REGIONAL SEDIMENT MANAGEMENT IN THE CORPS OF ENGINEERS

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ABSTRACT

Regional Sediment Management (RSM) refers to the effective utilization of littoral, estuarine, and riverine sediment resources in an environmentally effective and economical manner. RSM strives to maintain or enhance the natural exchange of sediment within the boundaries of the physical system. A "region" may include a variety of geologic features, uplands, beaches, inlets, rivers, estuaries, and bays. Implementation of RSM recognizes that the physical system and embedded ecosystems are modified and respond beyond the formal dimensions and time frames of individual projects. The larger spatial and longer temporal perspectives of RSM, as well as the broad range of disciplines with a stake in RSM projects, result in partnerships and co-leadership of RSM initiatives by the stakeholders. This paper discusses ongoing demonstrations of RSM by the U.S. Army Corps of Engineers (USACE). Six USACE District offices are implementing RSM demonstration projects, and two Districts within the State of Florida have developed their RSM plans with consensus and partnership with the State of Florida's Department of Environmental Protection (FDEP), Office of Beaches and Coastal Systems (OBCS). The paper concludes by highlighting numerical models that have been applied at the USACE District, New York for RSM, and Research and Development (R&D) being conducted and planned at the Coastal and Hydraulics Laboratory (CHL) in support of RSM.

1.0 INTRODUCTION

Regional Sediment Management (RSM), as defined above, essentially changes the focus of engineering activities within the coastal, estuarine, and riverine systems from

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the local, or project-specific scale, to a broader scale that is defined by the natural sediment processes and may include the entire watershed. As a result, decisions are made concerning the timing and scope of projects that move sediment or, alternatively, form a barrier to sediment movement within the understanding of the regional system.

Figure 1 illustrates a hypothetical example of two regions within a coastal watershed. Features are shown that provide a source of sediment (rivers and eroding headlands), and are a sink to sediment (sandy beaches, inlet/harbor entrance, and bay). Ideally, regions are defined by the large-scale sediment transport patterns as shown in Fig. 1, although in practical application, other factors influence regional boundaries, such as political delineation, ecosystems, and economics.

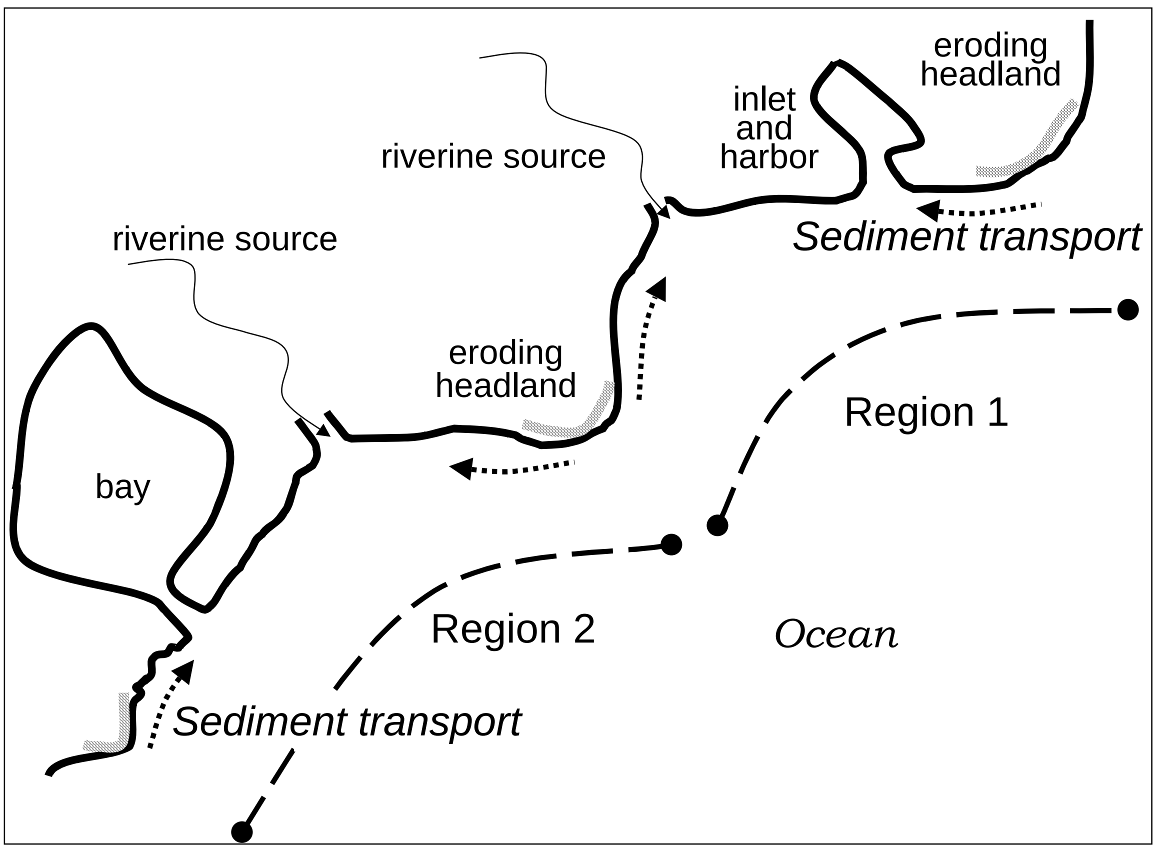


Figure 1. Example of regions for a hypothetical coastal setting

An example of "project-level sediment management" might be maintenance dredging of an inlet, with offshore placement of the mixed sand and silt material (the "least cost," most economically defensible alternative) despite an eroding adjacent beach. However, "regional sediment management" would consider the entire watershed in the problem, and perhaps place the dredged material in a nearshore berm offshore of the eroding beach. The intent would be that beach-quality material would ultimately move onshore (or at least provide wave dissipation) and reduce erosion of the beach. If nearshore placement increased the cost of the project, it may be justified by considering the additional economic and/or environmental benefits of providing storm protection for the eroding beach. Alternatively, state and local partners might share the additional cost.

The U.S. Army Corps of Engineers (USACE) has a unique role in the implementation of RSM. The mission areas of the USACE include navigation, environmental restoration, storm damage reduction, and flood reduction. In particular, the mission area ensuring the navigability of our Nation's waterways involves removing, transporting, and placing sediment, perhaps providing material that is utilized to support the other mission areas. In planning, designing, and executing RSM, the USACE works towards consensus with state and local partners.

In October 1999, a National RSM Demonstration program was initiated within the USACE to prove that an RSM approach to handling sediment can increase overall benefits or reduce overall costs. The program has been designed to accomplish this goal by minimizing the interruption of natural sediment transport processes or by enhancing these processes to maximize environmental and economic benefits. Independently, several states have been pursuing RSM within their boundaries. The USACE District, Mobile, was the first demonstration site (Lillycrop et al 2000). In October 2000, five more demonstrations were initiated. This paper discusses the history and economic benefits of RSM, and presents the unique goals and setting for each RSM demonstration project. Numerical models that have been applied for regional studies in the USACE District, New York, are discussed. The paper concludes by discussing ongoing and planned Research and Development (R&D) in support of RSM at the CHL.

2.0 HISTORY

2.1 Background. First, a brief history of the Federal agencies established to direct the Nation's coastal engineering is provided to aid in the following discussion. The Corps established the Board on Sand Movement and Beach Erosion (BSMBE) in January 1929, which was succeeded by the Beach Erosion Board (BEB) in September 1930 (Quinn 1977). The American Shore and Beach Preservation Association was the key organization in lobbying for creation of the BEB. The mission of the BEB was to review plans for coastal projects, make recommendations on them to the USACE Chief of Engineers, and oversee research in coastal engineering. Membership of the BEB included four officers of the Corps and three civilians, and therefore formed a unique organization in the government in that non-government employees participated in review functions generally considered to be purely the domain of government employees. The BEB was the key force in development of coastal projects for decades.

