PLANNING AND CONSTRUCTION OF SHORE PROTECTION AT SHAMROCK ISLAND, TEXAS: PROJECT UPDATE

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ABSTRACT

Shamrock Island is a private nature preserve located along the eastern shoreline of Corpus Christi Bay, Texas, approximately 2 miles west of Mustang Island. The island interior is uninhabited and is heavily vegetated with a series of lagoons and wetlands. The island serves as an ecologically important rookery to a number of nesting bird species, in particular, the royal tern. This habitat has recently come under threat, losing over 25% of its surface area to erosion since 1956.

To address erosion of the island and to create potential seagrass areas, a conceptual master plan was developed. This plan consisted of a series of 25 low-crested detached rock breakwaters to protect the northern half of the island, along with two small beach nourishment projects along the southern and western shorelines. The conceptual master plan incorporated mitigation requirements of the U.S. Army Corps of Engineers (USACE) nearby project at Packery Channel. The mitigation project 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.

Several of the proposed breakwaters are being used to meet the mitigation project goals because of their ability to create areas of calm water which will help protect the shoreline and decrease turbidity in areas where seagrass is expected to colonize. Numerical wave modeling and updated seagrass surveys were utilized to determine that a minimum of 7 breakwaters from the conceptual master plan were needed to achieve the 15.6 acres of SAV. The modeling results were also used to show how the habitat protection areas for varying breakwater segments of the overall master plan could be delineated and quantified. This benefit mapping and having an established master plan for the entire island has helped attract additional mitigation projects which are expected to complete the overall master plan. One additional mitigation project was added into the current project and another has recently received its USACE permit.

Construction of the initial phase of the master plan was bid in June 2005 with six base bid breakwaters and three alternates. Bid results accommodated the construction of all nine breakwaters, which is expected to provide enough sheltered area to exceed the project mitigation goals. Two additional breakwaters were added as mitigation for a local

pipeline project, bringing the construction total to eleven. Construction began in late December 2005 and was completed in January 2006.

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 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. The island formed as a series of spits that were connected to Mustang Island; however, dredging, hurricanes and erosion have severed the "land bridge" that connected the spit to land. As a result there is no longer a significant sediment source for the island which has caused continued chronic erosion of the island.

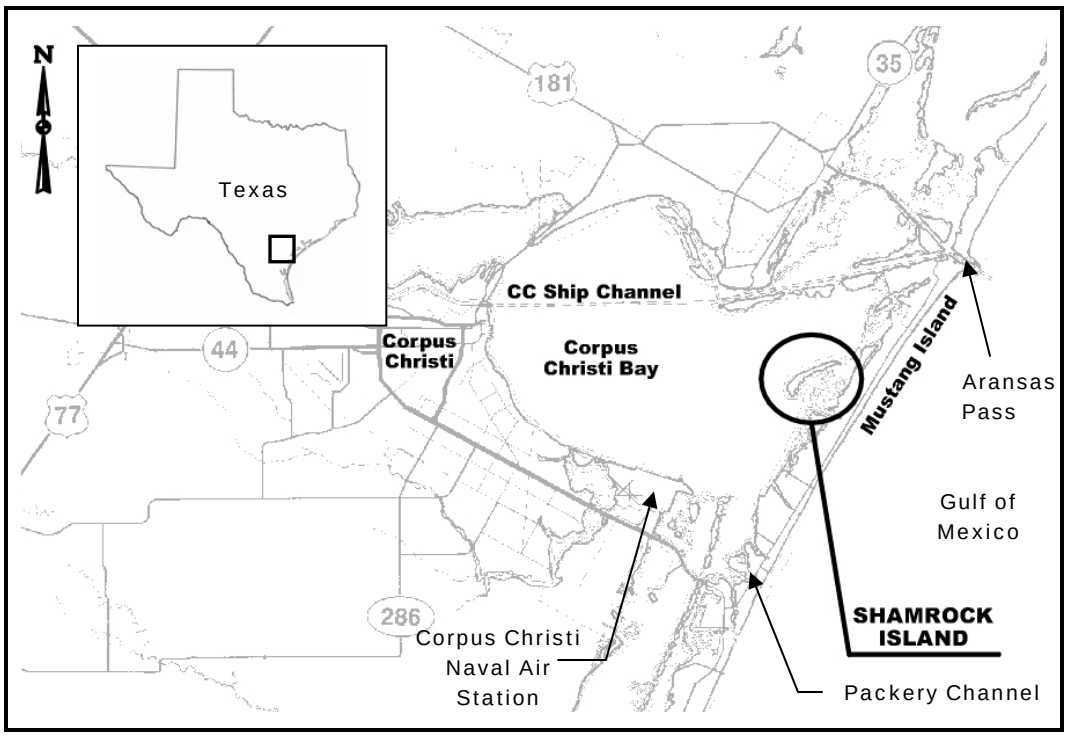

Figure 1 – Location Map

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 2. 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.

