SAND VOLUMES AND TRANSPORT PATHWAYS FOR GULF OF MEXICO REGIONAL SEDIMENT MANAGEMENT

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Abstract: The US Army Corps of Engineers (USACE) initiated the Regional Sediment Management (RSM) Demonstration Program in recognition of the interaction of engineered navigation and beach restoration projects with adjacent coastal projects. A major component of this initiative is the creation of a regional sediment budget for a 360-kilometer stretch of Gulf of Mexico shoreline that includes nine federal navigation projects and one federal beach restoration project. This paper outlines two elements of creating a sediment budget for a single inlet system within the RSM region: identifying sand transport pathways and computing changes in sand volume. Both elements rely heavily on comparison of successive SHOALS data sets collected at East Pass, Florida, USA. The paper then describes how the information inferred from the comparisons will be incorporated into the macrobudget for the entire region.

INTRODUCTION

The US Army Corps of Engineers (USACE) initiated the Regional Sediment Management (RSM) Demonstration Program in recognition of the interaction of engineered navigation and beach restoration projects with adjacent coastal projects. The goal of the RSM Demonstration Program is to develop a project management approach in which each navigation and beach restoration project is considered a

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single component of an interacting system (Lillycrop and Parson 2000). This approach allows greater flexibility for management at individual projects. For example, the impact of navigation channels on adjacent shorelines has long been recognized. However, regulations may not allow for disposal of dredged material on these shorelines. In a regional management scheme, disposal of dredged material on the adjacent beaches is often logical, because the beaches and longshore transport are the source of the dredged sand originally. For the case of beach restoration projects, large amounts of sand are placed on the beach. This sand may eventually wash into adjacent navigation channels. A model estimating the rate of channel shoaling caused by the beach restoration project can provide guidance for planning the time interval between dredging episodes.

The RSM demonstration region encompasses 360 kilometers of Gulf of Mexico shoreline stretching from the west end of Dauphin Island, Alabama, USA, east to Apalachicola Bay, Florida, USA (Figure 1). It encompasses nine federal navigation projects, one federal beach nourishment project, eight state parks, the Gulf Islands National Seashore, and Eglin and Tyndall US Air Force bases.

The approach for reaching a regional management scheme for the RSM Demonstration Program comprises two main parts: the collocation and comparison of historical data sets and the creation of tools to forecast future changes. Sand volume changes and sand transport pathways identified from comparison of historical data sets are used to create sediment budgets for each of the federal navigation and erosion control projects. These project sediment budgets will be incorporated into an RSM "macrobudget," or sediment budget covering the entire RSM demonstration region. The project sediment budgets and RSM macrobudget will be used to calibrate the numerical models that comprise project scale and regional scale forecasting tools.