From 1930 to 1963, the BEB reviewed and approved all coastal projects (Hunter and Dean 1995), conducted related research, and documented these studies as well as theory and guidance for coastal engineering (Wiegel and Saville 1995). In November 1963, Congress passed new legislation abolishing the BEB and replaced it with the present-day Coastal Engineering Research Board (CERB) and the Coastal Engineering Research Center (now part of the U.S. Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory, CHL). The primary reason for the change was that coastal research and development (R&D) had grown significantly and was more than a part-time job for the BEB to manage. The BEB recommended the formation of an R&D laboratory. The CERB was established by Public Law 88-172 as an advisory board to the USACE Chief of Engineers on matters pertaining to coastal engineering, and continues to have two meetings each year with discussions of Federal coastal engineering projects as well as research at the CHL.

2.2 Evolution of concepts related to RSM. The term “river of sand,” the idealized model of sediment moving parallel to the shoreline in a somewhat continuous manner due to oblique wave approach was first discussed in a 1933 BEB publication (Quinn 1977). The corollary to this concept, that obstructions to this movement will ultimately create erosion further down the “river,” is a fundamental consideration for RSM on developed shorelines. It was realized that sediment also moves cross-shore, and laboratory measurements of cross-shore sediment transport were made at the BEB in the mid-1930s.

The first sand bypassing systems at navigation projects, designed to reinstate net longshore sand transport to downdrift beaches, were put into operation in the mid-1930s at Santa Barbara, California (Penfield 1960) and South Lake Worth Inlet, Florida (Caldwell 1951). In the 1940s and 1950s, measurements of longshore sand transport were made through impoundment at jetties and groins, and semi-empirical formulae and theories were developed (Wiegel and Saville 1995). These formulae are still in use today (Shore Protection Manual 1984). In 1966, Bowen and Inman introduced the concept of littoral cells (Bowen and Inman 1966). Littoral cells represent sub-regions of the watershed within which sediment transport processes can be bounded, perhaps by “known” values. For the purposes of RSM, a region may be defined by one or many littoral cells. Komar and Inman (1970) developed the concepts of sediment budgets, sources, and sinks within defined littoral cells. A sediment budget is an accounting of gains (sources) and losses (sinks) of littoral material within a defined area (littoral cell).

Today, these ideas are fundamental in defining a regional system and in optimizing sediment management actions.

2.3 USACE's National RSM Demonstration Program. The USACE's National RSM Demonstration Program was initiated in October 1999 as a result of several CERB initiatives, and a "grass-roots" movement within several individual Corps District offices and their State partners. At the 60th CERB Board Meeting in 1994, the president of the CERB tasked the CERB with developing future directions that the Corps and the coastal engineering R&D program should take. A task force was formed, and recommended among other things that the Corps adopt a "systems approach to coastal sediment management." As a result, a Working Group on Sediment Resource Management was formed to develop an implementation plan for the initiative. The 67th CERB meeting held in 1998 was themed "Regional Sediment Management," and later CERB meetings entertained a proposal for a RSM demonstration within the Mobile District. The Mobile District was the first district that stepped forward with a RSM demonstration plan that received Congressional support. Funding for the National Demonstration Program began with this demonstration in October 1999. Separately, the grass-roots movement for RSM grew with Corps Districts pursuing RSM initiatives with State and local partnerships. In late 2000, the National RSM Demonstration Program expanded to include five additional demonstration sites in the U.S.

3.0 BENEFITS

3.1 Introduction. In simplest terms, economics is about getting the most for our money. The role of the economist in RSM is to help the study team identify the best Federal investment options for operating and maintaining coastal projects, both at given sites (local and regional systems) and at the program level (nationwide).

The main goal of RSM is to keep sand in the littoral system, avoiding disruptions to natural sand movement. Unfortunately, as a society we can't afford to return all sand to the system at once, so the best opportunities for wisely managing sand need to be identified for priority implementation. This is addressing the fundamental economic problem: how do we put our scarce resources to their best uses?

3.2 Sources. Benefits from RSM are derived from several different sources. The first is better information, specifically better knowledge about the physical makeup and processes in the coastal zone. By better understanding the problem, more efficient management approaches can be identified. RSM also generates benefits through better technology. New techniques, and refinement in older techniques, can lead to smarter management actions. RSM also brings a broader view of how to wisely manage sand. It incorporates a systems view of projects, rather than treating operations at projects in isolation, taking advantage of previously unidentified synergistic effects. The categories of benefits considered under RSM are also broadened in comparison to status quo management, so more desirable purposes can be achieved. Finally, RSM builds stronger partnerships among coastal stakeholders leading to a wide range of potential benefits in improving business processes, sharing data, expanding partners' overall scope of effectiveness, and greater cooperation among parties.

3.3 Economic Framework for RSM. Under the "old" approach to managing coastal projects, actions were determined by the least cost means of delivering the navigation benefits of the specified project. Frequently this resulted in actions that removed sand from the littoral system, through upland, isolated, or offshore placement. Additionally, each site or project was treated in isolation, rather than as part of the coastal system. Offsite and unintended effects were generally not recognized or considered. In retrospect, this approach can be seen as missing opportunities for more wisely managing the sand resource.

Under RSM, the economic effects of evaluating alternative sand management activities can be considered under two "tracks": cost savings; and wise management of sand resources. Cost savings can most easily be thought of as achieving the same results or benefits from a project through more efficient methods. Cost savings are realized by identifying production efficiencies, such as dredging cost savings across places or time, or by eliminating actions that are working at cross purposes, such as adjacent dredging and beach nourishment projects. Wiser management of sand resources can be achieved by expanding the scope of beneficial effects considered for alternative approaches to project operations and maintenance. It recognizes the value of sand as a resource. For example, keeping sand in the system may be slightly more expensive than disposing material offshore, but it may reduce costs at a downdrift beach nourishment site, thereby realizing overall net benefits. Another possibility is that dredged material can be put to a beneficial use, rather than be placed in a disposal area that may or may not have storage costs. The timing of effects may also play a role in realizing new benefits.

A range of anticipated benefit categories is shown below, organized by the system of four "accounts" established in the Principles and Guidelines (U.S. Water Resources Council, 1983):

- National Economic Development
    - Storm damage reduction
        - Commercial, residential structures
        - Undeveloped land
        - Infrastructure
    - Recreation
        - Domestic
        - International
    - Navigation
        - Reduced operations and maintenance outlays

- Environmental Quality
    - Ecosystem restoration
        - Beach habitats, dunes, freshwater wetlands

        - Endangered species
    - Aesthetics
    - Cultural resources

- Regional Economic Development
    - Income
    - Employment
    - Tax receipts

- Other Social Effects
    - Urban and community impacts
    - Life, health, safety
    - Environmental Justice

Note that policy, authorization, and appropriation laws give different benefit categories different priority under various circumstances, but all are potentially important in making RSM investment decisions.

3.4 The Six Step Planning Process. The Corps of Engineers typically employs a six-step process to take plans from conceptualization to implementation. These steps and a review of RSM activities that relate to these six steps are as follows:

1. Specify Problems and Opportunitites
Expand the scope of the problems and opportunities beyond navigation to other resource categories, beyond space and time
2. Inventory and Forecast Conditions
Need data for categories of interest such as inventories of buildings, development, or significant environmental resources
3. Formulate Alternative Plans
Important to assess efficiencies of approaches considered different methods and scales for approaching the problems
4. Evaluate Effects of Alternative Plans
It may be difficult to distinguish between with and without project conditions, where sand is, and what it impacts incrementally
5. Compare Alternative Plans
Must have good measurement to distinguish between plans
6. Select Recommended Plan
Criteria will differ depending on authorities, partnerships, and plans incorporating issues concerning the entire watershed

Priorities for RSM Demonstration Studies. Beneficial effects of RSM actions can be realized in reduced costs, increased revenues, and new benefits. They can be realized in the short term, as well as over the long term. Demonstration proposals that highlighted management actions to realize cost savings in the short term received highest priority within the RSM program. While all benefits across these variables are important, those actions demonstrating short-term cost savings will rapidly show the best of what RSM can achieve. Actions providing other effects have been included in the demonstration program to round out the range of experience that can be captured under the program.

