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2012 Operations, Maintenance, and Monitoring Report

for

East Timbalier Island Sediment Restoration, Phase 1 & 2 (TE-25 & TE-30)

State Project Number TE-25 & TE-30
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Preface

The East Timbalier Sediment Restoration (Phases 1 & 2) project is a coastal restoration project sponsored by the NOAA-National Marine Fisheries Service and the State of Louisiana Coastal Protection and Restoration Authority (CPRA) under the Coastal Wetlands Planning, Protection and Restoration Act of 1990.

This report includes monitoring data collected through July 2010, and annual Maintenance Inspections through June 12, 2012.

The 2012 report is the 2nd report in a series of reports. For additional information on lessons learned, recommendations and project effectiveness please refer to the 2005 Operations, Maintenance, and Monitoring Report on the CPRA web site.

I. Introduction

Barrier islands are a common feature of the continental United States coastline. Despite their ubiquity, their genesis and stability varies widely. The Mississippi River Deltaic Plain (MRDP) barrier islands are hypothesized to have originated through a process of: 1) delta building by the active river channel (deltaic progradation), 2) channel abandonment, 3) reworking of the delta into an erosional headland and a flanking barrier spit, 4) subsidence of the deltaic plain landward of the headland leaving a lunate barrier island arc that 5) migrates onshore through overwash activity and 6) eventually submerges to become a subtidal shoal when relative sea-level rise outpaces accretion (Davis and Fitzgerald 2004). When progradation ceases because of channel abandonment (step 2), shoreline retreat is an inevitable result. Barrier spits and islands (steps 3 & 4) help retard inland erosion by shielding marshes from storms and by trapping sediment, but ultimately these islands are destined to become sub-surface shoals (step 6).

Of the six identified MRDP complexes (Roberts 1997), the two most recent, the Balize and Atchafalaya-Wax Lake, are currently in the process of deltaic progradation and do not have barrier islands associated with them. The two oldest identified complexes, the Maringouin/Sale and Teche, have reached the final stage and are now represented primarily by shoals (*e.g.* Ship Shoal). The remaining two complexes, the St. Bernard and Lafourche, are at late-to-intermediate stages and both have barrier island arcs associated with them. The older St. Bernard complex has completed stage 4 and consists of the Chandeleur barrier island arc. The younger Lafourche delta complex (Figure 1) is still in the process of subsidence and consists of the Caminada headland and barrier islands to the east (Grand Isle) and west (East Timbalier, Timbalier, East, Trinity, Whiskey and Raccoon Islands). Of the western islands, East Timbalier has the highest rate of areal loss since circa 1980 (Figure 2) and prior to restoration was expected to disappear by 2001 (see Table 5 in Penland et al. 2003).

Over the past 125 years the two islands shielding Timbalier Bay—East Timbalier and Timbalier Islands—have migrated large distances. East Timbalier has moved predominately towards shore, while Timbalier Island has moved shoreward and laterally westward. As a result of these migrations and the increasing tidal prism from wetland losses, Raccoon Pass (Figure 3), which is between East Timbalier Island and the Caminada Headland, has widened considerably (Miner et al 2009). This widening has led to a decrease in longshore transport of sediment from the Caminada headland to East Timbalier Island. In addition, shoreface erosion at the Caminada headland has expanded both seaward and westward and now encompasses both Raccoon Pass and, to its west, Little Pass (Miner et al. 2009).

Shoreface erosion and an increasing tidal prism have also obliterated the tidal delta at Raccoon Pass (Miner et al. 2007), eliminating a source of sediment for East Timbalier Island. Compounding these natural processes, the placement (in 1935) and expansion (in the 1960s) of rock island jetties at Belle Pass have created a wave shadow, impeding the westward longshore current and, by extension, the westward movement of sediment. For East Timbalier Island, the result of these geomorphological changes is an average long term (1887 - 2005) shoreline erosional rate of 19.6 m/yr (64.3 ft/yr) and a corresponding decrease in area of ~51% since the 1880's (Martinez et al. 2009).

As well as protecting inland wetland marsh, the barrier islands serve essential structural functions imperative to the economy of southern Louisiana. Loss of all barrier islands is predicted to result in wetland loss of at least 47,350 ha (117,000 acres) in Terrebonne Bay (van Heerden et al. 1993) which could undermine the infrastructure around Port Fourchon, an important off-shore oil and gas port. In addition, a large number of oil and gas facilities exist in the shallow bays behind East Timbalier Island and would be vulnerable without the island's protection. The Barataria-Terrebonne estuary system, of which East Timbalier island is a part, supports an abundantly diverse and rich fishery (Lindstedt 2005) and serves as a prime nesting habitat for many neotropical migrants and other birds (BTNEP 2010). The important structure and function of East Timbalier Island to both the ecology and economy of the area underscores its need for restoration.

The habitat of East Timbalier Island consists of beach, low dunes, and back-barrier marsh. *Spartina alterniflora* (smooth cordgrass) is the dominant species of the salt marsh communities with *Spartina patens* (marshhay cordgrass) and *Distichlis spicata* (seashore saltgrass) also present. *Avicennia germinans* (black mangrove) is distributed across a large area of the island.

Gulf Oil Company initiated shoreline protection measures on East Timbalier Island in the 1950s by constructing an earthen berm along the Timbalier Bay shoreline (Figures 2 and 3). In the aftermath of Hurricane Betsy (1965), a series of groins and a rock dike were built along the Gulf of Mexico shoreline. Also, the existing back dike was capped with stone during this period. Hurricane Carmen breached these structures in 1974. The damage to the existing Gulf-side rocks and the back dike was repaired by adding additional stone to these structures (Gotech 1998). Segments of the existing Gulf and back dike rocks remain in place although storm activity damaged the majority of these structures and relocated the rock materials. The alignments of the existing rock dikes are illustrated in figures 3 and 4.

The East Timbalier Sediment Restoration Phase 1 (TE-25) and Phase 2 (TE-30) projects consist of dune, marsh creation, and shoreline protection features. Although these two projects were funded using two separate CWPPRA appropriations (PPL 3 & 4, respectively), they were built simultaneously using the same construction contract and function as a single project. The East Timbalier Island projects created 87.8 ha (217 acres), consisting of dune (22.7 ha; 56 acres) and marsh (65.2 ha; 161 acres) habitats. The dune feature was shaped into a 45 to 61 m (150 to 200 ft) wide dune with a 1.5 m (5 ft) National Geoditic Vertical Datum of 1929 (NGVD29) crest, and the marsh platform was constructed to a 0.61 m (2 ft) NGVD29 elevation with 152 to 229 m (500 to 750 ft) widths (Figures 2 and 3). The dune was narrowed to a 45 m (150 ft) width from station 96+91.99 to station 114+00 (Figure 5). Approximately 754,884 m^3 (987,351 yd^3) of sand, silt, and clay were hydraulically pumped inside the TE-25/TE-30 fill areas to create these features. To contain and elevate the dune and marsh features, 1,825 m (5,990 ft) of earthen containment dikes and 2,819 m (9,250 ft) of 440 class stone were constructed to a 1.5 m (5 ft) NGVD29 elevation. The containment dikes were built only on the extreme western segments of the barrier island and the rubble mound rocks (project rocks) were placed directly on the beach along the Gulf of Mexico shoreline (Figures 3 and 4). After sediment consolidation, the earthen containment dikes on the Timbalier Bay shoreline were lowered to 0.76-1.07 m (2.5-3.5 ft) NGVD29 (Figure 5). Plantings of *S. patens* and *Panicum amarum* (Figure 4), and the aerial-seeding of *Cynodon dactylon* (Bermuda grass) were completed in May 2001. Lastly, sand fencing consisting of a shore-parallel fence with varying orientations of spur fencing was placed to trap wind-blown sands and to aid in the development of dune habitat. That is, some areas of the island included spur fences that either intersected or crossed the linear, shore-parallel fence at near-45° angles and resulted in fencing segments that resembled an "A" or "V" alignment (Figure 4).

Although the TE-25/TE-30 projects did construct dune and marsh creation features, these projects were unable to complete their design template due to shoreface changes between design and construction and to poor sediment quality. Approximately 1,525 m (5000 ft) of dune and marsh platform were not built on the eastern part of the TE-30 fill area (Figure 5). The design surveys were conducted two years before construction and the shoreline experienced considerable erosion and steepening in the interim prior to construction. At this point, 8,171 m (26,810 ft) of earthen containment dikes were eliminated from the design and a substantial portion of the fill areas were pumped unconfined. Complicating matters further, the percentage of sand in the borrow area was less than anticipated steering lighter more mobile sediments into the fill areas (Picciola & Associates, Inc. 2000).

These two factors resulted in an extremely high cut-to-fill ratio (3:1) and problems shaping the dune. Approximately, 2,065,276 m^3 (2,701,279 yd^3) of sediment was cut from the borrow area and 754,884 m^3 (987,351 yd^3) remained in the fill areas after construction. Payment to the contractor was based on the volume of material removed from the borrow area, not the volume of in-place fill material in the project areas, causing the projects to prematurely exhaust their budgets. Therefore, due to sediment quality and economic reasons, the TE-30 template was not completed. Construction of the TE-25/TE-30 projects began on April 13, 1999 and dredging ended on January 10, 2000. Sand fencing was added in September 2000 and vegetation was planted by May 2001.

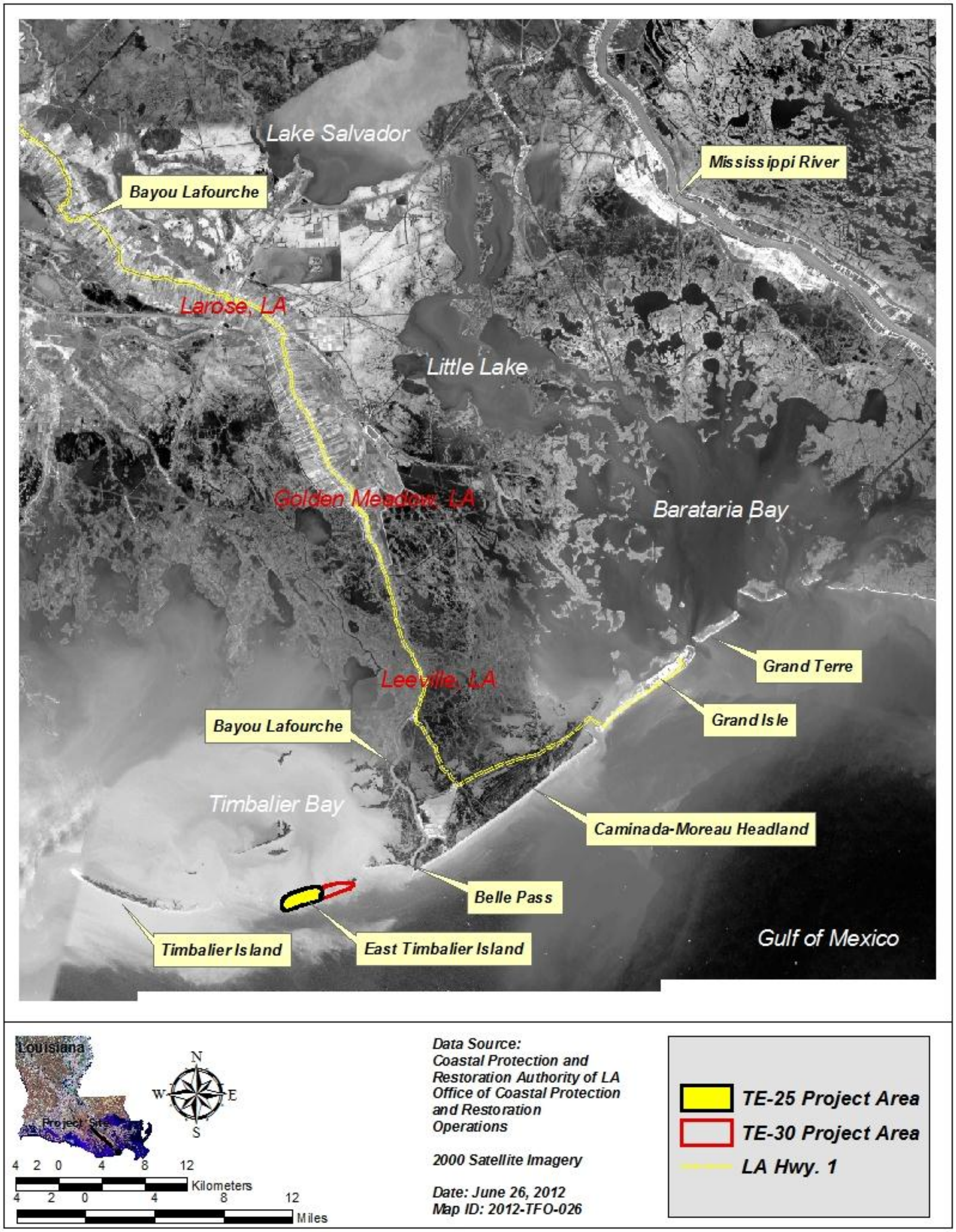


Figure 1. **Map of the general area of the Lafourche delta complex**.

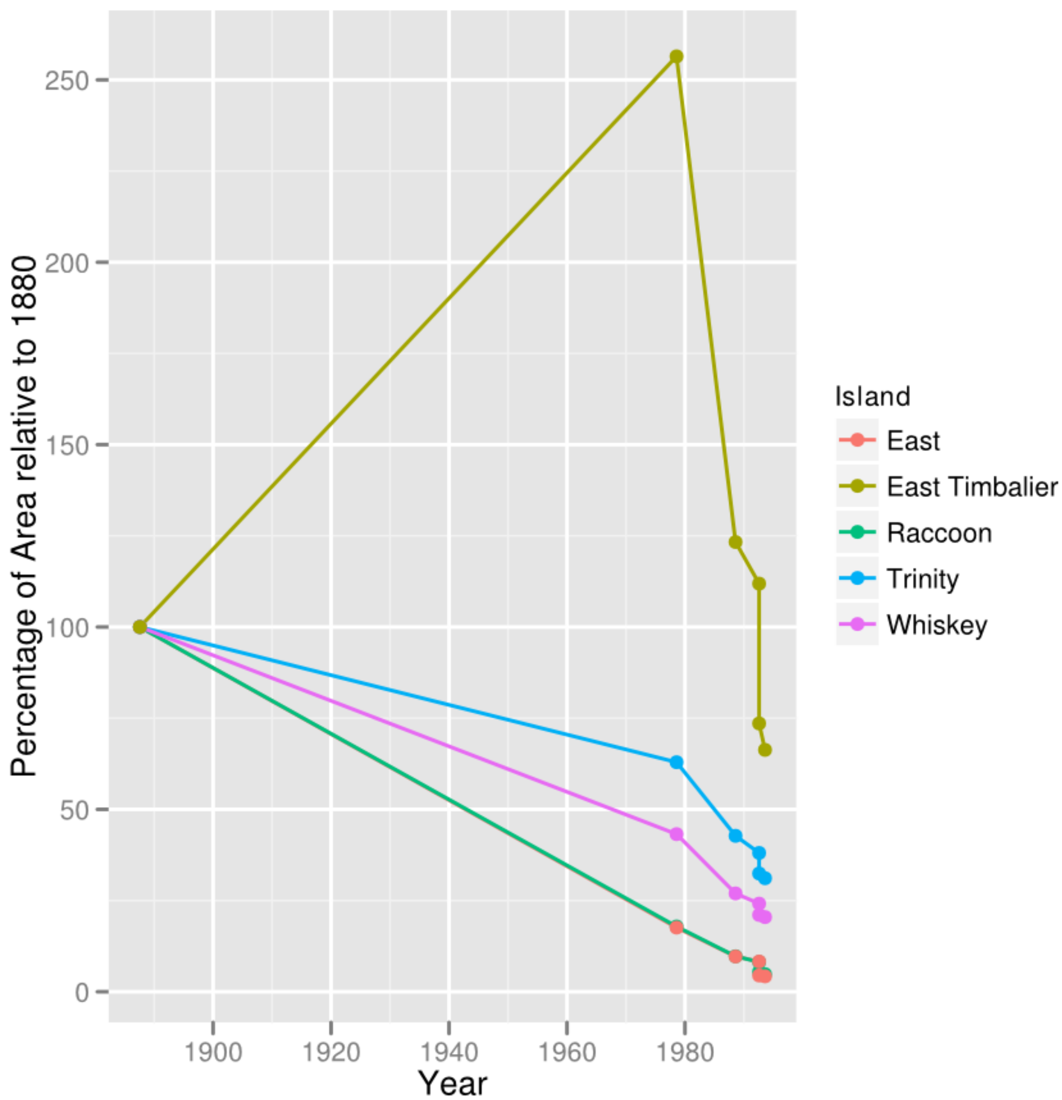


Figure 2. **Percentage of remaining area (as compared with the 1880s) for each of the Lafourche delta complex islands.**

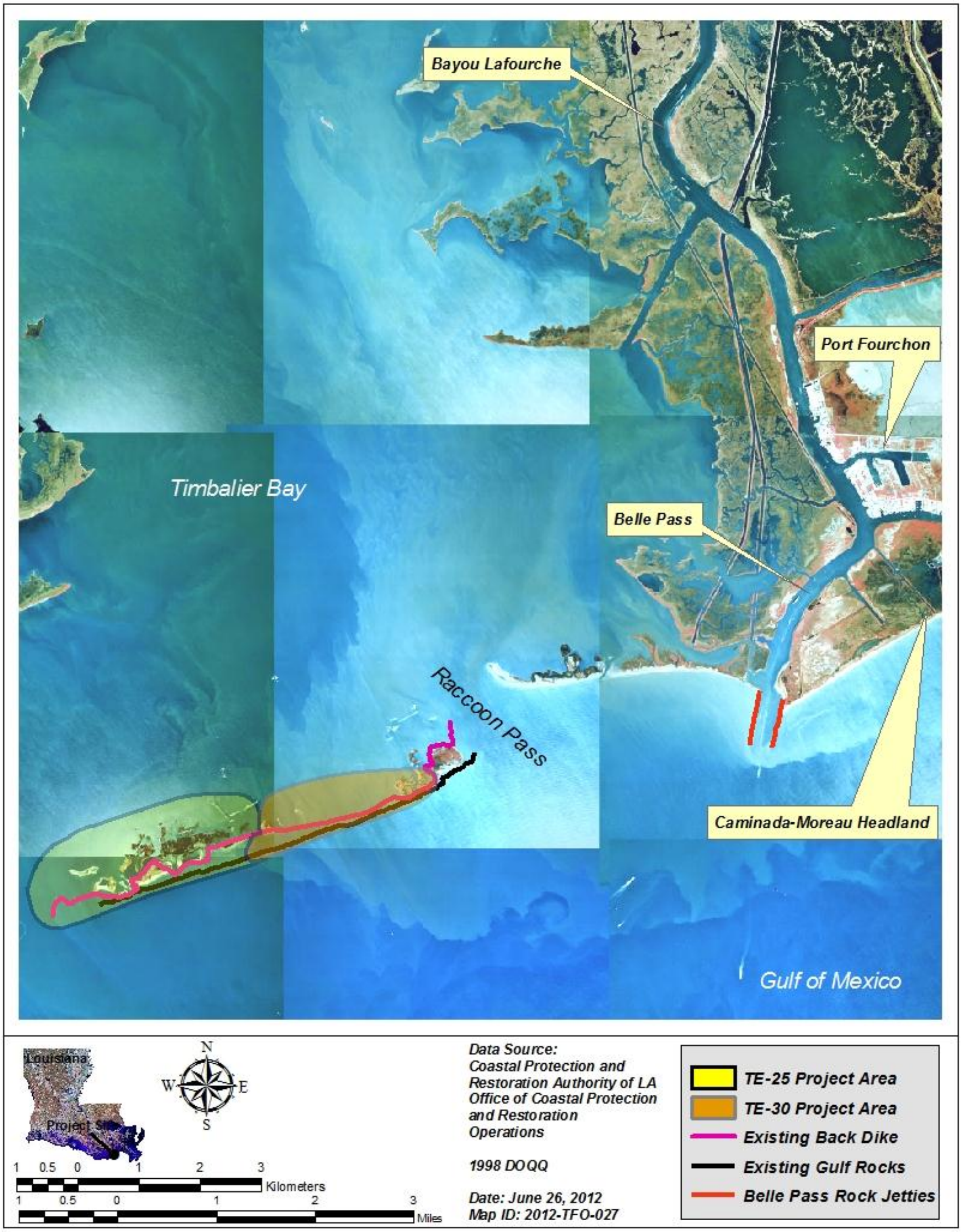


Figure 3. **Map of the TE-25 and TE-30 project areas in relation to West Belle Pass and the rock jetties.**

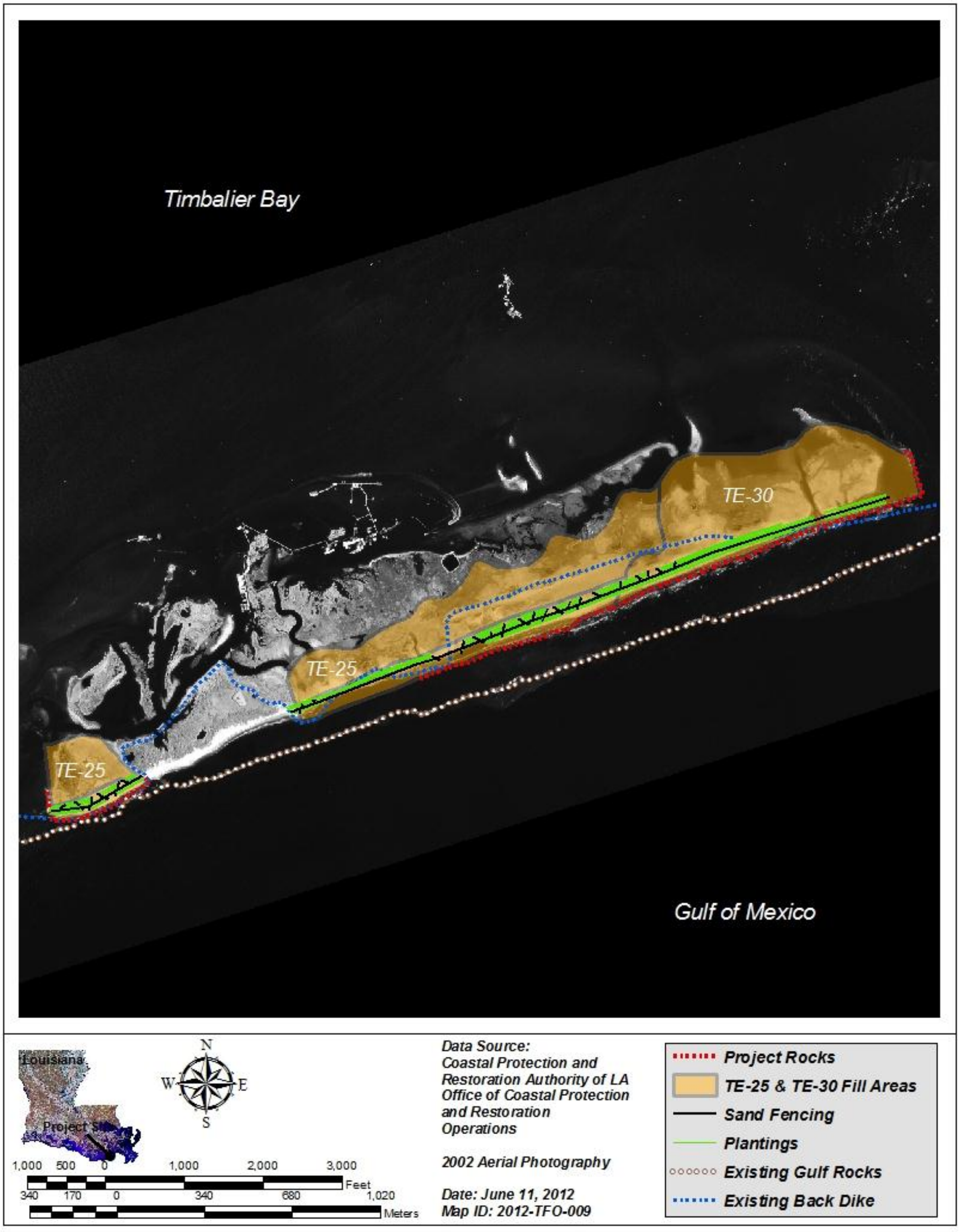


Figure 4. **A map of project features constructed as part of the TE-25/TE-30 projects and pre-existing rock features.**

