Renourishment of Corpus Christi Beach, Texas

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Abstract

In 1978, a major beach nourishment effort that incorporated a unique two-layer beach fill was constructed at Corpus Christi Beach, Texas. A coastal processes assessment was performed to determine the contributing roles of longshore and cross-shore sediment transport to project performance. Although some prior studies concluded that cross-shore transport is the predominant erosion mechanism, evidence developed as part of the present evaluation supports the concept that longshore transport is the predominant mechanism. Other new mechanisms identified included wave reflection from the hull of an aircraft carrier that is permanently berthed at the updrift end of the beach and currents induced by passing ships. A renourishment design was developed and implemented, but incorrect sieve testing by an independent laboratory during construction resulted in placement of imported fill material that contained excessive fines. A remediation effort is underway that will provide a two-layer beach that is similar to the original 1978 project.

Introduction

Corpus Christi Beach is a popular urban recreational area located within the southern portion of the Texas Gulf coast on Corpus Christi Bay (Figure 1). The beach is part of Rincon Point, a natural spit that partially separates Corpus Christi Bay from Nueces Bay, a shallower secondary bay. Corpus Christi Bay is one of the deeper bays on the Texas coast, having an average natural depth of about 12 ft. The tide range at Corpus Christi Beach is approximately 0.6 ft, although strong seasonal influences tend to produce semi-annual variations in water elevation that are much larger than the difference between daily high and low waters (for further discussion, see Ward 1997). Due to the relatively small tide range and shallow depths, Texas bays are dominated by meteorology, especially frontal passages. Averaged annually, Corpus Christi experiences the strongest winds of any city in the continental United States (Williams and Kraus 1999). The prevailing winds are from the southeast, with shifts occurring during fronts that typically cause strong winds from northerly directions. The average annual significant wave height is on the order of 1 ft, although wave heights commonly exceed 3 ft under strong winds (Williams and Kraus 1999; Pacific International Engineering (PIE) 2000).

Prior to 1959, Corpus Christi Beach was referred to as "North Beach," a name that is still commonly applied by local residents. The beach occupies a three-acre area with approximately 1.4 miles of public shoreline and lies immediately across the Harbor Bridge from downtown Corpus Christi. Once one of the most active coastal resorts anywhere on the Gulf coast, the area's popularity began to decline during the 1940s. In the early 1990s, efforts were initiated for revitalization of the area, including opening of the Texas State Aquarium and the berthing of the *U.S.S. Lexington*, which served as an

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aircraft carrier in World War II and now serves as a naval aviation museum at the south end of the beach (Figures 1 and 4). A detailed history of Corpus Christi Beach is presented in Shiner Moseley and Associates, Inc. (Shiner Moseley) (1999).

Erosion at Corpus Christi Beach has been a longstanding problem for local residents. The first authoritative study of the area was conducted by a widely-respected geologist, Dr. W. Armstrong Price, who concluded that the beach eroded at an approximate rate of 3.7 ft/yr between 1880 and 1950 (Price 1956). His assessment of the area was based on historical survey information and personal recollections of former residents dating back to the 1860s.

By the early 1970s, ongoing erosion had caused several beach-front buildings to be at severe risk of damage. In 1978, a joint project between the U.S. Army Corps of Engineers (USACE) and the City of Corpus Christi resulted in placement of approximately 800,000 cu yd of sand on the beach during a $4 million beach nourishment project. According to Kraus (1999), this project may have been the last constructed by the USACE with recreational benefits as a major justification. The project incorporated an innovative two-layer method consisting of a lower layer of 500,000 cu yd of silty sand hydraulically dredged from the bay and an upper layer of 300,000 cu yd of coarser sand having a median grain size of 0.4 mm that was truck-hauled from an inland source (Keislich and Brunt 1989). Spit development and elongation northward resulted in rapid losses at the north end of the beach, and a terminal groin with an additional 30,000 cu yd of truck-hauled sand were added at the north end of the beach in 1985. The groin is shown in Figure 4.

