**State of Louisiana**

**Coastal Protection and Restoration Authority (CPRA)**

# 2023 Operations, Maintenance, and Monitoring Report

for

# Oyster Bayou Marsh Restoration

State Project Number CS-0059
Priority Project List #21

April 2024
Cameron Parish

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**Suggested Citation:**

Wood, B. and Boudreaux, J. 2023. *2023 Operations, Maintenance, and Monitoring Report for Oyster Bayou Marsh Restoration (CS-0059),* Coastal Protection and Restoration Authority of Louisiana, Lafayette, Louisiana. 52 pp and appendices.

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For
Oyster Bayou Marsh Restoration (CS-0059)

Table of Contents

## Preface

This report includes monitoring data collected through December 2022, and the maintenance inspection through October 2023. The Oyster Bayou (CS-0059) project is a 20-year Coastal Wetlands, Planning, Protection, and Restoration Act (CWPPRA, Public Law 101-646, Title III, Priority List 21) project administered by the National Oceanic and Atmospheric Administration / National Marine Fisheries Service (NMFS) and the Coastal Protection and Restoration Authority of Louisiana (CPRA).

The 2023 report is the 1st in a series of reports. These reports will be made available for download at the following website: http://cims.coastal.la.gov/.

## I. Introduction

The Oyster Bayou Marsh Restoration Project (CS-0059) is located in the Calcasieu Sabine Basin west of the Calcasieu Ship Channel, south of the west fork of the Calcasieu River, and less than two tenths of a mile north of the Gulf of Mexico in Cameron Parish (Figure 1). The project encompasses 1105 acres, which consist of approximately 836 acres of confined marsh creation, 13 acres of unconfined marsh creation, 96 acres of unconfined nourished marsh, and 9,000 linear feet (15.5 acres) of terraces within the project boundary. The remaining acreage was mainly shallow open water in the northwestern corner of the project area. Additional construction features included 11,637 linear feet of trenasses (excavated pre-construction to -2.5 ft.) as well as 2,769 linear feet of secondary containment dikes. The secondary containment dikes along with natural containment were utilized to construct three (3) ponds within MCA 1 and MCA 3. The project is co-sponsored by the National Oceanic and Atmospheric Administration / National Marine Fisheries Service (NMFS) and the Coastal Protection and Restoration Authority of Louisiana (CPRA).

Approximately 133,343 acres (28%) of the Calcasieu Sabine hydrologic basin wetlands were lost to open water from 1932 to 2010 with an average loss rate of -1710 ac/yr (-1.3%/yr) due to impoundments and pond enlargement, saltwater intrusion into historically fresher wetlands from the Calcasieu Ship Channel (CSC), hurricane damage (Couvillion et al. 2011), and subsidence. Land loss in the project area has been continuous throughout this time frame but was punctuated by high loss rates during the hurricanes of 2005, 2008 and 2020. The Calcasieu-Sabine Basin lost 28 square miles (17,920 acres) (4.4%) as a result of Hurricane Rita (Barras et al. 2006). While land was lost in the project area during this event, continued interaction with the Gulf of Mexico via the Calcasieu Ship Channel has also played a large role in land loss from salinity, flooding, and sediment export.

The Calcasieu-Sabine basin has experienced anthropogenic hydrologic modifications over time. The Calcasieu Ship Channel was maintained to a 5-foot depth and 80-foot width beginning in 1874. In 1903, the CSC was deepened to 13-feet and widened to 250-feet. Finally, in 1968, the channel was widened to 400 feet and dredged to the current minimum depth of 40-feet. Prior to dredging the CSC, a 3.5-foot shoal was present at the mouth of the Calcasieu River, which mitigated the effects of saltwater and tidal inflow into the basin. When this bar was removed in 1874 and the CSC was continually widened and deepened, saltwater and tidal intrusion into the basin increased. This resulted in catastrophic marsh loss, tidal export of

organic marsh substrate, and an overall shift to more saline habitats in the region (USDA 1995). Several water control structures have been installed in the region to minimize salt water intrusion from the CSC into surrounding wetlands. Though these structures and features are successful in mitigating some effects of salinity on the marsh, they also increase the depth and duration of flooding in the interior marshes. Therefore, management plans have been employed to implement operational regimes that maintain appropriate salinity levels while also attempting to minimize flooding. However, Oyster Bayou, which directly impacts the project area via Oyster Lake, is minimally restricted (CPRA Master Plan 2012). As hydrology in this area has been modified, habitats have shifted to a more pedestaled broken marsh with minimal live below ground root production, resulting in increased susceptibility to tidal energy and storm damages. Habitat shifts can affect marsh productivity temporarily, while hydrologic stress productivity reduction is chronic and usually permanent, a critical component of vertical accretion in wetlands (Gosselink et al, 1979).

Three dominant freshwater sources including the Calcasieu, Sabine, and Neches rivers inflow into this region. Both the Calcasieu and Sabine rivers follow a north-south alignment, whereas the Neches River flows into the Sabine Lake from the northwest. In addition to these, a westward flow occurs via the GIWW and existing canals on the Sabine National Wildlife Refuge. Thus the hydrology in this area is greatly affected by freshwater river flows, the Gulf of Mexico tide, precipitation, and wind direction. The area is underlain by saline marsh deposits of the Holocene, consisting of gray to brown to black clay with silt with moderate to high organic content. Further south, the saline marsh is mixed with cheniers consisting of white to light gray fine sand and shell fragments. According to the Cameron Parish Soils Survey, the soils in the project area are equally composed of Bancker and Clovelly series. The Bancker series is found along the historic Calcasieu Lake rim while the Clovelly series is found in the interior marshes of the project area. Both series are very fluid organic soils typically found in poorly drained and ponded areas. Both soils support native vegetation and are considered well suited for wildlife habitat (USDA 1995).

According to The United States Geological Survey (USGS), the project area is saline marsh with the vegetation typically dominated by *Spartina alterniflora* and *Distichlis spicata* (Sasser et al. 2014). There is limited biological data that exists prior to 1930; however, subsequent surveys and studies have found evidence that indicates the area was considerably fresher than it is presently (Calcasieu-Sabine Basin Report). A survey from 1951 shows that sawgrass covered approximately 475 $mi^2$ of Cameron Parish and was the dominant vegetation type in the area. Sawgrass can tolerate salinities between 0 and 2 parts per thousand (ppt). In addition to sawgrass, cypress trees can be dated back to the 1930s. Cypress trees can also tolerate salinities up to 2 ppt. Along with vegetation surveys, local agricultural practices and industries support the records that the Calcasieu-Sabine Basin was historically fresher. In the late 1800s and early 1900s, water from Calcasieu Lake was used in irrigation of rice fields, which can only tolerate salinities up to 0.6 ppt. Also, the lower region of Calcasieu Lake was marginal habitat for oysters; however, where oysters once only occupied the lower portion of the Lake, oysters are now found throughout much of the lake bottom (Thompson et al. 2014).

A region wide die-off of sawgrass and other freshwater and intermediate vegetation occurred from the 1950s through the early 1960s. Hurricane Audrey made landfall at Cameron, Louisiana, on June 15, 1957. The significant shift in habitat cannot be solely attributed to

Audrey, but evidence suggests that Audrey struck an ecosystem that was already weakened by hydrologic alterations at CSC, the GIWW, and the Sabine-Neches channel. The combined effects of altered basin hydrology, saltwater intrusion, flooding, storms, droughts, and oilfield activity is the likely cause of the significant habitat shift of the basin (Gosselink et al 1979).

The purpose of the CS-0059 project is to create sustainable emergent marsh through the use of dredged sediments from an offshore borrow site in the Gulf of Mexico. The project restored saline marsh habitat in areas converted to open water via the above mentioned mechanisms. The project also created 9,000 linear feet of earthen terraces to reduce fetch and slow tidal forces. The project will aid in the prevention of further interior land loss by reinforcing the gulf shoreline, possibly avoiding a breaching event and reducing excessive tidal exchange from the Calcasieu Ship Channel through Oyster Lake and Oyster Bayou into the project and surrounding areas. The benefits provided by the project include the re-creation and nourishment of degraded wetlands that provide important wetland habitat for wildlife and the enhancement of storm protection for inland areas. The project will work in conjunction with other projects in the area to reduce saltwater intrusion, tidal exchange, and erosion within the Calcasieu Sabine Basin; specifically the beach nourishment project directly south of the project area, Cameron Parish Shoreline Restoration Project CS-0033 and Mud Lake CS-0020 (Figure 2A and B).

In order to meet the project goals of a marsh elevation that is comparable to the marsh elevation of nearby healthy marsh, 1.0 ft NAVD88 (Geoid 12A) was identified as the target marsh elevation inundated between 10% - 80% of the time. Approximately 6.7 million cubic yards of dredging material was available from a borrow site located approximately six miles offshore in the Gulf of Mexico. By 2018 roughly 4.9 million cubic yards of the dredge material was placed into the marsh creation cells north of Highway 82 and the Gulf of Mexico shoreline and south of Oyster Lake, to restore and nourish 836 acres of saline marsh (Figure 3). The borrow site was selected to avoid and minimize impacts to offshore infrastructure and sensitive aquatic habitats. The sediment was transported into the project area from the borrow site under Highway 82 via a permanently installed culvert. The permanent culvert will offer access under the Highway for future projects as a permanent pipeline right of way allowing further restoration of this critical transportation corridor. The project will result in approximately 680 net acres of saline marsh over the 20-year project life.


**Figure 1.** Oyster Bayou Marsh Restoration (CS-0059), Cameron Parish Shoreline Protection (CS-0033), and Mud Lake (CS-0020) project areas, features, and area CRMS sites.

**Figure 2A.** Gulf of Mexico shoreline before construction of the Cameron Parish Shoreline Restoration Project (CS-0033); beach erosion had reached HW 82 at the southern margin of the Oyster Bayou project area.

**Figure 2B.** Gulf of Mexico shoreline after construction of the Cameron Parish Shoreline Restoration Project (CS-0033).

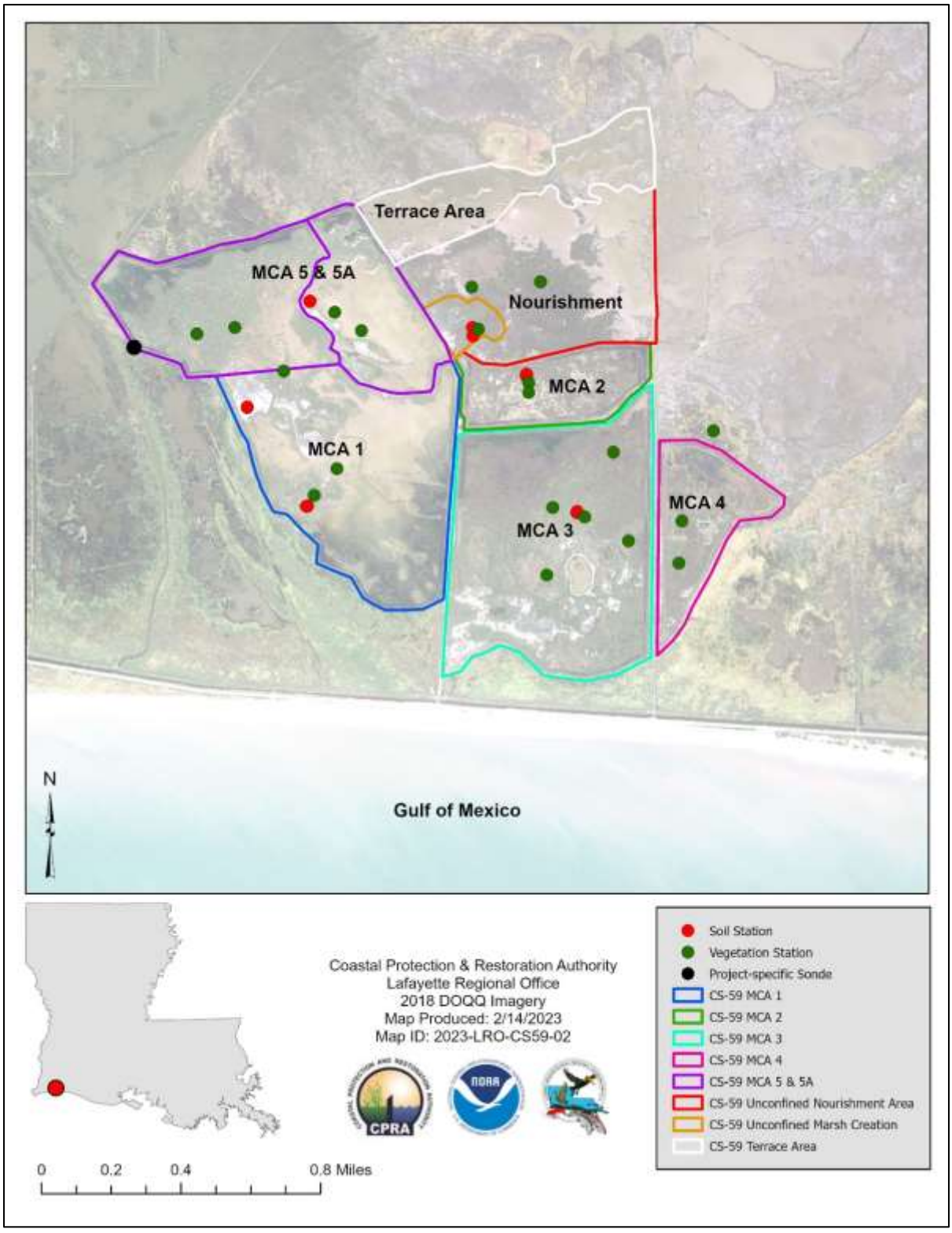


**Figure 3.** Oyster Bayou Marsh Restoration (CS-0059) project features and monitoring locations. The unconfined nourishment and unconfined creation area are combined in this report due to a continuous elevation gradient as one delineated area transitions into the other.

## II. Summary of Annual Inspection Report

### a. Inspection Purpose and Procedures

The purpose of the inspection of CS-0059 is to evaluate the constructed project features to identify any deficiencies, and prepare a report detailing the condition of project features and recommended corrective actions needed. Should it be determined that corrective actions are needed, CPRA shall provide, in the report, a detailed cost estimate for engineering, design, supervision, inspection, and construction contingencies, and an assessment of the urgency of such repairs (Aucoin 2020). The inspection report also contains inspection photos, a summary of maintenance projects which were completed since completion of constructed project features, an estimated projected budget for the upcoming three (3) years for operation, maintenance and rehabilitation, and an inspection checklist. Photographs are included in **Appendix A**. The three (3) year projected operation and maintenance budget is shown in **Appendix B**. A summary of past operation and maintenance projects completed since completion of CS-0059 are outlined in **Section II.b**.

