SHORE PROTECTION AND HABITAT CREATION AT SHAMROCK ISLAND, TEXAS

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ABSTRACT

Shamrock Island is located in Corpus Christi Bay, Texas. The island is undeveloped and serves as an ecologically important rookery to a number of nesting bird species, in particular, the royal tern. The island formed as a series of spits that were connected to Mustang Island at the eastern edge of Corpus Christi Bay. Due to natural and man0induced causes, the northern half of the island is subject to significant erosion that has effected critical beach, marsh, and upland habitat.

In 1998, a shoreline stabilization project was implemented by Shiner Moseley & Assoc., Inc. to address the continued erosion and to stabilize the northern portion of the island. Components of this project included an offshore geotextile tube (GT) breakwater, beach nourishment, and marsh creation. The beach nourishment was designed as a feeder beach to provide a continued sand supply to the downdrift southern beaches.

The feeder beach constructed in 1998 has currently reached its design life of 5 years. In addition, some of the GT's have been damaged, which has resulted in less protection of the island. The need to further protect the island and the requirement for mitigation as a result of the U.S. Army Corps of Engineers nearby project at Packery Channel have resulted in the current Shamrock Island Habitat and Enhancement Project. This project consists of the construction of a series of low crested detached rock breakwaters to promote the establishment of submerged aquatic vegetation (SAV), help stabilize the northern portion of the island, and protect the habitat and ecological function of Shamrock Island.

To predict the areas of protection and potential SAV creation, the limits of the wave shadow zones in the lee of the breakwaters was needed. The STWAVE numerical model was utilized to develop local fetch-limited wind-driven waves at the site. To determine the shadow zones, STWAVE was applied to calculate wave refraction and diffraction for various project layouts. The modeling results aided in the optimization of the project design to provide the most SAV and shoreline protection for the available construction budget. Final design of the project is currently underway, and construction is anticipated for Fall 2005 after the next bird nesting season.

INTRODUCTION

Background

Shamrock Island is located along the eastern shoreline of Corpus Christi Bay, Texas, approximately 2 miles west of Mustang Island (Figure 1). The island formed as a series of spits that were connected to Mustang Island, as shown in Figure 2. A number of navigation channels were dredged in the 1950's which severed the "land bridge" that connected the spit to land. Erosion of the land bridge by Hurricane Celia in 1970 further delineated the island, and primarily as a result of the detachment from Mustang Island, there is no longer a significant sediment source for the island. This lack of sand caused erosion to occur to the beach and wetlands along the northern end of the island. The island interior is heavily vegetated and includes a series of lagoons and wetlands, with the uplands and beaches being home to a number of nesting bird species, in particular the royal tern.

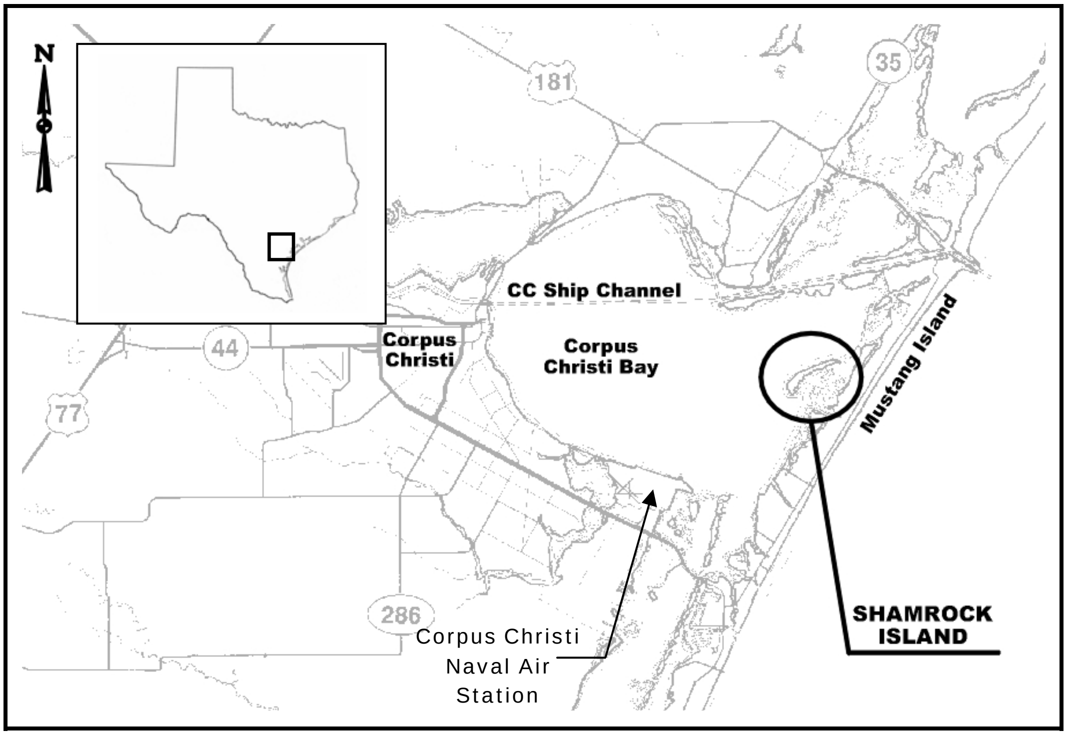
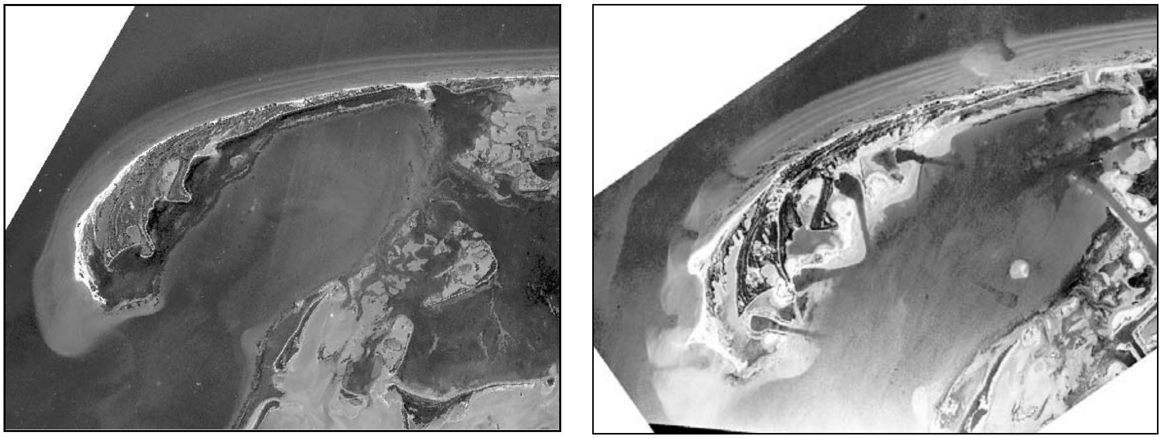


