



Performance Monitoring at the Galveston Island State Park Marsh Restoration and Protection (Phase I & Phase II) Project (CEPRA 1601)

Post Construction
Monitoring Report: Year 5

8/31/2023



Executive Summary

The National Fish and Wildlife Foundation (NFWF) Galveston Island State Park Marsh Restoration and Protection (Phase I & Phase II) (NFWF GEBF TX Project No. 40606 & 49988; TGLO CEPRA Project No. 1601) project was funded through the Gulf Environmental Benefit Fund (GEBF). Per requirements instated in 2014, GEBF-funded projects are required to be monitored for five years to determine if the project goals have been met and if adaptive management measures are necessary.

The marsh restoration was constructed through placement of sandy material dredged from nearby areas in West Bay. The material was discharged as clusters of mounds to provide growing platforms for marsh vegetation, creating marsh complex consisting of intertidal areas and open water. Two rock breakwaters were constructed to provide protection against wave action generated in West Bay. Breakwater construction was completed in February 2017 and dredged material placement was completed in July 2017.

This report summarizes the fifth year of post-construction monitoring performed in 2022 to assess project performance. A topographic and bathymetric survey was performed on August 29, 2022, a site visit was performed on September 21 and 22, 2022, and aerial photography was taken September 21, 2022. Monitoring was performed through site observations, ground digital photography, aerial digital photography, and RTK GPS measurements. The project was evaluated for marsh mound geometry and sediment composition; marsh mound vegetation survival and coverage; breakwater geometry, stone condition, and toe scour; marsh fringe stability and width; and hard substrate habitat along the breakwater.

Primary findings of the fifth year of monitoring include:

- Bayward perimeter mounds have been partially reshaped by wave action, and some have been significantly reshaped and have lost transplanted sprigs. However, these mounds complement the breakwaters in providing secondary protection to interior mounds and serve as a sediment source for interior mounds. All interior mounds are relatively stable.
- All mounds continue to consist of firm, sandy or shelly material.
- All mounds continue to support intertidal marsh vegetation.
- Estimated intertidal coverage ranges from 5% to 100%. Vegetation coverage remained consistent between Year 4 to Year 5, although sprig density appears to have increased. Because of natural seeding and propagation by rhizomes on many mounds, vegetation coverage has generally increased as the marsh complex has matured, although at a slower rate than previously.
- The breakwaters appear to be relatively stable and in good condition. Both breakwaters have experienced minimal settling and appear to be meeting the design intent. Minimal to no scour was observed, and scour is not expected to cause breakwater instability.
- Average shoreline change at randomly selected perimeter mounds was less than previously-reported short-term rates but greater than long-term historical averages. The rates measured during the Year 5 monitoring period are less than the rates measured during the previous monitoring periods.
- Encrusting species were observed along the entirety of both sides of the breakwaters.



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1. Introduction

1.1. Purpose and Scope

This report documents post-construction performance monitoring five years after the completion of CEPRA Project No. 1601. The marsh restoration project was completed in 2017 and restored approximately 75 acres of intertidal marsh complex within Carancahua Cove at Galveston Island State Park (GISP) through the construction of 81 marsh mounds and 5,415 linear feet (ft) of rock breakwater. Marsh mounds consist of sandy dredged material placed to create broad, gently sloping mounds. The breakwaters provide protection from wave action for new and existing marsh features. A project location map is provided in Figure 1.

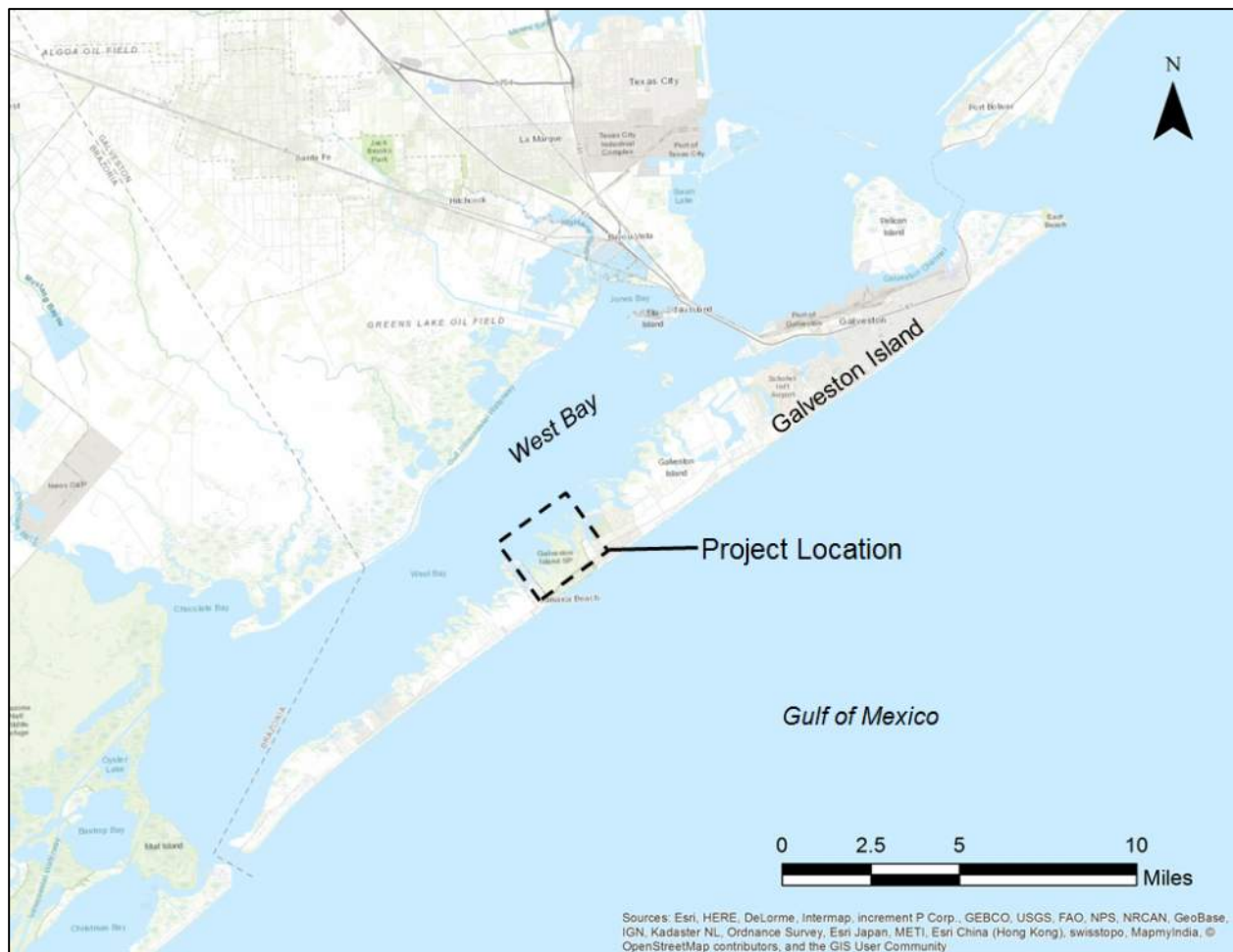


Figure 1. Project location.



The scope of work for the monitoring effort included assessment of marsh mound geometry and vegetative coverage, breakwater geometry and condition, and protection of estuarine habitat. The following criteria were assessed to evaluate the performance of the project:

- Marsh mound geometry
- Composition of marsh mound sediment
- Approximate survivability of sprigs planted on the constructed mounds
- Approximate coverage of smooth cordgrass (*Spartina alterniflora*) in typical growing elevations
- Condition of breakwater stone
- Breakwater crest elevation
- Scour along breakwater toe
- Shoreline change at perimeter mounds
- Hard substrate habitat along breakwater

The criteria were assessed for the Year 5 Monitoring effort through field observations, field and aerial photographs, and RTK GPS measurements on September 21 and 22, 2022.

1.2. Background

The construction contract for CEPRA Project No. 1601 was executed on July 21, 2016. The project was funded through the National Fish and Wildlife Foundation (NFWF) – Gulf Environmental Benefit Fund (GEBF) for the restoration and protection of estuarine marsh within West Bay in Galveston Island State Park (NFWF GEBF TX Project Nos. 40606 and 49988). Per GEBF requirements instated in 2014, any project funded by the GEBF must develop a Monitoring and Adaptive Management Plan (MAMP) to determine if the project has met or is expected to meet the intended conservation objectives and, if not, whether adaptive management actions may be warranted. To meet this requirement, HDR Engineering, Inc. (HDR) previously developed a MAMP (2016) for the NFWF Galveston Island State Park Marsh Restoration and Protection Project using guidelines provided by GEBF. The current performance monitoring effort was conducted in accordance with the MAMP.

Rock breakwater construction was completed in February 2017 and dredged material placement was completed in June 2017. Approximately 750 to 1,000 springs of smooth cordgrass (*Spartina alterniflora*, herein referred to as *Spartina*) were planted on each mound between +0.8 ft NAVD and +1.6 ft NAVD. These elevations were selected based on a reference marsh survey. A total of 81 mounds and 5,415 LF of breakwater was constructed (4,415 LF at Carancahua Cove and 1,000 LF at Butterowe Bayou). An aerial photograph was taken July 2017 by the construction contractor for project acceptance (Figure 2). During construction, mounds were designated into Areas A through H. The same mound area groupings are referred to in this report (see Figure 3).



Figure 2. Post-construction aerial photograph (July 2017).

Based on a reference marsh survey conducted at the site with a Texas Parks and Wildlife Department (TPWD) biologist, design elevations for the marsh mounds targeted the full range of intertidal marsh elevations. Mounds were constructed to elevations above typical intertidal elevations to allow for the upward migration of intertidal marsh vegetation in response to sea level rise, long term settlement, and land subsidence. In addition, upper portions of marsh mounds provide suitable habitat for other estuarine marsh species and nesting habitat for shorebirds.

