State of Louisiana
Coastal Protection and Restoration Authority
Office of Coastal Protection and Restoration

2015 Operations, Maintenance, and Monitoring Report

for

West Belle Pass Barrier Headland Restoration (TE-52)

State Project Number TE-52
Priority Project List 16

August 2015
Lafourche Parish

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Suggested Citation:

Curole, G. P., T. B. Byland, and D. M. Lee. 2015. *2015 Operations, Maintenance, and Monitoring Report for West Belle Pass Barrier Headland Restoration (TE-52).* Coastal Protection and Restoration Authority of Louisiana, Thibodaux, Louisiana. 54 pp. and Appendices.

Operations, Maintenance, and Monitoring Report
for
West Belle Pass Barrier Headland Restoration
(TE-52)

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Preface

This report includes monitoring data collected through January 2015, and annual Maintenance Inspections through March 2015. The West Belle Pass Barrier Headland Restoration (TE-52) project is federally sponsored by the National Marine Fisheries Service (NMFS) and locally sponsored by the Coastal Protection and Restoration Authority of Louisiana (CPRA) under the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA, Public Law 101-646, Title III). TE-52 is listed on the 16th CWPPRA Priority Project List (PPL-16).

The 2015 report is the 1st in a series of OM&M reports since the end of construction of this project in Marsh 2013. This Operations, Maintenance, and Monitoring Report as well as future reports in this series will be posted on the Coastal Protection and Restoration Authority (CPRA) website at *http://cims.coastal.louisiana.gov/DocLibrary/DocumentSearch.aspx*.

I. Introduction

The West Belle Pass Barrier Headland Restoration (TE-52) project is a beach, dune, and marsh creation restoration project. TE-52 is located at the western terminus of the 27 km (17 mi) long Caminada-Moreau Headland and is positioned approximately 3 km (2 mi) southwest of Port Fourchon and 0.8 km (0.5 mi) west of Belle Pass in Lafourche Parish, Louisiana (Figures 1 and 2). The project area consists of supratidal, intertidal, and subtidal habitat found on the headland (Figure 3). The dune creation phase extends for 2,835 m (9,300 ft) along the Gulf of Mexico shoreline raising the supratidal, intertidal, and subtidal environments to dune and supratidal elevations. The marsh creation phase of the TE-52 restoration project elevated subtidal and intertidal areas directly behind the dune to intertidal and supratidal elevations. The western portion of the headland is separated from the vastly larger eastern part via the Belle Pass Rock Jetties and forms its southern border with the Gulf of Mexico and its northern border with Timbalier Bay (Figures 2 and 3).

The formation of the Lafourche delta complex began approximately 3,500 years before present (Peyronnin 1962; Frazier 1967; Otvos 1969; Conaster 1971; Harper 1977). During this time, nutrient rich sediments were deposited along the banks of the Lafourche delta distributaries primarily through overbank flooding. This created a vast network of swamps, marshes, and ridges along its numerous subdeltas (Frazier 1967; Reed 1995). Bayou Lafourche was one of the final subdeltas to form during the Lafourche delta period before the river switched its flow to the Plaquemines and Modern delta complexes. This subdelta was an active distributary of the Mississippi River from approximately 1800 to 100 years before present (Morgan and Larimore 1957; Peyronnin 1962; Frazier 1967). At the mouth of the Bayou Lafourche subdelta, a regressing network of accretionary sand ridges developed to form the Caminada-Moreau Headland (Figure 2). These ridges were geomorphodynamically formed by shaping delta front sheet sands through wind, wave, tidal, and longshore transport processes (Otvos 1969; Conaster 1971; Ritchie 1972; Bird 2000).

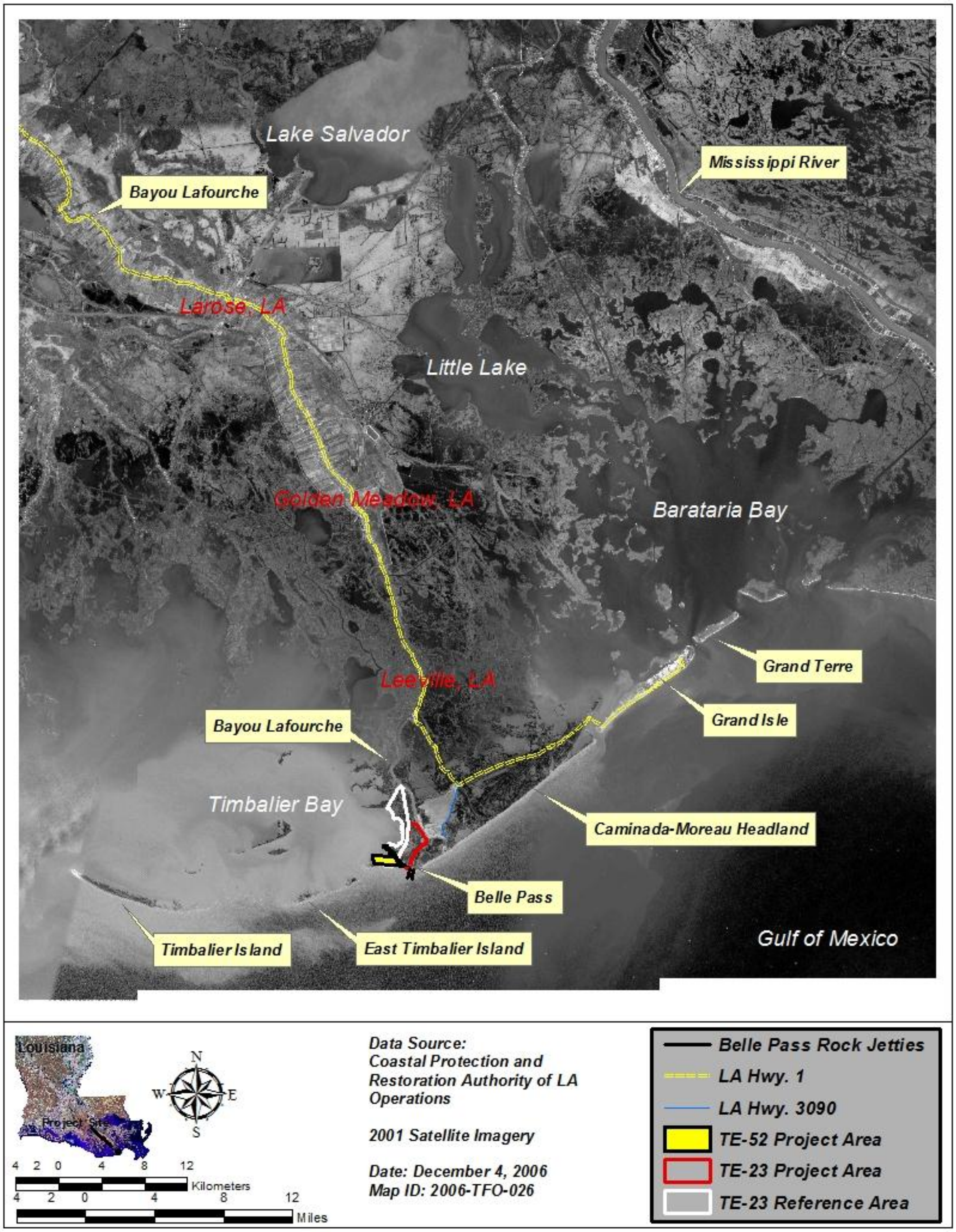


Figure 1. Location and vicinity of the West Belle Pass Barrier Headland Restoration (TE-52) project.

Figure 2. **Geomorphic and anthropogenic features of the Caminada-Moreau Headland.**

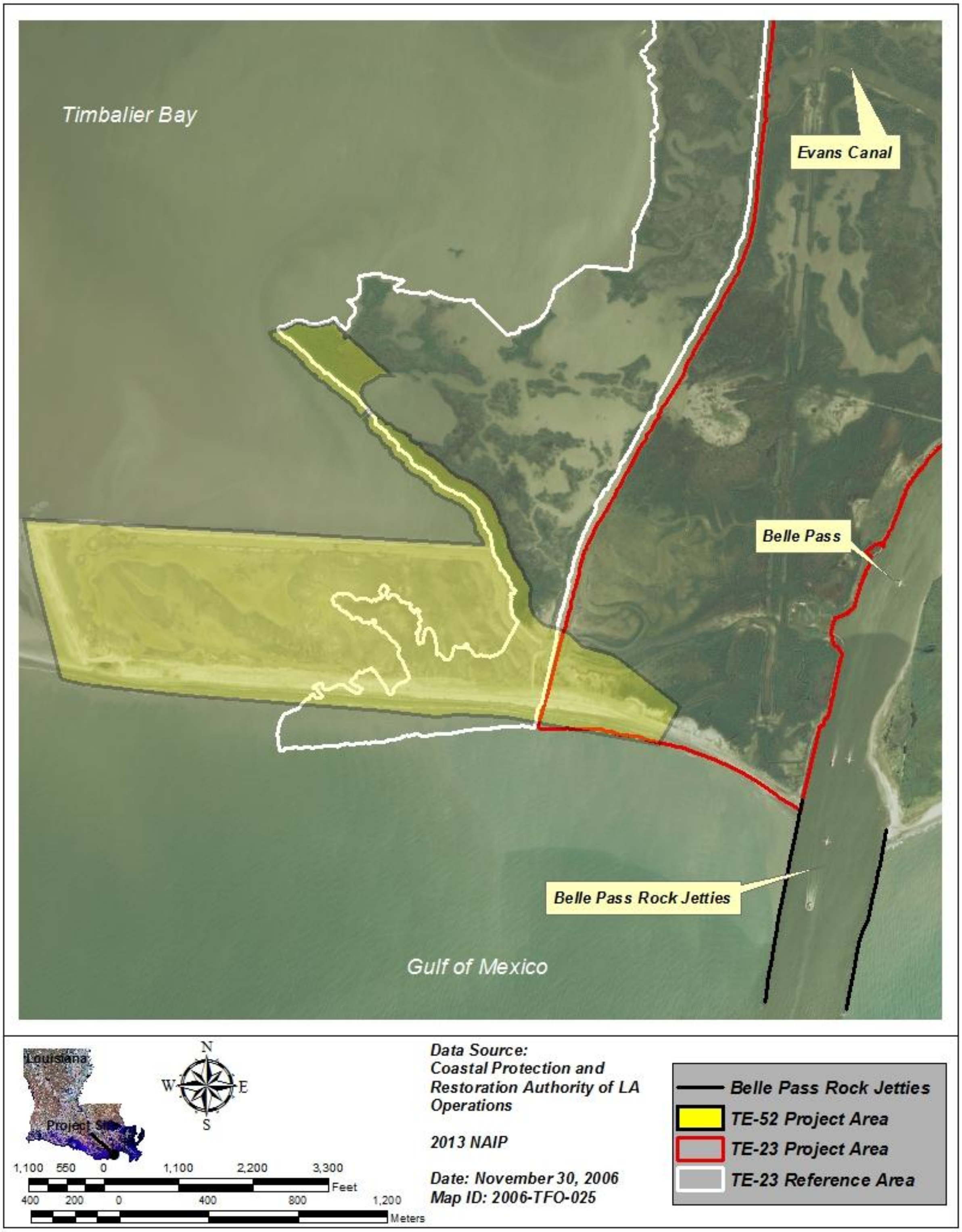


Figure 3 **Location of the West Belle Pass Barrier Headland Restoration (TE-52) project area.**

The soils in the project area are mostly composed of Felicity loamy fine sand soil. This soil is established along the Gulf of Mexico beaches and consists of a somewhat poorly drained sandy soil. Scatlake muck and Bellepass-Scatlake association soils are also found in or near the project area. The Scatlake muck soil is a very poorly drained mineral soil that is located along the Belle Pass and Bayou Lafourche shoreline while the Bellepass-Scatlake association is an organic and mineral soil that is found in very poorly drained saline marshes (USDA 1984).

Marsh vegetation in the project area is dominated by *Spartina alterniflora* Loisel. (smooth cordgrass) and *Avicennia germinans* (L.) L (black mangrove). *Spartina patens* (Ait.) Muhl. (marshhay cordgrass), *Salicornia virginica* L. (glasswort), *Solidago sempervirens* L. (seaside goldenrod), *Baccharis halimifolia* L. (eastern baccharis), *Iva frutescens* L. (bigleaf sumpweed), *Morella cerifera* (L.) Small (waxmyrtle), *Batis maritima* L. (saltwort), and *Distichlis spicata* (L.) Greene (seashore saltgrass) also inhabits the project area. Sasser et al. (2014) classified the project area as salt marsh habitat.

In the years since the creation of the Lafourche delta, the sediment and freshwater supply to the Caminada-Moreau Headland has decreased considerably while the shoreline has noticeably transgressed. The Mississippi River gradually changed its course to form the Plaquemine and Modern delta lobes significantly reducing the sediment supply to the Caminada-Moreau Headland (Frazier 1967; Reed 1995). By 1850, the Bayou Lafourche subdelta was discharging only 15.0 % of the Mississippi River's flow (Reed 1995). In 1904, a dam was placed at the junction of the Mississippi River and Bayou Lafourche essentially eliminating the source of river sediments to the headland (Morgan and Larimore 1957; Peyronnin 1962; Frazier 1967; Dantin et al. 1978; Reed 1995). Therefore, Bayou Lafourche has become a sediment starved, relict distributary of the Mississippi River (Peyronnin 1962; Ritchie 1972; Harper 1977; Dantin et al. 1978; Penland and Ritchie 1979; Boyd and Penland 1981; Ritchie and Penland 1988a; Ritchie and Penland 1988b; Penland and Ramsey 1990; Reed 1995; Pilkey and Fraser 2003). This sediment deficit and eustatic sea level rise (Scavia et al. 2002) has caused the subsidence rate along the Caminada-Moreau Headland to exceed 1.0 cm/yr (0.4 in/yr) (Coleman and Smith 1964; Swanson and Thurlow 1973; Penland and Ramsey 1990; Roberts et al. 1994). In addition, the placement of the Belle Pass jetties (Figures 2 and 3) and the net longshore transport have impeded the movement of sediments to the project area. Jetties and groins have been found to obstruct sand transport along beaches causing erosion on the downdrift side of these structures (Conaster 1971; Komar 1998) and are likely contributors to alterations in sediment transport in the project area. Net longshore transport west of the rock jetties is in the western direction (Peyronnin 1962; Dantin et al. 1978; Ritchie and Penland 1988b; Stone and Zhang 2001; Thomson et al. 2009) (Figure 2). Longshore transport processes have caused extensive shoreface erosion along the West Belle Pass area shifting sediments to downdrift barrier islands and tidal passes (Peyronnin 1962; Levin 1993; List et al. 1997; McBride and Byrnes 1997; Stone and Zhang 2001). The high frequency and intensity of tropical storm (Peyronnin 1962; Stone et al. 1997) and cold front (Boyd and Penland 1981; Ritiche and Penland 1998b; Dingler and Reiss 1990; Georgiou et al. 2005) events have been shown to induce erosion along the Caminada-Moreau Headland. Moreover, this area has been classified as a storm dominated coast (Harper 1977; Boyd and

Penland 1981) consisting of ephemeral dunes shaped by storm events (Ritchie 1972; Harper 1977; Penland and Ritchie 1979; Ritchie and Penland 1988a; Ritchie and Penland 1988b). The sediment deficit, subsidence, longshore transport, and the high frequency of storm events have resulted in high shoreline erosion rates along the low profile Caminada-Moreau Headland. The shoreline change rate on western Caminada-Moreau Headland has been estimated to be -25 m/yr (-82 ft/yr) in the long-term (1887-2002) (Penland et al. 2005) and -11 m/yr (-36 ft/yr) in the short-term (1996-2008) (Thomson et al. 2009).

The geomorphology of the Caminada-Moreau Headland also has been strongly influenced through the frequent passage of tropical storms (Figure 4) and cold fronts. Numerous tropical storms (Peyronnin 1962; Stone et al. 1997) and cold fronts (Boyd and Penland 1981; Dingler and Reiss 1990; Ritiche and Penland 1998b; Georgiou et al. 2005) have elevated water levels high enough to cause partial or total overwash along the low profile Caminada-Moreau Headland. Hurricanes have caused severe overwash along or in the vicinity of the headland since 1856 (Peyronnin 1962; Stone et al. 1997). Specifically, Hurricane Betsy in 1965 (Conaster 1971), Hurricane Carmen in 1974 (Harper 1977), Hurricanes Juan, Danny, and Elena in 1985 (Ritchie and Penland 1988b), Hurricane Andrew in 1992 (Stone et al. 1993), Hurricanes Cindy, Katrina, and Rita in 2005 (Barras 2006), and Hurricane Isaac in 2012 (Devisse and Thomson 2013) have been documented as causing breaching, overwash, and shoreline retreat along the Caminada-Moreau Headland substantially altering the dune and washover environments (Figure 4). Hurricanes Isidore and Lili in 2002 (Curole et al. 2012), T. S. Matthew in 2004 (Roudrigue et al. 2011), Hurricanes Gustav and Ike in 2008 (Curole and Lee 2013), and T. S. Lee in 2011 (Brown 2011) have also been found to effect the geomorphology of barrier islands and wetlands in the vicinity of the headland and likely had an impact on the future TE-52 project area shorelines (Figure 4). As a result, hurricanes have been postulated as the major force driving morphodynamic change along the Caminada-Moreau Headland (Stone et al. 1997).

The construction of the Belle Pass Navigation Channel and Rock Jetties (Figures 2 and 3) has altered the TE-52 project area shorelines. Belle Pass dredging and jetty construction began in 1940 by increasing the depth and width of the channel to unspecified dimensions and constructing parallel rock jetties 152 m (500 ft) in length and 61 m (200 ft) in width. The jetties were extended by 90 m (300 ft) in 1945 due to shoreline erosion (Dantin et al. 1978). In 1958, the navigation channel was enlarged to a depth of -4 m (-12 ft) Mean Low Gulf (MLG) and a width of 30 m (100 ft). The channel was expanded to a 38 m (125 ft) bottom width and relocated to the west of the jetties in 1963 leaving only an eastern jetty. A western jetty was installed in 1974, and Belle Pass was dredged to a -6 m (-20 ft) MLG depth and a 91 m (300 ft) wide extent in 1975 (Dantin et al. 1978). In 1980, the jetties were extended to their current 793 m (2,600 ft) length and 366 m (1,200 ft) width (Figures 2 and 3). Finally, the navigation channel was dredged to a -8 m (-27 ft) MLG depth in 2001 (D. Breaux, GLPC, pers. comm.). As previously discussed, the construction of these rock jetties disrupted the longshore transport processes along the Caminada-Moreau Headland considerably reducing

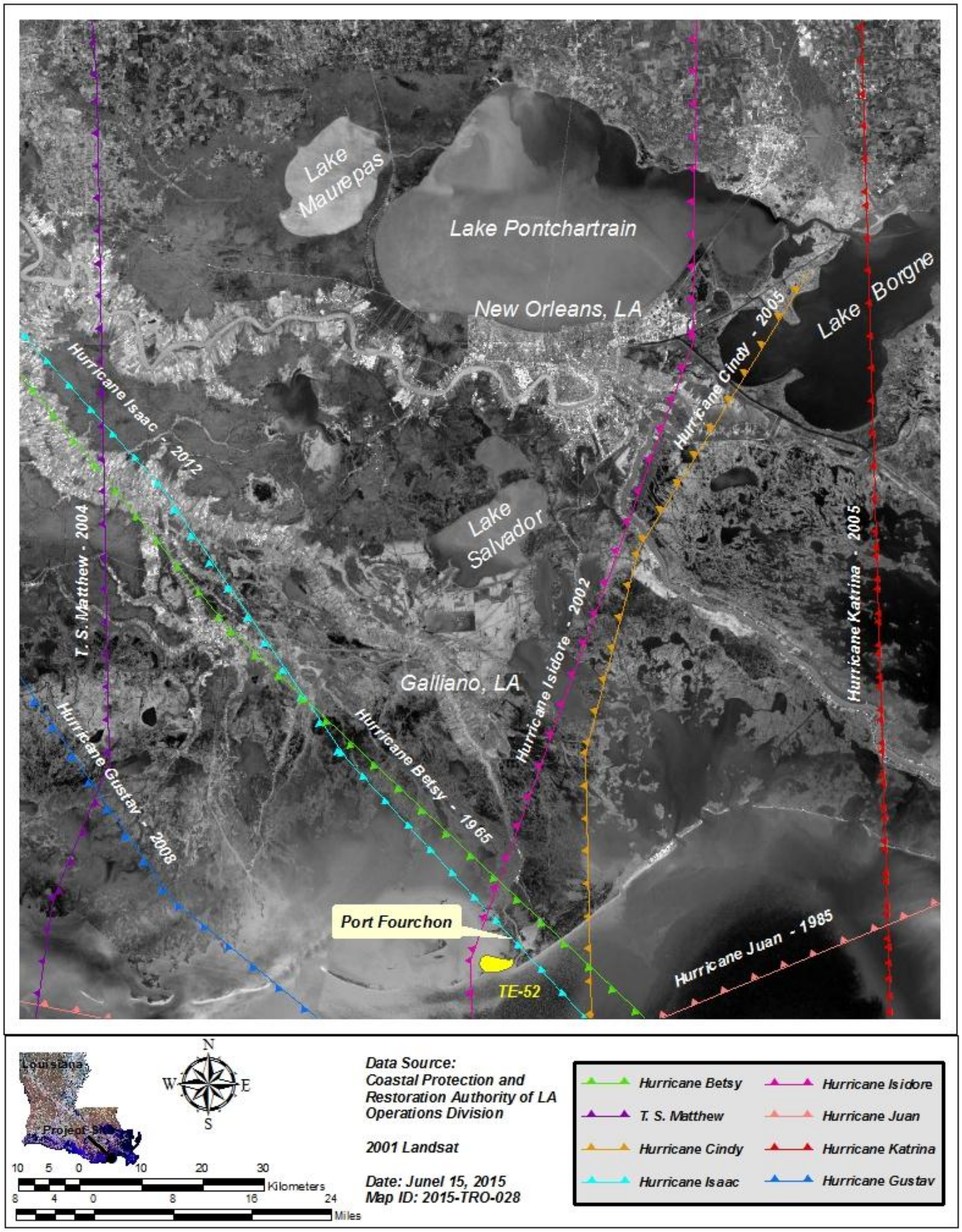


Figure 4. **Pre-construction (1965, 1985, 2002, 2004, 2005, and 2008) and construction (2012) tropical storms impacting the West Belle Pass Barrier Headland Restoration (TE-52) project area shoreline. Hurricanes Carmen (1974), Danny and Elena (1985), Andrew (1992), Lili (2002), Ivan (2004), Rita (2005), Ike (2008), and T. S. Lee (2011) are not shown because the eye wall of these storms traversed outside the extent of this map.**

the sand and sediment supply available to project area beaches (Harper 1977; Dantin et al. 1978; Boyd and Penland 1981; Ritchie and Penland 1988b; Stone and Zhang 2001).

In 1998, the Coastal Protection and Restoration Authority of Louisiana (CPRA) and the U. S. Army Core of Engineers (USACE) initiated the West Belle Pass Headland Restoration (TE-23) project (Figures 1, 2, and 3). This project discharged 1.12 million m^3 (1.46 million yd^3) of sediment into three disposal areas creating 65 ha (160 acres) of supratidal, intertidal, and subtidal habitats and armored 5,182 m (17,000 ft) of Belle Pass and Bayou Lafourche. Approximately, 941,000 m^3 (1.23 million yd^3) of the sediments discharged were placed in the TE-23 marsh creation areas and 174,000 m^3 (228,000 yd^3) were deposited on the West Belle Pass beach. The TE-23 project was not successful creating marsh habitat, but the shoreline protection structures reduced erosion and maintained their structural stability (Curole and Huval 2005). A 2007 maintenance event was undertaken to enhance the TE-23 project and to remove shoaling from the federal channel (Bayou Lafourche and Belle Pass). During this event, 326,000 m^3 (426,000 yd^3) of dredged material were pumped into the marsh creation area, 85,000 m^3 (112,000 yd^3) were deposited on the West Bell Pass beach, and Closure 1 was re-constructed with sheet pile. Figures 5 and 6 depict Gulf of Mexico shoreline change in the TE-23 project and reference areas from 1997 to 2008. Figure 5 shows the regressions in the project area shorelines (2001 and 2007 project shorelines) after the 1998 and 2007 sediment additions. However, these shorelines transgressed soon after the 2001 and 2007 shoreline positions were mapped possibly due to the high frequency of tropical storm events from 2002 to 2008 or the location of the TE-23 shorelines in the lee of the Belle Pass Rock Jetties. The TE-23 reference area shoreline illustrates constant shoreline transgression especially on the western reaches of this shoreline (figure 6). No further assessments of the 2007 maintenance event have been initiated to date.

