ASSESSMENT OF THE GROIN FIELD AND CONCEPTUAL PLAN FOR GROIN LENGTHENING

EDISTO BEACH SOUTH CAROLINA

January 2013

Prepared for:

Town of Edisto Beach

TECHNICAL REPORT

Assessment of the Groin Field and Conceptual Plan for Groin Lengthening at Edisto Beach, SC

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COVER PHOTO: Aerial image of Edisto Beach in September 2012.   [Photo by SB Traynum]

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1.0 INTRODUCTION

This report is an assessment of the groin field and beach conditions along Edisto Beach (SC) and a conceptual plan for groin lengthening. It is apparent to casual observers there are significant differences in the condition of the beach from the pavilion (between Groins 1 and 2) to the Point area (Groins 25–28).

Along the northern end of the island, homes are situated at the edge of a narrow, dry-sand beach with a negligible vegetative buffer and no dune protection (Fig 1). About 1.5 miles from the pavilion (near Groin 15 – Byrd Street), the beach is wider, and there are low vegetated dunes fronting homes. A 25–50 foot (ft) vegetation buffer persists along most properties from Groin 15 to Groin 24.

The short segment of beach at the Point (particularly an 800 ft reach centered between Groins 24 and 28) has no dune buffer in front of homes. Continuing around the Point to the west, the beach widens along with a vegetated dune field. Homes fronting St. Helena Sound are generally positioned hundreds of feet from the edge of the dry beach (Fig 2).

Earlier reports have shown these variations in beach condition result from several factors:

- Net sand transport is southerly from the pavilion area to the St. Helena Sound shoreline. The northern half of Edisto Beach has a long history of erosion while the downcoast end of the beach has accumulated sand.*

  *[*Prior to construction of the groin field, the northern end of Edisto Beach was eroding at up to 10 feet per year (ft/yr) (USACE 1969, Cubit 1981, 1987), while the southern end gained sand. Erosion rates around the pavilion diminished to about 1 ft/yr after installation of the groins (CSE 1992, 1993). The 2006 nourishment project initially buried all groins, rendering them non-functional. As the ends have become exposed, functionality has returned. Therefore, erosion losses since 2006 reflect a transition period during which sand has moved freely alongshore for a time. CSE (2011) reported net sand losses averaging 2.83 cubic yards per foot per year (cy/ft/yr) along the northern 2.24 miles of Edisto Beach (includes Edisto Beach State Park) and net gains averaging 1.69 cy/ft along the southern 3.13 miles since 2006. In linear terms, these rates are equivalent to ~4 ft/yr erosion and 2.5 ft/yr accretion. Erosion losses along the northern end of the island approximately equal accretion along the southern end of the island over the past seven years, demonstrating how sand has been conserved within the limits of Edisto Beach.]*

- Groins, the primary shore-protection measure to slow erosion rates, were constructed in groups from north to south. This shifted the zone of critical erosion to downcoast sections and led to variations in beach condition relative to building setbacks after groin installation. The original groins do not appear to have been designed to provide a uniform level of protection with respect to oceanfront homes.

- Groin deterioration in several forms produced other variations in the degree of protection. Timbers rotted, quarry stone settled, and sand-trapping declined at different rates within each groin cell, which left some cells with less sand than others.

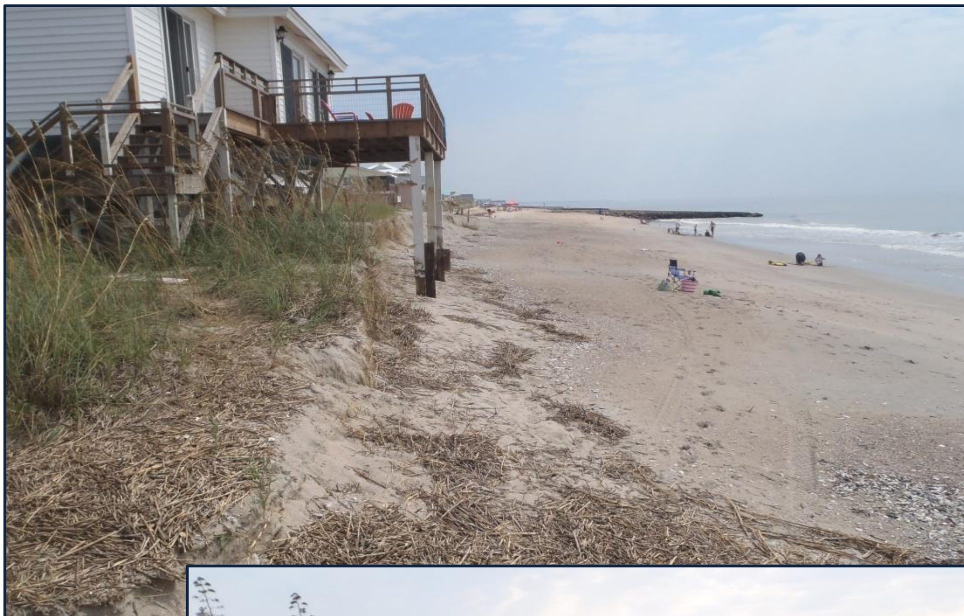


FIGURE 1.

Ground photos taken on 14 August 2012 showing variable conditions with respect to existing homes along (upper) cell 5, 0.5 mile from the pavilion, (middle) cell 15 at Nancy Street, and (lower) cell 26 at the Point.

[Photos by SB Traynum]

FIGURE 2.

Much of the sand lost along the oceanfront has accumulated down-coast along the St. Helena Sound shoreline of Edisto Beach.

[Photo by SB Traynum on 14 August 2102]

Details regarding Edisto's shoreline erosion history, groin installation, and repairs are available in a number of reports listed in the "References" section. Major groin repairs were initiated in 1995 with a project that involved restacking, shaping, and grouting existing structures (Kana et al 2004).

The purpose of the present report is to provide recommendations and conceptual alternatives for lengthening the groins and providing more uniform protection and sand retention along eroding areas of Edisto Beach. CSE's work included review of other concept plans, development of objective criteria for improvements, calculation of specific quantities associated with the lengthening, and estimation of probable construction costs.

Two levels of improvements were evaluated in detail: (1) minimal lengthening to approach the sand retention capacity and back-beach conditions of cell 15 (Nancy Street), and (2) lengthening and modification of the groin profile to provide a wider recreational beach and "10-year" storm protection. Each level of improvement would involve concomitant nourishment to satisfy the increased trapping capacity of the structures in accordance with present OCRM regulations. The level of detail in the report is conceptual but includes specific quantities for purposes of cost estimation.

1.1 Background

Edisto's groins were built beginning in 1948 (USACE 1969, Cubit 1981) when the first timber groin was constructed at the northern end of the Town's beach (near the pavilion). Downcoast erosion led to additional groin construction progressing to the south until 1975 (Kana et al 2004). In the 1960s, deterioration of timber warranted the addition of armor stone around the heads (seaward end) of the groins. In 1988, a town-directed project reinforced the groins with additional rock. More extensive repairs were completed in 1995 with the addition of armor stone along with restacking and grouting of Groins 1–16 and 24–28. The 1995 project included ~150,000 cubic yards (cy) of nourishment. Other improvements were made to groins in subsequent years including re-facing of timber sections with shotcrete and addition of concrete caps along the crest of some structures (Fig 3). Presently the integrity of the groins remains in satisfactory condition with minor slumping and displacement of armor stone being the most prevalent issue.

FIGURE 3. Groin 8 at low tide (14 August 2012) showing original timbers (1950s) capped by retrofitted concrete cap (ca 1997). Seaward quarry-stone section was restacked and grouted in 1995. The landward end slopes at ~1 on 50 while the seaward section slopes at ~1 on 20, with the crest terminating about 4 ft above mean low water in this case.

There are two basic design deficiencies which limit the ability of the groins to maintain an ideal beach condition and protective dune along many portions of Edisto. The first is that the groins were initially built to protect Palmetto Boulevard and do not extend far enough seaward to adequately protect houses on the seaward side of the road. Numerous houses were built on reclaimed land after the groins were installed.

The other issue is the profile of the groins. The original timber structures had a much flatter slope (~1 on 50) than the beach (~1 on 18) and terminated at an elevation above mean high water. Exposed timber at the head of each structure rotted, decreasing the sand-trapping capacity and further exposing the trunk sections. Armor stone, added in the 1970s, restored some functionality and scour protection. However, the size of the armor stone was insufficient to remain stacked properly and maintain a profile under yearly wave conditions. As rock shifted and settled, sand-trapping capacity declined. The 1995 repairs raised the profile and brought the seaward slopes closer to the slope of the natural beach, but did not incorporate best practices for groin design.

Modern groin design guidelines call for a generally flat berm section close to the natural dry-beach level, sloping beach face section, and a flat low-tide section (ASCE 1994; USACE 1992, 2002). The low-tide section is critical for holding the upper beach in place. It helps retain a broad, low-tide terrace which anchors the sloping section of beach across the intertidal zone. The recommended profile is an attempt to follow the natural shape of the beach, promote free sand movement over and around the ends of the structures, and reduce the exposure of the structure above the sand level. By reducing the "reveal" of the groin, beach vistas are improved, and structure longevity increases because most of it is buried (Traynum et al 2010). This results in less impact to users and the beach environment. The majority of groins in South Carolina were originally constructed like Edisto's and have experienced similar problems (Kana et al 2004).

The trapping capacity of groins is a function of length, height, and spacing (ASCE 1994, Kraus et al 1994, USACE 2002, Basco & Pope 2004). When Edisto's timber groins were built, the seaward ends were higher than present conditions and, possibly in some cases, longer. As they deteriorated and were rebuilt (1995), functionality declined relative to the original condition. Sand-trapping capacity decreased and the equilibrium profile within each groin cell receded landward, leaving a narrower beach. Maintenance efforts to date have been designed to maintain the structure profiles, using grout to hold smaller-than-ideal rock units in place. This has also created "impermeable" structures which lose less sand through gaps between rocks. Efforts by the Town of Edisto Beach have included addition of concrete caps on top of the groins which incrementally increase trapping capacity* (see Fig 3).

*[*Groin sand-trapping is proportional to the profile (beach cross-section) covered by the structure. If the groin is 140 ft long and a 1-ft-high cap is added, the trapping capacity increases by ~5 cy/ft at the structure. Note: 27 ft² of beach cross-section equal 1 cy/ft]*

Few groins in the US follow modern design guidelines for the profile (ASCE 1994, USACE 2002). Six groins at Hunting Island (SC) are among the installations that incorporate the three sections recommended (Traynum et al 2010). At Hunting Island, where the wet-sand beach is wider and flatter than at Edisto, groins are ~450 ft long. The “berm” sections are typically about 150 ft long; the sloping beach-face sections are about 225 ft long; and the low-tide terrace sections are about 75 ft long with a broad apron of loose quarry stone at the head of each groin. This profile places more of the structure below the high watermark and tends to reduce the reveal above the sand level (Fig 4). Based on present design guidance, **retrofits of existing groins should seek to achieve the three recommended sections to the extent practicable.**

FIGURE 4. A Hunting Island (SC) groin built in 2007 showing the three recommended sections which are designed to follow the natural slope of the beach: upper dry beach section (berm), sloping wet-beach section (beach face), and low-tide section (low-tide terrace). Note the broad apron of loose armor stone at the head of the structure placed to reduce scour. This functions as a “T-head” and is considered to improve the performance of the groin.

1.2 Best Management Practices for Groin Design

Along the eastern coast of the United States, groins have been emplaced to stabilize beaches for more than 100 years. The popular assessment of their performance is that they typically have not worked and have caused more problems than they have solved. In many cases, these assessments have been made based upon anecdotal information and without the benefit of long-term shoreline change data. As a consequence, some states and local governments have altogether banned the use of groins as a shoreline

> *protection structure. However, in many circumstances, groins have functioned effectively and stabilized an eroding beach without seriously harming adjacent areas.* [FA Galgano Jr, PhD, 2004, pg 3]

The history of groins at Edisto Beach supports this quote in several respects. It is true the construction of upcoast groins in the 1950s exacerbated downcoast erosion along the oceanfront after the 1954 nourishment eroded. This led to installation of more groins up through the 1970s, more or less following a wave of erosion to the south. However, the last groins built have not prevented accumulation of sand downcoast. More sand has bypassed the groin field and has deposited along St Helena Sound than has been trapped within the groin field or lost to Big Bay Creek. The upcoast groins have "functioned effectively and stabilized an eroding beach." Adverse downcoast impacts have been limited for the most part to the Edisto Beach oceanfront and the Point area. Importantly, Edisto's groins have had no impact on the "downcoast" islands—Harbor Island and Hunting Island. Years of monitoring along those islands proves that their sand supplies come from the south and are transported north into St Helena Sound (Stapor and May 1981, Zarillo et al 1981).

In 2004, Kraus and Rankin edited a collection of 22 professional papers on the *Functioning and Design of Coastal Groins: The Interaction of Groins and the Beach — Process and Planning* (Special Issue 33, Journal of Coastal Research). A number of findings resulted from these papers along with other works by the authors and their institutions from around the world:

1) Modern functional design of groins is an evolving process and must consider site-specific conditions.
2) *Groins should be (designed) to maintain a minimum, dry beach width for coastal storm damage reduction and/or limit further erosion of the backbeach line* (Basco & Pope 2004, pg 121).
3) Groins function best in the presence of a net longshore transport along a coastal segment. Where net longshore transport is low, the only way groin cells can fill is via onshore transport.
4) Groins should be designed to hold a particular beach line, a pre-determined beach volume, or a nourishment project in place — **<u>not</u>** to capture littoral material moving alongshore.*

   [**In many cases, groins have been designed and installed with the goal of trapping material from the littoral system to artificially advance the local shoreline beyond those of the adjacent shoreline. Groins designed in this manner will block alongshore-moving material, cause damage to downdrift shores, and possibly even deflect valuable littoral material offshore where it is lost to deeper water.* Basco & Pope 2004, pg 130]

5) Groin installation should be accompanied by artificial nourishment to fill cells to capacity and allow longshore transport and bypassing to downcoast areas.

