Sarasota County, Florida
HSDR Project

Analysis of Lido Key Groin Field
December 2014

US Army Corps
of Engineers
Jacksonville District

U.S. ARMY CORPS OF ENGINEERS
JACKSONVILLE DISTRICT

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TABLE of CONTENTS

List of Figures

List of Tables

Engineering Analysis
Lido Key Groin Field

Purpose and Goals of This Analysis.

The purpose of this analysis is to re-examine the overall design of the proposed groin field and the associated beach fill along southern Lido Key, with the goal of minimizing any adverse impacts to the region, particularly downdrift of the groin structures. To accomplish this goal, alternative methods of analysis will be used to determine the minimum possible lengths of the northern and middle groins that are required to hold the project berm in place along southern Lido Key. The importance of the terminal groin will be re-evaluated in light of the recommended changes to the design of the northern and middle groins. Finally, the beach fill placement plan will be re-examined to assure that fill will be placed along this region of Lido Key in the most effective manner possible, to maintain the design conditions that were laid out in the 2004 Sarasota County, Lido Key Feasibility Report throughout the 5-year renourishment interval.

History of Lido Key Groin Design.

Two previous studies have been performed to date, to establish the design of the groin field at the southern end of Lido Key. Each of these studies are briefly summarized:

1. The design of the three-groin system at the south end of Lido Key was originally formulated in the *2004 Sarasota County / Lido Key Feasibility Report*[1]. The resulting lengths of the structures from that analysis were 320 ft (north), 440 ft (middle), and 650 ft (south). The structures were included in the selected plan in the 2004 feasibility report to address the very high erosion rates along southern Lido Key beaches. That study concluded that a combination of groins and beach fill would provide the most cost effective storm damage reduction over the 50-year period of analysis; whereas beach fill alone would be more costly due to the need to renourish more frequently and with a higher overall volume of sand. The 2004 report noted that additional design and engineering work was recommended prior to construction to optimize the design of the groins. This report details this recommended final groin design process.

2. A *Value Engineering (VE) Study*[2] was performed in 2013 to examine various cost-savings measures for the project. One of the main recommendations of the VE study was to examine the possibility of constructing shorter groin structures. To support this re-analysis of groin lengths, a GENESIS numerical modeling shoreline change simulation was performed. The recommended structure lengths were shortened as a result of this analysis, to 270 ft (north), and 405 ft (middle). The southern terminal groin remained 650 feet in length. It should be noted that the length of the southern groin was not examined in that 2013 study effort, since it did not ever extend into the water and therefore could not be simulated using GENESIS. Figure 1 shows an aerial photograph of the study area with overlays indicating the positions of the three groins, and the lengths of the structures as recommended in the Feasibility Report and the 2013 VE Study. Figure 2 shows the recommended cross-section of each groin, from the 2013 VE Study.

Figure 1. South Lido Key groin field. Recommended structure lengths from the Feasibility Study (FS) and Value Engineering Study (VE).

