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EVOLUTION OF BARRIER ISLAND SAND SPITS AND EFFECTS ON BEACH MANAGEMENT PRACTICES. CASE STUDIES IN CENTRAL FLORIDA GULF COAST, USA

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Abstract

Evolution of sand spits occurs over large spatial and temporal scales and present challenging dynamics in developed coastal areas. This paper discusses the evolution of sand spits along central Florida coast where barrier islands provide the upland interface with the open waters of the Gulf of Mexico. Time scale of barrier island dynamics varies from formation at millennia level to centuries and years for natural evolution and responses to anthropogenic change. Data analysis and modeling of various case studies illustrates the the dynamics of sand spits and the various time scales of their evolution. The paper focuses on the physical processes that controls sand spits formations. Morphologic change of sand spits over large time scales may present challenges to developed coastal areas that tries to achieve shoreline stability. Two case studies for sand spits along the study area are discussed to illustrate the various stages of formation, growth and onshore welding of sand spits near tidal inlets.

Key words: Large scale morphology, Sand spits, Barrier islands, Sediment transport, Morphodynamics, Florida,

1. Introduction

Sand Spits are distinct morphologic features associated with barrier islands and tidal inlets along the gulf coast of Florida. The majority of the gulf coast of southwest and central Florida's is made of barrier islands separated by tidal inlets. Sand spits in this region are typically associated with natural inlet migration or closure of a mature inlet following relocation or opening of a newer inlet channel up-drift. In such cases the original mature inlet becomes more restrictive due to a larger ebb shoal volume than the equilibrium needed for its reduced tidal prism. This allows the newer inlet channel to be more dominant as it gradually captures larger shares of the tidal prism. This results in a temporary dual inlet system with a new ebb delta evolving around the new inlet channel while the older channel and its ebb shoal gradually collapses onshore. This process continues until the original inlet closes. In the absence of adequate tidal flow through the closing inlet channel, waves dominate the nearshore processes resulting in onshore movement of the derelict ebb shoal at the closed inlet. This provides a large volume of sediment to form nearshore shoals that continue to migrate on shore and attach to the down-drift beach forming a growing sand spit. Sand Spit's evolution includes gradual growth, migration, or onshore collapse over decades to centuries. This evolution process depends on several factors including the size of the inlet, volume of ebb shoal, wave climate and physical conditions of adjacent beaches.

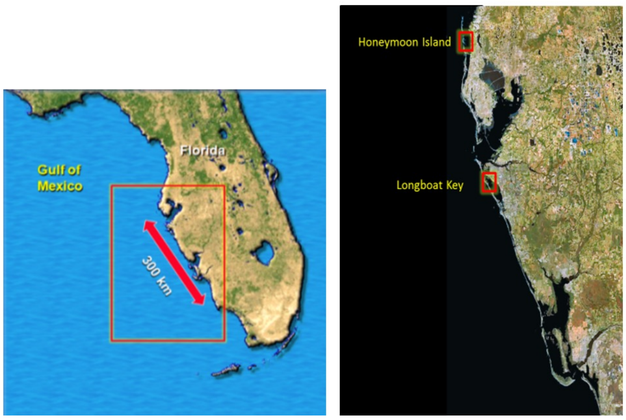


Figure 1. Study area and locations of case studies

It is important to consider the various time scales of the formation and evolution of barrier islands and sand spits when managing areas with such coastal morphologic features. Sand spits are much more dynamic than open coast or typical beach morphology processes. Morphologic change of sand spits over large time scales may present challenges to developed coastal areas that aim to achieve shoreline stability. Time scale of barrier island dynamics may be several decades to a century for natural evolution and responses to anthropogenic change).

2. Case Studies In Central Florida Gulf Coast

This paper reviews case studies of evolution of sand spits along central Florida gulf coast. The paper focuses on analysis of the natural and anthropogenic changes that influenced the evolution of sand spits in central Florida where barrier islands provide the upland interface with the open waters of the Gulf of Mexico.

2.1. *Honeymoon Island*

Honeymoon Island is part of a system of barrier islands and tidal inlets along the Gulf of Mexico coastline of Pinellas County, near Tampa, Florida. **Figure 2** shows the location of Honeymoon Island. The Figure shows multiple barrier islands separated by several tidal inlets that vary in size depending on the tidal prism share thorough each inlet. The evolution of this barrier Island system was influenced by natural and anthropogenic changes over the last century. Honeymoon Island is the north part of Hog Island which was breached by a storm in 1921, into Honeymoon Island to the north and Caladesi Island south.