6) Groin spacing-to-length ratios in the range 2–3 tend to insure fillets extend the length of each cell under a normal range of wave approach angles (Kraus et al 1994).

7) Groins neither manufacture nor destroy sand but simply modify the rate of profile change within the groin cell. Monitoring and tracking of sand budgets is a critical element of the design process and post-project analysis of performance.

8) "Triggers" should be established for decisions to modify, mitigate via additional nourishment, or remove groins if adjacent beach impacts are found unacceptable.

While the above-listed design guidance is not comprehensive, it includes many elements that are considered applicable to Edisto Beach. First is that only eight (8) of Edisto's initial field of groins were accompanied by nourishment.* As Kana et al (2004) reported, downcoast impacts were severe and led to a reverse sequence of groin construction, generally following the wave of erosion downcoast. Design guidance today (as well as the South Carolina Beach Management Act) requires nourishment with groin construction. Further, experience shows that if construction of a groin field is phased in over time, the order of construction should be from downcoast to upcoast (USACE 2002).

*[*Groins 1–4 were constructed in 1948–1949; Groins 4–12 were reconstructed/constructed (1953–1954) concomitant with nourishment in 1954. The remaining groins (13–34) were constructed without nourishment between 1958 and 1975 (Cubit 1981).]*

Second, Edisto's groin field was originally designed to protect Palmetto Boulevard. Despite deterioration of timbers and settlement of armor stone at the heads after 20–40 years, the structures were effective at maintaining a particular shoreline seaward of the road. The issue today is that the "equilibrium" shoreline (or stable dune line) for the existing groin lengths is landward of houses or where it needs to be maintained for shore protection.

Third, most of the groins are spaced ~600 feet (ft) apart. Design guidance suggests the "effective" length needs to be 200–300 ft long (ie — two to three times spacing*) for stable fillets to develop seaward of the desired beach line. The effective lengths for Edisto groins are generally shorter than ideal, yielding spacing-to-length ratios of >3 for many cells. In a majority of cases, only about 120–150 ft of groin is exposed and functional seaward of the existing high water mark.

*[*A check of the literature on spacing-to-length ratios shows repeated references to the 2–3 range. However, prior reports and practice do not generally distinguish differences in trapping related to alternate profiles. For example, Edisto's original groins were ~250 ft long, terminating above mean high water with a gentle slope over the length of the structure. As the timbers at the seaward end rotted and damaged sections were cut away, trapping capacity declined. Armor stone was added to restore functionality, but at*

> *a lower elevation than the original profile. Many of the present groins are nearly the same lengths as the original structures, but clearly have a lower trapping capacity. Therefore, the spacing-to-length ratios may be the same, but the effectiveness of the present groins does not match the original structures. More research is needed to refine this ratio, particularly in consideration of alternate groin profiles.]*

Over the past 20 years, Edisto Beach has been monitored in detail for purposes of tracking performance of groin improvements and nourishment. This has provided objective measures of volumetric losses and gains between upcoast and downcoast areas. Monitoring has confirmed rates of sand loss along the oceanfront and accumulations along St Helena Sound, and has demonstrated the near-balance in the overall sand budget for the island. The rate of loss along upcoast cells and the state park provides a measure of net longshore transport. Low rates of loss within the state park and short-term gains between park camp sites and Jeremy Inlet are providing evidence that **net** longshore transport rates are low. Other evidence of lower-than-expected longshore transport rates is the strong seasonal fillet development at the northern ends of each cell. During summer months under waves from the south, sand is seen accumulating against the "downcoast" or south side of each groin. This is counter to the net southerly transport that prevails.

Monitoring data show relatively low sand losses (order of 2.8 cy/ft/yr since 2006) which would yield net transport of the order 25,000–50,000 cy/yr along the eroding section of the oceanfront. An important implication of this is that groin cells cannot fill rapidly under the influence of longshore transport in this setting. For example, to accumulate ~1 million cubic yards from upcoast, the equivalent of 10–20 years of net transport would have to be intercepted. This volume would be drawn off with potentially detrimental impacts along the accreting sections of Edisto Beach. As CSE (2003a,b; 2006) has previously reported, the upcoast supply of sand (from Edingsville Beach) is diminished by the concentrations of mud. Edingsville has high erosion rates because the beach is rolling over into the marsh leaving exposed mud on the beach, not because of high rates of longshore sand transport. Further proof of this is the sand transport reversal (to net northerly transport) at the northern end of Edingsville Beach and Botany Island.

Based on the above-stated design guidance and site-specific measurements at Edisto Beach, CSE finds the following prerequisites are necessary for groin improvements:

1) Groins should be lengthened to maintain a desired beach line seaward of houses.
2) Nourishment should be incorporated into designs according to state laws under the Beach Management Act and because natural infilling via longshore and onshore transport processes is likely to require decades, with associated adverse downcoast impacts as sand is intercepted by the structures.

3) Groins should be lengthened such that the spacing to length ratio (measured seaward of the ideal beach line) is within the range 2–3, following modern design guidance.

4) Groin profiles should incorporate three sections with the sloping middle section displaced seaward to follow the ideal (design) profile of the beach alignment.

5) Groin profiles should allow free sand movement around or over the ends of the structures and not penetrate above the natural backshore beach level.

6) Reveal (section exposed above the sand level) should be minimized to the extent possible so as to increase structure longevity and reduce the aesthetic impact.

The next section describes CSE's methodology for developing two scenarios for groin improvement. After the results of the analysis, the alternative improvements are compared with conceptual plans offered by the US Army Corps of Engineers and the Beach Front Committee.

2.0 METHODS

2.1 Data Sources

A fundamental aspect of the analysis herein is establishing the current condition of the beach and groins with respect to a fixed reference. CSE used multiple data sets to define the condition of the beach and groins. These data included:

1) Orthorectified aerial imagery obtained 25 May 2011 by Independent Mapping Consultants (Charlotte NC) at the request of the Town. This high-resolution imagery provides a geo-referenced plan-view of the island and is useful for determining locations of structures, extent of vegetation, and general beach conditions.
2) Topographic and bathymetric data from a comprehensive beach survey obtained by CSE in July 2012. These data were used to develop cross-sectional beach profiles.
3) Topographic data of the groin centerline elevations obtained by CSE in April 2010. These data provide profiles and slopes along the crest of each groin.

2.2 Existing Condition Analysis

The 2011 aerial imagery was used to define a reference baseline along the visible centerline of Palmetto Blvd. This baseline essentially is the same as the baseline used during monitoring surveys, except for a few minor adjustments along the 100 block and around the Point Street area (herein "the Point"). The baseline defines the starting point (0 feet–ft) for beach profiles and also defines the distance alongshore of each groin [ie – Groin 1 is at the start of the baseline (station 0+00), and Groin 2 is at station 6+15 (615 ft along the baseline from the starting point)]. The baseline is shown in Figure 5.

The reference baseline was used to calculate the setback of each oceanfront house as well as the distance to the stable vegetation and the July 2012 mean-low-water (MLW) contour in front of each house. This produced a table of values for each house from which the width of stable vegetation and the beach width (from each house to MLW) could be extracted. These values were averaged for all houses within each groin cell to provide a representative condition for each cell/groin pair. While seasonal sediment transport patterns are significantly different at Edisto, CSE assumed for this study that the dominant transport is to the south, therefore, a groin will protect the beach on the northern side (updrift side). For example, the average width of vegetation at **cell 15** (between Groins 15 and 16) is assumed to be controlled by the length of **Groin 16**. The baseline was also used for creation of groin profiles so that the beach condition could be related to each groin profile. An example from Groin 16 is shown in Figure 6.

FIGURE 5. Reference baseline running along the centerline of Palmetto Boulevard. The baseline begins at Groin 1 (station 0+00) and extends to the southwest ~15,000 ft to Groin 28.

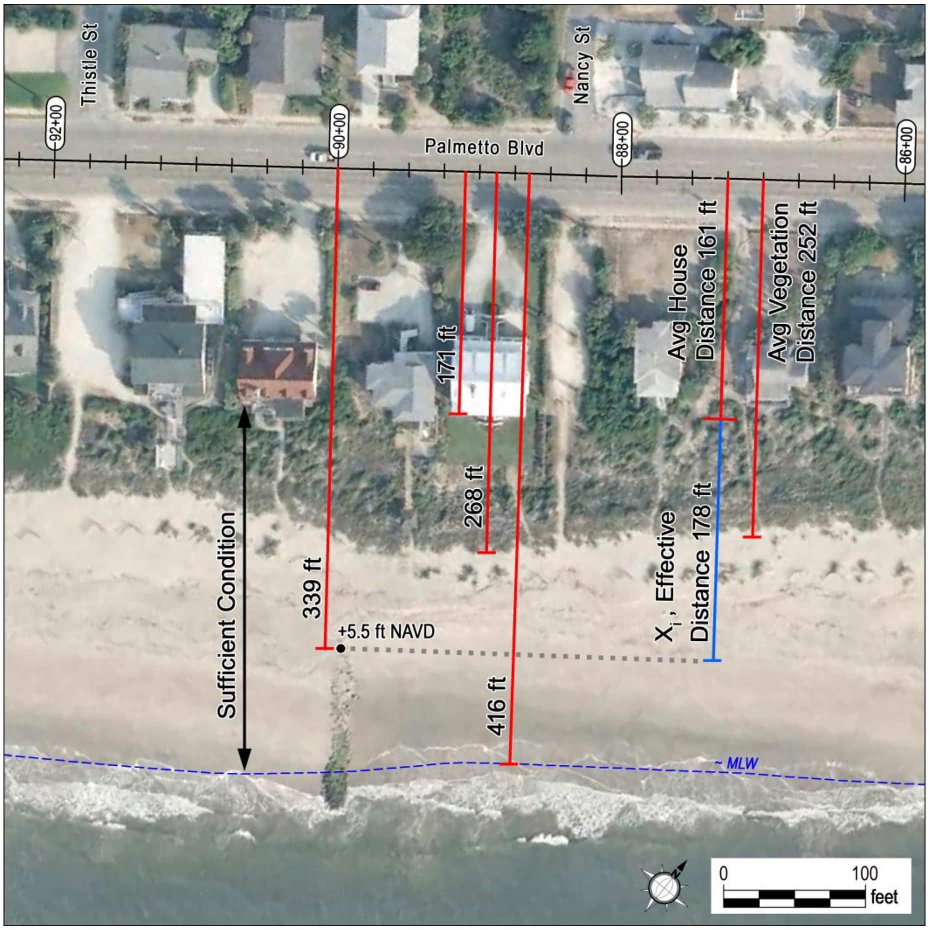
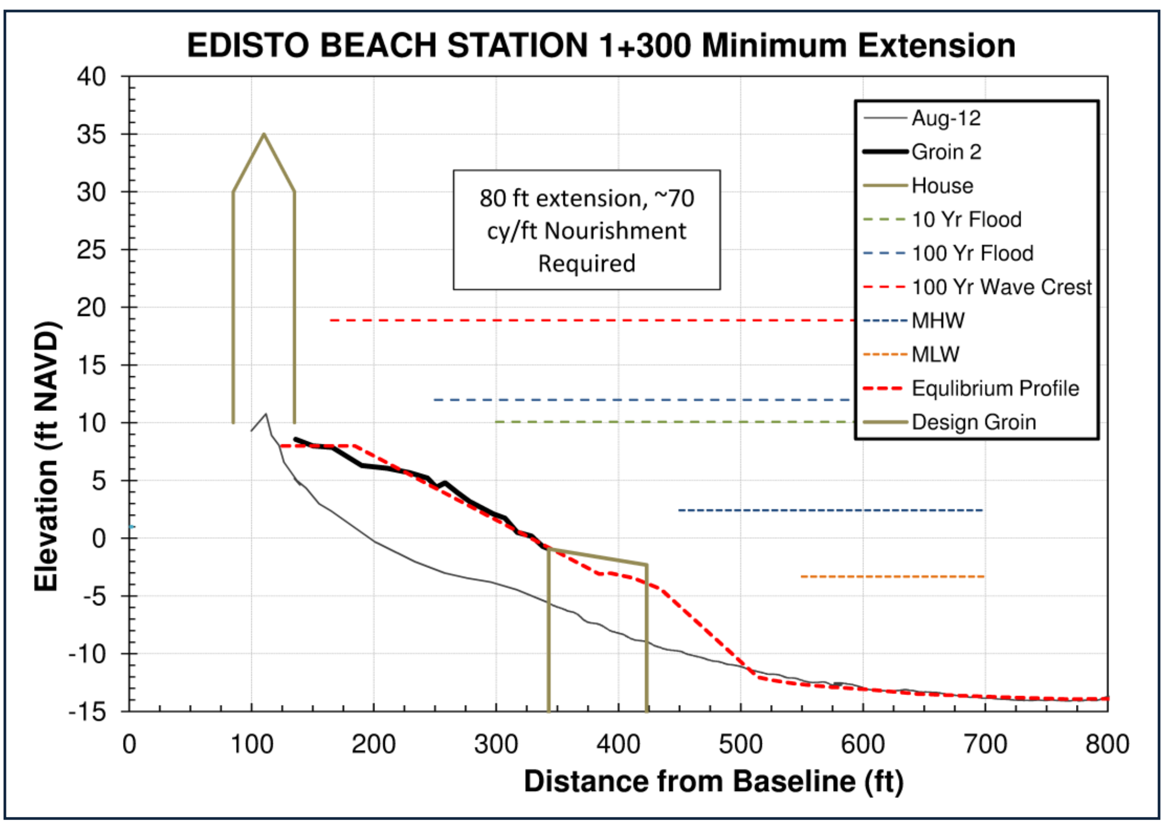


FIGURE 6.

