EVALUATION OF TIDAL INLETS CHANNEL MIGRATION AND MANAGEMENT PRACTICES IN SOUTHWEST FLORIDA

MOHAMED A. DABEES, BRETT D. MOORE and KENNETH K. HUMISTON

Humiston & Moore Engineers, Naples, Florida, USA md@humistonandmoore.com.

Abstract: This paper discusses evaluation of inlet channels morphologic response to natural evolution and management practices at various navigation inlets in southwest and central Florida. The scope of the evaluation includes the natural evolution of the inlet channel and effects of navigation dredging, as well as mining sand from other parts of shoal systems as sources of material for beach nourishment. This paper reviews three case studies of navigation inlets in southwest and central Florida with various inlet stabilization scenarios. The case studies include an inlet with two long jetties (Venice Inlet), an inlet with one jetty on the up-drift side (Longboat Pass) and an inlet without stabilization structures (Wiggins Pass). Data and model results for each of the three cases are analyzed to understand common factors that contribute to channel migration for inlets with/without jetties and maintenance dredging programs.

Introduction

The majority of the Florida gulf coast is made up of systems of barrier islands separated by multiple inlets sharing the tidal prism of large bay areas. Coastal development in south Florida during the past century has included improvement of numerous tidal inlets to stabilize their navigation channels. Inlet navigation improvements include maintenance dredging and construction of stabilizing structures such as jetties and terminal groins. Up-drift impoundments, and downdrift erosion has been a persistent consequence for navigation inlets with long jetties. Until the 1970s, inlet management practice in Florida included offshore disposal of dredged material, which interrupted natural bypassing and reduced sand supply to downdrift beaches. Chronic erosion downdrift of dredged inlets led to several inlet management studies in the 1980s and 1990s. Since that time, in cases of inlets with long jetties, a common practice to mitigate downdrift erosion has been through mechanical bypassing. Additionally, placement of maintenance dredged material on the adjacent monitored beaches is now a common practice for all inlets. Response of adjacent shorelines to existing inlet structures and the lack of tools to assess consequences have resulted in the potential for continuing adverse impacts, a valid concern to regulatory agencies. As a result, regulatory agencies in Florida have resisted permitting of new structures on unimproved inlets and preferred maintaining navigation channels through dredging and placing the disposal material on the beach to mitigate for potential impacts. In the absence of inlet stabilization structures, frequent dredging

may be necessary to stabilize channel location and maintain depth sufficient for reliable navigation in critical shoaling areas. In addition, ebb shoals have been used as sources of sediment for beach nourishment because of their close proximity to shore and probable compatibility of sediment grain size and color with those of the neighboring beaches. However, removals of sediment from ebb shoal morphologic features interrupt the natural sediment bypassing of the integrated sediment-sharing system. Beach erosion and channel migration are among potential consequences of cumulative effects of ebb shoal and channel dredging. Rosati and Kraus (2009) discussed empirical and analytical relationships for predicting channel shoaling based upon historical maintenance dredging data for channels that have been deepened, widened, and lengthened. Among their observations for deep navigation channels is expanding the dredging volume may result in an large increase in required dredging rates rather than reducing it. Inlet management programs continue to evaluate their inlet management policies and implementation to safeguard navigation and reduce impacts to adjacent beaches.

Case Studies

This paper discusses evaluation of inlet channels morphologic response to natural evolution and management practices at various navigation inlets in southwest and central Florida. The scope of the evaluation includes the natural evolution of the inlet channel and effects of navigation dredging, as well as mining sand from other parts of shoal systems as sources of material for beach nourishment.

This paper reviews three case studies of navigation inlets in southwest and central Florida with various inlet stabilization scenarios. The case studies include an inlet with two long jetties (Venice Inlet), an inlet with one jetty on the updrift side (Longboat Pass) and an inlet without stabilization structures (Wiggins Pass). The three navigation inlets are located within 200Km along southwest Florida gulf coast. Figure 1 shows a location map of the three selected case studies. The case studies are discussed in this paper in the order of the establishment of each inlet's navigation channel, Venice Inlet (1937), Longboat Pass (1977) and Wiggins Pass (1984).

