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INFLUENCES OF CHANNEL DREDGING ON FLOW AND SEDIMENTATION PATTERNS AT MICROTIDAL INLETS, WEST-CENTRAL FLORIDA, USA

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Abstract

Four inlets (Johns Pass and Blind Pass; and New Pass and Big Sarasota Pass) in two multi-inlet systems along the West-central Florida coast were studied. Johns Pass, New Pass, and Blind Pass are dredged every 4-9 years, whereas Big Sarasota Pass has never been dredged. The goal of this study was to investigate the morphodynamics of the four inlets and the influences of channel dredging on the flow patterns over the ebb tidal delta and sediment bypassing. Time-series aerial photographs and bathymetric maps starting from the 1920s were analyzed to assess the pathways of sand bypassing and morphodynamics at the inlets. The Coastal Modeling System (CMS), computing wave, current, sediment transport, and morphology change of tidal inlets, was applied and reproduced the observed medium-term morphology changes. CMS is then used to investigate influences of channel dredging on inlet morphodynamics.

Key words: tidal inlet, sediment transport, morphodynamics, sediment bypassing, dredging, modeling, barrier islands

1. Introduction

The morphodynamics of barrier-inlet systems are often characterized in terms of relative dominance of wave or tidal forcing (Davis and Hayes 1984). For the microtidal, low-wave energy Florida Gulf Coast, a small change in either tidal range or wave height may cause a substantial change in morphology (Davis and Barnard, 2003). This delicate balance between the relative dominance of tides and waves is the basis of a variety of coastal morphodynamic classifications ranging from tide-dominated to wave-dominated systems along the Florida Gulf coast. Tide-dominated inlets typically have a deep and stable channel with extensive ebb and flood tidal deltas. Wave-dominated inlets are characterized by unstable and migratory channels with typically small and asymmetric ebb tidal delta, or not ebb delta at all.

Under mixed energy settings, the inlet morphology is controlled by both wave and tide forcing. Dependent upon the geometry of the coast and the particular pattern of sediment bypassing, mixed-energy inlets may exhibit either a straight or offset morphology (Davis and Hayes 1984). Application of this morphodynamic classification based on relative dominance of wave and tide forcing becomes complicated particularly with engineered inlets where structures and channel dredging may play a significant role in the morphodynamics of the inlet. When interpreting the dominant energy in the system, as is the case for many modified inlets along the West-central Florida coast, attention to historical anthropogenic activities must be made in order to understand the dynamics of the barrier-inlet system.

The West-central Florida coast presents 29 barrier islands, 30 tidal inlets, and a diverse morphology (Davis 1989). A variety of tidal inlet morphodynamic types are found along this coast. Davis and Gibeaut (1990) and Gibeaut and Davis (1993) summarized the morphological characteristics of ebb tidal deltas along this coast, finding a majority of inlet classifications as mixed energy. Dean and O'Brien (1987) examined the interaction between tidal inlets and the adjacent shoreline along the Florida west coast. Davis and Barnard (2003) analyzed the influence on the anthropogenic modifications in the back-barrier area on tidal inlet stability. Mehta et al. (1976) examined various factors controlling the hydrodynamics and sediment transport processes at Johns Pass and Blind Pass.

This study focuses on West-central Florida tidal inlets, including four inlets in two multi-inlet systems: Johns Pass-Blind Pass, and New Pass-Big Sarasota Pass (Fig. 1). The four inlets are extensively influenced

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by anthropogenic modifications over the last six decades. The overall objective of this study is to examine the morphodynamics of these barrier-inlet systems under natural and anthropogenically altered processes. Specifically, trends of morphology change and sediment pathways are examined through comparison of time series aerial photographs and bathymetric maps. Hydrodynamics, sediment transport, and morphology change are modeled using the Coastal Modeling System (CMS). The numerical simulation system is calibrated and verified with measured hydrodynamic and morphologic data. Various anthropogenic modifications, particularly dredging, are investigated through application of the CMS.

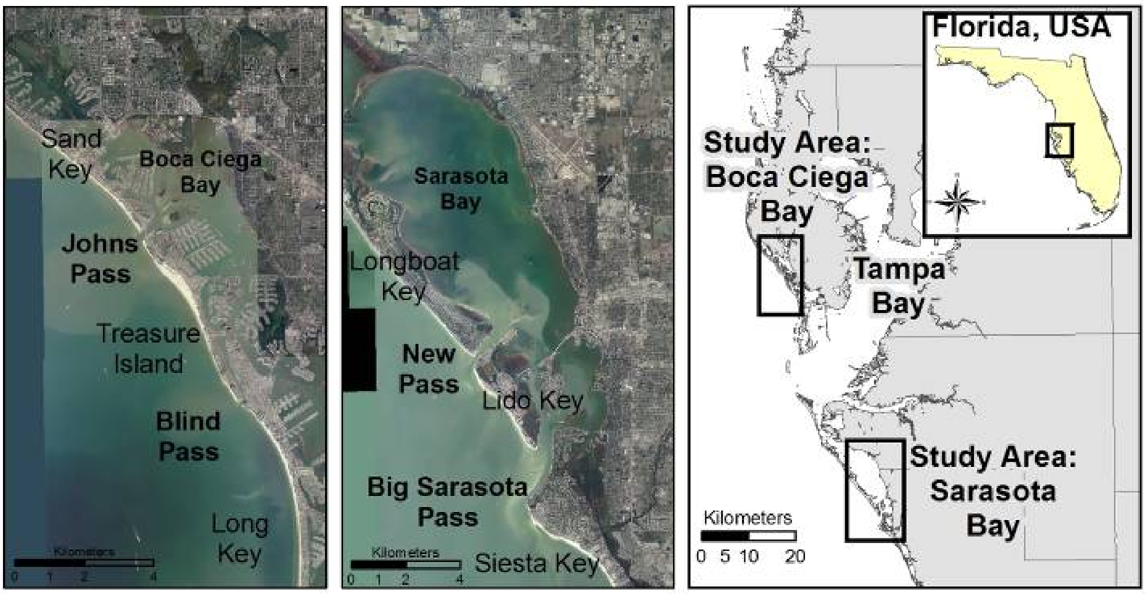

Figure 1. Study area maps: Johns Pass & Blind Pass (left); New Pass & Big Sarasota Pass (middle); Regional Study area (right).

2. Meteorological and Oceanographic Characteristics

Because of the limited fetch of the Gulf of Mexico, waves in the study area are controlled by both regional and local wind conditions. The microtidal coast is also significantly influenced by meteorological conditions. There are two distinct seasonal weather patterns associated with the low latitude of the study area (Davis and Barnard 2003). The Bermuda High dominates the regular summer pattern with gentle easterly winds. High-energy events during the summer are associated with passages of tropical storms; however, a direct hit by a hurricane strength storm is uncommon. The last such storm that passed within 40 km from the regional study area was an unnamed hurricane in 1946. During the winter season, the frequent passage of frontal systems is the main source for high wave-energy events. The sustained and relatively strong northerly wind accompanying the frontal passage is the major cause of the net southerly longshore sediment transport (Davis and Barnard, 2003; Elko et al., 2005).