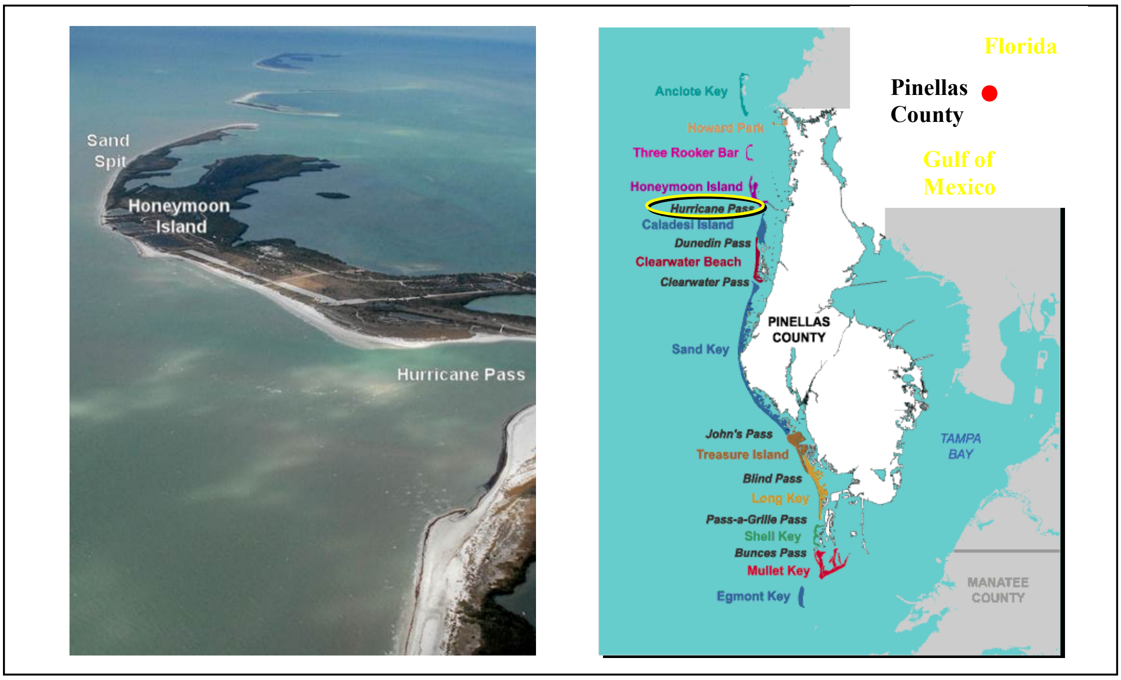


Figure 2. Honeymoon Island and Hurricane Pass location within Pinellas County barrier island system

Figures 3 illustrate the major evolution stages of Honeymoon Island and Hurricane Pass. Figure 3 shows morphologic change from the inception of Hurricane Pass in 1921, 1957, prior to major anthropogenic development of the 1960s and present conditions. The figure shows water depths in three color shades where blue indicate water depth exceeding 6 meters and yellow shades indicate water depth shallower than 2 m while green depth indicate transition depth between 2 and 6 meter deep.