3.5 Specific Beneficial Activities from RSM Demonstration Projects. The proposed RSM actions include a fairly wide range of measures that will be beneficially employed. These actions can be grouped into categories, even at this early stage of conceptualization. The first broad area can be described as accretion/erosion management. In these cases, coastal projects are disrupting the natural flow of sand. Measures to balance the sediment movement include various means of bypassing sand artificially, as well as restoring natural flows that have been impeded. Both accretion and erosion can be problematic, with too much sand clogging storm water outflow systems, and erosion threatening buildings or infrastructure.

Environmental or ecosystem restoration is another category of activity present in the initial demonstrations. Reinforcing natural berms that protect freshwater lakes or wetlands from saltwater intrusion is one example. Placing sediment behind an island to mimic historic natural overwash sediment dynamics (early successional habitat for colonial and nesting shorebirds) is another. There are a number of threatened and endangered species in the areas of the demonstration studies that should benefit from restored habitat under RSM.

Demonstration studies are also identifying new efficiencies in dredging for existing coastal projects. These efficiencies may result from scheduling maintenance for adjacent projects to share costs; from better understanding sediment flows to avoid "rehandling" of the materials; and by employing more refined technologies, such as pinpoint dredging systems.

Recognizing sand as a valuable resource (and expensive liability) depending on circumstances accounts for another area where savings are foreseen. Dredged material may be put to beneficial uses rather than dumped or placed in disposal areas. This results in positive benefits where the material is wisely use, and may be less expensive than finding other beach quality material. Additionally, there are savings that result from reduced costs in disposal areas, which can be especially important as existing areas reach capacity. Sediments trapped behind dams starve beaches of material that would be expensive to replace, and accumulation reduces both the volume and effectiveness of the dams' original purposes. Stockpiling sand for emergency recovery from hurricanes is also being considered to reduce recovery costs and improve readiness to alleviate the emergency.

3.6 Improved Processes and Partnerships. The approach taken to implementing RSM has involved substantial participation across levels and agencies of government. Participants in the Mobile District RSM Demonstration Project have identified a number of important intangible benefits of working together that will ultimately lead to wiser sand and coastal management, which have been divided by related category:

- Overarching program goals
    - Wider beaches, more protection, less maintenance
    - Keep sand in the littoral zone
    - Keeping sand in the system as a beneficial use of dredged material
- Aligned actions across agencies
    - Identifying programs that are working at cross-purposes (ex: trucking sand away from an area that needs sand)
    - Opportunities to align programs at the Federal, state, and local levels
- Improved understanding of physical processes
    - Sediment budget will identify areas of erosion/accretion to assist in modifying sediment management practices
    - Better models and understanding of the physical system will lead to better decisions

- Business process efficiency
  - Baseline data to make future Feasibility studies faster and cheaper
  - Building a common database for all agencies to use
  - Solving datum problems, which are currently costly to fix, but more costly to ignore if errors lead to bad or inefficient decisions
- Stakeholder collaboration
  - Improved communication between Federal, state, and local governments (and presumably non-governmental organizations too)
  - RSM is a catalyst for realizing the importance of managing the coastal resources
  - Eglin Air Force Base has joined as a participant in the East Pass management plan
  - Understanding where the various states are in terms of coastal management and policies (ex: Florida advanced, Alabama less developed)
- Preparedness
  - Identifying future problem areas, and acting now (expected concentrations in population growth, related development, recreational use)
  - Identification of where data collection is needed

3.7 Goals for National RSM Economic Assessment. The economics tasks for Fiscal Year 2001 include establishing the framework described in this paper and applying it to each of the demonstration projects. Efforts will focus on sharing measurement approaches and broadened concepts of benefits attributable to RSM. In Fiscal Year 2002, the scope of the analysis will widen to attempt to sum up the potential for RSM actions if undertaken on the demonstration districts as a whole. In Fiscal Year 2003, the scope will increase to assessing the potential of implementing RSM nationwide.

4.0 USACE'S NATIONAL RSM DEMONSTRATION PROGRAM

The USACE's National RSM Demonstration Program was started largely through the CERB initiative together with strong Congressional support from several Coastal and Great Lakes States. The five-year program is designed to run through Fiscal Year 2003.

The goals of the program are:

1. ***The USACE will have improved sediment management practice (as necessary)****.*
2. ***Demonstrations will highlight and document unique elements of RSM and provide guidance for future implementation of specific RSM actions as appropriate****.*
3. ***State and local partnerships for RSM will result in a unified vision, cost-sharing, and co-leadership of RSM actions****.*
4. ***RSM actions will seek to engage cross-mission objectives of the Corps.*** (More projects will be designed and constructed with the deliberate intent to achieve cross-mission benefits, e.g., storm protection, navigation, and environmental enhancement.)
5. ***Approaches for defining environmental and economic benefits for RSM will have been defined.***

And, a final goal depending on R&D support of RSM,

6. ***Decision-support technology for RSM will have improved.*** (Conceptual, analytical, and numerical models will have been adapted and improved to support RSM.)

Towards these goals, RSM demonstrations within the USACE are being conducted in six of the 18 coastal and Great Lakes Districts (Figure 2). The following section highlights only a part of each demonstration project, with the intent to describe how each demonstration is working towards the goals of the program.

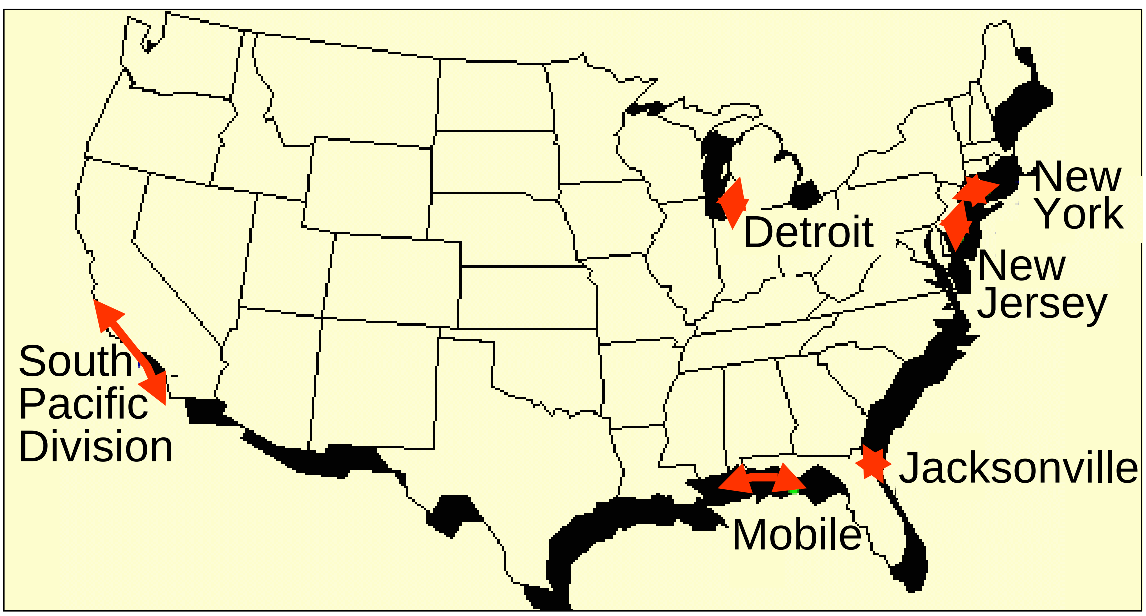


Figure 2. USACE's Fiscal Year 2001 National RSM Demonstration Projects

4.1 Mobile District. The Mobile District's demonstration project covers 345 miles of shoreline, extending from the St. Mark's River, Florida in the east through the Pearl River, Mississippi in the west. As such, the demonstration involves the coastal, estuarine, environmental, and geological agencies from three states, x counties, and other Federal offices. At the start of the demonstration in October 1999, historical data sets for the region were vastly different. Data were unavailable for large portions of the region. A primary goal, then, was to establish a baseline data set (bathymetry, shoreline position, and profiles) within a Geographic Information System (GIS), which is ongoing. Partnerships have been formed, and several sub-initiatives of the RSM demonstration are being appropriately directed by non-Corps agencies.