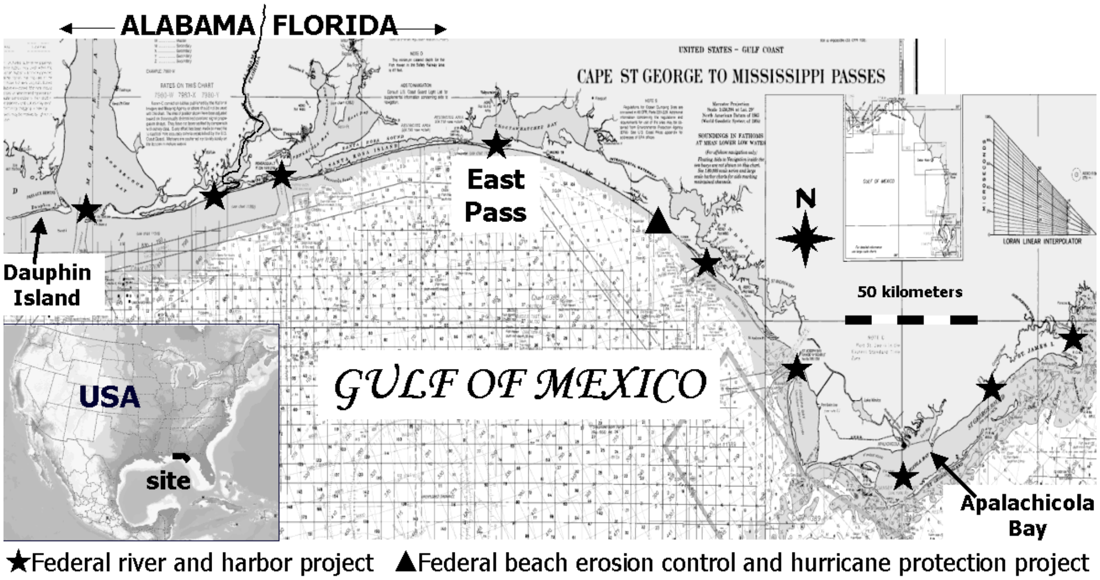

Figure 1. RSM Demonstration Program Region.

This paper outlines two elements of creating a sediment budget for East Pass, Florida, USA (Figure 1): identifying sand transport pathways and computing changes in sand volume. Both elements rely heavily on comparison of successive SHOALS (Scanning Hydrographic Operational Airborne Lidar Survey) surveys conducted at the pass. The SHOALS system uses lidar technology to quickly and accurately map the coastal zone in detail. Comparison between successive SHOALS surveys provides comprehensive volume calculations of the shoal features, navigation channel and dry beaches (Irish et al. 1997). The paper also describes how information inferred from the comparisons may be incorporated into the macrobudget for the entire RSM demonstration region.

EAST PASS, FLORIDA, USA

East Pass is a tidal inlet located on the panhandle of Florida between Santa Rosa Island and the city of Destin on Moreno Point (Morang 1993). It connects Choctawhatchee Bay with the Gulf of Mexico. Figure 2 contains an aerial photo taken at East Pass in 1989. The rubble mound jetties were built in a converging design between 1967 and 1969 as part of a Federal navigation project. A navigable depth of 4.3 m is maintained within the Federal channel alignment by periodic dredging activity. Norriego Point is the sand spit that has grown across the channel connecting the inlet interior with Old Pass Lagoon. Old Pass Lagoon marks an historic location for access to Choctawhatchee Bay from the Gulf of Mexico, when the inlet mouth was located several miles to the east. Other dominant features at the pass include extensive, sandy ebb and flood shoals.

