EDISTO BEACH
COASTAL STORM DAMAGE REDUCTION
GENERAL INVESTIGATION STUDY

APPENDIX A
COASTAL ENGINEERING

1.0 History of Shoreline Management

Coastal Science & Engineering (CSE) has been retained by the Town of Edisto Beach for a number of years to perform annual beach condition monitoring and numerous studies of the Edisto Island shoreline. Many of CSE's reports and beach monitoring data products have been used during this feasibility study to better understand the history of shoreline management and the existing conditions on Edisto Island.

Historical erosion of Edisto Island has lead to a long history of shoreline management activities. For instance, the first two groins were constructed near the pavilion in 1948. Construction of additional groins continued over the next decade, bringing the total number of groins on the Edisto Beach shoreline to 17 by 1958. The groins were built from north to south and as the erosion continued to move down the beach additional groins were constructed in an attempt to keep pace with the subsequent erosion moving downdrift (south). By 1975, a total of 34 groins had been constructed along the Edisto Beach shoreline. The last groin constructed (#34) is located approximately 3,000 feet from the mouth of Big Bay Creek, along the South Edisto River inlet shoreline (CSE 2006). Table 1 below provides details on the groin construction timeline.

Table 1: Groin Construction Chronology

Groin #	Construction Completion
1	(1948)
2	1948
3-4	1949
5-8	1954
9-12	1953
13-17	1958
18-19	1962
20-21	1964
22-25	1969
26	1970
27-29	1972
30-33	1974
34	1975

Despite the construction of groins, erosion continued to threaten Palmetto Boulevard near the pavilion. As a result, in 1954 the South Carolina Highway Department undertook the first nourishment of Edisto Beach. Approximately 830,000 cubic yards of material, consisting of a mixture of sand, shells, and mud, was dredged from the marsh behind the island and placed between groins 1 and 12. Unfortunately, much of the material was not suitable for beach fill and the fine portions washed away quickly. The coarser sand and shell fractions remained on the beach and added to those transported to Edisto from Edingsville Beach (CSE 2006).

Through their studies and monitoring program of Edisto Beach, CSE has concluded that while localized erosion problems have persisted along Edisto Beach, the groin field significantly reduces the rate of sand loss along the oceanfront. More specifically, their periodic surveys have shown that erosion rates in groin cells 1–27 have been less than 1 cubic yard per foot per year (cy/ft/yr) in recent years (CSE 2003). They conclude that such low rates are due to the exposure of the groins and the creation of nearly isolated groin cells that exchange little sand from cell to cell. During the past decade, groin exposures reached as high as 8 ft along the intertidal beach profile (CSE 2006).

The next beach nourishment project on Edisto Island took place in 1995 when approximately 155,000 cubic yards of fill was placed between groins 1 to 17 (Pavilion to Chancellor Street) and groins 24 to 28 (Laroche Street to Billow Street). This beach fill project was accompanied by major improvements to the groins in those areas.

Shoreline erosion continued along Edisto Beach and in 2001, two houses in the 700 block of Palmetto Blvd (near groin 12) were lost. Despite the groin improvement and beach fill project in 1995, the Edisto Beach shoreline continued to be vulnerable to chronic erosion and storm events. The Town of Edisto Beach and the South Carolina Department of Parks Recreation and Tourism decided to plan for another beach nourishment project. This most recent beach nourishment project on Edisto Island was constructed between March and May 2006. The project added approximately 850,000 cubic yards (192,100 cy in the State Park area) of beach compatible material along 18,258 feet (3,200 feet in the State Park) of shoreline from the State Park to groin 27. The project was completed by Great Lakes Dredge and Dock (GLDD) at a cost of $7,697,500 (CSE 2006). The locations of the 1954, 1995 and 2006 beach nourishment projects are illustrated in Figure 1.

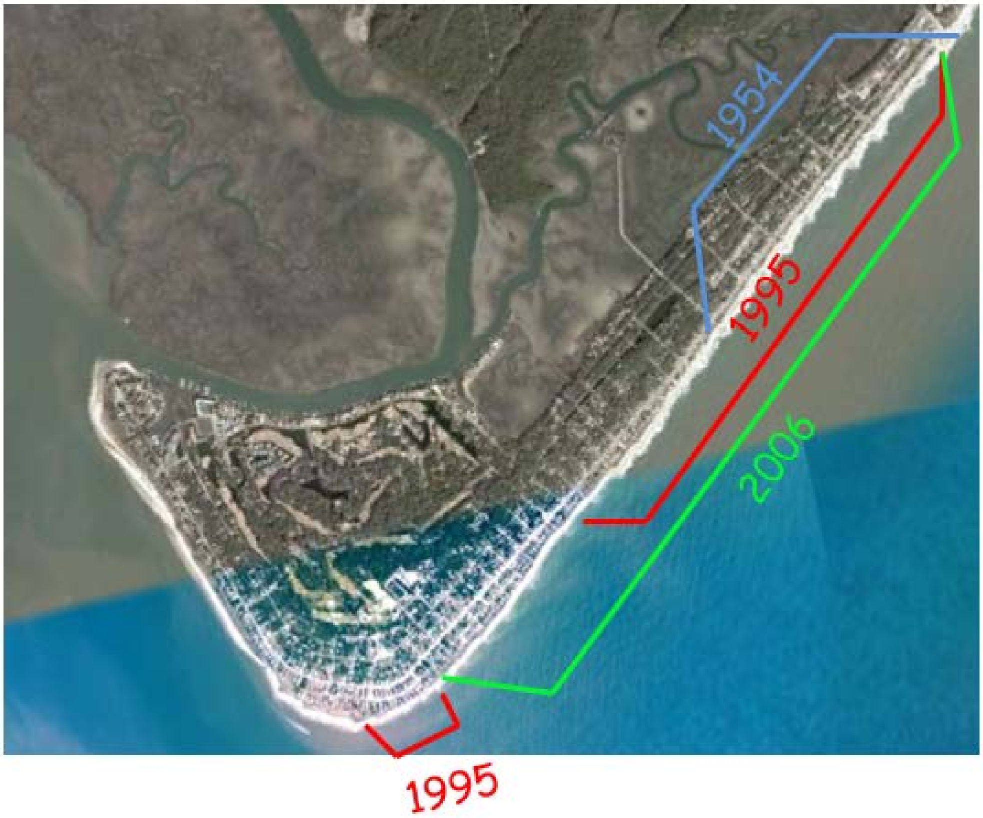


Figure 1: Historic beach nourishment placement areas.

2.0 Existing Coastal Processes

This section provides a summary of the key environmental conditions, active coastal processes, and the geological framework that characterize the vulnerability of Edisto Beach to economic losses through coastal storm-induced damages to existing infrastructure.

a. Coastal Storm Climatology

Existing coastal processes at Edisto Beach are driven by high energy waves and water levels generated by both tropical and extratropical storms. Significant tropical storm events impacted the Edisto Beach shoreline at a frequency of approximately once every 4 years over the past 100 years. These tropical storms occur between June and November with more than 65 percent of them occurring in the months of August and September. Extratropical storms, on the other hand, are a frequently occurring storm type that impacts Edisto Beach annually with significant events occurring on average once every year and a half. Extratropical storms typically occur in the late summer and early fall (September and October) and again in late winter and early spring (January through March) with most occurring in February. Tropical storm events are typically fast moving storms associated with elevated water levels and large waves whereas extratropical storms are slower moving with comparatively lower water level elevations and large wave conditions. Both storm types can produce beach erosion and morphology change as well as coastal inundation leading to economic losses to improved property backing the ocean and inlet shorelines of Edisto Beach. Although economic losses are most often realized in the wake of major storm events it is long-term chronic erosion that creates the vulnerability to major economic losses through volumetric depletion of beach material in the active profile, reduction in beach berm width and reduction in dune crest elevation and dune volume. Not all storms in the storm climatology produce measurable economic damages but they contribute to setting up vulnerability for economic losses. The long-term chronic erosion is driven by gradients in the longshore sand transport rate and depends on sediment supply from updrift beaches.

b. Longshore Sediment Transport Regime

Net longshore sand transport along Edisto Beach is from north to south and the magnitude of the longshore sand transport rate tends to increase moving from north to south. Intra-annual reversals in the longshore transport direction at Edisto Beach can be significant and are readily observed by shoreline position changes within groin compartments. These intra-annual transport direction reversals are driven by seasonal changes in the incident wave direction. Generally speaking, during the more stormy late Fall/Winter/early Spring seasons net transport direction is to the south, whereas during the milder fair weather late Spring and Summer season the net transport direction is often directed to the north. Within the groin compartments, an accretional berm fillet will develop on the updrift side of the groin and an associated erosional scarp will develop on the downdrift side of the groin. Consequently, when sand transport is in the long-term net direction (north to south) a wider beach berm is observed at southern end of the groin compartment whereas narrower beach berms are present at the northern end of the groin compartment. The opposite occurs during periods of net longshore transport reversals with accretion and wider beaches at the northern end of the groin compartment and narrower beaches at the southern end of the groin compartment. For this reason, characteristic representative beach profiles developed for modeling purposes were generated using an average of all surveyed profiles within a given groin compartment.

Taking a wider view of the regional coastal setting improves the overall understanding of the coastal processes that have lead to the increasing vulnerability of Edisto Beach to storm-induced damages. Figure 2 provides an aerial view of the South Carolina coastal region between North Edisto Inlet (upper right) and South Edisto Inlet (lower left). Net longshore transport is directed north along Botany Bay Island, located to the south of North Edisto Inlet, a reversal in the net transport direction to the south occurs near Edingsville Beach, which is centrally located between the two large inlets. The barrier island at Edingsville Beach is low lying and frequently overwashed during storm conditions. Sand is sequestered in the extensive inlet shoals and is washed over the low-lying barriers into the coastal marshes. As a result, the sand supply delivered to Edisto Beach by the prevailing coastal processes has diminished considerably over the past century and is expected to continue to diminish into the future. The presence of the groin field at Edisto Beach has significantly reduced shoreline erosion within the project study area and has been essential to the stabilization of the Edisto Beach shoreline. Nevertheless, sand supply to Edisto Beach from the north is insufficient to maintain natural storm protection in the form of significant beach berm widths and a protective dune feature. In the absence of beach nourishment erosion within the groin cells will continue and ultimately exchange of sediment between groin cells will be cut-off. When this occurs it is expected that shoreline erosion will increase first in the vicinity of the point and along the South Edisto Inlet shoreline and then progress to the north along the ocean-facing groin cells.

Gross longshore sand transport rates in the vicinity of Edisto Beach have been estimated at approximately 210,000 cy/year, about 44,000 cy/year directed to the north and about 167,000 cy/year directed to the south. The net longshore sand transport rate is estimated at approximately 123,000 cy/year and directed to the south (CSE, 1993).

Figure 2: Longshore sand transport regime between North Edisto Inlet and South Edisto Inlet.

c. Geomorphology of Edisto Beach

Edisto Beach is at the southern end of what was once a classical prograding drumstick shaped barrier island common in South Carolina. However, over time erosion in the central portion (Edingsville Beach area) of the larger barrier island system due to a net longshore transport divergence has resulted in opening of new tidal inlets (Frampton Inlet, Jeremy Inlet, and a un-named inlet north of Frampton Inlet) and loss of littoral sediments to developing shoal features at those inlets. Continued erosion has reduced the central barriers to little more than swash shoals that allow littoral material to wash over the barriers and become trapped in the coastal marshes. As a consequence the barrier island at Edisto Beach is transitioning to a landward migrating transgressive barrier island.

The geomorphology of Edisto Beach is unique among South Carolina beaches in that the sediment composition of the beach is coarser grained than most South Carolina beaches with a median grain size of approximately 0.4 mm (CSE, 2006) and significant shell content. The relatively coarse median sediment grain size results in comparatively steep foreshore slopes. Within the oceanfront groin compartments the foreshore slope is approximate 1 on 10, within the State Park north of Edisto Beach the foreshore slope is slightly milder at 1 on 15 and the foreshore slope along inlet shoreline is milder still at approximately 1 on 25. These steep foreshores slopes together with a fairly high tidal range (average spring tide range is 6.3 ft) reduces the beach area between the low-tide terrace and the foredunes compared to other South Carolina beaches. Due to these geomorphic conditions wave energy associated with storm conditions is not dissipated to any large degree before it reaches the relatively low foredunes present on the barrier island. The overall average dune crest elevation within the project study area is about 10.5 ft (NAVD88) although dune crest elevations vary between a minimum of 8.5-ft (NAVD88) and 12-ft (NAVD88) in different reaches within the study area. In the State Park area and in the vicinity of the point the average dune crest elevation is 10 ft (NAVD88). Along the Edisto Beach ocean-fronting shoreline the average dune crest elevation is 11.5 ft (NAVD88) and on the inlet-fronting shoreline the average dune crest elevation is approximately 9 ft (NAVD88). Dune volume above the berm elevation can be used as an indicator of storm vulnerability, within the project study area the overall average dune volume above the berm elevation was estimated at approximately 4.3 cy/ft based on representative idealized beach profiles developed for modeling purposes. However, as with the dune crest elevation this quantity varies between a minimum of approximately 1.4 cy/ft north of the camping area in the State Park and the inner inlet sub-reach to a maximum of 7.9 cy/ft in groin cell 6. In the State Park area the average dune volume above the berm elevation is 3.3 cy/ft. Along the Edisto Beach ocean-fronting shoreline the average dune volume above the berm elevation is 5.5 cy/ft whereas in the vicinity of the Point the average dune volume above the berm elevation drops to 3.7 cy/ft and along the inlet shoreline the average dune volume above the berm elevation drops to just 2.8 cy/ft.

A detailed description of the analysis performed to develop the representative idealized profiles for modeling purposes is provided in section 4.0.

d. Sea Level Rise

The mean sea level trend at Charleston, South Carolina (NOAA 8665530) is 3.28 millimeters/year (1.08 feet/century) with a standard error of 0.14 mm/yr based on monthly mean sea level data from 1921 to 1999 (Figure 3). The mean sea level trend for Fort Pulaski, Georgia (NOAA 8670870) is 3.05 millimeters/year (1.00 feet/century) with a standard error of 0.2 mm/yr based on monthly mean sea level data from 1935 to 1999.

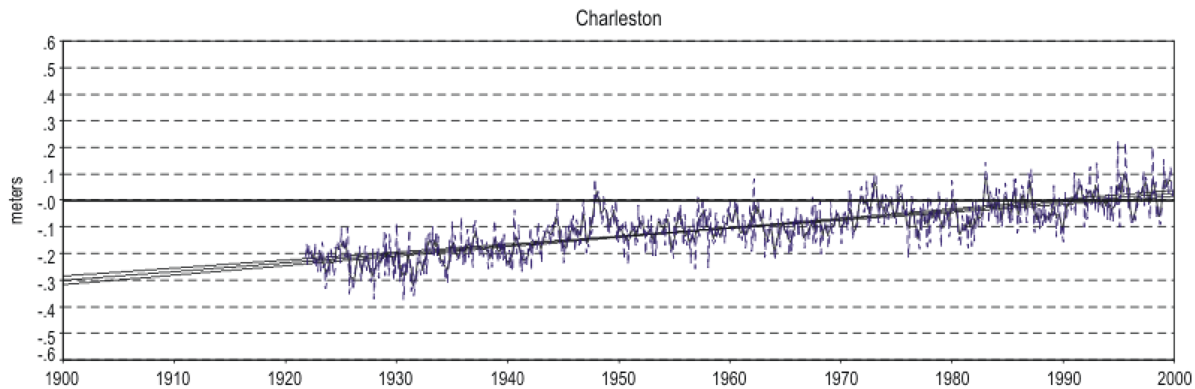


Figure 2: Mean sea level change trend at Charleston, SC.

The mean sea level trend for Edisto was estimated based on the relative position of Edisto to Charleston and Ft. Pulaski. Edisto is approximately 31.5 miles from Charleston and 47.0 miles from Ft. Pulaski.

$$MSL\ Trend = \left(1 - \frac{31.5}{78.5}\right)(3.28) + \left(1 - \frac{47.0}{78.5}\right)(3.05) = 3.19\ mm/yr$$

This historical rate of mean sea level change trend of 3.19 mm/year was applied in all Beach-fx simulations representing the "Low" future rate of sea level change in accordance with EC 1165-2-212. The "Intermediate" rate of future sea level change was computed using modified NRC Curve 1 and equations 2 and 3 in EC-1165-2-212 Appendix B. The "High" rate of future sea level change was computed using modified NRC Curve III and equations 2 and 3 in EC-1165-2-212 Appendix B. The relationships for future sea level change as outlined in EC-1165-2-212 are coded within Beach-fx and sea level change is internally computed continuously throughout the simulated project lifecycle.

3.0 Development of Storm Suite

Storm-generated water levels along the open coast and up the major tributaries of South Carolina have previously been investigated by Dr. Norman W. Sheffner of the U.S. Army Engineer Research and Development Center (ERDC) Coastal and Hydraulics Laboratory (CHL) of the Waterways Experiment Station (WES) in Vicksburg, Mississippi for the US Army Engineer District, Charleston. The findings of that investigation are presented in the report titled "Coast of South Carolina Storm Surge Study" and dated May 2000. Tropical and extratropical storm events that have historically impacted South Carolina were simulated with the ADCIRC (ADvanced CIRCulation) long-wave hydrodynamic model.

a. ADCIRC Modeling

The large-domain long-wave hydrodynamic Advanced CIRCulation (ADCIRC) model (Luettich, Westerink, and Scheffner 1992) has been used to provide water-surface elevations for this study. The ADCIRC model is an unstructured grid finite-element long-wave hydrodynamic model developed under the U.S. Army Corps of Engineers (USACE)

Dredging Research Program (DRP). The model was developed as a family of two- and three-dimensional codes with the capability of the following:

- Simulating tidal circulation and storm surge propagation over large computational domains while simultaneously providing high resolution in areas of complex shoreline and bathymetry. The targeted areas of interest include continental shelves, nearshore areas, and estuaries.
- Representing all pertinent physics of the three-dimensional equations of motion. These include tidal potential, Coriolis, and all nonlinear terms of the governing equations.
- Providing accurate and efficient computations over time periods ranging from months to years.

The ADCIRC model solves the depth-averaged Generalized Wave Continuity Equation (GWCE) formulation of the governing equations and has been extensively applied to projects requiring frequency analysis of storm events. The general methodology developed for these previous studies was applied to the South Carolina storm surge investigation (Scheffner, 2000). Tidal and storm surge water surface elevation data were archived at 38 stations, including one station immediately north of Edisto Island (-80.18945 32.56440) and one station immediately south of Edisto Island (-80.35598 32.48759).

b. Computational Grid

A problem often encountered in the modeling of nearshore flow dynamics is that the computational boundaries of the model are not well removed from the area of interest. For example, the continental shelf can substantially affect the amplitude and phase of a storm surge or tide propagating from open water onto the shelf. If the model boundary conditions are specified on the shelf, then boundary condition errors are introduced into the solution because the assumed boundary conditions are posed in a dynamic flow region, i.e., the transformation of the flow field over rapidly changing bathymetry. An advantage for the use of large domains is that boundary conditions can be defined in deep water where nonlinear effects of the continental shelf are minimal. This approach to specification of boundary conditions virtually eliminates contamination of model results from poorly defined boundary conditions (Scheffner, 2000).

The 20,000 node computational domain (shown in Figure 4) used in the generation of the DRP east coast, Gulf of Mexico, and Caribbean Sea tidal data base formed the initial grid for this study because the tidal boundary conditions along the eastern boundary (60^{o} east Longitude) had already been determined. Additionally, proper flow connectivity between the Gulf of Mexico, Caribbean Sea, and the South Atlantic Bight was assured by accurately defining the bathymetry of all basins. For example, by modeling the entire domain, the flow and surge distribution resulting from hurricanes moving toward the study area from the Caribbean or Gulf of Mexico is properly simulated. Minimum node-to-node spacing of this initial grid was on the order of 5 km. Minimum resolution along the open coast and up the major tributaries of the study area was decreased to approximately 700 m in order to provide sufficient detail of the local bathymetry and topography. The increased resolution of the study area shown is Figure 5.

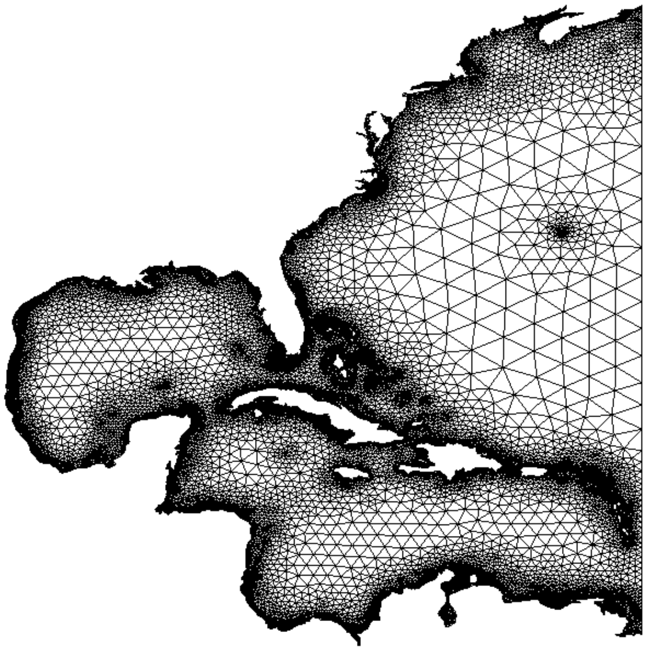


Figure 4: The Dredging Research Program grid of the East Coast, Gulf of Mexico and Caribbean Sea.

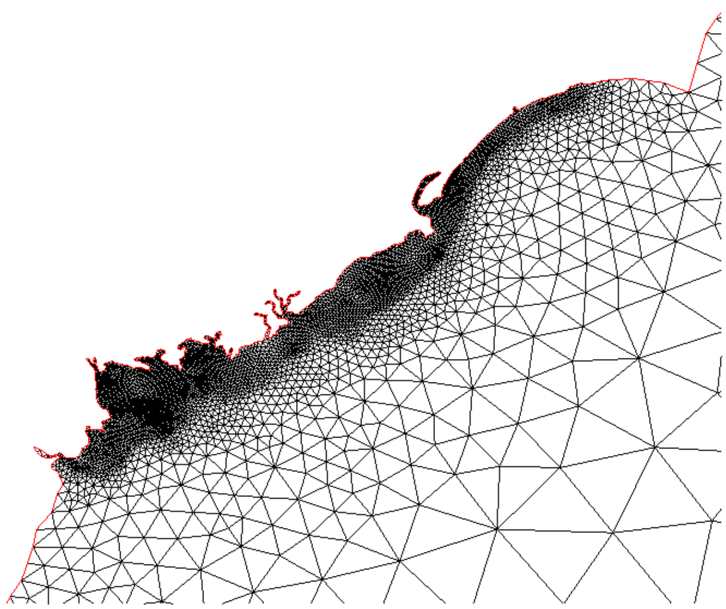


Figure 5: Grid resolution in the South Carolina study domain.

1) Tropical Storms

A tropical storm database (Scheffner, et al 1994) was generated during the DRP through simulation of 134 historically based storm events along the east coast, Gulf of Mexico, and Caribbean Sea. For 486 discrete locations along the U.S. coast, storm events which produced a storm surge of at least 1.0 ft. were archived and indexed according to event, location, and surge. This indexed database was used to define an initial training set for the present study (Scheffner, 2000).

Ideally, historical events represent the full range of possible event intensities. If this occurs, the historical events can be used directly to develop the full training set of storms. For extratropical events, this is generally the case because extratropical events occur often, cover extremely large areas, and persist for long periods of time (i.e., days). However, with tropical events this is often not the case. At many locations, the worst case tropical event scenario may not yet have occurred in the historical record, but may represented by a historic event with a slightly shifted path or larger/smaller radius to maximum wind. Because of this, some augmentation of the historic events is often necessary. This was found to be necessary for the South Carolina study because station locations of interest span over 150 miles. For example, Hurricane Hugo made a near-perpendicular landfall near Charleston on 21 September 1989. Hurricane Hugo produced severe surges for areas north and east of Charleston, however, areas south and west of landfall were not significantly impacted (Scheffner, 2000).

In order to supplement the training set so that all stations within the study experience a maximum intensity event, and thereby fill the vector space with events ranging from nominal to intense, six (6) additional storm events were added to the initial training set. Four of these events were developed as perturbations of Hurricane Hugo, and two were developed as perturbation of the unnamed hurricane of 1910, the two most intense events in the historical record. As a result, maximum surge elevations were experienced just east of landfall, however, negligible surge elevations were experienced southwest of landfall and the surges were minimal further northeast of landfall. Four hypothetical events were created by assuming the historical path of Hurricane Hugo was shifted 1 and 2 degrees west of landfall and 1 and 2 degrees east of landfall. These four combinations, along with the historical event produced maximum surges throughout the study area. For the 1910 hurricane two hypothetical events were created by assuming the historical path wave was shifted 1 degree both east and west of landfall. The final training set consisted of 30 events; 24 historical, and 6 hypothetical (4 representing perturbations of Hurricane Hugo and 2 representing perturbations of the hurricane of 1910). The final training set is shown in Table 2 (Scheffner, 2000).

Table 2: Tropical Storm Training Set Inventory.

HURDAT* Storm #		Given name	Date*(mm/dd/yyyy)
1.	194	NOT NAMED	10/09/1910
2.	194A	1910-A	--
3.	194B	1910-B	--
4.	196	NOT NAMED	08/23/1911
5.	217	NOT NAMED	07/11/1916
6.	292	NOT NAMED	09/06/1928
7.	296	NOT NAMED	09/22/1029
8.	299	NOT NAMED	08/31/1930
9.	353	NOT NAMED	08/29/1935
10.	398	NOT NAMED	08/05/1940
11.	440	NOT NAMED	10/12/1944
12.	449	NOT NAMED	09/12/1945
13.	463	NOT NAMED	09/20/1947
14.	465	NOT NAMED	10/09/1947
15.	521	NOT NAMED	08/28/1953
16.	526	FLORENCE	09/23/1953
17.	541	HAZEL	10/05/1954
18.	562	FLOSSY	09/21/1956
19.	589	GRACIE	09/20/1959
20.	597	DONNA	08/29/1960
21.	643	ALMA	06/04/1966
22.	669	GLADYS	10/13/1968
23.	777	DAVID	08/25/1979
24.	797	DENNIS	08/07/1981
25.	839	KATE	11/15/1985
26.	872	HUGO	09/10/1989
27.	872A	HUGO-A	--
28.	872B	HUGO-B	--
29.	872C	HUGO-C	--
30.	872D	HUGO-D	--

*The HURDAT storm number designation refers to the storm identification number of the events in the National Hurricane Center data base of historic tropical events and the time signifies the first time of storm on record.

2) Extratropical Storms

In a similar manner to the tropical event database described above, an extratropical storm event database was generated within the DRP. This database was constructed by driving the ADCIRC model with wind fields extracted from the U.S. Navy Fleet Numerical Meteorology and Oceanography Center's database of winds for the 16-year winter storm period (defined as September through March) of 1977 through 1993 (77-78, 78-79, etc). These data are provided at 6-hour intervals on a 2.5^{o} latitude and longitude grid. The extratropical storm database consists of surface elevation and current hydrographs at each of the 486 stations described above. These data contain severe events occurring during the 16-year sequence of winter months; however, unlike tropical events that are clearly distinguishable, identification of individual extratropical events within the records requires additional analysis (Scheffner, 2000).

Time series surface elevation plots corresponding to an archived station near the center of the study area were analyzed. Each time series represented surge with no tide. The time series of water surface elevations for the 16 year seasons were plotted and 9 extratropical events were identified and extracted from the time series to populate the extratropical storm event database. The 9 extratropical storm events selected were those that produced the highest elevation peak storm surge. Maximum wave height and storm duration did not enter into the extratropical storm selection process. The approximate starting time for each of the 9 events is shown in Table 3 (Scheffner, 2000).

Table 3: Extratropical Storm Training Set Inventory

Storm Number	Starting Date (mm/dd/yyyy)
1.	02/13/1979
2.	09/01/1979
3.	02/08/1983
4.	02/24/1983
5.	03/13/1983
6.	09/05/1984
7.	10/24/1985
8.	01/01/1987
9.	02/13/1987

c. Development of Plausible Storm Suite

The historical (and hypothetical) tropical and extratropical storm events identified as discussed above were expanded to form what is known as a plausible storm suite that will be used to drive beach evolution within Beach-*fx*. The procedure followed to generate a site-specific plausible storm suite for Edisto Beach for use in the numerical estimation of storm-induced beach morphology response during this feasibility study involved five (5) broad steps:

- Identification of project specific significant storm events (discussed previously).
- Extraction of the storm surge hydrographs corresponding to the identified significant storm events.
- Estimation of wind wave conditions corresponding to the identified significant storm events.
- Statistical characterization of project specific astronomical tides and estimation of representative high, mean, and low tidal ranges.
- Development of 12 plausible total water level hydrographs for each of the identified significant storm events.

The first two steps were completed by reviewing and utilizing the data from the SC Storm Surge study detailed above. Final storm surge hydrographs were constructed by averaging the hydrographs from the two Edisto stations for each tropical and extratropical storm in the database.7

Preparation of the storm surge hydrographs for their use in SBEACH simulations involved identifying the portion of the ADCIRC simulation relevant to morphology response modeling and processing the storm surge hydrographs, which involved clipping the storm surge hydrographs and applying a mild smoothing of the hydrographs as necessary. The storm surge hydrographs were analyzed to identify which portions of the modeled event were essential for capturing the beach response in SBEACH. For example, if the averaged, hydrograph from the SC Storm Surge Study was 150 hours long and only the 100 hours in the middle of the data were appropriate and necessary, the 25 hours at the beginning and the 25 hours at the end were clipped from the record. The next step was to smooth portions of the time series that required some degree of smoothing.

The contribution of astronomical tides to the total water elevation hydrograph was developed by first performing a statistical analysis of tides as Edisto Beach. The aim of the analysis was to estimate three statistically significant tidal ranges. Specifically, to quantify:

1. A high tidal range representing the mean of the highest 25 percent of all tidal ranges occurring at Edisto Beach;
2. A mean tidal range representing the mean of the central 50 percent of all tidal ranges occurring at Edisto Beach;
3. A low tidal range representing the mean of the lowest 25 percent of all tidal ranges occurring at Edisto Beach.

