0.17$) which suggests that the tidal range increased by a similar magnitude at the project and reference sites. Based on the tidal analysis, we would reject the hypothesis that CU1 and CU2 significantly reduced water level variability in the project area.

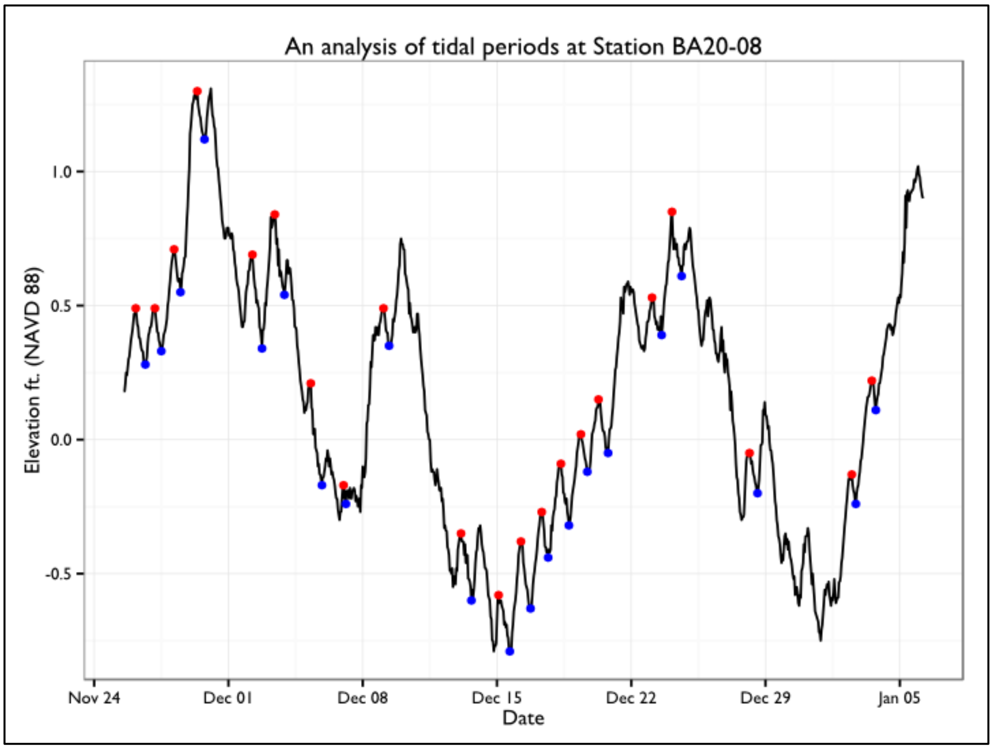

Figure 18: Tidal periods at BA20-08 from November 25, 1997 to January 6, 1998.

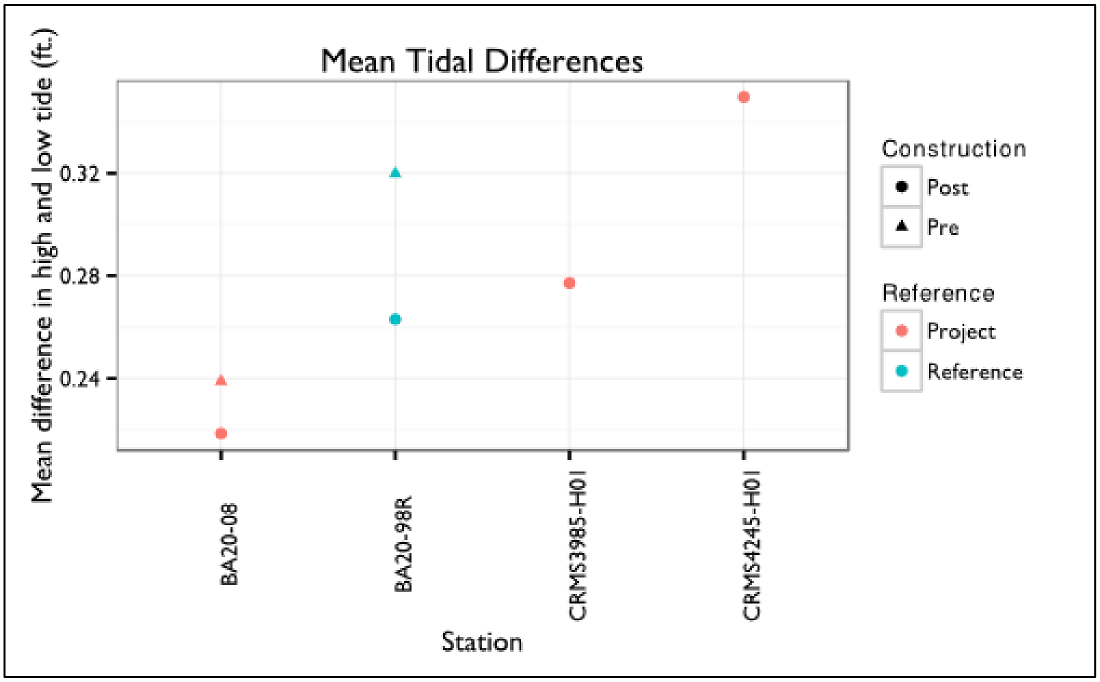

Figure 19: Mean tidal differences at the western project (BA20-08) and reference (BA20-98R) sites before and after construction of CU1 and at the CRMS sites (3985, 4245) from 2008 to 2013.

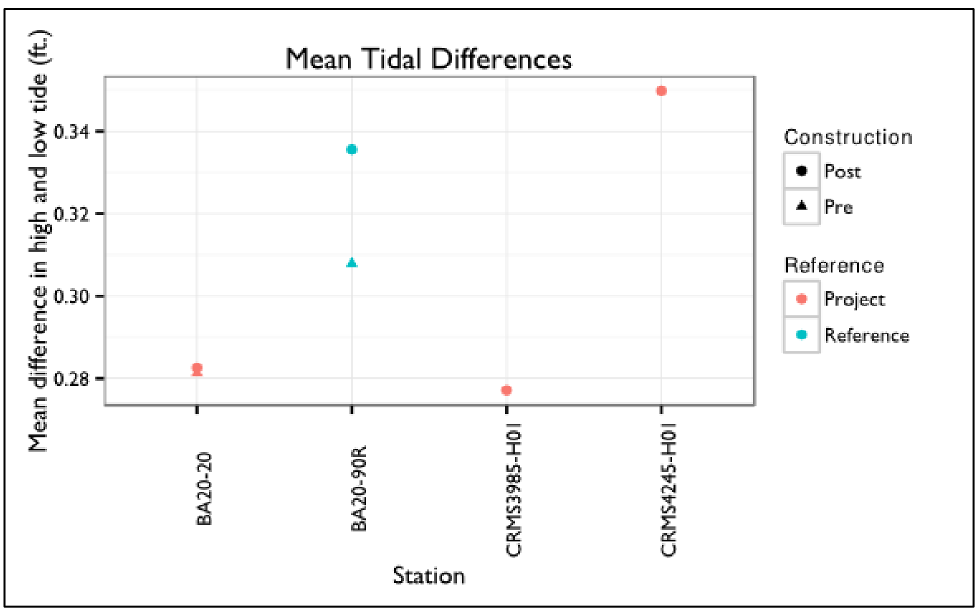

Figure 20: Mean tidal differences at the eastern project (BA20-20) and reference (BA20-90R) sites before and after construction of CU2 and at the CRMS sites (3985, 4245) from 2008 to 2013.

Mean tidal range from 2008 to 2013 was also calculated using water elevation data from CRMS3985 and CRMS4245 within the project area. These data were not used in the analysis due to the difference in time periods, but the results are shown in Figures 21 and 22 for comparison. Mean tidal range at CRMS4245, which is located in an area of highly fragmented marsh at the southern end of the project area, was higher than all of the other sites, including the reference stations (Figures 21 and 22). Tidal range at this site was most similar to reference site, BA20-90R, which it is closest to geographically. In the northern project area, CRMS3985 displayed a more moderate tidal range, which was between the tidal ranges measured at BA20-08 and BA20-20 in the earlier time period. Although the direct goal of CU4 was to reduce shoreline loss, an ANOVA was conducted to determine if CU4 had an effect on reducing water level variability at CRMS4245. One extreme outlier which occurred during the winter of 2010 was omitted from the analysis (Figure 22). Results showed that there was no significant difference in tidal range at CRMS4245 before and after CU4 construction ($F=0.67$, $p=0.416$). Due to there being no impact of the project of water variability at any of the stations, regions, or time periods in the Jonathan Davis Wetland, water variability analysis was not updated with CRMS data from 2014 through 2019, or since the 2014 report.

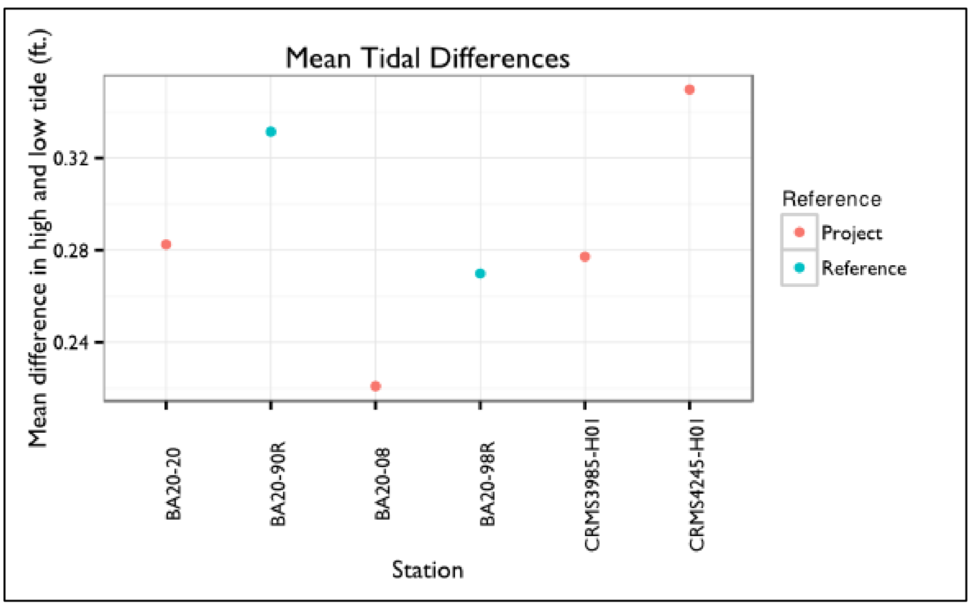

Figure 21: Mean tidal differences at BA-20 project and reference stations from November 1997 to November 2005, and at CRMS sites within the project area from 2008 to 2013.

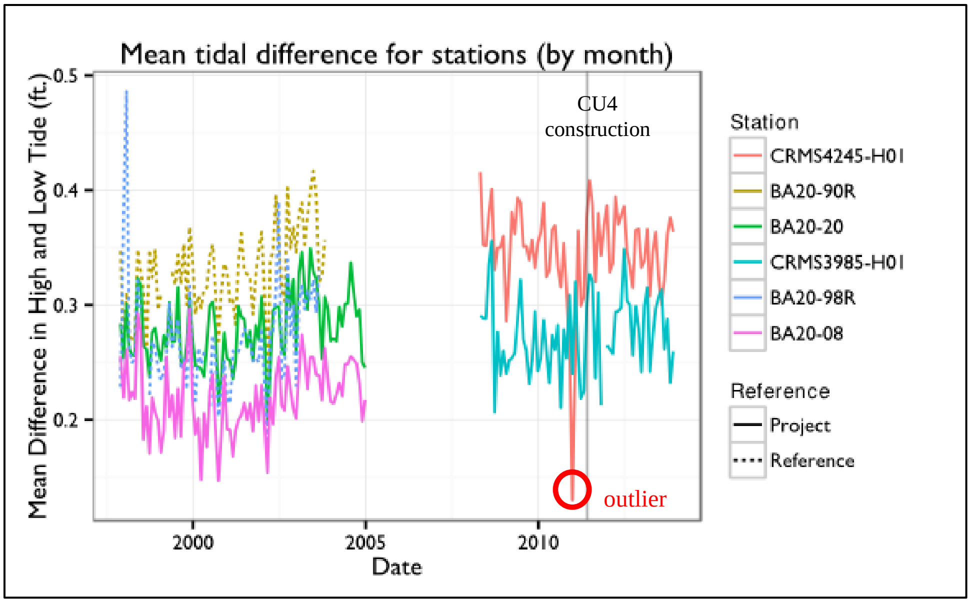

Figure 22: Mean monthly tidal differences at BA-20 project and reference stations from November 1997 to November 2005, and at CRMS sites within the project area from 2008 to 2013.

iv. Shoreline Change

In the previous OM&M Report (Hymel and Richard 2014), analyses of shoreline change rates were conducted for CU2 (Bayou Rigolettes Bank Stabilization), CU3 (Bayou Perot Bank Stabilization), and the reference areas using the change polygon method (Smith and Cromley 2012). To calculate the change rate (ft/yr) between two survey years, geo-rectified DGPS shoreline segments from each year were first converted to shapefiles. A polygon was then created from the two shoreline polylines to provide a total area (ft^2) of loss/gain between the two polylines. Next, the shoreline change rate was calculated by taking the area inside the polygon and dividing it by the average shoreline length between the two surveys.

Shoreline Change Rate (ft) = Area Change (ft^2) ÷ Average Shoreline Length (ft)

Finally, the shoreline change rate was divided by the number of years between the two survey events to determine shoreline change rate per year (ft/yr).

Shoreline Change Rate/Year (ft/yr) = Shoreline Change Rate (ft) ÷ # of Years between Surveys

For this report, shoreline change rate analyses were conducted for CU3 and CU4, but not CU2 since data collection for this unit was complete as of the 2014 report (Table 1). The analysis for CU3 was conducted on shoreline survey data from 2004, 2010, and 2015, and the new 2015 survey was compared to both 2010 and 2004. The analysis for CU4 was conducted on shoreline survey data from 2012, 2015, and 2018, and the 2018 data was compared to 2012 and 2015. A different shoreline change analysis method was used to calculate shoreline change rates for this report, than was used in the 2014 report. Shoreline change rate analyses were conducted using the Digital Shoreline Analysis System (DSAS) provided by the USGS (Himmelstoss et al. 2018a). This analysis provides average shoreline change rates based on a series of transects that originate from a user defined baseline through the various shoreline surveys (Figure 23 for example). In addition to average shoreline change rates, the DSAS also provides an estimation of how much of the change is statistically significant. For all analyses, transects were generated 25 meters apart (82 ft) and shoreline change was calculated for each transect and then averaged for the entire construction unit. For more details on the methods used in DSAS, see Himmelstoss et al. 2018b. It is important to note that there is floating marsh in the area, and ephemeral mats will often form along the shoreline between the existing marsh and the shoreline constructed feature; therefore, some areas may sometimes appear as land that will disappear for the following survey. While this most likely does not have a large impact on whole shoreline change averages, it may locally inflate or deflate gain and loss estimations.

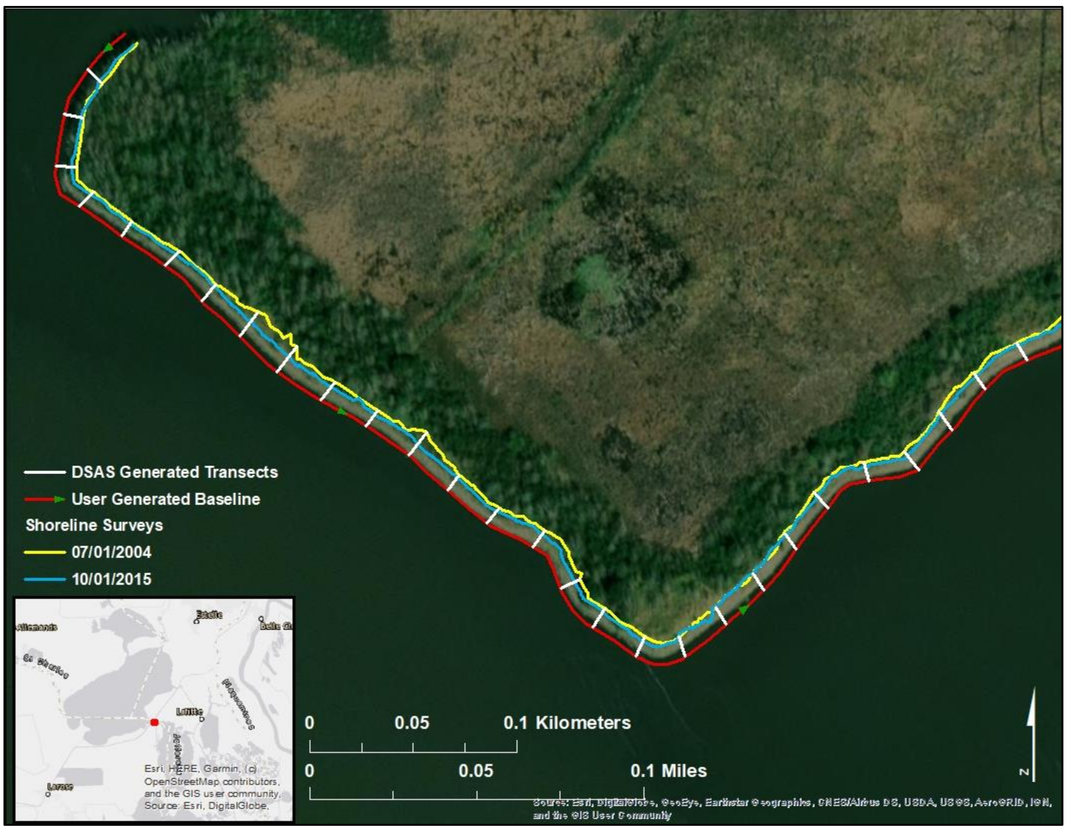

Figure 23: Example of transects generated by DSAS for shoreline change analysis. A shoreline change rate is calculated for each transect and then averaged for the entire construction unit.

Shoreline Change Through 2010

Positive shoreline change rates were observed in CU2 and CU3 during 2001-2010, whereas shoreline loss occurred in each of the reference areas over this same period

(Table 4). The shoreline analysis of CU2 from 2001 to 2004 showed an increase in land of 1.7 acres in the project area, and a loss of 3.6 acres in the adjacent eastern reference area (Figure 24). This corresponded to a shoreline change rate of +4 ft/yr in the project area and -8 ft/yr in the reference area from 2001 to 2004. Some land gained in the project area can be attributed to growth of vegetation between the rock structure and the original shoreline following construction. The eastern reference area has not been resurveyed since 2004 because it is now part of the Barataria Landbridge Shoreline Protection Project, Phase 4 (BA-27d) and has been protected with rock revetment since 2006.

A combined shoreline analysis of CU2 and the eastern portion of CU3 from 2004 to 2010 showed a net gain of 1.9 acres (+1.7 ft/yr) with negligible loss occurring (Figure 25). This increase in land occurred mostly in the CU3 area which had been constructed not long before the 2004 survey. As observed in the 2001-2004 analysis, the area between the rock structure and the original shoreline became vegetated, thereby causing an increase in shoreline acreage. The shoreline analysis of the western portion of CU3 exhibited a net land loss of 4.6 acres (+3.8 acres, -8.4 acres) for the period of 2004-2010 (Figure 26). However, the major extent of the land loss occurred along a large section of interior marsh located within the central portion of the project area. Therefore, separate land area calculations were made to determine the land changes to the 'shoreline' and 'interior marsh' independently. The 'shoreline' component exhibited a net gain of 3.34 acres (+3.51 acres, -0.17 acres), and the 'interior marsh' exhibited a net loss of 8 acres (+0.29 acres, -8.25 acres). The gain of land along the 'shoreline' component was again due to the vegetating of areas between the rock structure and the original shoreline between the first and second surveys. The shoreline gain rate (with the interior marsh area excluded) was determined to be +2.2 ft/yr.