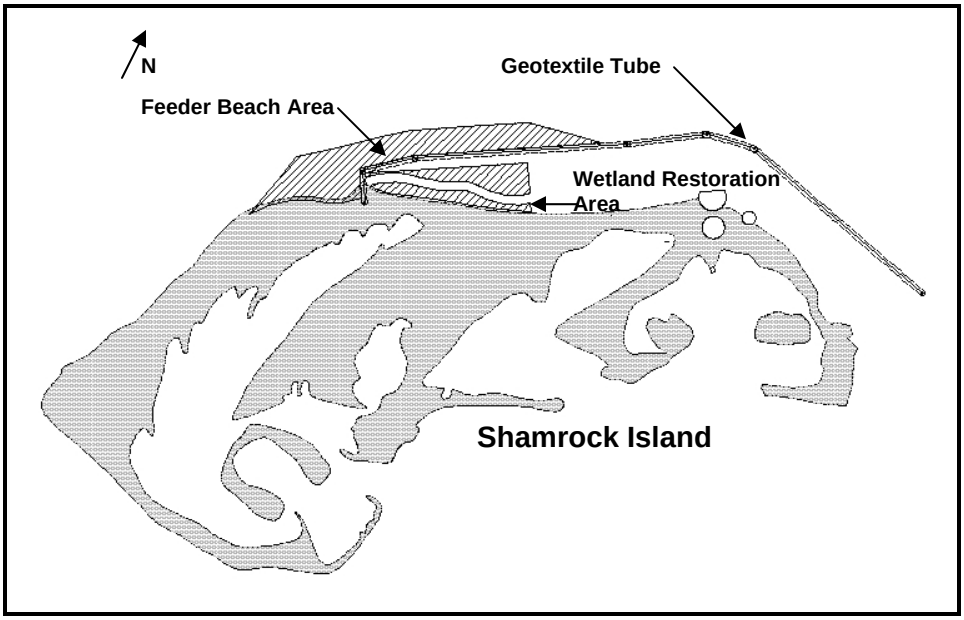

Figure 2 – 1998 Project

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 Figure 3, 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 show 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 are 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.

Waves: Wave conditions were developed through a wave hindcast based on the measured wind speeds described above and the associated fetch. The larger waves at the site propagate from the north through northeast directions with a largest significant wave height of 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.

