State of Louisiana

Coastal Protection and Restoration Authority (CPRA)

2021 Operations, Maintenance, and Monitoring Report

for

Pecan Island Terracing (ME-14)

State Project Number ME-14
Priority Project List 7

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Vermilion Parish

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Preface

This report includes monitoring data collected through December 2020, and the annual maintenance inspections through June 2015. The Pecan Island Terracing (ME-14) project is a 20-year Coastal Wetlands, Planning, Protection, and Restoration Act (CWPPRA, Public Law 101-646, Title III, Priority List 7) project administered by the National Marine Fisheries Service (NMFS) and the Coastal Protection and Restoration Authority of Louisiana (CPRA).

The 2021 report is the 4th and final in a series of reports. For additional information on lessons learned, recommendations and project effectiveness, please refer to the 2004, 2005, and 2009 Operations, Maintenance, and Monitoring Reports on the CPRA web site at http://coastal.Louisiana.gov/. These reports will be made available for download at the following website: http://cims.coastal.la.gov/.

I. Introduction

The Pecan Island Terracing (ME-14) project is located five miles north of the Gulf of Mexico just south of Pecan Island and Hwy 82 in the Cheniere Sub-basin of the Mermentau Basin, Vermilion Parish, Louisiana. The total project area comprises 3,654 acres (1,519 ha) of brackish marsh and open water. Area 1 is primarily open water and was formerly converted to leveed pasture land of approximately 1,938 acres (784 ha). Area 2 consists of 1,715 acres (694 ha) of open water and broken intermediate to brackish marsh (Figure 1).

The project area was initially classified as fresh marsh. Habitat analysis in 1956 classified Area 1 as 99.1 % fresh marsh and 0.9 % water and Area 2 as 89.7 % fresh marsh and 10.3 % water. The marsh in Area 1 was converted to a dry pasture in the late 1950's by constructing continuous dikes around the perimeter and draining the interior. By 1978, Area 1 was classified as 93.4 % pasture, 0.5 % water, 0.2 % fresh marsh, and 1% intermediate marsh with Area 2 comprised of 16 % intermediate marsh, 14.3 % brackish marsh, and 69.4 % open water, signifying a fairly drastic transformation in Area 2. Saltwater intrusion and both intentional and unintentional impoundments caused rapid habitat change and land loss in the project area; now isolated between the higher elevation features of the Hwy 82 corridor to the north and the Gulf of Mexico (GOM) rim to the south, GOM over wash events would trap high salinity waters in and around the ME-14 project area. Deterioration and loss of the perimeter levees between 1978 and 1988 converted the entirety of Area 1 into a shallow, open water lake with some sporadic small vegetated islands due to soil elevation loss as a result of oxidation of organic material. The analysis performed from 1988 through 1990 indicated that Area 1 had converted to 98 % water with 1.6 % brackish marsh. Additionally, Area 2 had converted to 68.2 % water and 31.7 % brackish marsh. This trend stabilized between 1990 and 2000 as only minimal land loss took place and was generally confined to marsh edge erosion as a vast majority of the project area land was already converted to open water.

Soils in the northern portion of Area 1 are Bancker muck with Clovelly muck in the southern part of that area. Area 2 consists solely of Clovelly muck. Bancker muck is very poorly drained, very fluid, mineral soil while Clovelly muck is very poorly drained, very fluid and organic soil. The dominant natural vegetation in both areas was *Spartina patens* (saltmeadow cordgrass). Other common plants in the area included *Juncus roemarianus* (needlegrass rush), *Paspalum vaginatum* (seashore paspalum), *Phragmites australis* (common reed), *Bolboschoenus robustus* (sturdy bulrush), *Schoenoplectus americanus* (chairmaker's bulrush), *Spartina alterniflora* (smooth cordgrass), and *Distichlis spicata* (saltgrass). Submerged Aquatic vegetation (SAV) historically consisted of *Ruppia maritima* (widgeongrass) and *Eleocharis parvula* (dwarf spikerush).

The ME-14 restoration project was designed to reduce marsh erosion by creating emergent terraces intended to minimize wave fetch across open water and, at the same time, create linear marsh edge habitat. Future marsh loss could be reduced and some lost brackish marsh may revegetate. Construction of the earthen terraces in shallow water areas could also convert areas of open water back to vegetated marsh creating more habitat for fish and wildlife. The project constructed adjacent terrace cells run east to west in a staggered gap formation, each bordered by other terraces all made from in situ borrow material. Breaks were constructed to permit water to move in and out of the interior, which may facilitate the settling of suspended soil particles and SAV growth. The terraces were also planted with *Spartina alterniflora* (smooth cordgrass) at the land water interface near the tow of the terrace. Plantings did not occur on all terraces as part of an intentional experimental design within the project.

The construction phase of the project consisted of the following components:

1. The construction of 197,000 linear feet (60,046 m) of terraces in 500 ft (152.4 m) sections with a 50 ft (15.24 m) break between each terrace, creating approximately 344 terraces (Figure 2).

2. The terraces were constructed by depositing borrow material with a 40 ft (12.19 m) berm with a crown width of 10 ft (3.04 m) and 4:1 side slopes. Initial constructed elevation was approximately 3.75 ft (1.14 m) NAVD 88 which in 5 years should have a final settled elevation approximately 1 ft above marsh elevation, or 2.5 ft NAVD 88.

3. *Spartina alterniflora* (smooth cordgrass) plugs were planted every five linear feet on both sides of most terraces (Figure 3a-b).

Construction of the project features was completed in August 2003.

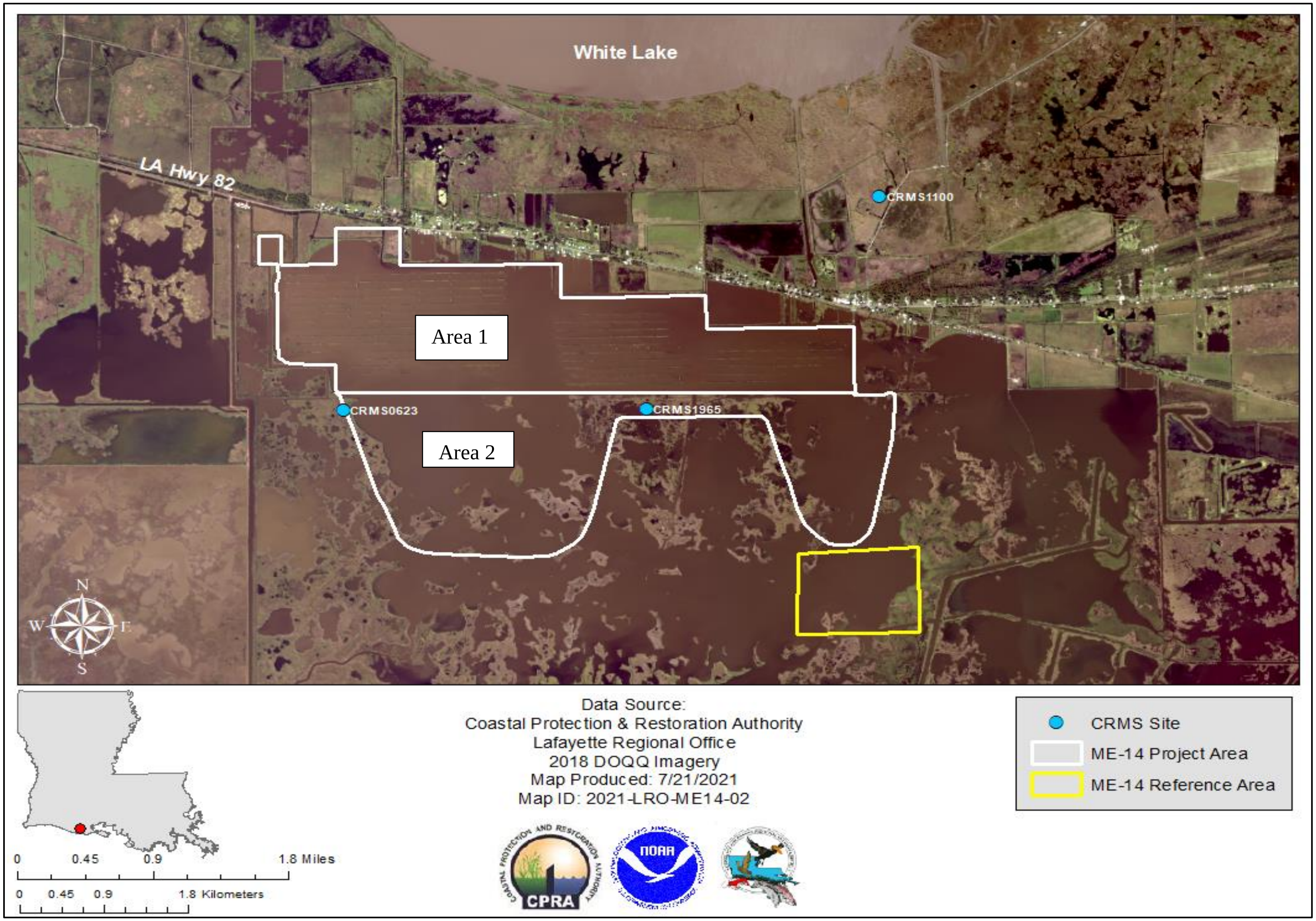

Figure 1. The Pecan Island Terracing (ME-14) project area and CRMS-*Wetlands* sites.

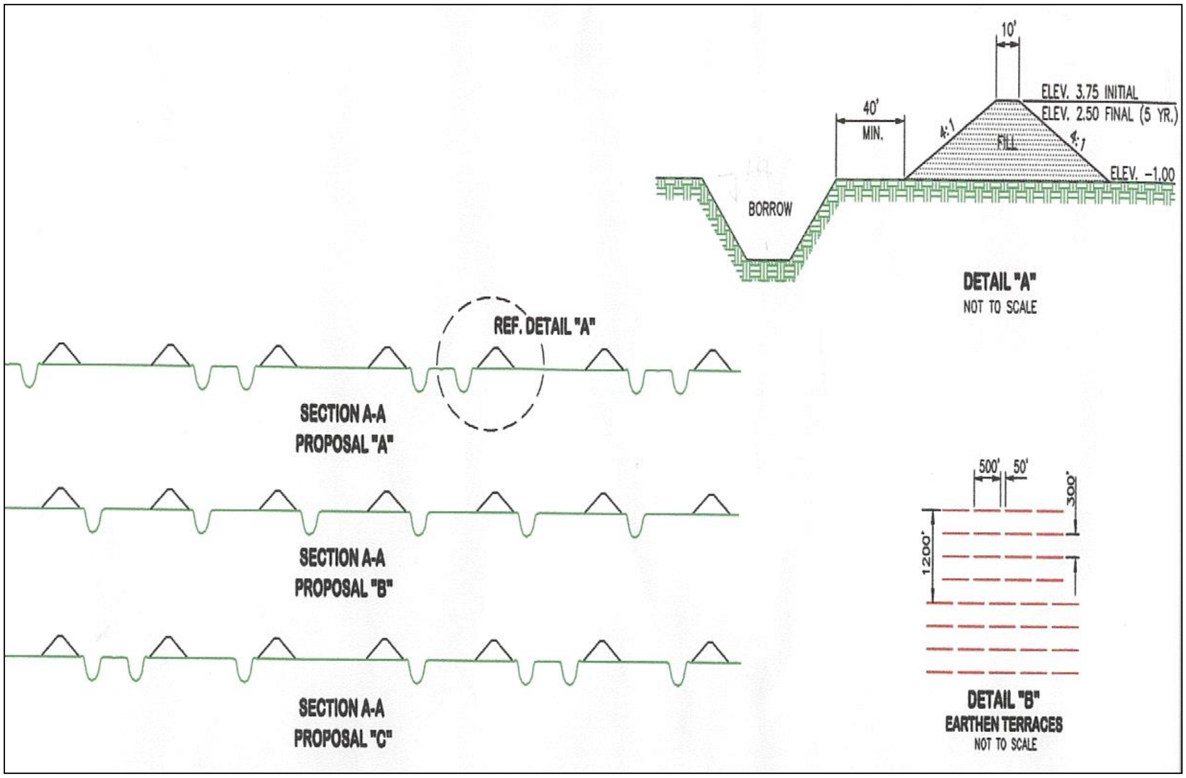

Figure 2. Pecan Island Terracing (ME-14) schematic of terraces.

Figure 3a. Pecan Island Terracing (ME-14) photo down the length of a terrace in 2005.

Figure 3b. Pecan Island Terracing (ME-14) photo across multiple terraces in 2005.

a. Project Feature Inspection Procedures

The purpose of the annual inspection of the Pecan Island Terracing Project (ME-14) is to evaluate the constructed project features, identify any deficiencies and prepare a report detailing the condition of project features and recommended corrective actions needed. Should it be determined that corrective actions are needed, OCPR 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. The annual inspection report also contains a summary of maintenance projects, if any, which were completed since completion of constructed project features and an estimated projected budget for the upcoming three (3) years for operation, maintenance and rehabilitation. The three (3) year projected operation and maintenance budget is shown in Appendix B.

