SARASOTA COUNTY, FLORIDA
HURRICANE AND STORM DAMAGE REDUCTION PROJECT
LIDO KEY SEGMENT

GENESIS SHORELINE MODELING STUDY
May 2014

Introduction
This report presents the results of a numerical modeling effort to optimize the design of a series of proposed groins along the southern end of Lido Key in Sarasota County, Florida. The groins are one component of the Selected Plan from the 2002 Feasibility Report. The purpose of this 3-groin system is to reduce the rate of beach erosion at the southern end of the island. A location map of the study area and the Lido Key HSDR Project Recommended Plan are shown in Figure 1.

Purpose and Scope
The purpose of this report is to evaluate the design as presented in the Feasibility Study, with respect to changing site conditions. The original structures as described in the 2002 Feasibility Report were based on shoreline positions that have changed significantly over the intervening 12 years. During a recent Value Engineering (VE) Study (USACE, 2013) it was proposed that one or more of the three groins could possibly be shortened, due to a changing shoreline configuration resulting at least partially from several beach fill placements since 2002. Shortening one or more of these structures could increase project performance and reduce project costs.

The purpose of this study is therefore to re-evaluate the 3-groin system under present-day conditions. The goal is to optimize the lengths of the structures to produce the required degree of protection while minimizing structure length and cost.

Project Design – 2002 Feasibility Report.
The primary numerical modeling tool used during the original design of the groins was GENESIS (GENEralized model for SImulating Shoreline changes). GENESIS is a shoreline evolution model developed by ERDC to simulate shoreline changes, and is regarded as a primary tool for determining the effects of coastal structures on adjacent shorelines. GENESIS is a USACE certified numerical model and was operated within the CEDAS (Coastal Engineering Design & Analysis System) software platform for this application.

Figure 1. Location map, major project features.

The original GENESIS analysis was performed in the 2002 Feasibility Report. The structures formulated in that report are described as follows, and shown in Figure 2 :

- The southernmost structure would function as a terminal groin, anchoring the south shore of Lido Key. The total length of the structure would be 650 feet, with the landward half of the structure constructed along the southern shoreline of Lido Key inside Big Sarasota Pass, and the seaward half extending across the Gulf of Mexico shoreline.

- The middle structure would be located 800 feet north of the terminal groin, and would extend 440 feet seaward of its landward terminus, which would be located at the +5-ft NGVD (+4 ft NAVD88) elevation contour.

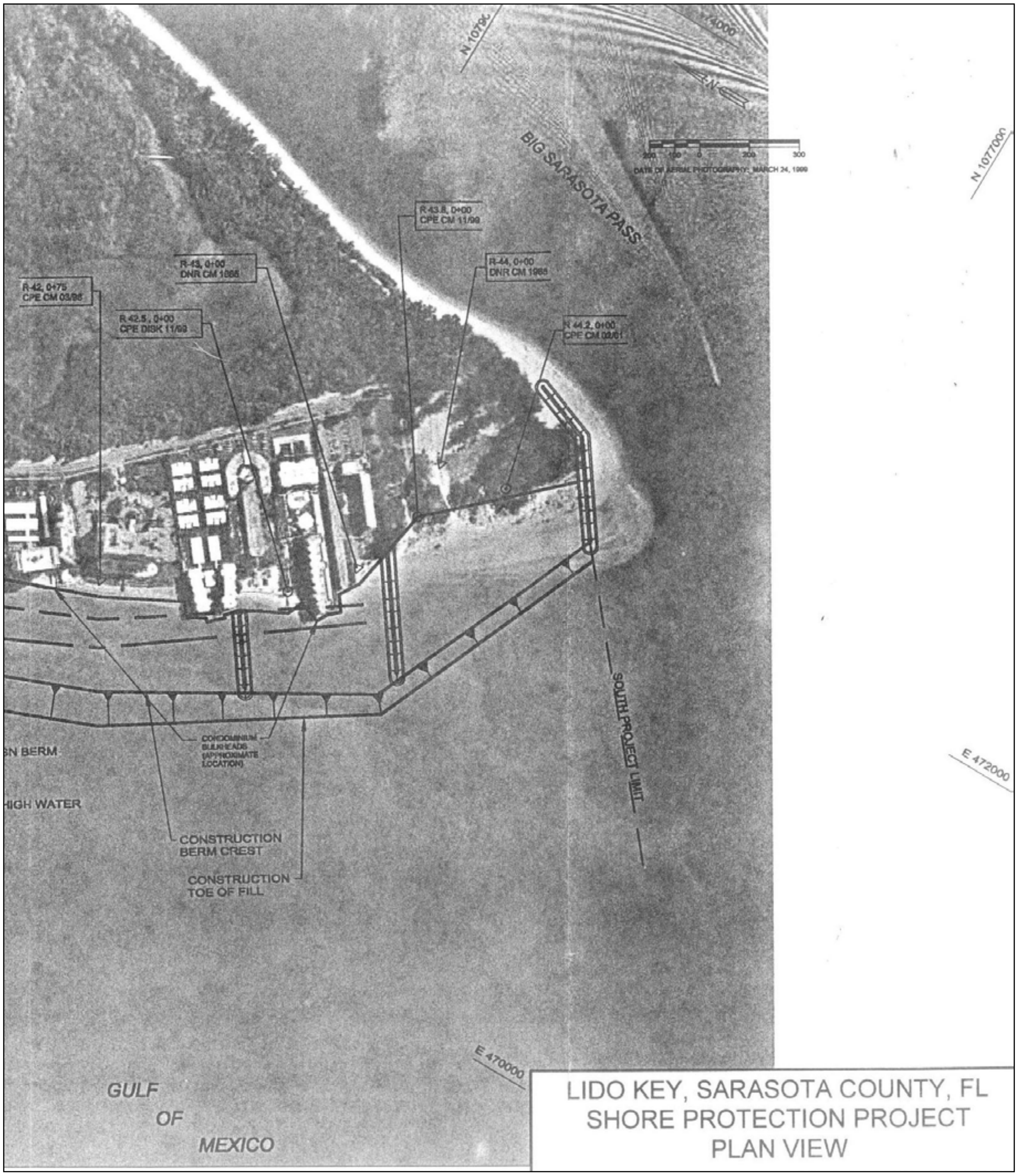

Figure 2. Plan view of recommended groin field – 2002 Feasibility Report.

- The northern structure would be located 1,400 ft north of the terminal groin, and would extend 320 feet from its landward terminus at the seawall located near survey monument R-42.5.

All three structures would be constructed using essentially the same cross-section, which is shown in Figures 3a and 3b. As shown in these design drawings, the three groins would be constructed with a sheet pile wall along the centerline to sand-tighten the structures.

The crest elevations would approximate the existing berm height of +5 ft NGVD (+4 ft NAVD88). This elevation would minimize sediment transport over the structures. The median armor stone size is 2 tons, the core stone size is 400 lbs, and the bedding layer consists of graded stone 1.5 feet thick, underlain by geotextile fabric. This design is adequate to withstand a 20-year storm. Specific design parameters are discussed in detail in Appendix A of the 2002 Feasibility Report and will not be repeated herein.

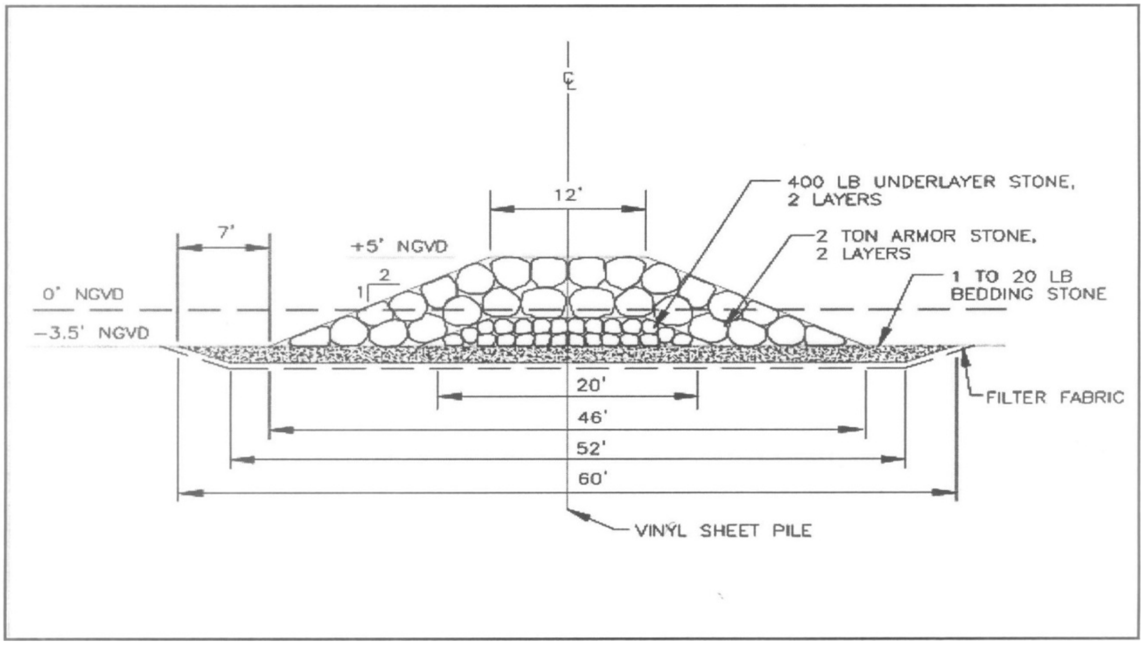

Figure 3a. Cross-section, groin design as recommended in 2002 Feasibility Report.

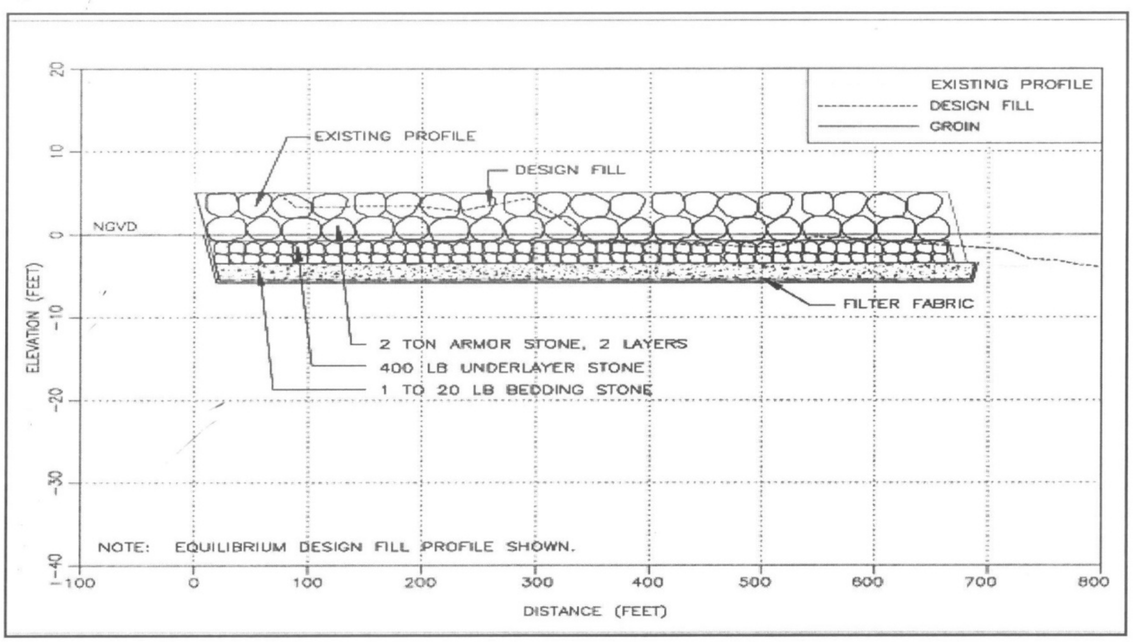

Figure 3b. Longitudinal cross-section of typical groin.

From the 2002 Feasibility Report, the total volumes of materials required to construct the three groins as described above are as follows : 15,400 tons of 2-ton armor stone, 3,000 tons of 400-lb core stone, 8,300 tons of graded bedding stone. All stone shall consist of 165 pcf granite. Additionally, 86,800 square feet of geotextile filter fabric and 34,200 square feet of sheet pile would be required.

Changes Proposed in 2013 VE Study.

A Value Engineering (VE) analysis on the subject study was completed in November 2013. Several cost-savings measures were adopted as a result of this VE study, including : optimizing groin cross-sectional dimensions, replacing the unconsolidated bedding layer with a thinner marine mattress layer, using locally-produced stone in foundation mattresses, replacing sheet pile with chinking stone to reduce permeability, and selectively shortening groin(s). The last measure requires additional numerical modeling to determine optimal groin lengths, and is the subject of this report. These recommended changes are described as Proposal P2E2 in the VE Study.

The recommended changes from the VE study were intended to reduce project construction costs without significantly affecting performance of the project, or reduction of the level of protection from storm damages. A full description of the VE Study, including its methodology, alternatives, and recommendations is available through the Jacksonville District, Corps of Engineers, and will not be repeated in this report. Summaries of the recommended design changes from the VE Study are shown in Figures 4a and 4b. Note that the lengths of the groins are unspecified, as these lengths will be determined by this study. Many of the design modifications from the VE Study will be incorporated into the modeling presented in the following sections of this report.