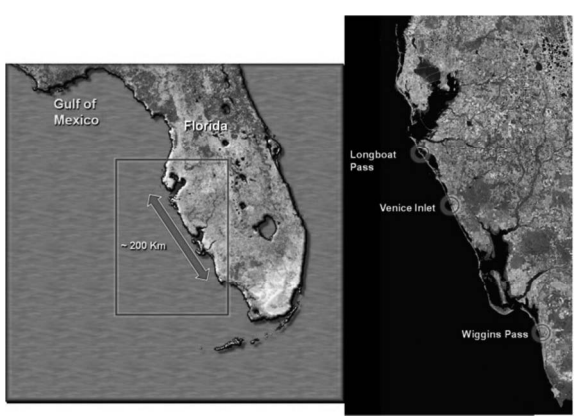

Fig. 1. Location map of the case studies

Venice Inlet Case Study

Venice Inlet, formerly known as Casey's Pass, is located between Venice Beach to the south and Casey Key to the north. This inlet is one of several tidal connections between the Gulf of Mexico and the Intracoastal Waterway (ICW), providing gulf access for the vicinity of Lyons Bay, Dona Bay, Roberts Bay, and Little Sarasota Bay. Figure 2 shows the present waterway configuration, including the location of the Federal Navigation Channel, the ICW, and inter-connected bays in the vicinity of Venice Inlet. In 1937, Casey's Pass was stabilized with two jetties in their present location and the U.S. Army Corps of Engineers authorized a Federal Navigation Project, which has been maintained since 1945. The pass became known as Venice Inlet. Humiston & Moore (H&M) (2008) study compiled recent and historic surveys, aerial photographs, and other data to document the morphologic evolution of the inlet and its system of channels and shoals. This information was also used to set up numerical models that simulate the inlet tidal hydraulics and coastal processes which have driven the inlet morphological changes at various stages in its evolution. Detailed wave and sediment transport modeling with the Coastal Modeling System (CMS) (Buttolph

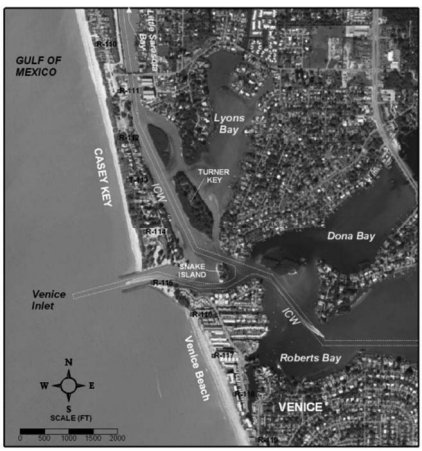

Fig. 2. Venice Inlet (Present conditions)

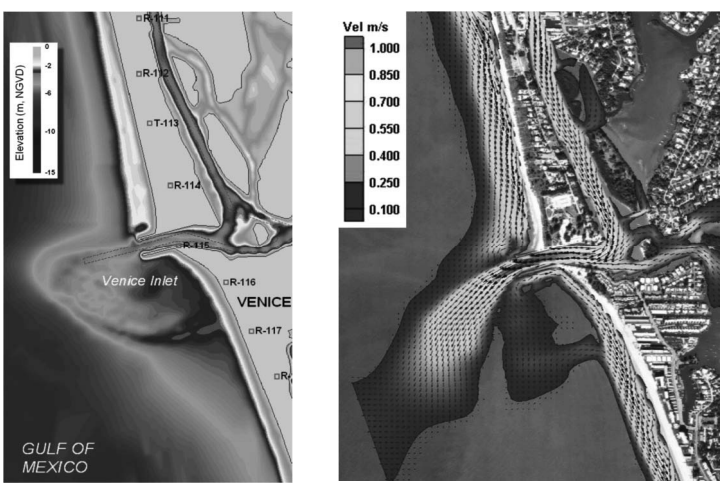

Fig. 3. Venice Inlet bathymetry and wave/current interaction for ebb tide condition

et al. 2006) was used to simulate wave and current interaction and sediment pathways for various temporal conditions. In this paper model results pertaining to the navigation channel are discussed. Further details of the Venice Inlet evolution are discussed in H&M (2008), and Dabees and Moore (2011).