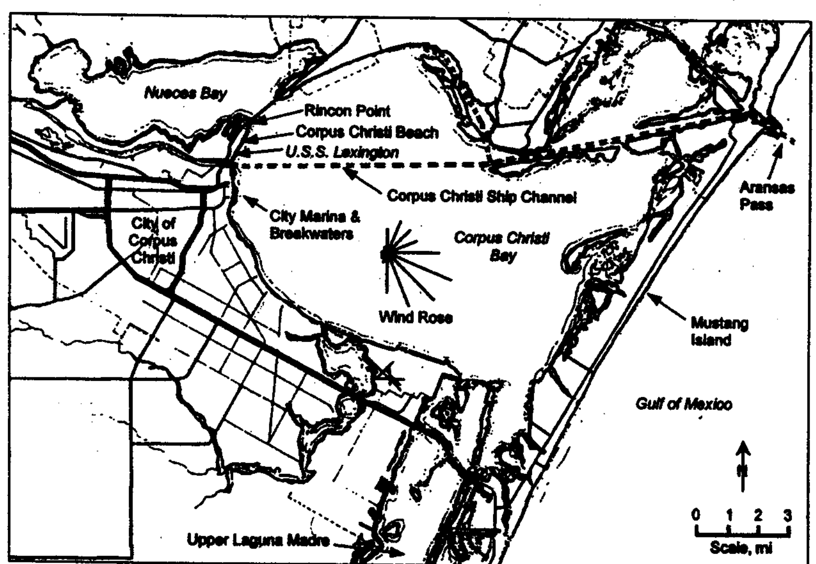

Figure 1: Project site.

By 1995, the central portions of the nourished beach had significantly eroded, threatening infrastructure and some of the public beach amenities constructed by the City as part of its obligation under the partially Federally-funded project. In 1998, the City received an $85,000 grant from the Texas General Land Office (TGLO) and undertook a sand back-passing effort. This effort moved approximately 23,000 cu yd of sand that had been trapped by the terminal groin back to the central portions of the beach. While this action provided some relief, it was only a short-term measure and did not help other areas to the south that were also eroding. Within about a year, approximately 50% of the dry-beach area created by the back-passing effort was gone, and it was evident that a new source of sand would be required to provide a more substantial solution. In 2001, the City and TGLO again joined forces and initiated another back-passing operation in conjunction with a major renourishment effort. The project was funded through the TGLO via the Coastal Erosion Planning and Response Act, with a 25% local match provided by the City. The analysis, design, and construction of this effort are described below.

Sediment Transport

During design of the 1978 nourishment project, the USACE analyzed wind and shoreline change data to conclude that longshore sediment transport was negligible and losses of the fine native sediments was caused primarily by offshore transport. An analysis of the grain-size distribution data presented in USACE (1969) revealed that, after omitting the shell fraction of the samples, native sands between the 1-ft and 3-ft depth contours had a median grain size of approximately 0.17 mm. The Corps' assessment of sediment transport was supported by a more recent study (PIE 2000), which involved application of the ACES model (Leenknecht and Szuwalski 1992) for development of a wave hindcast and evaluation of longshore transport and application of the SBEACH model (Rosati *et al.* 1993) to evaluate trends of cross-shore transport for post-nourishment conditions. Subsequent analysis by Shiner Moseley (2000) suggested that net northward longshore transport is likely the predominant erosion mechanism, particularly for the coarser post-nourishment sediments. Although additional sources of wave data for calculation of longshore transport did not exist, numerous other indicators were assessed to support this conclusion, including the following:

1. Morton and Paine (1984) described the formation of Rincon Point as a result of spit accretion due to net clockwise-directed longshore transport in southern Corpus Christi Bay produced by prevailing southeast winds. They stated that the original sand deposits on Corpus Christi Beach were supplied partly by updrift erosion along southern Corpus Christi Bay, and that the once-accreting beach became erosional after updrift areas were altered by channels and shoreline protection structures.

2. Morton and Paine (1984) documented historic changes in shoreline position for Corpus Christi Bay and showed that the shoreline within approximately two miles south of Rincon Point advanced at about 0.8 to 1.2 ft/yr from 1867 to 1931. The advance along this shoreline reach was associated with longshore transport induced by prevailing southeasterly winds.

3. Kraus (1999) analyzed spit growth, a longshore process, that occurred prior to construction of the terminal groin at the north end of Corpus Christi Beach, and showed that most of the volume lost from the beach could be accounted for in the spit. Kraus also stated that "the predominant direction of longshore transport is to the north, determined by predominant wind out of the southeast and by basin configuration, limiting the fetch to the north."

4. Williams and Kraus (1999) supported the findings of prior studies by Morton and Paine (1984) and Price (1956) that the net direction of sediment transport is clockwise in southern Corpus Christi Bay.

5. As part of the present analysis, plots of shoreline and beach volume change along Corpus Christi Beach were developed. This effort focused primarily on changes that occurred following construction of the terminal groin in 1985. Plots for post-1985 periods show an area of shoreline recession within the southern reach of the beach that transitions into a relatively stable and then advancing section along the northern reach. Figure 2 shows shoreline change data obtained from February 1987 and September 2000 aerial photographs and wading-depth surveys performed by the City of Corpus Christi in May 1992 and September 1997. Figure 3 shows volume change data obtained from closure-depth beach-profile surveys that were conducted by USACE in March 1987 and June 1989 and by Shiner Moseley in October 2000. The plots show that rates of recession/erosion within the southern reach generally decrease with distance north. The advancing shoreline and associated accreting beach to the north is a result of the sand supplied by the erosional south beach and the terminal groin trapping material transported alongshore. The pattern of erosion to the south and accretion to the north supports the predominance of net northward longshore sediment transport, with some bypassing occurring at the terminal groin.