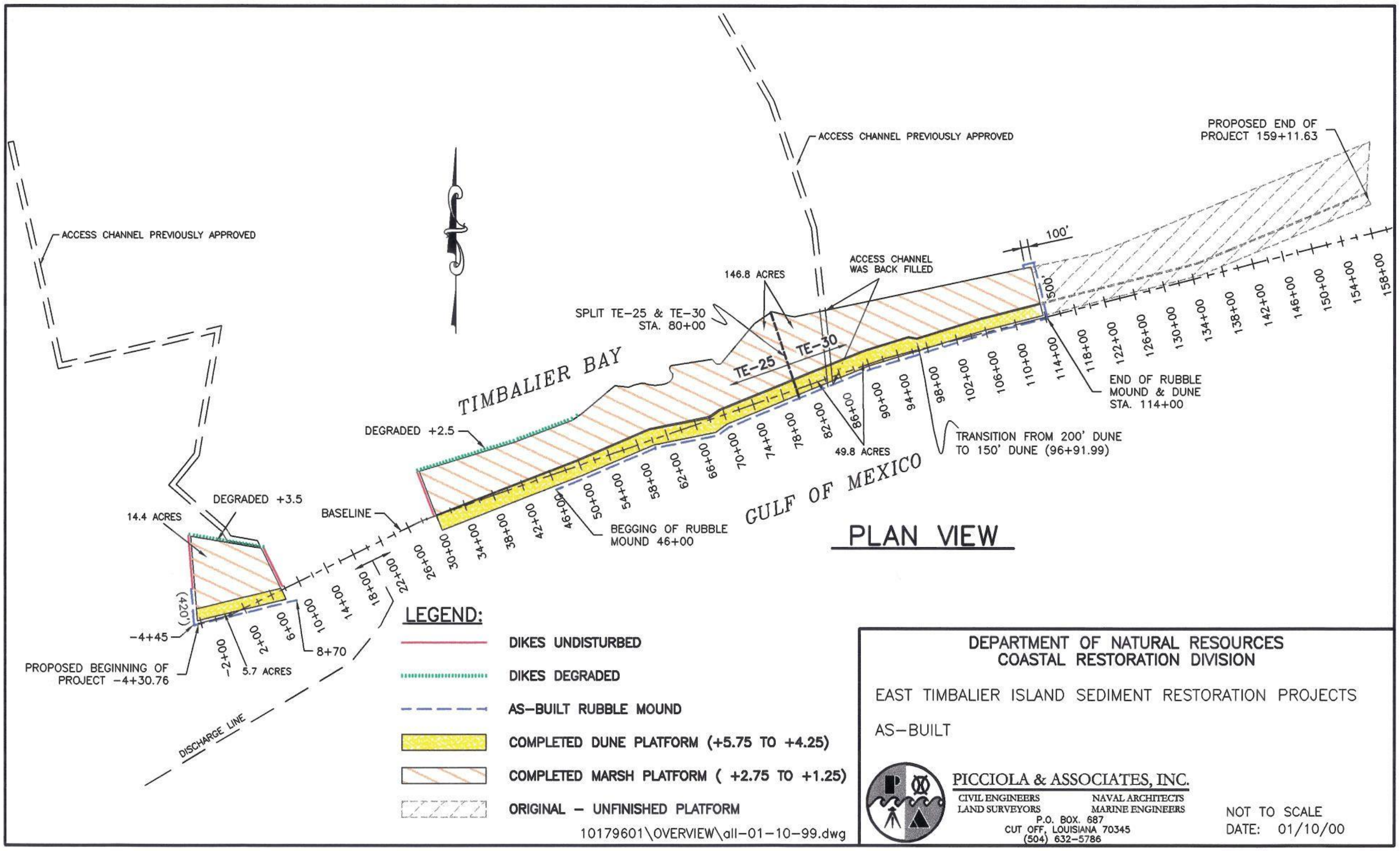


Figure 5. **As-built plans for the TE-25 and TE-30 projects.**

II. Maintenance Activity

a. Project Feature Inspection Procedures

The purpose of the inspection of the East Timbalier Island Sediment Restoration projects (TE-25/TE-30) is to evaluate current conditions of the project features and develop recommendations for future actions in regards to both this project and future projects. The most recent inspection of East Timbalier Island was conducted on June 12, 2012 and participants were Jason Curole, Darin Lee, Glen Curole, and Adam Ledet (CPRA), and Richard Hartman and John Foret (NOAA). The assessment began at approximately 10:00 am and proceeded from the eastern end of the island (near station 66+00) westerly to the western end of the eastern fill area (station 26+00; Figure 5).

b. Inspection Results

The June 12, 2012 inspection included visual observation of the remaining project features and comparisons of GPS locations with as-built features. Below are general observations made during the assessment, as well as recommendations and costs for possible corrective actions. Photos taken during the assessment, with comments, are found in Appendix A.

1. The project fill template is completely eroded from station 82+00 to the eastern end of the TE-30 fill area, with only sand spits and shoals remaining (App. A – Photo # 2). Additionally there is no evidence of the rock shoreline feature in this location (Appendix B)

2. The western fill area from station -4+00 through 10+00 is completely eroded. In addition, the western end of the island has retreated bayward while the pass has expanded toward the east, leaving the former project footprint within the Gulf (App. A – Photo # 22). Additionally there is no evidence of the rock shoreline feature in this location (Appendix B)

3. The eastern fill area from station 30+00 easterly to station 82+00 has limited amounts of fill remaining, the dune is completely removed and there is no evidence of the rock shoreline feature (Appendix B). The existing beach and low dune features are now located toward the rear of the marsh fill template as the shoreline has eroded and overwash events have moved sediment onto the marsh fill.

4. Low dune profiles in areas with remaining marshes to allow rollover, suggest that the project-derived beach and dune sediment remaining in the system have been severely reduced. Inspection photos taken in 2008 that suggest is sediment moving onshore after erosional events and rebuilding dunes. However, the lack of active dune formation indicates insufficient

sediment within the shoreface profile to allow dune formation in fair weather conditions (Figure 6).

5. Remaining marsh fill areas have converted to low dune and sandy overwash flats as island rollover has occurred. Little marsh remains in the TE25/30 fill footprint (App A – Photos # 13 - 16)

c. Maintenance Recommendations

i. Immediate/ Emergency Repairs

Project conditions are such that activities required to have long-term effects would constitute a new project, while little sediment remains to manage in the short-term with actions such as plantings and sand fencing. The scale and scope of necessary actions and CWPPRA's programmatic omission of maintenance funding for barrier island restoration projects forces us to forego repair recommendations at this time. Additionally, BICM survey data provides evidence that the rock shoreline protection feature has degraded or scattered, is no longer in place and, therefore, does not require removal (Appendix B).

ii. Programmatic/ Routine Repairs

The lack of an operations and maintenance budget provided through CWPPRA and the deteriorated state of the project features precludes any recommendations for maintenance.

d. Maintenance History

Maintenance activities have not been performed on these projects throughout their life. The lack of an operations and maintenance budget precludes such activities unless other funding sources are enlisted.

Figure 6. View of dune features near station 30+00 in March 2008 (left) and again in June 2012 (right). Note that there was enough sediment in the system in 2008 to maintain dune formations even with high shoreline erosion rates, while July 2012 inspection photos indicate very little sediment transport onshore even with little tropical activity in recent years.

III. Operations Activity

No operations activities are required on this project and these projects have no operations and maintenance budgets allocated. Inspections are paid with State funds.

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-25/TE-30 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. Barrier Islands were considered separate from other ecosystems and not incorporated into the CRMS-*Wetlands* design. Therefore, there are no CRMS sites located in the project area.

The Barrier Island Comprehensive Monitoring Program (BICM) was initiated in 2002 to provide a comprehensive approach to barrier shoreline monitoring similar to CRMS-*Wetlands* (Troutman et al. 2003). The decided advantage of BICM over project specific monitoring is that it provides long term data on all of Louisiana's barrier shorelines and is not limited to areas with constructed projects. As a result, a greater amount of long-term data is available to evaluate constructed projects, to facilitate planning and design of future barrier island projects in numerous other programs (CWPPRA, LCA, WRDA, CIAP), to assist with O&M activities, and to determine storm impacts. Because data are collected for the entire barrier island system concurrently and with identical methodologies, these data are more consistent, accurate, and comprehensive than previous barrier island data collection efforts.

Implementation of the BICM program began in 2005 because of the need to establish a new coastal baseline dataset after the impacts of hurricanes Katrina and Rita. Initial datasets collected include: 1) post-storm damage assessment photos and video, 2) shoreline positions, 3) habitat composition, 4) land/water analysis, 5) topography, 6) bathymetry, and 7) sediment characteristics. Additionally, these data have been compared to standardized historic data and they are provided digitally to user groups for future use.

The BICM program data has been incorporated with CWPPRA collected project specific data, as well as other available datasets, to evaluate the goals and objectives of the East Timbalier Island Sediment Restoration, Phase 1 & 2 (TE-25 & TE-30) projects.

a. Monitoring Goals

The objective is to increase the life expectancy of East Timbalier Island by placing dredged material along its shoreline.

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

1. Increase the elevation and width of East Timbalier Island using dredged sediments.
2. Reduce loss of sediments through the growth of aerially seeded and natural vegetation.

b. Monitoring Elements

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

Elevation

We employed topographic and bathymetric surveys to document elevation and volume changes inside the East Timbalier Sediment Restoration (TE-25 & TE-30) project fill areas. Contractors collected pre-construction (May – June 1999) and as-built (December 1999 – January 2000) elevation data using traditional cross sectional survey methods (NGVD29 datum). Subsequent post-construction topographic surveys were conducted using Light Detection and Ranging (LiDAR) procedures (Brock et al. 2002; NAVD88 datum). Post-construction surveys were conducted in March 2000 (John Chance Land Surveys, LTD), 2001 (USGS), 2002 (USGS), and July 2006 (USGS). The 2006 survey and a separate bathymetric survey were funded through the BICM program (Troutman et al. 2003). The bathymetric survey (UNO/USGS) recorded subaqueous elevations in the shoreface, inlet, and bay regions surrounding East Timbalier Island. The 2006 LiDAR and bathymetric surveys were joined to form a single continuous elevation contour of this barrier island system. All survey data were established using or adjusted to tie in with the Louisiana Coastal Zone (LCZ) GPS Network. The 2001 and 2002 LiDAR data were not applied to the following analysis because these surveys were not filtered for vegetation; however, data results for these two time periods were published in the West et al. (2005) report for these projects. The 2000 and 2006 LiDAR data were filtered for vegetation and more accurately illustrate island topography.

The June 1999, January 2000, March 2000, and July 2006 survey data were re-projected horizontally in meters to the UTM NAD83 coordinate system using Corpscon® software. The re-projected data were imported into ArcView® GIS software for surface interpolation. We generated triangulated irregular network models (TIN) from the point data sets, converted the TIN models to grid models (2.0 m^2 cell size), and mapped the spatial distribution of elevations. The grid models were clipped to the survey extents and then to the TE-25 and TE-30 fill area polygons to estimate elevation and volume changes within the fill areas.

We calculated elevation changes from June 1999 (pre) – January 2000 (as-built) and March 2000 (post) – July 2006 (post) by subtracting the corresponding grid models using the LIDAR Data Handler extension of ArcView® GIS. After the elevation change grid models were generated, we mapped the spatial distribution of elevation changes in the TE-25 and TE-30 fill areas in half meter elevation classes. Lastly, we calculated volume changes in the fill area in cubic meters (m^3) using the Cut/Fill Calculator function of the LIDAR Data Handler extension of ArcView® GIS. Note, these elevation and volume calculations are valid only for the extent of the overlap for individual surveys. Additionally, loss of survey control points due to erosion of the island did not allow for later LiDAR surveys to be compared to early pre- and post-construction surveys.

Vegetation

Hand-planted, naturally colonizing, and aerially-seeded vegetation was monitored along the shore-parallel sand fencing. Nine areas were selected randomly and divided into three treatments of various fence alignments: A-configuration, V-configuration, and linear fencing (no spur fence), known henceforth as treatments A, V, and L. Each alignment (treatment) consisted of three transects. Two transects were laid in a north-south direction from the intersection of a shore-parallel and spur fence and one transect was laid in a north-south direction equidistant between the spur fences. In dunes with no spur fences, transects were laid in a north-south direction at 45.7 m (150 ft) intervals. Species composition and percent cover of vegetation were determined using the Braun-Blanquet method (Mueller-Dombois and Ellenberg 1974; Steyer et al. 1995, revised 2000) in four 2 m x 2 m (6.56 ft x 6.56 ft) plots randomly placed along each transect. Two of the plots were randomly placed on the transect Gulf-side of the shore-parallel fence and two plots bayside. A 5 cm x 5 cm (2 in x 2 in) wooden stake was driven into the ground to mark the southeast corner of the plot. All plots were oriented north-south. All species were recorded and percent cover visually estimated. Cover classes are: solitary, <1%, 1-5%, 6-25%, 26-50%, 51-75%, and 76-100%.

Survival data for planted vegetation was collected for each row along the transect. The first individual plant was chosen randomly and the next four plants (from east to west) were determined to be alive or dead (five total plants). All plants were counted and survivability was determined in rows along spur fences. Vegetation data were collected in August 2001 and September 2002.

We used Tukey's post hoc comparisons in the SAS generalized linear model (GLM) procedure to analyze survival data of planted vegetation within each fencing treatment (*i.e.*, A, V, and L configurations) and between planted vegetation growing north and south of the shore-parallel fence (SAS 1999). Differences were considered significant if $p < 0.05$.

Habitat Mapping

Digital images taken in 1996, 2002 (both May and November), 2004 and 2005 were used for habitat identification and mapping. Habitat mapping was completed through the BICM program using the method outlined in Fearnley et al. (2009). Individual images were mosaicked to create a continuous and complete image of the shoreline segment and then clipped to remove surrounding seawater from the image. Spectral values are used to create "signatures" for each habitat class. Using these signatures areas were classified into habitat categories and the images manually cleaned to resolve discrepancies. These habitat maps were used for comparisons across years. The exclusive use of photographic and satellite imagery significantly reduces measurement errors to 2 m or less (Fearnley et al. 2009).

Aerial Photography-Width and Length of the Island

Width and length of the fill areas were estimated in ArcGIS using aerial photography from December 1996, February 1998, February 2001, May 2002, November 2002, January 2004, November 2005, September 2007, October 2008, and July 2010. All measurement data were acquired at a 1:2,000 scale. Length was measured following a single transect that bisected the fill areas. Width was measured at 19 transects spaced at 152 m (500 ft) intervals. Width was measured inside the fill areas and behind the fill areas (from edge of fill areas to the Timbalier Bay shoreline) independently. Only visible land was measured. If a transect was interrupted by water, the flanking land masses were used to estimate length.

c. Preliminary Monitoring Results and Discussion

Elevation

Pre-construction aerial photography (1996 and 1998) shows that East Timbalier Island was highly fragmented prior to the onset of construction (Figure 7), with a network of canals, scours, and cuts interlacing the island. Beginning in the 1950s, several rock walls were constructed on the island presumably to protect the remaining island and oil facilities located behind the island (Gotech 1998). Additionally, as oil and gas development continued canals north of the island were dredged and spoil banks created.

The elevation grid model of pre-construction survey data supports the observation that the island consisted of scours and cuts. Over half (58%) of the surveyed area was less than 0 m (NGVD29) in elevation and only 17% of the area had an elevation greater than 0.5 m (Figure 8). Various patches and stretches of low elevation (<−0.5 m) dotted the island, with thin ridges of moderately high elevation (>1.0 m) stretching east to west. In addition, the eastern end of the island consisted of a large area whose elevation is less than 0 m.

Project construction eliminated nearly all of these low lying areas and brought most of the fill area up to an elevation greater than 0.5 m (NGVD29; Figure 9). In contrast to the pre-construction survey, after construction nearly the entire area was above 0 m, with only a fraction (0.4%) of the area having an elevation between 0 and -0.5 m. A large proportion of the classified area fell into the 0-1.0 m elevation range (yellow areas in Figure 9). Most of the remaining area (24%) falls into the 1.0-2.0 m range and is mostly sand dune, clearly visible on the elevation grid as the orange strip along the Gulf side of the island.

The elevation change grid model for the pre-construction to as-built period shows substantial volume gain consistent with the large overall elevation gain. Across the project footprint, an area of 673,824 m^2 (881,362 yd^2) gained 754,884 m^3 (987,388yd^3) of sediment (Figure 10). Most areas (84% of total) experienced an elevation increase of 0 to 2 m. These are nearly evenly distributed among the 4 elevation classes that fall into this range (see the grid classification table in Figure 10). A small proportion of the total area (5%) lost elevation. Thus, during construction nearly all project areas experienced a large gain in volume concomitant with a 0-2 m increase in elevation.

In March 2000, approximately 3 months after the as-built surveys were conducted, additional elevation data were collected with LiDAR. Although these data sets are in different datums (NAVD88 *vs*. NGVD29), a visual inspection of the grid elevation models suggests that they are quite similar (*cf*. Figures 9 and 11). The Gulf-side sand dune is clearly visible in both models, as are the rock walls. In addition, for both models classified fill area is primarily distributed among the 0-0.5, 0.5-1.0 and 1.0-1.5 meter elevation classes.

Despite these similarities, some discrepancies are apparent between the as-built and March 2000 survey. The March 2000 survey data indicate that a much larger proportion of total area falls into the 0-0.5 m range (41% *vs*. 13%; *cf*. classification tables in Figures 9 and 11). This may be the result of settlement in the fill material over the course of the 3 months between the surveys or may be an artifact resulting from the switch in datums. In addition, what appears to be a higher elevation feature at the eastern end of the island, clearly visible in the as-built elevation model (Figure 9), is not present in the March 2000 elevation model (Figure 11). However, because the two surveys are in different datums, comparison of absolute heights is inappropriate. To better understand the pattern of land loss and to identify whether the loss of the eastern facing sand dune is an artifact resulting from the use of different datums, we constructed elevation profiles using the as-built and March 2000 elevation data. Transects for the as-built land-based surveys were placed every 200 feet; thus, for the purposes of this analysis we generated elevation profiles from transects 80+00 to 114+00 (Figure 5) and spaced the March 2000 transects every 200 ft. so as to overlap with the as-built data (*i.e.*, 80+00, 82+00, 84+00, 88+00, etc.).

Elevation profiles based on the as-built survey and the March 2000 LiDAR data are in good agreement in profile (Figure 12). The first three cross-sections presented in

Figure 12 (80+00, 88+00, and 112+00) are representative of all the elevation profiles except for 114+00, which is discussed below. Overall, a slight elevation shift between the two data sets is apparent but the elevation profiles of the two surveys track well. The as-built data show a slightly greater overall elevation (~0.1-0.2 m greater), which could be due to either a difference in datums or settlement of the project area. Given the near uniformity we suggest that the difference is due to inconsistent datums.

In contrast to the remarkable agreement found in nearly all the elevation profiles analyzed, the easternmost profile (114+00) shows poor agreement between the as-built and March 2000 survey (Figure 12). Consistent with the as-built elevation grid model, the as-built cross-section shows an elevation of ~1.3 m (4.3 ft) across the ~200 m (643 ft) transect. We interpret this feature as a dune that was built at the easternmost section of the project area. The March 2000 survey shows a significant decrease in elevation, far greater than can be accounted for by the difference in datums. In addition, the profiles are remarkably different. Whereas the as-built profile shows level dune, the March 2000 profile shows significant sloping.

The density of observations for the March 2000 LiDAR data allows a more detailed analysis. Because of the density of the LiDAR coverage virtual transects can be placed nearly anywhere within the spatial spread of the data. To better quantify the extent of project degradation, we created 5 m (16 ft) spaced virtual transects between point 114+00 and 112+00 (Figure 12). Visual inspection of these elevation profiles indicates that at no point does the higher elevation feature at the eastern end of the island appear to exist. In addition, within the first 5 meters of the 114+00 transect (profile 114+00-5m) the Gulf facing sand dune appears to be eroding. At 10 m west of the 114+00 transect (cross-section 114+00-10m) the outline of the Gulf facing dune is visible, although the maximum height is below 1 m.

These results are consistent with aerial photography and observations made during site visits. Aerial photography taken in the first half of 2001 (Figure 13) shows visible degradation of the eastern portion of the island. In particular, the southeast corner of the island is heavily eroded, with an apparent breach in the sand dune at the southeastern corner (corresponding to the right hand side of the 114+00 and 114+00-5m plots in Figure 12). By May 2002 this breach had greatly expanded and the far eastern portion of the project had partially degraded (Figure 14). In addition, the bay side of the island (and the project) experienced substantial loss along the eastern half of the combined project area. Post-hurricane season aerial photography from 2002 (Figure 14) shows that Hurricane Isidore and Hurricane Lili, both of which passed in 2002, had profound impacts on the island, again with substantial loss of sediment at the eastern end. The island remained relatively stable from November 2002 to 2004, but again saw substantial degradation during the hurricane season of 2005 when hurricanes Cindy, Katrina and Rita came ashore (Figure 15).