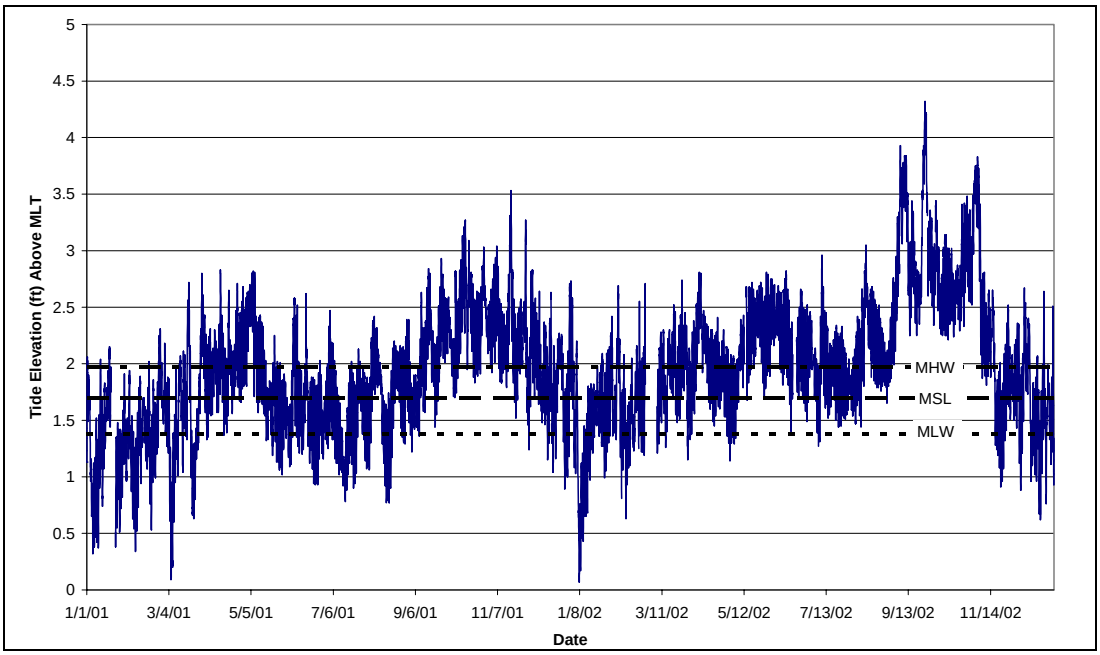

Figure 3 – Tide Elevations for CC-NAS Station, 2001-2002

CURRENT PROJECT DESIGN CONSIDERATIONS

The feeder beach constructed in 1998 has surpassed 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 USACE 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 Coastal Bend Bays and Estuaries

Program (CBBEP), Texas Center for Environmental Quality, Texas Parks & Wildlife, U.S. Fish & Wildlife, the Nature Conservancy, Texas General Land Office (TGLO), and the USACE. The island is owned by the Nature Conservancy.

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 were 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: A large scale bathymetric data set for Corpus Christi Bay was obtained from the Coastal Relief model series prepared by the National Geophysical Data Center, which is a part of the National Oceanic and Atmospheric Administration. Typical depths in Corpus Christi Bay range from five to twelve feet. This information was combined with a hydrographic survey conducted by Shiner Moseley in June 2004. In the areas where data were not available spot elevations were created based upon linear interpolation of the nearshore slope.

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° true north directions with speeds 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 initiation 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 4), with a grid cell spacing of 50 meters (approx. 150 feet). 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.

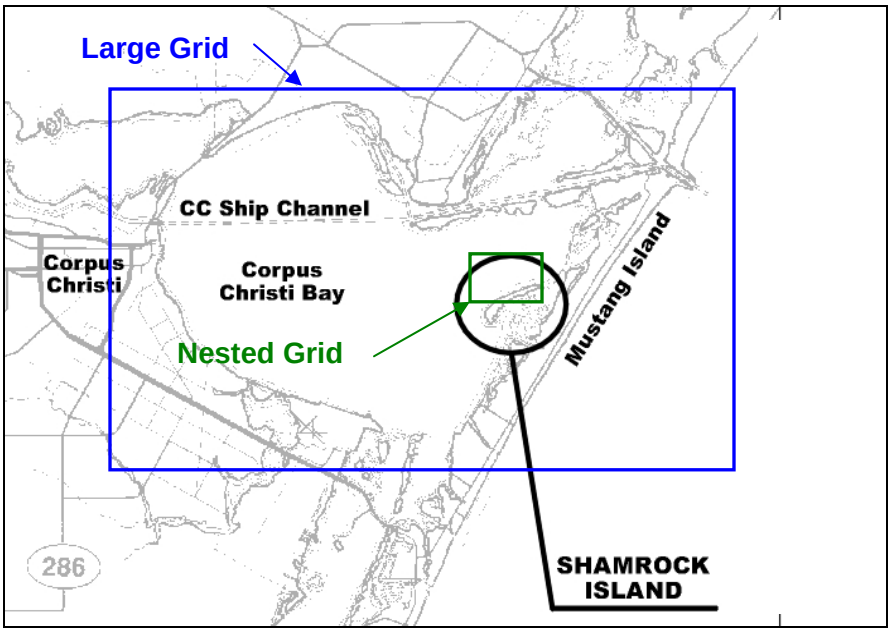

Figure 4 – Model Grid Limits

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 25 offshore rock breakwaters from the middle of the western shore to the northeastern shoreline. However, it was anticipated that budget limitations would accommodate only 6 to 7 breakwater segments. To identify which breakwaters were included in the different model simulations, a breakwater identification number was assigned and is shown in Figure 5. For each simulation, the model was run for the large grid that encompassed all of Corpus Christi Bay and the local nested grid. The resulting 1 foot wave height contour was then utilized to delineate the shadow zone.