An inspection of CS-0059 was held on November 3, 2023 under cloudy skies and cool winter temperatures. In attendance were Jacques Boudreaux and Bernard Wood of CPRA and Donna Rogers of NOAA. The annual inspection began at the entrance gate at the southern end of the CS-0059 marsh creation area, near the southernmost extents of MCA3.

### b. Summary of Past Operation and Maintenance Projects

To date, no completed maintenance projects nor operation tasks have been performed since the CS-0059 construction completion date of January 2019.

### c. Inspection Results

Marsh Creation Areas

The marsh creation and nourishment areas appear to be recruiting and maintaining healthy emergent vegetation consistent with saline marshes. During construction, portions of the CS-0059 marsh creation cells were pumped very high, less marsh creation material was required to construct the project than estimated in the project design, which resulted in an underrun of the contract quantity. After target elevations and allowable construction tolerances for marsh fill were met the construction team decided to pump additional material into the MCA 5A, additional material was also allowed to flow over a low-level weir into the unconfined nourishment area. During design of CS-0054, additional project features included three (3) duck ponds encircled by remnant marsh and containment dikes built with in situ material, as well as a total of 11,637 linear feet of trenasses positioned to provide hydrologic connectivity to the pond features. See figure 4A below for an example of present-day conditions of the duck pond and trenasse features, with more information available in APTIM 2019. Despite the high pump elevations and the settled elevation existing above design settlement curve for this point in its post construction lifespan, significant expanses of marsh vegetation were observed during the November 2023 inspection. In addition to the November inspection, emergent vegetation data was collected in the years leading up to the inspection, with onsite observations and vegetation data analysis showing saline marsh species proliferating in the area. Several end-of-construction-phase dike gapping locations were also observed, which appear to be functioning properly, and in some cases exhibiting signs of natural hydrologic exchange. While still early to tell, the CS-0059 team has observed at least one location likely to

recommend for additional dike gapping, which is located between MCA1 and MCA5, as the CS-0059 team recommends surveying to more accurately identify locations to be considered for additional dike gapping via future maintenance events. See photos in **Appendix A**.

Terrace Field

The terrace field north of MCA5 and the unconfined area appears to be functioning properly. Large expanses of marsh vegetation were seen to exist here, making the terraces themselves difficult to distinguish within the immediate vicinity—a sign of properly functioning terrace features and validating the terracing/nourishment approach used near this area during construction. No additional action is required here at this time. The CS-0059 team intends to recommend survey data is collected here during future data collection efforts supporting upcoming maintenance activity, though not the priority for the survey data collection event. See photos in **Appendix A**.

Additional Observations

The condition of Oil Field Road was observed during the site visit and inspection, and observed to be in proper working order. Several dike gapping locations were visited, and in particular the ones observed on the eastern side of the project appeared to be promoting proper hydrologic exchange. See photos in **Appendix B**.

### d. Inspection Conclusions and Recommendations

Marsh Creation Areas

As stated in Aucoin 2020, 48 gaps; the locations of which were chosen to be adjacent to nearby tidal creeks, waterbodies, or prior weir box locations of the containment dikes was done by the construction contractor at the end of construction. It is possible that additional gapping in the future may be necessary and will continue to be evaluated. In order to more fully promote hydrologic exchange at the project site, CPRA recommends to prepare for a dike gapping project in an upcoming O&M event, by first collecting survey data throughout the project site to best identify prospective gap locations. CPRA believes that this survey data could be timed a bit later in the post-construction lifespan of the project, to capture elevations at a later point in the settlement curve, when settled elevations across the project begin to approach an intersection with eustatic sea level rise rates.

Terrace Field

Similar to above, CPRA recommends some survey data be collected in the terrace field, to better understand the post-construction elevations in the terrace field, which appear to be functioning very well. This surveying should only be done in tandem with the more critical survey in the marsh creation areas, and since no maintenance activity is anticipated here, survey data collection here is not a priority. Survey data collected at the terrace field can be shared with monitoring staff in order to efficiently utilize budget.

Additional Observations

No further findings are established for the other observations made throughout the project site.

## III. Monitoring Activity

The Coastwide Reference Monitoring System (CRMS) - Wetlands is a network of 392 monitoring sites distributed throughout the coastal zone of Louisiana. Hydrographic, vertical accretion, elevation change, vegetation, soils, and aerial photography data are collected at each CRMS site. Although no CRMS monitoring stations are located in the CS-0059 project area, there are several CRMS stations located nearby (Figure 1) which will be used as references to determine project effectiveness.

### a. Monitoring Goals

The Oyster Bayou Marsh Restoration Project (CS-0059) was designed to restore areas that were previously lost due to storm impacts, flooding, and salt water intrusion. In addition, the project will reduce additional land loss through the reduction in tidal scour and wind driven erosion.

The specific goals of the Oyster Bayou Marsh Restoration project are:

1. Construct an emergent marsh that is 80% vegetated and contains 849 acres of created marsh and nourished marsh maintaining near 80% of that land area over the life of the project.

2. Construct a marsh that settles to the height predicted by the established settlement curves within the project area and maintains an elevation of 1 ft NAVD88, G12A at the end of the project life.

3. Create 9,000 linear feet of terraces to slow tidal exchange and reduce wave and wake erosion within the project area.

4. Construct a marsh that is flooded between 10% and 80% of the year and maintains water levels between 2” above and 6” below the marsh surface after settlement.

### b. Monitoring Elements

**Aerial Photography**

In order to evaluate land/water ratios in the fill areas, land/water data will be obtained from digital imagery with 1-meter resolution. The photography will be georectified using standard operating procedures described in Steyer et al. (1995, revised 2000), and land/water ratios will be determined. Aerial photography was collected in 2015 (pre-construction) and will be captured post-construction, when CRMS coastwide imagery is collected, in 2018, 2021, 2031, and at a later date if deemed necessary.

**Fill Area Surveys**

To monitor the changes in marsh surface, relative to target elevations, a cross sectional survey is required across the project area. Survey transects will be laid out every 500 feet at a minimum in the created marsh and extending into the open water and marsh adjacent to the marsh creation cells. Position, elevation, and water depth will be recorded at a minimum every 100 feet along each transect. There are twenty vegetation monitoring stations within the area that are marked with ¾ inch PVC poles. The surveyor will have to give those areas a 30 foot buffer. The preconstruction survey was obtained in 2012, an as built elevation survey was completed in 2017. There was also two drone surveys, a 120-day survey in March 2018 (Figure 7) and a 365-day drone survey in December 2018, the first post construction settled marsh platform survey was completed in 2021; others will be conducted in 2026 and 2033.

**Water Level**

Water level (ft) readings will be recorded hourly at one location within the project area and multiple CRMS sites within the vicinity of the project area. Water level readings will be used to determine the frequency, depth, and duration of flooding in the project area relative to the marsh elevation determined by the fill area surveys. These will be used to assess the goal of maintaining water between 2" above and 6" below marsh and percent time flooded between 10% and 80% of the year.

**Salinity**

Salinity data will also be recorded hourly at the one project specific location and multiple CRMS sites as well as discrete soil porewater stations at each of the vegetation plots, when vegetation is surveyed, to characterize salinities throughout the project and reference areas.

**Vegetation**

To document the condition of the emergent vegetation in the project area over the life of the project, vegetation will be monitored at 20 sampling stations using a modified Braun Blanquet sampling method as outlined in Folse et al. 2020. Stations will be established across the elevation gradient present among the 5 marsh creation areas and nourishment areas within the project boundary. The location of the stations will be such that they coincide with the elevation surveys. Percent cover, dominant plant heights, and species composition will be documented in 2m x 2m sampling plots marked with a corner pole to allow for revisiting the sites over time. Vegetation data from the relevant CRMS sites within the area will be used as reference stations to compare species composition over time. Data was collected in the fall of 2019, 2020, and 2022 and will be collected in 2027, 2031 and 2034.

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.

**Soil Properties**

Project specific soil cores were collected using a Russian peat corer (24 cm deep) at 6 sites (two replicates per station) in 2019 and 2022, and will be collected in 2027, 2031, and 2034. Analysis of soil properties will include but not necessarily be limited to bulk density, moisture, and percent organic matter.

**Dissolved Oxygen / Hypoxia Monitoring**

To identify potentially hypoxic conditions within the dredge borrow area, synoptic surveys will record dissolved oxygen (DO), depth, salinity, and temperature in the Gulf of Mexico borrow area monthly from May through October (Figure 24). Measurements will be taken in the deepest portion of the borrow area, approximately 2 ft. off of the bottom, and in a reference location approximately 0.25 to 0.50 miles outside of the borrow area. The location of the reference area will be based on results of the geophysical investigation (CB&I; BAMM 2013). Site visits were conducted once per month for data collection during 2018. During each synoptic event, vertical profiles were taken for depth, temperature, salinity and dissolved oxygen (DO) at each site. Vertical profile data were collected at three foot intervals.

## c. Monitoring Results and Discussion

**Aerial Photography**

Land/water analysis was completed for the 2018 post-construction aerial photography (Figure 4B). Results indicated 702 acres of land (63.6%) and 401 acres of water (36.3%) within the CS-0059 project area following construction. Much of what is classified as water is very shallow project area fill that had yet to vegetate and dewater fully at the time of image capture. Overall, the project area was 15% land and 85% water prior to construction (Thompson 2014). Future analyses will determine land/water ratios in the project area through time as the marsh creation areas settle, vegetates, and becomes more tidally connected. Overall, the project constructed 939.2 acres of marsh platform which is currently between 60-65% vegetated and 9000 linear feet of terraces which are nearly 100% vegetated (APTIM 2019). Currently the project seems on the correct trajectory to meet the land area and vegetated surface portions of its goals. There are three constructed tidal ponds in MCA1 and MCA3 along with 11,637 linear feet of pre-excavated trenasses (Figure 4A). These have functioned as waterways because they are at a lower elevation that the marsh platform. The trenasses vegetated quickly, but generally lacking a strong tidal connection have remained mostly isolated.


**Figure 4A.** Oyster Bayou Marsh Restoration (CS-0059) Google Earth imagery from 12/2022 showing a pre-excavated tidal pond in MCA 3, this has been the most successful of the project's three ponds, consistently holding water for wildlife usage.

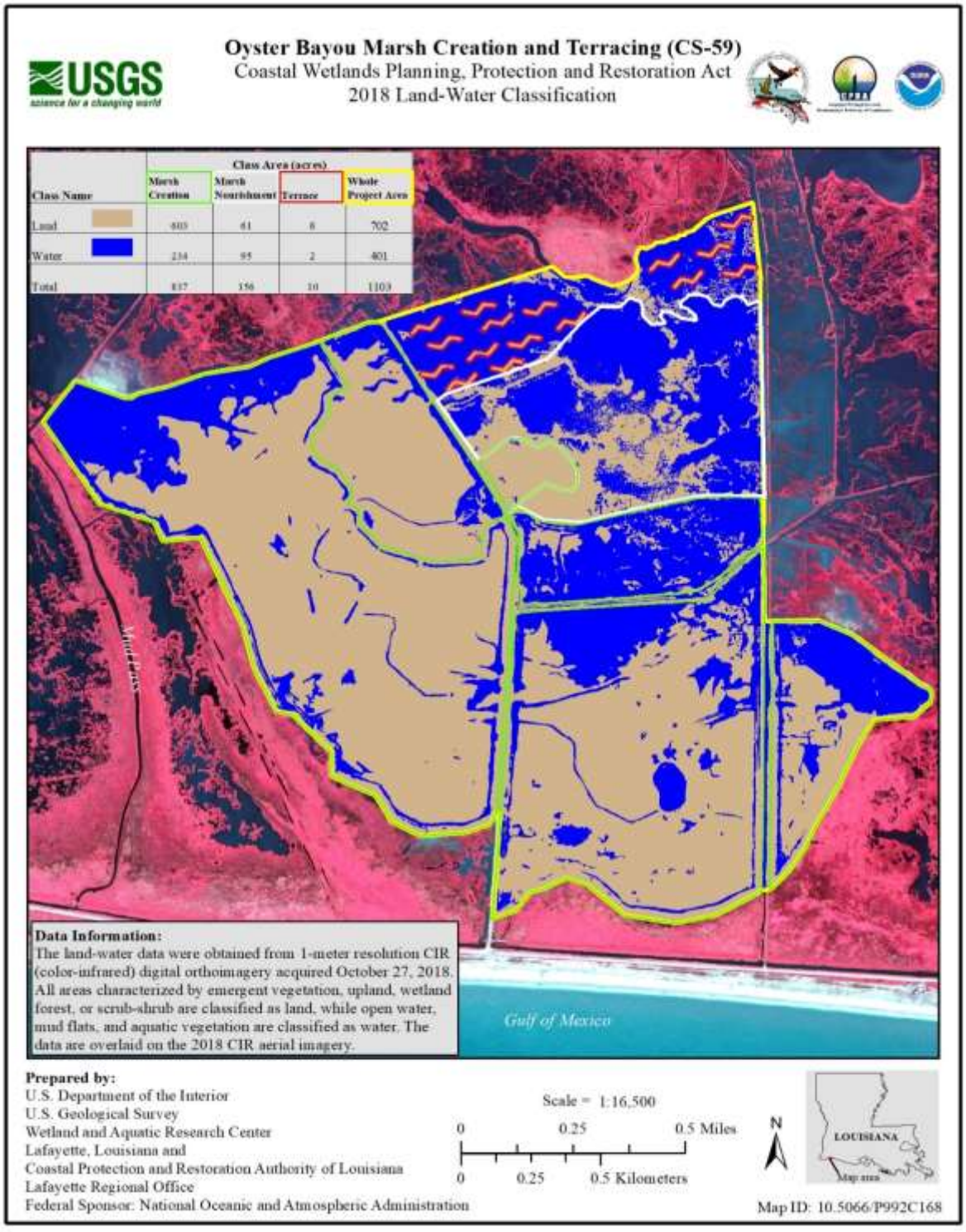


**Figure 4B.** Oyster Bayou Marsh Restoration (CS-0059) project 2018 land/water analysis post-construction. The marsh nourishment in this project was unconfined and there was also a 13 acre unconfined marsh creation area in the north central project area. Also there were three tidal ponds constructed in MCA1 and MCA3 along with 11,637 linear feet of pre-excavated trenasses as project features, to date some of these are functioning as intended, but all lack a good connection to the exterior tidal regime.

**Elevation Surveys**

The CS-0059 marsh elevation target was determined by incorporating multiple factors including existing healthy marsh elevation, percent inundation, and the physical properties of the borrow material. Other considerations were the bearing capacity of the foundation soils in each marsh creation area, years to marsh surface inundation via settlement, and sea level rise (Thompson, 2014). Ideally, the final marsh elevation would be inundated 40-60% of the time at the end of the 20 year project life and would spend the majority of the project life within the functional saline marsh range (10% - 80% inundated). To aid in this determination, settlement curves were developed to compare different marsh fill elevations in relation to mean high water and mean low water using local subsidence and relative sea level rise rates applied to water levels at CRMS0655 over the 20 year life of the project. For this project, 1.0 ft NAVD88 (Geoid12A) was selected as the final target marsh elevation. In order to achieve this final target elevation, the marsh platform initially has to be pumped above the functional saline marsh range and allowed to settle into the range by year eight post construction. To reach the final target marsh elevation, an initial constructed marsh fill elevation of 2.0 ft plus up to a 0.5 ft construction overage NAVD88 (Geoid12A) was determined for all the MCA's (Figure 5). All discussed and displayed elevations to datum for soil or water surfaces will be reported in NAVD88 (Geoid12A) unless otherwise noted.