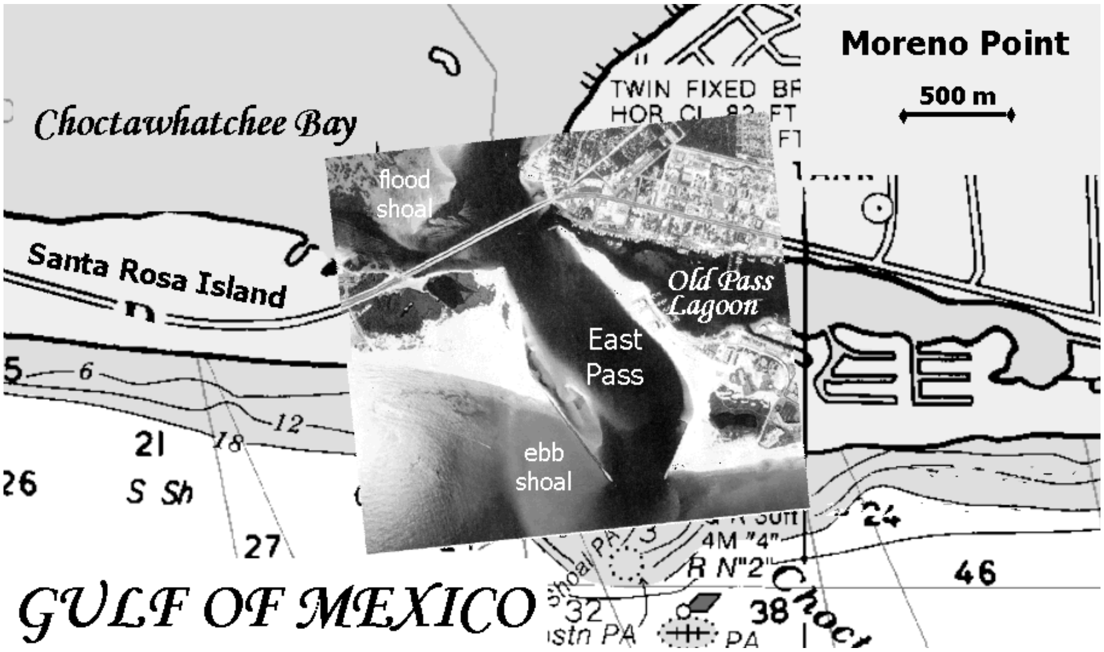

Figure 2. East Pass, Florida, USA. This figure shows an aerial photo taken in 1989 overlaying a NOAA nautical chart.

THE SHOALS SYSTEM

The US Army Corps of Engineers SHOALS system uses lidar technology to directly measure water depths and land elevations (Guenther et al. 1996). A laser transmitter/receiver (transceiver) mounted on an aircraft transmits a laser pulse. Each pulse travels to the air-water interface where a portion of the light energy reflects back to the transceiver (surface return, Figure 3). The remaining energy propagates through the water column and reflects off the sea bottom (bottom return, Figure 3). The water depth is calculated directly from the time lapse between the surface return and the bottom return and the geometry of the system.

Each sounding is positioned using either differential or kinematic GPS. Differential GPS gives the horizontal position of the aircraft, while kinematic GPS gives the three-dimensional position for the aircraft. When using differential GPS, each lidar measurement is positioned horizontally based on the position of the aircraft and vertically based on the elevation of the water surface as determined from a nearshore water level gauge. When using kinematic GPS, each lidar measurement is positioned in three dimensions based solely on the position of the aircraft, independent of water surface elevation. In both cases, the positioning accuracy for each sounding conforms to IHO Standards, or ±3 m in the horizontal and ±15 cm in the vertical (Guenther et al. 2000, Irish et al. 2000, Lillycrop et al. 1996, Pope et al. 1997, Riley et al. 1995). SHOALS can collect both bathymetry and topography simultaneously using either differential or kinematic GPS.

The SHOALS laser pulses at a rate of 400 Hz, providing 400 individual elevation measurements per second. An optical scanner mounted with the transceiver positions each laser pulse to provide uniform spacing of the measurements on the earth's surface. For coastal monitoring surveys, SHOALS typically collects data from an altitude of 400 m, resulting in a swath width of 220 m. With an aircraft speed of 60 m/s, measurement spacing is 8 meters and survey speed is 25 square kilometers per hour.

In practical application of lidar technology, laser energy is lost due to refraction, scattering, and absorption at the water surface, sea bottom, and as the pulse travels through the water column. The combination of these effects limits the strength of the bottom return and therefore limits the maximum detectable depth to around three times the Secchi (visible) depth. In clear water, SHOALS has successfully measured to depths of 50 meters.

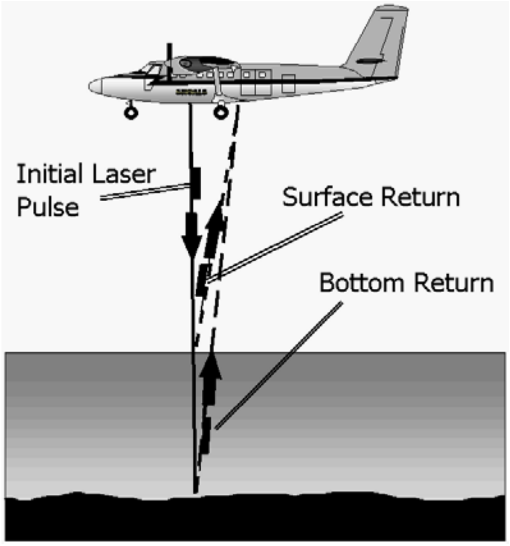

Figure 3. SHOALS operating principle.