Table 4: Summary of shoreline change (ft/yr) results for Construction Units 2-3 and two Reference Areas associated with the Jonathan Davis Wetland Restoration (BA-20) project.

Shoreline Location	Period	Shoreline Change (ft/yr)
CU 2	2001-2004	**+4**
Reference Area 2 (*East*)	2001-2004	**-8**
CU 2/3 East	2004-2010	**+1.7**
CU 3 West	2004-2010	**+2.2**
Reference Area 1 *(West)*	2004-2010	**-45**

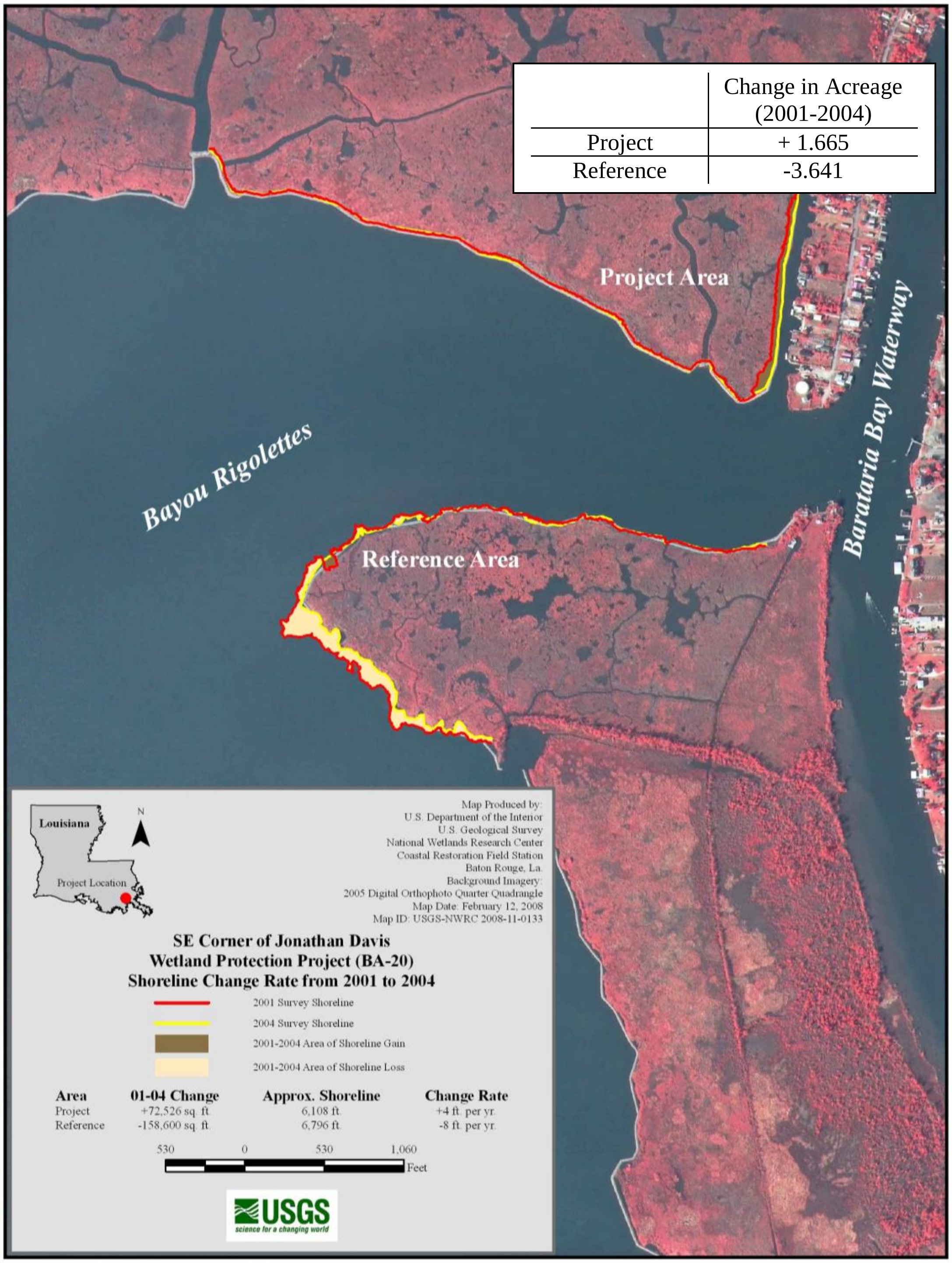

Figure 24: Shoreline change within Construction Unit 2 and the eastern reference area of the Jonathan Davis Wetland Restoration (BA-20) project from 2001 to 2004.

Figure 25: Shoreline change within Construction Unit 2 and the eastern portion of Construction Unit 3 of the Jonathan Davis Wetland Restoration (BA-20) project from 2004 to 2010.

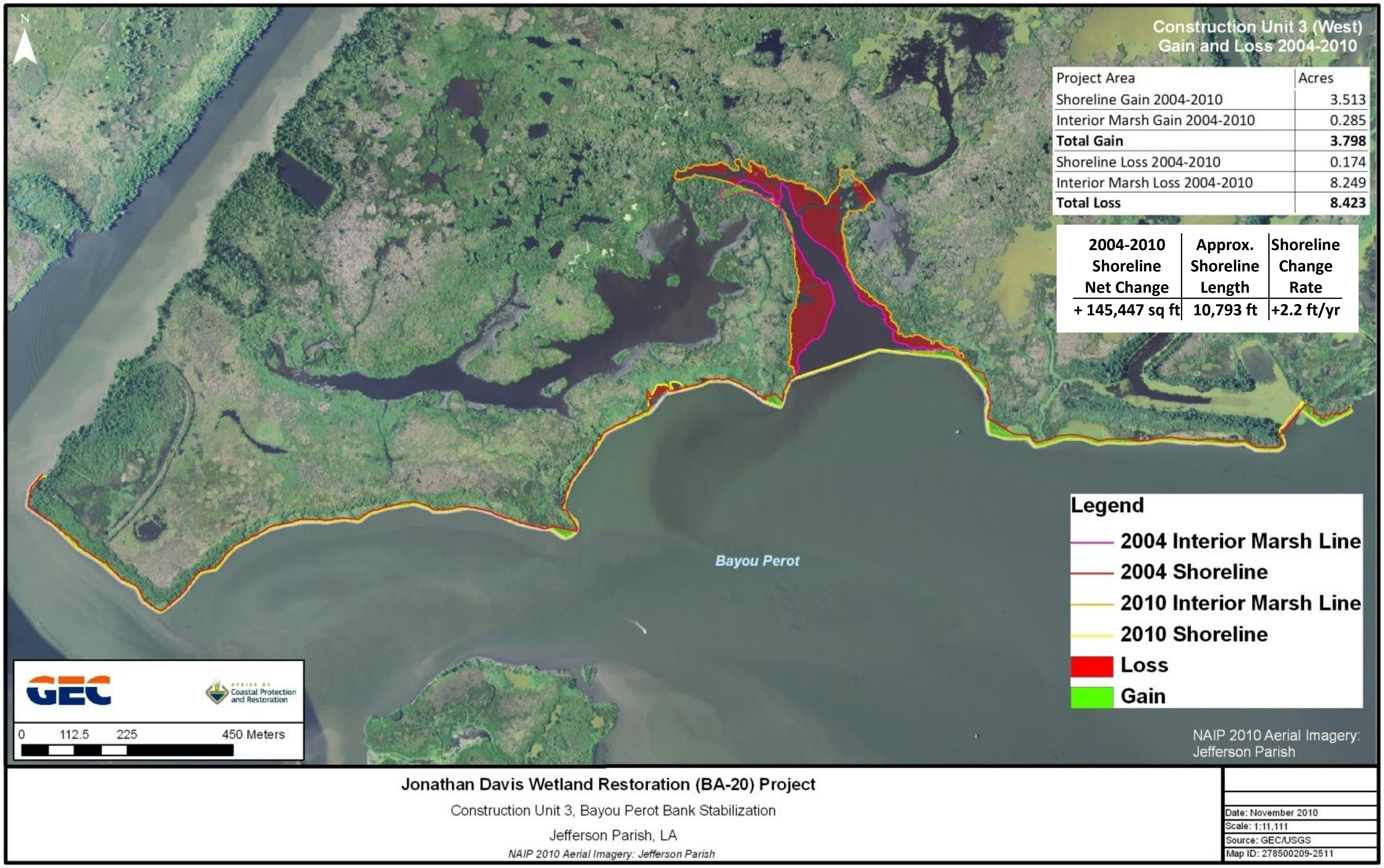

Figure 26: Shoreline change within the western portion of Construction Unit 3 of the Jonathan Davis Wetland Restoration (BA-20) project from 2004 to 2010.

Shoreline Change Update through 2018 Data Collection—CU3 and CU4

A third data collection event for CU3 occurred in October 2015, and was compared to data collected in 2004 and 2010 (Figure 27). As in the previous analysis, CU3 was analyzed as a whole, but also by separate 'Interior' and 'Shoreline' regions, because these two sections of shoreline were shown to differ in shoreline change patterns.

Figure 27: Three shoreline surveys associated with Construction Unit 3.

As mentioned above, the DSAS analysis draws transects to determine shoreline change rates at a user defined spacing. For the 2004 to 2015 comparison of CU3, there was a total of 151 transects drawn. Between 2004 and 2015, the average shoreline change along the entire length of CU3 was -0.57± 1.26 ft/yr (Figure 28). In this analysis, 37% of the transects were erosional and 63% were accretional. The analysis determined that 20% of the transects had shoreline change that was statistically significant, with 18% erosional and only 2% accretional. Therefore, most of the accretion during 2004-2015 was not statistically significant. When the interior marsh shoreline and exterior shoreline data were analyzed separately for 2004-2015, results showed that the interior change was mainly erosional or demonstrating shoreline retreat, while the shoreline change (directly behind the protection structure) was accretional. Average shoreline change rate of the interior shoreline was -9.5 ± 4.1 ft/yr. In the interior, there was a total of 37 transects with 92% erosional and 8% accretional. Approximately 70% of the transects had statistically significant erosion and none had significant accretion. Average change along the exterior shoreline sections was 0.7 ± 4.1 ft/yr. Along the exterior shoreline, there were 117 transects, 18% erosional and 82% accretional. Only 6% of the exterior shoreline transects had change that was statistically significant, 2.6% erosional and 3.4% accretional, indicating that most of the change detected along the shoreline was not statistically significant. A summary of shoreline change rates can be found in Table 5.

Figure 28: Shoreline change rate associated with Construction Unit 3 from 2004 to 2015. Note that most of the change is ± 5 feet.

For the 2010 to 2015 comparison of the CU3 shoreline, there was a total of 163 transects drawn. Between 2010 and 2015, the average shoreline change associated with CU3 was 0.02 ± 2.88 ft/yr (Figure 29). In this analysis, 72% of the transects were erosional and 28% were accretional. The analysis determined that 4% of the transects had shoreline change that was statistically significant, 1% erosional and 3% accretional; therefore, most of the shoreline change for 2010-2015 was not statistically significant. When the interior marsh shoreline and exterior shoreline data were analyzed separately for 2010-2015, results showed that the interior change was mainly accretional, while the shoreline change was erosional, which is opposite of the pattern seen from 2004 to 2015. The average shoreline change rate of the interior was 2.7 ± 9.5 ft/yr. In the interior marsh there was a total of 47 transects with 51% erosional and 49% accretional. None of the transects had statistically significant erosion and 8.5% had significant accretion. It appears that the majority of the shoreline retreat in the interior marsh occurred between 2004 and 2010, and between 2010 and 2015 the interior marsh recovered some of that shoreline loss, especially in the northeast corner (Figure 29). Average change along the exterior shoreline sections from 2010 to 2015 was -0.23 ± 2.88 ft/yr. Along the exterior shoreline, there were 118 transects, with 80% erosional and 20% accretional. Only 0.85% of the transects had shoreline change that was statistically significant and all of these were erosional. A summary of shoreline change rates can be found in Table 5.

Table 5: Summary of shoreline change rates associated with CU3, CU4 and reference area 1.

Shoreline Location	Period	Shoreline Change (ft/yr)	Uncertainty	% Statistically Significant Change
CU3	2004-2015	-0.57	±1.26	20
CU3 Interior	2004-2015	-9.5	±4.13	70
CU3 Shoreline	2004-2015	+0.7	±4.13	6
CU3	2010-2015	+0.02	±2.88	4
CU3 Interior	2010-2015	+2.7	±9.45	9
CU3 Shoreline	2010-2015	-0.23	±2.88	1
CU4	2012-2018	-0.03	±1.57	2
CU4	2015-2018	-0.75	±3.38	1
Reference Area 1	2004-2010	-53.22	±7.74	96
Reference Area 1	2010-2015	-29.46	±9.28	76
Reference Area 1	2015-2018	-49.18	±15.45	77
Reference Area 1	2004-2018	-43.86	±3.31	100

Figure 29: Shoreline change rate at Construction Unit 3 from 2010 to 2015. Note that most of the change is ± 5 ft.

In summary, there was little change along the CU3 shoreline between 2004 and 2015 and 2010 and 2015. The majority of the change took place in the interior marsh with substantial loss between 2004 and 2010 and then stabilization or gain between 2010 and 2015. In the northeast corner of the interior marsh, at the opening to a small bayou, there was a gain of 26 to 29 ft/year from 2010 to 2015, where it appears that the mouth of the small bayou is narrowing.

The CU4 shoreline was analyzed as a whole unit and not split up into smaller units. Shoreline location data was collected along CU4 in 2012, 2015, and 2018 (Figure 30). For the 2012 to 2018 shoreline comparison, there was a total of 303 transects drawn. Between 2012 and 2018, the average shoreline change along CU4 was -0.03 ± 1.6 ft/yr (Figure 31). In this analysis, 50% of the transects were erosional and 50% were accretional. The analysis determined that only 2% of the transects had shoreline change that was statistically significant, with 1.3% erosional and 0.7% accretional transects; therefore, most of the shoreline during this time period was not statistically significant. A summary of shoreline change rates can be found in Table 5. For the 2015 to 2018 shoreline comparison, there was a total of 307 transects drawn. Between 2015 and 2018, the average shoreline change along CU4 was -0.75 ± 3.4 ft/yr (Figure 32). In this analysis, 78% of the transects were erosional and 22% were accretional. The analysis determined that less than 1% of the transects had shoreline change that was statistically significant. Overall, it appears that the CU4 shoreline is relatively stable, not exhibiting substantial gain or loss along most of its length.

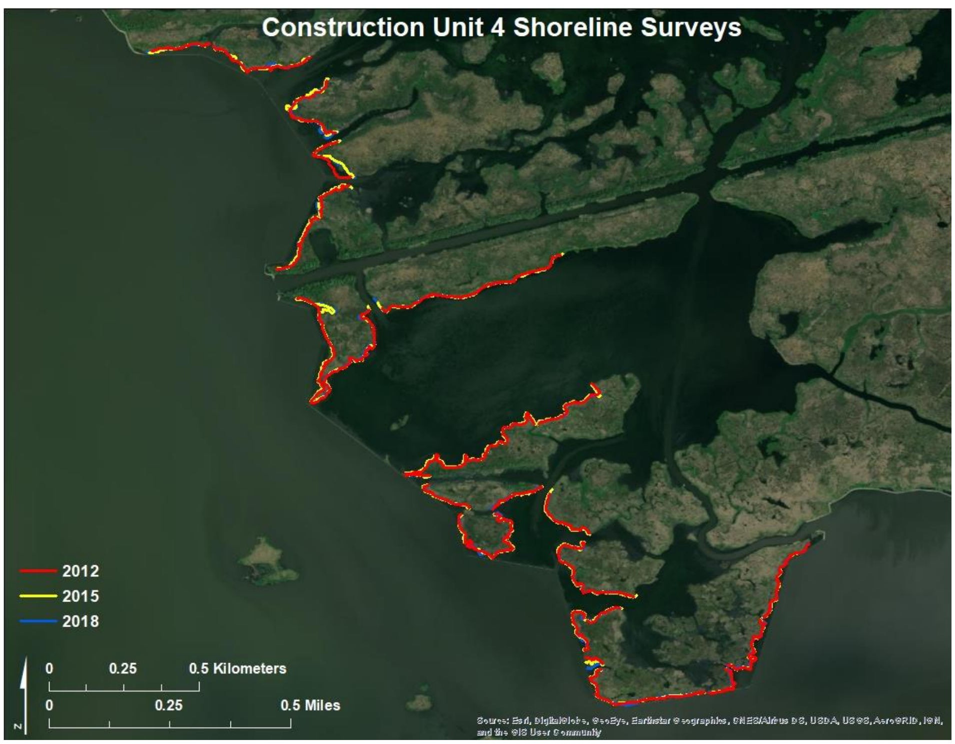

Figure 30: Three shoreline surveys associated with Construction Unit 4.

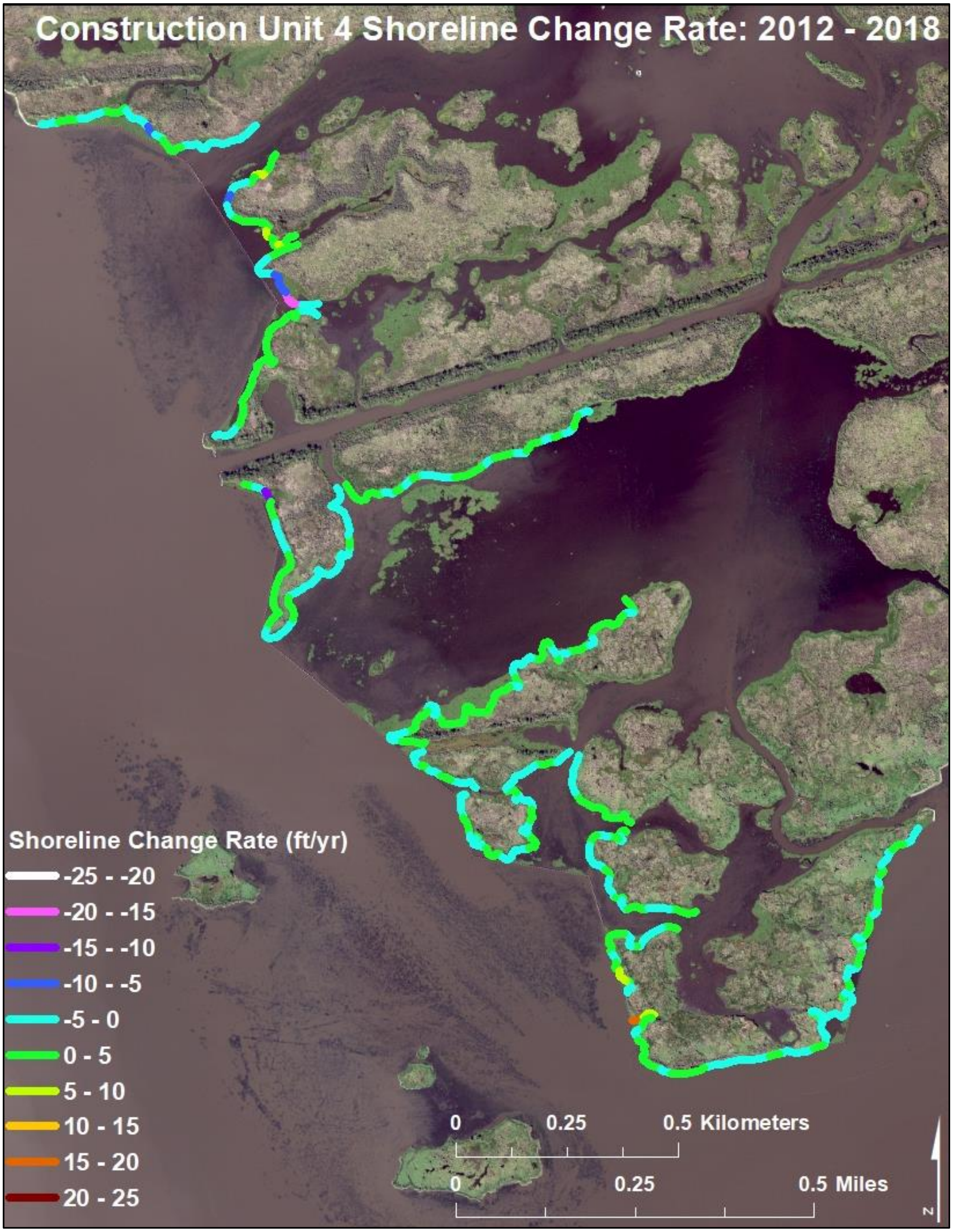

Figure 31: Shoreline change rate at Construction Unit 4 from 2012 to 2018. Note that most of the change is ± 5 ft.