Pre-construction a majority of the project MCA's were approximately -0.5 ft in elevation covered with open water and fringe marsh habitat, along with some remaining intact high marsh. The unconfined nourishment area was quantifiably lower at near -1.0 ft, and was a mix of habitats similar to the MCA's (Figure 6). This elevation information collected in 2012 was used as discussed above to determine constructed marsh platform elevation and settlement (Harper 2013). An as-built survey was completed in 2017, and interestingly this survey showed a broad range of elevations among the project MCA's. MCA 1 was constructed to approximately 3.9 ft and along with MCA 5, which includes MCA5A (3.8 ft) were the highest and well above the 2.0 ft as-built target, while MCA 3 and MCA 4 were slightly above target at 2.5 ft and 2.4 ft respectively. MCA 2 was intermediate at 3.3 ft, but was still above the target elevation. In 2018, an elevation grid model of the MCA's was completed and showed the relative topography within the project area in Geoid 09.

The results were very similar to the 2017 as-built survey variability across the constructed marsh platform with the highest locations bordering MCA 1 and MCA 5 in yellow and the lowest being on the northern end of MCA 3 and 4 in light green (Figure 7). This variability, while unintended, mimics the natural marshes of the Chenier Plain with areas of lower marsh elevation confined between landward ridges and the beach and dune complex of the GOM. Four years post construction the elevation differences among the MCA's remains essentially unchanged. However, extensive settlement has taken place across the project area with portions of MCA 3 and 4 now below the year four settlement curve projection of 1.1 ft (Figure 8). Overall, the marsh platform as of 2021 is 1.6 ft, approximately 0.5ft above predicted, compared to greater than 1.1 ft above planned construction elevation in 2017. This will likely be beneficial in the long term as CRMS0655 water level is frequently above the projected tidal frame for months at a time. The higher MCA's are still above the projected settlement elevation, but are now closer to one foot above predicted instead of two feet above planned, yet still providing ridge habitat for vegetative diversity, storm protection, and animal refuge. The unconfined nourishment and unconfined creation area are combined in this report due to

a continuous elevation gradient as one delineated area transitions into the other. The unconfined nourishment area was lower preconstruction (-1.0 ft), built to a lower elevation during construction by design (1.1 ft), and has settled to the lowest elevation four years post construction (0.6 ft) comparatively to the MCA's. But surprisingly it is now similar to MCA 4 (0.8 ft) which was built to a higher constructed elevation. This could be partly due to the vegetation in the unconfined nourished area not dying back during construction and adding organic root volume faster than the contained MCA 4. This will be interesting to follow throughout the project's life to better understand the interplay of sediment addition, inundation, and vegetative response at varied constructed elevations. To date a majority of the project area is still above the project settlement curve due to higher than expected constructed elevations, but it is also settling faster than anticipated possibly due to the additional loading of the foundation soils. Future surveys will determine the MCA's settlement through time and how it compares to the predicted elevations and the effects on marsh inundation.

Bathymetric surveys of the borrow area in the Gulf of Mexico were completed at the time of the as-built survey in 2017 (Figure 9). Average elevation in the borrow area at the time of the as-built survey was around 10 ft below preconstruction elevations. Significant infilling occurred in the first year following construction to about 5 ft below preconstruction seafloor elevations, as determined during the borrow area dissolved oxygen surveys. The cross sectional view of the borrow area displays significant quantities of permitted material still in situ, specifically on the southern end of the area (Figure 10).

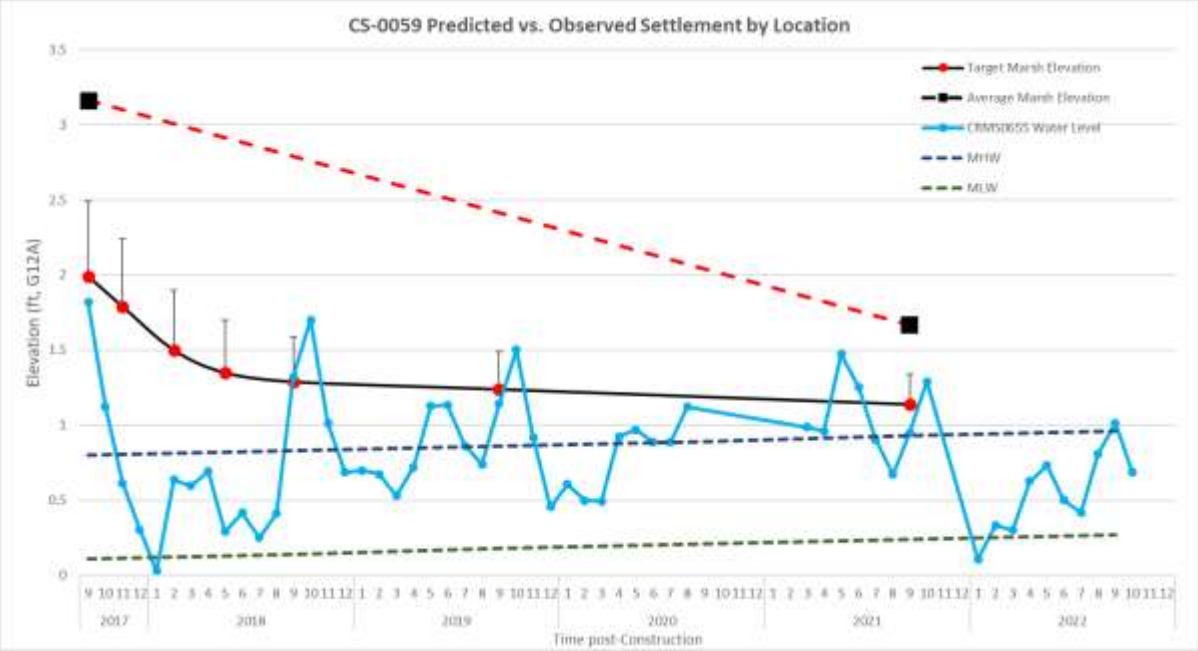


**Figure 5.** Predicted elevation settlement compared to observed elevations for the CS-0059 marsh creation area along with the predicted mean high water (MHW), mean low water (MLW), and actual water level at CRMS0655. The target marsh elevation was adjusted from 2.5 ft NAVD 88, G09 to 1.99 NAVD 88, G12A in order to align with the topographic and hydrologic data presented throughout the report. The positive error bar represent a construction overage tolerance, so the allowable constructed elevation in G12A was up to 2.49 ft.

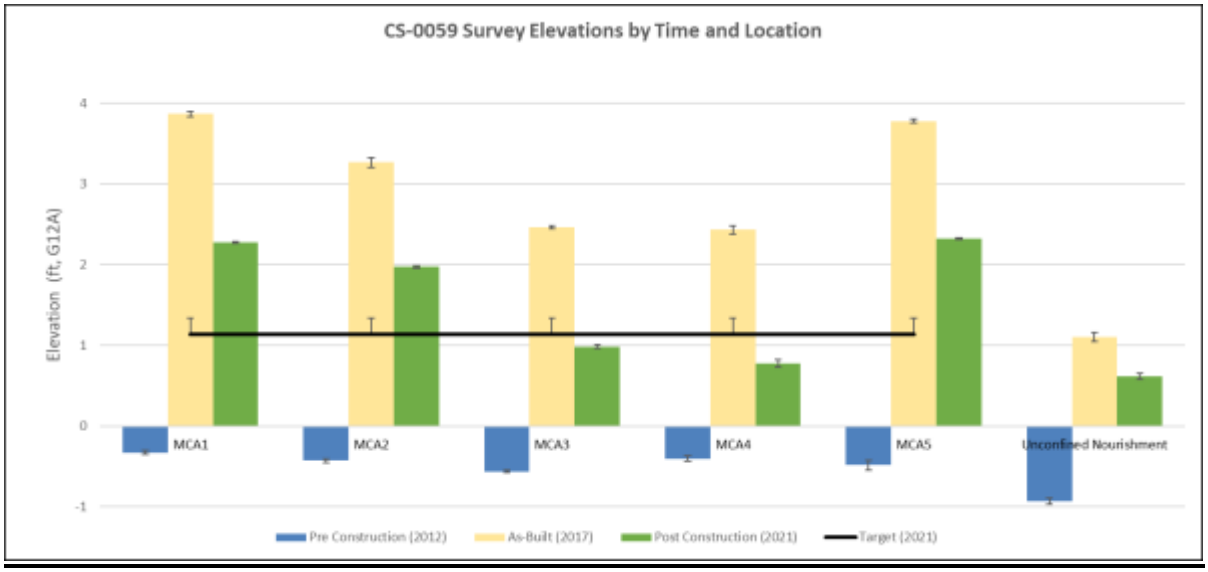


**Figure 6.** Elevation data from pre-construction (2012), as-built (2017), and post-construction (2021) for marsh creation areas (MCA) and unconfined nourishment area. The positive error bar represent a construction overage tolerance. MCA 5 and MCA 5A were combined for this report due to the lack of hydrologic separation.

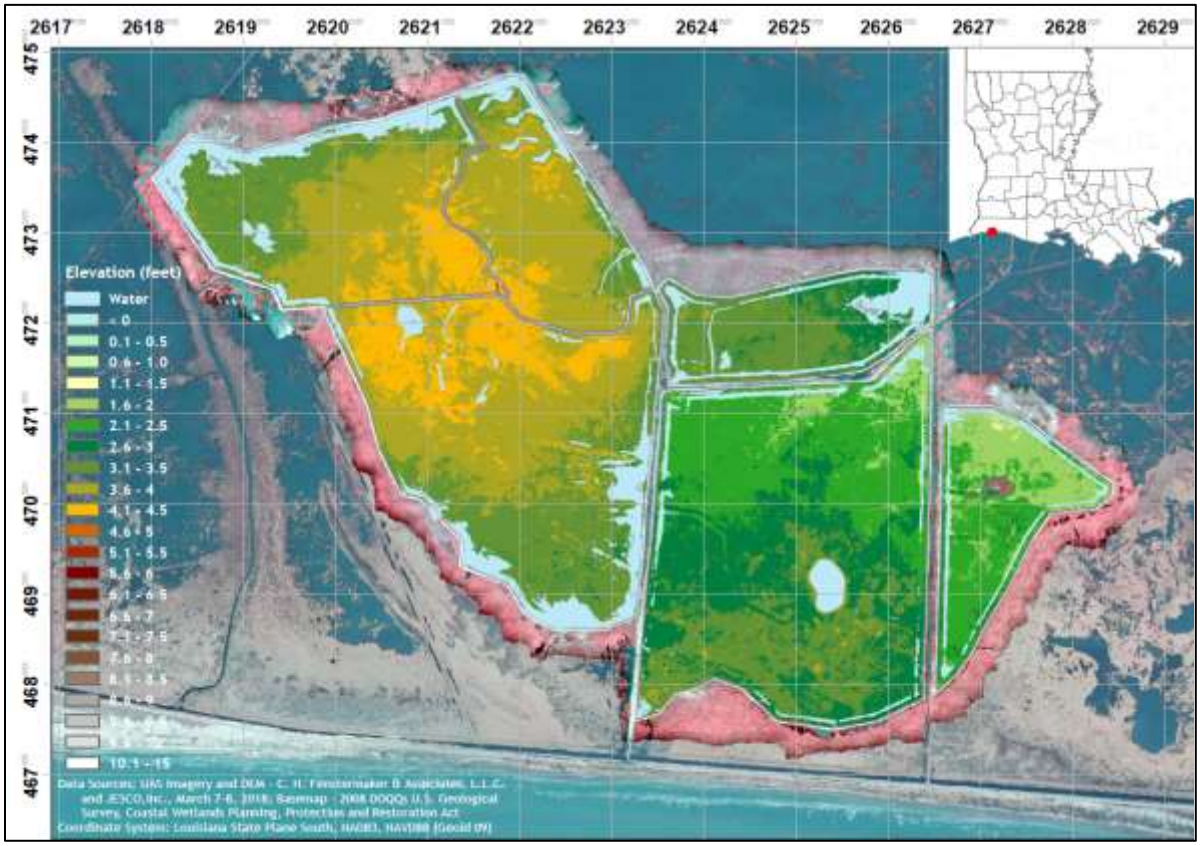


**Figure 7.** A drone captured elevation grid model for the CS-0059 marsh creation fill areas from a March 2018 post construction survey showing the relative topography within the project area in Geoid 09.

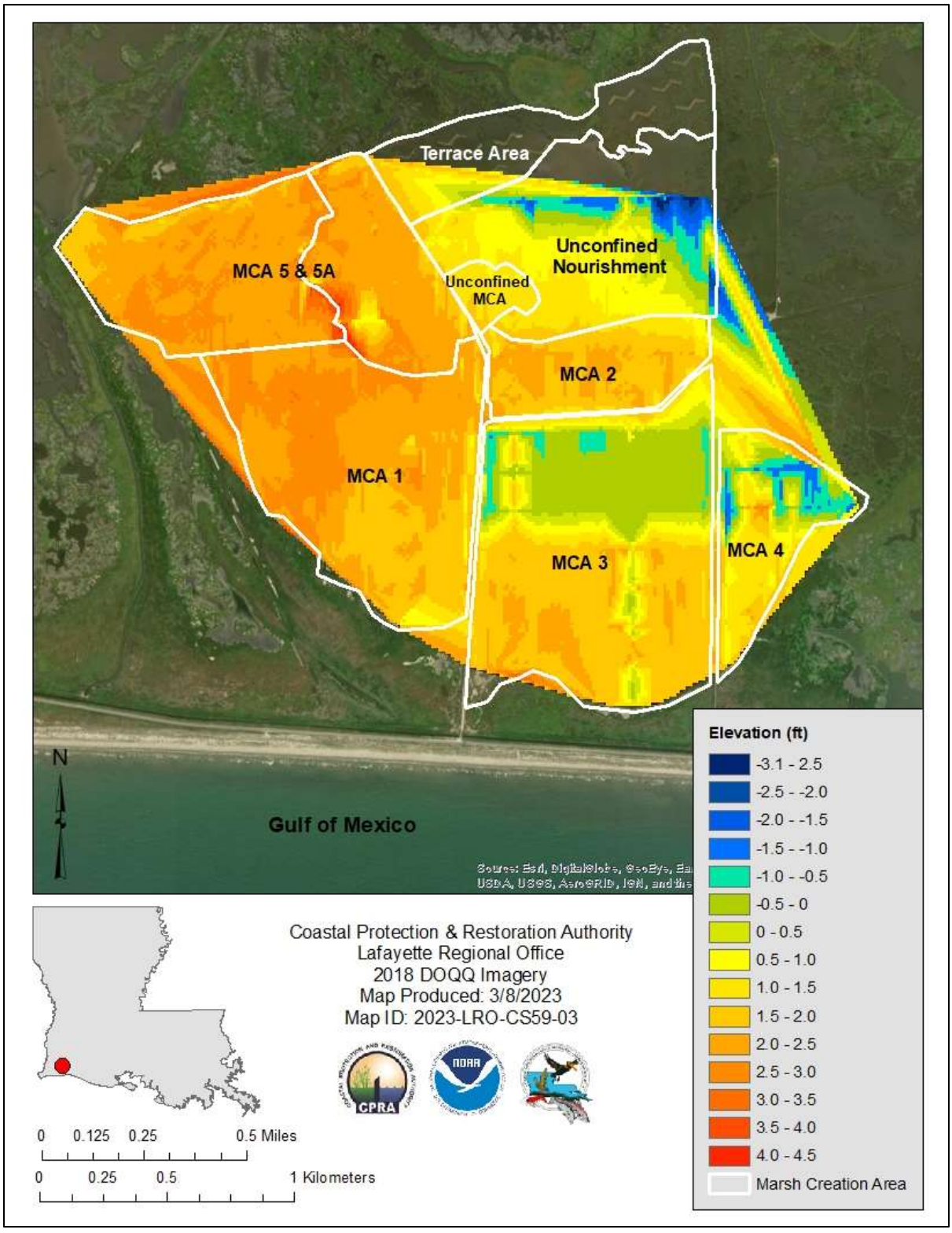


**Figure 8** Elevation grid models for the CS-0059 marsh creation fill areas from the September 2021 survey showing the relative topography within the project area in Geoid 12A.