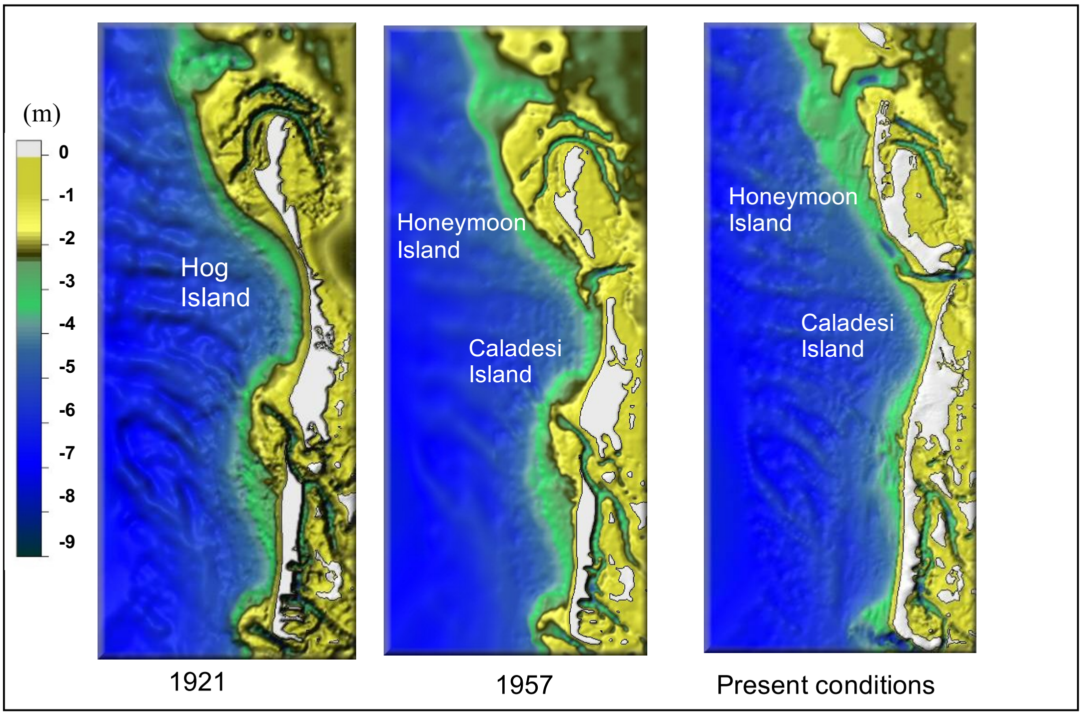


Figure 3. Regional bathymetry from 1921 to present

During the 1960s commercial and residential developments influenced the barrier island evolution. These included the construction of the Dunedin Causeway and Honeymoon Island landfill took place. Figure 4 shows the major natural and anthropogenic changes that influenced the evolution of Hurricane Pass and Honeymoon Island. The sand spit that developed north of Honeymoon Island is partly a morphologic response to both natural and anthropogenic changes that reduced the tidal prism through the tidal inlet north of Honeymoon Island. Consequently the large ebb tidal delta at the north end of the island was dominated by waves and the sand spit evolved and the derelict ebb delta maintained sand supply for the sand spit to grow in the updrift direction.

At the regional scale, comparison between the 1957 and present condition reveals closure of Dunedin Pass and the inlet directly north of Honeymoon Island. The elevation change indicates erosion of large amounts of sand that were on the ebb shoals of those inlets. After the inlets closed, those shoals were no longer active and collapsed onshore, temporarily providing a sand supply to the Honeymoon Island and Caladesi Island beaches. Honeymoon Island growth was manifested in the form of a long sand spit that grew to the north of the island. Caladesi Island gained a supply of sand that helped maintain a supply of sand from the south to Hurricane Pass and growth of a spit at the north end of Caladesi Island.

Dabees and Kraus 2005 discussed model results of regional waves, sediment transport, and hydrodynamics at various times that mark the main stages of the inlet system evolution. Wave and sediment transport modeling were performed for 1921, 1957, 1995, and present conditions. One year wave record representing typical wave climate conditions served as input for detailed wave and sediment transport modeling. Wave-driven sediment transport potentials were computed from modeled breaking conditions for each representative wave condition. Sediment transport potentials were calculated based on the Kamphuis (1991) formula. Sediment transport computations for the 1957 and present conditions were performed by calculating the sediment transport potentials at two layers. The first layer runs from the shoreline to a depth of 1.5 m, and the second layer from 1.5-m depth to the depth of closure (4.5m).