The Mobile District is also working towards the end vision of the program by changing operation and maintenance practices at three sites. At Perdido and East Pass Inlets, disposal sites for dredged material have been selected that minimize rehandling of material. The third initiative presently under consideration involves the disposal sites for dredged sediment along the Apalachicola River, located near the eastern boundary of the region. Disposal sites along the river are full, and the RSM demonstration project is considering the cost and benefits of bringing this sediment to the coast for beach nourishment and/or environmental enhancement. For more detail about the Mobile District's RSM demonstration project, the reader is directed to the web site for the Demonstration project

http://www.sam.usace.army.mil/sediment/sediment_homepage.htm.

4.2 Jacksonville District. The Jacksonville District formally began their National demonstration project in January 2001 for the Northeast Coast of Florida, although they had initiated State and local partnerships, cost-sharing with the State, conducted four regional workshops, and began three RSM initiatives prior to receiving formal demonstration funding (see Schwichtenberg and Schmidt 2000). RSM investigations in this region were accomplished under a Section 22 agreement between the Jacksonville District of the USACE and the Florida Department of Environmental Protection (FDEP), Office of Beaches and Coastal Systems (OBCS). Section 22 of the Water Resources Development Act of 1974 (Public Law 93-251), as amended, authorizes the Secretary of the Army, acting through the Chief of Engineers, to assist the states in the preparation of comprehensive plans for the development, utilization and conservation of water and related land resources. The agreement facilitated RSM practices in the Sea Islands and St. John's Beaches Sub-Regions of the Northeast Atlantic Coast Region as defined by the OBCS. As so defined, the limits of these sub-regions extend from the northern Nassau County line through Duval County to the southern St. Johns County line. The Jacksonville District provided technical assistance to the OBCS in coordinating RSM activities in the two sub-regions. A RSM web site (http://rsm.saj.usace.army.mil) has been developed as part of the agreement to facilitate coordination with other Federal and non-Federal agencies as well as the public sector.

RSM strives to enhance the planning, construction, operation and maintenance (O&M) of navigation, shore protection and environmental restoration projects while protecting natural resources. The USACE and the FDEP recognize that there are other agencies, entities and non-governmental organizations that are also integral to RSM initiatives and have solicited their insight. Workshops concerning RSM in northeast Florida were held in St. Johns, Duval and Nassau counties. During these workshops the Federal, state and local perspectives were presented and opportunities for RSM were identified. Potential Demonstration Projects (PDPs) were identified as cost effective and innovative regional approaches. A fourth workshop involving all of the regional interests focused on implementation of PDPs in Northeast Florida. Six specific PDPs identified during initial workshop efforts included, 1) Stabilize South End of Amelia Island, 2)

Bypass Sand at St. Marys Entrance, 3) Backpass and Bypass Sand at Ft. George and St. Johns River Entrances, 4) Bypass Sand at St. Augustine Inlet, 5) Offloading Disposal Areas and 6) Demonstrate Innovative Technologies.

The purpose of the fourth workshop was to identify and brainstorm actions required to implement demonstration projects under the framework of the USACE missions and the FDEP Strategic Beach Management Plan. The workshop included several overview presentations intended to provide baseline information upon which the group discussions were based. The discussions themselves were intended to elicit comments and suggestions from various stakeholders regarding the PDPs, as well as to obtain specific information requisite to the implementation of the PDPs. Specific recommendations were generated for each PDP regarding engineering, economic, environmental and policy issues. Participants identified specific economic and environmental benefits as well and these benefits were similar across all six PDPs. Economic benefits include reduction in future renourishment and O&M costs, enhanced recreational usage and increased protection for upland development. Environmental benefits of these PDPs include maintaining nesting habitats for turtles and shore birds, reestablishment and stabilization of dune systems, increased viability of local species (e.g., beach mouse populations) and overall improvement to public lands. Based upon the final comments of the workshop sponsors, the workshop provided useful information and recommendations for the USACE and the FDEP to prioritize the RSM demonstration projects. The priority PDPs were identified as 1) Stabilize South End of Amelia Island, and 2) Backpass and Bypass Sand at Ft. George and St. Johns River Entrances.

The southern tip of South Amelia Island presently experiences chronic erosion. The FDEP Strategic Beach Management Plan identifies a 3.1-mile segment of critical erosion along the ocean shoreline of South Amelia Island that needs renourishment. The Plan also recommends a feasibility study of shore protection structures. The influences of the

1994 beach fill borrow pit on wave refraction and action of the existing groins on transport processes will be evaluated. Short-term efforts to implement the "Stabilize South End of Amelia Island" PDP have recently been completed through a multi-agency (USACE, FDEP, Florida Inland Navigation District, South Amelia Island Shoreline Stabilization Association and others) cooperative RSM initiative. This initiative resulted in the placement of approximately 330,000 cubic yards of beach quality material from O&M dredging of the Atlantic Intracoastal Waterway and construction of geotextile shoreline stabilization tubes (see Figure 3). Ultimately, the goal of the PDP is to establish long-term solutions to the erosion problems on the south part of the island.

Figure 3. South Amelia Island O&M disposal area (January 25, 2001). Approximately 330,000 cubic yards of beach quality sand were placed as part of this multi-agency initiative

The "Backpass and Bypass Sand at Ft. George and St. Johns River Entrances" PDP involves the backpassing of beach quality material onto Little Talbot Island and bypassing material across the entrance to the Duval County beaches. The PDP also strives to identify the optimum location for placement of the bypass material. The FDEP Strategic Beach Management Plan has identified a 10-mile segment of critical erosion that extends from the St. Johns River entrance to the Duval-St. Johns County line. The Plan also calls for continued beach nourishment in Duval County and further study of the St. Johns River entrance. The Jacksonville District has identified several sources for beach renourishment including Buck Island and the Jacksonville Harbor deepening project. In addition, three alternative borrow sites have been identified in and around Ft. George Inlet (see Figure 4). These include 1) the extensive ebb shoal system, 2) the

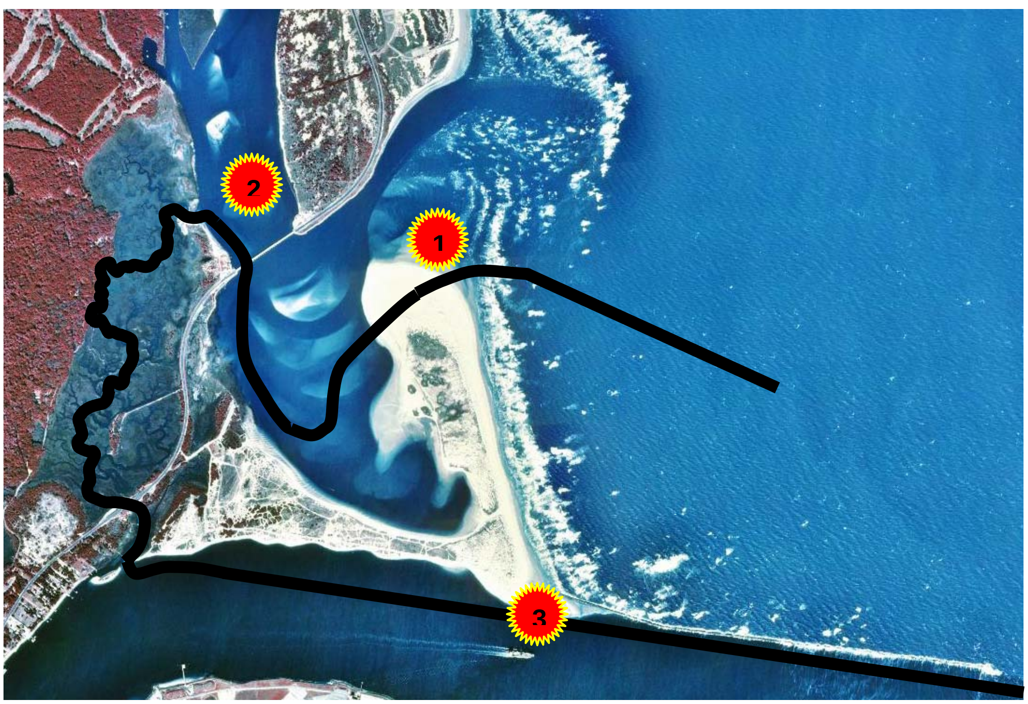


Figure 4. Three proposed borrow areas identified for the "Backpass and Bypass Sand at Ft. George and St. Johns River Entrances" potential demonstration project

flood shoal north of the A1A bridge, and 3) the shoal that forms just south of the north jetty at the southern tip of Wards Bank. Another purpose of this PDP involves backpassing of sand to persistent erosion areas located on the south end of Little Talbot Island.