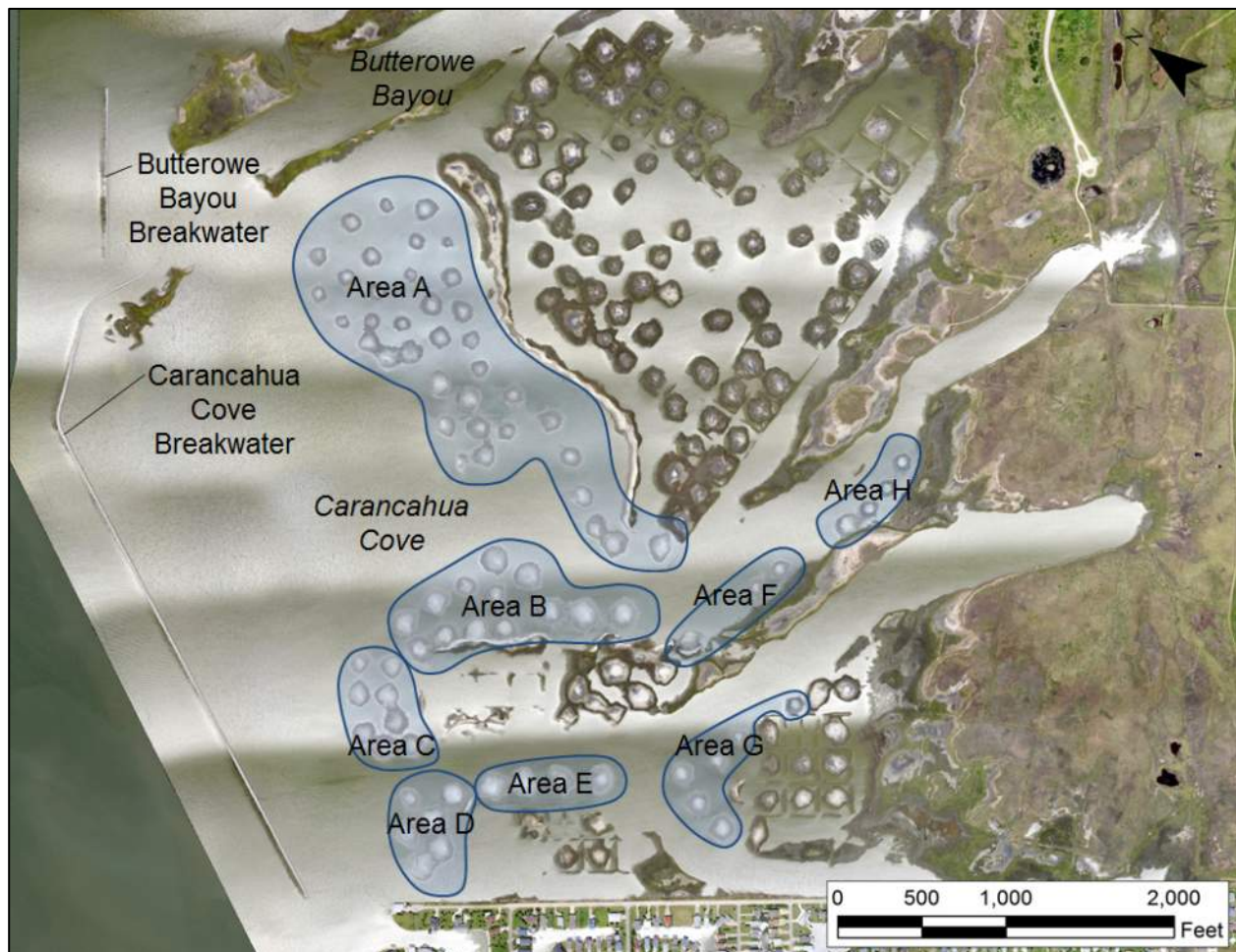


Figure 3. Project features as designated during project construction.

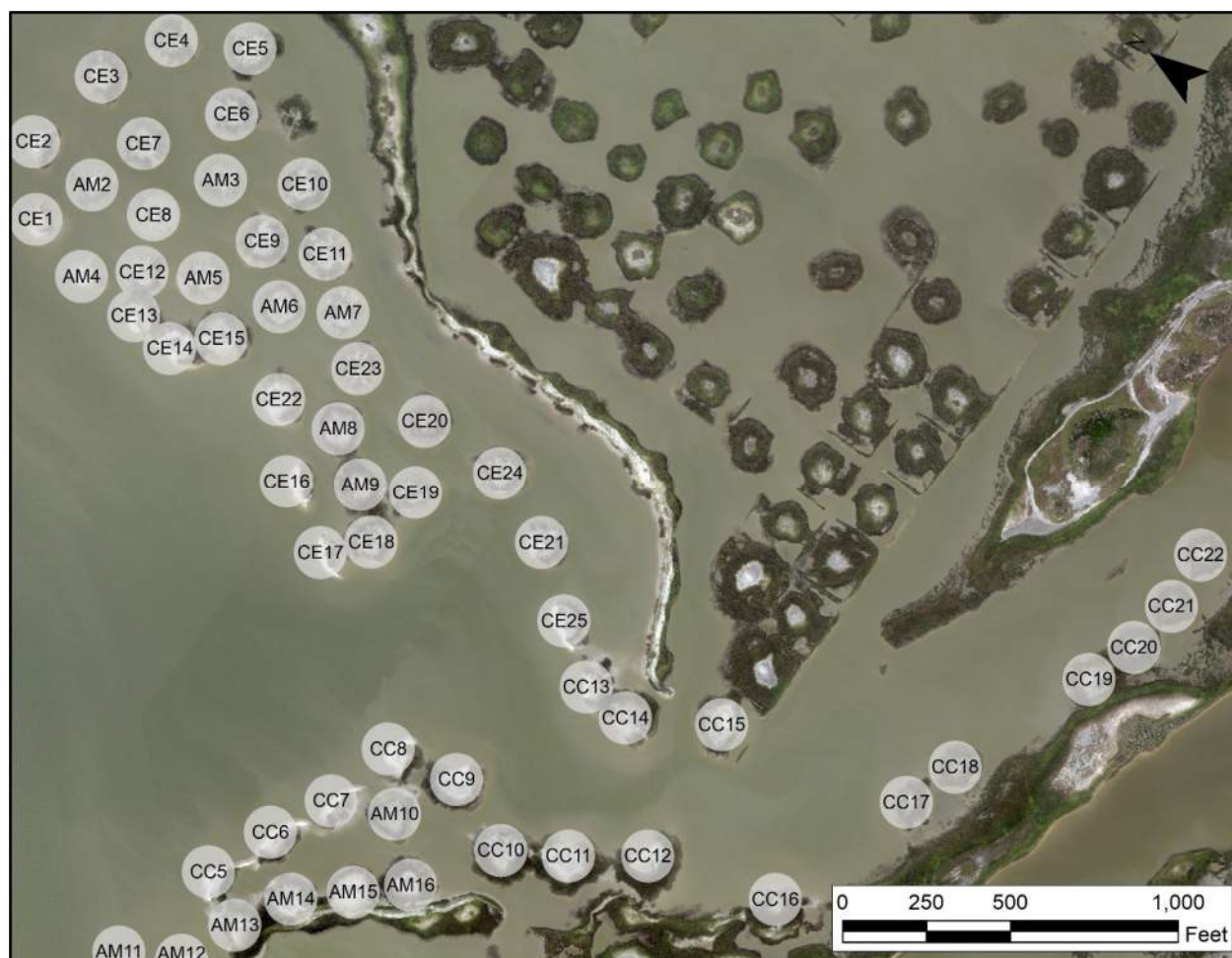


Figure 4. Mound labels (Area A, Area B, Area F, and Area H)

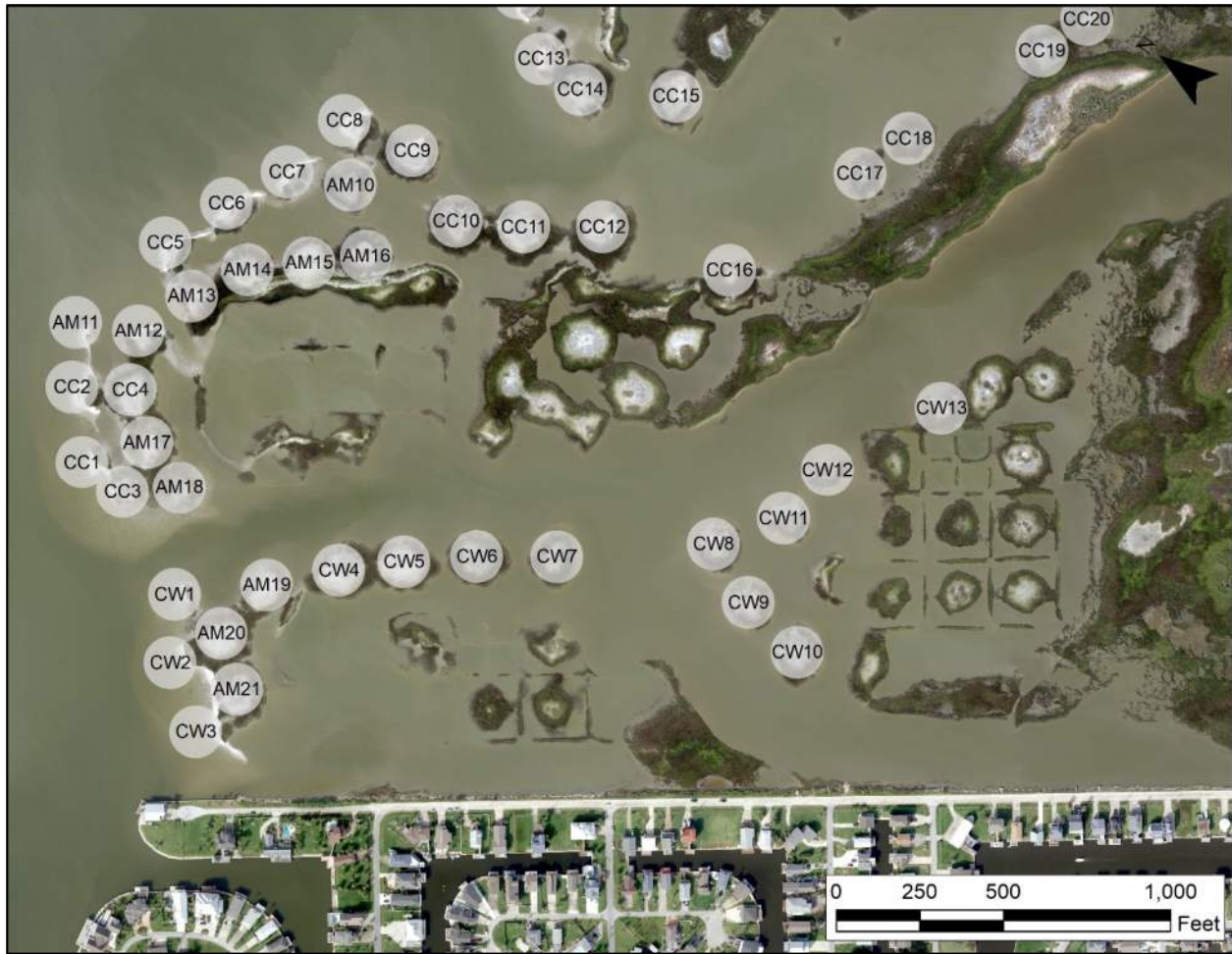


Figure 5. Mound labels (Area C, Area D, Area E, and Area G).