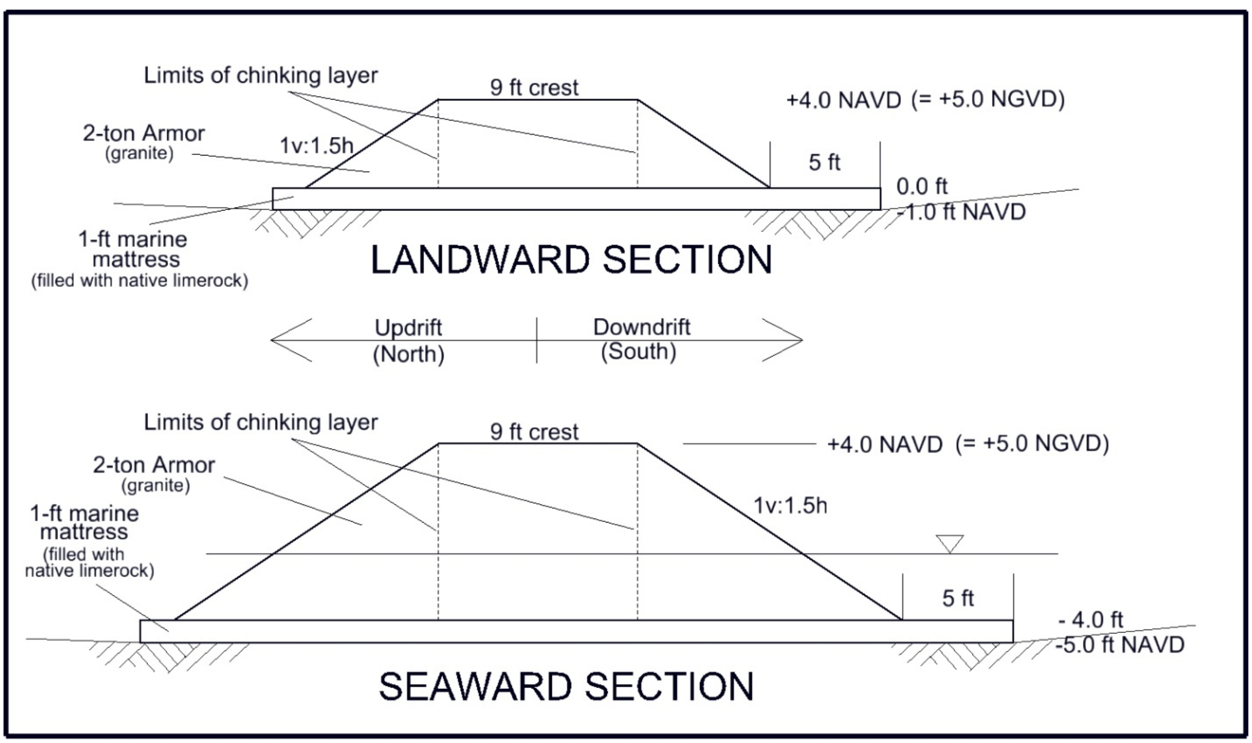

Figure 2. Recommended groin cross-section, from 2013 VE Study.

Some shortcomings were noted in the use of the GENESIS shoreline change model in this study effort. First, GENESIS is not particularly well-suited for use adjacent to tidal inlets, as tidal currents can drive significant amounts of sediment transport and the model is unable to account for this movement of material. Tidal currents can also refract the waves that drive longshore transport, and these effects cannot be fully accounted for either. The assumption of straight and parallel depth contours is often not valid near inlets, and the model uses this assumption to shoal waves in to breaking depths. Also, GENESIS was originally set up to simulate sediment movement along the full length of Lido Key (about 2.5 miles). As a result a coarse grid spacing (50 meters/164 feet) was used, and this large grid size did not provide the desired level of detail in the relatively confined region of the groin field at the south end of the island. For these reasons additional analysis of the groin field design was warranted, using alternative design methods. This report presents the results of these analyses.

Design Considerations Used in This Analysis.

Several methods of analysis are available to determine the most effective design of groin fields. Various predictive techniques have been formulated over the years that can determine shoreline responses to various groin / beach fill configurations, and these equilibrium shoreline positions are a key component of successful groin field design. As described above, the GENESIS numerical shoreline simulation model is a widely-used tool that can be applied under a wide variety of conditions for formulating groin field / beach fill design, but its application in this case was difficult for the reasons cited. Other analytical techniques have been presented in the Corps of Engineers' Shore Protection Manual (1984) and more recent Coastal Engineering Manual (2002). Other researchers including Silvester, Hsu, and Bodge have presented methods that are applicable to the conditions observed at southern Lido Key.

Under normal conditions, groin design is a relatively straightforward process and can be accomplished using a range of methods, from relatively simple empirical methods to detailed numerical analyses using predictive (and relatively complicated) models such as GENESIS. In many cases (such as for Lido Key) the results from the two methods corroborate each other.

Due to the location of the groin field within the area of tidal influence of Big Sarasota Pass, some special design considerations may apply. Some key points to consider in designing these structures are:

- Tidal currents can influence sediment transport along the shoreline in ways that may be difficult or impossible for the predictive models to account for. In the case of southern Lido Key, ebb and flood tidal currents could influence sediment movement as far north as the middle groin location. However, the groins can also provide some localized protection against tidal currents running directly along the beach.

- Two obvious sediment pathways exist for longshore transport along most of Lido Key, and particularly along the southern portion of the island. The primary pathway appears to be the offshore bar, which is well-defined and obvious in most surveys and aerial photographs. The seaward face of the bar is located about 150-200 feet seaward of the waterline along most of the barrier island, and larger storm waves break along this region, transporting sediment in a predominantly southward direction. Smaller waves pass over the bar with little effect, and result in much lower rates of transport directly along the shoreline.

- Beginning about 3,000 feet north of the pass, the bar begins to diverge from the shoreline. At the position of the northern groin the seaward edge of the bar is about 500 feet offshore, and at the middle groin it is over 800 feet offshore. Interference with transport along this bar system should be avoided, as this mechanism feeds sand directly into the Big Sarasota Pass shoal system, and this process plays a key role in replenishing the proposed borrow area. Since the groins would extend only a fraction of this distance off of the shoreline they will not impact the sediment transport along this offshore bar system, even accounting for natural fluctuations of the position of the bar system.

- The groins are intended to accumulate sand from the immediate vicinity of the shoreline only. This pathway will have much less effect on the shoaling rate of the inlet shoal than the outer bar, as described above. In order to confine the effects of the structures to the nearshore system, all groin construction should be contained within the active nearshore profile.

- In order to reduce downdrift effects and promote maximum bypassing of material, the groin field should be pre-filled with sediment at the time of construction.

- A relatively deep trough exists between the shoreline and the nearshore bar; the groins should in no case extend across this trough and interfere substantially with tidal currents. Care should be taken so that the groins do not 'jet' sediment out into this flow pathway, where sediment can be lost from the nearshore system. The offshore transport of sediment caused by the rip currents that frequently form along the updrift sides of groins can be minimized by increasing the porosity of the structures.