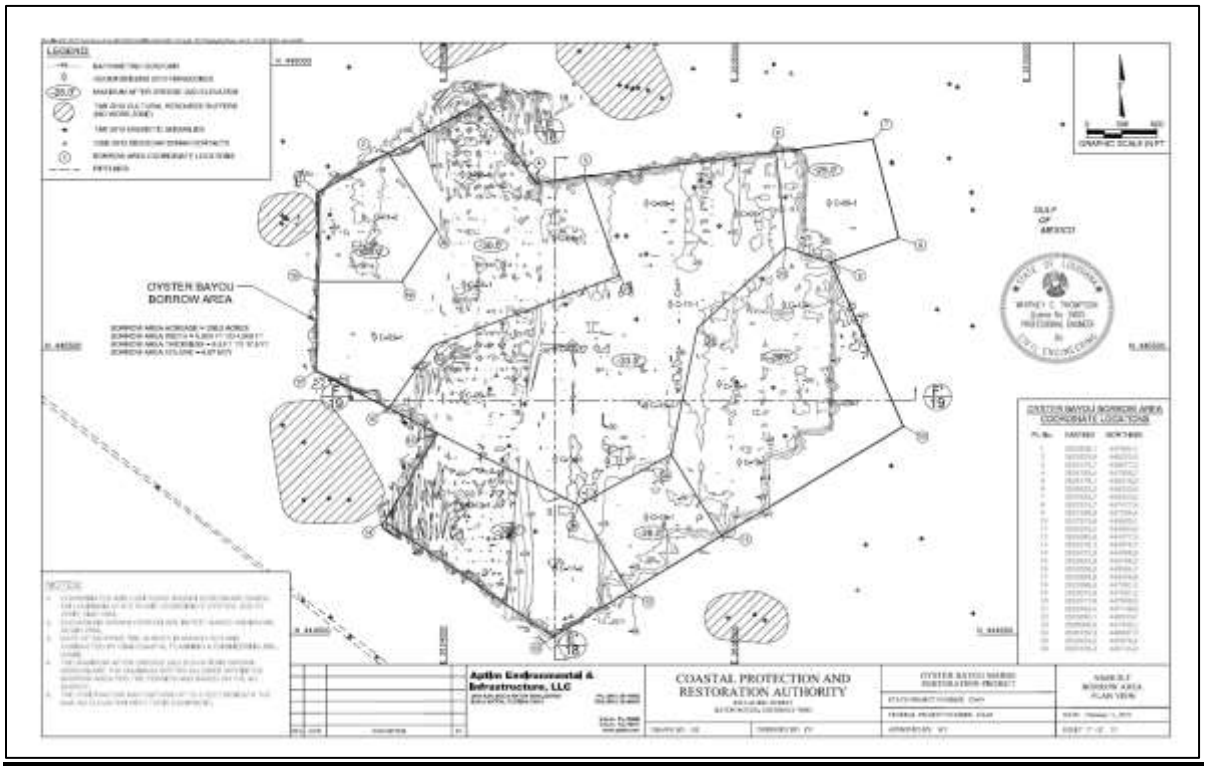


**Figure 9.** CS-0059 borrow area overview from the September 2017 Survey, approximately 6.67 mcy of material was available.

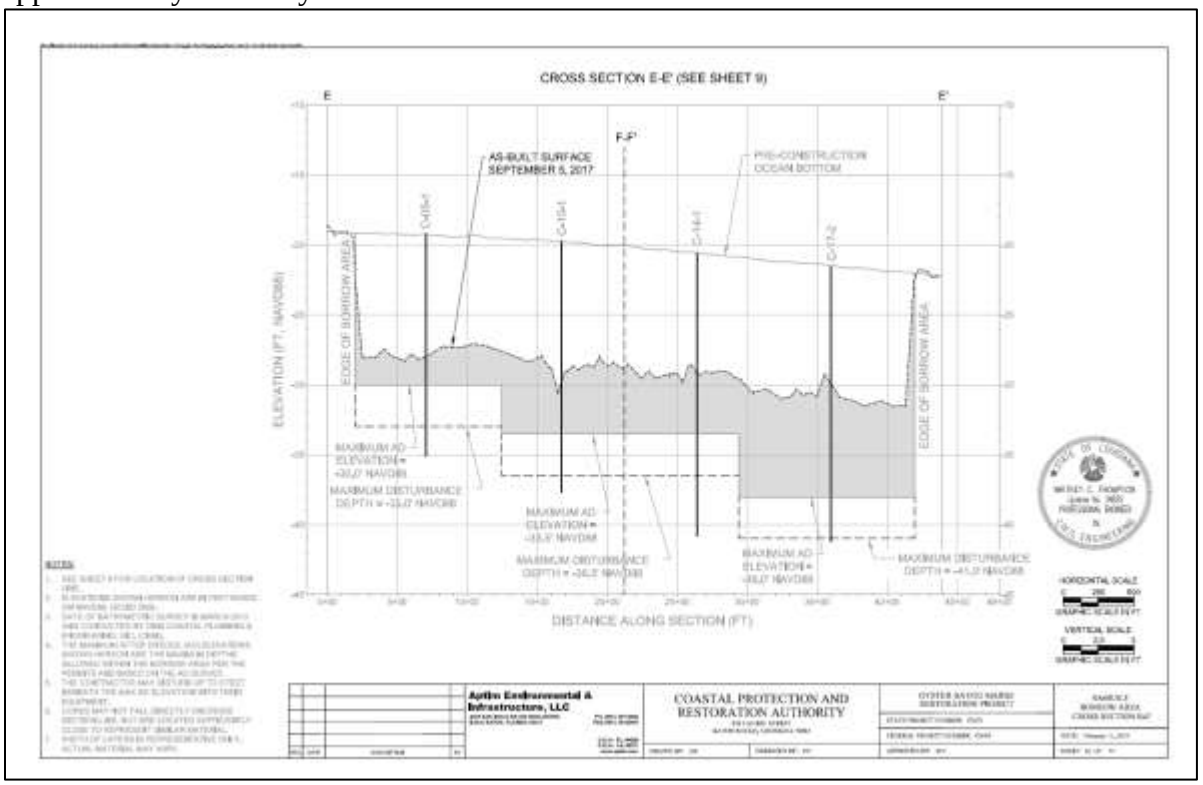


**Figure 10.** CS-0059 borrow area cross section from the September 2017 Survey, averaging near 10 feet in cut depth for preexisting GOM seafloor.

**Water Level**

Water levels in and around the project area are controlled by the Gulf of Mexico via the Calcasieu Ship Channel (CSC), a tidally driven system. For an assessment of the project and reference areas four CRMS sites were used along with a project specific station. CRMS0685 and CRMS0687 are both tidally connected sites along the CSC, which provide a good picture of outside conditions but are more dynamic due to daily tidal fluctuates. CRMS0655 and CRMS0672 are both in the CS-0020 project area and are managed impoundments; CRMS0655 was used in the modeling and project development for CS-0059. These two impounded sites behaved similarly on a daily basis to the project specific station CS59-01, because the project area is essentially at the end of the watershed, naturally impounded by CS-0033, the state funded beach and dune nourishment and HW82 to the south, HW 27 to the west, and the CSC to the east. Therefore, all drainage must travel north to Oyster Bayou via sheet flow across the marsh or through the main north south canal which empties into Oyster Lake. There is a fixed crest weir on Oyster Bayou north of the project area further reducing hydrologic exchange. On a monthly basis, the tidal CRMS sites behave very similarly to the impounded CRMS sites and the project station, generally tracking well together with average water levels near 0.75 ft G12A between 2014 and 2022 (Figure 11).

Multiple tropical systems impacted the project area during the 2020 Hurricane season that affected regional water levels. The largest, Hurricane Laura, made landfall in southwestern Louisiana on August 27th 2020. Reference CRMS0685 outside of the project area recorded a tidal surge of over 5.5 ft for Laura and is eight miles north of the project area. The estimated surge in the project area was between six and nine feet above ground level, though minimal impacts were seen in the project area other than dead vegetation, sediment over wash, and debris deposition (Pasch et al 2021).

A majority of the project marsh platform is situated above the tidal frame and as such would not be expected to be flooded much of the time (Figure 12). Pre-construction, the area was flooded near 100% of the time and was a series of lakes, ponds, and fringe marshes. Using the impounded CRMS site water elevation data between 2017-2018 during construction only the nourishment area was flooded on a weekly basis, approximately 20% of the time. Post construction in 2021-2022 MCA3 (16%) and MCA4 (29%) along with the nourishment area (60%) had elevations within the tidal frame and were experiencing tidal flooding on a weekly time frame. However, repeated on site data collection efforts have revealed the area retains rain and flood waters long after the drainage of tidally connected marshes take place (Figure 13). This is in part due to the higher elevations of the project area acting as ridges, along with the remaining containment dikes, and land owner activities. Some of the project areas act as perched wetlands with localized flooding, even when surrounding areas have a lower water level. Currently only the unconfined nourishment area and MCA 4 have a tidal connection that regulates water level. On a recent field trip, average water levels in the area were near 1.0 ft G12A (Figure 14). At vegetation station CS59-V14 in MCA2 the marsh elevation is approximately 2.0 ft G12A, a full foot above current water level, and the marsh platform was flooded. This water, while ephemeral, appeared to have been present for some time due to algae growth, aquatic life, and stress to flood sensitive plants such as *Salicornia* and *Batis* (Figure 15). This is evident repeatedly across the project area throughout the MCA's even on some of the highest elevation locations between MCA1 and MCA5, though some of the highest areas were likely only flooded extensively during Hurricane Laura in 2020. Much of the project

area is currently above the tidal frame but is flooded much more often than would be indicated by hydrologic data as is evident by the plethora of salt marsh vegetation and repeated observations of standing water over the marsh's surface. This is partially due to the remaining containment dikes and the oilfield road traversing the project area. As the area settles and becomes more tidal a better assessment of the actual flooding regime will be made. Overall, the area is a functional wetland with varying degrees of tidal connectivity among the MCA's and unconfined nourished marsh.

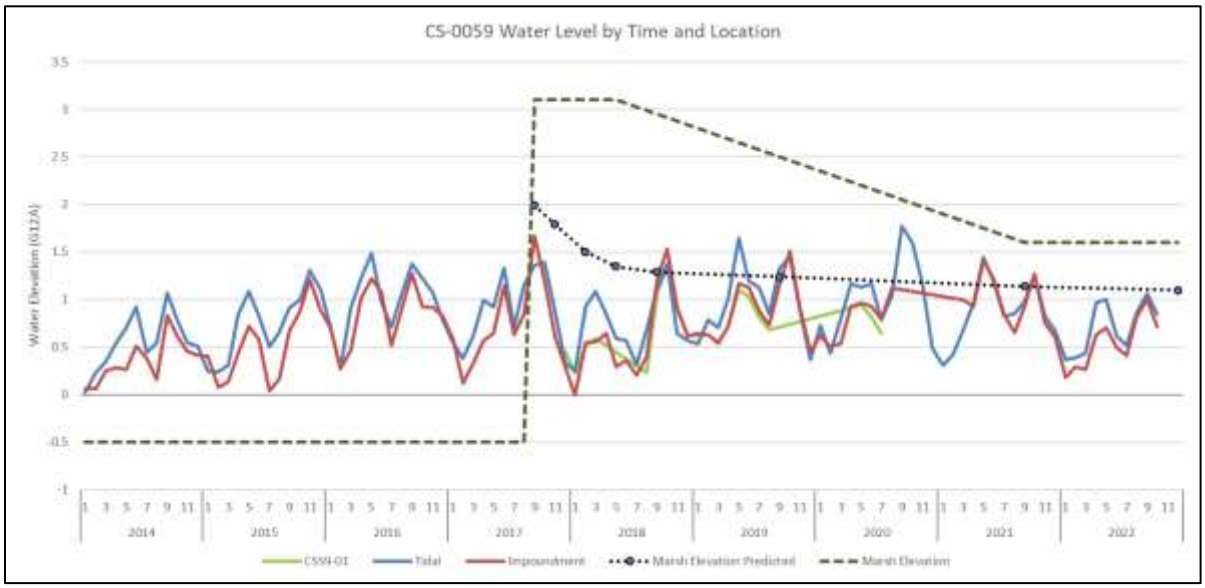


**Figure 11.** Monthly mean water levels at project and CRMS sites from 2014 through 2022, along with actual and predicted marsh elevation. CRMS 0685 and 0687 are tidal, while CRMS 0655 and 0672 are impoundments. The CS59-01 sonde is just outside the project area in a natural bayou and is noticeable lower than the adjacent MCA's.