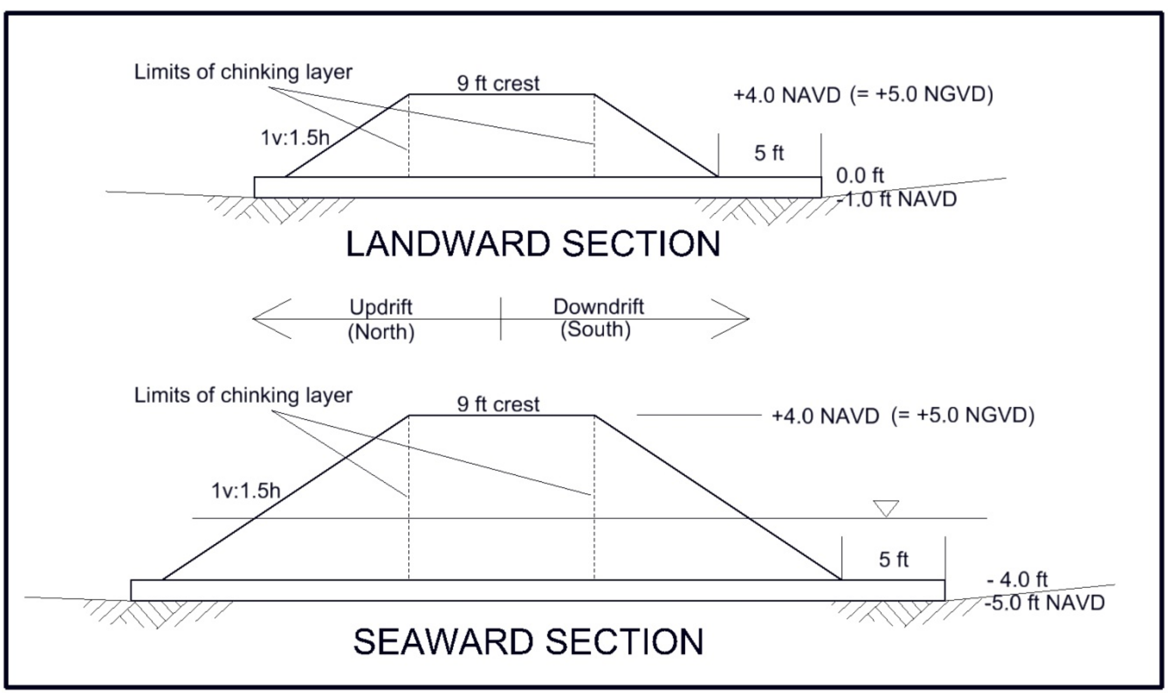

Figure 4a. Typical Groin Cross-Section Incorporating VE Study Recommendations.

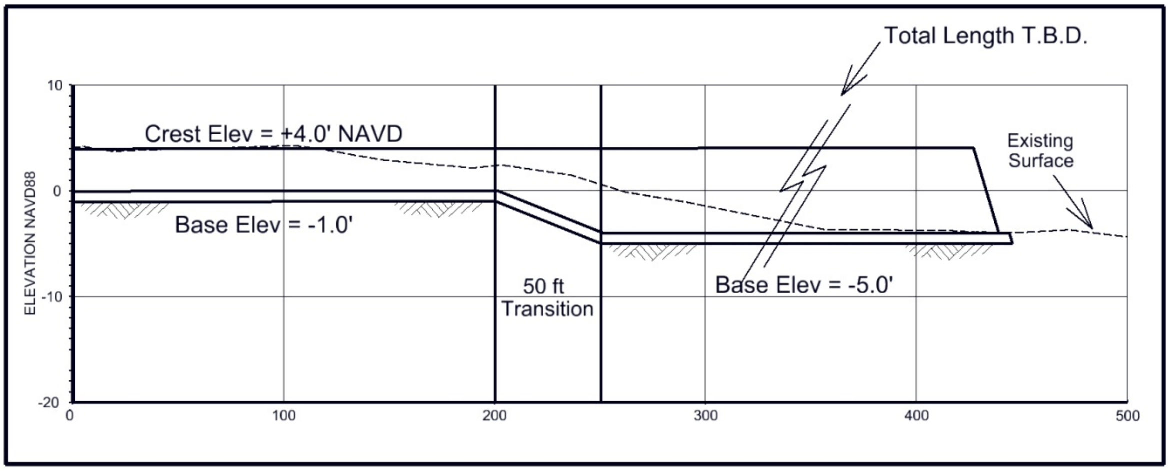

Figure 4b. Typical Groin Profile Incorporating VE Study Recommendations.

2013 GENESIS Shoreline Modeling.

A numerical modeling analysis of the study area was conducted earlier in 2013, prior to the initiation of the VE study. The purpose of this analysis was to determine in greater detail the movement of sediment in the nearshore region throughout the study area. Of particular concern was the movement of material near the proposed borrow areas, and any related effects that might occur downdrift of the borrow areas.

The numerical model CMS (Coastal Modeling System) was run to determine sediment movement within Big Sarasota Pass, since many of the proposed borrow areas were in (or very near) the pass. In developing a sediment budget for this numerical simulation the volume of material feeding into Big Sarasota Pass from the north was calculated using the shoreline simulation model GENESIS. This version of the GENESIS model, calibrated for use along the Lido Key shoreline, will be used in this study to conduct the optimization analysis for the lengths of the groins along southern Lido Key.

<u>Numerical Modeling Overview.</u>

GENESIS is a linear shoreline evolution model that uses a mass-balance routine to predict future shoreline positions. It is particularly useful for determining shoreline response due to the addition of stabilizing structures. Input required for running the model includes shoreline positions at several points in time, sequential wave data that spans these intervals, sediment characteristics, and positions and dimensions of any stabilizing structures.

The basic methodology to perform GENESIS simulations is to first set up a bathymetric grid of the spatial domain to be modeled, extending along the study shoreline and seaward into sufficiently deep water. Surveyed elevation data are superimposed onto this grid to construct a 3-dimensional surface of the offshore bathymetry. This grid is used by the numerical wave transformation model STWAVE to refract incoming waves from deepwater to the nearshore region. From a nearshore stationing line the refracted waves are extended to breaking depths using a more simplified linear routine. The longshore component of this wave energy drives sediment movement in GENESIS, which in turn causes shoreline change. To determine shoreline changes using GENESIS, the model must first be calibrated and verified.

Calibration is achieved by matching simulated shoreline responses over a specific time interval to known shoreline responses during the same interval. This is achieved by inputting two known shoreline positions at two different points in time into the GENESIS model, then running the model using wave data from the intervening time period. Two calibration coefficients can be adjusted to "tune" the model to the subject study area. Model output such as shoreline positions, transport rates, and volumetric changes are monitored as these coefficients are adjusted, and through a series of iterative model runs, GENESIS is calibrated for the study area as these model outputs converge on the actual measured values.

Following successful calibration, the process is repeated for a different time interval in the "verification" phase. Once the coefficients are correctly set and the model adequately predicts shoreline responses over these two time intervals, GENESIS is considered to be calibrated and ready to perform production runs. For the particular case of the model used in this analysis, calibration was performed over the period 1987-1998, and the verification was performed over the period 2005-2009.

The STWAVE / GENESIS methodology described above was used in the 2002 Feasibility Study to establish the original design of the groin field. Due to physical changes throughout the study area to shorelines, bathymetry, wave conditions, the addition of beach fills, etc., it was not possible to re-use these older models. New models were required and the following sections of this report detail the process of re-calibrating the STWAVE and GENESIS models for use in this study.

STWAVE.

The first step in performing the shoreline modeling for this study was to set up the wave transformation model. The model STWAVE (STeady-state spectral WAVE model) was used for this purpose. Both STWAVE and GENESIS were run within the CEDAS (Coastal Engineering Design & Analysis System) framework developed by the U.S. Army Corps of Engineers' Engineering Research and Development Center (ERDC), in cooperation with Veri-Tech, Inc.

The STWAVE bathymetry grid is much larger than the GENESIS grid, and extends alongshore for 50,000 ft (9.5 miles) between DEP survey monuments R-16 and R-60, as shown in Figure 5. This region corresponds approximately to the southern 3 miles of Longboat Key, the full length of Lido Key, and the northern 3 miles of Siesta Key. The GENESIS grid is embedded along the central portion of this larger grid, extending along the full length of Lido Key. The alongshore extent of the GENESIS grid is shown by the light blue "Stationing" line along the Lido Key shoreline in Figure 5. This line extends along the 4-meter depth contour and represents the point where wave data is "handed off" from STWAVE to GENESIS for refraction to breaking depths and subsequent sediment transport calculations.

The STWAVE grid also extends 88,500 ft (16.8 miles) in the cross-shore direction, out to a seaward depth of approximately 65 ft (20 m). The depth scale (in meters) is shown along the left-hand margin of Figure 5. All STWAVE grid cells were 164 ft (50 m) on a side, and a total of 162,000 grid cells comprise the bathymetric grid. The onshore grid direction was 60° as measured clockwise from due north. These and other STWAVE grid parameters are summarized in Table 1. Note that all models in CEDAS are typically executed in meters, but metric values will be converted to feet in this report where appropriate.

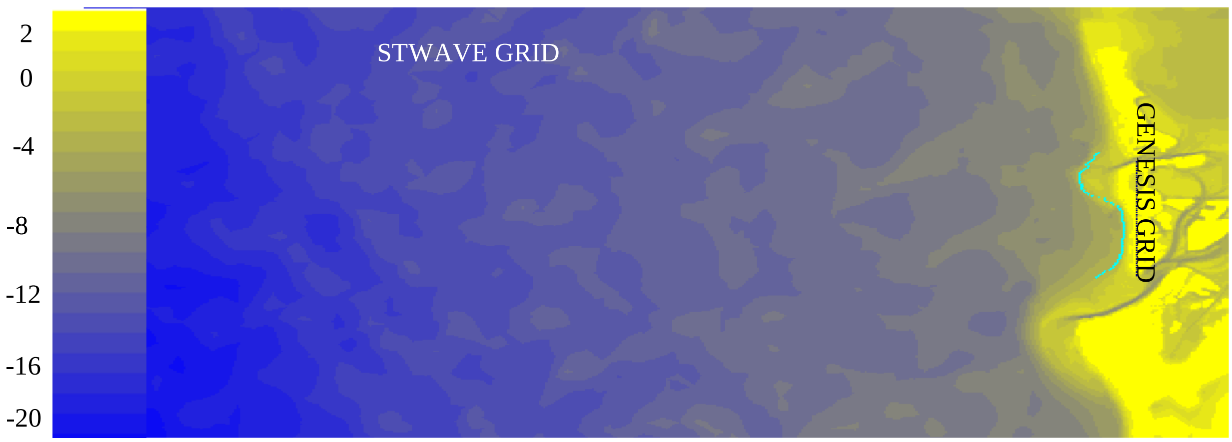

Figure 5. STWAVE bathymetry grid.

For this study, the bathymetry used to construct the STWAVE grid was derived from USACE LIDAR measurements distributed by the NOAA Coastal Service Center (www.csc.noaa.gov) and the NOAA NOS Coastal Relief Model (www.ngdc.noaa.gov/mgg/geodas/).

Table 1. STWAVE Grid Parameters

Grid Origin FL State Plane	**X_o**	**Y_o**	
	135047	316824	**m**
	443068	1039449	**ft**
X_azimuth (onshore dir)	60°	(NE)	
Cell Size	**Δx**	**Δy**	
	50	50	**m**
	164	164	**ft**
Grid Size	**R_x**	**R_y**	
	27,000	15,000	**m**
	88,500	50,000	**ft**
Approx depth	**Offshore boundary**	**Save station**	
	20	4.0	**m**
	65	13.1	**ft**

GENESIS Model Setup.

The GENESIS grid extends along the full length of Lido Key, as shown in Figure 5. Information required to construct the model domain includes the grid location, orientation, number and positioning of calculation cells, and positions of several shorelines that are needed to conduct calibration, verification, as well as production runs. Information is also required on the boundary conditions at both ends of the model grid. Shoreline positions and elevations through the surf zone and subaerial beach were obtained from the Florida Department of Environmental Protection website (www.dep.state.fl.us/beaches/data/his-shore.htm/). Positions of seawalls and other coastal armoring were derived from georeferenced aerial imagery. Other GENESIS modeling inputs include physical parameters such as median sediment grain size, berm elevation, and depth of closure; these values were obtained from the 2002 Feasibility Study.

The GENESIS grid extends 4000 meters alongshore between DEP survey monuments R-31 and R-44. The grid contains 81 cells; each cell is 50 meters (164 ft) wide. The GENESIS grid parameters are listed in Table 2. The horizontal datum used in this study was State Plane (Florida West, 902), and the unit of measurement for all modeling was meters. The vertical datum used was MSL. The relationship between this datum and other vertical datums was obtained from the NOAA tide gage stations at Mullet Key, Tampa, FL and Clearwater Beach, FL.

Table 2. GENESIS Grid Parameters

Origin	Easting	Northing
	143944 m	328513 m
STWAVE Indices of GENESIS Origin	I	J
	498	114
X - azimuth (alongshore dir)	330°	(NW)
GENESIS Cell Size Δx	50 m	164 ft
Ratio GENESIS to STWAVE cells	1 : 1	
Grid Distance (alongshore)	4000 m	13,100 ft
# GENESIS cells	81	

Wave Input.

Two different sets of wave data were investigated for use in this study: the Wave Information Study (WIS) and Wave Watch III (WW3) databases. The WIS is a 20-year hindcast of hourly wave heights, periods, and directions spanning the interval from 1980-1999. Similarly, the WW3 database includes hindcast wave heights, periods, and directions; the WW3 database used in this study spans the period 2005-2012. In general, the WIS data was used to calibrate the GENESIS model, and the WW3 data was used for model verification and production runs. The reason for using the two databases is that the

WIS time series corresponds to the period of calibration, and the WW3 time series corresponds to the more recent shoreline configurations which were used as a basis for the verification and production runs. The development of each wave database is described below.

WIS Database. The WIS database used in this study consists of a 20-year hindcast (1980-1999) of hourly wave heights, periods, and directions. This dataset was obtained at WIS Gulf of Mexico Station 73276, which is located at latitude 27.17^{o} N, longitude 82.75^{o}W in 19 meters (65 ft) of water depth. This location is about 14 miles southwest of Lido Key.