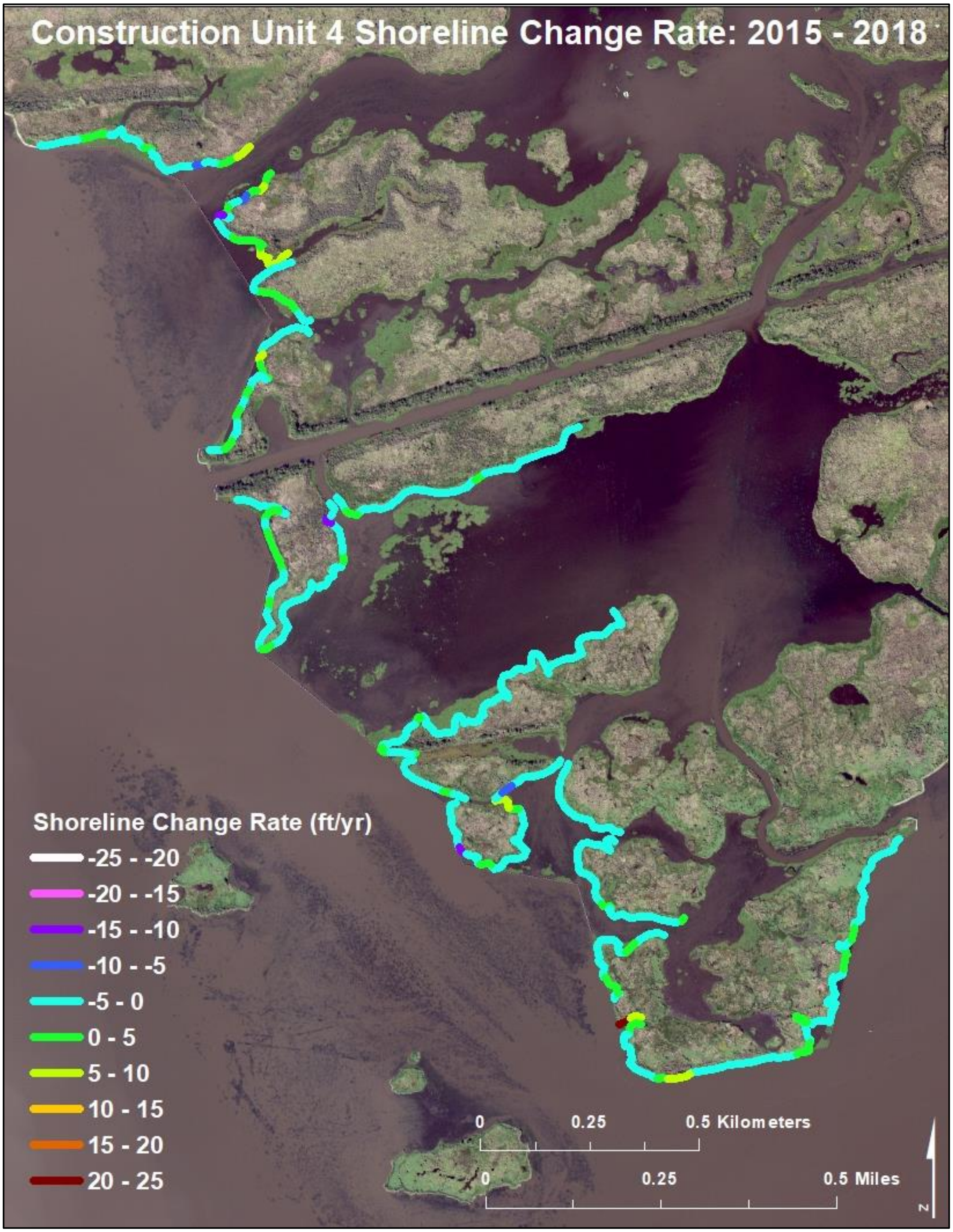

Figure 32: Shoreline change rate at Construction Unit 4 from 2015 to 2018. Note that most of the change is ± 5 ft.

Reference Area 1 Shoreline Data

Although DGPS shoreline data was not collected in the western reference area (Reference Area 1), it was visually evident that significant shoreline loss was occurring during the period of analysis. An estimation of the shoreline change rate in Reference Area 1 was made by digitally delineating the vegetated shoreline using 2004 and 2018 DOQQ, and 2010 and 2015 NAIP imagery (Figure 33). The delineated data was then subjected to the DSAS shoreline analysis method described above. It is important to note that there is some error introduced using this methodology as water levels were not controlled for between images, and some accretion or erosion could merely be a result of different water levels. However, shoreline erosion rates in this reference area were high and surpassed methodology error. It is obvious that substantial shoreline erosion is taking place along this shoreline.

From 2004 to 2018, shoreline erosion averaged -43.9 ± 3.31 ft/yr (Table 5). In this analysis, 100% of the transects were erosional and had statistically significant erosion over the time period. Erosion was particularly high on the northwest facing section or the on the "corner" of the reference area facing Lake Salvador, where erosion reached up to -90 ft/yr (Figure 34). Of note, between 2004 and 2018, in addition to the extensive shoreline retreat, an oil and gas canal in the northern portion of the reference area breached into Lake Salvador and a second canal is in danger of breaching to the south (Figure 35). The exposure of these canals could cause interior marsh loss as water is pushed down the canal causing edge erosion of the existing spoil banks. Erosion rates were highest between 2004 and 2010 at -53.2 ± 7.74 ft/yr (Table 5). Some of this increased erosion was most likely cause be Hurricanes Katrina and Rita. During this time period, all of the transects were erosional and 96% of the transects had statistically significant erosion. From 2010 to 2015, erosion rates decreased to -29.5 ± 9.28 ft/year. During this time period 96.5% of the transects were erosional and 76% had statistically significant erosion. Accretion was experienced at 3.5 % of the transects and 0.5% were significantly significant. Some of the accretion could mostly likely be attributed to some of the error introduced by this methodology, described above. Erosion rates increased again from 2015 to 2018 to -49.2 ± 15.45 ft/yr (Table 5). During this time period, 95.5% of the transects were erosional and 76.5% experienced statistically significant erosion. Accretion was experienced at 4.5% of the transects and none had statistically significant accretion. Again, the accretion captured during this time period could most likely be attributed to error introduced by this methodology described above. Overall, reference area 1 is experiencing high rates of shoreline erosion indicating that the shoreline protection features that have been installed (CU2, CU3, CU4) are either substantially slowing or stopping shoreline erosion in the project area. Lake Salvador, which reference area 1 boarders is most likely a higher energy body of water than Bayou Perot and Bayou Rigolettes which the project area boarders, because it is larger, and has more fetch, especially during northwest, west, and southwinds. However, the project area most likely experiences erosive waves during southerly winds, which are common in Louisiana and it would be expected that shoreline erosion would be occurring if project features were not in place.

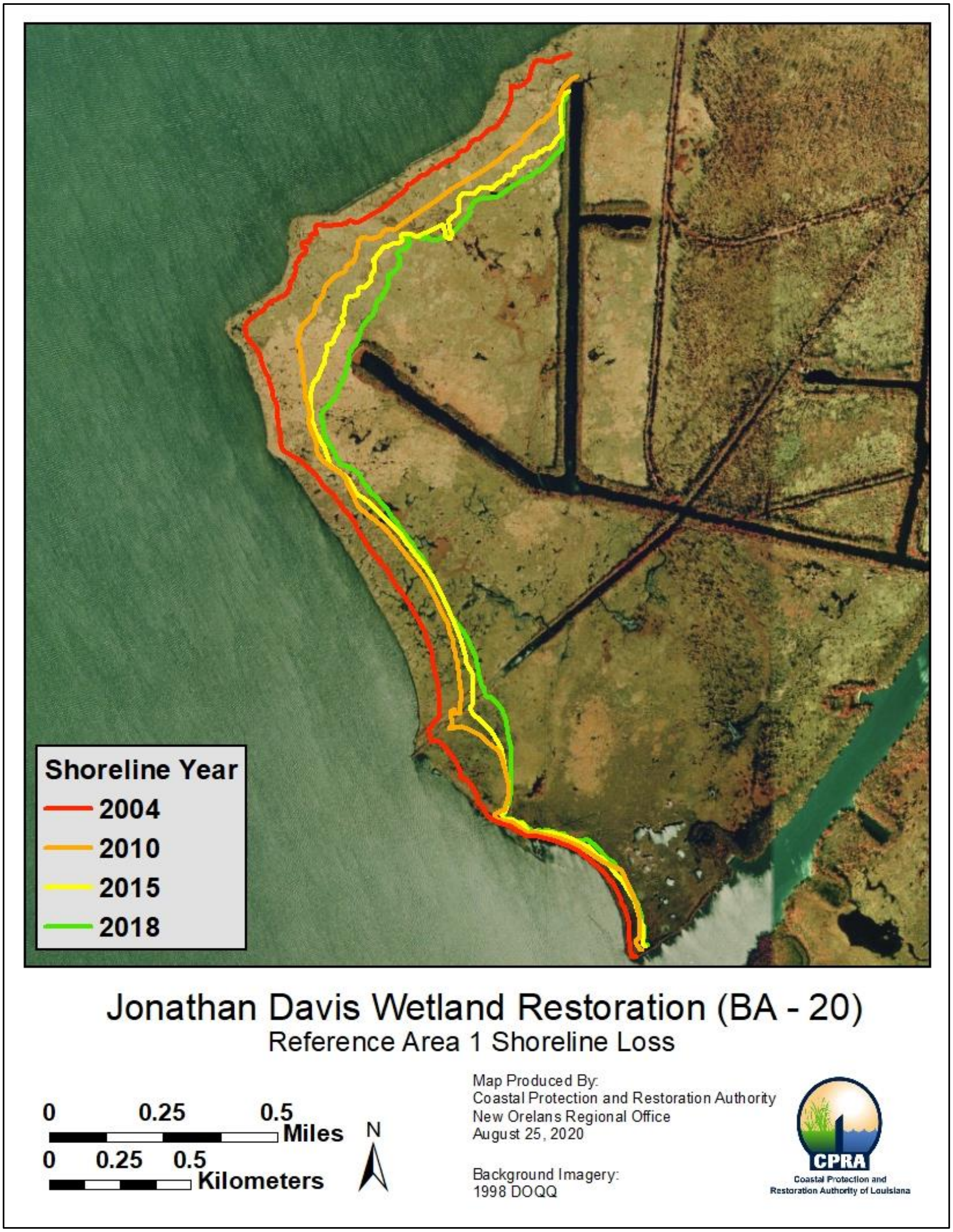

Figure 33: Shoreline location in Reference Area 1 in 2004, 2010, 2015, and 2018. Shoreline was hand drawn from existing imagery and differences in water level were not considered.

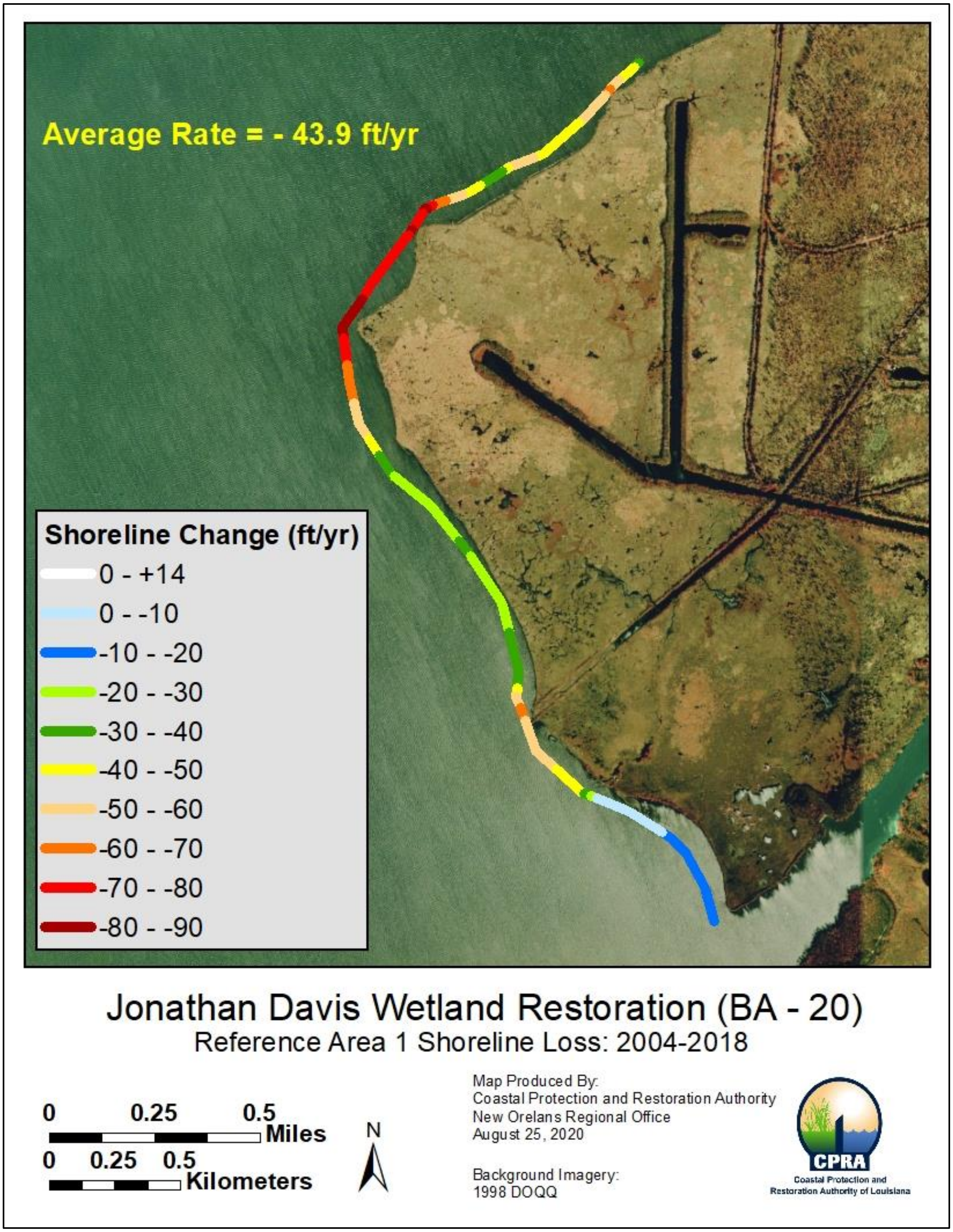

Figure 34: Shoreline change rate at reference area 1 from 2004 to 2018.

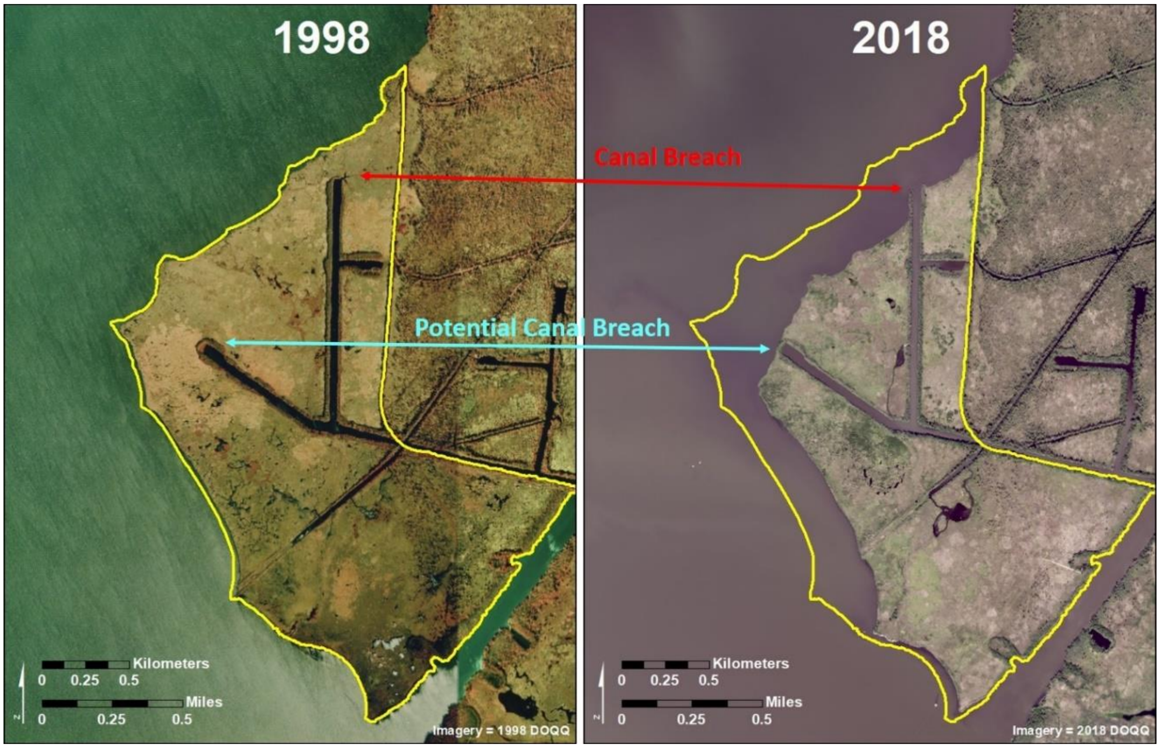

Figure 35: Shoreline erosion at Reference Area 1 has caused one canal to breach to open water and another is very close to breaching.