6. Historic and recent aerial photographs show a trend for breaking waves along Corpus Christi Beach to be located farther offshore with distance to the north. Examples are shown in Figures 4, 5, and 7. Through analysis of beach profile plots, this trend was determined to be a result of the sandbars being generally larger and farther offshore and/or the nearshore profile being more gently sloping to the north. This trend suggests that there is a lack of sand to the south and an abundance of sand to the north, supporting the concept of net northward longshore transport.

7. Analysis of shoreline position data developed from both wading-depth beach profile surveys and aerial photographs obtained prior and subsequent to the 1998 back-passing project indicated that, after the back-passing, the excavated area quickly re-filled, further supporting the concept of net northward longshore sediment transport.

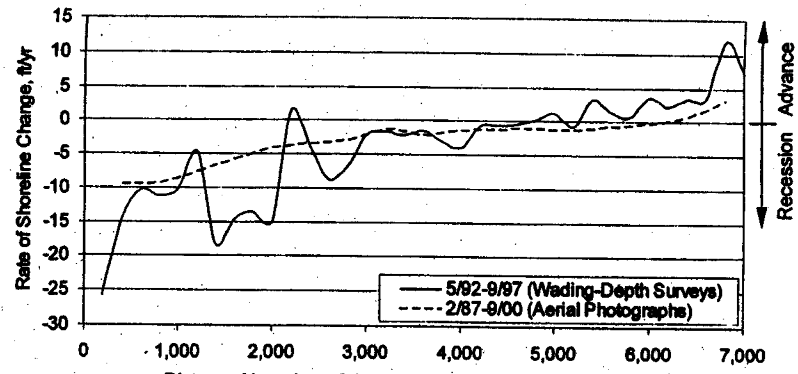

Figure 2. Rates of shoreline change for post-groin period.

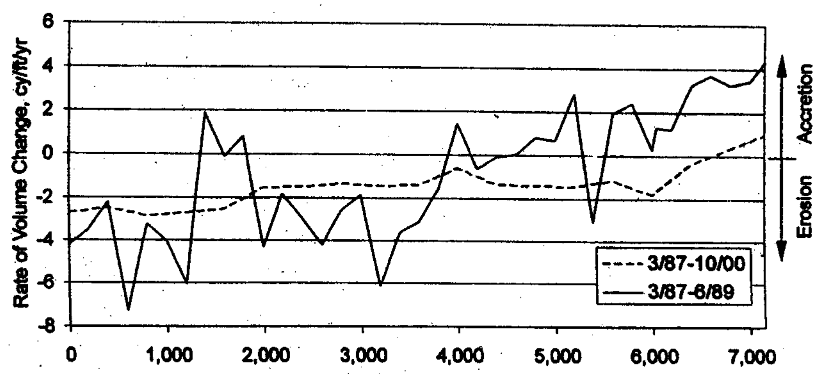

Figure 3. Rates of beach volume change for post-groin period.

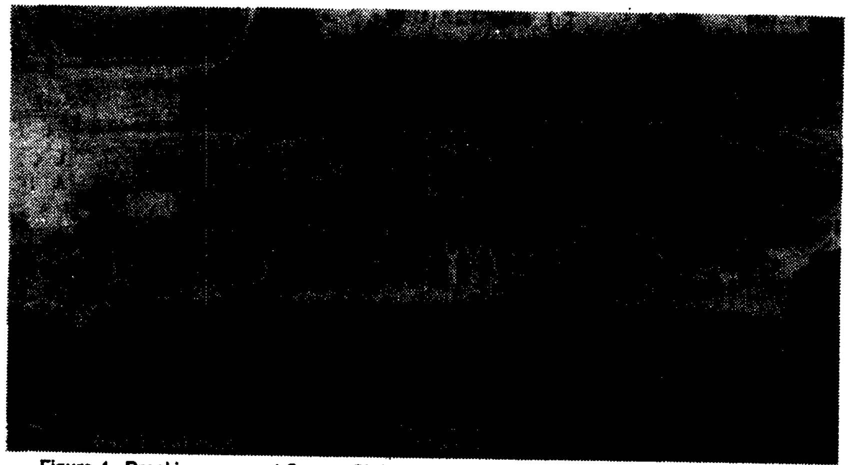

Figure 4. Breaking waves at Corpus Christi Beach (Lanmon Aerial Photography, Inc., 9/00).

Physical Alterations

Over the past eight decades, Corpus Christi Beach experienced at least four significant physical alterations that impacted the sand transport processes along the beach. To address erosion under existing conditions, an assessment of the interaction of the prior alterations with coastal processes at the site was performed. The assessment is summarized below.