The overall wave energy along this coast is low with average breaker heights for west-central Florida estimated to be 0.25-0.30 m (Tanner 1960). For much of the year the significant wave height is less than 1 m, approaching from an easterly direction and has a minimal effect on the inlets. The relationship between wave conditions and frontal passages is apparent with higher waves approaching from west-northwest. These highly oblique waves have a significant impact on the nearshore processes and the resultant inlet morphology. Wave-induced sediment transport in the study area is episodic, controlled by the high waves associated with cold front passages. However, during the rest of the year, wave forcing is not significant. On a smaller temporal scale, the sea breeze during the summer season may generate modest waves (< 0.5 m) in the nearshore.

Tide within the Gulf of Mexico progresses from south to north along the western Florida coastline. Tides in the region are classified as tropical, or mixed, switching from semi-diurnal neap tides to diurnal spring tides. The tidal range along West-central Florida is microtidal and typically around 0.5 m for neap tides and peaking at approximately 1.0 m during spring tides. Meteorological conditions also have substantial influences on the tide. For example, sustained strong post-frontal northerly wind tends to subdue flooding tides and often prolong and enhance the ebbing tide. In the case of both inlet-systems, the flooding tide through the southern inlet (Blind Pass and Big Sarasota Pass) leads the northern inlet by 20 to 60 min (Fig. 2). However, the ebbing tides are largely in phase.

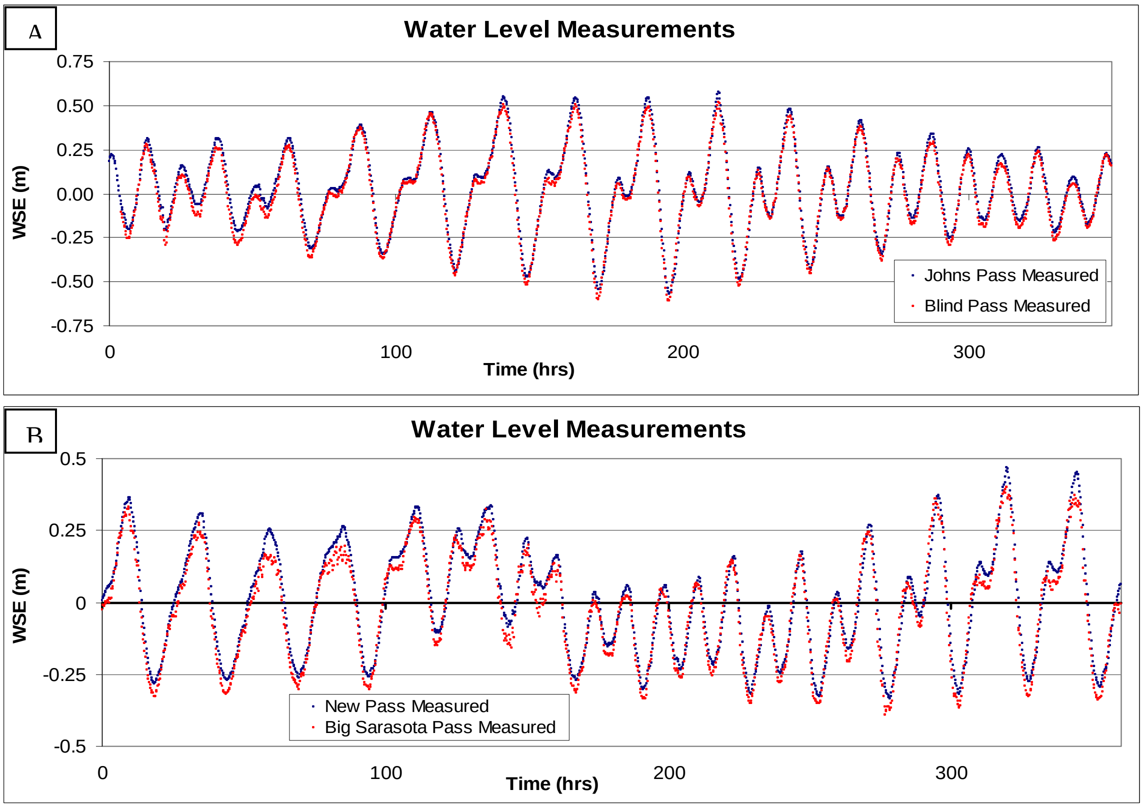

Figure 2. Water level measurements for the 2-inlet system: A) Johns Pass-Blind Pass, B) New Pass-Big Sarasota Pass.

3. Methodology

3.1 *Time-series Aerial Photographs and Bathymetry Maps*

Historical photographs provide valuable information for understanding the inlet morphodynamics and for identifying specific morphologic features and their trend of change. Such images also provide visual record of the large-scale anthropogenic modifications. Several time-series bathymetry maps were also analyzed for quantitative data of large-scale changes over time. Aerial photographs and navigation maps were digitized and rectified using ESRI ArcGIS software. Morphologic features, including shoreline, the updrift edge of the channel linear bar, and offshore bars are delineated and compared to examine trends of beach erosion and accretion.

Orientation change of the main channel through the ebb delta, as illustrated by the channel linear bar along the updrift edge provides qualitative information on infilling rates of the channel as well as longshore transport direction. Based on FitzGerald (1988) and Elko and Wang (2007), the nearshore bar may be an important sediment pathway from the beach to the ebb tidal delta complex. A dynamic relationship seems to exist at the confluence of the offshore bar to the updrift side of the ebb delta, sometimes separated by a marginal channel. Therefore, the morphology of the offshore bar was investigated to determine any trends of sediment bypassing to the ebb delta.

3.2 Field Measurements

Field Measurements at Johns Pass and Blind Pass, including time-series bathymetric surveys of the inlets and flow measurements, were conducted during two study periods, 2000-2004 and 2007-2009. The goal of the 2000-2004 study was to understand the mechanisms that drive the sedimentation in the Blind Pass inlet channel. Both upward-looking and side-looking ADCPs were used in the hydrodynamic measurements, with most measurements conducted in Blind Pass. For the 2007-2009 study, hydrodynamic measurements were taken at various locations for the purpose of providing boundary conditions and verifying the numerical model, as discussed in the following. Tides were measured at four locations, along with a flow measurement in the Blind Pass channel.

Two side-looking ADCPs were deployed to measure flow velocity simultaneously at Big Sarasota Pass and New Pass for more than 2 months, sampling every 15 min. The instruments were deployed on the south side of each channel at roughly the narrowest location of the main channel measuring tidal velocities in twenty 5-m cells with a 4 m blanking distance.

3.3 Numerical Modeling Using Coastal Modeling System (CMS)

The CMS is a product of the Coastal Inlets Research Program at the US Army Engineer Research and Development Center and composed of two coupled models, CMS-Flow and CMS-Wave (Buttolph et al., 2006). CMS-Flow is a finite-volume depth-averaged model that calculates water level and flow velocity. Sediment transport and morphology change can also be calculated. The CMS-Flow is coupled with CMS-Wave (Lin et al., 2008) which calculates spectral wave propagation including refraction, diffraction, reflection, shoaling, and breaking. Recently, wave setup and run up were added to CMS-Wave. The latest modification to the CIRP-Lund sediment transport computation is the implementation of the Non-equilibrium Sediment Transport (NET), which uses a total load approach in the advection-diffusion equation.