In July of 2006, LiDAR data were collected as part of the BICM program. We transformed these elevation data to the same datum and geoid as the March 2000

LiDAR data and built elevation grid and elevation change models. The grid elevation change model for March 2000 to July 2006 represents a culmination of the degradation that began immediately after construction (Figure 16). Over two-thirds (69%) of the project area showed a loss in elevation from 2000 to 2006. The remaining 31% showed a slight increase in elevation, with most positive elevation change being limited to less than 0.5 m. Overall, the project lost 764,365 m^3 of sediment which is 9,481 m^3 in excess of the sediment added for the TE-25/TE-30 project construction. Not surprisingly, the greatest losses (red shading) are at the eastern end of the project area, where nearly the entire TE-30 project fill template was eliminated. In addition, the southeast (or Gulf of Mexico) facing side of the project experienced substantial losses in both the TE-30 and TE-25 project areas. The small, far western fill area of TE-25 also sustained substantial losses. In contrast to the eastern and southeastern facing sections of the island, this far western portion seemed quite stable prior to the 2002 hurricane season. Overall, the analysis suggests that within 6 years the project has degraded beyond its initial pre-construction state.

The elevation data present a picture of rapid deterioration of the project due to environmental forces, particularly tropical events. The as-built and March 2000 elevation profiles are in good agreement, with one critical exception—transect 114+00 at the easternmost end of the project area. Further dissection of the profiles at this end of the island shows degraded dune nearly 10 m inshore from the eastern end. These data indicate that within three months of construction the eastern end of the project had been compromised.

The 2006 elevation data demonstrate the culmination of the relentless environmental forces which compromised the project shortly after construction. The volume of sediment eroded within 6 years is greater than the amount of sediment deposited on the island as part of the project (Figure 16). Based on this data we conclude that within 6 years most, if not all, of the sediment deposited during project construction has moved to either other parts of the island or, more likely, out into open water. Unfortunately, due to pre-construction and as-built survey protocols we cannot determine how much sediment remains in areas outside the fill template and the effects of the project on the island system as a whole.

Aerial photography from 2007 (Figure 17), 2008 and 2010 (Figure 18) reflect the grid change elevation model for 2000 to 2006 (Figure 16). These images clearly show that the project is in the process of continuing degradation. By 2010 nearly the entire fill area, having lost elevation and volume, was open water. In addition, between 2008 and 2010 the island has rolled back, as can be seen by the decreasing distance between the back-side production facility and the island shore.

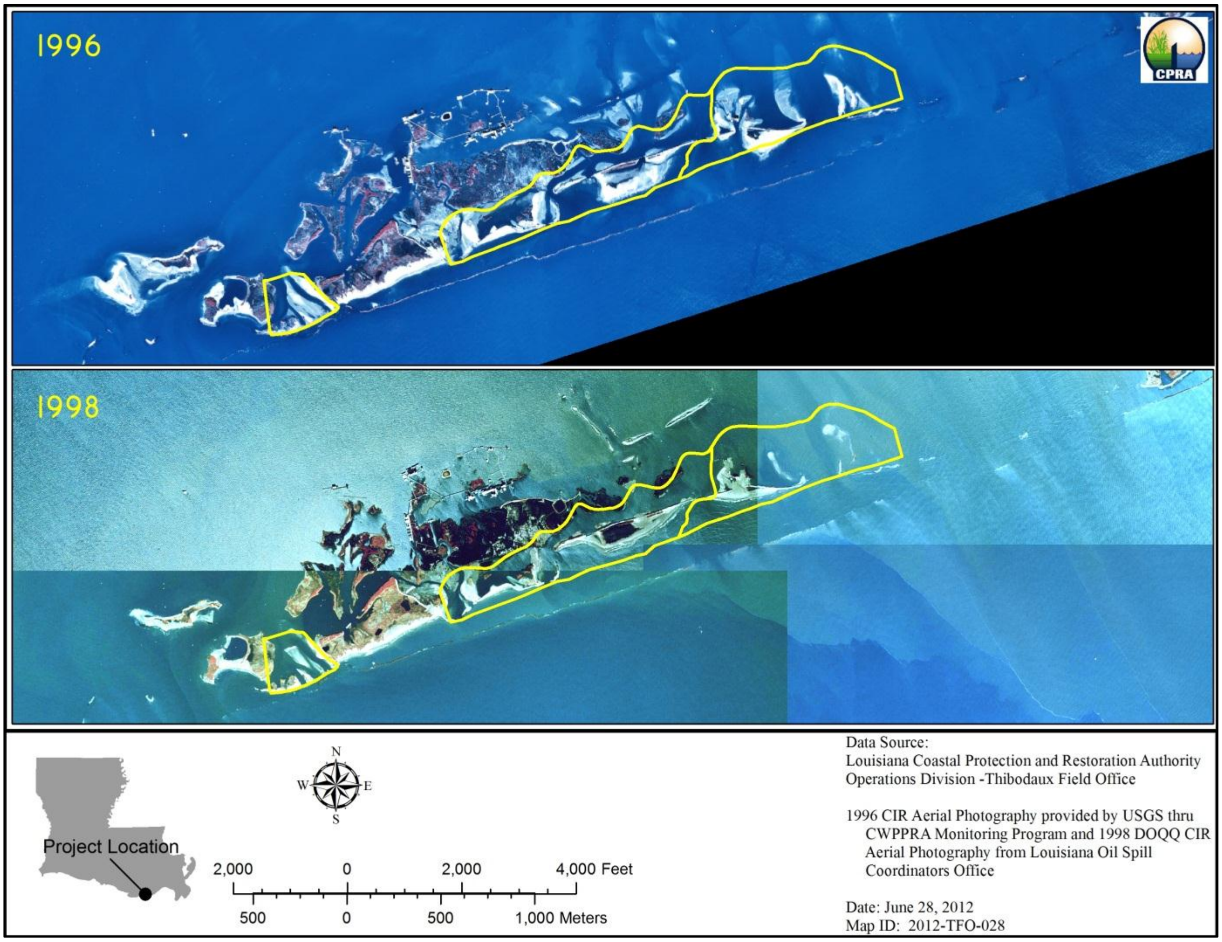


Figure 7. Aerial photography (1996 and 1998) of East Timbalier Island before construction. The outlined area represents the project boundaries.

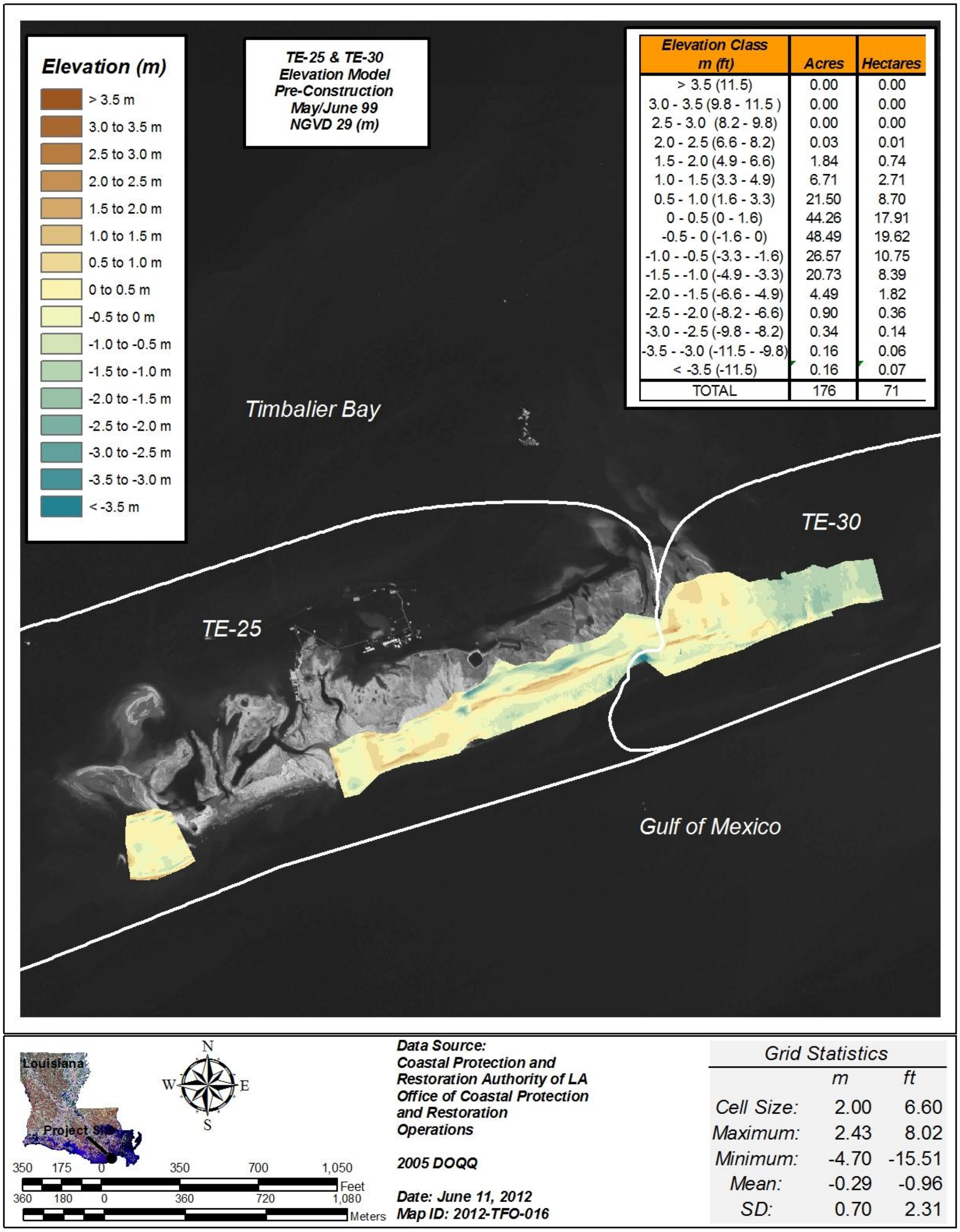
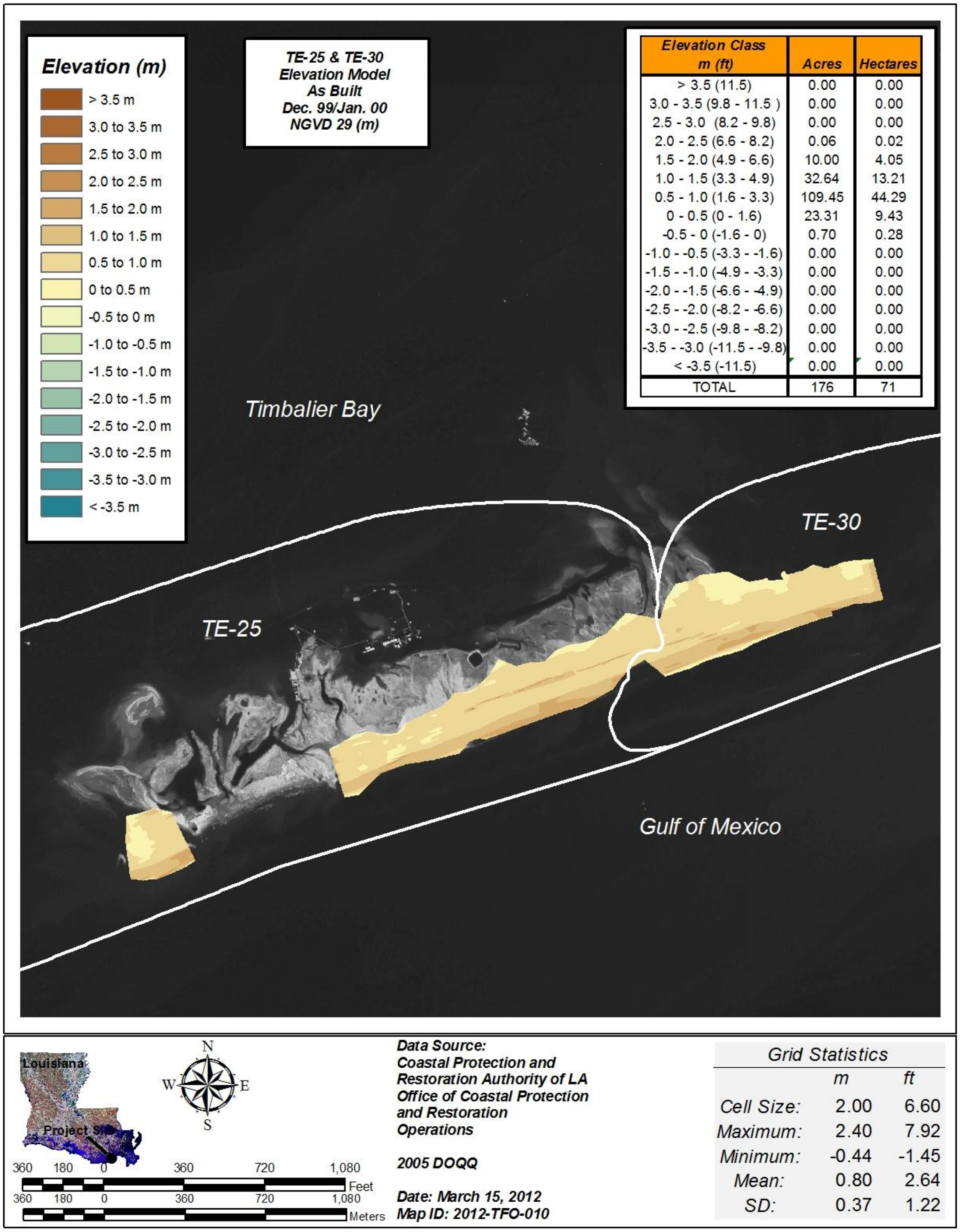


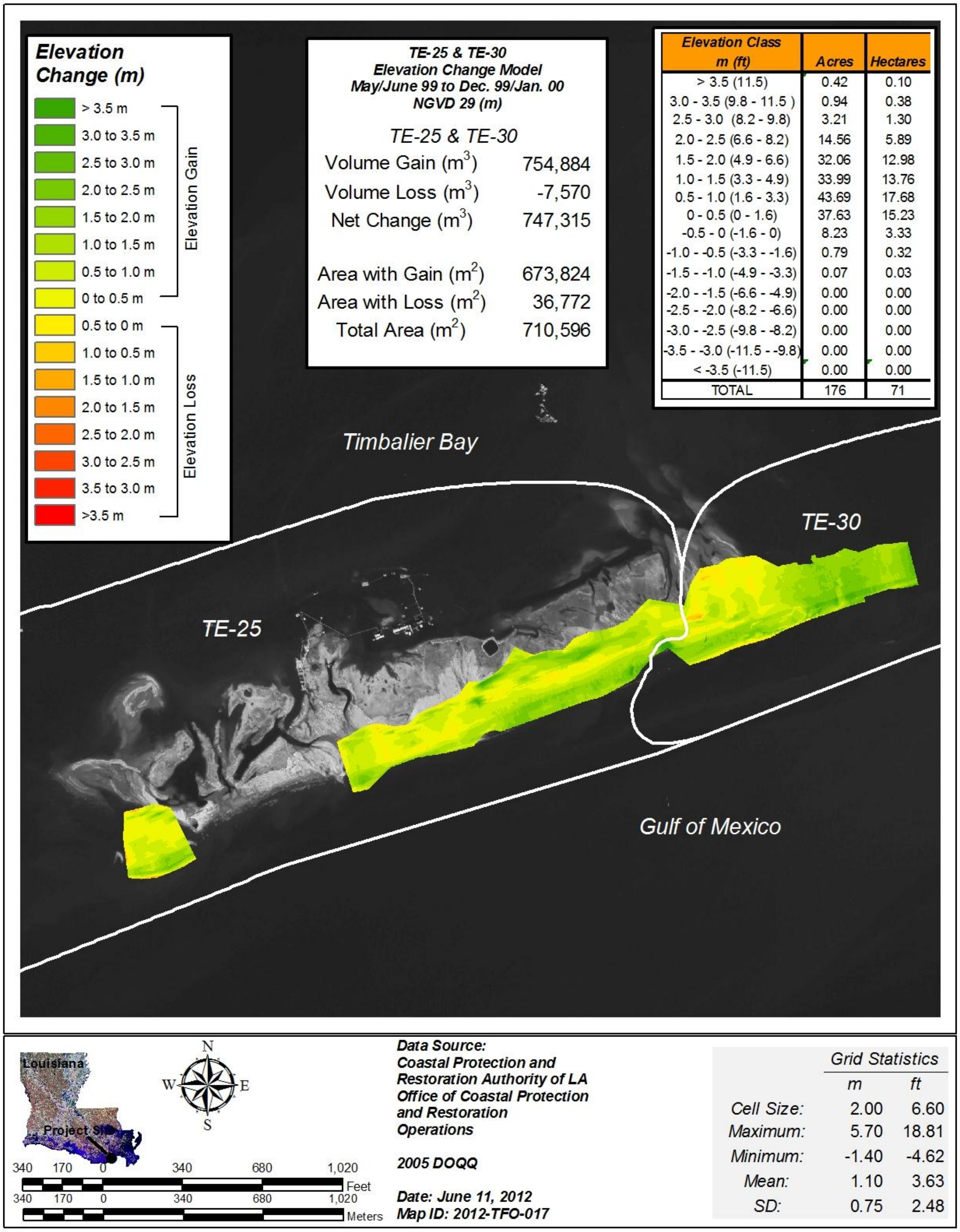
Figure 8. **Pre-construction digital elevation model of the TE-25 and TE-30 fill areas.**



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)	0.06	0.02
1.5 - 2.0 (4.9 - 6.6)	10.00	4.05
1.0 - 1.5 (3.3 - 4.9)	32.64	13.21
0.5 - 1.0 (1.6 - 3.3)	109.45	44.29
0 - 0.5 (0 - 1.6)	23.31	9.43
-0.5 - 0 (-1.6 - 0)	0.70	0.28
-1.0 - -0.5 (-3.3 - -1.6)	0.00	0.00
-1.5 - -1.0 (-4.9 - -3.3)	0.00	0.00
-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	176	71

Grid Statistics	m	ft
Cell Size:	2.00	6.60
Maximum:	2.40	7.92
Minimum:	-0.44	-1.45
Mean:	0.80	2.64
SD:	0.37	1.22

Figure 9. As-built digital elevation model of the TE-25 and TE-30 fill areas.



Elevation Class m (ft)	Acres	Hectares
> 3.5 (11.5)	0.42	0.10
3.0 - 3.5 (9.8 - 11.5)	0.94	0.38
2.5 - 3.0 (8.2 - 9.8)	3.21	1.30
2.0 - 2.5 (6.6 - 8.2)	14.56	5.89
1.5 - 2.0 (4.9 - 6.6)	32.06	12.98
1.0 - 1.5 (3.3 - 4.9)	33.99	13.76
0.5 - 1.0 (1.6 - 3.3)	43.69	17.68
0 - 0.5 (0 - 1.6)	37.63	15.23
-0.5 - 0 (-1.6 - 0)	8.23	3.33
-1.0 - -0.5 (-3.3 - -1.6)	0.79	0.32
-1.5 - -1.0 (-4.9 - -3.3)	0.07	0.03
-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	176	71

Grid Statistics	m	ft
Cell Size:	2.00	6.60
Maximum:	5.70	18.81
Minimum:	-1.40	-4.62
Mean:	1.10	3.63
SD:	0.75	2.48

Figure 10. Digital elevation change model of the TE-25 and TE-30 fill areas for the pre-construction to as-built period.

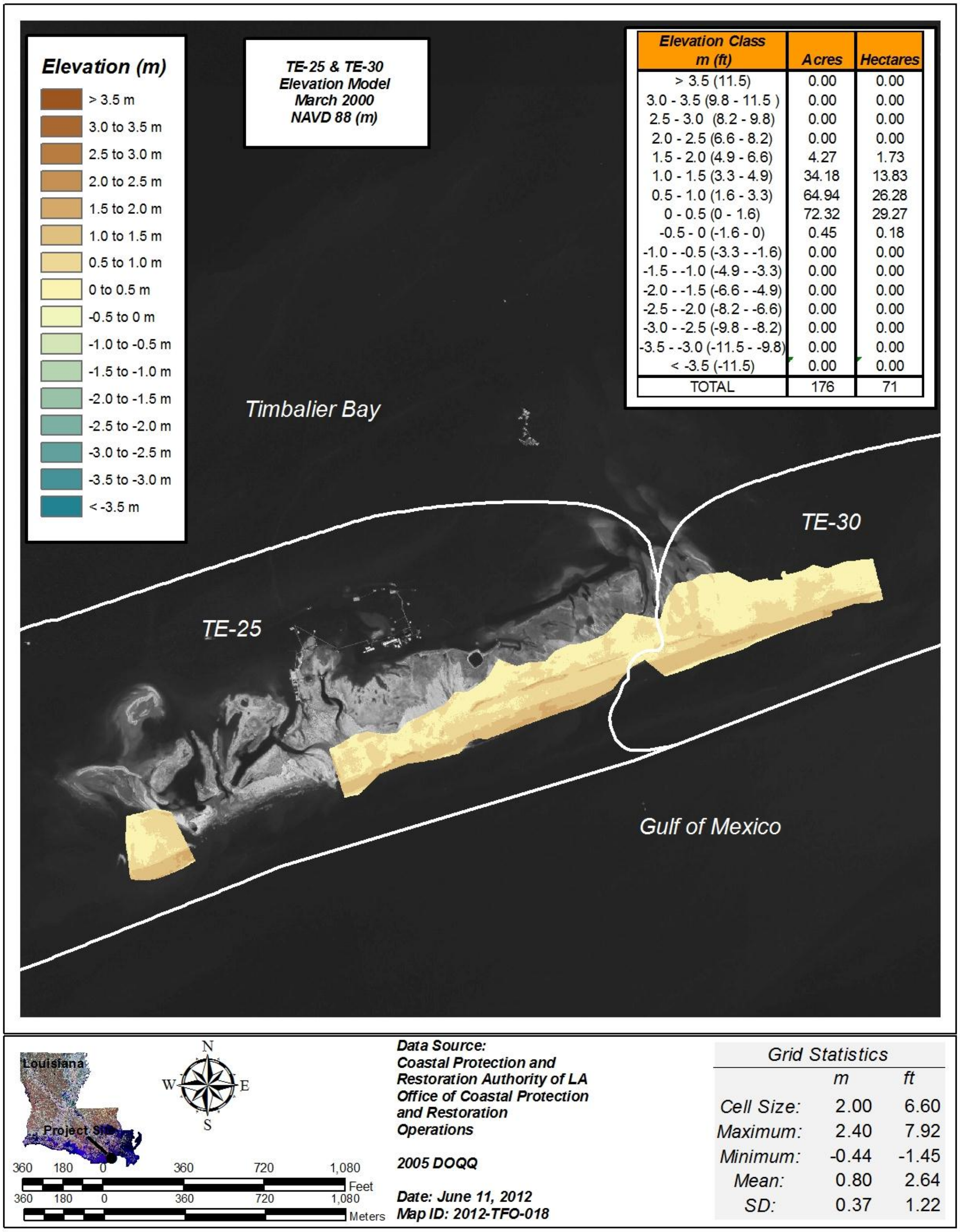


Figure 11. **March 2000 digital elevation model for the TE-25 and TE-30 fill areas.**