- A primary goal in this groin redesign process is to maintain at least the minimum required width of shoreline along southern Lido Key. This has proven difficult without stabilizing structures, especially in the region between survey monuments DNR- 42 to DNR-44, shown in Figure 3. Along this region in particular the post-renourishment shoreline typically recedes in a relatively short period of time, in some cases to landward of the Erosion Control Line (ECL) / seawall positions. As described in the 2004 Feasibility Report, the authorized project berm width is 80 feet as measured from the project baseline, and the baseline is defined in that report as follows : "*The project is defined in terms of a mean high water (MHW) extension. Over the project length, the May 2000 MHW shoreline position is adopted as the project baseline. The design shoreline lies 80 feet seaward of the baseline and defines the Lido Key project*". Along this reach of southern Lido Key (R-42 to R-44) the baseline generally extends along the seawall fronting the oceanfront developments, as shown by the red lines in Figure 3. The corresponding design MHW shoreline lies approximately 80 feet seaward of the seawall line along most of the length of the groin field, and is indicated in Figure 3 by the orange lines. A primary goal of groin redesign in this report will be to maintain the equilibrated MHW position at / seaward of this position during the entire interval between renourishments as outlined in the 2004 feasibility study.

Re-analysis of the groin system at southern Lido Key will proceed in the direction of littoral transport, i.e. from north to south. This will allow the equilibrated shoreline positions to be more accurately predicted based on analytical techniques. The lengths of the northern and middle groins will be calculated first, based on the minimum required positions of the resulting equilibrated shorelines. Then the design of the terminal (southern) groin will be examined separately, since the function of that structure is fundamentally different than that of the northern two groins.

Figure 3. Minimum required shoreline positions along southern Lido Key.

Redesign of the Northern and Middle Groins.

The purpose of the northern and middle groins is to maintain a stable beach berm along these erosive areas of Lido Key. The alongshore positions of these groins are shown in Figure 1. In the original design as presented in the 2004 Feasibility Report the lengths of the northern and middle groins were given as 320 and 440 feet, respectively. As a result of GENESIS shoreline modeling conducted as part of the VE Study effort in 2013, the lengths were reduced to 270 feet and 405 feet respectively, with no significant loss of performance anticipated. In Figure 1 the original lengths of the structures are indicated by the solid red lines; the seaward positions of the original and reduced structures are indicated numerically as shown.

As described above, using the required minimum 80-foot offset as the most landward allowable position of the MHW line, the minimum lengths of the northern and middle groin will be determined based on the estimated position of the equilibrated shoreline under incrementally adjusted values of groin lengths. The minimum lengths of groins that are required to hold the design 80-foot MHW extension will then be selected as the recommended plan. The two groins will be designed to hold the 80-foot offset MHW position along this erosive area and still have minimal impact on the downdrift shoreline. This can be accomplished by minimizing structure lengths while increasing permeability. Once the groin field has been properly backfilled and an adequate supply of sediment placed to the north, the beach planform will stabilize to its new equilibrium position. Existing littoral processes should then continue along southern Lido Key, largely unaffected by the presence of the structures.

Two different methods will be used to predict the equilibrated shoreline position under the influence of various groin lengths : a case study method, and empirical methods. In both analyses it will be assumed that the Lido Key shoreline will be provided with adequate supplies of sand in the future, either from bypassing southward around New Pass (whether material is provided naturally or mechanically is unimportant), or through periodic beach fill placements. By periodically placing adequate supplies of sand along the central and southern shoreline of Lido Key, sufficient volumes of sediment will remain available for natural littoral transport southward. This will in turn maintain the beaches along the southern tip of Lido Key, the southern shoreline inside Big Sarasota Pass, and the shoal within the Pass.

Method #1 – Case Study. As described in the U.S. Army Corps of Engineers' Shore Protection Manual[3], the "*best estimation of this* (equilibrated shoreline) *orientation is determined by observing fillets at nearby structures with similar coastal processes.*" Such a structure exists a short distance northward on Lido Key. A relic rubble-mound groin of similar dimensions as the proposed structures is located approximately 0.8 miles north of the project site. In order to determine the minimum effective lengths of the proposed northern and middle groins, the shoreline responses in the vicinity of this structure will be examined.

Using Google Earth, shoreline positions were examined in the vicinity of this groin throughout a 20-year period (1994-2014). Shoreline configurations varied between symmetrical positioning of the waterline on either side of the groin, to relatively large offsets of shoreline positions, with the shoreline to the north always extending further seaward. It can be assumed that these fluctuations in shoreline position are due to the volume of sediment in the system, as well as recent wave intensity and direction. In most cases when there is little or no shoreline offset north/south of the groin, either the area is fully impounded with large volumes of sand, and/or the offset has been equalized by recent northward sediment transport. Conversely, when large offsets are observed the shoreline is usually in a more depleted condition, and/ or sediment transport has been predominantly in a southward direction in response to recent wave activity.

For this analysis adequate volumes of sand must always be available north of the northern groin for transport, as a minimal shoreline offset is desired. To achieve a minimal offset the northern groin will also be reduced in length to the shortest possible structure required to maintain the design (80-ft) shoreline offset seaward of the ECL as shown in Figure 3. The most critical (farthest seaward) location of the ECL is along the property immediately north of the northern groin, where the seawall line is displaced further westward than adjacent properties. This is the point where shoreline recession first encroaches on the design berm, and shoreline response in this area will be examined in detail.