A bathymetric grid for the Johns Pass-Blind Pass system (JP-BP system) was generated using recent bathymetric data (2006-2008). Five dredging schemes were incorporated into the model grid resulting in five altered grids (Fig. 3). One altered grid includes the surveyed post-dredging of Blind Pass in 2000; two more grids are built to represent proposed future dredging designs for the Johns Pass ebb shoal; and two more are proposed dredging designs for Blind Pass. Boundary conditions for waves and tides were kept the same for all model grids. The model was driven by water-level measurements obtained in 2008 from a gage located approximately 3 km offshore Johns Pass, or roughly at the seaward boundary of the modeling domain. The offshore tide data compared well with water-level fluctuations measured at the three other locations (Fig. 2). All instruments collected data for nearly 4 weeks. Waves are represented using hindcast data from a nearby WIS station, which is located in 17 m depth and 30 km offshore from the model grid open ocean boundary. Two typical years of WIS waves were selected, 1997 and 1999, reduced from hourly wave data to every 3 hr, and transformed to the modeling domain (~ 7 m water depth) based on linear wave theory. Each of the six grids was run with the same boundary conditions. A steering module ran waves at a 3-hr interval, which is coupled with CMS-Flow computation. The model run duration was set for two years (17,517 hr) with a total of 5,839 wave runs. Therefore, all the dredged cases can be compared to the unaltered model run with identical input forcing.

Model grid setup for the New Pass-Big Sarasota Pass system was designed in a similar approach. Results from New Pass-Big Sarasota Pass are compared with those from Johns Pass and Blind Pass to identify similarities in the morphodynamics of the micro-tidal inlets. Two variations of a channel cut at New Pass were tested with one channel perpendicular (traditional dredging cut) and a proposed southward oriented dredging design (Fig. 4). Boundary conditions for waves and tides were set up following a somewhat different scheme as the JP-BP models and are consistent for each bathymetric grid tested. An idealized wave dataset with several storms of different magnitude and duration were compiled while low wave energy conditions are largely ignored. The input wave data were designed to simulate the active winter season with a total of 30 frontal passages representing approximately two years of significant wave energy. By omitting nearly all the calm weather for the NP-BSP simulations, the 2-year model run can be completed much quicker than the JP-BP runs.

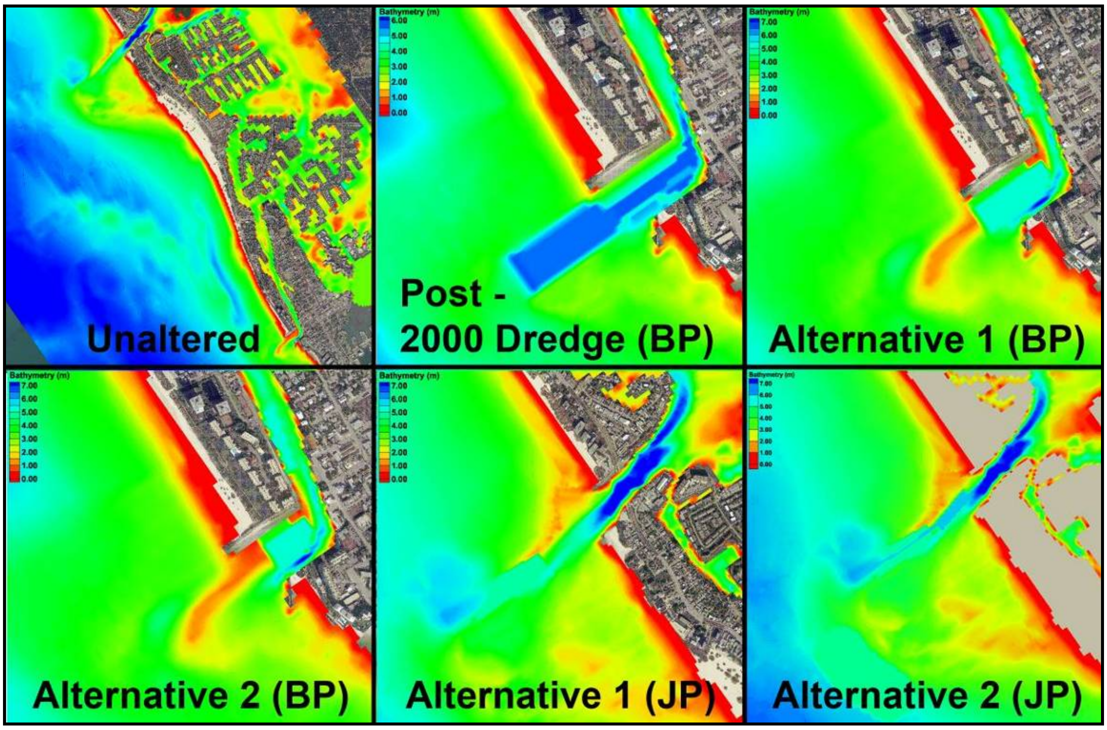

Figure 3. Model grids featuring different dredging designs for Johns Pass and Blind Pass.

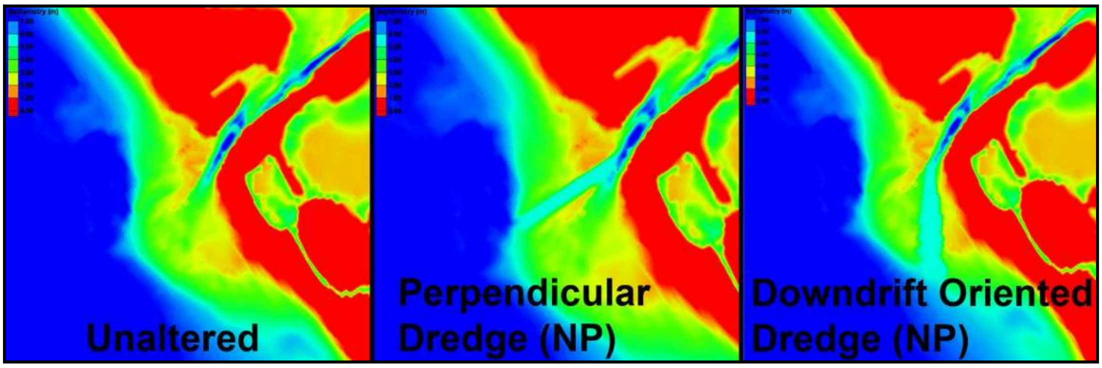

Figure 4. Model grids featuring the two different dredging designs for New Pass.

4. Results and Discussion

The overall goal of this study is to examine the morphodynamic characteristics of two multi-inlet systems based on historical photographs and bathymetry maps. The CMS is then applied to reproduce the observed trend of morphology changes. The CMS is further used to examine proposed dredging designs.

4.1 *Historical Morphodynamics of the Two Multi-Inlet Systems*

The net longshore sediment transport for the region is from north to south, with some localized reversals particularly near the inlets. This is evident in the morphology of the ebb tidal deltas at all four inlets. Blind Pass is unique in that the insufficient ebb flushing along the northern side of the inlet tends to trap sediment inside the channel that might otherwise be bypassed. With little or no ebb delta growth beyond the jettied channel, adjacent shorelines receive higher wave energy than typical of shoreline sheltered behind an ebb delta. Blind Pass is dredged every 4 to 7 years, with the sand typically used to nourish the erosional hotspot at the downdrift shoreline. Recently, shoaling at Blind Pass has increased significantly, most likely due to regional-scale beach nourishment projects along the Pinellas County coast in 2006, creating a small, downdrift-oriented channel linear bar seaward of the jettied channel. The slowly growing ebb delta now serves as a wave sheltering feature for adjacent shorelines (Fig. 5).