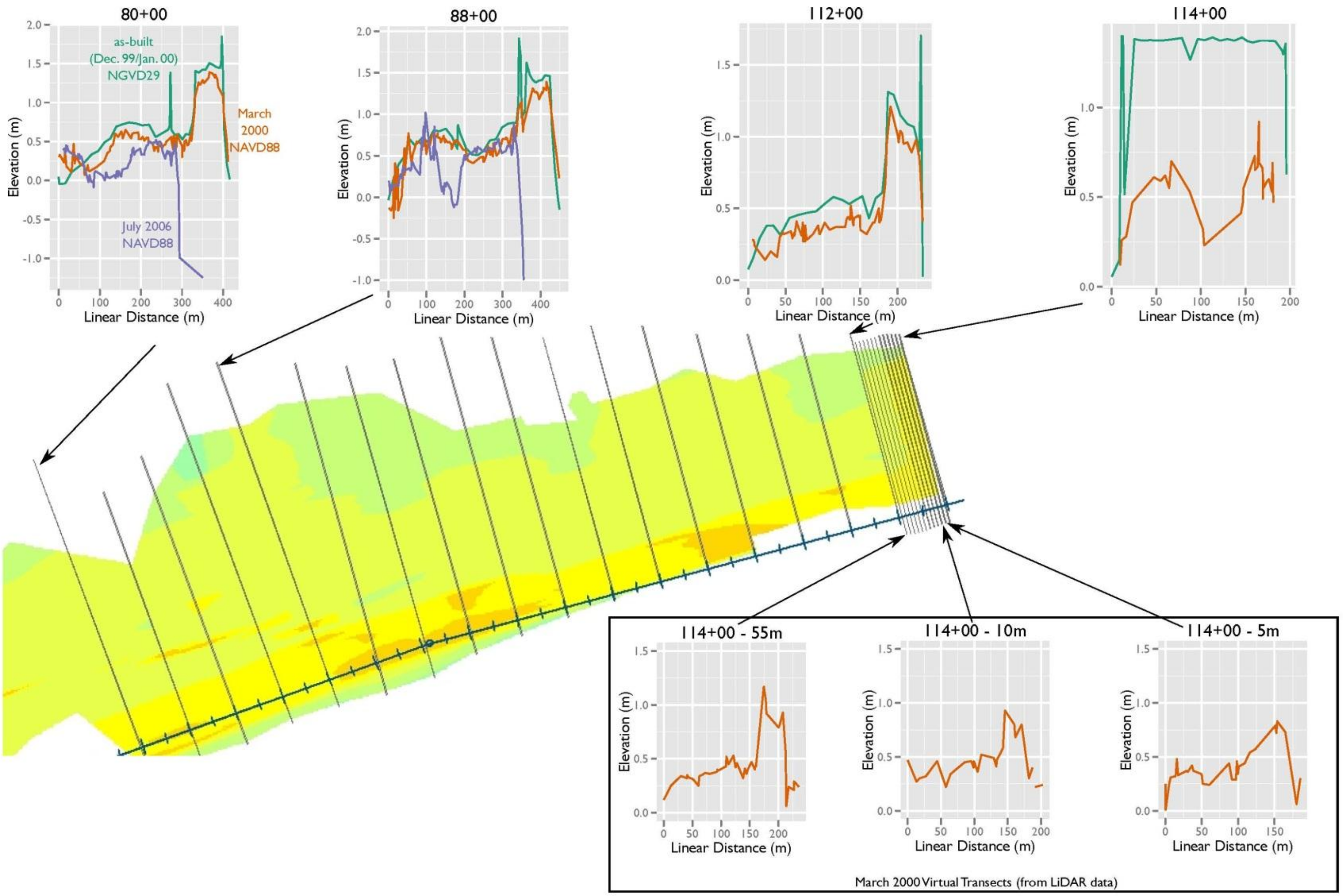


Figure 12. As built and March 2000 elevation profiles of the eastern portion of TE-30 derived from GIS elevation modeling. The x-axis is north to south, with 0 meters representing the bay (or northernmost) side of the island.

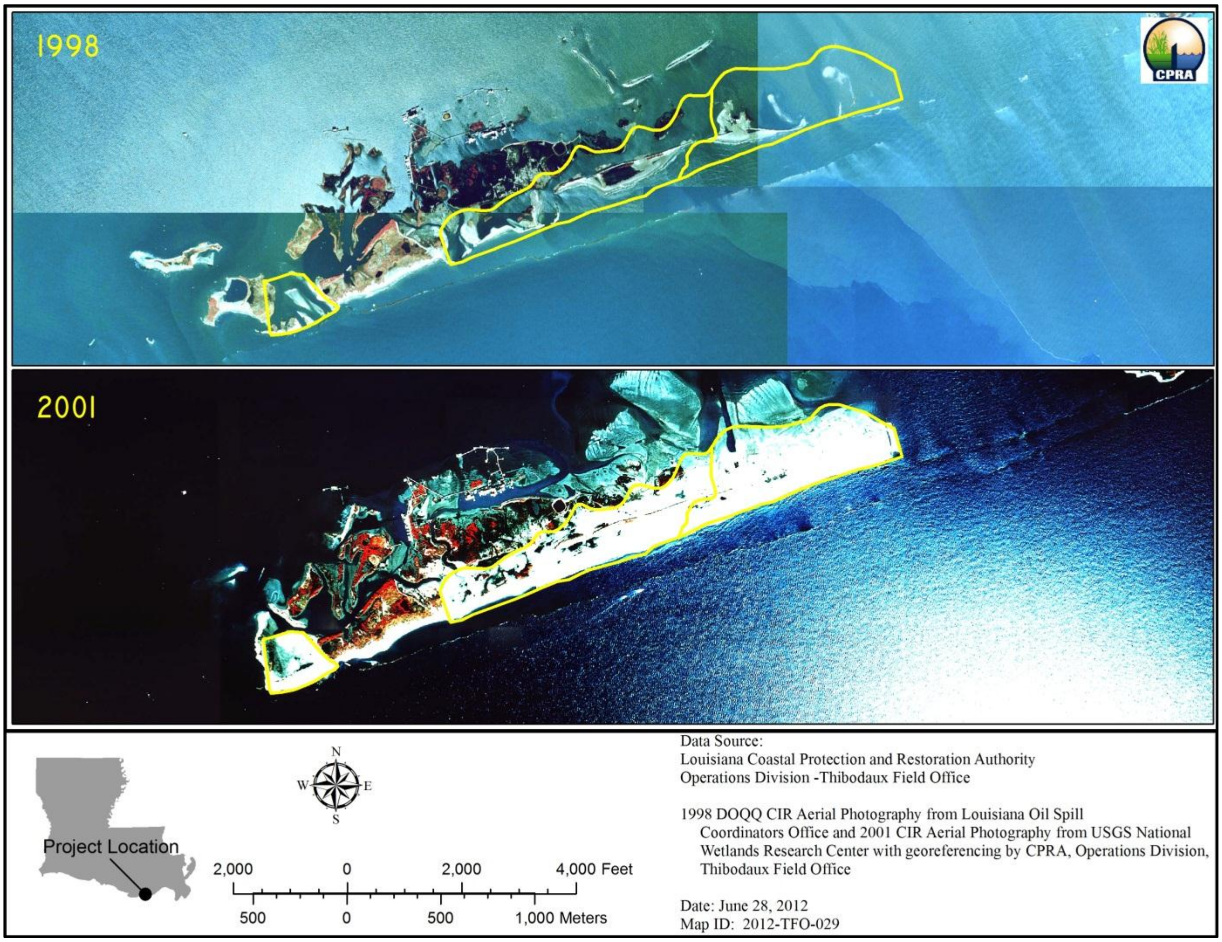


Figure 13. **Aerial photography (1998 and 2001) for East Timbalier Island. Note the addition of sand and sediment resources to East Timbalier Island by construction of the TE-25 and TE-30 projects.**

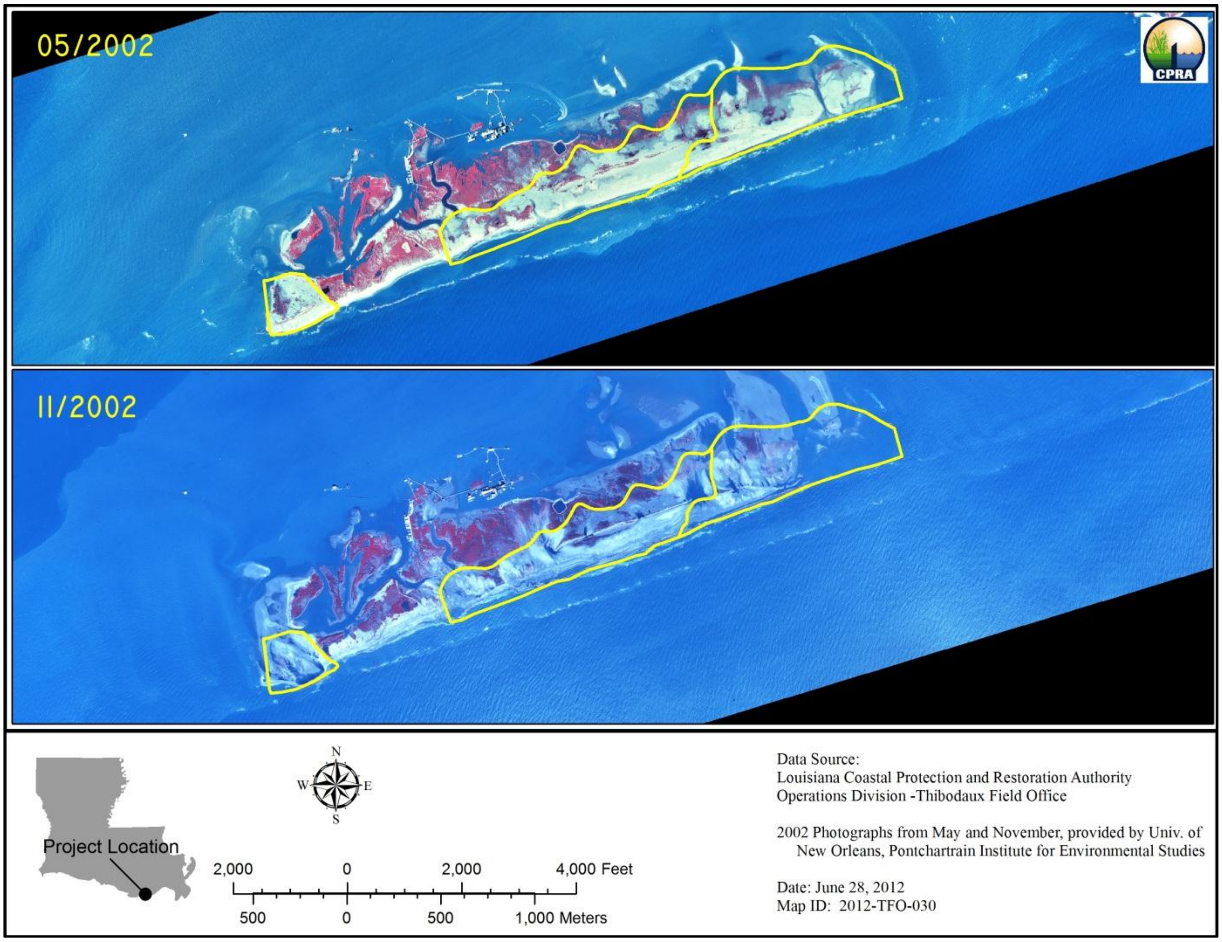


Figure 14. **Aerial photography (May and Nov 2002) for East Timbalier Island. Note the erosion induced by the 2002 hurricane season (Isidore and Lili).**

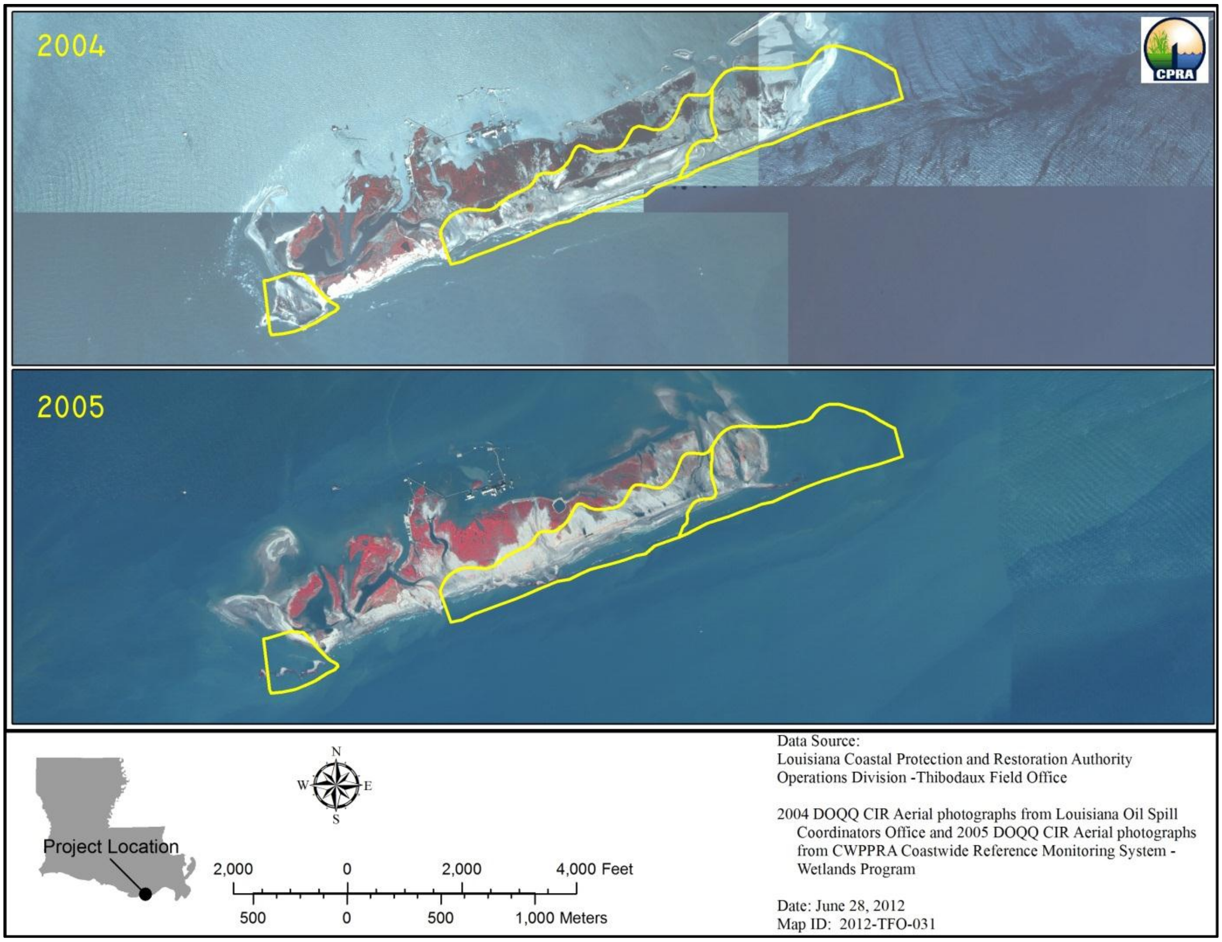


Figure 15. **Aerial photography of East Timbalier Island from 2004 and 2005. Note the erosion induced by the 2005 hurricane season (Cindy, Katrina, and Rita).**

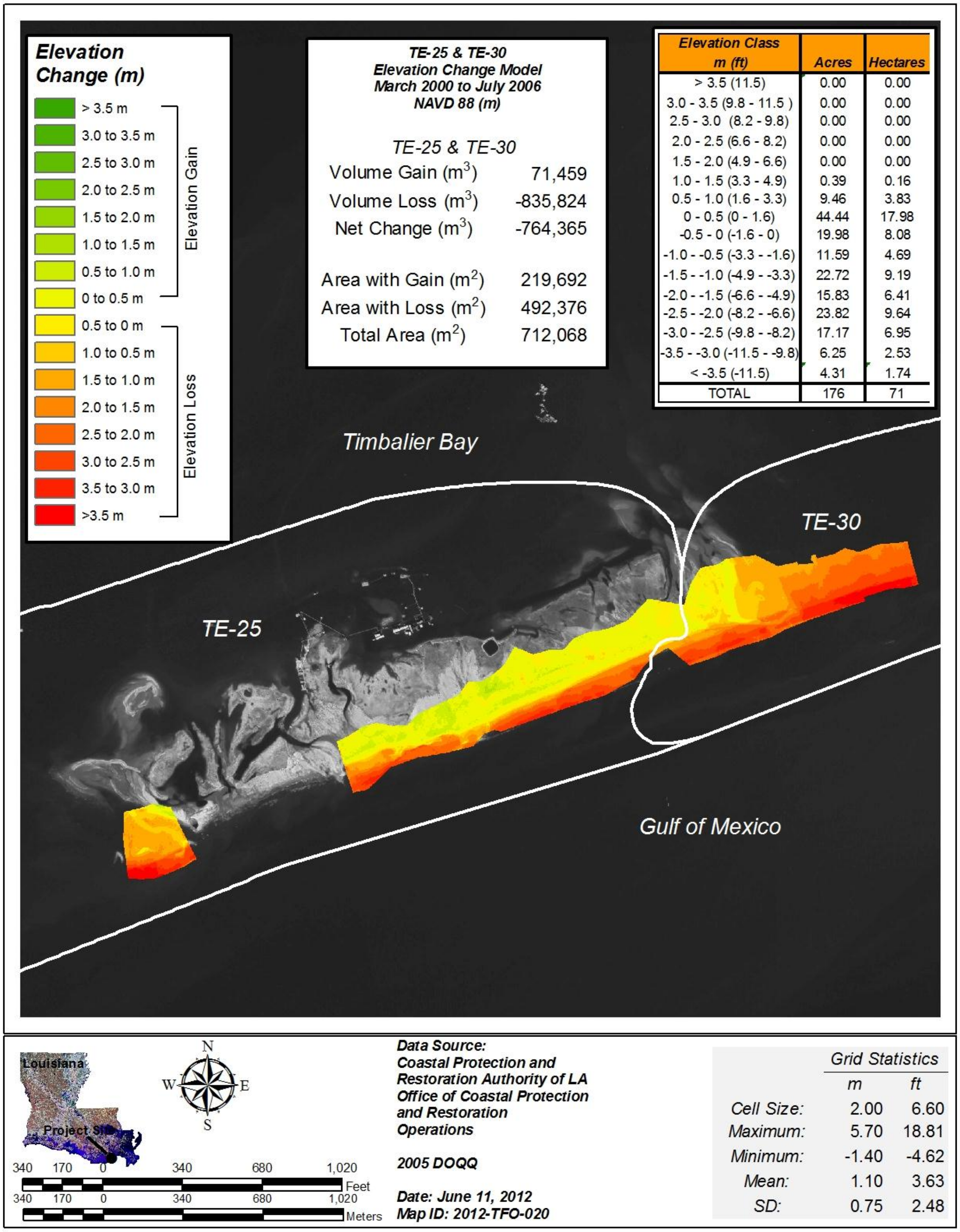


Figure 16. **March 2000 to July 2006 digital elevation change model for the TE-25 and TE-30 fill areas.**

Figure 17. Aerial photography of East Timbalier Island from 2005 and 2007. Note the post storm (Cindy, Katrina, and Rita) reworking of sand resources to East Timbalier Island during a period of low tropical weather activity.

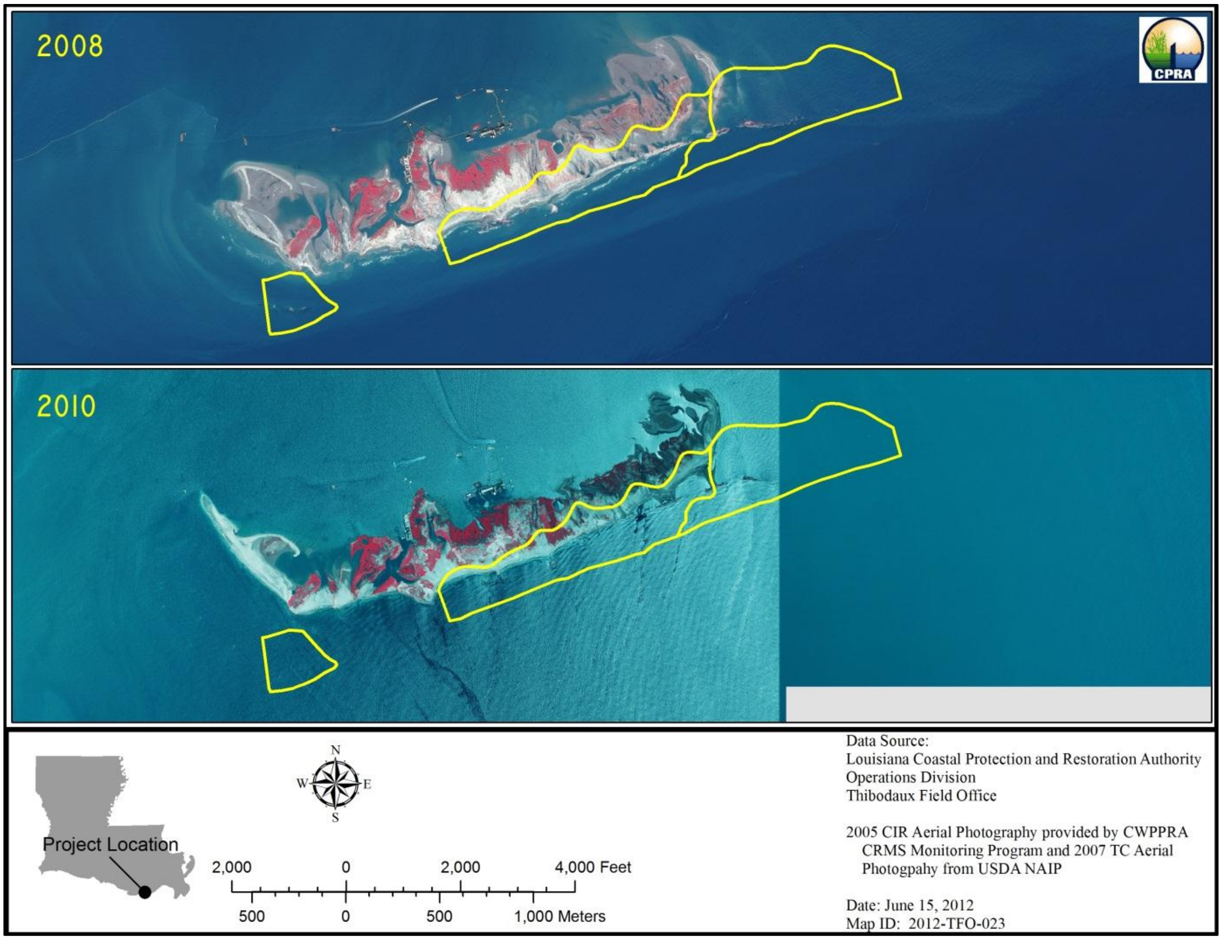


Figure 18. **Aerial photography of East Timbalier Island from 2008 and 2010. Note the erosion induced by the 2008 hurricane season (Gustav and Ike) and the absence of a post storm recovery on the island, especially inside the project areas.**

Vegetation

C. dactylon, *P. amarum*, and *Suaeda linearis* (sea-blite) were the most prevalent plants observed during the August 2001 vegetation sampling trip (Table 1; Figure 19). These species were observed in over 36% of the plots, with *C. dactylon* having the greatest mean cover in each of the three treatments and appearing to have filled in most vacant areas between plantings. Several over-wash areas were noticed during the sampling trip; planted rows were either dead or missing, and several planted rows closest to the Gulf of Mexico were washed away in several places. Many of the plantings of *S. patens* were reported to be dead or barely alive by field personnel. Furthermore, personnel reported that those still alive appeared to be stressed and no tillers were observed. In contrast, most plantings of *P. amarum* were alive except where washed away. *P. amarum* appeared to the field personnel to be tall and healthy although no tillers were observed. However, no significant differences for percent survival among fence treatments (Figure 20) and north/south of the fence (Figure 21) were apparent in sampled areas.