In 2003, the CWPPRA Task Force determined, due to the fact that OCPR was responsible for the operation and maintenance phase of the vast majority of CWPPRA projects, that OCPR would be the responsible party for all Post Storm/Hurricane Assessments. After Hurricane Ike, every project appeared to have been impacted by the storms; therefore, OCPR determined that all projects should be assessed for damages (Broussard, 2006). With concurrence from the federal sponsor, OCPR has decided to use the information obtained during this post hurricane assessment in this Annual Maintenance Inspection.

An inspection of the Pecan Island Terracing Project (ME-14) was held on June 30, 2015 under partly sunny skies and warm temperatures. In attendance were Mel Guidry of CPRA with John Foret representing NOAA/NMFS. All parties met at the CPRA Lafayette Field Office and proceeded to the boat launch on Hwy 82 adjacent to the Pecan Island Terracing Project (ME-14). The group traveled throughout the project area via NOAA/NMFS's boat inspecting the terraces.
The field inspection included a complete visual inspection of all earthen terraces. Staff gauge readings when available were used to determine approximate water level and earthen terrace elevation. Photographs were taken of various earthen terraces (see Appendix A) and Field Inspection notes were completed in the field to record measurements and any notable deficiencies (see Appendix C).

b. Inspection Results

<u>Terraces</u>

The majority of the earthen terraces are in good condition. There is some erosion taking place on the north side of the individual terraces. Previously noted erosion on the southernmost sacrificial terraces has worsened. On the west side of the terrace field, the first two rows of the southernmost sacrificial terraces are no longer visible above the water surface. The third row is also beginning to show signs of degradation. In addition, a portion of the first row of the east southernmost terraces is no longer visible above the water surface. (Photos: Appendix A, Photo 1-4)

<u>Vegetative Plantings</u>

The tops of the terraces are approximately 50 percent covered with vegetation. Species noted include *Spartina alterniflora*, *Juncus*, *Baccharis*, and *Spartina patens*. (Photos: Appendix A, Photo 5-7).

c. Maintenance Recommendations

i. Immediate/ Emergency Repairs

None

ii. Programmatic/ Routine Repairs

Install a staff gage.

d. Maintenance History

General Maintenance: Below is a summary of completed maintenance projects and operation tasks performed since September 2003, the construction completion date of the Pecan Island Terracing Project (ME-14).

December 2011 - Installation of two staff gauges.
1 – N 29° 38’49.48”, W 92° 30’ 30.62”
2 – N 29° 38’31.16”, W 92° 27’ 27.48”

III. Operation Activity

a. Operation Plan

There are no water control structures associated with this project, therefore no Structural Operation Plan is required.

b. Actual Operations

There are no water control structures associated with this project, therefore no required structural operations.

IV. Monitoring Activity

Pursuant to a CWPPRA Task Force decision on August 14, 2003 to adopt the Coastwide Reference Monitoring System-*Wetlands* (CRMS) for CWPPRA, updates were made to the ME-14 Monitoring Plan to merge it with CRMS and provide more useful information for modeling efforts and future project planning while maintaining the monitoring mandates of the Breaux Act. There are two CRMS sites located in or very near the project area (CRMS0623 and CRMS1965), and three located south of the project area which could be used as reference locations if necessary to address the project goals.

a. Monitoring Goals

The objective of the Pecan Island Terracing Project is to convert areas of open water to vegetated marsh through the construction of earthen terraces and vegetation plantings along with increasing SAV occurrence within the project area over the 20-year project life (Figure 4).

The following goals will contribute to the evaluation of the above objective:

1. Increase land to water ratios by constructing approximately 100 acres (41.3 ha) of earthen terraces in Area 1.

2. Increase land to water ratios by creating over 300 acres (121.4 ha) of land within Areas 1 and 2 over 20 years after construction.

3. Increase percent cover of SAV in remaining open water areas to 50% in Area 1 and 15% in Area 2.

4. Establish emergent vegetated marsh on planted terraces.

b. Monitoring Elements

Aerial Photography

For project specific data, near-vertical color-infrared aerial photography (1:12,000 scale) was used to measure vegetated and non-vegetated areas for the project area. The photography was obtained in the pre-construction year 2001 and post-construction in 2004 and 2018. The 2001 and 2004 imagery was delineated to classify all land in the project and reference areas as either (1) preexisting wetlands, (2) vegetated and non-vegetated terraces, and (3) non-terrace, newly developed wetlands (i.e., those that develop in open water areas between the terraces or adjacent to the preexisting perimeter levees). The original photography was checked for flight accuracy, color correctness and clarity and was subsequently archived. Aerial photography was scanned, mosaicked, and geo-rectified by USGS/NWRC personnel according to standard operating procedures (Steyer et al. 1995, revised 2000).

In addition, land change of the project area as a whole will be assessed from land/water data interpreted from TM satellite imagery (30 m^2 resolution) which is stored on the CRMS viewer website (http://www.lacoast.gov/crms_viewer/); pre- and post-construction comparisons will be made. Linear regressions were calculated for the period of record. The variability in percent land data points around the slope illustrate the influence of various sources of environmental variance or classification error. Positive slopes indicate increasing percent land or historical land gain and negative slopes indicate decreasing percent land or historical land loss (Couvillion et al., 2017). This data set is fairly course given the size and scope of the ME-14 project but is useful for trend analysis but not for exact acreage calculations or specific locations of loss or gain.

SAV:

To document changes in the frequency of occurrence of submersed aquatic vegetation, a modification of the rake method was employed. The project and reference areas were monitored along 15 transects: 6 transects in Area 1 of the project, 6 transects in Area 2 of the project and 3 in the reference area (Figure 4). Each transect had a minimum of 20 sampling stations. At each station, aquatic vegetation was sampled by dragging a garden rake on the pond bottom for about one second. The presence of vegetation was recorded to determine the frequency of aquatic plant occurrence (frequency = number of occurrences/number of stations x 100). When vegetation was present, the species present were recorded in order to determine the frequencies of individual species. SAV abundance was sampled in the fall of 2001 (pre-construction), in 2005 pre Hurricane Rita, and in 2020 pre Hurricane Laura. Continuous data recorders will document hourly salinity and water level data used to document environmental conditions that may have an effect on SAV occurrence.

Emergent Vegetation:

The condition of the emergent and planted vegetation on the terraces was monitored at sampling stations established systematically on 15 planted and 15 unplanted terraces using a modified Braun Blanquet sampling method (Figure 4). Transects were established uniformly across selected terraces with three sampling stations established uniformly along each transect. Three transects were established across the long (500 ft) terraces, and one transect was established across the shorter (120 and 250 ft) terraces. At each station, percent cover, dominant plant height, and species composition was documented in a 4 m^2 sample area. Vegetation was evaluated at the sampling sites in the fall of 2003 (as built), late summer 2005, and again in late summer 2020. A subset of 10 terraces (5 planted and 5 unplanted) was evaluated after Hurricane Rita in November 2005 and October 2007.

In addition to the project specific vegetation collection on the terraces, vegetation composition and cover estimated from 10 permanent 2x2 m plots that are randomly distributed along a transect in the emergent marsh within each of the 1 km^2 CRMS-*Wetlands* sites will be used for additional project area assessment. Data has been collected in summer from 2006 - 2020 using the Braun Blanquet method.

Individual species' cover data are summarized according to the Floristic Quality Index (FQI) method (Cretini and Steyer 2011). A list of plants occurring in Louisiana's coastal wetlands (~500 species) was provided to all known Louisiana coastal vegetation experts and their input on scoring was requested. The panel then provided an agreed upon group score (Coefficient of Conservatism or CC score) for each species. CC scores are weighed based on cover in the FQI for Louisiana coastal wetlands. All species known to occur in the coastal zone were given a floristic quality score on a scale of 0 to 10. Species that scored the lowest were considered by the panel to indicate disturbance or unstable marsh environments. CRMS sites inside (0623 and 1965) the project were used for this report.

Salinity

Salinity is monitored hourly utilizing two CRMS-*Wetlands* sites (0623 and 1965) within the project area. Continuous data will be used to characterize average monthly salinities throughout the project area. The salinity sondes are serviced on approximately a bimonthly basis. At each servicing, a measurement of interstitial water salinity is collected adjacent to each station. Interstitial water salinity is also determined at the 10 vegetation plots, when vegetation is surveyed. Salinity data will be used to characterize the spatial variation in salinity throughout the project area and to determine if project area salinity variability is affecting project effectiveness.

Water Level

Water level is monitored hourly utilizing two CRMS-*Wetlands* sites (0623 and 1965) within the project area. Continuous data will be used to characterize average monthly water levels throughout the project area. The sondes are surveyed relative to North American Vertical Datum (NAVD 88 GEOID 12A), based on a 2014 coastwide CRMS survey effort. The water level SONDE is serviced on approximately a bimonthly basis. Water level data is used to document variability in water level in the project and reference areas. Water level data will be used to characterize the spatial variation in water elevation throughout the project area and to determine if project area water level variability is effecting project effectiveness.

Elevation Change

Soil surface elevation change utilizing a combination of sediment elevation tables (RSET) and vertical accretion from feldspar horizon markers are being measured twice per year at each site. This data will be used to describe general components of elevation change and establish accretion/subsidence rates. The RSET was surveyed to a known elevation datum (ft, NAVD88 GEOID 12A) so it can be directly compared to other elevation variables such as water level at two CRMS-*Wetlands* sites (0623 and 1965) inside the project area. Data collection has been ongoing from 2006-2020.

Soil Properties

Soil cores were collected to describe major soil properties such as bulk density and percent organic matter. Three, 4" (10.16-cm) diameter cores were collected to a depth of 24 cm and divided into 6, 4-cm sections at each site. The soil was processed by the Department of Agronomy and Environmental Management at Louisiana State University. Soil cores were collected at the project and reference CRMS sites during station establishment in 2005-2007 and again in 2018. Cores were collected at two CRMS-*Wetlands* sites (0623 and 1965) inside the project area.

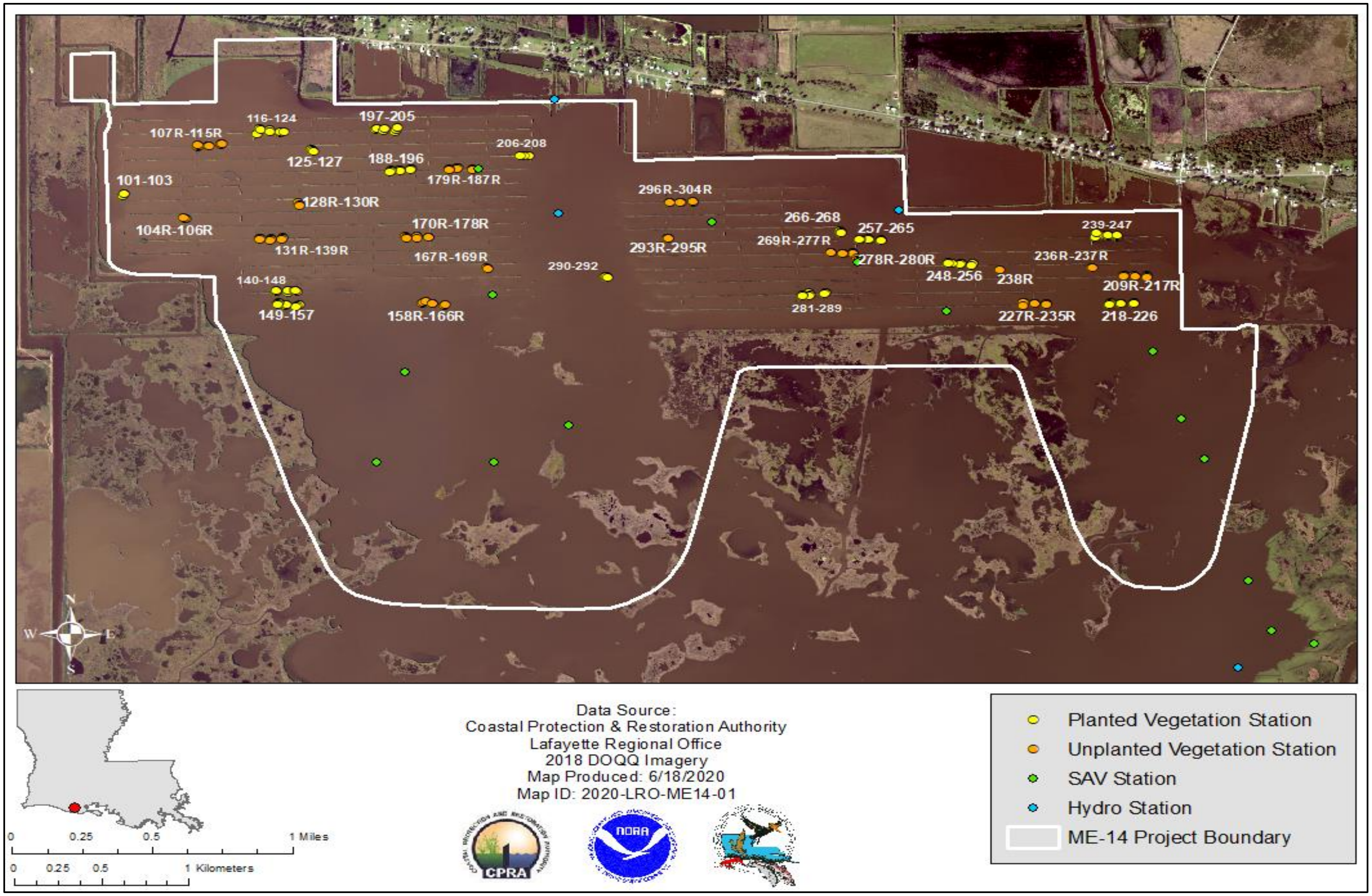

Figure 4. Location of project-specific monitoring stations within the Pecan Island Terracing Project (ME-14) project area and surrounding marsh.

