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Processes and Patterns of Sedimentation at Blind Pass, Florida

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ABSTRACT

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A field-oriented sedimentation study was conducted at Blind Pass Florida, shortly after the last channel dredging in the summer of 2000. Blind Pass is a wave-dominated tidal inlet that has been migrating southward for over 3,000 meters before it was stabilized by a series of hard-engineering structures since 1937. Thereafter, the inlet has been maintained by frequent dredging. The dredged material was typically used to nourish the adjacent beaches, especially the downdrift Upham Beach. Time-series measurements of tidal currents and bathymetry were conducted in the inlet channel. The ebb-dominated main channel, roughly 6 m deep, extends along the southern side, where peak ebb current approached 150 cm/s. Along the northern side of the inlet, the ebb currents are much weaker, as compared to both the flood current and ebb current in the main channel. Shortly after the 2000 dredging, rapid sedimentation was measured along the northern side of the inlet. This accumulation is likely resulted from the predominant southward longshore sand transport, bypassing the north jetty. The northern part of the inlet is dominated by flood-directed current and the weak ebb current is not adequate to flush the bypassed sediment out of the inlet. Along the southern side with the deep channel, active sediment flushing is evident as indicated by the coarse, shelly lag deposit on the bottom. Roughly 28 months after the channel dredging, the northern side near the entrance has become shallow enough to induce wave breaking over the shoal. Distinctive seasonal patterns of sedimentation are measured thereafter in the inlet channel, influenced by the seasonal wave climate.

ADDITIONAL INDEX WORDS: *Tidal inlets, nearshore sediment transport, coastal morphodynamics,*

INTRODUCTION

Blind Pass is located in the west-central Florida coast (Figure 1). It is a typical wave-dominated tidal inlet (DAVIS, 1997; DAVIS and HAYES, 1984) and has been migrating rapidly southward along shore, driven by the regional southward longshore sediment transport. The net rate of the southward longshore transport was estimated to be approximately 36,000 m^3 per year (WALTON, 1973; WANG *et al*., 1998a, 1998b). The south jetty was constructed in 1937 to stop the southward migration. Before that time, Blind Pass migrated southward for over 3,000 m. Historical aerial photos indicate that the pass moved approximately 600 m between 1926 and 1937. The pass was further stabilized with a northern jetty in 1962. Both jetties have since been extended. Although the inlet position has been stabilized, the channel filling has been extremely active. The channel has been dredged 12 times since 1937. The sand dredged from Blind Pass has been used to nourish the updrift Treasure Island to the north and the downdrift Upham Beach to the south. A summary of the morphological history of Blind Pass is presented in TIDWELL *et al*. (2003).

The tidal prism through Blind Pass has been decreasing steadily since the late 1800's. Most of the tidal prism has been captured by the John's Pass to the north, which was cut by the hurricane of 1848 (DAVIS and BARNARD, 2000). The decreasing tidal prism contributed significantly to the decreasing ability of sediment flushing at Blind Pass. Before the 1950's, an ebb-tidal shoal existed, as evident from the aerial photos. The wave sheltering, sand bypassing, and probably also onshore migration of the ebb shoal caused considerable accretion at the Upham Beach directly downdrift of the inlet (METHA *et al*., 1976). The ebb shoal started to diminish in the late 1950's due to further decrease of the tidal prism, partially accelerated by the causeway construction and the dredge-and-fill operations in Boca Ciega Bay (Figure 1). Losing the wave sheltering and sand bypassing, Upham Beach experienced chronic shoreline erosion since the 1970's. Frequent beach nourishment was necessary to maintain the beach, which has become a persistent erosional area among the generally successful beach nourishment projects in Florida (DAVIS *et al*., 2000).