Figure 1 – Location Map

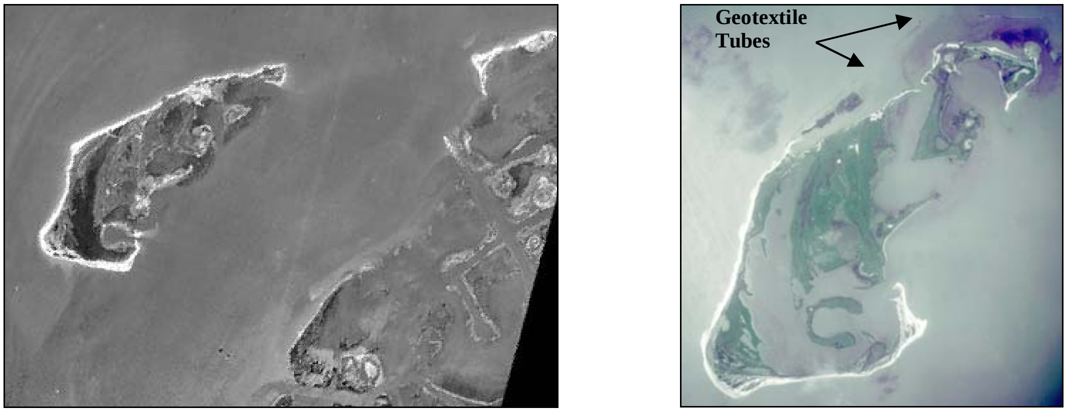
1998 Project

In 1998, a shoreline stabilization project was implemented to address the continued erosion and to stabilize the northern portion of the island (Shiner Moseley, 1998a, 1998b), as shown in Figure 3. Components of this project included an offshore geotextile tube (GT) breakwater, beach nourishment, and marsh/wetlands creation. The feeder beach was constructed where the GT connected to the island in order to maintain a sand supply to the downdrift southern beaches. This project had a construction budget of about $750,000.



1948 – Note connection intact

1956 – Note cut and canals



1979 – Post Hurricane Celia

2004 – Current condition with geotextile tubes

Figure 2 – Historical Aerial Photographs of Shamrock Island

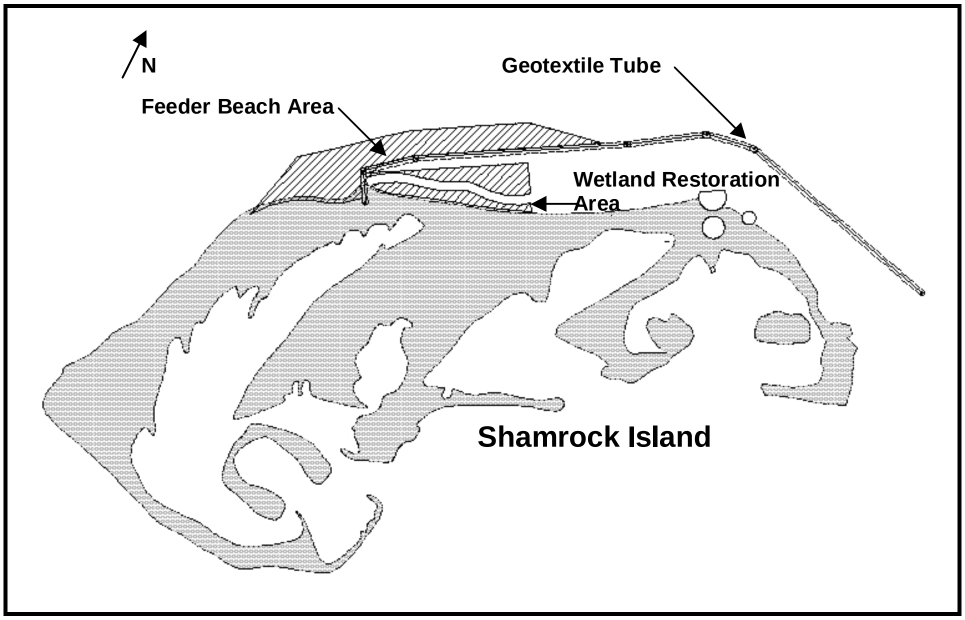


Figure 3 – 1998 Project

Current Project

The feeder beach constructed in 1998 has currently reached its design life of 5 years. In addition, some of the GT's have been damaged, which has resulted in less protection of the island. The need to further protect the island and the requirement for mitigation as a result of the U.S. Army Corps of Engineers nearby project at Packery Channel, have resulted in the current Shamrock Island Habitat and Enhancement Project. This project consists of the construction of a series of low crested detached rock breakwaters whose primary goals are to:

- Create or cause the creation of approximately 15.6 acres of submerged aquatic vegetation (SAV).
- Help stabilize the northern shoreline of Shamrock Island.
- Protect the habitat and ecological function of Shamrock Island

This project is performed under the direction of the Shamrock Island Project Advisory Team (Team), which includes representatives from CBBEP, Texas Center for Environmental Quality, Texas Parks & Wildlife, U.S. Fish & Wildlife, the Nature Conservancy, Texas General Land Office (TGLO), and the U.S. Army Corps of Engineers (USACE). The island is owned by the Nature Conservancy.

CLIMATIC CONDITIONS

The assessment of meteorological and oceanographic conditions at Shamrock Island relied on data collected by the Texas Coastal Ocean Observation Network (TCOON) at Station 001, located at the Corpus Christi Naval Air Station. Wind and tide data from 1995 through 2002 were obtained from TCOON and analyzed, and a summary is provided below.

Tides: The mean tidal range from Mean Low Water (MLW) to Mean High Water (MHW) for the project area based upon measurements at the TCOON station is approximately 0.6 feet. However, as shown in Figures 4, the actual range in tide can vary greatly due to seasonal meteorological effects. Of particular note is the increase in water level that occurs in the fall (September through November). During this period, the tides are consistently above the MHW datum and can reach elevations greater than +3.0 feet MLT (Mean Low Tide datum, U.S. Army Corps of Engineers). Conversely, the tides become very low during the winter months (December through March) with water levels dropping below 0.5 feet MLT. Two other seasonal variations occur, though not as significant, with the tides becoming higher in the spring (April through June), and lower in the summer (June through August).

Wind: Wind records from 1995 to 2002 were analyzed and the frequency of occurrence for varying wind speeds and directions were calculated. This information is presented graphically in the wind rose shown in Figure 5. From Figure 5, it is clear that the predominant wind direction is from the east through the south, with winds from these directions occurring approximately 63% of the time. However, due to shoreline orientation and basin geometry, these winds are expected to have minimal affect on the more severely eroding areas along the northern shoreline of Shamrock Island. As a result, the winds originating from the north to northeast may be of greater influence. The strongest winds originate from the northeast, which is typically the result of passing storm fronts that occur in the fall, winter, and spring.

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Waves: To determine the wave conditions expected at the project site, a wave hindcast based on the measured wind speeds described above and the associated fetch was performed. The results are shown in Figure 6. Although more waves originate from the southeast, the larger waves appear to propagate from the northeast, consistent with the greater wind speeds measured from this direction. The average significant wave height was approximately 0.4 ft and the largest significant wave height was approximately 5.4 ft (occurred on March 3, 1996). The larger waves and higher tides are likely significant factors in the erosion observed along the northern shoreline of Shamrock Island.