Figure 5. Oblique aerial photograph of Blind Pass in 2008, note the developing ebb delta.

New Pass and Johns Pass have distinct ebb deltas with a well-established and apparent bypassing pattern. These inlets display morphologic features over the ebb tidal deltas which are influenced by the dominant wave energy condition, i.e., frontal passages. During the passages of cold fronts, sand is transported south by northwesterly waves and deposited onto the updrift edge of the ebb delta. A portion of the sediment may be transported over the channel linear bar and infills the channel. Some of the sediment may be further transported around the outer edge of the shoal and may eventually bypass the inlet and reach the downdrift shoreline. This can be described by FitzGerald's (1988) natural bypassing morphology model. Both Johns Pass and New Pass have active swash bars over the downdrift portion of the ebb delta.

Aerial photographs and navigation maps show that the channel infilling from the southward longshore transport tends to cause channel migration, especially near the distal portion of the ebb delta, orienting the main ebb channel toward the south. This trend has been cited as the natural tendency for the inlet to reorient to a more stable or natural state (Cialone and Stauble, 1998; McClung and Douglass, 1999). For New Pass, Cialone and Stauble (1998) also found that after the channel and ebb shoal migrate to the south, the main channel may break through the ebb shoal resulting in the southern lobe welding to the shore along northern Lido Key (Fig. 6). Since the 1960s, the Army Corps of Engineers has been charged with mitigating the shoaling through channel dredging and realignment. As a consequence to the channel realignment, often notable swash bars emerge along the downdrift ebb delta and migrate onshore. This post-dredging onshore migration of swash bars was observed at both New Pass and Johns Pass.

As a result of the roughly $2x10^6$ m^3 of sediment removed from New Pass and subsequent nourishment along the 3-km long Lido Key (a short manmade barrier island between New Pass and Big Sarasota Pass), the ebb tidal delta at Big Sarasota Pass accumulated nearly $3x10^6$ m^3. Nearly $2x10^6$ m^3 of this accretion occurred in the form of shoaling within the inlet channel after construction of Lido Key. The encroachment of the shoal into the main channel may also be attributed to tidal prism changes due to bay reduction and channelization, as well as the significant increase in available littoral sediment (Fig. 7). This offset inlet has experienced limited migration and remains largely stable. In contrast to many Florida tidal inlets, this mixed-energy inlet had little modification in the form of jetties and has not been dredged. The main ebb channel along the southern part (downdrift side) of the inlet has remained at its present location for the last 60 years maintained by strong ebb currents (reaching 1.5 m/s). Sediment bypassing occurs naturally around the protruding tip of Siesta Key, and accretes to the downdrift Siesta Key beaches in the form of onshore migration of swash bars.

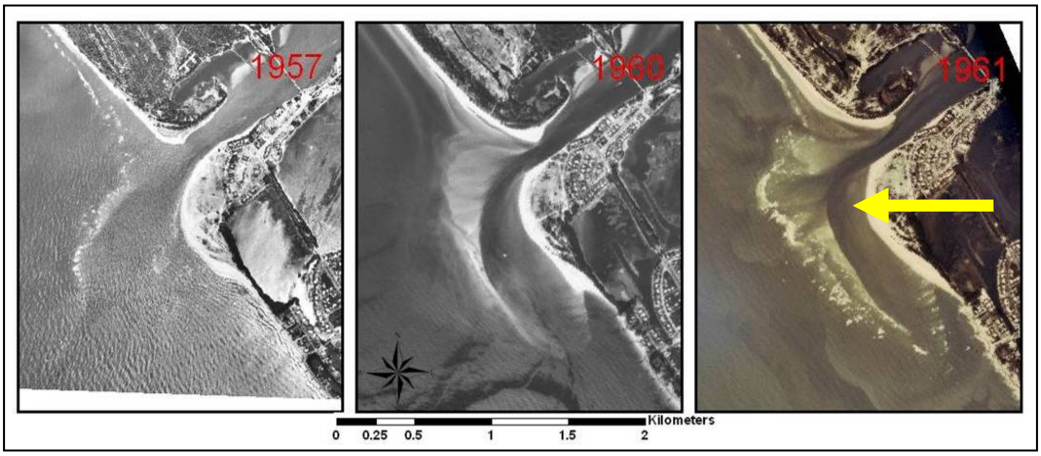

Figure 6. Three aerial photographs illustrating a perpendicular channel orientation at New Pass in 1957 transitioning into a downdrift oriented channel in 1960, note the attachment of the swash bar at the shoreline. The 1961 photograph shows a new perpendicular breach.

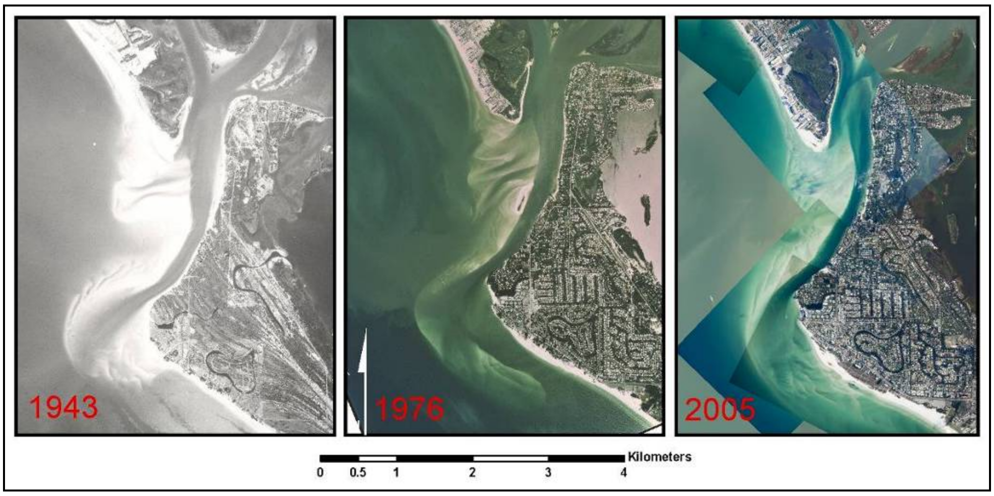

Figure 7. Aerial photographs of Big Sarasota Pass illustrating the morphology change of the ebb tidal delta over the last 60 years. Note the increase in shoaling within the inlet throat and the active swash bar attachment along N. Siesta Key, as clearly seen in 2005.

4.2 *Coastal Modeling System Simulations*

The above morphologic characteristics as observed from historical aerial photographs and bathymetry maps provide fundamental data for interpreting the morphology changes modeled by the CMS. Once verified with measured hydrodynamics data and observed morphology changes, the CMS modeling is used to examine potential morphological changes associated with various dredging options, as discussed above.

4.2.1 *Modeled Hydrodynamics*

The modeled water elevation and flow velocity are compared with measured values in Figure 8. Because CMS-Flow was driven by the measured water level, the calculated elevations provided nearly identical results. Overall, the modeled and measured velocities compare well (Fig. 8). However, careful examination of the modeled velocities at the two 2-inlet systems indicates that the modeled velocities at New Pass (Fig. 8) and Johns Pass matched better with the measured velocities than those at Big Sarasota Pass and Blind Pass. New Pass and Johns Pass are located near the middle of the back-barrier bay, while

Big Sarasota Pass and Blind Pass are located near the southern boundary of the modeling domain. The modeled back barrier bays are connected with other multi-inlet systems through the Intracoastal Waterway. Its influence to the modeling domain is not clear. This may attribute to the less well-represented velocities at one of the inlets in the 2-inlet system. Given the main goal of the modeling here is to examine medium-term morphology change, the slightly under-predicted velocities should not have significant influence.