The latest channel dredging at Blind Pass was conducted in the summer of 2000. Active channel filling started immediately after the dredging. This provided an excellent opportunity to study the processes and patterns of sedimentation in the inlet channel. The present field-oriented study includes time-series morphological surveys and hydrodynamic measurements in the inlet. An upward-looking Acoustic Doppler Profiler (U-ADP) was used to measure tidal flow through the main channel. A side-looking ADP (S-ADP) was deployed at the northern side looking across to the south, with the goal of quantifying the tidal flow patterns across the inlet. Field observations indicate that cross-channel variations in tidal flow patterns are crucial to the sediment-accumulation pattern. A directional (PUV) wave gage was deployed near the north jetty to measure the interactions of wave-current and the structure. Time series bathymetric surveys were conducted to quantify sand-accumulation patterns inside the inlet. Historical aerial photos were compared to identify the historical trend of inlet evolution. A series of bottom sediment samples was collected across the inlet channel to examine trends of selective sediment transport.

METHODOLOGY

Typical of a structurally stabilized wave-dominated migratory tidal inlet, the Blind Pass channel is characteristic of a sharp (nearly 90 degree) turn before entering the Gulf of Mexico (Figure 2). The channel widened substantially after the turn time-series bathymetry data were collected using a synchronized precision echo sounder and a GPS system. The influence of tides on the depth sounding was removed using *in situ* tide measurements during the survey. Since February 2002, the water depth along the northern side has become too shallow for the vessel-based survey due to the active sediment accumulation. To resolve this problem, nine survey lines were established and level-and-transit surveys were conducted using an electronic total survey station (Figure 2A). Sedimentation

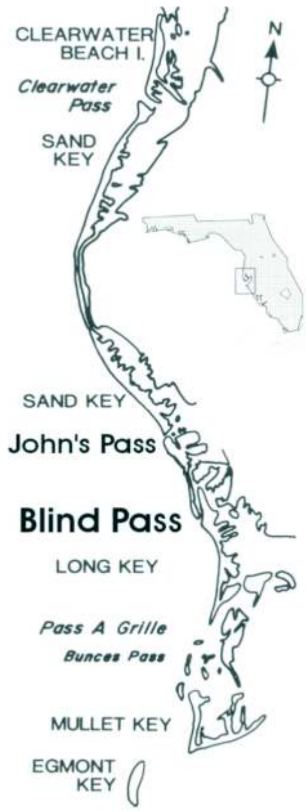

Figure 1. The study area. The water body landward of Blind Pass and John's Pass is the Boca Ciega Bay

and erosion patterns are obtained through comparison of the time-series bathymetry data with those obtained immediately after the 2000 dredging.

Tidal flow patterns were obtained using one upward-looking ADP (U-ADP) measuring current profiles and one side-looking ADP (S-ADP) measuring cross-channel flow distribution. The U-ADP was deployed in the main channel at two different locations (Figure 2B: circles). The sensor was deployed approximately 21 cm above the bottom on a platform driven into the sand by divers. Compared to the traditional tripod-type mounting and weight-anchored deployment, this innovative platform-mounting is stable, both vertically and horizontally, in a very dynamic tidal inlet environment. Subsidence due to the heavy weight is minimized. This is crucial for accurate measurement of tides. The S-ADP was deployed at the northern side of the inlet looking southward across the channel (Figure 2B: stars). The S-ADP was mounted on an 8-cm diameter aluminum pipe that was driven deep into the sand using a coring device. This deployment design allows the sensor to be mounted at any water level along the pipe. For the present measurements, the sensor was mounted roughly in the mid water depth. Data from the wave-gage measurements (Figure 2: square) are not discussed in this paper.

Five current measurements were conducted during January-February 2001, August-September 2002, November 2002January 2003, April-May 2003, and July-September 2003. A bathymetric survey was conducted during each current-sensor deployment, in addition to the survey directly after the channel dredging. The four measurements, two in the summer and two in the winter, during 2002-2003 allow the examination of seasonal variations. The level-and-transit survey was conducted monthly since February 2002 to examine, in detail, the sand migration over the shoal along the northern side of the channel and its seasonal variations.