c. Monitoring Results and Discussion

Aerial Photography

Aerial photography was collected pre-construction on December 18, 2001 and post-construction on November 25, 2004 and October 27, 2018 (Table 1, Figure 6 and 7). In Area 1, 201 acres of terraces were constructed, most of which were planted in 2004 post construction. Terraces in Area 2 and the reference area were constructed by Vermilion Corp and are not part of the ME-14 project. Overall, project Area 1 increased in land from 46 acres in 2001 to in 240 acres in 2004 and then fell to 110 acres by 2018 as erosion and multiple storms impacted the project. Area 2 decreased at each time interval quantified from 395 acres in 2004, to 340 in 2004, and finally 233 acres in 2018. The reference area increase from 28 acers to 38 acres in 2004 due to non-project terrace construction then decreased to 19 acres by 2018 as these terraces eroded. The constant land loss in Area 2 suggests the terrace construction in Area 1 did not provide the necessary wind and wave protection to stop existing marsh loss in the project area.

In general, the land change trend within the project area prior to construction was negative from 1985 to 2003, dropping from a high of near 40% to a low of 15% just prior to construction (Figure 5). Post construction in early 2005, there was a notable increase in percent land from approximately 14% to 25% from terrace construction and planting. This initial increase achieved the first goal of the project by creating more than 100 acres of marsh via construction of terraces. Land loss then occurred in 2005, 2008, and beyond following Hurricanes Rita and Ike, and the project area never recovered. This does not include data from the 2020 hurricane season which saw the area battered by two major hurricanes: Laura and Delta. These extremely damaging storms as well as high water in recent years due to heavy rainfall and a higher than average GOM prevented the project area from expanding upon the maximum 201 acres of marsh that was created in the form of terraces, which has seen a precipitous drop as of the final 2018 land water analysis to approximately half of that maximum near 100 acres. Consequently, the second goal of the project was not met as the area did not vegetate between terraces at a rate greater than erosion and marsh loss due to both the lack of a reliable sediment source and previously mentioned storm damage was dominant.

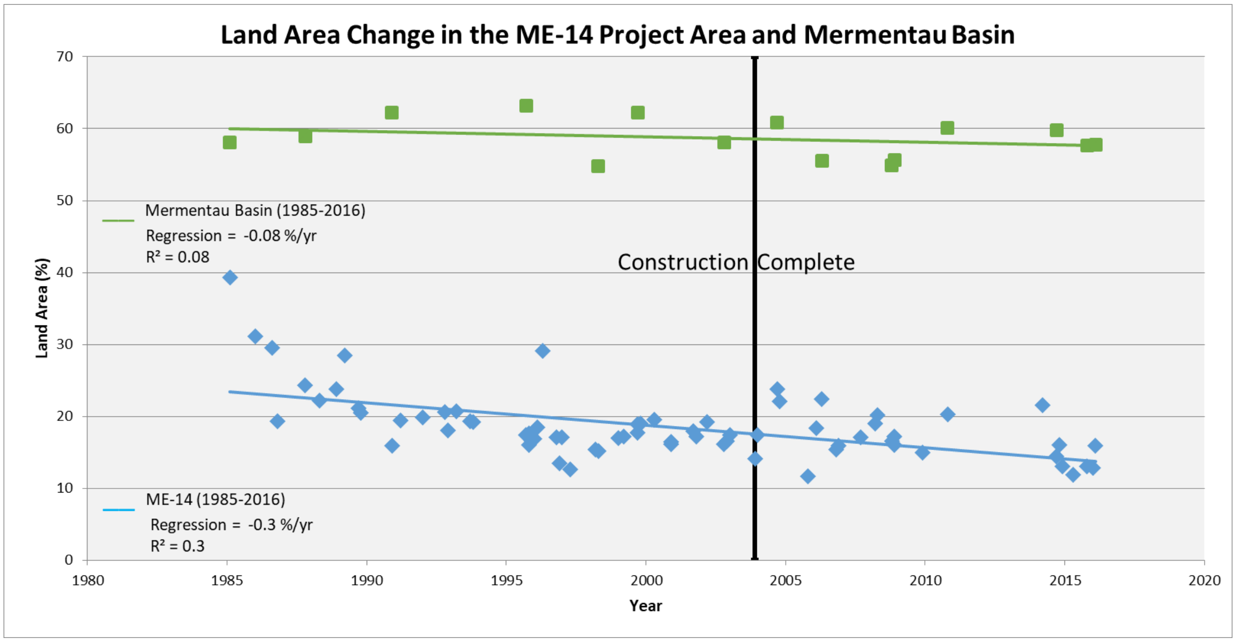

Figure 5. Project and basin scale percent land change for ME-14. Percent land values are displayed for all cloud free TM images available from 1985-2016. Percent land calculated as percent land of total project area. See Couvillion et al. 2017.

Table 1. Acreages and percentages for land water classifications from aerial photography collected in 2001, 2004, and 2018.

	Pre-Construction (December 18, 2001)								
	Area 1			**Area 2**			**Reference**		
	Acres	(ha)	%	Acres	(ha)	%	Acres	(ha)	%
Land	46	19	2.4	395	160	23.0	28	11	8.7
Water	1892	766	97.6	1320	534	77.0	294	119	91.3
Terrace, vegetated	0	0	0	0	0	0	0	0	0
Terrace, unvegetated	0	0	0	0	0	0	0	0	0
Total	1938	784		1715	694		322	130	
	Post-Construction (November 25, 2004)								
	Area 1			**Area 2**			**Reference**		
	Acres	(ha)	%	Acres	(ha)	%	Acres	(ha)	%
Land	39	16	2.0	337	136	19.7	24	10	7.5
Water	1698	687	87.6	1375	556	80.2	284	115	88.2
Terrace, vegetated	134	54	6.9	<1	<1	<1	1	0.4	0.3
Terrace, unvegetated	67	27	3.5	3	1	0.2	13	5	4.0
Total	1938	784		1715	694		322	130	
	Nearing End of Project (October 10, 2018)								
	Area 1			**Area 2**			Reference		
	Acres	(ha)	%	Acres	(ha)	%	Acres	(ha)	%
Land	NA	44.5	5.7	233	94.3	13.6	19	7.7	5.9
Water	1828	739.8	94.3	1483	600	86.5	303	123	94.6
Terrace, vegetated	110	44.5	5.7	NA	NA	NA	NA	NA	NA
Terrace, unvegetated	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total	1938	784		1716	694		322	130	

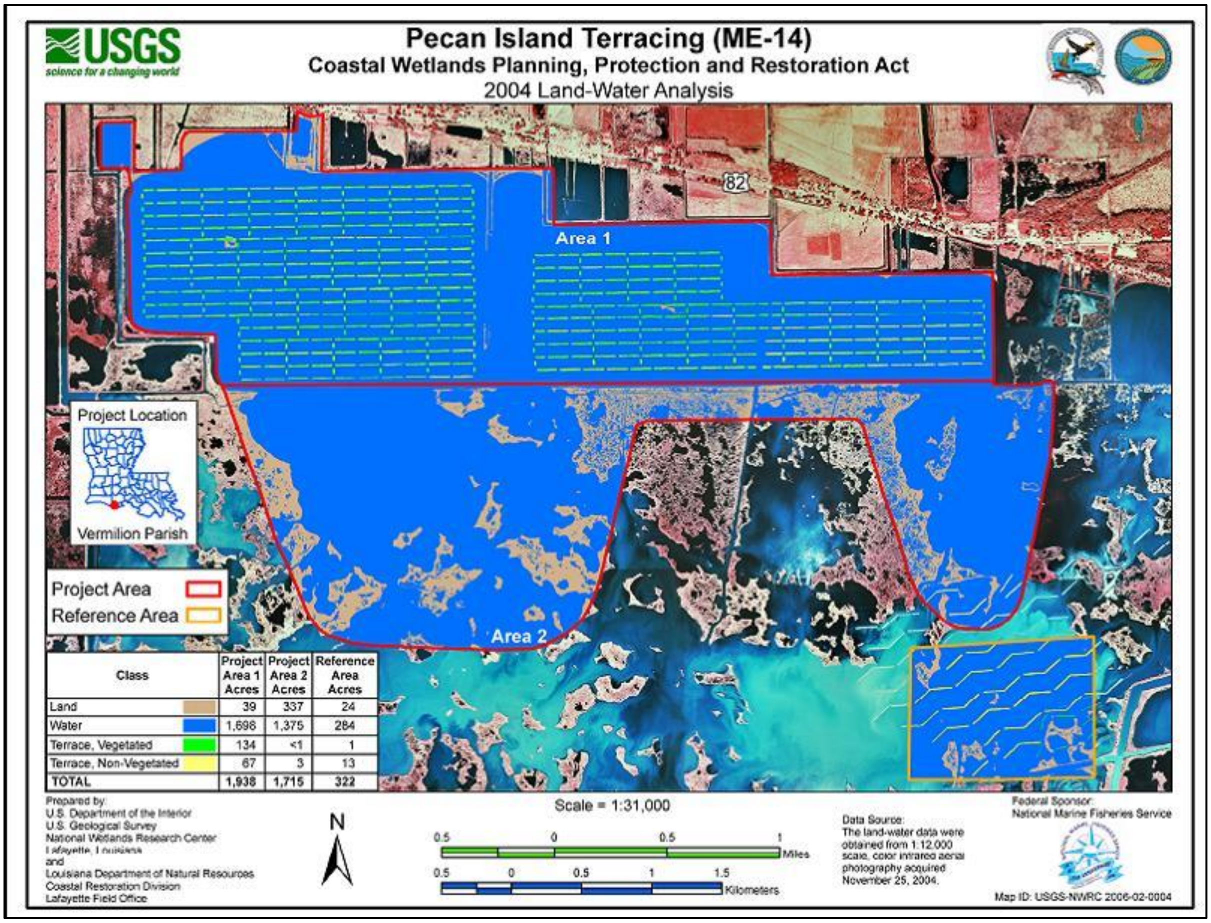

Figure 6. Pecan Island Terracing (ME-14) 2004 Land/Water analysis of the project and reference area. Land area was further broken down into existing marsh (land), vegetated terrace, and non-vegetated terraces.