The West Belle Pass Barrier Headland Restoration (TE-52) project consists of beach, dune, and marsh creation features (Figures 7 and 8). The following synopsis was summarized from the TE-52 project completion report (Devisse and Thomson 2013). Construction began by building 2,605 m (8,545 ft) of primary containment dike on the Timbalier Bay side of the headland and placing beach fill along the Gulf of Mexico shoreline. The beach fill extended the TE-52 project area southward and westward. Beginning on the western template of the beach and dune fill area, the sand was shaped into a dune feature with a 2.0 m (6.5 ft) NAVD88 centerline elevation. The dune was shaped to this elevation for approximately two-thirds of its original project template. The remaining eastern sections of the dune were built to a 2.3 m (7.5 ft) NAVD88 centerline elevation. The approximate volume used to fill the beach and dune template was 2,041,361 m^3 (2,670,000 yd^3). Once the dune was constructed, a single row of sand fencing was added along the centerline of the dune. A total of 3,249 m (10,660 ft) of sand fencing was installed. In addition to the original beach and dune template, the beach and dune features were extended eastward to tie-in with a USACE, Beneficial Use of Dredge Material (BUMP) project that was pumping dredged materials on to the West Belle Pass Beach (Figure 9). The BUMP project began by placing dredged materials on the edge of the Belle Pass Rock Jetties and moved westward. The expand beach and dune template resulted in a constructed dune with a 1.4 m (4.5 ft) NAVD88 centerline elevation. A change

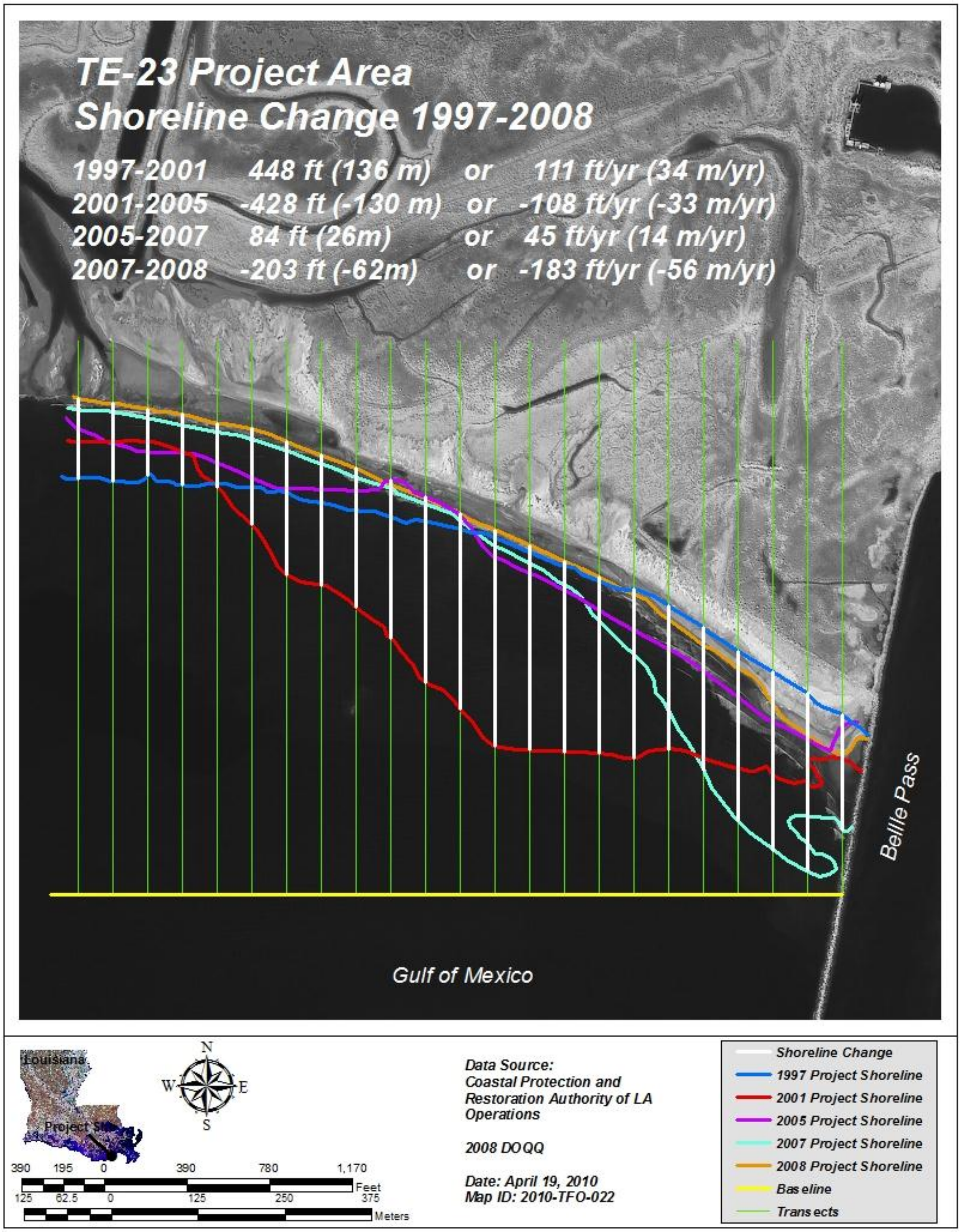


Figure 5. **Shoreline change along the West Belle Pass Headland Restoration (TE-23) project area reaches from 1997 to 2008.**

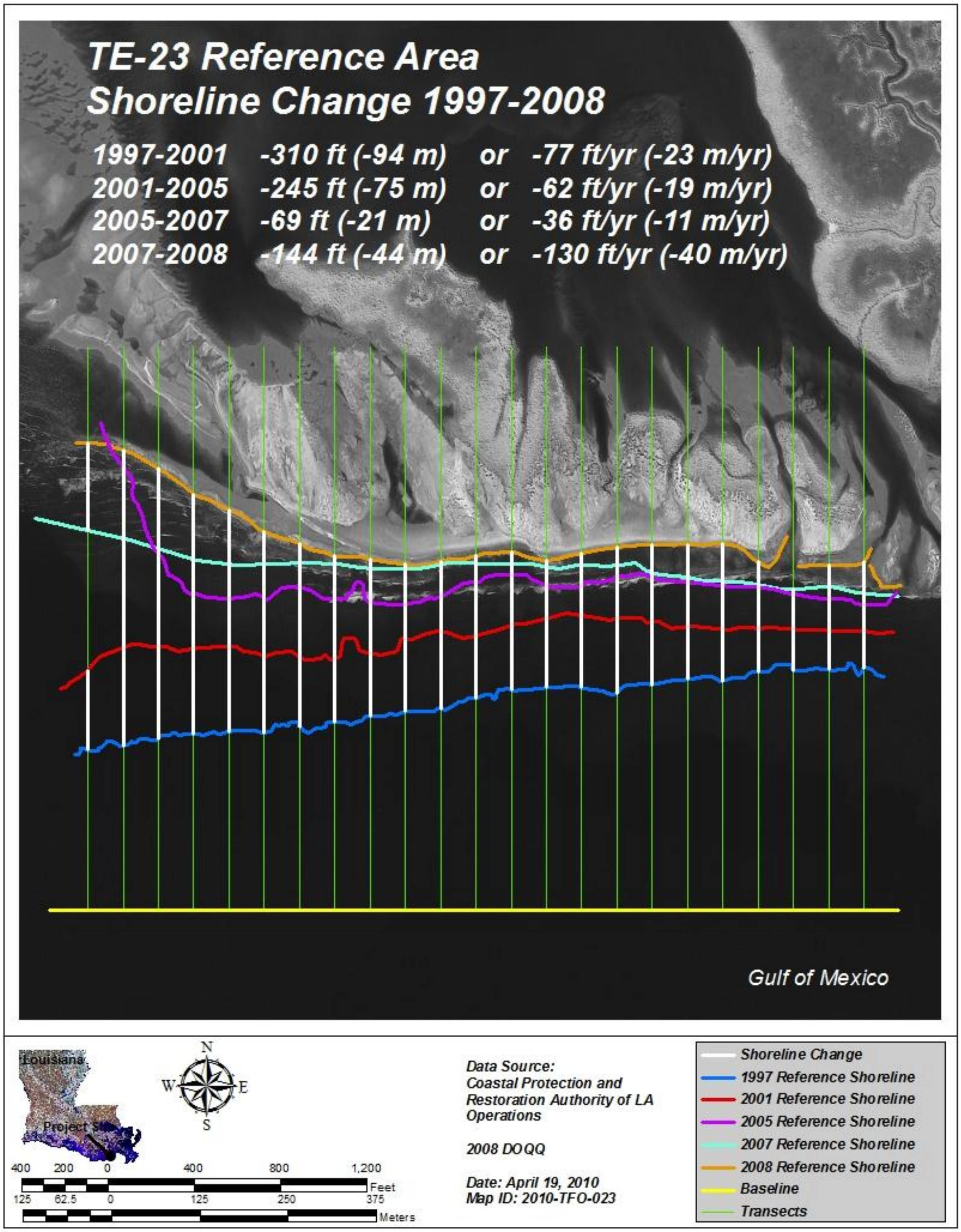


Figure 6. Shoreline change along the West Belle Pass Headland Restoration (TE-23) reference area reaches from 1997 to 2008.

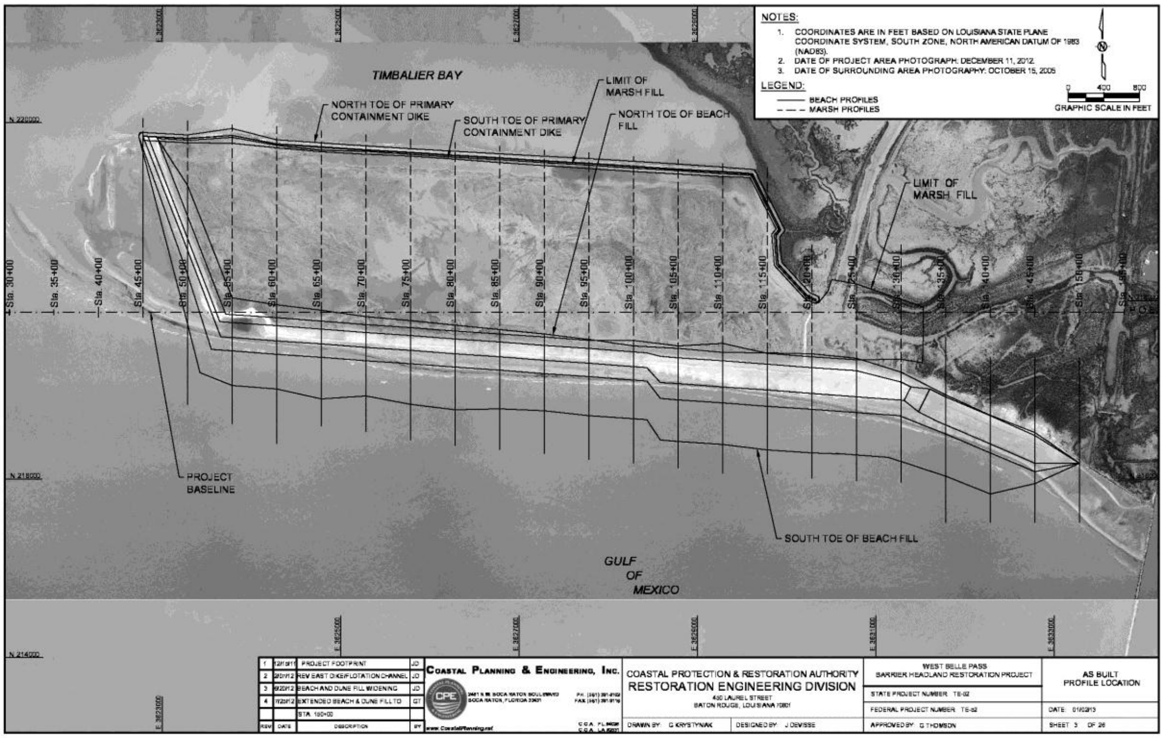


Figure 7. Location of the West Belle Pass Barrier Headland Restoration (TE-52) project features.

order was issued to construct this additional beach and supratidal feature due to potential sand loss between the two projects and to create a continuous beach from the rock jetties to the western limits of the TE-52 project (Figure 9). The added features increased the project's sand volume by 57,147 m^3 (74,745 yd^3) and the length of sand fencing utilized by 516 m (1,692 ft). Therefore, the in place volume of sand rose to 2,098,508 m^3 (2,744,745 yd^3) and the linear length of sand fencing increased to 3,765 m (12,352 ft) with the expanded template. On August 29, 2012 ten days after completing the beach and dune segments of the project, Hurricane Isaac made landfall on the Caminada-Moreau Headland (Figure 4) and breached the dune and the primary containment dike (Figure 10). The breach in the primary dike was closed by constructing a 61 m (200 ft) metal sheet pile wall with 9 m (30ft) deep sheet piles. The dune breach was plugged using heavy equipment and sand that had been over washed into the marsh creation area. The re-constructed dune plug was offset from the original dune centerline and includes an area of low relief (old dune location) between the beach and the dune (Figure 10). In addition to the breach closures, approximately 610 m (2,000 ft) of sand fencing were replaced after the hurricane. Marsh creation activities commenced immediately following the passage of Hurricane Isaac. Silt and clay sediments were placed in the area between the beach and dune area's northern extents and the primary containment dike (Figures 7, 8, 9, and 10). Sediments in the marsh creation area were pumped to a final elevation range of 1.0-1.7 m (3.3-5.5 ft) NAVD88. A total of 1,575,142 m^3 (2,060,208 yd^3) of sediments were placed into the marsh creation area creating 135 ha (334

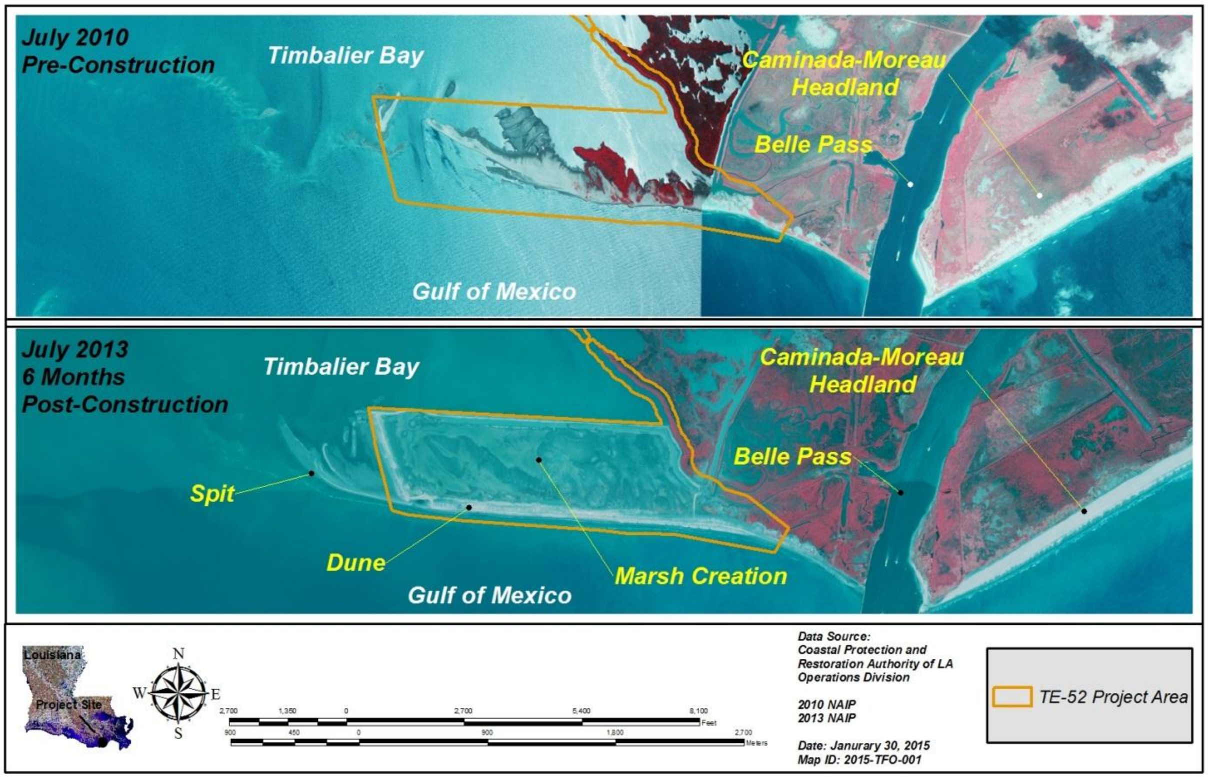


Figure 8. **Aerial photographs demarcating the pre- and post-construction West Belle Pass Barrier Headland Restoration (TE-52) project area and features. Note the extension and shaping of the spit immediately following construction.**

acres) of marsh. Six weir boxes were placed on the eastern edge of the marsh creation area between the dune and the primary containment dike to facilitate dewatering. After sediment consolidation, these weir boxes were removed and the dike was gapped to allow for tidal exchange between surrounding marshes and the marsh creation area. Vegetation was planted along the constructed beach and dune to stabilize these features and increase vegetation cover during the spring of 2013. *Panicum amarum* Elliot (bitter panicgrass), *Uniola paniculata* L. (seaoats), *Schizachyrium maritimum* (Chapm.) Nash (gulf bluestem), *Spartina patens* (Aiton) Muhl. (saltmeadow cordgrass), and *Distichlis spicata* (L.) Greene (saltgrass) were planted either in front of, behind, or on top of the dune feature. Construction of the TE-52 project began on October 25, 2011 and ended on March 12, 2013.

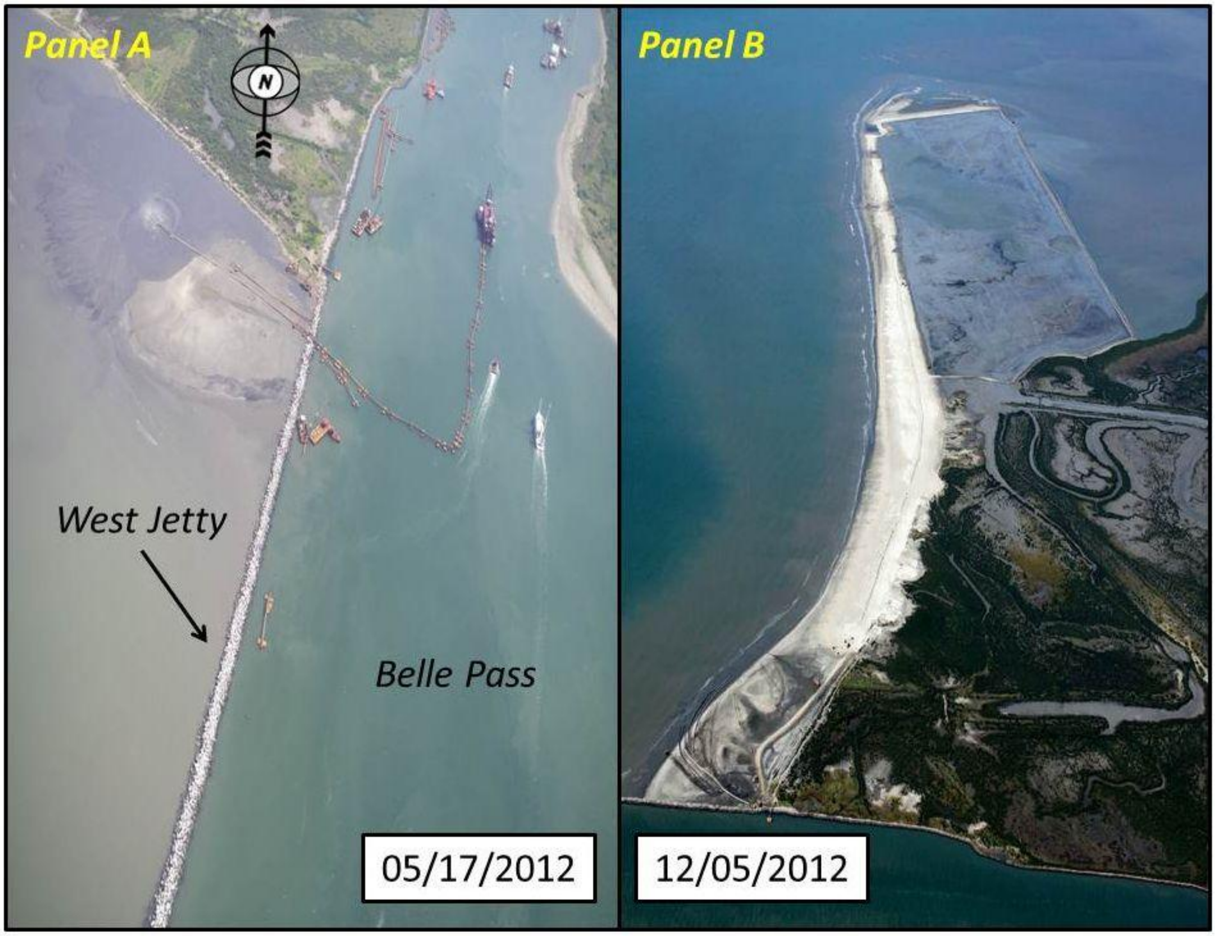


Figure 9 **Oblique aerial images showing the USACE's 2012 BUMP project under construction (Panel A) and the completed West Belle Pass Barrier Headland Restoration (TE-52) and BUMP projects (Panel B). Note the extent of the BUMP project can be delineated from Panel B by denoting the silt and clays in the sandy shoreline (black color).**

Figure 10. **Oblique aerial images depicting the West Belle Pass Barrier Headland Restoration (TE-52) project before (Panel A) and after (Panel B) Hurricane Isaac and after dredging operations were complete (Panel C). Panels A and B were taken before marsh creation activates began. The earthen structure in the foreground of Panel A is the floatation channel spoil and can be seen in subsequent photographs. Note the breaching of the primary containment dike and the dune by the hurricane (Panel B) and the embryonic stages of the spit development in Panels B and C. Also note the offset position of the dune in the breached area and erosion along the Gulf of Mexico shoreline in panel C and the large volume of sand that was overwashed into the marsh creation area during beach and dune construction in panel A.**

II. Maintenance Activity

a. Project Feature Inspection Procedures

The annual inspection of the TE-52 project took place on March 23, 2015. In attendance were Travis Byland and Glen Curole with CPRA, and Mel Landry with the National Marine Fisheries Service. The attendees met at a launch near Port Fourchon and traveled to the project by area by boat. The inspection began around 10:00 AM at the sheetpile structure within the northern containment dike and concluded around 12:00 at the same location. The trip included a visual inspection of all project features. Photographs on the inspection are located in Appendix A (A-1–A-8).

The purpose of the annual inspection of the West Belle Pass Barrier Headland Restoration (TE-52) project is to evaluate the constructed project features in order to identify any deficiencies. The inspection results are used to prepare a report detailing the condition of the project features and recommendations of any corrective actions considered necessary. Should it be determined that corrective actions are needed, the CPRA shall provide, in the report, a detailed cost estimate for engineering, design, supervision, inspection, construction, and contingencies, as well as an assessment of the urgency, of such repairs. An estimated projected budget for the upcoming three (3) years for operation, maintenance, and rehabilitation is included in Appendix B.

b. Inspection Results

Beach Fill

Overall, the beach fill appears to be in good condition. The beach profile is continuing to adapt to the environmental conditions. The dune scarping from Belle Pass to near Sta. 105 is continuing to increase, however there is no sign of immediate breach of the beach dune. The large sand spit on the western extend of the headland is continuing to increase in size. There are no recommendations for maintenance at this time.

Marsh Fill

The marsh fill appears to be in good condition. There are no signs of extensive settlement and vegetation is continuing to emerge near tidal water sources. All containment dikes are fully intact, with the exception of the outfall area near the eastern adjacent marsh. This gap in the containment dike is providing a hydrologic connection to the channel that was formed as a result of the containment dike borrow area. The northern containment dike will likely form some gaps over the next year and will provide additional connectivity to the interior marsh. The formation of these gaps should be monitored in the future. There are no recommendations for maintenance at this time.

Sand Fencing

The sand fencing from Sta. 45+00 to Sta. 105+00 appears to be in good condition. The fence is catching sand as designed and the vegetation is growing around it. The sand fencing from Sta. 105+00 to the eastern extent is badly damaged or nonexistent. The scarp in the dune has reached the fencing and destroyed it. The fencing in this area will need to be replaced after the beach has stabilized to its natural position. There are no recommendations for maintenance at this time.

c. Maintenance Recommendations

The beach fill and marsh fill appear to be functioning as designed. Some scarping of the beach dune is still occurring on the eastern portion of the project as a result of erosional shadowing from the Belle Pass jetty. This scarping has caused extensive damage to the sand fencing that was placed along this stretch of dune. The sand fencing will need to be replaced in the future after the beach and dune has stabilized into its natural position. A large spit of sand has formed on the western end of the headland as a result of longshore sediment transport. The formation of this spit was expected and provides excellent habitat for shorebirds and other marine species. The marsh appears to be in good condition and is not experiencing any excessive settlement. The northern containment dike is beginning to breach, which will help to provide a hydrologic connection to the interior portions of the marsh. If this breach does not occur, measures should be taken to breach the dike in strategic locations in the future. This should be noted during future inspections. There are no recommendations of maintenance to the beach fill, marsh fill, or sand fencing at this time.

III. Operations Activity

a. Operation Plan

There are no operations for the TE-52 project.

b. Actual Operations

There are no operations for the TE-52 project.

IV. Monitoring Activity

Pursuant to a CWPPRA Task Force decision on August 14, 2003 to adopt the Coastwide Reference Monitoring System-*Wetlands* (CRMS-*Wetlands*) for CWPPRA, updates were made to the TE-52 Monitoring Plan to merge it with CRMS-*Wetlands* and provide more useful information for modeling efforts and future project planning while maintaining the monitoring mandates of the Breaux Act. There are no CRMS sites located in the project area.

a. Monitoring Goals

The specific project strategies of the West Belle Pass Barrier Headland Restoration (TE-52) project are (1) to place sand on top of supratidal, intertidal, and subtidal habitats to increase the height and width of the headland, (2) to construct a marsh platform through the use of material dredged in the vicinity of the Caminada-Moreau Headland, and (3) to plant vegetation and construct sand fencing to stabilize and conserve newly placed sediments. Placement and settlement of dredged sediments created intertidal and supratidal back barrier marsh and appreciably increased the width and sustainability of the western part of the Caminada-Moreau Headland. Vegetative plantings in back barrier marsh area will hasten the development of marsh communities and support sediment retention. Dune formation, vegetative plantings, and sand fencing aided in sediment retention and prevented overwash on elevated dune segments during small cross-shore events.

The specific measurable goals established to evaluate the effectiveness of the project are:

1. Reestablish and increase headland longevity via dune and marsh creation.
2. Restore shoreline, dune, and back-barrier marsh to increase habitat utilization by essential fish and wildlife species both on the barrier headland and in the consequently developed quiescent bays through the creation of 150 acres of marsh habitat.
3. Prevent breaching along 9,300 feet of the headland over the 20-year project life.
4. Promote the re-establishment of historic longshore transport patterns along the Gulf shoreline.

b. Monitoring Elements

The following monitoring elements will provide the information necessary to evaluate the specific goals listed above:

Elevation

Topographic and bathymetric surveys were employed to document elevation and volume changes inside the West Belle Pass Barrier Headland Restoration (TE-52) project area. Design (August 2008), pre-construction (October 2011) and as-built (October 2012) elevation data were collected using traditional cross sectional and real time kinematic (RTK) survey methods. A subsequent post-construction survey was conducted in January 2015. These surveys were conducted on 26 cross sectional transects that were separated by 152 m (500 ft) intervals (Figure 11). Several of the periodic surveys were missing transects – 2008 design (T26), 2011 pre (T1 and T22-T26), and 2012 as-built (T22-T26). In addition, the length of the survey transects and spacing between points was not always consistent. The survey data were collected using the Louisiana Coastal Zone (LCZ) GPS Network and the TE23-SM-01 monument. All data surveys were referenced to LA State Plane South Zone (1702) coordinates, and vertical elevations were referenced to NAVD88 in feet. Three different geoid models were employed to estimate vertical positions during the 6.4 year span in the surveys. GEOID03 was utilized in 2008, GEOID09 was utilized in 2011 and 2012, and GEOID12A was utilized in 2015. All vertical positions were adjusted to tie in with the GEOID12A model using correction factors established on the TE23-SM-01 monument. Survey profiles were graphed for all transects utilizing the y-coordinates and the elevation points with the JMP (v10) statistical software.

The August 2008, October 2011, October 2012, and January 2015 survey data were re-projected horizontally and vertically to the UTM NAD83 coordinate system and the NAVD88 vertical datum in meters using Corpscon® software. The re-projected data were imported into ArcGIS® software for surface interpolation. Triangulated irregular network models (TIN) were produced from the point data sets. Next, the TIN models were converted to grid models [1.0 m^2 (3.3 ft^2) cell size], and the spatial distribution of elevations were mapped in half meter elevation classes. The grid models were clipped to the TE-52 polygons to estimate elevation and volume changes within the beach and dune creation area, the marsh creation area, the nourishment area, and the spit area. The TE-52 polygons were adjusted to fit the smallest survey extent (transect number and length).

Elevation changes from August 2008-October 2011, October 2011-October 2012, October 2012-January 2015, and August 2008-January 2015 (spit only) were calculated by subtracting the corresponding grid models using the Minus Tool utility of the Spatial Analyst extension of ArcGIS®. After the elevation change grid models were generated, the spatial distribution of elevation changes in the TE-52 areas were mapped in half meter elevation classes. Lastly, volume changes in the breakwater field and spit areas were calculated in cubic meters (m^3) using the Cut/Fill Calculator function of the 3D Analyst extension of ArcGIS®. Note, these elevation and volume calculations are valid only for the extent of corresponding survey areas.

Figure 11. Location of the West Belle Pass Barrier Headland Restoration (TE-52) project's topographic and bathymetric survey transects.

Shoreline Change

Gulf of Mexico shoreline change data was analyzed for the beach and dune and spit areas using the Digital Shoreline Analysis System (DSAS version 2.1.1) extension of ArcView® GIS (Thieler et al. 2003). Shoreline positions were determined by extracting the 0 m (0 ft) NAVD88 contour lines from established elevation grid models using the Contour List operation of the 3D Analyst extension of ArcGIS®. The procedures utilized to create the grid models are described in the elevation methodology listed above. The shoreline positions were created from the zero meter contour of the August 2008, October 2011, October 2012, and January 2015 elevation grid models. Once the shorelines were delineated a baseline was created and 1,500 m (4921 ft) simple transects were cast at 50 m (164 ft) intervals. Annual shoreline change rates (m/yr) were assessed and mapped for the ensuing periods August 2008-October 2011, October 2011-October 2012, October 2012-January 2015. These data were graphed and analyzed for significance using a one-way ANOVA and the JMP (v10) statistical software.