The 20-year wave time series from WIS station 73276 was first processed by binning the significant wave heights, peak spectral wave periods, and vector mean wave directions at the peak spectral frequencies, as shown in Figure 6. This figure is a histogram of wave heights, periods, and directions shown as percent occurrence. Bright yellow bins indicate those occurring most frequently and bright blue, least frequently. Wave direction data in this figure are referenced to the local shore normal which is to the southwest. The zero degree direction of wave approach is 240^{o} clockwise as measured from due north. Positive wave angles are those approaching the coast from the southwest (from the left of shore normal for a person standing on the beach looking offshore). The six wave height, wave period and wave direction bins, respectively, shown in Figure 6 are the same wave groupings as were used in the STWAVE analysis. Figure 6 shows that median wave heights are approximately 1.5 ft, median wave periods are approximately 4.5 seconds and that a significant percentage of the waves are from the northwest.

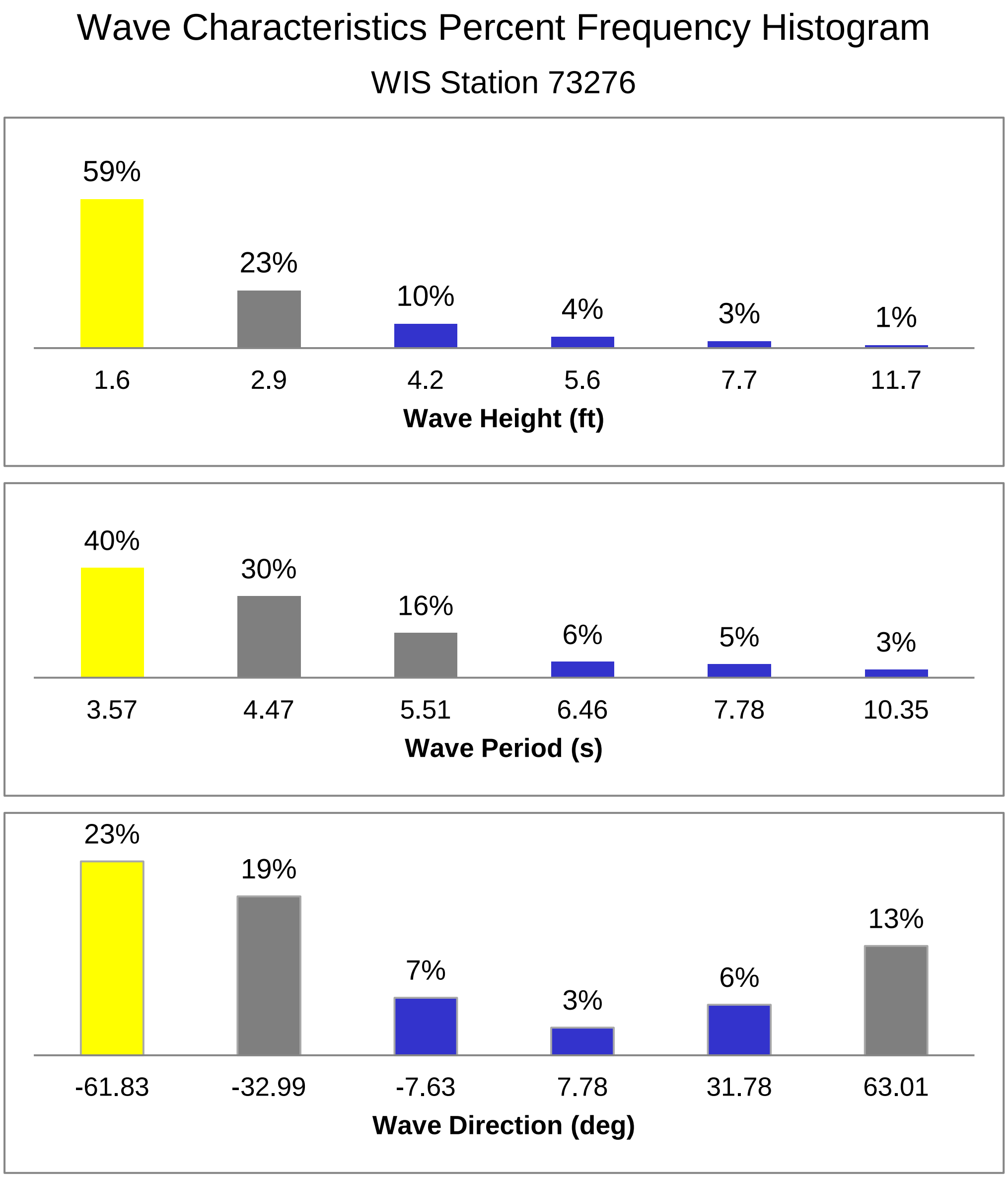

Figure 6. Wave histogram for WIS Gulf of Mexico Station 73276; latitude 27.17° N, longitude 82.75°W.

WW3 Database. In addition to the older 20-year WIS hindcast, more recent wave data was derived from the Wave Watch III database, which extends wave time-series data nearly up to the present time. The wave record used in this study consists of eight years of hindcast data (2005-2012) of 3-hr interval wave heights, periods and directions. This record was obtained from the WW3 Station for the Atlantic Global Multi-Grid Wave Model at grid cell i=297, j=244, latitude 27.27°N, longitude 82.80°W in a depth of 18.9 m (62 ft).

Similar to the analysis performed for the WIS wave hindcast, the 8-year wave climatology from WW3 station (i=297,j=244) between 2005 and 2012 was analyzed by creating histograms of wave characteristics. Figure 7 shows that median wave heights are approximately 1 ft, median wave periods are 4.5 seconds and that waves arrive at oblique angles both from the north and south.

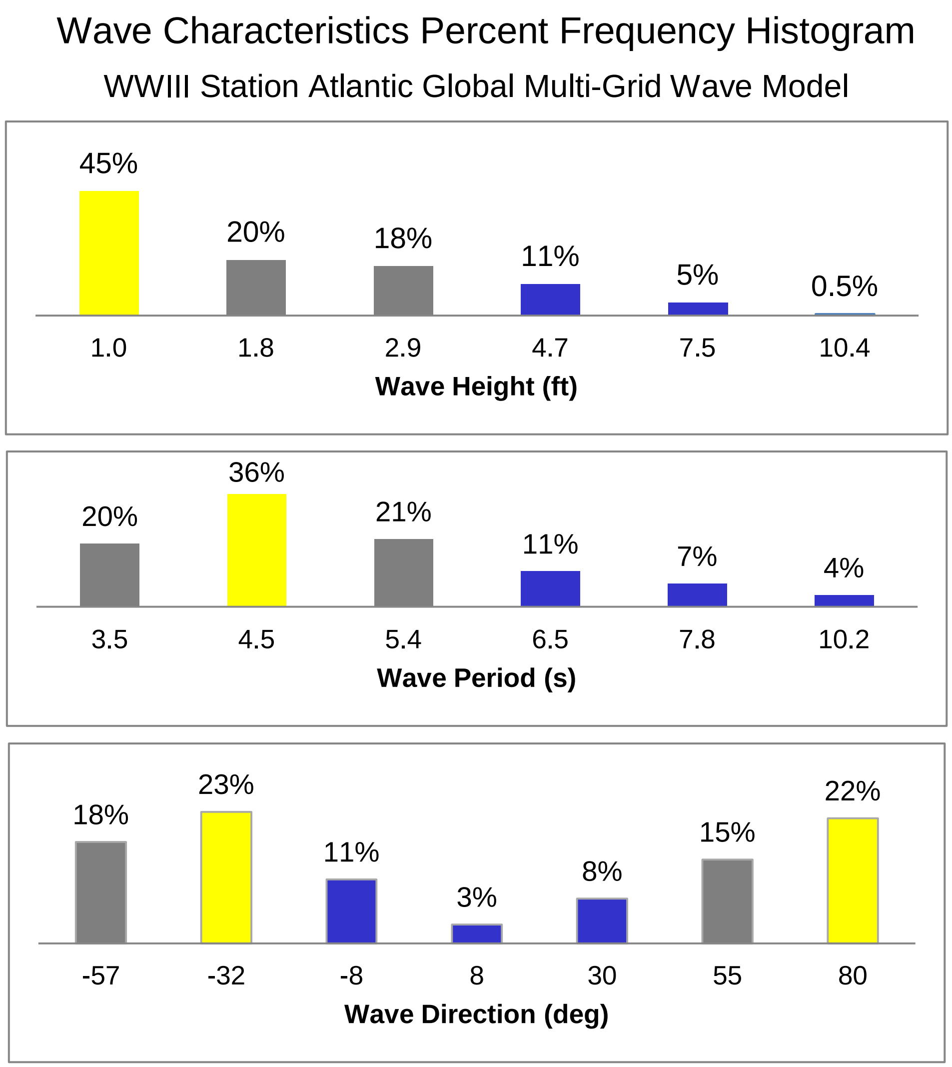

Figure 7. Wave histogram for WW3 data from the Atlantic Global Multi-Grid Wave Model at grid cell i=297, j=244, latitude 27.27°N, longitude 82.80°W

GENESIS Calibration.

The first step in preparing the GENESIS model for performing production runs is to calibrate the model to the study area. This is done by selecting shoreline positions at two points in time, and running the GENESIS model to calculate the change that occurs to the initial shoreline, using wave data from that time period. The two GENESIS calibration coefficients K1 and K2 are adjusted between each model run in an iterative procedure, to match model output as closely as possible to the measured shoreline changes during the calibration period. The model becomes calibrated when the *calculated* shoreline changes closely approximate the final *measured* shoreline changes. The points of comparison are not only the shoreline positions, but also include transport rates, volumetric changes, and a minimization of the 'calibration/verification error' provided in the model output.

For this Lido Key model calibration the 1987 shoreline was selected as the initial shoreline position, and the February 1998 (pre-nourishment) shoreline was selected to define the final shoreline position. The WIS dataset provided the necessary wave data (from 1987 to 1998) to drive the model during this time interval. The model was set up to represent actual physical conditions across the project area during that time period, so no groins were simulated, and the other physical parameters entered into the model (such berm height, depth of closure, grain size, boundary conditions, etc) represented actual conditions across the study area at that time. Note that two beach renourishment projects were constructed along the study area during this time; these fills are accounted for in the model input.

An iterative procedure is used to calibrate the GENESIS model: First, hindcast waves from the calibration period (1987-98) were refracted across the STWAVE grid to capture the effects of the irregular offshore bathymetry. These waves were propagated from deepwater to a nearshore stationing line along the 4 meter depth contour, where the refracted wave data was handed off from STWAVE to GENESIS. The entire wave dataset was then run through GENESIS, which was initially set up using default K1 and K2 values. Results from each model run were compared to actual measured changes during the same period, and adjustments to the coefficients were made to reduce the differences between the calculated and measured values. Then the procedure was repeated until the differences between calculated and measured shorelines (and other associated transport/ volumetric changes) were minimized. A summary of the calibration settings that resulted from this iterative process are shown in Table 3 below.

Table 3. GENESIS Calibration Parameters	
K_1	0.15
K_2	0.07
Median Grain Size D_{50}	0.24 mm
Berm Height	2.0 m
Depth of Closure	5.0 m
Left lateral BC	Gated (10 m from BC, 15^o orientation)
Right lateral BC	pinned
Regional Contour Trend	Temporally averaged shoreline

The shoreline comparison results from model calibration are shown in Figures 8a and 8b. Figure 8a shows an overlay of the positions of initial shoreline position (1987, measured) versus the modeled and measured shorelines of 1998. As highlighted on the graphic, the primary area of interest is the shaded zone at the left side of the graph, extending from roughly 0 to 1000 meters. The groins are located at approximately 10 m (terminal groin), 320 m (middle groin), and 500 m (northern groin). In addition to the shoreline positions within the groin field, the shoreline north of the north groin is of primary interest.

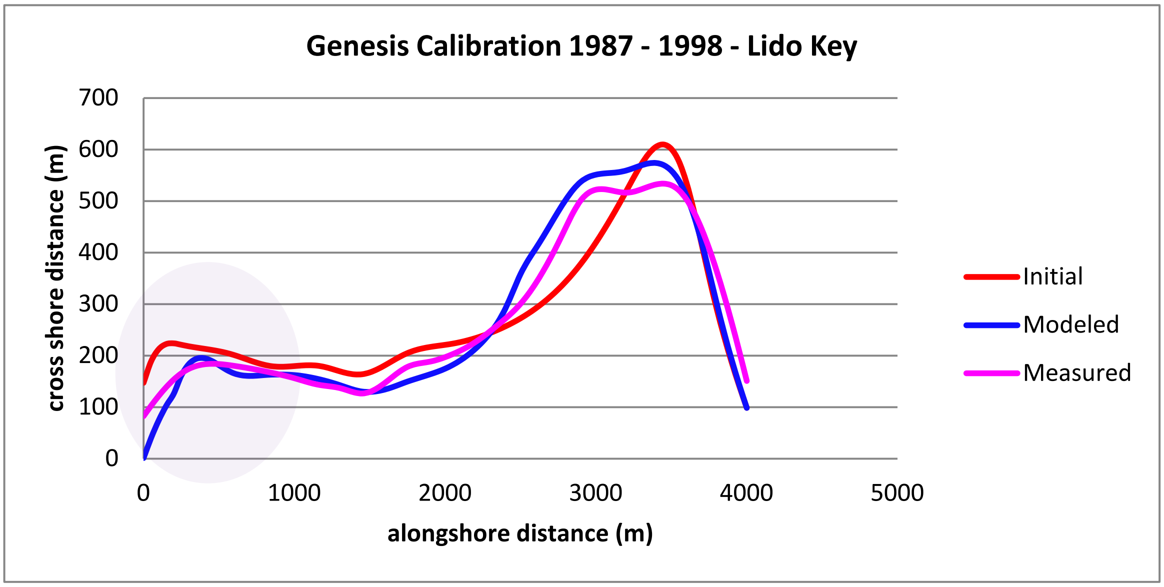

Figure 8a. GENESIS calibration results for shoreline position. Shaded region is location of proposed groin placement.