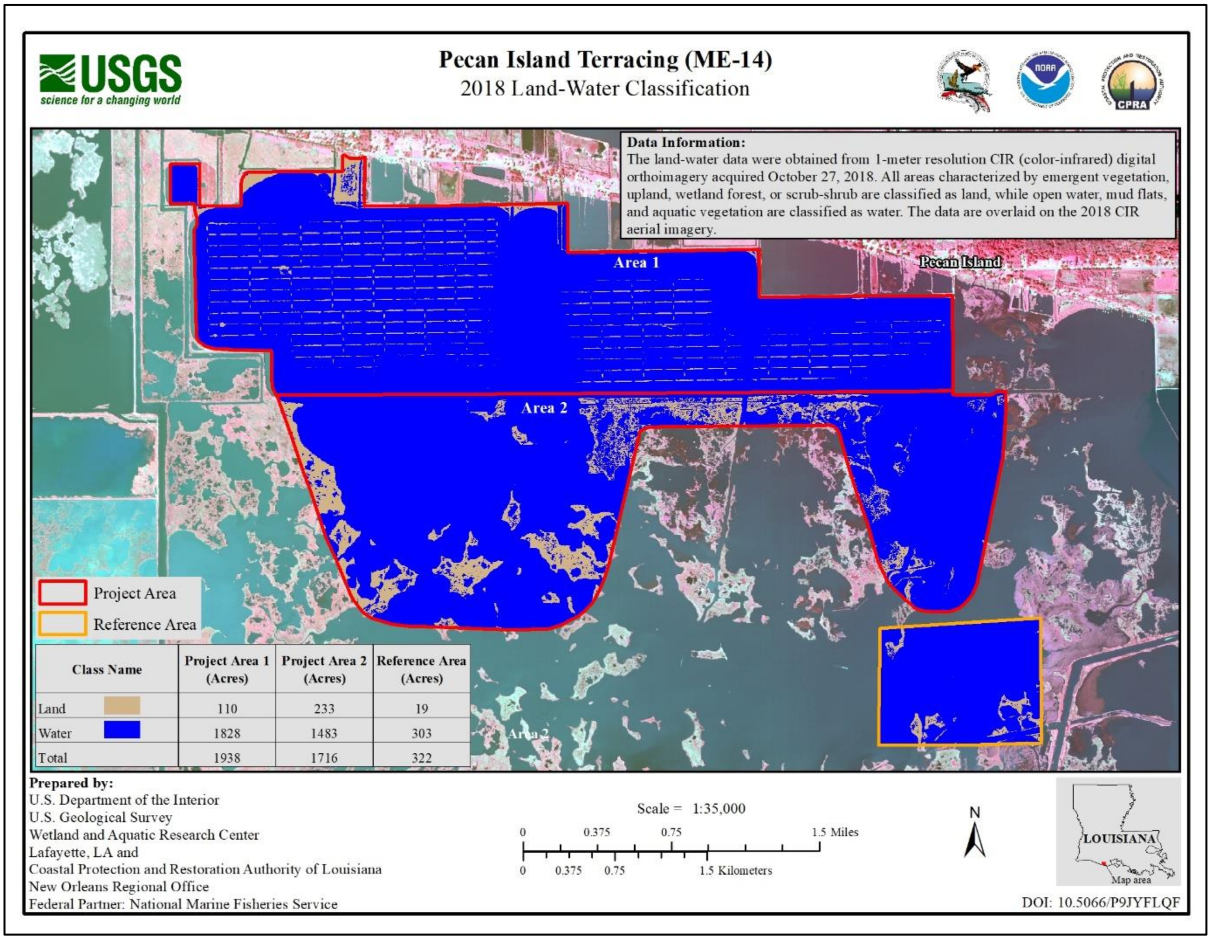

Figure 7. Pecan Island Terracing (ME-14) 2018 Land/Water analysis of the project and reference area. Land area was further broken down into project area and reference area. The vegetated and unvegetated categories from 2004 were removed because all remaining land was vegetated.

Submerged Aquatic Vegetation (SAV)

SAV data was collected in May of 2001, summer 2005, and summer 2020. Pre-construction, the only SAV present in either the project or reference area was an unknown Alga. Post-construction in 2005 pre Hurricane Rita there were several species of SAV in both of the project areas and none in the reference area (Figure 8). The presence and high frequency of occurrence of SAV in both the project areas post construction of greater than 60% without meaningful alterations to the hydrology points to the terraces and their effect on fetch, wind driven waves, and turbidity as the primary cause of SAV quality and quantity (Figure 9). During the same sampling period, the reference SAV transects failed to yield the same results of increased SAV occurrence further strengthening the inference that project features were responsible for increases in the project area. In the reference area non-project terraces were constructed between 2004 and 2005 and did not have a positive impact on SAV during the 2005 data collection effort likely due to the ongoing construction creating turbid water and mechanical disturbances in the area. As of the 2020 sampling there has been extensive damage to the project terraces with several rows of exterior terraces missing in multiple locations and extensive thinning and cut bank formation on most of the interior terraces. The non-project terraces in the reference area were completely gone by this sampling. However, even with this significant damage to the project infrastructure, there was still ample SAV beds present throughout Area 1; Area 2 far less so. The SAV beds were not evenly distributed between terraces or among the terrace fields, but isolated along the edges of the remaining terraces and confined to the most protected areas remaining within the project area (Figure 10). The most commonly occurring SAV in the project area was *Myriophyllum spicatum,* which is a generalist that grows well in disturbed areas, followed by *Ceratophyllum demersum* which was generally found at low levels throughout the project and reference areas in deeper waters, especially in 2020. The project area received frequent salinity spikes from Hurricane Rita in 2005, Ike in 2008, and the drought of 2010-2011 generating salinities near 10 ppt for months at a time. This was followed up by extended fresh water flooding with salinities between 1.5 and 4 ppt for years from 2012 through hurricanes Laura and Delta in 2020. These extremes and fluctuations explain why the generalist *Myriophyllum spicatum* was present in similar frequencies in 2020 as it was 15 years earlier in the 2005 campaign. Overall the project has met its SAV goals by increasing SAV occurrence to near 50% in Area 1 and close to 15% in Area 2 throughout the project life.

An ANOVA was conducted on the presence/absence of SAV species excluding Alga to test the effect of project area (A1, A2, Reference), year (2001, 2005, 2020) and the interaction between the two on SAV cover. The data used for the model were transect cover values (n samples with SAV present/total n samples) with six transects for each project area and three for the reference area. There was a significant difference in SAV presence in the three areas sampled ($F_{2,36}$=4.22, p=0.0225), with Area 1 having a significantly higher percent occurrence than the other locations at 40.7%. Area 2 had 24.9% SAV occurrence and the reference was 1.9% falling far below either of the project areas. The year component of the model was slightly more significant ($F_{2,36}$=6.66, p=0.003), revealing 2005 pre Hurricane Rita as the best time period for SAV occurrence. There was no interaction between Area and Year ($F_{4,36}$=1.72, p=0.167). These results conclude that the areas containing the project terraces (A1) and the area south of the project terraces (A2) are more conducive to the growth of SAV than the reference area and water parameters are generally consistent across the region as a whole, such as in 2005. It is important to note that Ducks Unlimited was actively building their own terraces in the reference area during sampling in 2005 which may have negatively impacted the potential for SAV growth in that area. Also of note is that these terraces were fairly short lived and the vast majority were gone by 2012; only a few pieces protected by existing marsh were present in the reference area during the 2020 sampling effort.

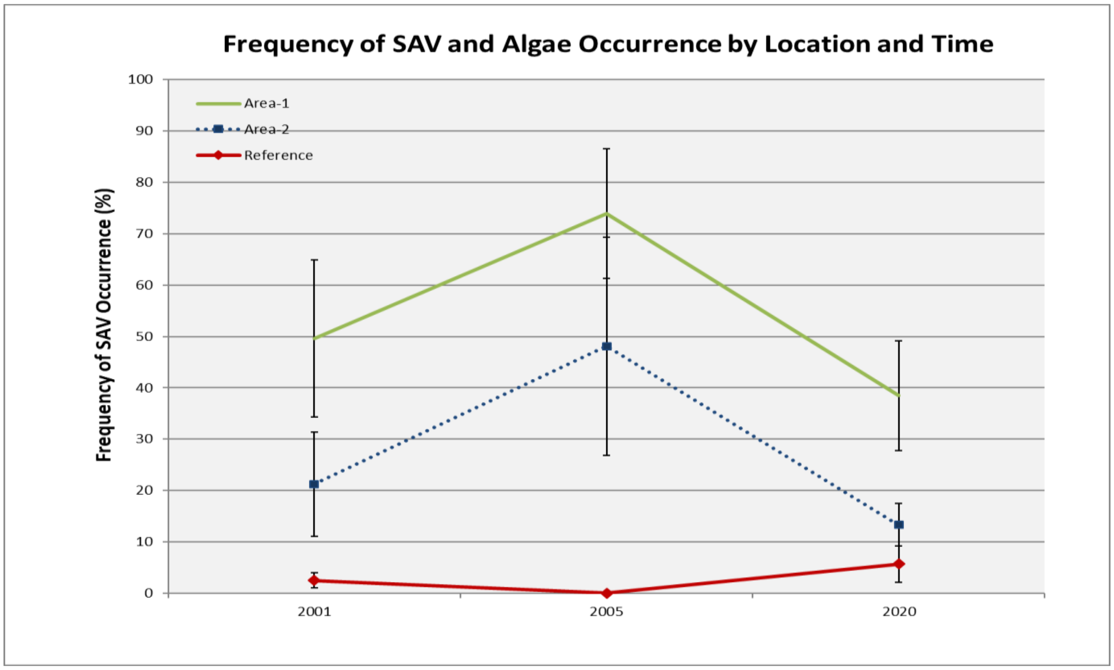

Figure 8. Pecan Island Terracing (ME-14) mean and standard errors for SAV frequency of occurrence in the project and reference areas from pre-project in 2001 to present.

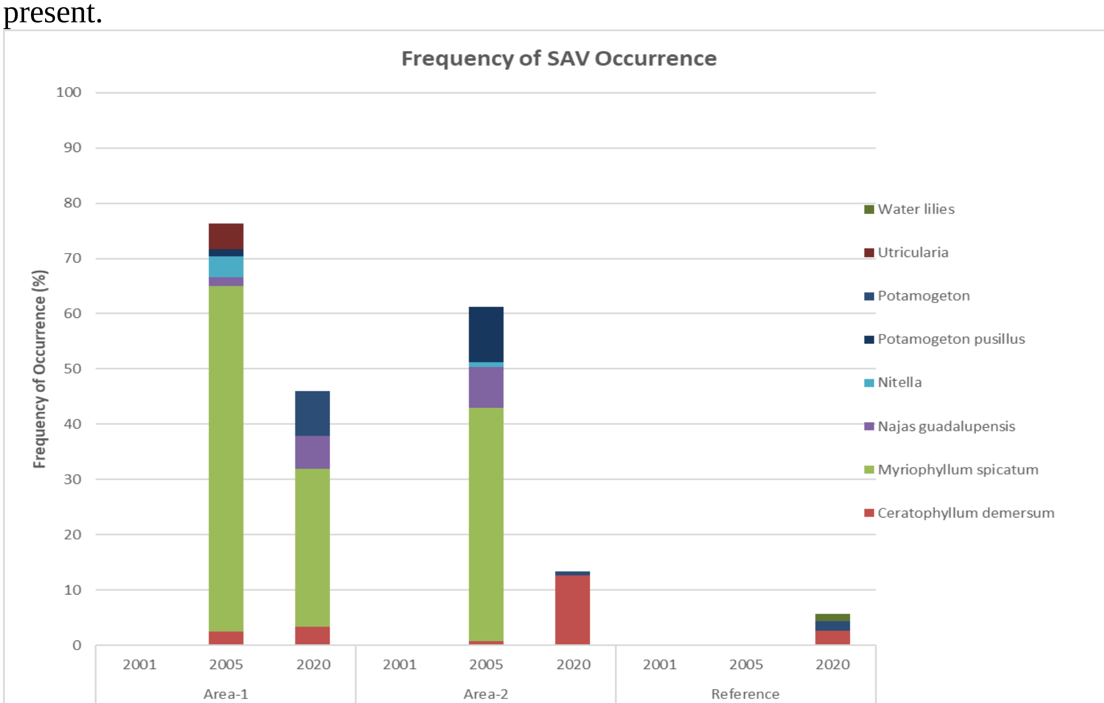

Figure 9. Pecan Island Terracing (ME-14) Percent occurrence of SAV species by sample area collected in 2001, 2005, and 2020. Values are the mean of transect values (n=6) per Area for each year and (n=3) for the reference.

Figure 10. Pecan Island Terracing (ME-14) SAV cover (darker areas) within a protected region of the remaining terrace field. This is in the far western end of the project area taken on 12/1/2017.

Vegetation

Emergent vegetation data was collected on terraces post construction in Sept 2003, twice in 2005 with a second sampling after Hurricane Rita in November 2005, Oct 2007, and in July of 2020. The total cover of emergent vegetation at stations on planted and unplanted terraces was utilized to determine whether initial planting of terraces had an effect on total cover over the project life. Vegetation quickly became established on both planted and unplanted terraces. In general there has not been a large difference in the two terrace types except in Nov 2005 and 2007, which were both a subsample of the total stations (Figure 11). However, this does not indicate the succession that has taken place in the vegetative species present and their dominance. From 2003-2007 *Spartina alterniflora* dominated the planted terraces indicating that there was a well-established vegetative buffer surrounding the terrace protecting the toe from wave energy and edge erosion. During this same period, unplanted terraces were dominated at first by early stage disturbance oriented successional species such as *Cyperus odoratus* and *Panicum dichotomiflorum*, followed by more resilient perennial species like *Spartina alterniflora* and *Paspalum vaginatum* in the following sampling efforts through 2007 (Figure 12). Over the 2003-2007 period, vegetation appeared to be expanding post hurricane Rita down the slopes of the terraces into deeper waters, generally expanding the footprint of the terraces. Sometime, either during or post hurricane Ike, this trend rapidly reversed itself with erosion of outlying terraces and thinning of interior terraces via toe scouring, causing cut bank formation. This was possibly a combined effect of prolonged flooding with stagnant saline waters and mechanical wind and wave driven damage. In any case, the effects of losing this protective vegetative buffer was obvious in 2020 and before, where a vast majority of the stations on either edge of the terrace were in open water with only the crown station remaining dominated by shrubs with distinct cut banks present (Figure 13). There were still some examples of emergent vegetation extending well beyond the original terrace during the 2020 sampling but these were minimal and limited to large stands of mostly *Phragmites australis* or *Typha*, with no trace of the once dominant *Spartina alterniflora* (Figure14).