RESULTS AND DISCUSSION

The patterns of sedimentation and erosion should be closely related to the characteristics of tidal flow through the inlet

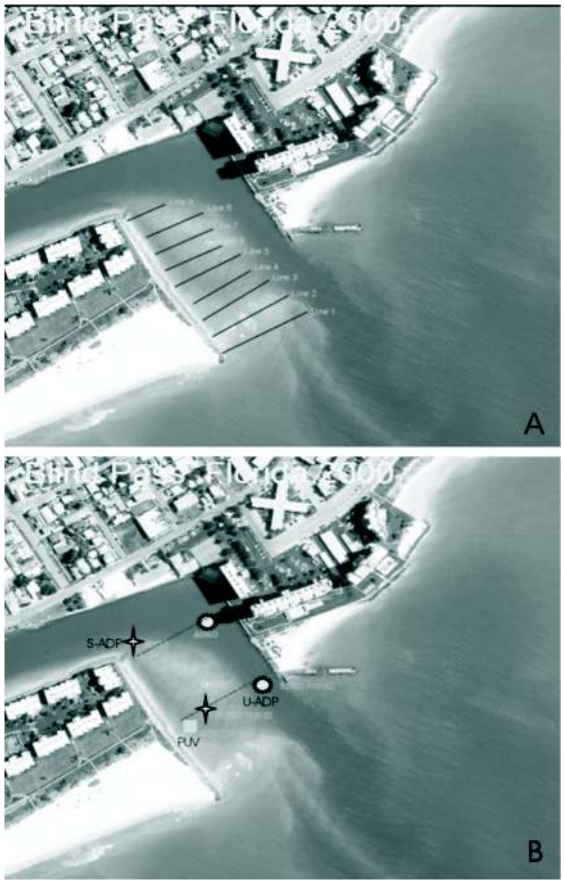

Figure 2. Locations of the nine level-and-transit survey lines (A) and current meters (B).

channel. In the following, characteristics of tidal flows across the inlet and throughout the water column are discussed first, followed by the discussion of sedimentation patterns. We then attempt to relate the patterns of sedimentation and erosion to the hydrodynamic characteristics.

Characteristics of the Tidal Flow

The deep channel along the southern side shows clear ebb dominance. Figure 3 shows the measured tidal currents over one spring tidal cycle. Negative numbers indicate ebb-directed current and positive numbers indicate flood current. The peak ebb-current velocity is much faster than the peak flood velocity. During spring tides, the peak ebb current exceeds 100 cm/s, while flood current is typically less than 50 cm/s, or only half of the ebb velocity (Figure 3).

The velocity profiles of the tidal current, both ebb and flood currents, are homogeneous throughout most of the water column (Figure 3). The upward-looking ADP is not capable of measuring current within approximately 1 m from the bed. However, no upward increasing trend, as typical of most open channel flows, can be identified. The homogeneous profiles indicate that the bottom friction has limited influence on the overall shape of the tidal current profiles. The reason for the homogeneous current profiles is not clear. Wave mixing and frequent change of flow directions may play significant roles.

Patterns and velocities of the tidal current are nearly identical shortly after the dredging in January 2001 (Figure 3A) and 2.5 year later in November 2002 (Figure 3B). As discussed in the following section, significant sediment accumulation occurred between the two measurements, especially along the northern side of the inlet. The overall cross-sectional area of the channel has changed substantially due to the accumulation. However, the tidal flow patterns along the southern side of the channel were not influenced by the change of the overall cross-sectional area. From a different perspective, the similar ebb-dominated tidal flow is likely the reason that the deep channel along the