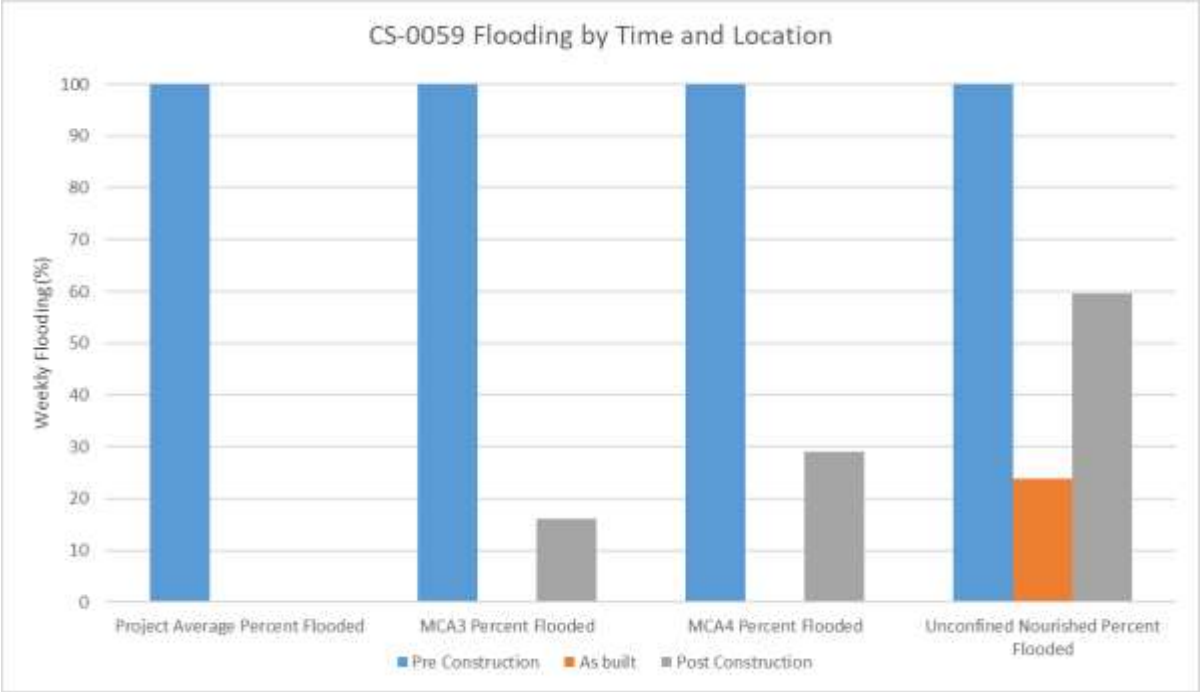


**Figure 12.** Percent of weekly flooding using CRMS 0655 and 0672 water levels compared to different project area marsh platform elevations across time. Absent bars indicate zero percent flooding. This does not accurately show flooding due to trapped local rainfall and high tides within the MCA's as observed during site visits.

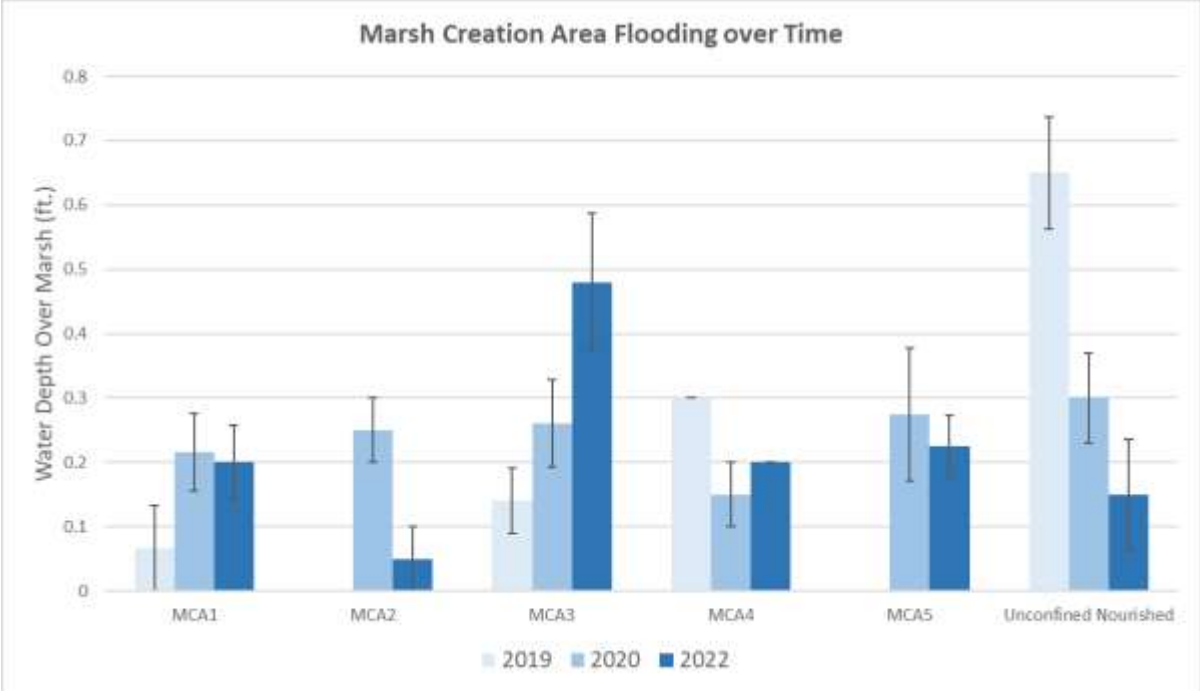


**Figure 13.** Vegetation monitoring station water depth in feet over the marsh platform in the different MCA's and nourishment areas annually during vegetation surveys. These observations suggest water is routinely over the marsh surface during the growing season.


**Figure 14.** Staff gauge reads 0.95 ft G12A during 2022 data collection site visit; CRMS sites 0655 and 0672 recorded 1.0 ft and 1.04 ft 26 minutes earlier at 9 AM.


**Figure 15.** Vegetation monitoring station V14 in MCA2 with a surface elevation of 2.0 ft, which when using hydro data was not flooded at the time of the photo. Showing the local effect of topography, rainfall, and trapped high tides on flooding.

## Salinity

Salinity in the project and reference areas are similar and consistent with saline marshes in Louisiana, averaging between 10-15 ppt on a monthly basis. During the brief drought of 2018 and 2022 salinities reached 25 ppt monthly as reduced local rain fall and limited freshwater discharge from the CSC caused a sharp increase (Figure 16). The project area is dominated by saline tolerant species and this had almost no effect on the marsh vegetation. However, as previously mentioned the project area is somewhat hydrologically isolated and can retain both fresh rain water and saline high tide flooding. This likely indicates that the project marsh platform is more dynamic than the surrounding salinity regime, both fresher during times of high rainfall and more saline post storm tides. The sediment used for project construction was borrowed from the Gulf of Mexico sea floor and as such contained marine levels of salinity. This concentrated via evaporation post construction during the 2018 drought but was quickly ameliorated by local rainfall as of the 2019 vegetation survey. The salinities in the project area have been controlled by the local hydrologic regime through 2022 and this is expected to continue as the short-lived localized increase in salinity from construction lasted less than 12 months.

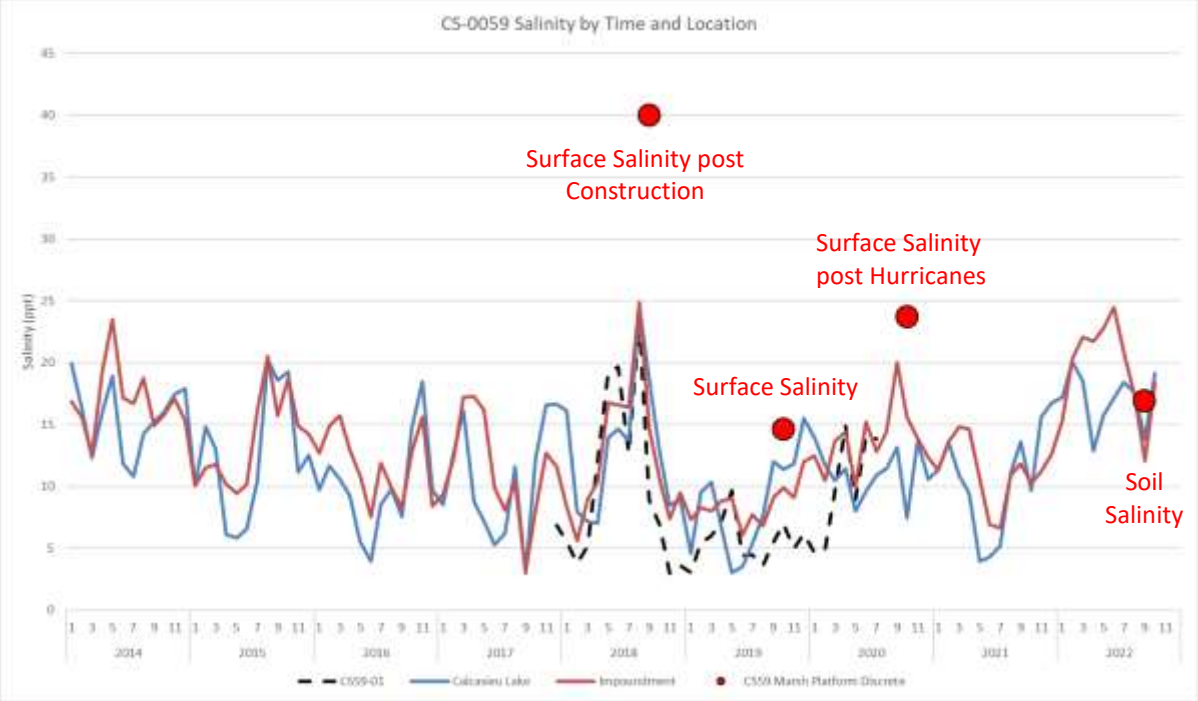


**Figure 16.** Monthly mean salinity at project and CRMS reference sites from 2014 through 2022. CRMS 0685 and 0687 are tidal, while CRMS 0655 and 0672 are impoundments. The red circles indicate discrete salinity measurements on the MCA platforms displaying a substantial drop post construction down to the local salinity regime.

**Vegetation**

Emergent vegetation data was collected post construction in 2019, 2020 post hurricane, and 2022. The project's goal for vegetation is to create and nourish new and existing saline marshes. The dominant species are *Spartina alterniflora* and *Distichlis spicata*, which are reflective of saline marshes throughout coastal Louisiana. Subordinate species, such as *Salicornia depressa* and *Borrichia frutescens* are present on the higher elevation areas of the marsh platform. While *Spartina spartinae* was not found during the vegetation surveys it has been identified at other restoration sites in the CS basin with similar habitats. It would be a possible candidate for planting on the highest locations once tidal drainage has increased thus reducing the amount of fresh rainwater held on the marsh surface. Species diversity was lowest in the unconfined nourished areas and the terraces containing a monoculture of *Spartina alterniflora*, which differs from the marsh creation areas. This reflects the existing vegetation being fostered in the unconfined nourished area whereas the marsh creation areas had a complete overhaul of the vegetation community. The unconfined nourished areas started post construction in 2019 at near 55% total cover and have stayed near this threshold through 2022 (Figure 17). The MCAs typically started at or near zero during the completion of marsh platform construction during the summer of 2017 and have steadily increased in total cover through 2022 to approximately 45% on average (Figure 18-20). MCAs 1-2 have lagged behind the other areas as of 2022 with about 25% total cover, though this is due to different stimuli. MCA1 is higher in elevation and contiguous with higher ground thus not receiving much tidal exchange and does not hold water. MCA2 is more intermediate in elevation but is completely isolated from all but the highest tidal action and is therefore almost completely rainwater dependent which is retained in excess.

During this period of project vegetation expansion CRMS sites 0655 and 0672, located within a managed marsh (CS-0020) north of the project with similar species assemblage, had total cover of only 35% and 10% respectively in 2022. These sites have seen a vegetation crash in recent years and overall land loss as saline flooding has been the dominant environmental stressor with both sites being at approximately 0.25 ft (NAVD, G12A) in elevation. These sites, being located within a saline impoundment, have experienced some fairly unique conditions that likely do not exist without anthropogenic involvement. These conditions have led to floating saltmarsh vegetation being observed multiple times via different data collection campaigns in both the CRMS vegetation and elevation change datasets. CRMS salt marsh sites 0685 and 0687 are tidally connected to the CSC and have higher elevations of 1.0 ft and 0.65 ft marsh surface. This results in a more robust and stable vegetative cover of around 75% in 2022, which is very respectable for saline marshes in coastal Louisiana. It is a positive sign that the hectic hurricane season of 2020 did not have a lasting impact on the vegetation of the CS-0059 project area. Overall the project area is on a positive trajectory, with vegetation synonymous with saline marshes thriving and spreading across the MCAs; some areas are supporting higher marsh and dune vegetation. The project area is already out performing impounded CRMS sites and in time, through settling and the establishment of more tidal connections, will only improve as a functional saline marsh on the shores of the Gulf of Mexico.

These differences are further delineated by species composition and their individual contribution to the different project areas. As previously mentioned, *Spartina alterniflora* and *Distichlis spicata* dominate the project area post construction making up a majority of the

emergent vegetation (Figure 21). The higher elevations are dominated by *Salicornia depressa* and *Borrichia frutescens* that are more adept at managing both saline flooding and drought conditions. These higher areas are generally confined to MCA1 and 5, and have had substantial dieback and recovery following the prolonged flooding from Hurricanes Laura and Delta in 2020 (Figure 22). The vegetative response to project construction is still in its initial phases of colonization and further surveys will determine where the plant community finds equilibrium, but the initial outcome has yielded positive results.

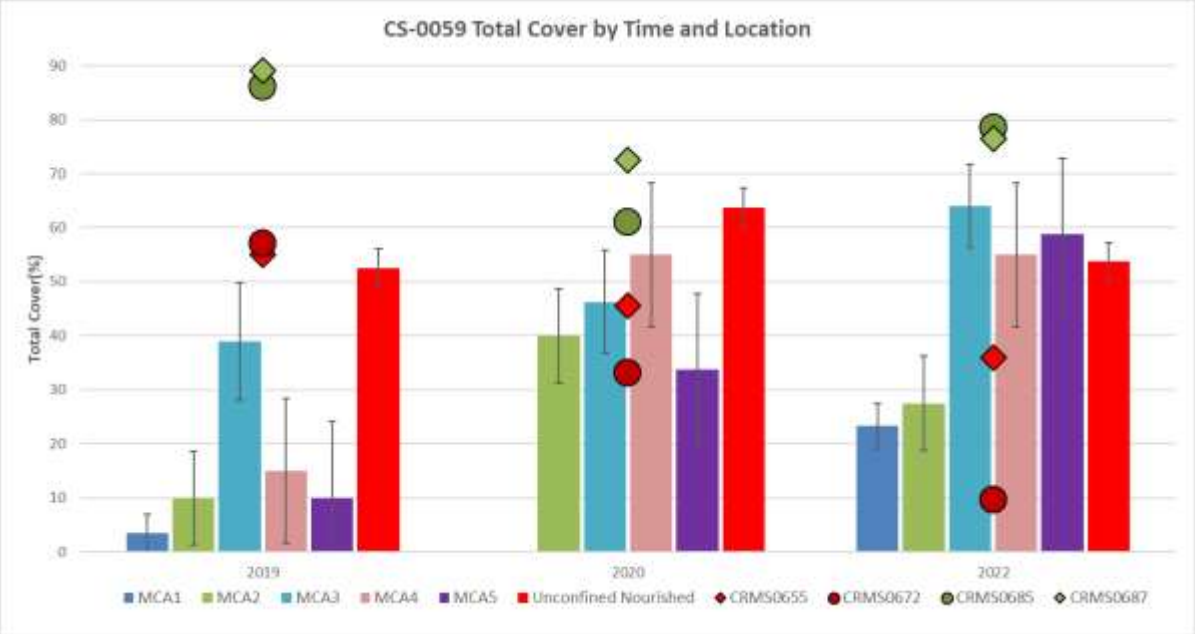


**Figure 17.** Total percent cover by marsh creation area and the unconfined nourished marsh locations from 2019, 2020, and 2022. Overall there is a steady increase in vegetation in the project area with some variability due to as-built elevations, storms, and droughts. Local CRMS site total cover is also displayed to frame vegetation cover over the same time span under varying elevations and flooding patterns. CRMS 0685 and 0687 are tidal and higher, while CRMS 0655 and 0672 are low impoundments.