From the various scenarios using 6 and 7 breakwaters and the limits of the shadow zones, it was determined that Simulation 2 (breakwaters 10 through 15) provided the best shoreline protection and potential SAV area within the project budget. Table 1 provides a summary of the results.

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 (BW9-15)	7	26.4	21.3	1,350
2 (BW10-15)	6	21.8	16.8	1,050
3 (BW10-16)	7	26.0	20.1	1,200
4 (BW11-16)	6	21.4	15.6	1,050

1. Seagrass area based upon June 2004 aerial.

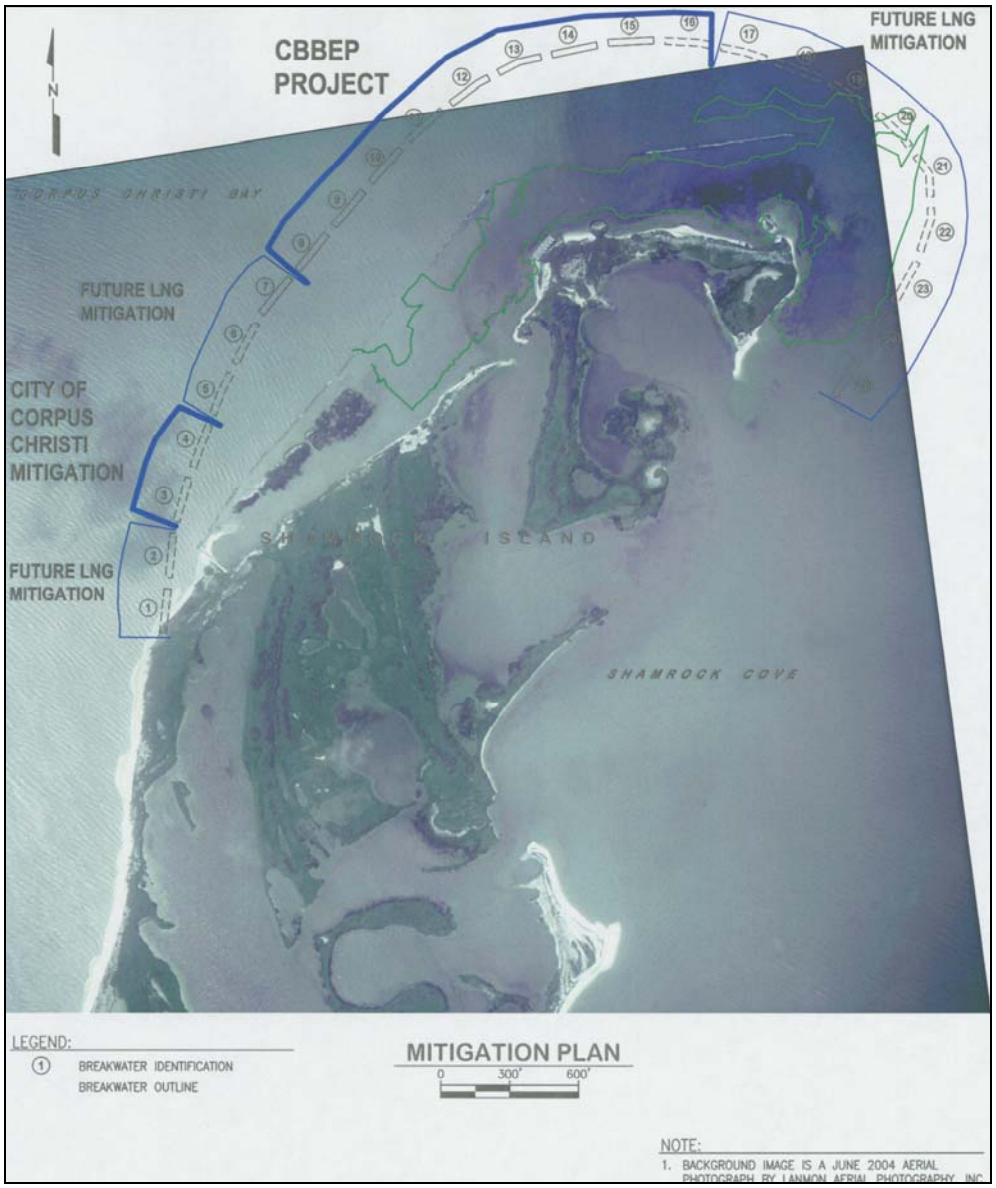

Figure 5 – Conceptual Master Plan Layout

However, the results shown in Table 1 were based on an aerial photograph, and to further determine the potential SAV area, Shiner Moseley biologists conducted a seagrass survey on October 28, November 8, and November 9, 2004. The resulting delineation showed that the actual existing seagrass area was more extensive than that delineated using aerial photography. As a result, there was a reduction in SAV area from the Simulation 2 shadow zone of 16.8 acres to 13.6 acres, which is below the required 15.6 acres.

The use of the layout shown in Simulation 3 (Figure 6), which included the addition of a seventh breakwater on the northeast side of the project, would be likely be required to meet the project goals. Considering the modeling results for this alternative and the recent seagrass survey, the SAV creation area is expected to be 16.9 acres, which exceeds the required 15.6 acres.