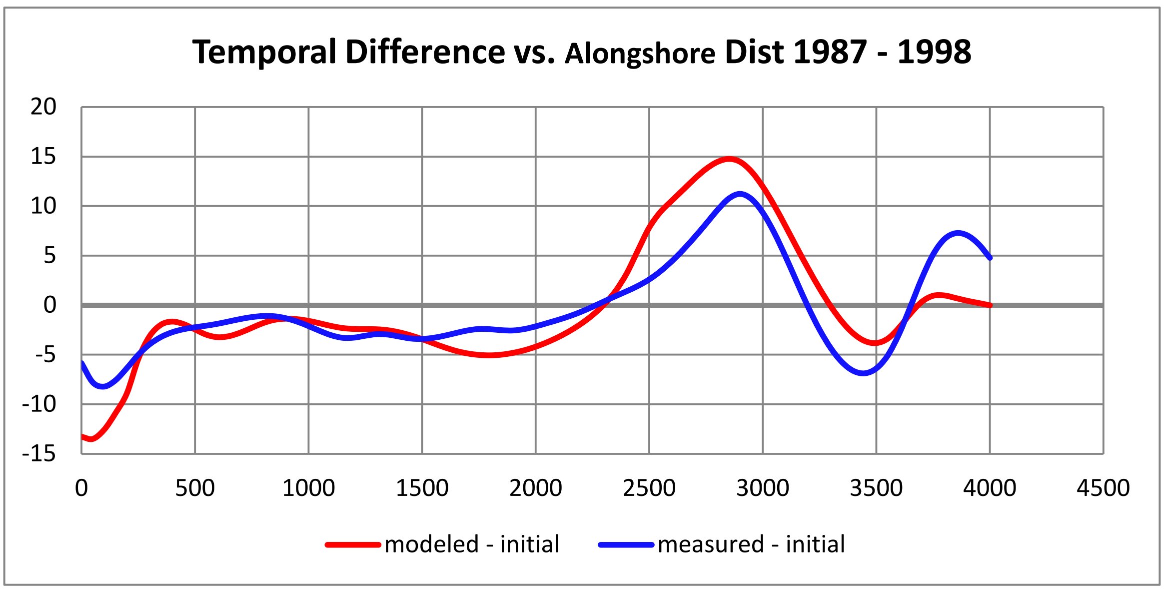

Figure 8b. Temporal Difference. Modeled 1998 – Initial 1987 (red) and Measured 1998 – Initial 1987 (blue) vs. alongshore distance.

As seen in Figure 8a, a comparison between the initial and final measured shorelines shows that the shoreline tends to erode fairly uniformly along the southern half of the island, and advance along the northern half, during the 1987-1998 time period. Again, these positions are measured by shoreline survey, and include the effects of two beach fill placements. The results shown in Figure 8a represent the best agreement between the final measured shoreline and the final modeled shoreline from the series of calibration model runs. Within the area of special interest along the southern portion of the island (shaded area) the predicted shorelines are in especially close agreement, with the exception of near the southern boundary of the model. Due to boundary effects the actual vs predicted shoreline positions diverge near the southern tip of the island, with the model predicting substantially greater erosion at the tip than was actually observed. This is likely due to the inability of the model to adequately recover material that is transported southward out of the GENESIS grid.

The model demonstrated good predictive ability in the region of greatest interest, in the vicinity of the northern two groins. Figures 8a and 8b show that the predicted and observed final shorelines agree closely throughout much of the remaining portion of the southern shoreline of Lido Key, with residual differences of typically a few meters per year (or less) between these two shorelines.

In order to further evaluate the differences between actual and predicted final shoreline positions, a regression analysis was performed. This metric was used to evaluate the accuracy of final shoreline predictions from each calibration model run. The two graphs shown in Figures 9a and 9b represent the differences between the measured and modeled final shorelines from the final calibration model run. The graph shown in Figure 9a represents the differences in positions from the two shorelines, shown by the plotted datapoints on the graph. A curve of best fit is drawn down the center of these points. The graph shown in Figure 9b shows the change rate between the predicted vs actual shoreline changes, again with a curve of best fit drawn down the middle of the dataset. As seen in the graphs of Figures 8 and 9, the model over-predicted erosion at the very southern tip of Lido Key, over-predicted accretion at the north end of Lido Key, and generally matched the actual shoreline change through most of the study area.

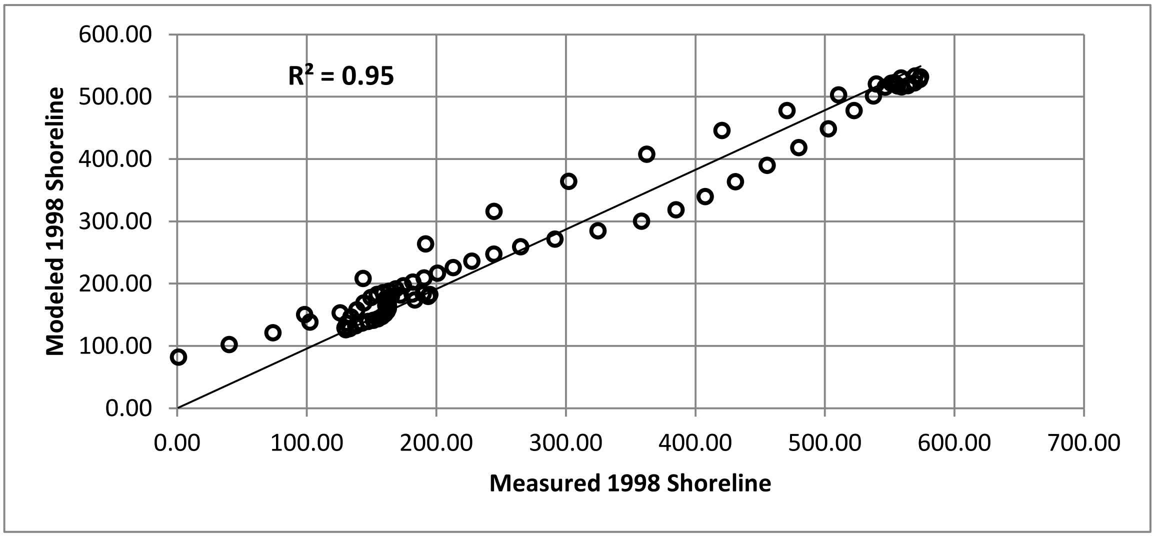

Figure 9a. Regression for shoreline position in 1998. Modeled vs. measured shoreline.

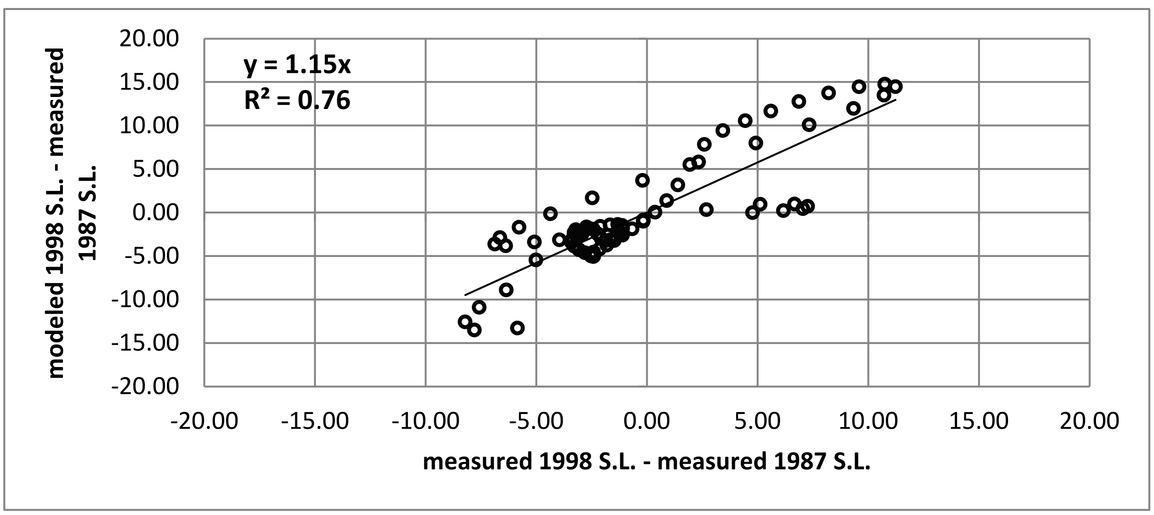

Figure 9b. Regression for temporal shoreline difference. (Modeled SL – Initial SL) vs. (Measured SL – Initial SL) .

A summary of statistics describing the differences between the modeled and measured shorelines from the calibration period are provided in Table 4.

Table 4. Descriptive Statistics - CALIBRATION	
Mean	1.6 m
Standard Error	3.9 m
Median	2.9 m
Standard Deviation	35.0 m
Sample Variance	1226 m^2
Range	148 m
Minimum	-81 m
Maximum	67 m
RMSE	34.8 m
RMSE	3.2 m/yr

GENESIS Verification.

Verification of the GENESIS model is the process of entering the calibration constants and all other input data as derived from the calibration phase described above, then running GENESIS during a different time period. As with the calibration process, two shoreline positions are selected, which are different than those used in calibration. The corresponding wave time series is used to run the calibrated model and to verify that the calibration constants produce realistic results for this different time period. If results are not acceptable, the calibration constants can be adjusted and the process repeated. If results are acceptable, the model is considered to be verified and ready for production runs.

Verification was performed by running the model using the 2005 shoreline as the initial condition and comparing the model results with the 2009 shoreline – the final condition. All other model parameters were the same as in the calibration phase, which are summarized in Tables 2 and 3. Results are shown in Figures 10 and 11, and closely follow the analysis presented above for model calibration. It should be noted that WW3 wave data was used in the verification phase, while WIS wave data was used in the calibration phase. This was necessary because the time intervals simulated spanned those respective databases.

As shown in Figure 10a, the predicted shoreline positions during verification were much closer to the measured values than during calibration. Importantly, all along the southern portion of the island the measured and modeled shoreline positions coincided very closely, even at the southern tip of the island. Some departure of the predicted shoreline from the measured shoreline is seen near the northern tip of the island, but this area is far removed from the area of interest in the vicinity of the groin field. The regression analyses shown in Figures 11a and 11b quantify the close correlation between the predicted and measured shorelines during the verification phase.

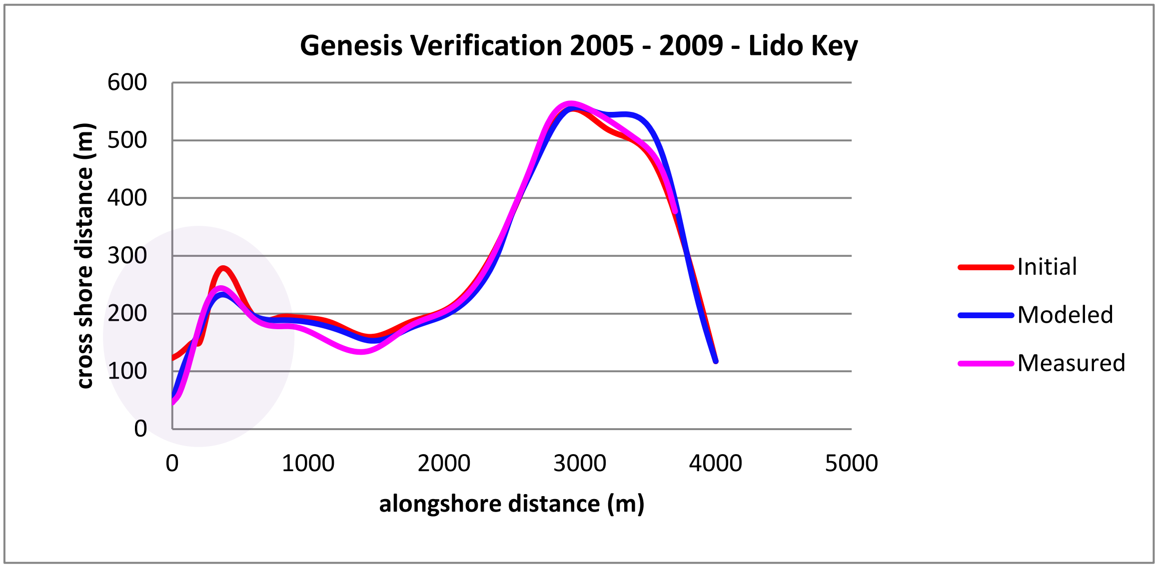

Figure 10a. Verification Shoreline. Shaded region is location of proposed groin placement.