For this case study, an appropriate set of shoreline positions at the existing structure must first be selected. The entire 20-year period of record of aerial photographs was examined in Google Earth to select these shoreline positions. These positions should ideally reflect the beach in a nourished condition (as the project shoreline will always be provided an adequate source of updrift sand), and the positions should not reflect an excessively high (or low) degree of offset due to recent storm activity. With these parameters in mind, a reasonable "average" shoreline condition was selected from the 24 January 2013 shoreline in Google Earth. This shoreline is shown in Figure 4.

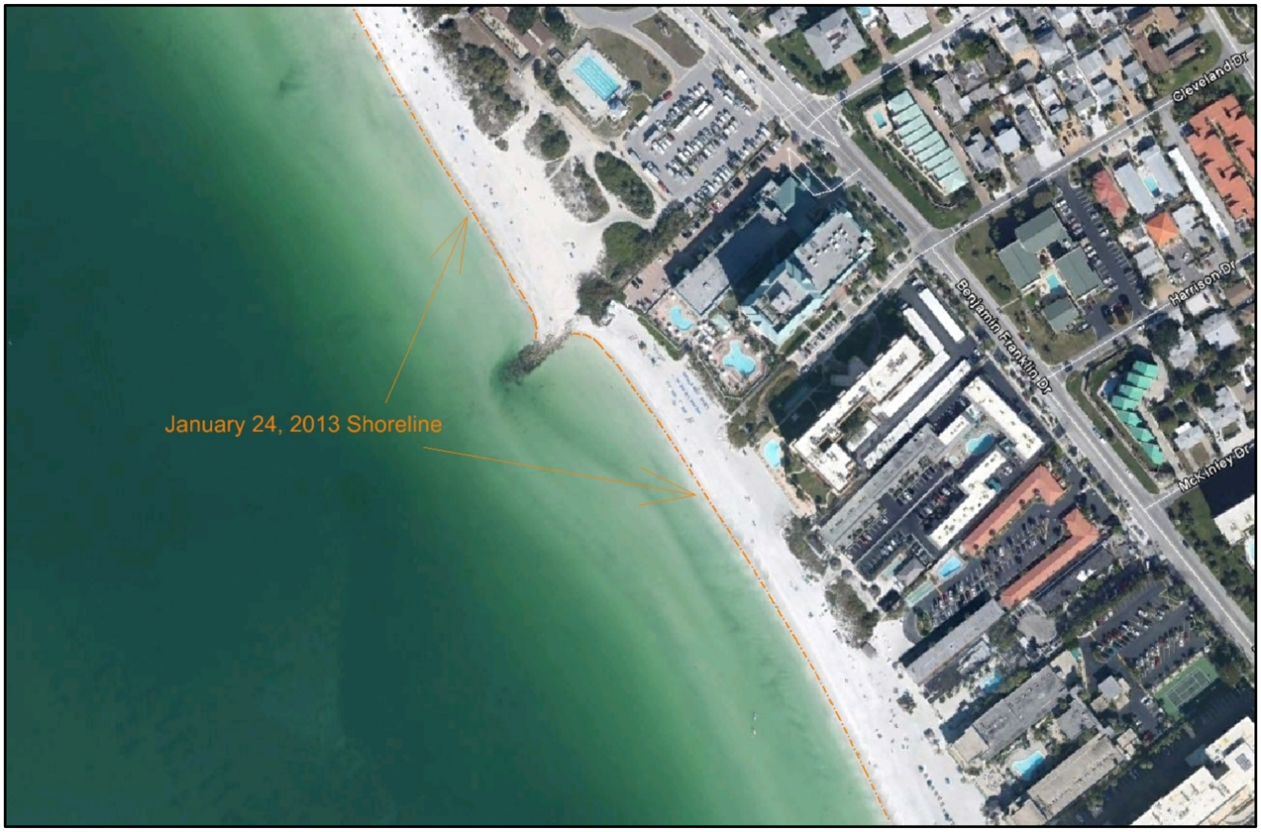

Figure 4. Shoreline positions at existing groin chosen for Case Study, Lido Key.

Once selected, this shoreline was transposed to the location of the proposed northern groin and adjusted landward/seaward in a CADD program, until the updrift shoreline approximated the position of the minimum allowable shoreline position shown in Figure 5. Care was also taken to ensure that the downdrift shoreline did not cross below the 80-ft threshold south of the groin. Once this position was set, the corresponding length of the groin could be measured. The length along the crest of the structure was measured as 163 feet.

Based on observations of the performance of the existing groin at central Lido Key, a 163-ft long northern groin will be adequate to maintain the desired berm width along the shoreline to the north, with minimal disruption to the natural southward flow of sediment along the coast. To further aid the southward bypassing of material, this northern groin will not be chinked (as was recommended in the VE Study). Similar to the groin at central Lido Key, the voids between the 2-ton armor stones will be left open; this will further aid in bypassing, while at the same time further reducing construction costs. Increasing the porosity of the groin will also reduce the potential for scouring around the structure, and reduce rip current formation as more longshore current is able to pass through the structure instead of around the seaward tip.