Vegetation

Vegetation stations were established in the West Belle Pass Barrier Headland Restoration (TE-52) project area to document species composition and percent cover over time. Thirty randomized plots were placed in both the beach and dune creation area and the marsh creation area (Figure 12). Vegetation data were collected in September 2013 (6 months post-construction), and October 2014 (1.5 years post-construction) via the semi-quantitative Braun-Blanquet method (Mueller-Dombois and Ellenberg 1974; Sawyer and Keeler-Wolf 1995; Barbour et al. 1999). Plant species at each station were identified, and cover values were ocularly estimated using Braun-Blanquet units (Mueller-Dombois and Ellenberg 1974) as described in Folse et al. (2014). The cover classes used were: solitary, <1%, 1-5%, 6-25%, 26-50%, 51-75%, and 76-100%. After sampling the plot, the residuals within a 5 m (16 ft) radius were inventoried. Sixty (60) stations were sampled in 2013 and 2014 using a $4m^2$ plot size.

Mean cover and importance value (IV) were calculated and graphed to summarize vegetation data. Both these parameters were grouped by creation area and year. Relative cover represents the cover of each species as a percentage of total cover (Barbour et al. 1999). An IV is calculated using a minimum of two relative measures. The following IV formula was applied to this analysis: IV = (relative cover + relative frequency)/2. IV represents each species relative contribution to the vegetative community (Barbour et al. 1999). Since IV is a relative measure, each species earns a value ranging from 0 to 100. Cover estimates were analyzed with SAS (v9.4) statistical software.

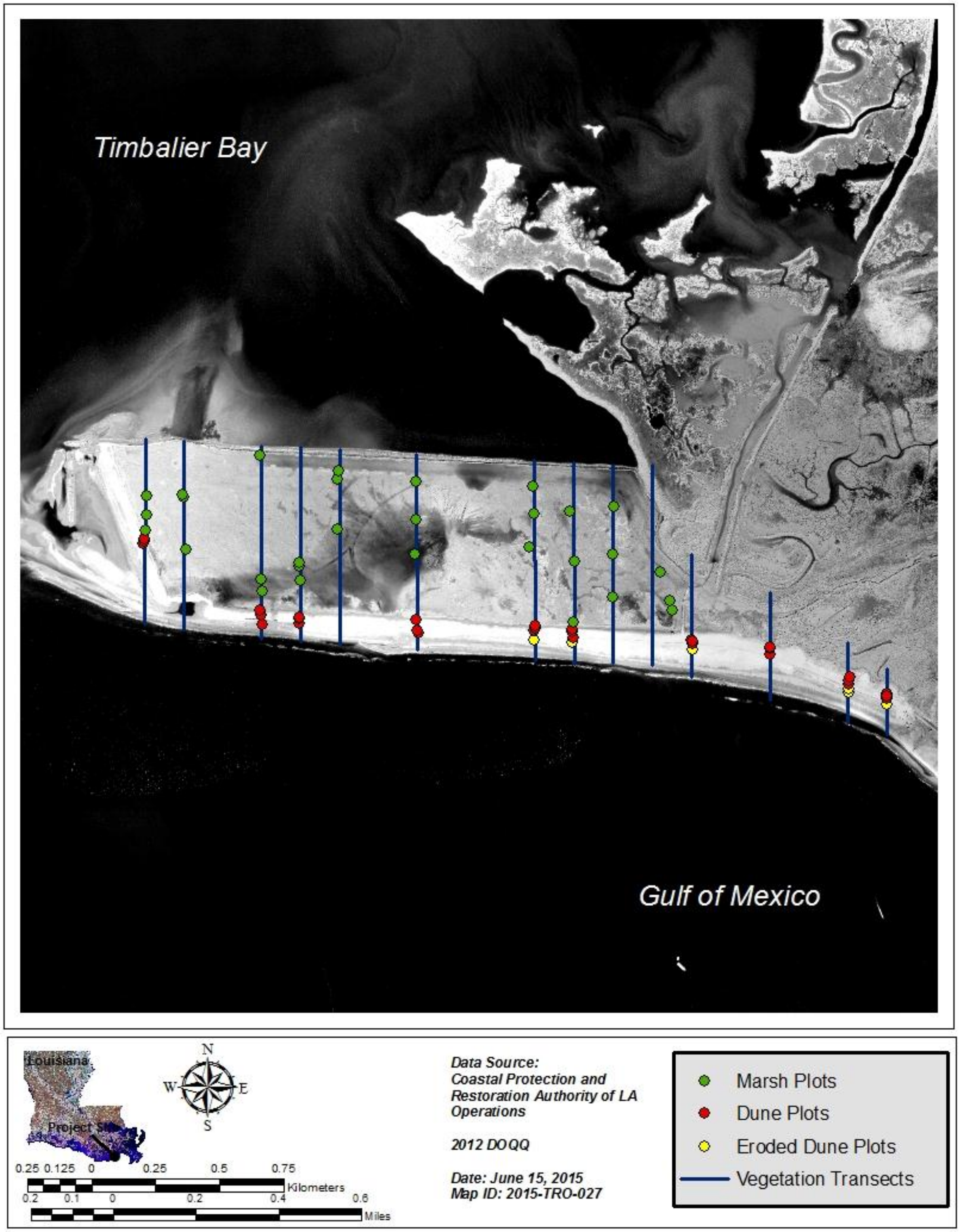


Figure 12. Location of the West Belle Pass Barrier Headland Restoration (TE-52) project's vegetation plots and transects.

Avian Habitat

Due to Critical Habitat designations for a large portion of the Louisiana coastline by the USFWS for the threatened Piping Plover (*Charadrius melodus*) and now the threatened Rufa Red Knot (*Calidris canutus rufa*), CPRA has been required to survey winter shorebirds during construction of large scale beach and dune restorations. Currently, the restoration of Caminada Headland via two projects originally proposed under the Louisiana Coastal Area (LCA) program, required winter shorebird surveys due to United States Fish and Wildlife Service (USFWS) biological opinions that determined "take" of Piping Plovers from disturbance. As such, the Barataria-Terrebonne National Estuary Program (BTNEP) has been conducting surveys along the Caminada Headland, and has covered the West Belle Pass Barrier Headland Restoration project (TE-52) area numerous times over the last 2 wintering seasons. Since this information was available and is being used to compare an older project's bird usage patterns to the newly placed sediment northeast of Bell Pass, CPRA decided to include limited discussion of this data within this report. However, pre-construction data is lacking for all these areas, and as such no comparisons can be made to pre-project bird abundance and distributions.

Winter shorebird surveys have focused on 4 species of concern. Piping Plovers, Rufa Red Knots, Wilsons Plover (*Charadrius wilsonia*), and Snowy Plover (*Charadrius nivosus*) are located and counted approximately every 2 weeks from late July thru April of each winter season. All species seen are noted, but specific locations, numbers of individuals, and identification marks (color bands) are recorded for these four species.

c. Monitoring Results and Discussion

Elevation

The West Belle Pass Barrier Headland Restoration (TE-52) project area has experienced pre- and post-construction volume changes and shoreline modifications. Volume changes over the period of the study are summarized in Table 3, and survey profiles are illustrated in appendix C. Elevation change and volume distributions for the TE-52 project (beach and dune creation, marsh creation, and nourishment areas) are shown in Figure 13 (Aug 2008-Oct 2011), Figure 14 (Oct 2011-Oct 2012), and Figure 15 (Oct 2012-Jan 2015). In addition, elevation change and volume distributions for the spit are presented in Figure 16 (Aug 2008-Jan 2015). Elevation grid models for all survey periods are also provided in appendix D. The TE-52 volume and mean elevation changes are also graphically shown in Figure 17 (beach and dune), Figure 18 (marsh creation and nourishment), and Figure 19 (spit only). In the discussion that follows, note that the as-built volumes computed for this narrative do not equal the volumes stated in the completion report (Devisse and Thomson 2013) because the beach and dune and marsh creation elevation grid models were clipped to different aerial extents.

Table 1. **Pre- and post-construction sediment volume changes in the TE-52 project area. Note that the volume changes include both the subaerial segments of the headland and the shoreface.**

Volume Change (m3)	*Aug 2008 Design - Oct 2011 Pre*	*Oct 2011 Pre-Oct 2012 As-blt*	*Oct 2012 As-blt-Jan 2015 2Yr Post*	*Aug 2008 Design–Jan 2015 2Yr Post*
Dune & Beach Creation Area	-588,785	1,339,240	-774,695	N/A
Marsh Creation Area	406,952	1,695,860	-693,640	N/A
Nourishment Area	36,369	29,039	-10,997	N/A
Spit Area	N/A	N/A	N/A	126,979

The pre-construction elevation models (2008-2011) display large losses in the future beach and dune creation area and large volume gains in the future marsh creation and nourishment areas. The sediment volume in the beach and dune area was reduced by -588,785 m^3 (-770,102 yd^3) while the volume in the marsh creation [406,952 m^3 (532,273 yd^3)] and nourishment [36,369 m^3 (47,569 yd^3)] areas expanded (Table 1 and Figures 13, 17 and 18). The large sediment volume loss along the shoreline and shoreface exhibit the signature of a transgressing shoreline while the capture and retention of 75% sediment removed signifies cross-shore transport. Interestingly, a rather large channel that bisected the project area in-filled and relocated to the west from 2008 to 2011 (Figures 13, 16, D-1, and D-2). The 2008 hurricanes (Gustav and Ike) (Figure 20) and T. S. Lee in 2011 (Brown 2011) impacted the

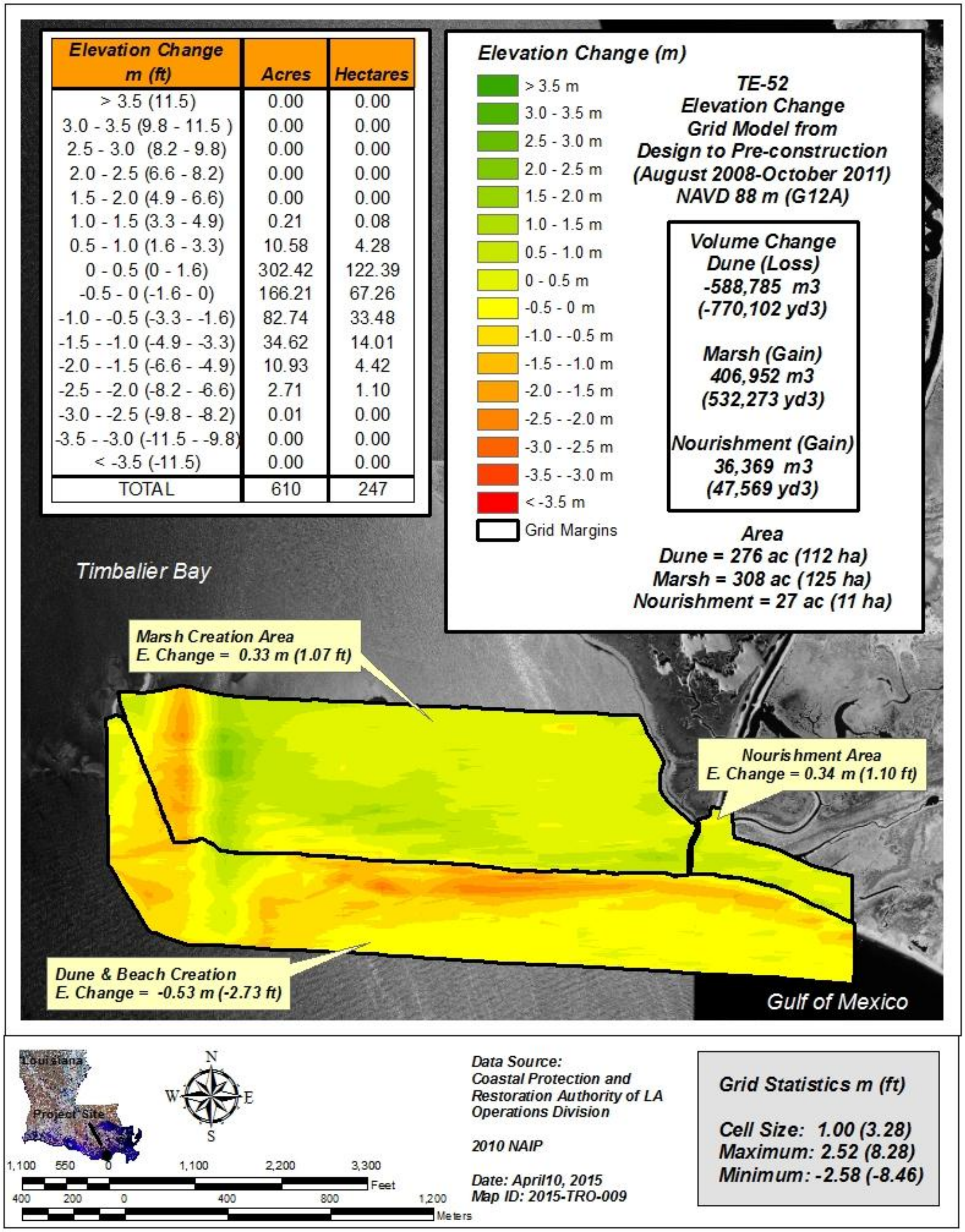


Figure 13. **Elevation and volume change grid model for the beach and dune, marsh creation, and nourishment areas from design (Aug 2008) to pre-construction (Oct 2011) at the West Belle Pass Barrier Headland Restoration (TE-52) project.**

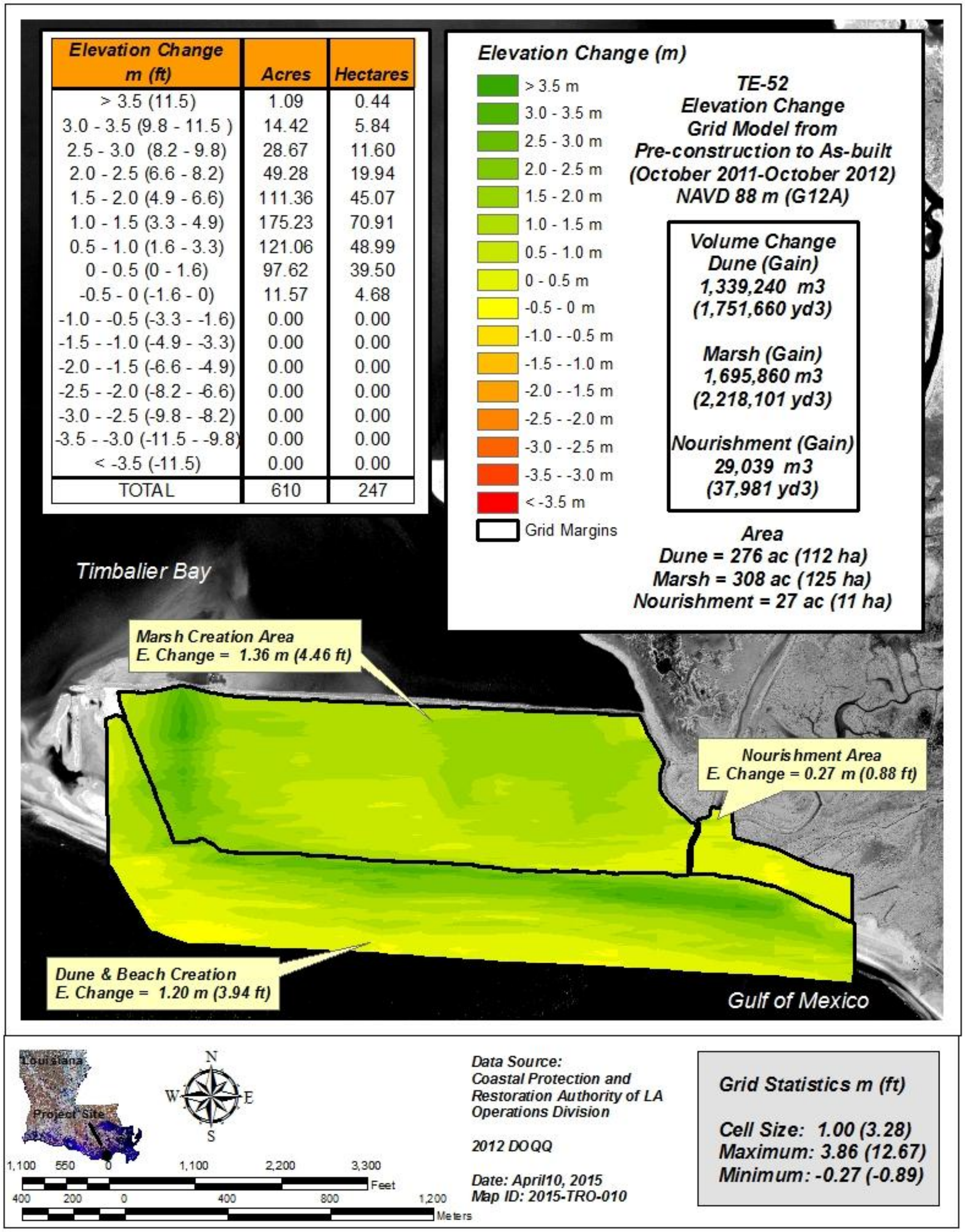


Figure 14. **Elevation and volume change grid model for the beach and dune, marsh creation, and nourishment areas from pre-construction (Oct 2011) to as-built (Oct 2012) at the West Belle Pass Barrier Headland Restoration (TE-52) project.**

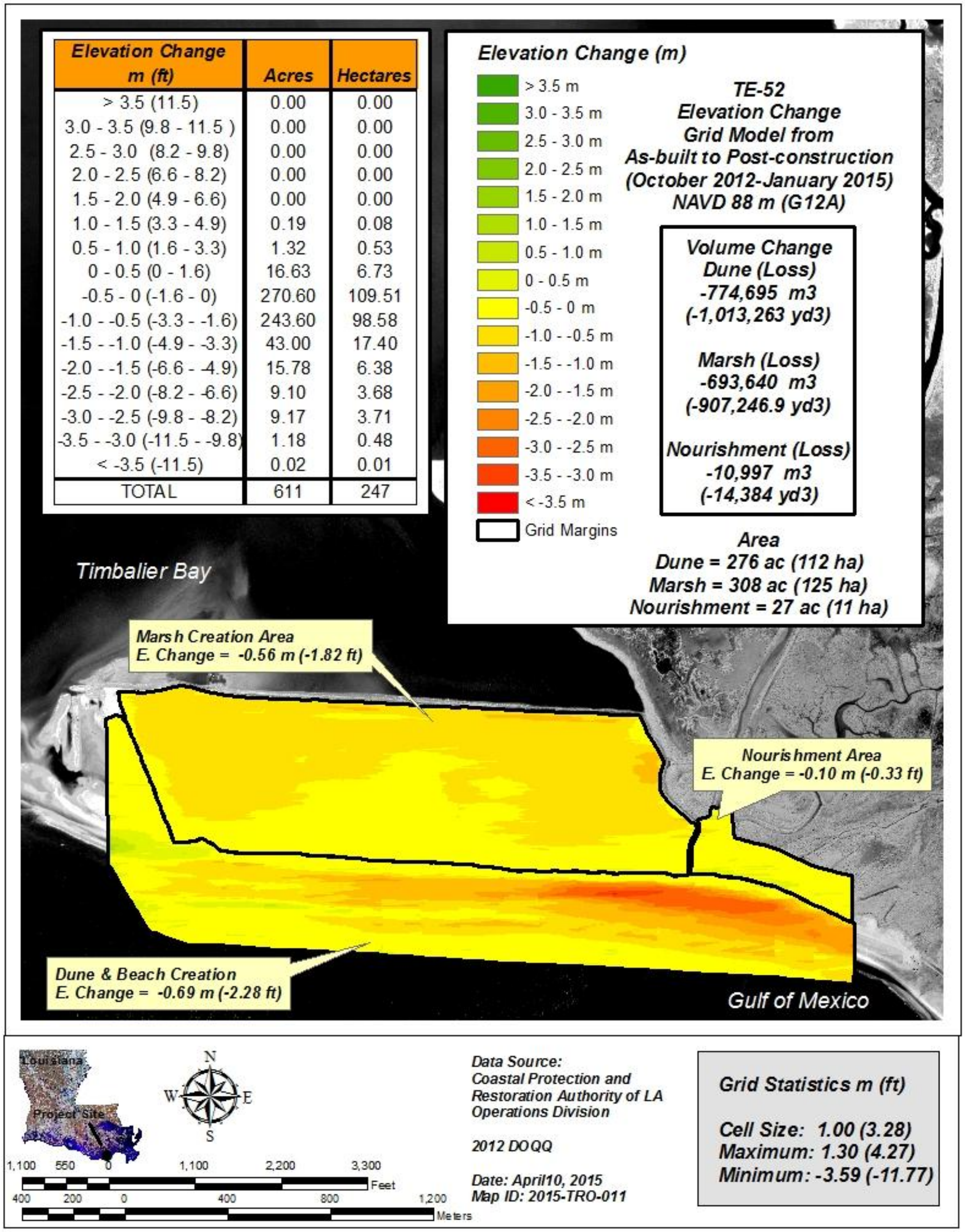
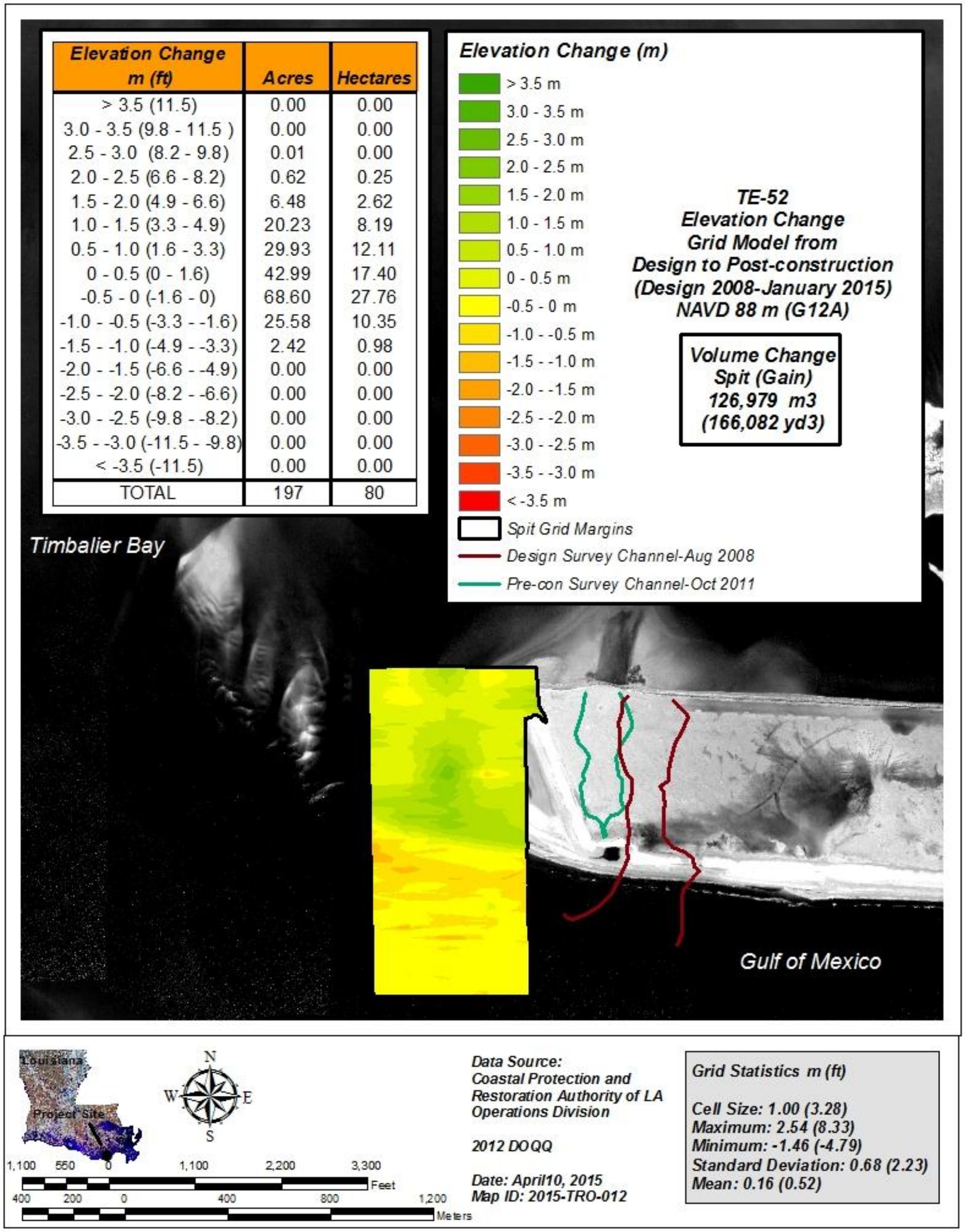


Figure 15. **Elevation and volume change grid model for the beach and dune, marsh creation, and nourishment areas from as-built (Oct 2012) to post-construction (Jan 2015) at the West Belle Pass Barrier Headland Restoration (TE-52) project.**



Elevation Change m (ft)	Acres	Hectares
> 3.5 (11.5)	0.00	0.00
3.0 - 3.5 (9.8 - 11.5)	0.00	0.00
2.5 - 3.0 (8.2 - 9.8)	0.01	0.00
2.0 - 2.5 (6.6 - 8.2)	0.62	0.25
1.5 - 2.0 (4.9 - 6.6)	6.48	2.62
1.0 - 1.5 (3.3 - 4.9)	20.23	8.19
0.5 - 1.0 (1.6 - 3.3)	29.93	12.11
0 - 0.5 (0 - 1.6)	42.99	17.40
-0.5 - 0 (-1.6 - 0)	68.60	27.76
-1.0 - -0.5 (-3.3 - -1.6)	25.58	10.35
-1.5 - -1.0 (-4.9 - -3.3)	2.42	0.98
-2.0 - -1.5 (-6.6 - -4.9)	0.00	0.00
-2.5 - -2.0 (-8.2 - -6.6)	0.00	0.00
-3.0 - -2.5 (-9.8 - -8.2)	0.00	0.00
-3.5 - -3.0 (-11.5 - -9.8)	0.00	0.00
< -3.5 (-11.5)	0.00	0.00
TOTAL	197	80

Figure 16. **Elevation and volume change grid model for the spit area from design (Aug 2008) to post-construction (Jan 2015) at the West Belle Pass Barrier Headland Restoration (TE-52) project.**

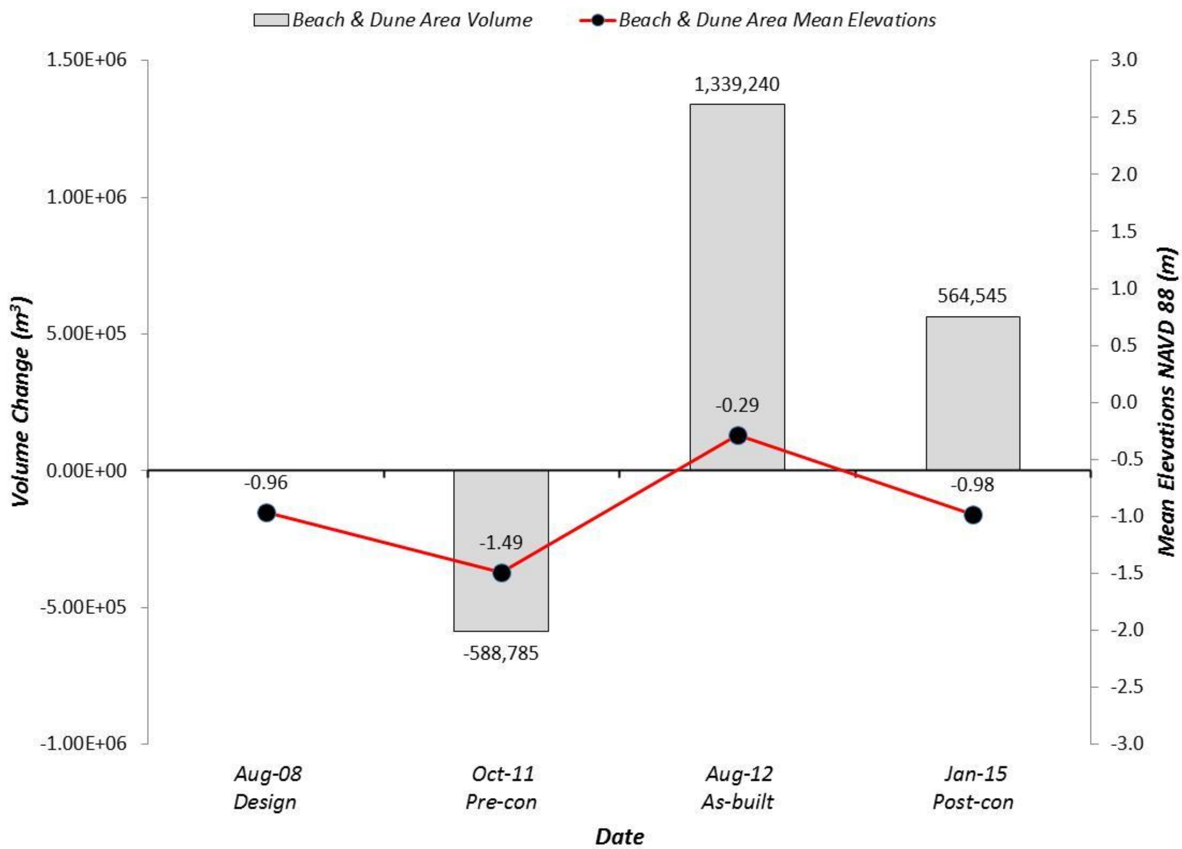


Figure 17. Sediment volume change and mean elevations over time along the West Belle Pass Barrier Headland Restoration (TE-52) project's beach and dune area.

project area during the pre-construction interval and likely aided in the sediment roll over in this area. The previously mentioned 2007 TE-23 maintenance event, which deposited 85,000 m^3 (112,000 yd^3) of sediment adjacent to the west jetty, also probably supported the sediment aggradation in the marsh creation and nourishment areas due to the partial removal of this material in 2008 (Figures 5 and 20) and almost complete removal of this material from its disposal area by 2010 (Figure 8).