An ANOVA was conducted on total cover data and included planted/unplanted terraces, sample date, and the interaction of the two to test for the effect these variables had on total cover. The overall effect of planting was not significant ($F_{1,781}$=0.89, p=0.345), suggesting across the life of the project the total cover of vegetation was essentially equal on planted and unplanted terraces. Sample date however had significant consequences on total cover differences ($F_{4,781}$=26.58, p<0.0001), with pre hurricane 2005 and 2007 having the highest total cover at 25.6 and 34.3 percent respectively. The years 2003, post hurricane 2005, and pre hurricane 2020 all had lower and undifferentiated total vegetative cover at 8.4%, 9.8%, and 14.9%. These lower cover years have similar percent total cover but differing reasons for these results. In 2003, cover was low due to the recent completion of construction, while Hurricane Rita on September 24th, 2005 heavily damaged vegetation in the project area which was sampled both before and after. In 2020 the terrace field was reduced in size via erosion and many of the vegetation stations were in open water. The interaction of sample date and planted/unplanted terraces ($F_{4,781}$=3.59, p=0.0063) was statistically significant, as the 2007 sampling date showed the planted terraces (42.46) as higher than the unplanted terraces (26.0). This was the only occurrence of this phenomenon and was likely caused by the still prevalent planted species *Spartina alterniflora* which both recovered and expanded quickly post Hurricane Rita damage.

As expected, neither the planted nor unplanted terraces were similar to the species assemblage in the nearby emergent brackish marches of CRMS0623 (Figure 15) and CRMS1965 (Figure 16), which were both dominated by *Spartina patens* and *Distichlis spicata*, likely do to an elevation difference. However the presence of *Phragmites australis* and *Typha* in later years in the natural marsh was likely do to overall coastal freshening and flooding which is likely also partially responsible for the same response on some terraces where more gradual slopes remained. The coverage of vegetation, overall, spread across all terraces post construction, planted or not, meeting the project goal. This was true even in the face of multiple negative climactic events. Project features have successfully maintained vegetation where elevation remains viable, though this is being reduced rapidly at the end of project life.

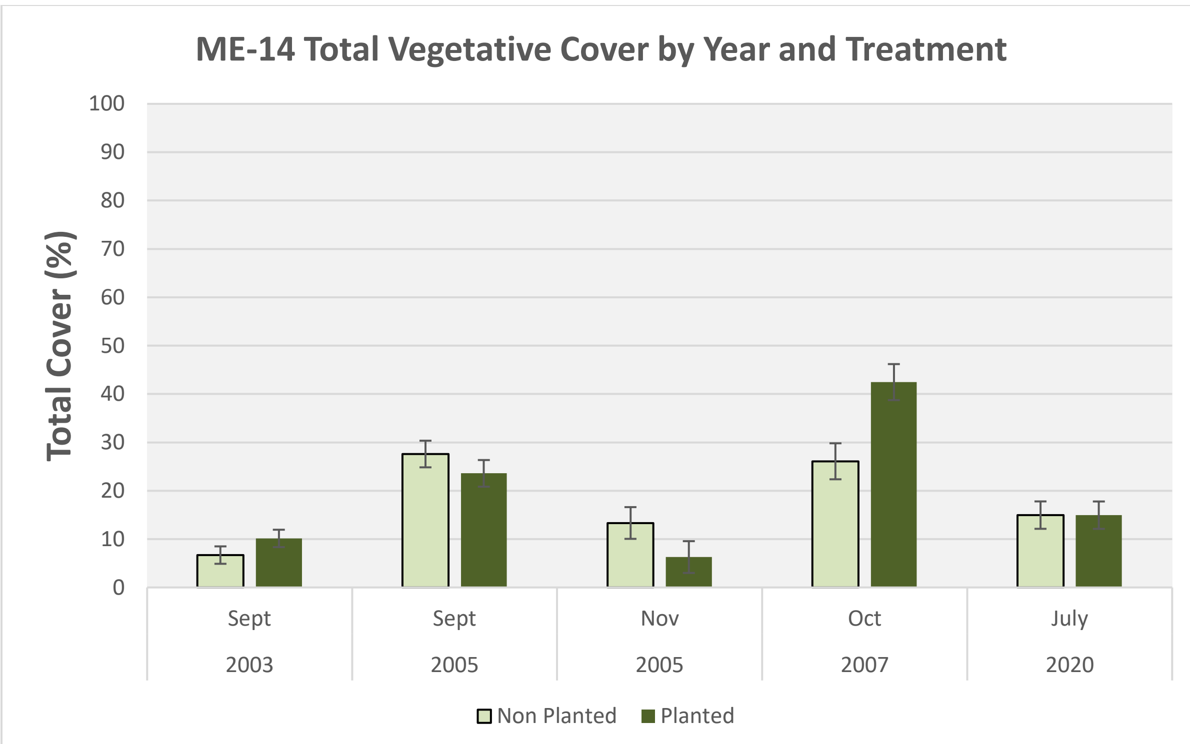

Figure 11. Total percent cover through time for ME-14, averaged across planted and non-planted terraces. Many of the 2020 stations were in open water.

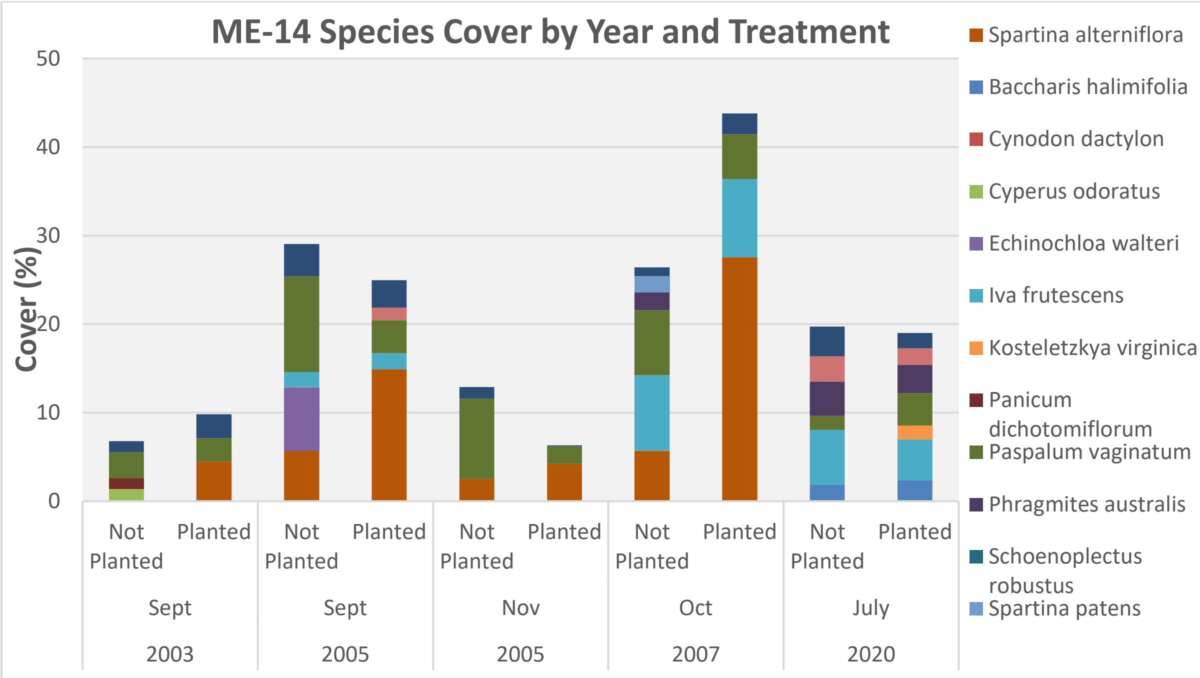

Figure 12. Percent species cover through time for ME-14, averaged across planted and non-planted terraces. Many of the 2020 stations were in open water, and those that were not were higher elevation terrace crowns dominated by shrubs and Phragmites.

Figure 13. Pecan Island Terracing (ME-14) photo from 7-8-2020 of emergent vegetation cover on a thinned and cut bank terrace with a heavy shrub presence. This was a typical terrace.

Figure 14. Pecan Island Terracing (ME-14) Photo from 7-8-2020 of emergent vegetation cover spreading out from a terrace in 2020. This was a rare occurrence.

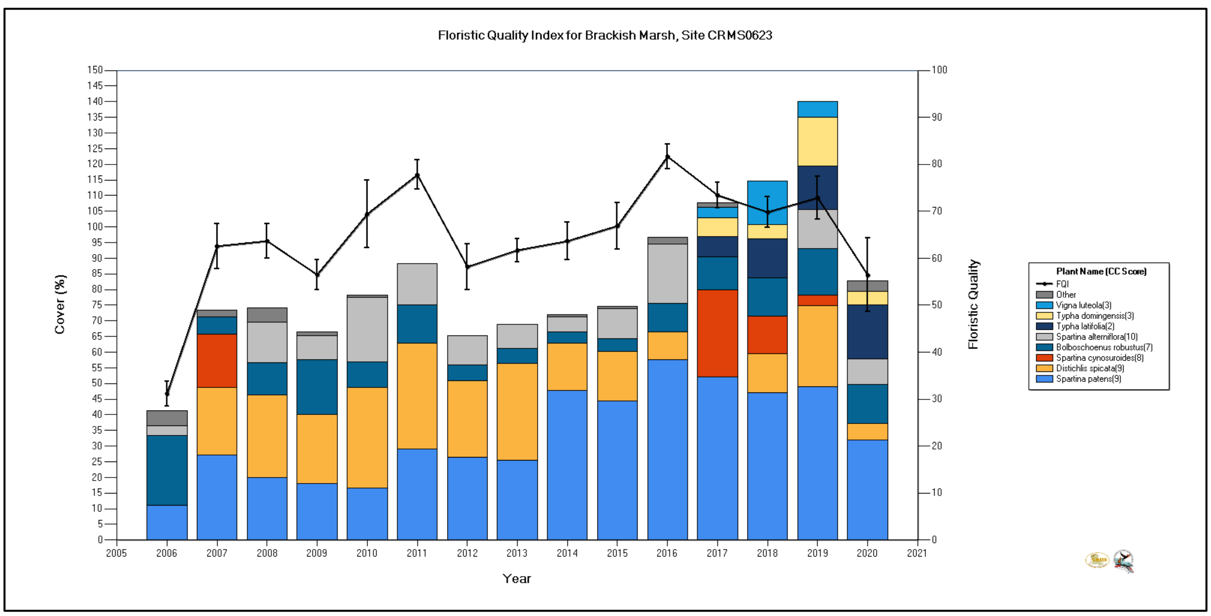

Figure 15. Percent coverage and floristic quality index of species collected from CRMS0623, Area 2, within the project area in years 2006 – 2020, showing fresher species moving in and competing with a more brackish community in recent years.

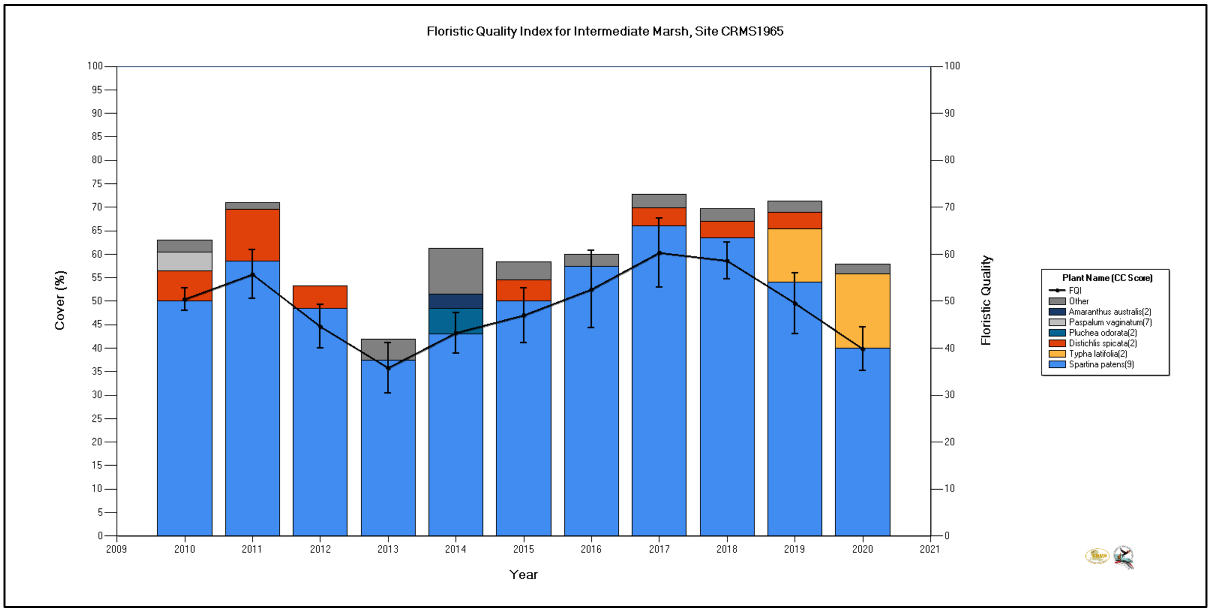

Figure 16. Percent coverage and floristic quality index of species collected from CRMS1965, Area 2, within the project area in 2010 – 2020, showing fresher species moving in and competing with a more brackish community in recent years.