Estimated Land Area Saved by Project

The land acreage that was potentially saved by having the shoreline protection project in place was estimated by applying the pre-construction land loss rate along the CU4 shoreline from 1998 to 2012 to the length of the protected shoreline. To obtain an estimate of the loss rate, the 1998 shoreline was digitized from DOQQ imagery and compared to the 2012 CU4 shoreline survey conducted immediately after construction (Figure 36). The same methodology used for Reference Area 1 above was used for this analysis and the same caveats about water level apply for the 1998 digitized shoreline. The results of the DSAS analysis revealed an average shoreline retreat rate of -9.88 ft/yr. along the CU4 shoreline. This average rate was then subtracted from the shoreline change rate post-construction (described above) to determine a net shoreline change rate. This net rate was then multiplied by the shoreline length for CU2, CU3, and CU4 to determine the net acres per year that were saved and multiplied by the number of years the structure has been in place to estimate the acres saved through 2020 (CU2 and CU3 have been in place for 16 years, and CU4 for 8 years). The same rate of acres per year was also multiplied by the number of years that project features will be in place at the end of the project life (2032) to predict the net acres to be saved throughout the whole project. Using this method, the net acres saved thus far (through 2020) is estimated to be 118 acres and the net acres to be saved over the life of the project is estimated to be 241 acres. The methodology used here makes some assumptions that must be considered: 1) the shoreline delineated from the 1998 imagery did not account for water level at the time of photo acquisition, and therefore could be over- or underestimating the shoreline location, 2) the loss rate from CU4 was applied to all construction units when rates could vary depending on fetch, shoreline orientation, prevailing wind directions, and soil types, 3) a steady rate is used to project forward in time when future rates could speed up or slow down, or there could be large weather events that impact the area, and 4) this methodology does not account for subsidence and interior marsh loss that may accelerate shoreline loss. Project features can protect the shoreline but do not address other processes that cause land loss beside shoreline erosion.

Figure 36: The 1998 and 2012 shoreline used to determine shoreline erosion rates prior to the construction of CU4. The 1998 shoreline was drawn from imagery and adjustments for water levels were not conducted.

v. **Vegetation**

Emergent vegetation surveys were conducted in 1996 (pre-construction), 1999 (1 year post-CU1), 2002 (4 years post-CU1, 1 year post-CU2) and 2012 (14 years post-CU1, 11 years post-CU2, 9 years post-CU3, 1 year post-CU4). By the time of the 2002 survey, CU1 was the only project phase that could have produced a measureable effect on vegetation. Vegetation response to CU1, CU2 and CU3 would be reflected in the 2012 survey, with CU4 being constructed only the previous year. In addition to the BA-20 surveys, annual CRMS vegetation surveys began at CRMS3985 and CRMS4245 in 2008, which will continue to provide a long term picture of the vegetation in the project area. However, it should be noted that the BA-20 sites provide broader coverage of the project area, and direct comparison to the CRMS sites may be confounded by localized differences in vegetation at those sites (Figure 5). For this report, only the CRMS vegetation data will be updated.

The vegetation structure within the BA-20 project area is a diverse, oligohaline community characterized by the presence of *Sagittaria lancifolia*, *Spartina patens*, and *Eleocharis spp* (Figure 37). Several changes in composition and abundance have occurred over the sampling period from 1996 to 2012. *S. lancifolia* was the dominant species in both the project and reference areas in 1996; however, percent cover of *S. lancifolia* has been steadily decreasing since that time (Figure 32). The project and reference areas exhibited a concurrent increase in *S. patens* cover until 2002, but a subsequent drop by 2012. By 2002 and 2012, the dominant species in the project area was *S. patens*. There is not an overall trend of increasing salinity in the project area (Figure 7) but there have been frequent disturbance events (drought and hurricanes) over the sample period which caused periodic spikes in salinity levels, which may explain the decline of *S. lancifolia*. Baldwin and Mendelssohn (1998) observed a synergistic effect of salinity stress following disturbance on the reduction of biomass of *S. lancifolia*. Alternatively, *S. patens* was affected by flooding and disturbance but not salinity. The frequency of salinity stressor events during the sample period may not have allowed for the necessary recovery of *S. lancifolia* leading to its overall decline. Total % cover declined in both the project and reference areas from 1996 to 2002 (Figure 37), but increased slightly in the project area by 2012. Total % cover in the reference areas, however, continued to decline in 2012 and was exacerbated by the conversion of three sampling plots to open water (Figure 7).

One of the measureable goals of the project was to stabilize or increase the abundance of intermediate-to-fresh marsh plant species. Species were classified as fresh, fresh-intermediate, intermediate, etc. (Visser et al. 2002). Percent coverage data from the BA-20 and CRMS sites was then used to summarize changes in marsh classifications over time (Figures 38 and 39). The classifications fresh, fresh/intermediate, and intermediate were then grouped together for comparison to the intermediate/brackish and brackish classifications (Figure 39). Brackish/salt and salt classifications were also included, but percent coverages in these categories were very low.

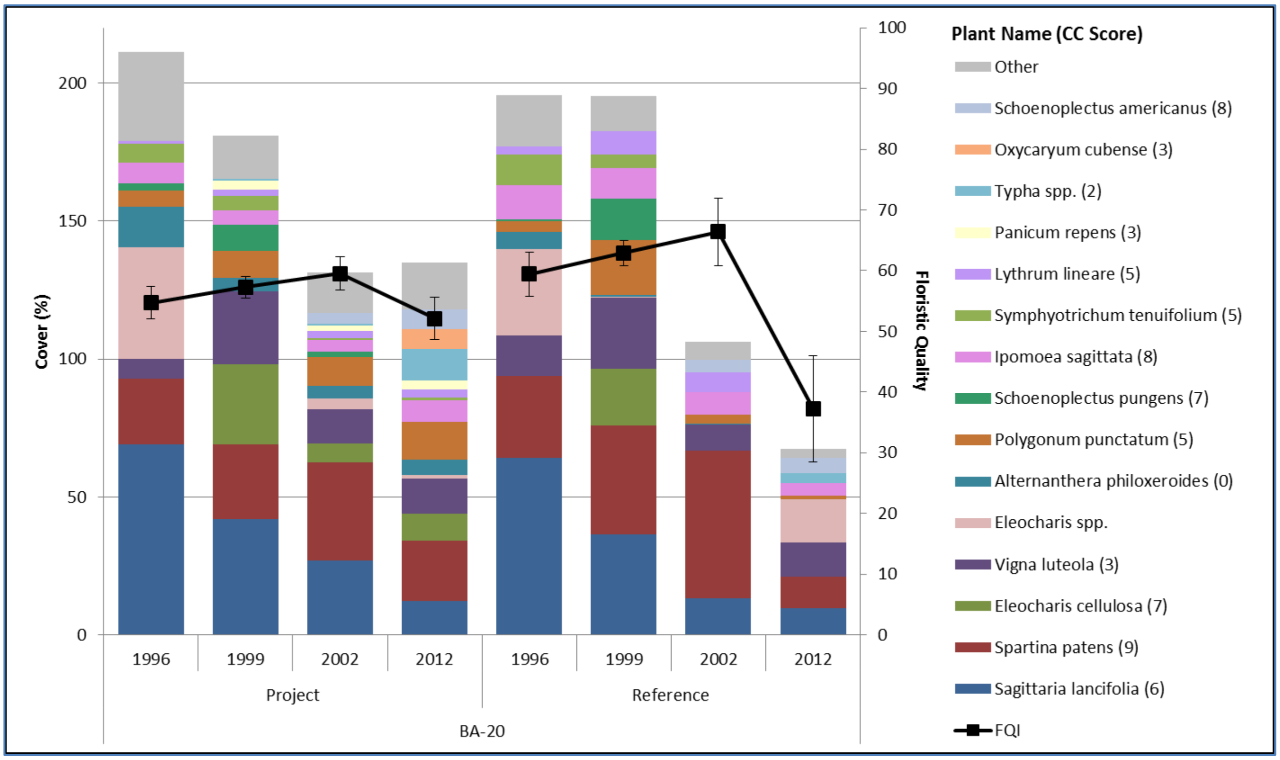

Figure 37: Mean percent cover of species within the BA-20 project and reference areas and the Floristic Quality Index (FQI) score for each year sampled. The CC Score represents the quality of the individual species on a scale from 1 to 10 where 1 represents disturbance species and 10 indicates stability

Results from the BA-20 plots showed a decrease in percent cover of fresh/intermediate species from 1996 to 2002 and an increase in fresh/intermediate species from 2002 to 2012 (Figure 38). A similar increase in fresh/intermediate species in the reference areas indicates that this is a region-wide occurrence and not due to project effects. The decrease in cover of fresh/intermediate species was pronounced between 1999 and 2002, which was most likely an effect of the drought that occurred from August 1999 to November 2000. The decrease was greater in the reference area than in the project area, however, which could indicate that the CU1, 2, and 3 project features may have had a protective effect.

Results from the CRMS sites have been updated through 2019 from the previous report (Figure 39). It appears that plants classified as fresh have increased slightly over time, almost exclusively at CRMS 3985 as there are very few fresh plants present at CRMS 4245. At the CRMS stations there was a large increase in fresh and intermediate species after 2008, most likely due to hurricane recovery from 2008 storms, and a decrease in 2010 which could have been caused by high Davis Pond diversion flows for 3 months

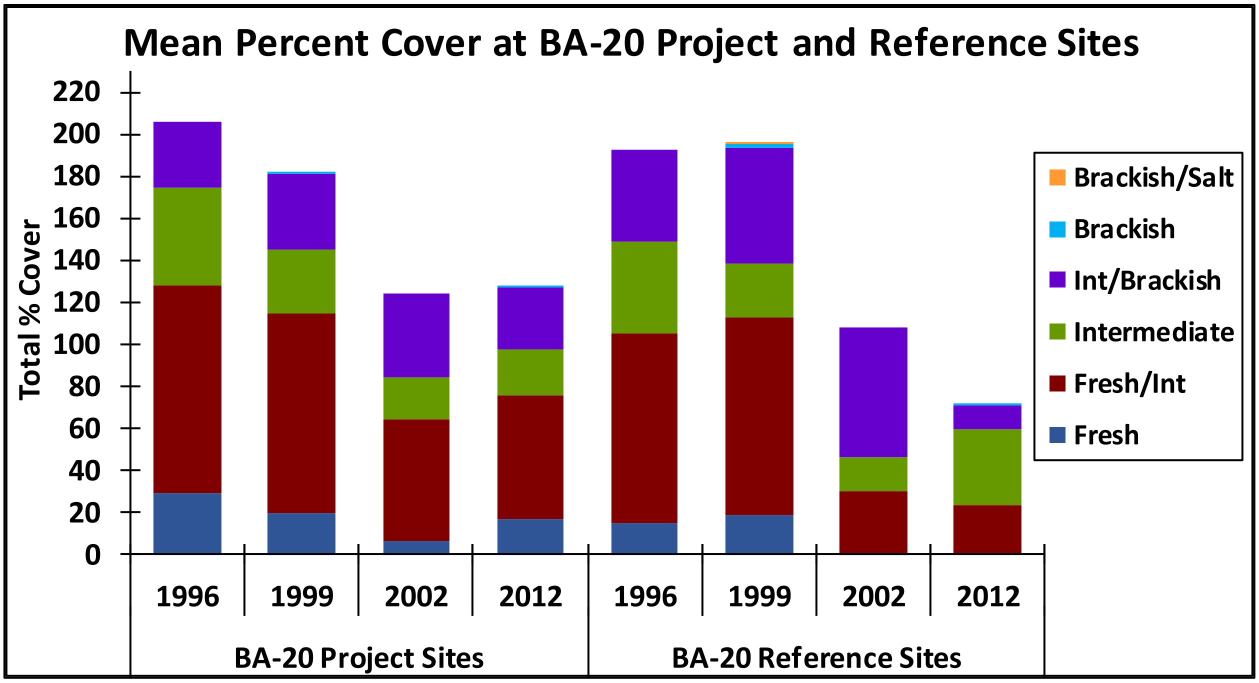

Figure 38: Total of mean % covers of all habitat classes at BA-20 project and reference sites in 1996, 1999, 2002 and 2012.

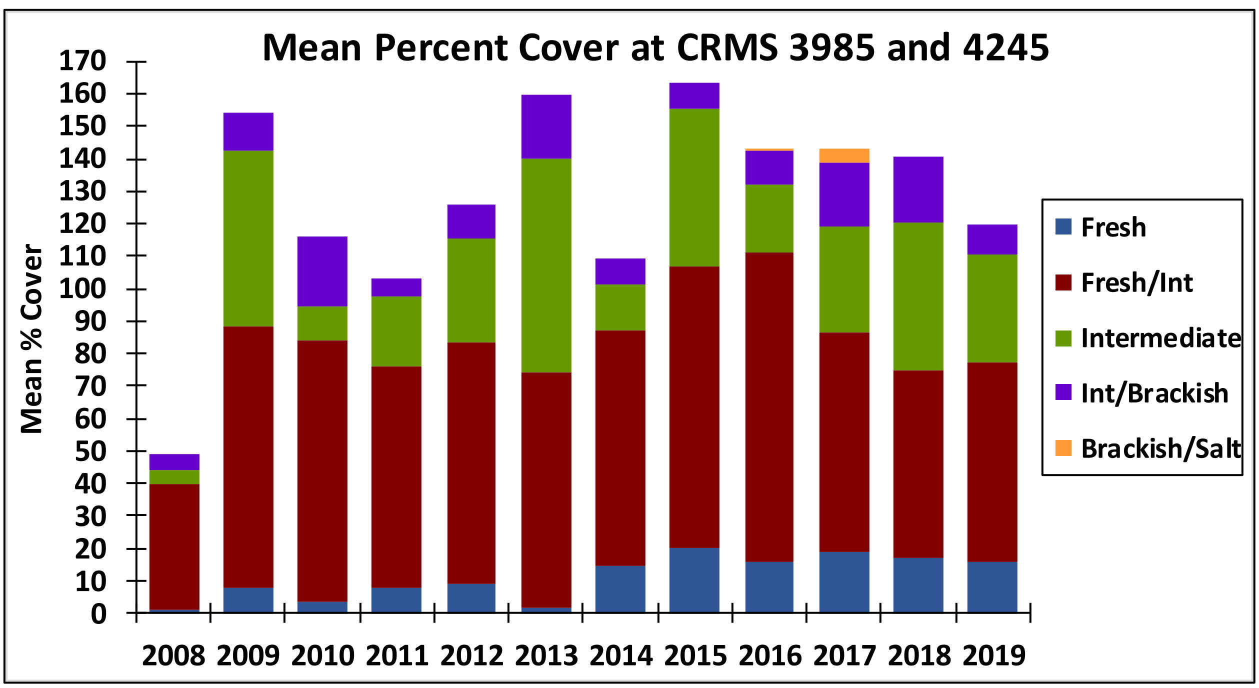

Figure 39: Total of mean % covers of all habitat classes at CRMS3985 and CRMS4245 from 2008 to 2018.

during the peak of the growing season to combat the Deepwater Horizon Oil Spill (Figures 39 and 40). These flows could have caused prolonged inundation, temporarily decreasing plant cover. Since 2010, fresh and intermediate species had been increasing slightly until 2014 when they declined and then increased again in 2015. Since 2015 there has been a slight decline in fresh and intermediate species. There is no pattern that would indicate that CU4, completed in 2011, impacted the percent cover of fresh and intermediate species. There was also no pattern of change in the intermediate and brackish species over time at the CRMS stations. Abundance of these species remains low and seems to fluctuate slightly in a cyclical pattern over time.

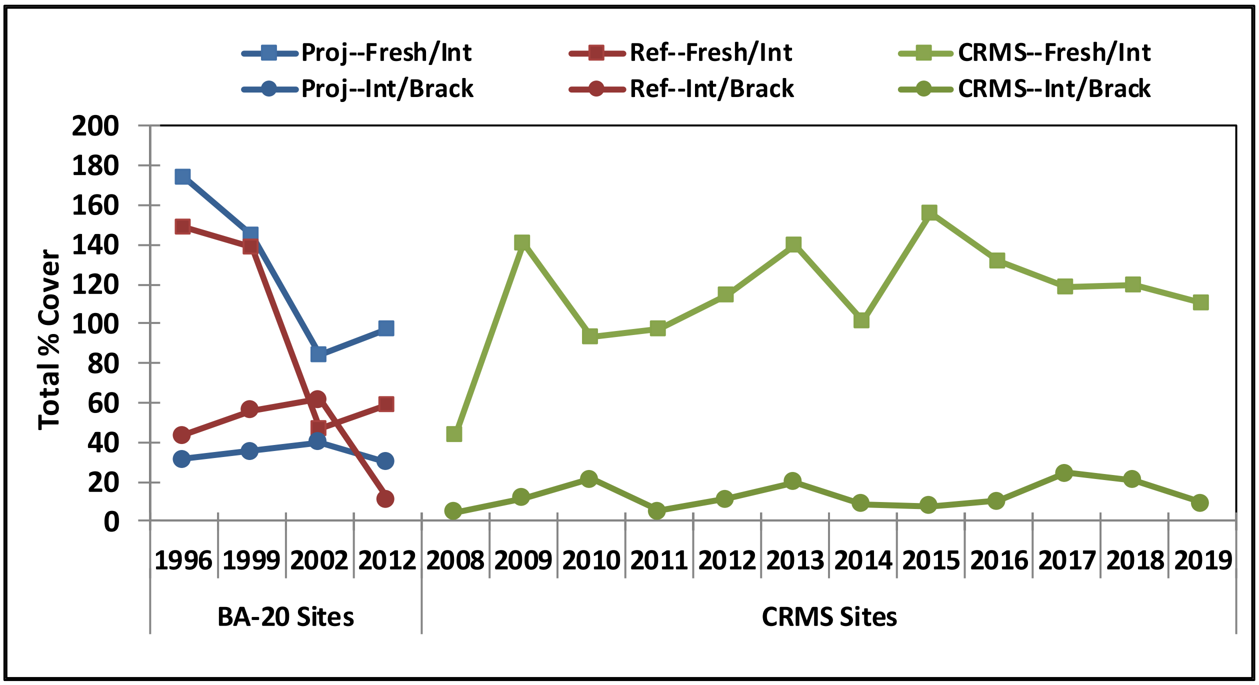

Figure 40: Total of mean % covers for fresh/intermediate species vs. intermediate/brackish species at BA-20 project and reference sites in 1996, 1999, 2002, and 2012, and at two CRMS sites (3985 and 4245) within the BA-20 project area from 2008 to 2019.

Mean percent cover of major species (>5% cover) observed at CRMS3985 and CRMS4245 is presented in Figures 41 and 42. Any species in a given year with a percent cover lower than 5% is grouped into the "other" category. At CRMS3985 and CRMS4245, the total percent cover of all species was lowest in 2008. This may be due to the fact that sampling occurred in October, only one month after Hurricanes Gustav and Ike. At CRMS3985, there was a subsequent increase in total percent cover each year through 2012, slight decreases in 2013 and 2014 and then peak cover in 2015. Since 2015 there has been a slight decline in cover over time. Total percent cover at CRMS4245 has shown much more annual variation, possibly due to this being a floating marsh site, but was higher in 2013 than in all previous years. From 2013 to 2014, the total percent cover decreased by 100% from approximate 220% cover in 2013 to 120% cover in 2014. The cover increased in 2015 and has remained relatively stable since, with a slight decrease in 2019. The vegetation community at the fresher site, CRMS3985, is locally different from the overall project area due to the absence of *S. patens*. The dominant species at CRMS3985 are *S. lancifolia* and *Alternanthera philoxeroides*. *Polygonum punctatum*, which was the dominant species in 2009 and 2013, has been generally decreasing over time and *Typha* species have been increasing over time. *S. lancifolia* cover has remained relatively stable over time with slight fluctuations. From year to year, the dominant species at CRMS4245 was either *S. lancifolia* or *Vigna luteola*. *V. luteola*, a species sometimes associated with disturbance, was dominant in post-hurricane years (2009 and 2013). Since 2012, the woody shrub *Baccharis halimifolia* colonized the site and remained until 2018, disappearing in 2019.