The two long jetties constructed in 1937 were prior to the development of the ICW in the 1960's. The bay development resulted in a large increase in the tidal prism flowing through Venice Inlet. Figure 3 shows Venice Inlet present conditions and model results of the wave and current interactions at maximum ebb tide condition. The wave input used in the selected case shown represent storm conditions of 1.5m waves from the northwest which generate transport from north to south. The restricted cross section of the inlet between the two jetties resulted in high velocities generating a strong ebb jet that extends far enough offshore to keep the navigation channel deep enough for navigation reducing the need for maintenance dredging. However, the long jetties and offshore shoal formation produced chronic downdrift erosion. Sand nourishment of Venice Beach is part of Venice Inlet management to mitigate for the inlet downdrift effect. Sand dredged from the inlet channels is placed on the downdrift beach, and Venice Beach was also nourished in 1994, 1996, and 2005 with sand from an offshore borrow source.

Longboat Pass case Study

Longboat Pass is a tidal inlet in west-central Florida connecting the north part of Big Sarasota Bay to the Gulf of Mexico. The inlet is part of a large multi-inlet bay system, made up of the large and shallow bay areas of Sarasota Bay which are connected to the Gulf of Mexico by several tidal inlets. The Longboat Pass study (H&M 2008) evaluated the inlet evolution at various temporal stages. The main modeling stages included three temporal conditions, the 1880s, the 1950s, and present conditions. The 1880s represented natural conditions before any development in the region, the 1950s represented the conditions immediately prior the major navigation improvements such as jetty constructions and dredging of navigation channels, and present conditions represented the hydrodynamic and morphologic response to the various natural and anthropogenic changes over the past half century. In this paper selected results pertaining to the inlet channel are discussed herein. Detailed analysis of the Longboat Pass evolution is discussed in H&M (2008) and Dabees and Kraus (2008). Figure 4 shows Longboat Pass at the 1955 conditions prior to the navigation improvements of the inlet. The federal channel authorized in 1977 is superimposed on this figure for illustrative reference. The figure also shows the flow results of the wave and tidal current modeling. The wave input used in the case shown represents storm conditions of 1.5m waves from the northwest generating southward transport. The figure shows the flow patterns on the ebb tide cycle during maximum ebb current velocities, and

the tidal flow interaction with wave driven currents. The figure also shows the schematized sediment pathways for that condition. The wave and current modeling for 1955 conditions were analyzed to explain the inlet dynamics prior to navigation improvements at the inlet. The model results indicated that during flood tide the ebb shoal provided a pathway for littoral transport to bypass the inlet, and it sheltered the shoreline from direct wave action. The ebb shoal therefore provided a level of natural beach erosion control and reduced sediment transport into the inlet during flood tide. During ebb flow, in the 1950s, the ebb shoal

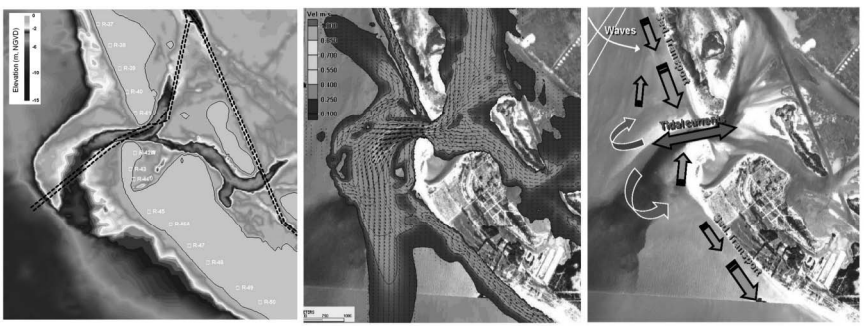

Fig. 4. Longboat Pass conditions prior navigation improvement (1950's)

provided the bypassing bars and channel margin shoals on both sides which extended the ebb jet seaward. The ebb currents created a near-symmetric ebb shoal by allowing sediment carried by the ebb jet to be deposited on both the north side as well as south side of the inlet.