Figure 5. Predicted groin lengths and shoreline positions resulting from the Case Study.

With the position of the northern groin established, the predicted shape of the downdrift shoreline (between the northern and middle groins) can be readily determined by using the transposed downdrift shoreline from the existing groin at central Lido Key. Translating this waterline configuration to the shoreline cell south of the 163-foot northern groin yields an approximate position for the reach of shoreline between the northern and middle groins. Repeating the methodology used at the northern groin, the required length of the middle structure is determined as 323 feet. Again, this length will coincide with the approximate position of the seaward end of the crest of the structure as shown in Figure 5.

Note that approximately half of the length of the middle groin is well inland of the beach berm, and is required only to tie the structure into the existing highly-recessed seawall. One possible variation to the recommended rubble-mound design could be to construct the landward 150 feet +/- (the region of the groin landward of the dune field) using sheet pile only. The sheet pile would still prevent flanking of the structure during extreme storm events, while also greatly reducing the footprint of the structure and saving on construction costs.

The same procedure is repeated once again to predict the shoreline configuration south of the middle groin. Due to the complex offshore bathymetry and strong tidal currents along this reach, this shoreline position is more difficult to predict, but applying the same methodology yields the approximate shoreline position shown in Figure 5. Although this figure indicates a substantial amount of erosion along this southernmost shoreline cell, this predicted position was based on a 'worst-case' scenario, so actual shoreline recession would most likely be considerably less.

<u>Method #2 – Empirical Analysis</u>. This alternative analysis will be performed using various methods to best suit the existing site conditions. Design will proceed from north to south, following the direction of littoral flow. As with the previous Case Study analysis, a primary assumption of this analysis will be that adequate volumes of sediment are present at all times along the beaches north of the groin field; the area to the north will in effect function as a feeder beach throughout each renourishment cycle.

The first step in this empirical analysis is to establish the position of the shoreline updrift/north of the northern groin. As described in Bodge[5], for shorelines with adequate supplies of updrift sediment (as the proposed project will be), the updrift depth contour will intersect the seaward end of the groin at 1.0 to 1.5 times the difference between mean sea level (MSL) and mean low water (MLW). In this case, the difference between MSL and MLW is 0.68 feet, based on tidal data for Sarasota from the 2004 Feasibility Study. Following this methodology and allowing for a 'maximum-erosion' scenario (1.5 x 0.68 ft = 1.02 ft), the -1.02 ft contour would be positioned along the seaward tip of the northern groin. Applying the 1v:12h beach slope to calculate the position of the MHW line yields a landward offset of 32 feet from the -1.02 ft contour. In the CADD file, graphically translating the position of the MHW line on/offshore to provide the proper 80-foot offset from the baseline (ECL) position results in a minimum corresponding groin length of 170 feet, as measured along the crest of the structure. This is in very close agreement with the value of 163 feet as determined in the Case Study. Due to the 1v on 1.5h front slope of the groin and the 5-ft wide scour apron, the corresponding position of the seaward tip of the foundation of the groin will be at 187 feet, relative to the ECL.

With the length and position of the northern groin established, the resulting equilibrated position of the shoreline between the northern and middle groins can be calculated. Many methods for performing this calculation have been proposed over the years, and most rely on a logarithmic spiral routine. The method described in the U.S. Army Corps of Engineers' Coastal Engineering Manual[4] (CEM) was selected as the most applicable, due to the compatibility of the actual project area with the parameters required by the methodology. This method was developed by Hsu, Silvester, and Xia and is described in the CEM, Part III, Chapter 2, Section 3(i).

A diagram showing the definitions of the variables used in these computations for Lido Key is shown in Figure 6. Using equation III-2-24 from the CEM (also shown in Figure 6), the variable R_o is set to the distance between the northern and middle groins, 585 feet. The wave angle Beta is incrementally varied from 10 to 40 degrees to cover the range of incident wave conditions and to perform a sensitivity analysis of wave angle vs shoreline response. For the sake of clarity, Figure 6 shows only one such series of calculations based on an incident wave angle of 17 degrees. This appeared to be the most prominent incident wave angle observed throughout the record of aerial photographs. The values for C_o, C_1, and C_2 are derived from the graph in Figure III-2-27 of the CEM. Equation III-2-24 is then solved for the equilibrated shoreline position R at each of the incrementally-adjusted values for the radial angle Theta (shown by orange lines varying from 3 to 85 degrees in Figure 6). In this manner a calculated log-spiral shoreline can be derived for each incident wave angle.