1. The first and most significant alteration was a combination of several engineering projects that reduced the transport of sand to Corpus Christi Beach. These alterations were the armoring of most of the south and southwest Corpus Christi Bay shorelines, the dredging of the Corpus Christi Ship Channel, and construction of the City marina and breakwater system. The shoreline armoring prevents sand that was formerly provided from eroding bay bluffs from entering the littoral system. The marina and breakwater system initially reduced sediment supply to the area due to excavation of a large amount of sand for fill during construction, and continue to act as a littoral barrier. The ship channel and north breakwater, which are located just south of Corpus Christi Beach, trap sand that bypasses the marina, further depleting the littoral system and preventing natural nourishment of beaches to the north.

2. The 1978 nourishment project also changed the physical characteristics at Corpus Christi Beach. The native beach material, which consisted of predominantly shell fragments along the upper beach and fine sand nearshore (USACE 1969), was completely covered by the nourishment material. The change in beach sediment size and type changed the slope of the beach and rates of sand transport. Although the shore-connected breakwater was in place at the south end of the beach, no other sand retention structures were in place at this time.

3. Construction of the terminal groin at the north end of the beach in 1985 changed the lateral boundary condition at the downdrift end of the beach, causing an adjustment in shoreline alignment and an associated reduction in rates of longshore sediment transport.

4. In 1992, the berthing of the *U.S.S. Lexington* near the shore at the south end of the beach altered wave and current patterns by acting similar to a detached breakwater. The ship also reflects incident wind-driven waves, as can be seen in Figure 7, which contributes to losses at an erosional hotspot near the south end of the beach.

Sand Sinks

Since construction of the terminal groin at the north end of the beach in 1985, the total erosion rate at Corpus Christi Beach has been approximately 7,000 to 11,000 cu yd/yr based on analysis of the shoreline position data and the beach profile survey data summarized in Figures 2 and 3. This range in erosion rates is similar to the rate of spit growth of 11,000 cu yd/yr calculated by Kraus (1999) that was based on analysis of aerial photographs taken prior to construction of the north terminal groin. Other calculated erosion rates that were based on analysis of pre-1985 (i.e., pre-groin construction) beach profile data include 25,000 cu yd/yr calculated by USACE (1969) for pre-nourishment conditions and 17,000 cu yd/yr and 11,000 cu yd/yr calculated by Kieslich and Brunt (1989) and one of the authors of the present paper (Goldston Engineering, Inc. 1983), respectively, for post-nourishment conditions. The following four potential erosion mechanisms were assessed to determine their relative contribution to the local sediment budget: (1) sand bypassing at the terminal groin, (2) trapping at the *U.S.S. Lexington*, (3) offshore transport, and (4) losses due to wind, tidal, or ship-induced currents. This assessment is summarized below.

Sand Bypassing

Bypassing at the terminal groin was evaluated through inspection of aerial photographs and beach profile data. Well-defined, continuous lines of waves breaking on longshore sandbars with waves breaking at or beyond the tip of the groin were identified on several photographs, an example of which is shown in Figure 5. In addition, a continuous, multiple-bar system extending around the end of the groin and to the north was clearly visible on most of the photographs. The presence of the breaking waves and continuous system of longshore sandbars around the groin indicate that sand bypassing occurs. Bypassing at the terminal groin is also supported by bathymetric data collected in October 2000, which show that the -4 ft NGVD contour, which is well within the limiting depth of active sediment transport, extends around the groin.

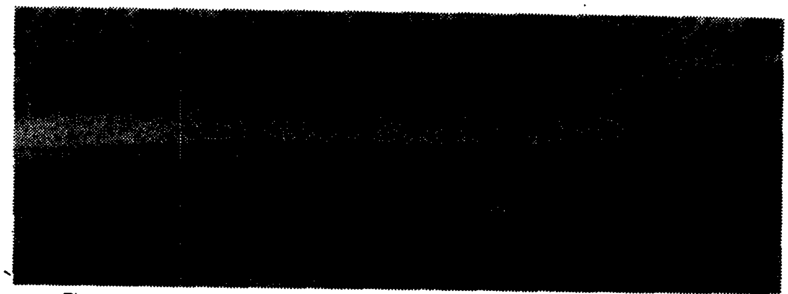

Figure 5. Breaking waves at groin (Lanmon Aerial Photography, Inc., 3/88).