The 2011 (pre) - 2012 (as-built) elevation change grid model (Figure 14) displays the substantial volume gains brought about by the construction of the TE-52 project. This figure depicts the dune and the location of the Oct 2011 channel (Figure 16) as incurring the greatest sediment volume increases (darkest green color). Figure D-3 also exhibits the high elevations of the dune, an almost ubiquitous elevation class in the marsh creation area [1.0-1.5 m (3.3-4.9 ft)] (yellow color), and the highest elevations in the nourishment area as occurring along the borders of the creation areas. The as-built (2012) volume and

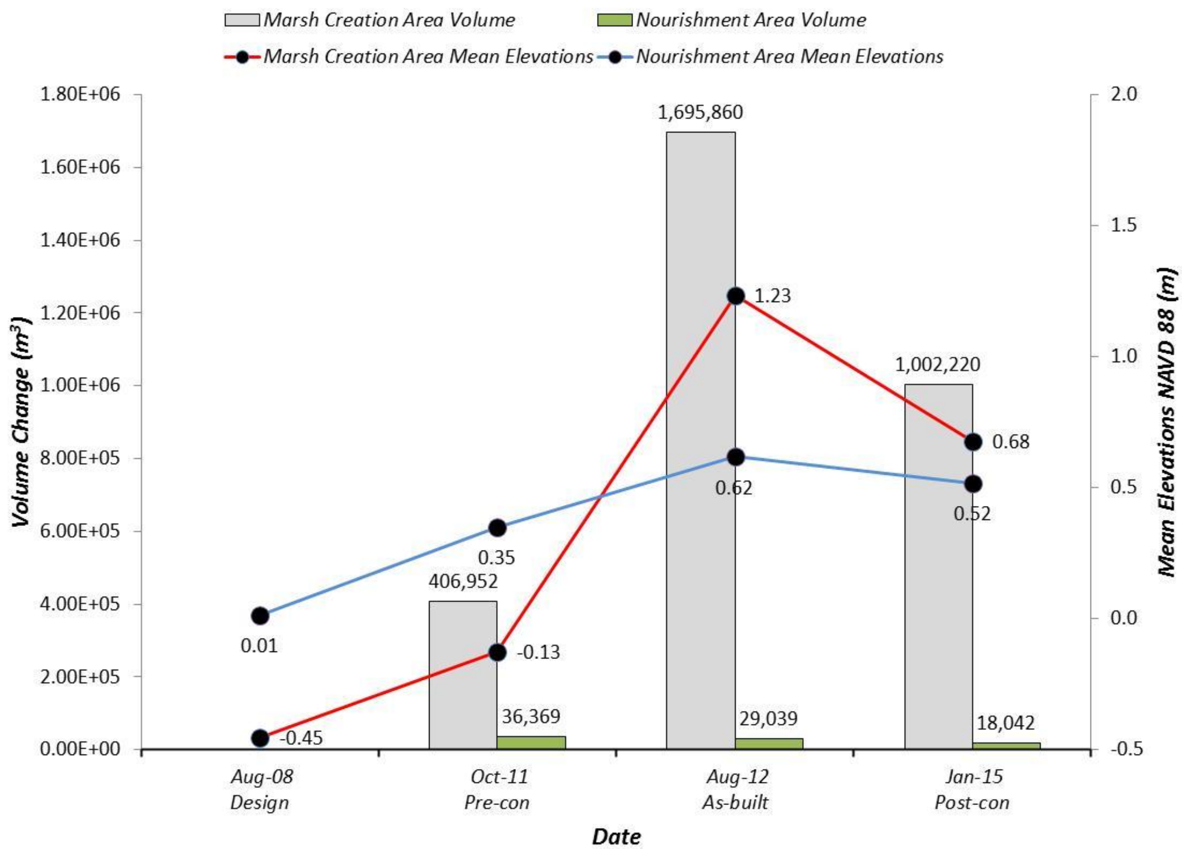


Figure 18. Sediment volume change and mean elevations over time along the West Belle Pass Barrier Headland Restoration (TE-52) project's marsh creation and nourishment areas.

elevation increases are graphically illustrated in Figures 17 and 18 and tabularized in Table 1. During the as-built time period, the sand volume in the beach and dune area increased by 1,339,240 m^3 (1,751,660 yd^3), the clay and slit volume in the marsh creation area increased by 1,659,860 m^3 (2,218,101 yd^3), and the sediment volume in the nourishment area increased by 29,039 m^3 (37,981 yd^3). The impacts of Hurricane Isaac and beach and dune project modifications induced by the storm are shown in Figure 10. This hurricane breached the dune, caused the dune to be offset at the breached location (change order), and initiated the embryonic spit development (Panels B and C). In addition, the marsh creation area was allowed to be pumped to a higher elevation to prevent further breaching of the dune and primary dike (Devisse and Thomson 2013). Therefore, the passage of Hurricane Isaac during construction altered the features of this headland restoration project.

The post-construction elevation models (2012-2015) display considerable sediment volume declines in the beach and dune and marsh creation areas and a more modest volume loss in the nourishment area. The sediment volume was reduced by 774,695 m^3(1,013,263 yd^3) in the

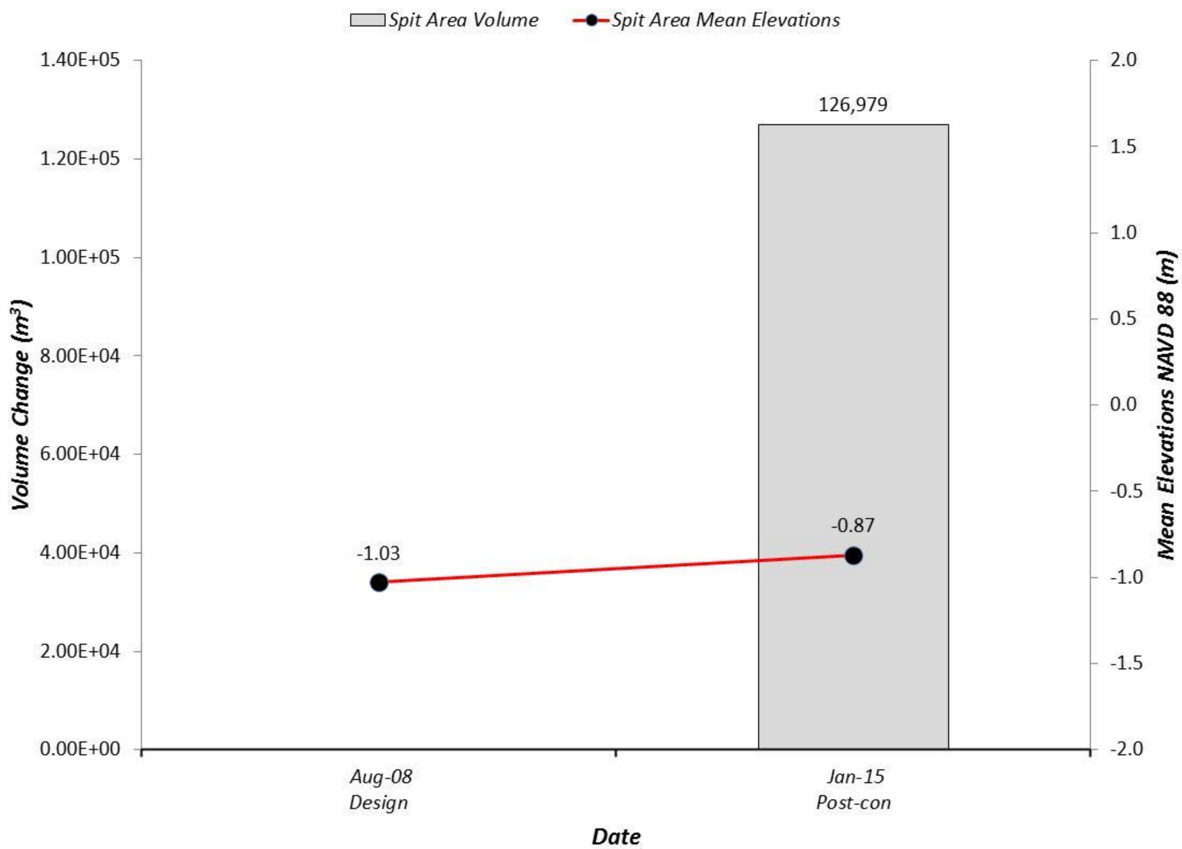


Figure 19. Sediment volume change and mean elevations over time along the West Belle Pass Barrier Headland Restoration (TE-52) project's spit area.

beach and dune creation area, by 693,640 m^3 (907,247 yd^3) in the marsh creation area, and by 10,997 m^3 (14,384 yd^3) in the nourishment area during the initial post-construction interval (Figure 15 and Table 1). The residual volumes are 564,545 m^3 (738,397 yd^3) (beach and dune), 1,002,220 m^3 (1,310,854 yd^3) (marsh creation), and 18,042 m^3 (23,598 yd^3) (nourishment) (Figures 18 and 19). This corresponds to 42% of the in place volume remaining in the beach and dune creation area, 59% of the in place volume remaining in the marsh creation area, and 62% of the as-built volume remaining in the nourishment area two years after construction. The considerable volume loss in the beach and dune area is a result of severe dune scarping and overwash (Figure 21). The extent and intensity of the beach and dune erosion is illustrated in Figure 15 (red and orange colors show areas with large volume deficits). All the segments of the dune that were installed parallel to the Gulf of Mexico shoreline was subjected to varying degrees of scarping. The scale of scarping generally increased to the east with the extreme eastern reaches being subjected to overwash and leveling. Approximately, 450 m (1,500 ft) of the eastern edge of the dune have been raised leaving only the beach and a small berm remaining. In addition, the sand fencing along the first 1,500 m (5,000 ft) of the eastern reaches has been dismantled

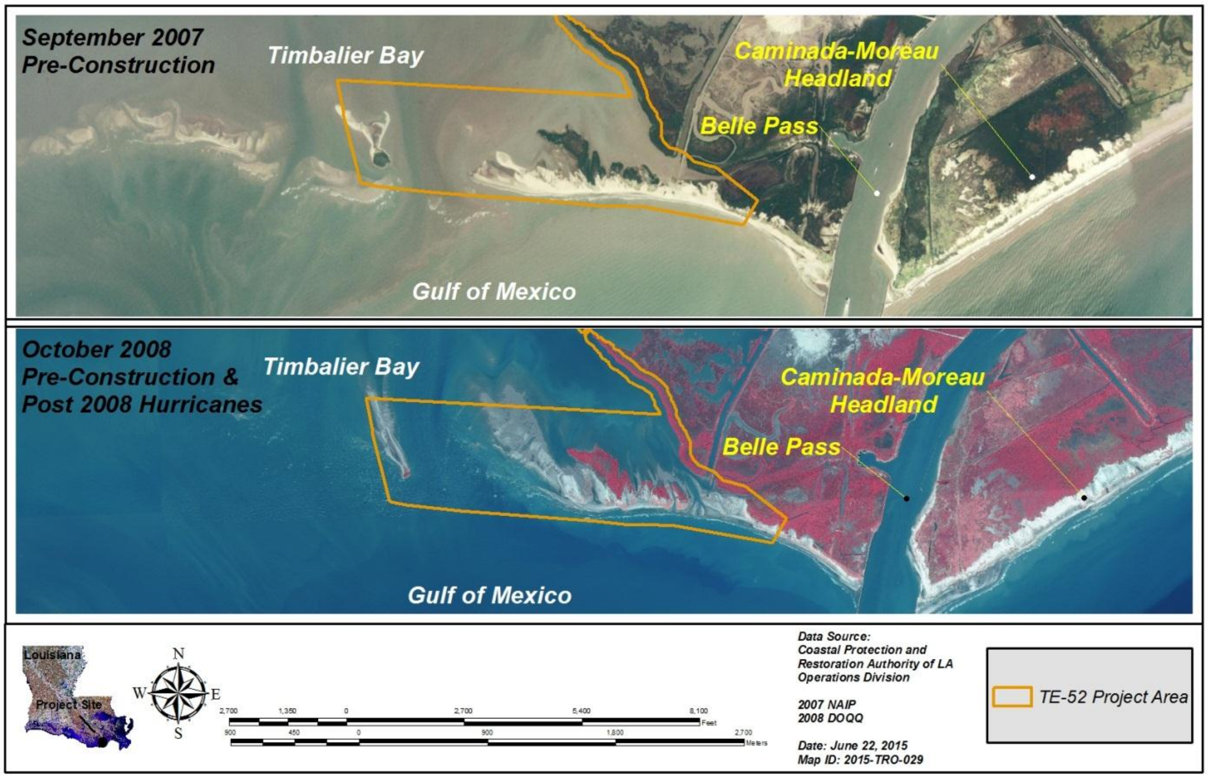


Figure 20. **Aerial photography (2007 and 2008) showing preconstruction geomorphic changes in the West Belle Pass Barrier Headland Restoration (TE-52) project area. Note the impact of the 2008 hurricanes on these shorelines and the 2007 addition of sediment along the west jetty by the channel maintenance event.**

by the severe scarping of the dune feature (Figure 21). Moreover, Figure 21 demonstrates that the erosion of the dune is progressing northward over time by showing the position of the sand fencing in 2013 (Panels A and B) and 2014 (Panels C, D, E, and F). It is rather alarming that the dune feature scoured at such a rapid rate in the absence of a major storm or more frequent tropical storm activity. In fact, only one tropical storm has entered the central Gulf of Mexico since construction, and this storm dissipated before landfall. Moreover, the substantial erosion of the dune far exceeds the Delft3D predictions postulated during the engineering and design phase of this project (Thomson et al. 2009). Therefore, it seems plausible that Hurricane Isaac (Figures 4 and 10) may have induced greater shoreface erosion than previously thought and accelerated the beach and dune volume loss. Winter storms were also probably instrumental in advancing the erosion of the beach and dune creation area (Boyd and Penland 1981; Dingler and Reiss 1990; Ritiche and Penland 1998b; Georgiou et al. 2005). A third possible causative mechanism leading to the large beach and dune volume loss is the Belle Pass Rock Jetties. Erosion and sediment volume loss on the downdrift side of jetty systems is well documented and can be predicted to occur (Stauble and Morang 1992; Komar 1998; Kraus et al. 1999; Bird 2000; Larson et al. 2002). Penland and Suter (1988)

Figure 21. Oblique images depicting scarping of the West Belle Pass Barrier Headland Restoration (TE-52) project's dune feature in 2013 and 2014. Note the severe scarping that occurred several months after construction and the distance to the sand fencing in 2013 (Panels A and B). Panel B also shows channel formation during high water events along the eastern reaches of the dune feature. Several channels formed on the supratidal elevated expanded beach and dune template. Panels C and D display the eastern edges of the remaining dune. The dune feature no longer exists along the eastern reaches of the project. The area can be currently classified as washover and dune terrace landforms. Panels E and F exhibit the erosion of the dune all the way to the sand fencing which was placed in the center of the dune. Sand fencing only remains on the western and central reaches of the dune. The sand fencing that was installed on the eastern reaches of the dune has been leveled by wind and wave energy.

surmised that the Belle Pass Rock Jetties have reduced the longshore transport to the Timbalier Islands (Figure 1), and Dantin et al. (1978) inferred from a physical model that sediments that by-pass the rock jetties are transported 1,530-2,440 m (5,000-8000 ft) to the west creating a shadowing effect in the immediate lee of the west jetty. Moreover, these rock jetties have been extended at least 457 m (1,500 ft) into the Gulf since the Dantin et al. (1978) model was created likely expanding the distance of the shadow effect. To illustrate further, the USACE has added sediment to the beach in the lee of the west jetty on three occasions (1998, 2007, and 2012) only to have the sediments reworked by coastal processes demonstrating that very little sediment is transported towards the western jetty (eastern littoral transport). While a sizeable volume of sediment was removed from the beach and dune, approximately 126,979 m^3 (166,082 yd^3) of these sediments were transported to the west aggrading and elongating the vertical profile of the spit (Figures 16, 19, and Table 1). However, a larger volume of sediments could have been retained in the West Belle Pass sediment budget if the proposed terminal groin was constructed on the western edge of the TE-52 project area (Dean 1997; Thomson et al. 2009). This structure was eliminated from the project design due to the fiscal constraints of the CWPPRA program. The loss of 41% of the marsh creation volume (Figures 15, 18 and Table 1) appears to be a by-product of sediment consolidation. Approximately, 0.6 m (1.8 ft) of sediment consolidation occurred from Oct 2012 to Jan 2015 (Figures 18, D3, and D4). As a result, it appears that the marsh creation area was still experiencing primary settlement at the time of the as-built survey. In conclusion although there was considerable erosion and volume loss in the beach and dune creation area, the reestablish and increase headland longevity and prevent breaching goals are currently being attained because the headland has been reestablished and has not breached since construction. The promote the re-establishment of historic longshore transport patterns along the Gulf shoreline goal is really not an attainable goal because historically the logshore transport nourished East Timbalier and Timbalier Islands. However, the net longshore transport continues to flow to the west as described in the historical record (Peyronnin 1962; Dantin et al. 1978; Ritchie and Penland 1988b; Stone and Zhang 2001; Thomson et al. 2009).

Shoreline Change

The West Belle Pass Barrier Headland Restoration (TE-52) project area has incurred shoreline transgressions and expansions over the monitoring period (2008-2015). Figure 22 graphically displays the TE-52 shoreline changes during the pre-construction interval (2008-2011), the as-built interval (2011-2012), and the post-construction interval (2012-2015). The shoreline positions (2008, 2011, 2012, and 2015) derived from the 0.0 m (0.0 ft) shoreline contours can be viewed in Figure E-1. For the pre-construction interval, the future TE-52 shorelines transgressed at rate of -19.62 m/yr (-64.37 ft/yr). A large part of the 2008-2011 shoreline erosion can be attributed to cross-shore transport generated from hurricanes and tropical storms. The 2008 hurricanes (Gustav and Ike) (Figure 4) caused overwash, breaching, truncation and shoreline transgressions along the West Belle Pass Headland (Figures 5, 6, and 20). T. S. Lee in 2011 caused tides to rise 1.2-1.8 m (4.0-6.0 ft) in the Terrebonne Basin (Brown 2011) and likely transgressed the project area shorelines during the pre-

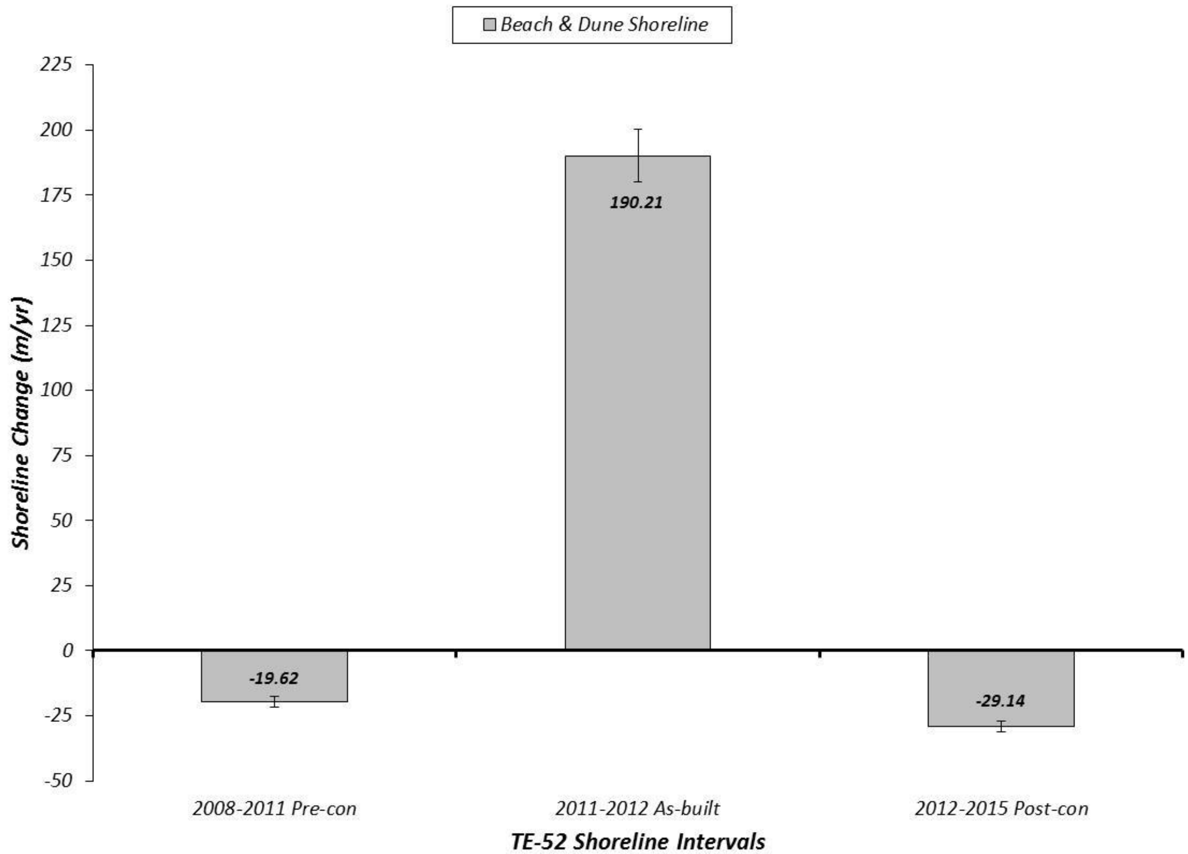


Figure 22. Shoreline transgressions along the West Belle Pass Barrier Headland Restoration (TE-52) project area from Aug 2008-Jan 2015.

construction interval. Construction of the beach and dune feature for the TE-52 project extended the West Belle Pass shorelines further into the Gulf of Mexico. These shorelines prograded at a rate of 190.21 m/yr (624.05 ft/yr) for the as-built interval. However, not long after construction the beach and dune feature began to transgress. For the post-construction interval, the TE-52 shorelines eroded at a rate of -29.14 m/yr (-95.60 ft/yr). This erosion rate is three times higher than the projected rate of -9.75 m/yr (-32.00 ft/yr) suggested in the project design report (Thomson et al. 2009). Figure 21 shows the severe scarping and overwash that occurred in the project area for the 2012-2015 time period. As discussed in the elevation results, these shoreline transgressions were probably induced by the passage of Hurricane Isaac (Figures 4 and 10) (Devisse and Thomson 2013), winter storms (Boyd and Penland 1981; Dingler and Reiss 1990; Ritiche and Penland 1998b; Georgiou et al. 2005), and the influence of the Belle Pass Rock Jetties (Dantin et al. 1978; Penland and Suter 1988). All temporal differences between intervals were significant ($P < 0.05$). Though substantial shoreline transgressions occurred, the prevent breaching goal is currently being achieved because no inlets have formed in the project area.