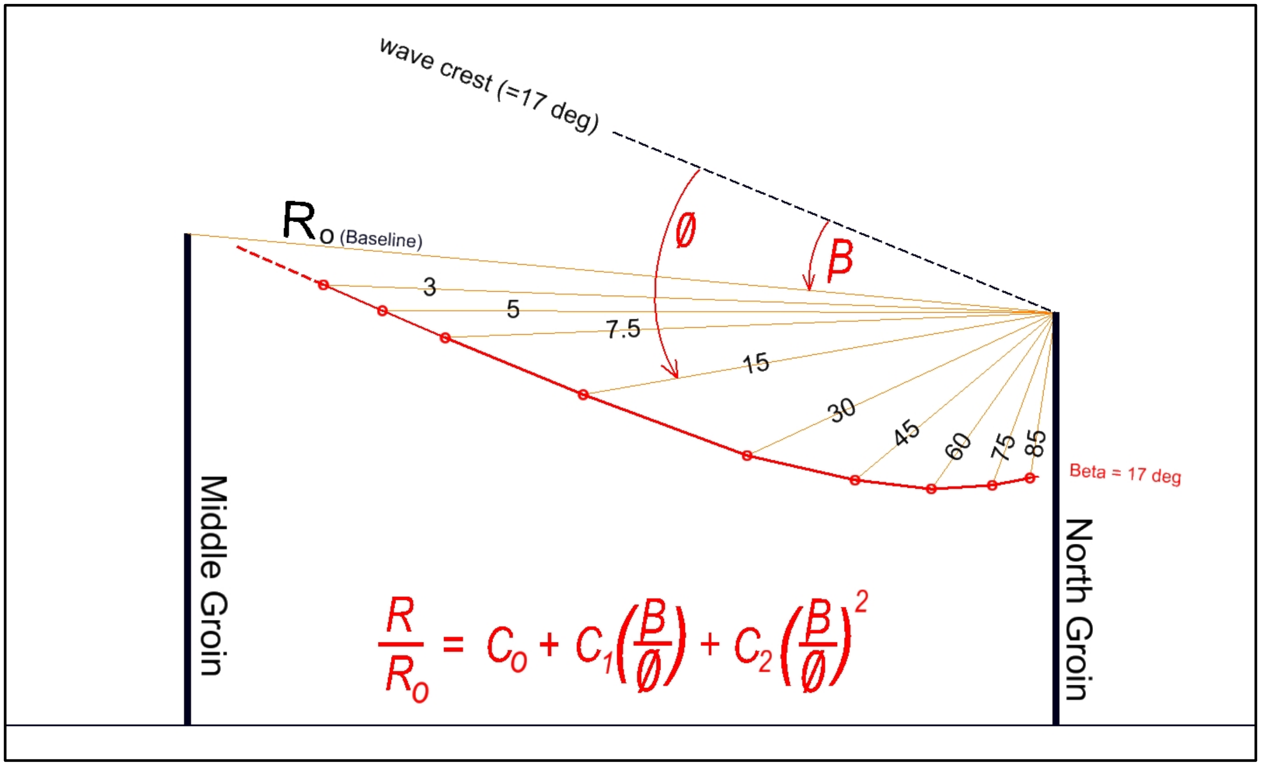

Figure 6. Definition of parameters for Eq. III-2-24.

Since the outer sandbar tends to align waves parallel to the shoreline before they can enter the nearshore area, smaller wave angles would be more applicable to calculations applied to the region of shoreline near the groin field. Based on historical aerial photography contained in Google Earth, a maximum nearshore incident wave angle of about 17 degrees is measured for visible swell. Greater angles can be observed for small wind-generated waves but the sediment-transport potential of those waves is very low. Shoreline positions for the 10, 17, and 20 – degree incident wave angles were calculated and plotted over an aerial photograph of the area. It was observed that the 10-degree calculated log-spiral shoreline best matched the observed site conditions, and agreed very closely with the shoreline from the case study. The 10-degree shoreline was therefore selected for further use in design of the groin field.

Once this design shoreline was selected the required minimum length of the middle groin could then be determined by using the proper offsets as described in the Bodge method (described above and in reference 5). It should be noted that the effects of wave angle on the equilibrium shoreline position decrease rapidly with distance from the updrift (in this case, northern) groin. Therefore the calculated position of the tip of the middle groin was not very sensitive to the wave angle selected, but increasing the incident wave angle did result in increasing erosion immediately downdrift of the northern groin.

In a manner similar to that used for design of the northern groin, the method suggested by Bodge was again used to properly position the seaward tip of the middle groin. By starting with the log-spiral shorelines calculated above, then extending the seaward end of the middle groin to coincide with the calculated position of the -1.02-ft contour (adjusting for slope down from the MSL line), the length of the crest of this structure is calculated to be 345 feet (or 362 feet along the length of the foundation). This value is 22 feet longer than the length calculated in the case study, and will be adopted as the recommended length of the middle groin because it represents a slightly more conservative value in terms of maintaining the design berm condition between the northern and middle groins. Downdrift erosion would be minimized by proper beach fill placement and by increasing the porosity of the structure by eliminating the placement of chinking stone, as was recommended for the northern groin.

This empirical method can then be repeated to calculate the approximate position of the shoreline on the downdrift (south) side of the middle groin. Due to a shift in shoreline orientation near Big Sarasota Pass, an incident wave angle of 20 degrees is recommended. Repeating the calculations using Equation III-2-24, the shoreline position south of the middle groin is determined. The final equilibrated MSL shoreline positions that were calculated using these empirical methods are shown in Figure 7.

Figure 7. Calculated final equilibrated shoreline positions.