Major development in the region during the late 1950s included construction of the jetty at the north side of the inlet to support the landing for the bridge across the inlet in 1957. The jetty impoundment over the years helped advance the shoreline on the north side of the inlet and pushed the ebb jet further offshore. The dredging of the navigation channel and jetty construction improved the hydraulic efficiency of Longboat Pass which increased the tidal prism through the inlet. As a result, the ebb shoal grew in volume and extended further offshore. The growth of the ebb shoal can be observed in the aerial photos and the survey data of the 1980's and 1990's (H&M 2008).

The Longboat Pass federal navigation channel was authorized and first dredged in 1977 after the US Corps of Engineers Detailed Project Report on Longboat Pass was completed in 1975. Including the initial dredging of that project in 1977, the inlet has been dredged five times as a federal project (Taylor 2002). Figure 5 shows the inlet conditions pre and post navigation dredging conditions in 1992. The strong tidal currents (ebb jet) scoured a natural inlet channel at depths greater

than the authorized navigation depth of 3.8m for over 1km offshore where the ebb shoal outer bar formed. The required maintenance dredging was limited to dredging the entrance to inlet channel across the seaward part of the ebb shoal to maintain the required navigation depth. The channel maintenance dredging was done at an average 6 year interval. The natural currents plus the 6-year maintenance dredging stabilized the navigation channel at the authorized location from the initial dredging until the mid 1990's when the channel started to migrate southward in response to the 1993 mining of the ebb shoal. The seaward portion of the Longboat Pass ebb shoal was dredged in 1993 to mine approximately 1.5 million cubic meters of sand for beach restoration on Longboat Key. The dredging which took place in 1993 significantly altered the geometry and volume of sand in the ebb shoal. Figure 6 shows the post 1993 dredging bathymetry for Longboat Pass. Wave, flow, and sediment transport were simulated for pre and post 1993 dredging to evaluate the changes caused by the dredging. Wave and current interaction for the pre and post dredging conditions were simulated with the CMS to quantify the change in sediment exchange pattern between inlet features. The model results indicate the effect of the dredging on changing the current circulation across the ebb shoal. Under the post dredging conditions, the seaward extent of the ebb jet current became much shorter due to the widening of the cross section area near the dredging location. The CMS was also run for condition 5 and 14 years post dredging conditions to identify the change in inlet dynamics as it evolves post mining of the ebb shoal. The process modeling of the pre and post dredging conditions identified the change in circulation patterns as the ebb jet and morphologic features migrate further south.

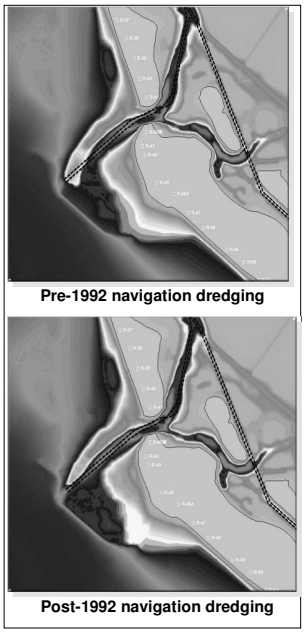

Fig. 5. Pre and post navigation dredging bathymetry (1992)

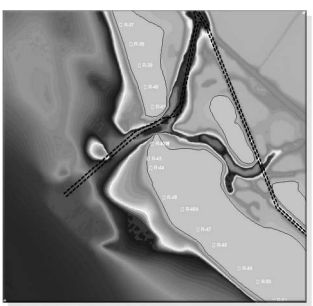

Fig. 6. Post borrow area dredging bathymetry (1993)

Figure 7 shows model results of the wave and current interaction for Longboat Pass, for pre and post 1993 dredging conditions. The wave input used in the

selected case shown represented storm conditions of 1.5m waves from the northwest generating southward transport. The figures show the flow at maximum ebb tidal currents and the tidal flow interaction with wave driven currents. The figure indicates the effect of the dredging on changing the current circulation across the ebb shoal. Under the post dredging conditions, the seaward extent of the