SHOALS DATA SETS COLLECTED AT EAST PASS, FLORIDA

Five SHOALS data sets have been collected at East Pass (Wozencraft and Irish *in press* and McClung 1998). US Army Engineer District Mobile commissioned the first two surveys as part of the emergency response to Hurricane Opal (Irish et al. 1996). These surveys were collected in October and November 1995 and cover approximately 2.5 square kilometers through the inlet throat and over the ebb shoal. The third survey was collected in November 1996 to provide navigation channel and jetty condition information. In November 1997, a fourth survey was flown to evaluate post-construction jetty condition following jetty repair. These two surveys cover approximately 8.6 square kilometers through the inlet throat, over the ebb and flood shoals, and along the adjacent beaches. And lastly, SHOALS data was collected for the entire panhandle of Florida, including East Pass, as part of the baseline survey effort for the RSM Demonstration Program. This survey covers approximately 4.2 square kilometers through the inlet throat, over the ebb shoal, and along the adjacent beaches.

An example of the SHOALS data sets is shown in Figure 4. The figure is a three dimensional rendering of the November 1997 SHOALS survey at East Pass, Florida. The large, shallow ebb-tidal delta is crescent shaped and stretches from 0.5 kilometers east of the inlet to 1 kilometer west of the inlet. In general, depths over the ebb tidal delta platform are 3 meters. This value decreases to 2 meters over the