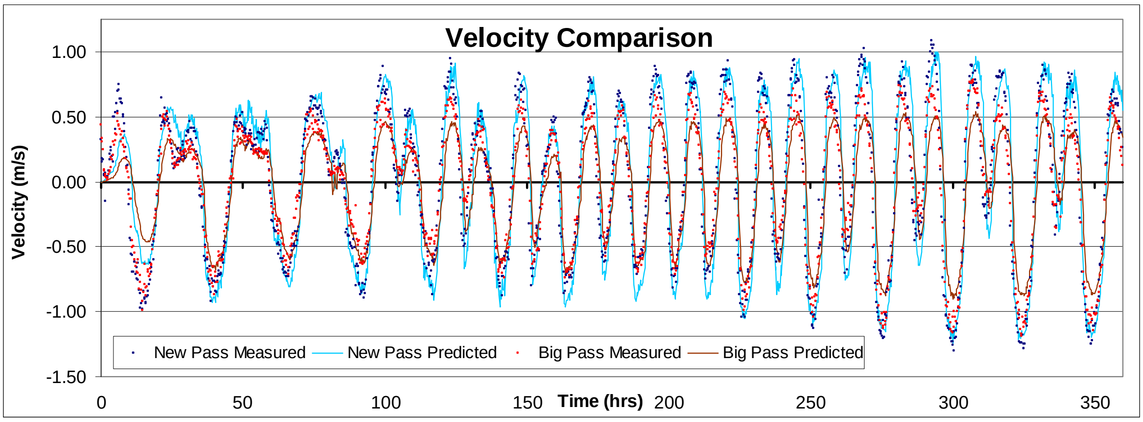

Figure 8. Comparison of measured and predicted velocity for New Pass and Big Sarasota Pass. Note the predicted velocities at New Pass matched more closely with the measured values than those at Big Sarasota Pass.

A comparison of the flow pattern between unaltered and dredged channel indicates that ebb flow, or ebb jet, tend to be further concentrated through the dredged channel (Fig. 9), with stronger velocity and a farther seaward extent. As a consequence of the more concentrated ebb flow through the dredged channel, the ebb currents over the rest of the shoal are reduced. This may affect the sediment transport pattern over the shoal and may contribute to the observed onshore migration of the swash bars after channel dredging.

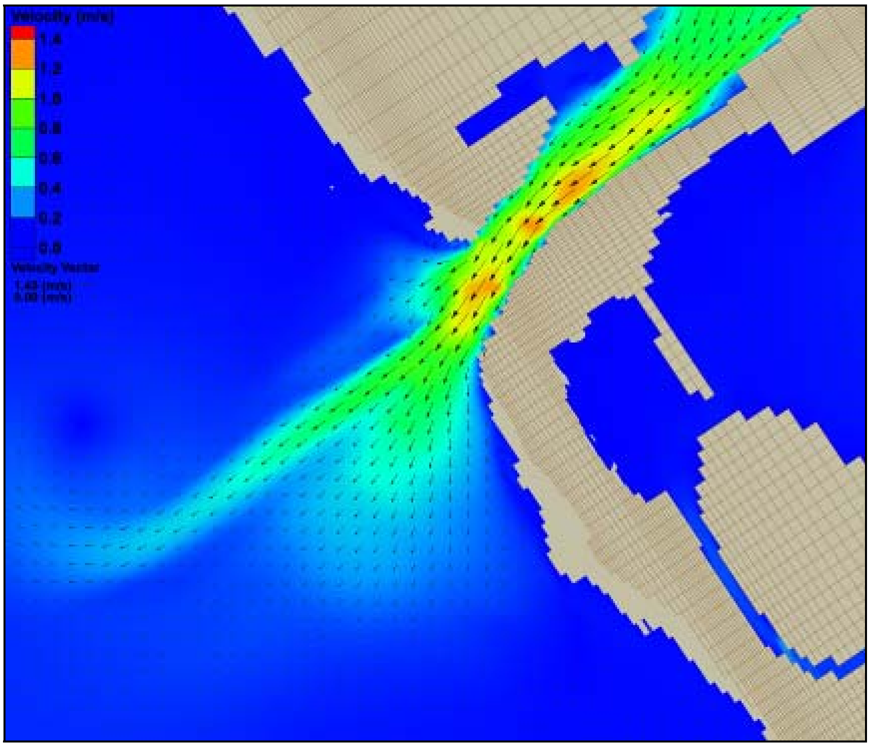

Figure 9. Example of modeled ebb current through New Pass over an altered grid. Note the intensified flow through the perpendicular dredged area over the New Pass ebb delta.

4.2.2 Modeled Waves

Numerous winter storm cycles are included in both modeled inlet systems where the waves are ran at 3-hour intervals in order to capture the evolution of wave patterns from pre-frontal southerly approaching waves to post-frontal northerly waves. The modeled wave heights and directions are shown in Figure 10. The wave heights are illustrated with color contours, while the direction and length of the vectors show wave direction and wave height, respectively. Figure 10 illustrates wave refraction patterns over the Johns Pass ebb tidal delta. The refraction pattern is strongly influenced by the ebb tidal delta bathymetry. Wave shoaling over the ebb deltas is apparent. Some refraction over the developing Blind Pass ebb delta (Fig. 5) is also evident, whereas the large-scale sheltering in combination with refraction occurs over the large Big Sarasota Pass ebb tidal delta.

In order to realistically represent sediment transport in the vicinity of tidal inlets and therefore, resulting morphology changes, current and sediment transport induced by wave breaking and wave-current interactions need to be predicted reasonably accurately. The longshore current velocity is calculated in CMS-flow using the radiation stress computed from CMS-Wave. The interaction between waves and currents is represented in the CMS by allowing the current to modulate the waves and the waves to create and modulate the currents. Figure 11 is an example of the wave current interaction over the ebb tidal delta of Johns Pass during high northerly waves. The reduction in wave shoaling or changes in refraction patterns are important in considering the changes in sediment transport over dredged or modified channels.