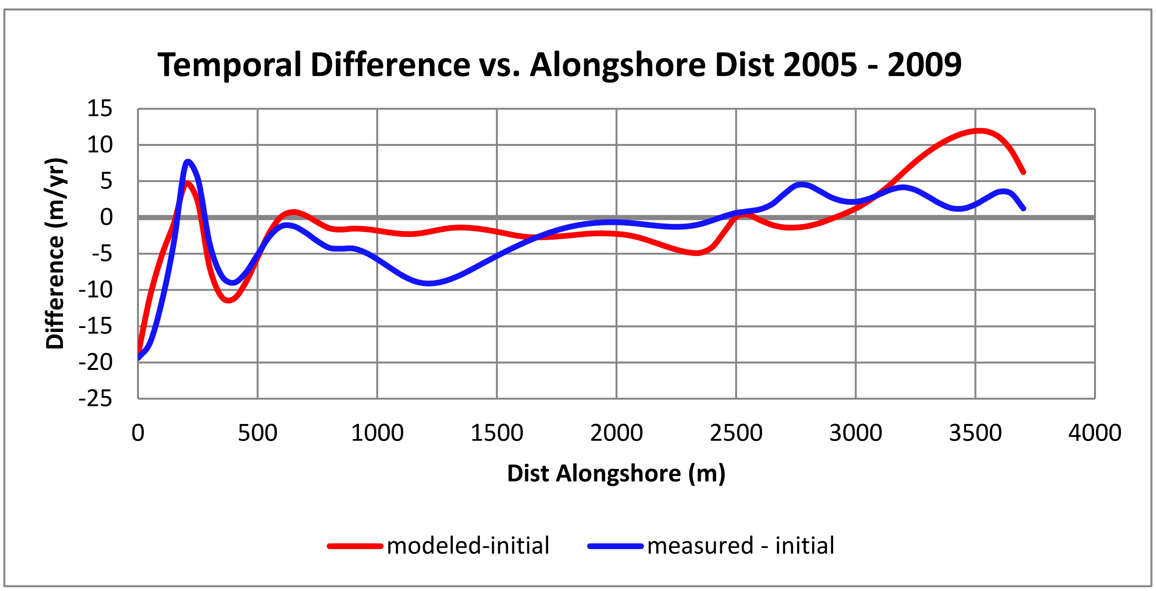

Figure 10b. Temporal Difference. Modeled 2009 – Initial 2005 (red) and Measured 2009 – Initial 2005 (blue) vs. alongshore distance.

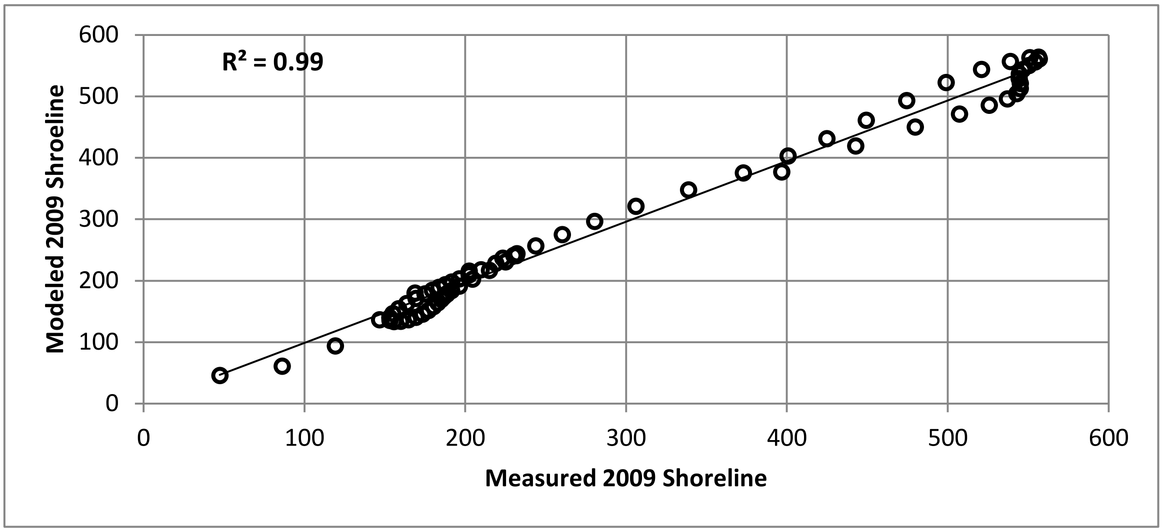

Figure 11a. Regression for shoreline position in 2009. Measured vs. Modeled shorelines.

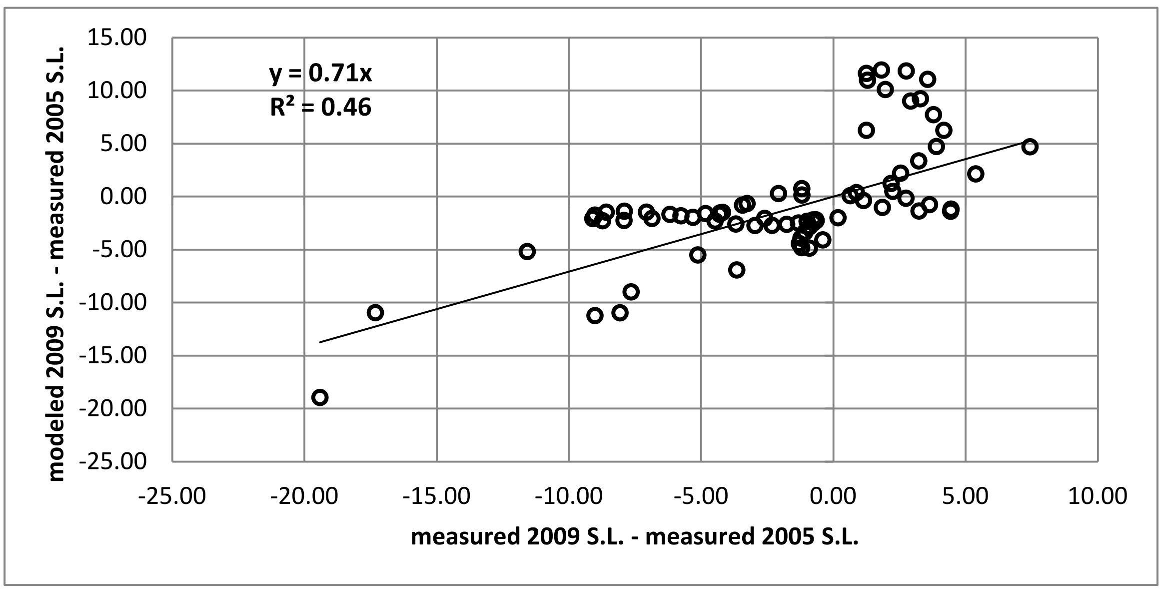

Figure 11b. Regression for temporal shoreline difference : Measured vs. Modeled shorelines.

As seen in the above summary graphics, the modeled shoreline calculated more uniform erosion in the alongshore direction, as compared to the calibration phase. A summary of descriptive statistics from the verification model run is provided in Table 5 below. Comparing these statistics to the values presented in Table 4 for the calibration phase, a much closer correlation is seen between the predicted vs measured final shoreline positions in the verification phase. The model parameters at this point are considered optimized, in that any changes to the K1 and K2 coefficients will tend to increase rather than decrease the differences between the measured and predicted shorelines.

Table 5. Descriptive Statistics – VERIFICATION	
Mean	5.7 m
Standard Error	1.8 m
Median	4.4 m
Standard Deviation	16.0 m
Sample Variance	257 m^2
Range	64.7 m
Minimum	-23 m
Maximum	41 m
RMSE	16.9 m
RMSE	4.23 m/yr

GENESIS – Production Runs.

Modeling Objectives and Strategy. Once calibrated and verified, the GENESIS model was set up to execute a series of production runs to examine the effects of incrementally varying the lengths of the groins at the southern end of the island. The basic strategy was to enter the dimensions of the proposed plan of improvement from the 2002 Feasibility Report into the GENESIS model, and simulate the evolution of the shoreline over a 5-year renourishment cycle. The shoreline positions resulting from this simulation would represent the baseline condition. Then follow-up runs would be executed to compare the incremental effects of shortening one or both of the northern two groins to this baseline. The ultimate goal was to reduce the lengths of the groins to the greatest extent possible, while still maintaining at least minimum berm dimensions along the project shoreline.

Baseline GENESIS Simulation. First, the "baseline" run was made using the groin configuration as defined in the 2002 Feasibility Study. The model was set up using the calibrated/verified K1 and K2 values of 0.15 and 0.07, respectively, along with all of the physical data for the project area as presented in Table 3. The original groin configuration as presented in the 2002 Feasibility Report was added, specifically: the north groin was 320 feet in length, located 1,400 feet north of Big Sarasota Pass; the middle groin was 440 feet in length, located 800 feet north of Big Sarasota Pass; and the terminal groin was 650 feet in length, located at the Pass. The initial shoreline was set to the post-nourishment configuration (full construction berm template), also presented in the 2002 report. The design shoreline consists of an 80-foot advancement of the high water line. But with the addition of 5 years of advanced nourishment the resulting construction berm varies from 230 to 380 feet in width, as measured from the Erosion Control Line. The positions of all construction berms, seawalls, and groins were measured from an aerial photograph of the project area, which was georeferenced into a CADD file with a GENESIS grid overlay. A portion of this CADD file/GENESIS overlay in the vicinity of the groin field is provided in Figure 12.

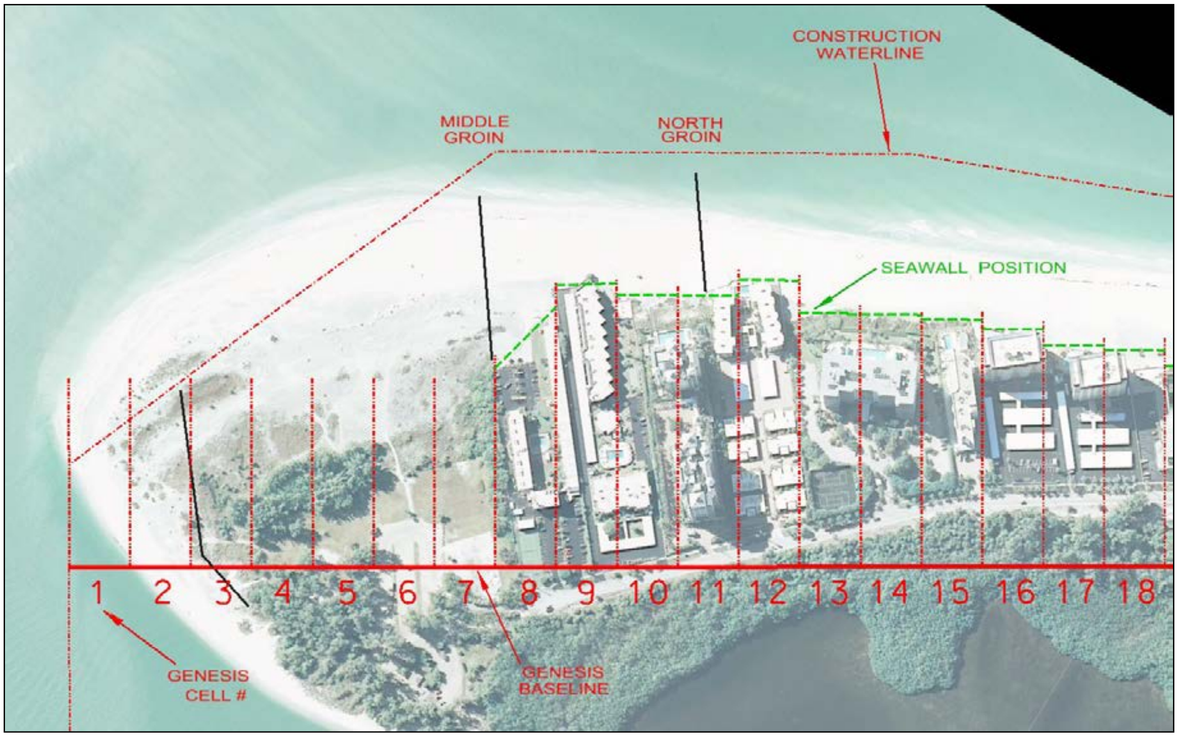

Figure 12. GENESIS grid, showing positions of groins and seawalls.

A five-year wave record was selected to drive the model, to coincide with the five-year renourishment interval specified in the 2002 report. Since the 2005-2010 Wave Watch III time series provides a good representation of "average" wave conditions in the area, this record was used to drive the production runs. Although 2005 was a very active hurricane year, no direct hits occurred near the project area. Several storms passed through the Gulf at some distance in 2005 (and other years), but no extreme wave events were observed along the project area during this time period. The inclusion of some non-extreme tropical storm wave events is desirable because the passage of hurricanes and tropical storms through the Gulf of Mexico is a regular occurrence and represents 'normal' project conditions.

The result of this 5-year "baseline" GENESIS simulation is shown in Figure 13a. In this standard output graphic from the model, the ocean is shown in blue; the land is green. The GENESIS baseline (along the bottom of the figure) extends along a roughly shore-parallel orientation; for proper spatial orientation refer to the north arrow at the upper right corner of the graphic. The initial (post-nourishment) shoreline is indicated by the black shoreline, and the simulated final 5-year shoreline is shown by the area under the green shoreline. The individual GENESIS model cell boundaries are indicated by the black vertical lines. Along the left side of the graphic the positions of the three groins and the seawalls in the vicinity of the groin field are represented by the small white vertical and horizontal lines (a better view of these features is provided in Figure 13b).

The initial shoreline position in this simulation is the post-renourishment shoreline. After a five-year simulation interval the shoreline along the length of the study area remains in excess of the minimum design berm width. The most severe erosion is observed at the north end of the island, outside of the project limits. It should be noted that erosion occurs in this area during all model simulations, and may be more of an indication of inadequate simulation of bypassing of material onto Lido Key at the northern boundary of the model. In reality this northern region of the island is quite stable over time, due mainly to the inflow of material across New Pass, and possibly due to wave sheltering effects of the New Pass ebb shoal. These complex processes would be beyond the capability of GENESIS to simulate, particularly at the model boundary. However, the study area is far removed from this region, and shoreline responses throughout the project limits are in accordance with historical observations. Material moving southward along Lido Key appears to be maintaining a wide berm along the central and most of the southern reach of the island.