Concrete rip-rap shore protection provided by the Florida Department of Transportation effectively stabilizes a segment of the north bank of the inlet channel in the vicinity of the eastern end of the State Road A1A bridge. However, the channel remains free to shift northward over its eastern segment. This process has led to the continued erosion of the southeastern corner of Little Talbot Island along with a northward growth of Wards Bank. In turn, the inlet channel has changed its former east-west orientation, and has increased in length. As a result of the ensuing shoreline recession, state park facilities on Little Talbot Island have been compromised. Several of the potential borrow sites for the St. Johns River bypass operations could also serve as backpassing sources for the southern tip of Little Talbot Island.

Funds provided by the USACE National RSM program along with matching State funds will be used to investigate various alternatives for implementation of these PDPs. The scope of work for this investigation involves applying Diagnostic Modeling System (DMS) tools and methodologies to examine the sediment transport mechanisms related to each PDP. Additionally, the DMS will identify existing shoaling sources to provide beach compatible material for erosion control. Finally, hydrodynamic modeling outlined by these scopes will employ the community model currently under development by the U.S. Army Engineering Research and Development Center. The scope of work for the investigation of these two PDPs includes the following:

Stabilize South End of Amelia Island

1. Compile and collect survey data
2. Identify existing shoaling sources of beach placement material
3. Model existing conditions and alternative plans
4. Evaluate alternatives effectiveness and impacts
5. Report results

Work will begin by conducting a hydrographic and high water survey of the Nassau Sound vicinity and amassing recent available hydrographic and shoreline data. Next, the region of interest (Nassau Sound vicinity) will be extracted from the community model mesh constructed by the U.S. Army Engineer Engineering Research and Development Center, Coastal and Hydraulics Laboratory. The survey data will provide high resolution, sub-region detail not included in the community model. Next, suitable calibration for the wave and current models will be located for the study area. ADCIRC and STWave, two USACE-supported models, will provide simulations of representative wave and tidal conditions and bathymetric controls on the nearshore wave pattern. Specifically, wave and current modeling will be linked through the steering module developed for the USACE. The steering module provides interaction between ADCIRC and STWave giving a more accurate representation of the wave and current climates. The existing conditions model provides the baseline conditions at Ft. George and the St. Johns River Entrance. Applying the DMS in conjunction with the above-described modeling will identify the areas of problematic shoaling in the Atlantic Intracoastal Waterway.

Application of the DMS will also identify potential shoaling sources of beach placement material and pathways associated with the shoaling areas. A maximum of three additional simulations will evaluate the wave and current conditions associated with three stabilization alternatives. By comparison to the baseline results, these simulation results will quantify the impacts and effectiveness caused by implementing these alternatives.

Backpass and Bypass Sand at Ft. George and St. Johns River Entrances

1. Compile and collect survey data
2. Apply DMS to identify existing shoaling sources of potential beach placement material
3. Model existing conditions (tidal current, waves) and alternative plans
4. Determine location of longshore transport node and characteristics of the nearshore wave climate downdrift of St. Johns River Entrance.
5. Report results

Work will begin by conducting a hydrographic and high-water survey of the Ft. George Inlet vicinity and amassing recent available hydrographic and shoreline data. Next, the region of interest (St. Johns River and Ft. George Inlet vicinity) will be extracted from the community model mesh constructed by the US Army Engineering Research and Development Center. The survey data will provide high resolution, sub-region detail not included in the community model. Next, suitable calibration for the wave and current models will be located for both the St. Johns River and Ft. George Inlet. The numerical models ADCIRC and STWAVE (for more information, see subsequent section titled "Numerical Models for RSM") will provide simulations of representative wave and tidal conditions. Specifically, wave and current modeling will be linked through the steering module developed for the USACE. The steering module provides interaction between ADCIRC and STWAVE giving a more accurate representation of the wave and current climates.

The existing-condition model provides the baseline conditions at Ft. George and the St. Johns River Entrance. Applying the DMS in conjunction with the above-described modeling will identify the areas of problematic shoaling in the Jacksonville Harbor Entrance and littorally influenced interior channel. Applying the DMS will also identify potential shoaling sources of beach placement material and pathways associated with the shoal located south of Wards Bank inside the jetties. Three additional simulations will evaluate the wave and current conditions associated with mining the three areas identified previously: Ft. George ebb shoal, Ft. George flood shoal, and the shoal within the jetties south of Wards Bank. By comparison to the baseline results, these simulations will quantify changes caused by these mining operations. Wave modeling will also aid in both identifying the location of the transport node downdrift of the St. Johns River Entrance and determining nominal location(s) for potential nearshore or onshore placement of dredged material. A report summarizing all work performed and conclusions reached will be prepared.

The scope of work also requires that the DMS work be used to summarize sediment inputs, outputs, and available shoreline and channel response information generated or developed in the overall summary in a Sediment Budget Analysis System (SBAS) application. The coastal issues described above are readily summarized and explored in a conceptual sediment budget that can be made quantitative through incorporation of magnitudes and directions of longshore and cross shore transport, volume change on the beaches, and engineering actions. Applicable results of the proposed studies, such as potential transport rates and directions, will be compiled in SBAS and transferred to study sponsors. The SBAS will contain both macro and individual preliminary budgets for initiation of an RSM approach to the study areas. It is understood that the sediment budgets are preliminary in that potential rates and inferences will form the basis of the SBAS input, not specific data collection and analysis (such as shoreline change, nearshore bathymetry change) that would require a separate and dedicated effort. The SBAS will also include metadata explaining the budget formulation.

In conclusion, the brainstorming and coordination provided through the workshop series and products derived from the DMS modeling efforts are being utilized by the USACE and FDEP to efficiently and effectively implement RSM demonstration projects in northeast Florida.

4.3 Philadelphia District. The initiative planned by the Philadelphia District ties closely with ongoing R&D at the CHL. The Philadelphia RSM demonstration extends approximately 130 miles from Sandy Hook in the north (located in the New York District), to Cape May (mouth of the Delaware Bay) in the south. A suite of wave, current, and sediment transport models will be applied to the region to characterize the longshore and cross-shore transport rates, as well as the regional sediment budget. The RSM demonstration involves moving sand from an accreting beach northeast (updrift) of Cape May Inlet to the eroding southwest (downdrift) side of the inlet. Accretion along the updrift beach is believed to be caused primarily by the construction of jetties at Cape May Inlet in 1911, and has resulted in at least two problems: storm water outfalls that do not drain because of beach accretion, and excessive beach widths that make recreational beach user access to the “shoreline” problematic. Nourishment of the downdrift shoreline has been obtained from an offshore borrow site, but that site has an insufficient reserve of material for future nourishment needs (approximately 153,000 cu m/yr) (McCormick et al 2001). Through application of the numerical models, and possibly a pilot implementation study, the RSM demonstration will evaluate two means of moving the sand, i.e., a continuous mechanical bypass system or trucking material as required.

4.4 New York District. The New York District has two initiatives under the National RSM Demonstration Project: backpassing of sand at Jones Inlet, New York, and creation of an artificial overwash fan using dredged material proposed for Seabright, New Jersey (Rahoy and Bocamazo, 2001). The first initiative will explore the benefits of removing an attachment bulge in the shoreline downdrift (west) of Jones Inlet, located on Long Island. This attachment zone formed as the ebb tidal shoal reached a size that it began bypassing sediment to the adjacent beach. It is hypothesized that the attachment zone is now acting as a barrier to eastward-directed sand transport. Immediately to the east of the attachment zone, and west of the inlet, the beach is severely eroded. The demonstration project will place sand scraped from the attachment zone into the severely eroded beach. In addition to providing an immediate source of sand for this area, it is believed that removing the attachment zone will allow east-moving sand to nourish the severely eroding region, at least until the ebb tidal shoal re-establishes the bypassing bridge. This demonstration project has the potential for national applicability, because many inlets in the U.S. share the same downdrift signature of Jones Inlet.