2. Data Collection

HDR performed a site visit on September 21 and 22, 2022 to assess general conditions within the marsh restoration site. Two TPWD staff joined HDR on the site visit. All 81 marsh mounds and the entire 5,415 LF of breakwater were observed during the site visit.

2.1. Ground Digital Photography

Digital photographs of each mound and breakwater were taken to document field conditions observed during the site visit. See Figure 6 for a typical ground digital photograph. Field conditions are discussed in Section 3 and photos are presented in Appendix A.



Figure 6. Photograph of Mound CW6 facing southeast.

2.2. Aerial Photography

On September 21, 2022, Terra Flight Aerial Imaging, Inc. took aerial photographs while HDR and TPWD performed the site visit. The aerial photography captured an approximately 4,500-acre area, covering the entire project site and surrounding areas, including the borrow area and the previously restored marsh at Carancahua Cove. Aerials were provided in true color and color infrared. The color infrared photography helps highlight marsh vegetation, which appears red. Figure 7 shows the true color aerial photograph and Figure 8 shows the color infrared photograph. The borrow area is hatched in both figures. High resolution files are included in Appendix B, and georeferenced digital files have been provided to TGLO.



Figure 7. Year 5 Monitoring true-color aerial photograph. Aerial taken by Terra Flight, 9/21/2022.



Figure 8. Year 5 Monitoring infrared-color aerial photograph. Aerial taken by Terra Flight, 9/21/2022.

2.3. Topographic Surveying

During the site visit, HDR conducted real time kinematic (RTK) surveying using a Virtual Reference Station (VRS). VRS eliminates the need to set up a base station at the project site by connecting to a network of permanent GPS base stations. The base station used for this project is on the southwestern end of Galveston Island near the intersection of San Luis Pass Road and Baywater Drive. RTK GPS equipment was used to measure crest elevation along each breakwater (Figure 9) and to measure the location and width of fringe marsh on selected mounds.

From August 29 to September 4, 2022, T. Baker Smith, LLC (TBS) collected additional topographic and bathymetric survey data to assess cross-sectional area changes of marsh mounds and the surrounding marsh complex.



Figure 9. RTK GPS measurement of the Carancahua Cove breakwater crest elevation. Photo facing northeast.

3. Monitoring Analysis and Results

3.1. Marsh Mound Geometry and Sediment Composition

Marsh mound geometry was evaluated through field observations, field photography, and aerial photography. All 81 mounds constructed in 2017 existed at the time of the Year 5 monitoring. Mound cross-sections were evaluated based on relative stability, with moderate reshaping expected from natural forces and settlement. This criterion was met by 59 of the 81 mounds (73%), and the mound cross-sections appeared similar to the immediate post-construction cross-sections. The following 22 (27%) perimeter mounds experienced moderate to significant reshaping from waves along their bayward edge: CE2, CE1, AM4, CE13, CE14, CE16, CE17, CE25, CC13, CC12, CC9, CC8, CC7, CC6, CC5, AM12, AM11, CC2, CC1, CW1, CW2, and CW3 (see Figure 10 through Figure 12). Based on a comparison of aerial photography taken in Year 0 and Year 3, most of the sediment from the reshaped mounds appeared to have remained in the marsh restoration area, and the mound area above the waterline has remained approximately constant. Additional topographic and bathymetric surveying were performed in Year 5 to better

understand elevations within the marsh complex. At the time of Year 5 monitoring, approximately 93% of the volume placed in the project footprint remains. A comparison of elevation change between the Year 0 survey and Year 5 survey is shown in Figure 13. Red areas show erosion which was generally observed along the perimeter of mound areas. Blue areas indicated accretion which was generally observed between interior mounds. Note that the mounds that experienced significant reshaping at the time of Year 2 monitoring have approximately retained that shape at the time of the Year 5 monitoring. All interior mounds are relatively stable.

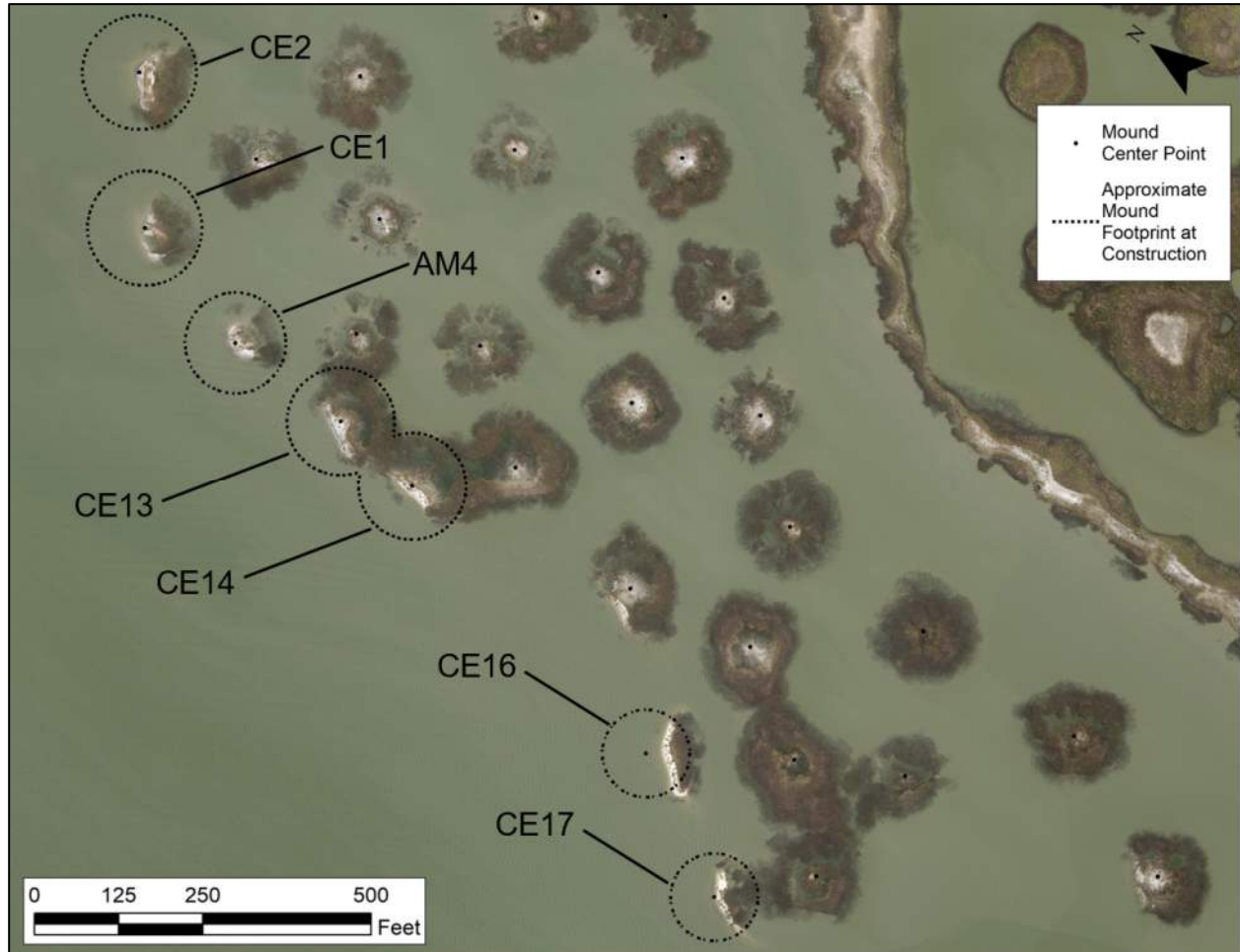


Figure 10. Reshaping at perimeter mounds in Area A.

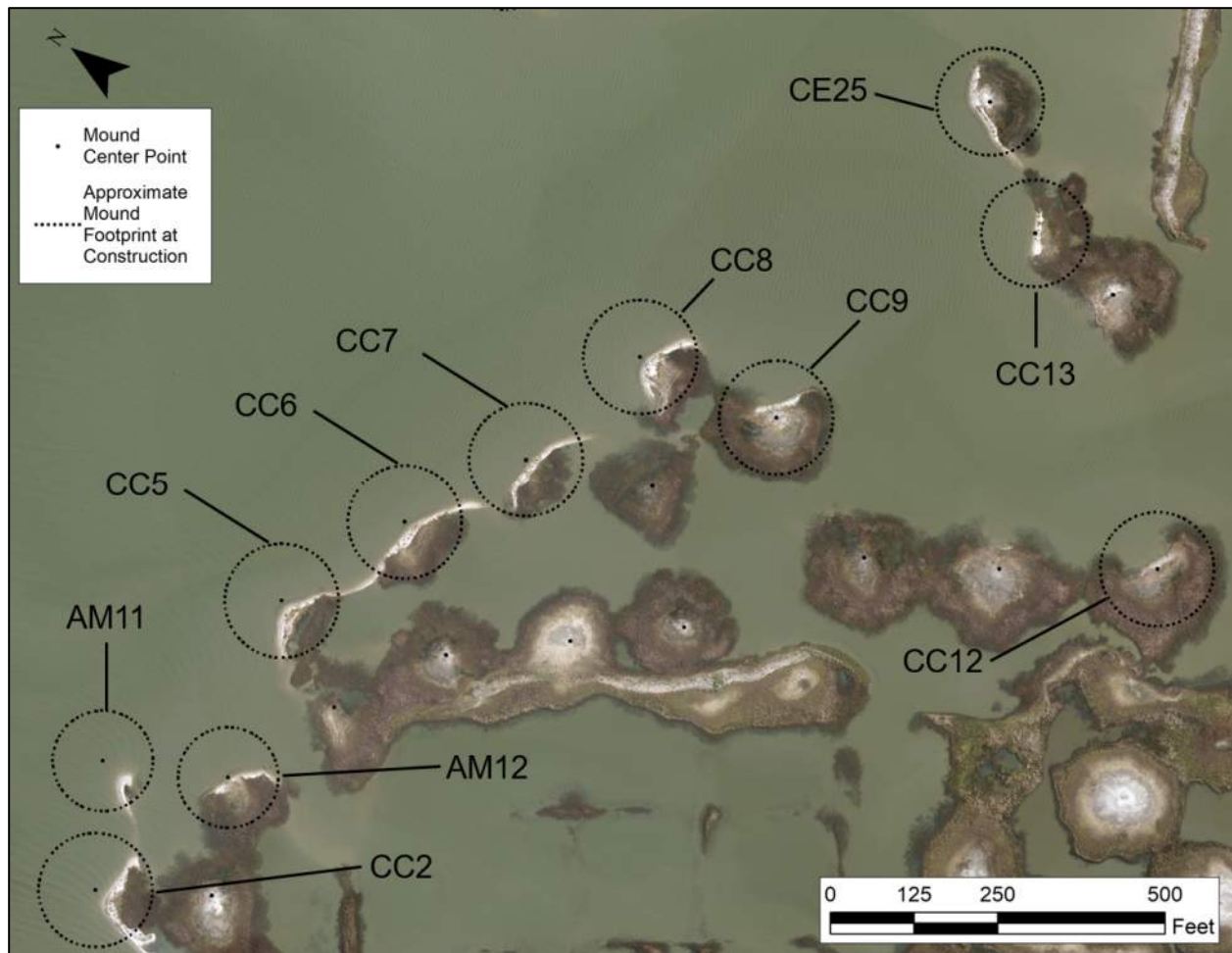


Figure 11. Reshaping at perimeter mounds in Area A, Area B, and Area C.