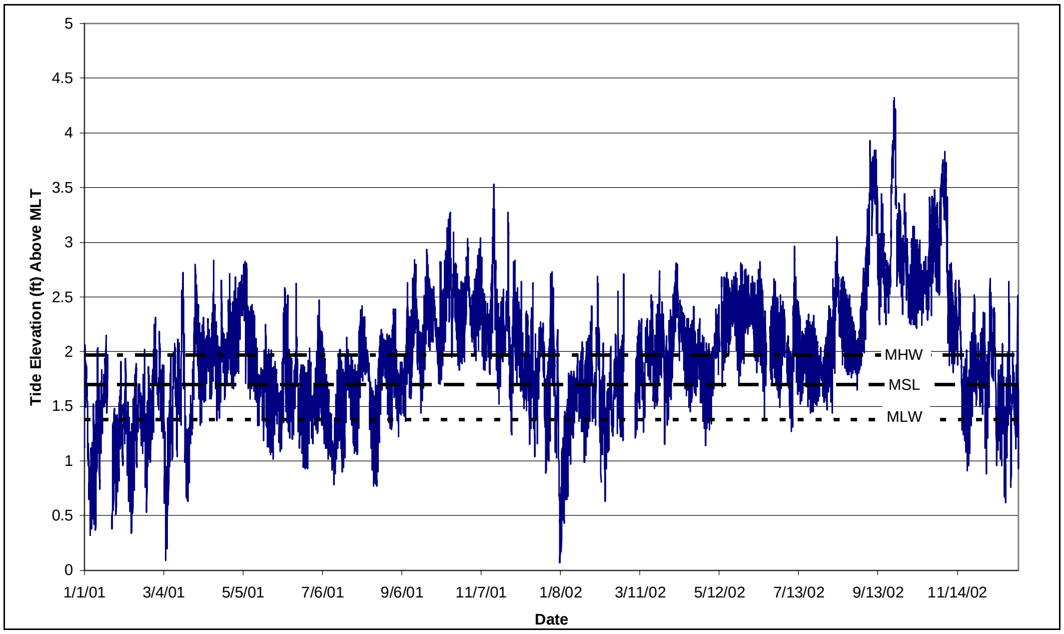


Figure 4 – Tide Elevations for CC-NAS Station, 2001-2002

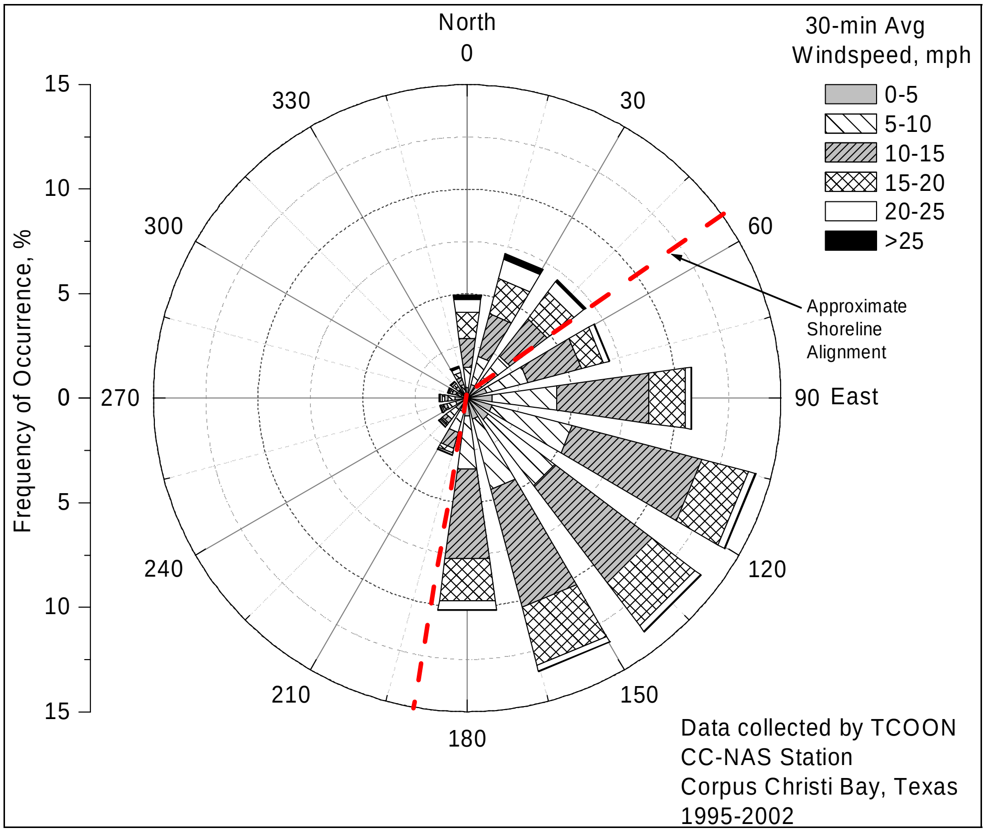


Figure 5 - Wind Rose

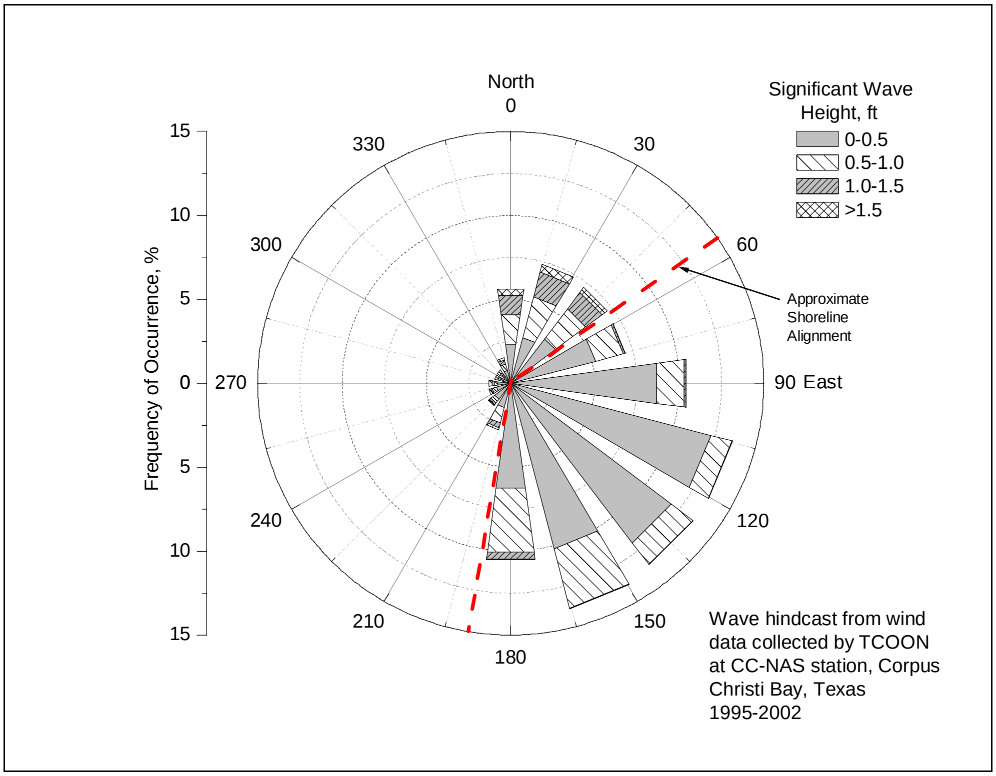


Figure 6 - Wave Rose

DESIGN CONSIDERATIONS

The creation of 15.6 acres SAV through the construction of breakwaters is intended to be achieved by establishment of calm areas, or shadow zones, in the lee of the structures. As waves impact the structures, they will begin breaking, thereby dissipating wave energy. The reduction in wave energy creates a shadow zone where wave energy and wave-induced currents are greatly reduced. This, in turn, decreases turbidity, which allows a higher percentage of sunlight to penetrate to the bay bottom. The combination of these effects is expected to promote the colonization and spreading of seagrass that exists but is sparse along the shallow shelf surrounding the island.