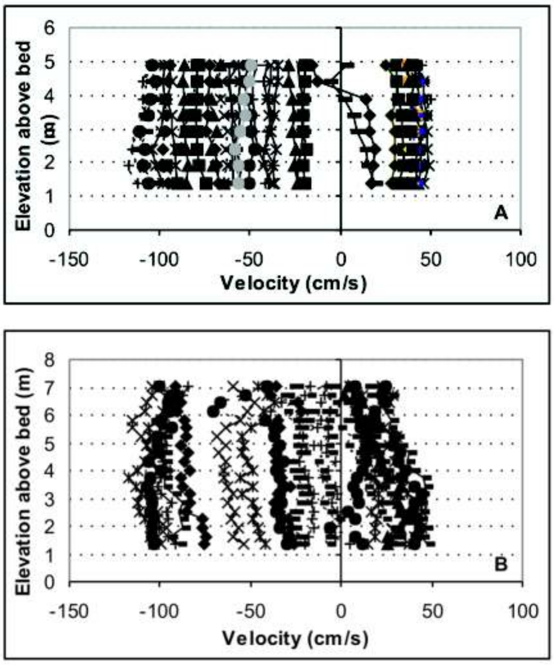

Figure 3. Profiles of tidal current measured in the main channel over a spring tidal cycle. A: current velocities measured in January 2001; B: currents measured in November 2002.

southern side has remained stable and has not significantly influenced by the accumulation along the northern side.

The overall tidal current patterns through the main channel measured at the two locations, one near the Gulf entrance and one at the bent (Figure 2B: circles), are similar. This is consistent with the similar shape of the main channel at the two locations.

Substantial cross-channel variations of tidal flow velocities are measured by the side-looking ADP (Figure 4). The cross-channel distribution patterns of tidal flows are quite different at the two locations (Figure 2: stars). Near the entrance to the Gulf of Mexico, strong ebb current (negative numbers) was measured over the main channel, consistent with the measurement from the U-ADP (Figures 3 and 4A). Along the northern side, the ebb currents were much weaker, less than 30 cm/s versus over 70 cm/s over the main channel. It is worth noting that the velocities in Figure 4 represent an average value of a 20-m distance in the cross-channel direction. Flood tidal current (positive numbers) is relatively uniform across the entire channel, in contrast to the ebb currents with a substantial peak over the main channel.

The cross-channel tidal-current distribution is quite different at the bent, as compared to that near the Gulf entrance. Faster currents, both ebb and flood, were measured near the bent than those near the entrance (Figure 4B). The currents remained relatively uniform across most of the channel and decreased near the corner of the bent. The peak ebb current during a spring tide exceeded 120 cm/s at the bent, which faster than flood current peaking at approximately 90 cm/s. The flood currents tend to be slightly more uniform across the channel than ebb currents. The stagnant current condition at the northeastern corner of the inlet channel is consistent with the sedimentation at that location observed from earlier aerial photos (TIDWELL *et al.*, 2003).

Patterns of Sedimentation and Erosion

Rapid sedimentation was measured after the 2 00 dredge. Compared to the July 2000 survey immediately after the dredge, tremendous amount of Oand accumulation was measured in August 2002. A large area along the northern side of the channel, especially near the entrance to the Gulf of Mexico, received over 2 m of sedimentation over the 2-year

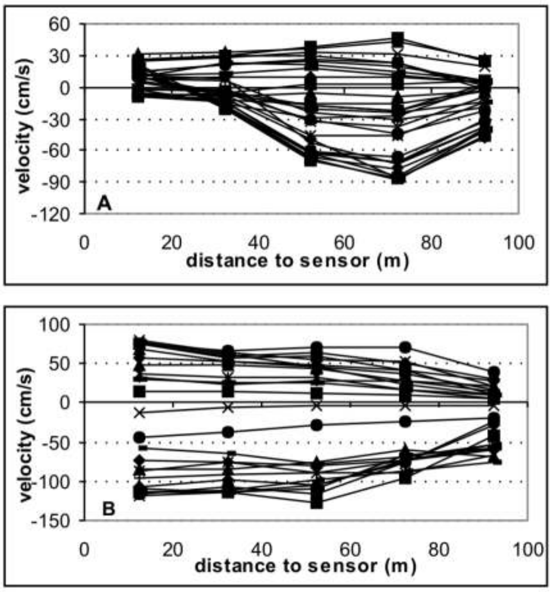

Figure 4. Cross-channel distribution of tidal flow, measured over a spring tidal cycle. A: near the Gulf entrance; B: near the bent.