Trapping at Lexington

As previously mentioned, the *U.S.S. Lexington* is permanently berthed at the south end of Corpus Christi Beach. As part of the present study, sand trapping at the ship was evaluated through comparison of bathymetric data that were collected before and after the carrier was berthed in June 1992. Inspection of beach profile plots indicates that within the southernmost approximate 800 ft of beach there exists an abundance of sand at the lower portion of the profile below elevation -4 ft NGVD. This abundance of sand causes the lower portion of the profile to have a distinct concave upward shape as opposed to the concave downward shape that characterizes the rest of the beach. The accumulation of this sand is likely due to wave sheltering and impoundment by the breakwater and *Lexington*.

Prior to estimating the volume of sand trapped adjacent to the *Lexington*, it was recognized that a backfilling operation was conducted as part of the initial berthing of the vessel in 1992. This operation involved placing virgin clay material dredged from the ship channel into the excavated area that remained along both sides of the vessel, but an unfilled area remained adjacent to the stern at the landward end. Most of the excavated area between the Lexington and the breakwater was completely backfilled, but not all of the area along the bayward (northeast) side was filled.

Although it is not apparent if an equilibrium condition has been achieved or if sand will continue to be trapped adjacent to the *Lexington*, aerial photographs show that the emergent portion of the shoreline fillet at the south end of the beach does not appear to be growing larger. However, the existence of a shoal that extends from the fillet towards the stern of the *Lexington* possibly indicates that sand is transported into the deep area at the stern. Equilibrium conditions may not be achieved until this area is completely filled. As summarized in Shiner Moseley (2000), the total rate of sand trapping at the Lexington was estimated to be approximately 1,000 cu yd/yr.

Cross-shore Transport

Inspection of a time series of beach profile plots that were developed by USACE as part of monitoring of their 1978 and 1985 projects revealed that considerable material was initially transported offshore following fill placement as the profile equilibrated from the steep construction slope. The profiles appear to have adjusted to equilibrium conditions by July 1981. During the equilibration period, it is likely that cross-shore transport played a significant role in sorting the fill material across the profile as coarser material was transported towards the berm and finer material was transported to deeper water. However, after one to two years, the profile shape remained relatively constant, with no apparent net onshore or offshore transport or net increase or decrease in the slope.

In addition to analysis of a time-series of beach profile data, as described above, the potential for a beach to erode or accrete in response to cross-shore transport can be estimated by application of an empirical predictor summarized in USACE (1990). This method was applied for typical median grain sizes and waves at Corpus Christi Beach. As documented by Shiner Moseley (2000), representative median grain sizes for the existing berm and nearshore are 0.42 mm and 0.18 mm, respectively. According to wave hindcast data presented in PIE (2000) and Williams (1999), the representative wave steepness for typical waves in Corpus Christi Bay is in the range of 0.02 to 0.05.

Considering the representative range of wave steepness, application of the empirical method mentioned above showed that sand having a median grain size of 0.18 mm is expected to be transported onshore or remain stable for waves having heights of up to about one foot. Because the average annual significant wave height for Corpus Christi Bay is about one foot, there is expected to be little net cross-shore movement of the existing nearshore material under typical waves as the sand is likely transported back and forth in both the onshore and offshore directions. Although a small percentage of the beach material that consists of very fine sand and silt is probably permanently transported offshore, observations by Williams and Kraus (1999) at a beach in southern Corpus Christi Bay confirmed the ability of local beaches composed of fine sand to recover from offshore transport. Additional analysis showed that sand having a median grain size of 0.42 mm is expected to be transported onshore or remain stable for waves having heights in excess of four feet, indicating that the existing berm material at Corpus Christi Beach is not likely to be lost offshore under typical waves.

Based on analysis of beach profile plots and application of the empirical predictor, cross-shore transport appears to play a relatively minor role when compared to longshore transport in contributing to erosion at Corpus Christi Beach. In addition and as discussed later in this paper, the proposed beach nourishment project was planned to consist entirely of coarser-grained imported sand, as opposed to a combination of fine silty-sand and coarser imported sand such as that placed during the 1978 nourishment project. Therefore, the renourished beach was expected to be less susceptible to losses due to offshore transport after initial profile equilibration.

Wind and Currents

The final erosion mechanisms considered at Corpus Christi Beach included wind-blown sand transport and transport by wind- and ship-induced currents. Although limited local data exist on these mechanisms, field observations and inspection of aerial photographs allowed reasonable estimation of their importance. Due to the relatively coarse size of the sand on the berm, the sand is not easily transported by winds. Stability of the coarse sand even under the strong winds that occur at the site is apparent by the lack of dunes and lack of material that has migrated to the backbeach and into adjacent lots and roads.

Analysis and limited measurements of wind-induced currents adjacent to Corpus Christi Beach are summarized in Williams and Kraus (1999) and by one of the authors of the present paper in Goldston Engineering, Inc. (1983). These studies generally confirm that nearshore wind-induced currents tend to flow in the same direction as currents induced by wind-induced breaking waves, and thus likely contribute to longshore sediment transport. Some deflection of northward-flowing currents likely occurs at the breakwater, contributing to the impoundment of sand near the Lexington.