__Summary of Design : Northern and Middle Groins.__ The northern and middle groins would each be constructed according to the two design cross-sections shown in Figure 8. The cross-sections as shown in Figure 8 differ from those in Figure 2 only in that the chinking stone has been removed. The length of the northern groin is calculated to be 170 feet, and the length of the middle groin is calculated to be 345 feet. Both values represent distances along the crest of the structures; the corresponding lengths along the foundations would be 187 and 372 feet, respectively. These values represent the minimum length of structures that can maintain the minimum-required 80-foot offset MHW shoreline along southern Lido Key throughout the 5-year renourishment interval. Due to their reduced lengths and increased porosity, these structures would have minimal impact on littoral processes along southern Lido Key and should not create significant adverse downdrift effects.

The proposed layout of the structures is described as follows. Construction of the north groin would begin at the southwest corner of the seawall shown in Figure 7, and would proceed seaward using the 'Landward Section' in Figure 8 for the first 50 feet, followed by a 50-foot transition, then the remaining 70 feet of the structure would be constructed using the 'Seaward Section'. For the middle groin, construction would tie into the southwest corner of the existing rock wall as shown in Figure 7 and would proceed seaward using the 'Landward Section' for the first 140 feet, followed by a 50-foot transition, then the remaining 155 feet of the structure would be constructed using the 'Seaward Section'. All lengths are measured along the crest of the structures. Both structures would be constructed along an azimuth of 235 degrees, measured clockwise from due north. The stone sizes and gradations as described in the 2013 VE Study would be used in the construction of both groins, as shown in Figure 8. The quantities of materials required to construct the two groins are shown in Table 1.

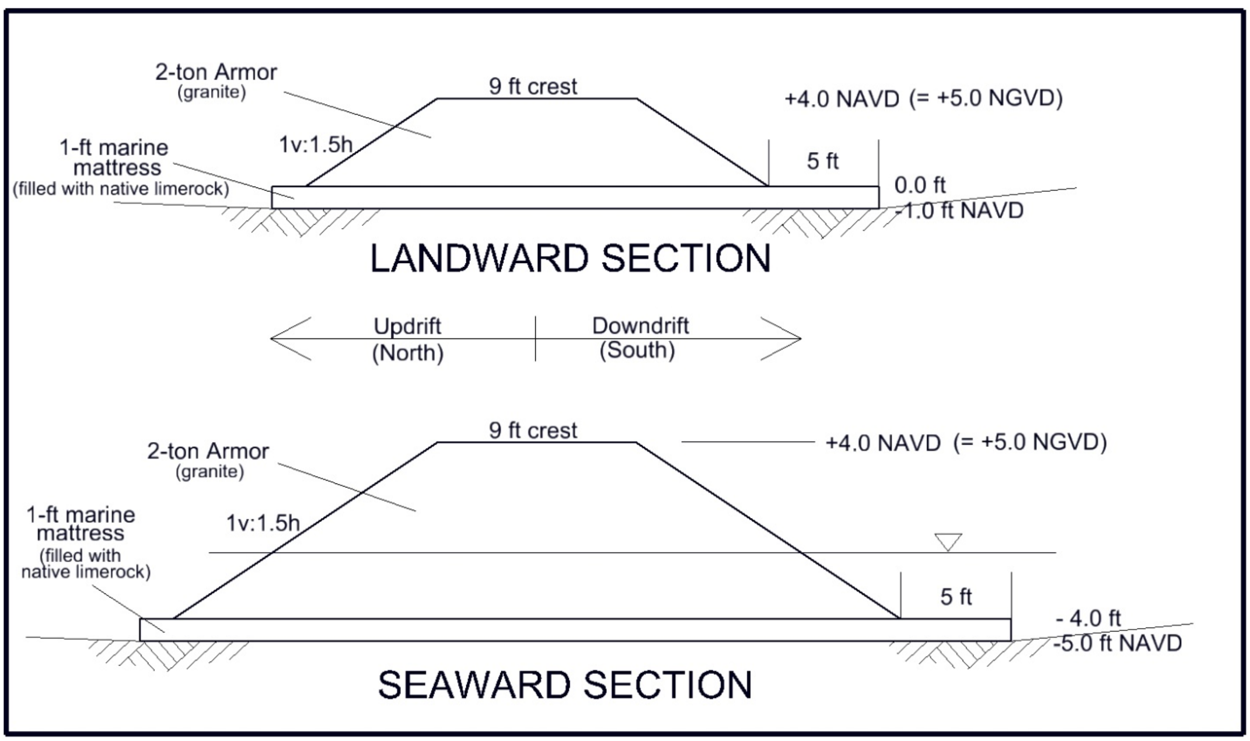

Figure 8. Recommended design cross-sections of northern and middle groins.

TABLE 1 QUANTITIES OF MATERIALS REQUIRED NORTH AND MIDDLE GROINS				
SUBTOTAL - NORTH GROIN (170') :				
Armor stone	814	CY	1496	Tons
Bedding stone	246	CY	332	Tons
12-inch Foundation mats	737	SY		
Geotextile fabric	737	SY		
SUBTOTAL - MIDDLE GROIN (345') :				
Armor stone	1543	CY	2835	Tons
Bedding stone	465	CY	628	Tons
12-inch Foundation mats	1394	SY		
Geotextile fabric	1394	SY		
TOTAL - BOTH STRUCTURES				
Armor stone (granite)	**2356**	**CY**	**4331**	**Tons**
Bedding stone (limerock)	**710**	**CY**	**960**	**Tons**
12-inch Foundation mats	**2131**	**SY**		
Geotextile fabric	**2131**	**SY**		

Redesign of the Southern (Terminal) Groin.