Next semi-diurnal cosine tide signals were generated with ranges corresponding to the computed high, mean, and low tidal ranges. Each of the historical and hypothetical storm surge hydrographs were combined with the idealized cosine astronomical tide hydrographs to generate the suite of plausible total water elevation time series. For each tide range (high, mean, and low) the storm surge hydrograph was added to the cosine astronomical tide hydrograph at four phases of the tide signal; aligning peak storm surge with high tide, mean tide falling, low tide and mean tide rising. This procedure produces 12 plausible total water elevation representations of each of the historical storm events. Those events associated with the mean tide range are weighted double the weight of those events associated with the high and low tide ranges. For the two historical storms that involved hypothetical representations, the hurricane of 1910 and Hurricane Hugo, the combined weight of all representations of the historical is equal to the combined weight of the other historical events. The plausible storm suite includes 5 representations of Hurricane Hugo, four hypothetical storm tracks and the historical storm track, whereas the other hurricanes (with the exception of the hurricane of 1910) involved just the historical storm track. So, for example, the combined total weight of the 12 representations of Hurricane Dennis is 16 (4 with a weight of 1 associated with the high tide range, 4 with a weight of 2 associated with the mean tide range, and 4 with a weight of 1 associated with the low tide range), whereas for Hurricane Hugo which involves 5 representations of the storm (1 historical and 4 hypothetical) the weighting is as follows: 20 with a weight of 0.2 associated with the high tide range, 20 with a weight of 0.4 associated with the mean tide range and 20 with a weight of 0.2 associated with the low tide range, which results in a combined weight of 16, the same as Hurricane Dennis.

Waves for the extratropical events were available from the Wave Information Studies (WIS) database. All of the wave height time series (tropical and extratropical) were reduced, where applicable and necessary, by limiting wave heights according to the depth limited breaking wave criteria based on water depth during the event at the SBEACH computational boundary. When the wave time series length was shorter than the surge time series, a standard minimum wave height and period were added to the time series. The minimum wave height was selected as a weighted average of the mean wave heights of the first two bins in the WIS analysis. Bin1 (0.0-0.5 m) was assigned 0.25 meters and represented 11.67% of the 20-year record, while Bin2 (0.5-1.0 m) was assigned 0.75 meters and represented 49.49% of the 20-year record.

$$0.25(0.1167/0.6116) + 0.75(0.4949/0.6116)=0.65 \text{ meters} = 2.1 \text{ feet}$$

Adjustments to the timing of the peak wave heights with regards to the timing of the peak storm surge so that the peaks were more or less aligned. Wind waves for the tropical storms were obtained from the WIS hindcast for those storms occurring between 1980 and the present. For those tropical storms occurring prior to 1980 a parametric prediction technique was employed as described in the Coastal Engineering Manual, Section II-2-2-c *parametric prediction of waves in hurricanes.*

4.0 Representative Beach Profiles

The Coastal Engineering Manual (CEM) provides some guidance on how to determine baseline damages by including the existing or without-project condition of the project study domain. Morphologic features of the existing beach, such as dune height, berm width, and offshore profile shape, typically vary along the project study domain. To accurately estimate storm erosion response for the existing condition, the CEM suggests developing a set of representative morphologic reaches to describe variations in profile shape along the project domain. Morphology analysis software applications such as BMAP or RMAP can be used to define morphologic reaches by analyzing profiles, grouping similar profiles, and calculating an average representative profile for each reach. According to the CEM, the profile characteristics that should be considered when developing morphologic reaches include dune height and width, berm width, nearshore and offshore profile slopes, sand grain size, presence of seawalls or other structures, and proximity to inlets.

The Edisto Beach Hurricane and Storm Damage Reduction feasibility study will employ BEACH-*fx*, the Corps' Monte Carlo life-cycle simulation model for estimating shore protection project evolution and cost benefit analyses. For a general description of the principles upon which Beach-*fx* operates the reader is directed to Gravens, et al. (2007). An overview of the general hierarchical data structure employed in Beach-*fx* is provided in Figure 6. Within Beach-*fx* the overall unit of analysis is the "project," a shoreline area for which the analysis is to be performed. The project is divided, for purposes of analysis, into "reaches," which are contiguous, morphologically homogeneous areas. The structures within a reach are referred to as Damage Elements (DEs), and are located within lots. All locations are geospatially referenced using a cartographic coordinate system such as state plane coordinates. This project definition scheme is shown schematically in Figure 7, in which the shoreline is linearized into reaches. Each reach is associated with a representative beach profile that describes the shape of the cross-shore profile and beach composition.

The profile is the basic unit of beach response. Natural beach profiles are complex; for the modeling, a simplified or idealized beach profile, representing key morphological features defined by points, is used as shown in Figure 8. The idealized profile represents a single trapezoidal dune with a horizontal berm and a horizontal upland landward of the dune feature.

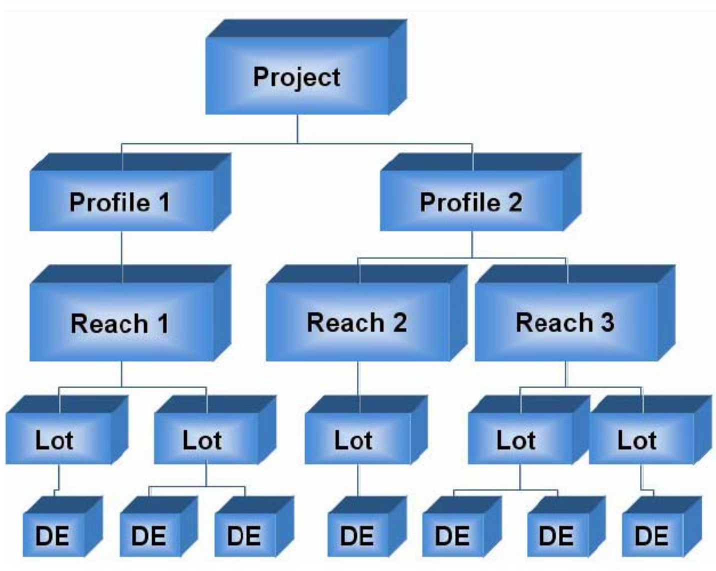


Figure 6: Hierarchical representation of Beach-fx data elements (taken from Beach-fx Users Manual, Version 1.0).

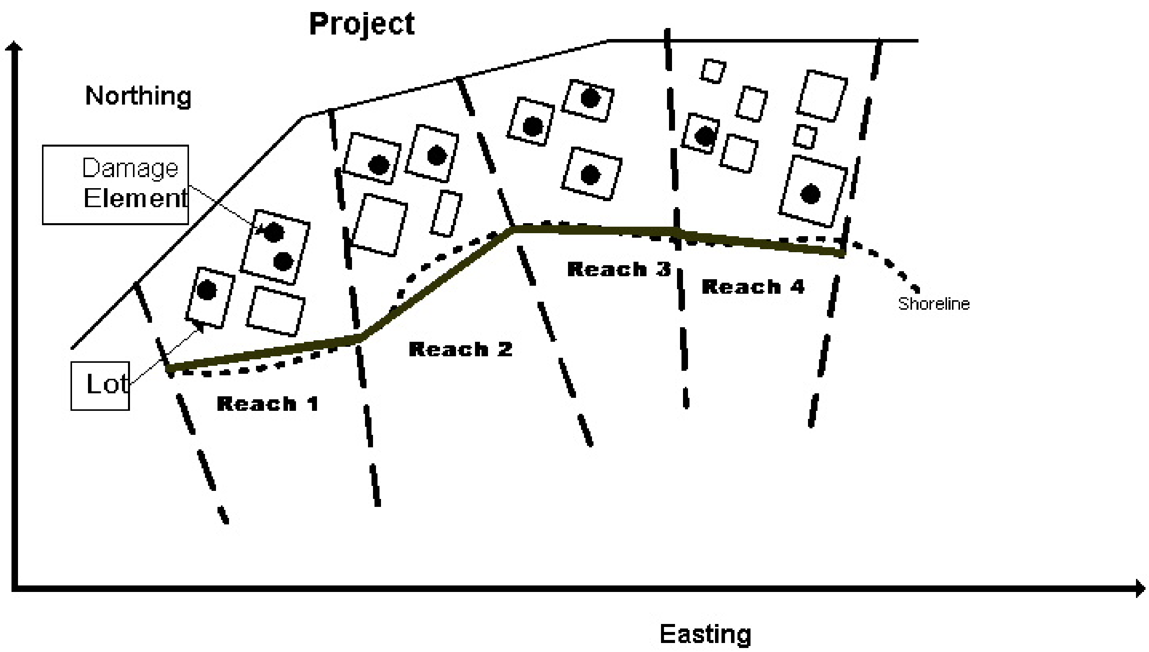


Figure 7: Beach-*fx* schematization of the project study area.

The submerged portion of the profile is represented by a detailed series of distance-elevation points that are determined through an analysis of available beach profile information. For the Edisto Beach project, the detailed submerged beach profile was developed by averaging across multiple surveyed beach transects containing similar offshore slopes.

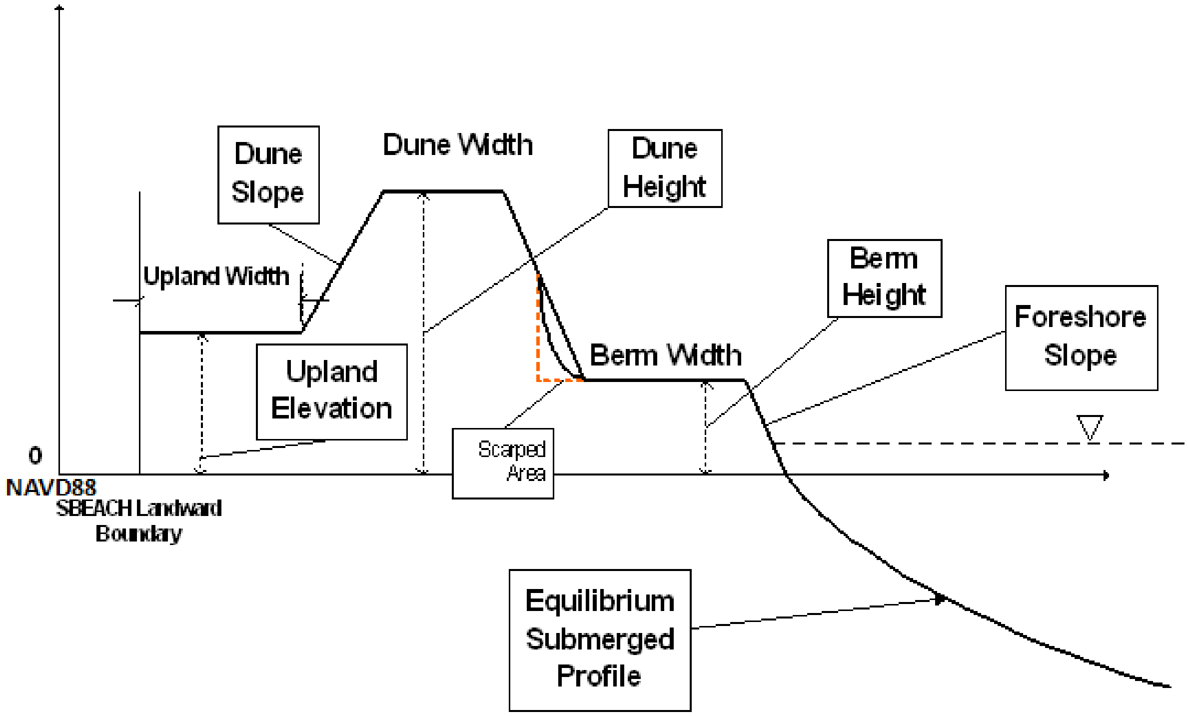


Figure 8: Beach-*fx* idealized beach profile.

The beach morphology of Edisto Island, particularly the Town of Edisto Beach, is heavily influenced by the presence of the 34 groins, which are spaced an average of every 600 feet along the Atlantic shoreline of the Town of Edisto Beach. The Town's coastal engineering consultant, Coastal Science and Engineering, Inc. (CSE), has laid out their beach monitoring stations in such a way as to be able to capture the beach profile characteristics at an average of three locations between successive groins. CSE has been monitoring Edisto Island with beach profiles at 90 locations along the Edisto shoreline yearly since 2004. Figure 9 shows the distribution of these 90 locations and clearly shows that the primary area of emphasis is the Atlantic shoreline of the Town of Edisto Beach. Figure 10 provides a more detailed view of some of the monitoring locations and their relationship to the groins. The beach profile monitoring data produced by CSE is not the only source of temporal and spatial varying beach profile data for the island, since the South Carolina Office of Coastal Resource Management (OCRM) also collects beach profiles along the island. Profiles have been collected since 1988 at 21 monument locations setup by the South Carolina Coastal Council (SCCC), which was the predecessor to OCRM. Table 4 provides a list of the available beach profile survey information that was available for this analysis.

Because of the greater number of profiles in the CSE dataset and the fact that the CSE dataset included profiles at some of the same locations as the OCRM dataset, the OCRM dataset was not used for determining representative morphologic profiles. The CSE dataset provides sufficient coverage of the project domain and enough detail of the beach profile characteristics in order to delineate discrete morphologic profiles.

Table 4: Summary of beach profile survey data.

Date	Source	Date	Source	Date	Source
Oct-1988	OCRM	Apr-1995	OCRM	Dec-1999	OCRM
June-1990	OCRM	May-1995	OCRM	May-2000	OCRM
Nov-1990	OCRM	Nov-1995	OCRM	Apr-2001	OCRM
May-1991	OCRM	Apr-1996	OCRM	Aug-2002	OCRM
Oct-1991	OCRM	June-1996	OCRM	June-2004	OCRM
Nov-1991	OCRM	Sep-1996	OCRM	Aug-2004	CSE
June-1992	OCRM	Apr-1997	OCRM	July-2005	OCRM
Sep-1992	OCRM	May-1997	OCRM	Nov-2005	CSE
Apr-1993	OCRM	Sep-1997	OCRM	Aug-2006	CSE
May-1993	OCRM	Apr-1998	OCRM	Nov-2006	OCRM
Sep-1993	OCRM	May-1998	OCRM	July-2007	CSE
Dec-1993	OCRM	Sep-1998	OCRM	Dec-2007	OCRM
Apr-1994	OCRM	Oct-1998	OCRM	July-2007	CSE
Oct-1994	OCRM	Jan-1999	OCRM		
Dec-1994	OCRM	Apr-1999	OCRM		

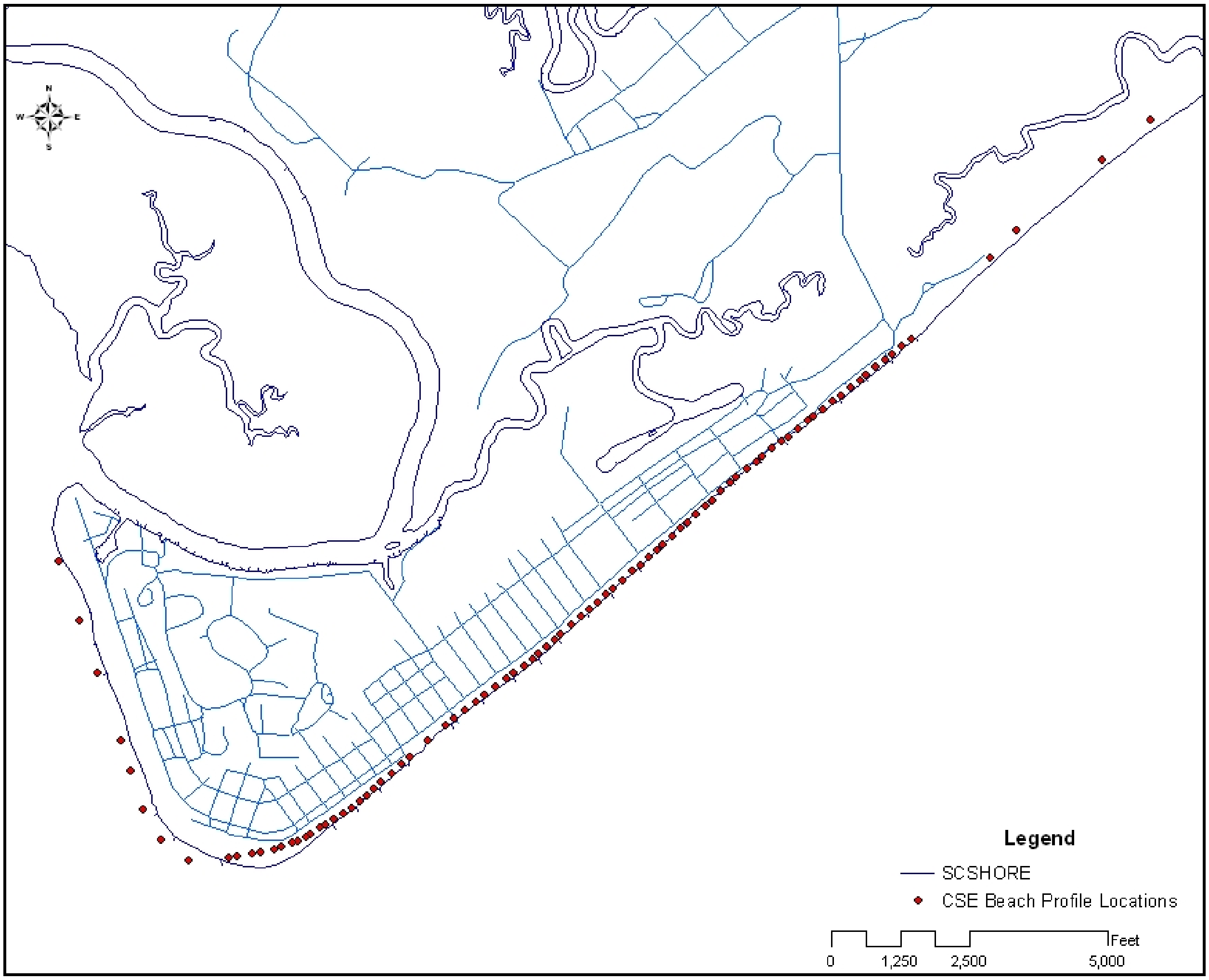


Figure 9: Location of CSE beach profile monitoring stations.

The beach profile analysis that lead to the development of the idealized representative beach profile began by first computing the average beach profiles within each of the groin compartment. The profile surveys employed in this analysis were those surveyed in August 2004, November 2005, July 2007, and July 2008. Although a survey was performed in July 2006 this survey data set was not used because of the influence of the beach nourishment that occurred between April and May 2006. As a result of the recently completed beach nourishment project offshore beach profiles were over-steepened due the placement of approximately 850,000 cy of nourishment sand. After computing the average submerged profile within each of the groin compartments the shape of the offshore profile was compared across all the groin compartments and similar profiles were combined and an average submerged profile was computed for similar shape offshore profiles across multiple groin cells. In the end, a total of 14 representative submerged beach profiles were developed to characterize the project study area as illustrated in Figure 11. In this figure the green polygons represent the lot parcels and the blue brackets show the spatial distribution of the developed representative submerged profiles. Table 5 defines the relationship between groin cells and the representative submerged beach profiles.

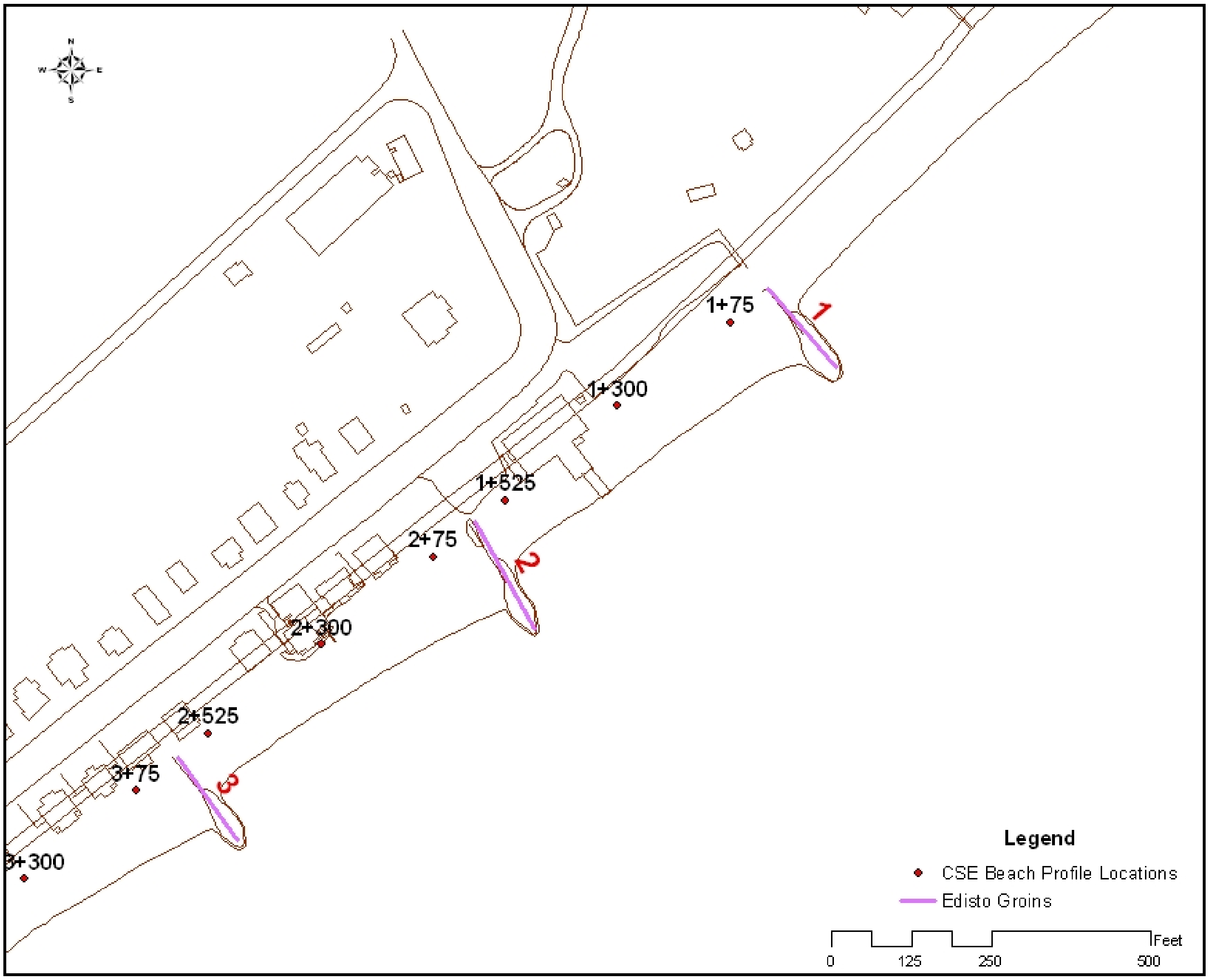


Figure 10: Location of CSE beach profile monitoring stations with respect to groins on Edisto Beach.

The next step in the development of the representative beach profiles for input into Beach-*fx* involved characterizing the upland dune and berm portion of the profiles. For this analysis only the July 2008 profile survey was used because the intent is to characterize the initial condition upper beach profile characteristics for initializing the lifecycle simulations performed within Beach-*fx*. The analysis involved first aligning the survey profile information within each groin cell such that the cross-shore position of the dune crest shared a common cross-shore position. Then an average profile was computed which yielded an average dune crest elevation within the groin cell as well as a representative average berm width within the groin compartment. Finally, an idealized profile suitable for input to Beach-*fx* (horizontal upland, trapezoidal dune section with constant landward and seaward dune slopes, a horizontal berm section, and constant a foreshore slope down to datum) was generated. In a number of the groin cells the upland, dune, and berm characteristics of the average upper beach profile was similar and in those cases a single idealized upper beach profile was generated. Figures 12 through 30 illustrate the idealized upper beach profiles that define the Beach-*fx* reaches used in this feasibility study. In Figures 12 through 30 the green line depicts the developed representative beach profile the red line depicts the idealized profile that defines the initial condition in Beach-fx. As seen in Figures 15 through 29 the placement of sand fencing along the back berm has resulted in berm accretion above the natural berm elevation. The idealized beach profiles (red line) reflect the natural berm elevation of 7 ft NAVD whereas, sand accumulation near the sand fencing results in berm elevations 1 to 2 ft higher than the natural berm on the representative profiles (green line).

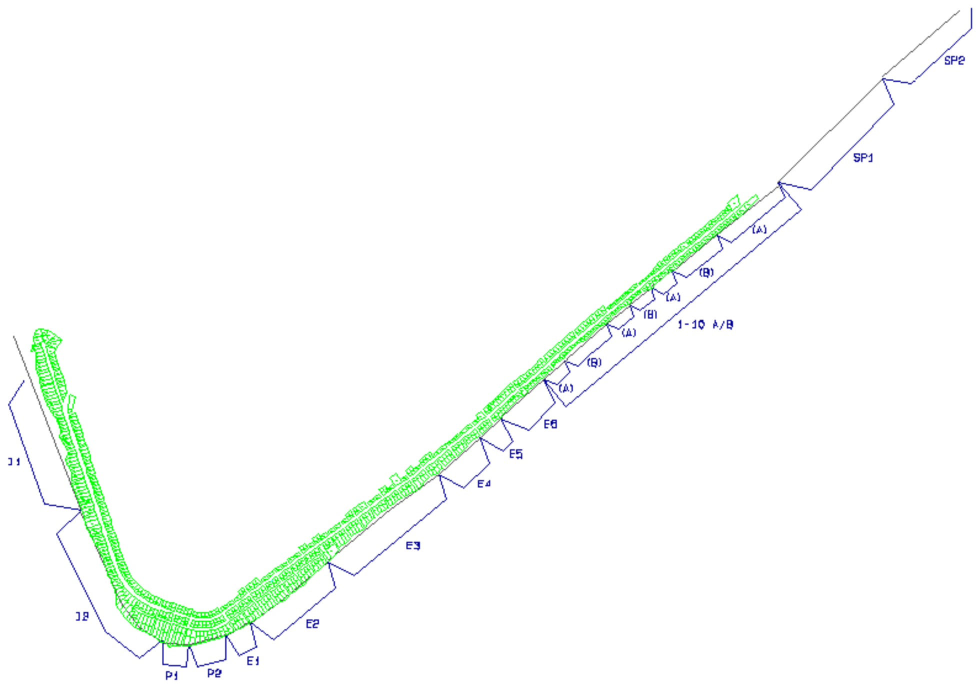


Figure 11: Spatial distribution of representative submerged beach profiles.

Table 5: Representative Submerged Profile Relationship to Groin Cells

Submerged Profile Name	Spatial Description
I1	0.75 mile segment of shoreline from Big Bay Creek towards the point
I2	0.6 mile segment of shoreline between I1 and the point
P1	Groin cell 28
P2	Groin cells 26 and 27
E1	Groin cells 24 and 25
E2	Groin cells 20, 21, 22, and 23
E3	Groin cells 16, 17, 18, and 19
E4	Groin cells 14 and 15
E5	Groin cell 13
E6	Groin cells 11 and 12
A	Groin cells 1, 2, 5, 7, and 10
B	Groin cells 3, 4, 6, 8, and 9
SP1	0.6 mile segment of shoreline extending north

	from groin 1
SP2	0.4 mile segment of shoreline north of SP2

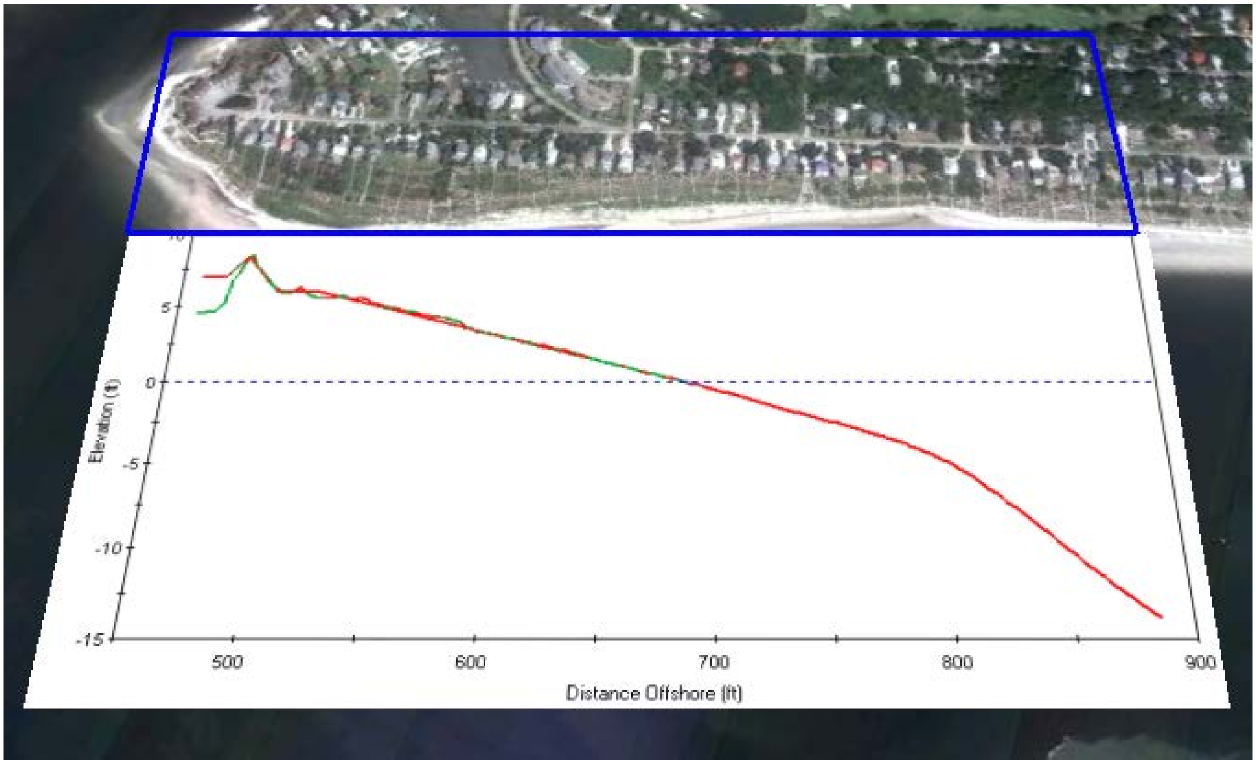


Figure 12: Representative and idealized beach profile for Reach I1.