period (Figure 5A). Over 3 m of sedimentation was measured along the northern slope of the main channel. Little sedimentation occurred in the main channel along the southern side of the inlet, as represented by the white area in Figure 5A. An accumulation of nearly 4-m thick was measured at the bent of the inlet channel (Figure 5A up right corner), where fast current was measured (Figure 4B). This sedimentation imposes a substantial obstruction to the flow through that portion of the inlet. The reason for this accumulation is not clear. Abnormal weather and/or abnormal tide conditions could be responsible. Continued rapid sedimentation was measured between August 2002 and May 2003. A large area along the northern side near the Gulf entrance has stabilized, showing less than 0.5 m sedimentation or erosion. Active sedimentation of up to 2-m thick was measured along the northern slope of the deep channel, particularly further landward into the inlet. This pattern indicates a trend of landward migration of the sedimentation. This is expected because the source of the sediment is form the southward longshore transport along the Gulf beach bypassing the north jetty. Therefore, the accumulation occurred first near the Gulf entrance (Figure 5A) and then migrated landward. The main channel along the southern side, although becoming narrower due to the sand accumulation, remained stable with less than 0.5 sedimentation or erosion. Also, the reducing overall cross-sectional area has not caused any substantial changes in the tidal-flow pattern and intensity in the main ebb channel, as identified from the flow measurements. The bottom of the main channel is covered by lag deposits composed of coarse shell debris of up to several cm in diameter. This indicates active sediment flushing leaving only the coarse sediment on the bottom. The sedimentation at the bent of the channel measured in August 2002 has been eroded by May 2003. The eroded sand was likely deposited along the eastern wall of the inlet, as indicated by active sedimentation of over 3 m in that area where low flow velocities were measured (Figure 4). This pattern of erosion and sedimentation is apparently related to the flushing of ebb current to maintain the conduit for ebb tidal flow. This also supports the previous interpretation that the sedimentation at the bent measured in August 2002 was event related.

In summary, rapid sedimentation occurred shortly after the summer 2000 dredging, as shown in Figure 5A. Since the sediments come from longshore transport bypassing the north jetty, the accumulation originated along the northern side of the inlet in the vicinity of the Gulf entrance. The main channel extending along the southern side of the inlet received little net