[UPPER] Methodology for Scenario 1, where groin lengthening is determined by comparing conditions at each groin with the condition of Groin 16 (shown).

The critical measurement is *Xi*, the averaged distance from the house to the groin reference point.

[LOWER] Example Scenario 1 from Groin 2, which would require an ~80 ft extension and ~70 cy/ft nourishment to achieve conditions similar to Groin 16.



2.3 Groin-Lengthening Scenario 1

CSE employed two methods for determining a groin-lengthening plan. The first method is similar to methods used by members of the Beach Front Committee, where an existing "sufficient" beach condition and groin length was used as a guide for lengthening other structures. CSE chose Groin 16 as the template condition because of its broad vegetative buffer fronting houses on the upcoast side (groin cell 15) and downcoast side (groin cell 16) (Fig 6, upper). To determine the effective length of each groin, profiles from all groins were plotted. Generally, a change in the slope of each groin occurs around +5.5 ft NAVD, which is close to the average daily wave runup elevation along Edisto Beach. This contour was used as a reference point for each groin, and the distance to this contour from the baseline was measured. This distance was then compared with the average distance to all houses within each groin cell. The comparison yields the average distance from the updrift houses to the normal high watermark and is a measure of effective groin length (a variable defined as X_i).

From these data, it is possible to relate each groin condition to that of Groin 16. These distances represent the minimum required groin lengthening to match the current condition of cells 15 and 16 (Fig 6, lower). CSE assumed that there is a 40-ft minimum extension threshold***** to reach before the effort would be cost effective. Extensions which were calculated to be less than 40 ft were lengthened to a minimum of 40 ft for cost estimating.

*[*Groin extensions using sheet-pile material are expected to be more cost effective than grouted, rubble-mound structures. If this is the case, certain equipment setup (eg — crane with pile guides) is needed for each groin. Once the expense of setup is incurred, the unit cost of pile driving decreases with length. Therefore, some minimum length allows more cost-effective apportionment of setup costs.]*

2.4 Groin-Lengthening Scenario 2

The other method involved establishment of an "ideal" minimum beach profile according to the profile-volume concept (Kana 1990, 1993) and recommendations of Basco and Pope (2004). In this method, a hypothetical ideal beach profile is created which includes a protective dune containing a volume of sand capable of withstanding a specific return-period storm event, a dry beach of sufficient size to withstand seasonal fluctuations in sediment transport direction, and a sloping beach face profile in equilibrium with the local wave climate and sediment characteristics. This method establishes a beach line that is to be maintained seaward of the existing beach. Therefore, nourishment would be required in conjunction with groin lengthening so as to fill the cells and maintain a flow of sand along Edisto Beach.

For the present analysis, CSE choose a dune volume of 8 cy/ft, which is the recommended minimum for protection during a 10-year storm event. This dune volume follows the FEMA standard (Fig 7, after Hallermeier & Rhodes 1988), which yields the required dune cross-sectional area, *E* (ft²), as a function of the stillwater level of a storm with a certain return period, *T* (years).

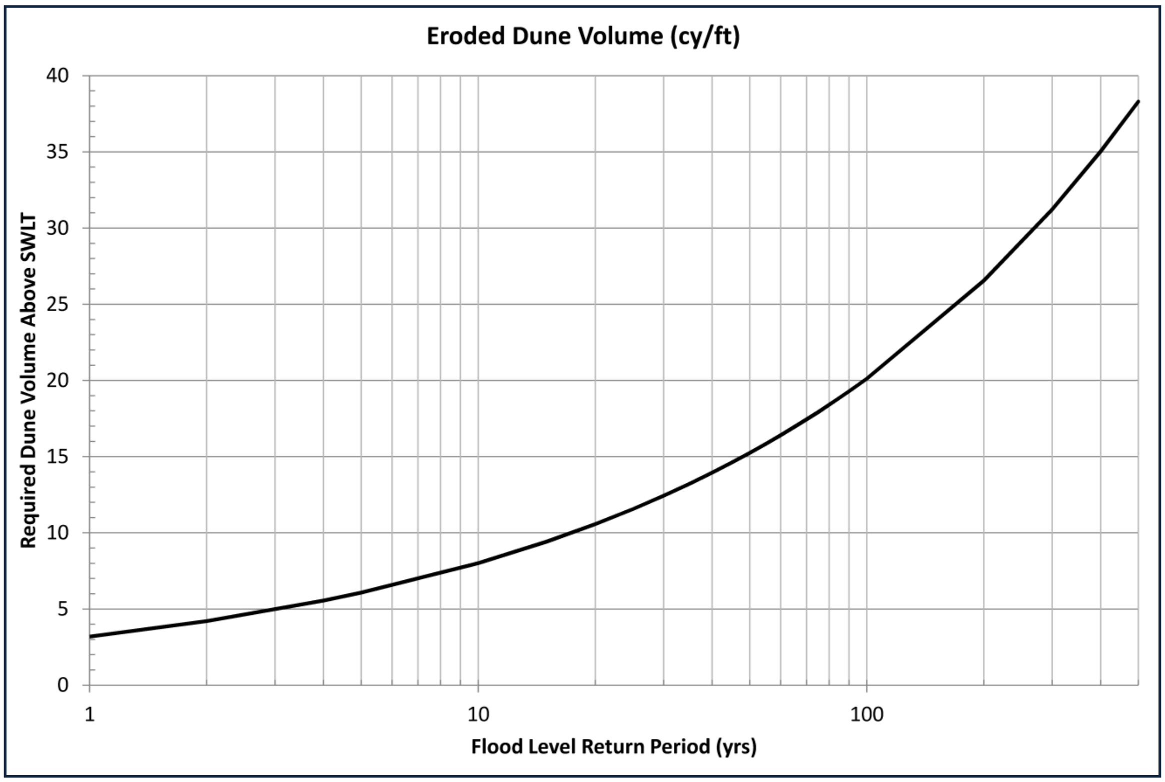


FIGURE 7. FEMA dune criteria for storm protection for a given flood-level return period (*T*). Volumes are above the stillwater elevation for the flood level (SWL_T). For Edisto Beach, the 10-year SWL_T is 10.1 ft NAVD. Recommended dune volumes increase geometrically as the desired level of protection rises.

For example, the 10-year storm event (SWL_T = 10.1 ft) yields a cross-section of 216 ft² which is equivalent to 8 cy/ft. A 25-year storm would require a dune cross sectional area of 312 ft² (11.6 cy/ft) above the *25-year stillwater elevation*. A common dune size used by FEMA for community ratings is for the 100-year flood level, which yields a dune volume of 540 ft² (20 cy/ft) above the **100-year stillwater flood level**. Flood elevations were obtained from the FEMA Flood Insurance Study for Colleton County (SC) and Incorporated Areas (7 November 2001).

Template groins were then developed to match the ideal profile. Groins were designed following USACE guidelines (ASCE 1994, USACE 2002) and recent project experience (Traynum et al 2010, CSE 2011) and incorporate the berm, beach face, and low-tide terrace sections (Fig 8). Lengths and elevations of the sections depend on the local beach morphology and desired results (design post-project beach width). CSE overlaid the new groin profiles on the ideal beach profile to determine the required lengthening of the new groins.

Groin-lengthening recommendations for this method were determined by measuring the distance from the end of the existing groin to the end of the sheet-pile section of the new groin. An additional measurement was the required retrofit distance, which is the length of the existing groin seaward of the +5.5 ft contour. This section of existing groin would require some type of alteration to elevate the crest to match the ideal groin (new) profile.

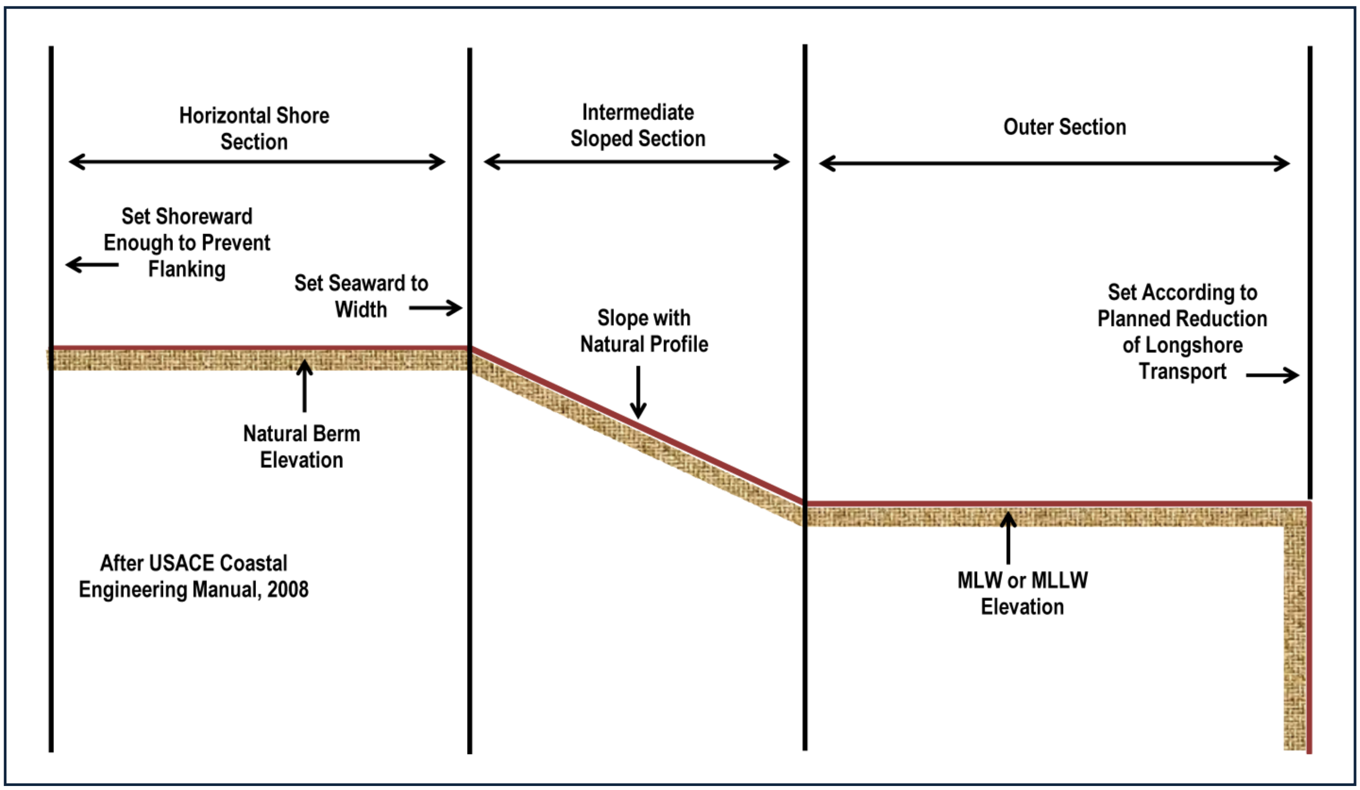


FIGURE 8. Schematic of a recommended "template" groin profile with sloping section and horizontal outer (low-tide terrace) section (after ASCE 1994, USACE 2008). Groins at Hunting Island (Traynum et al 2010) are among the few installations in the United States which incorporate all three sections. Repairs to groins at Edisto Beach in 1995 improved the intermediate sections to approximate mid-tide level, but did not complete the full sloped section or any of the outer section.

2.5 Nourishment Requirement

Nourishment requirements were determined by calculating the beach volume per linear foot between the existing and proposed profile. This volume was averaged for the ends of each groin cell and multiplied by the cell length (for example, the nourishment requirement for cell 3 is the average of the profile volume difference at Groins 3 and 4, multiplied by the length between Groins 3 and 4). For the minimum lengthening scenario, the new beach template was developed by shifting the "ideal" beach profile landward until the low-tide terrace area matched the groin extension. This eliminates the new protective dune and a portion of the berm area from the "ideal" profile. Under both scenarios, a unique uniform rate of nourishment is estimated for each groin cell with no adjustment for fillet geometry. This results in a nourishment volume greater than the trapping capacity of the groins which is immediately available to feed down-coast areas.

2.6 Preliminary Opinion of Probable Construction Cost

Construction costs from recent similar projects are available from various sources. CSE used costs for projects at Hunting Island (2006-2007), Arcadian Shores (2008), Isle of Palms (2008), Nags Head (2011) and elsewhere to develop an opinion of probable construction costs for groin improvements and nourishment at Edisto Beach. These estimates are prepared with the understanding that the present conceptual plans are for feasibility purposes and not for final design and budgeting. Probable costs were determined on a unit basis ($/linear ft) and multiplied by the total length required. Certain adjustments were made to the total volumes based on findings from previous projects (CSE 1996, 1999; Traynum et al 2010) that groin-trapping capacity is less than the volume of the ideal profile. More details of the preliminary cost and quantity estimates are given in Section 4.