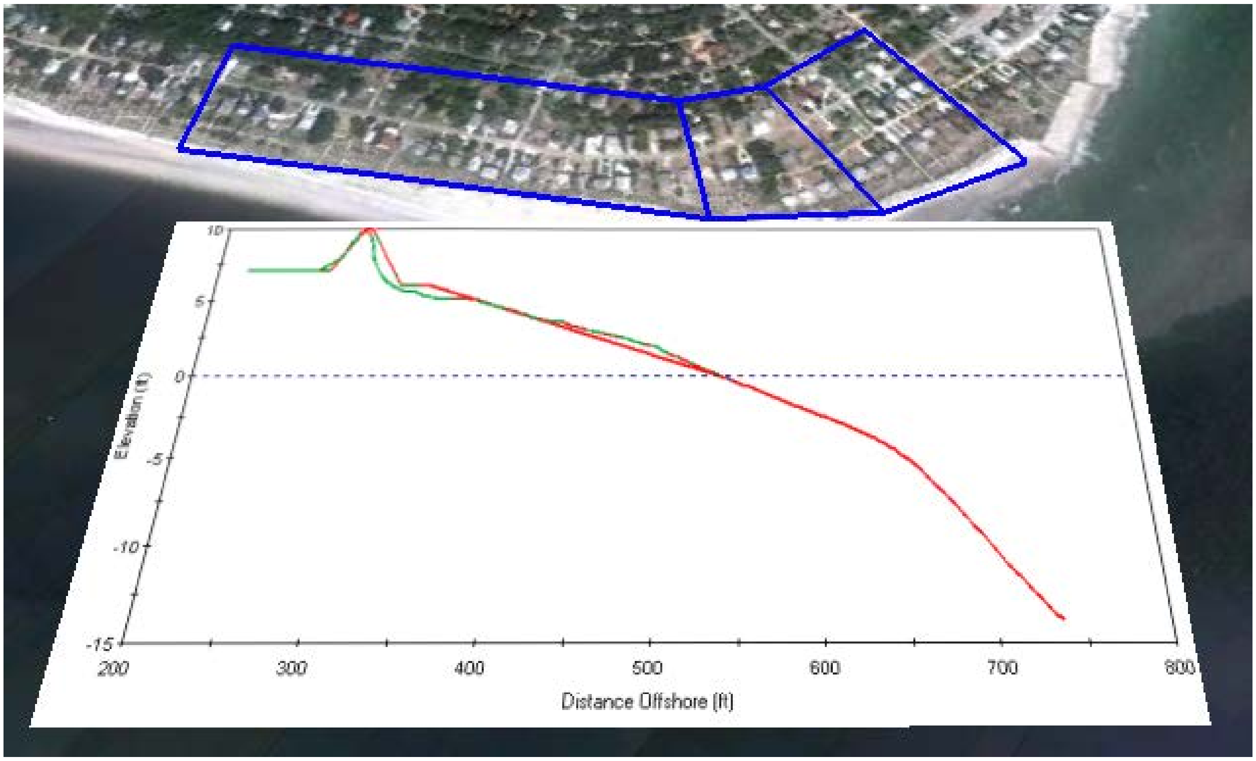


Figure 13: Representative and idealized beach profile for Reaches I2 through I4.

Figure 14: Representative and idealized beach profile for Reach P1.

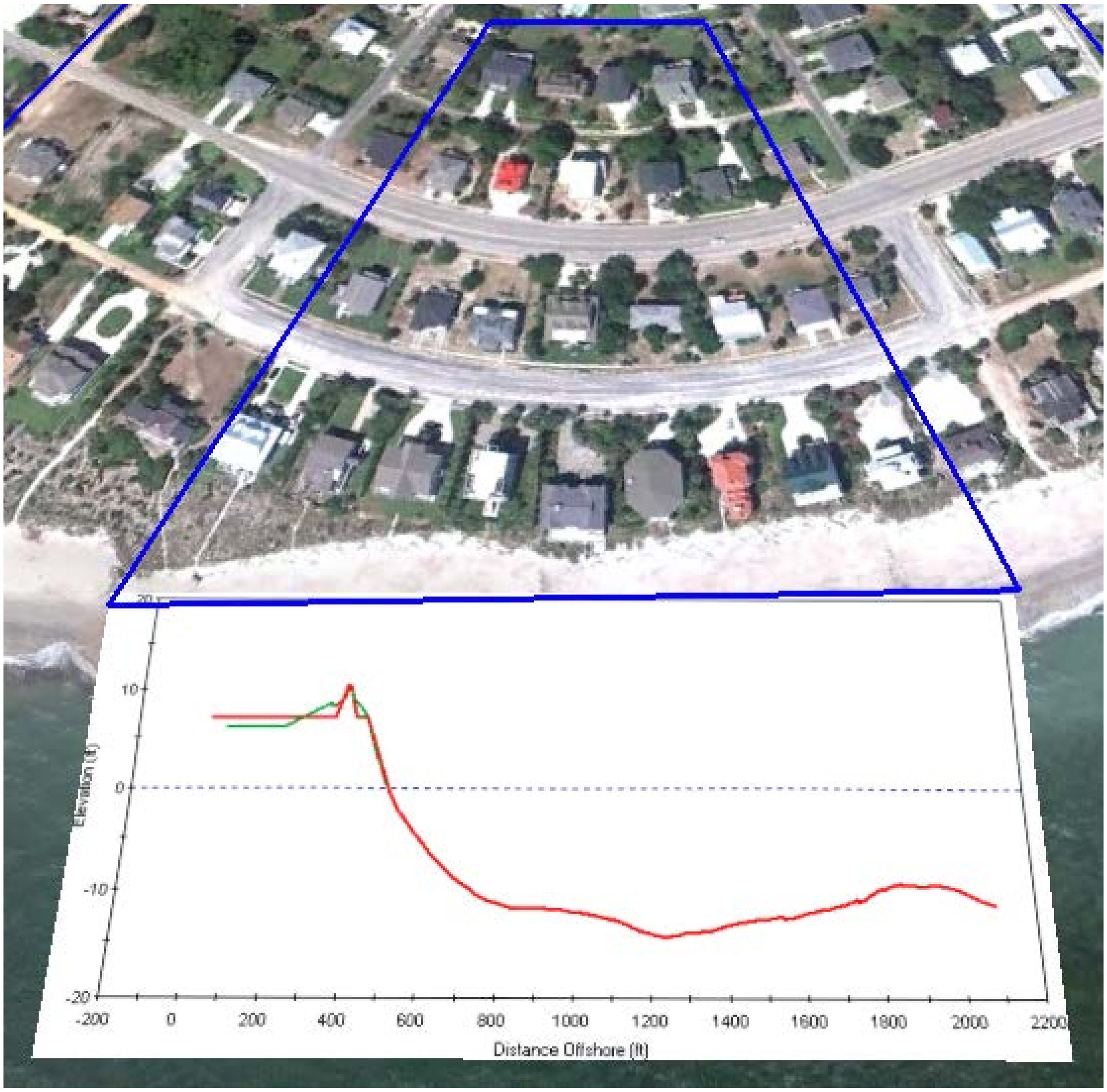


Figure 15: Representative and idealized beach profile for Reach P2.

Figure 16: Representative and idealized beach profile for Reach E1.

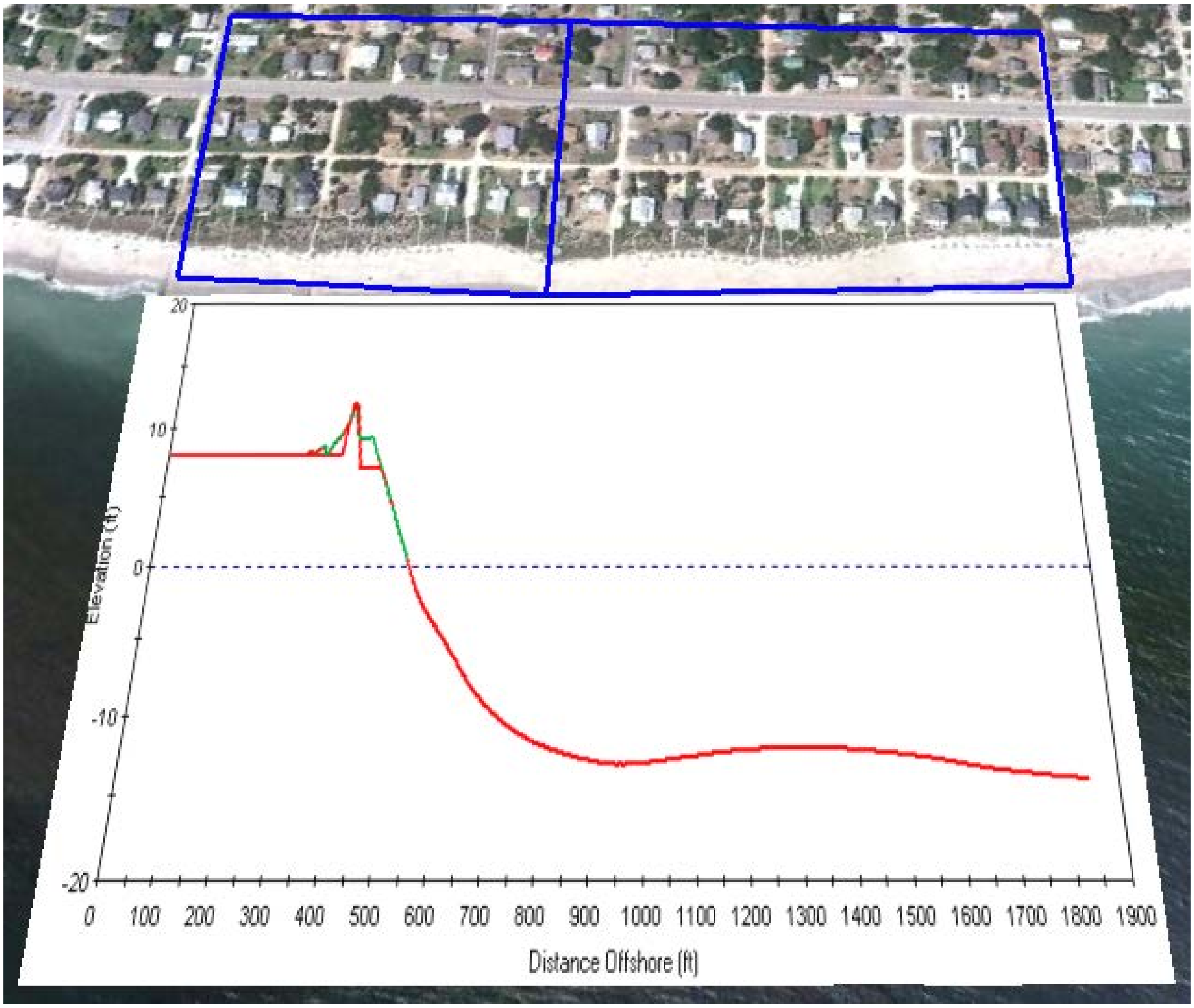


Figure 17: Representative and idealized beach profile for Reaches E2 and E3.

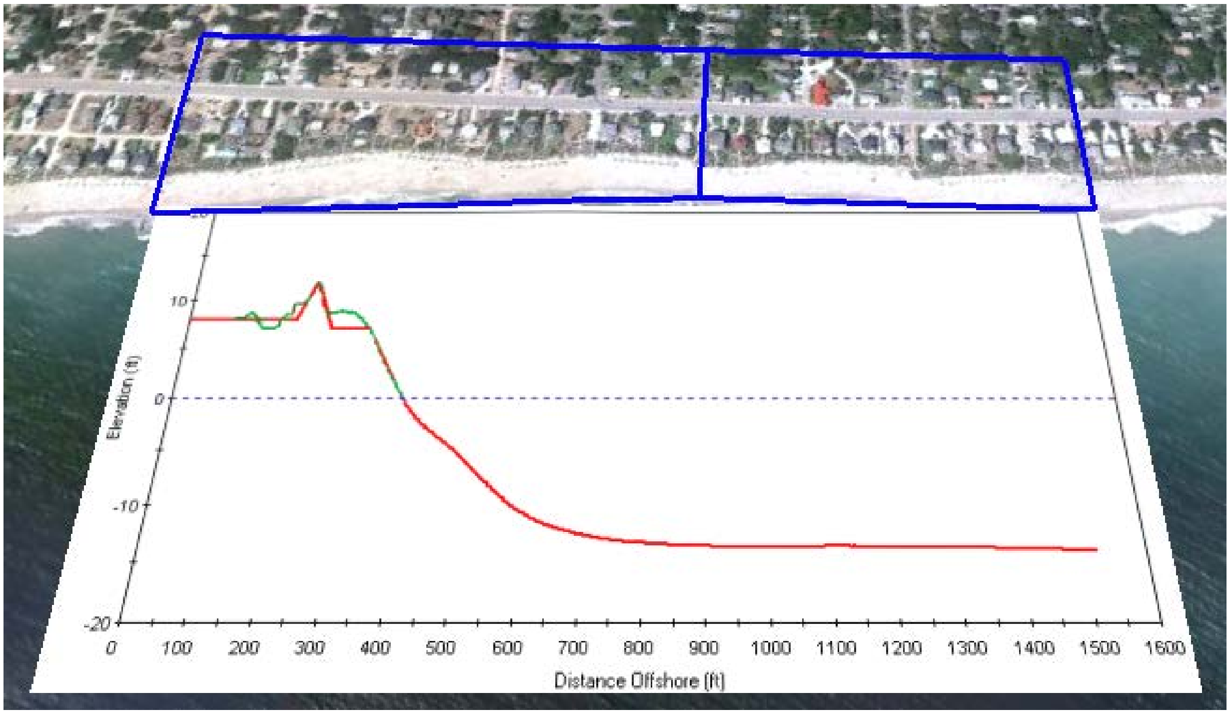


Figure 18: Representative and idealized beach profile for Reaches E4 and E5.

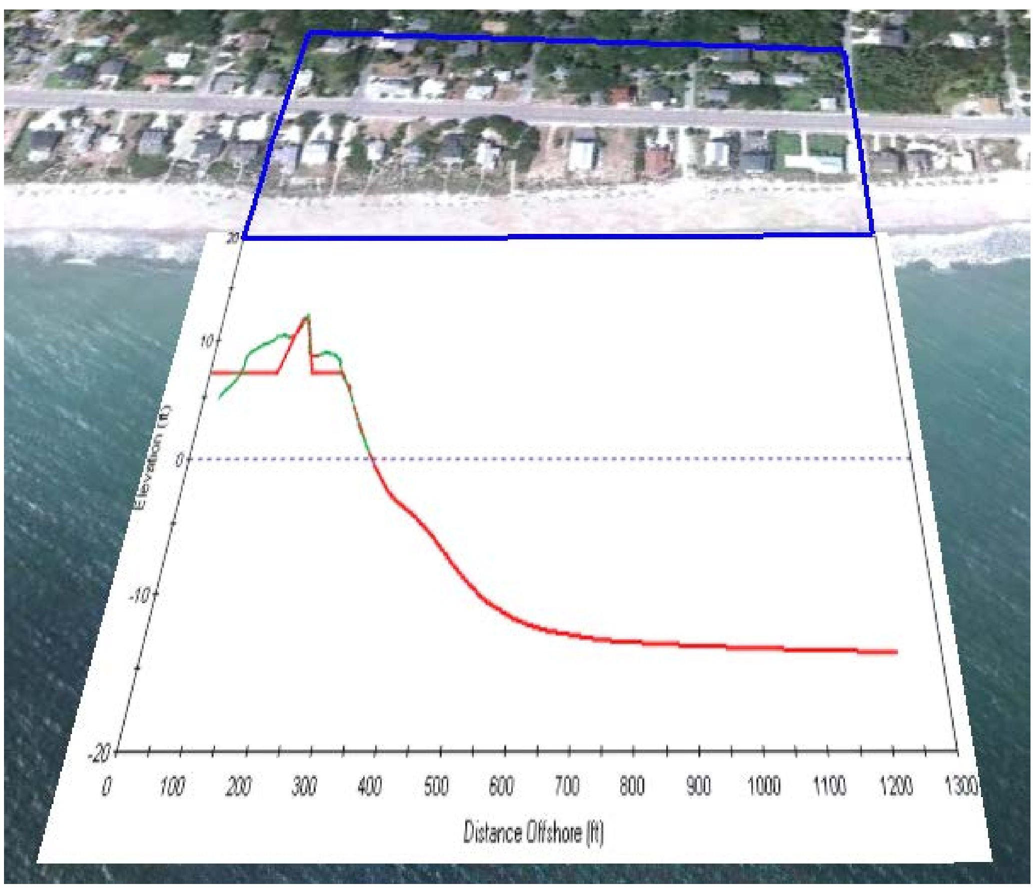


Figure 19: Representative and idealized beach profile for Reach E6.

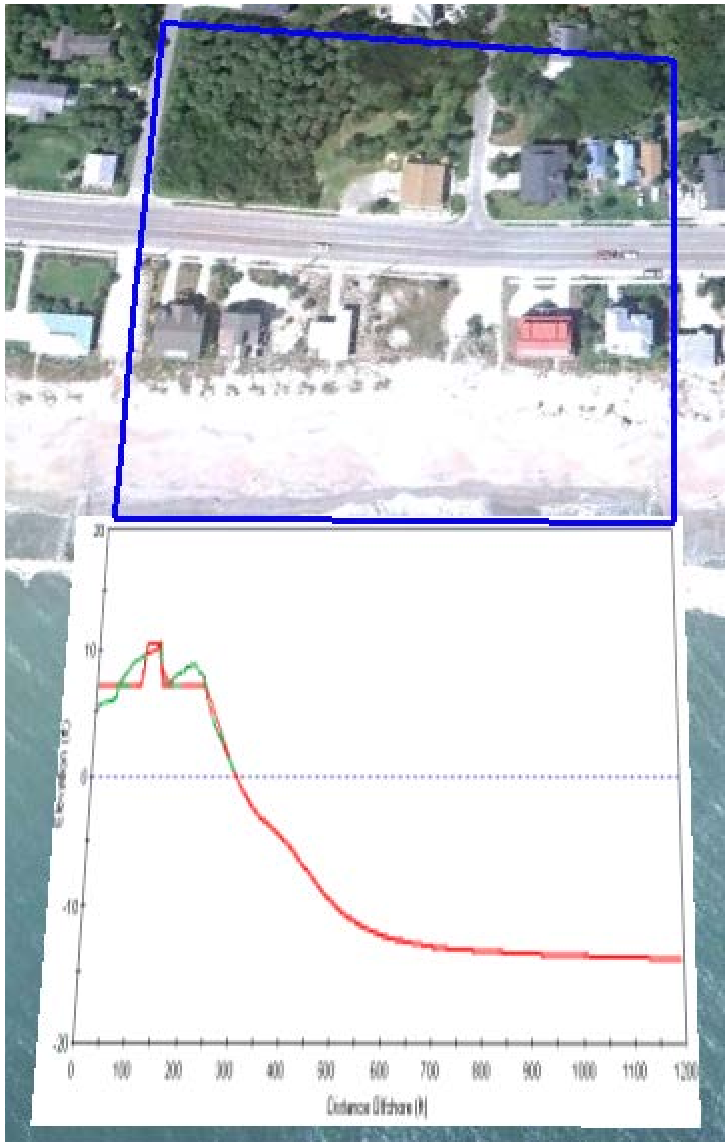


Figure 20: Representative and idealized beach profile for Reach E7.

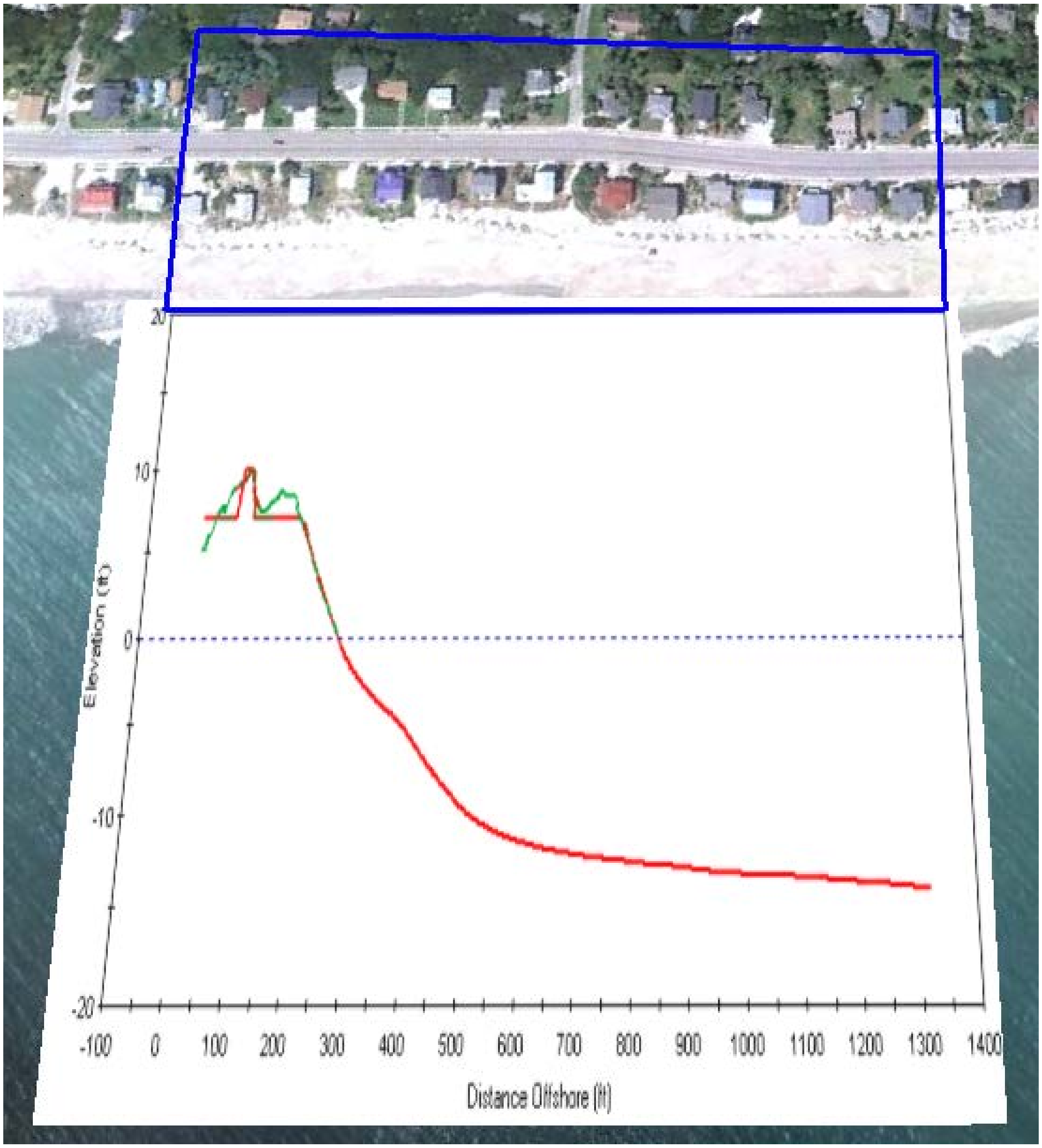


Figure 21: Representative and idealized beach profile for Reach E8.

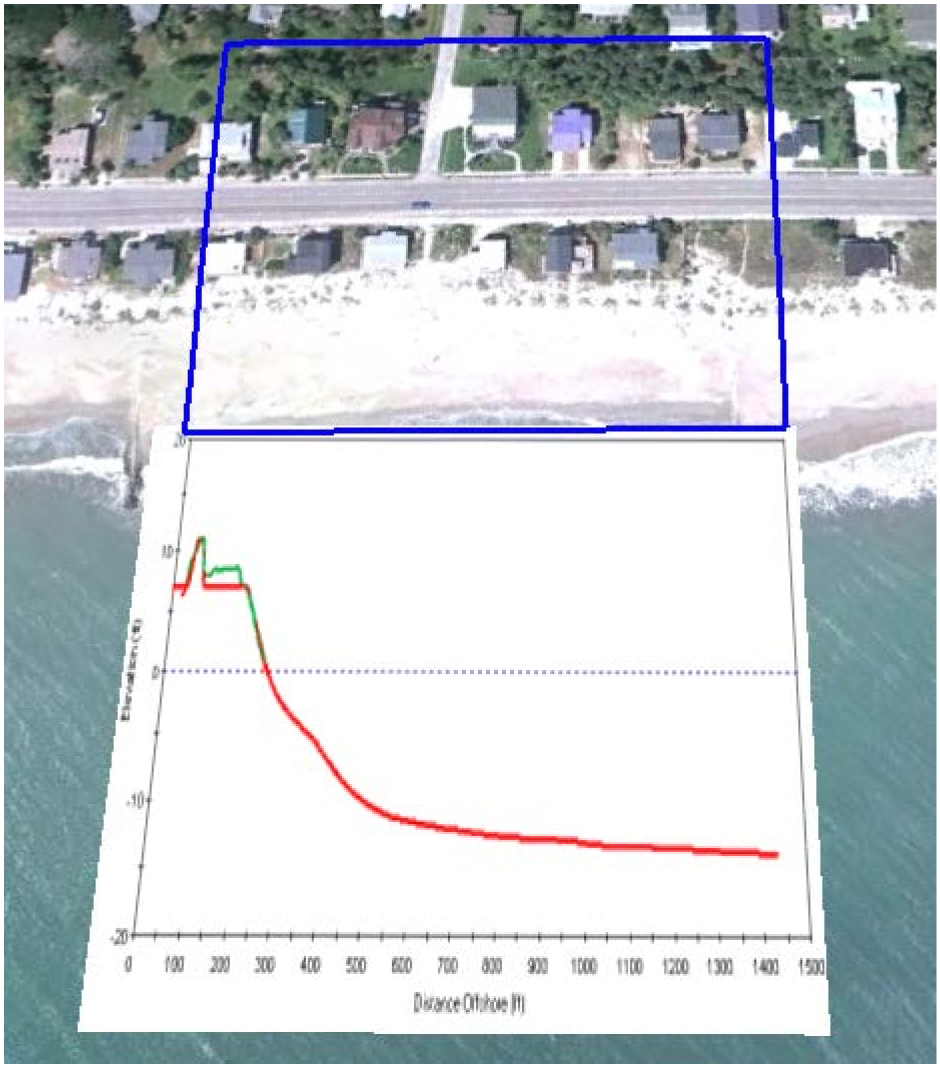


Figure 22: Representative and idealized beach profile for Reach E9.

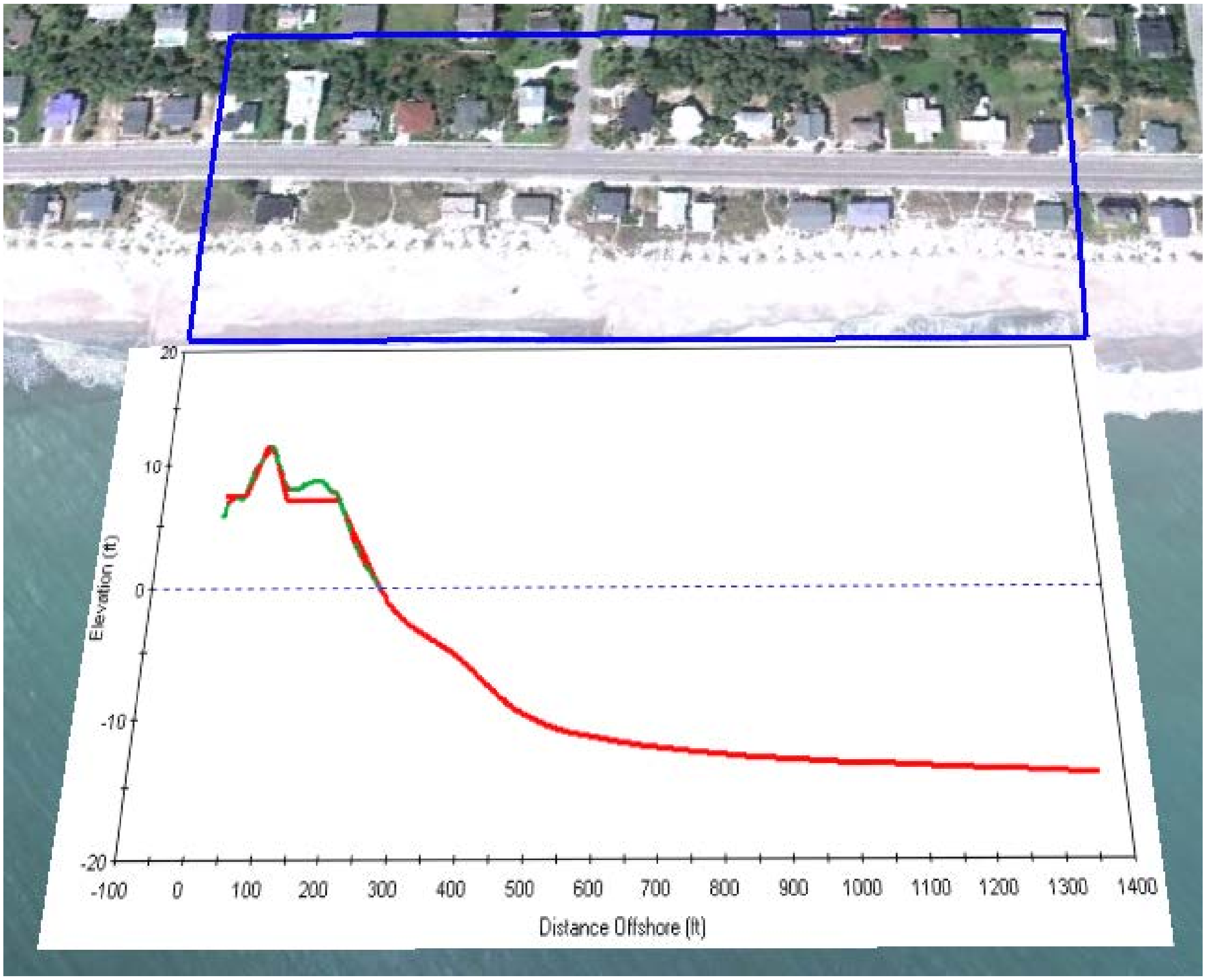


Figure 23: Representative and idealized beach profile for Reach E10.