One tool that has been used to assess the quality of the vegetation community at the CRMS sites is the Floristic Quality Index (FQI) (Cretini et al. 2011). The FQI is calculated by assigning each species a CC score, or coefficient of conservatism, which is scaled from 1 to 10 and reflects a species' tolerance to disturbance and habitat specificity. A modified FQI was developed by the CRMS Vegetation Analytical Team, which assembled a team of experts to assign CC scores to Louisiana's wetland plant species. The modified FQI equation takes into account not only the CC scores, but also the percent covers of species at a site, and the resulting score is scaled from 0 to 100.

Mean FQI scores were calculated for the BA-20 project and reference areas for each of the sampling years. FQI scores in the project area were relatively stable from 1996 to 2012 and ranged from 52-60, which is below the ideal range of 80-100 for intermediate marsh, as estimated by the CRMS Vegetation Analytical Team (Cretini et al. 2011) (Figure 37). FQI scores in the project area mirrored the FQI scores in the reference area through 2002 with a small increase each sample year. The increase through 2002 is likely due to the drought-induced decrease in fresh/intermediate species, some of which are associated with disturbance and therefore have low CC scores, and also to the concurrent increase of *Spartina patens*, which has a high CC score of 9. FQI decreased in both the project and reference areas in 2012, but the decrease in the reference area was much greater, largely due to the conversion of three sampling plots to open water. The loss of these plots was caused by direct shoreline loss in the western reference area, so the higher FQI in the project area in 2012 was less due to enhanced quality of habitat in the project area, but more a factor of direct land loss in the reference area. There are a few plots near the shoreline within the project area that may have also been lost if the protective shoreline features of BA-20 had not been in place. FQI scores at the two CRMS sites were lowest in 2008, probably as a result of Hurricanes Gustav and Ike (Figures 41 and 42). FQI scores at CRMS3985 ranged from 32 to 49 (excluding the 2008 low of 16). FQI scores at this site have remained stable over time after a large increase in 2009; however, the FQI declined to the lowest score since 2009 in 2019. FQI scores at this site are generally lower than scores observed in the BA-20 sampling years. FQI scores at CRMS4245 ranged from 45 to 64 (excluding the 2008 low of 20). FQI scores at this site have fluctuated over time, showing no real pattern of increase or decrease. FQI scores at this site are generally in the same range as those observed for the BA-20 sampling years. This may be because this CRMS site is more similar to the BA-20 sites with the presence of *S. patens*, while CRMS3985 did not have *S. patens*. As mentioned previously, however, the CRMS sites provide a snapshot within a 200 x 200-m sampling area and may not reflect the project area as a whole.

Species richness was low at both CRMS sites in 2008 and then increased and stabilized at both locations. At CRMS 3985, species richness ranged from 14 to 22 species (after a low of 7 in 2008). Species richness was highest in 2012. However, between 2018 and 2019, species richness declined from 19 species to 14 species, the lowest since 2008. At CRMS 4245, species richness ranged from 10 to 16 (after a low of 4 in 2008). This site is less diverse than CRMS 3985, which is expected since CRMS 3985 is fresher and supports more fresh species, although many of the species have very low percent cover. Species richness as CRMS 4245 has remained relatively stable over time.

In summary, the project goal of increasing fresh and intermediate species in the project area does not seem to have been met across the entire project area, but may be meeting this goal in some locations. However the project could be contributing to a stabilization in the cover of these species over time, preventing a decline.

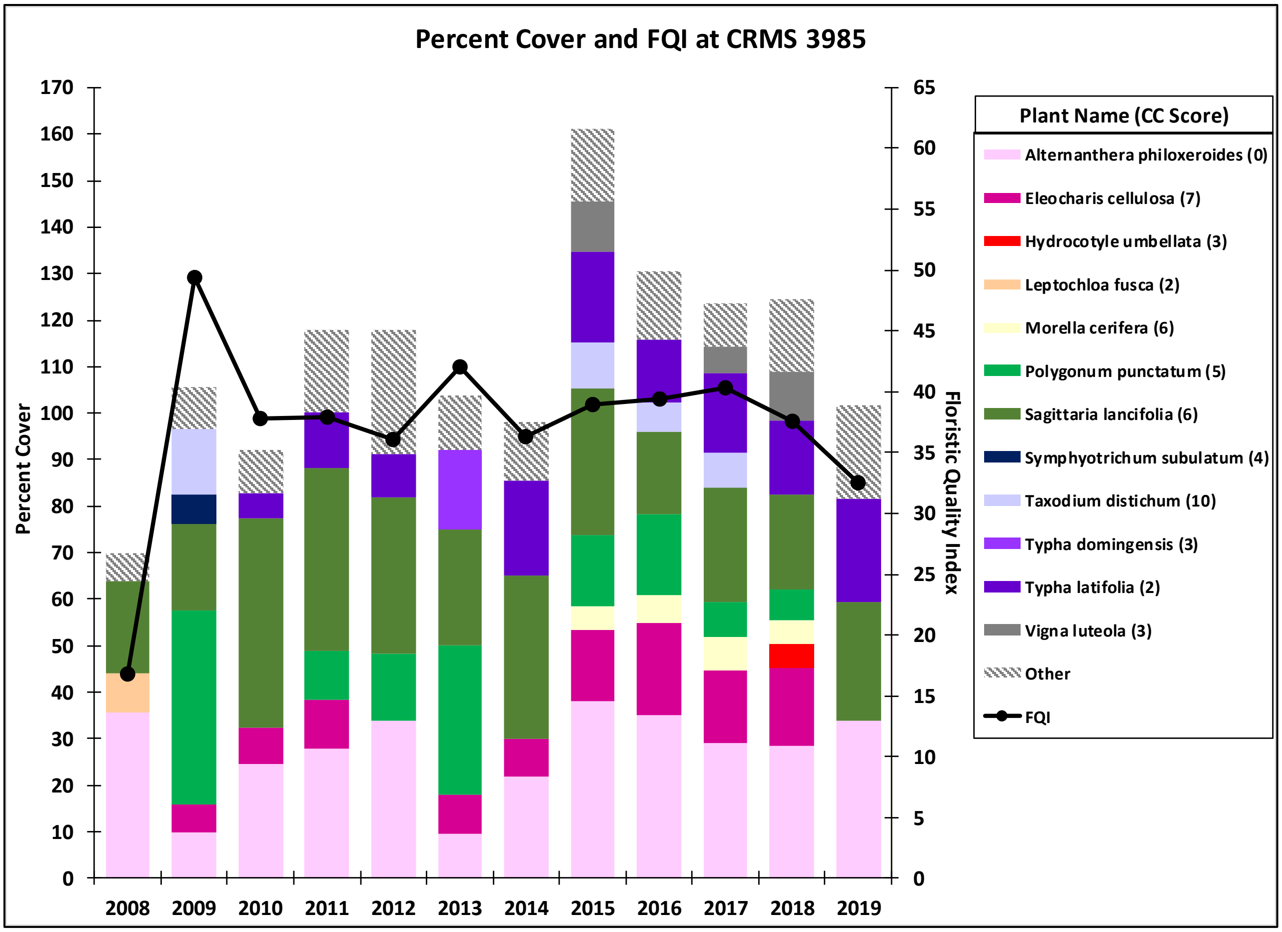

Figure 41: Mean % cover of major species and FQI score at CRMS 3985 in 2008 through 2019.

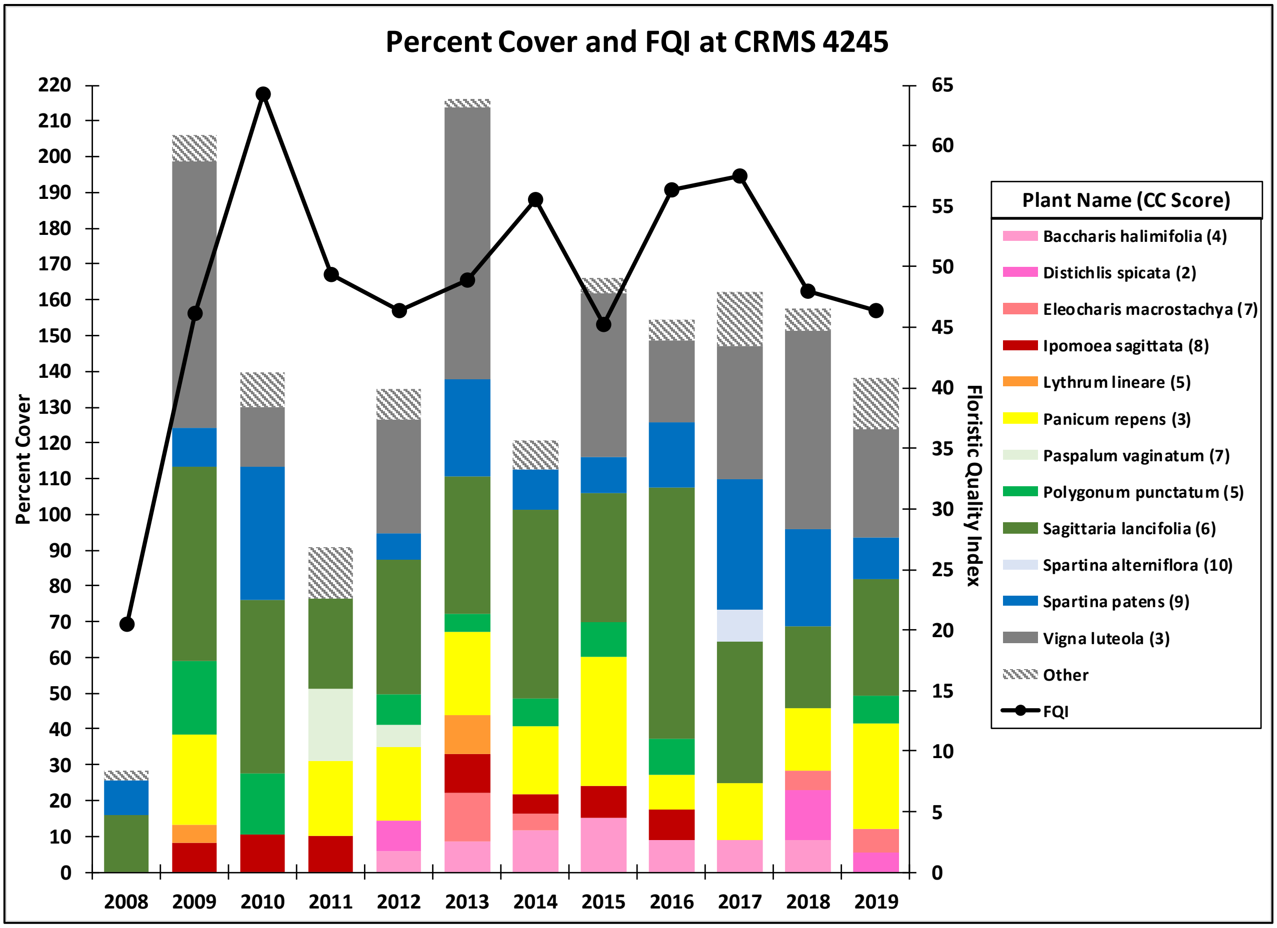

Figure 42: Mean % cover of major species and FQI score at CRMS 4245 in 2008 through 2019.

vi. Soils

At CRMS3895, bulk density (BD) did not change substantially from 2008 to 2018 (Figure 43). BD decreased slightly from 0 to 8 cm depth and then remained similar to the bottom of the core (24 cm depth). Bulk density at CRMS3895 was not significantly different by year or the interaction of depth by year, but was by depth ($p=0.027$). Pairwise comparisons revealed that the deepest depth (20 to 24 cm) had significantly higher BD at 0.11 ± 0.03 g/cm^3 than the shallowest depth (0-4cm) at 0.6 ± 0.02 g/cm^3) ($p=0.009$). A survey of BD and organic matter (OM) at all CRMS sites across the coast was conducted to determine typical BD and OM in various marsh types (Wang et al. 2017). The BD found at CRMS3895 was typical of a freshwater marsh in that study. At CRMS4245, BD was higher than CRMS3985 and similar between the two years at all depths except 4-16 cm, which showed an increase in 2018 (Figure 44). BD at CRMS4245 was not significantly different by depth or the interaction of depth and year, but was significantly different by year ($p=0.017$) with 2018 having higher BD (mean = 0.22 ± 0.07 g/cm^3) than 2008 (mean = 0.15 ± 0.05 g/cm^3). The BD at CRMS4245 was between what is typical of an intermediate and brackish marsh (Wang et al. 2017). Significance results are summarized in Table 6.

At CRMS3985, OM increased from 2008 to 2018 at most depths (0-8 cm, 12-24 cm) but remained similar at the depth of 8-12 cm (Figure 45). Organic matter at CRMS3985 was significantly different by depth ($p< 0.001$) and year ($p<0.001$) but not the interaction of the two. The deepest depth interval (20-24 cm) was significantly lower than the top three depth intervals of 0-4 cm ($p<0.001$), 4-8 cm ($p<0.001$), and 8-12 cm ($p=0.002$). Also, OM was significantly higher in 2018 (mean = 66.4 ± 9.6 %) than 2008 (mean = 56.3 ± 10.0%). Organic matter in 2008 was similar to what is typical for a freshwater marsh, but in 2018 OM was higher than what is typical for any marsh type in Louisiana (Wang et al. 2017). At CRMS 4245, OM was lower than CRMS3985 and showed an increase in 2018 at the shallowest (0-4 cm) and deepest depths (20-24 cm) and a decrease in 2018 at the middle depths (4-20 cm; Figure 45). The OM at CRMS4245 was significantly different by year ($p=0.017$) and the interaction of depth and year ($p=0.003$) but not by depth (Figure 46). The OM was significantly higher in 2008 (mean = 38.1 ± 8.0 %) than in 2018 (mean = 32.6 ± 8.6 %). The OM at CRMS4245 was in a range between what is typical for intermediate and brackish marshes (Wang et al. 2017); however, it is not typical for both organic matter and bulk density to increase as they usually have an inverse relationship. Significance results are summarized in Table 6.

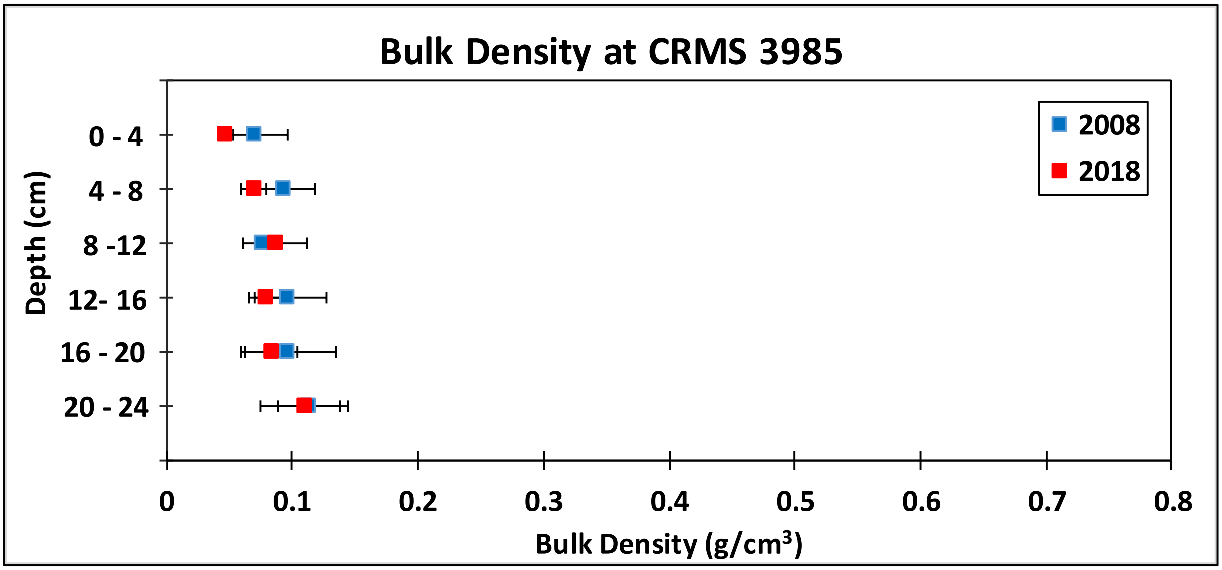

Figure 43: Bulk density at CRMS3985 in 2008 and 2019.

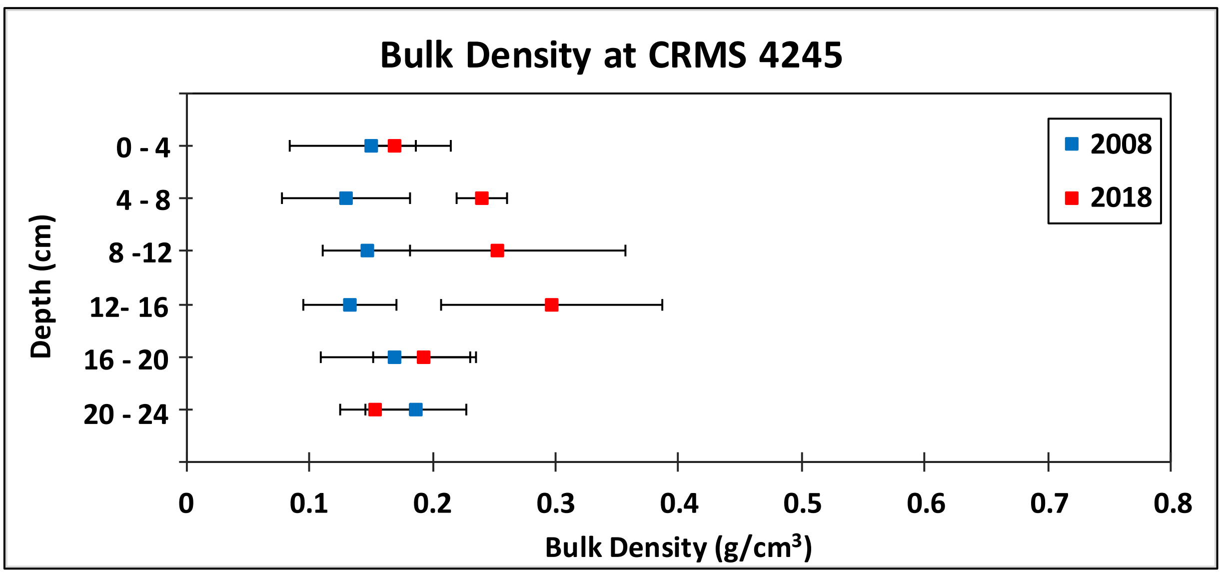

Figure 44: Bulk density at CRMS4245 in 2008 and 2019.