The original purpose of the southern, or terminal, groin as formulated in the 2004 Feasibility Report was to stabilize the southern tip of Lido Key. This would be accomplished by impounding a large volume of material to the north of this 650-foot long structure, to guard against excessive downdrift erosion that could be caused by the much longer northern and middle groins that were recommended in that report. The originally-proposed lengths and positions of all three structures are shown in Figure 1.

The seaward end of the terminal structure was originally located at/near the waterline at the time of the 2004 Feasibility Study. Due to steady accretion of this area the structure was located well inland at the time of the 2013 VE Study. The 2013 VE Study recommended that the structure remain in place as an assurance against loss of the south end of Lido Key due to either ongoing erosion, or in the event of catastrophic storm damage. However, due to the re-engineering of the northern and middle groins at southern Lido Key as part of this current redesign effort, the risk of these types of damages occurring has now been greatly reduced.

The southern tip of the island has proven highly stable in recent years, and this stability is expected to continue following construction of the groins and beach fill placement. The ongoing renourishment of Lido Key as a result of the Federal HSDR project should maintain the stability of this area into the future, without the addition of the terminal structure. The pre-project littoral processes along the south end of the island will continue largely uninterrupted after project construction: in addition to allowing material to bypass the northern and middle groins and nourish the Gulf shoreline, material will be free to flow around the southern tip of the island and nourish the bay-side shoreline inside Big Sarasota Pass. A portion of this material will ultimately be transported into the Big Sarasota Pass shoal system, as presently occurs. Continuation of these natural processes should promote a stable, and possibly slightly accretionary, shoreline along the southern end of the island.

Since the risk of potential damages along the southernmost end of Lido Key has been greatly reduced as a result of this groin redesign effort, it is recommended that the construction of the terminal groin be deferred. The southern Lido Key shoreline should be monitored following construction of the beach fill and groins, and construction of the terminal groin would proceed only if it is proven necessary in the future. In the event that a terminal groin is determined to be necessary, it is further recommended that a sheet-pile design be examined instead of the rubble-mound structure recommended in the 2004 Feasibility Study. This would greatly reduce construction costs as well as the overall footprint of the structure.

Redesign of Beach Fill.

In accordance with the design of the groin system as presented above, the plan for placement of beach fill has been modified to shift a portion of the placement volume from the southern tip of Lido Key to the central region of the island, where it will be used to much greater benefit as a feeder beach. This will ensure that a steady supply of sediment is available to feed into the groin system throughout the 5-year period between renourishments. To accomplish this without increasing the overall volume of fill to be placed, the volume placed throughout the groin field will be reduced and the volume placed north of the groin field will be correspondingly increased.

Specifically, the construction berm will be reduced to the width required to extend to the tips of the northern and middle groins, after post-construction slope adjustment. This will accomplish the pre-filling of the shoreline cells between the groins that is required in order to minimize downdrift erosion. According to information presented in the 2004 Feasibility Study, the construction template features a 1v : 10h slope and the equilibrated slope averages 1v : 12h above MLW. Therefore, as this steeper construction slope equilibrates, the seaward edge of the level berm will recede landward by approximately 18 feet. In order to position the seaward edge of the equilibrated berm at the tip of the groin crest, the berm will be constructed 18 feet wider than the position of the northern and middle groin tips. The resulting construction berm widths along the length of the groin field will vary, but the maximum width will be about 190 feet as measured from the ECL.

In the shoreline cell south of the middle groin, the equilibrated shoreline position (as determined by the log-spiral method) indicates the potential for some minor downdrift erosion along the first 300 feet +/- south of that structure. Therefore, in order to adequately pre-fill that region, fill will be placed to the full construction template along the first 300 feet south of the middle groin. At that point a taper would be constructed at a 30-degreee angle to tie into the existing +4.0 ft contour on the existing shoreline. The proposed fill placement plan is shown in Figure 9.

Figure 9. Proposed beach fill placement.

Conclusions.

In order to promote a more favorable shoreline response along the southern portion of Lido Key the following design changes are recommended. The northern groin would be reduced in length to 170 feet. The middle groin would be reduced in length to 345 feet. These values represent the lengths along the crest of the structures; adding the front slopes and 5-foot scour aprons at the end of each structure yields total lengths along the foundations of 187 feet and 362 feet, respectively. In order to promote more efficient bypassing of sediment and to reduce downdrift impacts, the permeability of the two groins will be increased by removing the chinking stone that was proposed in the VE analysis. Other than this minor change, the cross-sections of each groin would remain the same as was proposed in the VE Study. Finally, the beach fill configuration has been modified to shift some material from the southern tip of the island northward to central Lido Key, to act as a feeder beach. The seaward edge of the berm for the revised beach fill construction template is shown in Figure 9. The exact volumes of placement will be determined based on surveys taken prior to project construction.

References.

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