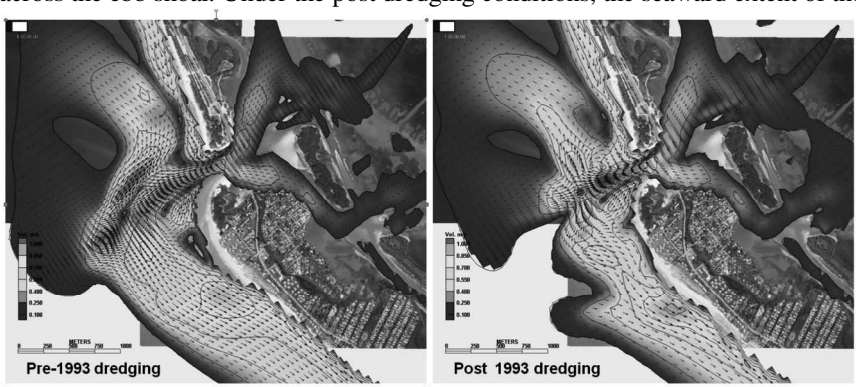

Fig. 7 Wave/ tidal currents model results for pre and post 1993 dredging of the ebb shoal.

ebb jet current became much shorter due to the widening of the cross section area near the dredging location. The model results indicate that, the seaward ebb jet extent post dredging was approximately 300m less than pre dredging. The shorter ebb jet resulted in sand depositing much closer to shore in the channel to form the outer ebb shoal bar. Consequently the channel was forced to migrate southward as the tidal currents and waves eroded the downdrift channel marginal shoal.

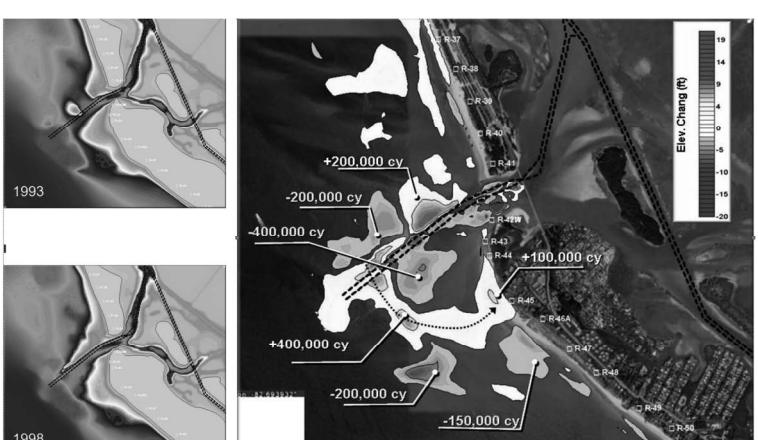

Fig. 8 Morphology change 5 years post 1993 dredging of the ebb shoal.

Figure 8 shows the morphologic change 5 years from post dredging conditions 1993 and 1998. The figure shows the inlet adjustment to reestablish bypassing across a smaller ebb shoal volume. Figure 9 shows the morphologic changes between 1998 and 2007 conditions showing the infilling of the authorized federal channel as the channel migrated south in response to the downdrift shoal erosion.

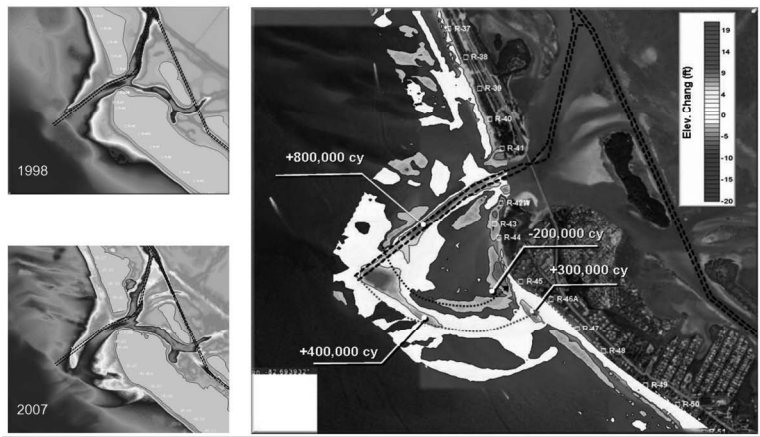

Fig. 9. Morphology change 1998-2007.