**Figure 18.** View of vegetation station V08 in MCA 5 on October 2019; the colonization of salt marsh vegetation has begun.

**Figure 19.** View of vegetation station V08 in MCA 5 on October 2020, with noteworthy vegetation expansion.


**Figure 20.** View of vegetation station V08 in MCA 5 on September 2022 with some drought stressed vegetation.

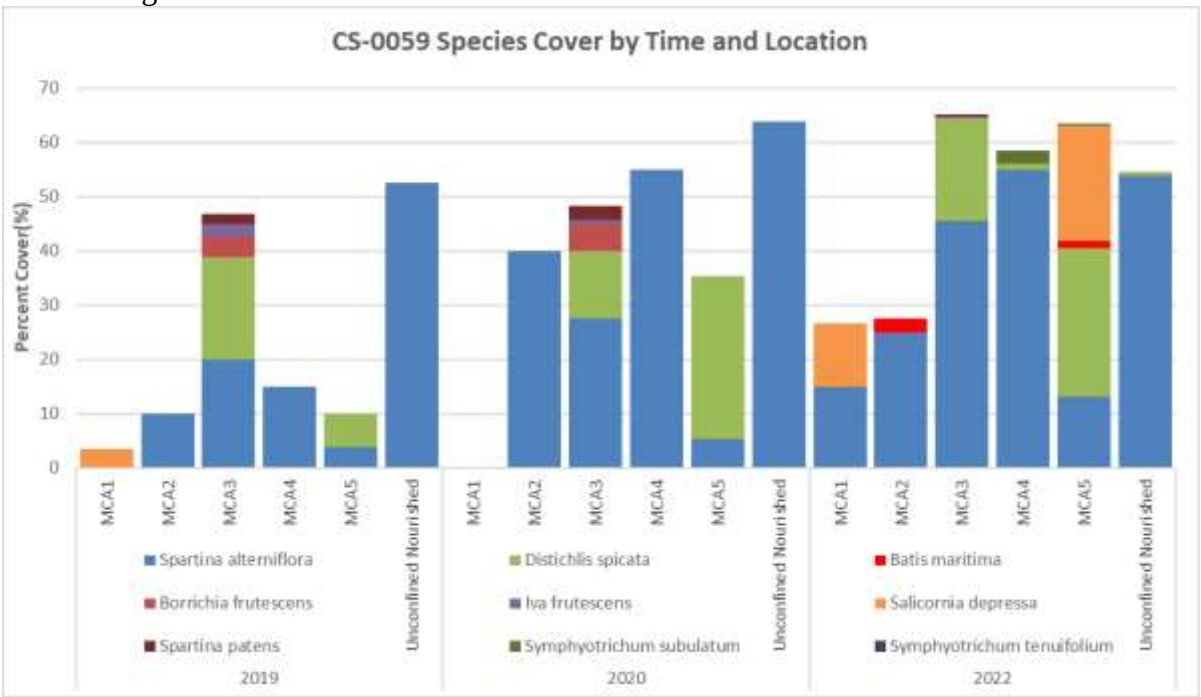


**Figure 21.** Percent coverage of species collected from CS-0059 during 2019-2022. The project area is dominated by *Spartina alternaiflora*, but there are also high marsh species present. MCA1 had no live vegetation cover in 2020 post hurricane as storm surge flooding killed a majority of the high marsh succulents which rebounded by 2022.

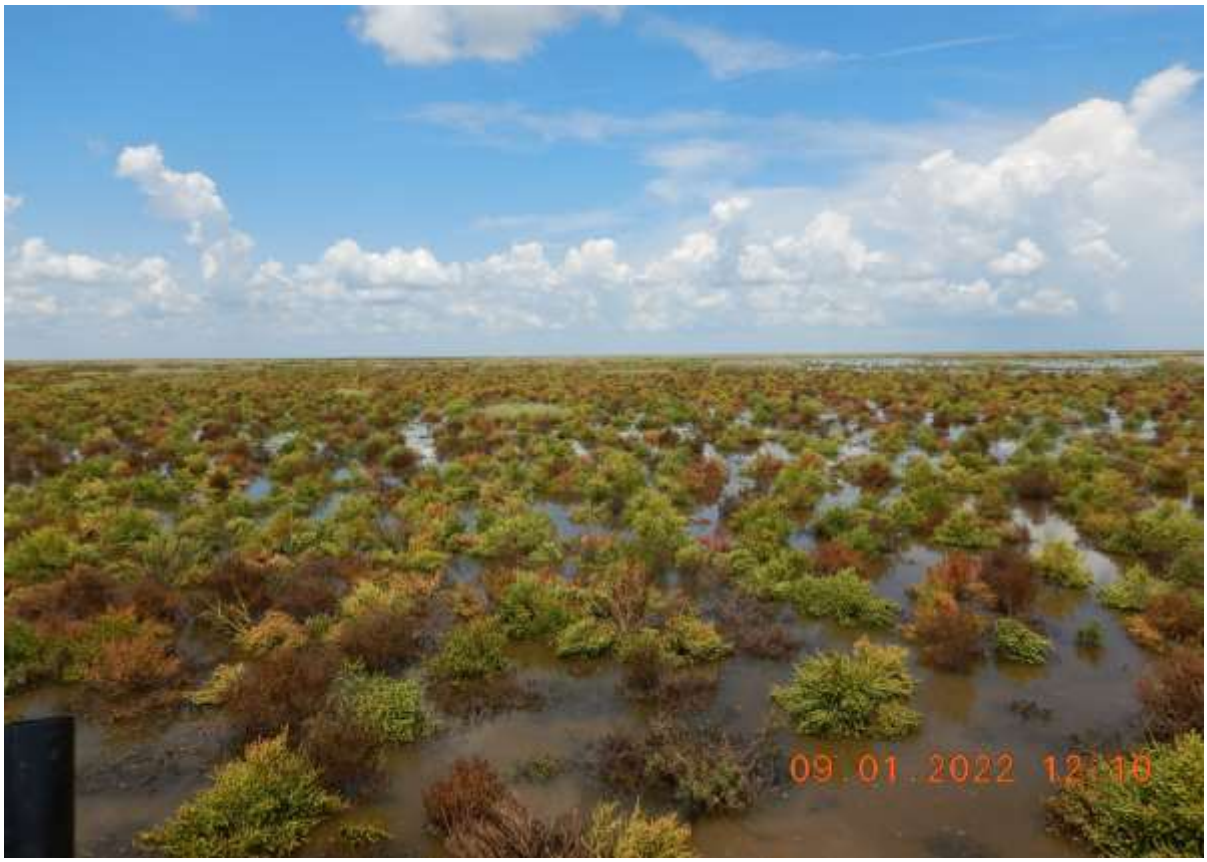


**Figure 22.** View of some of the highest elevations in the project area between MCA1 and MCA5 dominated by *Salicornia* in September 2022.

**Soil Properties**

Soil samples were collected around the CS-0059 project area in both the MCAs and the unconfined nourishment areas in 2019 and again in 2022. These were compared to four CRMS sites that were sampled during 2018. Two of the CRMS sites were tidal, CRMS0685 and CRMS0687 while two were impoundments, CRMS655 and CRMS0672. The soil cores were sampled in 4 cm increments. Higher bulk densities occurred at the project sites as was expected because of the recent addition of marine sediments which are heavier material. The less dense soils were found at the CRMS sites with both the tidal and impounded sites being quite similar which was somewhat surprising (Figure 23). CRMS sites, both tidal and impounded, had a higher organic matter percent due to consistent vegetation production that remained in situ season after season being incorporated into the local soil matrix. The impounded sites did show an interesting pattern of minimal organic matter on the surface and substantially more at 12 cm in the soil profile. This suggests minimal recent vegetative growth with more organic matter contributing to the soil in previous years (Figure 24). The project area has very little organic matter and is very consistent throughout the soil core profile; this is due to the recent placement of high mineral content marine material and limited growing seasons since project completion. Another factor contributing to this lack of organic material in the first 4 cm soil increment with high vegetative growth is the storm surges of 2020, possibly sweeping much of the standing crop north and inland as the project area is situated on the edge of the Gulf of Mexico.

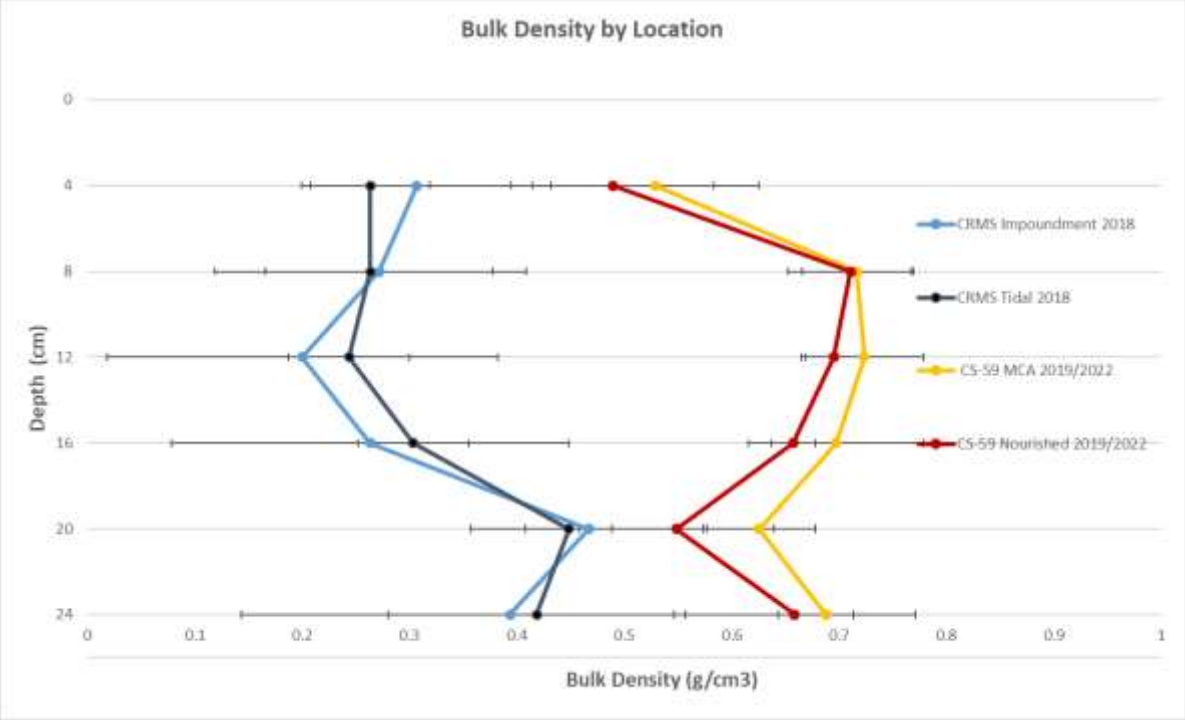


**Figure 23.** Mean ± Standard error of soil bulk density collected in the project MCAs and unconfined nourished locations and at CRMS tidal and impounded marsh sites. CS-0059 data from 2019 and 2022 were averaged for clarity and brevity and were not different from one another.

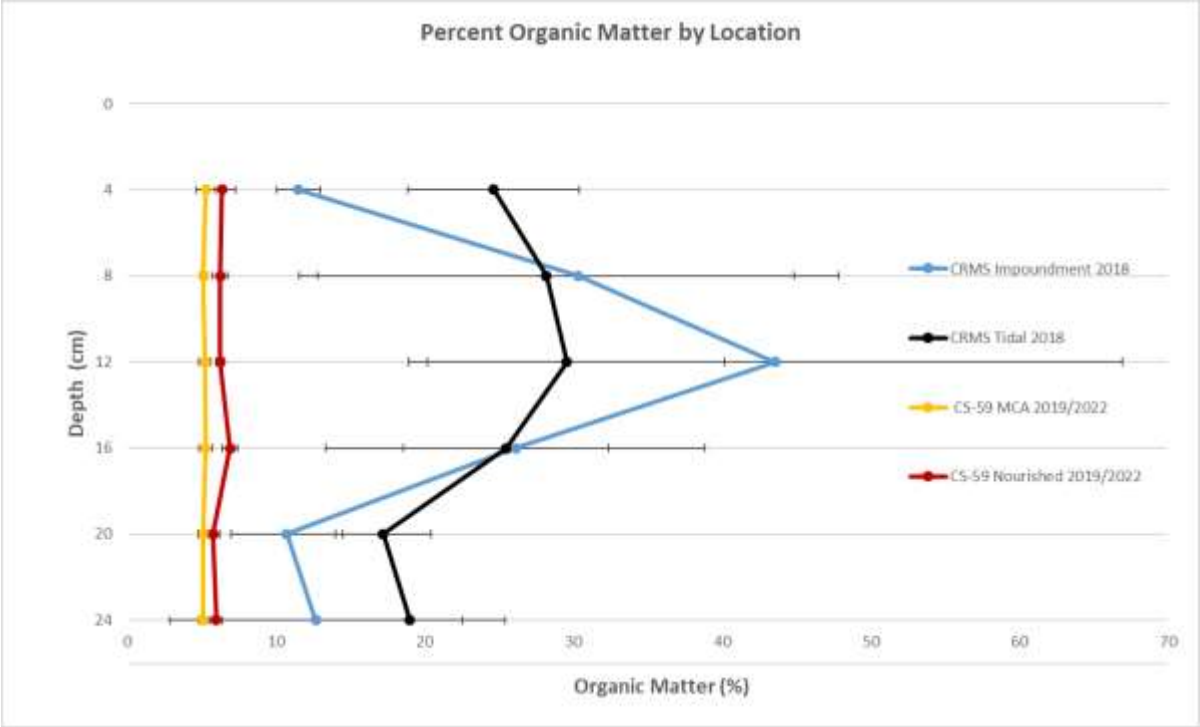


**Figure 24**. Mean ± Standard error of soil organic matter collected in the project MCAs and unconfined nourished locations and at CRMS tidal and impounded marsh sites. CS-0059 data from 2019 and 2022 were averaged for clarity and brevity and were not different from one another.