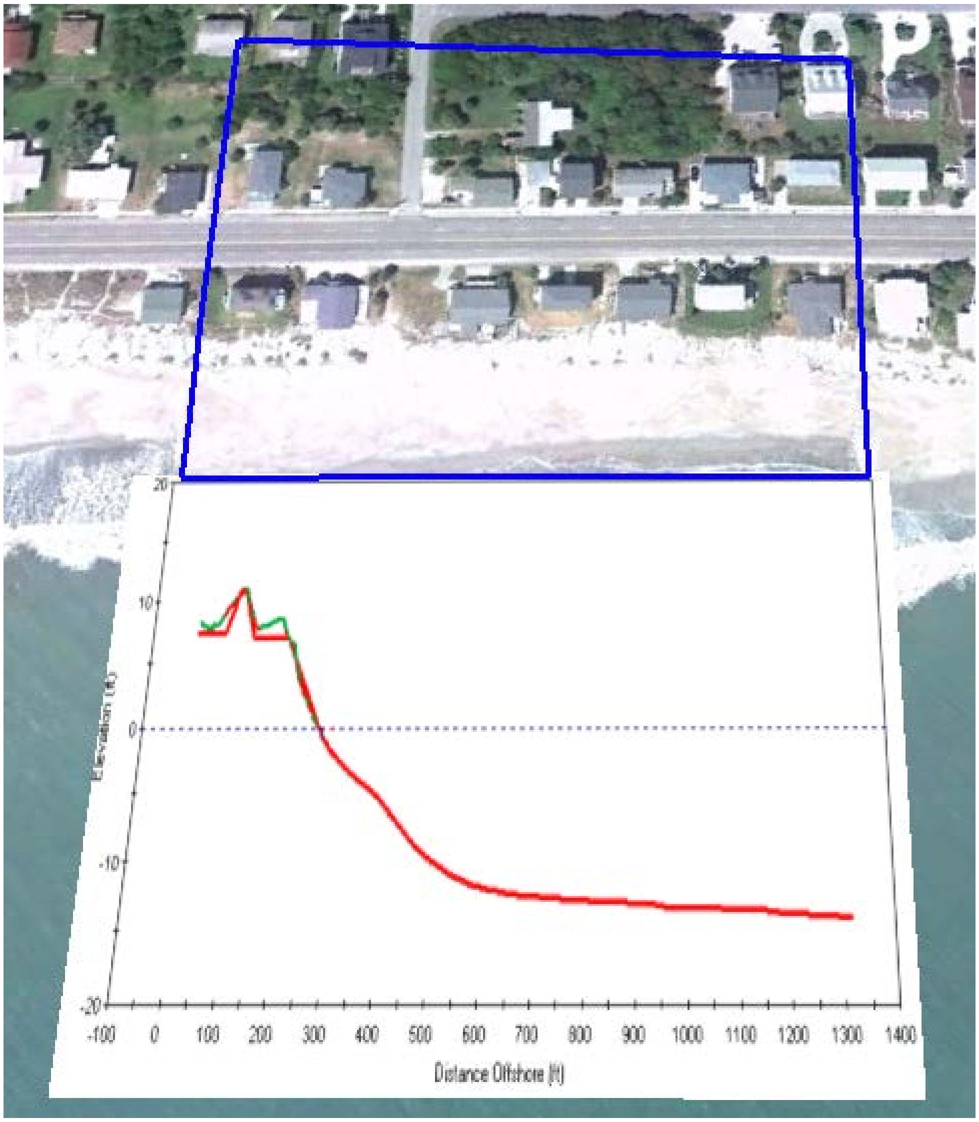


Figure 24: Representative and idealized beach profile for Reach E11.

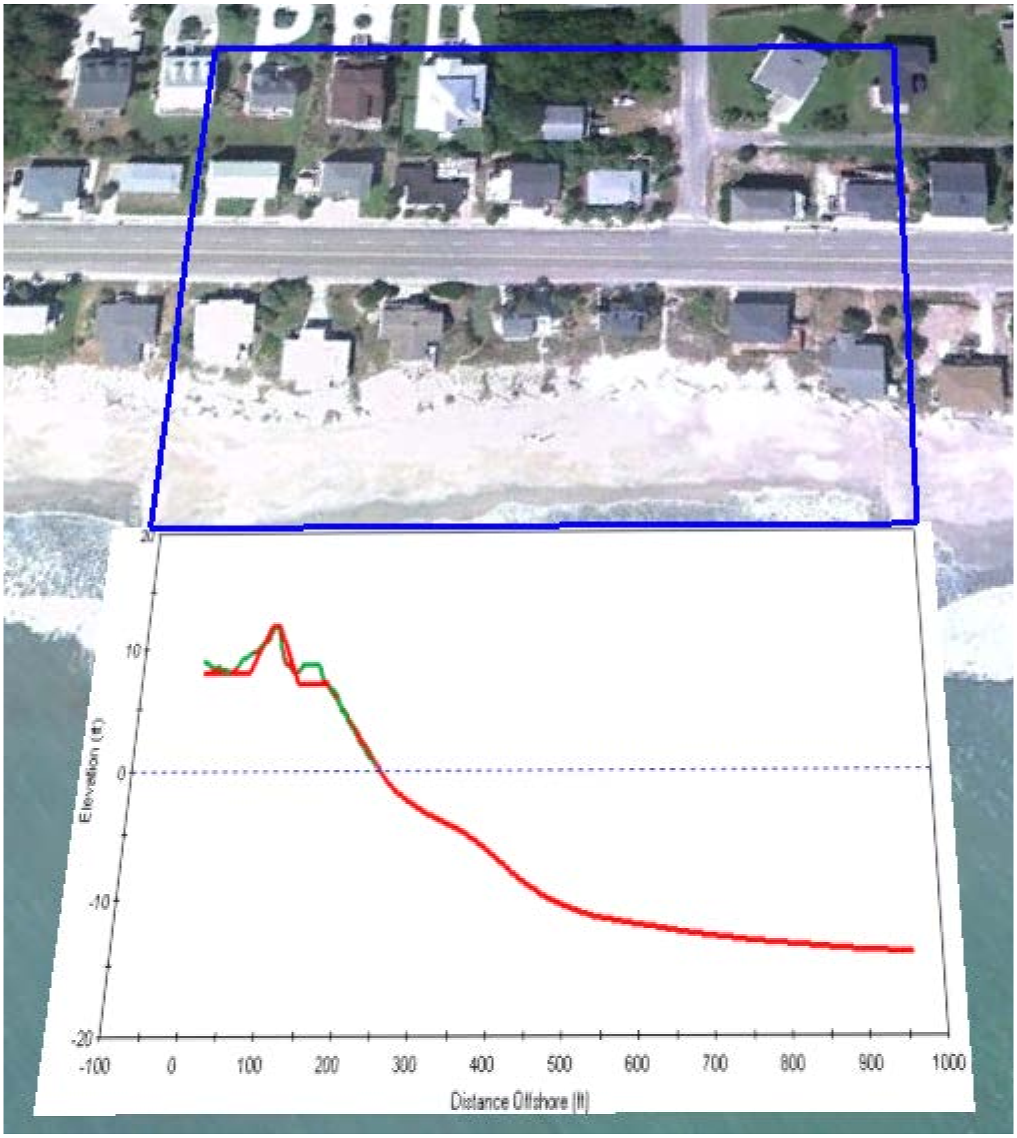


Figure 25: Representative and idealized beach profile for Reach E12.

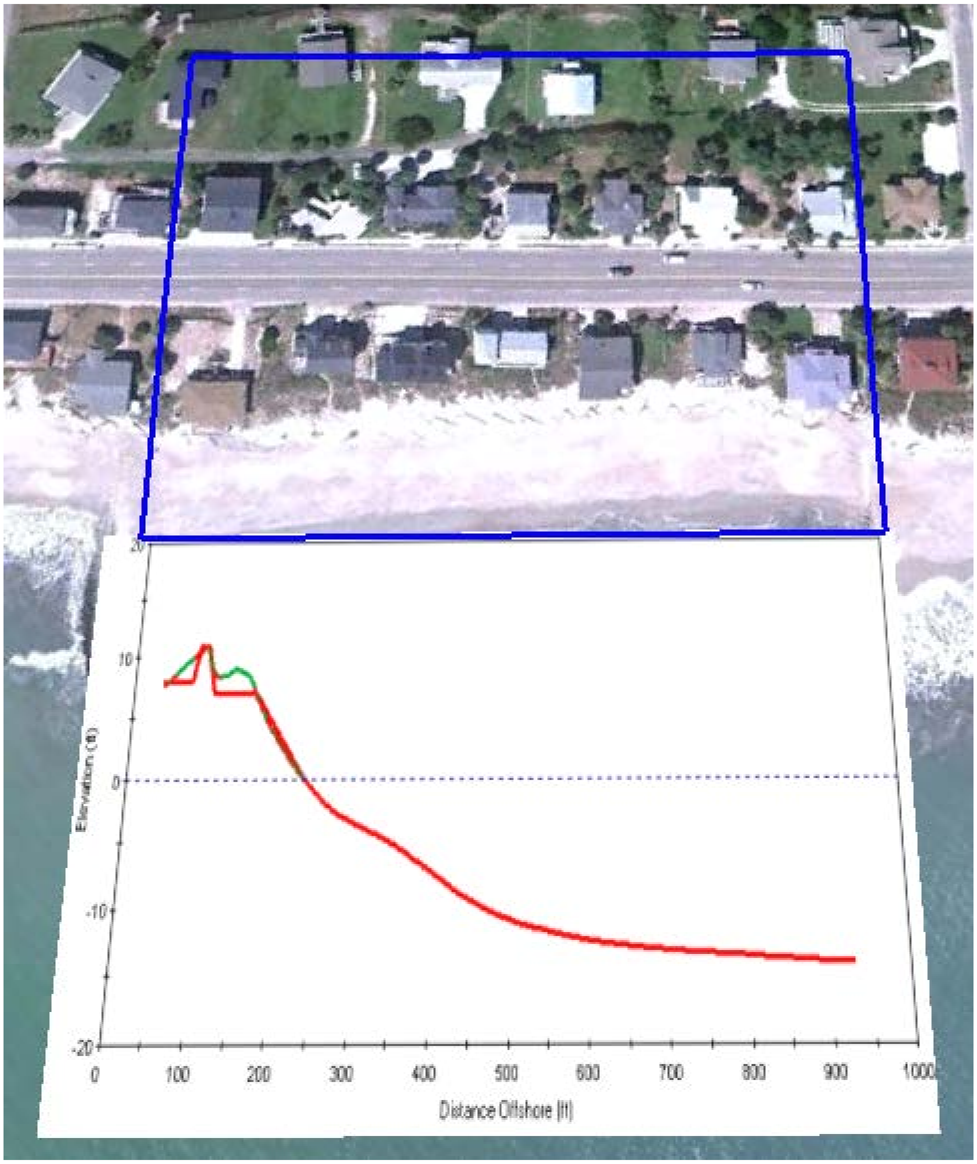


Figure 26: Representative and idealized beach profile for Reach E13.

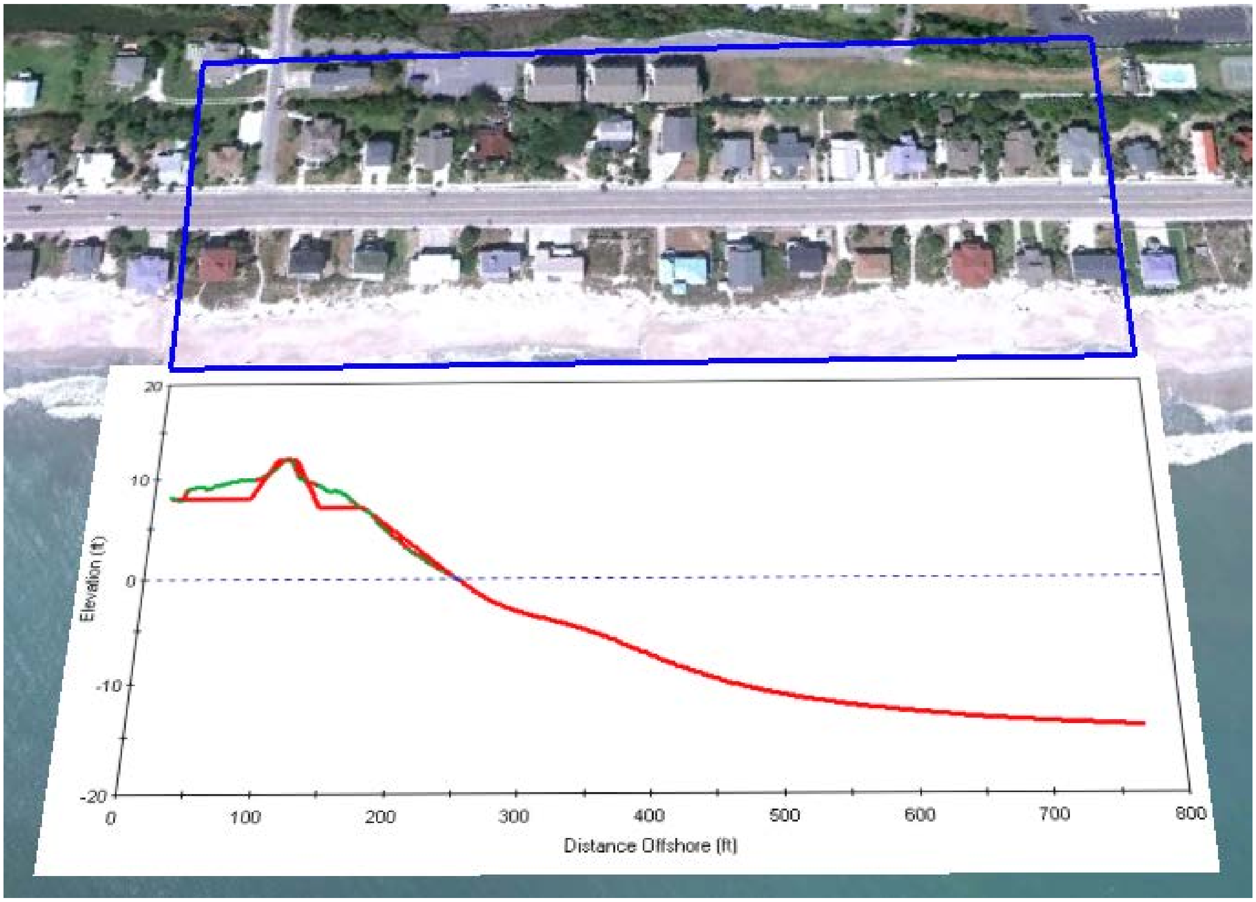


Figure 27: Representative and idealized beach profile for Reach E14.

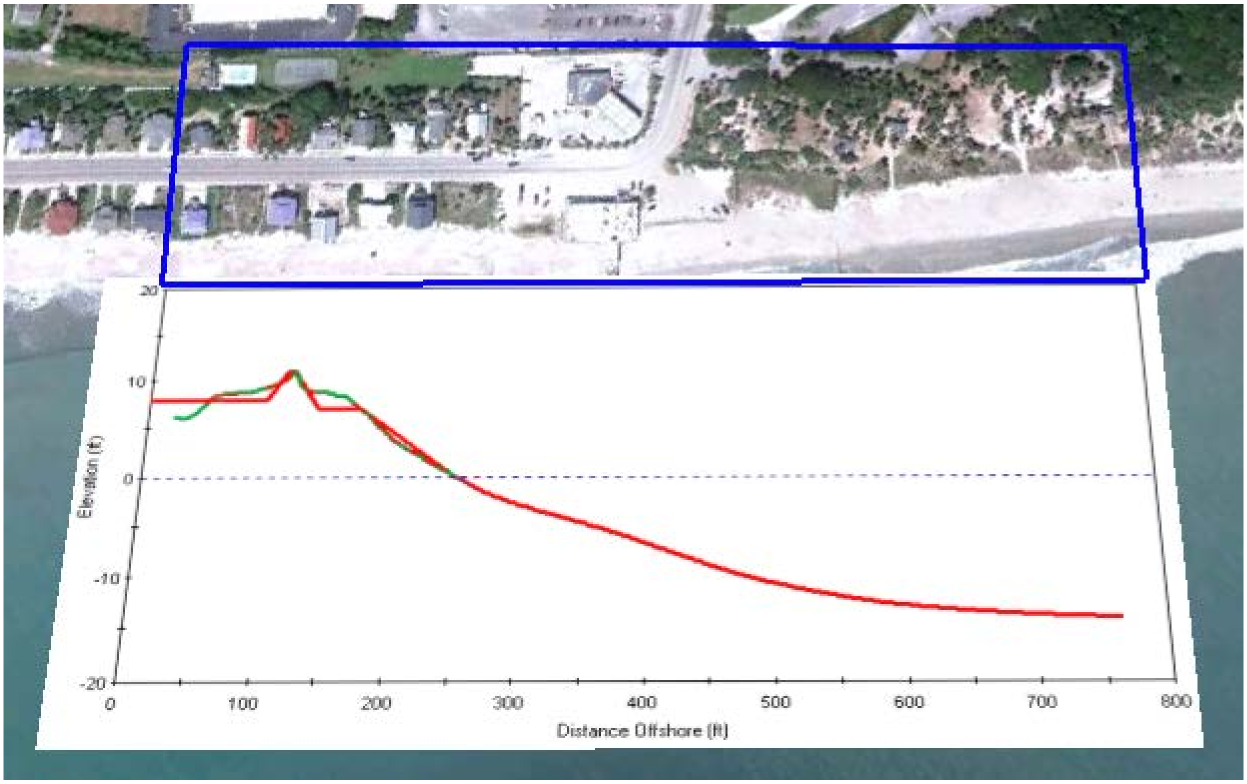


Figure 28: Representative and idealized beach profile for Reach E15.

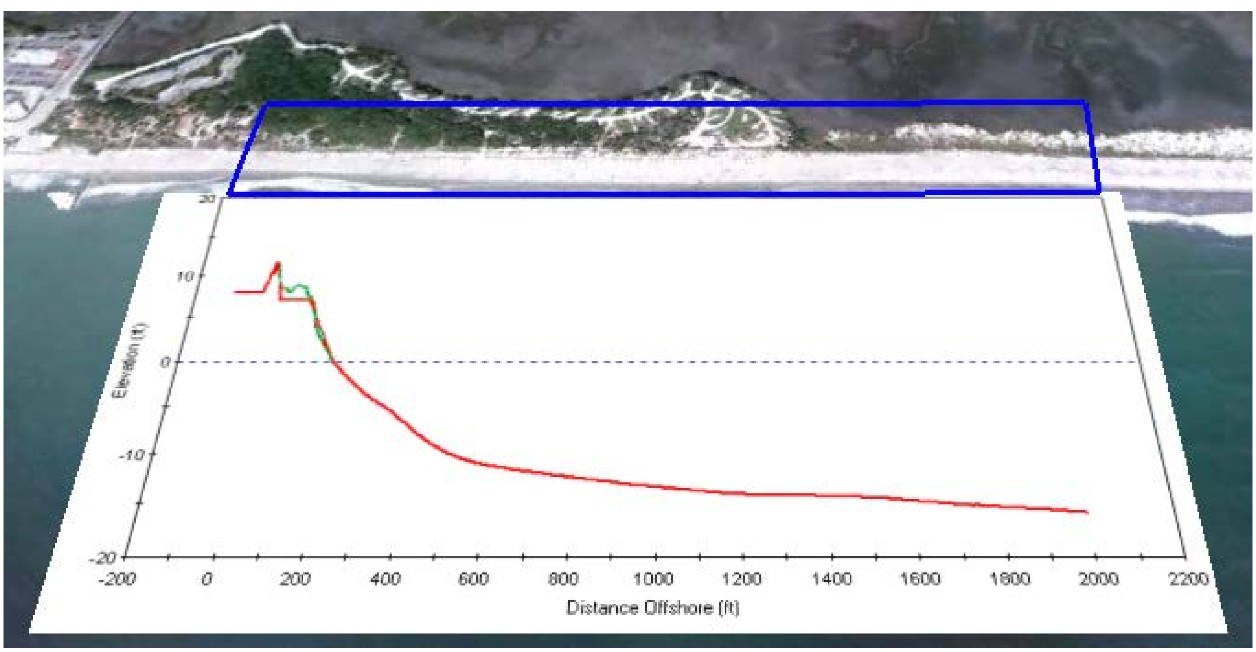


Figure 29: Representative and idealized beach profile for Reach SP1.

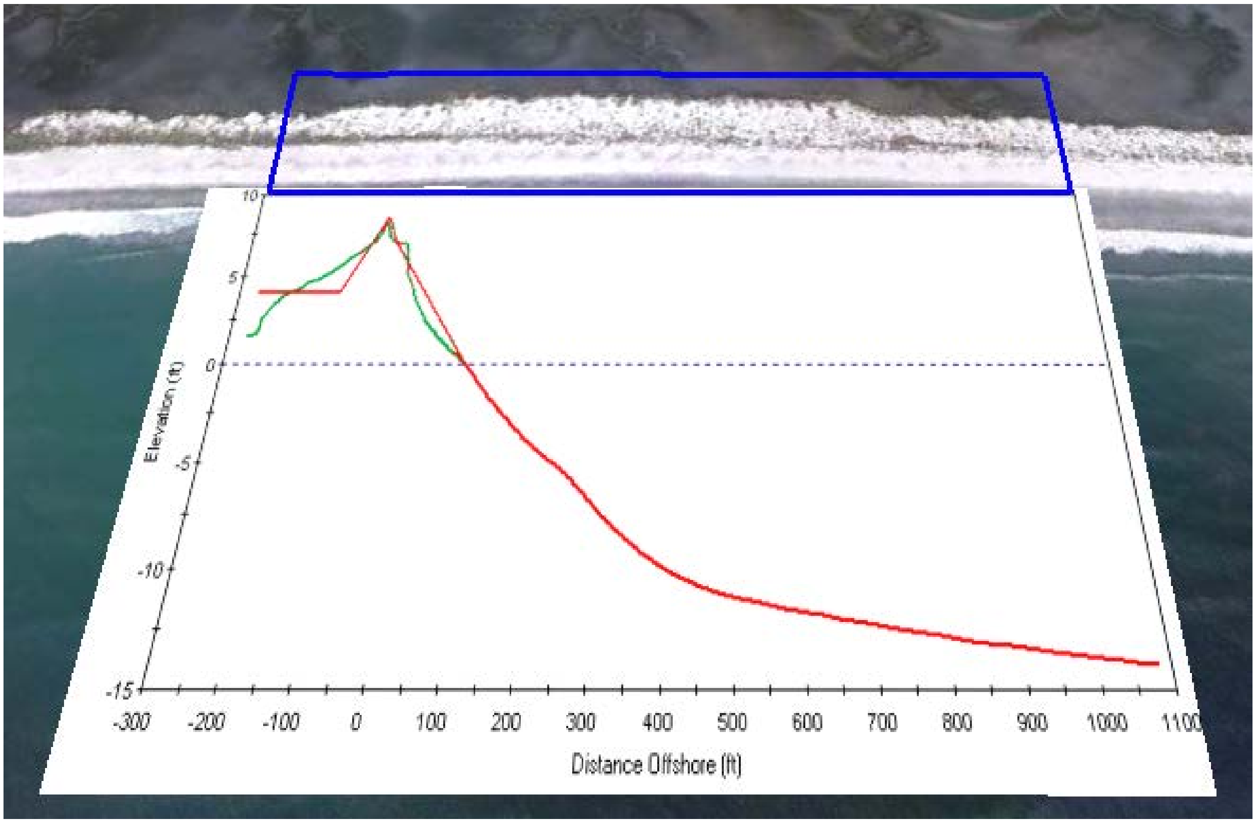


Figure 30: Representative and idealized beach profile for Reach SP2.

5.0 Reach Determination

The Beach-*fx* analysis reaches are largely defined by the morphologically driven development of representative profiles discussed in the previous section. Due to subtle shoreline orientation differences and the requirement to simulate different upland widths to capture the first row of damage elements on the landward side Palmetto Blvd. further subdivision of the Beach-*fx* analysis reaches was necessary. Specifically, Beach-*fx* reaches I2, I3 and I4, were defined based on the same representative beach profile to account for differing shoreline orientations and upland width. Likewise, Beach-*fx* reaches E2 and E3 as well as E4 and E5 were defined from common representative beach profiles. Figure 31 shows the lay-out of the Beach-*fx* analysis reaches for the Edisto project. The blue polygons denote the reach boundaries and the purple lines are the SBEACH reference lines that define the shoreline orientation within each reach. The SBEACH reference line which is defined by cartographic coordinates is required to establish a common cross-shore frame of reference between the one-dimensional SBEACH coastal process model and Beach-fx. Damage elements within each reach are projected on to the SBEACH reference line to obtain the damage element's cross-shore position which is subsequently used to determine the magnitude of the damage driving parameters (erosion, water depth, and wave crest elevation) which are all tied to the SBEACH cross-shore coordinate system.

Figure 31: Beach-fx reaches and SBEACH reference lines.

6.0 Beach-fx Coastal Processes Input Data Development

Storm-Induced Beach Profile Responses

The availability of a large database of beach profile response to the each storm in plausible storm suite is central to the operation of Beach-*fx*. This database is known to Beach-*fx* modelers as the *shore response database* (SDB). Two kinds of data are stored in the SDB for each storm/profile simulation: changes in berm width, dune width, dune height and upland width, and cross-shore profiles of erosion, maximum wave height, and total water elevation. The morphology changes (berm width, dune width, dune height and upland width) are used to modify the pre-storm beach profile to obtain the post-storm profile. The damage driving parameters (cross-shore profile of erosion, maximum wave height, and total water elevation) are used in the estimation of damages to damage elements within reaches associated with that representative profile. The SDB is a pre-generated set of beach profile responses to storms comprising the plausible storm suite, for a range of profile configurations that are expected to exist for different sequences of storm events and management action scenarios. The numerical model for simulating storm-induced beach change (SBEACH), (Larson and Kraus, 1990) was used to estimate beach profile responses to each of the storms contained in the plausible storm suite. As discussed in section 3.0 the historically-based storm suite includes 24 historical tropical storm events, 6 hypothetical tropical storm events, and 9 extratropical storm events. When combined with the statistical representation of astronomical tides the number of storms increased by a factor of 12, resulting in a plausible storm suite involving 360 tropical storm events and 108 extratropical storm events. A companion range of beach profile configurations were developed to encompass all expected beach configurations encountered under each of the evaluated without-project scenarios. The most robust end of beach profile configurations considered was defined by the existing condition representative beach profile (see section 4.0). The most vulnerable end of the beach profile configurations assumed that the dune feature was entirely removed and the upland was fronted with a zero berm width and foreshore slope down to the water's edge. Profiles were developed at 10 ft increments on berm width, 5 ft increments on dune width, and 1 ft increments on dune height between the most robust and most vulnerable beach profiles. This procedure generated a total of 2,335 unique beach profiles. The response of each of these beach profiles to the entire storm suite consisting of 468 plausible storm events was simulated using the SBEACH model. A total of 1,092,780 SBEACH simulations were performed and the results were imported to populate the SDB used as input to the Beach-fx model. Because of the large size of the resulting SDB the Edisto project was divided into three project domains:

1. Edisto South covering reaches I1, I2, I3, I4, P1, P2, E1, E2, E3, E4, and E5.
2. Edisto Central covering reaches E6, E7, E8 and E9.
3. Edisto North covering reaches E10, E11, E12, E13, E14, E15, SP1, and SP2.

Profile Shoreline Position Changes

The next step required to fully implement the Edisto Beach project in Beach-*fx* is calibration of Beach-*fx* such that the model reproduces, on average over multiple lifecycle simulations, the historical shoreline rate of change. To do this one must first develop an estimate of the historical shoreline rate of change. The available beach profile information as outlined in Table 4 was employed as input to make this required estimate. Because the beach profile data consists of distance and elevation pairs across the dune, berm, foreshore, and portions of the offshore and are collected at constant positions (monuments) along the length of the island it is possible to use the profile data to analyze the evolution of the beach over time. The most common, easily understood, and useful shoreline positions are defined by the intersection of the sandy beach with the mean high water tidal datum.

In general, a datum is a base elevation used as a reference from which to determine heights or depths. A tidal datum is a standard elevation defined by a certain phase of the tide and is applicable for a specific time period. The National Tidal Datum Epoch is the specific 19-year period adopted by the National Ocean Service as the official time segment over which tide observations are taken and reduced to obtain mean values for tidal datums.

This analysis utilizes shoreline positions defined by mean high water in order to calculate shoreline change (erosion/accretion) amounts and rates. Mean High Water (MHW) is defined as the average of all the high water heights observed over the National Tidal Datum Epoch. According to the bench mark sheet for Edisto Beach (ID 8667630), published by the National Oceanic and Atmospheric Administration (NOAA) National Ocean Service (NOS), the elevation of the MHW tidal datum is +2.48 feet (+0.756 meters) relative to the North American Vertical Datum of 1988 (NAVD88).

The magnitude of shoreline position change from one year to the next and the rate of change over longer periods are extremely important pieces of information for engineers, scientists, economists, etc.

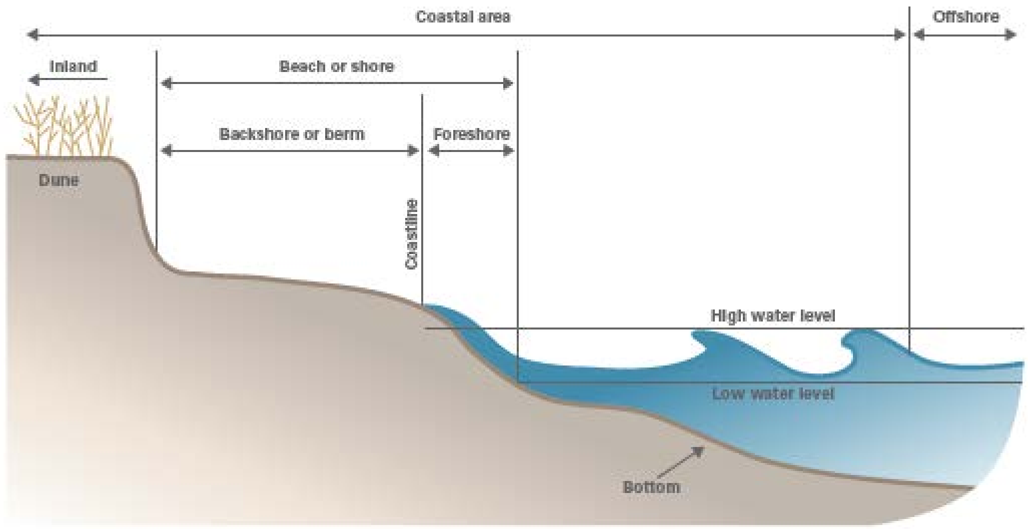


Figure 32: Diagram of the features of a typical sandy beach (from How Beach Nourishment Works, USACE 2007).

South Carolina OCRM is very interested in the condition of the state's beaches and issues an annual report summarizing the changes to the beaches during the previous year. The 2008 Annual State of the Beaches Report states that Edisto Island has a low long-term erosion rate, but an extreme lack of sand. The report does not quantify the long-term erosion rate, but does contend that the low erosion rate is due to the presence of the extensive groin field. According to the report, the southern half of the developed portion of Edisto Beach has the widest oceanfront beach on the island, while the northern half was one of the most critically eroded sections of beach anywhere in the state until the 2006 renourishment.