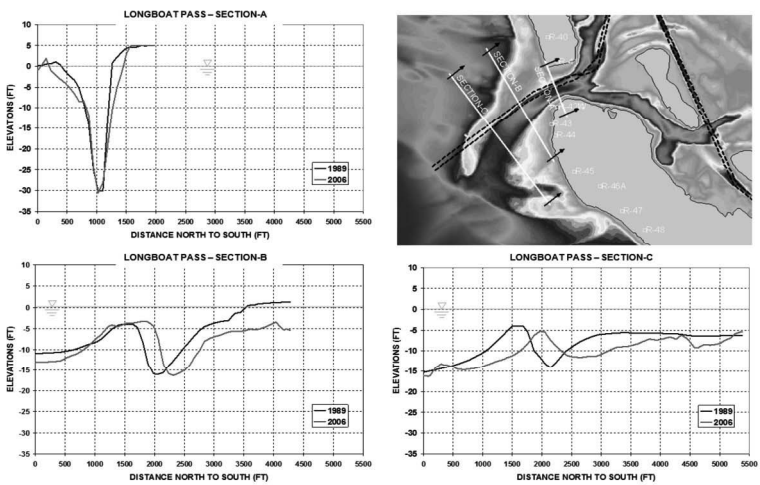

Fig. 10. 2007 bathymetry and inlet channel cross-sections 1989-2007

Figure 10 shows the 2007 condition of Longboat Pass and three profiles across the ebb shoal channel from the inlet throat to the seaward limit of the channel. The inlet cross sections show erosion on the south side of the channel near the throat, the south migration of the inlet, and the large volume loss from the two shoals adjacent to the channel. The figure also indicates shoaling of the seaward extent of the channel as the ebb shoal migrated closer to shore. Analysis of historic changes, available data, and modeling of coastal processes indicate minor recovery in total ebb shoal volume has occurred. However, because of the altered channel orientation and position closer to shore, the authorized federal channel no longer follows the natural tidal channel.

Wiggins Pass Case Study

The case study of Wiggins Pass (Collier County, Florida) is for an inlet without stabilization structures which is maintained for navigation through dredging. Wiggins Pass has a natural channel depth of approximately 2.5m and relatively small ebb shoal (approximately 400,000 m^3). The inlet was first studied in 1980 (USACE 1980) and was first dredged by Collier County, Florida, in 1984. Before the first dredging, the critical depth for navigation at the seaward limit of the ebb channel was approximately 1.8 m MWL at a distance greater than 250 m offshore.

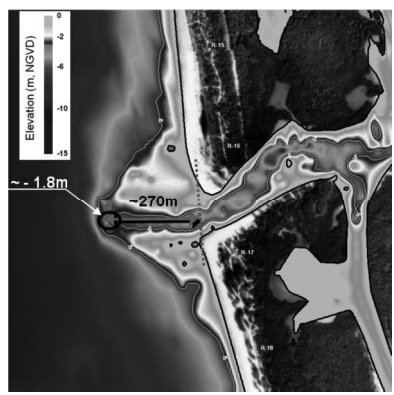

Fig. 11. Wiggins Pass bathymetry prior to initial navigation dredging (1970's)

Figure 11 shows the contour map of the inlet system in the 1970's, prior to initial dredging of the inlet. This figure shows channel depths of greater than 2.5 m due to scouring by tidal currents, however, the controlling navigation depth was approximately 1.8 m at the seaward limit of the channel where it crossed the seaward part of the ebb shoal more than 270m offshore. At present, after frequent dredging (average 2-year interval since 1984), the critical depth has become less than 1m and at a distance less than 130 m offshore. Figure 12 illustrates recent