**Dissolved Oxygen / Hypoxia Monitoring**

Dissolved oxygen (DO) percentages were monitored in the borrow area and reference areas, just outside of the borrow area, in May through October of 2018 (Figure 25). It was found that DO % levels were very similar in both areas on corresponding dates and at similar depths, 101.6% ± 1.3% (project area) and 106.3% ± 2.5% (reference area). Dissolved oxygen readings of greater than 100% air saturation can occur in waterways because of the production of pure oxygen by photosynthetically active organisms and/or because of non-ideal equilibration of dissolved oxygen between the water and the air above it. The lowest DO percentage occurred on June 6$^{th}$ in the borrow area and was 58%, still well above the 30% saturation generally referenced as hypoxic (Figure 26). Given the data collected, there was insufficient evidence to indicate that the dredging for the CS-0059 project had an adverse effect on the existence of hypoxia in the area. This concluded that the low DO levels observed were not likely to affect local aquatic organisms and it was decided to forego the 2019 DO monitoring. The borrow area is just west of the Calcasieu Ship Channel and experiences turbulent waters along with wave and wake energy; this may contribute to its lack of hypoxic findings and rapid infilling. There was a stratification of dissolved oxygen under some sampling conditions and not during others suggesting that wind, tide, weather, and other environmental processes had a much larger impact on the CS-0059 borrow area DO conditions than did the impact of the 10-15 feet of temporary additional depth the project created. The DO surveys completed in 2018 showed significant infilling of the borrow area during the year, post construction, and DO in the borrow area was generally about the same as the reference area.

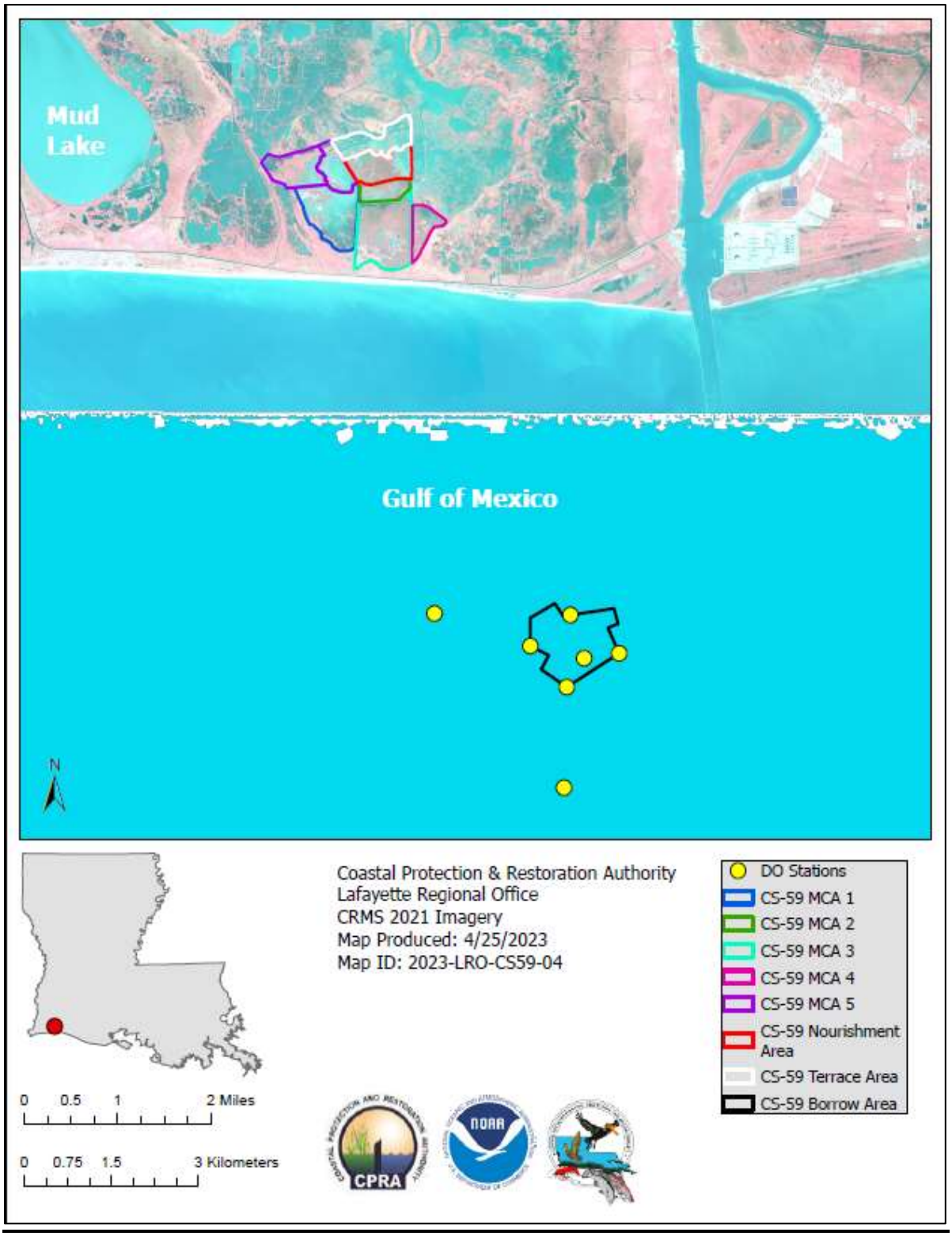


**Figure 25.** CS-0059 project and offshore borrow area locations with dissolved oxygen sampling stations. The white polygons offshore are an artifact of the imagery termination.

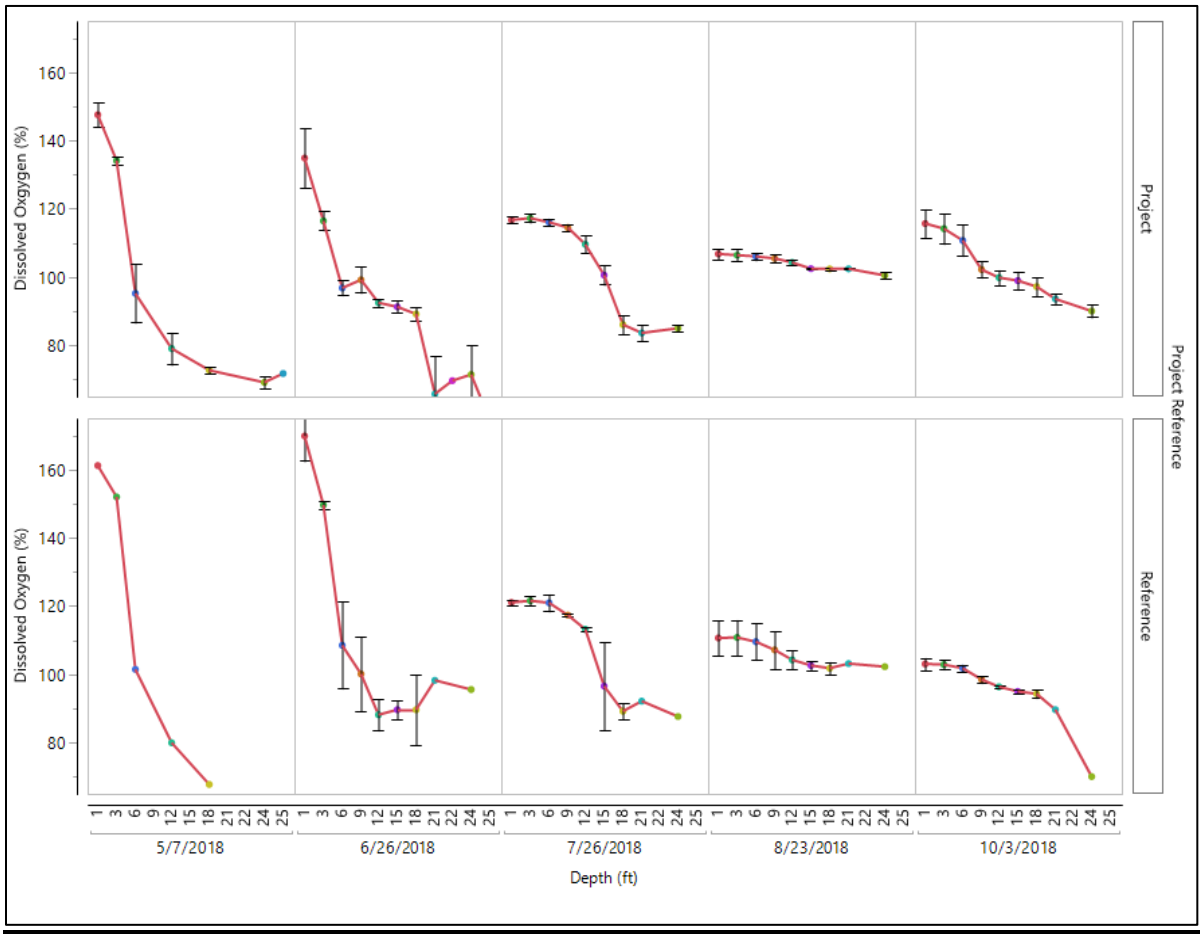


**Figure 26.** Average dissolved oxygen percent in the CS-0059 project borrow and reference areas by date and depth. Generally the DO tracked similarly along the depth profile inside and outside of the borrow area on the same date.

## V. Discussion

The CS-0059 project has successfully met the initial goals established during project design, having multiple marsh creation areas at different elevations and hydrologic connectivity allows for expansive vegetation growth and varied wildlife habitat in formally shallow open water. This project also offers extended protection to the Highway 82 corridor in conjunction with the state funded beach nourishment project to the south on the Gulf of Mexico shoreline. Currently the project is on the correct progression to meet the land area and vegetated surface portions of its goals. Much of what is currently classified as water is minimally flooded land that had not vegetated fully at the time of image capture. To date, a majority of the project area fill is still above the project settlement curve due to higher than expected constructed elevations, but it is also settling faster than anticipated possibly due to the additional loading of the foundation soils. Future surveys will determine the MCA's settlement through time and how it compares to the predicted elevations and the effects on marsh inundation and vegetation.

Much of the project area is currently above the tidal frame but is flooded much more often than would be indicated by hydrologic data as is evident by the abundance of salt marsh vegetation and repeated observations of standing water over the marsh surface. As the area settles and becomes more tidal, a better assessment of the actual flooding regime will be made. However, as previously mentioned, the project area is somewhat hydrologically isolated and can retain both fresh rain water and saline high tide flooding. This likely indicates that the project marsh platform is more dynamic than the surrounding salinity regime, both fresher during times of high rainfall and more saline post storm tides or during drought conditions.

The vegetative response to project construction is still in its initial phases as the plant community finds equilibrium, but the initial outcome has yielded very encouraging results. Overall the project area is on a positive trajectory, with vegetation synonymous with saline marshes thriving and spreading across the MCAs; some areas are supporting higher marsh and dune vegetation. The project area is already out performing impounded CRMS sites and in time, through settling and the establishment of more tidal connections, will only improve as a functional saline marsh on the shores of the Gulf of Mexico. The sediment used for project construction was borrowed from the Gulf of Mexico sea floor and as such contained marine levels of salinity. This concentrated via evaporation post construction during the 2018 drought but was quickly ameliorated by local rainfall as of the 2019 vegetation survey. The salinities in the project area have been controlled by the local hydrologic regime through 2023 and this is expected to continue as the short-lived localized increase in salinity from construction lasted less than 12 months.

Very high bulk densities and low organic matter occurred at the project sites as was expected because of the recent addition of marine sediments and limited growing seasons since project completion.

A dissolved oxygen survey was completed in 2018 and showed significant infilling of the borrow area during the year, post construction. Given the data collected, there was insufficient evidence to indicate that dredging for the CS-0059 project had an adverse effect on hypoxia in the area. Overall, the project has generated extensive habitat restoration and infrastructure protection that was tested during the 2020 hurricane season. The beach, dune, and high back marsh protected the transportation corridor with minimal damage and the marsh in the CS-

0059 project area, both rebounded quickly and was minimally effected by these extreme events.

## VI. Conclusions

### a. Project Effectiveness

To date the CS-0059 project has been very effective at saltmarsh habitat restoration along a severely degraded reach of gulf shoreline; this has occurred in conjunction with infrastructure hardening along highway 82. The construction of multiple marsh creation areas to different elevations will provide an excellent opportunity to see not only settlement differentiation but marsh vegetation succession along that elevation continuum. The early data suggests this project will meet and perhaps exceed its goals throughout its project life as more of the MCAs transition into the tidal frame, soils are reworked, and final marsh equilibrium is reached. The project has already proven to be storm resilient after multiple hurricanes impacted the area in 2020. The terraces in the northern portion of the project area have expanded substantially as of field observations in late 2023, likely due to lower than average water levels and the additional sediments from the nourishment event.

### b. Recommended Improvements

The project may require some additional hydrologic modifications if expedited tidal connectivity is desired due to the increased elevation of some of the MCAs. This would likely be in the form of additional gapping, strategically where open water and the project features coalesce. Depending on the desired effect and available budget, extending the gapping into the project interior may be considered.

### c. Lessons Learned

Marsh vegetation can and will grow at relatively high elevations depending on the level of hydrologic connectivity. In the case of CS-0059, *Spartina alterniflora* was growing at higher than normal elevations due to the impounding effects of the containment dikes, adequate rainfall, and high tide flooding. It was initially expected that due to the higher than planned elevations, the project area would be dominated by dune and salt flat species, which did occur in the highest marsh creation areas a few years post construction, but this vegetation type is being outcompeted by more intertidal saline marsh species. This data was reinforced with recent observations during a site inspection late in 2023 post exceptional drought where the dominant species were *Spartina alterniflora* and *Distichlis spicata*. Also, the combination of nourishment in open water with terraces as a backstop seemed to be very effective in this environment. Marsh nourishment with Gulf of Mexico sand is performing very well and may be superior to other interior sediment sources for marsh nourishment applications. Soil salinity was the same as surface water salinity by 2019, approximately two years post construction.

## VII. Literature Cited


APTIM. 2019. OYSTER BAYOU MARSH RESTORATION PROJECT (CS-59) Project Completion Report, Contract Number 4400007082, Baton Rouge, LA. 56 pp.

Aucoin, S. 2020. *Operations, Maintenance, and Rehabilitation Plan for Oyster Bayou Marsh Restoration Project (CS-59).* Coastal Protection and Restoration Authority of Louisiana, Lafayette, LA. 9 pp.