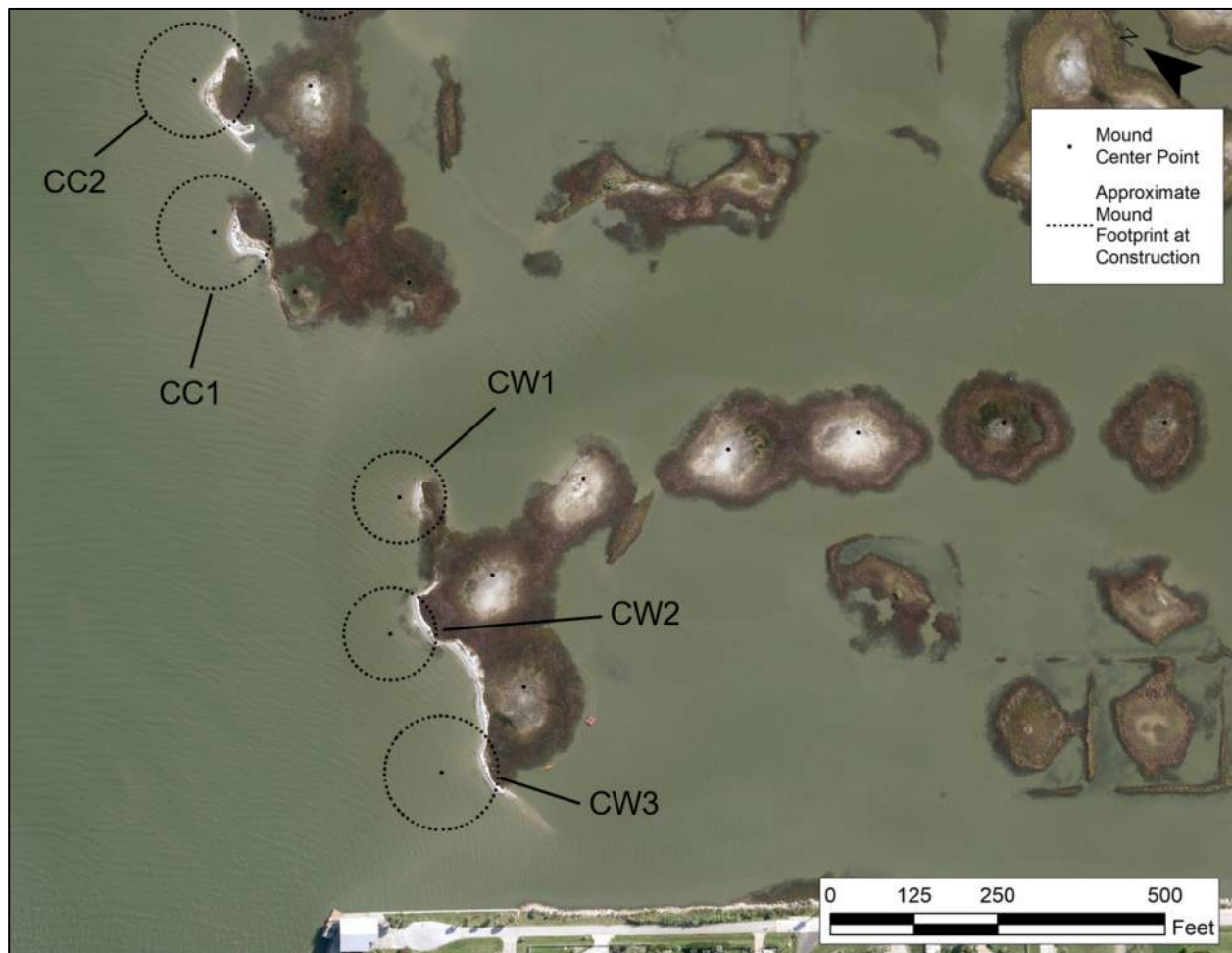


Figure 12. Reshaping at perimeter mounds in Area C and Area D.

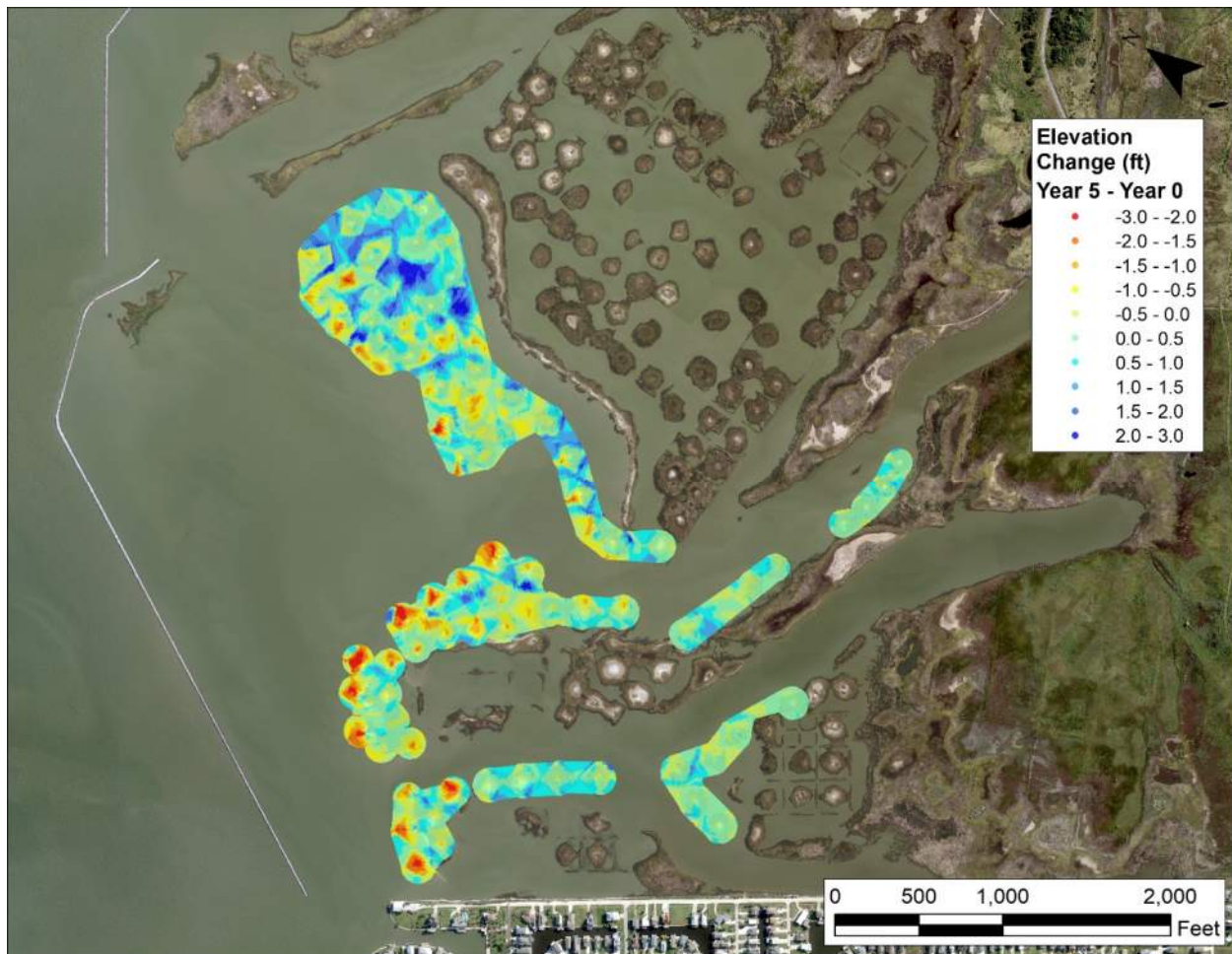


Figure 13. Elevation comparison between Year 0 and Year 5.

The sediment composition of each mound was observed to verify that the mounds are predominantly composed of sand, shell hash, and/or shell as opposed to silt and clay. All 81 mounds met this criterion and consisted of predominately firm non-cohesive sediments. The amount of shell hash and/or shell varied among the mounds. In general, more shell was visible in bayward perimeter mounds (see Figure 14), likely due to natural sorting of sediments caused by the greater exposure to wave action. Overall, the mounds in Area A typically contained more shell than mounds in other areas (for example, see Figure 15), likely due to variations in the borrow area.



Figure 14. Shell ridge on Mound CE25 in Area A facing south.



Figure 15. Typical mound composition of sand, shell, and shell hash on Mound CC15 in Area A. Photo facing west.

3.2. Vegetation Survival and Coverage

Per the MAMP, a survivability rate of 80% of sprigs planted immediately following construction should be observed during the first two years of monitoring. During the third, fourth, and fifth years of monitoring, a minimum of 70% aerial coverage of targeted vegetation should be observed. During the Year 1 site visit, survivability rate was estimated through visual observations and field photographs for transplanted sprigs only. Sprigs growing through natural seeding or propagation by rhizome were not considered in the analysis. However, between the Year 1 and Year 2 site visits, most mounds experienced a large amount of natural propagation, making it impossible to discern sprigs transplanted immediately after mound construction from naturally propagated vegetation. It was generally assumed that survivability rate following Year 1 remained constant except on mounds that experienced significant reshaping as noted on subsequent site visits. Due to the amount of natural seeding and propagation by rhizomes that has occurred since the sprigs were planted, the vegetation planting performance criteria for Year 2 through Year 5 was based on aerial coverage of targeted vegetation within the planted intertidal zone rather than the survival of individual transplanted sprigs.