Salinity

The project area surface water salinity as measured at CRMS0623 and CRMS1965 from 2008-2020 has varied meaningfully from well over 10 ppt on a monthly average to under 1ppt over the life of the project. This should not come as a surprise as the project area is in one of the more dynamic areas of the coast, influenced by the fresh Mermentau Lakes Sub basin to the north via the ME-01(Mouledous et al 2016) fresh water introduction project under Hwy82 and the ever present saline GOM to the south. While the GOM's direct effects are muted by the presence of the Rollover Bayou structure and the Freshwater Bayou structure under average water levels, storm surge events carry saline water into the project area which does not drain out efficiently. This is reflected in the interstitial soil salinities remaining high long after surface salinity drops, showing that each over wash event has a long term effect on the project's vegetation and SAV habitat (Figure 17).

Overall, though, salinities have been trending downward since the drought of 2010-2011. However, this pattern is not unique to the project as this trend has been on display coastwide during this timeframe. While the project has no goals related to reducing salinities in the area, salinity along with flooding play a large role in determining which species of emergent vegetation and SAV are present and what is likely to remain long term. Many of the species present during the 2020 vegetation sampling are not as salinity tolerant as the originally planted vegetation and have likely outcompeted it during the fresh flooded decade post drought. This community in combination with the deteriorated condition of much of the project features indicate a return to high salinities would likely be detrimental for the project as the phase of community switching would lead to exposed soil and unvegetated surfaces in this erosive environment.

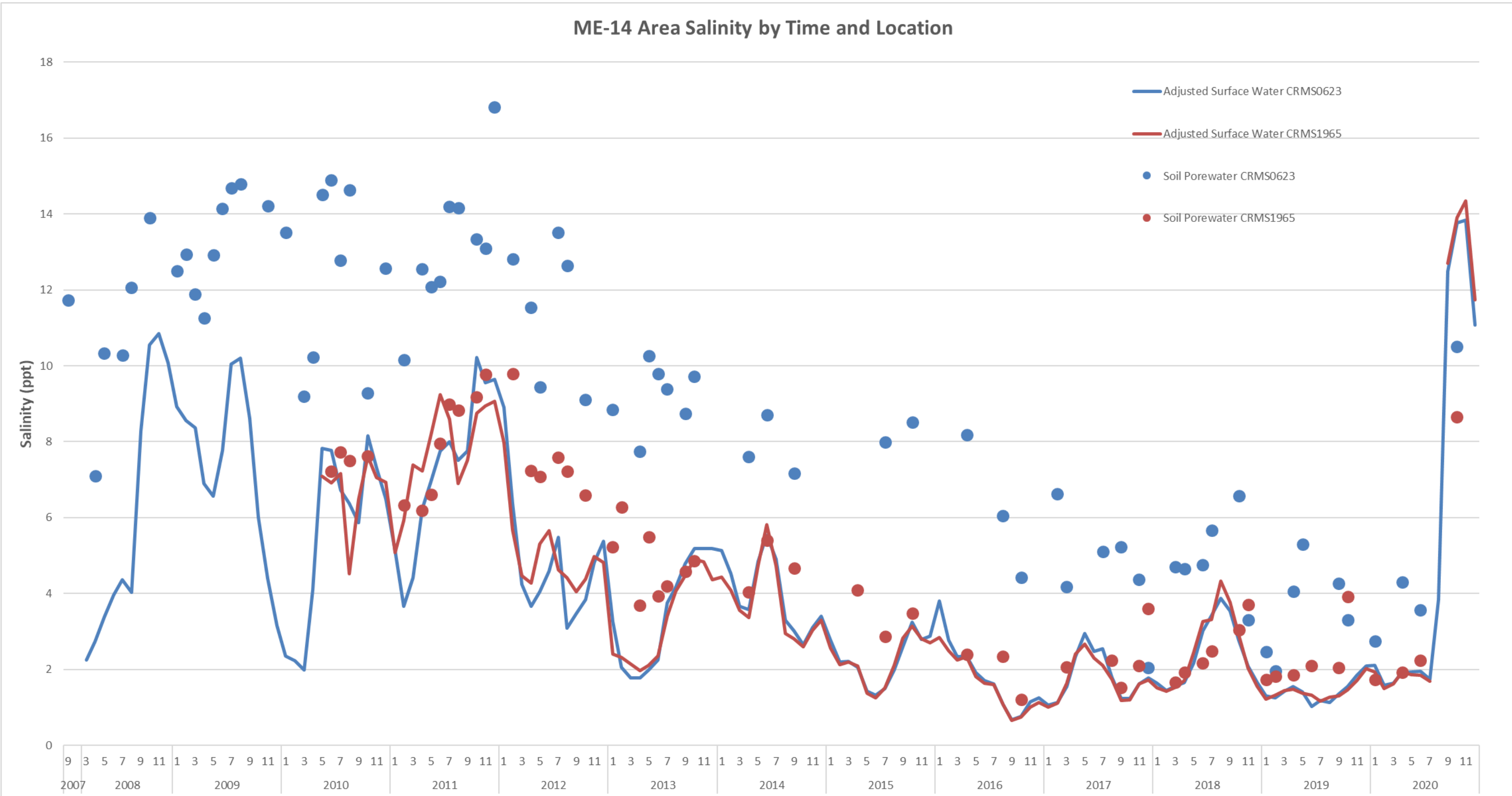

Figure 17. Monthly salinity means from CRMS0623 and CRMS1965 along with interstitial soil salinities at both sites, generally showing a period of high variability and spikes from 2008-2011 followed by a decrease in both variability and salinity until Hurricanes Laura and Delta in fall 2020.

Water Level

Water level and flooding data were collected from 2008-2020 at CRMS0623 and CRMS1965 in project Area 2 (Figure 18). Post-construction, water levels have oscillated through time, seasonally, but persistent rainfall and higher than average GOM since 2015 has increased water levels and reduced salinities throughout the project and reference areas. This persistent flooding and lack of drainage, mixed with moderate soil salinity, may be responsible for the complete loss of *Spartina alterniflora* from the intertidal zone. During saltier epochs *Spartina alterniflora* has little competition in this zone, but as the coast freshened numerous competitors vied for the land water interface niche, chiefly *Phragmites australis* and *Typha*. Both can tolerate short elevated salinity pulses along with significant permanent flooding, combine this with both species' height advantage and the vegetation community completely shifted. The community shift from brackish saline to fresh intermediate was not instantaneous and as vegetation diminished, struggled, and died it was replaced, in some cases within a growing season but generally over several. This, coupled with herbivory and storm surge damage, could have led to the wide spread terrace thinning and cut bank formation seen on so many of the interior terraces.

Four major hurricanes have impacted the project area through the monitoring period, temporarily flooding the project area with up to 10 feet of GOM water: Hurricanes Rita (2005), Ike (2008), and in 2020 Hurricanes Laura and Delta (McGee et al. 2006; East et al. 2008; NOAA Hurricane Laura's Storm Surge 2021).

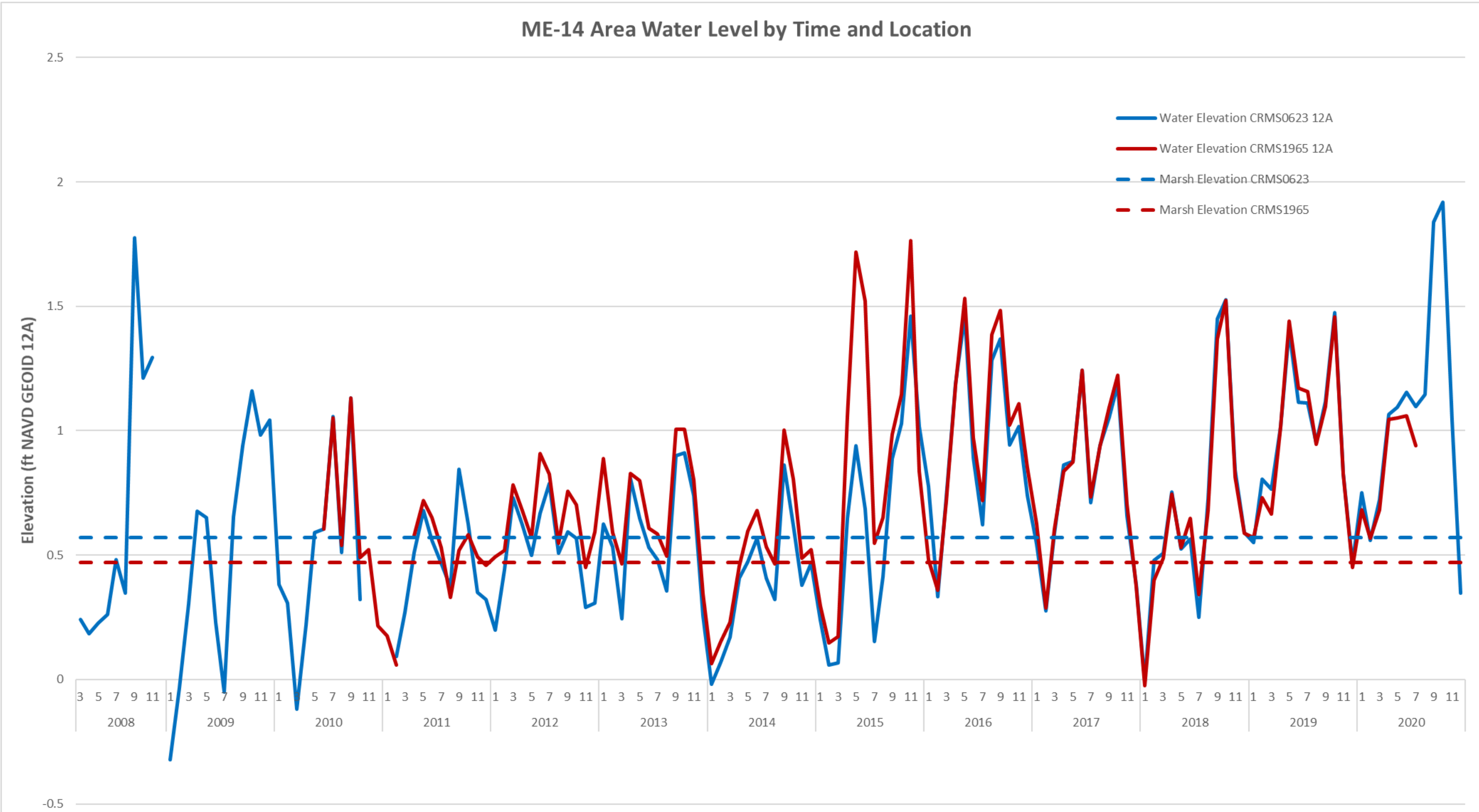

Figure 18. Monthly means of water level data collected post-construction inside (CRMS0623 and CRMS1965) of the ME-14 project area.

Elevation Change

Elevation change and accretion data at the ME-14 project CRMS sites 0623 and 1965 show that the project area has generally gained elevation through time (Figures 19-20). However, these positive gains in elevation occurred under the most persistent high water period in the CRMS hydrologic database and call into question whether these gains are a sign of vegetative response to permanent flooding. Went directly comparing the accretion data to this elevation change both sites show shallow expansion, in which there is considerably more elevation gain than can be explained by accretion. These sites are, however, maintaining elevation when compared to the Sabine Pass NOAA tide gauge sea level rise estimate of 0.6 centimeters per year (Zervas 2009). CRMS0623 and 1965 showed fairly significant positive elevation change rates of 0.64 and 1.44 cm/yr, respectively. This is more likely due to soil expansion, detachment, and buoyant or floating root masses than sedimentation or below root zone peat formation. Which makes these locations more susceptible to hurricane damage than the mineral soils of the project terraces.