P. amarum and *S. linearis* were still fairly prevalent in 2002 (Table 2; Figure 22). *C. dactylon* displayed a decrease in cover and prevalence in 2002. Vegetative cover had increased over bare ground in treatments A and V but decreased in L (see Figure 4 for treatment design). During the September 2002 sampling trip, field personnel noticed that segments on the eastern end of the island were destroyed and most of the area was intertidal. However, some plant segments north of the sand fencing were still intact at the eastern end of the island. Percent survival was significantly higher ($p < 0.001$) in treatment V as this fencing configuration buffered vegetation to the inside of the V-configuration from over-wash, wave action, or scour (Figure 23). In contrast, treatment A appeared to be funneling over-wash into the fencing configuration and causing scour. Percent survival of planted vegetation was greater to the north of the sand fencing (Figure 24). The GLM was significant ($p < 0.05$). However, pairwise contrasts yielded no significant comparisons between species or north/south of the dune fence. That is, we may be seeing an overall effect in the location of planted vegetation, but we lack the statistical power to determine any significant differences between any two treatments/species (*i.e.*, inadequate sample size).

Table 1. Estimated mean percent cover for all species occurring during the August 2001 sampling of 2x2 m Braun-Blaunqet vegetation plots at East Timbalier Island (TE-25/30) project dredge material fill areas..

	A		V		L	
Species	**% Stations**	**Mean Cover**	**% Stations**	**Mean Cover**	**% Stations**	**Mean Cover**
Bare ground	100.0	90.9	100.0	84.8	100.0	85.6
Amaranthus greggii S. Wats.	2.8	5.0	5.6	0.8		
Cynodon dactylon (L.) Pers.	47.2	9.0	86.1	14.0	66.7	18.2
Heliotropium curassavicum L.	8.3	0.5	22.2	4.8	2.8	5.0
Iva frutescens L.			2.8	0.5		
Panicum amarum Ell.	52.8	3.1	58.3	0.8	44.4	1.4
Panicum virgatum L.			5.6	0.1		
Sesuvium portulacastrum (L.) L.	13.9	2.3	13.9	9.2	13.9	6.1
Solidago sempervirens (L.)	2.8	0.5				
Spartina patens (Ait) Muhl.	8.3	0.1	25.0	1.6	25.0	0.6
Suaeda linearis (Ell.) Moq.	66.7	4.5	36.1	2.2	47.2	0.7

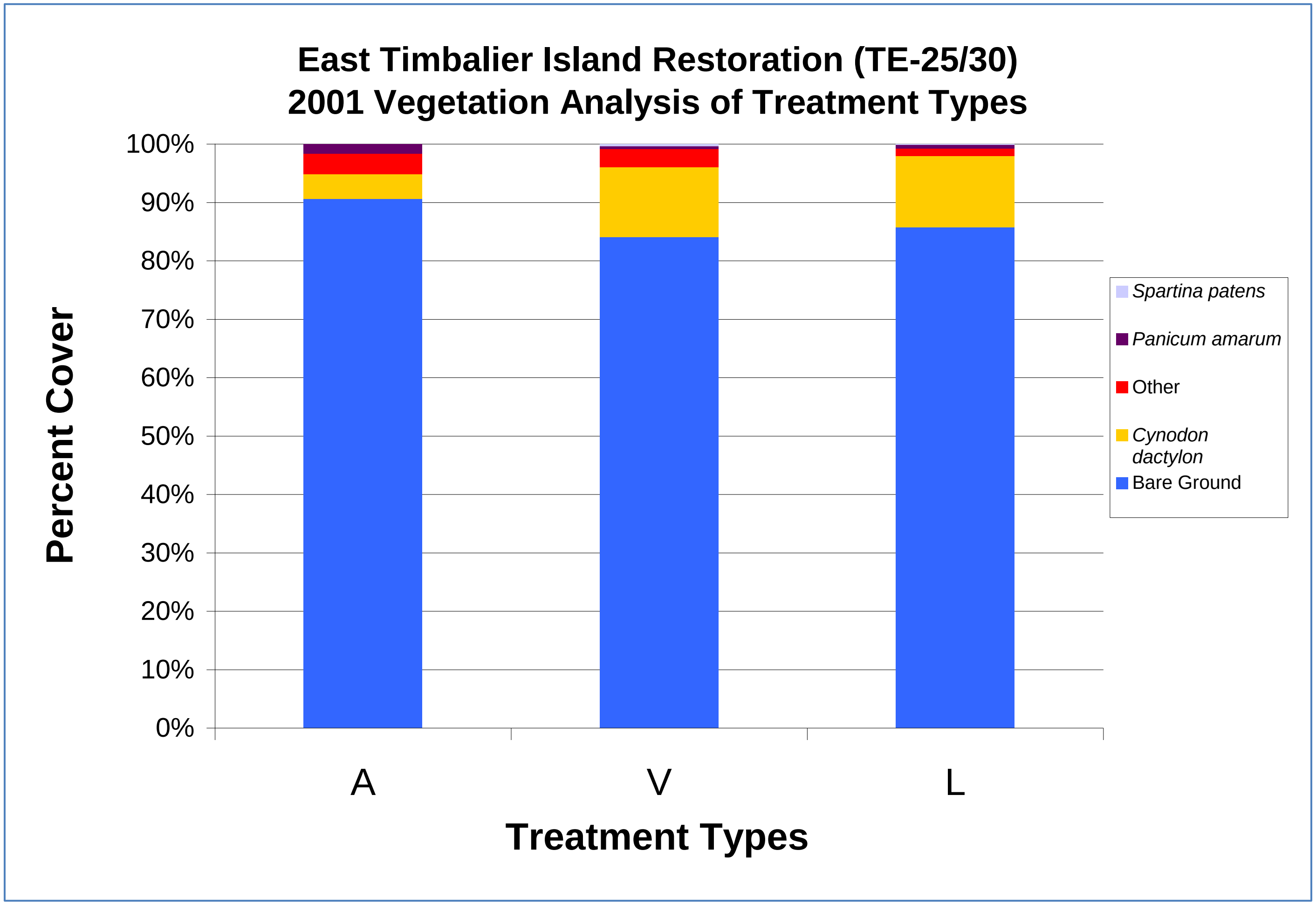


Figure 19. East Timbalier Island Restoration Phases I and II (TE-25/30) mean cover of selected species by treatments A, V, and L collected in August 2001 (6 months post-planting).

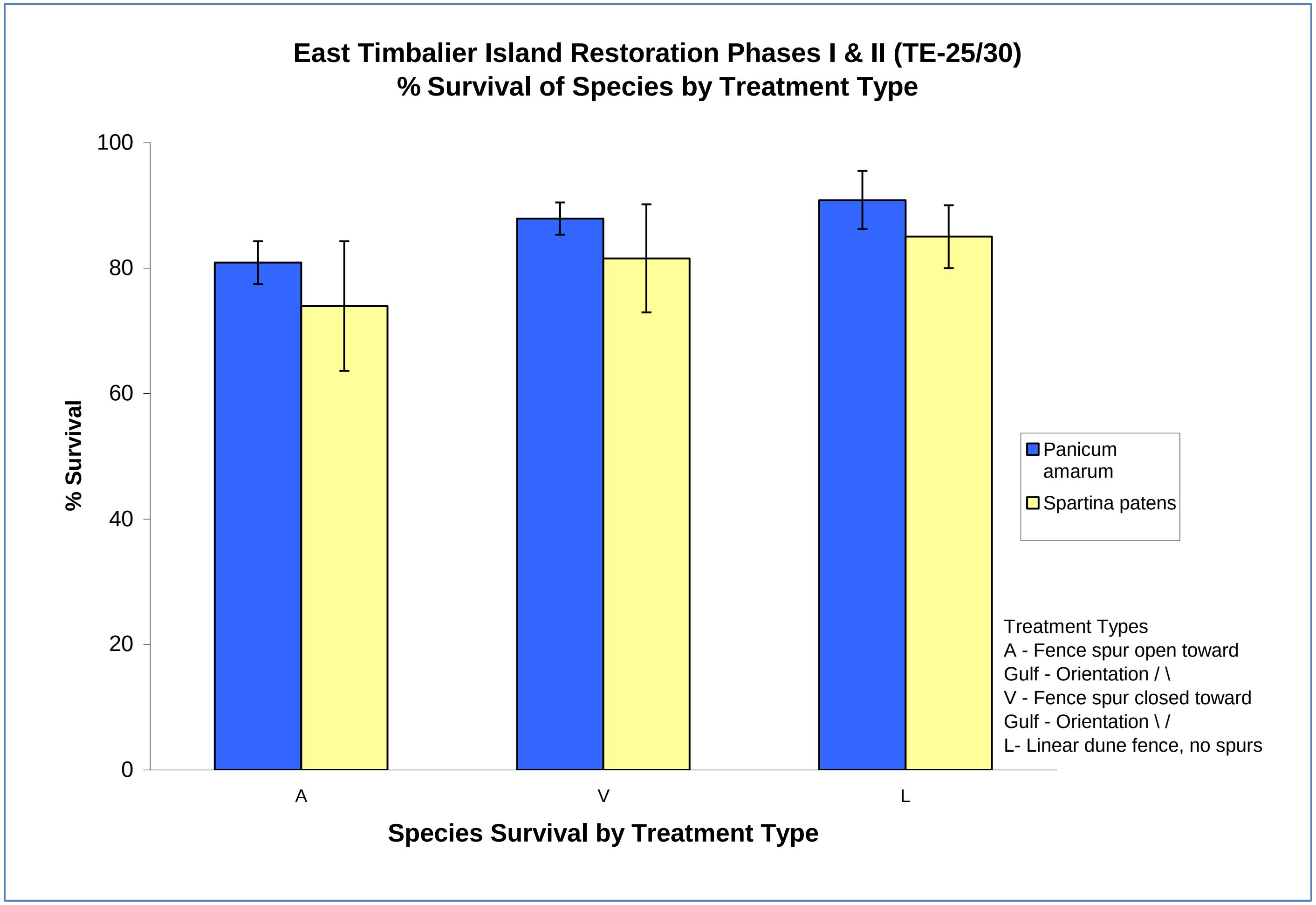


Figure 20. **East Timbalier Island Restoration Phases 1 and 2 (TE-25/30) percent survival of planted species within the A, V, and L treatments collected August 2001 (6 months post-planting). There were no significant differences in plant survival among treatments.**

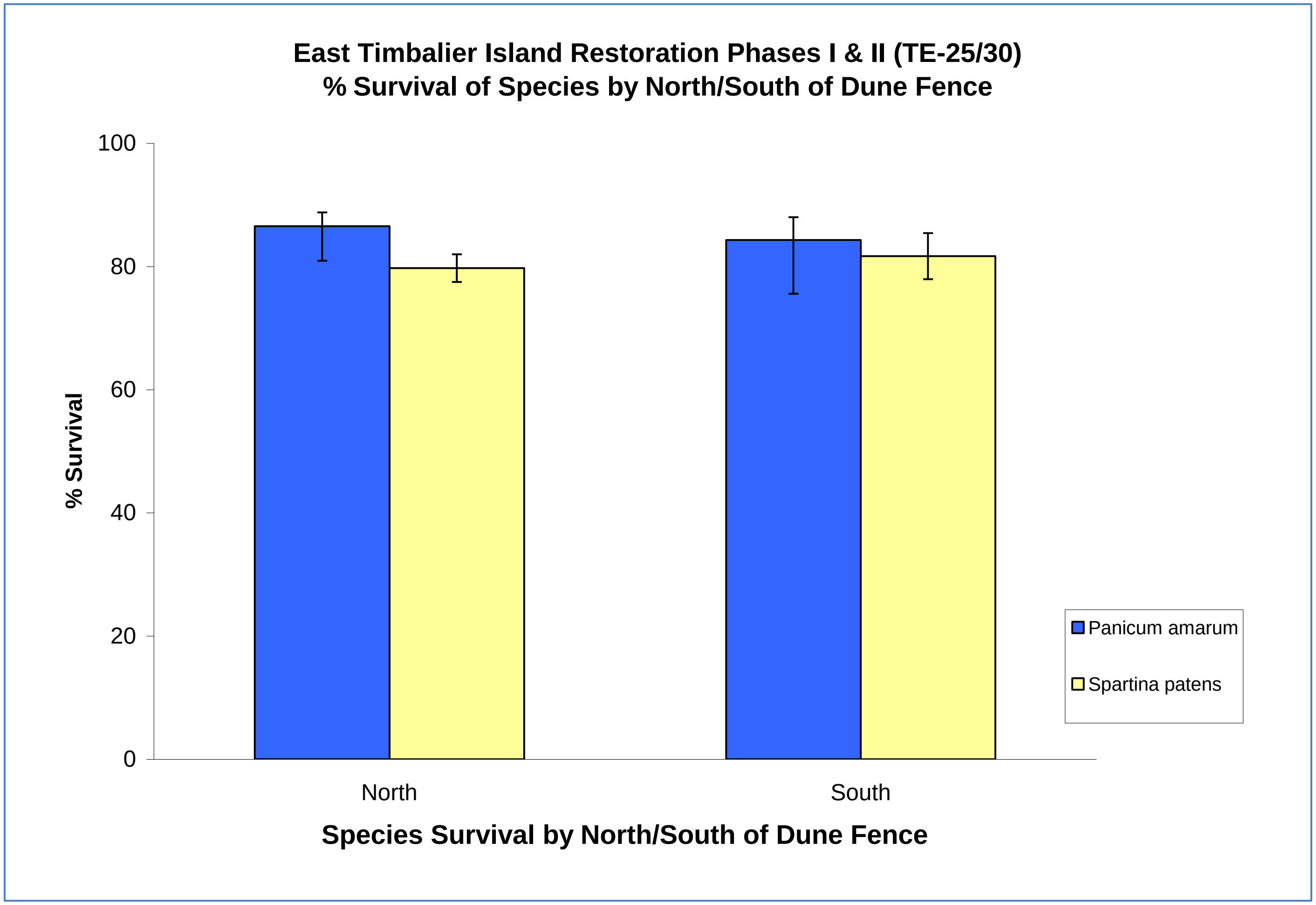


Figure 21. **East Timbalier Island Restoration Phases 1 and 2 (TE-25/30) percent survival of planted species north or south of shore-parallel dune fence collected August 2001 (6 months post-planting). There were no significant differences in plant survival.**

Table 2. Estimated mean percent cover for all species occurring during the September 2002 sampling of 2x2 m Braun-Blaunqet vegetation plots at East Timbalier Island (TE-25/30) project dredge material fill areas.

	A		V		L	
Species	**% Stations**	**Mean Cover**	**% Stations**	**Mean Cover**	**% Stations**	**Mean Cover**
Bare ground	100.0	82.4	100.0	72.2	100.0	92.6
Baccharis halimifolia L.	5.9	3.5	5.6	0.1		
Cynodon dactylon (L.) Pers.	17.6	7.2	77.8	13.3	19.4	10.3
Eustoma exaltatum (L.) Salisb. ex G. Don	2.9	1.0				
Heliotropium curassavicum L.	8.8	0.4	8.3	1.5		
Panicum amarum Ell.	44.1	29.7	77.8	16.1	35.5	21.8
Sesuvium portulacastrum (L.) L.	5.9	0.6				
Solidago sempervirens L.	2.9	10.0				
Spartina patens (Ait.) Muhl.	11.8	18.8	27.8	7.7	9.7	5.0
Strophostyles helvula (L.) Ell.			2.8	5.0		
Suaeda linearis (Ell.) Moq.	26.5	9.0	36.1	10.0		

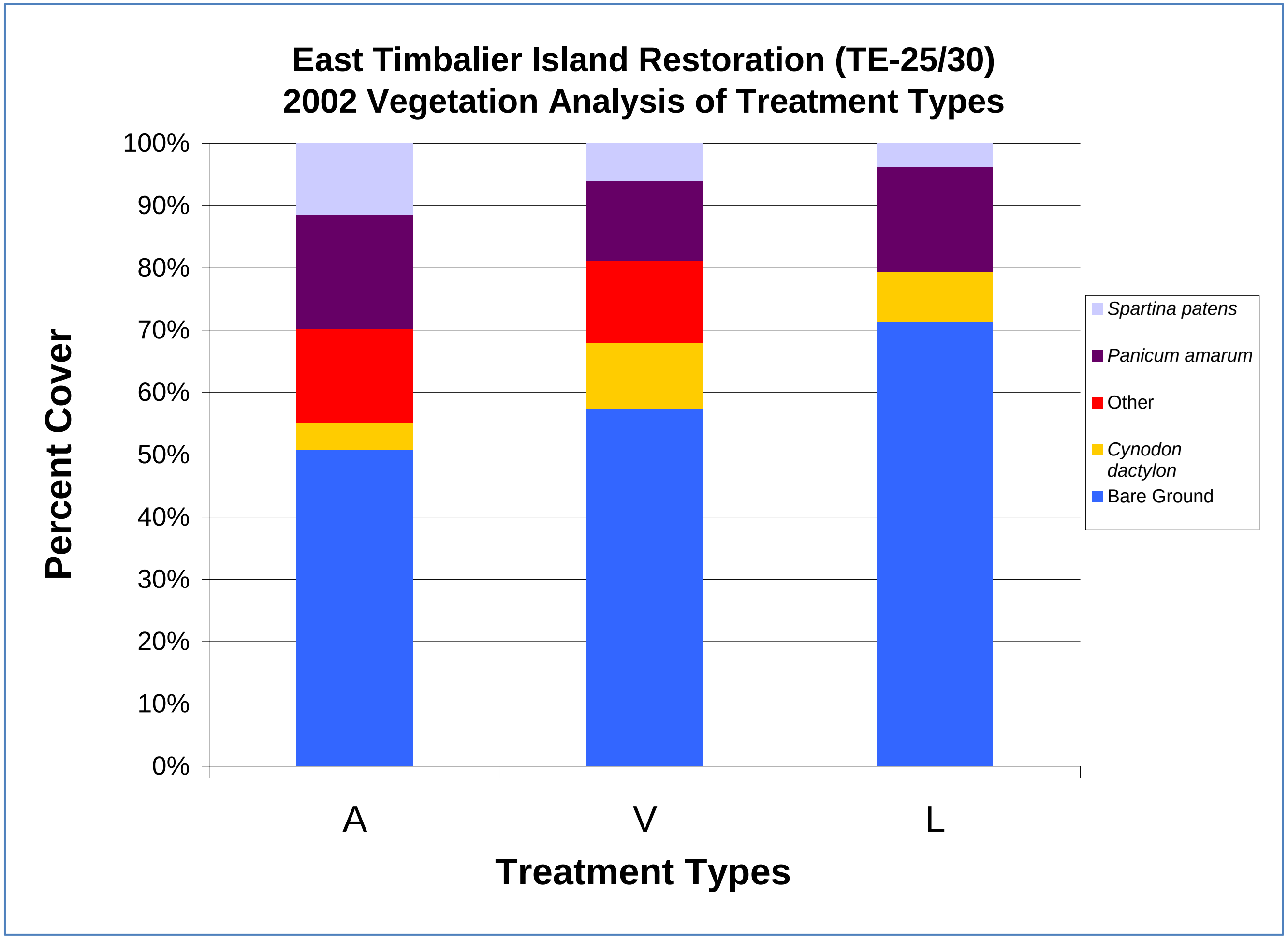


Figure 22. East Timbalier Island Restoration Phases I and II (TE-25/30) mean cover of selected species by treatments A, V, and L collected in September 2002 (18 months post-planting).

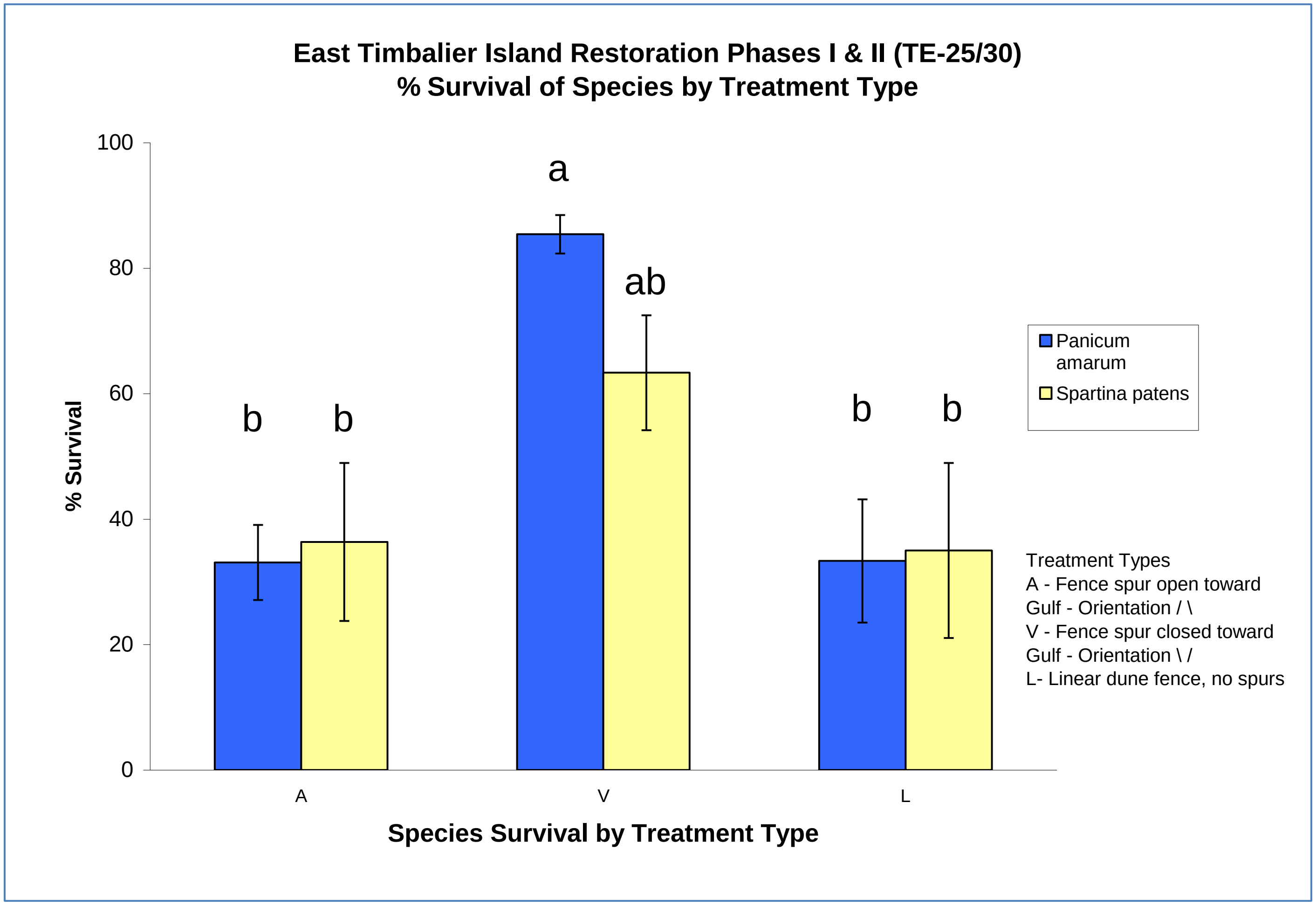


Figure 23. East Timbalier Island Restoration Phases 1 and 2 (TE-25/30) percent survival of planted species within the A, V, and L treatments collected September (18 months post-planting). *Panicum amarum* in treatment V showed a significantly higher percentage of survival ($p < 0.001$) 18 months after planting probably due to the wave and washover protection provided by the V fence configuration.