Percent aerial coverage was estimated only for the planted intertidal zone (approximately +0.8 ft NAVD to +1.6 ft NAVD). Of the 81 mounds, 55 mounds (68%) met the performance criteria of 70% aerial coverage. The overall average estimated coverage was 76% and the median was 90%, a decrease of 1% and no change from Year 4, respectively. Between the Year 4 and Year 5 site visit, 31% of mounds increased in vegetative coverage, 41% remained the same, and 28% decreased in coverage. Of mounds that decreased in coverage, 28% still met the 70% coverage threshold. Percent coverage increased significantly between the Year 1 and Year 2 site visits; no mounds met the coverage criteria in Year 1 and 52 met the criteria in Year 2. Increase in coverage appears to have leveled off somewhat since Year 2, although natural propagation has continued to increase and is expected to continue as the project matures and will likely increase the percent of vegetation coverage and the vegetation density on each mound. As of the Year 5 monitoring effort, natural seeding and propagation by rhizomes has increased the vegetation coverage on nearly all mounds since planting took place. Although the overall estimated coverage in the planted area remained constant, vegetation density appeared to have increased between Year 4 and Year 5. Additionally, propagation increased vegetation coverage outside of areas planted for the project including coalescing areas between mounds and areas that have been reshaped by waves and currents. Figure 16 and Figure 17 show estimated vegetation coverage in the intertidal region and Figure 18 shows a yearly aerial comparison of coverage between Year 0 and Year 5 in Area A. Refer to Table 1 for a summary of vegetation coverage.

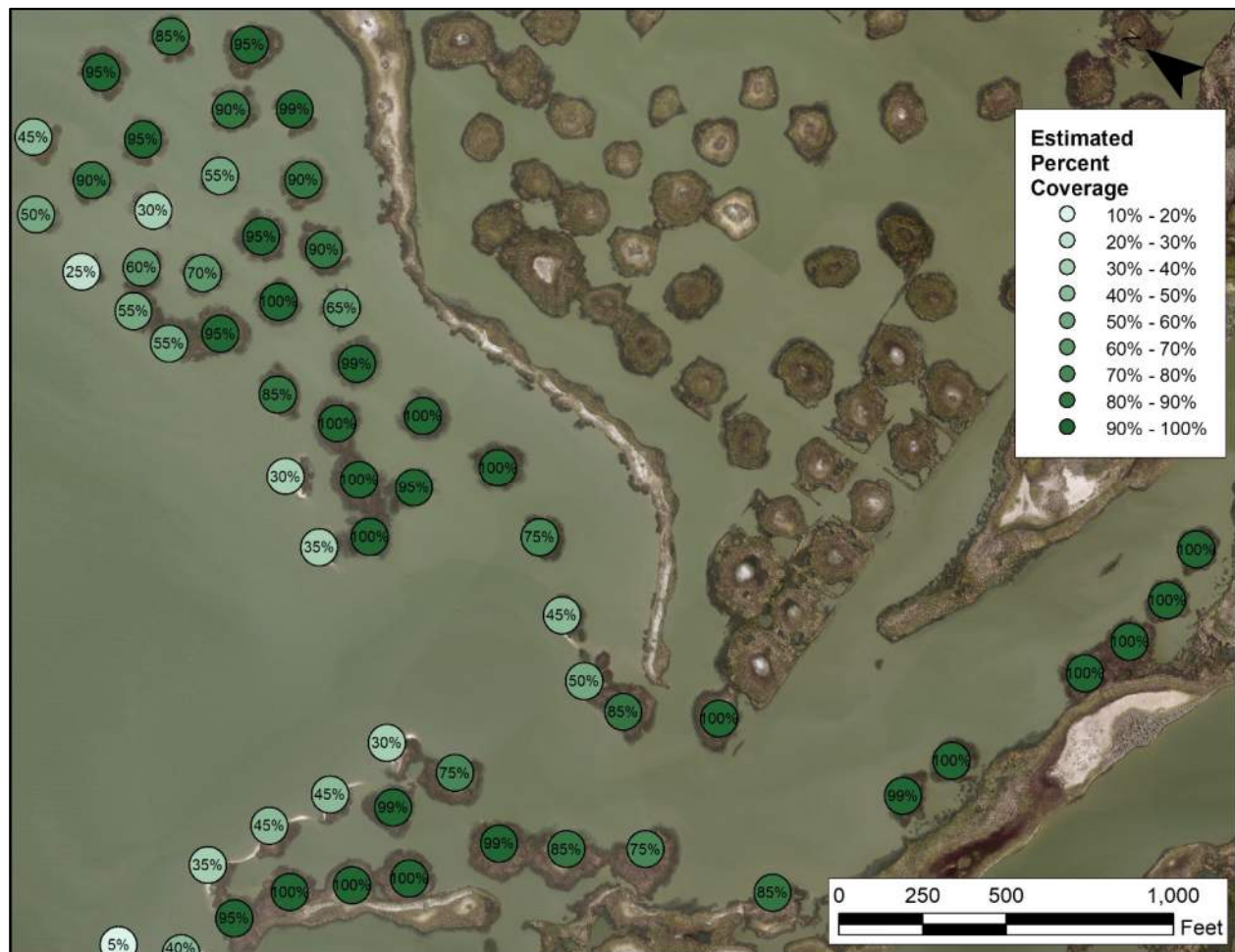


Figure 16. Estimated percent vegetation coverage in intertidal region for Area A, Area F, and Area H.

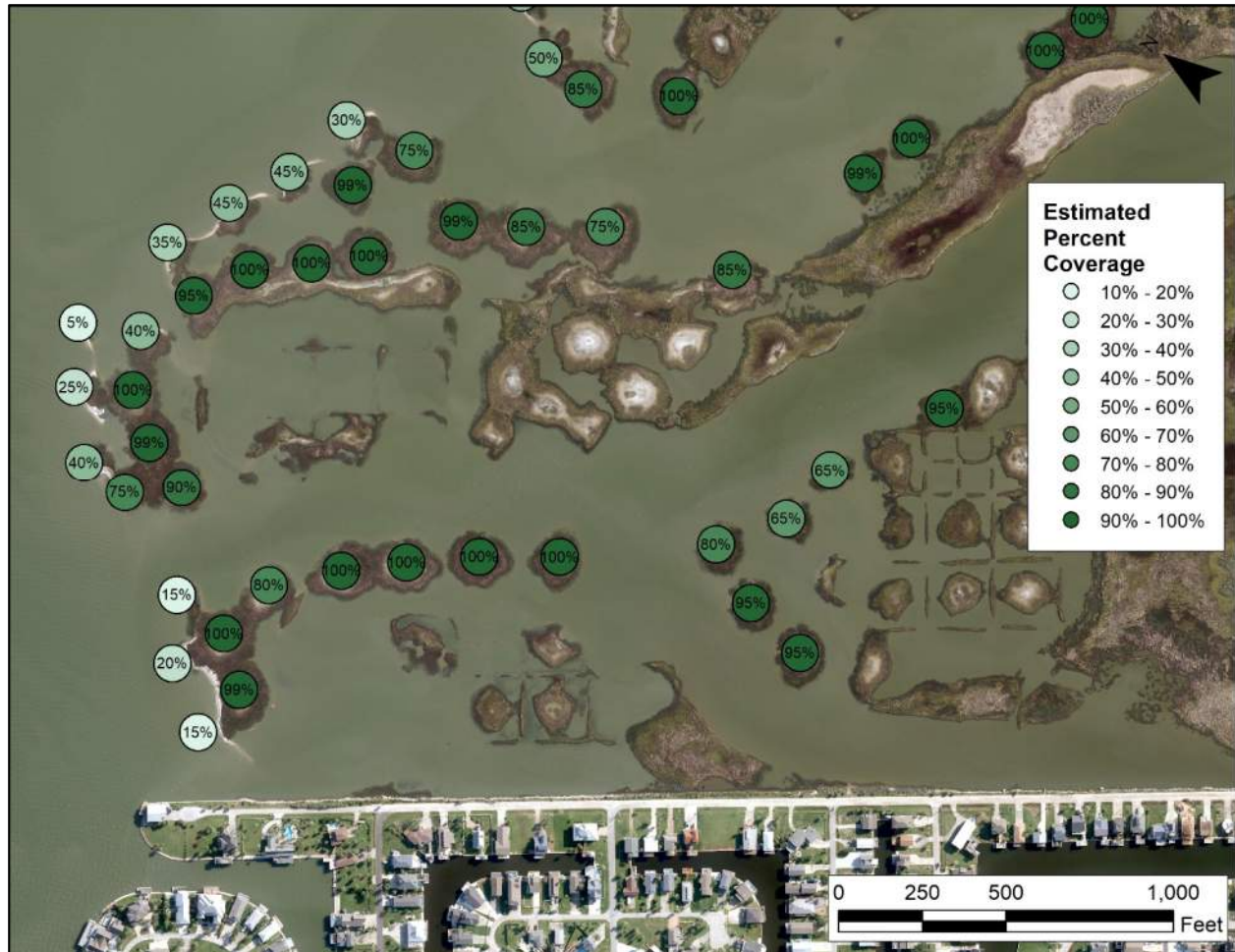


Figure 17. Estimated percent vegetation coverage in intertidal region for Area B, Area C, Area D, Area E, and Area G.