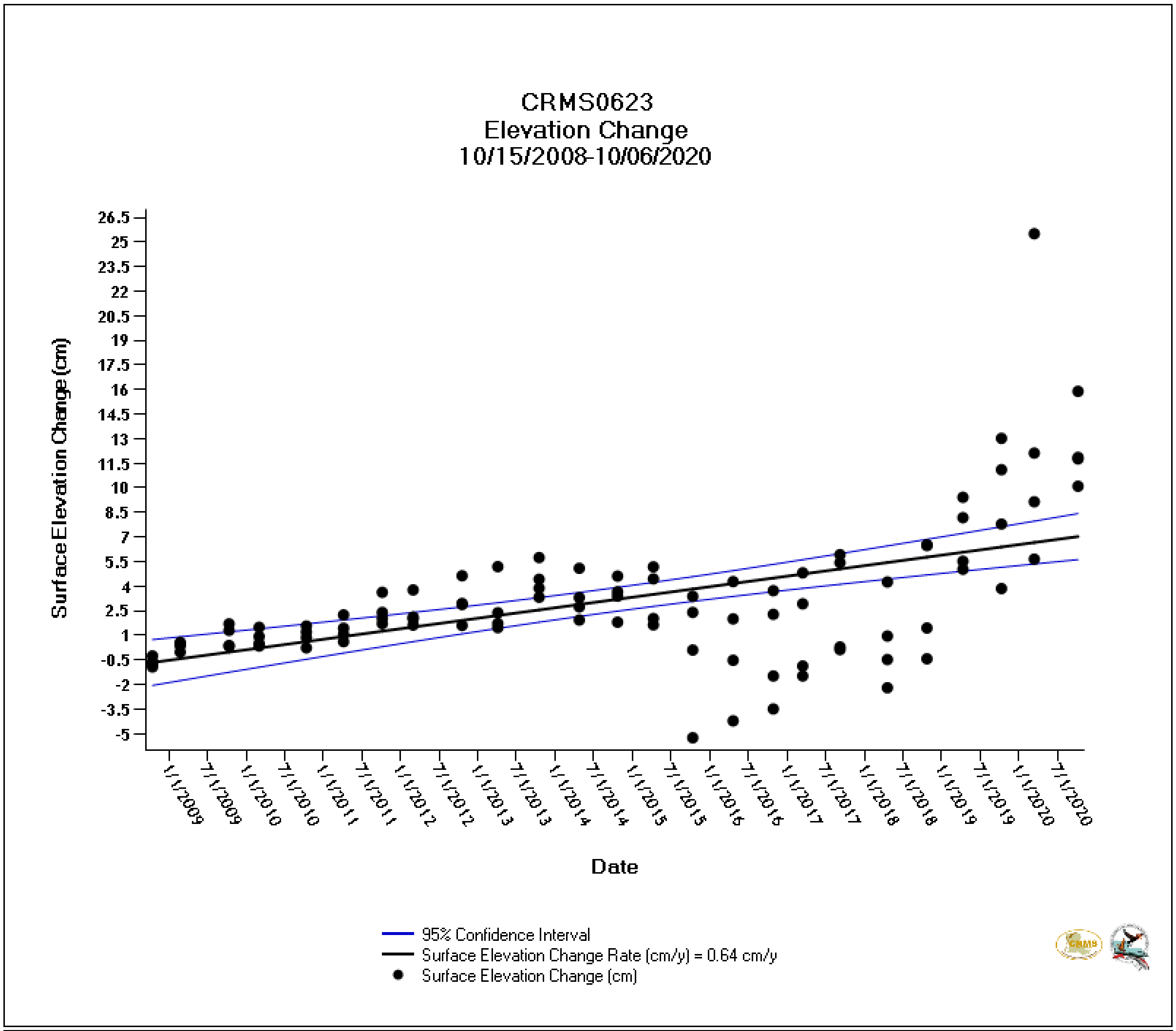

Figure 19. Elevation change per year experienced in the ME-16 project CRMS sites CRMS0623.

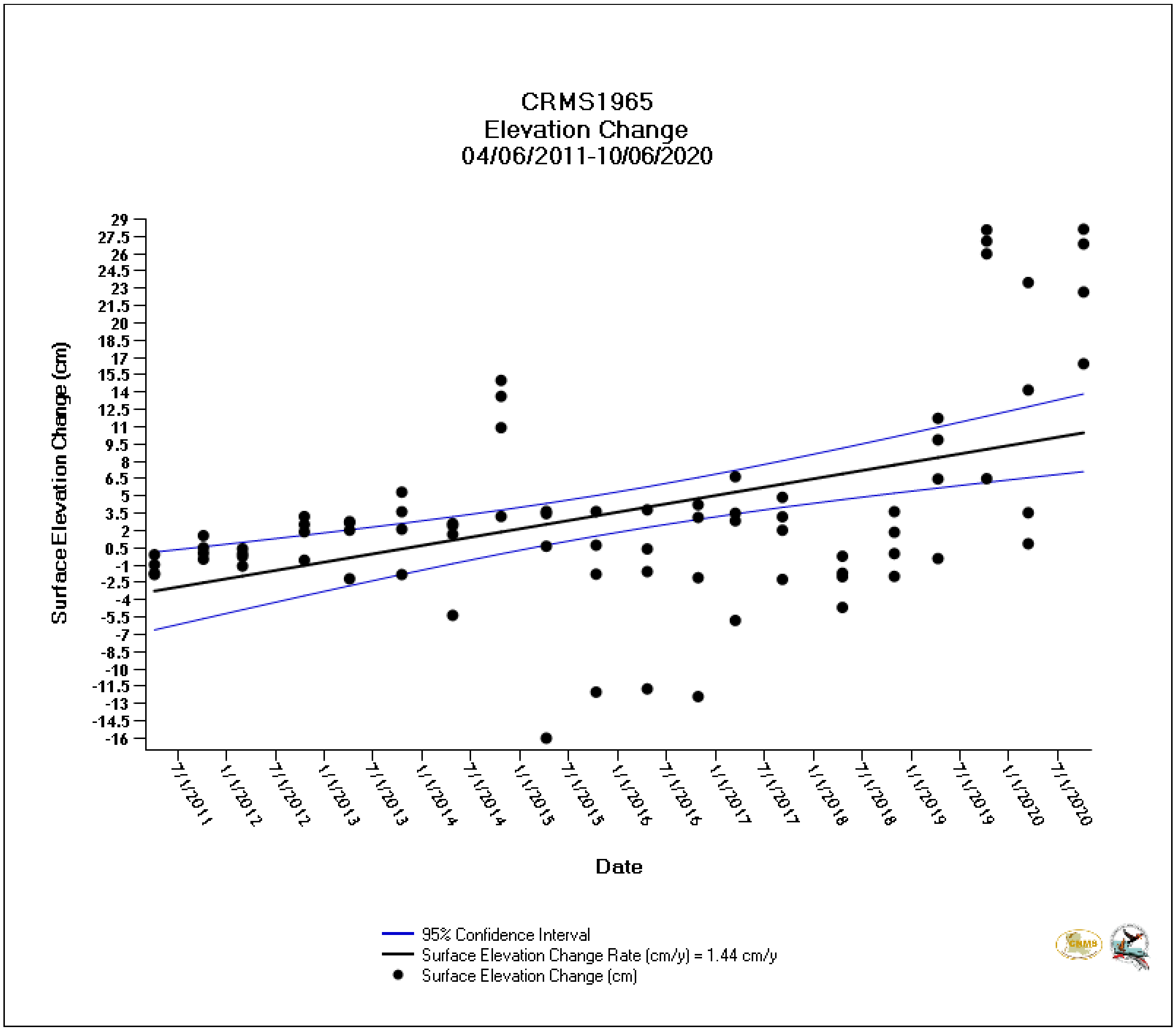

Figure 20. Elevation change per year experienced in the ME-14 project CRMS site CRMS1965.

Soil Properties

Soil samples were collected at each of the CRMS-*Wetlands* sites in the project area (0623 and 1965) in 2008 and again in 2018. The soil properties data were sampled in 4 cm increments. All locations were sampled twice after site establishment. Figures for mean bulk density and percent organic matter (OM%) by CRMS site are presented in Figures 21 and 22. Higher bulk densities occurred at CRMS0623, which would be expected because it is a more intact marsh located on a natural lake rim (Figure 21). This site also had a lower OM% in the 2008 sample; the upper 12 cm of the core is very similar to CRMS1965 in 2018 suggesting some organic peat accumulation as waters rise (Figure 22). Lower bulk densities and higher OM% were found at CRMS1965, which also showed more shrink swell potential in the elevation change data.

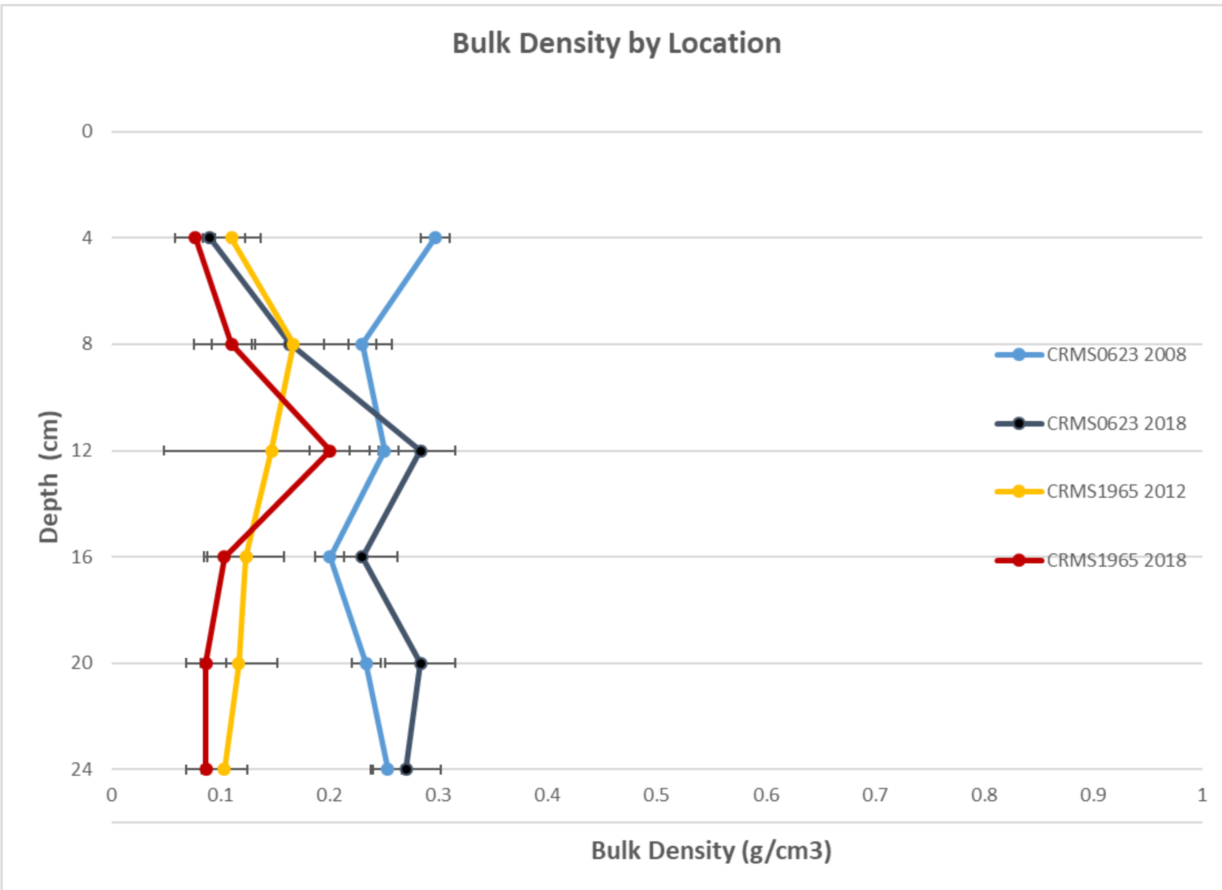

Figure 21. Mean ± 1 Standard error of soil bulk density collected at project and reference CRMS sites.