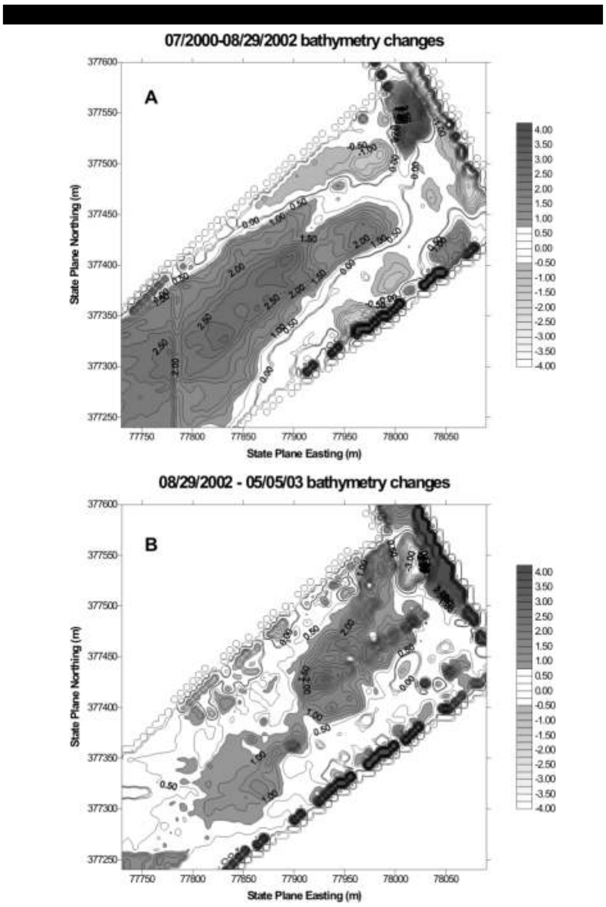

Figure 5. Patterns of sedimentation and erosion. White areas represent areas with less than 0.5 m sedimentation or erosion. Depth is referred to mean low tide. A: bathymetry changes between 07/2000 and 08/2002; B: bathymetry changes between 08/2002 and 05/2003.

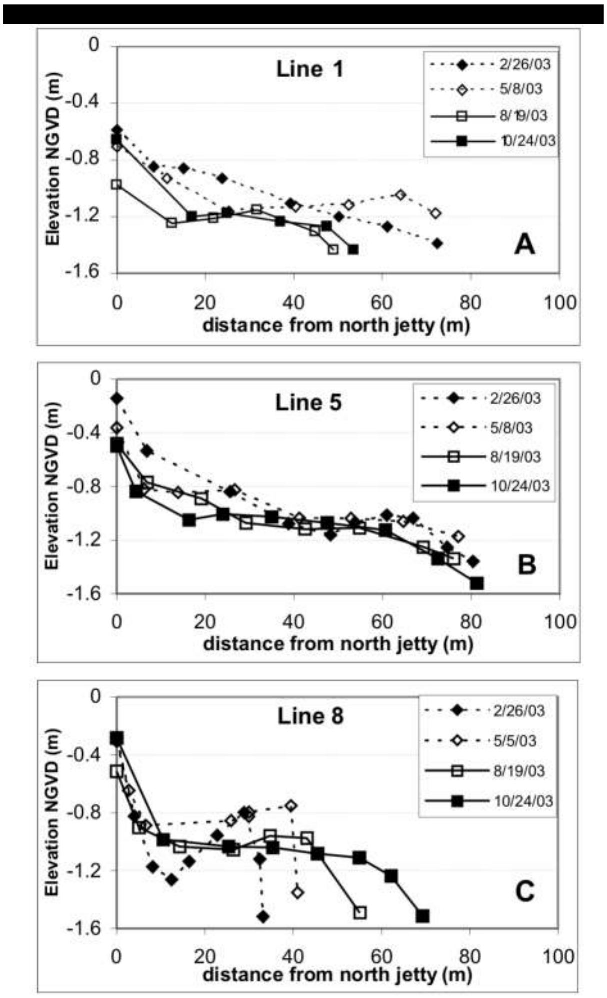

Figure 6. Patterns of sediment accumulation and erosion over the northern shoal. Locations of the lines are plotted in Figure 2.

Sedimentation due to the active flushing by the strong ebb currents exceeding 100 cm/s during spring tides. The sand accumulation demonstrated a landward migration pattern two years after the dredging. The northern slope of the deep channel has been a persistent active area for sedimentation over the past 3 years. However, the narrowing main channel has not yet resulted in increased ebb current velocity.

To investigate the detailed morphodynamics of the northern shoal, monthly surveys were conducted from February 2003 to October 2003, spanning part of the 2003 winter and most of 2003 summer. The objective of this aspect of the study is to examine the influence of seasonal wave climate changes on the sedimentation and erosion patterns. Generally, northerly waves dominate during the winter season driven largely by strong northerly wind accompanying the frequent passages of winter cold fronts (ROBERTS *et al*., 1987). Southerly waves tend to dominate during the summer season. Over the entire year, northerly waves dominate in terms of total wave energy, resulting in the predominant southward longshore transport.