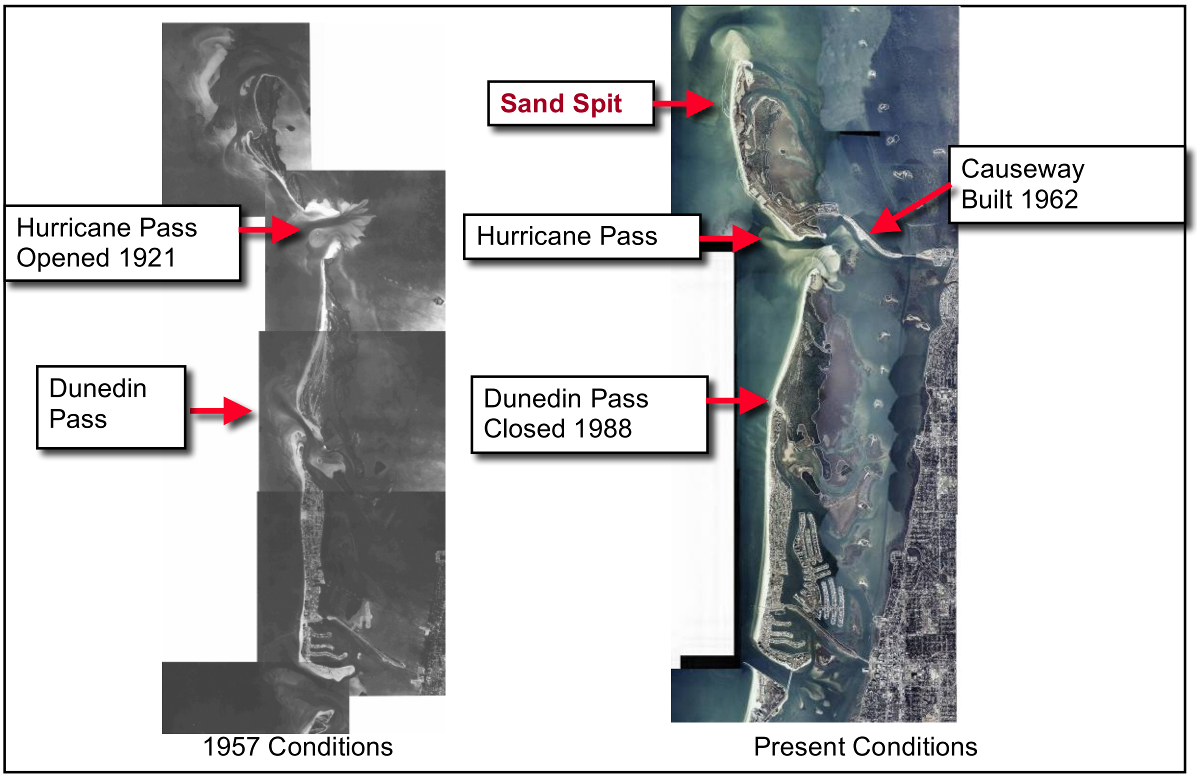


Figure 4. Major natural and anthropogenic changes affecting Honeymoon Island.

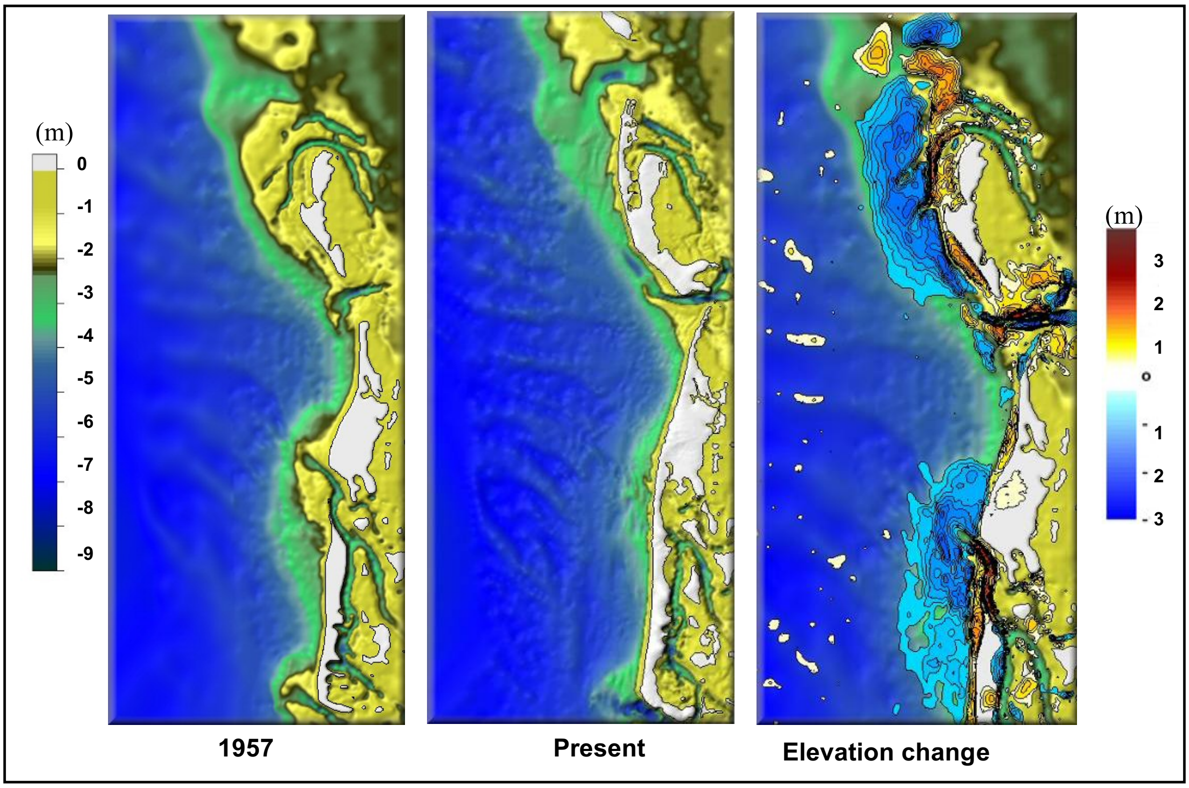


Figure 5. Regional bathymetry and morphological change from 1957 to present

Figure 6 shows the computed sediment transport potential for 1921, 1957, and 2004 conditions, for the shorelines of Honeymoon Island and Caladesi Island. The scaled vectors in the figure indicate the magnitude and direction of the sediment transport. The results indicate the variability of sediment transport at the three temporal stages. The 1921 conditions represented a wave-dominant situation prior to the opening of Hurricane Pass. The sediment transport was predominantly south as the general regional trend. The 1957 conditions represented mixed inlet dynamics subject to wave and tidal currents. The sediment transport computation was done at two layers to provide more details of the sediment transport patterns near the inlet when the contours are not necessarily parallel to the shoreline. The 1957 results showed the influence of the ebb shoal of Hurricane Pass on sediment transport gradients and magnitudes. However, net sediment transport direction remained southward, as is evident from the shape of the ebb shoal.