This analysis of shoreline change used the Corps' RMAP software package to calculate the changes to the MHW and MLW contours between consecutive yearly beach profiles for each profile in the CSE and OCRM datasets. The OCRM dataset contains fewer monuments than the CSE dataset, but it does have a much longer period of record. The analysis benefited from having both the spatial detail provided by the CSE dataset and the historical perspective of the OCRM dataset.

Table 6 provides the results of the MHW shoreline change analysis for the CSE dataset. Results are provided for the yearly changes between 2004 and 2008 and the change rates. The MHW shoreline change rates were determined for the entire time period, identified as "With Fill", and for the period not affected by the 2006 renourishment project, identified as "Without Fill". One can see from the "2005-2006" and "With Fill" columns, that the 2006 renourishment project had significant influence on the position of the MHW shoreline. More specifically, the 2006 renourishment was sufficient enough to counteract the short- and long-term erosion rates and result in positive (accretional) shoreline change rates at all but 9 of the 90 CSE beach profiles. In addition, of the 9 profiles with negative "With Fill" MHW change rates, 7 of these are immediately downdrift of a groin. The MHW shoreline change rates from Table 6 are also presented graphically, in three dimensions (3D), in Figure 33. In order to provide the rates enough separation from the zero value and make them more easily seen and interpreted, the magnitude of the rates were multiplied by a factor of fifty (50). It is clear from the sawtooth shape of the change rates that the magnitudes are affected by the groin field. The magnitudes of the "With Fill" MHW change rates are larger at those profile locations immediately south of a groin and decrease while moving to the south within the same groin cell. Likewise, the magnitudes of the "Without Fill" MHW change rates are larger immediately south of a groin and decrease while moving south within the same groin cell.

Table 6: Mean High Water (MHW) Shoreline Change for CSE Profile Data

	MHW Shoreline Change (ft)				MHW Shoreline Change Rate (ft/yr)	
Benchmark	(2004-2005)	(2005-2006)	(2006-2007)	(2007-2008)	**With Fill**	**Without Fill**
SCCC 2270	-36.58	43.37	4.26	-6.72	1.09	-18.78
SCCC 2250	-50.09	39.56	0.04	12.78	0.58	-14.73
SCCC 2230	-44.17	137.96	-23.11	-3.96	16.81	-20.60
SCCC 2210	-38.21	154.10	-38.95	-14.03	15.85	-23.12
1+75	-8.22	125.43	-55.00	17.12	19.98	5.09
1+300	-19.34	98.43	-38.17	-9.94	7.80	-13.12
1+525	-12.19	48.52	-14.10	-36.07	-3.49	-23.17
2+75	-1.07	129.40	-55.94	22.19	23.82	10.64
2+300	-1.76	99.23	-35.71	-7.51	13.66	-4.50
2+525	-4.97	52.68	-8.36	-37.32	0.51	-20.76
3+75	-6.07	116.49	-51.98	19.87	19.73	7.38
3+300	-4.80	70.94	-26.00	-12.15	7.05	-8.10
3+525	-17.47	28.46	-0.32	-40.21	-7.44	-27.47
4+75	-0.45	105.99	-53.72	17.43	17.44	8.53
4+300	-0.52	62.25	-27.35	-12.29	5.56	-6.36
4+525	-6.86	16.35	-3.78	-39.48	-8.51	-22.63
5+75	2.49	129.99	-54.41	9.74	22.12	5.92
5+300	0.22	94.64	-33.36	-21.86	9.98	-10.84
5+525	-5.46	48.14	-14.82	-47.16	-4.86	-25.88
6+75	4.27	132.97	-42.57	-1.01	23.59	1.30
6+300	-0.72	112.11	-29.12	-20.54	15.55	-10.57
6+525	2.88	63.17	-6.56	-47.86	2.93	-22.72
7+75	-0.60	146.38	-29.65	-1.00	29.00	-0.75
7+300	-1.73	118.17	-12.68	-23.25	20.28	-12.35
7+525	-2.86	71.02	15.49	-38.67	11.33	-20.54
8+75	-5.86	145.87	-27.45	11.89	31.35	3.47
8+300	-10.42	108.10	-1.91	-16.41	19.99	-12.60
8+525	-13.06	55.13	22.83	-37.64	6.87	-24.33
9+75	4.93	127.64	-14.90	8.13	31.69	6.14
9+300	-0.38	88.64	3.22	-11.28	20.20	-5.80
9+525	-6.91	42.31	30.05	-31.04	8.67	-18.43
10+75	-6.93	149.40	-16.88	13.97	35.15	4.06
10+300	-2.82	112.18	5.13	-7.52	26.94	-4.95
10+525	-4.77	67.52	27.73	-29.62	15.33	-16.82
11+75	-16.43	159.20	-26.22	13.34	32.72	-0.26
11+300	-17.94	132.93	-16.20	-10.84	22.15	-12.98
11+525	-23.62	100.37	-4.31	-29.85	10.73	-24.88
12+75	-19.54	166.25	-30.37	11.52	32.21	-2.48
12+300	-9.47	136.70	-19.74	-12.54	23.92	-10.26
12+525	-5.26	106.91	-14.30	-31.61	14.04	-18.02
13+75	-10.22	135.84	-25.27	11.90	28.27	1.64

	MHW Shoreline Change (ft)				MHW Shoreline Change Rate (ft/yr)	
Benchmark	(2004-2005)	(2005-2006)	(2006-2007)	(2007-2008)	**With Fill**	**Without Fill**
13+300	-15.08	117.42	-16.36	-12.73	18.45	-12.72
13+525	-25.24	90.88	-5.69	-31.32	7.21	-26.30
14+00	-12.64	135.37	-25.47	10.31	27.10	-0.17
14+350	-15.61	98.93	-9.24	-7.80	16.70	-10.48
14+600	-29.00	54.34	12.19	-26.58	2.76	-25.52
15+65	-0.73	95.76	-31.33	20.33	21.17	9.86
15+245	-11.62	83.14	-27.30	1.98	11.64	-3.91
15+450	-26.66	55.65	-15.63	-16.72	-0.85	-19.60
16+75	-5.20	105.14	-22.07	10.58	22.28	3.10
16+300	-14.95	95.74	-26.62	-4.96	12.40	-8.78
16+525	-31.85	70.04	-24.74	-21.69	-2.08	-24.27
17+75	-13.70	144.20	-49.35	9.11	22.74	-1.22
17+300	-17.97	121.72	-21.25	-21.71	15.31	-18.43
17+525	-32.08	84.85	-16.37	-19.73	4.20	-23.39
18+75	-10.98	137.91	-32.70	4.30	24.82	-2.48
18+300	-7.64	117.30	-24.88	-8.86	19.12	-7.65
18+525	-21.28	94.73	-15.43	-19.94	9.59	-18.94
19+100	-14.27	137.34	-26.74	2.00	24.77	-5.02
19+525	-7.83	101.92	-1.37	-11.63	20.43	-9.12
19+955	-3.39	38.22	27.55	-24.19	9.62	-13.52
20+100	11.69	90.87	-29.49	2.15	18.95	6.00
20+350	-2.61	76.07	-3.07	-20.26	12.63	-11.23
20+600	-14.93	29.46	33.24	-39.78	2.01	-26.18
21+75	-2.16	76.44	-21.67	6.73	14.95	2.45
21+265	-8.33	64.89	-14.31	-8.69	8.45	-7.86
21+430	-28.96	47.16	3.17	-28.96	-1.91	-26.69
22+75	5.15	75.01	-17.91	14.43	19.31	9.39
22+268	0.28	68.85	-5.81	-10.06	13.42	-4.91
22+460	-18.06	41.78	10.80	-33.44	0.27	-24.33
23+100	1.95	48.24	-12.48	8.28	11.58	4.96
23+220	1.41	41.07	-2.46	-13.54	6.67	-6.18
24+100	1.57	48.17	-1.63	-10.07	9.58	-4.37
24+190	-0.18	39.56	-1.07	-21.86	4.14	-11.01
25+100	-9.45	70.01	-23.57	7.59	11.23	-0.19
25+200	-13.89	58.72	-18.47	-6.65	4.96	-9.18
26+115	-6.77	95.54	-54.72	1.22	8.88	-2.24
26+235	-12.30	86.10	-43.19	-13.58	4.29	-11.98
27+145	6.31	110.55	-26.73	-53.27	9.28	-23.97
27+290	8.92	69.15	13.74	-59.63	8.11	-26.05
28+130	-7.21	75.16	33.48	-28.94	18.26	-17.51
28+277	-8.59	47.83	32.39	-20.72	12.82	-13.98
SCCC 2135	46.56	-20.98	83.76	-59.06	12.66	-9.90
CSE 2130B	49.54	1.07	117.29	40.31	52.45	41.04
CSE 2130A	7.00	11.90	155.93	23.71	50.01	14.81
SCCC 2130	-13.01	-57.78	134.10	3.91	16.93	-3.53
SCCC 2120	30.19	-28.01	-30.62	52.89	6.16	39.17
SCCC 2115	21.11	-26.25	4.79	-15.58	-4.01	1.11
SCCC 2113	-19.80	-0.57	-68.11	44.94	-10.97	14.12
SCCC 2110	25.21	-24.93	65.20	12.61	19.67	16.93

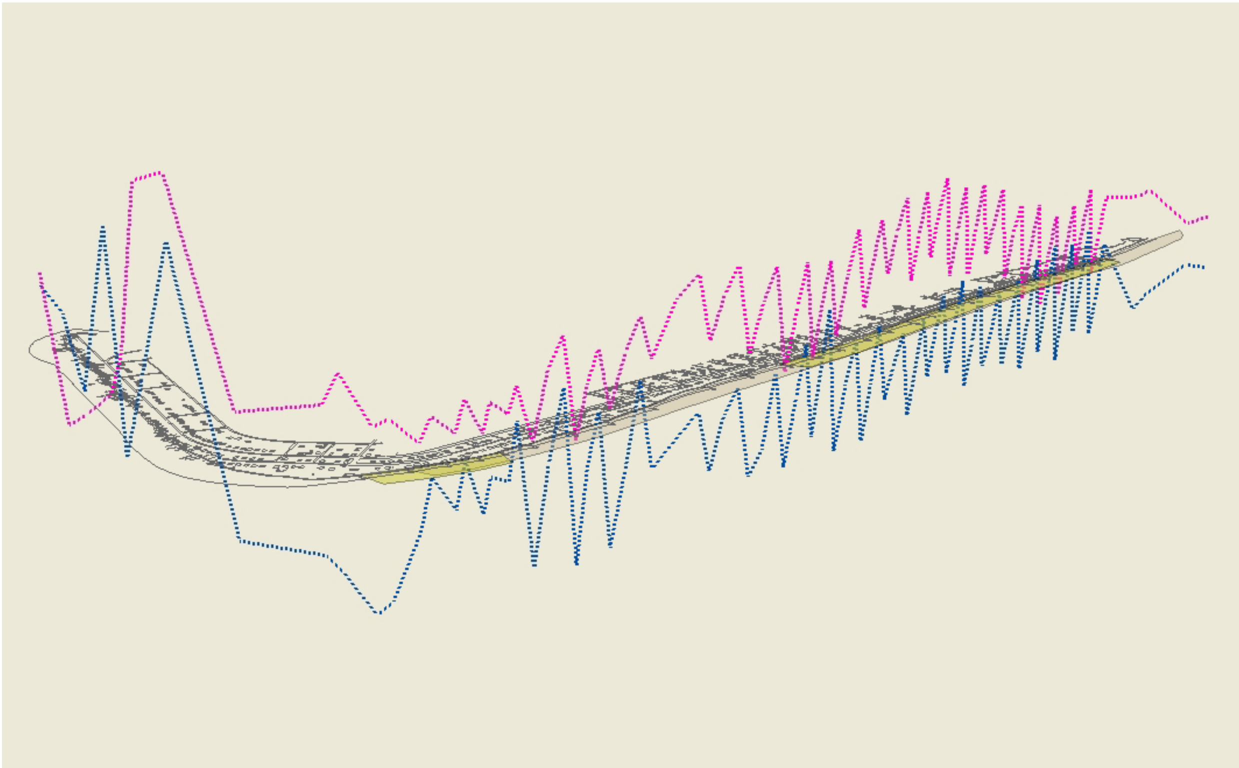


Figure 33: Three dimensional representation of MHW shoreline change rates (ft/yr) for CSE beach profiles along Edisto Island (pink represents rates including the 2006 nourishment, blue represents rates excluding the 2006 nourishment).

The length of record of the OCRM beach profiles was too long to present all of the MHW shoreline change magnitudes, so only the shoreline change rates are presented in Table 7. The shoreline change rates in Table 7 are listed from north to south along the coastline of Edisto Island, from the County Park to the South Edisto River. Because the beach profile records begin in 1988, the "With Fill" rates in Table 7 include two beach nourishment projects, the first in April 1995 and the second in 2006. The "Without Fill" rates neglect the influence of these beach fill projects by excluding the shoreline changes directly attributable to the fill and the subsequent changes as the beach equilibrates. The "With Fill" change rates are missing from SCCC 2198 because no beach profile data exists for the periods surrounding the nourishment projects. Likewise, the "Without Fill" change rates for SCCC 2150 through 2113 are missing because at the time of this analysis OCRM beach profile data was only available for 2006 and 2007. With the exception of SCCC 2198 (only 5 years of data), the shoreline change rates for SCCC 2230 through SCCC 2155, which represent the overwhelming majority of the Atlantic facing shoreline, are calculated from at least 17 years worth of beach profiles. Such a long period of record results in a high level of confidence that the change rates being calculated capture the long-term morphologic processes affecting the island.

Examining the MHW "With Fill" rates versus the "Without Fill" rates reveals that the two beach nourishment projects, in 1995 and 2006, have performed well in offsetting the normal erosion rate and stabilizing the recreational beach. The long-term MHW shoreline change rate without the fill projects is uniformly erosional, but is not uniform in the magnitude of erosion, as it varies from -0.21 to -10.1 feet per year.

The MHW shoreline change rates from Table 7 are also presented graphically, in three dimensions (3D), in Figure 34. The large peaks of the "With Fill" change rates along the South Edisto River inlet shoreline, green in Figure 34, at SCCC 2130 are only based on two years of profile data.

Table 7: Shoreline Change Summary for OCRM Beach Profile Data

OCRM	MHW Shoreline Change Rate (ft/yr)	
Benchmark	With Fill	Without Fill
SCCC 2230	-0.16	-3.94
SCCC 2200	1.52	-2.13
SCCC 2198	N/A	-10.10
SCCC 2195	2.44	-0.21
SCCC 2193	3.36	-2.25
SCCC 2190	4.09	-1.58
SCCC 2185	5.52	-3.41
SCCC 2180	3.48	-4.18
SCCC 2178	-0.15	-8.49
SCCC 2173	2.92	-6.93
SCCC 2170	3.74	-1.77
SCCC 2165	3.11	-0.95
SCCC 2160	1.33	-3.20
SCCC 2155	3.38	-2.04
SCCC 2150	-14.79	N/A
SCCC 2145	-0.64	N/A
SCCC 2135	17.24	N/A
SCCC 2130	121.85	N/A
SCCC 2120	15.58	N/A
SCCC 2113	27.03	N/A
SCCC 2110	4.23	-10.56

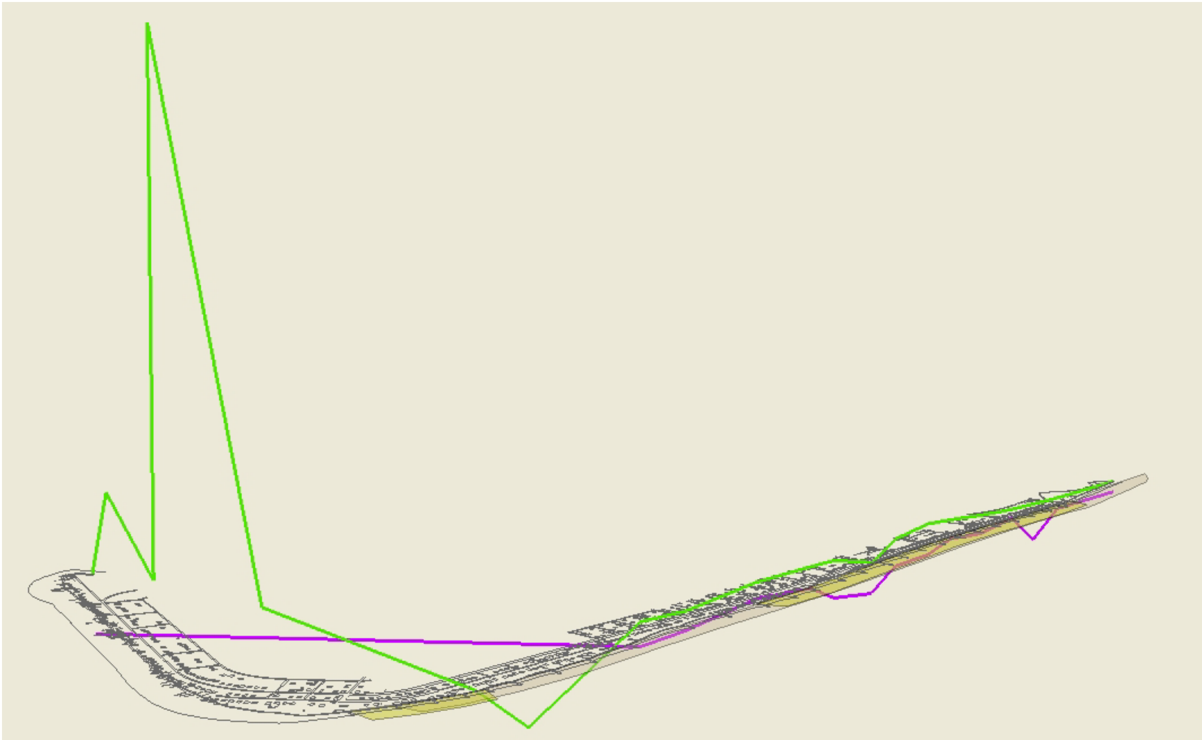


Figure 34: Three dimensional representation of MHW shoreline change rates (ft/yr) for OCRM beach profiles along Edisto Island (green represents rates including the 1995 & 2006 nourishments, purple represents rates excluding the 1995 & 2006 nourishments).

Historical Shoreline Rate of Change

Based on the annual rates of shoreline change presented in the previous section and interpolation to the established Beach-*fx* analysis reaches the long-term historical rate of change corresponding to each of the Beach-*fx* reaches was estimated and plotted as the red line in Figure 35. As seen in the figure, there are extreme discontinuities in the estimated long-term shoreline change rates, frequently greater than 2 ft/year and exceeding 6 ft/year between reaches E7 and E8. These discontinuities are not sustainable over the long-term in that if they were to persist over a long time period large discontinuities in shoreline orientation would develop and the shoreline would evolve to a highly irregular form. However, we know from experience and observation that the shoreline at Edisto Beach is expected to maintain its present general form and orientation over the foreseeable future. To resolve this issue, smoothing was applied to the historical shoreline change rate data and the shoreline rates of change as depicted by the blue line were derived as a reasonable expectation of the future rate of shoreline change in the absence of shoreline management activities. Table 8 provides a listing of the target shoreline rate of change values for each of the Beach-fx reaches.

Table 8: Target Historical Shoreline Rate of Change (SRC) for Edisto Beach by Beach-*fx* Reach

Reach	Target SRC (ft/yr)	Reach	Target SRC (ft/yr)	Reach	Target SRC (ft/yr)
I1	1.37	E3	-1.45	E11	-2.93
I2	0.62	E4	-1.91	E12	-2.85
I3	0.38	E5	-2.21	E13	-2.85
I4	0.16	E6	-2.52	E14	-3.03
P1	0.01	E7	-2.95	E15	-3.56
P2	-0.22	E8	-3.01	SP1	-4.38
E1	-0.43	E9	-3.03	SP2	-5.13
E2	-0.90	E10	-2.98		

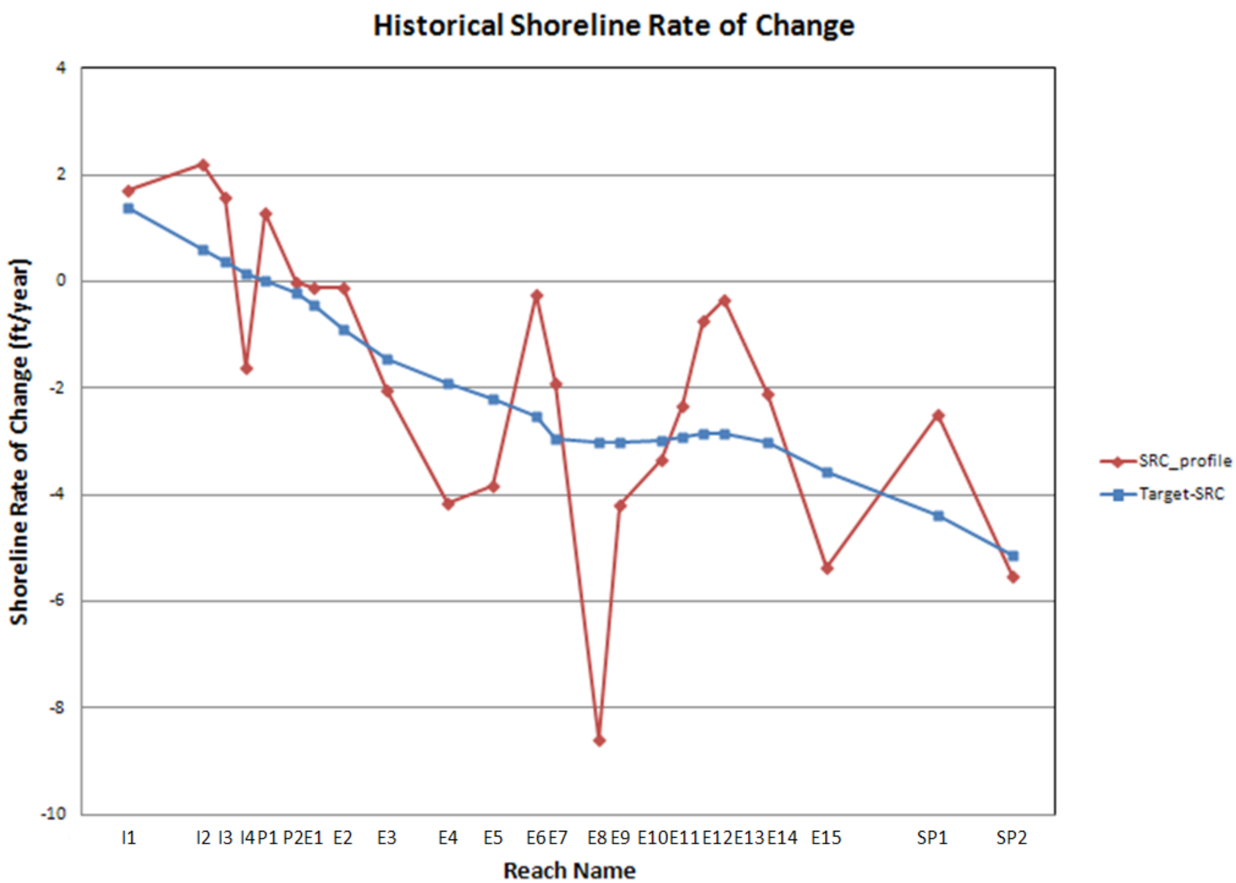


Figure 35: Historical shoreline rate of change based on profile data and synthesized target shoreline rate of change.

Conclusions

Historically the ocean-fronting shoreline within the Edisto Beach study area has been erosional with the rate of erosion generally decreasing from north to south. Near the Point, the shoreline change rate decreases to nearly zero and transitions to accretion along the inlet-fronting shoreline. Of course the natural variability in annual wave energy and storm occurrence can and does produce significant variations in this overall trend of shoreline change. Shore protection measures also have a direct influence on shoreline change rates. For example, following groin construction near the northern end of Edisto Beach erosion accelerated south of the constructed groins which lead to construction of more groins to the south. Likewise, after the nourishment projects in 1995 and 2006 the rate of shoreline accretion along the inlet-fronting increased as nourishment material was transported to the south and around the Point. Overall shoreline change trends within the Edisto Beach study area are well understood and as expected depend to a large degree on sediment supply from the north. If the sediment supply is reduced due to natural processes such as increased overwash into marsh or human intervention such as groin construction, erosion can be expected to the south. Likewise, if new sediment is introduced into the system through beach nourishment, a stabilization of the shoreline or even a transitioning to a prograding shoreline can be expected to the south of the placement area. Both of these scenarios have been observed and recorded in the past within the project study area.

7.0 Beach-fx Calibration

The calibration procedure for Beach-*fx* involves specification and tuning of a reach-level attribute known as the *applied erosion rate*. The applied erosion rate accounts for long-term shoreline change not attributed to storm-induced shoreline changes which are captured within the model by the random sampling of storm events as the model progresses through the lifecycle simulation. The concept employed here is that there are two essentially separable components of beach evolution, the first is cross-shore transport dominated shoreline change due to storm events which is mostly recoverable due to post-storm berm width recovery and the second is longshore transport dominated shoreline change that is driven by longshore sediment transport gradients, underlying geological setting and other factors such as relative sea level change. This second component of beach evolution is considered non-recoverable. The Beach-*fx* calibration concept is that the combination of these two drivers of beach evolution should, on average, over multiple simulated project lifecycles return the long-term average rate of shoreline change. Because the Beach-*fx* simulated life cycle iteration employs a random sequence of storm events the returned shoreline change rate differs for each lifecycle simulated. The Beach-*fx* calibration task is to determine an appropriate applied erosion rate for each reach such that the computed average rate of shoreline change on a reach-by-reach basis is equal to the estimated target historical shoreline change rate over multiple lifecycle simulations.

For the Edisto Beach project, Beach-fx was calibrated across 300 iterations of a 55-year lifecycle using an assigned depth of closure specification of -14 ft NAVD. The depth of closure estimate was developed based on an analysis of the available beach profile data presented in section 6.0 (previous section). The 55-year lifecycle duration stems from the use of the August 2008 beach profile survey to define the initial condition leading to a start year specification of 2009 and the specification of year 2014 as the base year for calculating the economics and an economic analysis horizon corresponding to a 50-year project life. The use of 300 iterations was selected in order to obtain a stabilization of the model results in the context of capturing the expected variability in the environmental forcing. Evidence of the stabilization of results can be gauged by examining the moving average in various model outputs as compared to the individual iteration values. An example of this is shown in Figure 36 where the total number of storms per iteration is plotted along with the moving average number of storms across all iterations. Here it is seen that although the number of storms per iteration varies between a maximum of 63 storms and a minimum of 27 storms the average number of storms stabilizes at approximately 44 storms after about 150 iterations of a 55-year lifecycle.

After a number of calibration iterations Beach-*fx* was calibrated to precisely reproduce the target historical SRC on average over 300 55-year lifecycles. Figure 37 shows the target historical SRC (blue line), the Beach-*fx* calculated average rate of shoreline change over 300 iterations (red stars), together with the calibration determined applied erosion rates on a reach by reach basis (green line).

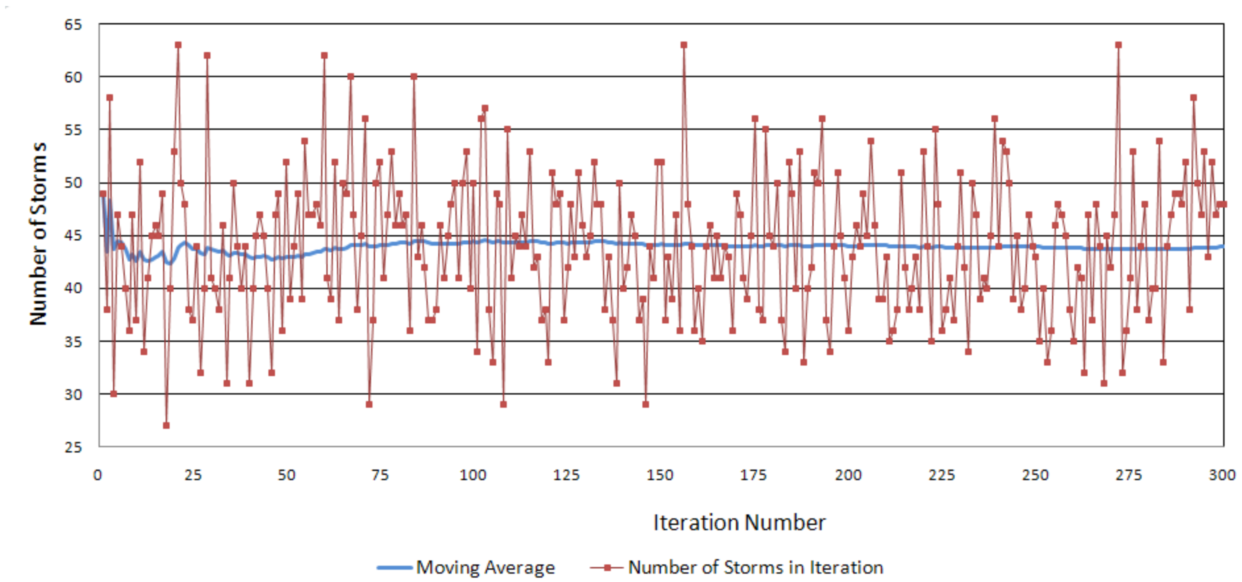


Figure 36: Number of storms per and moving average number of storm per iteration.