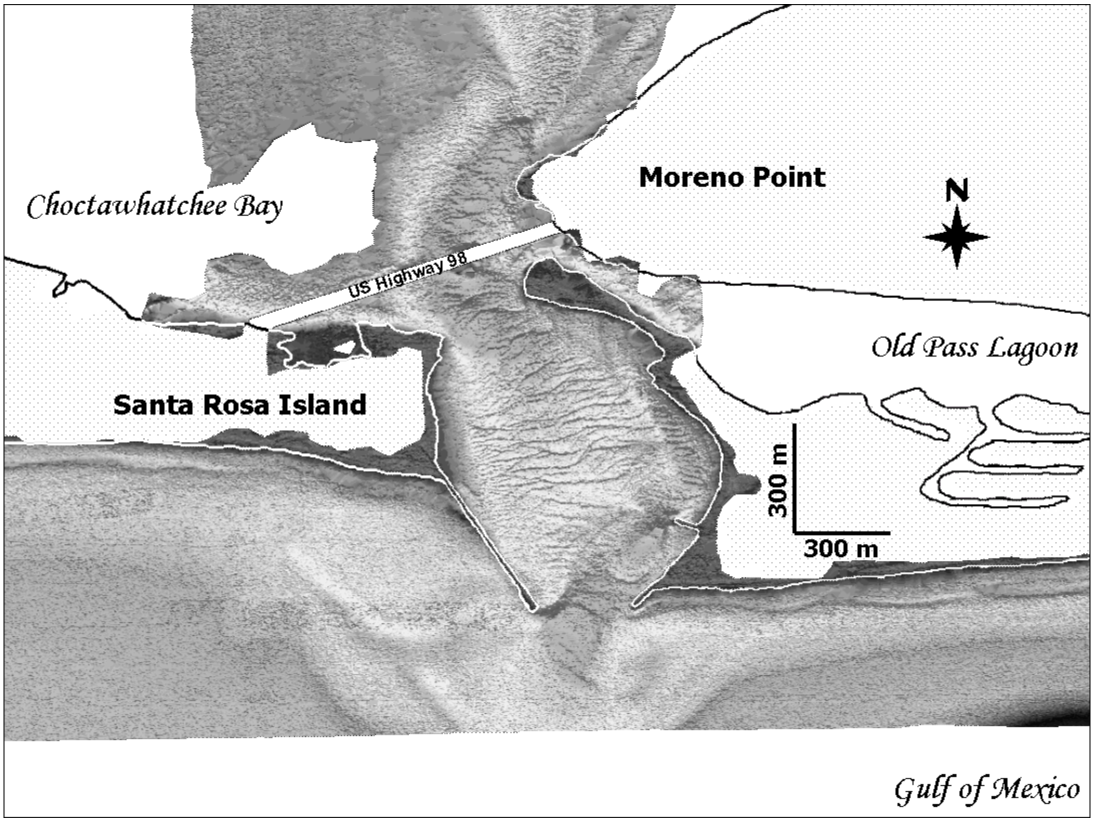

Figure 4. East Pass, Florida, USA. Example SHOALS data set collected in October 1997.

swash bars that have formed on the ebb-tidal delta platform. Scour at the ends of the west jetty and spur jetty (perpendicular to the eastern shoreline of inlet interior) reaches to depths of 12 meters. Sand waves through the inlet throat have an amplitude of around 1 meter. A deep natural channel impinges on the eastern shoreline of the inlet interior, along Norriego Point. Alongshore bars have formed offshore both east and west of East Pass. All the features mentioned above persist through all the SHOALS surveys and are mentioned for reference here.

SHOALS DATA ANALYSIS FOR EAST PASS, FLORIDA

Comparisons of SHOALS data sets show morphological changes that have occurred between surveys both quantitatively and qualitatively. To compare the data sets, an elevation difference between two surveys is computed for each measurement location. A negative difference indicates erosion, or that the elevation at a particular location is lower in the more recent survey. A positive elevation difference indicates accretion, or that the elevation at a particular location is higher in the more recent survey. Quantitatively, the elevation differences are used to compute changes in sand volume for the survey area. Qualitatively, information regarding sand transport pathways can be inferred from a visual representation of the elevation differences, such as contour lines or a three-dimensional elevation model. Adjacent areas of erosion and accretion can indicate that sand has moved from one location (erosional area) to another (accretional area). For example, the landward or seaward migration of alongshore sand bars often appears this way in a bathymetric comparison.

A series of volumes were computed between successive SHOALS data sets collected at East Pass, Florida. The volumes were computed for discrete areas within the surveys, such as inlet throat, east and west ebb shoal, channel thalweg, and east and west adjacent beach. Figure 5 shows the cumulative results of the comparisons between October 1995, November 1995, and November 1996. Figure 6 shows the cumulative results of the comparisons between November 1996, November 1997, and January 2000. The numbers shown in Figures 5 and 6 indicate the change in sand volume in hundreds of cubic meters for each delineated area. Negative numbers indicate erosion while positive numbers indicate accretion. The thin solid lines defining each area are drawn based on the maximum common coverage of the five surveys included in the comparison. Gray patches mark areas of erosion in Figure 5 and areas of accretion in Figure 6. White areas within each delineated inlet area indicate accretion in Figure 5 and erosion in Figure 6.

Figures 5 and 6 illustrate two phases of morphology that have occurred following the landfall of Hurricane Opal near East Pass, Florida, in October 1995. The first phase is erosional. In Figure 5, the comparisons from October 1995 to November 1996 resulted in erosion for every part of the inlet. Locations where the erosion has occurred are gray in color. For the inlet throat, storm surge induced by Hurricane Opal caused tremendous inlet infilling when both jetties were overwashed by sand from the adjacent beaches (Irish et al. 1996). The loss of sand from the inlet throat shown in Figure 5 from October 1995 to November 1996 is movement of the infilled sand out of the inlet throat.