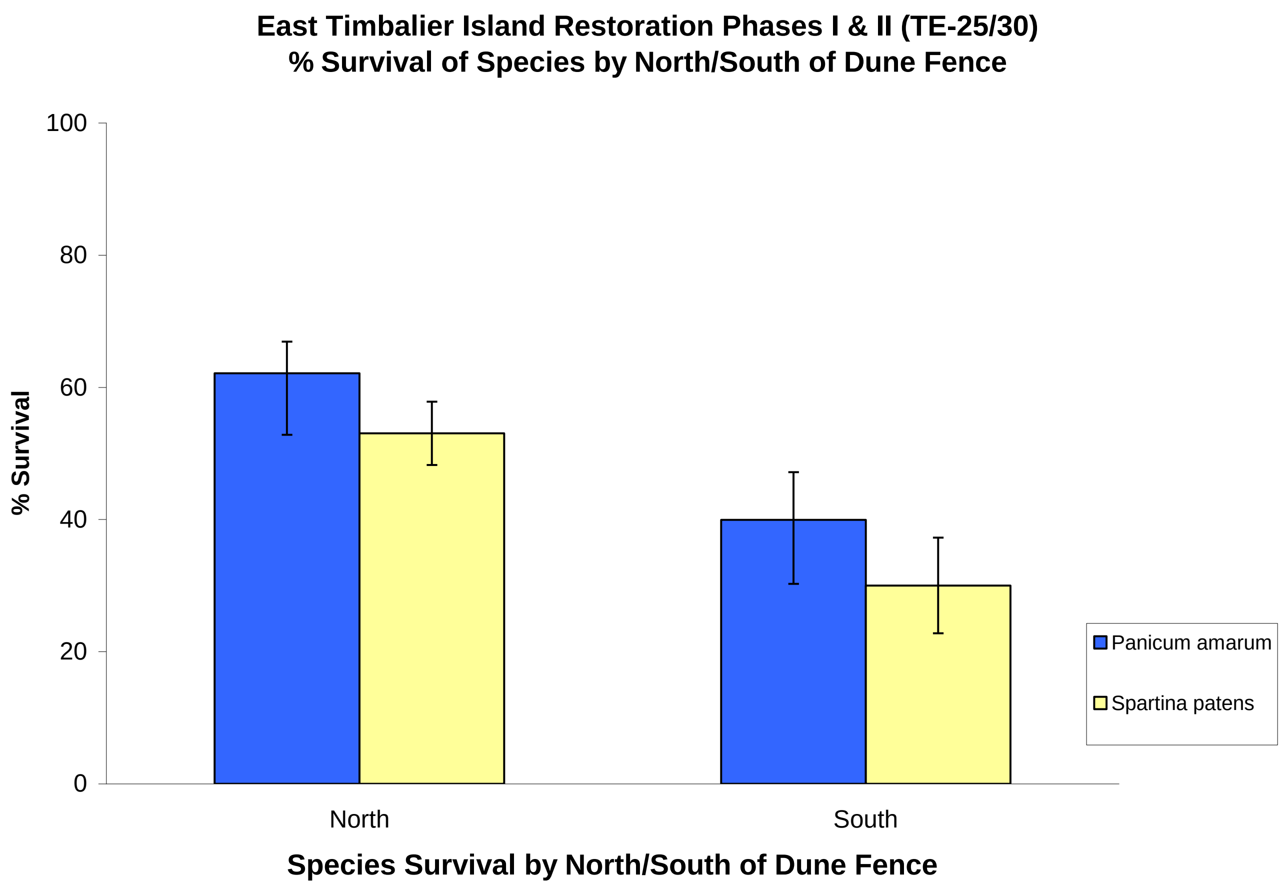


Figure 24. **East Timbalier Island Restoration Phases 1 and 2 (TE-25/30) percent survival of planted species north or south of shore-parallel dune fence collected September 2002 (18 months post-planting). There were no significant differences in plant survival.**

Habitat Mapping

Between 1996 and May 2002 the proportion of total land for the entire island increased substantially from 7% of total area (91.5 ha; 226 acres) to 10% (135 ha; 334 acres) (Figure 25). This increase was driven nearly exclusively by increases inside the project footprint (Figure 26) where bare land increased 27% (25 ha; 62 acres), marsh increased 11% (9.7 ha; 24 acres) and beach increased 9% (18 acres). Outside the project (Figure 27), bare land and beach areas marginally increased (13 and 1.6 ha, respectively; 18 and 4 acres).

Within 6 months most of these gains were lost. By November 2002, after hurricanes Isidore and Lili struck, the total land for the entire island dropped back to the near pre-construction level (7% of total area or 95 ha; 235 acres). This decrease was driven by losses inside (27.5 ha; 68 acres) and outside (12 ha; 30 acres) the project area. Inside the project footprint all land classes saw sharp decreases in area. Beach habitat was reduced to the pre-construction level and bare land was halved. Marsh habitat saw the smallest decreases. Outside the project area, decreases were less drastic but also occurred in all land classes.

After November 2002 total land for the entire island continued to decrease at a linear rate (Figure 25). Between 2002 and 2004, the project area lost beach habitat and to a much greater extent bare land (Figure 26). Outside the project area there was a small increase in total land driven by a gain in bare habitat (Figure 27). Between 2004 and 2005, when hurricane Katrina struck, there was a gain in beach both inside and outside the project area, but these were offset by a loss of marsh habitat and bare land.

The habitat data support the conclusions drawn from the elevation data. Between 1996 and May 2002 construction of the project added nearly 100 acres to the island. Most of this was lost during the 2002 hurricane season, with continuing loss occurring from late 2002 to 2004. There was a small gain in 2005, but this gain was negligible in the context of the overall project size. The projects, which had been compromised so soon, stood little chance against the panoply of storms buffeting the island. In particular, Hurricane Isidore passed directly over the island in September 2002 (Figure 28) and clearly caused significant erosion. After the 2002 hurricane season there was additional loss and then a small recovery, but the island remained on an overall decreasing trajectory.

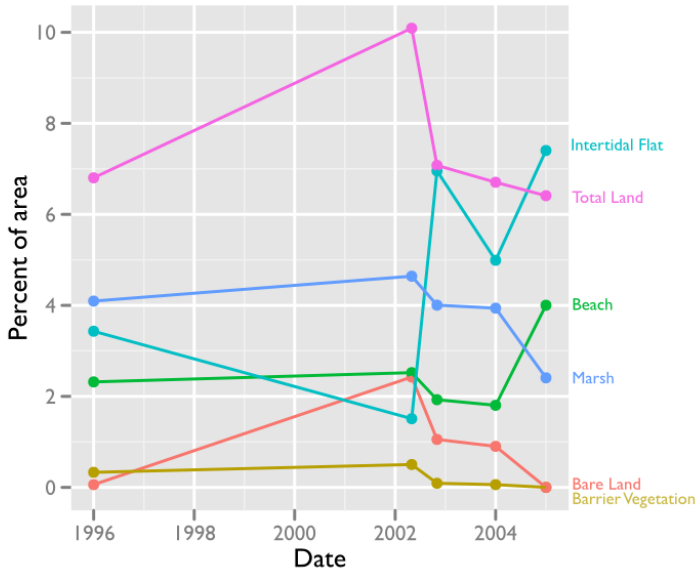


Figure 25. Proportion of habitat (relative to total area) for the entire East Timbalier Island.

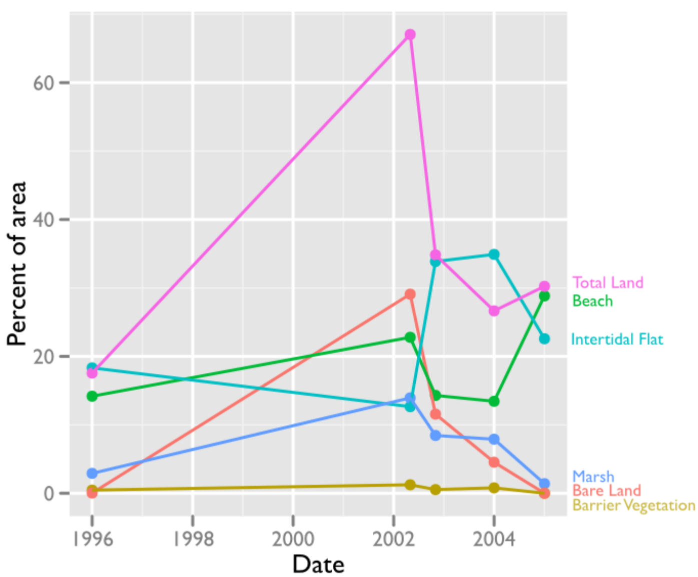


Figure 26. Proportion of habitat (relative to total area) for the TE-25 and TE-30 fill areas.

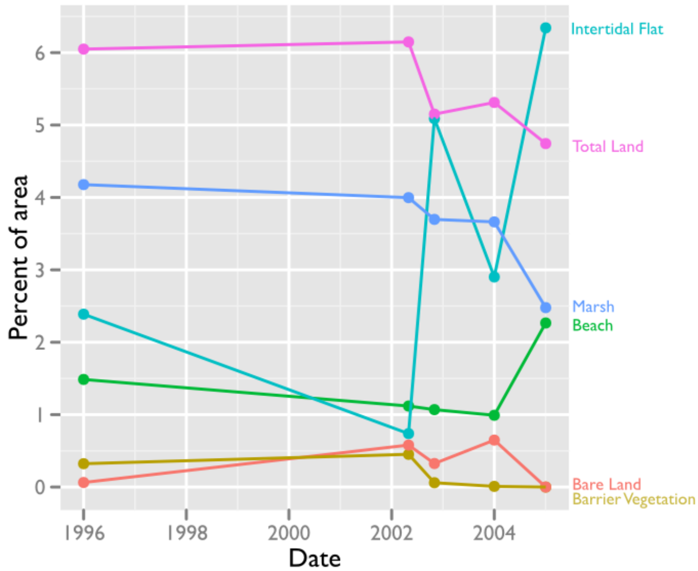


Figure 27. Proportion of habitat (relative to total area) for the area outside the TE-25 and TE-30 fill areas (*i.e.* Total minus Inside).

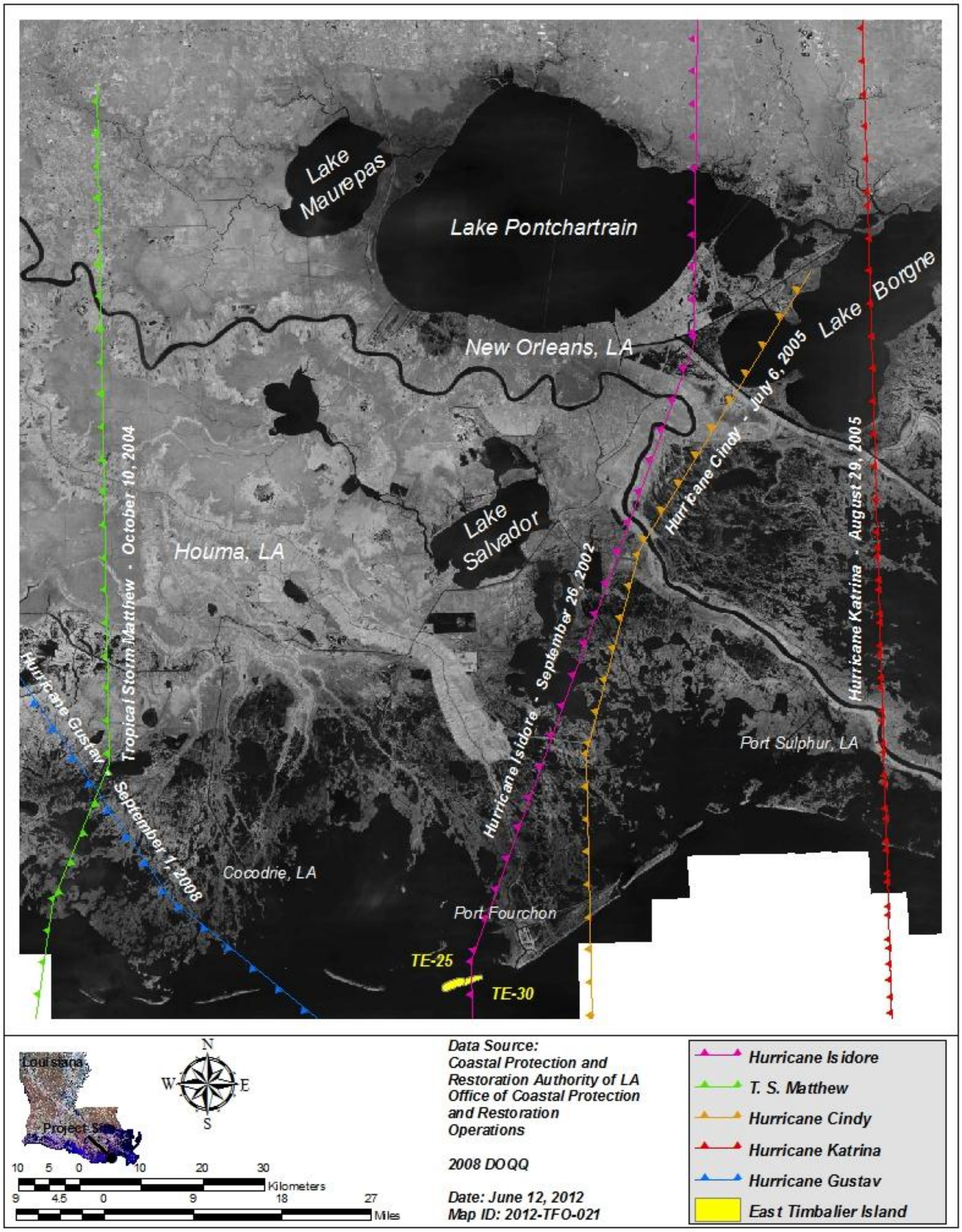


Figure 28. Hurricane tracks for storms that have passed near East Timbalier Island. Hurricanes Lili, (2002), Rita (2005), and Ike (2008) passed to the south of the pictured area.

Aerial Photography-Width and Length of the Island

Prior to construction fill area length was 720 m (2,362 ft) in 1996 and 861 m (2,825 ft) in 1998 (Table 3), consistent with the observation that the island was heavily degraded. In 2001, the first period after construction, the length of the island increased 3.6-fold to 2,848 m (9,344 ft). Fill area length decreased 139 m (456 ft) by May 2002 and by November 2002 had seen a greater decrease of 550 m (1,804 ft). Over the following two years (2002-2004) fill area length increased by 160 m (525 ft), but then over the next year (2004-2005) the fill area decreased by a staggering 1,845 m (6,053 ft). By 2008 no land was present along the fill area transect.

Fill area width responded similarly (Table 4). Prior to construction (1998), average width was 106 m (348 ft), 5 of the 19 transects had a width of 0 and nearly all less than 150 m (492 ft). After construction (May 2002) average width increased to 297 m (974 ft) and all transects were greater than 150 m (492 ft), with 14 of 19 greater than 200m (656 ft) and 5 greater than 300 m (984 ft). The average in May 2002 was 253 m (830 ft) and by November 2002 this had decreased slightly to 230 m (755 ft). Between 2004 and 2005 the width was nearly halved, from 230 m to 147 m (482 ft). By 2008 average width was 83 m (272 ft), less than the pre-construction estimate of 106 m.

Prior to construction width was greater on the bay side of the island (behind the fill areas) than for the fill area (Table 5). In 1998, average width measured 208 m (682 ft). After construction (2001), inside the fill area and the bay-side area had nearly equal widths (262 m *vs.* 297 m; 860 ft *vs.* 974 ft), but bay-side area decreased sharply to 149 m (489 ft) by May of 2002. Width remained relatively constant from May of 2002 through 2005. In 2007, bay-area width showed a rebound to the pre-construction level (207 m; 679 ft.), dipped slightly in 2008 and in 2010 returned to the pre-construction level.

Table 3. TE-25 and TE-30 fill area lengths in meters.

Station	1996	1998	2001	May-02	Nov-02	2004	2005	2007	2008	2010
TE-30	209	194	1160	1030	607	680	0	44	0	0
TE-25E	338	602	1405	1405	1405	1405	500	425	0	0
TE-25W	173	65	283	274	173	260	0	0	0	0
Total	720	861	2848	2709	2185	2345	500	469	0	0

Table 4. **TE-25 and TE-30 fill area widths in meters.**

Station	Transect	1996	1998	2001	May-02	Nov-02	2004	2005	2007	2008	2010
TE-30	1			173							
TE-30	2	41		341	189						
TE-30	3			327	260		83				
TE-30	4			337	231		260				
TE-30	5	44	125	379	269	206	361				
TE-30	6	121	91	436	351	351	365	282	278	31	
TE-30	7	186	134	362	301	292	347	249	243	96	42
TE-30	8			379	326	196	356	116	266	112	102
TE-25E	9	37	87	279	264	235	231	121	161	88	27
TE-25E	10	132	128	338	338	322	287	180	218	165	102
TE-25E	11	97	126	257	250	250	218	111	167	93	85
TE-25E	12	20	56	337	331	287	285	186	254	159	176
TE-25E	13	75	59	253	224	219	217	150	176	114	96
TE-25E	14	163	120	241	201	206	197	142	165	95	86
TE-25E	15	67	76	215	182	164	147	108	129	76	52
TE-25E	16	84	28	193	177	138	139	120	102	53	34
TE-25E	17	163	102	236	203	196	157	104	129	52	34
TE-25W	18	205	173	300	297	222	222	48			
TE-25W	19	176	184	266	159	144	36				
Average		107	106	297	253	229	230	147	191	95	76
		n=15	n=14	n=19	n=18	n=15	n=17	n=13	n=12	n=12	n=11

Table 5. **Width behind (bay side) the TE-25 and TE-30 fill areas in meters.**

Station	Transect	1996	1998	2001	May-02	Nov-02	2004	2005	2007	2008	2010
TE-30	1										
TE-30	2										
TE-30	3				53	34	142				
TE-30	4			242			23				
TE-30	5			204			10				
TE-30	6										
TE-30	7			158	41	20		75	85	48	86
TE-30	8	52		505	72	63	114	104	100	149	168
TE-25E	9	88	59	409	78	152	167	167	164	180	179
TE-25E	10	130	76	358	144	156	139	143	145	137	135
TE-25E	11	142	114	302	106	180	191	182	177	171	172
TE-25E	12			163	38	43	42	44	51	50	77
TE-25E	13	178	178	180	173	176	180	175	177	174	175
TE-25E	14	248	244	242	238	241	249	244	242	241	242
TE-25E	15	266	266	274	243	245	247	241	238	239	235
TE-25E	16	261	280	290	225	225	224	217	220	210	213
TE-25E	17	438	443	435	413	463	477	472	482	454	469
TE-25W	18			61	114		52	150	408	187	336
TE-25W	19			111				37		124	210
Average		200	208	262	149	167	161	173	207	182	207
		n=9	n=8	n=15	n=13	n=12	n=14	n=13	n=12	n=13	n=13

V. Conclusions

a. Project Effectiveness

The objective of the TE-25 and TE-30 projects is to increase the life expectancy of East Timbalier Island. To evaluate this objective two monitoring goals were identified: 1) increase the elevation and width of East Timbalier Island using dredged material and 2) reduce the loss of sediment through vegetative growth.

Survey, LiDAR and aerial photography data show that the goal of increasing the elevation and width of East Timbalier Island was achieved as a result of project construction. Nearly 100% of the area surveyed increased in elevation over the construction period, with a large proportion of area increasing between 0.5 and 2.5 m. In addition, transect widths and lengths show that the goal of increasing the width of East Timbalier Island was met. Project area width increased two-and-a-half fold with project construction and average width did not fall below the pre-construction average until 2008. Project area length also increased with construction and also did not fall below the pre-construction average until 2008.

The TE-25 and TE-30 projects clearly achieved their objective—to increase the life expectancy of East Timbalier Island. Although estimates vary, the island was predicted to disappear by 2001 (Penland et al. 2003; but see McBride and Byrnes 1997); however, even in 2007 the island was nearly equivalent to its size in 1998. In contrast, the life expectancy of a CWPPRA project is 20 years and evaluated by this standard these projects were not successful, as their life was short-lived. Without additional data on area and volume outside of the project area, evaluating the failure or success of the project is challenging. Future projects would benefit from identification of long term goals as opposed to goals that are met immediately after construction (as is the case for this first goal), or a broader goal based on island size and geomorphology through time.

Evaluating whether planted vegetative growth reduced sediment loss is also challenging. Between 1996 and May of 2002 the project area showed a substantial increase in total land. Between May and November of 2002 Hurricane Isidore passed directly over the island and Hurricane Lili passed nearby. These storms were devastating to the project, with a significant reduction in total land between May and November of 2002. Comparing losses among habitat types within the project area, bare (presumably unvegetated) land showed the sharpest decline; in contrast, marsh declined but at the lowest rate among the habitat areas. However, a quantitative evaluation of the plantings is impossible as most of the planting area was lost by 2004.

Regardless of the project meeting this particular goal, the rapid deterioration of the fill areas raises concerns. This island is undergoing the natural processes of the deltaic cycle and cannot be expected to last. Given the location of East Timbalier Island, the lack of a regular sediment source, conflicting oil and gas activities, and the accelerated degradation of the fill area, any additional projects to bolster this island should receive careful evaluation.