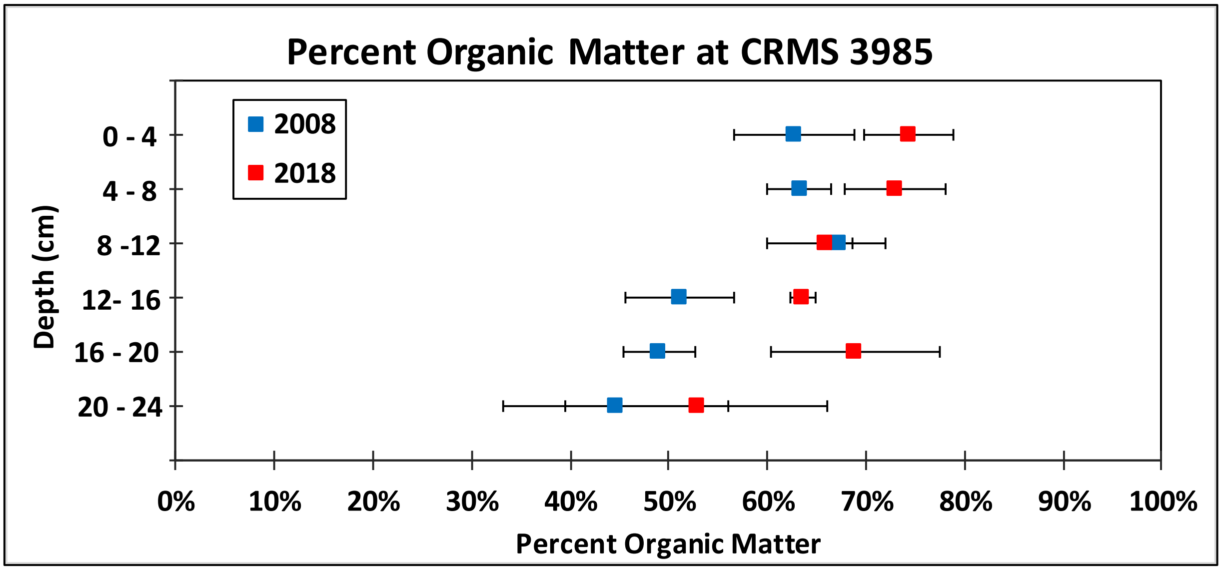

Figure 45: Organic matter content at CRMS3985 in 2008 and 2019.

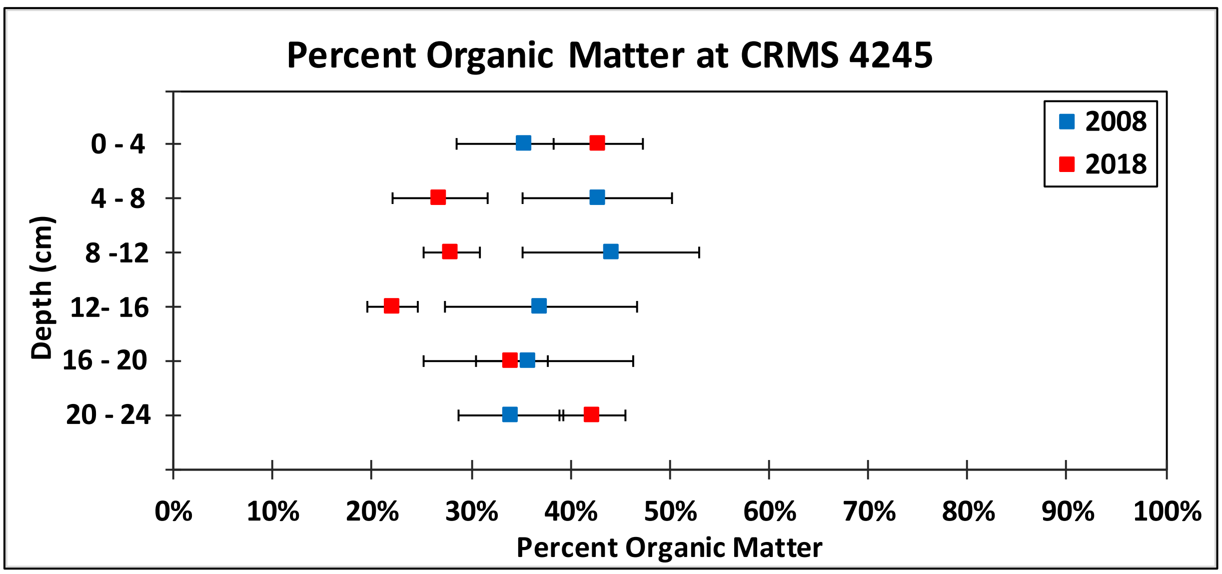

Figure 46: Organic matter content at CRMS4245 in 2008 and 2019.

Table 6: The P-values resulting from the ANOVA of bulk density and organic matter at CRMS 3985 and CRMS 4245. Number in bold indicate a significant interaction.

		Depth	Year	Depth by Year
CRMS 3985	Bulk Density (g/cm^3)	**0.027**	0.156	0.816
	% Organic Matter	**0.00016**	**0.00017**	0.219
CRMS 4245	Bulk Density (g/cm^3)	0.582	**0.0018**	0.0515
	% Organic Matter	0.188	**0.017**	**0.003**

Surface elevation and accretion have been measured at CRMS3985 since October 2009 through March 2020. During that period, surface elevation change rate at this site has been 0.67 cm/yr (0.26 in/yr). During that same time period, accretion rates at the site have been 0.88 cm/yr (0.35 in/yr). By comparing accretion and elevation, a rate of shallow subsidence can be determined by subtracting elevation gain from accretion. Therefore, at this site, shallow subsidence rates were approximately 0.21 cm/yr (0.08 in/yr). In the last 10 years, this site has experienced low accretion rates, elevation gain rates and subsidence rates, indicating that the land is relatively stable now but may not be able to keep pace with future sea-level rise. Short term accretion rates (last 2 years) were also low at 0.8 cm/yr (0.31 in/yr). Short term accretion rates can be higher because newly accreted soil or organic matter has not experienced substantial compaction or de-watering, which occurs over time. Surface elevation and accretion have been measured at CRMS4245 since September, 2018 through March, 2020. However, due to the short duration of this data set and that CRMS 4245 was a floating marsh site, and still may be in the process of attaching but not fully attached, elevation and accretion data at this site will not be presented. While there is no specific project goal about soil stability, these data can indicate if project features are helping to stabilize marsh areas. Unfortunately, CRMS4245 is located very close to CU4 but longer term data do not exist for that site. CRMS3985 is located in the northern end of the Jonathan Davis Wetland, in a more contiguous marsh platform, while CRMS4245 is located in the southern end of the wetland in an area where there is more open water, with some break up over time. Therefore, CU4, may have stabilized further loss in the marsh near CRMS4245 but sufficient data do not currently exist to verify this.

V. Conclusions

a. Project Effectiveness

The shoreline protection features associated with the BA-20 project were highly effective in achieving project goals. The goal of reducing erosion through shoreline protection has been achieved based on the 2018 land/water analysis. Although some land loss continues to occur in the project area, the land/water analysis of the adjacent reference area showed significant shoreline loss and a higher corresponding land loss rate. The shoreline change analysis showed that there was little statistically significant shoreline loss behind the shoreline structures CU2, CU3 and CU4 from 2004 to 2018 (all three units experienced a net gain), while the adjacent reference area lost approximately 43 ft/yr of shoreline during the same time period. Therefore, while it is not part of the BA-20 project, it is recommended that Reference Area 1 be considered for shoreline protection in the future. With one breach into an interior canal and a second such breach about to occur, interior marsh loss rates could increase as waves from nearby waterbodies can now propagate down the canal into the marsh. The rate of shoreline loss is substantial and could be slowed with shoreline protection.

The land acreage that was potentially saved by having the shoreline protection project in place was estimated by applying the pre-construction land loss rate along the CU4 shoreline from 1998 to 2012 to the length of the protected shoreline for CU2, CU3, and CU 4. The net acres saved thus far (through 2020) is estimated to be 118 acres and the net acres to be saved over the life of the project is estimated to be 241 acres.

The delayed and staggered construction regime combined with a strong environmental stress (the drought) led to difficulties in testing for hydrologic effects of the plugs and weirs. The drought caused a prolonged period of elevated salinity which may have confounded the analysis if all stations were not equally affected. Possible effects of the project on salinity were found, but the changes in salinity between the project area and the reference area are so minute that no definite conclusions can be made. The goal of decreasing variability in salinity and water level within the project area was evaluated for impacts from all construction Units. Unfortunately, project features did not appear to have a measurable effect on salinity or water level variability, as indicated by daily salinity range or mean tidal range. This is true for both project specific monitoring sites and CRMS sites. Changes to salinity and water level seem to occur on a regional basis and are not project specific.

The goal of stabilizing or increasing the relative abundance of freshwater-intermediate vegetation has not been met at this time, although some positive project effects were observed. Unfortunately, the drought which occurred in the post-CU1 period caused a sharp decrease in freshwater-intermediate species coverage between 1996 and 2002, and has not rebounded to pre-drought levels. The decrease in coverage of freshwater-intermediate species was less pronounced in the project area versus the reference area, however, which may indicate some positive effect from the CU1 structures. While there was a subsequent increase in abundance of freshwater/intermediate species in the project area from 2002 to 2012, there was a similar increase observed in the reference area indicating this was system-wide and not due to project effects. The Floristic Quality Index (FQI) score, which indicates the relative health and stability of marsh communities, was more sharply reduced in the reference area than the project area due to the conversion of reference sample plots to open water. In summary, the project goal of increasing fresh and intermediate species in the project area does not seem to have been met across the entire project area, but may be meeting this goal in some locations.

However, the project could be contributing to a stabilization in the cover of these species over time, preventing a decline.

b. Recommended Improvements

There are no recommendations at this time.

c. Lessons Learned

The most important lesson learned, in regards to biological monitoring, was that a staggered, long-term construction regime can have an adverse effect on data interpretation. In the future, monitoring of a project should be scheduled from 1-3 years pre-construction and 3-5 years post-construction, as determined by the final date of construction, not the start of construction. It is unrealistic to assume construction will always be completed at a single point in time. In addition, CWPPRA projects are normally monitored throughout a 20-year project life span, with O&M and monitoring budgets being calculated for a 20-year post-construction period. However, since the BA-20 construction period spanned 13 years, the end of the project life has been extended from 2019 to 2032. Currently, all data collection has been completed that was outlined in the BA-20 monitoring plan. Remaining monitoring funds may be used for additional data collection near the end of the project life.

The concrete wall configuration for CU4 was easier to install than the BA-27 concrete wall configuration and appears to be performing well at this time. It is recommended for consideration on future projects. However, upon completion of the concrete wall for CU4 it was observed that someone was removing the stainless steel hardware used to clamp the panels to the pilings. A contractor was mobilized quickly, but by the time they mobilized enough hardware had been removed that some panels had fallen over and were required to be moved back into place. The repair contract involved welding the hardware into place to a greater extent than what the original contract called for which solved the problem of theft. It is recommended that future contracts take into account vandalism and theft when hardware is used.

VI. References

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VII. Appendices

Appendix A
(Inspection Photographs)

Photo #1 – Structure #13

Photo #2 – Structure #15

Photo #3 – Structure #16

Photo #4 – Structure #19

Photo #5 – Bayou Perot Shoreline Protection (CU3)

Photo #6 – Panel Wall Shoreline Protection (CU4)

Appendix B
(Field Inspection Notes)

MAINTENANCE INSPECTION REPORT CHECK SHEET

Project No. / Name: **BA-20 Jonathan Davis Wetland** Date of Inspection: 03/08/2019 Time: 9:30 AM

Structure No. Construction Unit No.1 -Site No. 12 Inspector(s): Collier, Richard, Kinler

Structure Description: Rock rip-rap armored plug Water Level Inside: N/A Outside: +1.0 ft.

Type of Inspection: Annual Weather Conditions: Mostly sunny, light wind

Item	Condition	Physical Damage	Corrosion	Photo #	Observations and Remarks
Signage and supports	Good	None	None		
Armored plug	Good	None	N/A		No change since last inspection; maintenance not required at this time.

Construction Unit No.1

Structure Description: 294 linear ft. of rock rip-rap armored rock-filled plug located in a pipeline channel north of Bayou Perot, west of Bayou Barataria, and east of the GIWW. The crest of the weir was set at an elevation of +3.9 ft. NGVD. The rock-fill plug contains 2,689 tons of rock filled with 2,518 tons of rip-rap armor. Aluminum warning signs are also located through the rock embankment.

MAINTENANCE INSPECTION REPORT CHECK SHEET

Project No. / Name: **BA-20 Jonathan Davis Wetland** Date of Inspection: 03/08/2019 Time: 9:30 AM

Structure No. Construction Unit No.1 -Site No. 13 Inspector(s): Collier, Richard, Kinler

Structure Description: Rock rip-rap armored weir Water Level Inside: N/A Outside: +1.0 ft.

Type of Inspection: Annual Weather Conditions: Mostly sunny, light wind

Item	Condition	Pysical Damage	Corrosion	Photo #	Observations and Remarks
Signage and supports	Good			2	
Armored Weir	Fair			2	Structure has experienced some settlement, but maintenance is not required at this time.

Construction Unit No.1

Structure Description: 300 linear ft. of rock rip-rap armored rock filled weir with a 50 ft. wide boat bay located north of Bayou Perot and Site 12, west of Bayou Barataria, and east of the GIWW. The crest of the weir is set at an elevation of +1.0 ft. NGVD. The invert of the boat bay is set at an elevation of -5.0 ft NGVD. Rock wingwalls were constructed to an elevation of +3.6 ft. NGVD. On the west side and +4.0 ft. NGVD on the east side of the weir. The rock filled weir contains 1,093 tons of rock filled with 772 tons of rip-rap armor. Aluminum warning signs are located adjacent to the structure.

MAINTENANCE INSPECTION REPORT CHECK SHEET

Project No. / Name: **BA-20 Jonathan Davis Wetland** Date of Inspection: 03/08/2019 Time: 9:30 AM

Structure No. Construction Unit No.1 -Site No. 14 Inspector(s): Collier, Richard, Kinler

Structure Description: Rock rip-rap armored plug Water Level Inside: N/A Outside: +1.0 ft.

Type of Inspection: Annual Weather Conditions: Mostly sunny, light wind

Item	Condition	Pysical Damage	Corrosion	Photo #	Observations and Remarks
Signage and supports	Good				**Observations:**
Armored Plug	Good				Slight settlement noted, but no repairs needed at this time.
Construction Unit No.1 Structure Description: 138 linear ft. of rock rip-rap armored rock filled channel plug located in a pipeline channel north of Bayou Perot, west of Bayou Barataria and east of GIWW and Site 13. The crest of the plug was constructed to an elevation of +3.2 ft. NGVD. The rock-fill plug contains 2,580 tons of rock filled with 1,346 tons of rock rip-rap armor. Aluminum warning signs are located through the rock embankment.					

MAINTENANCE INSPECTION REPORT CHECK SHEET

Project No. / Name: **BA-20 Jonathan Davis Wetland** Date of Inspection: 03/08/2019 Time: 9:30 AM

Structure No. Construction Unit No.1 -Site No. 15 Inspector(s): Collier, Richard, Kinler

Structure Description: Rock rip-rap armored weir w/ boat bay Water Level Inside: N/A Outside: +1.0 ft.

Type of Inspection: Annual Weather Conditions: Mostly sunny, light wind

Item	Condition	Pysical Damage	Corrosion	Photo #	Observations and Remarks
Signage and supports	Good	None	None	3	
Armored Plug	Good	None	N/A	3	This structure was converted into a channel plug as part of the completed CU4 maintenance work.

Construction Unit No.1

Structure Description: 132 linear ft. of rock rip-rap armored weir with a 50 ft. wide boat bay located in a pipeline channel north of Bayou Perot, west of Bayou Barataria and east of the GIWW and Site 14. The crest of the rock weir was constructed to an elevation of +4.0 ft. NGVD. The invert of the boat bay is at an elevation of -3.0 ft. The rock filled weir contains 1,248 tons of rock filled with 728 tons of rock-rip armor. Two (2) aluminum warning signs are located through the rock armored embankment on each side of the boat bay.

MAINTENANCE INSPECTION REPORT CHECK SHEET

Project No. / Name: **BA-20 Jonathan Davis Wetland** Date of Inspection: 03/08/2019 Time: 9:30 AM

Structure No. Construction Unit No.1 -Site No. 16 Inspector(s): Collier, Richard, Kinler

Structure Description: Rock rip-rap armored plug Water Level Inside: N/A Outside: +1.0 ft.

Type of Inspection: Annual Weather Conditions: Mostly sunny, light wind

Item	Condition	Pysical Damage	Corrosion	Photo #	Observations and Remarks
Signage and supports	Good	None	None	4	
Armored Plug	Fair	None	N/A	4	No maintenance needs identified at this time.

Construction Unit No.1

Structure Description: 303 linear ft. of rock rip-rap armored rock filled plug located in a pipeline channel north of Bayou Perot, west of Bayou Barataria, east of the GIWW and Site 15. The crest of the plug was constructed to an elevation of +4.0 ft. NGVD. The rock-fill plug contains 6,483 tons of rock filled with 1,766 tons of rock rip-rap armor. Two (2) aluminum warning signs are located through the rock plug embankment.

MAINTENANCE INSPECTION REPORT CHECK SHEET

Project No. / Name: **BA-20 Jonathan Davis Wetland** Date of Inspection: 03/08/2019 Time: 9:30 AM

Structure No. Construction Unit No.1 -Site No. 17 Inspector(s): Collier, Richard, Kinler

Structure Description: Rock rip-rap armored plug Water Level Inside: N/A Outside: +1.0 ft.

Type of Inspection: Annual Weather Conditions: Mostly sunny, light wind

Item	Condition	Pysical Damage	Corrosion	Photo #	Observations and Remarks
Signage and supports	Good	None	None		
Armored Plug	Good	None	N/A		No maintenance is required at this time.

Construction Unit No.1

Structure Description: 197 linear ft. of rip-rap armored rock plug located in a pipeline channel north of Bayou Perot, west of Bayou Barataria, and east of the GIWW. The crest of the plug was constructed to an elevation of +3.8 ft. NGVD. The rock-fill plug contains 2,253 tons of rock filled with 1,201 tons of rock rip-rap armor. Aluminum warning signs supported by galvanized pipe are located through the rock embankment.

MAINTENANCE INSPECTION REPORT CHECK SHEET

Project No. / Name: **BA-20 Jonathan Davis Wetland** Date of Inspection: 03/08/2019 Time: 9:30 AM

Structure No. Construction Unit No.1 -Site No. 19 Inspector(s): Collier, Richard, Kinler

Structure Description: Rock rip-rap armored weir Water Level Inside: N/A Outside: +1.0 ft.

Type of Inspection: Annual Weather Conditions: Mostly sunny, light wind

Item	Condition	Physical Damage	Corrosion	Photo #	Observations and Remarks
Signage and supports	Fair	See remarks	Minor	5	Signage replaced since last inspection; no maintenance needs were identified.
Armored Weir	Good	None	N/A	5	No change since last inspection; no maintenance needs were identified.

Construction Unit No.1

Structure Description: 239 linear ft. of rock rip-rap armored rock filled fixed crest weir with a 60 ft. wide boat bay located in a pipeline channel east of the GIWW, north of Bayou Perot, and west of Bayou Barataria. The crest of the weir was constructed to an elevation of +1.9 ft. NGVD on the north side and +2.0 ft. NGVD on the south. The boat bay invert was constructed to an elevation of -2.5 ft. NGVD. The rock-fill plug contains 1,014 tons of rock filled with 572 tons of rock rip-rap armor. Aluminum warning signs are located on each side of the barge bay through the rock embankment.

MAINTENANCE INSPECTION REPORT CHECK SHEET

Project No. / Name: **BA-20 Jonathan Davis Wetland** Date of Inspection: 03/08/2019 Time: 9:30 AM

Structure No. Construction Unit No.1 -Site No. 20 Inspector(s): Collier, Richard, Kinler

Structure Description: Rock rip-rap armored plug Water Level Inside: N/A Outside: +1.0 ft.

Type of Inspection: Annual Weather Conditions: Mostly sunny, light wind

Item	Condition	Physical Damage	Corrosion	Photo #	Observations and Remarks
Signage and supports	Good	None	None		
Armored Plug	Good	None	N/A		No change since previous inspection; maintenance is not required at this time.