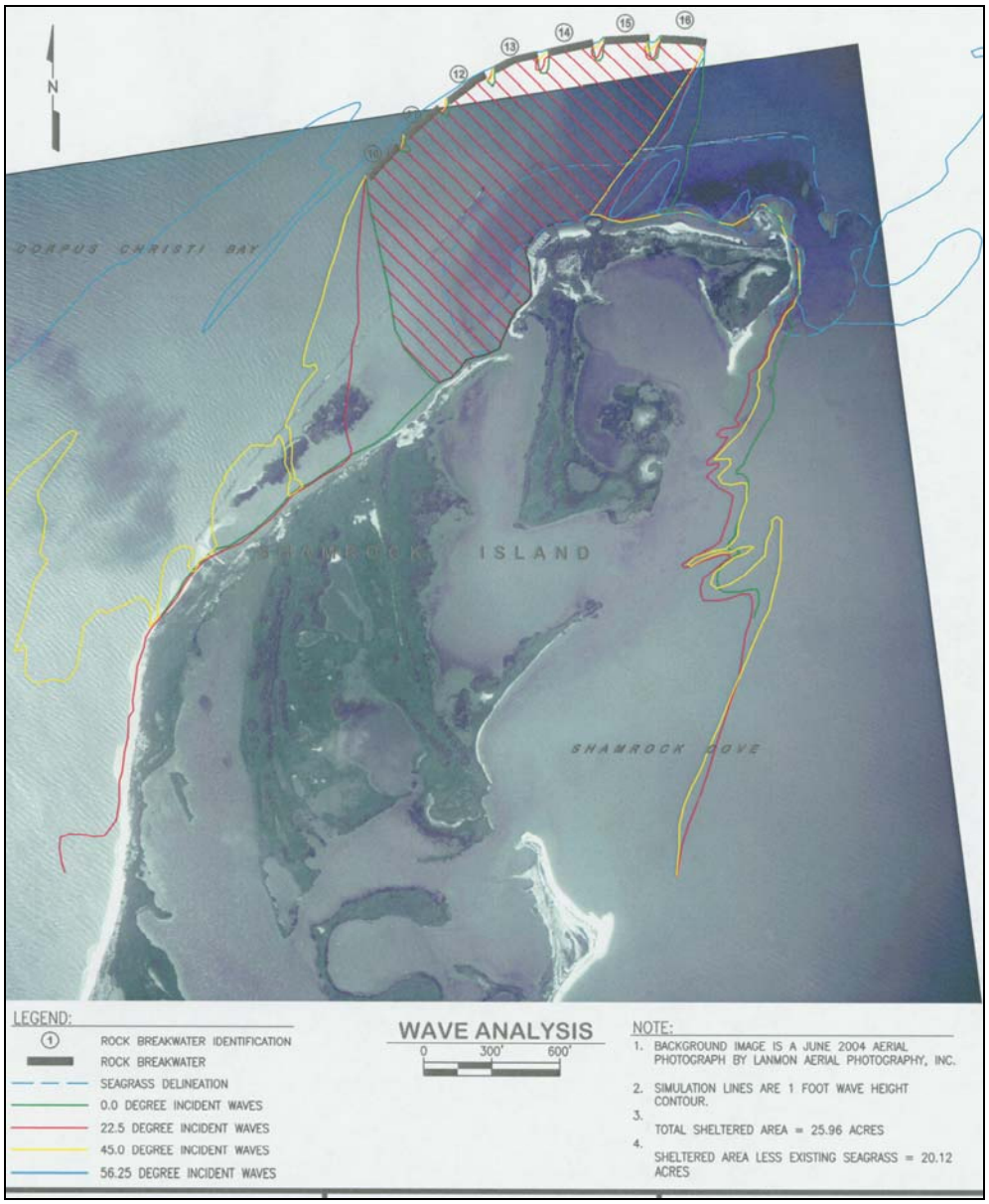

Figure 6 – Simulation 3 Results

Based on discussions by the Team and regulatory agencies, the ability to determine the influence area of this project as well as any potential future mitigation projects is a concern. To address influence areas of other projects, a simulation of a future mitigation project immediately adjacent to the proposed mitigation project was performed. To evaluate the effects of each project separately, the simulation was performed without the current proposed project. A six breakwater project extending from breakwater 17 to 22 was modeled with the same input as the other simulations. The resulting 1 foot wave height contours were traced to determine the shadow zone for this project. The combination of this potential future mitigation with the current proposed project shows that there is now an additional area of protected area that is outside each project's

individual shadow zone, as shown in Figure 7. This additional area is an extra benefit resulting from extending the current project through additional mitigation opportunities by others

PROJECT DESIGN

Design parameters, as described previously, dictated that the breakwaters would be low crested and that overtopping during strong seasonal storms was acceptable. A review of tide records, wave heights, and geotechnical properties led to the establishment of a crest height of +3.5 ft MLT. The structure locations approximately followed the -2.0 ft MLT contour, which was the minimum depth in which light-loaded barge based construction was expected to occur. The breakwater segments were 200 feet in length, with 50 ft gaps and 2H:1V side slopes. The stone sizing analyses determined that a modified USACE 2200# gradation, as shown in Table 2, would be sufficient. The project design also allowed for the use of the project specific rock gradation (Table 3) for core stone at the ongoing nearby Packery Channel project. This was done to allow for potential cost savings on rock.