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3.0 RESULTS

3.1 Scenario 1

Scenario 1 compared the relative distance between houses and each groin (X_i) to the existing condition of Groin 16. Groin 16 was selected as the template condition because of its relatively broad vegetative buffer between the house and the beach on either side of the groin. It should be noted that while dune width is present, dune elevation and volume still fall below FEMA standards for 10-year storm events. Cells 15 and 16 show an average vegetative buffer of 91 ft and 81 ft (respectively). The average distance from houses in cell 15 to the +5.5 ft NAVD contour (defined as X_{16}) on Groin 16 is 178 ft. An X_i value was computed for each groin cell using the condition of the updrift houses (houses on the north side of the groin). These values were subtracted from X_{16} to determine the required extension, *E*.

$$Extension, E = X_{16} - X_i$$

E ranged from 80 ft to −127 ft (values below zero represent conditions exceeding the present condition of Groin 16) as shown in Figure 9.

Extensions to achieve Scenario 1 are greatest at the northern groins (from 1 to 9), averaging 63 ft. Groins 10–12 require extensions less than 40 ft and Groins 13 and 14 require 68 and 58 ft extensions (respectively). From Groin 16 to Groin 24, only Groin 18 requires an extension under this scenario. Groins 25–27 require extensions from 40 ft to 103 ft. Table 1 details the required extensions under Scenario 1. Extensions less than 40 ft would not likely be cost effective, therefore where the value of *E* falls between 10 ft and 39 ft, the design extension is increased to 40 ft. Extensions less than 10 ft are omitted from the design scope as they would not have a significant impact.

The total length of all groin extensions under Scenario 1 is 1,130 ft.

Figure 10 shows a typical schematic groin and nourishment profile under Scenario 1 (not to scale). The existing sand level is well below the crest of the groin. Landward slopes of the groin tend to be gentler than the outer slope with an inflection near the +5.5-ft NAVD contour. This contour is a typical runup limit of the high-tide swash line and provides a measure of the berm width seaward of houses (X_i) at the groin. Under Scenario 1, groins would be lengthened by a variable amount which is established by the reference length of Groin 16 (X_{16}).

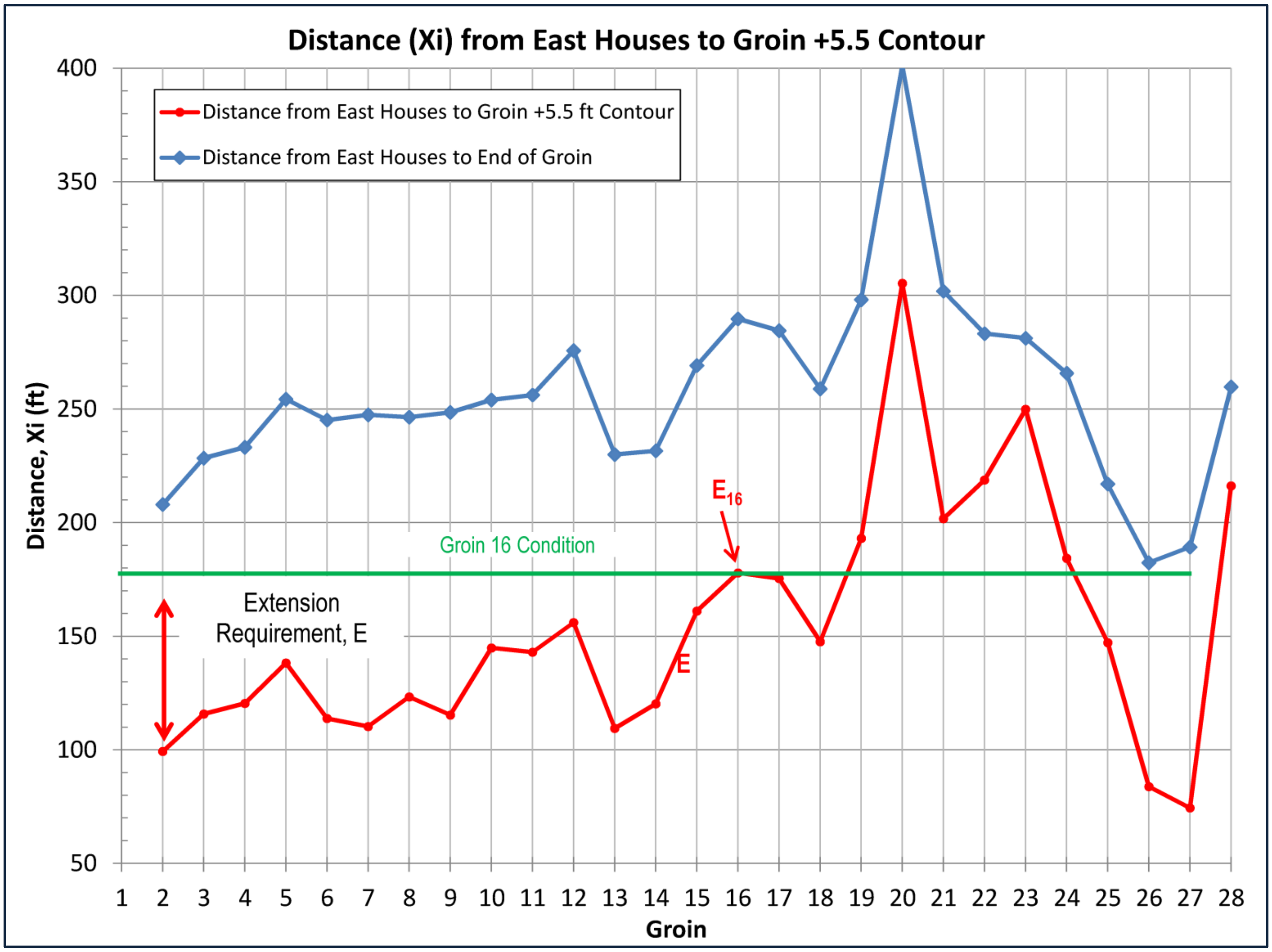


FIGURE 9. Graph showing the average distance from updrift houses (on the north side of a groin) to the +5.5 ft contour of the groin. This value was compared for each groin to that of groin 16 (green line), which has a target minimum vegetative buffer between the houses and the ocean. The distance between the red and green lines is the required extension to match the groin 16 condition (where the red line is below the green line, the groin must be extended). The seaward end of each groin is the blue line.

TABLE 1. Results of the analysis for Scenario 1 (green background) along with existing dimensions.

Edisto Beach Groin Extension Scenarios		Existing Condition				Relative to Groin 16 (Mimimum Scenario)			
Groin	Groin Station along Baseline	AVG Distance from Baseline to Updrift Houses	Distance from Baseline to Groin +5.5 (ft)	L, Distance from Baseline to Groin End (ft)	Xi, Distance from Updrift Houes to Groin +5.5 (ft)	Extension to Match Groin 16 (ft)	**E, Design Extension* (ft)**	Palmetto Blvd to Extended Groin End (ft)	Nourishment Volume Required*** in Updrift Cell (cy)
1	0+00		217	341	-	-	**80**	421	-
2	6+16	135	234	343	99	79	**79**	422	42,296
3	12+00	115	230	343	116	62	**62**	405	33,135
4	18+00	107	227	340	120	57	**57**	397	31,152
5	24+00	95	233	349	138	40	**40**	389	21,574
6	30+00	98	212	343	114	64	**64**	407	34,017
7	35+83	95	205	342	110	68	**68**	410	35,930
8	42+00	84	207	330	123	55	**55**	385	30,275
9	48+00	92	207	340	115	63	**63**	403	33,823
10	54+00	88	233	342	145	33	**40**	382	21,457
11	60+00	85	228	341	143	35	**40**	381	21,579
12	65+60	101	257	377	156	22	**40**	417	20,690
13	72+38	114	223	344	109	68	**68**	412	39,708
14	77+90	132	253	364	120	58	**58**	422	30,394
15	84+74	153	314	422	161	17	**40**	462	24,023
16	89+89	161	339	451	178	0	**0**	451	0
17	95+57	161	336	445	175	2	**0**	445	0
18	102+40	167	315	426	148	30	**40**	466	24,423
19	109+42	151	344	449	193	-15	**0**	449	0
20	119+80	175	480	576	305	-127	**0**	576	0
21	126+86	351	553	653	202	-24	**0**	653	0
22	132+12	362	581	645	219	-41	**0**	645	0
23	137+50	353	603	634	250	-72	**0**	634	0
24	141+00	362	547	628	184	-6	**0**	628	0
25	143+56	365	512	582	147	31	**40**	622	10,068
26	145+82	373	456	555	84	94	**94**	649	25,669
27	147+88	375	449	564	74	103	**103**	667	34,105
28	150+00	366	582	626	216	-38	**0**	626	0
						Total	**1,130**		**514,318**
						Shoreline length	15,485		

* No houses are updrift of Groin 1, therefore extensions for Groin 1 were given the value from Groin 2.

** Groin 1 compared the beach condition on the south side of the groin

*** Calculated by multiplying the nourishment quantity of a groin by the length of the updrift cell

*** Calculated by average end area method

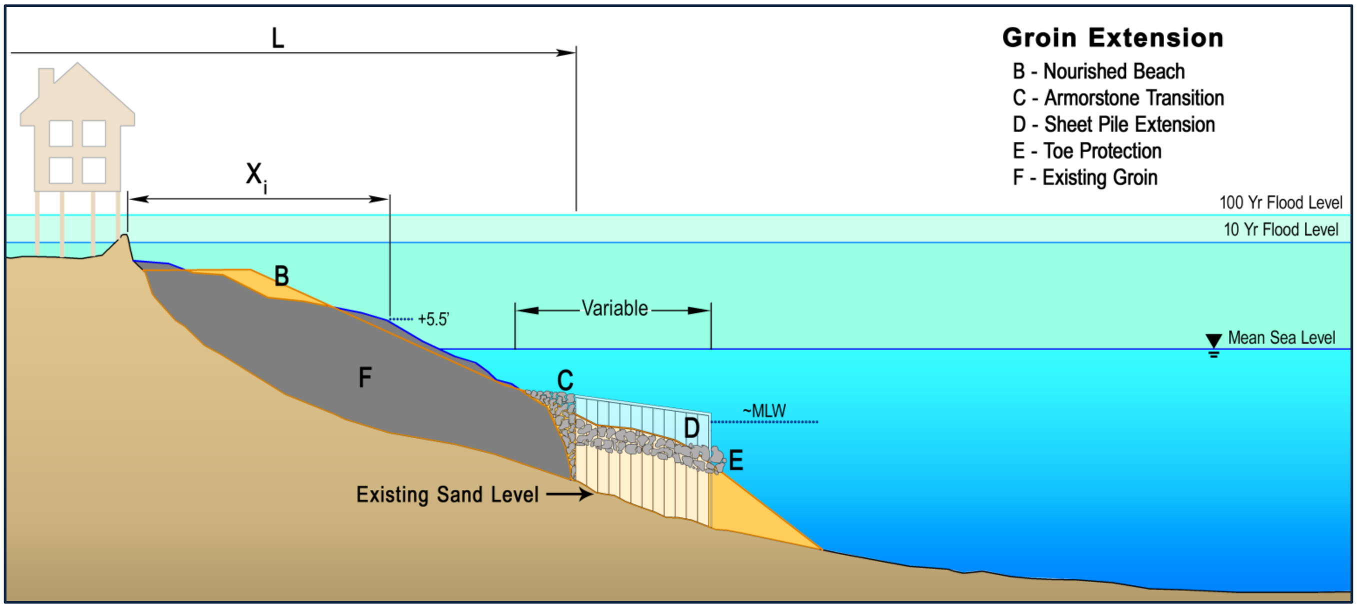


FIGURE 10. Typical schematic groin and nourishment profile under Scenario 1 (not to scale). Variable *L* is the distance from the baseline (Palmetto Boulevard) to the existing groin end given in Table 1. Variable *Xi* is the average distance from houses to the +5.5-ft NAVD contour of the groin (normal edge of the dry beach).

CSE assumes that sheet-pile type structures will be more cost effective than quarry stone based on the rock volumes and unit sizes needed for stability in the surf zone (see CSE 1993 and Traynum et al 2010). Sheet pile cannot be driven into buried rock, so it would have to be offset seaward or alongshore from existing groin heads. It is assumed armor-stone toe protection could be extended landward to the existing structure and grouted around the transition section (C in Fig 10). The profile of the armor stone and sheet-pile cap would begin level with existing heads and terminate close to MLW at the new head of the structure. Therefore, its crest slope would be variable but closer to horizontal than the existing ends of the groins.