Limited field observations at the south end of Corpus Christi Beach revealed that strong currents between the *Lexington* and the breakwater and through the breakwater are induced by drawdown and surge during passage of tankers and barges entering and leaving port. These currents likely contribute to losses at the south end of the beach as sand is transported through the breakwater, carried offshore between the *Lexington* and the breakwater, and/or deposited in the deep area at the stern of the *Lexington*. Although the cumulative amount of energy induced by passing vessels is relatively small when compared to the total energy induced wind waves along the exposed beach north of the *Lexington*, losses caused by passing vessels are possibly significant within the constricted area between the Lexington and the breakwater.

Sediment Budget

In a prior independent analysis, investigators concluded that the annual net longshore transport rate at Corpus Christi Beach is approximately zero based on wave hindcast data generated through application of the ACES computer program (PIE 2000). An average erosion rate of 18,000 cy/yr was then proposed and accounted for by assuming that 25% of the beach material is lost due to bypassing at the north groin, 3% to 6% is lost due to trapping at the *Lexington* at the south end, and 69% is lost due to offshore transport. In the present paper, evidence has been presented that suggests the direction of net longshore transport is to the north, and that longshore processes contribute up to 97% of the total erosional losses identified for the site. A summary of the sediment budgets for existing conditions at Corpus Christi Beach from both the prior analysis and Shiner Moseley (2000) is presented in Table 1. The sediment budget developed by Shiner Moseley is also displayed graphically in Figure 6.

Table 1. Sediment budget for Corpus Christi Beach.		
Mechanism	Average Approximate Rates, cu yd/yr	
	Prior Study	Shiner Moseley (2000)
Trapping at South End:	1,000	1,000
Trapping at North Groin:	(not estimated)	200
Bypassing at North Groin:	4,500	8,500
Other Losses:	12,500 (offshore transport)	500 (incl. offshore transport, windblown transport, transport through south breakwater)
Total Erosion:	18,000	10,000

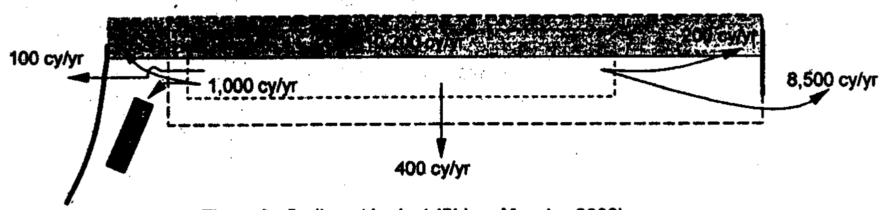

Figure 6. Sediment budget (Shiner Moseley 2000).

Project Design

After analysis of coastal processes and establishment of existing conditions at the site, the project proceeded to the design phase, as described below.

Sand Source

Application of locally-available silty-sand from the bay bottom in combination with trucked-hauled coarser sand as borrow material was not a cost effective option due to the relatively small size of the project as compared to the original 1978 project. Therefore, only upland commercial sources of sand were investigated. To maximize sand retention time and minimize required volume for a given dry-beach width, an effort was made to identify sources containing sand having a grain size similar to or larger than the existing sand. Application of the empirical method for estimating the potential for cross-shore transport was applied to determine that sand having a median grain size of about 0.30 mm should be stable for wave heights of up to about 2.5 feet. According to the wave statistics developed by PIE (2000), waves having a height greater than two feet occur less than five percent of the time. Therefore, 0.30 mm was targeted as the minimum acceptable median grain size of the nourishment material.

Several local quarries were contacted, including the supplier for the 1978 project, to determine the cost and availability of the required sand, and six potential suppliers were identified. Based on discussion with personnel at the quarries and local hauling contractors and a minimum fill requirement of 100,000 cu yd, the cost of the imported sand, including loading, delivery, and spreading, was estimated to be $15/cu yd.

Design Alternatives

The erosion problems at the project site are primarily within the southern half of the beach. The principal erosion mechanisms identified during the coastal processes assessment were sand bypassing at the north terminal groin and trapping by the *Lexington* and breakwater at the south end. Other mechanisms, such as offshore transport, wind-blown transport, and transport through the south groin, also contribute, but to a lesser extent. Several design alternatives, all in combination with beach fill, were developed to address the two principal erosion mechanisms. These alternatives included extension of the north terminal groin to increase impoundment capacity and reduce bypassing, back-passing of sand from the north to the south end of the beach, and/or construction of a groin near the south end to prevent migration and trapping of sand at the *Lexington*. These alternatives were evaluated in terms of cost, interaction with coastal processes, and the results of shoreline-response modeling using numerical and analytical methods. For the alternatives analysis, the project construction budget was estimated to be $1.3 million.