To determine the potential area in which seagrass may colonize and expand, the limits of the shadow zones were considered. The limits of the effective shadow zone also require a wave height threshold, under which seagrass is expected to grow. Based on observations on the effects of other breakwater projects and the colonization of seagrass in low energy areas, the critical wave height limit is estimated at 1.0 foot. Therefore, the shadow zones will be defined by the areas in which waves are consistently below this limit. This assumption is based upon seagrass colonization in the lee of the existing geotextile tube breakwaters.

The other mitigation requirement was to protect Shamrock Island as a rookery. This requirement can be accomplished through the construction of the breakwaters as well. The reduction in wave energy in the lee of the structures reduces the potential for erosion to the shoreline, thus helping to preserve the island.

The effect of tides on waves and constructability should also be taken into account during project design. High tides can allow increased wave energy to overtop the proposed breakwaters. In addition, low tides and structure placement in shallow water can place limits on constructability of the project.

WAVE MODELING

To simulate the wave conditions, the performance of the proposed breakwaters, and the resulting shadow zones at Shamrock Island, wave modeling was performed. The software used for this evaluation was **STWAVE** (**ST**eady State spectral **WAVE**). This modeling program simulates nearshore wind-wave growth and propagation. STWAVE also includes wave characteristics such as depth-induced wave refraction and shoaling, current-induced refraction and shoaling, depth- and steepness-induced wave breaking, diffraction, wave growth because of wind input, and wave-wave interaction and white capping that redistribute and dissipate energy in a growing wave field (Smith et al. 2001 and USACE, website).

The wave refraction and diffraction components of the model are particularly important to the Shamrock Island project. These components describe how waves lose energy and bend around the structures as they approach shore. Knowing these details allows for a better definition of the calm areas or shadow zones that occur in the lee of the proposed breakwaters. Although the diffraction simulation in STWAVE is limited, the results are useful in determining the shadow zones. It is within these areas that seagrass colonization is expected to occur.

Bathymetry: Various data sets were used to provide a representation of the bay and Shamrock Island. A large scale data bathymetric set for Corpus Christi Bay was obtained from the Coastal Relief model series prepared by the National Geophysical Data Center (NGDC), which is a part of the National Oceanic and Atmospheric Administration (NOAA). Bathymetric data used in the Coastal Relief model series were compiled from hydrographic surveys conducted by the National Ocean Service (NOS) and from various academic institutions (NGDC website). The compiled data were placed into a terrain model and the results were provided in a grid with data points spaced approximately 550 feet apart. The large grid spacing provided adequate coverage for the large scale bay area, however, more detailed bathymetry was required in the project vicinity.

To provide more precision to the wave modeling a hydrographic survey conducted by Shiner Moseley in June 2004 was included in the bathymetric data set. This survey included nominal 1000-foot long transects spaced approximately 500 feet around the entire island. Because the survey was performed during bird nesting season, nearshore and beach profile surveys were not performed. This created a data gap in the nearshore region, which was partially filled using data from the Shiner Moseley's 1998 pre-GT survey. In the areas where data were not available from the 1998 survey, spot elevations were created based upon linear interpolation of the nearshore slope. The existing GTs were not included in the data set as they are not expected to perform as breakwaters,

Wind and Wave Conditions: Based on the climatic data for Shamrock Island presented above, the predominant waves that will affect the shoreline are wind generated and fetch dependent. In addition, the predominant wind directions that will create chronic wave conditions along the northern shoreline were determined to occur from the 0° to 56.25° directions. There are significant winds that occur from more easterly and southerly directions; however, due to the orientation and location of the proposed breakwaters and the small fetch, no significant waves are anticipated in the project area from these winds.

Wind generated wave heights are dependent upon wind speeds, with greater wind speeds creating larger waves. A review of the wind statistics described above indicated that the wind speeds with significant, or chronic, percentages of occurrence are in the 20 to 25 mph range. To be conservative within the model, a wind speed of 30 mph was used to generate the waves from the predominant directions. The initial wave heights along the model boundary for Corpus Christi Bay were set to zero at the start of the model, and winds were applied to the bay water surface.

Tide Conditions: The changes in water level within the bay can vary significantly during the year. The higher water levels will allow larger waves to be transmitted over and around the proposed breakwaters, which results in larger waves in the lee of the structures and on the shoreline. A review of the tide data shows that water levels reach +2.5 feet MLT approximately 12% of the time, with higher water levels occurring significantly less frequently. This higher water level also tends to occur during periods of strong winds from the north to northeast directions. Therefore, this higher water level should be included in the model. To be conservative in the modeling, a water level of +3.0 feet MLT was utilized.

STWAVE does not include wave transmission over or through the breakwaters. However, given the conservatism imposed by the application of a 30 mph wind speed and +3.0 ft MLT tide, exclusion of wave transmission was judged acceptable.

Model Grids: To model the wave generation across Corpus Christi Bay as described above, a large grid was created (Figure 7). Based on the fairly uniform depths that occur across the bay, a grid cell spacing of 50 meters (approx. 150 foot) was determined to provide adequate coverage and minimal computational time. Within this large grid, waves were generated by the winds and propagated to the project site.

To provide increased detail of the wave characteristics and proposed breakwaters within the area of interest at Shamrock Island, smaller, or nested grids, with a finer grid spacing of 2 meters (approx. 6.5 feet) were created. The input for the nested grids was generated by the large grid. The finer spacing allows for the inclusion of narrow structures and provides better detail of the wave behavior.