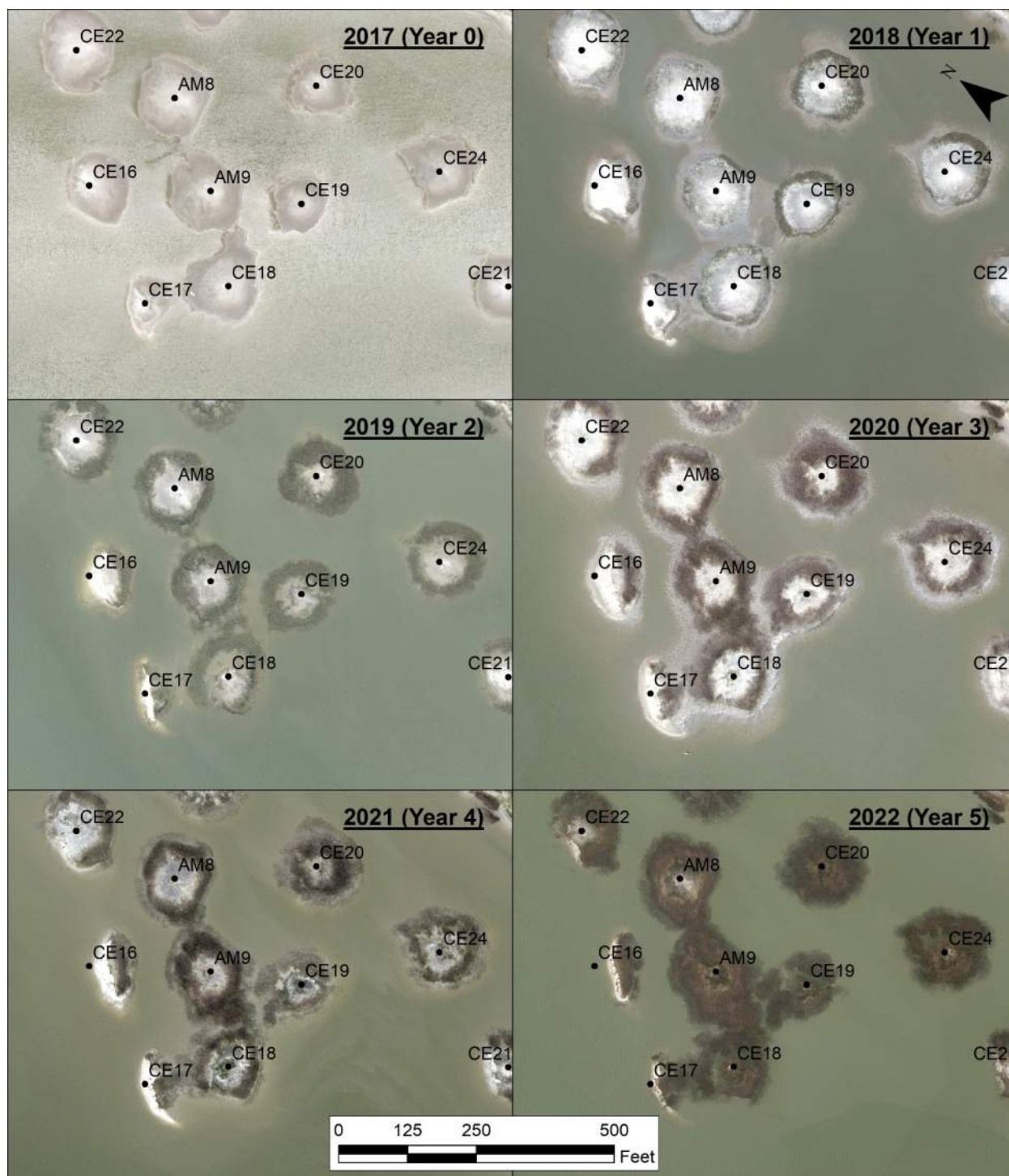


Figure 18. Yearly aerial comparison of vegetation coverage in Area A between Year 0 and Year 5.



Table 1. Mound vegetation coverage and survival.

Mound		Estimated Percent Coverage in Intertidal Region					Change			
Area	ID	Year 1	Year 2	Year 3	Year 4	Year 5	Year 2 – Year 1	Year 3 – Year 2	Year 4 – Year 3	Year 5 – Year 4
A	CE1	20%	45%	45%	45%	50%	25%	0%	0%	5%
A	CE2	25%	55%	35%	40%	45%	30%	-20%	5%	5%
A	CE3	40%	85%	80%	90%	95%	45%	-5%	10%	5%
A	CE4	40%	85%	85%	90%	85%	45%	0%	5%	-5%
A	CE5	20%	85%	90%	90%	95%	65%	5%	0%	5%
A	CE6	40%	75%	70%	80%	90%	35%	-5%	10%	10%
A	CE7	20%	75%	80%	90%	95%	55%	5%	10%	5%
A	CE8	10%	35%	40%	20%	30%	25%	5%	-20%	10%
A	CE9	25%	90%	90%	90%	95%	65%	0%	0%	5%
A	CE10	20%	85%	85%	95%	90%	65%	0%	10%	-5%
A	CE11	15%	70%	85%	95%	90%	55%	15%	10%	-5%
A	CE12	15%	70%	55%	75%	60%	55%	-15%	20%	-15%
A	CE13	25%	70%	55%	70%	55%	45%	-15%	15%	-15%
A	CE14	25%	65%	70%	65%	55%	40%	5%	-5%	-10%
A	CE15	30%	70%	80%	95%	95%	40%	10%	15%	0%
A	CE16	30%	40%	45%	30%	30%	10%	5%	-15%	0%
A	CE17	25%	30%	35%	35%	35%	5%	5%	0%	0%
A	CE18	65%	90%	90%	95%	100%	25%	0%	5%	5%
A	CE19	65%	95%	80%	90%	95%	30%	-15%	10%	5%
A	CE20	60%	99%	95%	100%	100%	39%	-4%	5%	0%
A	CE21	50%	80%	55%	65%	75%	30%	-25%	10%	10%
A	CE22	35%	75%	70%	80%	85%	40%	-5%	10%	5%
A	CE23	25%	80%	85%	85%	99%	55%	5%	0%	14%
A	CE24	60%	95%	85%	90%	100%	35%	-10%	5%	10%
A	CE25	30%	65%	60%	55%	45%	35%	-5%	-5%	-10%
A	CC13	35%	65%	65%	50%	50%	30%	0%	-15%	0%
A	CC14	35%	70%	80%	80%	85%	35%	10%	0%	5%
A	CC15	45%	90%	95%	100%	100%	45%	5%	5%	0%
A	AM1	20%	80%	90%	90%	99%	60%	10%	0%	9%
A	AM2	30%	80%	85%	90%	90%	50%	5%	5%	0%
A	AM3	20%	85%	75%	75%	55%	65%	-10%	0%	-20%
A	AM4	10%	30%	35%	25%	25%	20%	5%	-10%	0%
A	AM5	20%	85%	85%	80%	70%	65%	0%	-5%	-10%



Table 1. Mound vegetation coverage and survival.

Mound		Estimated Percent Coverage in Intertidal Region					Change			
Area	ID	Year 1	Year 2	Year 3	Year 4	Year 5	Year 2 – Year 1	Year 3 – Year 2	Year 4 – Year 3	Year 5 – Year 4
A	AM6	25%	95%	95%	100%	100%	70%	0%	5%	0%
A	AM7	20%	70%	65%	80%	65%	50%	-5%	15%	-15%
A	AM8	35%	90%	100%	100%	100%	55%	10%	0%	0%
A	AM9	35%	95%	100%	100%	100%	60%	5%	0%	0%
B	CC5	20%	35%	40%	25%	35%	15%	5%	-15%	10%
B	CC6	25%	40%	55%	40%	45%	15%	15%	-15%	5%
B	CC7	20%	20%	35%	35%	45%	0%	15%	0%	10%
B	CC8	10%	35%	35%	40%	30%	25%	0%	5%	-10%
B	CC9	25%	85%	75%	70%	75%	60%	-10%	-5%	5%
B	CC10	30%	75%	90%	95%	99%	45%	15%	5%	4%
B	CC11	15%	60%	75%	85%	85%	45%	15%	10%	0%
B	CC12	40%	60%	75%	75%	75%	20%	15%	0%	0%
B	AM10	30%	90%	100%	100%	99%	60%	10%	0%	-1%
B	AM13	20%	85%	95%	95%	95%	65%	10%	0%	0%
B	AM14	30%	65%	100%	100%	100%	35%	35%	0%	0%
B	AM15	35%	99%	100%	100%	100%	64%	1%	0%	0%
B	AM16	35%	95%	100%	100%	100%	60%	5%	0%	0%
C	CC1	15%	25%	25%	20%	40%	10%	0%	-5%	20%
C	CC2	25%	35%	30%	30%	25%	10%	-5%	0%	-5%
C	CC3	20%	65%	90%	85%	75%	45%	25%	-5%	-10%
C	CC4	25%	60%	90%	100%	100%	35%	30%	10%	0%
C	AM11	20%	15%	10%	10%	5%	-5%	-5%	0%	-5%
C	AM12	20%	45%	60%	50%	40%	25%	15%	-10%	-10%
C	AM17	20%	65%	85%	100%	99%	45%	20%	15%	-1%
C	AM18	20%	65%	85%	90%	90%	45%	20%	5%	0%
D	CW1	20%	20%	20%	15%	15%	0%	0%	-5%	0%
D	CW2	25%	25%	25%	35%	20%	0%	0%	10%	-15%
D	CW3	10%	20%	20%	35%	15%	10%	0%	15%	-20%
D	AM20	50%	50%	95%	100%	100%	0%	45%	5%	0%
D	AM21	30%	65%	85%	95%	99%	35%	20%	10%	4%
E	CW4	30%	90%	95%	100%	100%	60%	5%	5%	0%
E	CW5	40%	85%	95%	100%	100%	45%	10%	5%	0%
E	CW6	35%	90%	95%	100%	100%	55%	5%	5%	0%



Table 1. Mound vegetation coverage and survival.

Mound		Estimated Percent Coverage in Intertidal Region					Change			
Area	ID	Year 1	Year 2	Year 3	Year 4	Year 5	Year 2 – Year 1	Year 3 – Year 2	Year 4 – Year 3	Year 5 – Year 4
E	CW7	35%	85%	100%	100%	100%	50%	15%	0%	0%
E	AM19	20%	75%	75%	80%	80%	55%	0%	5%	0%
F	CC16	40%	85%	85%	90%	85%	45%	0%	5%	-5%
F	CC17	50%	90%	85%	95%	99%	40%	-5%	10%	4%
F	CC18	45%	95%	95%	100%	100%	50%	0%	5%	0%
G	CW8	35%	80%	85%	85%	80%	45%	5%	0%	-5%
G	CW9	40%	85%	75%	80%	95%	45%	-10%	5%	15%
G	CW10	40%	90%	85%	95%	95%	50%	-5%	10%	0%
G	CW11	30%	70%	60%	70%	65%	40%	-10%	10%	-5%
G	CW12	45%	85%	65%	70%	65%	40%	-20%	5%	-5%
G	CW13	65%	95%	95%	95%	95%	30%	0%	0%	0%
H	CC19	30%	90%	100%	100%	100%	60%	10%	0%	0%
H	CC20	65%	99%	100%	100%	100%	34%	1%	0%	0%
H	CC21	50%	100%	100%	100%	100%	50%	0%	0%	0%
H	CC22	50%	99%	100%	100%	100%	49%	1%	0%	0%
Average:		31%	71%	74%	77%	76%	40%	3%	3%	0%
Median:		30%	75%	85%	90%	90%	45%	1%	5%	0%

3.3. Breakwater Geometry

Breakwater geometry was assessed based on stone condition, crest elevation, and scour along the breakwater toe. Stone condition was assessed for loose, displaced, cracked, or deteriorating stone by field observations and field photographs. Nearly all stones observed were stable and in good condition. Few stones were observed with cracks or were loose within the breakwater. Loss of crest elevation was assessed for stone movement or breakwater settlement. Settlement was evaluated through field observations, field photographs, and RTK GPS measurements (Figure 19). According to the MAMP, breakwater cross-section should be relatively stable and loss of crest elevation should be less than 6 inches. Elevation measurements were taken approximately every 50 ft along the breakwater crest. Nearly all (99%) measured locations settled less than 6 inches (crest elevation above +3.0 ft NAVD) and most (83%) locations remained above the crest elevation of +3.5 ft NAVD specified for construction. (Note that the breakwater design was based on approximately 6 to 8 inches of settlement occurring after construction.) Scour along the breakwater toe was assessed through field observations. Observations were focused at the ends

of the breakwaters and at corners where scour is most likely to occur. Additional observations were made along straight sections. Minor scour (less than 6") was noted at the eastern end of the Butterowe Bayou breakwater and the western end of the Carancahua Cove breakwater. Scour observations are approximately consistent with previous monitoring site visits. Scour of this magnitude is not expected to cause instabilities in the breakwater. The breakwaters appear to be in stable condition and are performing as designed.