Table 2 - USACE 2200# (Modified) Gradation

Weight (lbs)	% Lighter
900 – 2000	100
500 – 930	50
130 – 460	15
75 - 130	5

Table 3 - Packery Channel Gradation

Weight (lbs)	% Lighter
2,000	100
1,000 – 2,000	25
200	10

The construction budget for the project was approximately $850,000, which dictated the number of breakwaters possible. Conceptual-level opinions of probable cost showed that six breakwaters could conservatively be constructed within the current budget. To achieve the seventh breakwater if bid prices exceeded the original budget, additional funds would be required, if available. Therefore, the project was designed with a base of six breakwaters and three additives to help ensure that a minimum of six breakwaters could be built without the need to re-bid the project.

ADDITIONAL MITIGATION PROJECTS

Pursuant to the modeling results which showed that additional mitigation projects could have their specific benefits or impacts assessed, additional mitigation partners were sought. The City of Corpus Christi is constructing a pipeline crossing across a portion of the southern end of Corpus Christi Bay. This project will incur some seagrass impacts and to mitigate for these impacts, the City has permitted and agreed to provide funding for two additional breakwaters at Shamrock Island as a part of the current project.

There are also plans to construct a LNG terminal in Corpus Christ and its construction will also result in the need for mitigation. The partners in this project have currently completed permitting of the remaining breakwater sections in the conceptual master plan.