Table 1 gives lengths and distances for the existing conditions and proposed extensions under Scenario 1. The distance from the baseline on Palmetto Boulevard (baseline) to the extended groin end is also given in the table. Under this scenario, Groins 1–14 would be extended 40–80 ft and would terminate 381–422 ft seaward of Palmetto Boulevard.*****

*[*Groin16, on which the Scenario 1 plan is based, extends 451 ft from the baseline along Palmetto Boulevard. Groin 15 and Groin 14 presently extend 422 ft and 364 ft (respectively) from Palmetto Boulevard. These differences partly reflect a landward shift of the road in this area. Between Groin 2 and Groin 13, Palmetto Boulevard is relatively straight and parallel to the shoreline with existing groins extending 330 ft to 377 ft from the centerline of the road (Table 1).]*

With respect to the average house setback within each cell, the new distances from house line to groin ends would be ~290 ft (equals Groin 16), with the exception of Groin 5 (294 ft), Groin 10 (294 ft), Groin 11 (296 ft), and Groin 12 (316 ft). These four groins fall within the minimum 40-ft threshold for lengthening. Groin 15 and Groin 18 also fall under the threshold and would result in Scenario 1 increases to 309 ft and 299 ft (respectively) from existing houses. The above-stated extension scenarios are intended to increase the distance between existing houses and the +5.5-ft high water contour to at least 178 ft (present condition for Groin 16) at each groin.*****

*[*The Beach Front Committee advised CSE on 30 January 2013 that house setbacks are subject to change and the platted lots and Palmetto Boulevard should be used as a reference point for properties along the northern end of the island. The committee provided alternate extension scenarios reflecting this difference in reference line, which has been incorporated into a consensus plan given in a later section of the report.]*

The other groins requiring lengthening under this scenario would be:

- Groin 25 (40 ft lengthening to achieve an offset of 187 ft from houses to the +5.5-ft contour and a total distance of 257 ft to the extended end).
- Groin 26 (94 ft lengthening to achieve an offset of 178 ft from houses to the +5.5-ft contour and a total distance of 276 ft to the extended end).
- Groin 27 (103 ft to achieve an offset of 178 ft from houses to the +5.5-ft contour and a total distance of 292 ft to the extended end).

Distances from Palmetto Boulevard baseline to these groins are also given in Table 1.

The nourishment requirement for Scenario 1 is based on comparing the existing beach cross-section to the lengthened cross-section of the groins (only applicable to Groins 1–15, 18, and 25–27). A rough rule of thumb for unit nourishment volumes in this setting is 80 ft of groin lengthening will trap 70 cy/ft at the structure. Table 1 shows the computed volumes by cell and a total nourishment of 514,318 cy to fill the cells to maximum capacity. A cumulative total of 1,130 ft of groin lengthening is estimated under Scenario 1.

3.2 Scenario 2

3.2.1 Flood Levels

For Edisto Beach, only the 10-year and 100-year flood elevations were available from the FEMA Flood Insurance Study (FEMA 2001). The 10-year flood elevation (stillwater) is 10.1 ft NAVD (11.1 ft NGVD), while the 100-year flood elevation is 12 ft NAVD (13 ft NGVD) (Fig 11). These elevations represent the stillwater elevations (not including waves) which have a 10 percent and 1 percent chance of occurring during any year (10-year and 100-year floods, respectively). If the effect of waves is included, then the 100-year flood elevation along the open coast "V-zone" rises to 18.9 ft NAVD (19.9 ft NGVD).

CSE used the 10-year flood criteria for development of an ideal profile because it represents a significant improvement over the current level of protection while limiting the cost of implementation. Incorporation of higher levels of protection can be accomplished by enlarging the design dune and multiplying the difference in volume by the length of beach. For example, a 25-year dune would require ~4 cy/ft more volume over the ~15,500 linear feet of beach for a net of 62,000 cy additional sand required. However, as volumes increase, the dune height for protection during larger storms will impact views and necessarily entail encroachment on existing vegetation or the beach.

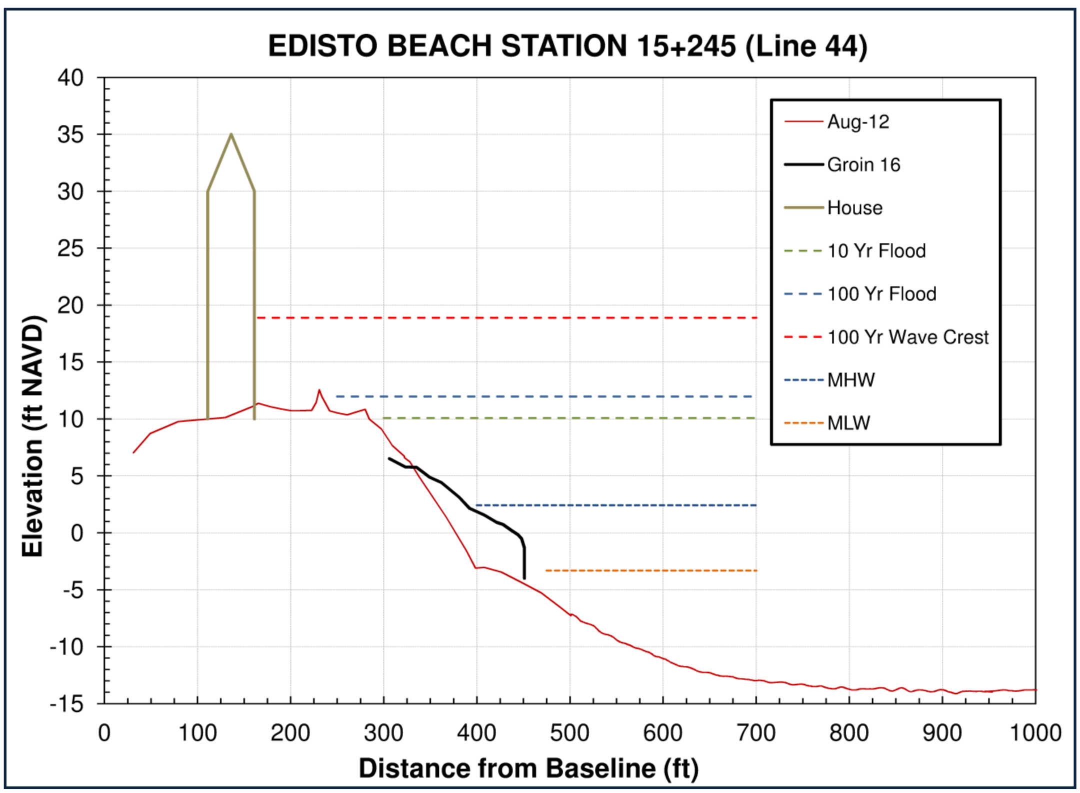


FIGURE 11. Reference water levels for Edisto Beach (SC). The example house is for illustrative purposes only and is not drawn to actual dimensions.

3.2.2 Generation of Ideal Profile

For this study, the design ideal profile consists of a 10-ft buffer between houses and the land-ward side of the dune base; a trapezoidal dune with crest width of 27 ft, a height of +16.1 ft (6 ft above the 10 year flood level), and side slopes of 1 on 3; an 80 ft berm width (dry-beach zone); and a beach sloping at 1 on 18 to MLW (Fig 12). The beach below MLW was designed to have a low-tide terrace section similar to the natural beach and a slope to the local closure depth (~1 on 15) steeper than the upper beach to reflect influence of the proposed groin section.

The resulting ideal profile volume between the house and the −13-ft depth contour (~700 ft from the baseline) is ~287 cy/ft. The nourishment volume to achieve the ideal is the difference between the existing profile and the ideal cross-section (converting the area difference to a unit volume difference and applying that volume over the length of the cell, or to the next available profile). Figure 12 shows the profile for the center of cell 15 and the crest of Groin 16. Under Scenario 2, a "10-year" dune would raise backshore elevations by about 5 ft above existing ground level. Appendix A includes design profiles for all groins under the Scenario 2 methodology.

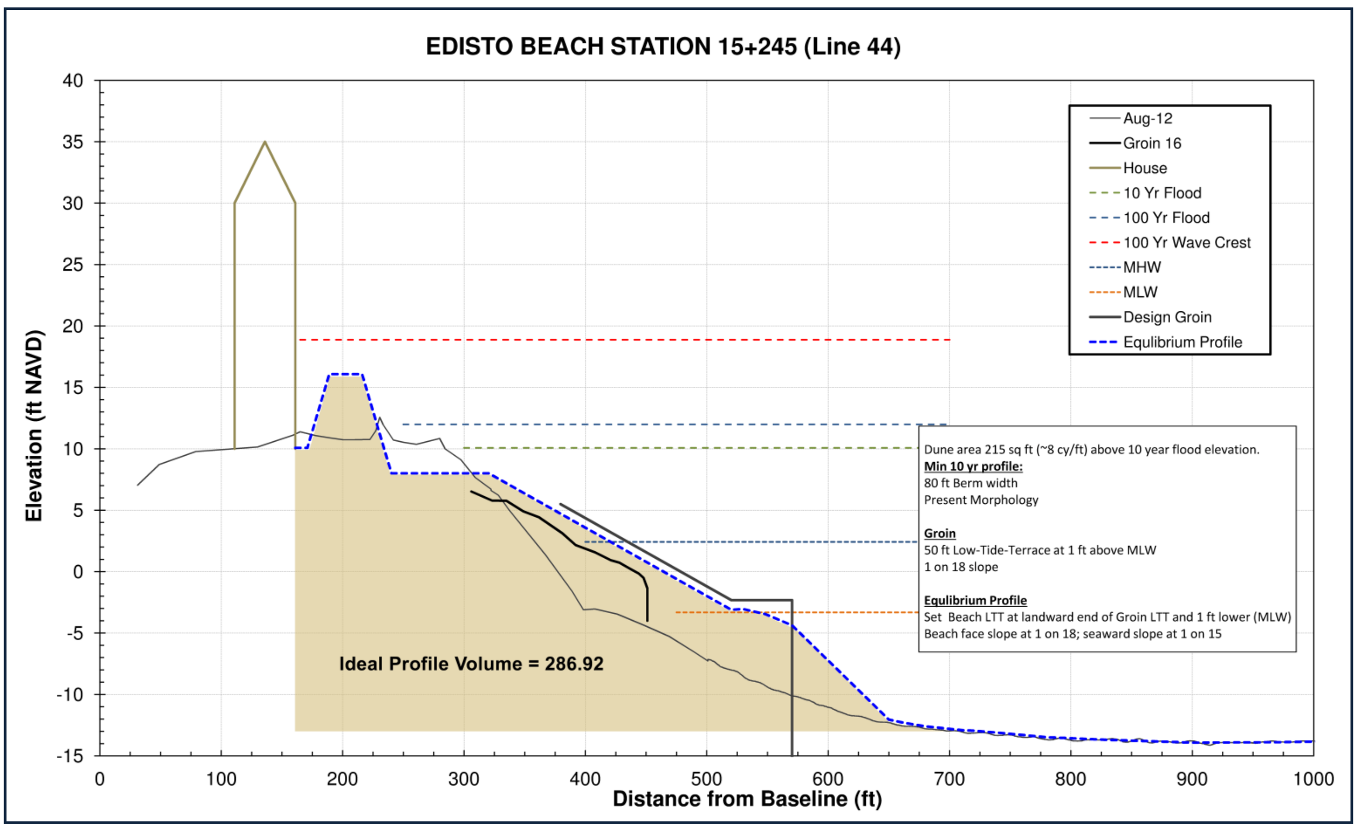


FIGURE 12. Ideal profile (blue dashed line) of the center of groin cell 15 (between Groins 15 and 16) compared to the August 2012 condition. The ideal profile volume (cy/ft) indicated provides a target volume to maintain via nourishment which is in excess of the expected trapping capacity of the groin.

3.2.3 Groin Design

The recommended groin profile consists of a 50-ft-long low-tide terrace section, a beach-face section sloped at 1 on 18 to match the ideal beach profile, a berm section extending landward to the existing groin, and armor-stone toe protection (Fig 13). This profile was chosen based on recent experience with groin construction and design at Hunting Island, SC (2007 – six groins) and Folly Beach, SC (2004 and 2012 – one groin). The design should be considered a preliminary conceptual design for the purposes of a feasibility study and general cost estimate. Final design will require individual analysis of each groin and some level of modeling. It will also require consultation with a structural engineer familiar with retrofitting techniques in coastal settings. [CSE recommends Mike Weatherly PE who assisted CSE with the 1995 project and 2003 shotcrete improvements, and Mike Rentz PE who is working with CSE on the 2012 Folly Beach terminal groin design.]

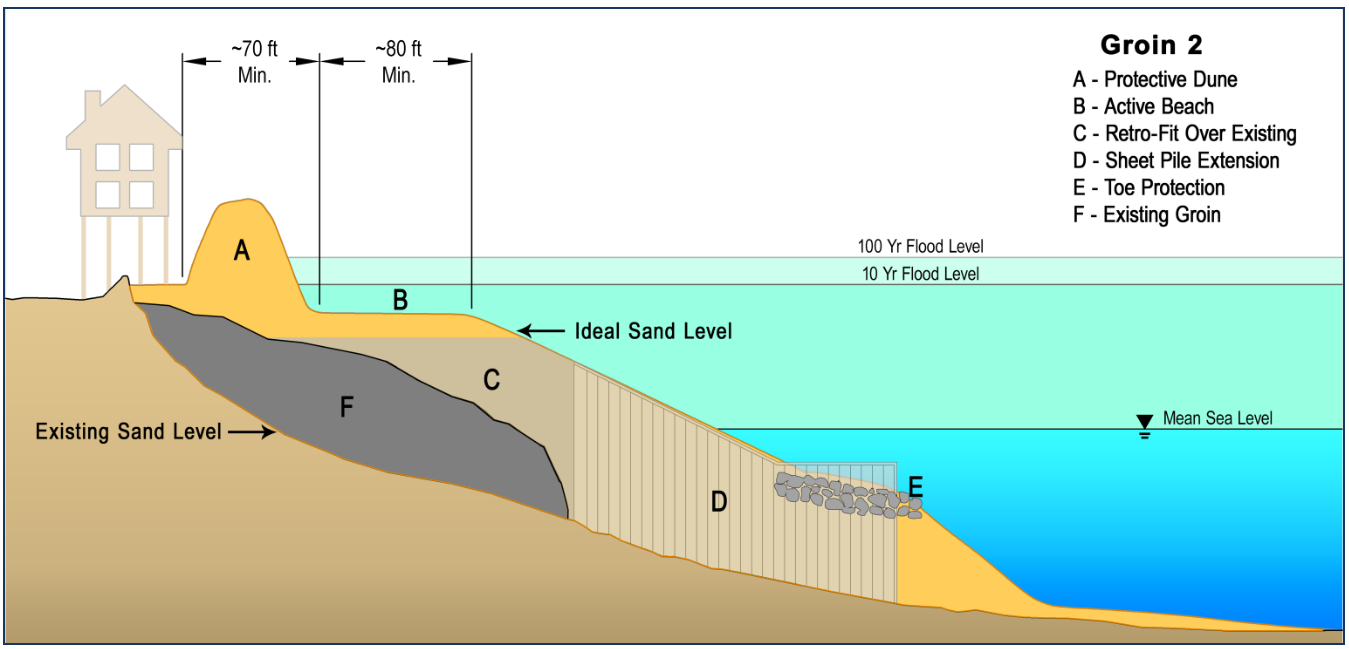


FIGURE 13. Typical groin extension plan for a severely eroded profile (this example is from groin 2 and cell 1) showing the recommended ideal dune, beach, and groin profile for "10-year" level storm protection.