The second demonstration, creation of an overwash fan, attempts to restore this type of habitat on these populated barrier islands. On an undeveloped barrier island, storms with elevated wave and water levels will overwash the island and move sand into the bay. This material forms an “overwash fan,” and provides habitat for specific endangered species. The infrastructure of the South Shore of Long Island prohibits this process from occurring on a regular basis. The success of an artificial overwash fan will be evaluated as an alternative for dredged material disposal, and, if successful, guidance for construction will be developed.

4.5 Detroit District. The Great Lakes provide a unique setting for RSM. Beach quality sediment available to nourish eroding beaches is scarce. The clay bluffs can erode rapidly when unprotected by a sandy beach and nearshore profile. As part of the National RSM Demonstration Project, the Detroit District is striving to develop a sand placement schedule and warning system for protecting the fragile bluffs. Also under the demonstration, they are exploring the feasibility of implementing a “Sand Bank” policy in which proponents of new private shore protection projects would have the option to pay into a trust fund dedicated to financing larger scale beach nourishment projects (Ross et al 2001). Alternatively, individual sand placements would be required to mitigate for coastal structures that prevent sand from entering the littoral system.

4.6 South Pacific Division (San Francisco, Sacramento, and Los Angeles Districts). The South Pacific Division began partnerships with the State, counties, and various grass-roots agencies with a goal to develop a state-wide RSM plan in FY00, prior to formal funding. Regional studies have been conducted in Southern California since the 1980s. Funds from the National Demonstration Project are being used to finalize the statewide RSM plan, as well as explore the feasibility of moving material trapped behind dams on rivers feeding the coast to the coastline. Ownership of this material has long been a topic of discussion and debate in California (O'Brien 1936, Magoon and Edge 1998). Reservoirs on many rivers in Southern California have reached sediment capacity, and some have degraded to such an extent that the infrastructure must be repaired, replaced, or removed. Several options have been discussed: remove the dams and allow riverine transport processes move the material; excavate and truck the material to the coast; and pump the material via pipeline. The RSM demonstration is evaluating the cost, benefits, and time required for each of these options (Domurat and Sloan 2001).

5.0 GEOGRAPHICAL INFORMATION SYSTEMS FOR RSM

5.1 Introduction. The Spatial Data Branch, Operations Division, USAE District Mobile, created a Geographic Information System (GIS) to address the data management and data analysis requirements of the Regional Sediment Management Demonstration Program undertaken by USAED Mobile. The resulting GIS provides RSM scientists and engineers an interface to hydrographic, topographic, photogrammetric, and historic dredge material data for the RSM Demonstration Region, as well as custom applications designed to facilitate engineering analyses. The RSM GIS serves as the link between engineering analyses and regional numerical models. To date, development of the RSM GIS has included: input of spatial data for the RSM region, use of built-in ArcView applications to enhance data manipulation and display, and creation of custom applications to extend the utility of ArcView for RSM specific goals. This section will give an overview of the effort to create the RSM GIS including data preparation for inclusion in the GIS, data display using ArcView, creation of custom applications for RSM, and other capabilities currently under development.

5.2 Spatial Data Input. Spatial data that are currently included in the RMS GIS include: hydrographic and topographic survey data, aerial and oblique photography, dredge material records, digital nautical charts, and generic GIS information.

5.2.1 Hydrographic and Topographic Survey Data. Hydrographic and topographic survey data are required for the RSM Demonstration Program in two forms. First, a unique data set must be created for each survey collected in the region. Second, the data sets must be merged into a single most recent, or "baseline" data set that covers the entire region. The RSM GIS data sets include three types of hydrographic and topographic data: singlebeam fathometer data, multibeam fathometer data, and airborne lidar bathymetry and topography.

The most extensive data set used to create the RSM baseline data set was obtained from National Geophysical Data Center (NGDC). These data are the data that appear on NOAA nautical charts and are the result of several years of hydrographic surveying. The NGDC data is referenced to MLLW based on NOAA specifications that require transfer of tidal datum based on comparisons of simultaneous tide measurements collected at a gauge near the survey site and an established gauge (NOAA 1999). In most areas, the distance between adjacent points ranges from 300 meters near shore to 1500 meters farther offshore. Exceptions are the navigation channels at Mobile Pass, Alabama, Pensacola Pass, Florida, and the Panama City Entrance Channel, Florida. In these areas the data density approaches 30 meters.

The USACE District Mobile's Irvington Site Office provided the second type of data included in the RSM baseline data set. The data take the form of navigation channel condition surveys collected using a singlebeam fathometer. This type of data was included in the baseline for Mobile Pass and Perdido Pass, both located in Alabama. These data were originally referenced to MLLW using tidal gauges at the passes. The survey coverage includes only the authorized navigation channel, with data points collected in profile lines spaced approximately 100 meters apart along the length of the navigation channel. Data spacing along the profile lines is sub-meter. These data were collected in spring of 2000.

The final type of data included in the RSM baseline is that collected by the USACE SHOALS (Scanning Hydrographic Operational Airborne Lidar Survey) system (Lillycrop et al. 1996). These data were collected at a density of 4 meters for project condition surveys at East Pass, Pensacola Pass, Panama City, and Perdido Pass. The project condition surveys were collected for USAED Mobile. Survey coverage includes the navigation channel, ebb and flood shoals, and adjacent shorelines and offshore areas. For these surveys, depth data were collected relative to the water surface and were referenced to tidal gauges in each of the inlets. The tidal gauges were set relative to NOAA tidal benchmarks in the area.

In addition to the SHOALS project condition surveys, SHOALS shoreline surveys were also included in the RSM baseline data set. SHOALS data have been collected for the entire coastline of the RSM demonstration region. The Florida Department of Environmental Protection (FLDEP) commissioned SHOALS data extending from the Panama City Entrance Channel to Apalachicola Bay, Florida, to support coastal erosion monitoring. The data were collected relative to a short baseline of NOAA benchmarks relative to NGVD29 using kinematic GPS. The remaining coastline was surveyed by SHOALS as part of the RSM baseline initiative. These data were collected relative to the water surface and were referenced to tidal benchmarks in the area by interpolation between the benchmarks. These last two data sets were collected at a density of 8 meters. The surveys follow the coastline, covering 300 meters of inshore dry beach and 800 meters of offshore bathymetry.

Each of the data sets listed above were converted to the same horizontal and vertical datums. The horizontal datum chosen by the user is Universal Trans Mercator (UTM) projection defined by the North American Datum 1983 (NAD83). The vertical datum chosen by the user is North American Vertical Datum 1988 (NAVD88).

As mentioned above, the baseline data set represents the most recent data for each part of the demonstration region. This means data collected most recently for each area supercedes all other data for that area. For example, near East Pass, Florida, the baseline data set includes NGDC data, the RSM SHOALS shoreline data set (collected in 2000), and a SHOALS project condition survey (collected in 1997). The NGDC data is superceded by the more recent SHOALS surveys. So, the NGDC data retained for the RSM baseline data set only covers the offshore areas beyond the extent of the SHOALS surveys. The SHOALS project condition survey of 1997 includes data for the flood and ebb shoals, adjacent beaches and inlet throat at East Pass. The RSM SHOALS shoreline data set collected in 2000 covers an area along the shoreline extending from 300 meters onshore to 800 meters offshore. The 2000 data set supercedes the 1997 data set in this alongshore swath. The 1997 data for the flood and ebb shoals and inlet throat that lie outside of this swath are retained for the baseline data set.

A graphical representation of the data retained in the RSM baseline data set near East Pass, Florida, is shown in Figure 5. The triangles shown in Figure 5 represent individual NGDC data points, while the 4- to 8-meter density SHOALS data sets are represented by filled polygons.