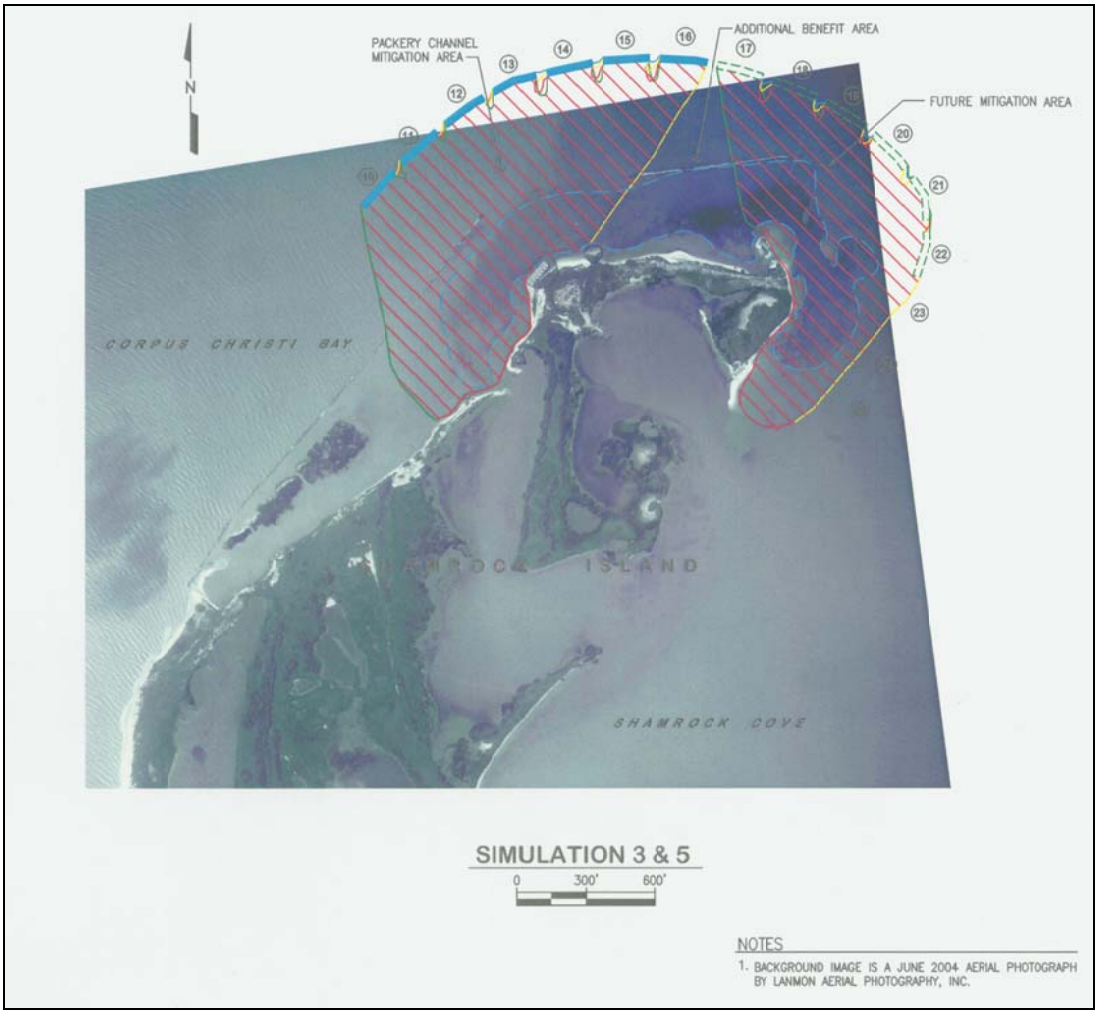

Figure 7 – Additional Mitigation Influence Area

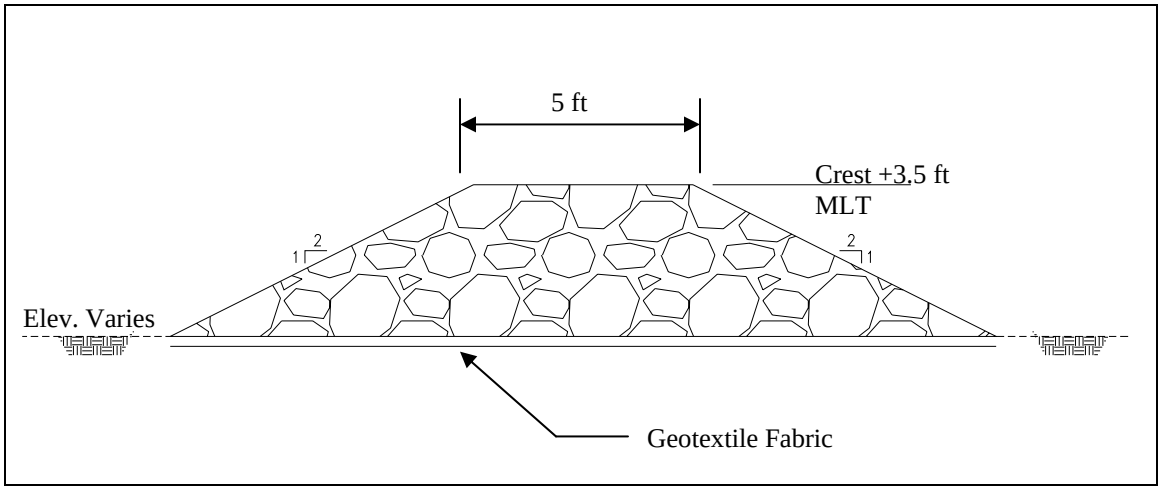

Figure 8 – Typical Breakwater Section

These additional projects will finish the breakwater construction and provide valued SAV habitat and protection of the Shamrock Island shoreline. A graphical summary of the additional mitigation commitments is shown in Figure 5.

CONSTRUCTION

The project design was completed in early 2005, however, the bird nesting season for migratory birds began on February 15, 2005. Therefore, instead of seeking a variance to allow construction during nesting season, it was decided to wait until the end of the nesting season on September 1st when there would also be significantly deeper water due to the seasonal high tides. The project was bid in June 2005 and the contract was awarded to Luhr Bros., Inc. in mid-August with a Notice to Proceed (NTP) on September 2, 2005. The bid prices were such that all 9 breakwaters were awarded with a construction cost of $866,500, which was just within the project budget. A 150 day construction window was granted for the project to give the contractor flexibility considering other commitments in the area.

The timing of the award and NTP, however, coincided with the landfalls of the destructive hurricanes Katrina and Rita along the Louisiana and Texas coasts. As a result, the contractor was called upon to help perform marine work in the New Orleans and Louisiana area in the aftermath of the storms. This work delayed the start date of the Shamrock Island project.

The project was further delayed by the need to perform extensive magnetometer and gradiometer surveys within the project and ingress/egress areas. Shamrock Island and much of Corpus Christi bay are surrounded by oil and gas production wells and processing facilities. As a result, a large number of live and inactive pipelines are located within the project area and these pipelines needed to be thoroughly mapped before bringing equipment into the shallow waters of the site and spudded down.

The project began rock placement on December 26, 2005 and continued through January 13th, 2006. Due to the shallow water, a barge “roadway” was constructed (Figure 9) that consisted of three barges tied together with an excavator to place the rock on one end, and a light loaded rock barge at the other. In between, a front end loader placed rock into a dump truck that delivered rock from the rock barge to the excavator. A smaller barge was used to lay the geotextile fabric in front of the rock barges. This method proved highly successful and progress was swift, even with multiple handling of the rock.