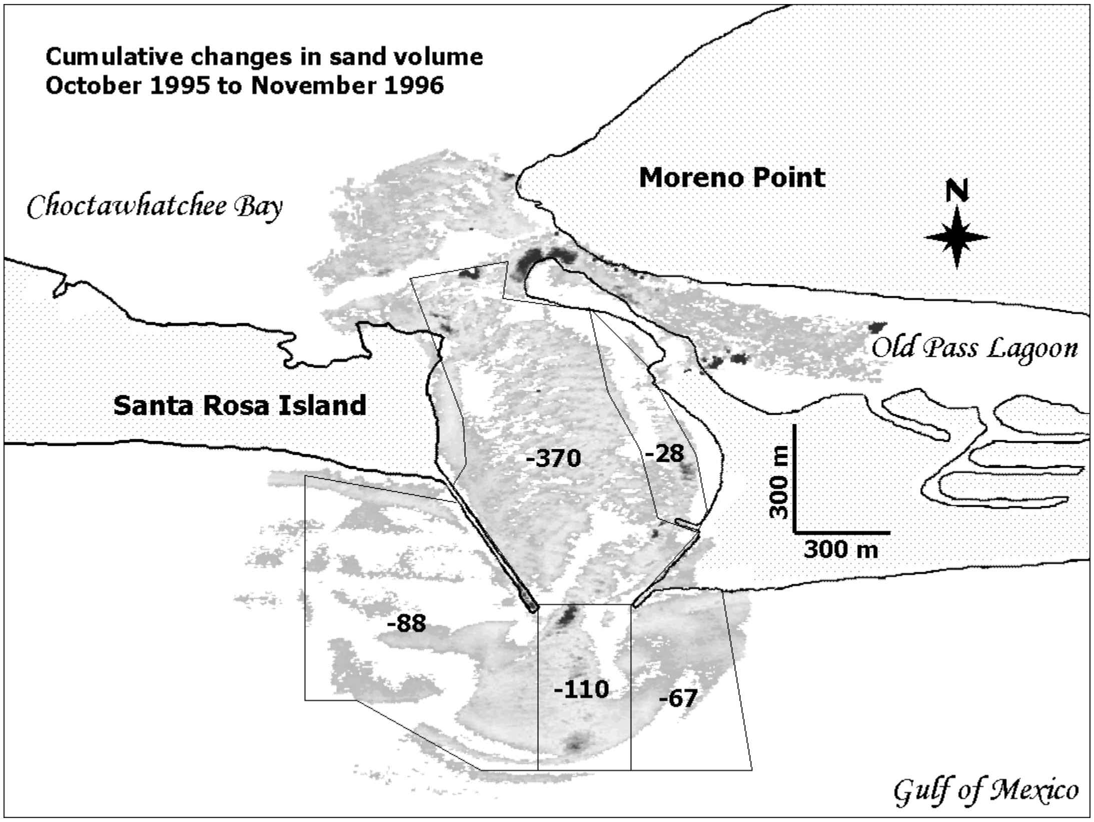

Figure 5. East Pass, Florida. Cumulative changes in sand volume from October 1995 to November 1996. Numbers indicate sand volume change within each delineated area in hundreds of cubic meters. The gray patches indicate areas of erosion.

Erosion in the remainder of the comparison area represents a trend of southerly ebb delta growth documented in Morang 1993. As the delta accretes in a southerly direction, erosion occurs on the part of the ebb delta platform closest to shore. The extent of the SHOALS surveys is such that only the inshore erosion is captured by the comparison. The offshore accretion may occur beyond the delineated comparison area. The deepening of scour holes accounts for some of the erosion in the zone directly between and south of the ends of the jetties.

The second phase, from November 1996 to January 2000, is mostly depositional. As mentioned earlier, sand overwashed the west jetty, resulting in natural nourishment of the western shoreline of the inlet throat. Sand has eroded from the nourished shoreline and may have deposited in the western side of the inlet throat, possibly causing the accretion shown in that area of Figure 6. Accretion to the south and west of the inlet mouth is due largely to the growth of the ebb tidal delta. Large swash bars have formed on the ebb tidal delta platform east and west of the main ebb channel. During the comparison interval, the swash bar west of the inlet has migrated toward the shoreline west of the inlet, while the swash bar east of the inlet has migrated toward the main ebb channel. Accretion to the east of the inlet formed a large offshore bar.