Barras, J.A., 2006, Land area change in coastal Louisiana after the 2005 hurricanes—A series of three maps: U.S. Geological Survey Open-File Report 2006–1274. (Also available at http://pubs.usgs.gov/of/2006/1274/.)

Calcaseiu-Sabine Basin Report. http://lacoast.gov/reports/static/HILCP_3.pdf

CB&I. 2013. Louisiana Borrow Area Management and Monitoring; Shaw Environmental and Infrastructure, Baton Rouge, LA. 29 pp.

Cretini, K.F., and Steyer, G.D. 2011, Floristic Quality Index-An assessment tool for restoration project and monitoring sites in coastal Louisiana: U.S. Geological Survey Fact Sheet 2011-3044, 4p.

Coastal Protection and Restoration Authority of Louisiana. 2012. *Louisiana's Comprehensive Master Plan for a Sustainable Coast.* Coastal Protection and Restoration Authority of Louisiana. Baton Rouge, LA.

Couvillion, B.R.; Barras, J.A.; Steyer, G.D.; Sleavin, William; Fischer, Michelle; Beck, Holly; Trahan, Nadine; Griffin, Brad; and Heckman, David, 2011, *Land area change in coastal Louisiana from 1932 to 2010: U.S. Geological Survey Scientific Investigations Map* 3164, scale 1:265,000, 12 p. pamphlet

Google Earth Pro 7.3.6 (2024), 15R 461359.58 m E 3293778.08 m N, elevation 1050 ft [online]. Available from: https://earth.google.com/web/ [Accessed 6-6-2024].

Gosselink, J.G., C. L. Cordes and J.W. Parons. 1979. An ecological characterization study of the Chenier Plain coastal ecosystem of Louisiana and Texas. 3 vols. U.S. Fish and Wildlife Service, Office of Biological Services. FWS/OBS-78/9 through 78/11.

Lonnie G. Harper and Associates, Inc. (2013). *Final Survey Report – Oyster Bayou Marsh Restoration (CS-59) – Topographic Survey*. Lonnie G. Harper and Associates, Inc., Bell City, Louisiana. Report submitted to CPRA.

Richard J. Pasch, Robbie Berg, David P. Roberts, and Philippe P. Papin, National Hurricane Center 26 May 2021. TROPICAL CYCLONE REPORT HURRICANE LAURA (AL132020)

Sasser, C.E., Visser, J.M., Mouton, Edmond, Linscombe, Jeb, and Hartley, S.B., 2014,

Vegetation types in coastal Louisiana in 2013: U.S. Geological Survey Scientific Investigations Map 3290, 1 sheet, scale 1:550,000.

Steyer, G.D., R.C. Raynie, D.L. Steller, D. Fuller, and E. Swenson. 1995 (revised 2000). Quality management plan for the Coastal Wetlands Planning, Protection, and Restoration Act monitoring program. Open-file series no. 95-01 (Revised June 2000). Baton Rouge: Louisiana Department of Natural Resources, Coastal Restoration Division. 97 pp.

Thompson, W., 2014. *Oyster Bayou Marsh Restoration Project (CS-59) – 95% Design Report*. Baton Rouge, Louisiana: CB&I Coastal Planning & Engineering, Inc. 45p. (Report prepared for the Louisiana Coastal Protection and Restoration Authority).

Todd M. Folse, Thomas E. McGinnis, Leigh A. Sharp, Jonathan L. West, MelissaK. Hymel, John P. Troutman, Dona Weifenbach, William M. Boshart, Laurie B. Rodrigue, Danielle C. Richardi, W. Bernard Wood, C. Mike Miller, Elizabeth M. Robinson, Angelina M. Freeman, Camille L. Stagg, Brady R. Couvillion, and Holly J. Beck. 2020. A Standard Operating Procedures Manual for the Coastwide Reference Monitoring System-Wetlands and the System-Wide Assessment and Monitoring Program: Methods for Site Establishment, Data Collection, and Quality Assurance/Quality Control. Louisiana Coastal Protection and Restoration Authority. Baton Rouge, LA. 252 pp.

U.S. Department of Agriculture (USDA), 1995 Soil Survey of Cameron Parish, Louisiana. Soil Conservation Service, Alexandria, LA. 1335 pp, plus appendix.

# APPENDIX A
# (Inspection Photographs)

**Photo 1**: LA 27/82 near Entrance to CS-0059 Project Site, Highway Rehabilitation Patch Pictured (looking Southwest), 11/3/2023

**Photo 2**: Photo of CS-0059 Project From Southern Extents of Project Site, Team Vehicle and Airboat on Oil Field Road Shown to the Right, Pictured Near LA 27/82 (looking Northwest), 11/3/2023

**Photo 3**: Photo of CS-0059 Project Team Vehicle and Airboat on Oil Field Road, Pictured Near Access Gate, Marsh Creation Areas in the Background (looking North), 11/3/2023

**Photo 4**: Photo of Oil Field Road with MCA3 Shown to the Right, MCA1 Pictured to the Left (looking North), 11/3/2023

**Photo 5**: Photo of MCA1 near Oil Field Road (looking South), 11/3/2023

**Photo 6**: Photo Depicting Active Landowner/Recreational Use of Project Area, 11/3/2023

**Photo 7**: Photo of MCA3 with Duck Pond Visible in Background (looking West), 11/3/2023

**Photo 8**: Photo Depicting Road Bridge at the Northern Extents of MCA3, MCA3 Pictured to the Left, 11/3/2023

**Photo 9**: Photo of CS-0059 Project Team Launching Airboat, 11/3/2023

**Photo 10**: Photo of Open Water and Marsh outside of CS-0059 Project Area, at the southernmost extents of MCA3/MCA4 (looking South), 11/3/2023

**Photo 11**: Photo Showing Restored Marsh within MCA4 (looking North), 11/3/2023

**Photo 12**: Photo of Constructed Terraces near unconfined nourishment area (looking North), 11/3/2023

**Photo 13**: Photo Showing Nourishment Area near unconfined nourishment area and MCA5A (looking North), 11/3/2023

**Photo 14**: Photo Showing MCA1 Area Pictured From MCA5, 11/3/2023

**Photo 15**: Photo of Remnant Earthen Containment Dike Between MCA1 and MCA5, MCA5 Pictured to the Right, MCA1 Pictured to the Left (looking East), 11/3/2023

**Photo 16**: Photo Emphasizing High Containment Dike Area Near MCA1/MCA5 Boundary, This Location Likely to Receive Gapping via Future O&M Event, 11/3/2023

# APPENDIX B
# (Three Year Budget Projection)

**OYSTER BAYOU MARSH RESTORATION / (CS-0059) / C.140059.8 / PPL 21**

**Three-Year Operations & Maintenance Budgets 07/01/2024 - 06/30/2027**

| Project Manager | O & M Manager | Federal Sponsor | Prepared By |
|---|---|---|---|
| Jacques Boudreaux | Jacques Boudreaux | NOAA | Jacques Boudreaux |

| | 2024/2025 (-5) | 2025/2026 (-6) | 2026/2027 (-7) |
|---|---|---|---|
| ***Maintenance Inspection*** | $ 21,004.98 | $ 21,004.98 | $ 21,004.98 |
| ***State Administration*** | $ 8,485.00 | $16,970.00 | $ 25,455.00 |
| ***Federal Administration*** | $ 3,440.00 | $ 3,502.00 | $ 3,565.00 |

24/25 Description:

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

25/26 Description: E&D and Surveying for Upcoming Dike Gapping and Associated O&M

| | | |
|---|---|---|
| *E&D* | | $123,000.00 |
| *Construction* | | $ - |
| *Construction Oversight* | | $ - |
| Sub Total - Maint And Rehab | $ | 123,000.00 |

26/27 Description: Dike Gapping and Associated O&M

| | | |
|---|---|---|
| *E&D* | | $ - |
| *Construction* | | $110,000.00 |
| *Construction Oversight* | | $38,500.00 |
| Sub Total - Maint And Rehab | $ | 148,500.00 |

| | 2024/2025 (-5) | 2025/2026 (-6) | 2026/2027 (-7) |
|---|---|---|---|
| ***Total O&M Budgets*** | $ 32,929.98 | $ 164,476.98 | $ 198,524.98 |

| | |
|---|---|
| **O &M Budget (3 yr Total)** | **$ 395,931.94** |
| **Unexpended O & M Budget*** | **$ 504,673.05** |
| **Remaining O & M Budget (Projected)** | **$ 108,741.11** |

*Includes available incrementally requested funds not yet requested

## OPERATION AND MAINTENANCE BUDGET WORKSHEET

OYSTER BAYOU MARSH RESTORATION / (CS-0059) / C.140059.8 / PPL 21 / 2024-2025

| DESCRIPTION | UNIT | EST. QTY. | UNIT PRICE | ESTIMATED TOTAL |
|---|---|---|---|---|
| O&M Inspection and Report | EACH | 1 | $21,004.98 | $21,004.98 |
| Engineering and Design | LUMP | 0 | $0.00 | $0.00 |
| Construction Oversight | LUMP | 0 | $0.00 | $0.00 |

**ADMINISTRATION**

| | | | | |
|---|---|---|---|---|
| STATE Admin. | LUMP | 1 | $8,485.00 | $8,485.00 |
| FEDERAL SPONSOR Admin. | LUMP | 1 | $3,440.00 | $3,440.00 |
| SURVEY Admin. | LUMP | 1 | $0.00 | $0.00 |
| OTHER | | | | $0.00 |
| | | | TOTAL ADMINISTRATION COSTS: | $11,925.00 |

**MAINTENANCE / CONSTRUCTION**

***SURVEY***

| | | | | | |
|---|---|---|---|---|---|
| SURVEY DESCRIPTION | Pipeline Inspection & Testing | | | | |
| | 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 Dike | 0 | 0.0 | 0 | $0.00 | $0.00 |
| Bank Paving | 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 (25%) | | LUMP | 0 | $0.00 | $0.00 |
| Vegetative Plantings | | LUMP | 0 | $0.00 | $0.00 |
| OTHER | | LUMP | 0 | $0.00 | $0.00 |
| OTHER | | | | $0.00 | $0.00 |
| | | | | TOTAL CONSTRUCTION COSTS: | $0.00 |

**TOTAL OPERATIONS AND MAINTENANCE BUDGET:** $32,929.98

## OPERATION AND MAINTENANCE BUDGET WORKSHEET

OYSTER BAYOU MARSH RESTORATION / (CS-0059) / C.140059.8 / PPL 21 / 2025-2026

| DESCRIPTION | UNIT | EST. QTY. | UNIT PRICE | ESTIMATED TOTAL |
|---|---|---|---|---|
| O&M Inspection and Report | EACH | 1 | $21,004.98 | **$21,004.98** |
| Engineering and Design | LUMP | 1 | $33,000.00 | **$33,000.00** |
| Construction Oversight | LUMP | 0 | $0.00 | **$0.00** |

**ADMINISTRATION**

| | | | | |
|---|---|---|---|---|
| STATE Admin. | LUMP | 1 | $8,485.00 | $8,485.00 |
| FEDERAL SPONSOR Admin. | LUMP | 1 | $3,502.00 | $3,502.00 |
| SURVEY Admin. | LUMP | 1 | $8,485.00 | $8,485.00 |
| OTHER | | | | $0.00 |
| | | | TOTAL ADMINISTRATION COSTS: | **$20,472.00** |

**MAINTENANCE / CONSTRUCTION**

***SURVEY***

| | | | | | |
|---|---|---|---|---|---|
| SURVEY DESCRIPTION | Survey project area | | | | |
| Secondary Monument | | EACH | 0 | $0.00 | $0.00 |
| Staff Gauge / Recorders | | EACH | 0 | $0.00 | $0.00 |
| Marsh Elevation / Topography | | LUMP | 1 | $90,000.00 | $90,000.00 |
| TBM Installation | | EACH | 0 | $0.00 | $0.00 |
| OTHER | | | | | $0.00 |
| | | | | TOTAL SURVEY COSTS: | **$90,000.00** |

***GEOTECHNICAL***

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

***CONSTRUCTION***

| | | | | | |
|---|---|---|---|---|---|
| CONSTRUCTION DESCRIPTION | Vegetative plantings, and engineering monitoring. | | | | |
| Rip Rap | LIN FT | TON / FT | TONS | UNIT PRICE | |
| Rock Dike | 0 | 0.0 | 0 | $0.00 | $0.00 |
| Bank Paving | 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 (25%) | | LUMP | 0 | $0.00 | $0.00 |
| Vegetative Plantings | | LUMP | 0 | $0.00 | $0.00 |
| OTHER | | LUMP | 0 | $0.00 | $0.00 |
| OTHER | | | | $0.00 | $0.00 |
| | | | | TOTAL CONSTRUCTION COSTS: | **$0.00** |

**TOTAL OPERATIONS AND MAINTENANCE BUDGET:** **$164,476.98**

## OPERATION AND MAINTENANCE BUDGET WORKSHEET

OYSTER BAYOU MARSH RESTORATION / (CS-0059) / C.140059.8 / PPL 21 / 2026-2027

| DESCRIPTION | UNIT | EST. QTY. | UNIT PRICE | ESTIMATED TOTAL |
|---|---|---|---|---|
| O&M Inspection and Report | EACH | 1 | $21,004.98 | $21,004.98 |
| Engineering and Design | LUMP | 0 | $0.00 | $0.00 |
| Construction Oversight | LUMP | 1 | $38,500.00 | $38,500.00 |

**ADMINISTRATION**

| | | | | |
|---|---|---|---|---|
| STATE Admin. | LUMP | 1 | $25,455.00 | $25,455.00 |
| FEDERAL SPONSOR Admin. | LUMP | 1 | $3,565.00 | $3,565.00 |
| SURVEY Admin. | LUMP | 0 | $0.00 | $0.00 |
| OTHER | | | | $0.00 |
| | | | TOTAL ADMINISTRATION COSTS: | $29,020.00 |

**MAINTENANCE / CONSTRUCTION**

***SURVEY***

| SURVEY DESCRIPTION | Pipeline Inspection & Testing | | | | |
|---|---|---|---|---|---|
| | 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 Dike | 0 | 0.0 | 0 | $0.00 | $0.00 |
| | Bank Paving | 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 | 1 | $30,000.00 | $30,000.00 |
| | Contingency | | LUMP | 1 | $10,000.00 | $10,000.00 |
| | General Structure Maintenance (25%) | | LUMP | 0 | $0.00 | $0.00 |
| | Vegetative Plantings | | LUMP | 0 | $0.00 | $0.00 |
| | OTHER - Dike Gapping | | LUMP | 1 | $70,000.00 | $70,000.00 |
| | OTHER | | | | $0.00 | $0.00 |
| | | | | | TOTAL CONSTRUCTION COSTS: | $110,000.00 |

**TOTAL OPERATIONS AND MAINTENANCE BUDGET: $168,524.98**