Hurricanes and winter cold fronts impact barrier islands through overwash activity (Dingler and Reiss 1990; Boyd and Penland 1981; Ritchie and Penland 1988). Cold fronts can elevate water levels by 0.9 m above mean sea level (MSL) and tropical storms and hurricanes can elevate seas 2-7m above MSL (Dingler and Reiss 1990). When this occurs water washes over these flat islands and carries sediment from the seaward to the landward side. These data show that both types of storms can significantly impact project life. Survey data demonstrate the power of cold fronts. The initial compromising of the project, between January and March 2000, is well outside of the hurricane season but is a period of frequent cold fronts. Degradation of the fill area is likely attributable to these fronts.

Although less frequent, hurricanes clearly have astounding impacts on the island. During the 2002 hurricane season Isidore passed directly over the island and Lili passed to the south and west (Figure 28). Habitat data show that between May and November 2002 (before and after hurricane season, respectively), the fill area was substantially degraded, losing a large proportion of land area. Our data support the hypothesis that increased tropical storm activity during the 2005 and 2008 hurricane seasons (Figure 28) reshaped the shoreface of East Timbalier Island (Figures 13, 15, and 16) as has been reported elsewhere (Barras 2006; Martinez et al. 2009; Fearnley et al. 2009).

Given the highly dynamic environment occupied by these islands and the basic geologic framework of barrier island evolution, eventual degradation of the island is unavoidable. However, the rapid deterioration of this island is somewhat surprising given the method of construction and CWPPRA barrier island projects elsewhere in Louisiana. The original design specified the construction of containment dikes prior to the pumping of dredged fill material. However, a lag between the design phase and the start of construction made this impossible. During this time lag some areas designated for containment dikes had transitioned and were then in 6 to 8 feet of water (Picciola & Associates, Inc 2000). The contractor and project sponsors agreed to a modified protocol whereby the area from 30+00 to 159+00 along the Gulf and 50+00 to 159+00 along the bay side would be filled without containment dikes. This decision resulted in a higher cut-to-fill ratio (see the Picciola & Associates Final Engineering Report for details on problems encountered in construction). The cause of the high cut-to-fill ratio is hypothesized to be due to most of the fine silts and clays in the fill material being washed away, leaving behind primarily sand. This heavier sand fill was expected to result in "a more durable island" (Picciola & Associates, Inc. 2000). That the island was "more durable" is a conclusion the data would be taxed to support. Unfortunately, whether the project might have been more "durable" if containment dikes had been constructed is not ascertainable. Regardless, durability and longevity of the island (and therefore the project area) are strongly influenced by local geology.

Sand supply is the primary factor affecting coastal change along Louisiana's transgressive shorelines (Miner et al. 2009). Longshore transport from the Caminada headland to the west occurs at a rate of 11,000 m^3/yr (Georgiou et al. 2005). Ideally, tidal inlets like Raccoon Pass, which is located between the Caminada headland and East Timbalier Island (Figure 2), develop a tidal delta. Tidal deltas serve as a storage buffer for sand that is moved along the shoreline by longshore transport (Davis and Fitzgerald 2004). Historically, this sediment continually moves westward through downdrift ebb-tide deltas (primarily Cat Island Pass) until it is ultimately deposited in coastal bights (Miner et al. 2009). However, significant and rapid westward lateral expansion of the Caminada headland shoreface erosional zone since the 1880's has resulted in the loss of the ebb-tidal delta at Raccoon Pass; *i.e.*, the deltaic lobe that would extend seaward from the mouth of the Raccoon Pass tidal inlet is absent (Miner et al. 2009). This loss has profound implications for East Timbalier Island. Because the deltaic lobe is absent from Raccoon Pass and because this tidal inlet is shallow (4 m scour depth), shoreface erosion leads to rapid loss of deposited sediment.

Compounding this are the jetties at Belle Pass and the pre-project rock shoreline features on East Timbalier Island. The jetties and the rock seawall have created a shadow that inhibits both the westward movement of sediment by the longshore current and cross shore deposition of sediment on East Timbalier Island (Penland and Suter 1988; Stone and Zhang 2001). At Belle Pass, the western shoreline has eroded so extensively that its face is now angled behind East Timbalier Island and the residual longshore transport probably moves most sediment into Timbalier Bay (Figure 3).

Additionally, the continued maintenance of deep water sediment sinks directly behind the island, in the form of oil and gas access canals, must be addressed in any future efforts (Figure 29). Overwash of sediment onto a shallow marsh or bay platform is a major factor increasing barrier island longevity. Therefore, "conservation of mass" is prevented by maintenance of sediment sinks which capture overwash sediments in deep holes. Sediment is then removed and dispersed by canal maintenance activities.

Altogether, these processes—shoreface erosion, elimination of tidal lobes, the longshore current shadow, and the failure to "conserve mass"—starve East Timbalier Island of life-giving sediment. Rectifying this sediment starvation by establishing a sediment source is probably the greatest challenge facing this island. Whether this source should be natural, as in a modification of the jetties to allow greater longshore transport, or manmade, through additional restoration projects, is unclear. However, if the island is to remain, a sediment source must be established.

Figure 29. **Maintenance dredging of oil and gas access canals behind East Timbalier Island immediately before Hurricanes Katrina and Rita caused island overwash (photo taken by CPRA June 21, 2005).**

b. Recommended Improvements

There are no recommended improvements at this time. Any improvements would have to be incorporated into a new restoration project.

c. Lessons Learned

These projects experienced several difficulties during construction. Many of the lessons learned from these obstacles have been documented elsewhere, but as they are not unique to these projects they may bear repeating here. In addition, we include lessons in monitoring that have arisen as a result of recent data analysis.

Perhaps one of the most important lessons and yet the most difficult to address is timeliness. Two years lapsed between conclusion of design and the beginning of construction. During this lapse site conditions changed such that the original project design was unfeasible. The shoreline of the TE-25 and TE-30 project areas had receded and a breach in the TE-30 project area had deepened. These changes led to abandonment of a confined fill project design; construction of containment dikes was impractical. Projects now require the selected contractor to perform a pre-construction survey to verify changes and quantities before construction begins. This allows design changes to be discussed and approached before construction begins, thereby greatly benefitting these efforts. We recommend continuing this approach.

A second complication was the dredging approach. To begin, borings were taken throughout the borrow site from the mud line to a 32' depth. Analysis of these borings by both Gore Engineering and Eustis Engineering indicated a minimum sand composition of 70%. These analyses were based on the exclusion of cohesive material (clay), which appears to have inflated the estimate of sand composition as the proportion of sand in the borrow area was closer to 60% (Picciola & Associates, Inc 2000). This led to artificially high expectations for dredging production.

A dust-pan dredge was chosen for initial construction by the contractor. Dust-pan dredges use water jets to dislodge material and a pump vacuums the suspended matter, resulting in a product that consists mostly of sand with little clay or silt. This sand-rich material is ideal for barrier island restoration. The downside of this approach is that production rates are dependent on the proportion of sand in the borrow area, which, in this case, was low. The dust-pan dredge "Beach Builder" began production on July 7th. After a month of dredging the contractor was disappointed with the production rate, which was much lower than expected. A smaller cutter-head dredge was mobilized but by mid-October weather forced demobilization of this dredge. Finally, a larger cutter-head dredge was brought in to complete the project. The smaller cutter-head produced at a rate 2.1 times faster than the dust-pan dredge. The larger cutter-head brought this efficiency up to 2.74 times faster. However, both cutter-head dredges pumped unsorted fill (*i.e.* sand with silt and clay). During the confined phase the ratio of material removed to material filled (cut-to-fill) stood at 1.2 to 1. As the phase of unconfined construction began, the cut-to-fill ratio increased to 2.1 to 1. When construction reached areas of the project that were both uncontained and had no offshore protection (*e.g.* rock walls), the cut-to-fill ratio skyrocketed to 5 to 1 (Picciola & Associates, Inc 2000).

These multiple factors conspired in hindering construction of the project. The geotechnical analysis of the borrow area led to high expectations. When these expectations were not met, the contractor moved to a less selective form of dredging. This approach was adequate when the dredged material was contained, but when construction began on the uncontained portion of the project this approach was dubious. The contractor could not construct containment dikes because the project footprint included areas open to surf, which had eroded and opened up during the delay between design and construction. Because of this the cut-to-fill ratio skyrocketed as unconstrained wave action carried away low-density clay and silt particles.

The delay in construction along with the overestimated quality of the borrow site are the sparks that set off a chain reaction of responses which ultimately led to incomplete construction of the project. The lesson to be learned here is that delays in construction can cause challenges beyond those directly related to the delay. In such a dynamic system the ideal approach is better geophysical analysis of borrow sites and to eliminate delays. This latter issue is unpragmatic for a number of reasons. A more pragmatic approach may be to plan for contingencies. For example, if a containment dike cannot be built, are there alternate construction templates for the project or will the area be filled unconfined. In addition, permits, sediment sources, and funding must be adequate to address any potential changes. An immediate pre-construction survey has proven to be invaluable in these situations.

Whether to enforce a design template for future projects at East Timbalier Island or to fill uncontained is also important for future consideration. Construction without a template seems an unorthodox approach that would lead to rapid deterioration of the project, and is not valued highly within the current Wetland Value Assessment (WVA) model used to define project benefits. The TE-25 and TE-30 projects were constructed with a template and even when filled uncontained a design template was followed. Yet, the TE-30 fill area was quickly reshaped by the dynamic forces in the area. With this particular system (East Timbalier Island specifically), a more cost-effective approach may be to pump sediment on to the island without any containment or template and allow the natural forces to shape the area. This approach could reduce costs by eliminating mobilization of equipment and manpower to shape the dune and fill area which storm and wave action would likely rapidly reshape anyway. Additionally, the overall geology of areas similar to East Timbalier Island may be better served through greater sediment inputs rather than achieving specific dune heights, particularly where shoreface erosion creates steep profiles.

Another lesson to be learned is the transparent and appropriate use of data and analyses. Analysis of sediment cores followed the ASTM D-1140 standard, but this resulted in an inflated estimate of sand content in the borrow area. The final construction report (Picciola and Associates 2000) suggested decreasing the boring spacing and analysis of all material taken in the boring. These are sound suggestions and an updated protocol on the exploration and analysis of offshore sand sources has been produced by CPRA (Khalil 2010). In addition, we recommend inclusion of a complete description of the analysis and open access to the data. Open access to the data allows for expectations, such as the sand content of a borrow area, to be independently evaluated. Data for sand source analysis is openly available to contractors through the LaSARD database.

A final aspect of construction that requires attention is the calculation of payment. These projects paid on the cut, which was cost-effective when the cut-to-fill ratio was low. When the cut-to-fill ratio skyrocketed to 5-to-1, paying on-the-cut rapidly ate away the budget, forcing construction of a smaller template. Other projects have payed on-the-fill which encourages contractors to use quality fill material that will not easily wash away during construction. However, this places added risk on the contractor and consequently project costs have increased. Discussion and evaluation of payment methods need to continue and decisions should be based on the quality of

Figure 30. **Panoramic photo mosaic showing the effects of non-shore parallel sand fencing at the Isle Derniers – East Island CWPRRA project (TE-20). Note the scour on the left where the overwash was focused along the dune to the bayside of the island causing complete vegetative cover removal post storm.**

the borrow site and issues associated with the fill area, such as containment, depth, and breaches in the shoreline.

Lessons learned for monitoring also reflect issues related to the construction of a project in a dynamic system. The first lesson is differentiation of the project area and the study area. Analysis of elevation data was limited to the project footprint because the initial surveys covered only this area. However, the impacts of this project likely were felt outside of the project area. Between 1996 and May 2002, the project area saw a large increase in bare land habitat; outside the project area there was also an increase in bare land. In fact, this increase was nearly one-third the size of the project area's increase (18 and 62 acres, respectively). We suggest that this increase was likely the result of a shift in sediment from within the project area to outside. Documentation of such an indirect benefit is vital to evaluating the success of the project. Monitoring of the project area, a secondary impact area, and an appropriate reference would be ideal and would allow elucidation of impacts outside of the project footprint.

The experimental analysis of sand fencing alignment on vegetation plantings provided valuable insight. *Panicum* planted within fencing with a V-shaped alignment (fence spur closed toward the Gulf) showed significantly greater survival. Although not significant, *Spartina* planted within fencing with the "V" alignment also showed greater survival. The increased survival is hypothesized to be the result of a buffering effect which dampens scouring from overwash and wave action. Based on survivorship, these experiments suggest that the 'V' alignment is best. This alignment, however, leads to severe scour on the outside of the 'V' spurs (*i.e.* where it would form one arm of an 'A' spur). Additional data have shown that any alignment of fencing that is not shore parallel results in focusing of overwash activity and scouring

(Figure 30). Therefore, the current recommendation is for rows of shore parallel fencing and for alternative methods of planting and sediment retention (Khalil 2008).

Hard structure shoreline protection features (*e.g.* rock walls) in this type of environment need more consideration. As was demonstrated during these two projects, the effects of a steep shoreface profile caused by regional geology cannot be overcome with a hard structure. The engineering and design report suggests that the shoreline protection feature was designed to offset this steep profile (Picciola & Associates, Inc 2000). The complete destruction of this feature (appendix B) and the evidence of quick sand removal behind it indicate that other approaches, such as unconfined beach fill or different structure types, should be evaluated. Additionally, impacts of an intact structure on cross-shore transport must be considered in their design.

A final lesson learned is the standardization and storage of data and reports. This is particularly relevant to elevation data where cross-comparison is vitally dependent on a common standard. Data do not necessarily need to be brought to a common standard by contractors (although this is ideal), but CPRA must have the ability to transform data to a single standard for future comparison. In addition, all relevant meta-data must be provided by contractors. Clear and thorough data standards are irreplaceable and should be adhered to by all contracting groups and governmental agencies.

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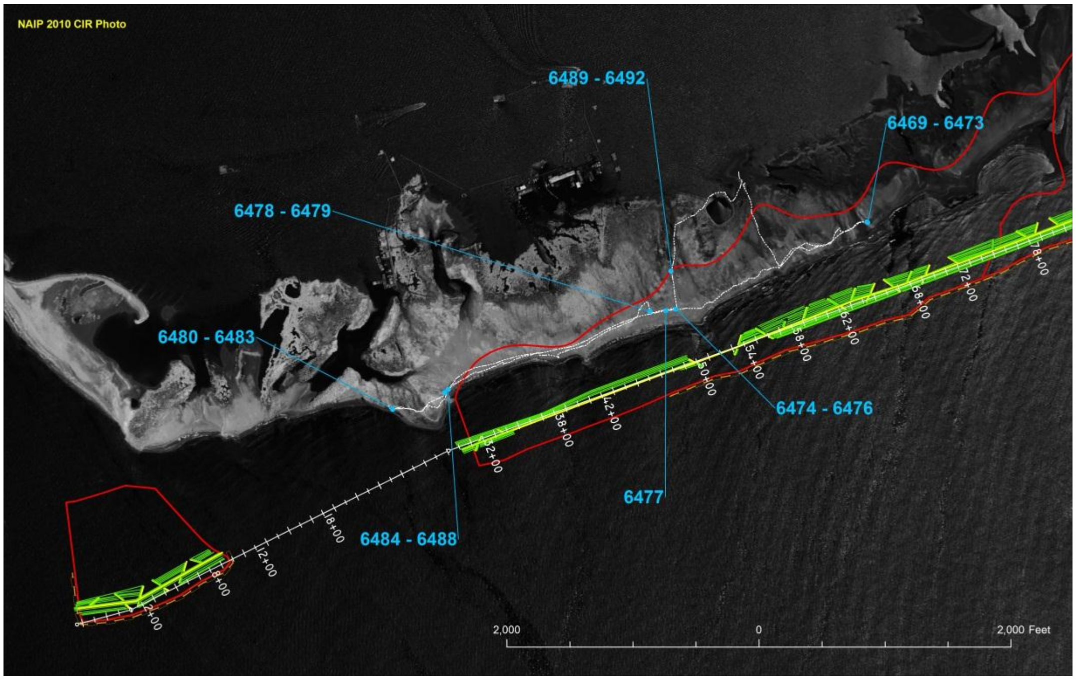
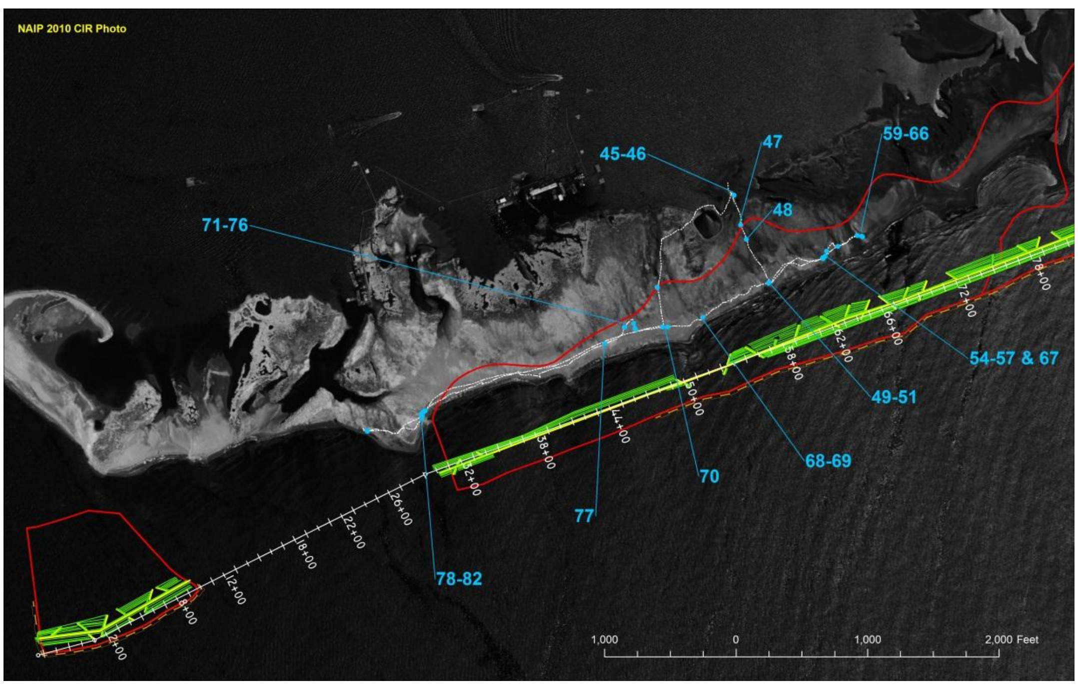
Appendix A
(Inspection Photographs)



Map 1: Location of CPRA photos from the June 12, 2012 inspection in relation to project features.



Map 2: Location of NOAA photos from the June 12, 2012 inspection in relation to project features.

Photo 1: Gulf Shoreline near station 66+00 looking E (CPRA #100_6469). Note pre-project rocks formerly on the bayside of the island are now on the gulf shoreline.

Photo 2: Gulf Shoreline near station 66+00 looking ENE (CPRA #100_6470).

Photo 3: Gulf Shoreline near station 66+00 looking NE (CPRA #100_6471).

Photo 4: Gulf Shoreline near station 66+00 looking NNE (CPRA #100_6472).

Photo 5: Gulf Shoreline near station 66+00 looking N (CPRA #100_6473).

Photo 6: Gulf Shoreline near station 66+00 looking ENE (NOAA #P1000062). Note the lack of fill template evident above the waterline.

Photo 7: Gulf Shoreline near station 62+00 looking ENE (NOAA #P000054). Note that GPS data confirms that these are pre-existing rock features formerly on the bayside of the island, now located on the gulf shoreline.

Photo 8: Gulf Shoreline near station 58+00 looking SSW (NOAA #P1000057). Note the timber bulkhead formerly behind the project dune feature now in the gulf shoreline.

Photo 9: Gulf Shoreline near station 49+00 looking SW (CPRA #100_6476). Note the steep shoreline profile and lack of beach. Also there is little elevation to the dune habitat.

Photo 10: Looking NNW near station 49+00 (CPRA #100_6474). Note the former marsh platform has been converted to dune and back barrier habitats due to over wash processes, yet there is little dune elevation.

Photo 11: Gulf Shoreline near station 49+00 looking NW (CPRA #100_6475). Note the former marsh platform has been converted to dune and back barrier habitats due to over wash processes, yet there is little dune elevation.

Photo 12: Gulf Shoreline near station 50+00 looking SSE (NOAA #P1000070). Note pre-existing rocks formerly on the bayside of the island, currently gulfward of the shoreline.

Photo 13: Gulf Shoreline near station 46+00 looking NW (CPRA #100_6479). Note the former marsh platform has been converted to low dune and back barrier habitats and the CPRA employee on the right is located at bayside marsh fill boundary approximately 50 yards from the gulf.

Photo 14: Marsh fill bayside boundary near station 46+00 looking SE (NOAA #P1000074). Note distance to gulf shoreline approximately 50 yards and marsh is now low dune habitat.

Photo 15: Marsh fill bayside boundary near station 46+00 looking SW (NOAA #P1000075). Note distance to gulf shoreline approximately 50 yards and marsh is now low dune habitat.

Photo 16: Low dune habitat near station 46+00 looking WNW (NOAA #P1000071). Note Bitter Panicum (*Panicum amarum*) coverage as former marsh fill has converted to low dune.

Photo 17: Gulf Shoreline near station 30+00 looking NE (CPRA #100_6488). Note steep shoreline profile and lack of beach. This location is near NW corner of the eastern fill area.

Photo 18: Gulf Shoreline near station 30+00 looking SW (CPRA #100_6484). Note pre-existing bayside rocks now on the gulf shoreline.

Photo 19: Gulf Shoreline near station 30+00 looking NNW (CPRA #100_6486). Note. This location is near NW corner of the eastern fill area.

Photo 20: Gulf Shoreline near station 30+00 looking N (CPRA #100_6487). Note this location is near NW corner of the eastern fill area.

Photo 21: Gulf Shoreline near station 30+00 looking NNE (NOAA #P1000082). Note the personnel on the right of the photo are standing at the former NW corner of the eastern fill area.