Armor-stone quantities were estimated assuming a design of 50 ft long by 40 ft wide by 3 ft thick and a volume-to-weight ratio of 1 cy equals 1.5 tons. A safety factor of 1.5 was applied to provide a conservative estimate. CSE assumes extensions would be constructed of 16-ft steel sheet piles and a concrete cap to protect the exposed top of the sheets.***** Recent cost analysis by CSE and Mike Rentz, PE, for the Folly Beach terminal groin project indicates an alternate sheet pile material (FRP composite) has a similar strength as steel and is lighter weight, but costs 10-20 percent more. The higher material cost may be offset by lower installation costs (M. Rentz, PE, personal comm., September 2012). For Scenario 1, a 25-ft connection section was assumed to link the existing groin to the new sheeting. Scenario 2 requires a more involved retrofit to raise the existing groin profile to the new design template.

> *[*Marine-grade sheet pile is typically assumed to have a 20-year design life in marine applications without serious deterioration (M Rentz PE, personal communication). A thorough analysis of structure design life is outside the scope of the present report. In CSE's experience, design life increases significantly for groins that remain mostly buried with low reveal. Many timber groins from the 1950s and 1960s in South Carolina deteriorated and lost functionality in well under 20 years (Kana et al 2004).]*

Results from the analysis show that required groin extensions range from 107 ft to 227 ft (Table 2). This results in a total of 4,312 linear feet of new groin section. The required retrofit distance ranges from 0 ft to 144 ft for each groin. This represents the length of existing groin which would have to be altered to raise the existing crest elevation to the design groin profile elevation. The total length of retrofitting is 1,993 ft spread over 25 groins. Four groins would not require a retrofit section because existing groin elevations are equal or greater than the design template (eg — Groins 20, 22, 23, and 28).

Assuming the beach between each groin maintains a post-construction profile matching the profile at the groin, the nourishment quantity required for Scenario 2 is 1,536,000 cy. This is considered a maximum quantity because it is not realistic that the beach between the groins will maintain the ideal profile. There will be some recession of the beach within each groin cell as fillets develop just as present conditions demonstrate. CSE assumes that the actual trapping capacity of the groins will be 65 percent of the maximum fill less the quantity in the dune. The dune volume is the FEMA standard for a 10-year storm (8 cy/ft) multiplied by the length of beach (~15,500 ft between Groin 1 and Groin 28), which is 124,000 cy. This gives a minimum nourishment volume of:

The minimum nourishment is an approximation of the volume that state regulations would require to be placed to satisfy the trapping capacity of the new groins.

Table 2 shows the Scenario 2 improvements would extend Groins 1–14 to a distance of ~493–544 ft from the baseline along Palmetto Boulevard. With respect to the existing setback of houses in each groin cell, the new ends would be ~409 ft seaward. This also applies to groins around the Point. The only exception to this is Groin 20 which is situated in the section of beach where an extra row of houses begins along Point Street. Groin 20 is lengthened proportionally to provide a smoother transition between Groin 19 and Groin 21.

Figure 14 shows the alignment of groin ends under Scenario 1 and Scenario 2 superimposed on rectified aerial photography. Both lines have the effect of evening the seaward limit of the groins compared with existing conditions, although some variability remains under Scenario 1 due to the “40-ft” threshold applied. Scenario 2 provides a nearly uniform offset between existing houses in each cell and the new ends, with the Groin 20 length (84 ft addition) interpolated between those of Groin 19 and Groin 21.

3.2.4 No Improvement Condition

Existing groin conditions are variable from cell to cell with respect to absolute lengths and lengths relative to existing house setbacks. It is reasonable to assume the trapping capacity of each groin is potentially uniform to the +5.5-ft contour (high-tide swash line). Landward of that contour, each groin can impound the same amount of sand per-foot of groin length. However, if there are variations in groin profiles seaward of that contour, trapping capacity will vary both with length and height of the structure. Such differences will account for some of the unequal functioning observed by local officials over many years (D. Lybrand, pers comm).

TABLE 2. Results of the analysis showing the required groin extension ranges for Scenario 2, providing 10-year storm protection.

Edisto Beach Groin Extension Scenarios		Existing Condition				Profile Method (10 yr Storm Condition)			
Groin	Groin Station along Baseline	AVG Distance from Baseline to Updrift Houses	Distance from Baseline to Groin +5.5 (ft)	L, Distance from Baseline to Groin End (ft)	Xi, Distance from Updrift Houes to Groin +5.5 (ft)	**Groin Extension from Existing End (ft)**	Nourishment Volume Required**** in Updrift Cell (cy)	Retrofit Distance** (ft)	Palmetto Blvd to Extended Groin End (ft)
1	0+00		217	341	-	**203**	-	124	544
2	6+16	135	234	343	99	**201**	124,512	119	544
3	12+00	115	230	343	116	**181**	90,012	103	524
4	18+00	107	227	340	120	**176**	82,383	98	516
5	24+00	95	233	349	138	**155**	82,263	80	504
6	30+00	98	212	343	114	**164**	79,622	105	507
7	35+83	95	205	342	110	**162**	78,165	108	504
8	42+00	84	207	330	123	**163**	74,622	95	493
9	48+00	92	207	340	115	**161**	70,726	103	501
10	54+00	88	233	342	145	**155**	65,864	74	497
11	60+00	85	228	341	143	**153**	59,295	76	494
12	65+60	101	257	377	156	**134**	38,292	62	511
13	72+38	114	223	344	109	**179**	47,236	109	523
14	77+90	132	253	364	120	**178**	66,353	98	542
15	84+74	153	314	422	161	**140**	68,404	57	562
16	89+89	161	339	451	178	**120**	37,983	41	571
17	95+57	161	336	445	175	**125**	33,598	43	570
18	102+40	167	315	426	148	**150**	51,830	71	576
19	109+42	151	344	449	193	**111**	57,916	25	560
20	119+80	175	480	576	305	**84**	95,957	0	660
21	126+86	351	553	653	202	**107**	70,091	17	760
22	132+12	362	581	645	219	**126**	39,397	0	771
23	137+50	353	603	634	250	**128**	29,241	0	762
24	141+00	362	547	628	184	**144**	14,443	34	772
25	143+56	365	512	582	147	**192**	16,719	71	774
26	145+82	373	456	555	84	**227**	30,290	135	782
27	147+88	375	449	564	74	**220**	47,996	144	784
28	150+00	366	582	626	216	**150**	40,829	0	776
						4,388	**1,594,040**	**1,993**	

* No houses are updrift of Groin 1, therefore extensions for Groin 1 were given the value from Groin 2.

** Groin 1 compared the beach condition on the south side of the groin

*** Calculated by multiplying the nourishment quantity of a groin by the length of the updrift cell

*** Calculated by average end area method

FIGURE 14. Alignment of groin ends under lengthening Scenario 1 and Scenario 2. Where the red line is missing, no groin extension would be completed under Scenario 1.

Figures 15 and 16 show the variations in each groin profile with respect to the +5.5-ft contour. Each profile is overlaid using the +5.5-ft contour as the zero distance. Lengths, elevation at the seaward end (head), and cross-sectional areas (unit volumes) seaward of the +5.5-ft contour are given in Table 3. Elevation at the head and distance to the end provide simple measures of which groins are likely to present a greater cross-section across the littoral zone. The computed cross-sections quantify the differences.

As Table 3 shows, the average cross-section (unit volumes) for Groins 1–21 is 26.4 cy/ft. Groins 5–9, 13–15, and 18 exceed the average section by as much as 25 percent. Groins 1–4, 10–12, 16–17, and 19–21 are as much as 20 percent below the average. When these differences are applied over the length of the adjacent upcoast cell, they yield significant deficit and surplus trapping capacity. For example, Groins 6–9 and 13–14 potentially trap ~1,500–3,700 cy more sand in their respective cells than the average for Groins 1–21. Groins 2, 12, 16–17, and 20–21 have a trapping capacity at their ends that is potentially ~1,500 to 4,900 cy less than average.

Similar differences are evident for Groins 22–28, although some of the variation is expected because of different structure types (eg — Groins 24–28 were originally "rubble-mound" structures constructed of permeable armor stone without timber sections) and changing profile shape around the Point.

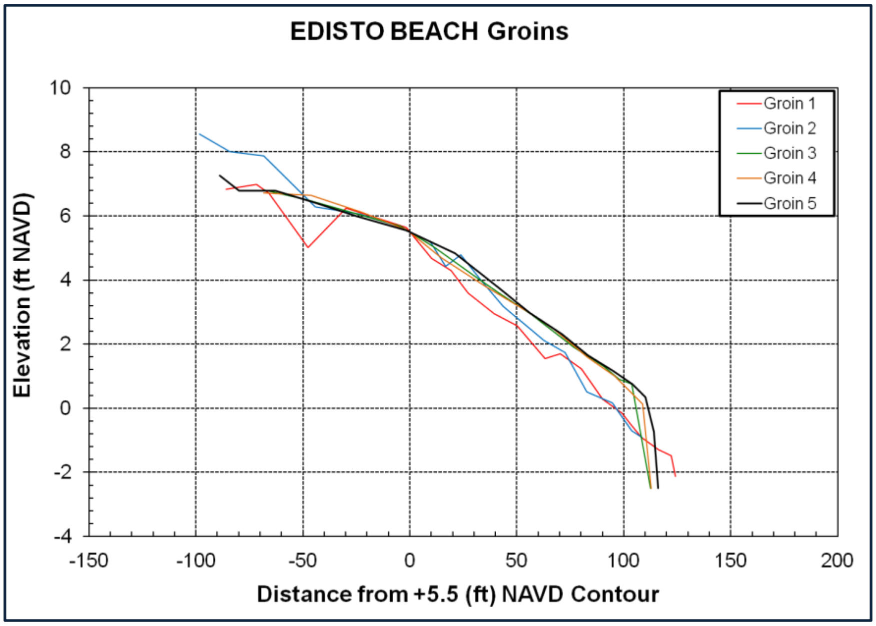
If no improvements are made to the groins, these differences in trapping capacity will persist. While it cannot be proven from the data available, the smaller cross-sections of Groins 10–12 may have contributed to erosion and property damage in the 700 block of Palmetto Boulevard over the past decade. Groins 10–12 can potentially trap upward of 4,000 cy less than Groins 6–9 and 13–14. The proposed groin extensions under Scenario 1 only partially address these differences because they would not change the groin profiles between the +5.5-ft contour and the existing end. This illustrates a basic flaw in Scenario 1 or any methodology which simply assumes a particular extension length is needed. As Section 3.1 noted, existing lengths of Groins 10–12 are greater than adjacent groins, and the extensions would be shorter despite their lower trapping capacity. The Scenario 2 plan incorporates changes over the existing groins to produce a uniform profile with respect to existing houses.

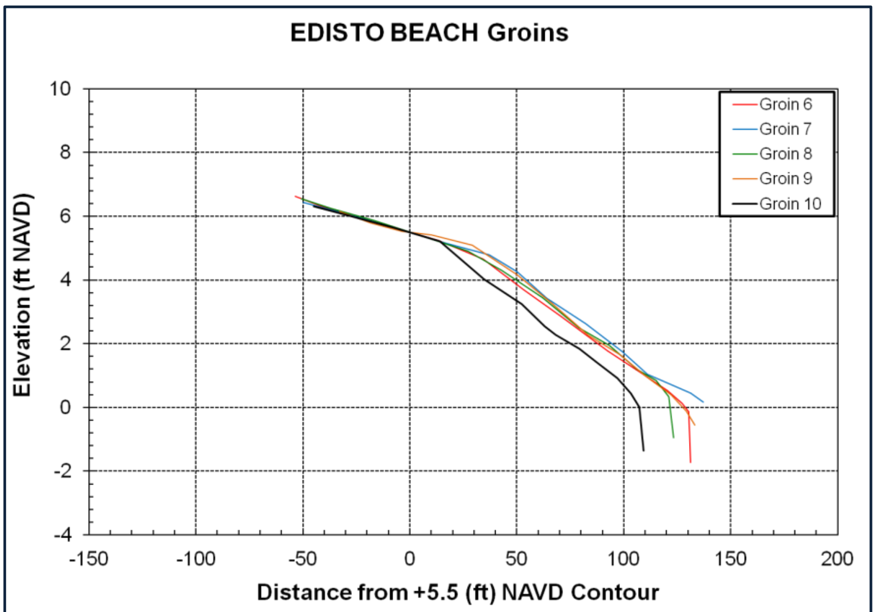
FIGURE 15.