The two additional breakwaters (No. 3 and No. 4 of the overall conceptual master plan) for the City of Corpus Christi were authorized as construction of the CBBEP project was commencing. A review of the original conceptual layout showed that the breakwater alignment shifted from the -2.0 ft MLT contour and eventually connected to the shore. Concerns over potential downdrift impacts and shallow water depths in the proposed breakwater locations led to a revision of the design. The layout was revised to follow the -2.0 ft MLT contour similar to the other breakwaters. Field verification and onsite

engineering allowed for a redesign and shift of the breakwaters to allow water based construction and maintain project consistency.

Figure 9 - Barge Roadway

Figure 10 - Transfer of rock from barge to truck

Figure 11 - Delivery of rock to placement excavator

Figure 12 - Rock placement and geotextile barge

Figure 13 - Breakwater gap

Figure 14 – Completed breakwaters

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 project was bid with six breakwaters as a base bid and three alternates. The successful contractor, Luhr Bors., Inc., was able to construct all nine breakwaters for a cost of $866,500, which was within the project budget.

- The increase in the number of breakwaters from six to nine should help to increase the success of the SAV mitigation requirements.

- The wave model was also utilized to determine the shadow zones or areas of influence of adjacent projects. This allowed permitting agencies to quantify mitigation benefits for other projects. As a result, one mitigation project is already being implemented (for the City of Corpus Christi) and another has just received its USACE permit.

- The additional mitigation project for the City of Corpus Christi has increased the number of breakwaters to eleven and was constructed in conjunction with the CBBEP project. However, The two breakwaters were shifted offshore of the original proposed location, to reduce downdrift impacts and accommodate construction.

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