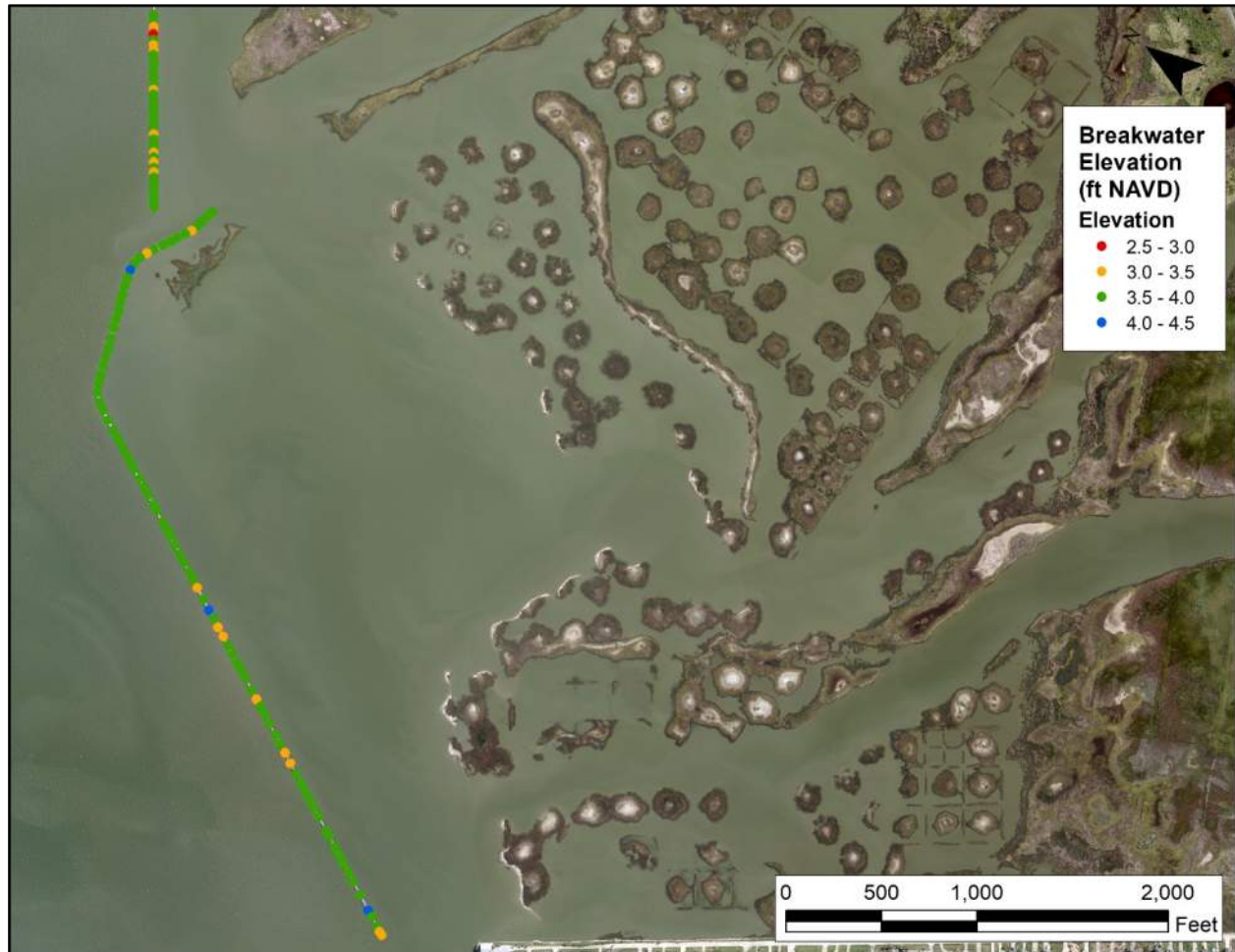


Figure 19. Breakwater elevations measured using RTK GPS.

3.4. Protection of Estuarine Habitats

The general level of protection provided by the breakwaters to the restored habitats was assessed through field observations and aerial photography. HDR and TPWD made observations of plant density and erosional scarping along exposed edges of marsh mounds. As previously mentioned, perimeter mounds in Areas A, B, C, and D experienced reshaping and sediment redistribution along their bayward edge. This erosion resulted in the loss of nearly all sprigs planted along the bayward edge of the perimeter mounds, and in some cases mounds have shifted landward. Although these perimeter mounds resulted in sparsely vegetated *Spartina*, shell ridges formed along the exposed shoreline, providing nesting habitat for wading and shorebirds and allowing for the growth of high marsh vegetation including *Salicornia bigelovii*, *Salicornia virginica*, *Batis maritima*, *Sesuvium sp.*, and *Avicenna germanins*. Scrape nests were observed during previous



monitoring visits on perimeter mounds with shell ridges but were not observed during Year 5. Note that the Year 5 visit was performed in late September and the previous monitoring visits were performed in late June to mid-July when shorebirds are more likely to be nesting. Additionally, most sandy material eroded from perimeter mounds appears to have remained within the project area as indicated by surveying performed for Year 5. Evidence of mound accretion was observed in less-exposed areas of the project, including perimeter mounds of previous restoration phases.

Hurricane Harvey impacted the project vicinity with storm surge and strong winds in late August 2017. This event occurred approximately 2 months after dredged material placement and sprig transplanting were completed. At the time of the storm, the root systems were likely not fully established, leaving the newly completed mounds more vulnerable to reshaping by waves. Natural marsh behind the breakwaters with established vegetation appears to be relatively stable.

3.5. Erosion Rate of Marsh Mounds

The shoreline recession rates of the perimeter marsh mounds were evaluated based on survey data and aerial photography comparisons for the Post-Construction (Year 0) and Year 5 conditions. Mounds were selected based on stratified random sampling by randomly selecting 30% of perimeter mounds in areas where the breakwaters provide all of the wave protection (i.e., areas that are not protected by other marsh mounds or features). This sample group consists of Areas A, B, C, and D. Nine mounds were selected. Based on the MAMP, the goal is to reduce shoreline recession rates below the historical long-term rate of 2.9 ft/yr calculated between 1930 and 2003 (Gibeaut *et al.*, 2003), and the short-term rate at Carancahua Cove of 33 ft/yr calculated between 2010 and 2011 (HDR, 2013).

The mounds measured during Year 5 are the same mounds measured during previous years. The shoreline location at completion of construction was approximated as the bayward edge of the planting zones, which was assumed to roughly follow the +0.8 ft NAVD contour because this elevation was the lower elevation limit specified for sprig planting. Marsh mounds measured for this purpose are presented in Table 2. Eight of the nine mounds measured experienced reshaping along their bayward edge, resulting in loss of transplanted sprigs and shoreline recession. The average fringe width was approximately 35 ft. The average shoreline recession rate between Year 4 and Year 5 was 3 ft/yr, approximately the same as the long-term rate of 2.9 ft/yr, and less than the rate between previous years of monitoring and the short-term rate of 33 ft/yr calculated by HDR (2013) between 2010 and 2011 following the first year after construction of a previous restoration project at Carancahua Cove. The average shoreline recession rate between Year 0 and Year 5 was 11 ft/yr, which is greater than the long-term rate of 2.9 ft/yr. As noted in Section 3.4, impacts from Hurricane Harvey likely accelerated shoreline recession rates during the Year 1 monitoring period.



Table 2. Shoreline recession rate of selected perimeter mounds.

Area	Mound ID	Approximate Shoreline Recession Rate (ft/yr)					
		Year 0 to Year 1	Year 1 to Year 2	Year 2 to Year 3	Year 3 to Year 4	Year 4 to Year 5	Year 0 to Year 5
A	AM4	7.6	-19.3	0.3	-6.6	0.0	-4.3
A	CE13	-2.0	-10.6	-16.7	7.8	-6.8	-7.1
A	CE16	-21.8	-8.0	-20.6	-2.7	0.8	-12.5
A	CE17	-8.9	-5.9	-13.2	-1.3	0.6	-6.9
B	CC8	-34.4	-13.8	-7.2	-2.8	-4.1	-15.2
B	CC5	-39.6	-3.4	-8.4	-2.0	-4.5	-14.1
C	CC1	-37.6	-2.6	-5.5	-8.8	3.0	-12.3
C	CC3	-3.6	-6.0	-8.8	1.5	-9.7	-6.8
D	CW3	-30.6	-28.0	-9.3	-24.7	-3.5	-23.2
Average:		-19.0	-10.9	-9.9	-4.4	-2.7	-11.4
Median:		-21.8	-8.0	-8.8	-2.7	-3.5	-12.3

3.6. Hard Substrate Habitat

Field observations and field photography were applied to document the presence of encrusting species and algae attached to the breakwater (Figure 20). Observations were made along a total of 10,830 LF of breakwater (i.e., 4,415 LF along each side of the Carancahua Cove breakwater and 1,000 LF along each side of the Butterowe Bayou breakwater). Species presence and frequency were noted. The entire length of the breakwaters provided hard substrate habitat. Green algae species (*Chlorophyta*) and brown algae species (*Phaeophyceae*) were observed along both sides of the entire breakwaters. Eastern oysters (*Crassostrea virginica*) and barnacles were observed frequently along the Carancahua Cove and Butterowe Bayou breakwaters. Green algae was present more consistently than brown algae along the landward side of the Carancahua Cove and Butterowe Bayou breakwaters. Barnacles were abundant on both sides of the breakwaters. Oysters were more abundant on the landward side of the breakwaters. Hermit crabs (*Clibanarius vittatus*) were observed at a few areas along the Carancahua Cove breakwater.