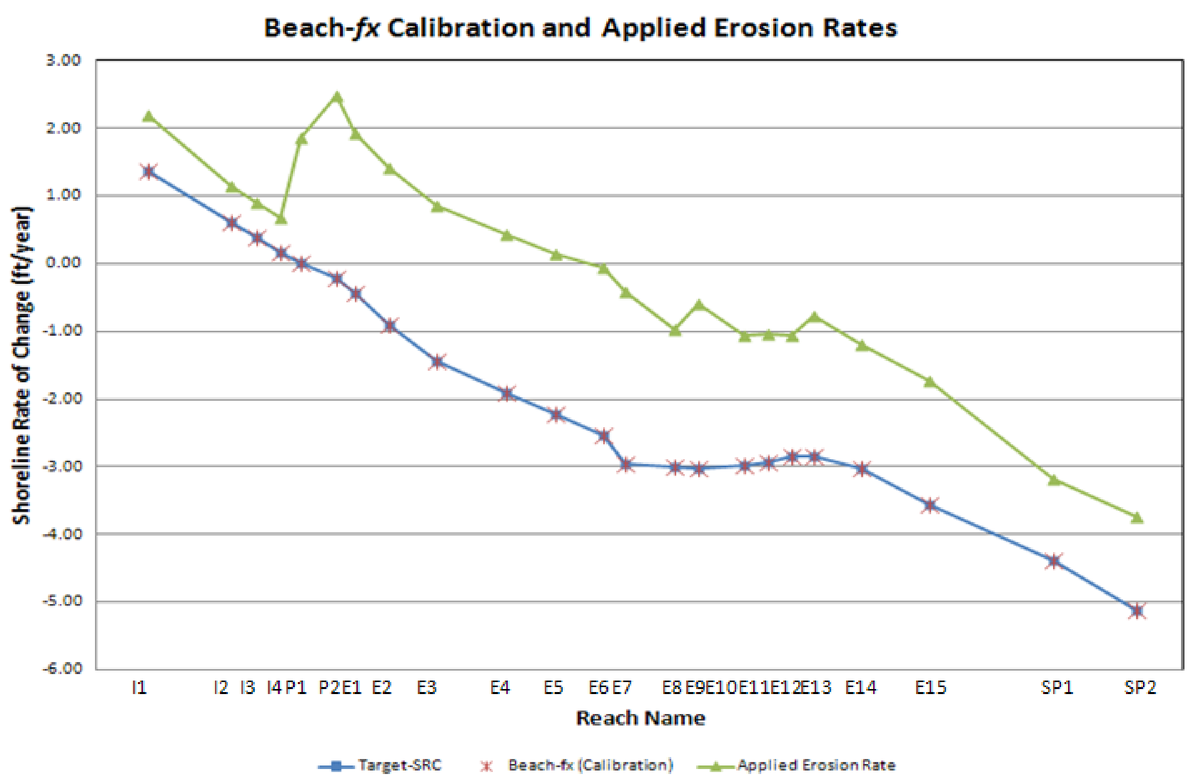


Figure 37: Beach-fx calibration results and applied erosion rates.

8.0 Future Without-Project Beach-fx Simulations

Two future without project scenarios of Edisto Beach evolution were simulated using the calibrated Beach-*fx* model the first scenario involved no action on the part of private land owners or local or state governmental agencies. This scenario illustrates the high vulnerability of developed properties, Palmetto Blvd (Hwy 174), and Edisto Beach State Park to losses due to continued coastal erosion, storm-induced inundation, and direct wave impact. The second future without project scenario includes limited emergency actions including emergency dune reconstruction on an as needed basis as well as armoring of Palmetto Blvd. if the highway becomes vulnerable to loss of function during the simulation. This future without-project is considered the most likely future as it best reflects the proactive shore protection posture of the community of Edisto Beach, the State of South Carolina and the South Carolina Department of Transportation.

No Action Scenario

The calibrated Beach-*fx* model for Edisto Beach was configured for simulation of the *no action* scenario of the without project to estimate beach evolution and economic consequences of a 55-year future that involves no action on the part of private land owners or local or state governmental agencies. This without-project scenario is based on the community of Edisto Beach assertion that in light of current economic circumstances within the State of South Carolina, Colleton County, and the City of Edisto Beach, the resources necessary to sustain historical shore protection measures are not anticipated being available.

The simulation again involved the simulation of 300 55-year lifecycles ending in the year 2064. The average shoreline position at the end of the without project simulation is shown as the brown line in Figures 38 through 41. In Figure 38 which spans the area between Beach-fx reaches I1 and E3 (groin cell 21) it is seen that along the inlet shoreline of Edisto Beach the shoreline is expected to be nearly stable or advance slightly. Slight ongoing erosion is predicted in the vicinity of the Point. Along the ocean-fronting shoreline just north of the Point, erosion begins to increase.

In Figure 39, which covers the area between Beach-*fx* reach E3 (groin cell 20) through reach E8 (groin cell 12), the predicted 2064 shoreline indicates erosion increasing to the north. Based on this prediction it is expected that wave swash will be under the existing homes beginning at approximately groin cell 17. Beginning at about groin cell 14 the homes appear to be highly vulnerable to complete loss. At groin cell 12 the shoreline is predicted to immediately adjacent to Palmetto Blvd. indicating that the developed properties on the ocean side of the highway will likely be destroyed.

In Figure 40, which covers the area between Beach-fx reach E8 (groin cell 11) and reach E15 (groin cell 1), the predicted 2064 shoreline reflects strong erosion indicating complete loss of all developed properties on the ocean side of Palmetto Blvd. Beginning at approximately groin cell 7 the shoreline is predicted to coincide with Palmetto indicating that the Highway will be impassible. To the north, at groin cells 1 though 3 the shoreline is predicted to be at the upland side of Palmetto Blvd. indicating that the Highway will be completely loss and developed properties on the upland side of Palmetto Blvd. will be vulnerable to damages from coastal storms.

Figure 41, which encompasses the Edisto State Park area north of the city of Edisto Beach, shows extreme erosion. The predicted 2064 shoreline indicates that the barrier island will undergo extreme overwash processes and migrate approximately one barrier island width into the upland marsh. The present camping area will be extremely vulnerable and it is likely that necessary infrastructure to support recreational use will be lost.

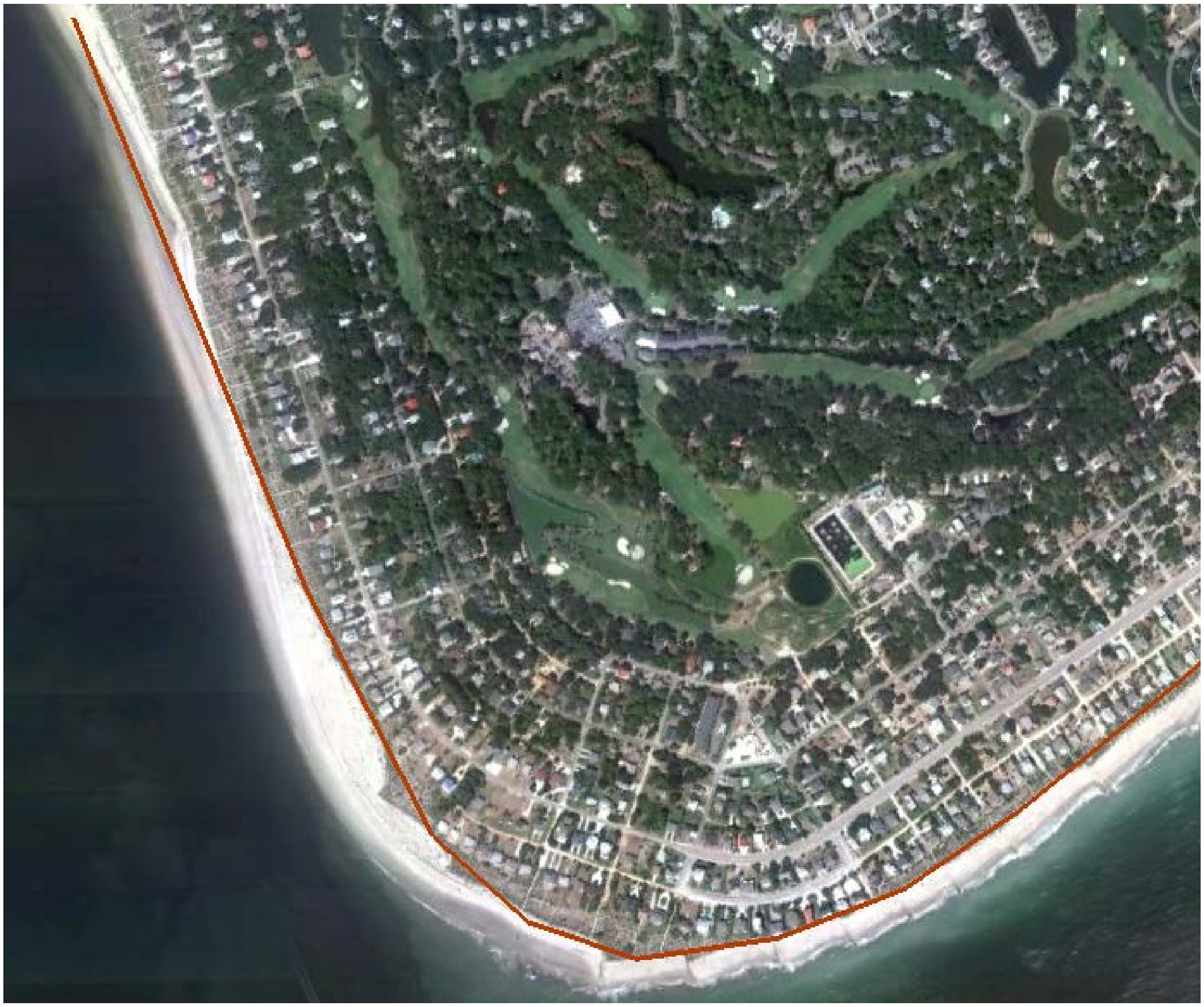


Figure 38: Without-project forecast of average shoreline position in 2064 along the inlet shoreline and around the Point to Groin cell 21.

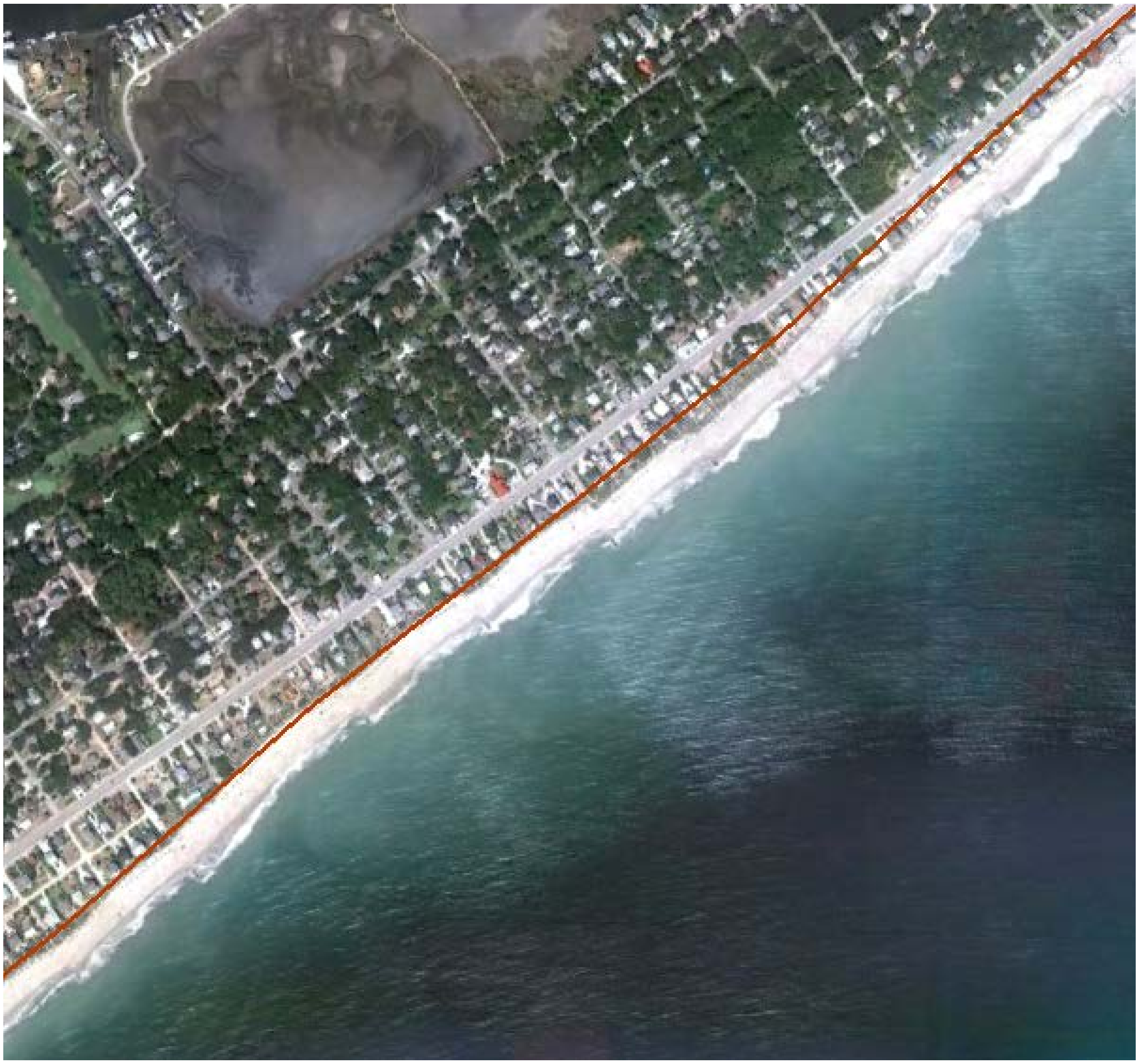


Figure 39: Without-project forecast of average shoreline position in 2064 between groin cells 12 and 20.

Figure 40: Without-project forecast of average shoreline position in 2064 between groin cells 1 and 11.

Figure 41: Without-project forecast of average shoreline position in 2064 at Edisto State Park.

Summary

The results of the *no action* without-project scenario as simulated with Beach-*fx* indicate an unfavorable future within the project study area. Significant losses to privately held developed properties are indicated. Publically held infrastructure will be extensively damaged including loss of the use of Palmetto Blvd. and associated utilities including electrical power lines and water mains. Indications are that Edisto State Park will be subject to extreme losses due to coastal erosion including the inability to support recreational camping within the State Park.

Limited Emergency Action Scenario

The calibrated Beach-*fx* model for Edisto Beach was configured for simulation of the *limited emergency action* scenario of the future without project to estimate beach evolution and economic consequences of a 55-year future that involves emergency dune reconstruction actions on an as needed basis as well as armoring of Palmetto Blvd. if the road becomes vulnerable to loss of function during the simulation. This future without-project scenario is considered the most likely future as it best reflects the proactive shore protection posture of the community of Edisto Beach, the State of South Carolina, and the South Carolina Department of Transportation. The community of Edisto Beach has indicated that they will take whatever shore protection actions that are within their means to protect existing infrastructure and to maintain recreational use of the beaches in their community. Since Palmetto Blvd. is a State highway and the only hurricane evacuation route off the island it is expected that the South Carolina Department of Transportation will take action to maintain the road as an evacuation corridor by armoring the ocean side of the road should coastal erosion threaten the functionality of the highway.

The emergency dune reconstruction action simulated in this future without-project scenario is implemented within the following constraints: On a reach by reach basis, if the simulated dune crest elevation falls below 9 ft NAVD an emergency dune nourishment action will be triggered. When the emergency nourishment action is triggered a nourishment action is scheduled assuming a 30-day mobilization time and the dune is nourished with a fill density of 10 cu yd/ft of beach. The fill material is placed on the dune feature with a target dune elevation of 11 ft NAVD. Any excess fill volume remaining after the target dune crest elevation is achieved is used to increase the dune crest width. Armoring of Palmetto Blvd. is triggered when the seaward edge of the berm erodes to within 10 ft of the road shoulder. Within Beach-fx armoring functions only to prohibit erosion damages, direct wave attack damages and inundation damages are still incurred with armoring in place.

The simulation of this future without-project scenario involved the simulation of 300 55-year lifecycles ending in the year 2064. The results indicate that on average approximately 1.61 million cubic yards of emergency nourishment fill material will be required to maintain the dune feature over the 55 year lifecycle simulation. The standard deviation in the average emergency nourishment fill volume is approximately 445 thousand cubic yards which can be viewed as the uncertainty in the estimated emergency nourishment fill volume over the 55-year lifecycle simulation. Table 9 provides a list of the number of emergency nourishment actions, total average emergency nourishment fill volume and standard deviation.

Table 9: Future Without-Project Emergency Dune Reconstruction Nourishment Summary

Reach	Number of Fill Actions	Fill Volume (yd^3)	Standard Deviation	Reach	Number of Fill Actions	Fill Volume (yd^3)	Standard Deviation
I1	NA	NA	NA	E7	11.0	61,693	15,796
I2	NA	NA	NA	E8	13.1	164,416	36,041
I3	NA	NA	NA	E9	12.1	72,500	18,430
I4	NA	NA	NA	E10	9.3	107,932	29,770
P1	6.1	32,471	10,302	E11	10.6	65,172	16,015
P2	10.9	96,197	26,833	E12	9.4	56,180	12,708
E1	7.4	36,712	14,946	E13	11.4	66,290	13,334
E2	8.0	69,897	27,149	E14	10.1	122,371	26,922
E3	9.1	111,117	38,035	E15	14.1	243,204	44,228
E4	4.8	83,787	42,903	SP1	NA	NA	NA
E5	6.2	77,557	32,723	SP2	NA	NA	NA
E6	11.8	145,509	39,248				

Because this future without project scenario involves emergency dune reconstruction and armoring of Palmetto Blvd. the estimated future without-project shoreline rate of change differs from the target historical rate of shoreline change as indicated in Figure 42.

The average shoreline position at the end of the future without-project simulation is shown as the purple line in Figures 43 through 46. In Figure 43, which spans the area between Beach-fx reaches I1 and E3 (groin cell 21) the shoreline along the inlet is nearly stable. Minor ongoing erosion is predicted along the ocean-fronting shoreline just north of the Point.

In Figure 44, which covers the area between Beach-*fx* reach E3 (groin cell 20) through reach E8 (groin cell 12), the predicted 2064 shoreline indicates erosion increasing to the north albeit slightly less than the *do nothing* without-project scenario due to periodic emergency dune reconstruction. Based on this prediction it is expected that wave swash will be under the existing homes beginning at approximately groin cell 16. At groin cells 13 and 12 the homes appear to be highly vulnerable to complete loss.

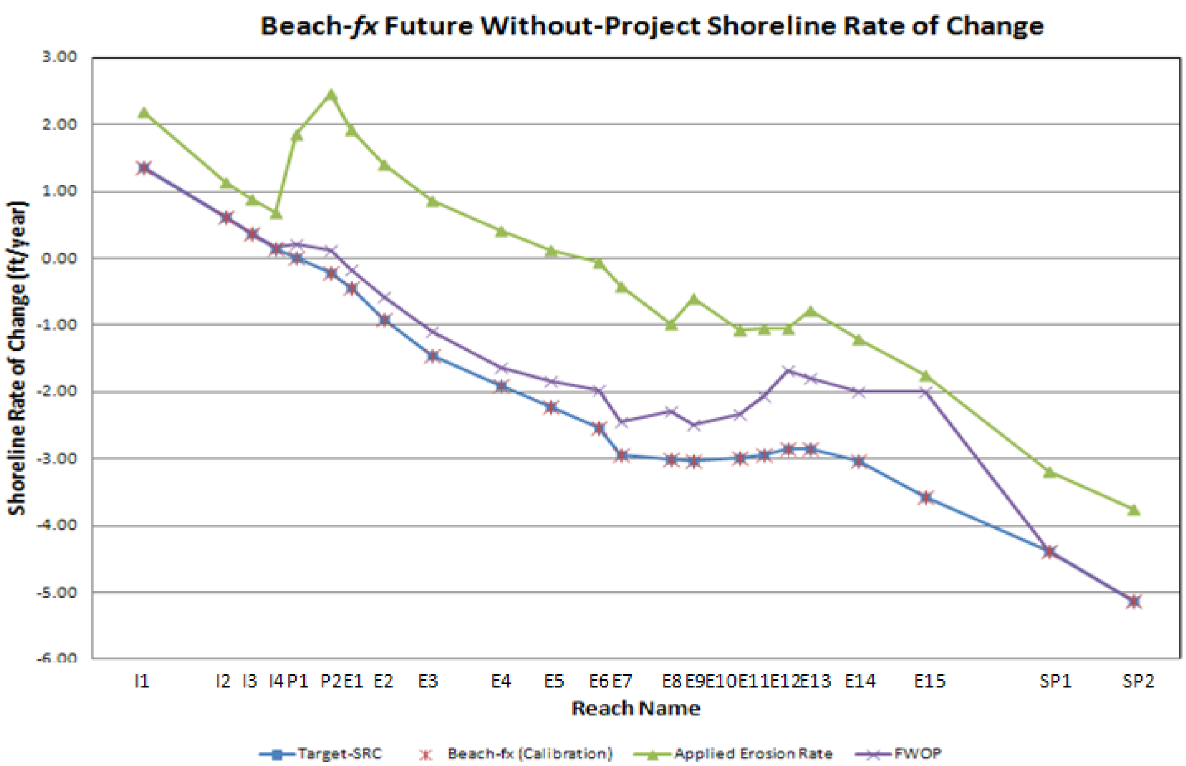


Figure 42: Beach-fx calibration results and applied erosion rates.

Figure 43: Without-project forecast of average shoreline position in 2064 along the inlet shoreline to Groin cell 21.

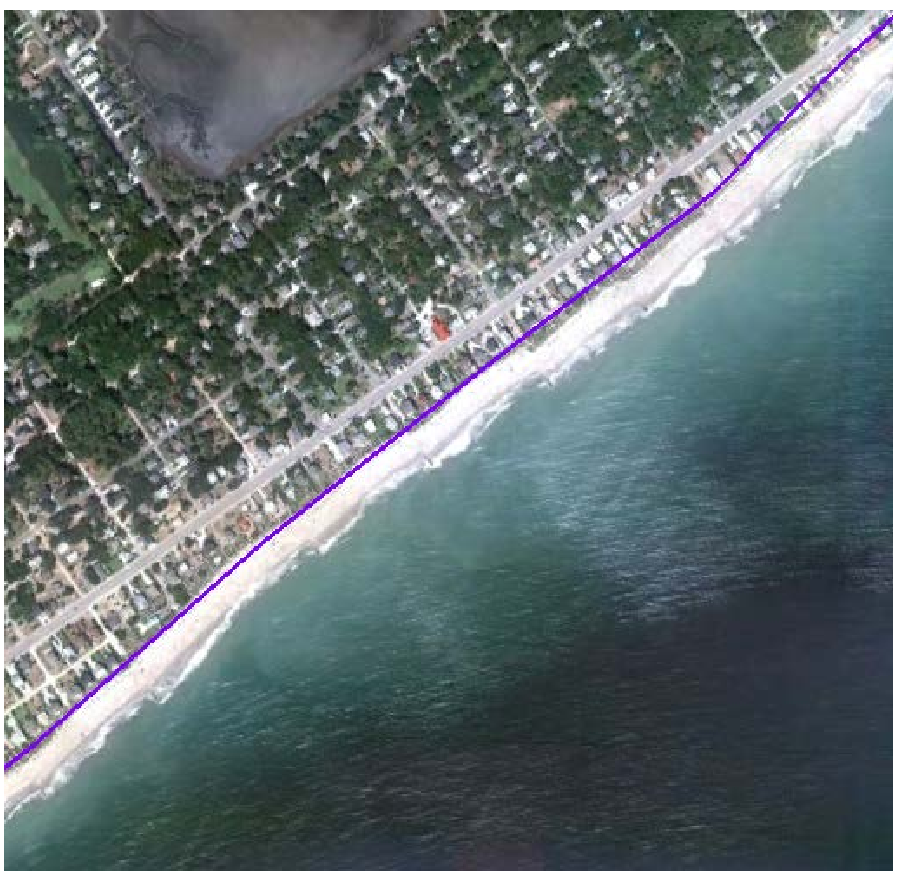


Figure 44: Without-project forecast of average shoreline position in 2064 between groin cells 12 and 20.

In Figure 45, which covers the area between Beach-fx reach E8 (groin cell 11) and reach E15 (groin cell 1), the predicted 2064 shoreline reflects erosion indicating likely a complete loss of all developed properties on the ocean side of Palmetto Blvd. The shoreline is held just seaward of Palmetto Blvd. due to emergency dune reconstruction and armoring of the Highway. However, most if not all developed properties on ocean side of Palmetto Blvd. in this segment of beach are predicted to be destroyed by coastal storms.

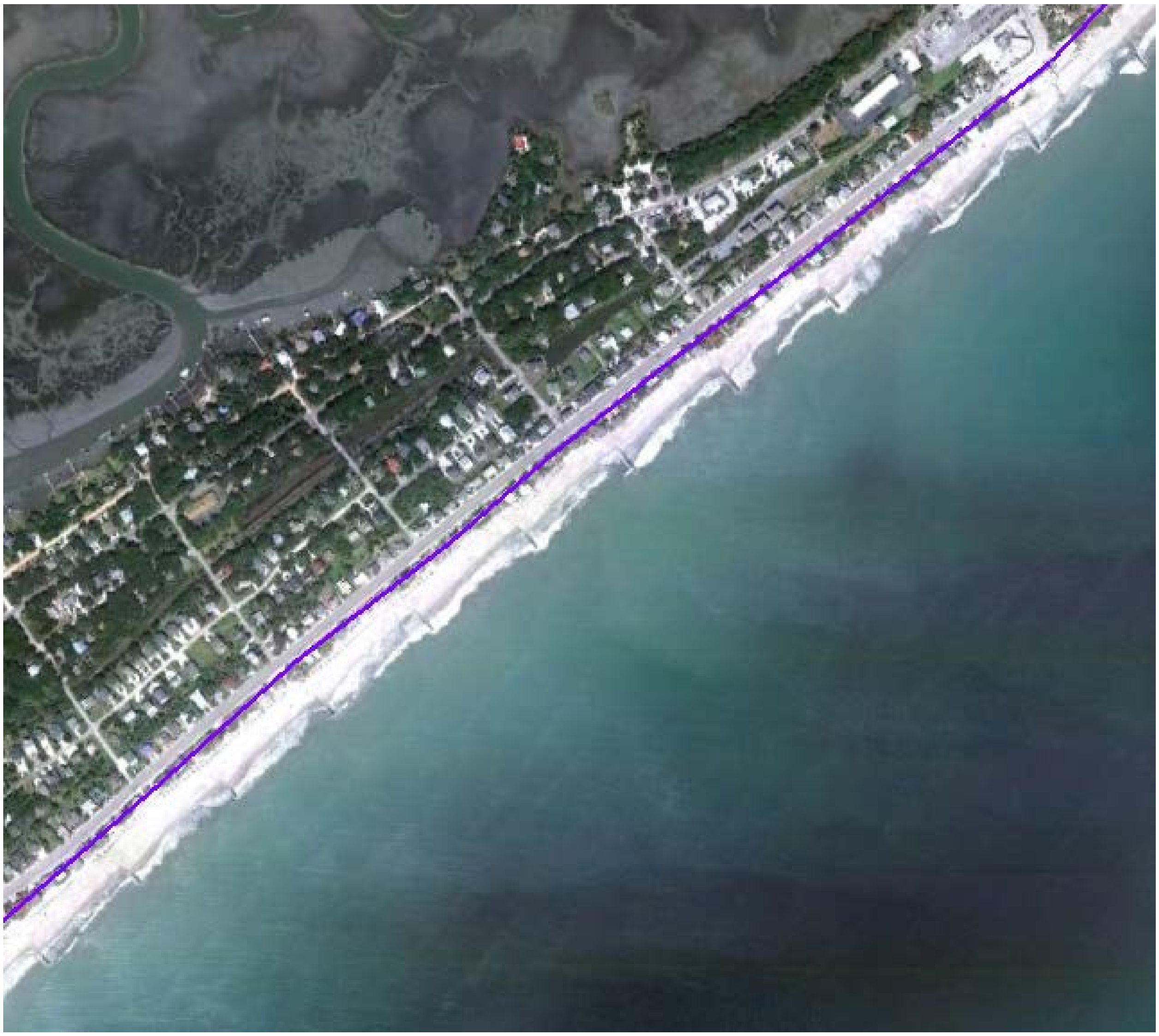


Figure 45: Without-project forecast of average shoreline position in 2064 between groin cells 1 and 11.

Figure 46, which encompasses the Edisto State Park area north of the city of Edisto Beach, shows the same extreme erosion as indicated for the *do nothing* without-project scenario as the emergency dune reconstruction actions are limited to the developed community of Edisto Beach. The predicted 2064 shoreline indicates that the barrier island will migrate approximately one barrier island width into the upland marsh through barrier island overwash processes. The present camping area will be extremely vulnerable and it is likely that necessary infrastructure to support recreational use will be lost.

Figure 46: Without-project forecast of average shoreline position in 2064 at Edisto State Park.

Summary

The results of the *limited emergency action* without-project scenario as simulated with Beach-*fx* indicate that emergency dune reconstruction and armoring of Palmetto Blvd. will reduce erosion along the Atlantic facing shoreline of Edisto Beach and preserve the Palmetto Blvd. as the only hurricane evacuation route off the barrier island. However, considerable loss of privately held developed properties is likely particularly in the north between groin cells 1 and 13. Edisto State Park will be subject to extreme losses due to coastal erosion including the inability to support recreational camping within the State Park.

Total lifecycle without-project damages to structures and contents are estimated at $44.4 million. Costs associated with emergency dune renourishment over the 55-year lifecycle are estimated at $17.5 million and average costs of armoring Palmetto Blvd. are estimated at $2.2 million.

Beach-fx computes damages resulting from erosion, inundation and direct wave impact. The future without-project damages in the Inlet Planning Reach (Beach-fx reaches I1-I4) damages are distributed across the three damage drivers as follows: erosion 9.9%; inundation 12.3%; and wave attack 77.8%. The vast majority of damages in the Inlet Planning Reach are driven by wave attack and inundation indicating that beach elevation and a protective dune system in this planning reach is of primary importance. The future without project damages in the Atlantic South Planning Reach (Beach-fx reaches P1-P2 and E1-E6) are distributed across the three damage drivers as follows: erosion 13.8%; inundation 11.5%; and wave attack 74.6%. Without project damages in the Atlantic South Planning Reach is also dominated by wave attack induced damages with erosion induced damages coming in a distant second. This section of beach will need both a protective dune system and a wider beach to provide storm damage reduction. Future without project damages in the Atlantic North Planning Reach (Beach-fx reaches E7-E15) are distributed across the three damage drivers as follows: erosion 64.5%; inundation 5.1%; and wave attack 30.4%. Without project damages in the Atlantic North Planning reach are dominated by erosion damages followed by wave attack damages. This section of the project will require increased beach width as well as a protective dune system to achieve storm damage reductions.