Selected Alternative

Based on the relatively low cost of applying back-passing, whereby sand is mechanically excavated from the north end of the beach and hauled to the south end of the beach as a source of nourishment material, back-passing was selected for inclusion in the project. Because the cost of importing sand from an upland commercial source was relatively high, the inclusion of expensive structural alternatives that would consume a large percentage of the construction budget placed undesirable limitations on the size of the beach fill. For example, construction of a new quarrystone groin near the south end of the beach was considered, but would leave only enough of the budget left for about 55,000 cubic yards of beach nourishment material, including the back-passed sand. Construction of a new south groin using less-expensive material, such as geotubes, was also considered. However, geotubes would be subject to vandalism and other damage, have adverse aesthetic impacts, and would not have the habitat benefits of rock. In addition, according to permit review personnel at the U.S. Fish and Wildlife Service, mitigation would be required if geotubes were constructed near the south end of the beach.

The project alternative eventually selected was beach nourishment with imported sand in combination with sand back-passing from the north to the south end of the beach. This alternative was expected to provide a fill volume of approximately 100,000 to 150,000 cu yd and an equilibrated berm width of approximately 90 to 130 feet. The fill was to be placed with a greater volume density to the south within the erosional hotspot, providing a wider beach fill section at the south and narrower section to the north. Figure 7 shows the project layout. The nourished beach is expected to have a design life of about ten years based on average recession rates since groin construction and numerical and analytic modeling. The numerical modeling was performed through application of the GENESIS model (Hanson and Kraus 1989) and the analytical modeling was performed through application of the Pelnard-Considere solution (USACE 1995).

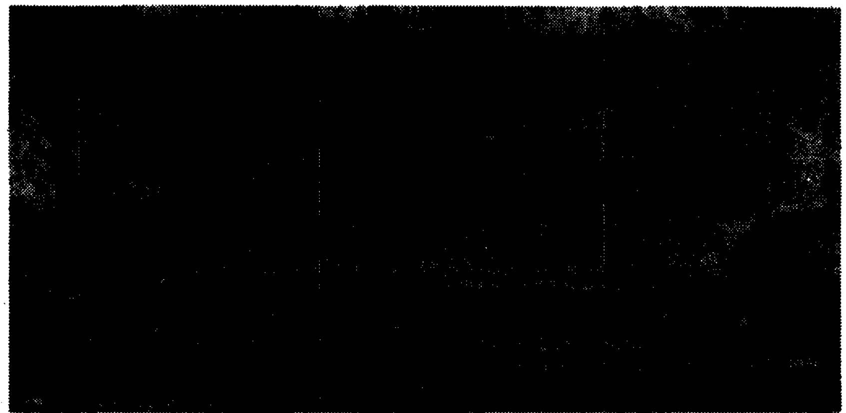

Figure 7. Project layout (Lanmon Aerial Photography, Inc., 1/99).

Construction

Project bids were received in December 2000 and the construction was awarded for $1,456,000. The project specifications required placement of 125,000 cu yd of imported sand and 25,000 cu yd of back-passed sand for a total fill volume of 150,000 cu yd. The imported material was to be furnished by the contractor and was required to meet specified quality and gradation criteria. The construction appeared to be nearing completion in September 2001 when an unanticipated response of the imported fill material to heavy rains raised concerns regarding the quality of the sand. Following the rain, the material became tightly packed and developed a hard crust on the upper surface of the berm, providing a beach that was not appealing for recreation. A subsequent review of the method being applied by the independent laboratory that was performing quality assurance testing revealed deficiencies related to the manner in which sieve analyses were being conducted. Test samples, which were collected weekly at the project site during construction, had apparently not been washed during the mechanical sieving process, as called for in the specified testing protocol. This deficiency resulted in the imported material containing up to 15% by weight of fines (silts and clays) instead of the 3% allowed per project specifications. In addition, the median grain size of the sand, after removal of fines, was approximately 0.25 mm, less than the minimum 0.30 mm targeted for design. Figures 8 and 9 show the condition of the beach in March and September of 2001.