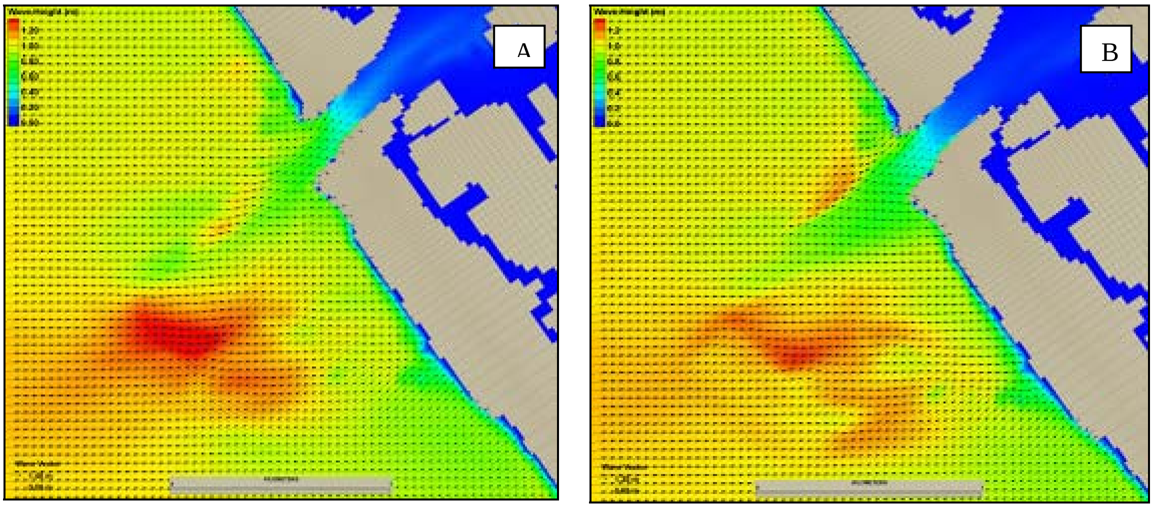

Figure 10. Modeled wave refraction patterns at Johns Pass under a 1.0 m wave. Peak wave heights of 1.2 m are shown in red. A) Modeled wave run over unaltered bathymetry. B) Modeled wave run over altered bathymetry.

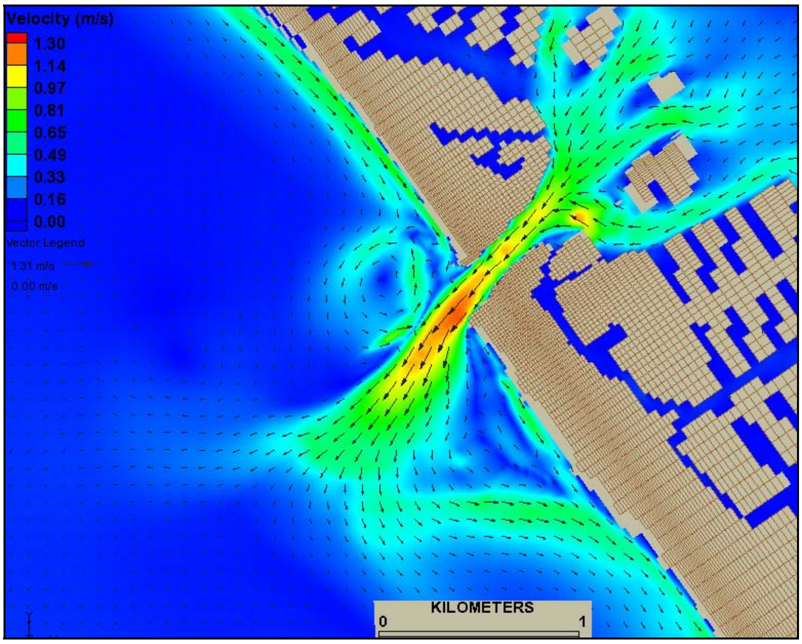

Figure 11. Modeled wave-current interaction over the ebb tidal delta of Johns Pass. Peak ebb currents are jetted out over the shoal with a large eddy to the north. Longshore current under wave action dominates the current field over the downdrift portion of the ebb tidal delta.

4.2.3 Modeled Sediment Transport and Morphology Change

Compared to the verifications of hydrodynamic predictions, as discussed above, verifying the predicted sediment transport rates and therefore, morphology changes are more difficult. In the following, the predicted morphology changes are compared somewhat qualitatively with those observed and compiled from time-series surveys at Blind Pass. Generally speaking, the net rate of sediment transport should be in the correct direction, i.e., toward the south, and within the same order of magnitude. In addition, the magnitude of sediment transport should correspond to high wave-energy events, e.g., passages of cold fronts. This should result in calculated morphology change within the same order of magnitude. Estimated gross and net rates of longshore sediment transport in the Johns Pass and Blind Pass areas can be found in Walton (1976), Elko et al. (2005), Elko and Wang (2007). The gross longshore sediment transport rate for this area is approximately 80,000 m^3 per year with a net southward transport of ~25,000 to 35,000 m^3. After the Blind Pass dredging in 2000, time-series bathymetry surveys of the dredged scar indicated a consistent rate of channel infilling at approximately 35,000 m^3 per year (Wang et al., 2007). Overall, the modeled annual sedimentation in the dredge pits is on the same order of magnitude as compared to the net rate of longshore transport. At Blind Pass, for the Alternative 1 dredging design (Fig. 12), the model predicted sedimentation of 21,000 m^3 per year, which is slightly lower than the net longshore transport rate of roughly 30,000 m^3 obtained from the eroding downdrift Upham Beach (Elko et al., 2005), but reasonable. Sedimentation within a proposed Johns Pass dredged pit was predicted to be approximately 60,000 m^3 per year, which compares well with the gross rate of roughly 80,000 m^3.

Modeled sediment concentration and transport rates reveal the dominant paths of sediment transport across these mixed energy inlets. Much of the longshore current and associated sediment transport occurred in the breaker zone, i.e., in the nearshore zone, over the shallow swash bars, along the shallow distal lobes of the ebb delta. An example of the modeled sediment concentration and transport direction at Johns Pass is shown in Figure 13. The areas with higher concentrations coincide mostly with the area of wave breaking. This transport path is dominated by the longshore current that was developed along the updrift coastline. The sediment transport over the downdrift side of the shoal is strongly influenced by waves refracting over the ebb delta. Refraction patterns, as shown in Figure 10, drive a slightly weaker longshore current and lower sediment concentration over the downdrift portion of the shoal and are directed toward the attachment point.

Figure 12. Modeled morphology change at Blind Pass for a dredged cut (alternative 1 for Blind Pass). Deposition within the dredged channel reached approximately 21,000 cubic meters after one year.

New Pass and Big Sarasota Pass are situated along a similarly oriented stretch of the barrier coastline and have a similar wave climate as Johns Pass and Blind Pass. Results of recent studies by CPE (1993b) and CEC (2006) estimate gross and net longshore sediment transport rates similar to the inlets to the north. Net sediment transport rates for the erosional hotspot at central and southern Lido Key are estimated to be approximately 80,000 m^3 to the south. Rates given for New Pass tend to be smaller as compared to the eroding Lido Key; however, with a wider range than that at adjacent areas, ranging from 20,000 m^3 to 70,000 m^3. The Modeled sedimentation rates for the proposed dredged pit at New Pass are similar to the Johns Pass rates, which seems reasonable for the 2-year run neglecting calm weather conditions (Fig. 14).

Over the entire ebb tidal delta, all modeled cases demonstrated some degree of erosion of relatively positive morphology features resulting in a smoothed bathymetry during the first year. The offshore WIS waves were propagated to the model boundary neglecting friction dissipation. It is likely that the input wave conditions might be too high. However, for most altered grids with dredged cuts, there is significant erosion (0.5 to 1.5 m) of the shallow portions of the ebb delta. This is not so for the unaltered model cases; where after the initial smoothing there is little to no erosion to the rest of the ebb delta. This may be attributed to the difference in flow patterns over altered and unaltered bathymetries, where altered bathymetries tend to further channelize flow through the dredged cut (Fig. 9). Currents then decrease over the shallow shoal, which may lead to a landward trend of sediment transport. This seems to agree qualitatively to the observed post-dredging onshore migration of swash bars. Also, wave action over the shallow portions of the ebb tidal delta tends to increase sediment transport resulting in erosion. The deflation of the ebb delta occurs over the entire shoal; however, it is more notable along the updrift side which is exposed to much of the energy associated with cold front passages (Fig. 15).