9.0 Alternative Formulation

Storm damage reduction alternatives were developed based on project site observations and known performance of past beach nourishment projects at Edisto Beach. Apparent during on- site inspection of project beach was the lack of a significant dune feature seaward of the existing infrastructure. Developed properties seaward of Palmetto Blvd. are essentially constructed within the existing dune line. Little if any vegetation is present seaward of the developed properties north of Cheehaw St. (Groin 14, Beach-fx Reach E7) indicating that active swash processes propagate to within close proximity of the structures with such frequency as to preclude the establishment of vegetation. South of this location, a wider vegetated buffer is present between the structures and the active shore face although elevations within the vegetated buffer zone are typically just a few feet higher than the berm elevation. In order to provide meaningful storm damage reduction along the Edisto Beach project shoreline a robust dune feature should be constructed along the entire project shoreline to serve as a barrier to storm surge and waves propagating landward toward developed properties and to provide a reservoir of sand for erosion forces associated with the storms events. To be effective the dune feature should be exposed to active swash processes only during significant storm events and higher than typical water levels. Consequently, the project must also include a constructed berm feature to absorb long-term erosion processes and to ensure that the dune feature is in place at the occurrence of significant storm events. The constructed berm feature will require periodic renourishment to restore its design dimensions and depending on the intensity of the storms encountered since the previous nourishment the dune feature may also require restoration to its design dimensions. A berm feature alone (without an accompanying dune feature) will serve to reduce wave energy and to some extent provide protection against erosion losses but cannot protect against inundation and direct wave impact damages during significant storms and elevated water levels driven by storm surge and wave setup.

The construction and monitoring of the 2006 Edisto Beach restoration project provides valuable site-specific information with respect to beach nourishment design and performance at Edisto Beach. This successful project was used as a guide for the development of alternative beach nourishment the design templates that would be evaluated using Beach-fx to identify the alternative that maximizes net benefits. Three alternatives were initially developed. All alternatives involved the creation of a protective dune along the inlet shoreline (Beach-fx reaches I1 through I4, and P1) and along the Atlantic facing shoreline a design berm feature of varying widths.

Alternative 1, identified as the "Medium" plan, involved a 12 ft dune crest elevation and 15 ft dune crest width along the inlet shoreline (Beach-fx reaches I1 through I4, and P1). Seaward and landward dune slopes were set at one on three. Along the Atlantic facing shoreline the design template involve at 14 ft dune crest elevation and 15 ft dune crest width. The design template berm width transitions from 0 ft at Reach P1 to 50 ft at Reach E1. The design template berm width remains at 50 ft through Reach E6 where it then transitions across Reach E7 to a width of 75 ft at Reach E8. The Alternative 1 design template berm width remains at a 75 ft width through Reach E15 and transitions to a width of 0 ft north of Groin 1. Alternative 1 is referred to as the "Medium" plan because it closely follows the observed added berm widths following the 2006 beach restoration project. The 2006 beach restoration project is viewed as an effective project that has performed well over the 7+ years since construction. Analyses performed by CSE indicated that periodic renourishment would be required at approximate 10 year intervals and based on current conditions this estimate of renourishment interval appears to be reasonably accurate.

Alternative 2, identified as the "Minimum" plan, involved a 15 ft dune crest width at a 10 ft NAVD crest elevation along the inlet shoreline. Along the Atlantic facing shoreline the design dune template involved a 15 ft dune crest width at a 12 ft NAVD crest elevation. The design template berm width transitions from 0 ft at Reach P1 to 25 ft at Reach E1. The design template berm width remains at 25 ft through Reach E6 were it transitions across Reach E7 to a width of 50 ft at Reach E8. The design template berm width remains at a 50 ft width through Reach E15 and transitions to a width of 0 ft north of Groin 1. Alternative 2 is referred to as the "Minimum" plan because it is believed that the dimensions of the Alternative 2 design template represent the minimum beach cross-section that would provide measureable storm damage reduction benefits at Edisto Beach.

Alternative 3, identified as the "Maximum" plan, involved a 15 ft dune crest width at a 14 ft NAVD crest elevation along the inlet shoreline. Along the Atlantic facing shoreline the design dune template involve a 15 ft dune crest width at a 16 ft NAVD crest elevation. The design template berm width transitions from 0 ft at Reach P1 to 75 ft at Reach E1. The design template berm width remains at 75 ft through Reach E6 where it transitions across Reach E7 to a width of 100 ft at Reach E8. The design template berm width remains at 100 ft through Reach E15 and transitions to a width of 0 ft north of Groin 1. Alternative 3 is referred to as the "Maximum" plan because it is believed that the dimensions of the

Alternative 3 design template are the largest that could be justified through storm damage reduction benefits.

Alternatives 1, 2, and 3, were simulated with Beach-fx and based on the results a fourth alternative was developed to optimize the design template to maximize storm damage reduction and minimize project costs. The Alternative 4 design template is smaller than the Alternative 3 (Maximum plan) but slightly larger than the Alternative 1 (Medium plan) design template. Dune crest elevation along the inlet shoreline is 14 ft NAVD, the same as Alternative 3, whereas the dune crest elevation along the Atlantic facing shoreline is 15 ft NAVD, between Alternative 1 and Alternative 3. The design template berm width for Alternative 4 is identical to Alternative 1 except for a longer transition zone at the southern end. The design template berm width transitions from 0 ft at Reach P1 to 50 ft at Reach E2. Table 10 provides reach-by-reach design template dimensions for each of the design alternatives.

Table 10: Dimensions of the four Beach Fill Alternatives Analyzed.

Reach	Alternative 1: Beach and Dune Fill (medium)			Alternative 2: Beach and Dune Fill (minimum)			Alternative 3: Beach and Dune Fill (maximum)			Alternative 4: Beach and Dune Fill (bracketing)		
	Berm Width	Dune Height	Dune Width	Berm Width	Dune Height	Dune Width	Berm Width	Dune Height	Dune Width	Berm Width	Dune Height	Dune Width
I1		12	15		10	15		14	15		14	15
I2		12	15		10	15		14	15		14	15
I3		12	15		10	15		14	15		14	15
I4		12	15		10	15		14	15		14	15
P1	taper	12	15	taper	10	15	taper	14	15	taper	15	15
P2	25	14	15	13	12	15	38	16	15	13	15	15
E1	50	14	15	25	12	15	75	16	15	25	15	15
E2	50	14	15	25	12	15	75	16	15	50	15	15
E3	50	14	15	25	12	15	75	16	15	50	15	15
E4	50	14	15	25	12	15	75	16	15	50	15	15
E5	50	14	15	25	12	15	75	16	15	50	15	15
E6	50	14	15	25	12	15	75	16	15	50	15	15
E7	63	14	15	38	12	15	88	16	15	63	15	15
E8	75	14	15	50	12	15	100	16	15	75	15	15
E9	75	14	15	50	12	15	100	16	15	75	15	15
E10	75	14	15	50	12	15	100	16	15	75	15	15
E11	75	14	15	50	12	15	100	16	15	75	15	15
E12	75	14	15	50	12	15	100	16	15	75	15	15
E13	75	14	15	50	12	15	100	16	15	75	15	15
E14	75	14	15	50	12	15	100	16	15	75	15	15
E15	75	14	15	50	12	15	100	16	15	75	15	15
SP1	taper			taper			taper			taper		

Upland Construction Baseline

As mentioned previously the developed properties seaward of Palmetto Blvd. are constructed within the existing dune line, as such the project design template must be offset seaward of the existing dune such that the landward toe of the constructed dune intersects the existing condition beach profile is seaward of the existing infrastructure. To accommodate this requirement a construction baseline was established and mapped to ensure the constructability of the proposed project. The location of the construction baseline is shown in Figures 47 through 49). However, because there is an offset between the Beach-fx baseline (defined by the landward toe of the existing condition dune feature) and the construction baseline (located seaward of all habitable structures), the estimates of initial construction volumes calculated in Beach-fx are under estimated because the model has no provision for implementing an upland width offset at the time of project construction. That is, within Beach-fx, construction of a planned nourishment dune feature begins at the landward toe of the existing condition dune and extends seaward from that location according to the specified design template. The additional initial construction volume for each of the alternatives was computed externally from the model and added to the volume estimates generated within Beach-fx. The additional sand volume associated with the offset between the construction baseline and the Beach-fx baseline was estimated as follows:

1. Compute fill volume between the 2009 initial condition representative beach profiles and the design template referenced to the Beach-fx baseline on a reach-by-reach basis.
2. Compute fill volume between the 2009 initial condition representative beach profiles and the design template referenced to the construction baseline on a reach-by-reach basis.
3. The fill volume associated with the offset between the construction baseline and the Beach-fx baseline is estimated as the total volume computed in step 2 less the total volume computed in step 1.

This analysis indicated that the initial construction fill volume associated with the offset between the Beach-fx baseline and the construction baseline is approximately 364,000 cy, 198,000 cy, 443,000 cy and 388,000 cy for Alternatives 1, 2, 3, and 4, respectively. The reach-by-reach fill densities and total construction baseline offset fill volumes for each of the four beach and dune fill alternatives are provided in Tables 11 through 14.

Table 11: Construction Baseline offset fill Volume, Alternative 1.

	Beach-fx Baseline		Construction Baseline		
Reach	Fill Density	Reach Volume	Fill Density	Reach Volume	Offset Volume
	cy/ft	cy	cy/ft	cy	cy
I1	5.6	21280	5.6	21280	0
I2	2.9	6127.7	2.9	6127.7	0
I3	2.9	1870.5	2.9	1870.5	0
I4	2.9	1841.5	2.9	1841.5	0
P1	2.8	1472.8	2.8	1472.8	0
P2	5.1	4498.2	5.1	4498.2	0
E1	23.8	11733.4	28.1	13853.3	2119.9
E2	16.5	14338.5	16.5	14338.5	0
E3	16.6	20351.6	31.8	38986.8	18635.2
E4	2.6	4544.8	2.6	4544.8	0
E5	2.6	3268.2	19.1	24008.7	20740.5
E6	2.4	2952	15.1	18573	15621
E7	4.8	2688	33.2	18592	15904
E8	18.4	23128.8	39.8	50028.6	26899.8
E9	5.4	3245.4	41.3	24821.3	21575.9
E10	2.7	3121.2	41.1	47511.6	44390.4
E11	4.7	2895.2	60.6	37329.6	34434.4
E12	17.2	10320	82.2	49320	39000
E13	41.3	24036.6	86.9	50575.8	26539.2
E14	33.8	40898	82.1	99341	58443
E15	48.3	83172.6	71.4	122950.8	39778.2
Total		287785		651867	364082

Table 12: Construction Baseline offset fill Volume, Alternative 2.

	Beach-fx Baseline		Construction Baseline		
Reach	Fill Density	Reach Volume	Fill Density	Reach Volume	Offset Volume
	cy/ft	cy	cy/ft	cy	cy
I1	2.6	9880	2.6	9880	0
I2	0	0	0	0	0
I3	0	0	0	0	0
I4	0	0	0	0	0
P1	0	0	0	0	0
P2	1.3	1146.6	1.3	1146.6	0
E1	1	493	1.3	640.9	147.9
E2	0.3	260.7	0.3	260.7	0
E3	0.3	367.8	2.4	2942.4	2574.6
E4	0	0	0	0	0
E5	0	0	4.3	5405.1	5405.1
E6	0	0	1.6	1968	1968
E7	1	560	5.6	3136	2576
E8	2.9	3645.3	6.1	7667.7	4022.4
E9	1.6	961.6	7.3	4387.3	3425.7
E10	0	0	7.1	8207.6	8207.6
E11	0.2	123.2	26.6	16385.6	16262.4
E12	0	0	48.1	28860	28860
E13	7.2	4190.4	52.8	30729.6	26539.2
E14	0	0	48.1	58201	58201
E15	14.3	24624.6	37.4	64402.8	39778.2
Total		46253		244221	197968

Table 13: Construction Baseline offset fill Volume, Alternative 3.

	Beach-fx Baseline		Construction Baseline		
Reach	Fill Density	Reach Volume	Fill Density	Reach Volume	Offset Volume
	cy/ft	cy	cy/ft	cy	cy
I1	10.2	38760	10.2	38760	0
I2	7.2	15213.6	7.2	15213.6	0
I3	7.2	4644	7.2	4644	0
I4	7.2	4572	7.2	4572	0
P1	6.6	3471.6	6.6	3471.6	0
P2	22.6	19933.2	22.6	19933.2	0
E1	58.3	28741.9	62.6	30861.8	2119.9
E2	49.9	43363.1	49.9	43363.1	0
E3	50	61300	65.1	79812.6	18512.6
E4	14.4	25171.2	14.4	25171.2	0
E5	14.4	18100.8	53.5	67249.5	49148.7
E6	22.6	27798	49.9	61377	33579
E7	26.9	15064	68.1	38136	23072
E8	52.7	66243.9	74.1	93143.7	26899.8
E9	30.7	18450.7	76.3	45856.3	27405.6
E10	21	24276	76.4	88318.4	64042.4
E11	39.7	24455.2	95.6	58889.6	34434.4
E12	52.2	31320	117.1	70260	38940
E13	76.3	44406.6	121.8	70887.6	26481
E14	68.7	83127	117.1	141691	58564
E15	83	142926	106.1	182704.2	39778.2
Total		741339		1184316	442978

Table 14: Construction Baseline offset fill Volume, Alternative 4.

	Beach-fx Baseline		Construction Baseline		
Reach	Fill Density	Reach Volume	Fill Density	Reach Volume	Offset Volume
	cy/ft	cy	cy/ft	cy	cy
I1	8.9	33820	8.9	33820	0
I2	6.7	14157.1	6.7	14157.1	0
I3	6.7	4321.5	6.7	4321.5	0
I4	6.7	4254.5	6.7	4254.5	0
P1	8.9	4681.4	8.9	4681.4	0
P2	7.3	6438.6	7.3	6438.6	0
E1	10.8	5324.4	14.8	7296.4	1972
E2	23.5	20421.5	23.5	20421.5	0
E3	23.5	28811	38.7	47446.2	18635.2
E4	4.8	8390.4	4.8	8390.4	0
E5	4.8	6033.6	26.2	32933.4	26899.8
E6	4.6	5658	22.2	27306	21648
E7	7	3920	40.4	22624	18704
E8	25.5	32053.5	47	59079	27025.5
E9	7.6	4567.6	48.5	29148.5	24580.9
E10	5	5780	48.3	55834.8	50054.8
E11	11.9	7330.4	67.8	41764.8	34434.4
E12	24.4	14640	89.4	53640	39000
E13	48.5	28227	94.1	54766.2	26539.2
E14	41	49610	89.3	108053	58443
E15	55.4	95398.8	78.6	135349.2	39950.4
Total		383839		771727	387887

Figure 47: Construction baseline, Reaches I1 – I4, P1 – P2 , and E1.

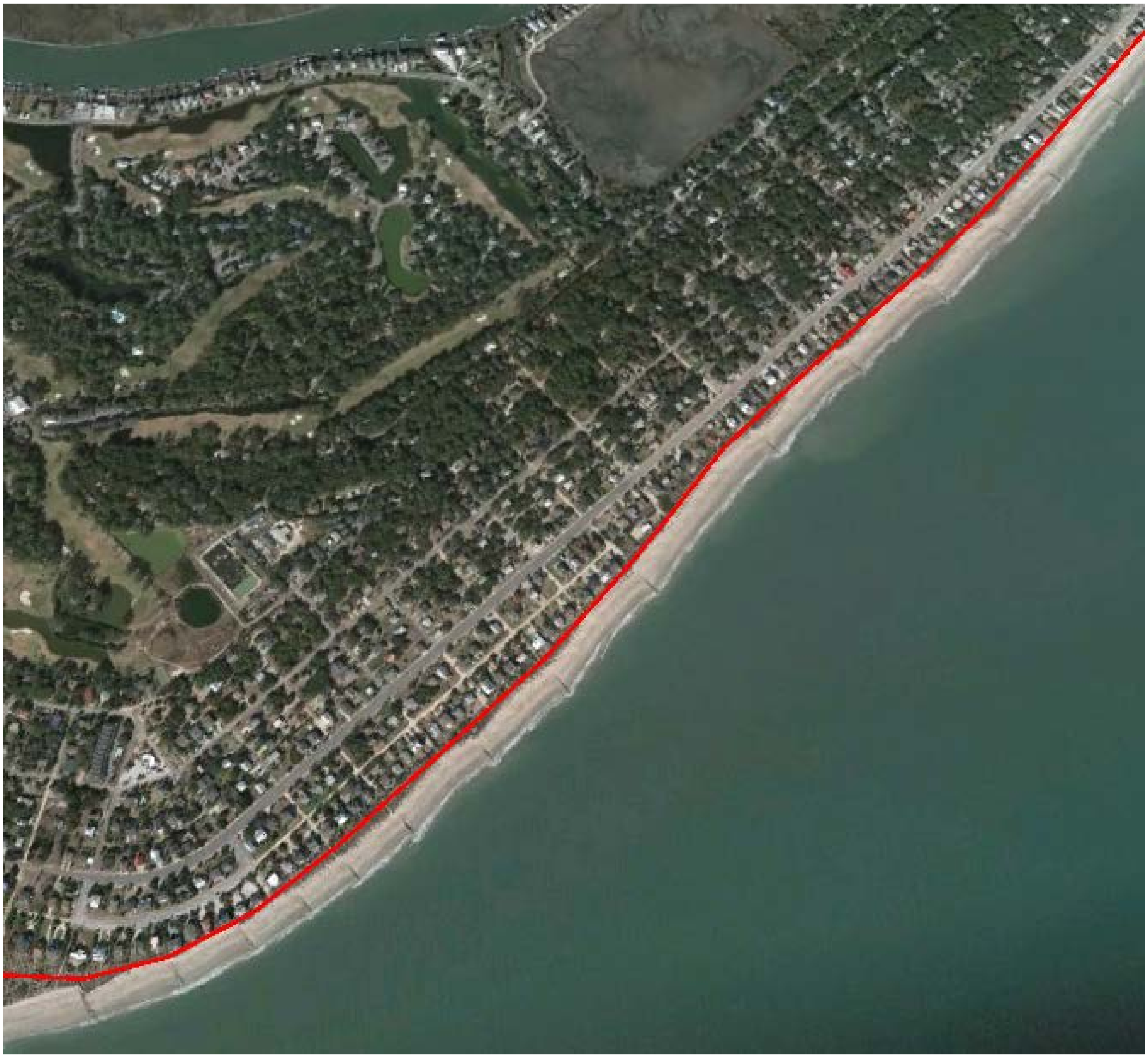


Figure 48: Construction baseline, Reaches P2 and E1 – E6.

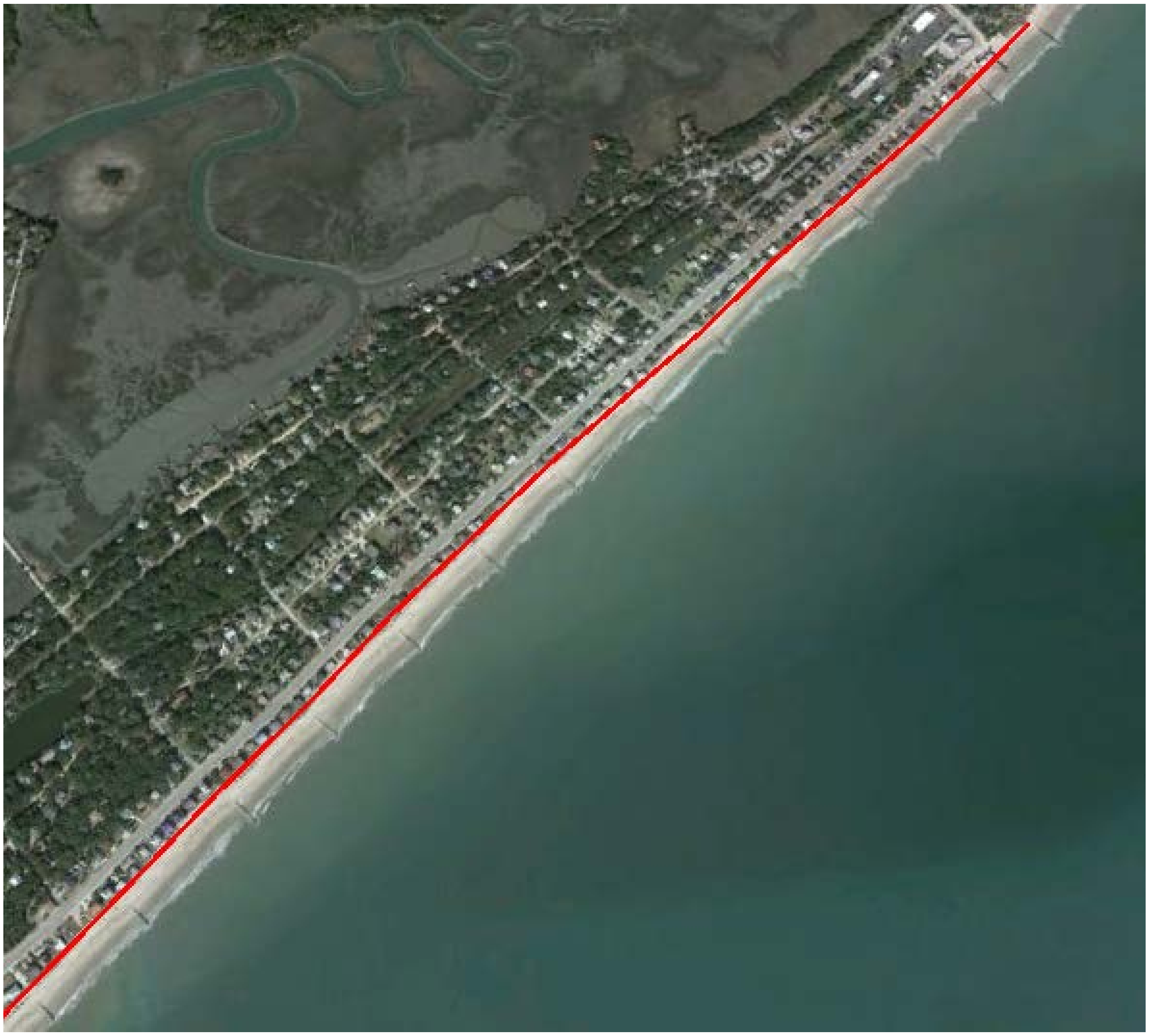


Figure 49: Construction baseline, Reaches E7 – E15.

Methodology and Procedure for Estimating Required Groin Lengthening

This section provides background information related to the importance and function of the groin field at Edisto Beach and document the procedure employed to estimate the amount of groin lengthening necessary to support the proposed project design template.

a. Introduction and Background

Existing coastal processes at Edisto Beach are driven by high energy waves and water levels As discussed in section 1.0 of this appendix the construction of groins at Edisto Beach began in 1948 in an effort to reduce the rate of shoreline erosion and protect upland infrastructure including commercial property (the Pavilion at the north end of Edisto Beach), Palmetto Blvd. (SC 174), and private property. Groins were constructed from north to south along the Atlantic facing shoreline and as erosion continued to move down the beach additional groins were constructed in an attempt to keep pace with the subsequent erosion moving down drift (south). By 1958 a total of 17 groins had been constructed covering approximately 65% of the Atlantic facing shoreline of Edisto Beach. By 1975 17 more groins had been constructed, 29 along the Atlantic facing shoreline and 5 along the inlet shoreline for a total of 34 groins. The chronology of groin construction at Edisto Beach is provided in Table 1 (Section 1.0 of this appendix). This groin field plays a central role in the stabilization of the Edisto Beach shoreline and although long term shoreline erosion persists along the ocean front, the groin field functions to reduce the rate of sand loss. Specifically, periodic beach profile monitoring surveys have shown that the rate of sand loss in groins cells 1 through 27 has been less than 1 cy/ft/yr in recent years compared to an erosion rate of 1.5 cy/ft/yr in the southern part of the State Park reach where there are no groins (CSE 2003). CSE has estimated that without groins 1 through 15, at least two rows of houses and Palmetto Blvd. would be destroyed by natural adjustment of the shoreline within 10 years (CSE 2003). This assertion is supported by observation of the more seaward location of of the shoreline in Edisto Beach as compared to the State Park illustrated in Figure 50. Therefore the groin field at Edisto Beach is viewed as an essential element in the stabilization the beach which in turn provides coastal storm damage protection to the upland infrastructure. The groin field also exerts a critical influence on current and future shoreline position in the Edisto Beach study area.

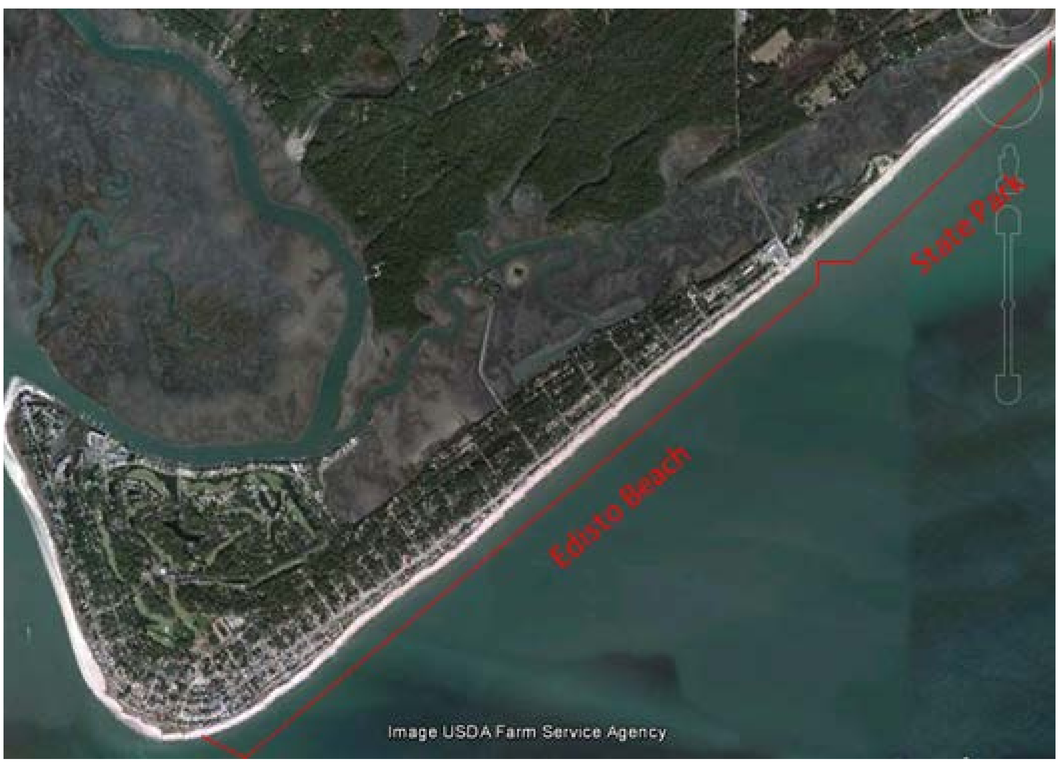


Figure 50: Edisto Beach study area.

Locally funded beach nourishment projects were constructed along the Atlantic facing shoreline in 1995 and 2006. The 1995 project involved the placement of 155,000 cy of beach quality fill material and the 2006 project involved the placement of 850,000 cy of beach quality fill material. The subsequent down drift migration of this fill material has resulted in the burial of the five groins constructed along the inlet facing shoreline. Long term shoreline change rates along the inlet shoreline vary from nearly stable (+0.01 ft/yr) at the point to accretional (+1.36 ft/yr) at the northwest end of the inlet shoreline near Big Bay creek. Along the Atlantic facing shoreline long term shoreline change rates vary from nearly stable (+0.01 ft/yr) at the point to erosive (-3.56 ft/yr) at the northern end of Edisto Beach. Shoreline change rates become even more erosion moving north into the State Park (-4.38 to -5.13 ft/year).

b. Requirement for Groin Lengthening

Existing condition dune heights along the Atlantic facing shoreline at Edisto Beach vary between 10 and 12 ft NAVD and the existing condition berm width varies between 35 and 105 ft. An analysis of the engineering and economic performance of a number of beach nourishment design alternatives has been conducted using Beach-fx and the results of that analysis indicate that a design beach cross-section involving dunes of varying crest elevations and berm widths varying between 25 and 100 ft are needed to provide the desired coastal storm damage reduction. Because the distance between the construction baseline and the seaward edge of the alternative design template berm exceeds the distance between the construction baseline and the seaward edge of the existing condition berm along certain reaches within the project, the effective length of the many of the existing groins will need to be increased in order to create and maintain beach width necessary to support the design template.