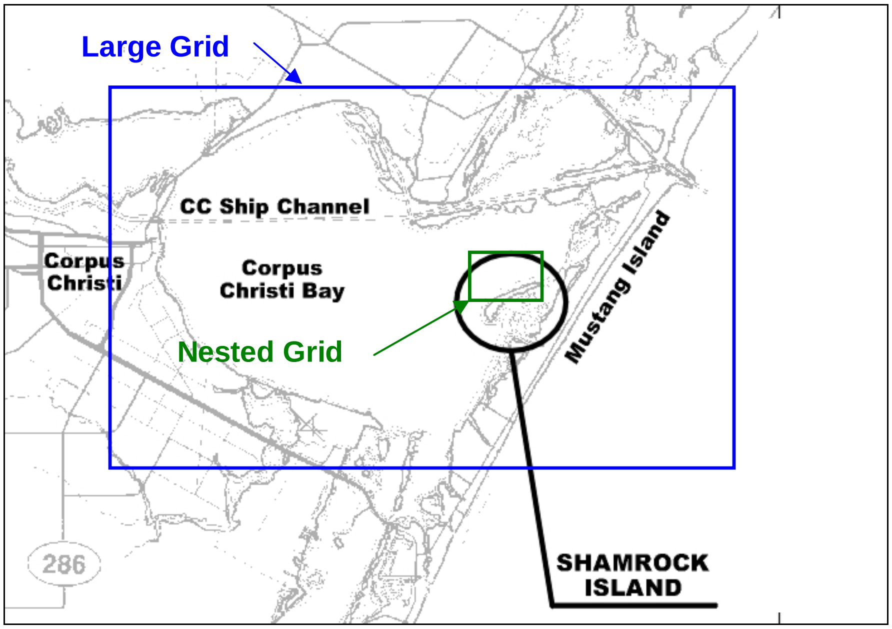


Figure 7 – Model Grid Limits

Model Simulations and Results

STWAVE model runs were performed for various breakwater configurations and wind directions. To protect the entire northern portion of the island, a conceptual master plan was proposed consisting of a series of offshore rock breakwaters from the middle of the western shore to the northeastern shoreline. However, current budget limitations will accommodate only six to seven breakwater segments. To identify which breakwaters were included in the different model simulations, an identification number was assigned and is shown in Figure 8. For each simulation, the model was run for a large grid that encompassed all of Corpus Christi Bay. These model runs provided the input conditions for the nested grid simulations described below. The resulting 1 foot wave height contour was then utilized to delineate the shadow zone. Table provides a summary of the results.

Simulation 1: This simulation consisted of the 7 breakwaters numbered 9 through 15. The model results showed that the continually protected area with waves under 1 foot were defined by the 0° incident waves at the western edge of the breakwaters and 45° incident waves at the eastern edge of the breakwaters. A summary of the 1 foot wave height contours is provided in Figure 9. The total shadow zone, or sheltered area was approximately 26.4 acres and is designated by the hatched area in the figure. Within this area lies some existing seagrass, and when this area is removed from the sheltered area, 21.3 acres remain. The model results also indicate that the area of the island breach should be significantly protected from chronic wave action, however, this area will still be open to episodic high wave energy that originates from the westerly directions.

Simulation 2: This simulation consisted of only 6 breakwaters, with breakwater #9 removed from the previous model run. The results shown in Figure 10 indicate that the total sheltered area would be approximately 21.8 acres. Considering existing seagrass, the sheltered area would be adjusted to 16.8 acres, which is still above the required 15.6 acres. The removal of breakwater 9 brings the edge of the sheltered area nearer to the breach area; however, the area is still within the shadow zone and should be protected from large waves from the north to northeast.

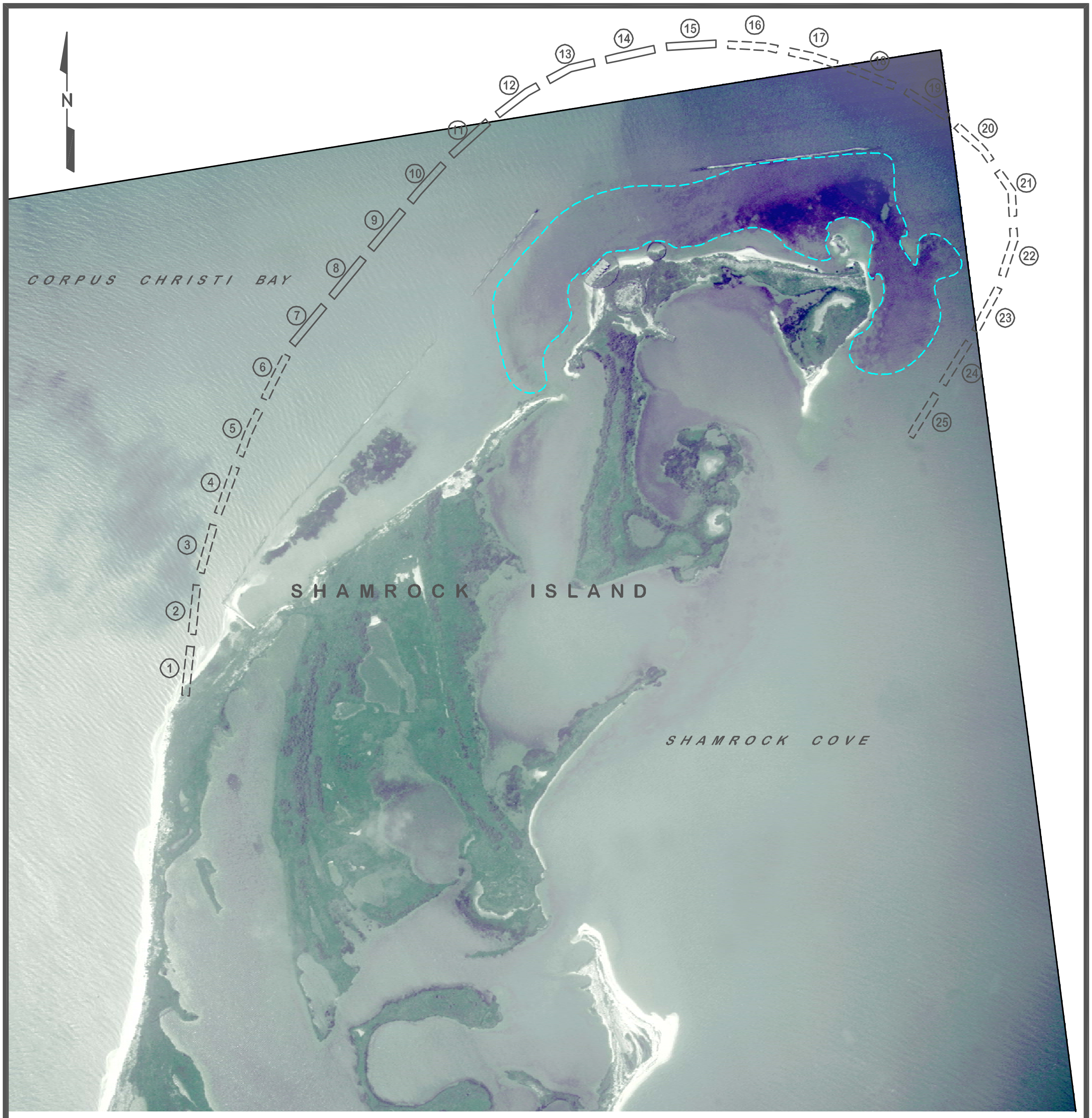
Simulation 3: A review of the previous two simulations indicated that the easterly limit of the shadow zone was very close to the edge of the northwest corner of the island. Therefore, to provide increased protection to this area, the breakwater configuration was shifted slightly to the east. Simulation 3 included 7 breakwaters from number 10 through number 16. The model results shown in Figure 10 indicated that the northwester corner of the island should be should be better protected and the breach area was also still located within the shadow zone. The total sheltered area within the shadow zone was approximately 26.0 acres (20.1 after subtracting existing seagrass).