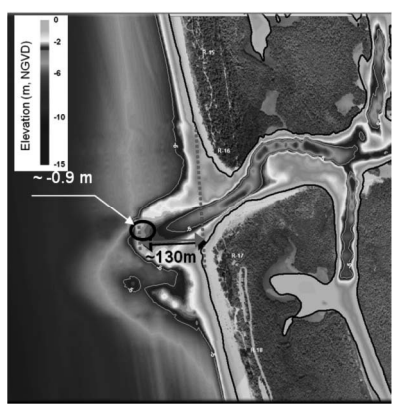

Fig. 12. Wiggins Pass bathymetry 2007

conditions of Wiggins Pass prior to the 2007 maintenance dredging. Between 1970 and 2007 the controlling navigation depth had decreased from approximately 1.8 to 0.9m, and the offshore distance to this shallowest area had decreased from approximately 270m to 130m. In recent years, shoaling has typically occurred rapidly after dredging is completed resulting in shallower navigation depths than those which existed prior to the initial dredging of the inlet in 1984. The frequent dredging depleted the updrift lobe of the ebb shoal and resulted in chronic beach erosion, inlet channel migration, and ebb shoal migration to shallower water. To safeguard navigation, more emergency dredging and expanded dredging templates were implemented, which exacerbated the problem. Detailed wave and sediment transport modeling with the CMS was done to identify morphologic features and sediment pathways for conditions before the 1984 initial dredging to present conditions. The modeling was done to provide evaluation of dredging effects on channel and inlet evolution.

The initial dredging design in the early 1980's established -8.0ft (2.4m) MLW as the maintenance dredging depth which is close to the natural channel depth contour except at the seaward end of the channel where the depths are shallower. The goal of the dredging program for Wiggins Pass to maintain a channel that boaters could rely on for navigation. The template which was first dredged in 1984 generally followed the natural channel alignment. Model results illustrated in Figure 13 show detailed maximum ebb velocities for an average tide at Wiggins Pass for conditions prior to initial dredging of 1984. The figure also shows the limits of the initial dredging template. Velocities higher than the critical shoaling velocity (maximum velocity at which shoaling can occur) are indicated in red. The dredging template was modified in the 1995 Inlet Management Study (CP&E 1995) by dredging the channel deeper to -4.0 m and moving the dredge template to the north and increasing the width to include a deposition basin along the north side of the channel. The extended dredging in width and depth was

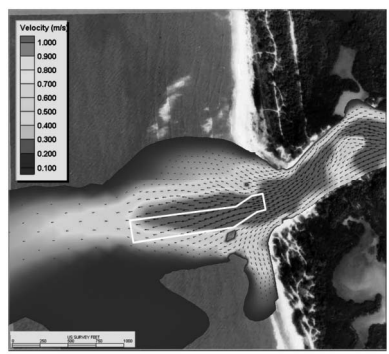

Fig. 13. Ebb current velocities for conditions prior to 1984 dredging

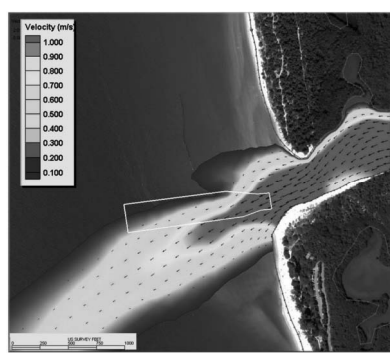

Fig. 14. Ebb current velocities for 2007 conditions post expanded dredging

designed as advance dredging in an attempt to reduce frequency of required maintenance dredging. The modified template was first dredged in 2000. Since then however, maintenance dredging requirements have increased. The larger dredge template increased the capacity of the channel to accumulate sand before it would form a shoal shallow enough to require dredging; however, the wider and deeper template resulted in lower velocities and a more rapid rate of shoaling. Figure 14 shows detailed maximum ebb velocities for an average tide at Wiggins Pass for 2007 conditions. The figure also shows the limits of the expanded dredging template adopted in the year 2000. In contrast to the 1970's conditions, the portion of the natural channel with currents higher than the critical shoaling velocity is a very small part of the dredging template for 2007 conditions. The high velocities drop significantly at a short distance seaward of the inlet throat and do not continue offshore as a strong ebb jet to keep the dredged channel open. The velocities prior to the initial dredging in 1984 produced an ebb jet which continued more than 260 feet seaward of the inlet throat because flow was confined to a small cross section between the symmetric lobes of the ebb shoal. The shoreline retreat and loss of a large volume of sand from the north side of the ebb shoal eliminated the north bank of the entrance channel. The result is a very large cross sectional area where the velocities diminish and shoaling occurs. Figure 15 shows a comparison of the inlet cross section for 1970 and 2007 pre dredging conditions.