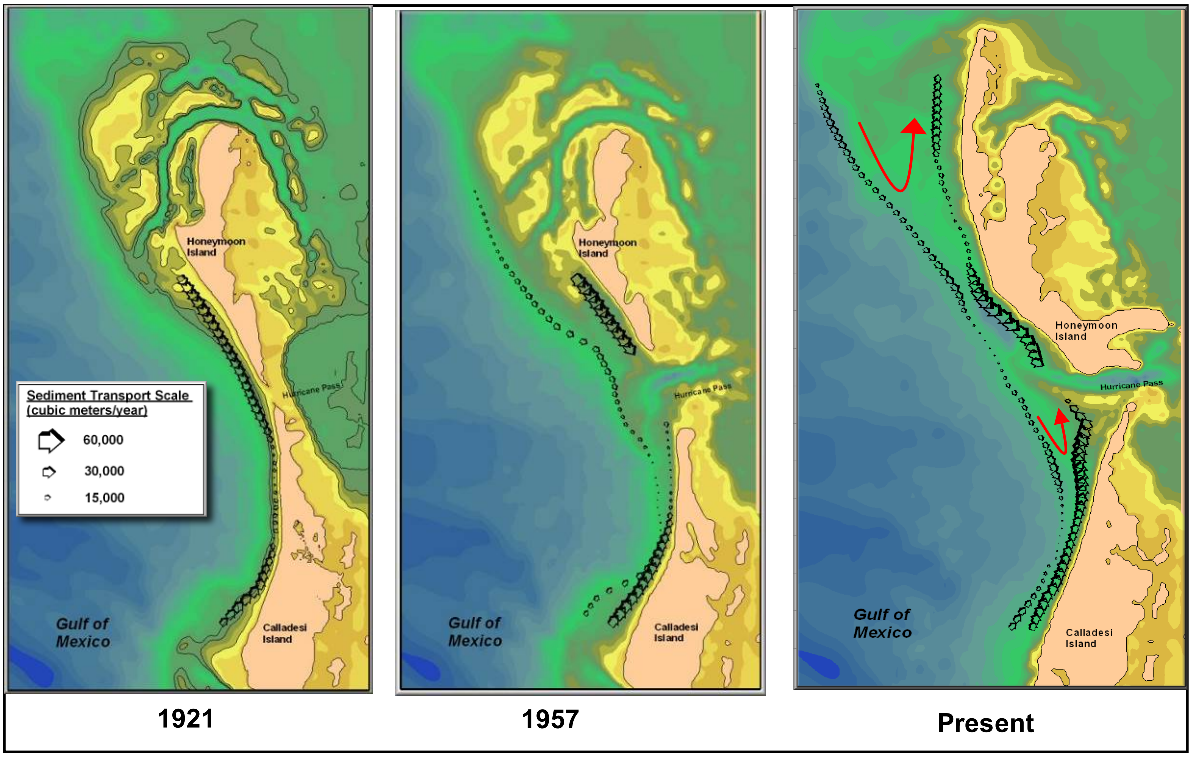


Figure 6. Calculated regional sediment transport potentials for various conditions

The present condition represent the mixed inlet dynamics and the impacts of anthropogenic changes. The present-condition sediment transport incorporates the response to closure of Dunedin Pass and the inlet north of Honeymoon Island on nearshore transport as shown in Figure 6. The net sediment transport along the offshore contours in general remained southward. However, the net sediment transport along the sand spit at the north part of Honeymoon Island is northward. This reversal indicates the sediment transport circulation associated with the collapse of the derelict shoal system and the growth of the sand spit to the north.