Our preliminary data indicate that sediment accumulation and erosion patterns over the shallow northern shoal reflect the above seasonal variations of wave condition. At line 1 near the Gulf entrance, erosion was measured during the summer time as compared to the situations in the winter (Figure 6A). The elevations were lower and the extension of the platform was shorter in the summer than in the winter. Similar trend was measured at lines 2 and 3. In the middle of the shoal, including lines 4, 5, and 6, little change was measured from February to October (Figure 6B). Substantial accumulations were measured at lines 7, 8, and 9 toward the landward end of the shoal (Figure 6C). The shoal extended southward toward the main ebb channel for nearly 40 m from February to October. Very steep slope of nearly 28 degrees was measured at the south side extending into the main channel in the winter. This slope is almost identical to the angle of repose. This steep slope is probably maintained by the strong tidal current around the bent of the channel. The slope along the south side was much gentler in the summer time, although still quite steep. The reason for this change of slope in the winter and summer seasons is not clear. The erosion of the sand accumulation at the bent (Figure 5B) may have contributed to the slope change. Continued profile surveys and offshore wave measurements are being conducted to further quantify these seasonal changes.

A preliminary interpretation of the seasonal variation is discussed in the following. The predominant northerly wave in the winter should result in active sediment bypass around the north jetty (WANG and KRAUS, 2003). The bypassed sand tends to deposit near the Gulf entrance at lines 1 through 3. In the summer, the dominant southerly waves are not very effective in transporting sand into the inlet because 1) no sand source is available along the south side of the inlet (Figure 2) and 2) the strong ebb current along the southern side should flush the limited amount of northward-moving sand out of the inlet. Therefore, the net sand gain in the inlet channel is probably limited in the summer. However, the southerly waves may re-distribute the sand accumulated along the northern side in the winter. The sand is pushed further into the inlet, resulting in the net sedimentation at the landward lines of 7, 8, and 9. While the middle section, at lines 4, 5, and 6, quasi-equilibrium has been reached during the study period. No substantial seasonal variations of accumulation or erosion were measured. Continued data collection will further verify the above interpretation.

The above interpretation originated from field observations of wave propagation patterns in the inlet. Due to the substantial accumulation in the inlet channel, the water has become very

Figure 7. Active wave breaking over the northern shoal in the inlet channel. Upper: wave breaking during low tide; lower: wave breaking during a winter storm.

shallow. Substantial wave breaking occurs during low tide and during storm conditions (Figure 7). During February 2002, a considerable portion of the shoal became exposed during spring low tide. The active sediment suspension due to wave breaking at low tide and the relatively strong flood current over the northern shoal area (Figure 4A) may provide a mechanism for landward sediment transport. This mechanism is believed to be responsible for the erosion near the Gulf entrance and accumulation further in the channel measured during the summer season.

No large sand waves were observed during this field investigation, although ripples of approximately 5 to 10 cm high and 15 to 30 cm long are commonly observed by the divers. The lack of migrating sand waves and the lag deposits on the bottom of the main channel seem to indicate that suspended sediment transport is the dominant mode, instead of bed-load transport.

CONCLUSIONS

The wave-dominated Blind Pass has been stabilized by a series of hard-engineering structures. Frequent channel dredging is necessary to remove the sand accumulation in the inlet channel. The present field-oriented study documented the sedimentation patterns after the latest channel dredging in the summer of 2000.

The main channel extending along the southern side of the inlet is strongly ebb dominated. Peak ebb currents during spring tides exceed 100 cm/s, while peak flood current is approximately 50 cm/s. Tidal flow patterns through the main channel remained largely the same over the study period despite the dramatic change in the cross-sectional area induced by the channel dredging and the subsequent fill along the northern side.

Tidal flow patterns show substantial changes across the inlet, especially near the entrance to the Gulf of Mexico. Over the main channel along the southern side, ebb current shows clear domination, approximately twice the speed of flood current. Along the northern side, the ebb current is much weaker, as compared to both flood current and ebb current over the main channel. Fast currents of over 100 cm/s, both flood and ebb flows, are measured just seaward of the bent of the inlet. At the northeastern corner of the inlet bent, a relative stagnant area with weak flood and ebb currents exists.