Detailed wave and sediment transport modeling using CMS simulated wave and current interaction and sediment pathways for conditions before the 1984 initial dredging, present conditions, and for evaluating other channel geometry alternatives. The model results indicate the effects of erosion of the ebb shoal bar and shoreline retreat on the north side of the inlet. The 1970's condition indicates how the shoal provided a pathway for littoral transport to bypass the inlet and shelter the shoreline from direct wave action. The shoal therefore provided a level of natural shoreline erosion control and reduced sediment transport into the inlet during flood tide.

Figure 15 shows comparison of wave/ current flow for the ebb tide condition and northwest waves. For the 1970's condition the symmetric ebb shoal lobes provided channel banks on both sides to extend the ebb jet seaward. This explains why the 1970's ebb shoal extended further offshore than present conditions. The ebb currents created the symmetric ebb shoal by allowing sediment carried by the ebb jet to be deposited on both the north side as well as south side of the inlet.

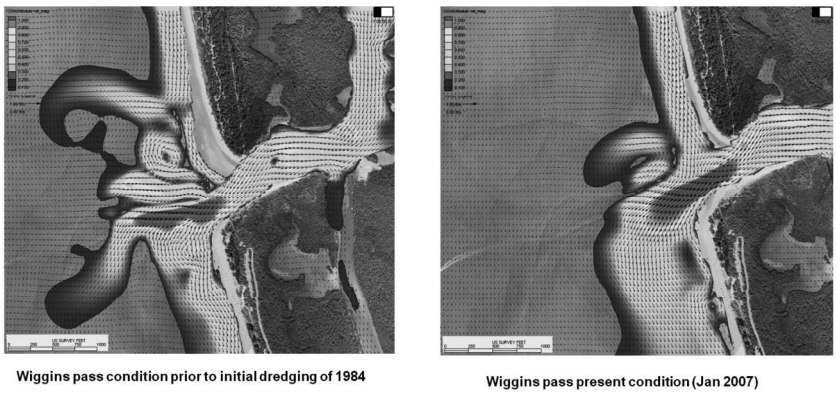

Fig. 15. Wave/ tidal currents model results for pre initial dredging and present condition

Cumulative effects of the dredging depleted the north side of the ebb shoal. The absence of an adequate ebb shoal on the north side of the channel allowed the momentum of wave driven currents to force the ebb jet to the south. This resulted in southward migration of the shoal, and as the ebb jet migrated south, the majority of sediment carried by the currents was deposited on the south side of the inlet. Additionally, the model results show that erosion of the ebb shoal and shoreline retreat north of the inlet shortened the seaward extent of the ebb jet. The shorter ebb jet contributes to the higher rate of shoaling closer to shore.

Summary and Conclusions

Three case studies of tidal inlets in southwest and central Florida are discussed. The paper focused on dredging effects on channel evolution. The case studies of Venice Inlet, Longboat Pass, and Wiggins Pass presented varying natural evolution and navigation management practices. Venice Inlet case study discussed the case of an inlet channel stabilized by two long jetties providing a stable navigation channel. The long jetties, however, caused reduction in inlet bypassing and chronic downdrift beach erosion problem. The case study of Longboat Pass discussed an inlet with a single jetty on the up-drift side. The navigation channel which was first dredged in 1977 was maintained by a 6 year dredging cycle of its entrance. When the ebb shoal of Longboat Pass was mined for over 1.5 million cubic meters for beach nourishment, the morphologic response to the large scale dredging included channel migration in the downdrift direction. The case study for Wiggins Pass represented a small inlet without stabilizing structures that was maintained though dredging. In an attempt to improve dredging frequency an expanded dredging was adopted over 10 years ago. The cumulative effects of the

expanded dredging resulted in depletion of the ebb shoal, higher infilling rates and channel migration.

Data and model results for each of the three cases are analyzed to understand common factors that contribute to channel migration for inlets with/without jetties and maintenance dredging programs. The goal of the analysis is to evaluate long-term effects of previous inlet management practices as well as concepts such as depth over-dredging and up-drift advanced dredging designed to reduce dredging frequency. The data and analysis indicate that in some cases the navigation dredging program helps to stabilize the channel location, and in other cases it contributes to the channel migration which could lead to high infilling rates and increase in dredging frequency that complicates the sand management of the inlet and effects on adjacent beaches.

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