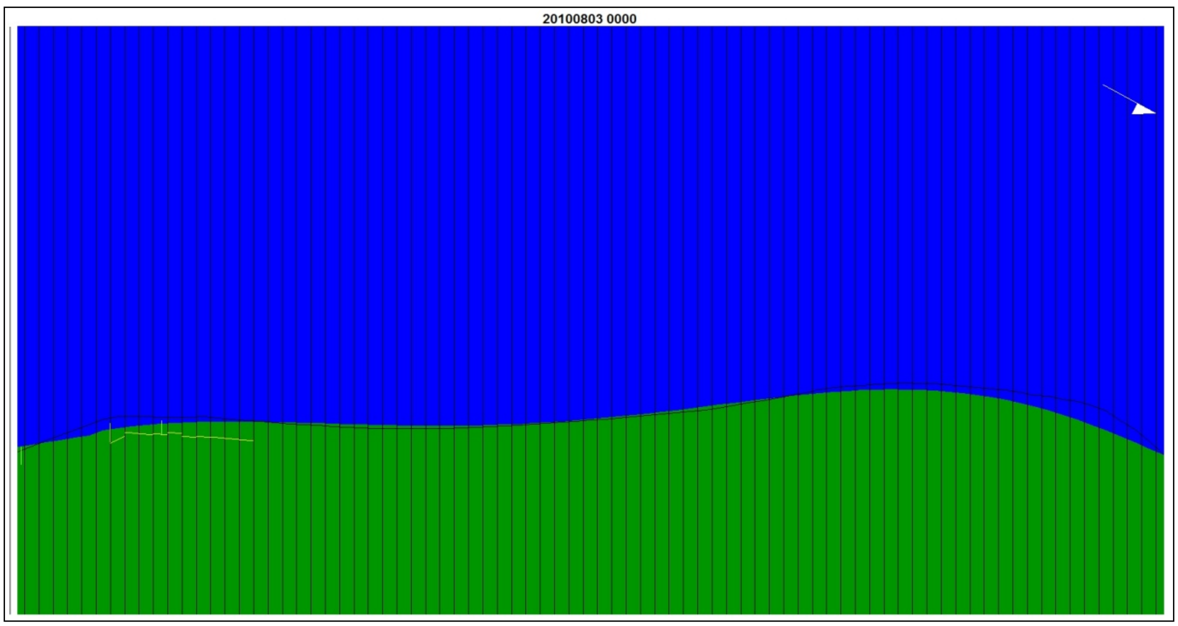

Figure 13a. Shoreline change across entire model domain, 5-year simulation, Recommended Plan from 2002 Feasibility Report.

A more detailed view of the groin field area is provided in Figure 13b. This graphic is simply a zoomed-in and vertically exaggerated view of the left-hand region of Figure 13a, showing shoreline response along the southern portion of the island. In both Figures 13a and 13b, the three vertical white lines represent the proper positions and lengths of the three groins as described in the 2002 Feasibility Report. The horizontal white lines represent the average position of the seawall at each cell location. The seawall coincides closely with the ECL along this region of the island.

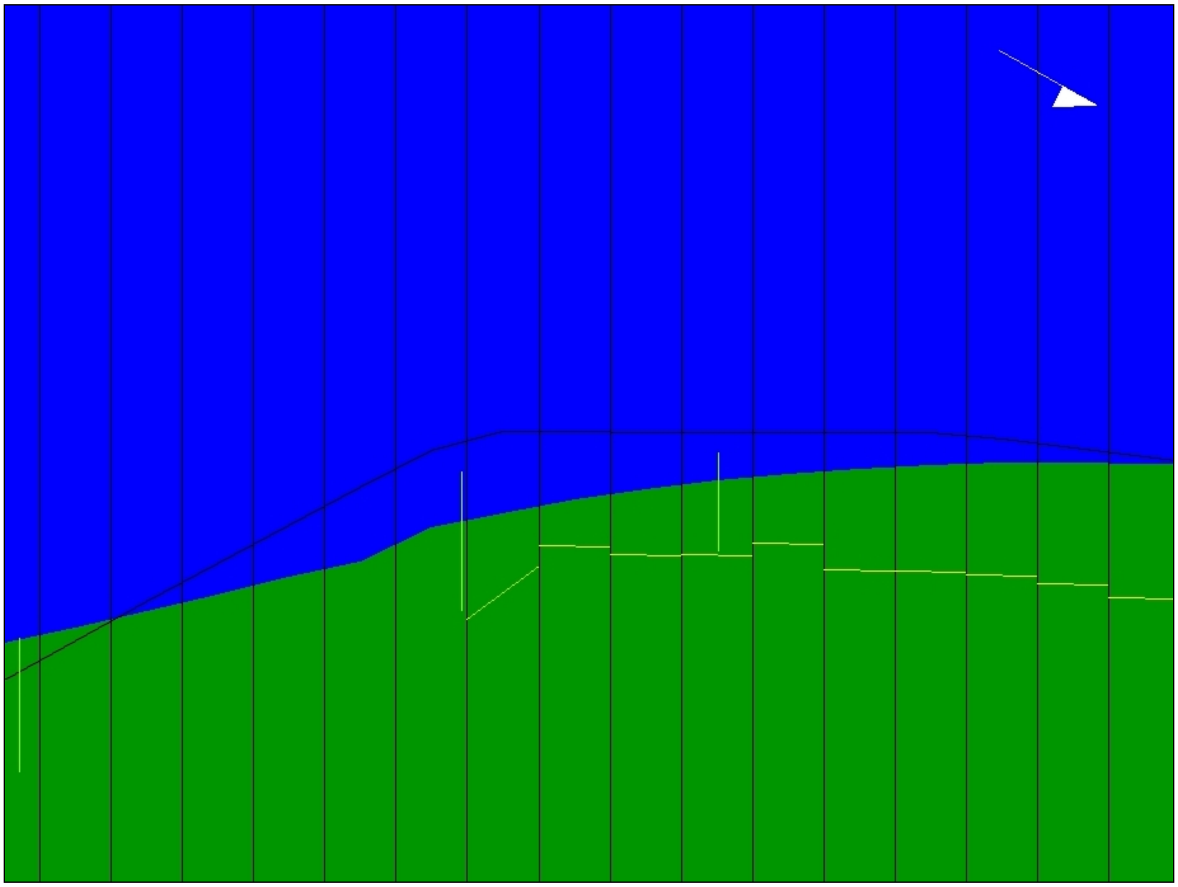

Figure 13b. Close-up of initial and final shoreline positions along proposed groin field, 5-year simulation, Recommended Plan from 2002 Feasibility Report.

Excluding the northern end of the island, the most erosive area along Lido Key is shown in Figures 13a and 13b above, spanning a 750-meter (2,500-ft) reach of shoreline, centered on the groin field. Although the groins reduce the rate of erosion along this region, considerable material is still lost from this area – largely a function of the wide beach fill and sharp bend in the coastline (initial shoreline indicated by black line). Shoreline changes can be better seen in Figure 14, which presents the positions of the initial and final shorelines, and the measured differences between these two shorelines. By examining intermediate shoreline positions it is seen that in every case, the greatest shoreline recession occurs in the first year of simulation, then the shoreline rapidly stabilizes.

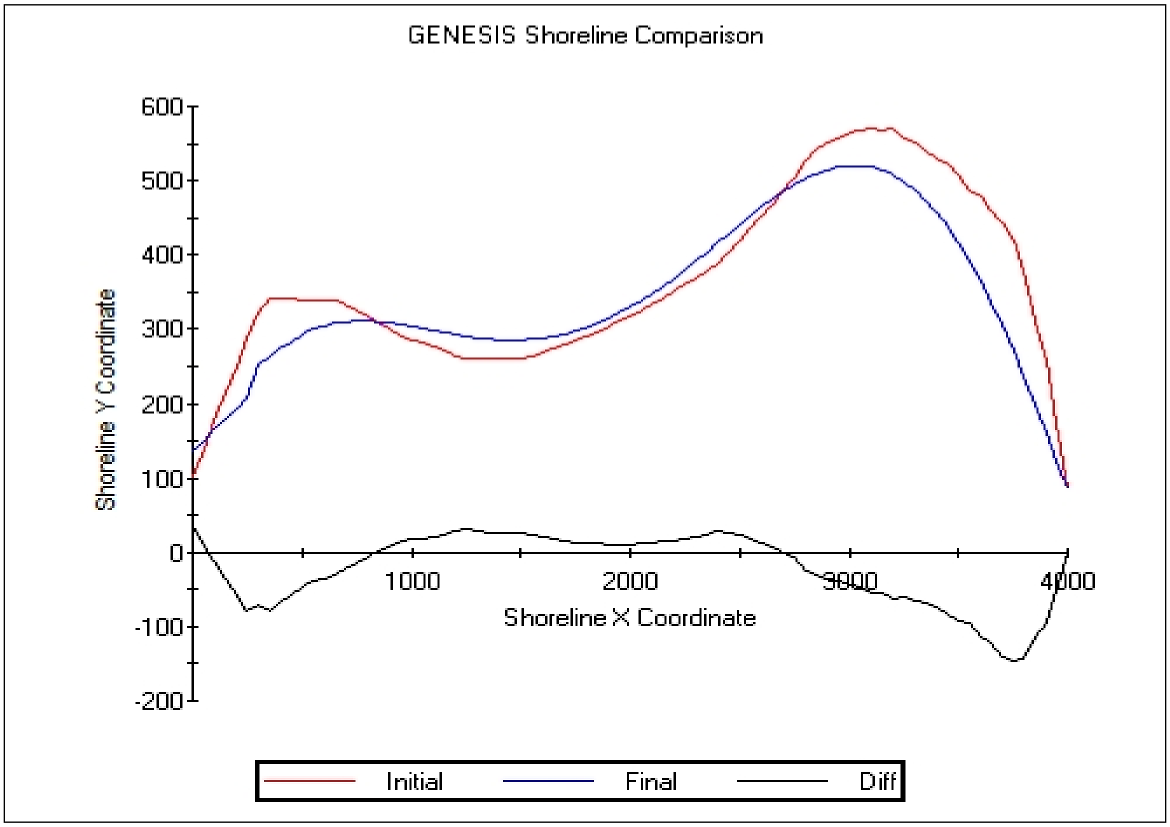

Figure 14. Shoreline comparisons : 5-year GENESIS model run, Plan as recommended in 2002 Feasibility Report.

Exact measurements are difficult to obtain from GENESIS output graphics, so the model's numerical output files are examined to determine quantitative shoreline changes at specific points of interest. The primary points of interest along southern Lido Key include cells 6 and 9, which are immediately downdrift and updrift, respectively, of the middle groin. Also of interest are cells 10 and 12, which are immediately downdrift and updrift, respectively, of the northern groin. The shoreline positions immediately updrift of each structure are of interest because the oceanfront development along southern Lido Key extends furthest seaward in these two locations, and these represent the most vulnerable areas of the project. The areas downdrift of the two groins are of interest, because erosion can be most severe immediately downdrift of groins and other coastal protective structures.

In all areas of the Federal project it is desired to maintain at least an 80-foot (24.4 meters) offset between the seawall line and the waterline, in accordance with the authorized project dimensions. By examining the numerical output files it is seen that for this baseline condition all offset values exceed the minimum 80-foot dimension at every location across the model domain. For this baseline model run the shoreline offset values after 5 years of model simulation vary from 42 m (138 ft) to 66 m (216 ft) at these key locations, and are much wider across the remaining areas of the project. Model results for the baseline condition are shown as "Model Run #1" at the top of Table 6.

The model results presented above show that the configuration as recommended in the 2002 Feasibility Report is more than adequate to maintain the required level of shore protection for the specified 5-year renourishment interval. An analysis of intermediate shorelines from this model run - output at one-month intervals - shows that the construction berm erodes rapidly during the first 6 months following construction, then stabilizes considerably, eroding at a much reduced rate over the remaining months and years. One reason for this phenomenon is that initially the groins are buried by the wide construction fill. As they become increasingly exposed the groins become more effective, limiting further losses.

The remaining shoreline widths at the end of the 5-year baseline simulation exceed the required minimum values by considerable margins in many areas. This model run therefore suggests that shorter groins and/or a narrower construction berm in the vicinity of the groins may still provide the necessary level of protection, while greatly reducing construction costs. A sensitivity analysis will be performed to determine if incrementally shortening the middle and/or northern structures can still effectively maintain the project berm while lowering construction costs.

Sensitivity Analysis – Reduce Structure Length. The objective of this series of model runs was to determine the effects of shortening the lengths of the northern and middle groins as compared to the baseline condition defined above. Several series of simulations were performed in which one or both structures were shortened by 5-meter increments, and the resulting effects on the adjacent shoreline were examined. The objective of this effort was to determine the minimum structure lengths required to maintain the 80-project berm at the end of a 5-year simulation period. For this series of simulations the same basic GENESIS model configuration parameters were used as in the "baseline" runs described above. The same initial shoreline, seawall, and input wave files were also used. The only variable changed between subsequent model runs was the length of the northern and middle groin(s). By changing only one variable at a time a better relationship between groin length and shoreline position could be determined.

The results from the baseline model run indicated that the narrowest berm after a 5-year simulation was located between the middle and northern groin, near cell #9. As seen in Figure 12, cells #9 and #12 correspond to the two locations where the seawall extends furthest seaward. As seen in this figure, the seawall actually extends seaward to a "point" at cell #9, but the average position of the seawall (approximately 20 feet landward of the point) will be used in this analysis for berm offset calculations.

As seen in the model output for the "baseline" condition, a berm well in excess of the required minimum width remained at the end of a 5-year simulation along the reach of shoreline north of the northern groin. The final berm position between the two groins was narrower however, largely because of the seaward location of development in this area, and possibly because of the north groin blocking sediment transport into this region. Therefore, for the first set of iterations the north groin was decreased in length by 5 meters for each model run, and the length of the middle groin was left unchanged.