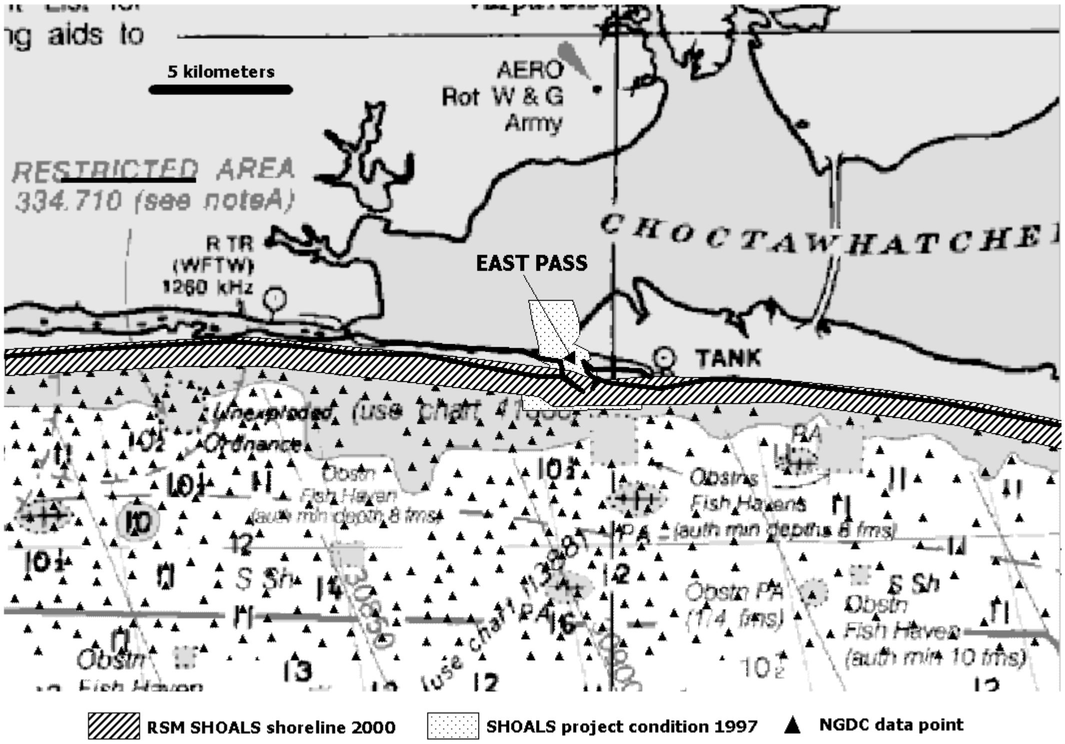


Figure 5. East Pass, Florida. Graphical representation of data retained for RSM baseline data set. Triangles represent actual NGDC data points while SHOALS 4- to 8-meter density data sets are represented by filled polygons.

5.2.2 Aerial and Oblique Photography. Both aerial and oblique photos are included in the RSM GIS. All aerial photography currently included in the RSM GIS was provided to the Spatial Data Branch ortho-rectified and of various geographic projections (See Figure 6). The individual images were tiled together (mosaicked) using the Image Analysis extension of ArcView. Mosaics were then imported into ArcINFO, converted into grids, and reprojected to the desired projection of the RSM GIS project. The projected grids were converted back into image files and compressed using Multiresolution Seamless Image Database (MrSID) software.

Oblique photos, along with corresponding descriptions, were provided to the Spatial Data Branch in hardcopy form. The photos were scanned and saved in JPEG file interchange formats. Photo descriptions were typed and saved as text files. Through

Figure 6. Aerial photo mosaic built for the area near Perdido Pass, Alabama

the Historical Photos application inside the RSM GIS, oblique photos are viewed and printed with corresponding descriptive data.

5.2.3 Dredged Material Records. Historical dredged material records are stored in a customized database. The database stores information regarding dredging history for each of the nine federal navigation projects in the region. Every known dredging event is included in the RSM GIS dredge material database, along with associated removal sites, dredge material quantities, placement sites, dredge contractors, and costs associated with the dredging contract. This information was collected from the USAED Mobile Operations Division's Irvington and Panama City Site Offices. The original form of the information was 3" X 5" notecards.

5.2.4 Digital Nautical Charts. NOAA nautical charts serve as the background for all other graphic entities built into the RSM GIS. These nautical charts were obtained from MapTech distributed CD's. Three steps were required to prepare the digital nautical charts for inclusion in the RSM GIS. First, the charts were reprojected from MapTech's proprietary .kap format into a UTM83 projection using the *Chart Reproject* DOS utility available through the NOAA webpage. Second, the .kap files and their associated .bsb files were imported into ArcView and converted into the Tagged Image File (TIFF) Format with corresponding world files. This process was achieved using the Chart Reproject extension to ArcView, also provided by NOAA. Finally, the TIFF format charts were "cleaned" to remove extraneous graphics and text as well as colorized to produce an accurate depiction of a nautical chart. This last step was achieved using the Paint Shop Pro image editor.

5.2.5 Generic GIS Data. The US Census Bureau releases extracts from the Census Topologically Integrated Geographic Encoding and Referencing (TIGER) database. The database is built on a county by county basis. For each county, TIGER/Line files include roads; railroads; hydrography; transportation information; power lines; pipe lines; municipal boundaries; landmarks (schools, churches, parks and cemeteries); and key geographic locations like shopping centers and factories (US Census Bureau 2000). These data are released in GIS format and are directly importable into the RSM GIS, provided that they are in the proper projection. In the case of the RSM GIS, generic GIS data was projected into UTM83 through the Projection Utility of ArcView.

5.3 Data Manipulation and Display Using ArcView. ArcView and its extensions provide a great deal of data manipulation capability. This section outlines the use of built-in ArcView functionality for the creation of new coastal entities like the mean high water line and bathymetric contours.

5.3.1 Shorelines. Shorelines were created directly in ArcView. The shoreline was determined from the position of the debris line on the ortho-rectified aerial photographs. The debris line often denotes the location of mean high water (MHW), which is the desired shoreline for most coastal applications. The shoreline was delineated using heads-up digitizing in ArcView. The position of the debris line on the orhto-rectified aerial photographs were marked approximately every 50 feet. Through the X tools extension in ArcView, a linear interpolation was performed between each point to create the MHW shoreline.

5.3.2 Triangulated Irregular Network. Using an ArcView extension called 3D Analyst, a triangulated irregular network (TIN) was created from each of the hydrographic and topographic data sets included in the RSM GIS, including the baseline data set. TINs allow RSM data users to use these data sets as surfaces, rather than as two-dimensional data points with an elevation attribute. The surfaces allow for more accurate volume computations between data layers and are included as a data layer in the GIS.

5.3.3 Grids. 3D Analyst was also used to create a grid of each data set. A grid is a set of regularly spaced data points created from a set of irregularly spaced data points, like the topographic and hydrographic data sets. In the RSM GIS, grids were created from TINS in order to most accurately represent elevation changes about the surface. Grids are used to facilitate calculations between data sets and volume computations. At each XY grid point an elevation is interpolated based on the elevation of the TIN at that same XY grid point. Each grid has been assigned a color scale based on elevation of the grid points. This colorizing of the grid points has the effect of creating color-filled contours for each data set. The grids are included as a data layer in the GIS.

5.3.4 Contours. Linear contours are also included as a layer in the RSM GIS. The contours were created using 3D Analyst. The contours are spaced at 1.5m intervals. The contours are drawn based on the elevations given by the grid surfaces.

5.4 Creating Custom Applications for ArcView. Several custom applications have been written to extend the capability of ArcView to meet RSM specific goals. These applications are generally written in AVENUE script and Visual Basic and take advantage of ArcView and ArcView extension functionality. AVENUE is ESRI's programming language.

5.4.1 Oblique Photo Tool. Aerial photography and oblique photography often contain valuable qualitative information regarding the condition of beaches, dunes, offshore shoals, and other coastal features. Oblique photography, generally taken with a standard camera from the beach itself, from nearshore buildings, or sometimes from the air, cannot be integrated into a GIS because it lacks positioning information. Aerial photography can be integrated with a GIS if necessary rectification information is available such as camera angles, which are related to aircraft roll and pitch. However, especially with older aerial photography, often the only information available is the contact print itself.