Simulation 4: As with Simulation 2, the number of breakwaters was reduced to 6, with breakwater #10 being removed from the simulation. Figure 11 shows that the breach area and northwest corner of the island remain within the sheltered area. The acreage of the sheltered area was 21.4 acres. After subtracting the existing seagrass area, the sheltered area was only 15.6 acres, which is just at the limit for the proposed mitigation project.

Table 1 – Simulation Summary

Simulation	No. of Breakwaters	Total Sheltered Area (acres)	Sheltered Area less Seagrass[1] (acres)	Approx. Length of Protected Shoreline (ft)
1	7	26.4	21.3	1,350
2	6	21.8	16.8	1,050
3	7	26.0	20.1	1,200
4	6	21.4	15.6	1,050

1. Seagrass area based upon June 2004 aerial.



LEGEND:

① BREAKWATER IDENTIFICATION

- - - - BREAKWATER OUTLINE

LAYOUT PLAN

0 300' 600'

NOTE:

1. BACKGROUND IMAGE IS A JUNE 2004 AERIAL PHOTOGRAPH BY LANMON AERIAL PHOTOGRAPHY, INC.

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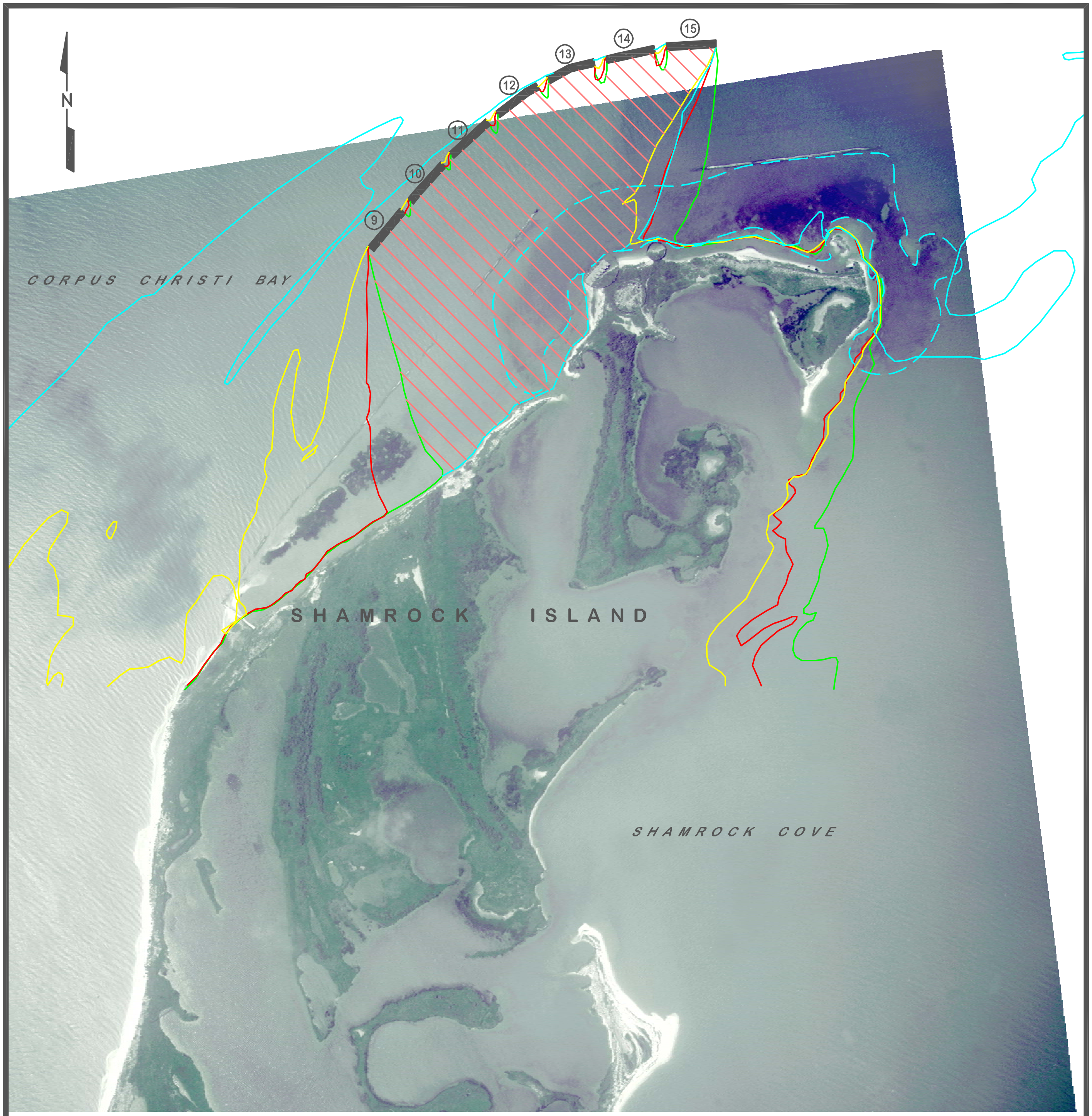
LAYOUT PLAN

SHAMROCK ISLAND

FIGURE 8



LEGEND:

①	ROCK BREAKWATER IDENTIFICATION
▬	ROCK BREAKWATER
– – –	SEAGRASS DELINEATION
—	0.0 DEGREE INCIDENT WAVES
—	22.5 DEGREE INCIDENT WAVES
—	45.0 DEGREE INCIDENT WAVES
—	56.25 DEGREE INCIDENT WAVES

WAVE ANALYSIS

0 300' 600'

NOTE:

1. BACKGROUND IMAGE IS A JUNE 2004 AERIAL PHOTOGRAPH BY LANMON AERIAL PHOTOGRAPHY, INC.
2. SIMULATION LINES ARE 1 FOOT WAVE HEIGHT CONTOUR.
3. TOTAL SHELTERED AREA = 26.35 ACRES
4. SHELTERED AREA LESS EXISTING SEAGRASS = 21.34 ACRES