Vegetation

The West Belle Pass Barrier Headland Restoration (TE-52) vegetation data show that dune and marsh creation vegetation communities are following different trajectories. The results of the mean cover and importance value (IV) analyses are graphically illustrated in Figure 23 (dune mean cover), Figure 24 (dune IV), Figure 25 (marsh mean cover), and Figure 26 (marsh IV). One big difference between the dune and marsh communities is that the dune was planted in the spring of 2013 and the marsh was not. The marsh creation area is slated to be planted in the spring of 2016. The dune had a percent cover of 12.6% in 2013 and 21.3% in 2014. The top five species found were all planted species while the other species covered approximately 1.0% of the dune for both sampling years (Figure 23). Although the

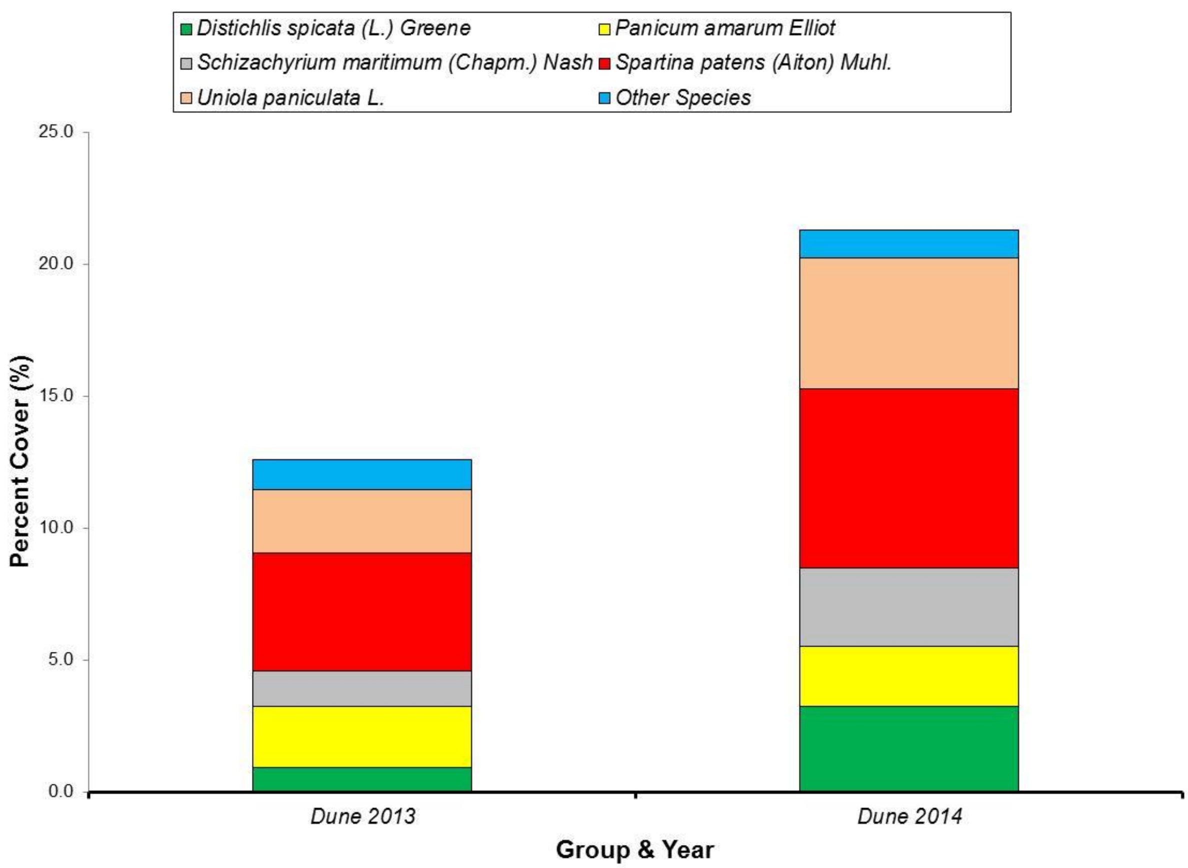


Figure 23. **Mean cover of the top five vegetation species populating the West Belle Pass Barrier Headland Restoration (TE-52) beach and dune creation area in 2013 and 2014. Ocular vegetation data were grouped by creation area and year.**

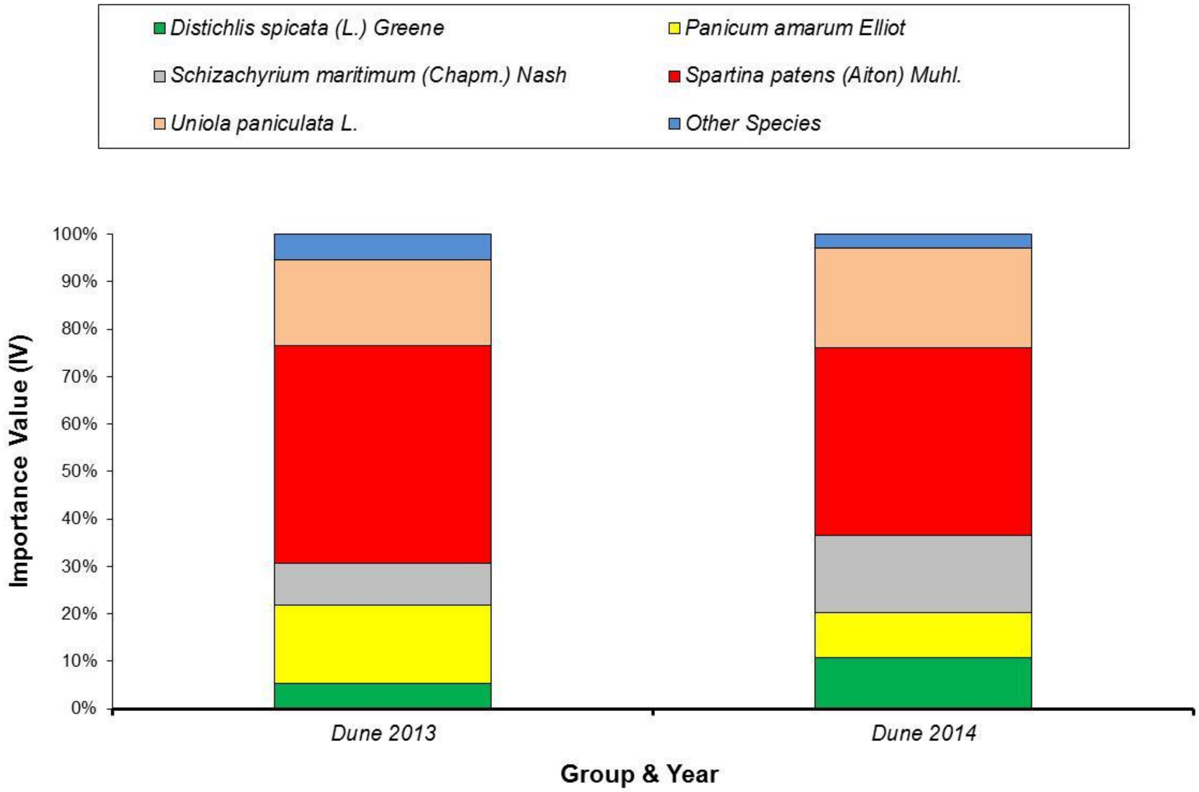


Figure 24. **Importance value (IV) of the top five vegetation species populating the West Belle Pass Barrier Headland Restoration (TE-52) beach and dune creation area in 2013 and 2014. Ocular vegetation data were grouped by creation area and year.**

other species occupy a small proportion of the plot cover, approximately eighteen species are part of this cover class and many are found on the outer perimeter of the plots. In addition, many of these species are common inhabitants of dune environments - *Sesuvium portulacastrum* (L.) L. (shoreline seapurslane), *Heliotropium curassavicum* L.(salt heliotrope), and *Croton punctatus* Jacq. (gulf croton). This incremental growth in dune vegetation indicates that the planted dune species are surviving and experiencing a modest amount of vegetative growth. All of the planted species except *P. amarum* had increases in mean cover from 2013 to 2014 (Figure 23). The very small decline in *P. amarum* mean cover is probably a result the destruction of vegetation plots south of the dune due to beach and dune erosion. *S. patens* remains the most important dune species although it's IV declined from 2013 to 2014. *P. amarum* and the other species also had lower IV over the period of the study while *U. paniculata*, *S. maritimum*, and *D. spicata*, increased in importance over time (Figure 24). Other dune creation projects in coastal Louisiana have experienced low vegetative cover of planted species in the first few growing seasons after installation only to have mean cover expand in subsequent samplings (West and Dearmond 2007; West et al. 2007). Therefore, the

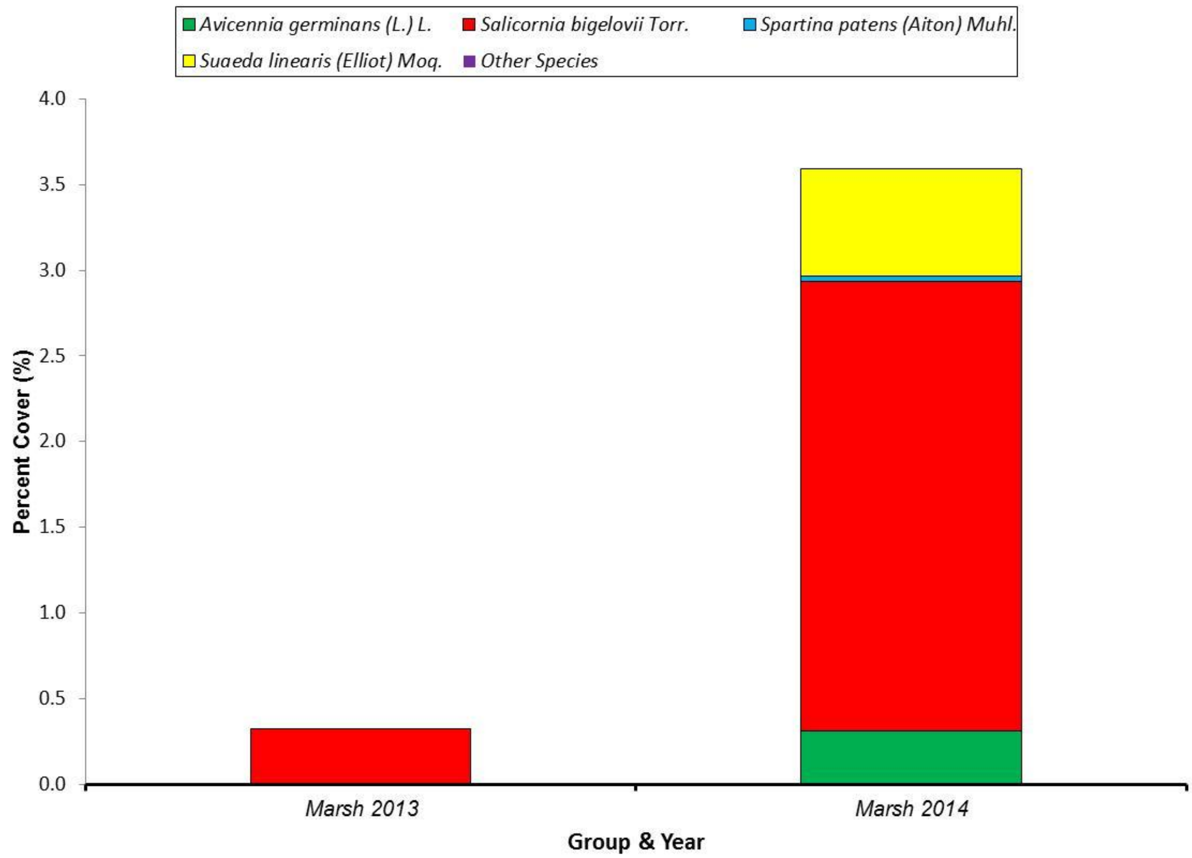


Figure 25. **Mean cover of the top five vegetation species populating the West Belle Pass Barrier Headland Restoration (TE-52) marsh creation area in 2013 and 2014. Ocular vegetation data were grouped by creation area and year.**

vegetative cover of the dune should increase over time. However, nitrogen deficiency in coastal dune habitats has been well documented (Woodhouse 1978; Kachi and Hirose 1983; Shumway 2000; Gilbert et al. 2008; Sigren et al. 2014) and may inhibit the growth and dispersal of the dune community. The marsh creation area had a percent cover of 0.3% in 2013 and 3.6% in 2014. *Salicornia bigelovii* Torr. (dwarf saltwort) was the only species found in the marsh creation area plots in 2013. This species was joined by *Suaeda linearis* (Elliot) Moq. (annual seepweed), *Avicennia germinans* (L.) L. (black mangrove), and *S. patens* in 2014 (Figure 25 and 26). No other species were encountered in the marsh creation area and *S. patens* only existed on the edge of the dune. *S. bigelovii*, *S.linearis*, and *A. germinans* are all known for inhabiting salt flats (Tiner 1993), which perfectly describes the community constructed in the marsh creation area at this time. The only segment of the marsh creation area to be influenced by tidal activity is the marsh adjacent to the gapped section of the containment dike. At this location, a naturally formed tidal creek has initiated vegetation colonization along the banks of the low lying borrow area for the

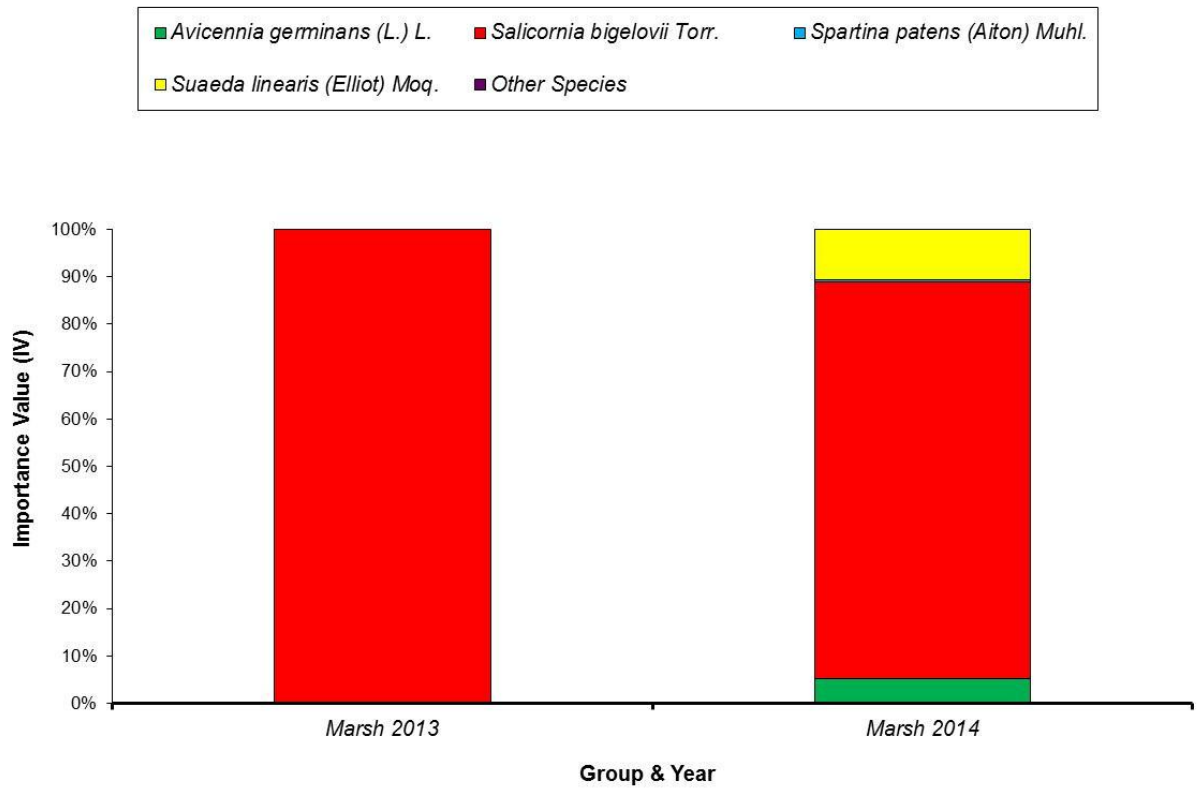


Figure 26. **Importance value (IV) of the top five vegetation species populating the West Belle Pass Barrier Headland Restoration (TE-52) marsh creation area in 2013 and 2014. Ocular vegetation data were grouped by creation area and year.**

containment dike (Figure 27). The other segments of the marsh creation area are shielded from tidal activity due to the continued presence of remaining containment dike. Though parts of the containment dike have narrowed, the dike has yet to breach naturally. Other back barrier marsh creation projects have not vegetated appreciably due to containment remaining in place (Curole and Lee 2013) or irregular tidal flooding (Texas GLO 1996). Moreover, increasing the area of tidal creeks has been shown to advance the establishment and maturation of saline back barrier marshes (Tyler and Zieman 1999). Two recent back barrier marsh creation projects did not initially respond to vegetative plantings due to lack of tidal connectivity, one on Grand Terre Island (Lear 2007) and one on Whiskey Island (Hester et al. 2012). However, once regular tidal flushing began vegetation rapidly colonized these marshes (Lear 2007; Unpublished Data). Therefore, it is highly likely that TE-52 marsh creation area will vegetate when the barriers to tidal activity are broken. In closing, the restore shoreline, dune, and back barrier marsh to increase habitat utilization by essential fish and wildlife species goal is currently not being supported by the vegetation data because the marsh has not vegetated and the cover of the dune plantings is lower than desired. However, there is a great possibility that the created habitats will promote extensive utilization by fish and wildlife species if tidal connectivity is expanded and dune vegetative cover is enhanced.

Figure 27. **Jan 2015 Google Earth image and Oct 2014 oblique image depicting tidal connectivity and vegetation colonization through the gapped containment dike at the West Belle Pass Barrier Headland Restoration (TE-52) project. Note the vegetation colonization along the edges of the low elevated containment dike borrow area.**

Avian Habitat

Winter shorebird usage of the West Belle Pass Barrier Headland Restoration (TE-52) project area has shown a pattern similar to the usage of the Caminada Headland (Figures 28 and 29). Fall distribution of birds indicates individuals spread out along the shoreline and then during the late winter (January – February) the birds tend to congregate into larger flocks in particular areas. Additionally, once spring arrives they spread out again along the shoreline. This pattern has been observed in each winter season and maybe related to any number of habitat and environmental variables, including tide levels, weather, and prey availability.

Specifically at West Belle Pass Project, shorebird usage was limited along the approximately 1 year old beach and dune during the first winter season (2013-14). However by fall 2014, the now 2 year old beach and dune feature shows bird usage along all portions of the project gulf shoreline. Also, the spit habitat formed through longshore sediment transport produce habitats

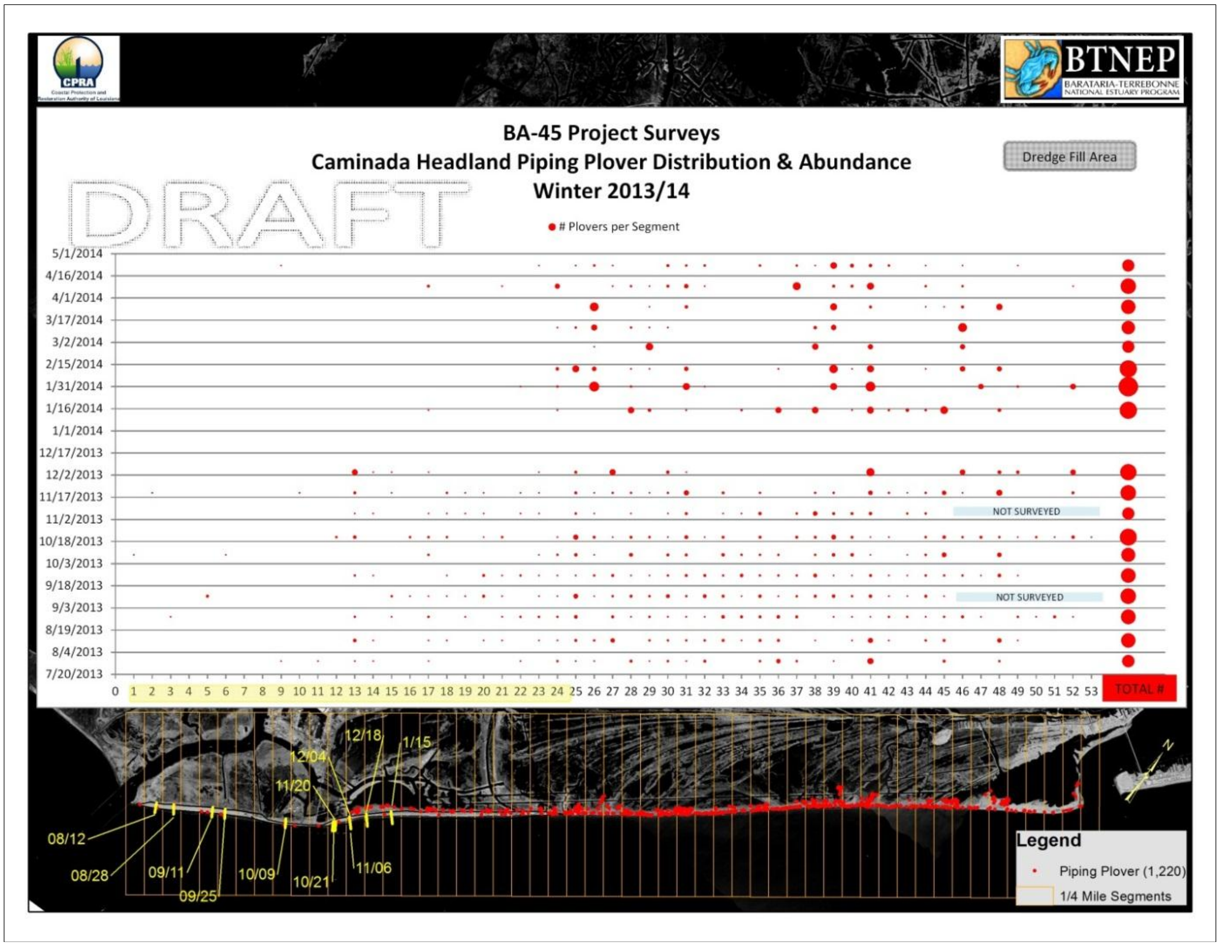


Figure 28. **Abundance and distribution of Piping Plovers along the Caminada Headland during the 2013/14 winter season. Dated yellow marks indicate the sediment fill location at the time of the survey.**

heavily utilized by wintering shorebirds. In fact, abundance of birds increased in beach zone 3 as spit formation created new areas that did not exist prior to construction (Figure 30). This expansion in intertidal and supralittoral habitats has increased the foraging area available to shorebirds (Dugan and Hubbard 2006; Schulte and Simons 2015).

Studies indicate benthic prey items can take up to 3 years to recover from sediment deposition and may be a reason for limited usage early on in the project. However, usage by year 2 possibly indicates recovery of prey items. Additionally, shoreface slope adjustment after initial deposition takes time and could also be a contributing factor in initial usage of the shoreline. Again, the Caminada Headland restoration data indicates a similar pattern along portions of the project between Belle Pass and Hwy 3090. Sediment was placed along this reach of shoreline from August to November 2013, and initial surveys indicate little Piping Plover usage (Figure 28). However, by fall 2014 usage of this portion of the project had increased.

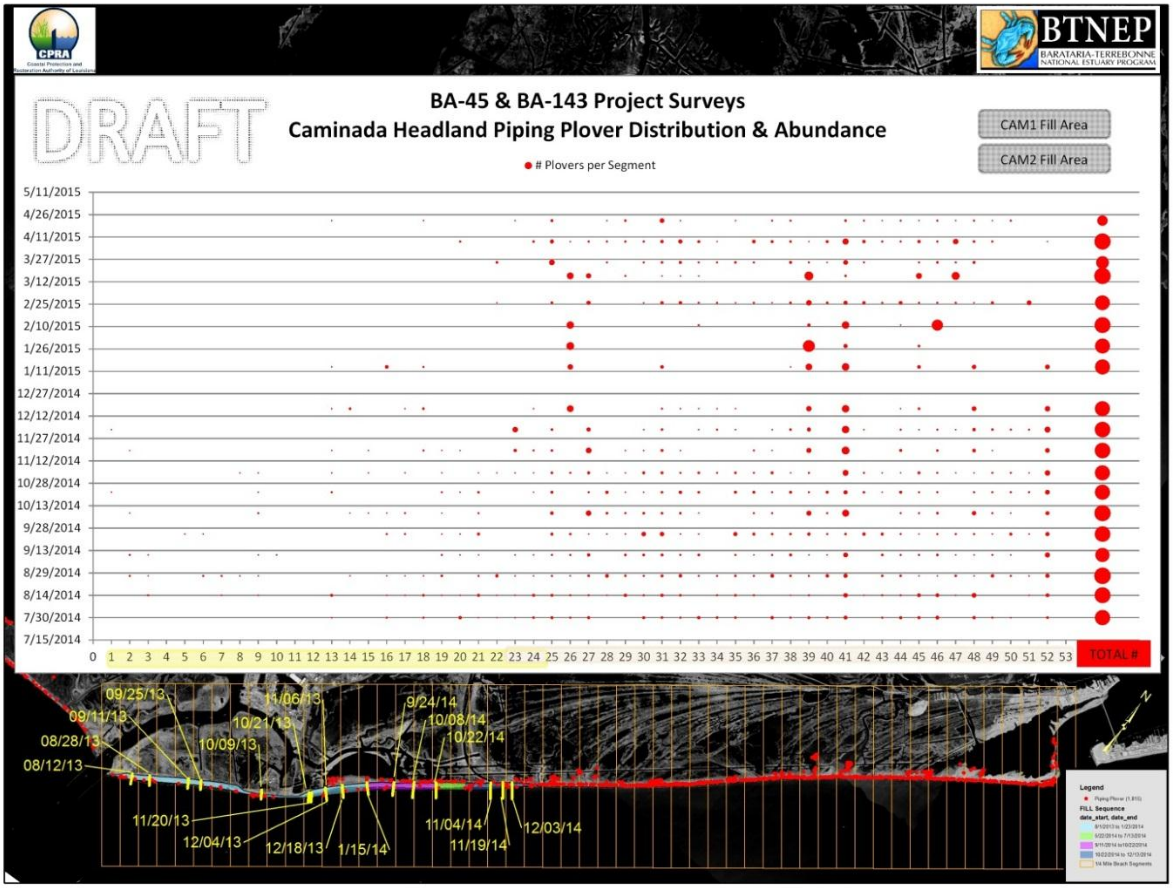


Figure 29. **Abundance and distribution of Piping Plovers along the Caminada Headland during the 2013/14 winter season. Dated yellow marks indicate the sediment fill location at the time of the survey.**

Benthic invertebrate sampling along the Caminada shoreline has been conducted to determine recovery of prey items. A benthic invertebrate survey in April 2013, before construction of the Caminda Headland project, was compared to an April 2014 survey in which 2 locations had received sediment 8 and 4 months prior to the 2014 sampling. Comparisons at this early stage indicate both a decrease in diversity and a decrease in density of intertidal benthic prey items (McLelland 2014). However, there is some indication of recovery, as site 1 (8 months post-fill) showed much higher density than site 2 which had been filled only four months prior (Figure 31).

Overall, the winter bird usage of the project has shown patterns similar to other areas surveyed and provides a limited indication that habitats valuable to wintering shorebirds are developing rapidly due to project construction. Also, increased longevity of the area will.

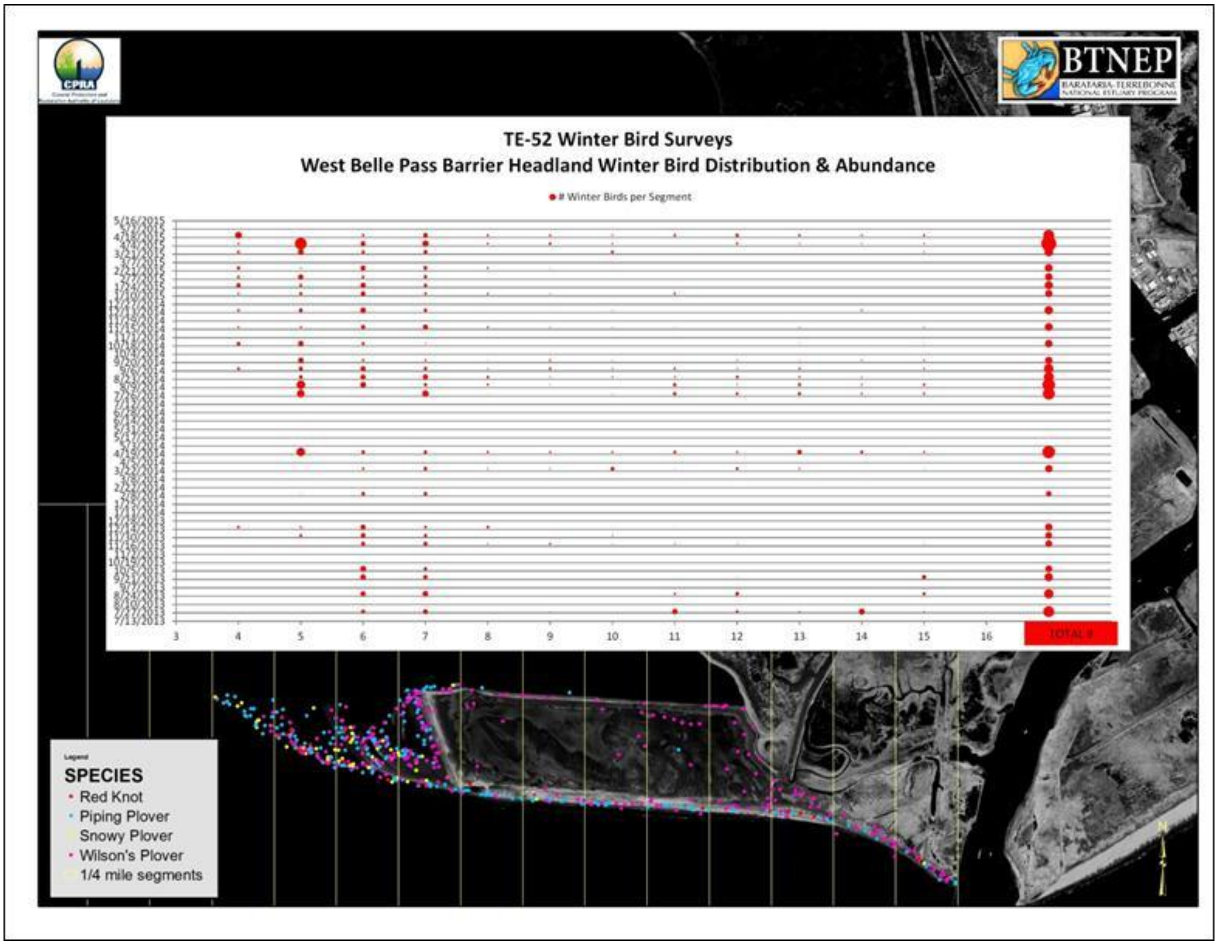


Figure 30. **Abundance and distribution of four wintering shorebirds in the West Belle Pass Headland Restoration (TE-52) project.**

potentially compensate for limited disturbances due to construction and prey item recovery. Therefore, the goal to restore shoreline, dune, and back-barrier marsh to increase habitat utilization by essential fish and wildlife species is being supported by the shorebird data at this time because the beach and spit habitats created by this project is being utilized by shorebirds and their foraging habitats are expanding.