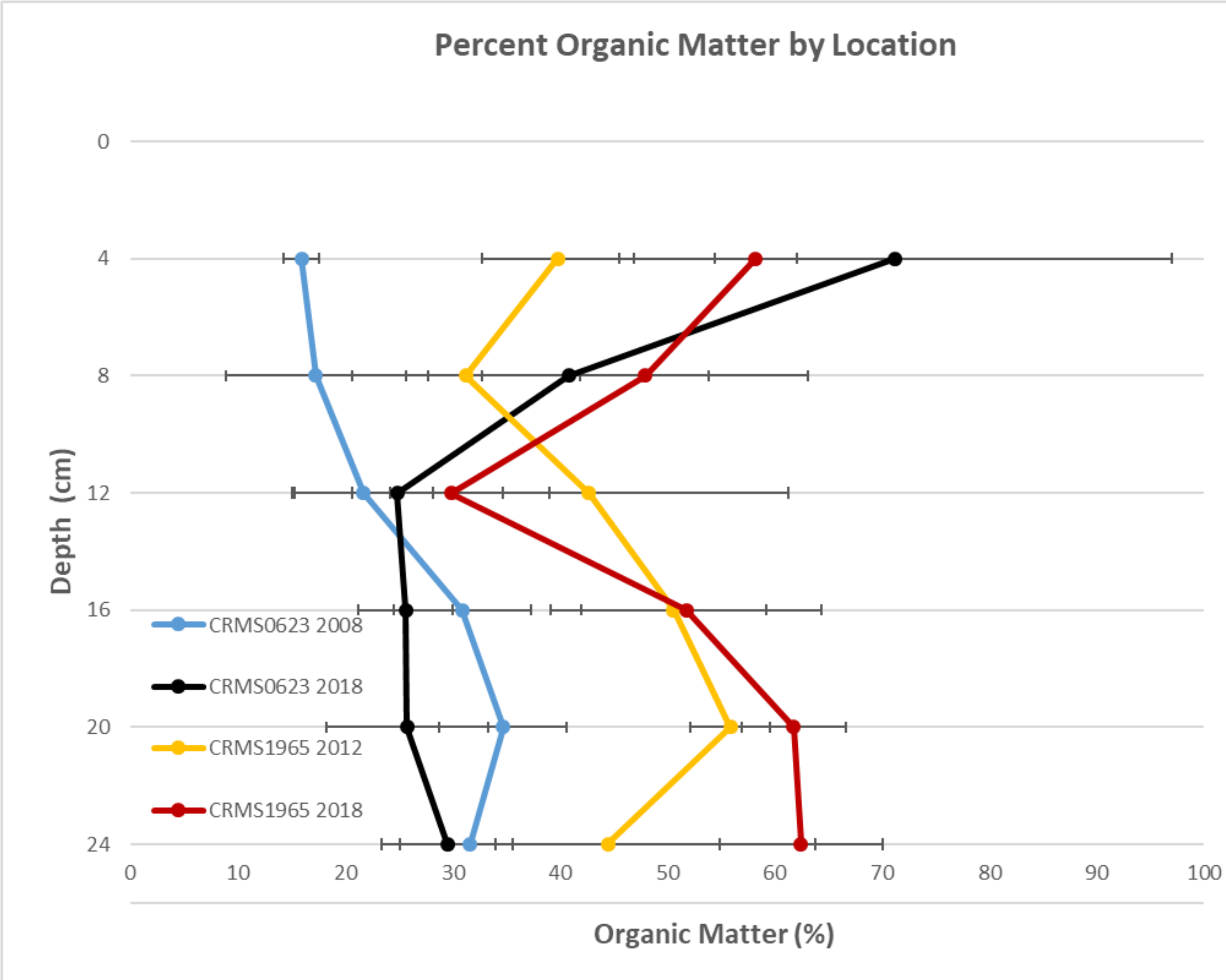

Figure 22. Mean ± 1 Standard error of soil organic matter collected at project and reference CRMS-*Wetlands* sites.

V. Discussion

a. General Discussion

The ME-14 project has provided ample water wetland interface (edge habitat) over its 20 year economic life, while also sustaining a healthy population of submerged aquatic vegetation in the inter terrace waterways. These areas of dampened wind and wave driven fetch provided the conditions necessary for SAV growth and provided habitat for the animals that use this resource. The project area terraces have also maintained healthy emergent marsh vegetation through the project's life, in the face of some historic environmental extremes, namely Hurricanes Rita, Ike, Barry, Laura, and Delta, significant drought in 2011 and high water since 2015. These events all had impacts on the project features and the vegetative response they elicited, and generally these were negative, with hurricane storm surges heavily damaging SAV beds and emergent vegetation on the terraces, while also causing erosion and cut bank formation throughout the project area. The emergent marsh response to the drought conditions of 2011 was likely positive as lower water levels allowed for broader expansion of vegetation into previously flooded areas, which is strongly supported in the CRMS data. However frequent drastic swings in salinity generally negatively affect SAV growth and occurrence as rapid species shifts are required. As such, the 2015-2020 prolonged high freshwater conditions within the project area and the coast as a whole likely provided some stability for the SAV community. The project originally had some land area expansion post construction in 2004 as vegetation thrived and expanded. This, however, came to an abrupt end during the hurricane season of 2005. This event, namely Hurricane Rita, began a cycle of erosion and land loss in the project area that has continued into 2020 and was exacerbated by storms Laura and Delta. As of the final monitoring event, much of the original project area terraces are either missing or badly compromised, with a majority of the remaining terrace field, emergent vegetation, and SAV beds on the western end of the project area as seen in figure 7, 10, and 14. Overall the project has provided habitat, forage, and protection for plants and animals alike, but due to an overall lack of sediment availability in the area and repeated storm surges, it has not been able to maintain land area as anticipated through the end of project life.

This project was expected to create and sustain emergent marsh throughout its 20 year life, however due to multiple hurricanes and the lack of a dependable sediment source, this was not achievable as designed. The terraces appear to be built on too wide of a grid with spacing too far apart; evidence of this is many interior terraces have cut banks on both sides, indicating wind driven fetch across the inter terrace space was a major factor in this project's erosive outcome. It was not just exterior terraces failing and exposing the next layer of terraces to the prevailing winds that drove the entirety of shoreline erosion and cut bank formation in the terrace field. Soils in the area may also be a problem for this technique as the non-project terraces built in the reference area failed in approximately five years. The project features still provide wave reduction to the residence and the highway 82 corridor to the north and the area would be a good candidate for marsh creation using material from the GOM which is approximately 6 miles south. This would provide not only habitat restoration but infrastructure hardening synergistically.

VI. Conclusion

a. Project Effectiveness

Overall, the project has successfully increased emergent marsh in the project area compared to preconstruction, with the creation of 201 acres of terraces. This acreage increased slightly post construction as the established vegetation spread into shallow waters adjacent to the terraces. However, the expansion was short lived as erosive forces in the form of hurricanes and wind born fetch started reducing the terrace acreage, and ultimately with no consistent sediment source from which to recover, the project was not able to sustain land building.

The project successfully established vegetation on both planted and non-planted terraces which had a fairly similar cohort of plant species by fall 2005 and remained similar throughout the project life, ending almost identically in 2020. The planted *Spartina alterniflora* eventually gave way to taller competitors on the terrace crowns, such as *Phragmites australis* and the shrubs *Baccharis halimifolia* and *Iva frutescens.*

Submerged aquatic vegetation was present in the project area pre project and increased by the summer of 2005 post construction. These percent occurrences of SAV were above the targets set by the project, but did not remain at these higher levels as the aforementioned erosive phase of the project started in the fall of 2005 and continued through 2020. However, even with these negative environmental forces, SAV was still present in the project area in 2020. This suggests that the remaining project features still offer some habitat that is conducive to SAV production and growth even under challenging climactic forces.

b. Recommended Improvements

The armoring of the outermost terraces in the project area and reducing the size of open water between terraces would likely lead to an extended functional project life and enhanced project performance over the life of the project. Sacrificial terraces built at the perimeter of a terrace field when exposed to wind and wave energy are designed to fail, but once this has occurred the next group of non-sacrificial terraces is subjected to these same forces and will also fail. By armoring the outer terraces the project features are allowed to function as designed with the reduced disruption from exterior wave energies.

c. Lessons Learned

The terraces were likely built on too wide of a grid with 250 ft spacing being too far apart, this caused many of the terraces to have cut banks on both sides, demonstrating wind driven fetch across the inter terrace space. It was not just exterior terraces failing due to the prevailing winds. Soils in the area may also be a problem for this technique as the non-project terraces built in the reference area failed in approximately five years.

d. End of Project Life

The ME-14 project will likely continue the erosive cycle that has dominated much of the project life post 20 year economic planned effectiveness. However it is expected that some isolated areas of the project terraces will likely remain long after, specifically on the western side of the project area and other smaller pockets of terraces protected by existing marsh. No maintenance is expected to be performed and the project features will be allowed to naturally degrade through time, maintaining some of the originally intended project functions as this occurs.

VI. Literature Cited

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APPENDIX A
(Inspection Photographs)

Photo No. 1, Typical intact terrace with health vegetation. (2015)

Photo No. 2, Typical intact terrace with health vegetation. (2015)

Photo No. 3, Typical thinning eroding terrace with health vegetation. (2015)

Photo No. 4, Typical thinning eroding terrace with health vegetation. (2015)

Photo No. 5, Typical intact terrace with health vegetation. (2015)

Photo No. 6, Typical intact terrace with stressed vegetation. (2015)

Photo No. 7, Typical intact terrace with stressed vegetation. (2015)

APPENDIX B
(Three Year Budget Projection)

PECAN ISLAND TERRACING/ ME-14 / PPL 7

Three-Year Operations & Maintenance Budgets 07/01/2022 - 06/30/2024

Project Manager	O & M Manager	Federal Sponsor	Prepared By
Mel Guidry	*Mel Guidry*	*NMFS*	*Mel Guidry*

	2022/2023 (-19)	2023/2024	
Maintenance Inspection			$ -
Structure Operation			
State Administration	$14,500.00	$ 2,000.00	$ -
Federal Administration		$ -	$ -
Maintenance/Rehabilitation			

17/18 Description:

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

18/19 Description:

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

19/20 Description:

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

	2022/2023 (-19)	2023/2024	0
Total O&M Budgets	$ 14,500.00	$ 2,000.00	$ -

O &M Budget (3 yr Total)	**$ 16,500.00**
Unexpended O & M Budget	**$ 26,471.46**
Remaining O & M Budget (Projected)	**$ 9,971.46**

OPERATION AND MAINTENANCE BUDGET WORKSHEET

PECAN ISLAND TERRACING PROJECT / PROJECT NO. ME-14 / PPL NO. 7 / 2023/2024

DESCRIPTION	UNIT	EST. QTY.	UNIT PRICE	ESTIMATED TOTAL
O&M Inspection and Report	EACH	0	$0.00	**$0.00**
General Structure Maintenance	LUMP	0	$0.00	**$0.00**
Engineering and Design	LUMP	0	$0.00	**$0.00**
Operations Contract	LUMP	0	$0.00	**$0.00**
Construction Oversight	LUMP	0	$0.00	**$0.00**
ADMINISTRATION				
CPRA Admin.	LUMP	1	$2,000.00	$2,000.00
FEDERAL SPONSOR Admin.	LUMP	0	$0.00	$0.00
SURVEY Admin.	LUMP	0	$0.00	$0.00
OTHER				$0.00
			TOTAL ADMINISTRATION COSTS:	**$2,000.00**

MAINTENANCE / CONSTRUCTION

SURVEY

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

GEOTECHNICAL

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

CONSTRUCTION

CONSTRUCTION DESCRIPTION:						
	Rip Rap	LIN FT	TON / FT	TONS	UNIT PRICE	
	Rock Rip rap	0	0.0	0	$0.00	$0.00
	Aggregate Surface Course	0	0.0	0	$0.00	$0.00
		0	0.0	0	$0.00	$0.00
	Filter Cloth / Geogrid Fabric		SQ YD	0	$0.00	$0.00
	Navigation Aid		EACH	0	$0.00	$0.00
	Signage		EACH	0	$0.00	$0.00
	General Excavation / Fill		CU YD	0	$0.00	$0.00
	Dredging		CU YD	0	$0.00	$0.00
	Sheet Piles (Lin Ft or Sq Yds)			0	$0.00	$0.00
	Timber Piles (each or lump sum)			0	$0.00	$0.00
	Timber Members (each or lump sum)			0	$0.00	$0.00
	Hardware		LUMP	0	$0.00	$0.00
	Materials		LUMP	0	$0.00	$0.00
	Mob / Demob		LUMP	0	$0.00	$0.00
	Contingency		LUMP	0	$0.00	$0.00
	General Structure Maintenance		LUMP	0	$0.00	$0.00
	OTHER				$0.00	$0.00
	OTHER				$0.00	$0.00
	OTHER				$0.00	$0.00
					TOTAL CONSTRUCTION COSTS:	**$0.00**

TOTAL OPERATIONS AND MAINTENANCE BUDGET: $2,000.00

APPENDIX C
(Field Inspection Notes)

MAINTENANCE INSPECTION REPORT CHECK SHEET

Project No. / Name:Pecan Island Terracing ME-14

Date of Inspection: June 30, 2015 Time: 11:00 am

Structure No.

Inspector(s):Mel Guidry (CPRA)
John Foret (NMFS)

Structure Description: Earthen Terraces

Water Level @ PVC Wall:

Type of Inspection: Annual

Weather Conditions: Partly Sunny and Warm

Item	Condition	Physical Damage	Corrosion	Photo #	Observations and Remarks
Steel Bulkhead / Caps	N/A				
Steel Grating	N/A				
Stop Logs	N/A				
Hardware	N/A				
Timber Piles	N/A				
Timber Wales	N/A				
Galv. Pile Caps	N/A				
Vegetation	Good				Good coverage of Spartina alterniflora, Spartina patens, Baccharis. A few spots of Roseau Cane.
Signage /Supports	N/A				
Rip Rap (fill)	N/A				
Earthen Terraces	Good			1,2	Two rows on west sourthernmost field of terraces are eroded below water surface. Portion of first row on east southernmost field of terraces is eroded below water surface. There is good vegetation on terraces. Northern side of each individual terrace is experiencing some erosion.

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