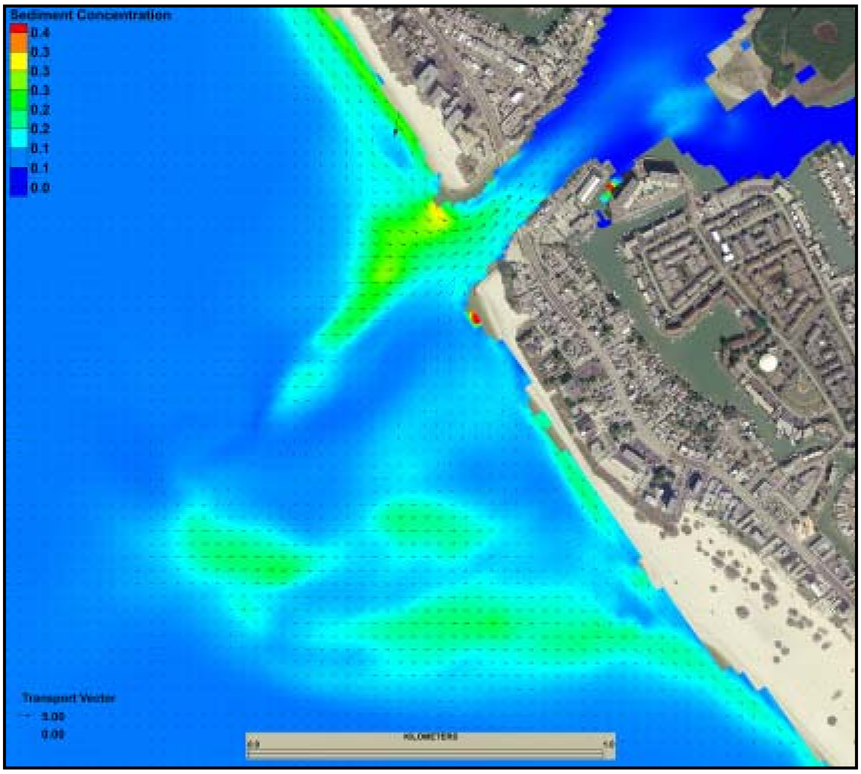

Figure 13. Modeled sediment concentration and transport at Johns Pass for an unaltered case. Note the high sediment concentration in areas with wave breaking.

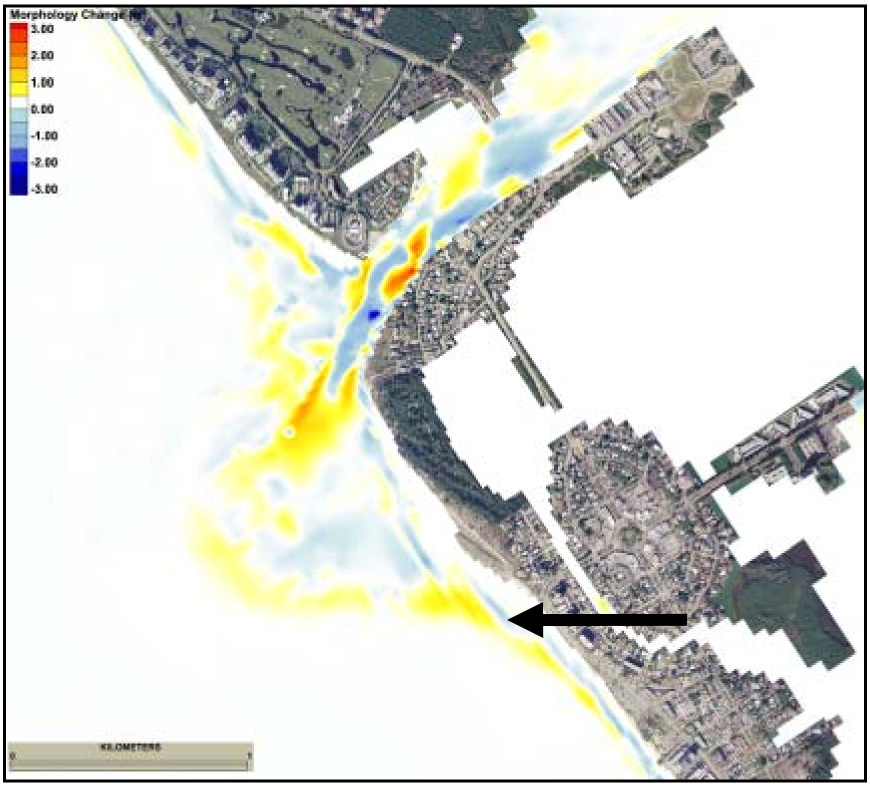

Figure 14. Modeled morphology change at New Pass for the unaltered bathymetry. Note the deposition (yellow) along the downdrift portion adjacent to the attachment point.

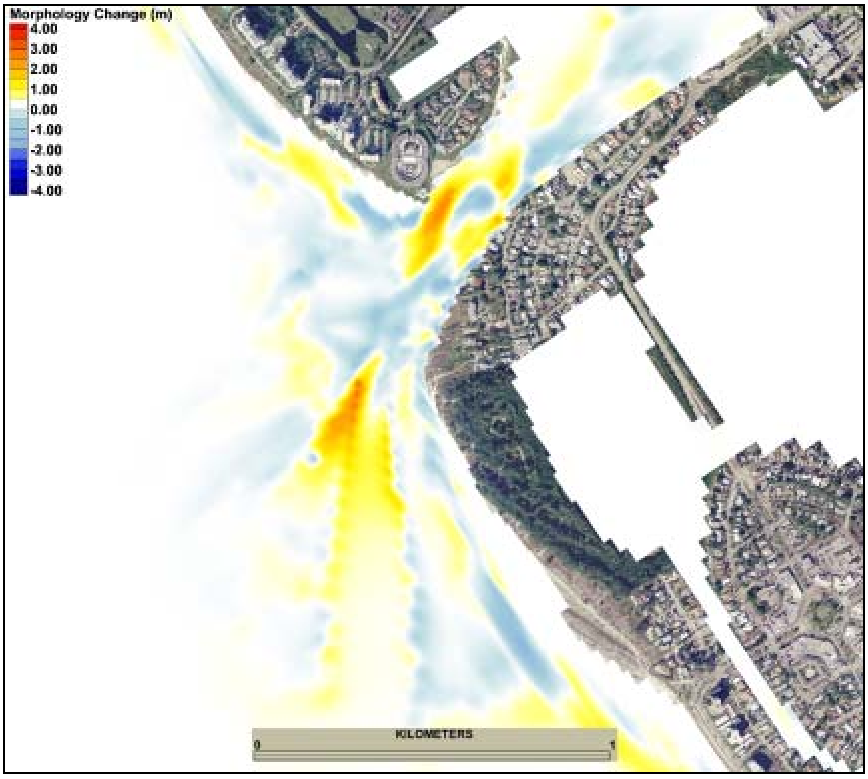

Figure 15. Modeled morphology change at New Pass for the unaltered bathymetry. Note the erosion (blue) along the updrift and downdrift portion of the ebb tidal delta.