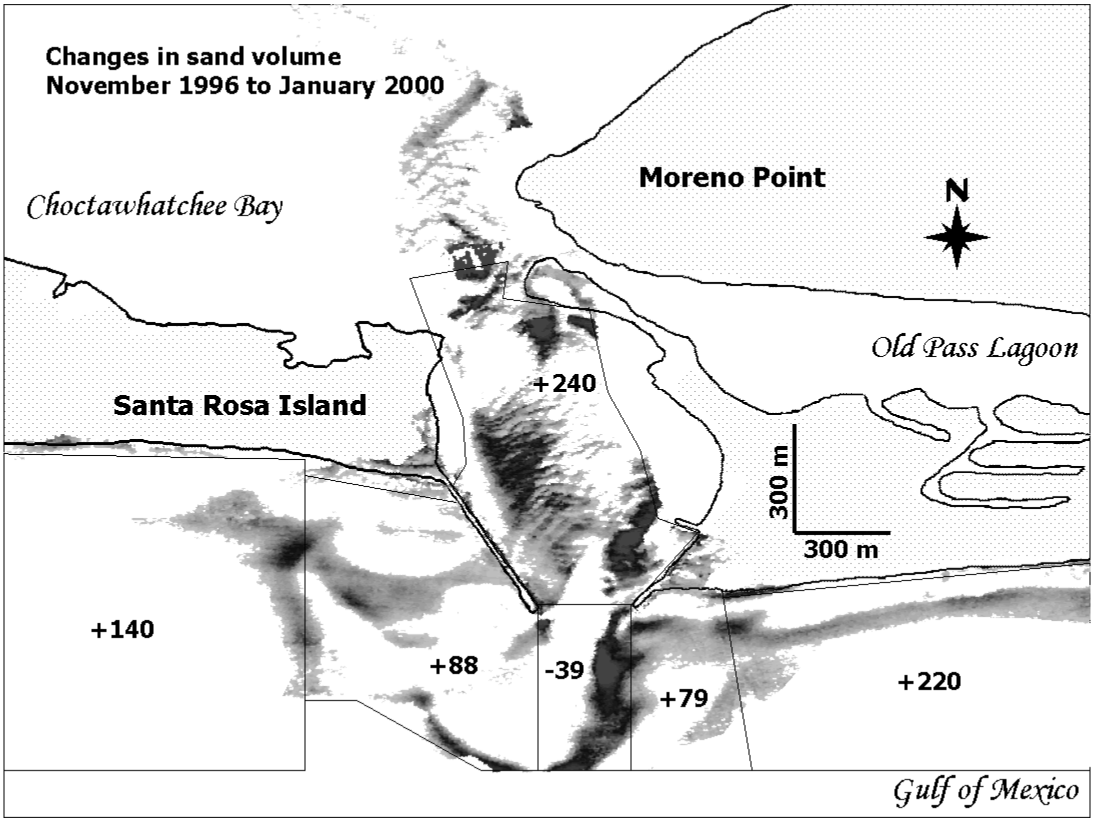

Figure 6. East Pass, Florida. Cumulative changes in sand volume from November 1996 to January 2000. Numbers indicate sand volume change within each delineated area in hundreds of cubic meters. The gray patches indicate areas of accretion.

From November 1996 to January 2000, erosion continued only in the zone directly south of the ends of the jetties. The scour holes in this area deepened. In addition, the channel through the ebb delta has moved to the west in response to the buildup of sand in the form of a swash bar east of the channel.

SAND VOLUMES AND TRANSPORT PATHWAYS IN REGIONAL SEDIMENT MANAGEMENT

An RSM "macrobudget", or sediment budget that covers the entire RSM demonstration region, has been developed based on an extensive literature review. The RSM macrobudget consists of cells each comprising a single component: an inlet, navigation project, or beach restoration project. Stretches of beach that lie between these components also comprise individual cells. The boxes of Figure 7 approximate cells defined as part of the RSM Demonstration Program. Each cell has an associated value of erosion or accretion based on information published in the literature. A confidence value has been assigned to each cell value based on objective evaluations of the quality of the data and investigative techniques described in the literature.