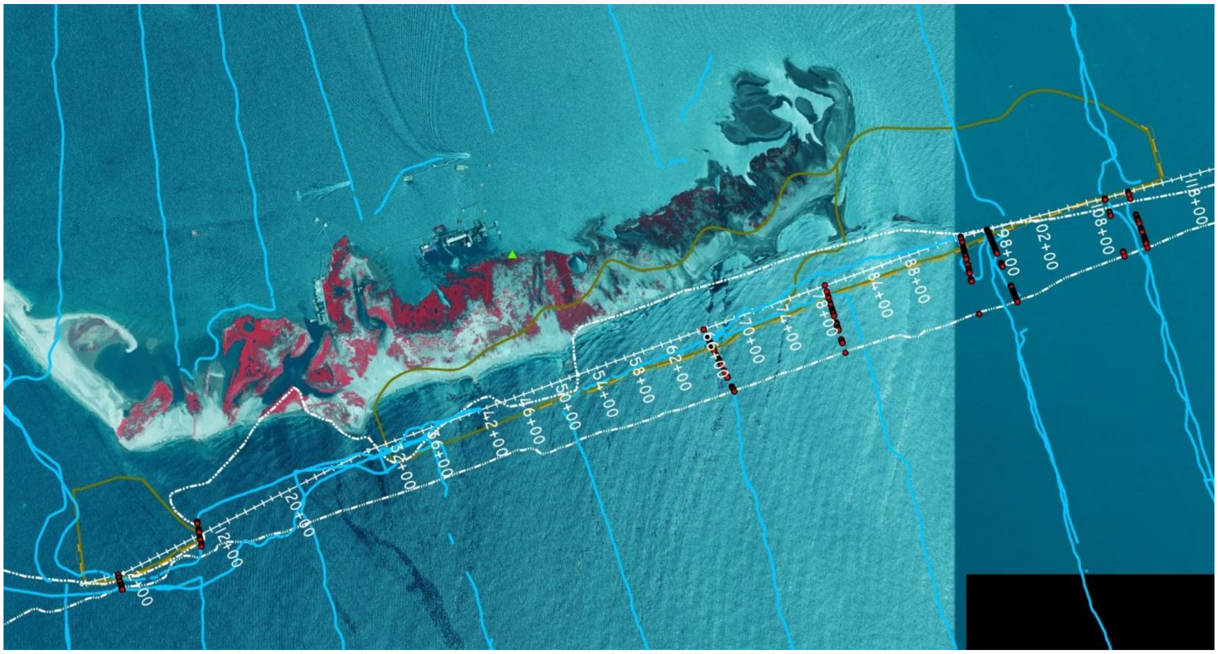
Photo 22: Gulf Shoreline near station 26+00 looking SW (CPRA #100_6482). Note there is no evidence of the western fill area.

Photo 23: Gulf Shoreline near station 26+00 looking NE (CPRA #100_6480). Note these rocks pre-existed the project and the foreground habitats were not a part of the CWPPRA projects.

Photo 24: Gulf Shoreline near station 26+00 looking SW (CPRA #100_6482). Note there is no evidence of the western fill area.

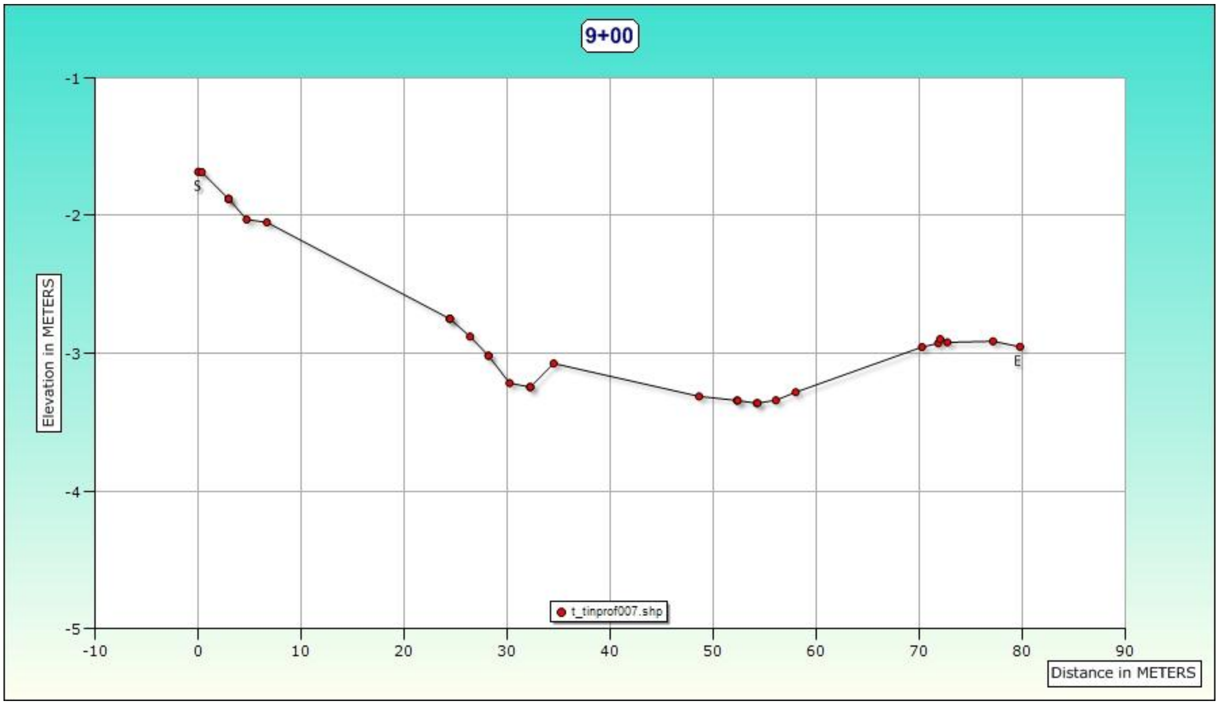
Photo 25: Gulf Shoreline near station 26+00 looking W (CPRA #100_6481). Note these rocks pre-existed the project and the foreground habitats were not a part of the CWPPRA projects. Also, note the breach in the shoreline just west of the rocks near station 20+00

Appendix B
(Select Elevation Profiles from 2006 BICM Bathymetry [NAVD88 meters])

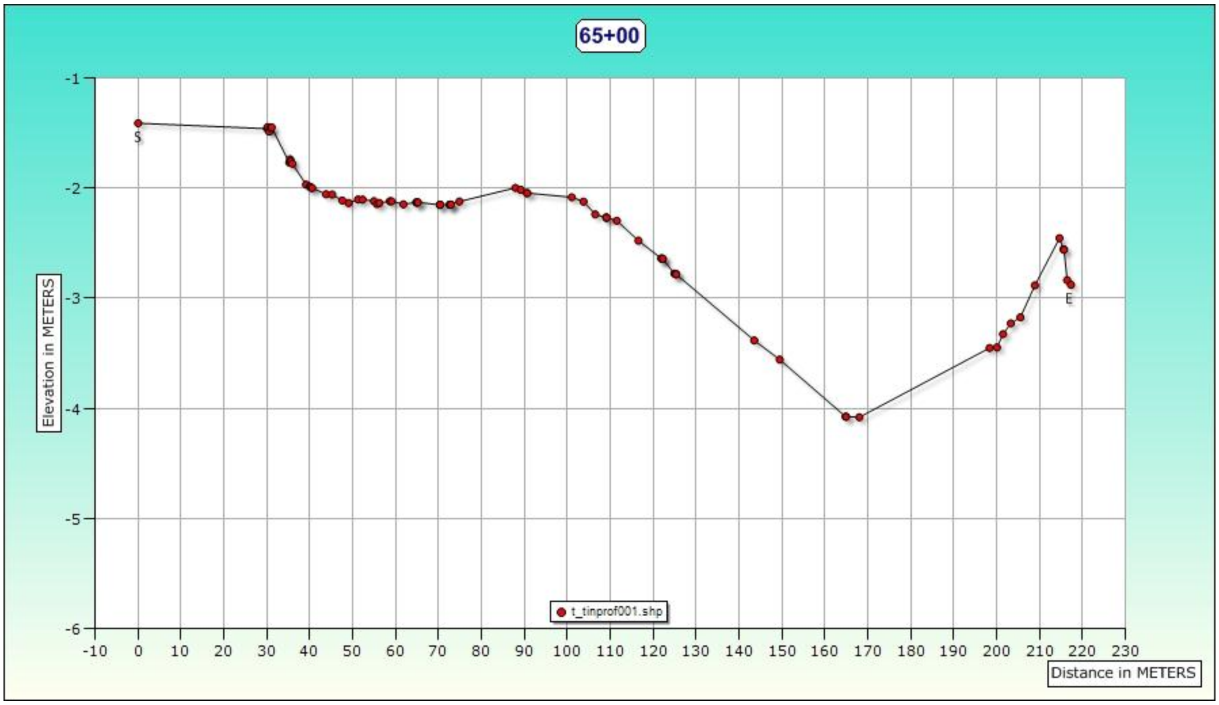


BICM 2006 bathymetry data (blue lines) was used to develop elevation profiles at selected project stations (red dots) to determine the status of East Timbalier Sediment Restoration Phase 1 (TE-25) and Phase 2 (TE-30) project rock shoreline protection features. All elevations are NAVD88 in meters.

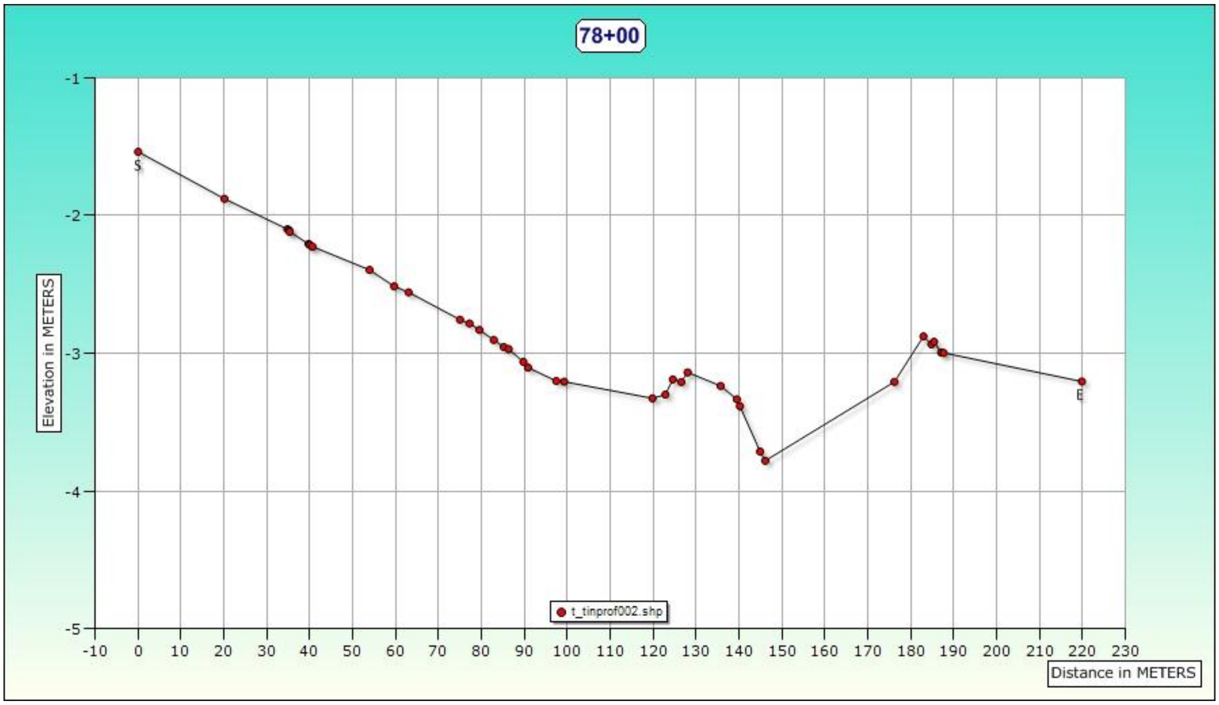
BICM 2006 elevation profile at project station -1+00. Rock feature would be located at approximately 17 m along the profile.



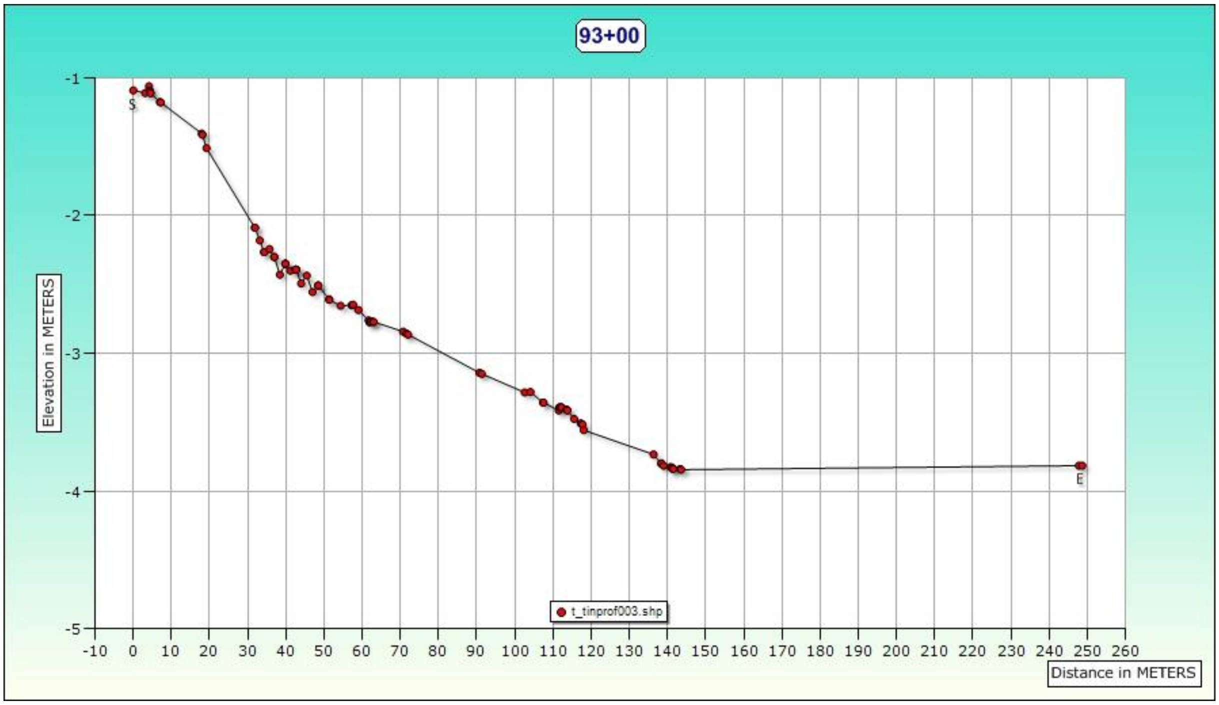
BICM 2006 elevation profile at project station 9+00. Rock feature would be located at approximately 5m and 30m along the profile.



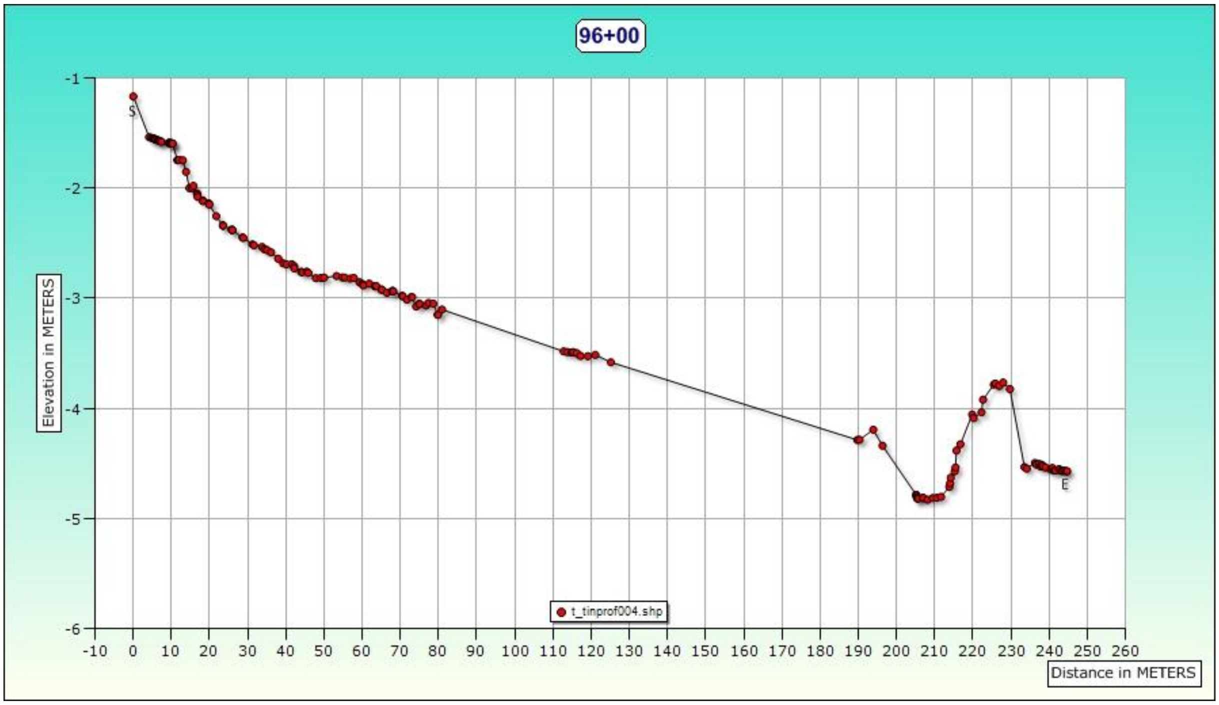
BICM 2006 elevation profile at project station 65+00. Rock feature would be located at approximately 70m along the profile. Pre-existing Gulf rock structure would be located at approximately 215m.



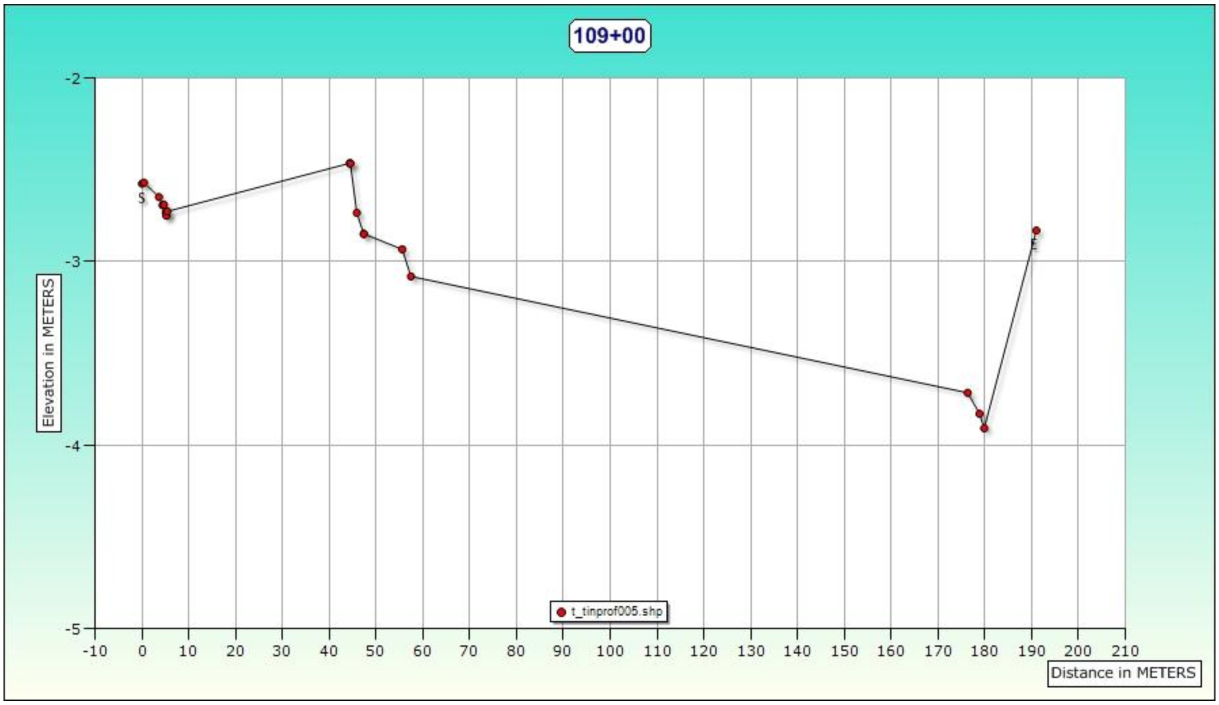
BICM 2006 elevation profile at project station 78+00. Rock feature would be located at approximately 35m along the profile.



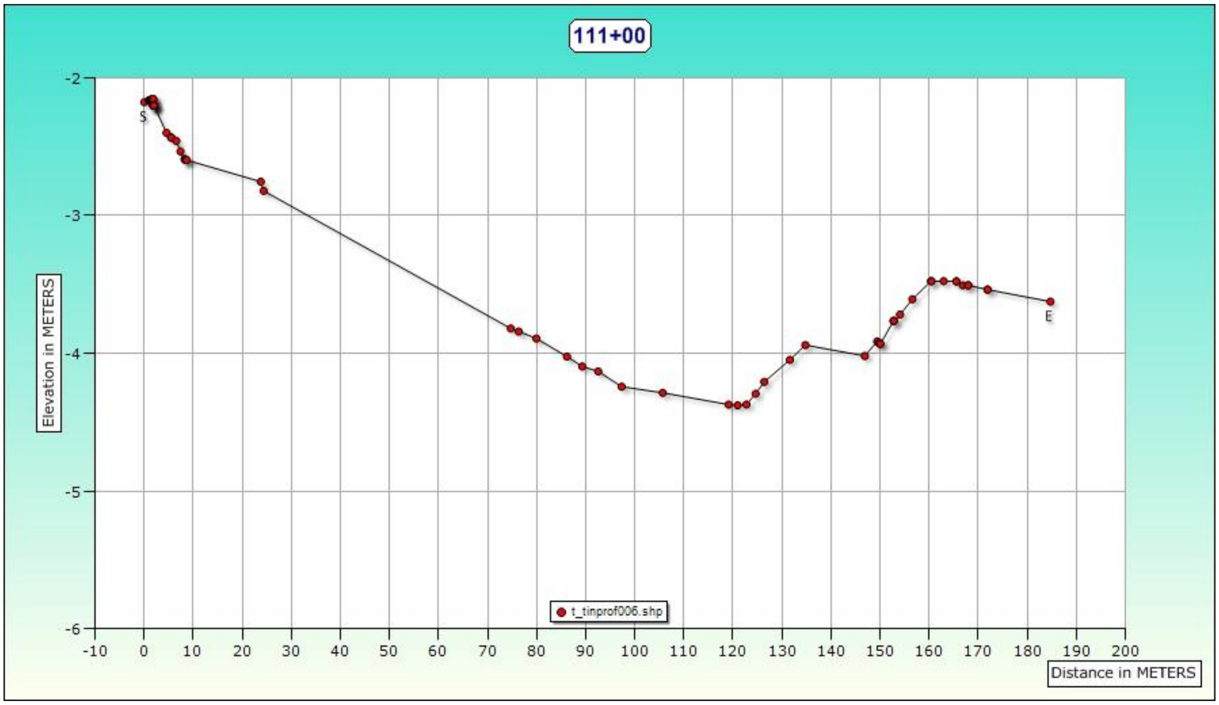
BICM 2006 elevation profile at project station 93+00. Rock feature would be located at approximately 38m along the profile.



BICM 2006 elevation profile at project station 96+00. Rock feature would be located at approximately 24m along the profile. Pre-existing Gulf rock structure would be located at approximately 230m.



BICM 2006 elevation profile at project station 109+00. Rock feature would be located at approximately 4m along the profile.



BICM 2006 elevation profile at project station 111+00. Rock feature would be located at approximately 3m along the profile.