A remediation effort was initiated to improve the quality of the nourished beach. After careful consideration, it was decided to excavate the top 1.5 ft of the material containing excessive fines and relocate it to the submerged portion of the beach. The

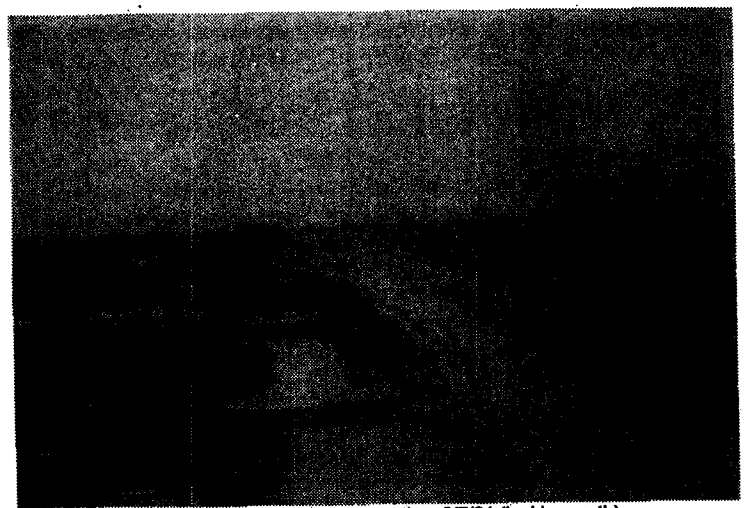

Figure 8. Beginning of construction, 3/7/01 (looking north).

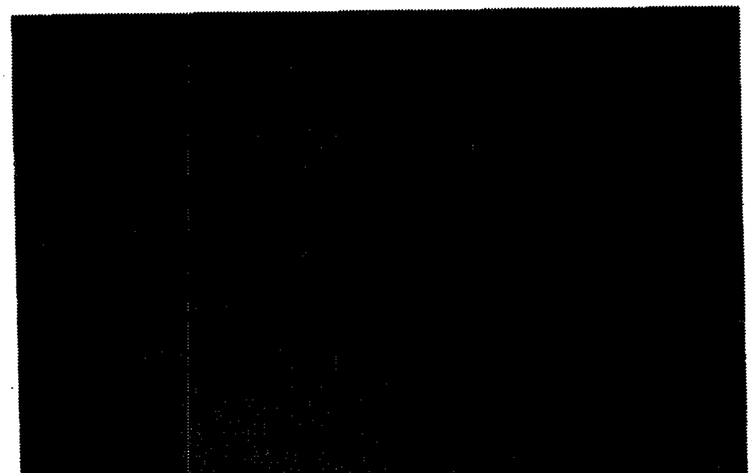

Figure 9. Nourished beach containing excessive fines, 9/25/01 (looking north).

excavated area would then be capped with new imported sand that met original project specifications. This concept was similar to the two-layer approach applied for the original 1978 nourishment project, which was proven to be successful. Figure 10 is a typical section of the beach depicting the remediation plan. The remediation effort is expected to commence in January 2002 and be completed by Spring Break.

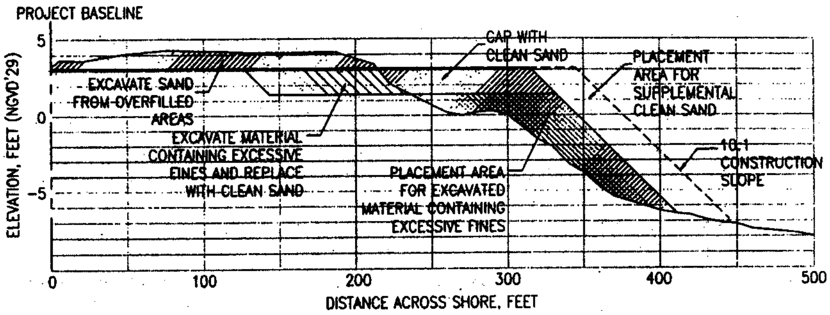

Figure 10. Beach fill construction template for remediation phase.

Conclusions

An analysis of sand transport processes at Corpus Christi Beach resulted in the conclusion that longshore transport is the predominant erosion mechanism at the site. This finding contradicts some prior studies that concluded that cross-shore transport is the predominant mechanism. Other mechanisms, such as wave reflection from the hull of the *U.S.S. Lexington* and strong ship-induced currents, also play a role in erosion, but to a lesser extent. The relative importance of these other mechanisms was estimated through development of a sediment budget. More detailed analysis, aided through collection of field measurements, should be considered in subsequent investigations. Subsequent investigations should also include development of accurate wave data through application of sophisticated hindcasting techniques or deployment of a wave gauge. The wave data could then be applied for calculation of rates of gross and net longshore transport.

The renourishment effort undertaken in 2001 involved importing new sand and back-passing onsite sand from the impoundment area adjacent to the terminal groin at the downdrift end of the beach. The back-passing component is considered a particularly cost-effective and practical sand management approach at this site that should be performed on a regular basis. Construction-phase deficiencies related to incorrect sieve analyses of the imported material by an independent testing laboratory resulted in excessive fines on the beach, and a remediation effort was initiated. The remediation will involve removal of the upper 1.5 ft of the material containing excessive fines and replacement with cleaner sand meeting project specifications. The remediation approach is similar to the original two-layer beach fill constructed in 1978.

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