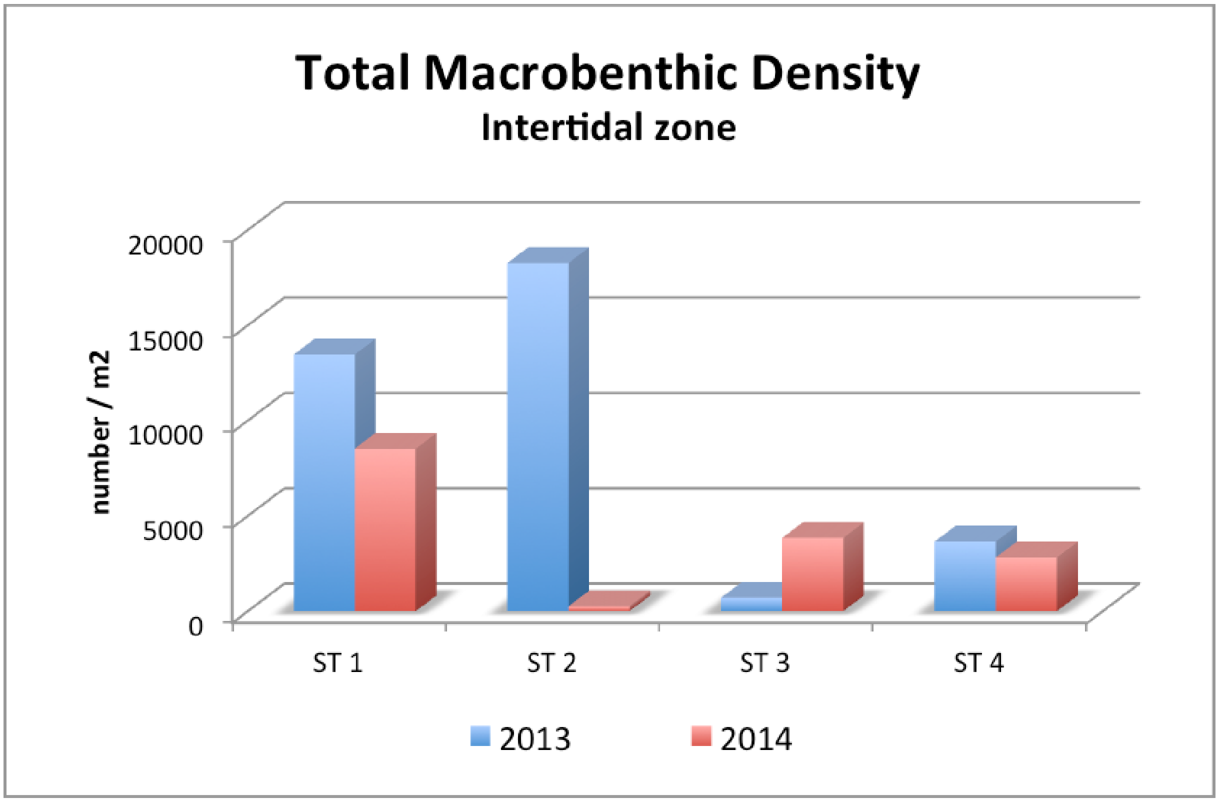


Figure 31. **Pre- and During- construction intertidal benthic density at 4 locations along the Caminada Headland (McLelland 2014). Sites 1 and 2 had been filled 8 and 4 months prior to the 2014 sampling, respectively. Sites 3 and 4 had not been filled prior to either sampling event.**

V. Conclusions

a. Project Effectiveness

The results of the West Belle Pass Barrier Headland Restoration (TE-52) project reveal that two of the project goals were achieved, one was partially realized, and the fourth goal does not seem to be attainable as of this time. The first goal to reestablish and increase headland longevity via dune and marsh creation is presently being attained because the headland has been substantially enhanced by creating an over 3,048 m (10,000 ft) dune and a 121 ha (300 acre) back barrier marsh. The headland length is currently expanding due to longshore transport of beach and dune sediments to the downdrift spit, which is aggrading and elongating. However, a sizeable volume of sediment was removed from the beach and dune area during the initial post-construction interval due to severe dune scarping, overwash, and leveling. Surprisingly, the extensive erosion of the dune feature occurred during a period of minimal tropical storm activity, and the pre-construction models vastly underestimated this volume loss (Thomson et al. 2009). The dune segments constructed parallel to the Gulf of Mexico shoreline were scarped and the extreme eastern reaches were leveled while the northwestern facing dune segments (constructed parallel to the spit) did not incur scarping or large volume losses. Moreover, a large, continuous section of sand fencing was destroyed due to this scarping and leveling of the eastern and central project dunes. The shoreline transgressions were probably induced by the passage of Hurricane Isaac (Figures 4 and 10), winter storms, and the influence of the Belle Pass Rock Jetties. While extensive shoreline transgressions occurred along the Gulf of Mexico shoreface, the marsh creation area did not erode; it only incurred settlement. Moreover, the longevity of the headland seems to have been prolonged by creating a wide back barrier marsh platform.

Secondly, the goal to prevent breaching along 9,300 feet of the headland over the 20-year project life is also currently being attained. No breaching occurred along the greater than 3,048 m (10,000 ft) of shoreline constructed for this project. Actually, the headland elongated during the study period through creation of the subaerial spit. However, the beach and dune creation area was substantially reshaped by the shoreline transgressions that occurred in the initial post-construction interval. The large volume loss in the beach and dune area is a result of severe dune scarping and overwash, and leveling. Moreover, the dune was scarped over the entire length of its Gulf of Mexico shoreline, and the lower relief eastern segments of the dune were leveled to berm elevations. However, the erosion in the TE-52 project area was compartmentalized to beach and dune area because no erosion occurred in the marsh creation area. Furthermore, the creation of a wide marsh creation area for the TE-52 project reduces the possibility of breaching and inlet formation.

The restore shoreline, dune, and back-barrier marsh to increase habitat utilization by essential fish and wildlife species goal is being partially realized at this time. The beach and spit habitats created by the TE-52 project are being utilized by shorebirds and their foraging habitats are expanding. Moreover, the intertidal and supralittoral habitats created through aggradation and elongation of the spit has increased the foraging area available to shorebirds.

As a result, the shorebird data supports this goal. While the beach and spit habitats enhance shorebird utilization, the constructed marsh is not enhancing marine fisheries habitat because there is very little tidal connectivity and vegetative cover on this platform due to the containment dike remaining in place. The area currently consists of dry, non marsh habitat. However, saline marsh creation areas in Louisiana have been shown to rapidly vegetate when tidal connectivity is induced. Therefore, there is a great possibility that the created habitats will promote extensive utilization by marine fisheries if tidal connectivity is expanded.

The promote the re-establishment of historic longshore transport patterns along the Gulf shoreline goal is really not an attainable goal because historically the longshore transport nourished East Timbalier and Timbalier Islands. These barrier islands are currently southwest of the headland and are no longer downdrift of the headland's littoral current. However, the net longshore transport continues to flow to the west as described in the historical record.

b. Recommended Improvements

Several improvements would enhance the sustainability and increase habitat utilization of the West Belle Pass Barrier Headland Restoration (TE-52) project. First of all, the primary containment dike should be gapped in two to three locations if natural breaching of this earthen structure does not occur within the next two years. Gapping or natural breaching of this dike will improve tidal exchange between Timbalier Bay and the marsh platform. It would be ideal if this gapping or natural breaching transpired soon after spring 2016 marsh creation plantings. Currently the marsh platform consists of salt flat habitat. Two recent back barrier marsh creation projects have vegetated after tidal connectivity was established. Moreover, vegetation has colonized the creation area marshes adjacent to the gapped section of the containment dike because of tidal creek formation. Therefore, it is highly likely that the TE-52 marsh creation area will vegetate when tidal connectivity is enhanced.

Secondly, in the future (later in the TE-52 project life) additional sand resources should be added to the West Belle Pass Headland system as per the States Master Plan (CPRA 2012) through a beach nourishment event to increase the width and elevation of the beach and enrich natural process development (Penland and Suter 1988; Feagin et al. 2010). Adding sand resources to the western headland littoral system via a beach nourishment event would prolong the longevity of the headland and reduce the possibility of breaching and inlet formation. Additionally, a terminal groin structure placed on the western edge of the spit should be considered to improve sediment retention on the western headland. Indeed, the preservation of limited sand resources is critical along the western headland because the Belle Pass Rock Jetties inhibit the transport of sediments from a potential major source.

c. Lessons Learned

Five lessons were learned from the first two years of the West Belle Pass Barrier Headland Restoration (TE-52) project. The first lesson is that a considerable volume of sediment was removed from the beach and dune area during the initial post-construction interval due to severe dune scarping, overwash, and leveling. Approximately, 58% of the beach and dune volume was either relocated within or removed from the western headland's sediment budget two years after construction and with little tropical storm activity. Moreover, the project's design models did not foresee such substantial volume losses during the early post-construction period (Thomson et al. 2009). All the segments of the dune that were installed parallel to the Gulf of Mexico shoreline were scarped and the extreme eastern reaches were leveled. In addition, nearly half of the installed sand fencing was forcibly removed from the center of the dune as a result of the extreme scarping and leveling which occurred after construction. These shoreline transgressions were probably induced by the passage of Hurricane Isaac (Figures 4 and 10), winter storms, and the influence of the Belle Pass Rock Jetties. The erosion incurred during Hurricane Isaac seems to have been underestimated. Figure 10 indicates that the beach and dune were narrowed during Hurricane Isaac and this storm which made landfall approximately 1.6 km (1.0 mi) east of the TE-52 project on the Caminada-Moreau Headland produced an extensive storm surge (Figure 4). The Belle Pass Rock Jetties also wields a substantial influence on transport of sediments to and within the western headland. This is best illustrated by examining the results of the three USACE's sediment additions (1998, 2007, and 2012), which added sediment to the beach in the lee of the west jetty only to have the sediments reworked by coastal processes. Hence, these events demonstrate that very little sediment is transported towards the western jetty (eastern littoral transport).

The second lesson learned from the TE-52 project is that a western terminal groin should have been installed. This feature was considered as an alternative during the engineering and design of the TE-52 project. However, the project was approaching the upper limits of CWPPRA funding and the groin structure was removed from the project design. While a sizeable volume of sediments were transported to the spit, the western headland's sediment budget could have been substantially enhanced with the addition of a terminal groin. These terminal structures are necessary to hold limited sand resources in place when a headland or barrier island is truncated (Dean 1997) like the West Belle Pass Headland. Furthermore, the Belle Pass Rock Jetties serves as an impediment to the littoral transport of sand to the western headland forcing sediment retention to be essential to the sustainability of this sand deficient coastline.

The third lesson learned from the TE-52 project is that the primary containment dike is hindering tidal exchange between Timbalier Bay and the marsh platform. Currently the marsh platform consists of salt flat habitat which does not support marine fisheries utilization. Back barrier creation projects on Grand Terre and Whiskey Islands demonstrate that the influence of tides can hasten saline marsh vegetation colonization and establishment. Moreover, the formation of a small tidal creek inside the TE-52 marsh creation area has enhanced vegetation colonization in its immediate vicinity. Therefore, it is plausible to infer that the marsh platform will vegetate when tidal connectivity is established. Additionally, the question of when to gap containment dikes is a frequent problem inherent to back barrier marsh creation projects. When are the sediments sufficiently consolidated to allow gapping with minimal loss of dredged materials? Performance standards need to be derived to answer this question.

For the TE-52 project it is clear that sediments have consolidated (Figures 18, D3, and D4) and tidal connectivity needs to occur to create vegetated marsh habitat.

The fourth lesson learned from the TE-52 project is that the formation of the spit has enhanced shorebird utilization on the western headland. The beach and spit habitats created by the TE-52 project are being utilized by shorebirds and their foraging habitats are expanding (Figure 30). Moreover, the intertidal and supralittoral habitats created through aggradation and elongation of the spit has increased the foraging area available to shorebirds. As a result, the shorebird data provides evidence showing that spit formation can increase the acreage available to shorebirds. However, spit habitats are extremely vulnerable to storm induced cross-shore transport (Figure 20) (Curole and Lee 2013).

The last lesson is that the entire shoreface of the West Belle Pass Headland should have been topographically and bathymetrically surveyed during all sampling events. These surveys should have originated at the western jetty and extended to Raccoon Pass (Figure 1) to ascertain the influence of the sediment budget on the project. In addition, several of the periodic surveys were missing transects – 2008 design (T26), 2011 pre (T1 and T22-T26), and 2012 as-built (T22-T26). Moreover, the length of the survey transects and spacing between points was not always consistent. This led to narrowing the grid model extent to that of the most limited survey. Also, the extended dune feature and the BUMP projects influence were not able to be determined because these features were outside the extent of the surveys. Moreover, the placement of sediment affects the sediment budget for the whole headland including the spit, passes, and areas adjacent to hard structures like jetties. Therefore, the elevation surveys should have verified changes on all of the geomorphic features of the headland to determine the effect of these volumetric differences on the residual sediment budget.

VI. References

Barbour, M. G., J. H. Burk, W. D. Pitts, F. S. Gilliam, and M. W. Schwartz. 1999. Terrestrial Plant Ecology. 3rd Edition. Benjamin/Cummings Publishing Company, Inc. 649 pp.

Barras, John A. 2006. Land area change in coastal Louisiana after the 2005 hurricanes a series of three maps: U.S. Geological Survey Open-File Report 06-1274.

Bird, E. 2000. Coastal Geomorphology: An Introduction. John Wiley & Sons, Chichester, West Sussex, England. 322 pp.

Boyd, R. and S. Penland. 1981. Washover of Deltaic Barriers on the Louisiana Coast. Transactions of the Gulf Coast Association of Geological Societies. 31: 243-248.

Brinson, M. M. and R. Rheinhardt. 1996. The Role of Reference Wetlands in the Functional Assessment and Mitigation. Ecological Applications 6: 69-76.

Brown, D. P. 2011. Tropical Cyclone Report Tropical Storm Lee (AL132011) 2-5 September 2011. National Hurricane Center, National Weather Service, Miami, Florida. 35 pp.

Coastal Protection and Restoration Authority of Louisiana (CPRA). 2012. Louisiana's Comprehensive Master Plan for a Sustainable Coast. Coastal Protection and Restoration Authority of Louisiana. Baton Rouge, LA 189 pp.

Coleman, J. M. and W. G. Smith. 1964. Late Recent Rise of Sea Level. Geological Society of America Bulletin. 75: 833-840.

Conaster, W. E. 1971. Grand Isle: A Barrier Island in the Gulf of Mexico. Geological Society of America Bulletin. 82: 3049-3069.

Curole, G. P. and D. L. Huval. 2005. West Belle Pass Headland Restoration (TE-23) Comprehensive Report. Louisiana Department of Natural Resources, Coastal Restoration Division, Baton Rouge, LA. 54 pp.

Curole, G. P. and D. M. Lee. 2013. 2013 Operations, Maintenance, and Monitoring Report for Raccoon Island Shoreline Protection/Marsh Creation (TE-48), Coastal Protection and Restoration Authority of Louisiana, Thibodaux, Louisiana. 54 pp.

Curole, J. P., D. M. Lee, and J. L. West. 2012. 2012 Operations, Maintenance, and Monitoring Report for East Timbalier Sediment Restoration (TE-25 & TE-30), Coastal Protection and Restoration Authority of Louisiana, Thibodaux, Louisiana. 55 pp.

Dantin, E. J., C. A. Whitehurst, and W. T. Durbin. 1978. Littoral Drift and Erosion at Belle Pass, Louisiana. Journal of the Waterway, Port, Coastal, and Ocean Division. 104: 375-390.

Dean, R. G. 1997. Models for Barrier Island Restoration. Journal of Coastal Research 13: 694-703.

Devisse, J. and G. Thomson. 2013. West Belle Pass Barrier Headland Restoration (TE-52) Project Completion Report. Coastal Planning & Engineering, Inc. (CP&E), Boca Raton, Florida. 21 pp.

Dingler, J. R. and T. E. Reiss. 1990. Cold-Front Driven Storm Erosion and Overwash in the Central Part of the Isles Dernieres, a Louisiana Barrier-Island Arc. Marine Geology. 91: 195-206.

Dugan, J. E., and D. M. Hubbard. 2006. Ecological Responses to Coastal Armoring on Exposed Sandy Beaches. Shore and Beach. 82 (4): 5-12.

Frazier, D. E. 1967. Recent Deltaic Deposits of the Mississippi River: Their Development and Chronology. Transactions of the Gulf Coast Association of Geological Societies. 17: 287-315.

Feagin, R. A., W. K. Smith, N. P. Putsy, D. R. Young, M. L. Martinez, G. A. Carter, K. L. Lucas, J. C. Gibeaut, J. N. Gemma, and R. E. Koske. 2010. Journal of Coastal Research 26: 987-992.

Folse, T. M., L. A. Sharp, J. L. West, M. K. Hymel, J. P. Troutman, T. E. McGinnis, D. Weifenbach, L. B. Rodrigue, W. M. Boshart, D. C. Richardi, W. B. Wood, and C. M. Miller. 2008, revised 2014. A Standard Operating Procedures Manual for the Coastwide Reference Monitoring System-Wetlands: Methods for Site Establishment, Data Collection, and Quality Assurance/Quality Control. Louisiana Coastal Protection and Restoration Authority. Baton Rouge, LA. 228 pp.

Georgiou, I. Y., D. M. Fitzgerald, and G. W. Stone. 2005. The Impact of Physical Processes along the Louisiana Coast. Journal of Coastal Research. SI 44: 72-89.

Gilbert, M, N. Pammenter, and B. Ripley. 2008. The Growth Responses of Coastal Dune Species are Determined by Nutrient Limitation and Sand Burial. Oecologia 156: 169–178.

Harper, J. R. 1977. Sediment Dispersal Trends of the Caminada-Moreau Beach-Ridge System. Transactions of the Gulf Coast Association of Geological Societies. 27: 283-289.

Hester, M. W., J. M. Willis, C. N. Pickens, and M. J. Dupuis. 2012. CWPPRA - Enhancement of a Barrier Island and Salt Marsh Vegetation Demonstration (TE-53) Project Final Report, Coastal Protection and Restoration Authority of Louisiana, Baton Rouge, Louisiana. 54 pp.

Kachi, N. and T. Hirose. 1983. Limiting Nutrients for Plant Growth in Coastal Sand Dune Soils. Journal of Ecology. 71 (3): 937–944.

Komar, P. D. 1998. Beach Processes and Sedimentation. 2nd ed. Prentice-Hall, Upper Saddle River, New Jersey. 544 pp.

Kraus, N. C., M. R. Byrnes, and A. L. Lindquist. 1999. Coastal Processes Assessments for Brevard County, Florida, with Special Reference to Test Plaintiffs ERDC/CHL-99-6. Vicksburg, MS: US Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory. 64 pp.

Larson, M., J. D. Rosati, and N. C. Kraus. 2002 (rev. 2003). Overview of Regional Coastal Processes and Controls. Coastal and Hydraulic Engineering Technical Note ERDC/CHL CHETN-XIV-4. Vicksburg, MS: US Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory. 22 pp.

Lear, E. 2007. 2004 Operations, Maintenance, and Monitoring Report for Vegetative Plantings of a Dredged Material Disposal Site on Grand Terre Island (BA-28), Louisiana Department of Natural Resources, Coastal Restoration Division, Thibodaux, Louisiana. 29pp.

Levin, D. R. 1993. Tidal Inlet Evolution in the Mississippi River Delta Plain. Journal of Coastal Research. 9: 462-480.

List, J. H., B. E. Jaffe, A. H. Sallenger, Jr., and M. E. Hansen. 1997. Bathymetric Comparisons Adjacent to the Louisiana Barrier Islands: Processes of Large-Scale Change. Journal of Coastal Research. 13: 670-678.

McBride, R. A. and M. R. Byrnes. 1997. Regional Variations in Shore Response Along Barrier Island Systems of the Mississippi River Delta Plain: Historical Change and Future Prediction. Journal of Coastal Research. 13: 628-655.

McLelland, J. 2014. Caminada Headland Beach Benthic Organism Survey: Year 2. Prepared for Barataria-Terrebonne National Estuary Program by Gulf Benthic Taxonomy Assessment, Hattiesburg, MS. 31 pg.

Mitsch, W. J. and R. F. Wilson. 1996. Improving the Success of Wetland Creation and Restoration with Know-How, Time, and Self-Design. Ecological Applications 6: 77-83.

Morgan, J. P. and P. B. Larimore. 1957. Change in the Louisiana Shoreline. Transactions of the Gulf Coast Association of Geological Societies. 7: 303-310.

Mueller-Dombois, D. and H. Ellenberg 1974. Aims and Methods of Vegetation Ecology. New York: John Wiley & Sons, Inc. 547 pp.

Moy, L. D. and L. A. Levin. 1991. Are Spartina Marshes a Replaceable Resource? A Functional Approach to Evaluation of Marsh Creation Efforts. Estuaries 14: 1-16.

Otvos, E. G. Jr. 1969. A Subrecent Beach Ridge Complex in Southeastern Louisiana. Geological Society of America Bulletin. 80: 2353-2357.

Penland, S., P. Conner, A. Beall, S. Fearnley, and S. J. Williams. 2005. Changes in the Louisiana Shoreline: 1855-2002. Journal of Coastal Research. SI 44: 7-39.

Penland, S. and K. E. Ramsey. 1990. Relative Sea-Level Rise in Louisiana and the Gulf of Mexico: 1908-1988. Journal of Coastal Research. 6: 323-342.

Penland, S. and W. Ritchie. 1979. Short Term Morphological Changes Along the Caminada-Moreau Coast, Louisiana. Transactions of the Gulf Coast Association of Geological Societies. 29: 342-346.

Penland, S. and J.R. Suter. 1988. Barrier Island Erosion and Protection in Louisiana: A Coastal Geomorphic Perspective. Transactions of the Gulf Coast Association of Geologic Societies. 38: 331-342.

Peyronnin, C. A., Jr. 1962. Erosion of the Isles Dernieres and Timbalier Islands. Journal of the Waterways and Harbors Division, American Society of Civil Engineers. 88: 57-69.

Pilkey, O. H. and M. E. Fraser. 2003. A Celebration of the World's Barrier Islands. Columbia University Press, New York. 309 pp.

Reed, D., ed. 1995. Status and Trends of Hydrologic Modification, Reduction in Sediment Availability, and Habitat Loss/Modification in the Barataria-Terrebonne Estuarine System. Barataria-Terrebonne National Estuary Program, Thibodaux, LA, 20: 388 pp.

Ritchie, W. 1972. A Preliminary Study of the Distribution and Morphology of the Caminada/Moreau Sand Ridge. Southeast Geology. 14: 113-126.

Ritchie, W. and S. Penland. 1988a. Cyclical Changes in the Coastal Dunes of Southern Louisiana. Journal of Coastal Research. Special Issue 3: 111-114.

Ritchie, W. and S. Penland. 1988b. Rapid Dune Changes Associated with Overwash Processes on the Deltaic Coast of South Louisiana. Marine Geology. 81: 97-122.

Roberts, H. H, A. Bailey, and G. J. Kuecher. 1994. Subsidence in the Mississippi River Delta-Important Influences of Valley Filling by Cyclic Deposition, Primary Consolidation Phenomena, and Early Diagenesis. Transactions of the Gulf Coast Association of Geological Societies. 44: 619-629.

Rodrigue, L B., G. P. Curole, and D. M. Lee. 2011. 2011 Operations, Maintenance, and Monitoring Report for Timbalier Island Dune/Marsh Restoration Project (TE-40), Coastal Protection and Restoration Authority of Louisiana, Office of Coastal Protection and Restoration, Thibodaux, Louisiana. 27 pp.

Sasser, C. E., J. M. Visser, E. Mouton, J. Linscombe, and S. B. Hartley. 2014. Vegetation Types in Coastal Louisiana in 2013. U.S. Geological Survey Scientific Investigations Map 3290, 1 sheet, scale 1:550,000.

Sawyer and Keeler-Wolf. 1995. Manual of California Vegetation. California Native Plant Society, Sacramento, CA. 471 pp.

Scavia, D., J. C. Field, D. F. Boesch, R. W. Buddemeier, V. Burkett, D. R Cayan, M. Fogarty, M. A. Harwell, R. W. Howarth, C. Mason, D. J. Reed, T. C. Royer, A. H. Sallenger, and J. G. Titus. 2002. Climate Change Impacts on the U.S. Coastal and Marine Ecosystems. Estuaries. 25:149-164.

Schulte, S. A. and T. R. Simons. 2015. Factors Affecting the Repoductive Success of American Oyster Cstchers Haematopus Palliatus on the Outer Banks of North Carolina. Marine Ornithology. 43: 37–47.

Shumway, S.W. 2000. Facilitative Effects of a Sand Dune Shrub on Species Growing Beneath the Shrub Canopy. Oecologia 124: 138–148.

Sigren, J. M., J. Figlus, and A. R. Armitage. 2014. Coastal Sand Dunes and Dune Vegetation: Restoration, Erosion, and Storm Protection. Shore and Beach. 82 (4): 5-12.

Simenstad, C. A. and R. M. Thom. 1996. The Functional Equivalency Trajectories of the Restored Gog-Le-Hi-Te Estuarine Wetland. Ecological Applications 6: 38-56.

Stauble, D. K. and A. Morang. 1992. Using Morphology to Determine Net Littoral Drift Directions in Complex Coastal Systems CETN II-30. Vicksburg, MS: US Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory. 8 pp.

Stone, G. W., J. M. Grymes III, J. R. Dingler, and D. A. Pepper. 1997. Overview and Significance of Hurricanes on the Louisiana Coast, U.S.A. Journal of Coastal Research. 13: 656-669.

Stone, G. W. and X. Zhang. 2001. A Longshore Sediment Transport Model for the Timbalier Islands and Isle Dernieres, Louisiana. Coastal Studies Institute, Louisiana State University, Baton Rouge, LA. 28 pp.

Swanson, R. L. and C. I. Thurlow. 1973. Recent Subsidence Rates Along the Texas and Louisiana Coasts as Determined from Tide Measurements. Journal of Geophysical Research. 78: 2665-2671.

Texas General Land Office (GLO). 1996. Evaluation of Marsh Creation and Restoration Projects and Their Potential for Large-scale Application, Galveston-Trinity Bay System. Texas General Land Office, Austin, Texas. 91 pp.

Thomson, G., A Wycklendt, and M. Rees. 2009. West Belle Pass Barrier Headland Restoration Project (TE-52) - 95% Design Report. Boca Raton, Florida: Coastal Planning & Engineering, Inc. 176p. (Report prepared for the Louisiana Office of Coastal Protection and Restoration).

Thieler, E. R., and D. Martin, and A. Ergul 2003. The Digital Shoreline Analysis System, Version 2.0: Shoreline Change Measurement Software Extension for ArcView: USGS U.S. Geological Survey Open-File Report 03-076.

Tiner, R. W. 1993. Field Guide to Coastal Wetland Plants of the Southeastern United States. University of Massachusetts Press, Amherst, Massachusetts. 328 pp.

Tyler, A. C. and J. C. Zieman. 1999. Patterns of Development in the Creekbank Region of a Barrier Island Spartina alterniflora Marsh. Marine Ecology Progress Series. 180: 161-177.

United States Army Corps of Engineers (USACE). 2004. Louisiana Coastal Area (LCA) Ecosystem Restoration Study Final Report. Volume 4: Appendix A. Science and Technology Program.

United States Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS). 1984. Soil Survey of Lafourche Parish, Louisiana. 288 pp.

West, J.L and D. Dearmond 2007. 2004 Operations, Maintenance, and Monitoring Report for Isles Dernieres Restoration East Island (TE-20). Louisiana Department of Natural Resources, Coastal Restoration Division, Thibodaux, Louisiana. 21pp.

West, J.L., D.A. Dearmond, B.J. Babin, and K.S. Gray. 2007. 2005 Operations, Maintenance, and Monitoring Report for East Timbalier Island Sediment Restoration, Phases 1 and 2 (TE-25 & 30), Louisiana Department of Natural Resources, Coastal Restoration Division and Coastal Engineering Division, Thibodaux, Louisiana. 48 pp.

Woodhouse, W.W. Jr. 1978. Dune Building and Stabilization with Vegetation. U.S. Army Corp of Engineers. Vol.3: 9-104.