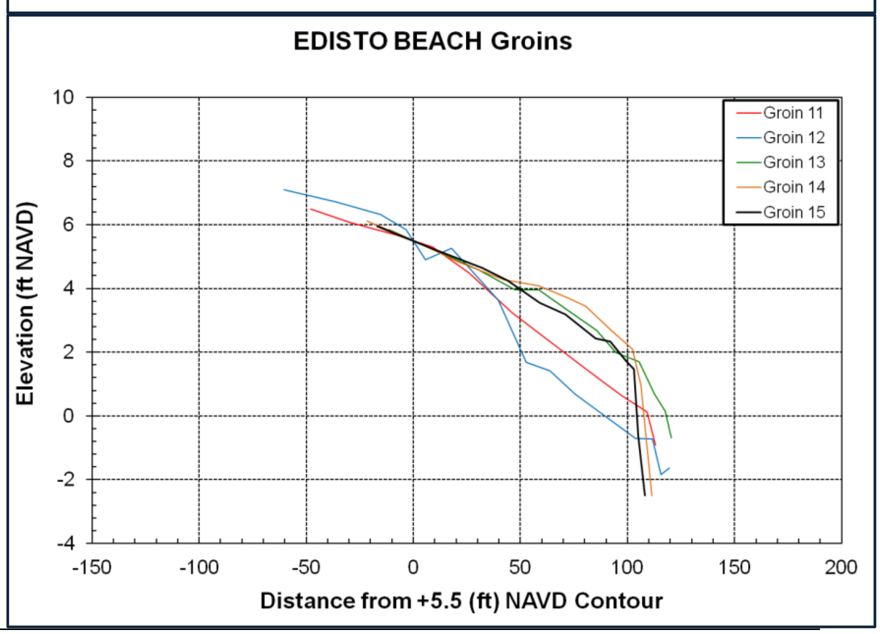
The seaward ends of each groin profile superimposed at the +5.5-ft NAVD contour.

See Table 3 for measured differences in lengths, height at the end of each structure, and cross-sectional areas (unit volumes) computed to MLW.

Note the much lower profiles along Groins 10, 11, and 12 relative to the other groins.







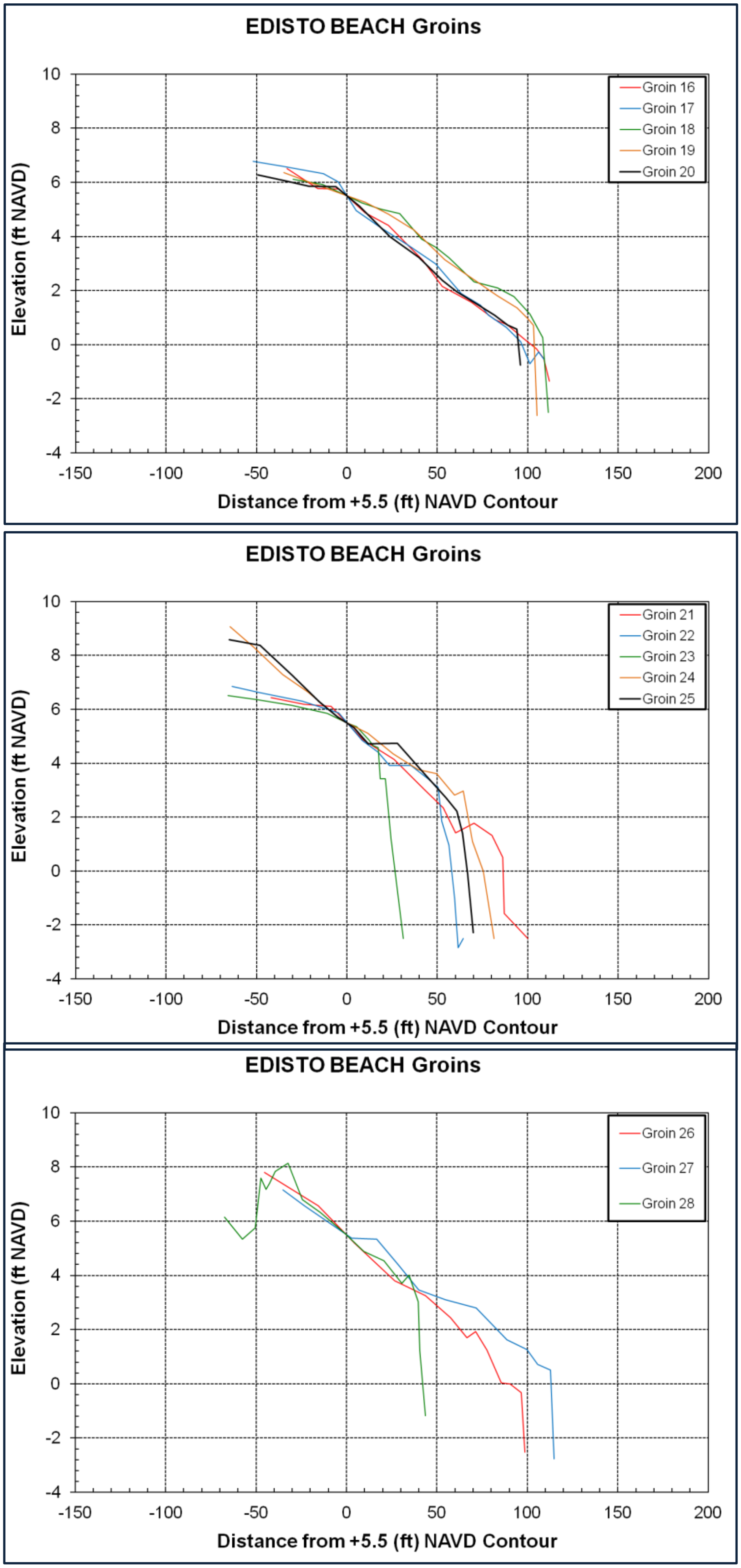


FIGURE 16.

The seaward ends of each groin profile superimposed at the +5.5-ft NAVD contour.

See Table 3 for measured differences in lengths, height at the end of each structure, and cross-sectional areas (unit volumes) computed to MLW.

TABLE 3. Existing groin dimensions relative to the +5.5-ft NAVD (normal high-water contour). This provides a measure of the relative trapping capacity of each structure. See Figures 15–16 for individual groin profiles. [**The data are normalized around averages for two groups: Groins 1–21 and Groins 22–27.*]

Date	Length Cell (ft)	Length To End (ft)	Elevation At Head (ft-NAVD)	Unit Volume Lens (cy/ft)	Unit Volume* Normalized Profile (%)	Potential Cell Trapping Deficit/Surplus (cy/ft)	Potential Cell Trapping Net Volume Difference (cy)
Groin 1		125	-1.4	23.8	90.2		
Groin 2	616	110	-0.8	23.6	89.4	-2.79	-1,718
Groin 3	584	110	0.8	25.5	96.8	-0.84	-491
Groin 4	600	110	0.0	25.5	96.8	-0.86	-513
Groin 5	600	115	0.4	26.7	101.1	0.30	178
Groin 6	600	130	0.0	30.8	116.8	4.44	2,663
Groin 7	583	135	0.0	32.7	124.2	6.38	3,718
Groin 8	617	122	0.4	30.0	114.0	3.69	2,276
Groin 9	600	130	-0.5	31.7	120.1	5.31	3,186
Groin 10	600	110	0.0	25.6	97.1	-0.75	-451
Groin 11	600	110	0.0	25.5	96.6	-0.90	-543
Groin 12	560	112	-0.8	23.4	88.8	-2.95	-1,650
Groin 13	678	120	1.8	30.0	114.0	3.68	2,494
Groin 14	552	110	2.0	29.2	110.8	2.84	1,567
Groin 15	684	108	1.5	27.6	104.9	1.28	876
Groin 16	515	110	-0.5	23.5	89.3	-2.83	-1,458
Groin 17	568	110	-0.5	23.2	88.2	-3.11	-1,766
Groin 18	683	112	0.4	26.9	101.9	0.51	345
Groin 19	702	104	0.9	25.6	97.2	-0.75	-525
Groin 20	1038	95	1.0	21.7	82.2	-4.69	-4,872
Groin 21	706	100	0.7	21.0	79.7	-5.35	-3,774
Averages (1-21)		114	0.3	26.4	100.0		
Groin 22	526	60	3.2	15.6	89.4	-1.86	-976
Groin 23	538	30	4.8	7.7	44.1	-9.78	-5,261
Groin 24	350	80	3.0	20.1	115.1	2.65	926
Groin 25	256	70	2.3	18.1	103.2	0.55	141
Groin 26	226	99	-0.4	21.8	124.6	4.31	974
Groin 27	206	115	0.8	27.2	155.3	9.67	1,992
Groin 28	212	45	4.0	12.0	68.3	-5.54	-1,175
Averages (22-28)		71	2.5	17.5	100.0		
Averages (All)		103	0.8	24.2			

4.0 QUANTITY ESTIMATES AND PRELIMINARY OPINION OF PROBABLE COSTS

On the basis of the foregoing analyses, CSE has prepared two sets of quantity estimates under Scenario 1 and Scenario 2. Also offered is a preliminary opinion of probable construction costs based on recent experience with similar projects. Tables 4 and 5 provide details for each scenario. In both cases, beach nourishment represents the major portion of the cost. Details on the armor stone sections, cap dimensions, grout, and related material quantities which were derived from previous studies (cf — CSE 1993, Kana et al 2004) have been omitted.

CSE assumes that nourishment in the range 500,000 cy to 1,400,000 cy will require an off-shore borrow area and ocean-certified dredge, similar to the 2006 project (CSE 2006). Such projects involve high mobilization costs before any sand can be pumped. Therefore, larger projects spread the mobilization cost and produce economies of scale. The unit costs assumed for nourishment are mobilization at $2.5 million and unit pumping at $8.00 to $8.50 per cubic yard. (Note: Unit pumping cost in 2006 was ~$6.75/cy.) Each scenario includes estimates for a minimum and maximum volume. The maximum volumes provide extra sand for bypassing to downcoast areas and extending the time before maintenance renourishment is required.

The structure costs under each scenario are aggregated for the applicable groins without groin-by-groin detail. Under Scenario 1 (minimum extensions), 19 groins would be lengthened by an average of ~60 ft. CSE assumes the sheet-pile lengths will be 16 ft, yielding ~18,000 ft^2 of sheet pile and ~1,130 ft of cap in the aggregate. Unit prices for steel sheet pile, concrete cap, and armor stone are based on recent experience, including bids for the proposed groin at Folly Beach County Park (D Taylor, per comm, Charleston County PRC, January 2013). Unit prices for these items vary slightly from an estimate CSE provided to the Town in December 2012. Total project costs are the sum of the nourishment costs and groin extension costs with an estimate for engineering, permitting, and related soft costs given as a percentage of total construction. The percentages for the design and administration are varied according to the project totals.

TABLE 4. Quantities and preliminary costs (CSE — January 2013).

Groin and Nourishment Quantity Estimates - Minimum Extensions					
Units	**Sheet Pile (ft^2)**	**Quarry Stone (tons)**	**Cap (ft)**	**Concrete & Grout (cy)**	**Quarry Stone @2 tons/ft**
1) Groin Extensions - Sheetpile (1,131 ft cummulative length)	18,096		1,131	-	-
2) Groin Extensions - Armorstone Toe Protection		9,850			
3) Existing to New Connection (475 ft)				120	950
4a) Nourishment - Minimum (80%) Min Trapping/No Dune					500,000 cy
4b) Nourishment - Maximum (Full Groin Capacity-19 groins)					630,000 cy
5) Dune Construction - @8 cy/ft (10-yr Protection)					0 cy

Minimum Groin Extensions and Nourishment Budget Estimates - Construction						
Sheet-Pile Groin						
	Steel	Quarry Stone	Cap	Grout	Quarry Stone	Project
Unit Costs - Installed	$28	$140	$160	$180	$140	Subtotal
Costs of Proposed Groin Extensions	$506,688	$1,379,000	$180,960	-	-	$2,066,648
Costs of Proposed Groin Connections				$21,600	$133,000	$154,600
Beach Nourishment						
Dredge Mobilization/Demob					$2,500,000	
Dredge Pumping -Min Volume @ 8.50/cy					$4,250,000	$6,750,000
Dredge Pumping -Max Volume @$8.35/cy					$5,260,500	$7,760,500
Design Scenarios						**Project Totals**
Groin Extensions + Min Nourishment + ~10.3% Engrg/Permitting						$9,900,000
Groin Extensions + Max Nourishment + ~9.7% Engrg/Permitting						$10,950,000

TABLE 5. Quantities and preliminary costs (CSE — January 2013).