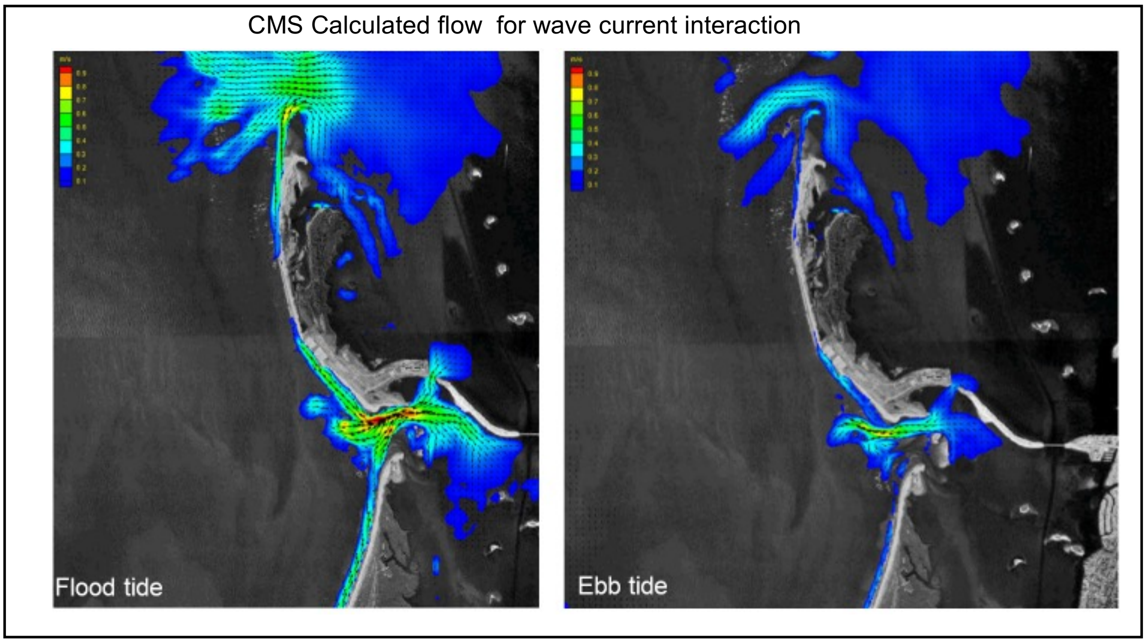


Figure 7. CMS calculated flow velocities for wave current interaction

Detailed wave and sediment transport modeling with the Coastal Modeling System (CMS) (Buttolph et al. 2006) was also used to simulate wave and current interaction and sediment pathways for various conditions. The model was run for combinations of predominant wave conditions and tides to gain an understanding of the patterns of littoral transport in and around the inlet system. Figure 7 shows CMS calculated flow velocities which indicates the northward longshore current along the north part of the sand spit but in the opposite direction along the shoreline south of the spit. This flow and sediment transport divergence is dependent on sand supply at the ebb shoal attachment bar where the sand spit originated from the shoreline. The circulation identified by the sediment transport calculation can only be sustainable if the inlet at the terminal end of the sand spit has adequate tidal flow to recycle the sand offshore to maintain the ebb shoal delta. Otherwise, a sand spit may continue to grow only as a response to a collapsing derelict ebb shoal. In the absence of tidal flow waves will dominate the sand transport cycle and eventually a sand spit would collapse or weld onshore. However, this process can be span over decades to a century which is a large time periods relative to beach management time scale. In southwest and central Florida most development occurred around the mid-20th century. At this time, several cases of chronic beach erosion problems near inlets are related to sand spit evolution.

3.1. *Longboat Pass Case Study*

The sand spit at the north end of Longboat Key is another case to illustrate the evolution of sand spits and the challenges to coastal development that exist is in the vicinity of evolving sand spits. The tidal inlet in this case is Longboat Pass which is located between Anna Maria Island to the north and Longboat Key south. Dabees et al 2011 provides detailed discussion of the inlet evolution. Figure 8 shows the inlet conditions in 1876 and 1957 and shoreline comparison superimposed on the 1957 aerial photo. The inlet configuration in the early 1900’s following the opening of the inlet up-drift of the precedent consisted of a two-channel system. In the l880’s, Longboat Pass was located approximately 500 meters south of its present location, as illustrated in Figure 8 (the federal channel authorized in 1977 is superimposed on this figure for illustrative reference).