Zedler, J. B. 1993. Canopy Architecture of Natural and Planted Cordgrass Marshes: Selecting Habitat Evaluation Criteria. Ecological Applications. 3: 123-138.

Appendix A
(Inspection Photographs)

Photo A-1. View of sheet pile plug in northern containment dike, looking east.

Photo A-2. View of northern containment dike, looking west.

Photo A-3. View of successful vegetative planting, looking south.

Photo A-4. View of dune near offset segment of dune, looking east. Note the ponding in the area of low relief between the beach and dune.

Photo A-5. View of damaged sand fencing, looking east.

Photo A-6. View beach and dune with vegetative planting and sand fencing, looking east.

Photo A-7. View of beach erosion, looking east.

Photo A-8. View of northern containment dike and emergent vegetation, looking west.

Appendix B
(Three Year Budget Projection)

WEST BELLE PASS BARRIER HEADLAND RESTORATION (TE-52)
Three-Year Operations & Maintenance Budgets 07/01/2015- 06/30/18

Project Manager	O & M Manager	Federal Sponsor	Prepared By
	Byland	*NMFS*	*Babin*

	2015/2016	2016/2017	2017/2018
Maintenance Inspection	$ -	$ -	$ -
Structure Operation	$ -	$ -	
CPRA Administration	$ 105,358.00	$ 43,611.00	$ 21,447.00
NMFS Administration	$ -	$ -	$ -
Maintenance/Rehabilitation			

15/16 Description: Vegetative Plantings and Engineering/Monitoring Survey
NMFS Administration included under E&D Costs

	2015/2016
E&D	$ -
Construction	$ 148,875.00
Construction Oversight	$ -
Sub Total - Maint. And Rehab.	$ 148,875.00

16/17 Description: Tidal Creek/Containment Dike Gapping, Sheet Pile Removal, and
NMFS and CPRA Administration included under E&D Costs

	2016/2017
E&D	$ 91,773.00
Construction	$ 323,750.00
	$ -
Sub Total - Maint. And Rehab.	$ 415,523

17/18 Description:

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

	2015/2016	2016/2017	2017/2018
Total O&M Budgets	**$ 254,233.00**	**$ 459,134.00**	**$ 21,447.00**

O&M Budget (3 Yr Total)	**$ 734,814.00**
Unexpended O&M Funds	**$ 2,055,790.00**
Remaining O&M Funds	**$ 1,320,976.00**

OPERATIONS & MAINTENANCE BUDGET WORKSHEET

Project: **West Belle Pass Barrier Headland Restoration (TE-52)**

FY 15/16 –

CPRA Administration			$ **105,358**
NMFS Administration:			$ 0
Operation:			$ 0
Maintenance:			$ **148,875**
E&D, Const. Oversight:	$		
Construction:	$ 148,875		

Construction Costs

Construction Cost Breakdown

Mobilization (Lump Sum):		$ 20,000
Vegetative Plantings:		$ 99,100
Smooth Cordgrass; (28,500@ $3.00 each)	$85,500	
Seashore Paspalum: (3,400 @ $4.00 each)	$13,600	
Contingency (25%):		$ 29,775
TOTAL		**$ 148,875**

CPRA Direct Costs

Plantings Project - CPRA Design, Construction Administration and Inspeciton

E&D:	
Engineer Intern (150 hrs @ $45/ hr.):	$ 6,750
Engineer 6 (40 hrs. @ $73/ hr.):	$ 2,920
Surveying:	$Completed
Construction Administration: (100 hrs. @ $45/hr.)	$ 4,500
Inspection: (170 hrs @ $45/hr.)	$ 7,650
Contingency: (25%):	$ 5,455
Total:	**$ 27,275**

Inspection:

CPRA Engineer 3 – 12 hrs@ $60/hr.:	$ 720
CPRA Engineer 6 – 12 hrs @ $73/hr.	$ 876
CPRA Scientist 4 – 10 hrs @ $50/hr.	$ 500
	$ 2,096

Report:

CPRA Engineer 6 – 60 hrs. @ $73/hr.	**$ 4,380**
Total Direct CPRA Costs:	**$ 33,751**

CPRA Inirect Costs

CPRA Design, Construction Administration and Inspeciton

E&D:	
Engineer Intern (150 hrs @ $95.47/ hr.):	$ 14,321
Engineer 6 (40 hrs. @ $154.88/ hr.):	$ 6,195
Surveying:	$Completed
Construction Administration: (100 hrs. @ $95.47/hr.)	$ 9,547
Inspection: (170 hrs @ $95.47/hr.)	$ 16,230
Contingency: (25%):	$ 11,573
Total:	**$ 57,866**

Inspection:	
CPRA Engineer 3 – 12 hrs@ $127.30/hr.:	$ 1,528
CPRA Engineer 6 – 12 hrs @ $154.88/hr.	$ 1,859
CPRA Scientist 4 – 10 hrs @ $106.08/hr.	$ 1,061
	$ 4,448
Report:	
CPRA Engineer 6 – 60 hrs. @ $154.88/hr.	**$ 9,293**
Total Indirect CPRA Costs:	**$ 71,607**

FY 16/17 –

CPRA Administration		**$ 43,611**
NMFS Administration:		$ 0
Operation:		$ 0
Maintenance:		**$ 415,523**
E&D and Const. Oversight:	$ 91,773	
Construction:	$ 323,750	

Construction Costs

Construction Cost Breakdown

Mobilization (Lump Sum):	$ 75,000
Dike Gapping:	$ 48,000
Access Dredging:	$ 106,000
Sheet Pile Removal:	$ 30,000
Contingency (25%):	$ 64,750
Total:	**$ 323,750**

Engineering, Design, and Construction Oversight

Engineering/Design:	$ 25,900
Surveying: (7 days @ $3,000/day)	$ 21,000

Inspections: (100 hrs @ $150/hrs.)	$ 15,000
Construction Administration: (50 hrs @ $171/hr)	$ 8,550
Contingency (25%):	$ 21,323
Total E&D, Construction Oversight:	**$ 91,773**

CPRA Direct Costs
Dike Gapping and Sheetpile Removal Project

Construction Administration: (100 hrs. @ $73/hr.)	$ **7,300**
Inspection:	
CPRA Engineer 3 – 12 hrs@ $60/hr.:	$ 720
CPRA Engineer 6 – 12 hrs @ $73/hr.	$ 876
CPRA Scientist 4 – 10 hrs @ $50/hr.	$ 500
	$ 2,096 x 3% = **$2,159**
Report:	
CPRA Engineer 6 – 60 hrs. @ $73/hr.	$ 4,380 x 3% = **$4,511**
Total Direct CPRA Costs:	**$ 13,970**

CPRA Indirect Costs
Dike Gapping and Sheetpile Removal Project

Construction Administration: (100 hrs. @ $154.88/hr.)	**$ 15,488**
Inspection:	
CPRA Engineer 3 – 12 hrs@ $127.30/hr.:	$ 1,528
CPRA Engineer 6 – 12 hrs @ $154.88/hr.	$ 1,859
CPRA Scientist 4 – 10 hrs @ $106.08/hr.	$ 1,061
	$ 4,448 x 3% = **$4,581**
Report:	
CPRA Engineer 6 – 60 hrs. @ $154.88/hr.	$ 9,293 x 3% = **$9,572**
Total Indirect CPRA Costs:	**$ 29,641**

FY 17/18 –

Administration		**$ 21,447**
NMFS Administration:		$ 0
O&M Inspection & Report		$ 0
Operation:		$ 0
Maintenance:		$ 0
E&D:	$ 0	
Construction:	$ 0	
Construction Oversight:	$ 0	

CPRA Direct Costs
Inspection:
$ 2,159 x 3% = $2,224
Report:
$ 4,511 x 3% = $4,646

Total Direct CPRA Costs: $ 6,870

CPRA Indirect Costs

Inspection:
$ 4,581 x 3% = $4,718
Report:
$ 9,572 x 3% = $9,859

Total Indirect CPRA Costs: $ 14,577

O&M Accounting:

Total O&M Budget:	$ 2,106,853.00
CPRA Expenditures to Date (LaGov):	$ 51,063.00
Unexpended O&M Budget:	$ 2,055,790.00

Appendix C
(TE-52 Survey Profiles)

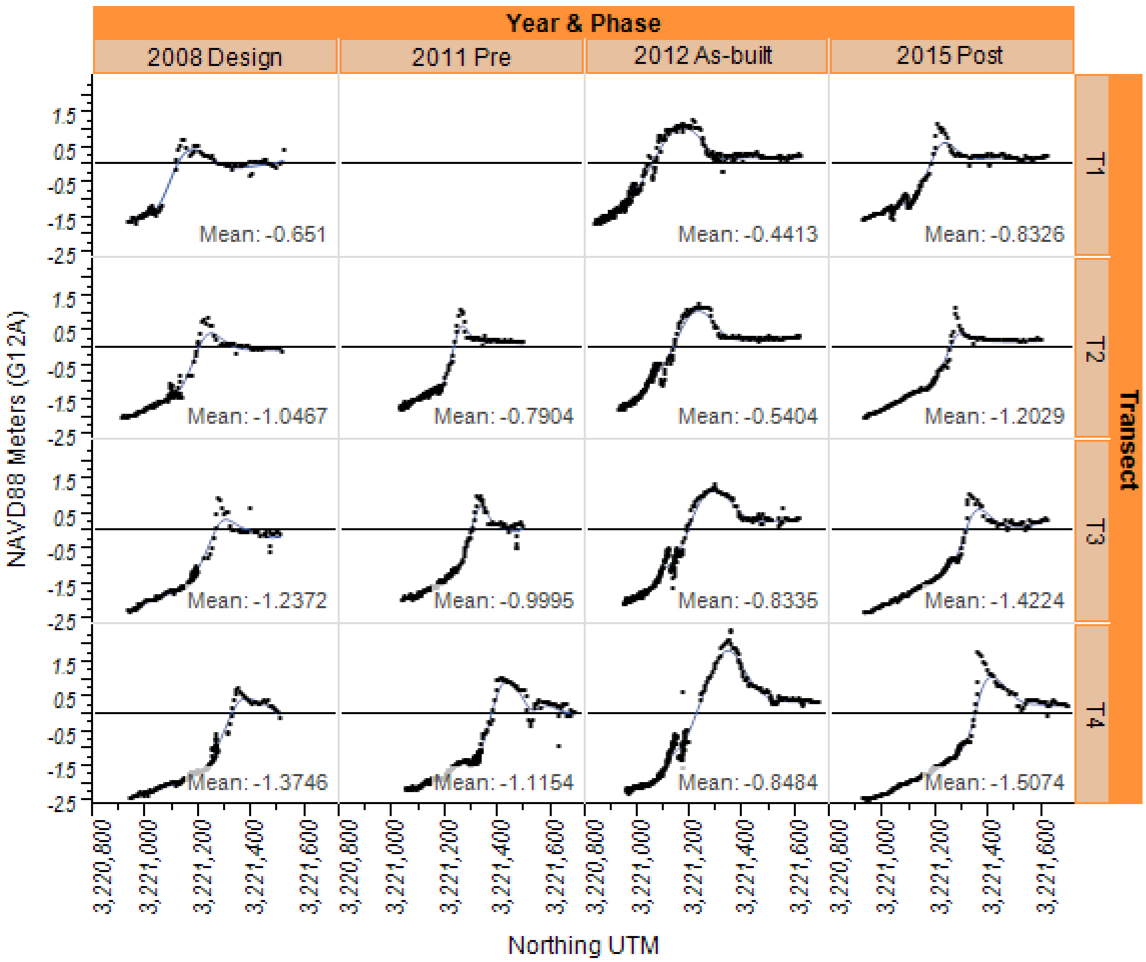


Figure C-1. **T1 to T4 survey profiles over time at the West Belle Pass Barrier Headland Restoration (TE-52) project. The graphs depict the elevation of the shoreface, beach, dune, and marsh habitats from 2008 to 2015.**

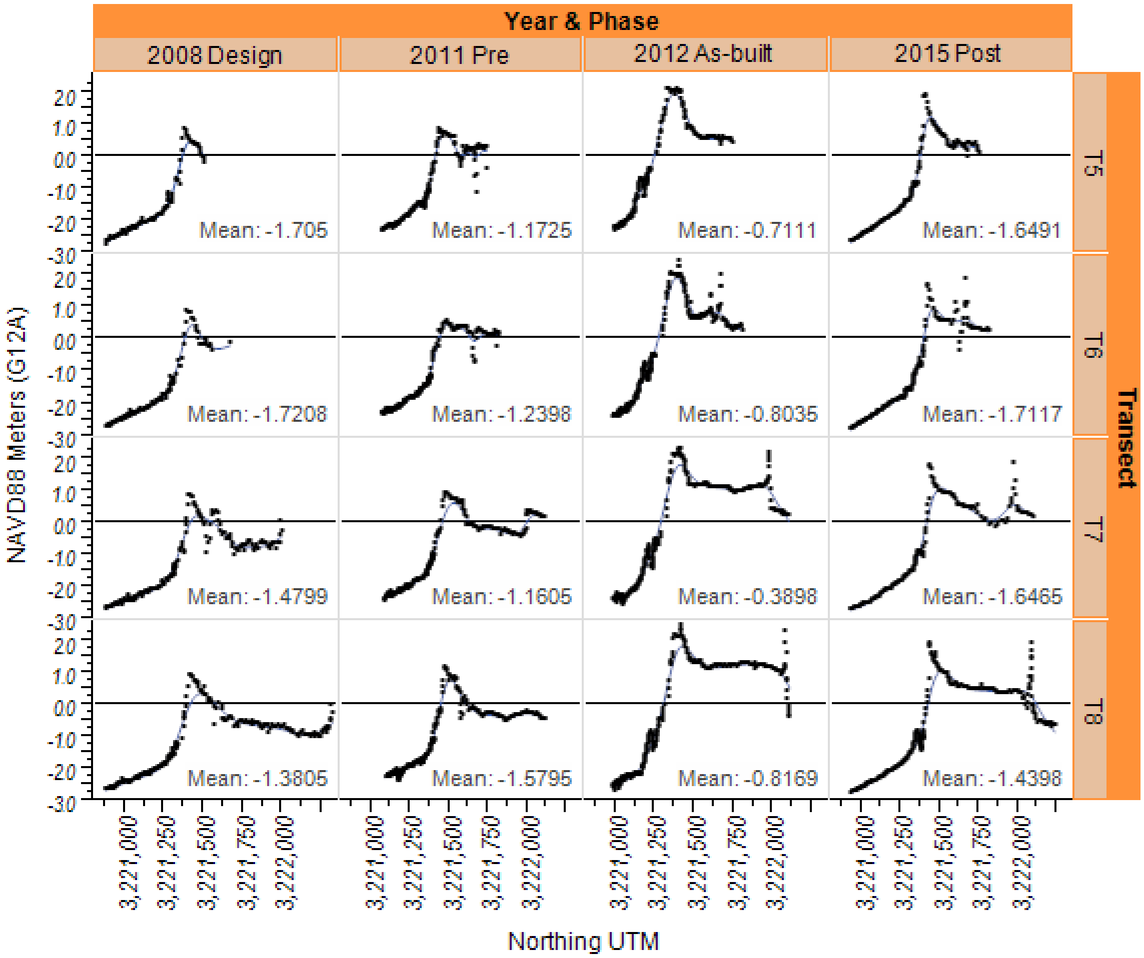


Figure C-2. **T5 to T8 survey profiles over time at the West Belle Pass Barrier Headland Restoration (TE-52) project. The graphs depict the elevation of the shoreface, beach, dune, and marsh habitats from 2008 to 2015.**

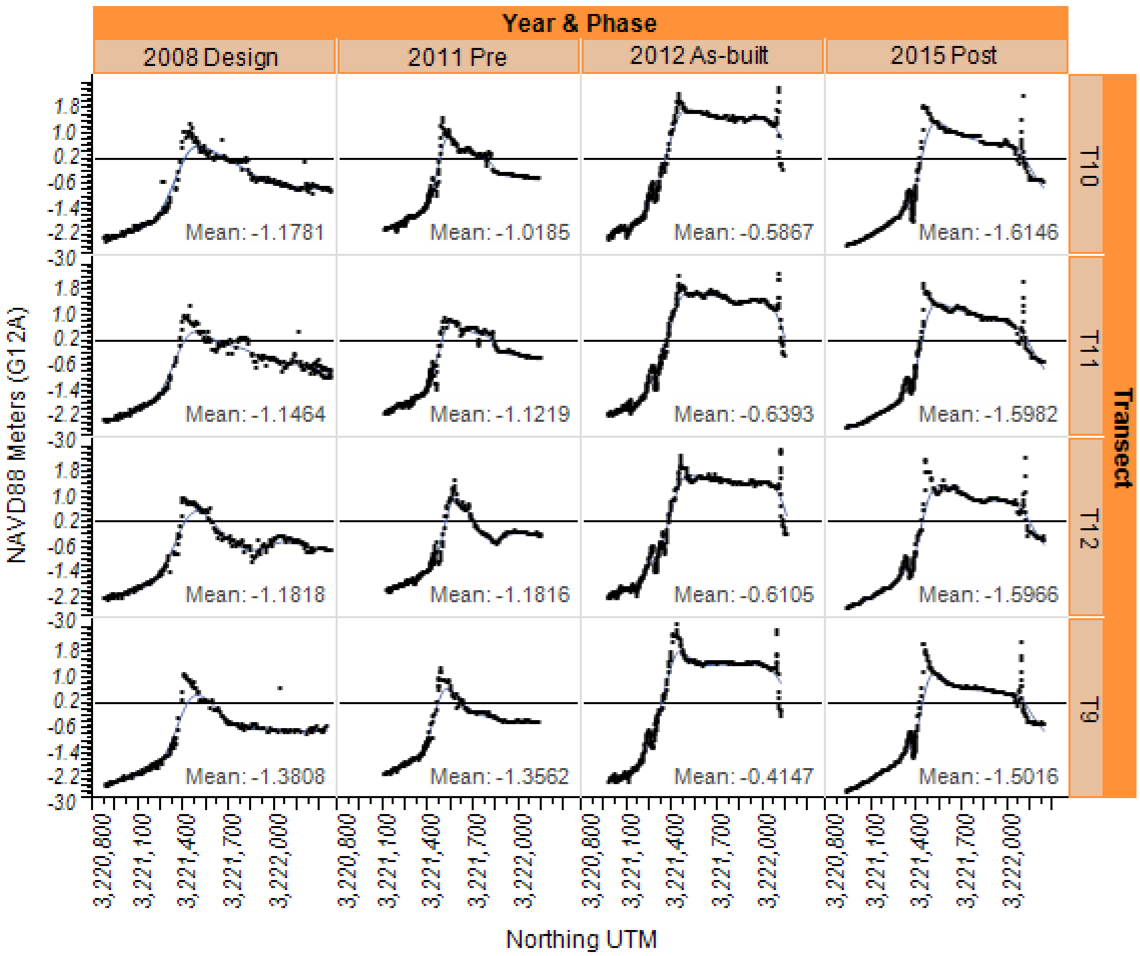


Figure C-3. **T9 to T12 survey profiles over time at the West Belle Pass Barrier Headland Restoration (TE-52) project. The graphs depict the elevation of the shoreface, beach, dune, and marsh habitats from 2008 to 2015.**

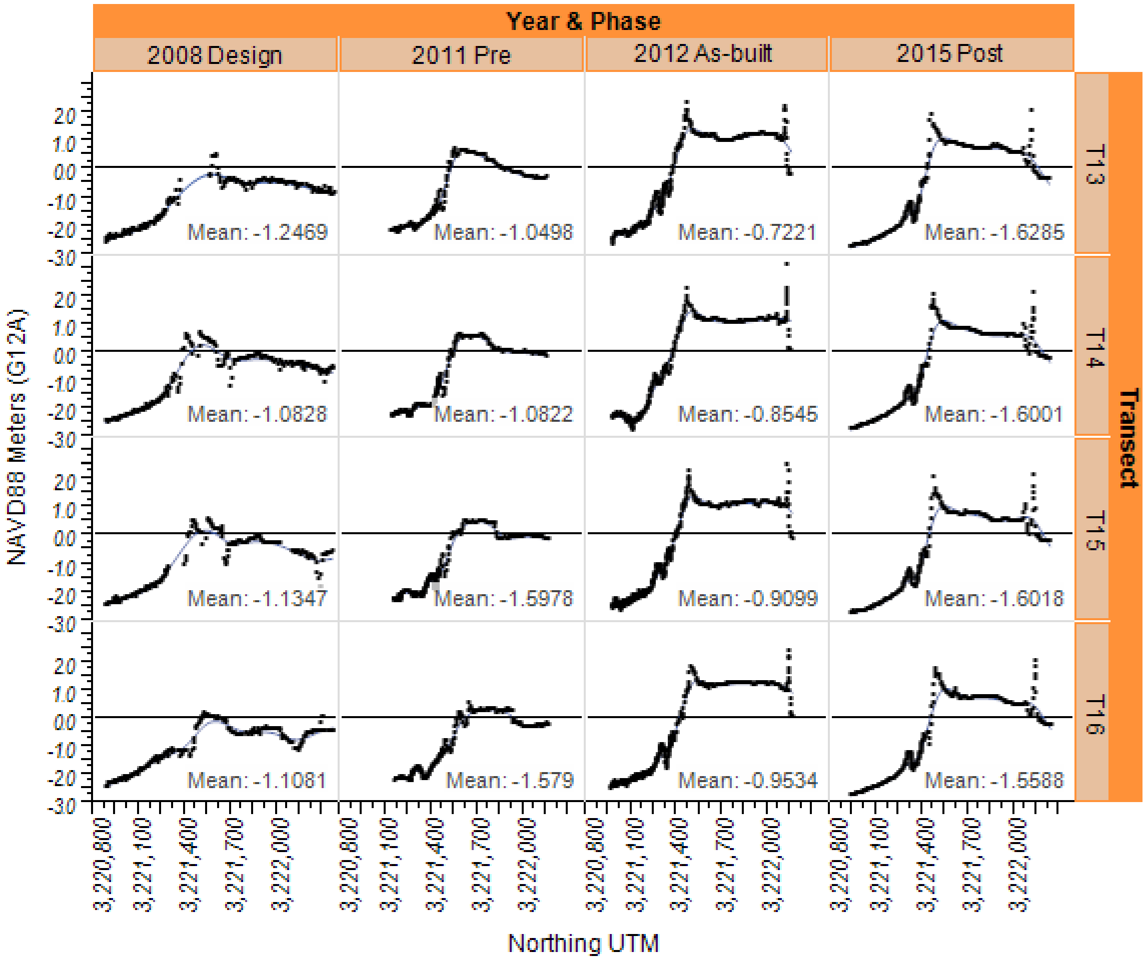


Figure C-4. **T13 to T16 survey profiles over time at the West Belle Pass Barrier Headland Restoration (TE-52) project. The graphs depict the elevation of the shoreface, beach, dune, and marsh habitats from 2008 to 2015.**

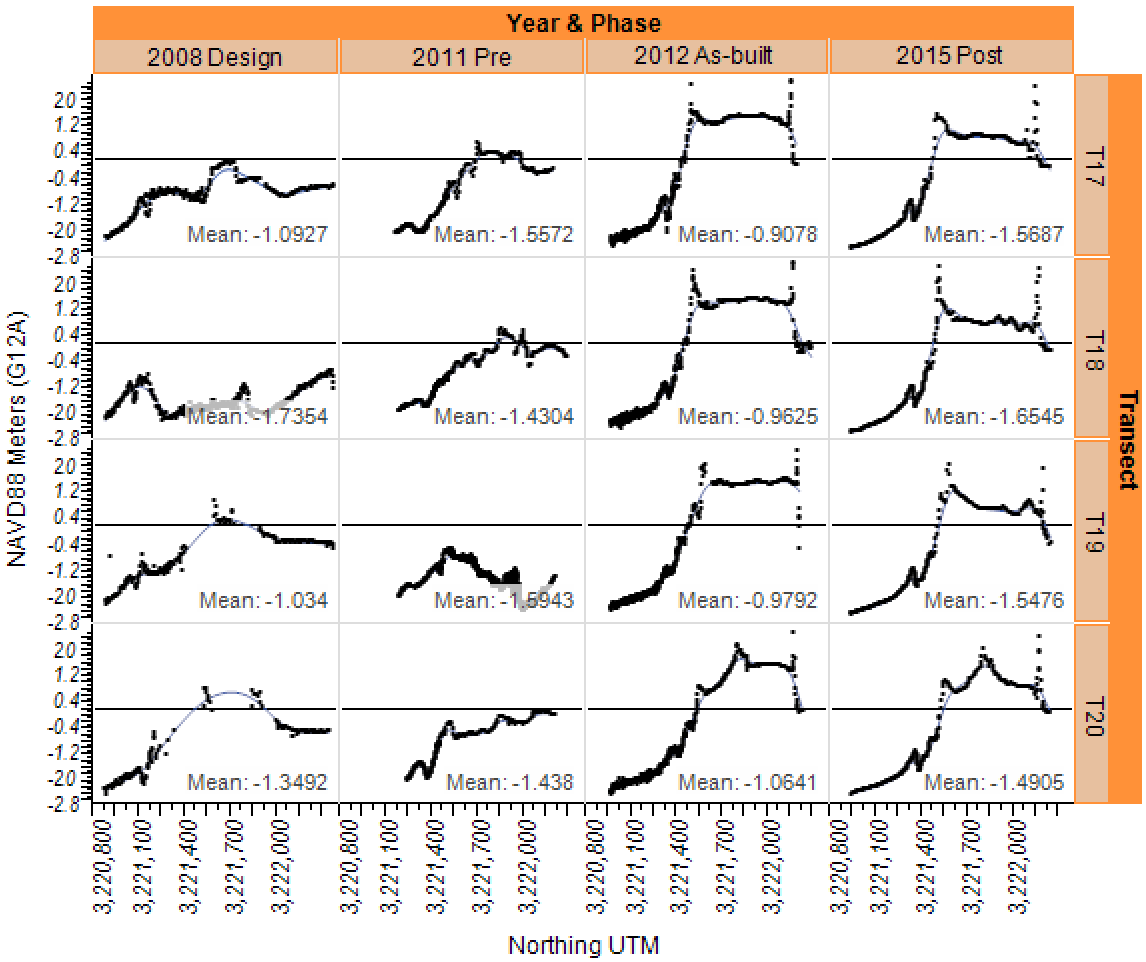


Figure C-5. **T17 to T20 survey profiles over time at the West Belle Pass Barrier Headland Restoration (TE-52) project. The graphs depict the elevation of the shoreface, beach, dune, and marsh habitats from 2008 to 2015.**