Run #	Description of Model Simulation	Downdrift, mid groin Cell 6	Updrift, mid groin Cell 9	Downdrift, north groin Cell 10	Updrift, north groin Cell 12
	TABLE 6 **Shoreline Widths at Critical Areas of Lido Key**				
1	Rec. Plan - 2002 Feasibility Report				
	Initial shoreline	286.8	340.8	340.2	339.2
	Final shoreline	219.4	276.6	288.4	301.1
	Difference (Initial - Final)	67.4	64.2	51.8	38.1
	Berm width remaining (24.4 meters min)	52	42	59	66
NORTH GROIN SHORTEN ONLY					
2	North Groin -5 m; middle groin unchanged				
	Difference (Initial - Final)	67.1	63.9	51.7	38.4
	Berm width remaining (24.4 meters min)	55	43	60	66
3	North Groin -10 m; middle groin unchanged				
	Difference (Initial - Final)	66.8	63.4	51.7	38.6
	Berm width remaining (24.4 meters min)	65	45	63	66
4	North Groin -15 m; middle groin unchanged				
	Initial shoreline	286.8	340.8	340.2	339.2
	Final shoreline	220.3	277.7	288.5	300.4
	Difference (Initial - Final)	66.5	63.1	51.7	38.8
	Berm width remaining (24.4 meters min)	63	45	64	66
5	North Groin -20 m; middle groin unchanged				
	Difference (Initial - Final)	66.2	62.8	51.7	38.9
	Berm width remaining (24.4 meters min)	65	46	64	67
6	North Groin -25 m; middle groin unchanged				
	Difference (Initial - Final)	66.0	62.5	51.9	39.0
	Berm width remaining (24.4 meters min)	63	46	64	66
7	North Groin -30 m; middle groin unchangec				
	Difference (Initial - Final)	65.5	62.3	52.4	39.0
	Berm width remaining (24.4 meters min)	64	47	65	66
8	North Groin -35 m; middle groin unchangec				
	Difference (Initial - Final)	65.5	62.3	52.4	39.0
	Berm width remaining (24.4 meters min)	64	47	65	66
SOUTH GROIN SHORTEN ONLY					
9	North Groin unchanged; middle groin -5 m				
	Difference (Initial - Final)	67.3	65.9	53.3	39.2
	Berm width remaining (24.4 meters min)	64	42	62	65
10	North Groin unchanged; middle groin -10 m				
	Initial shoreline	286.8	340.8	340.2	339.2
	Final shoreline	219.6	273.4	285.4	299
	Difference (Initial - Final)	67.2	67.4	54.8	40.2
	Berm width remaining (24.4 meters min)	62	40	60	63
11	North Groin unchanged; middle groin -15 m				
	Difference (Initial - Final)	67.1	69	56.3	41.3
	Berm width remaining (24.4 meters min)	62	39	59	63
12	North Groin unchanged; middle groin -20 m				
	Difference (Initial - Final)	67.1	70.6	57.8	42.2
	Berm width remaining (24.4 meters min)	62	38	57	62
13	North Groin unchanged; middle groin -25 m				
	Difference (Initial - Final)	67.1	72.2	59.3	43.1
	Berm width remaining (24.4 meters min)	62	35	55	63
14	North Groin unchanged; middle groin -30 m				
	Difference (Initial - Final)	67.1	73.7	60.7	44
	Berm width remaining (24.4 meters min)	62	35	54	62
15	North Groin unchanged; middle groin -35 m				
	Difference (Initial - Final)	67	75	62	44.8
	Berm width remaining (24.4 meters min)	62	34	53	63
COMBINATION RUNS					
16	North groin -15 m; South groin -10 m				
	Initial shoreline	286.8	340.8	340.2	339.2
	Final shoreline	220.6	274.6	285.7	298.11
	Difference (Initial - Final)	66.2	66.2	54.5	41.09
	Berm width remaining (24.4 meters min)	65	42	61	63
16	North, South Groins minimized - 20m long				
	Difference (Initial - Final)	61.9	78.2	67.8	51.7
	Berm width remaining (24.4 meters min)	79	30	48	53
17	North groin -20 m; South groin -15 m, MOD SL				
	Difference (Initial - Final)	281.6	319.4	323.4	323.7
	Berm width remaining (24.4 meters min)	59	35	53	55

In the first series of simulations the north groin was shortened by 5-meter increments, within the range of -5 to -35 meters. A summary of calculated shoreline positions from this series of runs is provided in Table 6. Shortening the north groin had a positive but minimal effect on shoreline position both north and south of the north groin. From this analysis the optimal length of shortening the north groin appeared to be -15 meters. In this configuration the shoreline north of the groin was minimally influenced, as material transported into the region from the north was largely unaffected by the shorter length of the structure. South of the groin the shoreline advanced by approximately 5 meters immediately downdrift of the structure and by 3 meters at the narrowest cell (#9) relative to the baseline condition, since more material was able to bypass the north groin. South of the middle groin the shoreline advanced by about 11 meters relative to baseline, a result of more material entering the groin field from the north.

For the next set of iterations the length of the north groin was held constant at its baseline (original) length, and the middle structure was reduced in length by 5-meter increments, again ranging from -5 to -35 meters. In general, decreasing the length of the middle groin resulted in a nonlinear decrease in the final berm width along the shoreline cell between the two groins. Little impact on shoreline position was noted north of the north groin. The optimal shoreline response appeared to occur with a reduction of 10 meters from the original length of the middle structure. At this reduced structure length the shoreline was only 2 meters narrower than the baseline condition, but still in excess of the minimum design standard. More material had bypassed to the south side of the middle groin with the 10-meter length reduction, and the downdrift impacts south of that structure were reduced accordingly; the post-simulation shoreline immediately downdrift of the middle groin was 10 meters seaward of its baseline position.

Taking these model runs individually, it would appear that the optimum tradeoff between groin length and shoreline performance would occur with the north groin reduced by 15 meters (49 ft) and the middle groin reduced by 10 meters (33 ft). This would result in structure lengths of 271 feet (north) and 407 feet (middle). Due to the interactive effects of one groin's impact on the other, a series of simulations was performed to verify the optimal combination of reduced groin lengths. As with the previous series of simulations, the "apparent optimum" design lengths of 271 feet (north) and 407 feet (middle) were adjusted in 5-meter increments. The resulting simulated shoreline positions did not depart significantly from the values observed during the individual runs, which are summarized in Table 6. For structure lengths less than 271 feet (north groin) and 407 feet (middle groin) the shoreline begins to encroach upon the minimum design berm after 5 years, and portions of the project may become vulnerable to damage in the event of a large storm. Therefore, the recommended groin lengths as a result of GENESIS shoreline modeling remain at 271 feet for the north groin (rounded to 270 feet for construction), and 407 feet for the middle groin (rounded to 405 feet for construction).

Note that the seaward tips of both groins are positioned almost identically with respect to the waterline, but the middle groin is substantially longer because of the distance inland to the required tie-in location. Figure 15 shows the evolution of the shoreline at one-year intervals over the five-year simulation period, with the recommended shorter groins in place. Figure 16 shows a summary plot of differences in shoreline position along the project length. Compared to a similar plot for shoreline configurations resulting from the original groin configuration (Figure 14), no significant changes in patterns or magnitudes of shoreline change are noted. Shortening the northern and middle groins by 15 meters and 10 meters, respectively, will result in substantial cost savings with no significant adverse impact on shoreline response.

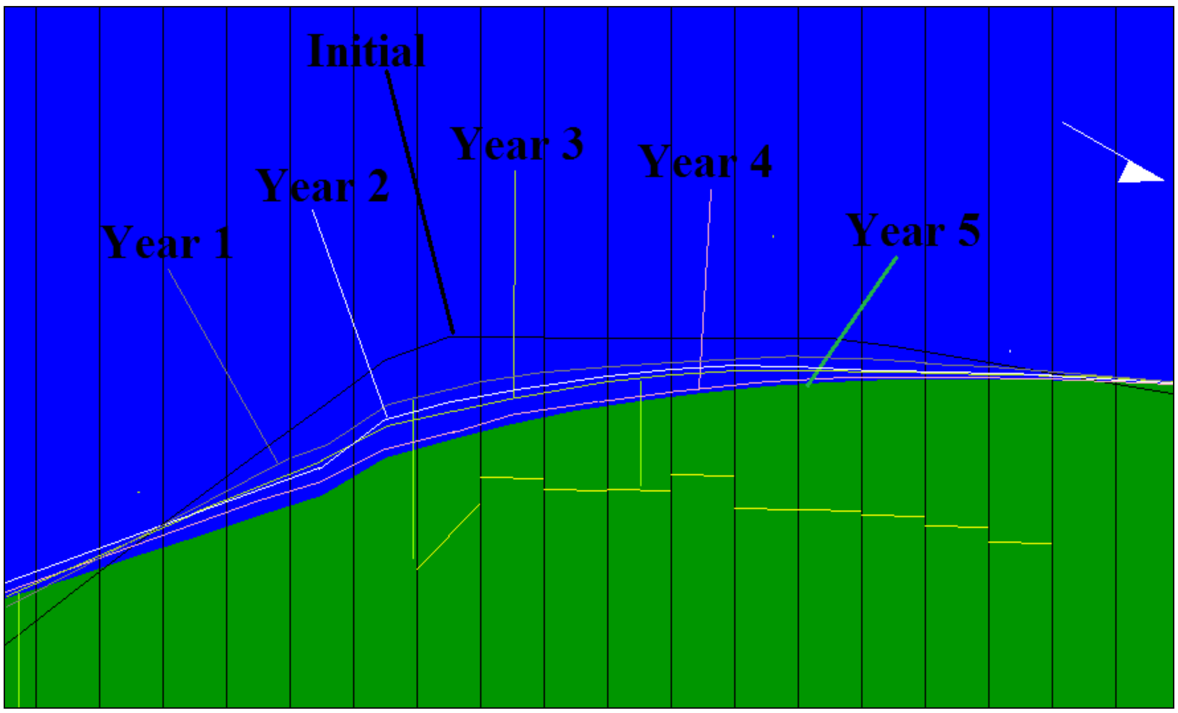

Figure 15. Evolution of shoreline over 5-year GENESIS simulation interval, with recommended groin modifications.

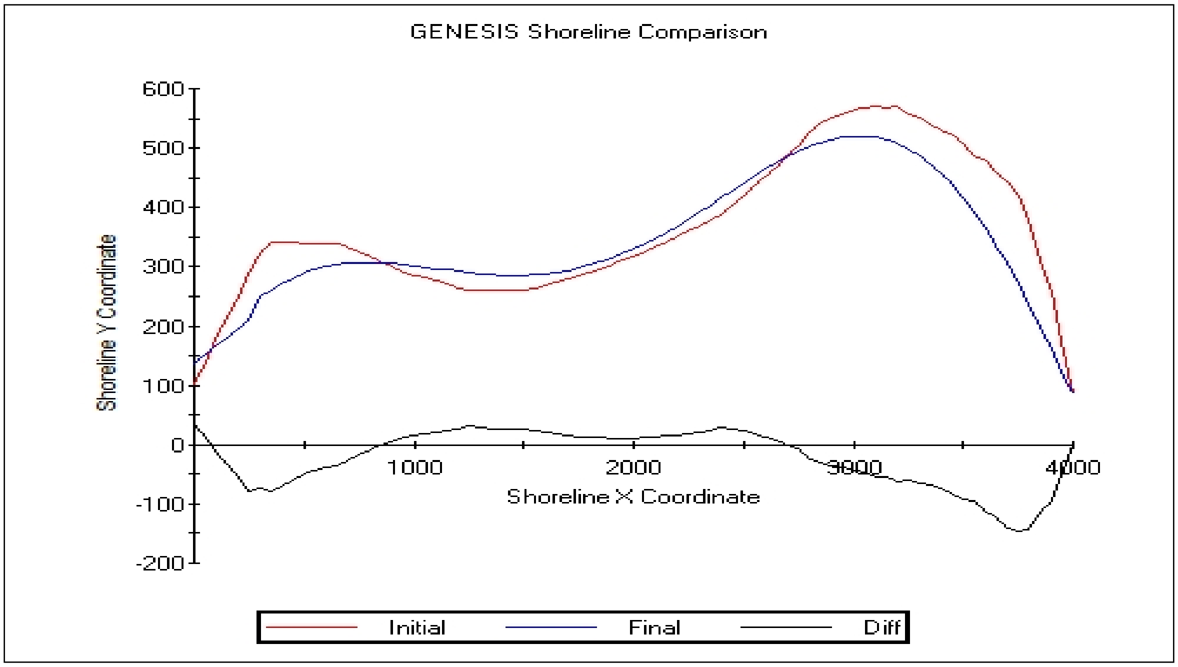

Figure 16. Comparison of initial vs final shoreline positions, modified groin configuration.

Impacts on Beach Fill Design. The beach fill design as recommended in the 2002 Feasibility Report was configured such that the seaward edge of the berm intersected the seaward tip of each groin. Since shortening of the groins is recommended, the seaward 10-15 meters of the beach fill would be unprotected if the berm were constructed to the original width. Additionally, the placement of this material creates an even larger perturbation in the shoreline as fill is placed further seaward into relatively deep waters, which can further increase erosional losses. In accordance with the historically high erosion rates observed at the south end of the island this unprotected material could be expected to rapidly erode, and would be of little practical benefit to the project. Therefore, one final series of model simulations was performed to examine the effects of eliminating the placement of this unprotected material and reducing the berm width to intersect with the new locations of the groin tips.

The existing berm was reduced in width from near the southern end of fill northward over a distance of about 2,000 feet, where it intersected the original berm dimensions as shown in Figure 17. The reduction in berm width along this reach averages about 50 feet, and would result in a reduction of beach fill placement of approximately 22,000 cubic yards. A comparison of the original vs the modified berm layouts, plus the original and modified groin lengths, are shown in Figure 17.