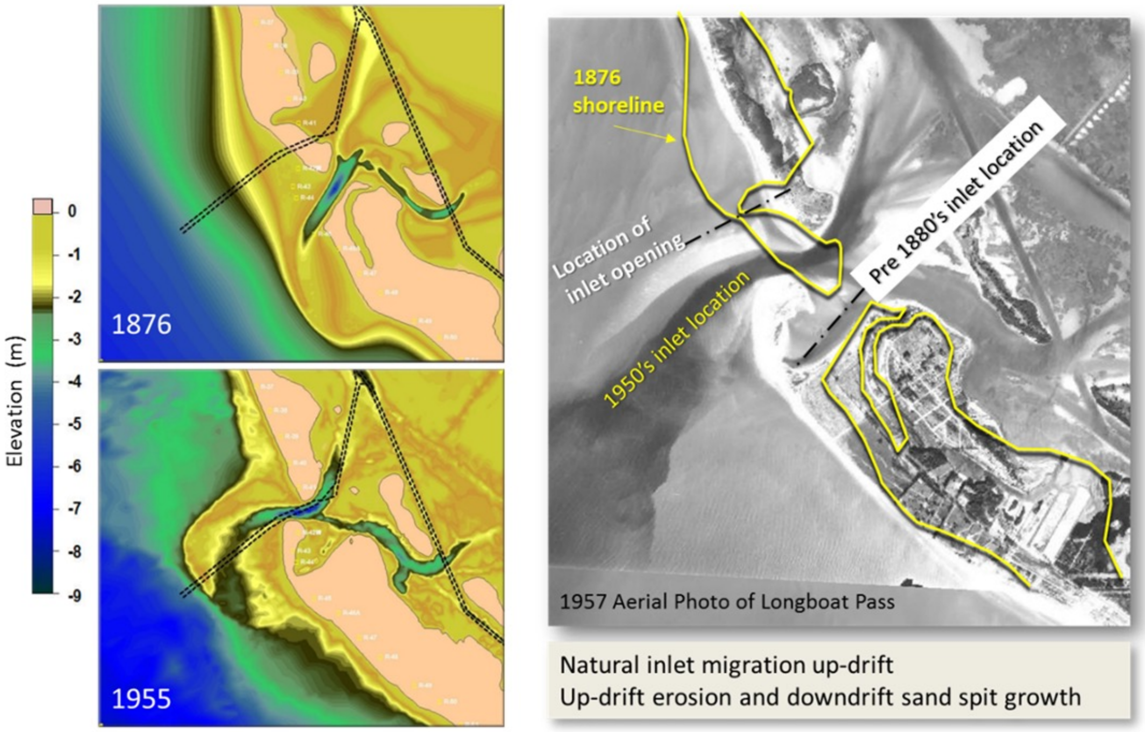
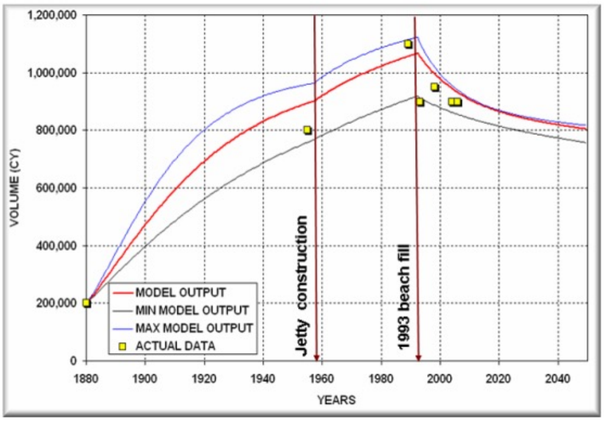


Figure 8. Longboat Pass bathymetry and shoreline change from 1876 to 1957

Because the original inlet was more restrictive, the newer inlet became more dominant as it gradually captured a larger share of the tidal prism. This dual inlet process continued until the south inlet closed in the 1950s. Onshore movement of the ebb shoal at the closed inlet provided a large volume of material to the down-drift beach (Longboat Key) and formation of the active ebb shoal to the north. Formation of the new ebb shoal caused significant erosion on the north side of inlet, along the south end of Anna Maria Island. Comparisons of 1880s and 1955 surveys indicate over 2 million cubic meters eroded from the beach and nearshore shoals along Anna Maria Island to form the Longboat Pass shoal system (Dabees and Kraus, 2008). Closure of the old inlet in the early 1950s and the onshore migration of the ebb shoal resulted in formation and growth of a sand spit at the north end of Longboat Key. The seaward advance of the shoreline at the south side of the inlet coupled with the shoreline retreat on the north side created a shoreline offset between the two sides of the inlet.

The sand spit on the south side of Longboat Pass reached an equilibrium size and shape during the 1980's and 1990's. At that time the ebb delta and the sand spit maintained equilibrium conditions where wave and current interactions maintained stable shape of the ebb shoal south lobe which supported the processes marinating the sand spit. Figure 9 shows calculated wave current interaction when the sand spit was stable. Ebb shoal dredging for sand nourishment in 1993 removed approximately 2 million cubic meters of sand for beach nourishment. The large scale dredging of the ebb shoal resulted in large scale morphologic change in the ebb shoal features and increased exposure of oblique waves along the sand spit. Consequently, this resulted in chronic beach erosion and onshore migration of the sand spit. Process modeling of regional hydrodynamics, waves and sediment transport was used to simulate the physical processes at various temporal stages of the inlet and sand spit evolution. The long-term evolution of the sand spit and the effect of the ebb shoal mining was simulated using the Inlet Reservoir model (Kraus 2000). Figure 9 shows the sand spit shoreline positions from the 1952 to 2006 and the results of the and spit evolution model with comparison to measured sand spit volumes