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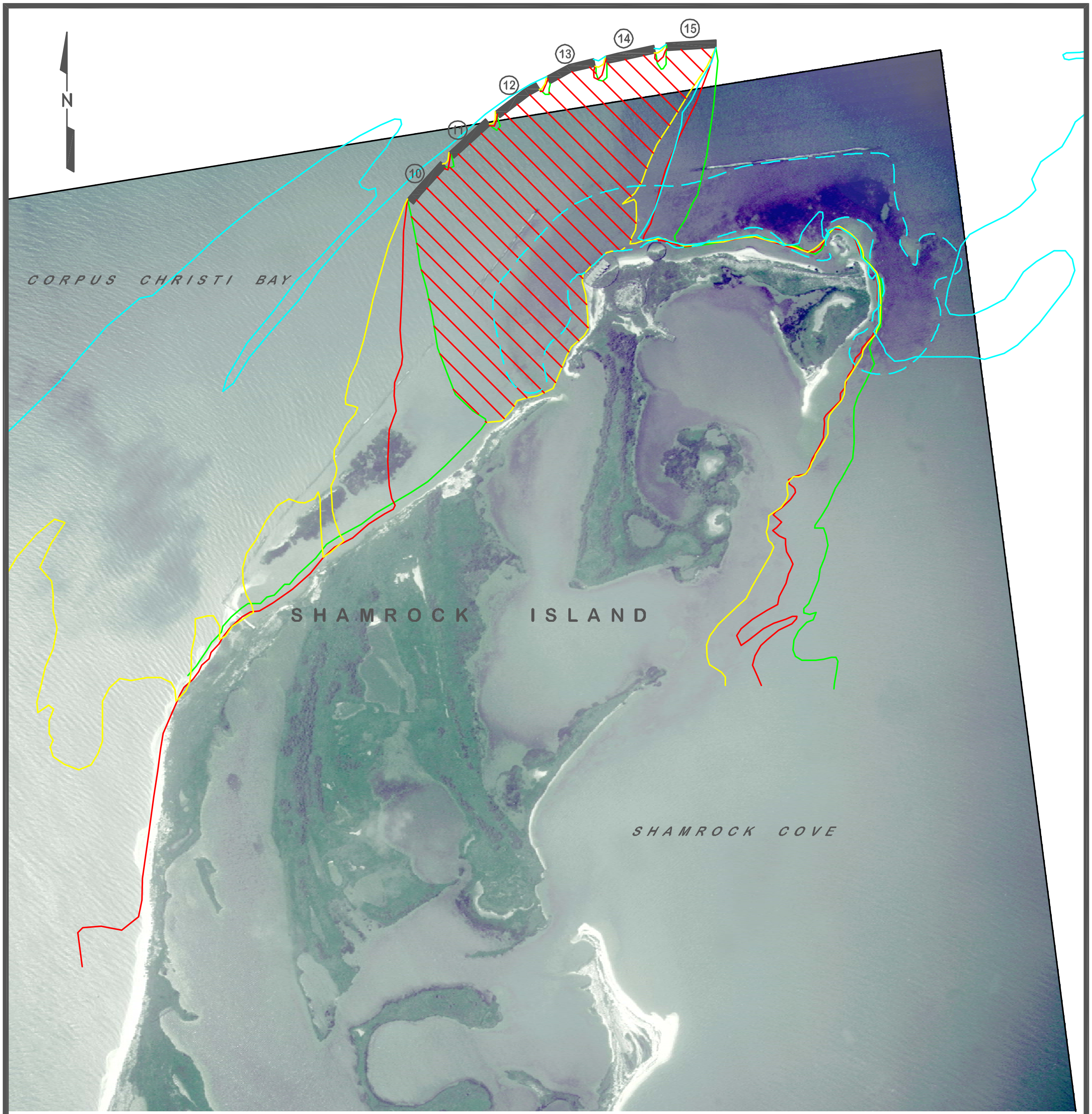
SHAMROCK ISLAND

SIMULATION 1

FIGURE 9



LEGEND:

①	ROCK BREAKWATER IDENTIFICATION
▬	ROCK BREAKWATER
– – –	SEAGRASS DELINEATION
—	0.0 DEGREE INCIDENT WAVES
—	22.5 DEGREE INCIDENT WAVES
—	45.0 DEGREE INCIDENT WAVES
—	56.25 DEGREE INCIDENT WAVES

WAVE ANALYSIS

0 300' 600'

NOTE:

1. BACKGROUND IMAGE IS A JUNE 2004 AERIAL PHOTOGRAPH BY LANMON AERIAL PHOTOGRAPHY, INC.
2. SIMULATION LINES ARE 1 FOOT WAVE HEIGHT CONTOUR.
3. TOTAL SHELTERED AREA = 21.84 ACRES
4. SHELTERED AREA LESS EXISTING SEAGRASS = 16.82 ACRES

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SIMULATION 2

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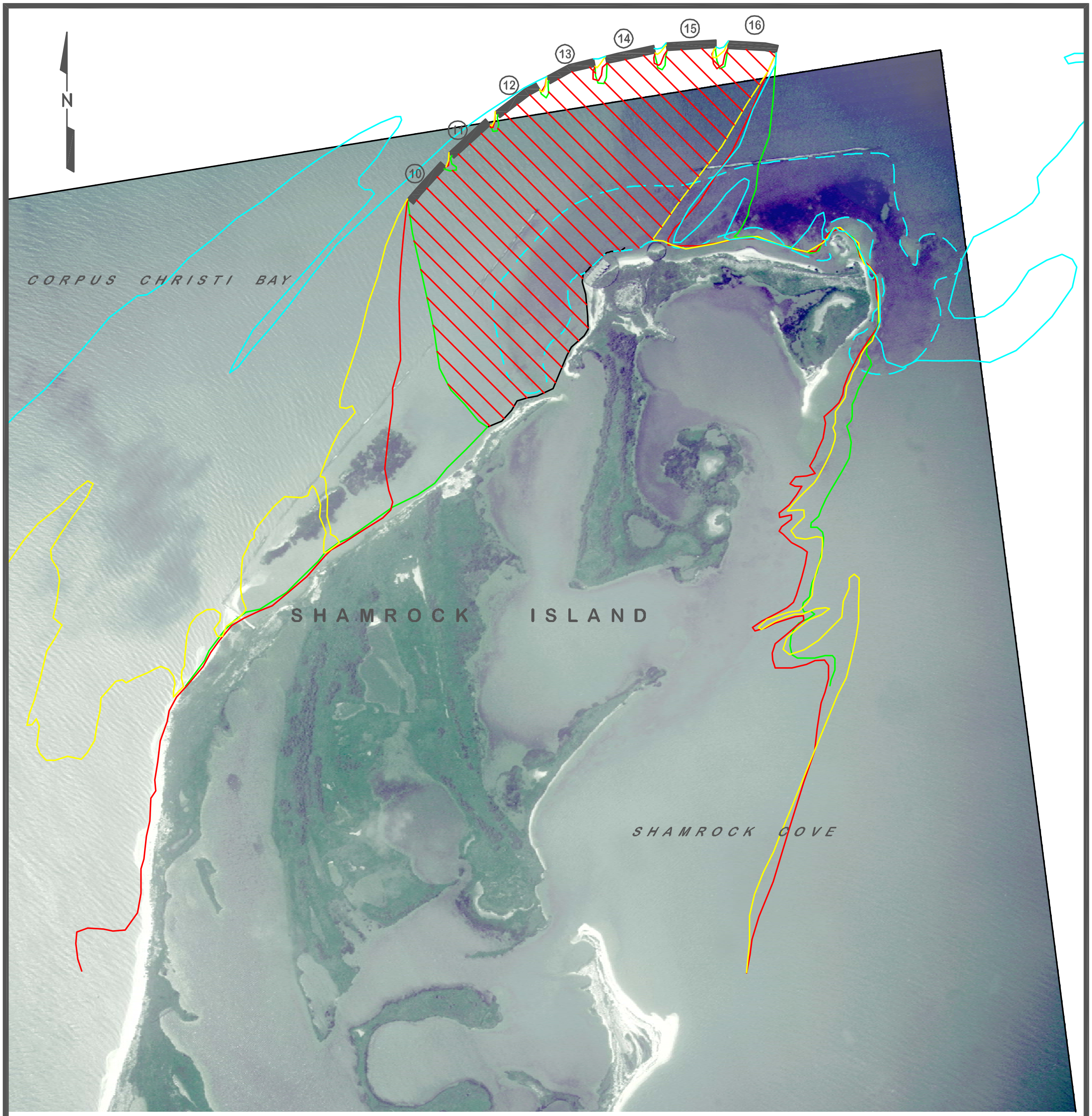
FIGURE 10