Construction Unit No.1

Structure Description: 170 linear ft. of rock rip-rap armored rock filled plug located north of Bayou Rigolettes, west of Bayou Barataria, and east of Bayou Perot. The plug crest was constructed to an elevation of +4.0 ft. NGVD. The rock-fill plug contains 1,829 tons of rock filled with 795 tons of rock rip-rap armor. Two (2) aluminum warning signs are located on each end of the structure through the armored rock plug embankment.

MAINTENANCE INSPECTION REPORT CHECK SHEET

Project No. / Name: **BA-20 Jonathan Davis Wetland** Date of Inspection: 03/08/2019 Time: 9:30 AM

Structure No. Construction Unit No.1 -Site No. 21 Inspector(s): Collier, Richard, Kinler

Structure Description: Rock rip-rap armored plug Water Level Inside: N/A Outside: +1.0 ft.

Type of Inspection: Annual Weather Conditions: Mostly sunny, light wind

Item	Condition	Physical Damage	Corrosion	Photo #	Observations and Remarks
Signage and supports	Good	None	None		
Armored Plug	Good	None	N/A		Maintenance is not required at this time.

Construction Unit No.1

Structure Description: 83 linear ft. of rock rip-rap armored rock filled plug located north of Bayou Rigolettes, west of Bayou Barataria, and east of Bayou Perot. The plug crest was constructed to an elevation of +4.0 ft. NGVD. The rock-fill plug contains 285 tons of rock filled with 220 tons of rock rip-rap armor. Two (2) aluminum warning signs supported by galvanized pipe are located on each end of the structure through the rock embankment.

MAINTENANCE INSPECTION REPORT CHECK SHEET

Project No. / Name: **BA-20 Jonathan Davis Wetland** Date of Inspection: 03/08/2019 Time: 9:30 AM

Structure No. Construction Unit No.2 -Site No. 22 Inspector(s): Collier, Richard, Kinler

Structure Description: Steel sheet pile structure w/ boat bay Water Level Inside: N/A Outside: +1.0 ft.

Type of Inspection: Annual Weather Conditions: Mostly sunny, light wind

Item	Condition	Physical Damage	Corrosion	Photo #	Observations and Remarks
Steel Bulkhead	Good	None	Minor		No significant defects noted. Structure does not require maintenance at this time.
Handrails, Hardware, etc.	Good	None	None		
Signage and supports	Good	None	None		
Earthen Wingwalls	Good	None	N/A		
Rock Armored Earthen Embankment	Good	None	N/A		

Construction Unit No.2

Structure Description: 58 linear ft. of steel sheet pile bulkhead with a crest elevation of +1.95 ft. NGVD and a 24' - 8-1/2" wide boat bay with a crest elevation of -0.93 ft. NGVD located off of Bayou Regolettes, west of Bayou Barataria and east of GIWW. The structure consists of a steel sheet pile weir with 1,426 square feet of sheet piling set at +1.95 ft. NGVD. At the bottom the boat bay, is a 1.5 ft. thick rock rip-rap scour pad seciton with an invert of -0.93 ft. NGVD. This structure ties into structure 22A on the west side. Aluminum warning signs supported by 12" diameter timber piles are located at the entrance of the boat bay.

Project No. / Name: **BA-20 Jonathan Davis Wetland** Date of Inspection: 03/08/2019 Time: 9:30 AM

Structure No. Construction Unit No.2 -Site No. 22A Inspector(s): Collier, Richard, Kinler

Structure Description: Canal Bank Stabilization Water Level Inside: N/A Outside: +1.0 ft.

Type of Inspection: Annual Weather Conditions: Mostly sunny, light wind

Item	Condition	Physical Damage	Corrosion	Photo #	Observations and Remarks
Signage and supports					
Rock Armored Bank	Good	None			No maintenance needs were identified.
Earthen Embankment	Good	None			

Construction Unit No.2
Structure Description: Canal bank stabilization consisting of 1,385 linear ft. of rock rip-rap protection on the west bank of the access channel at the Baltazaar Point Subdivision. The rip-rap was constructed to an elevation of +3.0 ft. NGVD

MAINTENANCE INSPECTION REPORT CHECK SHEET

Project No. / Name: **BA-20 Jonathan Davis Wetland** Date of Inspection: 03/08/2019 Time: 9:30 AM

Structure No. Construction Unit No.2 Inspector(s): Collier, Richard, Kinler

Structure Description: Rock dike along Bayou Rigolettes Water Level Inside: N/A Outside: +1.0 ft.

Type of Inspection: Annual Weather Conditions: Mostly sunny, light wind

Item	Condition	Physical Damage	Corrosion	Photo #	Observations and Remarks
Rock Dike	Good; see remarks				Minor settlement observed in some areas, no repairs needed at this time.

Construction Unit No.2
Structure Description: The rock dike consist of 3,967 linear ft. of rock dike with a 6 ft. top width and a crest elevation of +3.5 ft. NGVD.The shoreline stabilization extends from Site 22A west to Structure No.20.

MAINTENANCE INSPECTION REPORT CHECK SHEET

Project No. / Name: **BA-20 Jonathan Davis Wetland**   Date of Inspection: 03/08/2019   Time: 9:30 AM

Structure No. Construction Unit No.3   Inspector(s): Collier, Richard, Kinler

Structure Description: Rock dike along Bayou Perot   Water Level   Inside: N/A   Outside: +1.0 ft.

Type of Inspection: Annual   Weather Conditions: Mostly sunny, light wind

Item	Condition	Physical Damage	Corrosion	Photo #	Observations and Remarks
Rock Dike	Good; see remarks	None	N/A	1	Minor settlement observed in some areas, no repairs needed at this time.

Construction Unit No.3

Structure Description: The rock dike consist of 13,088 linear ft. of rock dike with a 6 ft. top width and a crest elevation of +3.5 ft. NGVD. The shoreline stabilization extends from Site 12 west to the Gulf Intracoastal Waterway.

MAINTENANCE INSPECTION REPORT CHECK SHEET

Project No. / Name: **BA-20 Jonathan Davis Wetland** Date of Inspection: 03/08/2019 Time: 9:30 AM

Structure No. Construction Unit No. 4 Inspector(s): Collier, Richard, Kinler

Structure Description: Concrete panel wall Water Level Inside: N/A Outside: +1.0 ft.

Type of Inspection: Annual Weater Conditions: Mostly sunny, light wind

Item	Condition	Physical Damage	Corrosion	Photo #	Observations and Remarks
Signage and supports	Good	See remarks	Minor	6	Some fading noted, minor spray-paint vandalism to border of one sign was observed, and one sign was missing. Sign faces and text were legible; no repairs needed at this time.
Concrete wall panels, piles, hardware	Good	None	None	6	No defects noted; structure was performing as designed.
Rock Dike	Good	None	N/A	6	No defects noted; structure was performing as designed.

Construction Unit No.4
Structure Description: The wall consists of approx. 12,850 linear ft. of pre-cast concrete wall sections supported by 848 pre-cast concrete piles, in addition to approx. 4,290 linear feet of rock rip-rap bank stabilization/shoreline protection. C.U. #4 extends across the northern edge of Bayou Rigolettes and Bayou Perot, from just east of Structure #12 to Structure #20.

Appendix C
(O&M Budget Projection)

Jonathan Davis Wetland Restoration Project (BA-20)
Federal Sponsor: NRCS
Construction Completed : 01/12/2012
PPL 2

Current Approved O&M Budget June 2009	Year 0 FY13	Year - 1 FY14	Year -2 FY15	Year -3 FY16	Year -4 FY17	Year -5 FY18	Year -6 FY19	Year -7 FY20	Year -8 FY21	Year -9 FY22	Year -10 FY23	Year -11 FY24	Year -12 FY25	Year -13 FY26	Year -14 FY27	Year -15 FY28	Year -16 FY29	Year - 17 FY30	Year -18 FY31	Year -19 FY32	Project Life Budget	Currently Funded
State O&M	$4,200	$4,309	$4,421	$4,536	$84,433	$504,924	$4,899	$5,027	$5,157	$111,609	$2,668,178	$5,570	$5,715	$218,766	$170,377	$3,462,144	$11,333	$11,498	$11,667	$11,840	$7,310,604	$7,310,604
Corps Admin																					$0	$0
Federal S&A																					$0	$0
Total																					$7,310,604	$7,310,604

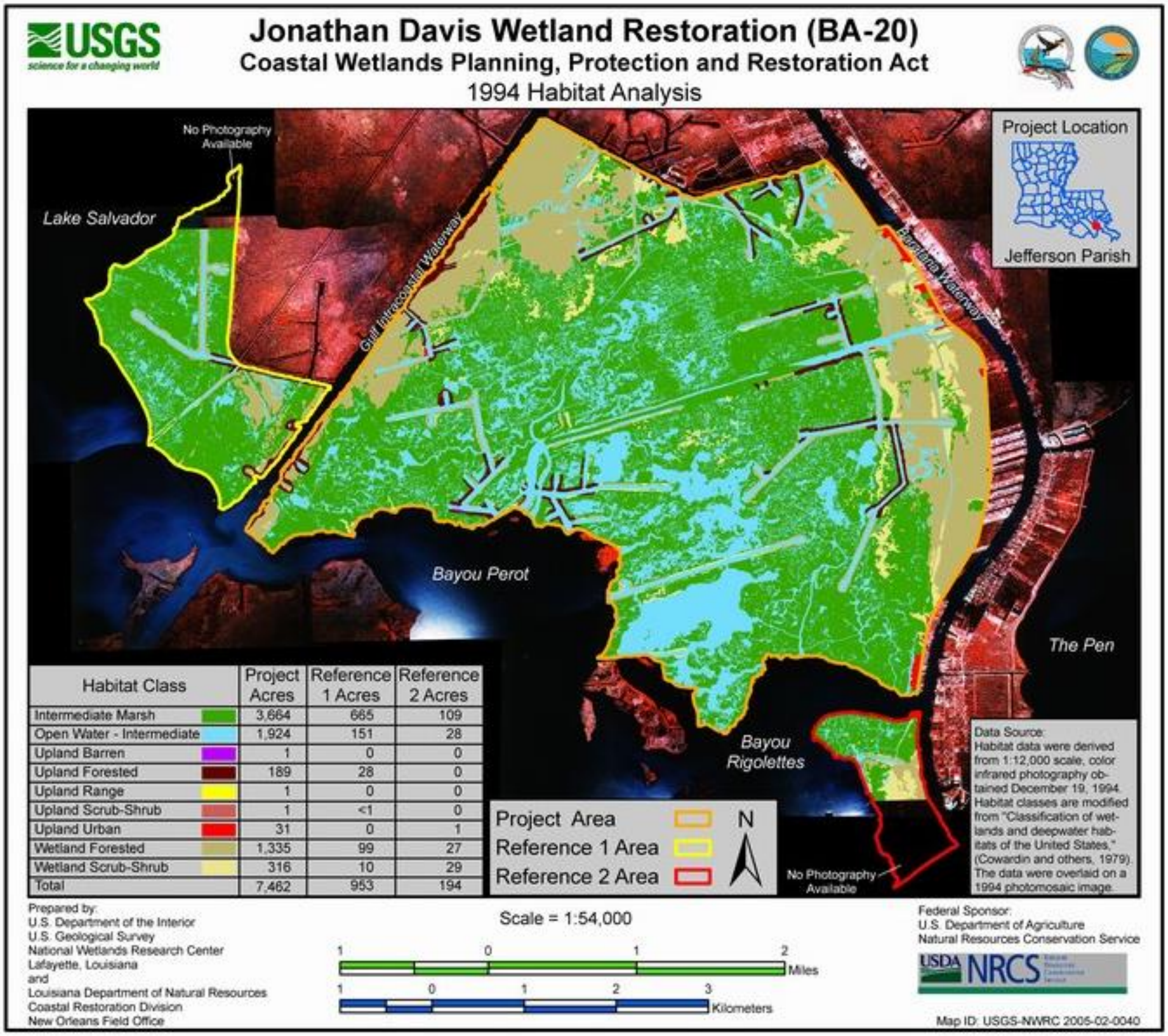
Projected O&M Expenditures	Year 0 FY13	Year - 1 FY14	Year -2 FY15	Year -3 FY16	Year -4 FY17	Year -5 FY18	Year -6 FY19	Year -7 FY20	Year -8 FY21	Year -9 FY22	Year -10 FY23	Year -11 FY24	Year -12 FY25	Year -13 FY26	Year -14 FY27	Year -15 FY28	Year -16 FY29	Year - 17 FY30	Year -18 FY31	Year -19 FY32	Remaining Project Life	Current 3 year Request
Maintenance Inspection	$4,200	$4,309	$4,421	$4,536	$4,654	$4,775	$4,899	$5,027	$5,157	$5,291	$5,429	$5,570	$5,715	$5,864	$6,016	$6,172	$6,333	$6,498	$6,667	$6,840	$71,552	$15,878
General Maintenance																					$0	$0
Surveys					$75,000					$100,000					$150,000						$250,000	$100,000
Sign Replacement														$200,000							$200,000	$0
Federal S&A					$4,779	$19,420				$6,317	$102,622			$12,352	$9,361	$132,967					$263,620	$108,940
Maintenance/Rehabilitation																					$0	$0
E&D						$32,688					$155,327					$198,005					$353,332	$155,327
Construction						$430,809					$2,312,307					$3,000,000					$5,312,307	$2,312,307
Construction Oversight						$17,232					$92,492					$120,000					$212,492	$92,492
Total	$4,200	$4,309	$4,421	$4,536	$84,433	$504,924	$4,899	$5,027	$5,157	$111,609	$2,668,178	$5,570	$5,715	$218,215	$165,377	$3,457,144	$6,333	$6,498	$6,667	$6,840	$6,663,303	$2,784,944

O&M Expenditures from COE Report	$1,300,565
State O&M Expenditures not submitted for in-kind credit	$0
Federal Sponsor MIPRs (if applicable)	$0
Total Estimated O&M Expenditures (as of July 2018)	$1,300,565

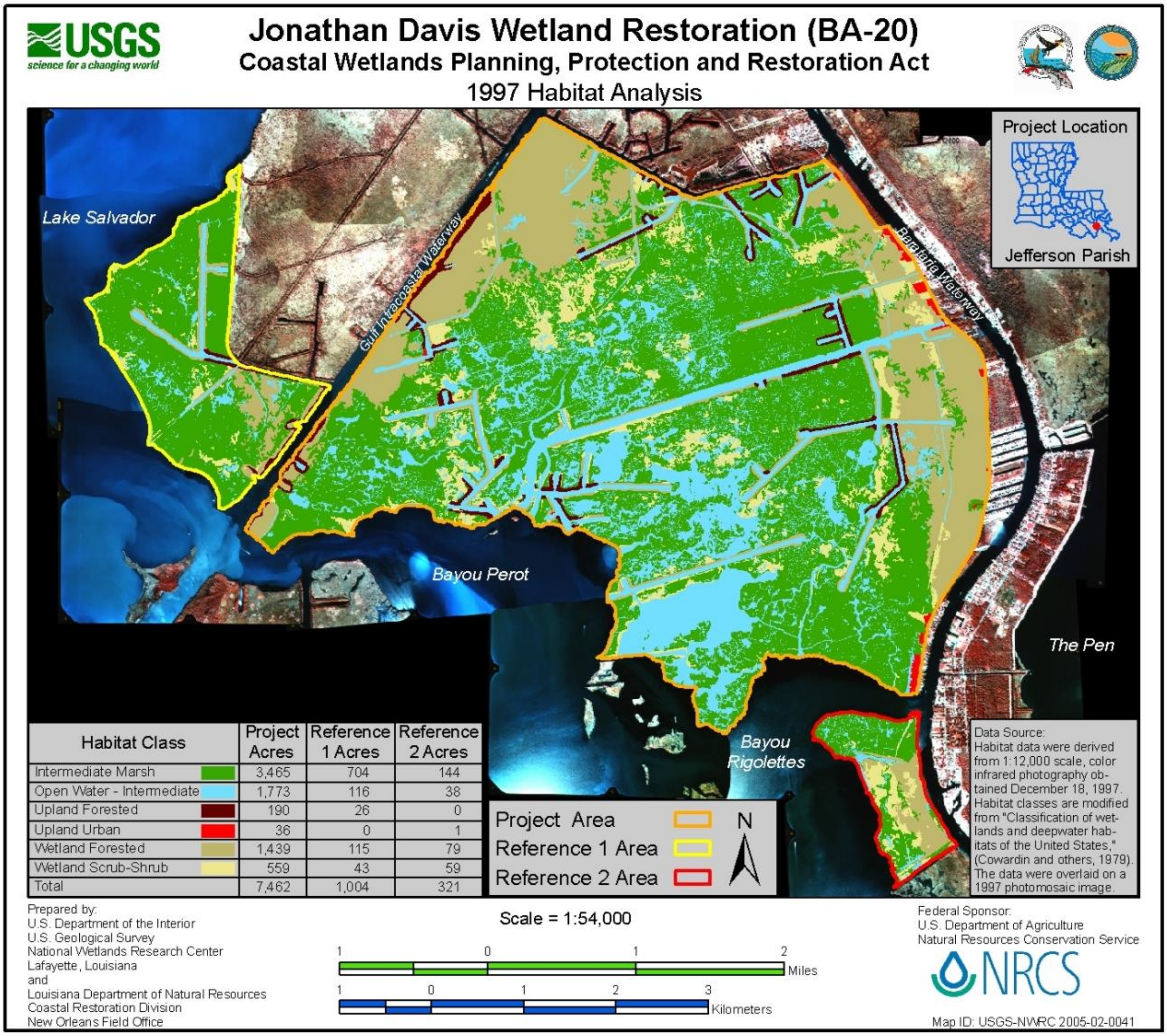
Current O&M Budget less COE Admin	$7,310,604
Remaining Available O&M Budget	$6,010,039
Incremental Funding Request Amount FY19-FY21	**-$3,225,095**

Current Project Life Budget less COE Admin	$7,310,604
Total Projected Project Life Budget	$7,963,869
Project Life Budget Request Amount	**$653,264**