Shoreline positions at north Longboat Key



Calculated and measured volumes for sand spit at north Longboat Key

Figure 9. Sand Spit shoreline change and model results of sand spit volume for Longboat Pass

The changes in the ebb shoal delta following the major dredging of the outer part of the ebb shoal resulted in gradual migration of the channel and ebb shoal further south. Consequently the alignment and shape of the ebb shoal changed from the conditions that supported the shape of the sand spit. This resulted in the wave onshore migration of the sand pit and beach erosion threating exiting upland structures. Efforts to restore the sand spit shoreline by sand nourishment was not able to maintain the previously stable sand spit and seawalls and erosion control structures are considered to provide shore protection to exiting upland development. Figure 10 shows recent conditions of the sand spit and local erosion control structural measures to address the beach erosion.

Figure 10. Recent conditions and erosion control structures to address chronic beach erosion along the sand spit at the north end of Longboat Key

3. Summary of Findings

The analyses of sand spits along the barrier islands of central Florida gulf coast indicate the large time scale their natural evolution and response to anthropogenic changes. Case studies for Honeymoon Island And Longboat Key sand spits indicate that beach restoration efforts and coastal management along sand spit shorelines are more complex than open coast shoreline due to the long-term evolution of such features. Early development and shoreline encroachments on sand spits established a fixed plan shape and position of upland beach areas that may have been stable at time of development. In the case of southwest and central Florida major coastal developments occurred in the 1940's to the 1960's. In many areas coastal development was attracted to sand spits at the stage of sand spit growth. The data analysis and coastal processes modeling indicated the role of ebb shoal morphologic features in supporting flow and sediment transport circulation necessary for sand spit stability. The circulation identified by the sediment transport calculation can only be sustainable if the inlet at the terminal end of the sand spit has adequate tidal flow to recycle the sand offshore to maintain the ebb shoal delta. Otherwise, a sand spit may continue to grow only as a response to a collapsing derelict ebb shoal. In the absence of tidal flow waves will dominate the sand transport cycle and eventually a sand spit would collapse or weld onshore. As the onshore sand movement diminishes the sand supply from the derelict ebb shoal, the sand spit becomes more erosional. However, this process can span over decades to a century which is a large time periods relative to beach management time scale. In southwest and central Florida most development occurred around the mid-20th century. At this time, several cases of chronic beach erosion problems near inlets are related to sand spit evolution.

In cases where development encroached on an active sand spit, coastal management's efforts to stabilize the shoreline typically follow a desired beach plan shape of the sand spit at time of development rather than the effective equilibrium shape supported by the current time morphology. In some cases shoreline hardening through seawalls and revetments are built when beach erosion threatened existing buildings and infrastructures. This paper provides analysis for two cases demonstrating the natural evolution of sand spits and anthropogenic influences along the study region of central Florida.

References

Buttolph, Reed, Kraus, Ono, Larson, Camenen, Hanson, Wamsley, and Zundel. 2006. Two-dimensional depth-average d circulation model CMS-M2D: Version 3.0, Report 2: Sediment transport and morphology change. Coastal and Hydra ulics Laboratory *Technical Report ERDC/CHL TR-06-09*. Vicksburg, MS: U.S. Army Engineer Research and Develop ment Center.

Dabees M. A. and Kraus, N. C (2005). General Methodology for Inlet Reservoir Model Analysis of sand Management Near Tidal Inlets. *Proc. Coastal Dynamics 2005,* World Scientific, 14pp.

Dabees, M. A. and Kraus, N. C. (2008): Cumulative Effects of Channel and Ebb Shoal Dredging on Inlets in Southwest Florida. *Proc. International Conf. on Coastal Engineering 2008,* pp. 2303-2315.

Dabees, M. A., and Moore, B. D. (2011) Inlet Evolution Modeling of Multiple Inlet Systems In Southwest and Central Florida. Journal of Coastal Research, Special Issue 59.

Dabees M. A., Moore, B.D., and Humiston, K. (2011) Evaluation of Tidal Inlets Channel Migration and Management Practices in Southwest Florida , *Proc. Coastal sediments 2011, WS,*

Kamphuis, J.W. 1991. Alongshore Sediment Transport Rate. *JWPCOE*, 117, 624-640.

Kraus, N.C. 2000. Reservoir Model of Ebb-tidal Shoal Evolution and Sand Bypassing, *J. Waterway, Port, Coastal and Ocean Eng*., 126(6), 305-313..