The motivation for lengthening groins in the Edisto Beach study area is exclusively for the purpose of providing necessary beach width to accommodate and maintain the alternative design template. Each of the four alternatives require some amount of groin lengthening, the alternatives involving larger cross-sections, those involving higher dune crest elevations and wider berms, require more groin lengthening than those alternatives involving smaller cross-sections. The proposed groin lengthening is not provided as a means for trapping more sand and increasing beach width or significantly changing the rate of sand bypassing the groins. The amount of required groin lengthening was estimated using a technique that employed geometric considerations based on measured beach profile and groin structure survey data as opposed to a numerical simulation-based estimation approach. Use of the described geometric data-based estimation technique is justified and believed to be superior to a numerically-based estimation approach because the available survey data represent actual on-site performance of the existing groin field and measured morphology response to those structures whereas, a numerically-based estimation would rely on theoretical representation of the groin field performance and estimated morphological response to the groin structures. If any amount of groin lengthening was determined to be necessary a minimum increased length of 20 ft was specified, also groin lengthening beyond 20 ft was specified in even 10 ft increments for practical reasons.

c. Estimation of Groin Lengthening Amount

The technique employed to estimate the amount of needed groin lengthening is based on the assumption that the representative existing condition beach profile is in dynamic equilibrium with, and held in place by, the existing groin and the groins intersection with the sea bed. Consequently, the amount of required groin lengthening was taken as approximately equal to the distance between the seaward edge of the existing condition representative beach berm and the seaward edge of the design template beach berm. Figure 51 illustrates the technique for Alternative 4 and Beach-fx Reach E15. In this case the distance between the seaward

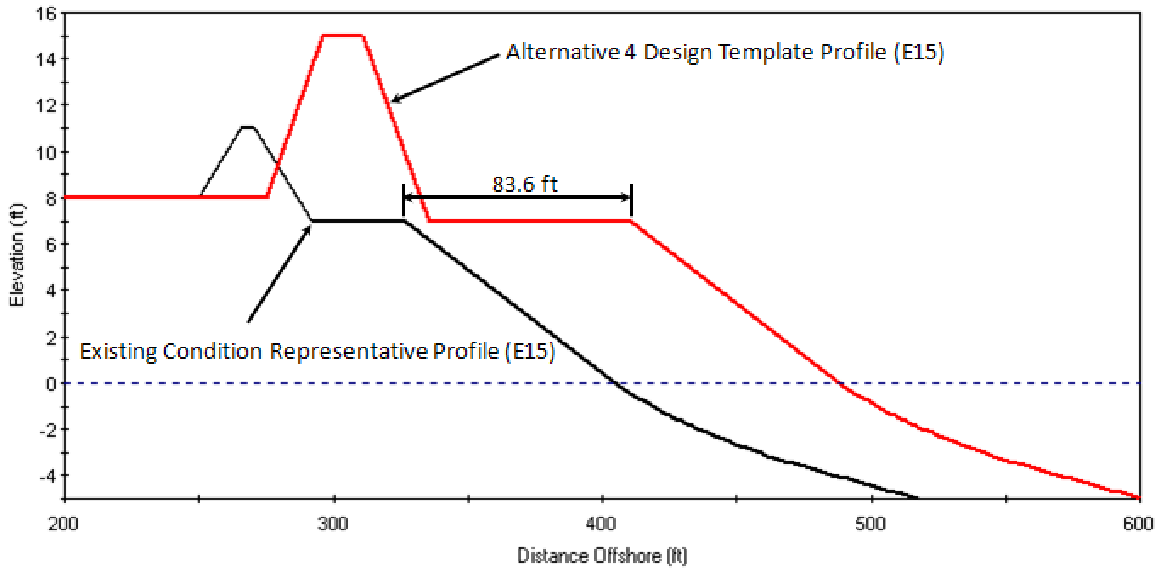


Figure 51: Groin Lengthening Estimation Technique.

edge of the existing condition representative beach berm profile and the seaward edge of the Alternative 4 design template beach berm is 83.6 ft, so, the recommended amount of groin lengthening will be 80 ft, rounding to the nearest 10 ft increment. As result groins 1 and 2 which, are contained within Beach-fx Reach E15, are recommended for lengthening of 80 ft. This approach was applied for all Beach-fx reaches and all evaluated alternative design templates to estimate the amount of required groin lengthening. The resulting recommended amount of groin lengthening for each of the alternatives is listed in Table 15. The total estimated amount of groin lengthening for 1090 ft, 360 ft, 1970 ft and 1130 ft for Alternatives 1, 2, 3, and 4, respectively. As seen in the table amount of required groin lengthening increases from south to north and reflects the greater set back distance between the shoreline and the developed infrastructure in the southern parts of Edisto Beach compared to the northern parts of Edisto Beach.

d. Assessment of Groin Lengthening Influence on Sand Transport and Shoreline Change

The down drift impacts of groins and groin fields depend to a large extent on the effective length of the groin or groins comprising the groin field. The effective length of a groin can be thought of as the length of groin extending beyond the shoreline. Likewise, the sand trapping capacity of a groin depends on the water depth at the seaward tip of the groin. As water depths at the seaward tip of the groin decreases longshore transport rates bypassing the groin increase. The beach and dune fill project alternatives formulated for Edisto Beach are designed to reduce future storm damages to upland infrastructure by: 1) increasing the set back distance between the existing infrastructure and the shoreline which will allow for increased wave energy dissipation; 2) providing a physical barrier to elevated water levels associated with the storm surge; and 3) providing a reservoir of sand to absorb the erosion forces associated with the storm waves and water levels. The design berm provides for the wave energy dissipation component of the protective system and the dune feature provides

Table 15: Recommended Groin Lengthening for all Alternatives.

	Groin Extension Length (ft)			
Groin #	Alt 1	Alt 2	Alt 3	Alt 4
1	80	40	110	80
2	80	40	110	80
3	80	50	120	90
4	90	50	130	90
5	90	60	130	100
6	90	60	130	100
7	80	40	110	80
8	50	20	90	60
9	40		80	50
10	40		80	50
11	40		80	40
12	40		80	40
13	30		70	40
14	20		60	30
15	20		50	20
16	20		50	20
17	20		50	20
18	20		30	20
19			20	
20	20		40	20
21	30		70	30
22	20		60	30
23	20		50	20
24	20		60	20
25	30		70	
26	20		40	
Total	1090	360	1970	1130

the physical barrier component to the elevated water levels and the berm and dune together provide the reservoir of sand need to absorb the storm associated erosion forces. However, construction of the beach and dune fill necessitates a seaward displacement of entire Atlantic facing project shoreline compared to existing conditions. Because the existing shoreline is already being held in place largely by the existing groin field at Edisto Beach any constructed project that further displaces the shoreline in a seaward direction will be short-lived and can be expected to perform poorly without an equivalent seaward displacement of the groin field that holds the shoreline in place. However, because the groin length extensions will be filled to capacity by the fill project and maintained over the life of the project, the delivery of sediment to down drift beaches is expected to largely unaffected by the recommended groin lengthening. That is, the effective length of the groins comprising the Edisto groin field will not increase because not only are the groins being lengthened but the beach is also being renourished causing the shoreline to displaced seaward by the same amount that the groins are being lengthened. The equilibrium water depths at the seaward tips of the extended groins will be the same as the water depths at the seaward tips of the existing condition groins. Consequently, sand bypassing the post-project groin field is expected to remain the same as the existing condition. Overall sand volume delivery to the inlet shoreline of Edisto and the shoal systems and islands of St. Helena Sound are expected to remain constant or to slightly increase due to the introduction of new sediments to the littoral system from the construction and maintenance of the coastal storm damage reduction project at Edisto Beach. The reasonableness of this expectation is supported by observations of increased sand volume and progradation of the shoreline along the Edisto Beach inlet shoreline following nourishment projects in 1995 and 2006.

10.0 Alternative Evaluations

This section describes the results of the Beach-fx lifecycle simulations of the Beach and Dune fill project alternatives formulated in the previous section. The details of each of the four project alternatives were specified in Beach-fx and 300 55-year-long lifecycle simulations were performed for each of the alternatives. Each lifecycle simulation started in the year 2009 and involved emergency dune nourishment and armoring of Palmetto Blvd actions as defined for the "Limited Emergency Action Future Without-Project scenario" between 2009 and 2014. Starting in the year 2014 the alternative beach and dune project was constructed and the physical and economic performance of the project was simulated for a 50-year project life concluding at the end of the year 2063(start of 2064). Each year after initial construction of the fill alternative the need for renourishment of the project was checked within the model simulation. If specific beach morphology and volume requirement thresholds were met then a renourishment was scheduled and constructed. Project costs associated with beach nourishment and nourishment volumes were computed and stored as were storm induced damages to structures and contents. For each alternative net average annual project benefits were computed by comparing Without-Project damages and costs to With-Project alternative damages and costs. For the without project simulation damages are taken as the sum of the computed structure and content damages, without project costs are taken as costs associated with emergency dune nourishment actions and costs associated with armoring and repair of armoring along Palmetto Blvd. Without-project damages and costs were computed on a reach-by-reach basis within Beach-fx. For the with-project alternatives damages were again taken as the sum of the computed structure and content damages. Emergency nourishment and armoring costs accrued during the first 5 years of the simulation were also recorded. With-project benefits were computed as: Without-Project damages less With-Project damages plus Without-Project emergency nourishment costs less With-Project emergency nourishment costs plus Without-Project armoring costs less With-Project armoring costs. In other words, with-project benefits include reductions in computed storm-induced damages plus avoided costs associated emergency nourishment actions and armoring of Palmetto Blvd. With-Project costs included project nourishment placement costs (including cost of sand volume associated with the offset between the Beach-fx baseline and the construction baseline), construction mobilization and demobilization costs, and groin lengthening costs. Total net average annual benefits of each alternative were computed as with-project benefits less with-project costs plus land-loss benefits. Land-loss benefits were computed based on a reduction of shoreline erosion rates on a reach-by-reach basis and apply only to those reaches that are erosional for the without-project condition. The individual damage and cost quantities employed average values computed across the 300 lifecycles simulated. Table 16 lists the net average annual benefits for each of four beach and dune alternatives evaluated. Net benefits are given for each of the Beach-fx reaches as well as for the three larger planning reaches. Table 16 shows that beach and dune Alternative 4 produces the maximum net average annual benefits of all the alternatives evaluated with an average annual benefit of approximately $1,600,000. Alternative 4 is identified as the optimized National Economic Development (NED) plan in that Alternative 4 it is bracketed from the perspective of project size by Alternative 1 (a smaller project) and Alternative 3 (a larger project) and produces net average annual benefits exceeding those produced by Alternatives 1 and 3. Although other Alternatives may generate greater net average annual benefits in specific individual reaches over the entire project and within the three planning reaches Alternative 4 generates the greatest net average annual benefits.

Table 16: Net Average Annual Benefits.

	Net Benefits			
Reach	**Alt 1**	**Alt 2**	**Alt 3**	**Alt 4**
I1	$122,469	$15,882	$222,424	$222,424
I2	$57,558	$7,021	$107,922	$107,922
I3	$14,156	$2,234	$22,820	$22,820
I4	$19,108	$2,416	$33,788	$33,788
P1	$9,658	$9,076	$14,436	$17,528
P2	-$14,101	$22,457	-$1,185	-$5,344
E1	$3,472	$13,017	-$4,736	$9,951
E2	$21,848	$22,470	$11,313	$21,978
E3	$36,315	$46,123	$26,654	$38,632
E4	$81,740	$28,222	$98,315	$93,723
E5	$46,145	$27,247	$43,832	$51,606
E6	$58,933	$66,524	$53,368	$59,216
E7	$18,021	$21,968	$13,804	$16,423
E8	$130,028	$104,432	$121,698	$133,471
E9	$64,325	$21,001	$91,613	$76,090
E10	$135,694	$70,100	$145,367	$151,388
E11	$135,277	$67,594	$142,937	$145,952
E12	$15,223	$14,570	$7,986	$16,015
E13	$60,498	$46,982	$59,520	$61,747
E14	$194,443	$113,188	$207,823	$213,951
E15	$126,759	$120,963	$112,765	$130,192
Inlet Reach (I1-I4)	**$213,290**	**$27,553**	**$386,954**	**$386,954**
AS Reach (P1-2, E1-E6)	**$244,010**	**$235,136**	**$241,996**	**$287,289**
AN Reach (E7-E15)	**$880,268**	**$580,798**	**$903,515**	**$945,230**
Total	**$1,337,568**	**$843,487**	**$1,532,465**	**$1,619,473**

11.0 Renourishment Cycle Optimization

Having identified the NED plan the next step in the analysis was to determine the optimum renourishment cycle. Detailed analyses have shown that the total cumulative volume of fill material place on a nourishment project over a 50-year project life is approximately the same regardless of the length of the renourishment cycle (CEM, Part V, Chapter 4, 2008). As such, optimization of the renourishment cycle effectively reduces to balancing the cost of frequent mobilizations and demobilizations for short duration renourishments against the risk of storm-induced damages in the event the project needs renourishment for a prolonged period before a scheduled renourishment occurs. As stated previously, the initial suite of model simulations were performed in a way that allowed renourishment to occur whenever it was determined to be required. That is, within the simulation the beach morphology was check each year and if certain morphology conditions existed and a specified renourishment mobilization threshold volume was exceeded then a renourishment was scheduled and constructed. The lifecycle results from these simulations were analyzed and the frequency distribution of the computed renouishment cycle was determined to be as shown in Figure 52. From this figure it is seen that required renourishment at Edisto Beach takes on a very broad distribution with renourishment needed in as short as one year and a long 30 plus years. A mean renourishment interval of approximately 16 years was computed from the distribution shown in Figure 52. This broad distribution of renourishment intervals is an indication that the need for renourishment Edisto Beach is primarily driven by the random occurrence of strong storm events as opposed to a persistent background erosion rate.

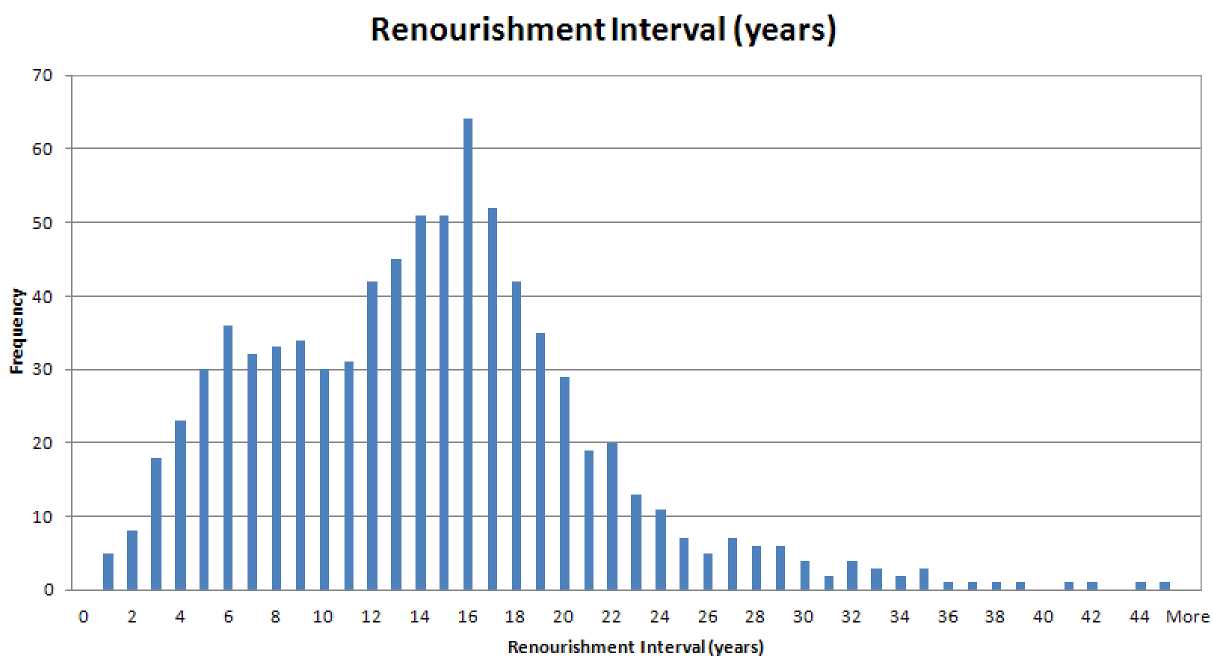


Figure 52: Frequency Distribution of Renourishment Cycle.

A series of additional lifefcycle simulations were performed to determine the optimum renourishment cycle for NED plan (Alternative 4) at Edisto Beach. Simulations were performed for renourishment cycles of 4, 6, 8, 10, 12, and 16 year renourishment cycles. Net average annual benefits were computed for each of the simulated renourishment cycles and the results are shown in Figure 53. This figure shows that net average annual benefits increase substantially between 4 year and 6 year renourishment intervals and again between 6 year and 8 year renourishment intervals. However, the results indicate that renourishment intervals of 8 years and longer produce approximately the same net average annual benefits. Although a notable decrease in net average annual benefits is seen between the 12 year renourishment cycle and the 16 year renourishment cycle. The 12 year renourishment cycle generates net average annual benefits that exceed the 8 year renourishment cycle average annual net benefits by approximately $4500. However, this difference represents an increase of just 0.3% of the total average annual net benefits. Figure 54 shows the cumulative probability distribution function of when renourishment at Edisto Beach is required. This figure shows that there is approximately a 40% probability that renourshment will be required at Edisto at an interval of 12 years or less. Likewise, the plot shows that the

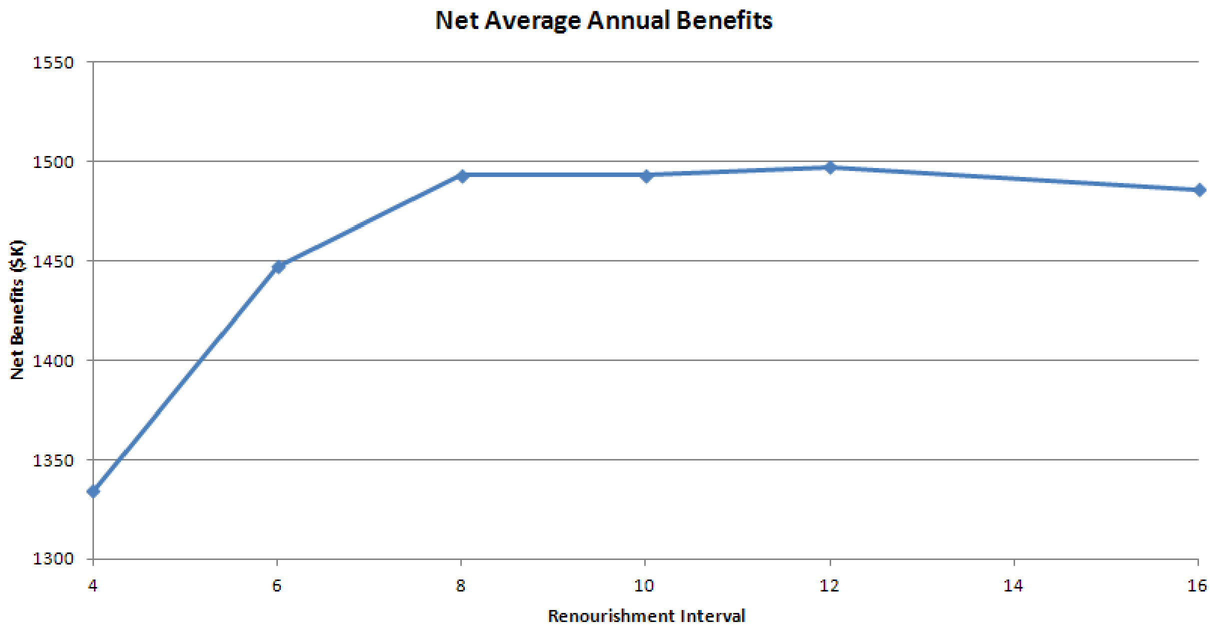


Figure 53: Frequency Distribution of Renourishment Cycle.

probability of a renourishment being required at 8 years or less is approximately 23%. Consequently, the risk of the project requiring renouishment before it is scheduled to occur is reduced by 17% with a 8 year renourishment cycle compared to a 12 renourishment cycle. In light of the 17% risk reduction and the relatively small difference (0.3%) in average annual net benefits nearly an 8 year renourishment cycle for Edisto Beach is identified as the optimum renourishment cycle.

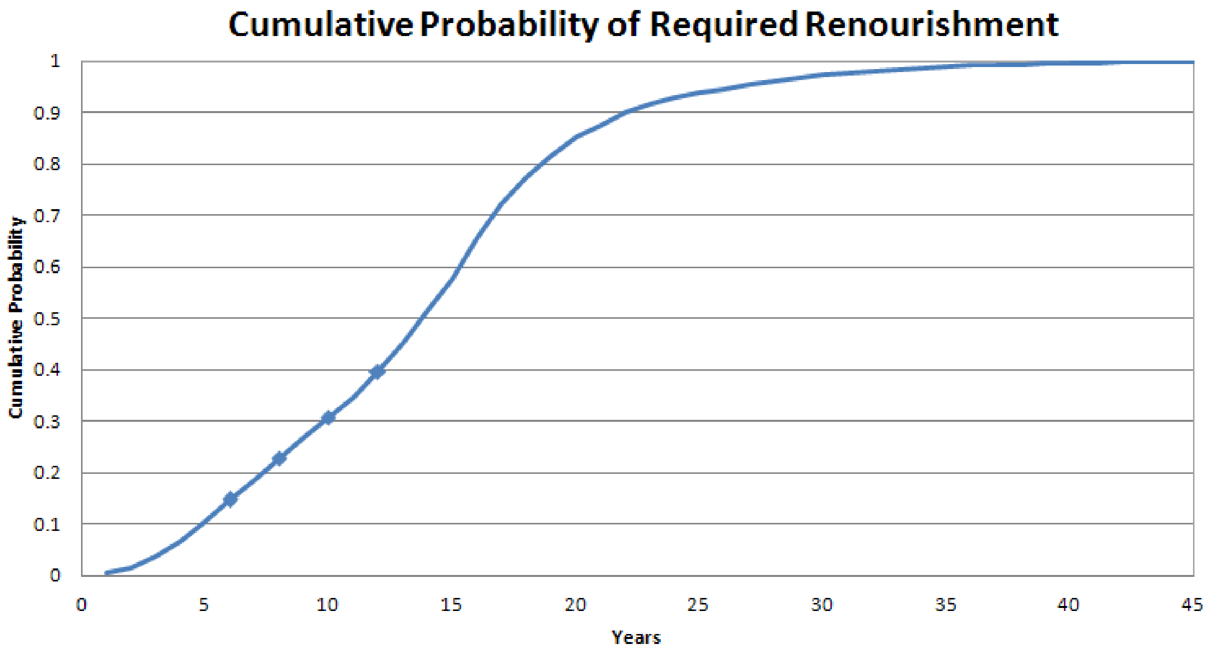


Figure 54: Cumulative Probability Function of Required Renourishment.

12.0 Project Sensitivity to Future Sea Level Change

In accordance with EC 1165-2-212 the direct and indirect effects of future sea level change on the identified NED beach and dune fill alternative (Alternative 4) was evaluated using the Beach-fx model. The engineering and economic performance of the NED plan was evaluated under three scenarios of future sea level change in accordance with official guidance as articulated in EC 1165-2-212. Relative sea level change at Edisto Beach is one of rising sea levels. The historical rate of sea level rise was determined to be 3.19 mm/year (Appendix A, Section 2.0 *d*). The future low rate of sea level change was taken as a linear projection of this historical rate of change. The future intermediate rate of sea level change was computed using modified NRC Curve I and equation 2 and 3 in EC 1165-2-212 Appendix B. The future high rate of sea level change was computed using modified NRC Curve III and equations 2 and 3 in EC 1185-2-212. These relationships for future sealevel change as defined in ED 1165-2-212 are coded within Beach-fx and sea level change is internally computed continuously throughout the simulated project lifecycle. Figure 55 provides a plot of the Beach-fx computed sea level rise for each of the three sea level change scenarios. This figure shows that incremental sea level rise across the simulation period (2009 to 2069) was computed at 0.62 ft, 1.10 ft, and 2.65 ft, for the low, intermediate, and high rates of sea level change, respectively.

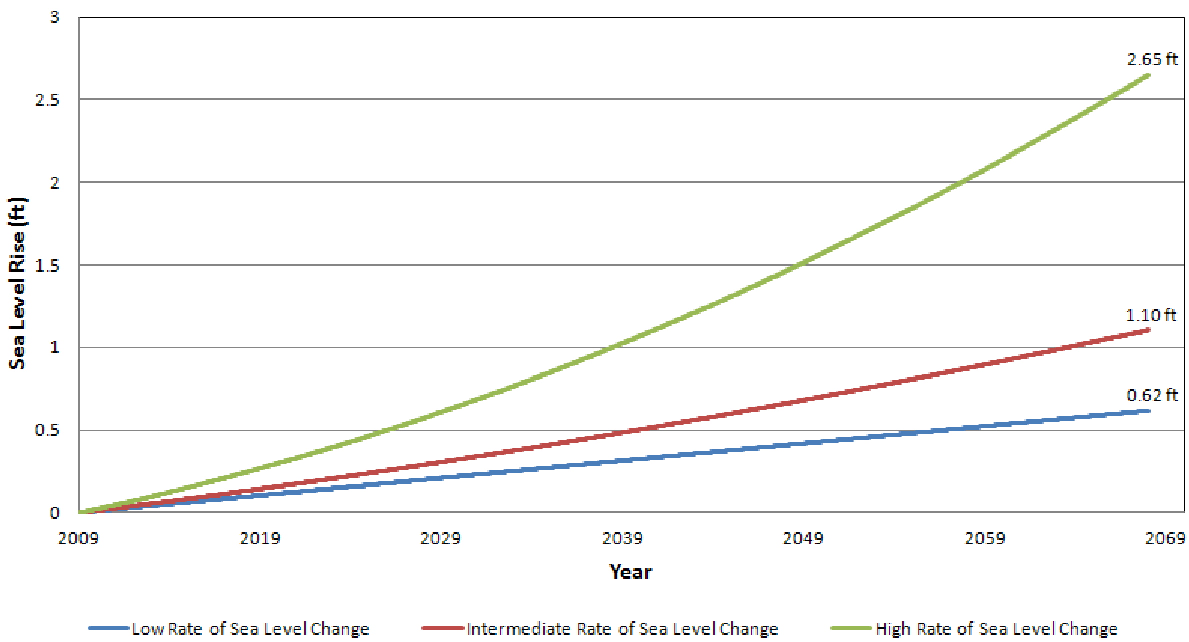


Figure 55: Cumulative Probability Function of Required Renourishment.

The effect of potential future sea level change on the economic performance of the NED alternative (Alternative 4) is illustrated in Figure 56. This plot shows that average annual project costs, average annual project benefits, and net average annual benefits all increase with increasing rates of future sea level rise. However, average annual benefits increase at a faster rate than average annual project costs resulting in net average annual benefits that are greater for higher future rates of sea level rise. These results indicate that from an economic

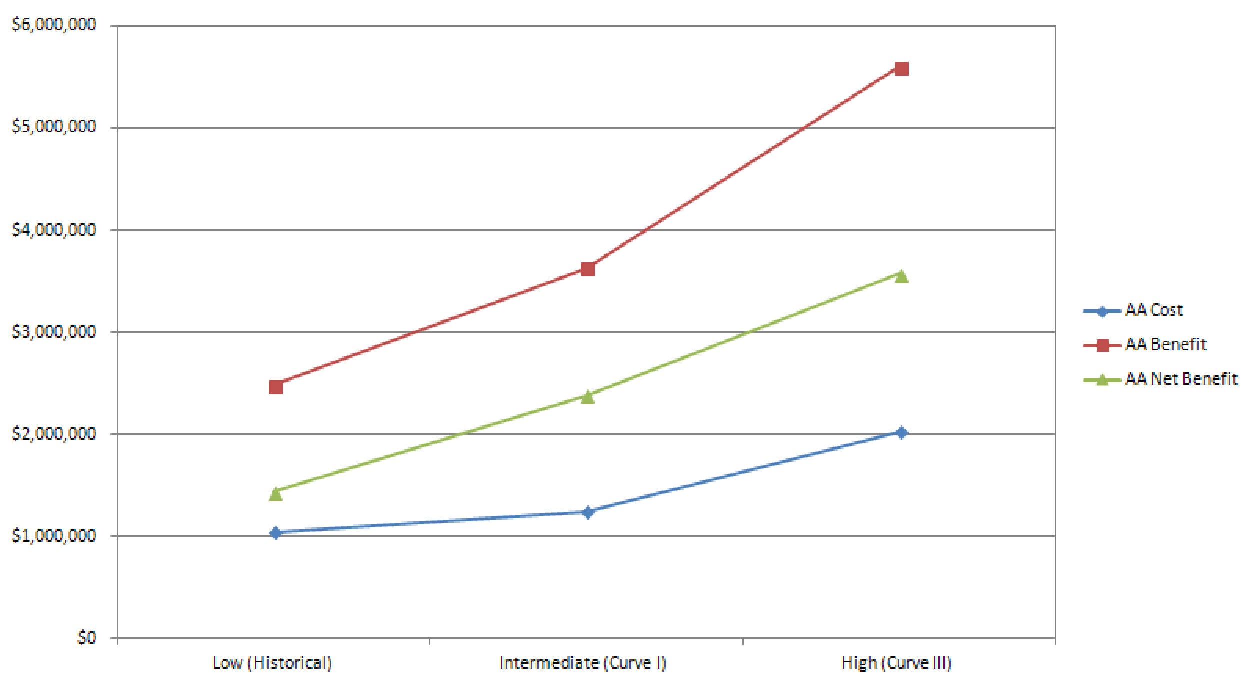
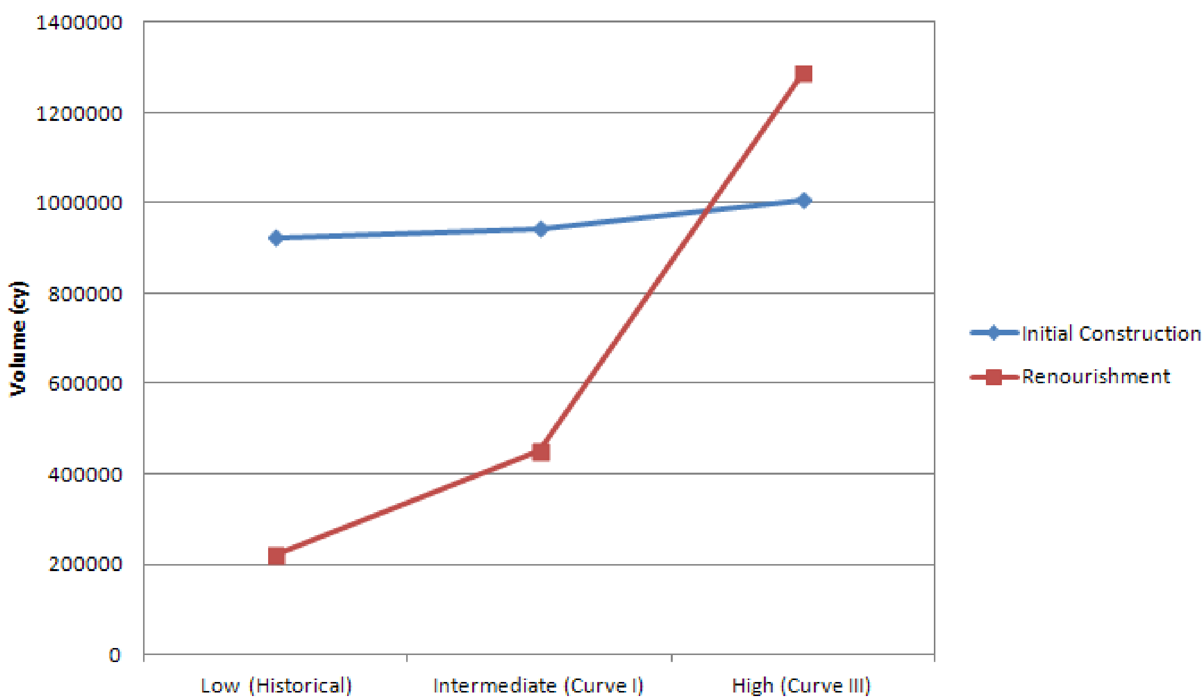


Figure 56: Effect of Future Sea Level Change on Economic Performance of Alternative 4.

perspective a Federal storm damage reduction project at Edisto Beach will remain justified if accelerating rates of future sea level rise occur as some have predicted.

From an engineering perspective, future sea level rise will require more sand volume to maintain the designed project features. Figure 57 shows the estimated fill volume requirements for initial construction and the 8-year interval renourishment for each of the three future sea level change scenarios. Here it is seen that the future sea level rise scenario has little effect on the initial construction volume but a large effect on the average renourishment volume. For the low rate of sea level rise the average 8-year renourishment volume is estimated at 220,400 cy, whereas for the intermediate rate of sea level rise the average 8-year renourishment volume increases by more than double to 450,500 cy, and for the high rate of future sea level rise the average 8-year renourishment volume increase by nearly six-fold to 1,278,300 cy.



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