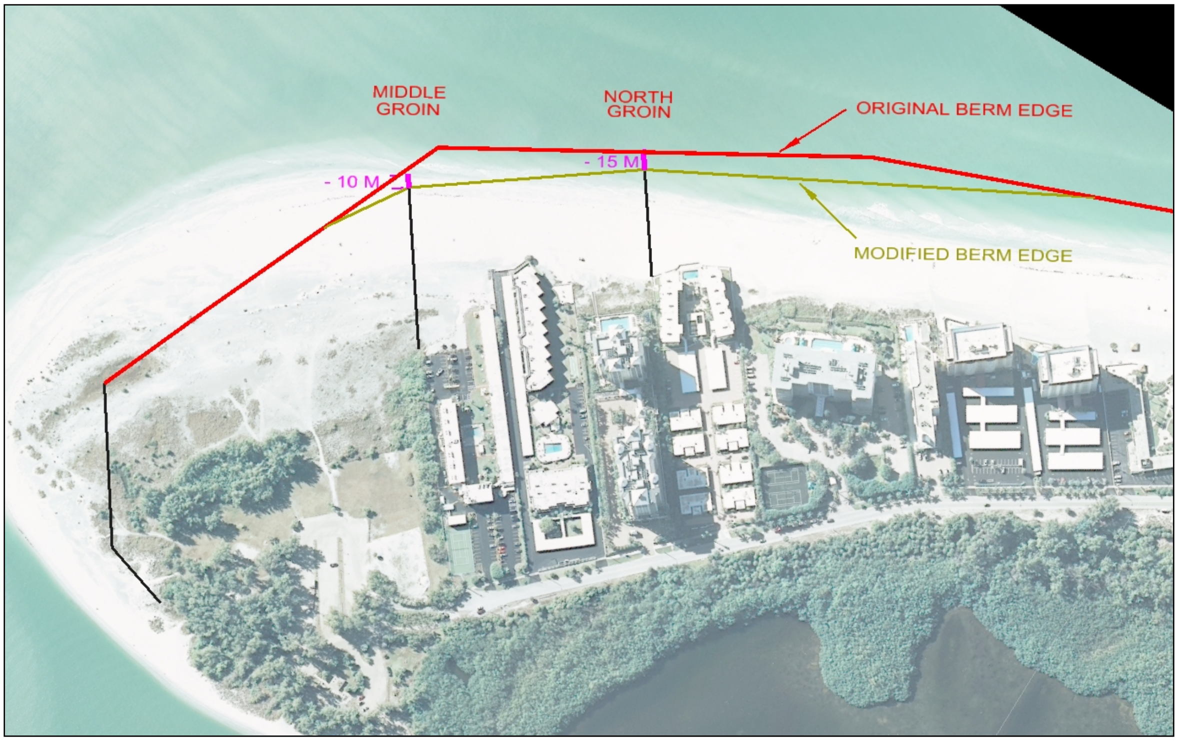

Figure 17. Original vs modified berm layouts.

Summary of GENESIS Shoreline Modeling. As a result of the foregoing GENESIS shoreline change modeling, the recommended plan of improvement has been modified to reduce the lengths of the two northern groins by a total distance of 85 linear feet. The north groin would be reduced from 320 to 270 feet, and the middle groin would be reduced from 440 feet to 405 feet. The beach fill would be reduced in width accordingly, such that the seaward edge of the berm intersects the seaward tips of the groins. This results in an average berm width reduction of about 50 feet along the southern 2,000 feet of the project, and reduces the volume of fill by approximately 22,000 cubic yards. A plan view of the layout of these recommendations is provided in Figure 17.

Alternative Shoreline Analysis – Case Study.

As a supplement to the GENESIS shoreline simulation modeling, a study was conducted of the performance of a nearby groin structure with similar physical characteristics, in a similar wave environment. As shown in Figure 18, a relic rubble-mound groin of similar design to the proposed structures is located about midway along the Lido Key shoreline, less than one mile to the north of the project site. This groin is one of several structures that were constructed decades ago (most of which have since been removed) to stabilize the central portion of the island prior to the construction of the shore protection project.

Due to the close proximity and strong similarities between wave environment, shoreline orientation, sediment characteristics, and groin design it can be assumed that the shoreline near the southern tip of the island would under most circumstances behave similarly to the shoreline in the vicinity of this relic structure. The only significant departure from conditions near the central portion of the island is the presence of tidal currents, and the curvature of the shoreline near the terminal groin structure. Due to the presence of these complicating factors this analysis will only be applied to the northern two groins, which are separated from the pass by over 1,000 feet.

The shoreline behavior in the vicinity of the relic groin displays some consistent trends which may be applicable to the project site. Assuming an adequate supply of sand to the north, the shoreline on the updrift (north) side of the groin tends to be offset by about 50 feet +/- from its seaward end. In cases where the shoreline is in a moderately eroded condition the offset of the downdrift shoreline with respect to the tip of the groin averages about 75 feet. A relatively narrow range of shoreline offset values (as measured from the seaward tip of the groin) is observed over the years, based on variations in wave climate. But these 50 ft / 75 ft offset values appear to represent the most eroded condition of the shoreline under normal circumstances. As is typically observed near groins, the shoreline advances seaward on the updrift side of the structure, and typically shows a concave eroded "pocket" immediately downdrift, as shown in Figure 18. In this analysis both the average shoreline offsets (50 ft / 75 ft) and the general shoreline shapes observed at this existing structure will be transposed to the two project groin sites at the south end of the island.

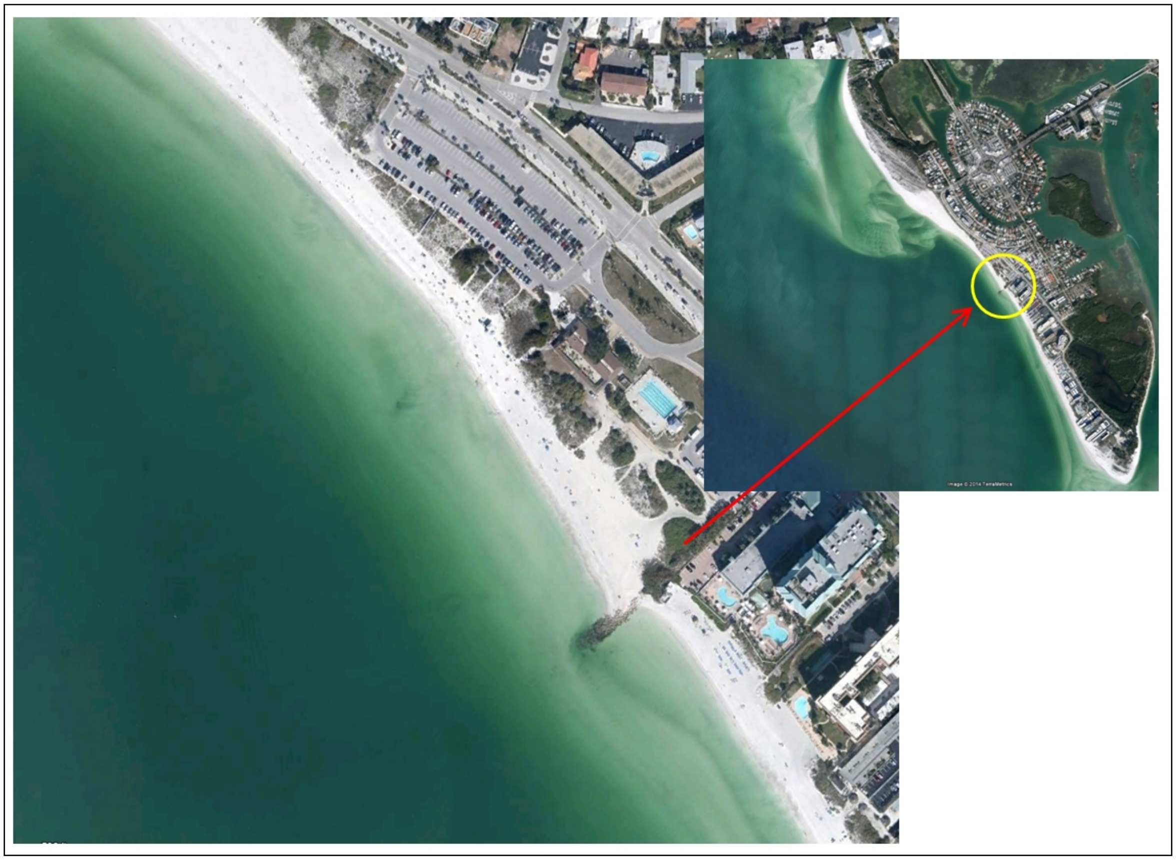

Figure 18. Location and close-up of relic groin, similar to proposed structures.

These average offsets apply to the approximate position of the waterline as obtained visually from aerial imagery in Google Earth. Due to the very low tide range along the Florida gulf coast, this waterline will be assumed to approximate the mean sea level (MSL) line. The authorized project design consists of a seaward advancement of the waterline of 80 feet. Therefore, in order to maintain the minimum allowable project dimension, the waterline can be no closer than 80 feet from the project baseline.

The same shoreline configuration observed at the relic groin (with respect to shoreline positions and updrift/downdrift offsets from the groin), were copied and transposed to the locations of the proposed northern two groins at the south end of the island. These equilibrated shoreline positions were then moved landward/seaward at each of the two proposed groin locations, until the shoreline position corresponded to the minimum allowable offset (80 ft) from the project baseline. The resulting equilibrated shoreline positions and corresponding groin lengths are shown in Figure 19.

Figure 19. Predicted equilibrium shoreline positions based on case study analysis.

According to this case study analysis, the minimum allowable beach width can be maintained by constructing the groins according to the configuration shown in Figure 19. Specifically: the northern groin can be shortened by about 40 feet to a total length of 280 feet, and the middle groin can be shortened by about 40 feet to a total length of 400 feet. Again, the primary assumptions in this analysis are that the shoreline will behave in a manner consistent with observations at the relic groin 4,000 feet to the north, and that an adequate supply of sand exists updrift (north) of the proposed structures to provide for continuous renourishment of the southern portion of the island.

The modified groin lengths obtained from this case study agree closely with the values calculated in the GENESIS shoreline simulation analysis, and this close agreement increases confidence in the recommendation to reduce the lengths of the groins by the prescribed amounts. Since the GENESIS analysis is more quantitative, those values will be adopted for use in project design.

Revised Volumes of Material Required. The quantities of material required to construct the three groins were re-calculated as per the recommendations of the Value Engineering Study and the recommendations set forth in this report (see Figures 4a and 4b). To summarize the changes to the original design as recommended in the VE Study :

- The sheet pile wall was removed, and ungrouted chinking stone will be added to the interior of the groins to decrease the permeability of structures.

- As a result of the sheet pile removal, the crest widths were reduced from 4 stones to 3 (12 feet to 9 feet).

- Structure side slopes were steepened from 1v : 2h to 1v : 1.5 h, except at the heads of structures, where they will remain at 1v : 2h.

- 1-ft thick foundation mattresses will be used instead of thicker unconsolidated bedding stone. Mattresses will be filled with locally-produced limerock and underlaid with geotextile fabric.

- To prevent scour damage, the foundation mattresses will be extended 5 feet beyond the toe of the armor layer on the downdrift side of the structures.

- In place of a uniform foundation elevation, bottom elevations of the northern two groins will be stepped, in accordance with existing depths: -1.0 ft NAVD88 along the upland portions of structures, increasing to -5.0 ft NAVD88 along the offshore portions.

- The northern and middle groin were to be re-examined to determine if either structure could be shortened without compromising project performance. This is the subject of this report, and it was determined by the analysis presented herein that the northern groin could be reduced by 50 feet to a length of 270 feet, and the middle groin could be reduced by 35 feet to a length of 405 feet. The southern (terminal) groin would remain at 650 feet in length.

The volumes of materials required to construct the three groins as recommended in the 2002 Feasibility Report are summarized in Table 7.

QUANTITIES OF MATERIALS PRESENTED IN 2004 REPORT :					
Armor stone				15400	TONS
Core stone				3000	TONS
Bedding stone				8300	TONS
12-inch Foundation mats	N/A				
Geotextile fabric	9644	SY			
Vinyl sheet piles	34200	SF			

Table 7. Quantities of materials required to construct the plan as recommended in the 2002 Feasibility Report.

The quantities of materials required to construct the groins as recommended in the analysis presented in this report are summarized in Table 8.

RECOMMENDATIONS FROM GENESIS MODELING :					
Armor stone (granite)	6944	CY	1.838	12764	TONS
Bedding stone (limerock)	1819	CY	1.593	2897	TONS
12-inch Foundation mats	5456	SY			
Geotextile fabric	5456	SY			
Chinking stone (granite)	775	CY	1.715	1329	TONS

Table 8. Quantities of materials required to construct the plan recommended plan in this report.

Summary

It is recommended that the lengths of the two northern groin structures at the south end of Lido Key be reduced in accordance with the findings of this report. The north groin would be reduced from 320 to 270 feet, and the middle groin would be reduced from 440 feet to 405 feet. The southernmost terminal groin would remain unchanged at 650 feet in length. The quantities of materials required to construct the three groins are presented in Table 8. The width of the beach fill would be reduced accordingly, such that the seaward edge of the berm intersects the seaward tips of the groins. This results in an average berm width reduction of about 50 feet along the southern 2,000 feet of the project and reduces the volume of fill by approximately 22,000 cubic yards. These values were calculated using the GENESIS numerical shoreline change model, but a case study of a nearby rubble groin shows behavior similar to that predicted by GENESIS and adds confidence to the acceptable performance of this modified groin system.

References.

1) Sarasota County, Florida, Hurricane and Storm Damage Reduction Project, Lido Key, Feasibility Report with Draft Environmental Impact Statement, U.S. Army Corps of Engineers, Jacksonville District, January 2002.

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