Groin and Nourishment Quantity Estimates - 10-yr Level Protection					
Units	**Sheet Pile (ft^2)**	**Quarry Stone (tons)**	**Cap (ft)**	**Concrete & Grout (cy)**	**Quarry Stone @3 tons/ft**
1) Groin Extensions - Sheetpile (4,388 ft cummulative length)	70,190		4,388	-	-
2) Groin Extensions - Armorstone Toe Protection		14,000			
3) Groin Trunk Retrofit (1,753 ft)				490	5,860
4a) Nourishment - Minimum (~60%) Min Trapping/No Dune					955,000 cy
4b) Nourishment - Maximum (Includes Dune Volume)					1,594,000 cy
5) Dune Construction - @8 cy/ft (10-yr Protection)					125,000 cy

Groin Extensions and Nourishment Budget Estimates - Construction						
Sheet-Pile Groin Extensions						
	Steel	Quarry Stone	Cap	Grout	Quarry Stone	Project Subtotal
Unit Costs - Installed	$25	$140	$160	$180	$140	
Costs of Proposed Groin Extensions	$1,754,750	$1,960,000	$702,080	-	-	$4,416,830
Costs of Proposed Groin Retrofit				$88,200	$820,400	$908,600
Beach Nourishment						
Dredge Mobilization/Demob					$2,500,000	
Dredge Pumping -Min Volume @ 8.20/cy					$7,515,300	$10,015,300
Dredge Pumping -Max Volume @$8.00/cy					$11,280,000	$13,780,000
Design Scenarios						**Project Totals**
Groin Extensions + Min Nourishment + ~8.5% Engrg/Permitting						$16,650,000
Groin Extensions + Max Nourishment + ~7.7% Engrg/Permitting						$20,575,000

4.1 Scenario 1 — Minimum Extensions

The estimated costs for Scenario 1 range from $9,900,000 to $10,950,000. Nourishment represents 68–71 percent of project costs. Groin extensions are estimated to cost (~)$2.22 million (approximately $117,000 per groin on average).

4.2 Scenario 2 — 10-Year Protection Level Extensions

The estimated costs for Scenario 2 range from $16,650,000 to $20,575,000. Nourishment represents 60–67 percent of project costs. Scenario 2 nourishment includes volumes for a protective "10-year" dune, whether placed over existing vegetation or positioned seaward of the present vegetation line. Unit pumping costs will likely be lower for larger quantities under Scenario 2. Groin extensions are estimated to cost (~)$5.33 million with about $900,000 covering costs of retrofitting existing structures to the recommended design profile. These costs would be apportioned over 28 groins, yielding average $190,000 per groin.

4.3 Alternate Nourishment Scenarios

Following review of an initial draft of this report by the Beach Front Committee, CSE was asked to consider alternative nourishment scenarios. Nourishment represents at least 60 percent of project costs under Scenarios 1 and 2. The committee recommended that consideration be given to borrowing surplus sand from accreting sections of Edisto Beach along St. Helena Sound under the assumption that this area will be replenished naturally by sand eroded from the oceanfront. Such projects have been implemented at other sites without adverse impacts to existing development (Kana and Svetlichny 1983; CERC 1984).

Coastal engineers refer to the practice as "back-passing" whereby sand is excavated from downcoast spits or inlets and shifted back to upcoast areas. It is generally less expensive than offshore dredging because it does not require costly mobilization of equipment. A key to successful implementation is close monitoring of the sand budget and establishment of buffer zones to leave adequate protection along the segment of beach used for borrow. Such projects should also be performed in winter when biological productivity is lowest. Isle of Palms recently implemented such a project under Permit P/N 2010-1041-2IG at unit costs of (~)$2.95/cy. The sand transfer distances from borrow area to eroded area were ~4,000 ft in that case (CSE 2012).

Edisto Beach has gained about 60,000 cy over the past six years along St. Helena Sound (Reach "Downcoast 2" – CSE 2011). Assuming such trends continue, this area is likely to gain ~200,000 cy over a 20-year period. A gain of this magnitude would have the effect of widening

~4,000 linear feet by an average of at least 75 ft (ie — 50 cy/ft volume accretion equates to ~75 ft of additional beach width in this setting, Kana 2012). The Beach Front Committee has noted that some sections of Edisto's St. Helena Sound shoreline have a wide dune field which is transforming to dense shrub vegetation and maritime forest. Additional accretion will promote expansion of the forest and change views for existing properties, a situation that has created management issues at other beaches such as Sullivan's Island (CSE/S&W/Dewberry 2010).

Alternate nourishment scenarios for Edisto Beach would be some level of borrowing from the St. Helena Sound shoreline commensurate with rates of natural accretion or a combination of such "back-passing" with offshore borrowing. Alternatives include the following.

I Nourishment via back-passing only from the beach along St. Helena Sound:

- Maximum volume: 200,000 cy (assumed surplus volume available over the next 20 years)
- Construction via off-road trucks at $5.00/cy (maximum haul distance is ~4 miles)
- Can provide minimum nourishment for about 50 percent of the groins recommended for Scenario 1 lengthening or a reduced lengthening for all groins
- Estimated cost (~)$1.2 million (includes funds for permitting, surveys, and design)

II Nourishment via back-passing and offshore dredging under Scenarios 1 and 2: back-passing for 200,000 cy at $5.00/cy lowers offshore volumes required for a savings of (~)$600,000–$700,000 under each scenario

III Nourishment via a federal project according to designs recommended by USACE and a supplementary, local nourishment via back-passing to accomplish extra groin lengthening recommended under a "locally preferred plan"

CSE recommends that some initial nourishment involve offshore borrow sources so as to increase Edisto's sand supply. This quantity would extend the design life of the project and provide a long-term source for back-passing as needed. If the renourishment interval for offshore dredging can be increased to 20 years compared with the approximate "ten-year cycle" since the mid 1990s, the cost of beach maintenance will be significantly reduced. The economics of various nourishment alternatives should be evaluated in more detail by the Town prior to selecting a strategy.

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5.0 RELATIONSHIP OF CSE SCENARIO PLANS TO OTHER GROIN-LENGTHENING PLANS

CSE met with the Beach Front Committee prior to completion of the present report and received input from the members. The U.S. Army Corps of Engineers is also assisting the Town of Edisto Beach with a Feasibility Study – Coastal Storm Damage Reduction. As part of that study, USACE officials offered informal recommendations for groin lengthening, although this is not mandated under the study. This section of the present report outlines differences between the two CSE scenario plans and the recommendations of the Beach Front Committee and USACE.

CSE received correspondence from Town of Edisto Beach committee members, David Lybrand and David Cannon, between October 2012 and January 2013. They recommended that Groin 15 should be used as a model for other groins along the beach given the relatively healthy condition of the backshore. CSE has applied this recommendation in Scenario 1. Our analyses for Scenario 2 are independent of conditions at any particular groin because they are based on achieving a defined beach width and dune dimension with respect to existing house setbacks. The USACE provided recommendations for groin extensions in a memorandum in January 2013 (reproduced in Appendix B).

Table 6 lists the various groin-lengthening plans given by CSE, the Beach Front Committee, and USACE. We have applied the same scaling factor to estimate nourishment requirements for a given groin lengthening without regard to variations in groin profile elevations. The committee plan calls for an aggregate total lengthening of 1,430 ft applicable to 21 groins (average is ~68 ft per groin). The estimated maximum nourishment for the committee plan is ~693,500 cy (Table 6). Groins 1–11 would be lengthened 83–92 ft. The other ten groins (12–15, 18, 20, and 24–27) would be lengthened by varying amounts (7 ft to 80 ft) for an average of 48 ft. As Table 6 indicates, the committee plan is similar in scope as CSE's Scenario 1 plan.

At a meeting with the Beach Front Committee on 30 January 2013, there was a consensus that the committee plan and CSE's Scenario 1 plan be combined into a revised Scenario 1 plan. These revisions would apply the higher lengthening recommended under either plan. Table 6 shows the revised lengths rounded to the nearest 5 ft for a total of 1,660 ft of lengthening in the aggregate. The estimated maximum nourishment quantity for this length would be ~800,000 cy.

TABLE 6. Various groin-lengthening plans given by CSE, the Beach Front Committee, and USACE.

Edisto Beach Groin Extension Scenarios		Relative to Groin 16 (Mimimum Scenario)	Profile Method (10 yr Storm Condition)	Cannon Recommendation	Lybrand Recommendation	Combined Cannon/Lybrand (Larger Extension)		USACE Plan		Revised Scenario 1	
Groin	Groin Station along Baseline	**E, Design Extension* (ft)**	**Groin Extension from Existing End (ft)**	Extention (ft) Required to Reach 426 ft from Palmetto Blvd/Point St			Nourishment Quantity***	Min Groin Extension (ft)	Max Groin Extension (ft)	Scenario 1	Scenario 1 Length Beyond USACE Max
1	0+00	**80**	**203**	-	88	**88**	-	40	60	90	30
2	6+16	**79**	**201**	-	85	**85**	45,364	40	60	85	25
3	12+00	**62**	**181**	-	88	**88**	47,742	30	50	90	40
4	18+00	**57**	**176**	-	87	**87**	47,365	20	50	90	40
5	24+00	**40**	**155**	-	88	**88**	46,743	20	50	90	40
6	30+00	**64**	**164**	-	88	**88**	46,782	20	40	90	50
7	35+83	**68**	**162**	-	88	**88**	48,820	20	30	90	60
8	42+00	**55**	**163**	-	92	**92**	49,761			90	90
9	48+00	**63**	**161**	-	84	**84**	45,059			95	95
10	54+00	**40**	**155**	-	84	**84**	45,317			95	95
11	60+00	**40**	**153**	-	83	**83**	42,932	30	30	95	65
12	65+60	**40**	**134**	-	46	**46**	26,701	30	30	45	15
13	72+38	**68**	**179**	-	80	**80**	42,205	30	30	80	50
14	77+90	**58**	**178**	59	66	**66**	39,638			65	65
15	84+74	**40**	**140**	7	-	**7**	3,342			40	40
16	89+89	**0**	**120**	-28	-	**-28**	0				0
17	95+57	**0**	**125**	-17	-	**-17**	0				0
18	102+40	**40**	**150**	8	22	**22**	13,736			40	40
19	109+42	**0**	**111**	-13	-	**-13**	0				0
20	119+80	**0**	**84**	63	-	**63**	39,293		20	80	60
21	126+86	**0**	**107**	-16	-	**-16**	0		20		0
22	132+12	**0**	**126**	-5	-	**-5**	0	20	20	20	0
23	137+50	**0**	**128**	-2	-	**-2**	0	30	30	30	0
24	141+00	**0**	**144**	10	-	**10**	2,517	30	30	30	0
25	143+56	**40**	**192**	50	-	**50**	13,648	20	20	40	20
26	145+82	**94**	**227**	71	-	**71**	23,415	20	20	90	70
27	147+88	**103**	**220**	60	-	**60**	23,157			100	100
28	150+00	**0**	**150**	-3	-	**-3**	0				0
Total	15,485	**1,130**	**4,388**	**328**	**1,169**	**1,430**	**693,537**	**400**	**590**	**1,660**	**1,090**

The USACE informal recommendations suggest a minimum of 400 ft of lengthening applied to 15 groins (average is ~27 ft per groin). Groins 1–7, 11–13, and 22–26 are included in the USACE "minimum" plan. CSE has not prepared an estimate of nourishment required for this plan, which in aggregate is roughly 35 percent of CSE's Scenario 1 and ~28 percent of the committee plan. USACE also provided a "maximum" lengthening plan which increases some lengths and adds Groins 20 and 21 for a total of up to 590 ft of extensions (Table 6).

CSE's Scenario 2 plan is the largest and most costly plan given the number of groins and lengthening proposed. A thorough cost-benefit analysis of the plan is outside the scope of services for the present study. Should the Town elect to proceed with any plan, CSE recommends that the decision include consideration of potential project longevity and damage reduction. While the Scenario 2 plan is costly, the resulting beach improvements, storm-damage reduction, and favorable impact on the community rating by FEMA are likely to mitigate the costs, particularly in relation to present property values along the oceanfront.

Upon review of the four conceptual plans for groin lengthening, the Scenario 2 plan best addresses the profile deficit and short lengths of existing groins relative to oceanfront development. The other plans offer measureable improvement in sand trapping but are not considered optimal for long-term improvements and storm protection. Even though the committee plan and revised Scenario 1 plan are based on "healthy" conditions at Groin 16, dune elevations and beach width would likely remain well below 10-year storm protection levels recommended by FEMA.

Hurricanes like *Hugo* (1989) are expected to impact Edisto Beach at least once every 50 years. To absorb such storms, the beach needs to be much wider or the foredune much higher. Wide beaches dissipate waves and reduce their height before reaching houses, even if dune elevations are low and overtopped by a storm surge. If dunes are higher than surge levels, they need to be wide enough to absorb waves or they will breach. Large dunes that absorb the brunt of a storm provide better protection while also preserving the littoral sand budget.

Erosion shifts sand offshore but it remains in the active beach zone after the storm where it can shift back to the beach during normal conditions. Low dunes, by comparison, allow wave overtopping and washover formation. Sand is shifted into Palmetto Boulevard and removed from the beach system, increasing damages and the cost of cleanup. Chronic washover conditions will likely persist under the smaller-scale concept plans. Only Scenario 2 (or an even larger-scale project) would eliminate the relatively frequent washovers that occur along some parts of Edisto Beach.

Costs of all scenarios should be viewed on an annualized or unitized basis. The groin extensions as outlined herein would have a design life of at least 20 years with minimal maintenance. Nourishment at the maximum volume would provide upward of 10 years of restoration before renourishment is required (based on performance of the 2006 project). Using these longevities and an assumed 15,500 ft shoreline length yields present costs of roughly $17 per foot per year for the groins and $89 per foot per year for nourishment under Scenario 2. A typical oceanfront property spanning 100 ft of shoreline would gain protection costing (~)$10,000 per year. Other benefits would include reduced damages to community infrastructure and a wider recreational beach. Annualized costs under Scenario 1 or the revised committee plan would be roughly 50–65 percent of these costs.

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