The CMS also demonstrates promising potential for predicting trends of erosion and deposition along shorelines adjacent to the inlets. For example, results from the unaltered bathymetry grids illustrate erosive trend downdrift of each inlet where erosion has been documented historically. At a certain distance downdrift of New Pass, Big Sarasota Pass, and Johns Pass, accretion (shown in hot colors) has been observed historically at locations of the ebb delta attachment point where active onshore migration of swash bars is often observed. This accretionary trend is predicted qualitatively by the medium-term CMS runs (Figs. 12 and 14). Overall, general erosional and accretionary trends along the shoreline adjacent to the inlets were represented reasonably well.

All of the studied inlets, not including Blind Pass, illustrate similar morphology over the ebb shoal and along the inlet channel. The location of the deep channel thalweg is typically located along the downdrift (south) side of the inlet, as is also the case for Blind Pass. Modeled morphology changes indicate an apparent tendency of channel migration toward the south that is held fixed by the structured downdrift side of each inlet. As a result, the main channel tends to erode substantially (~2-3 m over the 2-year period) as channel infilling along the northern side decreases the channel width (Fig. 16). This occurs in all inlets for all the modeled cases except for Blind Pass, where the channel thalweg only experiences this erosion for the unaltered bathymetry case. For all altered (dredged) model cases, each inlet experiences channel infilling dominantly over the area that is in close proximity to the nearshore zone along the updrift side, where wave-breaking induced sediment transport is significant. Therefore, wave breaking induced sediment transport seems to be realistically represented by CMS. At some point within the first year, channel infilling begins to encroach landward along the inlet throat (Fig. 16). This is an interesting morphology feature that is also observed at Big Sarasota Pass (Fig. 17).

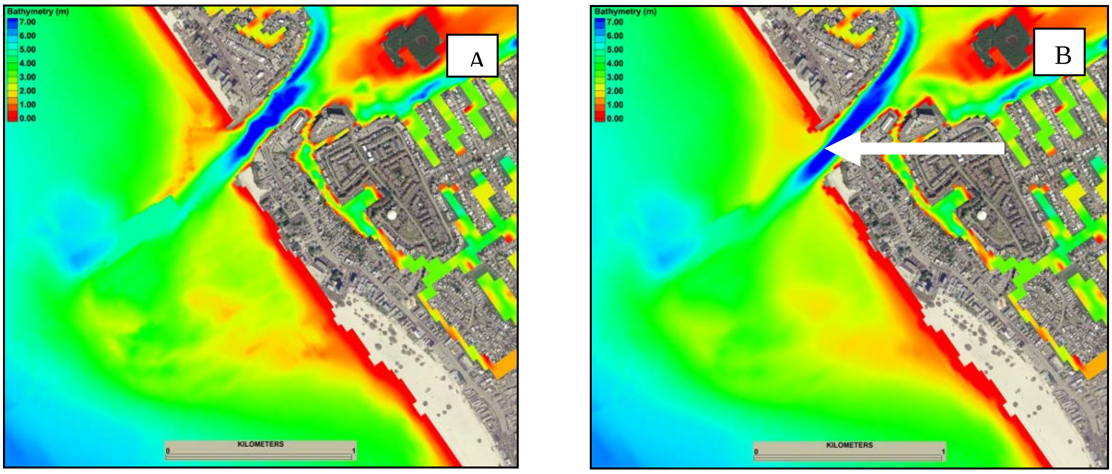

Figure 16. Initial bathymetry (A) and modeled (B) bathymetric change at Johns Pass for an alternative (dredged) model. Note the deposition (yellow) along the updrift channel linear bar well into the main channel.

The crest of the channel margin linear bar, on the updrift side of the inlets, tends to be eroded along with other shallow morphologic features, as predicted by the CMS. Adjacent to the eroded marginal linear bar, the channel is infilled under both dredged and unaltered cases. This is illustrated in Johns Pass (Fig. 16) and New Pass, of which both have a well defined channel with a perpendicular alignment. Also, the marginal channel along the updrift side of Johns Pass and New Pass (where there is typically only one channel) remains stable and does not experience significant change. However, the changes along the updrift side of the inlet have a strong effect on the large, complicated ebb shoal at Big Sarasota Pass and the newly emergent shoal at Blind Pass. Blind Pass does not have marginal channels, but experiences the same erosion and channel infilling patterns along the updrift side. The offset ebb tidal delta at Big Sarasota Pass, however, has typically two or more marginal channels that carry a large volume of tidal prism. Modeled morphology change over the updrift side of Big Sarasota Pass, as illustrated in Figure 17, produce some channel migration toward the south.

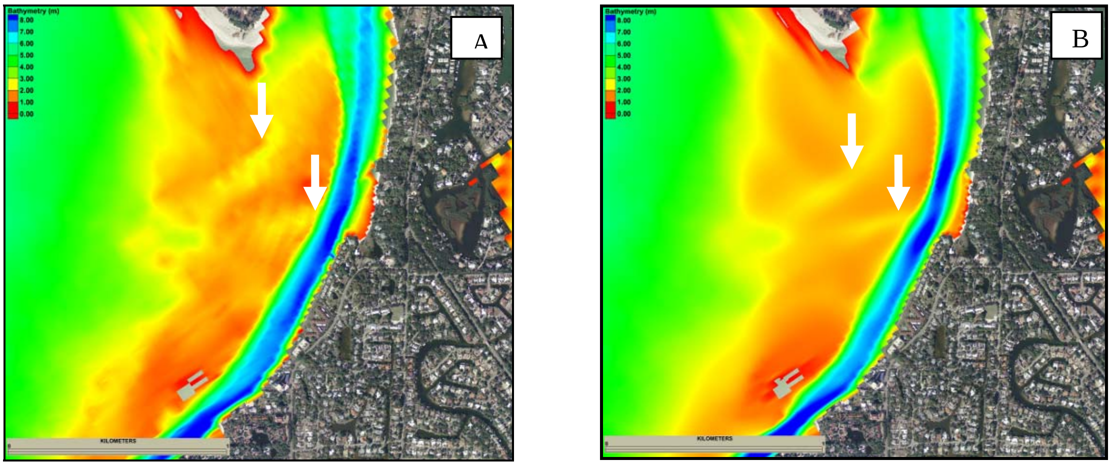

Figure 17. Initial bathymetry (A) and modeled (B) bathymetric change at Big Sarasota Pass (unaltered bathymetry). Note the migration of the marginal channels (yellow) along the updrift side of the ebb tidal delta.

5. Conclusions

This study concerned three interactive aspects. The first aspect was to analyze various historical data to determine the long- and short-term trends in morphology change, especially the sediment bypass patterns, under both natural and anthropogenically modified conditions. At Big Sarasota Pass, which has never been dredged, a significant amount of sediment is transported naturally around the ebb delta and reaches the downdrift beach. At New Pass and Johns Pass, frequent channel dredging intensifies the ebb jet. Increased activity of onshore migration of swash bars is often observed shortly after the dredging. In addition, the southward longshore transport tends to bend the ebb channel toward the south.

A subsequent task of this study was to employ and examine the capabilities of the Coastal Modeling System (CMS) in reproducing the observed major trends of morphology changes. The numerically simulated inlet hydrodynamics, sediment transport directions and magnitudes, and some key morphology changes compared well with observed trends. In addition, the trends were obtained using default values for the empirical coefficients without extensive manipulation. Trends of bypassing, both wave induced transport and by tidal flushing, are represented reasonably well. Finally, the CMS was used to predict possible changes associated with various inlet modifications, and physically plausible results were found.

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