Active sedimentation, predominantly along the northern side, occurred immediate after the 2000 dredging. During the first 26 months, over 2 m of sedimentation occurred over a large portion of the northern side of the inlet near the Gulf entrance. Locally and along the northern slope of the main channel, over 3 m of sedimentation was measured. Approximately 2.5 years after the dredging, the northern side of the inlet has become so shallow that it was exposed during spring low tide. Also, wave breaking is active over the northern shoal. The channel filling originated from the northern side near the Gulf entrance. A trend of landward migration was measured recently. The accumulation patterns correlate well with the tidal flow patterns, particularly the cross-channel tidal flow pattern.

A detailed monthly monitoring of the morphology of the northern shoal indicated that the sedimentation and erosion patterns are considerably influenced by the seasonal variation of wave climate. During the winter season, the dominant northerly waves cause active sediment bypassing around the north jetty, resulting in substantial sedimentation on the northern shoal near the Gulf entrance. During the summer season, the dominant southerly waves tend to redistribute the sediment over the northern shoal, resulting in erosion near the Gulf entrance and accumulation further landward in the inlet near the bent, especially along the northern slope to the main channel there. Wave breaking and its associated sediment suspension play significant roles in not only transporting sediment into the inlet but also redistributing sediment over the northern shoal.

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LITERATURE CITED

DAVIS, R.A., 1997. Regional coastal morphodynamics along the United States Gulf of Mexico. *Journal of Coastal Research*, 595-605.

DAVIS, R.A. and HAYS, M.O., 1984. What is a wave-dominated coast? *Marine Geology*, 60, 313-329.

DAVIS, R.A. and BARNARD, P.L., 2000. How anthropogenic factors in the back-barrier area influence tidal inlet stability: examples from the Gulf Coast of Florida, USA. In K. PYE and J.R.L. AlLen (eds.) *Coastal and Estuarine Environments: sedimentology, geomorphology, and geoarchaeology*. Geological Society, London, Special Publications, 175, 293-303.

DAVIS, R.A.; WANG, P., and SILVERMAN, B.R., 2000. Comparison of the performance of three adjacent and differently constructed beach nourishment projects on the Gulf Peninsula of Florida. *Journal of Coastal Research*, 16, 396-407.

METHA, A.J.; JONES, C.P., and ADAMS, W.D., 1976. *John's Pass and Blind Pass, Glossary of Inlets Report #4*. Coastal and Oceanographic Engineering Laboratory, University of Florida, Gainsville, Florida, 66p.

ROBERTS, H.H.; HUH, O.K.; HSU, S.A.; ROUSE, L.J., and RICKMAN, D., 1987. Impact of cold-front passages on geomorphic evolution and sediment dynamics of the complex Louisiana coast. *Proceedings of Coastal Sediments'87*, ASCE, 1950-1963.

TIDWELL, D.A.; WANG, P.; DAVIS, R.A.; VINTHER, N.; and ELKO, N.C., 2003. Hydrodynamics and sediment pathways at Blind Pass, Florida. *Proceedings of Coastal Sediment'03*, ASCE Press.

WALTON, T.L., 1973. Littoral drift computations along the coast of Florida by means of ship wave observations. *Coastal and Oceanographic Engineering Laboratory Technical Report #15*, University of Florida, Gainsville, Florida, 97p.

WANG, P.; KRAUS, N.C., and DAVIS, R.A., Jr., 1998a. Total longshore sediment transport rate in the surf zone: field measurements and empirical predictions. *Journal of Coastal Research*, 14, 269-282.

WANG, P.; DAVIS, R.A., Jr., And KRAUS, N.C., 1998b. Cross-shore distribution of sediment texture under breaking waves along low-wave-energy coasts. *Journal of Sedimentary Research*, 68, 497-506.

WANG, P. And KRAUS, N.C., 2003. Movable-bed model investigation of groin notching. *Journal of Coastal Research*, Special Issue, in press.