Both the qualitative and quantitative information resulting from comparison of SHOALS and other elevation data are an integral part of the RSM Demonstration Program. The sand pathways inferred from the comparisons and the sand volumes

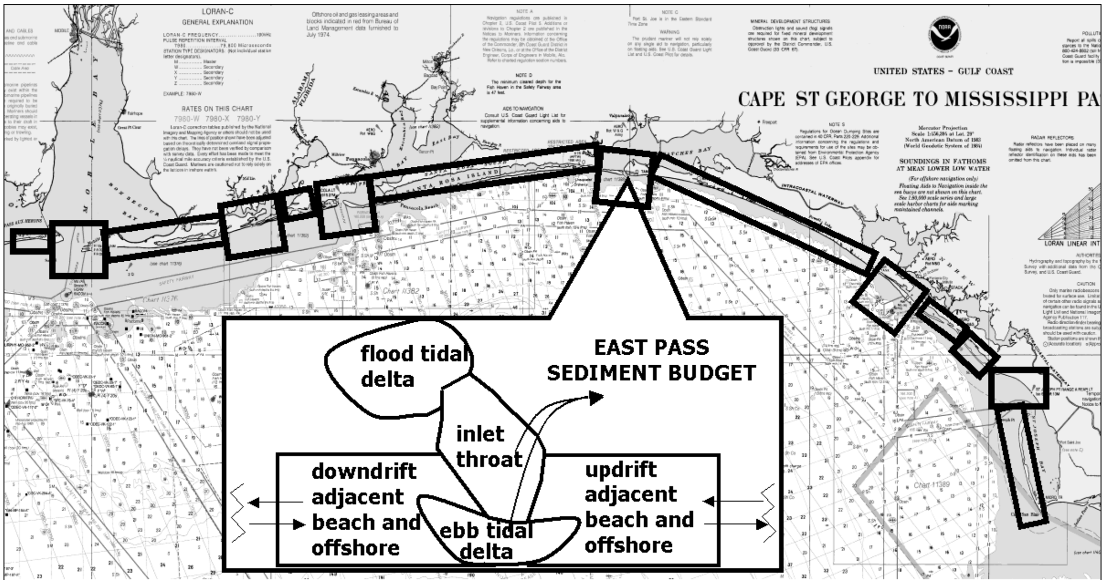

Figure 7. Incorporation of East Pass sediment budget into macrobudget for entire RSM Demonstration Region.

computed will assist investigators in determining a new sediment budget for the project. The new project sediment budget at East Pass will be used to refine the RSM macrobudget cell that represents East Pass (Figure 7), if investigators determine that the new information is of better quality than that already included in the RSM macrobudget.

The new East Pass sediment budget will also be used to calibrate potential sediment transport rates estimated for the inlet. As part of the RSM Demonstration Program, regional scale models have been developed to describe wave climate and tidal currents. Results of the models are used to estimate sediment transport potential at the inlet. RSM investigators will calibrate model hindcasts based on historical changes observed at the inlet, like the information inferred from the SHOALS data set comparisons at East Pass. The calibrated model can then forecast impacts of management initiatives at the project. For example, the change in sediment transport potential due to deepening a navigation channel or placing sand on a beach for hurricane protection can be modeled. Impacts to adjacent and downdrift projects can be determined based on the macrobudget.

CONCLUSIONS

Comparison of successive SHOALS surveys results in information regarding sand volume changes and sand transport pathways in the vicinity of East Pass, Florida. The RSM Demonstration Program relies on this information to improve the regional scale macrobudget by refining it at the project level. The information will also be used to calibrate numerical model hindcasts of potential sediment transport. The calibrated model will provide a tool capable of improving sand management at East Pass by forecasting, with confidence, the impact of management initiatives on the project. Incorporating the forecasts with the RSM macrobudget can help determine impacts on adjacent and downdrift projects.

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