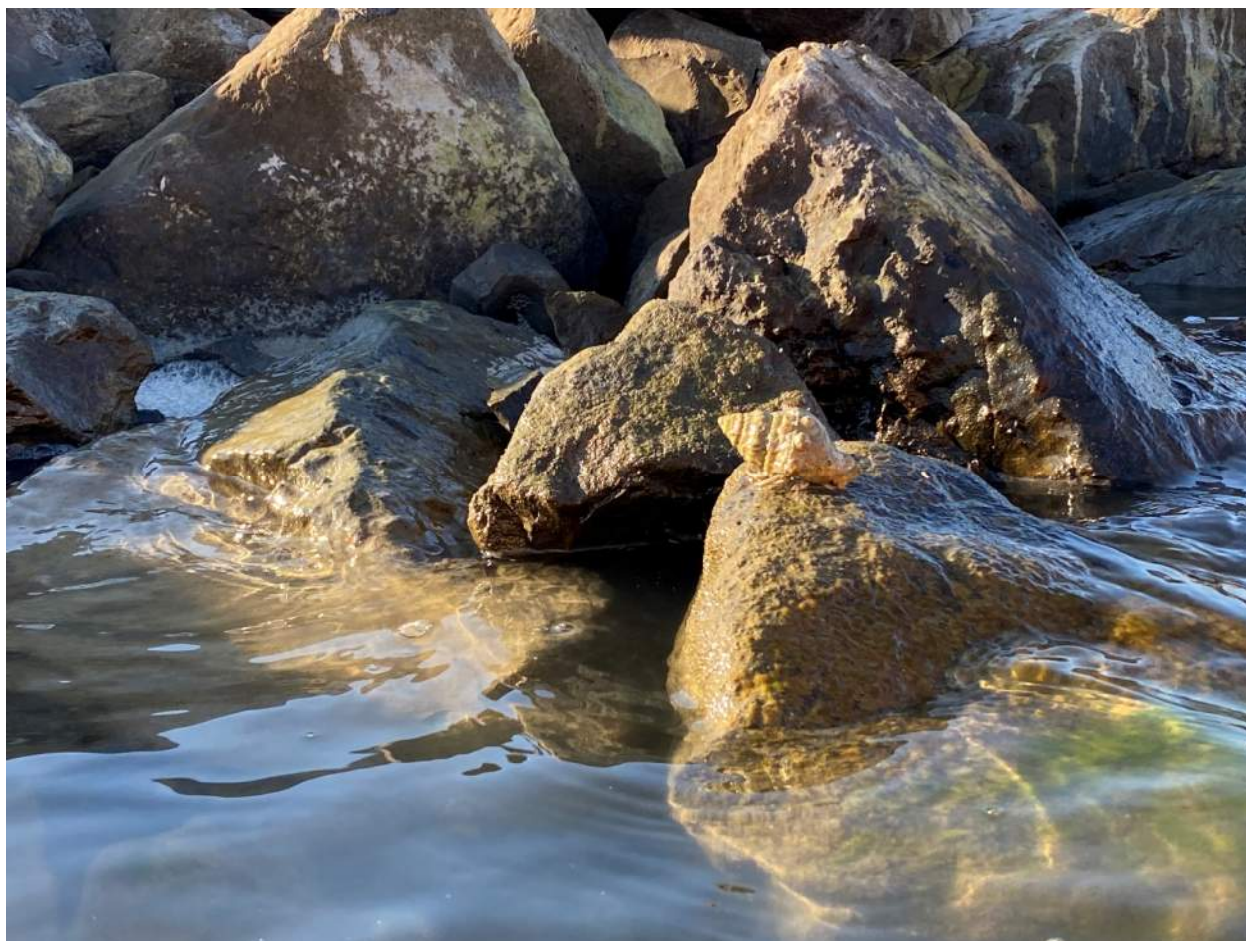


Figure 20. Hermit crab on bayward side of Carancahua Cove Breakwater.



4. Summary and Conclusions

This report documents the Year 5 post-construction performance monitoring performed in September 2022, five years after the completion of CEPRA Project No. 1601. The objective was to assess engineering performance of the marsh restoration project at GISP completed in 2017. The project was evaluated based on the following criteria:

- Marsh mound geometry and sediment composition
- Vegetation survival and coverage
- Breakwater geometry, stone condition, and toe scour
- Protection of estuarine habitats
- Marsh erosion rate and fringe marsh width
- Hard substrate habitat along breakwater

As of the Year 5 monitoring, the marsh mounds have continued to evolve in response to natural forces including waves, currents, rain, and settlement. Marsh vegetation, both planted and naturally propagated, has expanded. Despite protection from larger waves by the breakwaters, many of the perimeter mounds have been reshaped along their exposed edge, although surveying performed for Year 5 indicates most of the material has remained in the project area. As the sandy sediment is redistributed and sorted by waves, larger shell hash and shell is left in the higher-energy areas. Based on previous observations of marsh mound performance at GISP, perimeter mounds will likely remain more sparsely vegetated due to exposure to greater wave action and higher shell content.

A summary of the project performance through Year 5 is provided below.

- All 81 marsh mounds constructed in 2017 still existed at the time of the Year 5 monitoring (September 2022). Many of the perimeter mounds have been reshaped, but interior mounds are relatively stable. Topographic and bathymetric surveying performed for Year 5 monitoring suggests over 90% of the material placed for the construction of marsh mounds has remained within the project area.
- All mounds continue to support intertidal marsh vegetation. Estimated percent vegetation coverage of the planted region ranged from 5% to 100% per mound, with a median estimated coverage of 90%. Natural seeding and propagation by rhizomes have increased coverage of nearly all mounds.
- Interior mounds are expected to continue to increase in vegetation coverage from natural seeding and propagation. Perimeter mounds generally consist of shelly sediment and are subject to greater wave impacts, creating conditions difficult for new sprigs to survive. The shelly sediment provides habitat for high marsh vegetation and nesting habitat for shorebirds.
- Breakwater geometry appears to meet the design intent. Observed stones were nearly all in good condition and relatively stable. Crest elevation has remained consistent, with nearly all measured locations showing less than 6 inches of settlement.
- Encrusting species are supported along the entire length of both sides of the breakwater.



- Field observations indicate that minimal (less than 6 inches) scour has occurred along the breakwater toe and should not cause instabilities.
- Shoreline change was estimated for randomly selected perimeter mounds. The average recession rate (Year 0 to Year 5) was approximately 11 ft/yr, less than the pre-project short-term (one-year post-construction) average of 33 ft/yr reported by HDR (2013) prior to breakwater construction, but greater than the long-term historical average of 2.9 ft/yr reported by Gibeaut et al. (2003). Recession rates have generally decreased over time since project construction. Comparison to historical long-term rates will be more meaningful as the project continues to adjust to a more natural condition.
- Fringe marsh width was measured at randomly selected perimeter mounds. Eight of the nine mounds had a gap in fringe marsh coverage (vegetation was not supported around the entire mound). Average fringe width was approximately 35 ft.
- Additional sprig planting is not recommended at this time. Areas without vegetation coverage are generally exposed to higher wave climates or consist of shelly sediment and new sprigs are unlikely to survive. A possible adaptive management strategy is the construction of new marsh mounds in the open water area immediately east of the Carancahua Cove breakwater. Mounds constructed in this area would be very sheltered by the breakwater and would reduce the exposed fetch of the existing perimeter mounds, providing sheltering benefits.



5. References

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- HDR Engineering, Inc (HDR) 2020. Performance Monitoring at Galveston Island State Park Marsh Restoration and Protection (Phase I & Phase II) Project (CEPRA 1601). Post Construction Monitoring Report: Year 3. Prepared for Texas General Land Office.
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Appendix A: Ground Digital Photographs



Figure A1. Area A: Mound CE1





Figure A2. Area A: Mound CE2





Figure A3. Area A: Mound CE3





Figure A4. Area A: Mound CE4





Figure A5. Area A: Mound CE5





Figure A6. Area A: Mound CE6





Figure A7. Area A: Mound CE7





Figure A8. Area A: Mound CE8





Figure A9. Area A: Mound CE9





Figure A10. Area A: Mound CE10





Figure A11. Area A: Mound CE11





Figure A12. Area A: Mound CE12





Figure A13. Area A: Mound CE13





Figure A14. Area A: Mound CE14





Figure A15. Area A: Mound CE15





Figure A16. Area A: Mound CE16





Figure A17. Area A: Mound CE17





Figure A18. Area A: Mound CE18





Figure A19. Area A: Mound CE19





Figure A20. Area A: Mound CE20





Figure A21. Area A: Mound CE21





Figure A22. Area A: Mound CE22





Figure A23. Area A: Mound CE23





Figure A24. Area A: Mound CE24





Figure A25. Area A: Mound AM1





Figure A26. Area A: Mound AM2





Figure A27. Area A: Mound AM3





Figure A28. Area A: Mound AM4





Figure A29. Area A: Mound AM5





Figure A30. Area A: Mound AM6





Figure A31. Area A: Mound AM7





Figure A32. Area A: Mound AM8





Figure A33. Area A: Mound AM9





Figure A34. Area A: Mound AM10





Figure A35. Area A: Mound AM11





Figure A36. Area A: Mound AM12





Figure A37. Area A: Mound AM13





Figure A38. Area A: Mound AM14





Figure A39. Area A: Mound AM15





Figure A40. Area A: Mound AM16





Figure A41. Area A: Mound AM17





Figure A42. Area A: Mound AM18





Figure A43. Area A: Mound AM19





Figure A44. Area A: Mound AM20





Figure A45. Area A: Mound AM21





Figure A46. Area A: Mound CW1





Figure A47. Area A: Mound CW2





Figure A48. Area A: Mound CW3





Figure A49. Area A: Mound CW4





Figure A50. Area A: Mound CW5





Figure A51. Area A: Mound CW6





Figure A52. Area A: Mound CW7





Figure A53. Area A: Mound CW8





Figure A54. Area A: Mound CW9





Figure A55. Area A: Mound CW10





Figure A56. Area A: Mound CW11





Figure A57. Area A: Mound CW12





Figure A58. Area A: Mound CW13





Figure A59. Area A: Mound CC2





Figure A60. Area A: Mound CC3





Figure A61. Area A: Mound CC4





Figure A62. Area A: Mound CC5





Figure A63. Area A: Mound CC6





Figure A64. Area A: Mound CC7





Figure A65. Area A: Mound CC8





Figure A66. Area A: Mound CC9





Figure A67. Area A: Mound CC10





Figure A68. Area A: Mound CC11





Figure A69. Area A: Mound CC12





Figure A70. Area A: Mound CC13





Figure A71. Area A: Mound CC14





Figure A72. Area A: Mound CC15





Figure A73. Area A: Mound CC16





Figure A74. Area A: Mound CC17





Figure A75. Area A: Mound CC18





Figure A76. Area A: Mound CC19





Figure A77. Area A: Mound CC20





Figure A78. Area A: Mound CC21





Figure A79. Area A: Mound CC22





Figure A80. Area A: Breakwater1





Figure A81. Area A: Breakwater2





Figure A82. Area A: Breakwater3





Appendix B: Aerial Photographs



YEAR 5 POST CONSTRUCTION MONITORING TRUE-COLOR AERIAL PHOTOGRAPH

APPENDIX B

PHOTO TAKEN BY TERRA FLIGHT AERIAL IMAGING (9/22/2022)

PERFORMANCE MONITORING AT THE WEST GALVESTON ISLAND MARSH RESTORATION PROJECT (CEPRA 1601)





YEAR 5 POST CONSTRUCTION MONITORING INFRARED-COLOR AERIAL PHOTOGRAPH

APPENDIX B

PHOTO TAKEN BY TERRA FLIGHT AERIAL IMAGING (9/22/2022)

PERFORMANCE MONITORING AT THE WEST GALVESTON ISLAND MARSH RESTORATION PROJECT (CEPRA 1601)