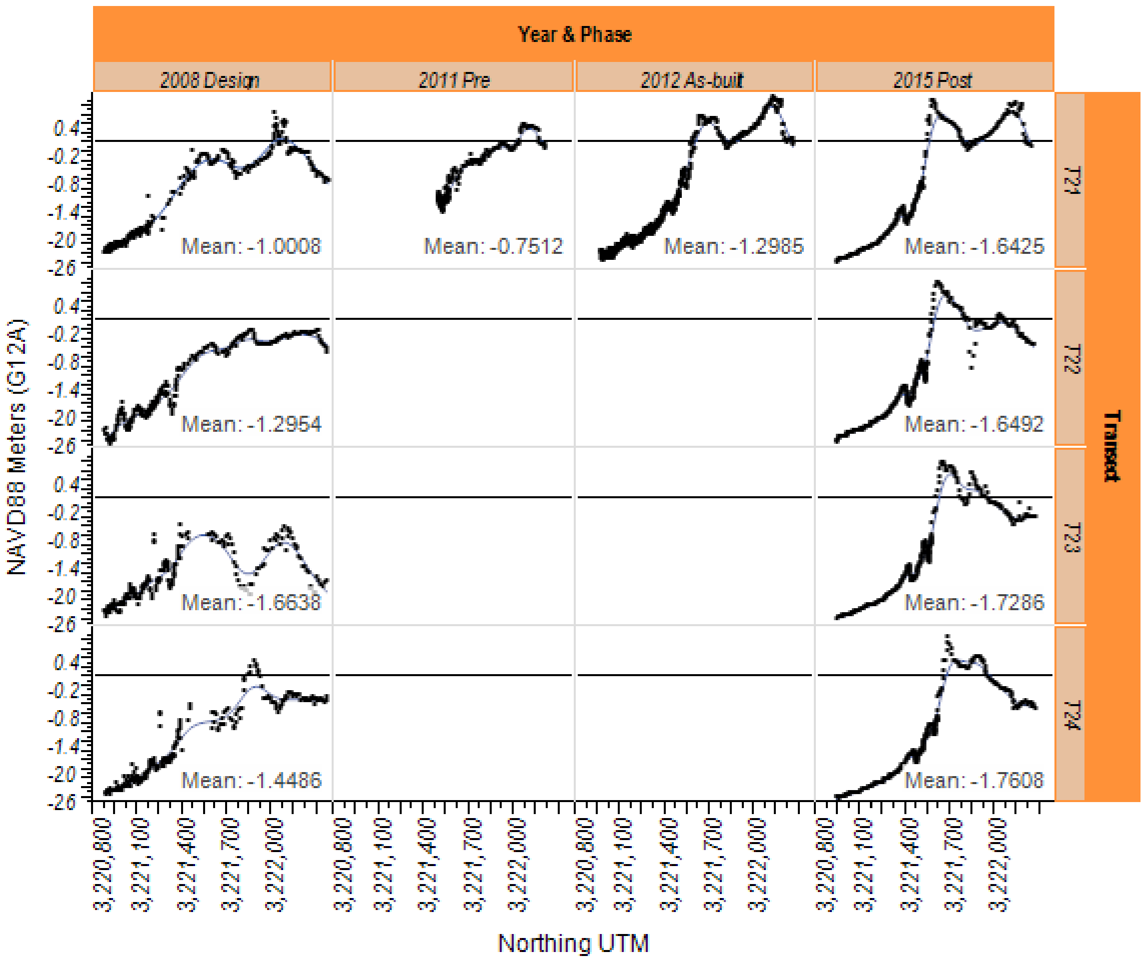


Figure C-6. **T21 to T24 survey profiles over time at the West Belle Pass Barrier Headland Restoration (TE-52) project. The graphs depict the elevation of the shoreface, beach, dune, and marsh habitats from 2008 to 2015.**

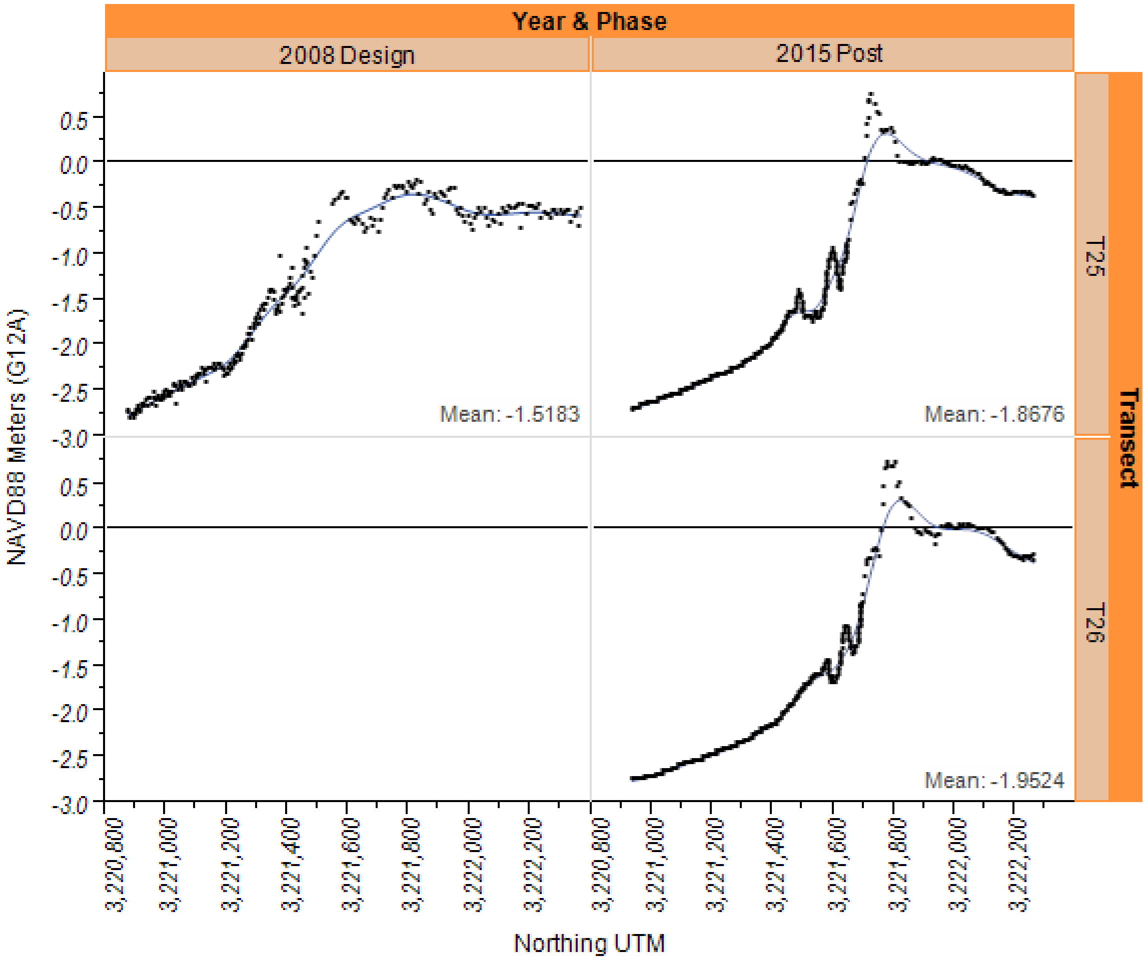


Figure C-7. **T25 to T26 survey profiles over time at the West Belle Pass Barrier Headland Restoration (TE-52) project. The graphs depict the elevation of the shoreface, beach, dune, and marsh habitats from 2008 to 2015.**

Appendix D
(TE-52 Elevation Grid Models)

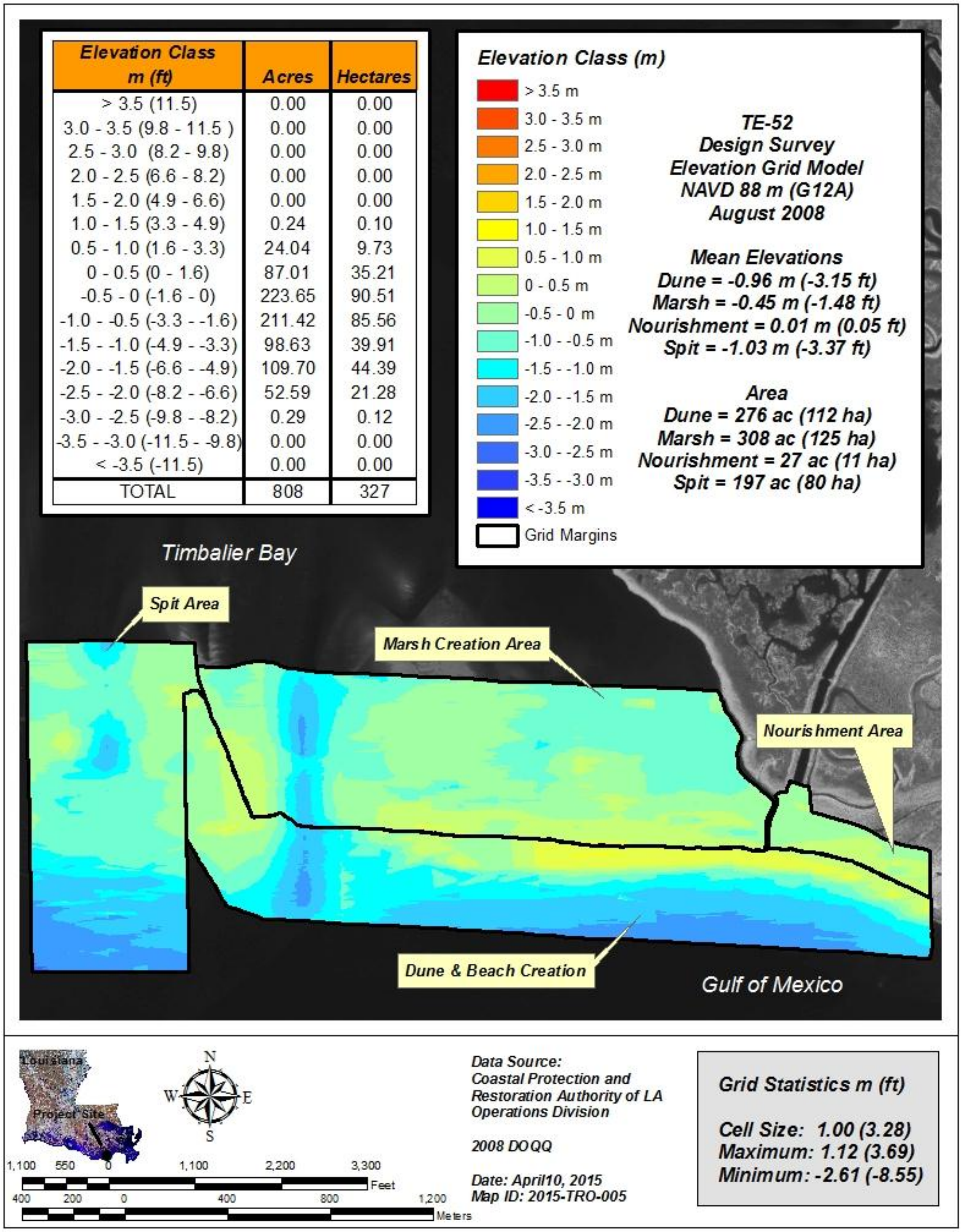
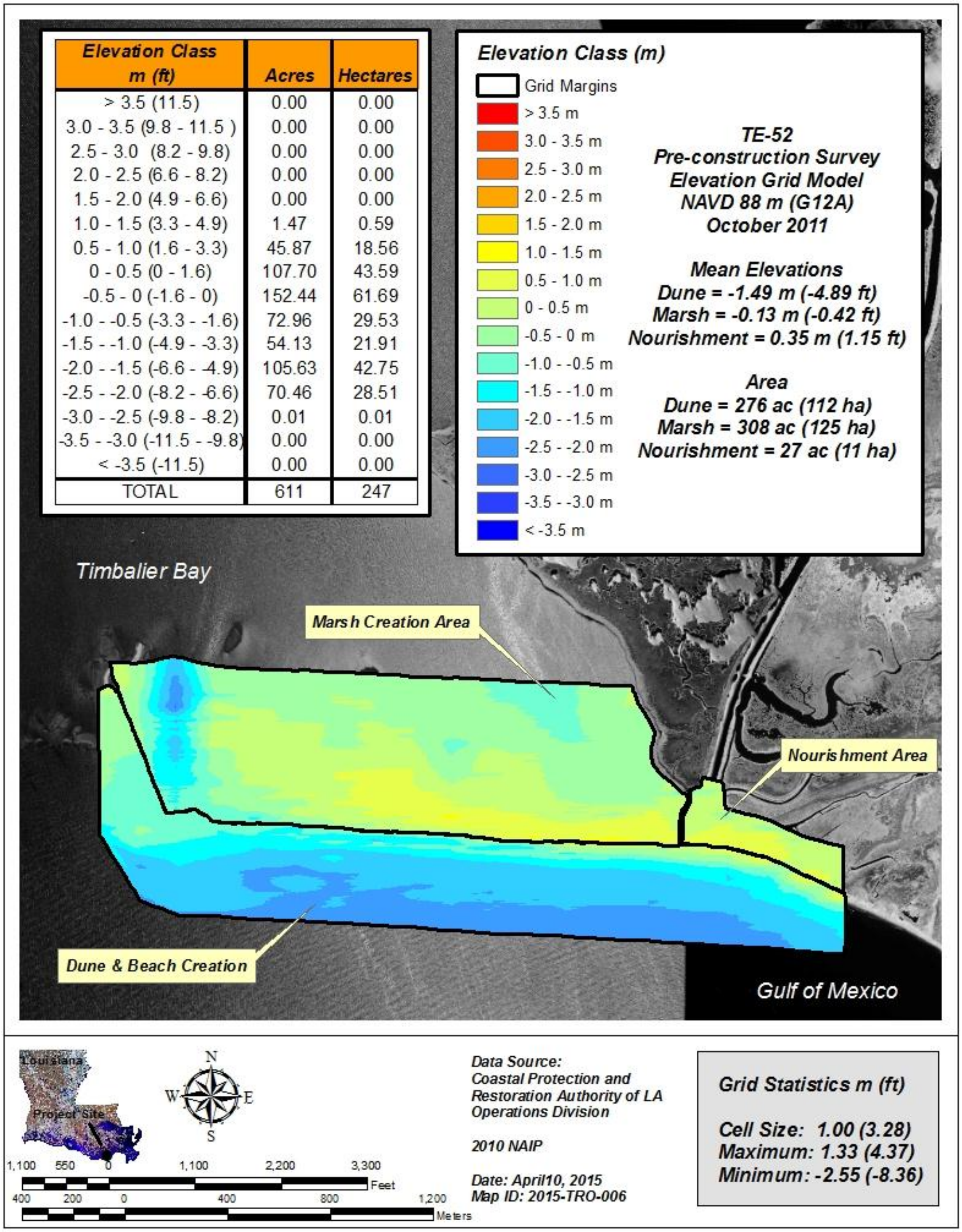


Figure D-1. **Design (Aug 2008) elevation grid model of the beach and dune, marsh creation, nourishment, and spit areas at the West Belle Pass Barrier Headland Restoration (TE-52) project.**



Elevation Class m (ft)	Acres	Hectares
> 3.5 (11.5)	0.00	0.00
3.0 - 3.5 (9.8 - 11.5)	0.00	0.00
2.5 - 3.0 (8.2 - 9.8)	0.00	0.00
2.0 - 2.5 (6.6 - 8.2)	0.00	0.00
1.5 - 2.0 (4.9 - 6.6)	0.00	0.00
1.0 - 1.5 (3.3 - 4.9)	1.47	0.59
0.5 - 1.0 (1.6 - 3.3)	45.87	18.56
0 - 0.5 (0 - 1.6)	107.70	43.59
-0.5 - 0 (-1.6 - 0)	152.44	61.69
-1.0 - -0.5 (-3.3 - -1.6)	72.96	29.53
-1.5 - -1.0 (-4.9 - -3.3)	54.13	21.91
-2.0 - -1.5 (-6.6 - -4.9)	105.63	42.75
-2.5 - -2.0 (-8.2 - -6.6)	70.46	28.51
-3.0 - -2.5 (-9.8 - -8.2)	0.01	0.01
-3.5 - -3.0 (-11.5 - -9.8)	0.00	0.00
< -3.5 (-11.5)	0.00	0.00
TOTAL	611	247

Figure D-2. Pre-construction (Oct 2011) elevation grid model of the beach and dune, marsh creation, and nourishment areas at the West Belle Pass Barrier Headland Restoration (TE-52) project.

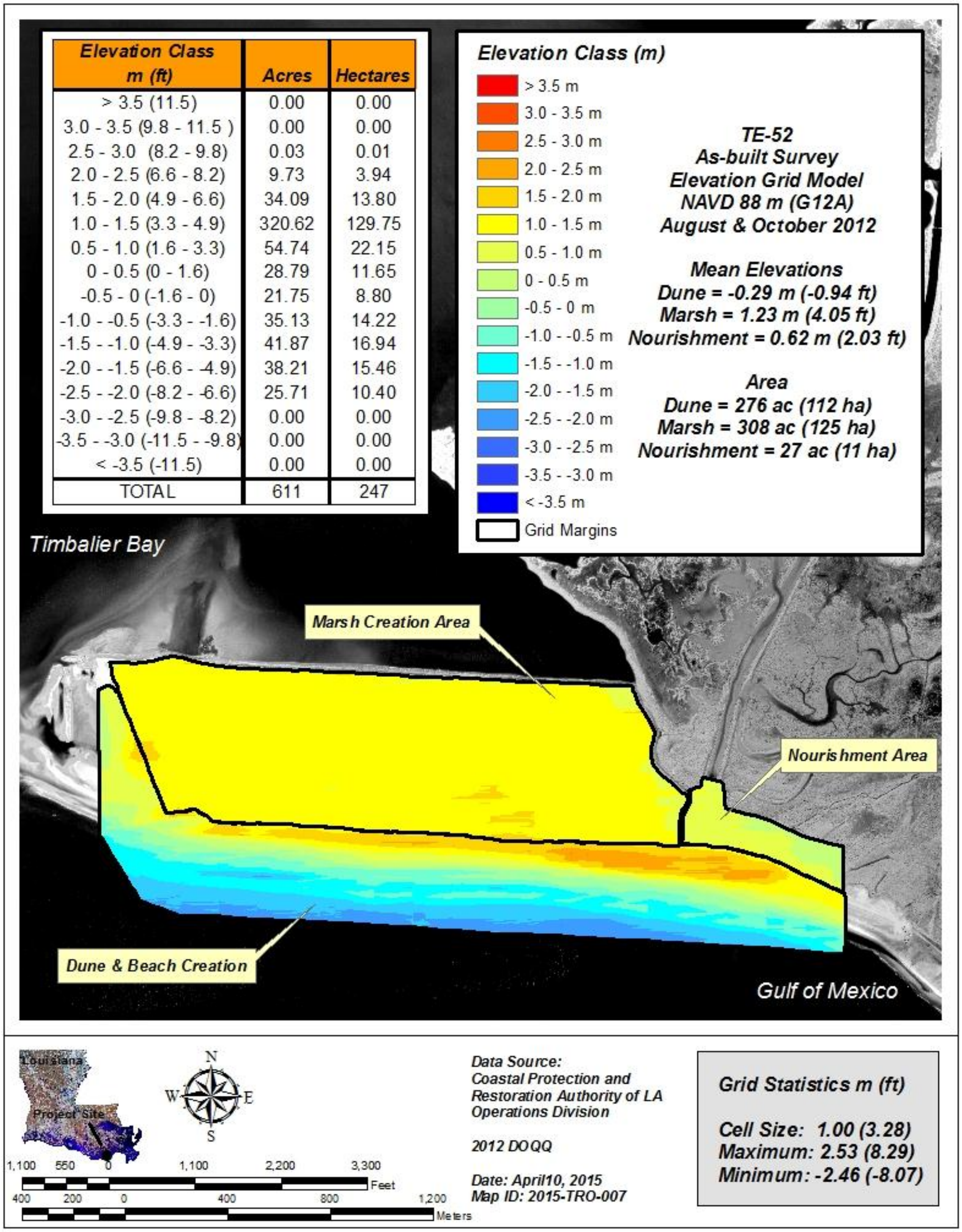
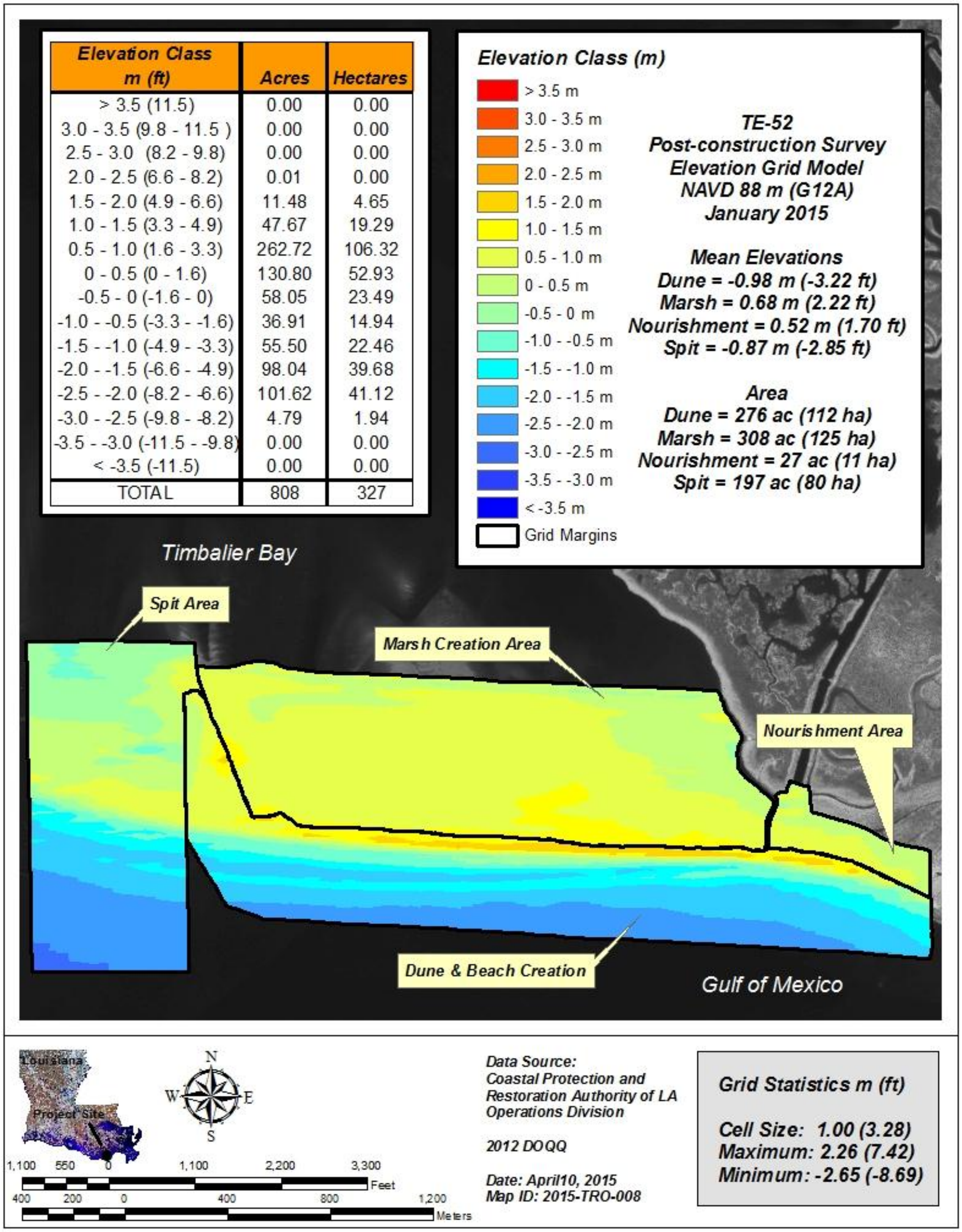


Figure D-3. **As-built (Oct 2012) elevation grid model of the beach and dune, marsh creation, and nourishment areas at the West Belle Pass Barrier Headland Restoration (TE-52) project.**



Elevation Class m (ft)	Acres	Hectares
> 3.5 (11.5)	0.00	0.00
3.0 - 3.5 (9.8 - 11.5)	0.00	0.00
2.5 - 3.0 (8.2 - 9.8)	0.00	0.00
2.0 - 2.5 (6.6 - 8.2)	0.01	0.00
1.5 - 2.0 (4.9 - 6.6)	11.48	4.65
1.0 - 1.5 (3.3 - 4.9)	47.67	19.29
0.5 - 1.0 (1.6 - 3.3)	262.72	106.32
0 - 0.5 (0 - 1.6)	130.80	52.93
-0.5 - 0 (-1.6 - 0)	58.05	23.49
-1.0 - -0.5 (-3.3 - -1.6)	36.91	14.94
-1.5 - -1.0 (-4.9 - -3.3)	55.50	22.46
-2.0 - -1.5 (-6.6 - -4.9)	98.04	39.68
-2.5 - -2.0 (-8.2 - -6.6)	101.62	41.12
-3.0 - -2.5 (-9.8 - -8.2)	4.79	1.94
-3.5 - -3.0 (-11.5 - -9.8)	0.00	0.00
< -3.5 (-11.5)	0.00	0.00
TOTAL	808	327

Figure D-4. Post-construction (Jan 2015) elevation grid model of the beach and dune, marsh creation, nourishment, and spit areas at the West Belle Pass Barrier Headland Restoration (TE-52) project.

Appendix E
(Shoreline Change Graphics)

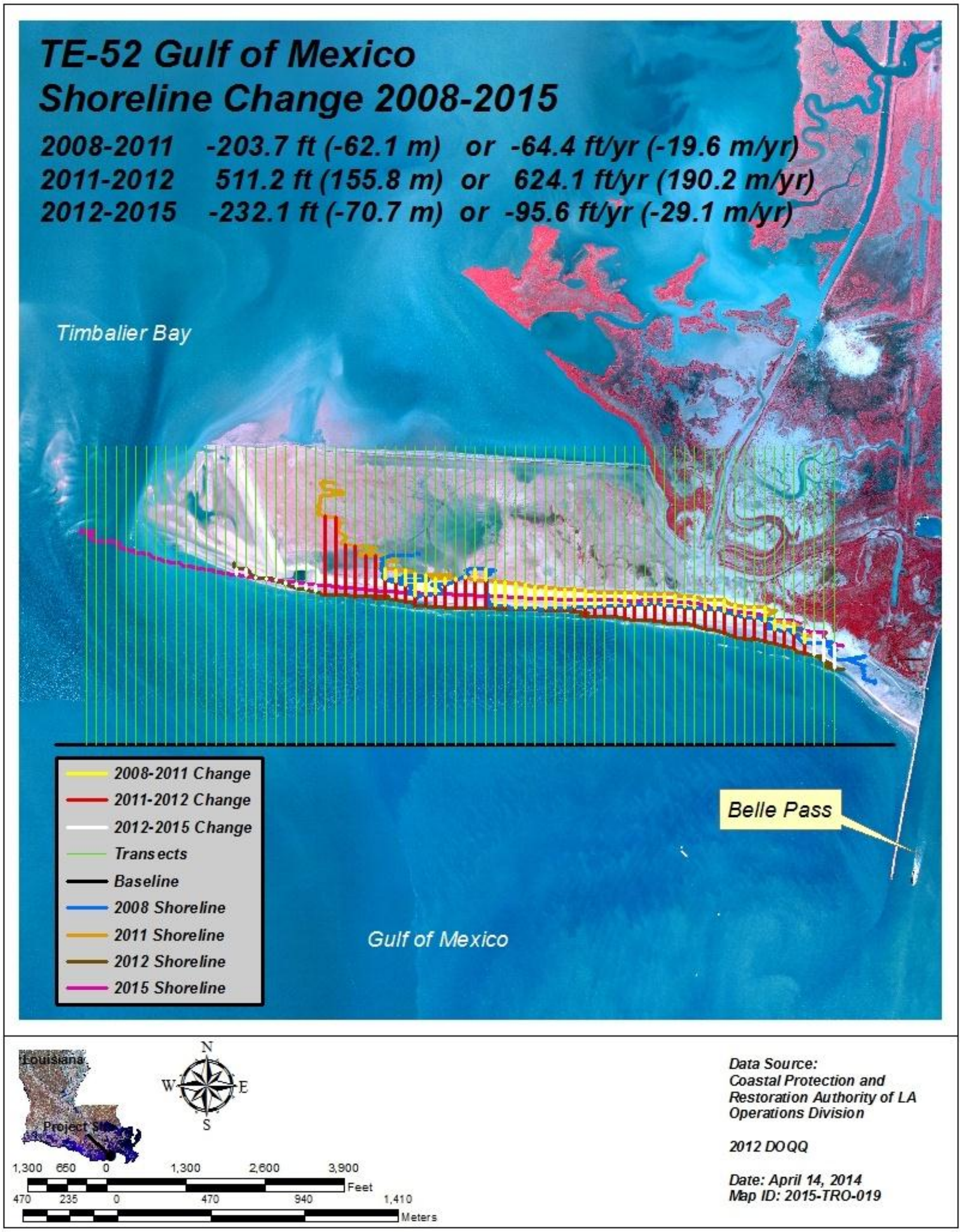


Figure E-1. **Shoreline change and zero meter contour lines used to delineate the shoreline position of the beach and dune area in Aug 2008, Oct 2011, Oct 2012, and Jan 2015 at the West Belle Pass Barrier Headland Restoration (TE-52) project.**