LEGEND:

①	ROCK BREAKWATER IDENTIFICATION
▬	ROCK BREAKWATER
— — —	SEAGRASS DELINEATION
——	0.0 DEGREE INCIDENT WAVES
——	22.5 DEGREE INCIDENT WAVES
——	45.0 DEGREE INCIDENT WAVES
——	56.25 DEGREE INCIDENT WAVES

WAVE ANALYSIS

0 300' 600'

NOTE:

1. BACKGROUND IMAGE IS A JUNE 2004 AERIAL PHOTOGRAPH BY LANMON AERIAL PHOTOGRAPHY, INC.
2. SIMULATION LINES ARE 1 FOOT WAVE HEIGHT CONTOUR.
3. TOTAL SHELTERED AREA = 25.96 ACRES
4. SHELTERED AREA LESS EXISTING SEAGRASS = 20.12 ACRES

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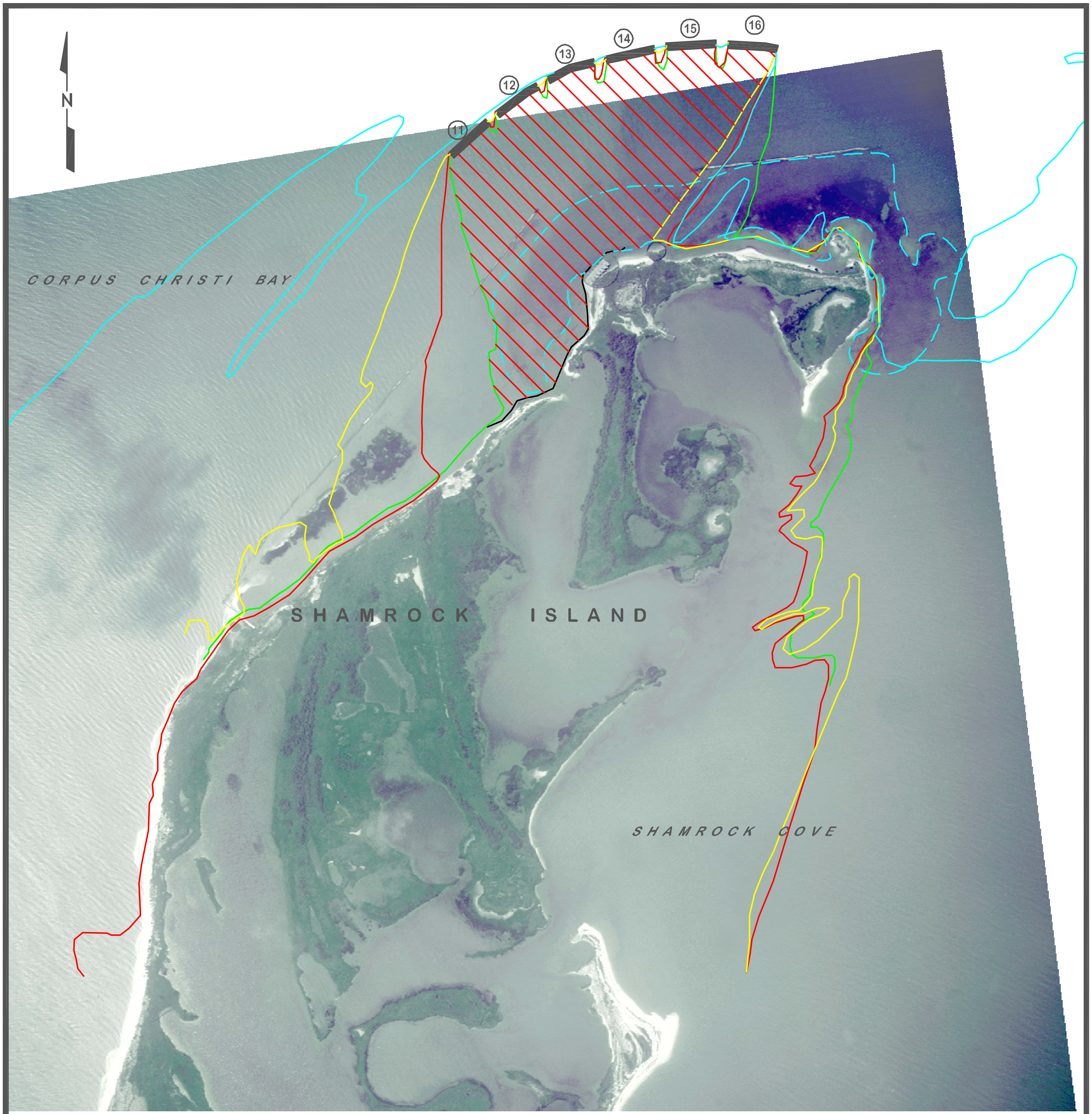
SIMULATION 3

FIGURE 11



LEGEND:

①	ROCK BREAKWATER IDENTIFICATION
▬	ROCK BREAKWATER
– – –	SEAGRASS DELINEATION
─	0.0 DEGREE INCIDENT WAVES
─	22.5 DEGREE INCIDENT WAVES
─	45.0 DEGREE INCIDENT WAVES
─	56.25 DEGREE INCIDENT WAVES

WAVE ANALYSIS

0 300' 600'

NOTE:

1. BACKGROUND IMAGE IS A JUNE 2004 AERIAL PHOTOGRAPH BY LANMON AERIAL PHOTOGRAPHY, INC.
2. SIMULATION LINES ARE 1 FOOT WAVE HEIGHT CONTOUR.
3. TOTAL SHELTERED AREA = 21.39 ACRES
4. SHELTERED AREA LESS EXISTING SEAGRASS = 15.55 ACRES

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SIMULATION 4

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FIGURE 12

CONCLUSIONS AND RECOMMENDATIONS

- The numerical model STWAVE was utilized to develop local fetch limited waves at the project site and to determine the shadow zones (sheltered areas) created by the proposed breakwaters. The modeling results aided in optimization of the project design to provide the most SAV and shoreline protection within the construction budget. The wave model was also utilized to determine the shadow zones or areas of influence of adjacent projects.

- The breakwater layout presented in Simulation 2 was recommended for the base project design. These breakwaters are numbers 10 though 15. After deducting the estimated limits of existing seagrass, this layout is expected to provide 16.8 acres of sheltered area in which SAV should colonize.

- Additional breakwaters will be included as additive bids in the project design. Should rock costs be lower than estimated, additional breakwaters can be constructed within the project budget. This will result in an increase in sheltered area.

- Due to shallow that may interfere with construction access depths at the proposed breakwater locations, timing of the project will be an important factor when bidding and constructing the work. The tides can vary significantly due to seasonal effects. The best time to construct the project is during the higher tide events that occur in either the Fall (September to November) or in the Spring (April through June). The increased water level will allow barges with larger loads access to the site, which in turn should reduce the rock price by reducing transportation and re-handling cost

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