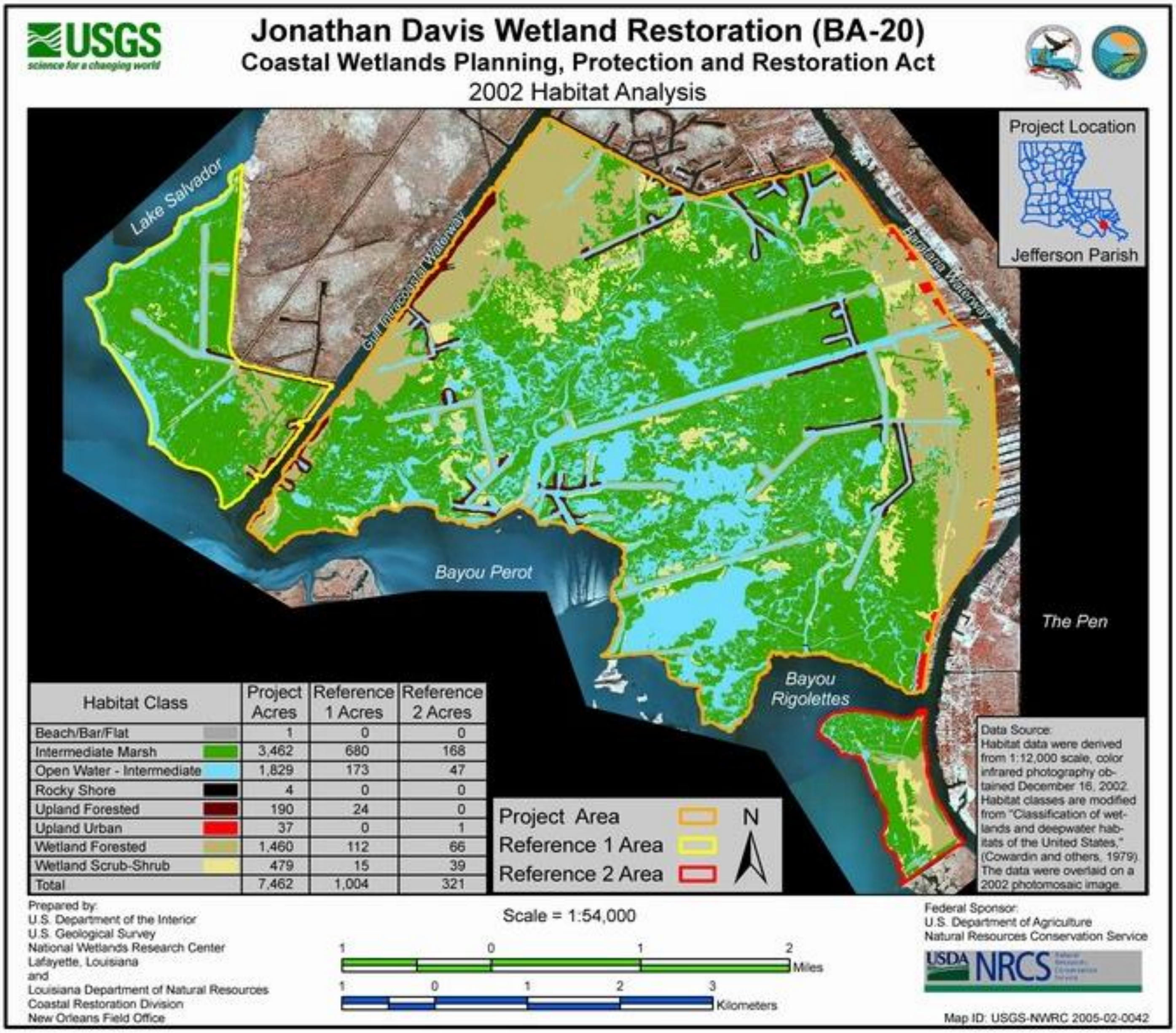
Appendix D
(Land/Water Analyses)



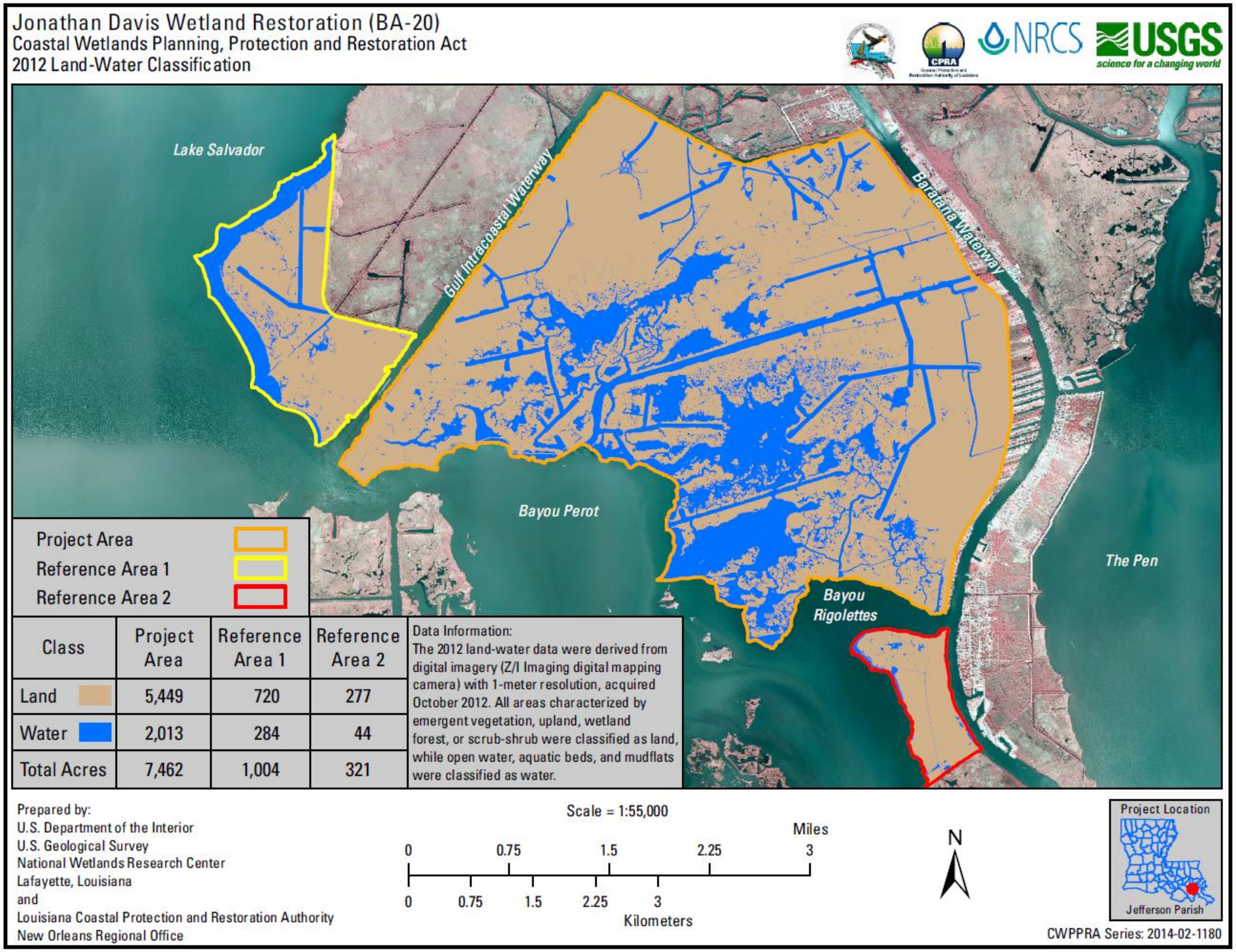
Appendix D1. 1994 habitat analysis of the Jonathan Davis Wetland Restoration (BA-20) project and reference areas.



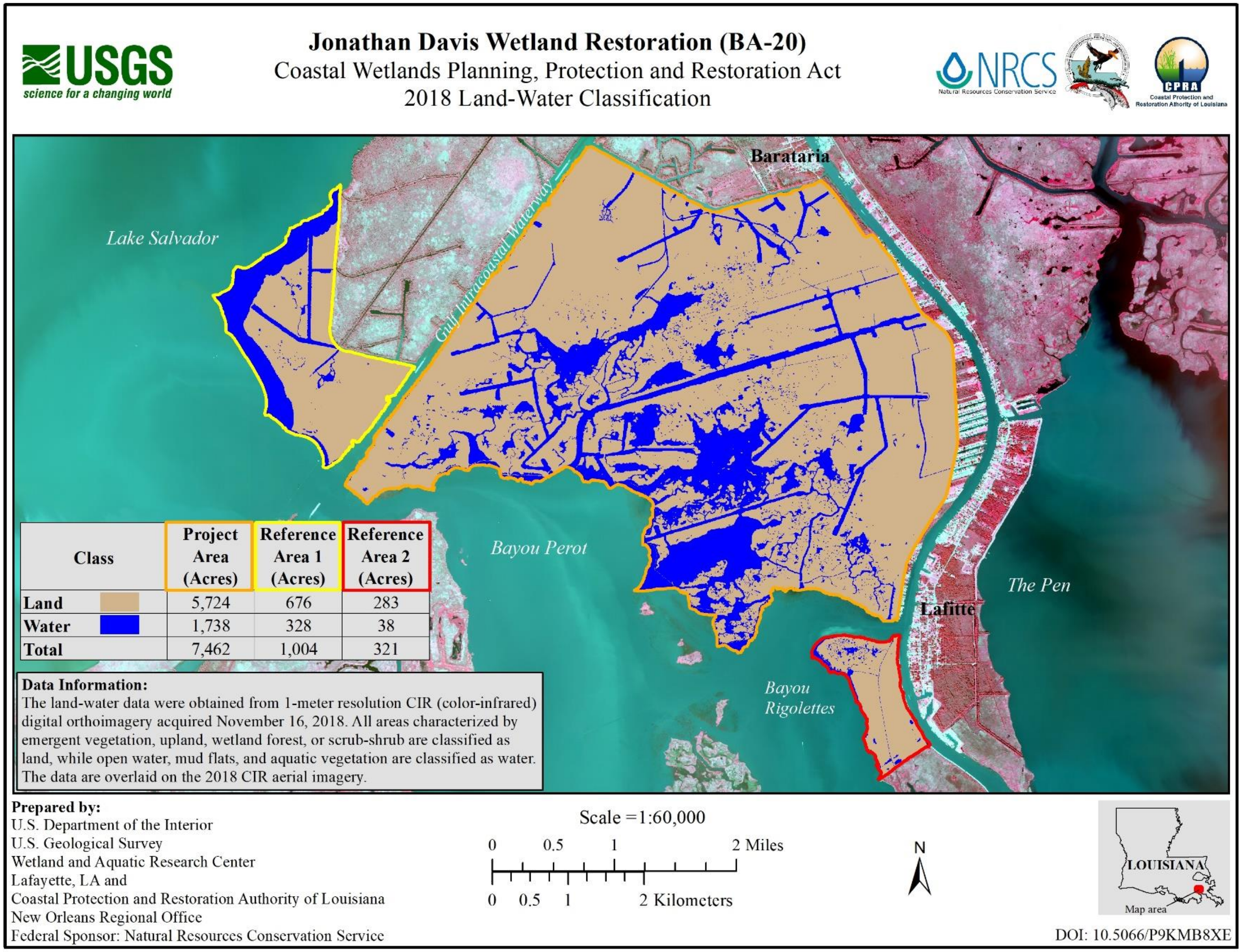
Appendix D2. 1997 habitat analysis of the Jonathan Davis Wetland Restoration (BA-20) project and reference areas.



Appendix D3. 2002 habitat analysis of the Jonathan Davis Wetland Restoration (BA-20) project and reference areas.

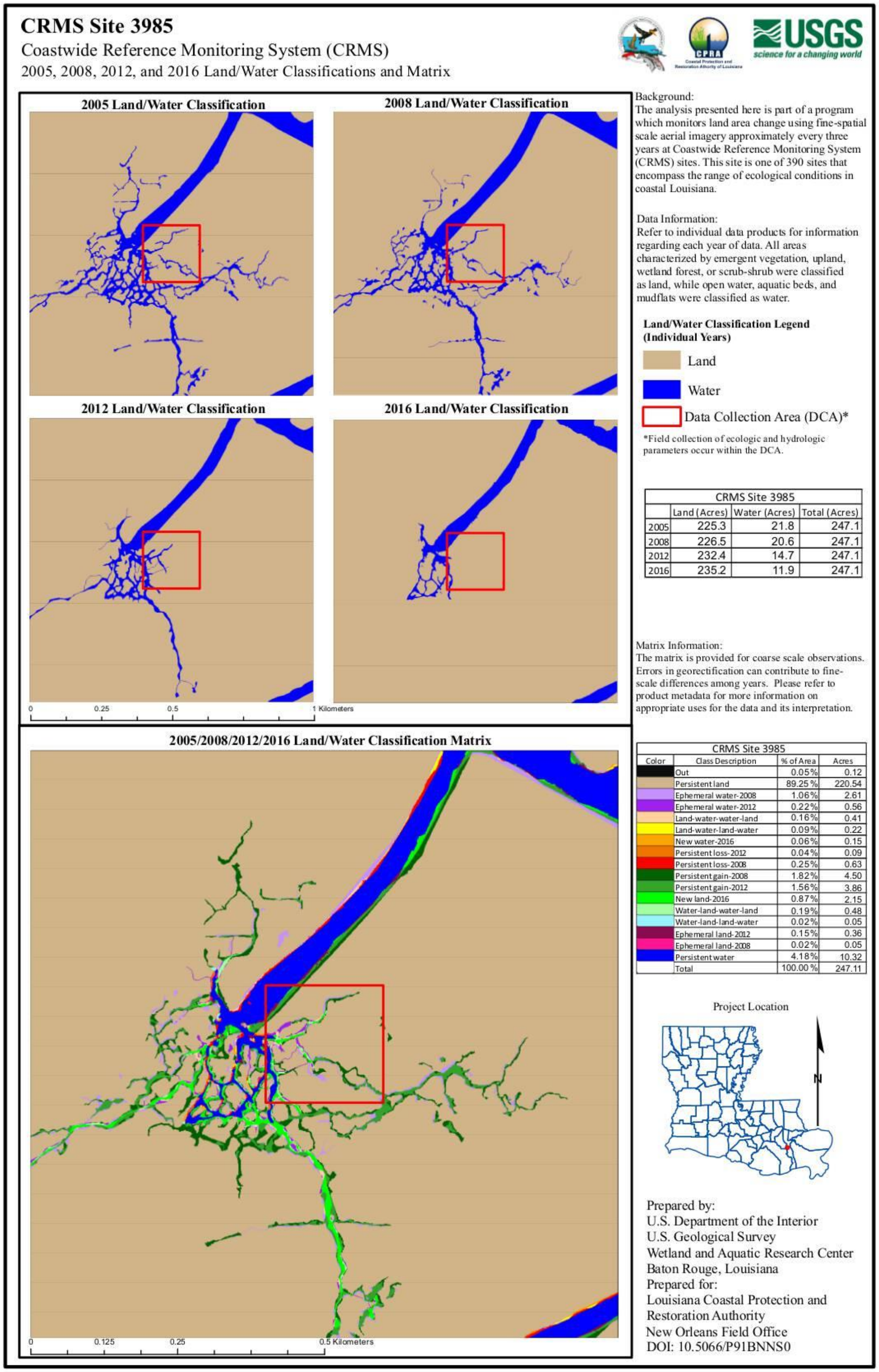


Appendix D4. 2012 land-water classification of the Jonathan Davis Wetland Restoration (BA-20) project and reference areas.

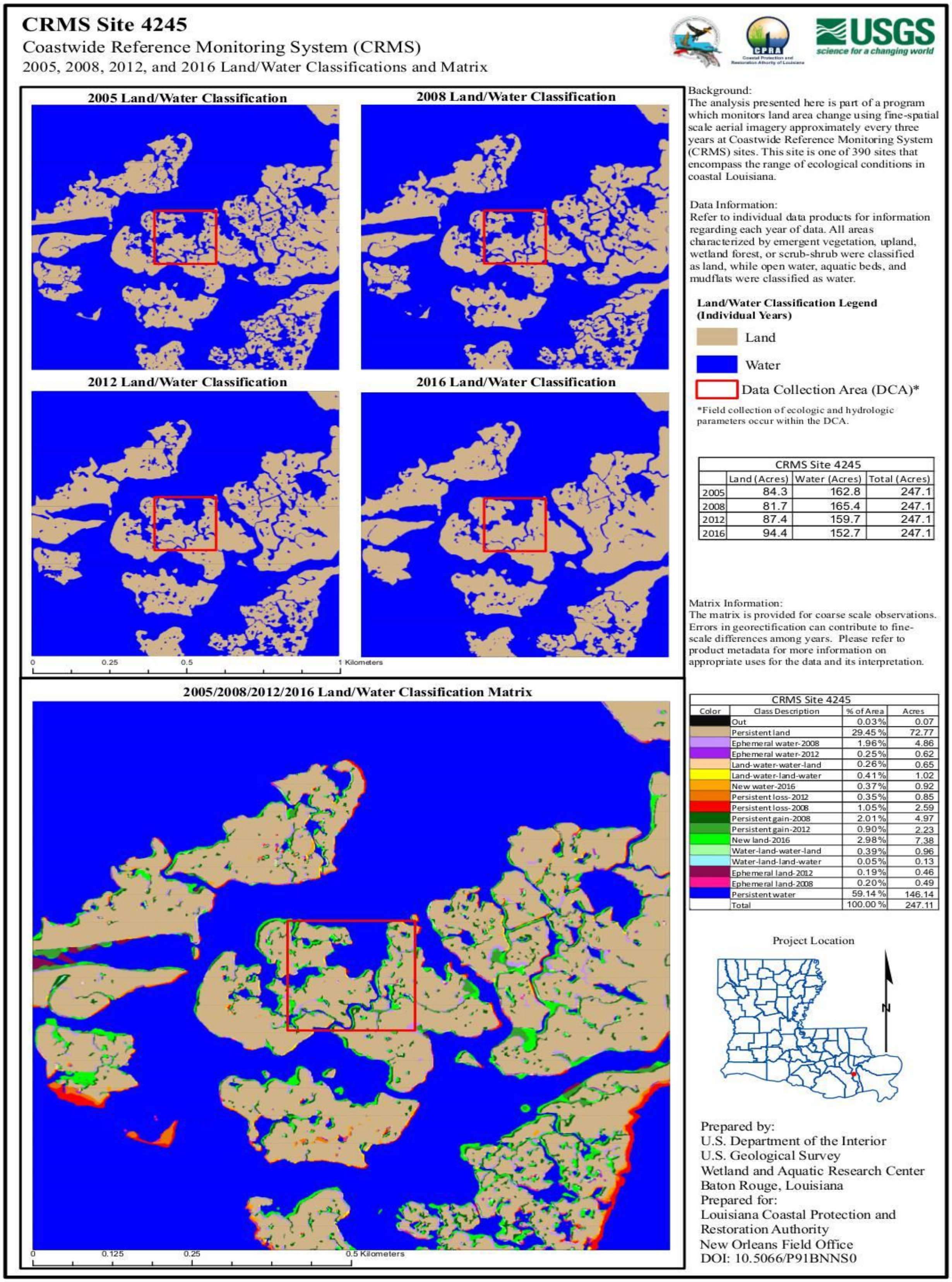


Class	Project Area (Acres)	Reference Area 1 (Acres)	Reference Area 2 (Acres)
Land	5,724	676	283
Water	1,738	328	38
Total	7,462	1,004	321

Appendix D5. 2018 land-water classification of the Jonathan Davis Wetland Restoration (BA-20) project and reference areas.



Appendix D6. 2005, 2008, 2012, and 2016 Land/Water Classifications and Matrix for CRMS3985.



CRMS Site 4245			
	Land (Acres)	Water (Acres)	Total (Acres)
2005	84.3	162.8	247.1
2008	81.7	165.4	247.1
2012	87.4	159.7	247.1
2016	94.4	152.7	247.1

CRMS Site 4245			
Color	Class Description	% of Area	Acres
	Out	0.03%	0.07
	Persistent land	29.45 %	72.77
	Ephemeral water-2008	1.96%	4.86
	Ephemeral water-2012	0.25%	0.62
	Land-water-water-land	0.26%	0.65
	Land-water-land-water	0.41%	1.02
	New water-2016	0.37%	0.92
	Persistent loss-2012	0.35%	0.85
	Persistent loss-2008	1.05%	2.59
	Persistent gain-2008	2.01%	4.97
	Persistent gain-2012	0.90%	2.23
	New land-2016	2.98%	7.38
	Water-land-water-land	0.39%	0.96
	Water-land-land-water	0.05%	0.13
	Ephemeral land-2012	0.19%	0.46
	Ephemeral land-2008	0.20%	0.49
	Persistent water	59.14 %	146.14
	Total	100.00 %	247.11

Appendix D7. 2005, 2008, 2012, and 2016 Land/Water Classifications and Matrix for CRMS4245.