To include these valuable photos in the GIS, even though no positioning information is available, an oblique photo tool was created that hotlinks these photos to the areas in which they were taken. For example, several photos have been collected at East Pass, Florida, that cannot be rectified for input into the GIS. The oblique photo tool allows the RSM GIS user to select a location. Available photography for that location is displayed with relevant information.

An example of the oblique photo tool is shown in Figure 7. In the dialog, a small, or "thumbnail" version of a photo taken at East Pass, Florida, is displayed. By clicking the *Full Size* button, users can access a larger version of the photo. All relevant information stored in the photo database is displayed to the right of the photo. This includes the date of the photo, the file the photo is stored in, and a caption describing the photo.

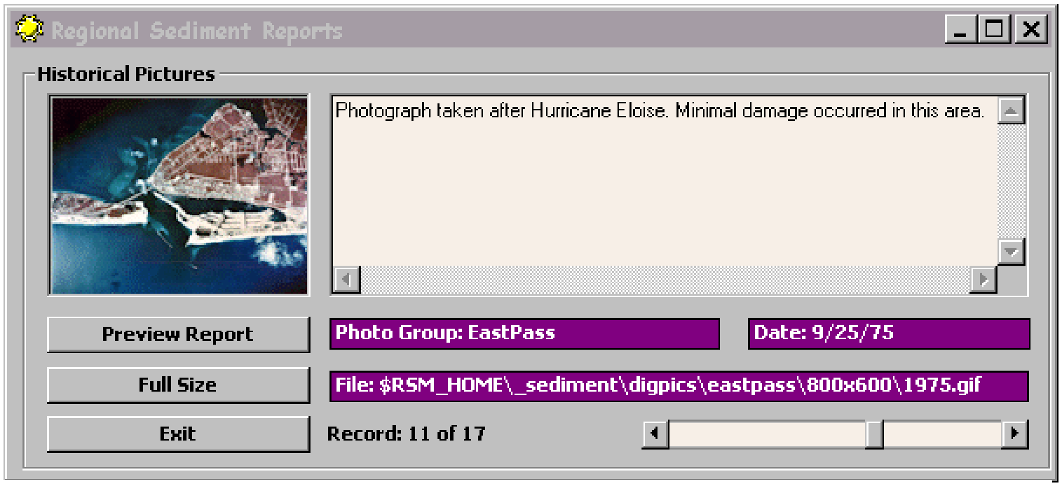
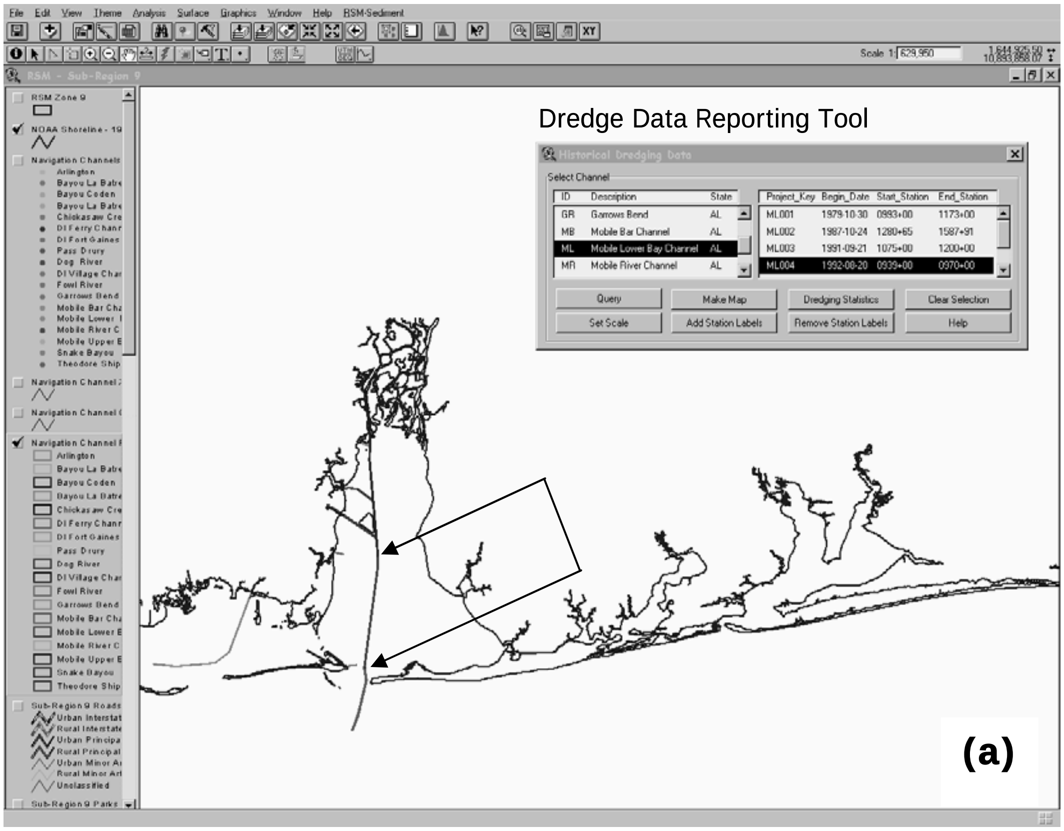
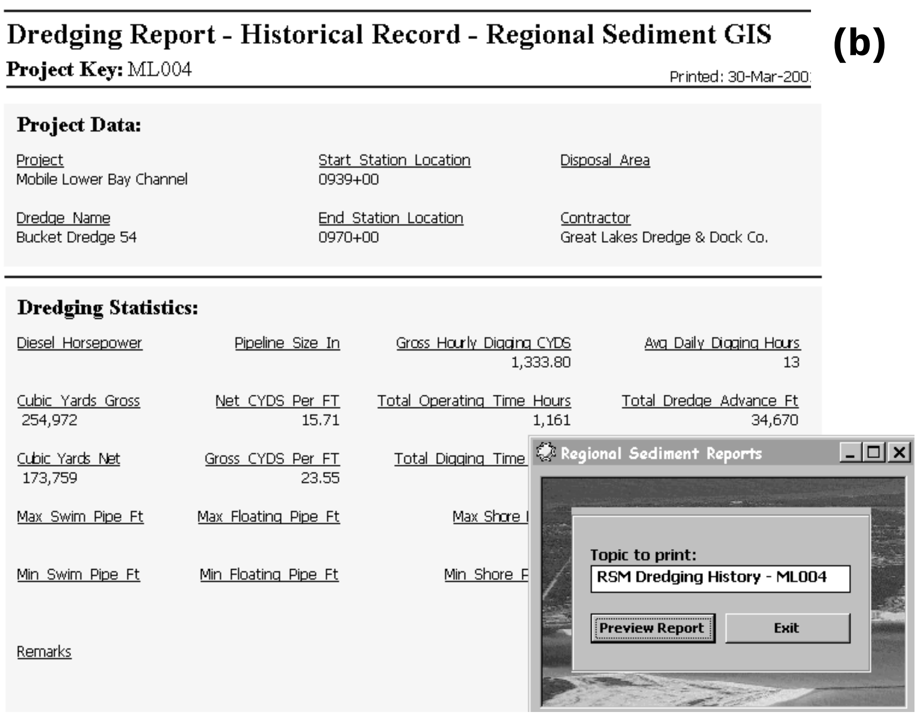


Figure 7. Custom oblique photo viewing tool built for the RSM GIS. The left side of the dialog shows a thumbnail view of a photo taken at East Pass, Florida, while the right size contains the photo location, date, and a caption stored for the photo.

5.4.2 Dredge Data Reporting Tool. The dredge material database is accessed through the dredge data reporting tool. The reporting tool calls up all known dredging events from the dredge material database. The user may access a *Dredging Report* by selecting an event from the scroll down list. The user may also select a particular navigation channel from the spatial domain of the RSM GIS and view reports for every event within that particular channel.

An example of a dredge data report is shown in Figure 8. Figure 8a shows the spatial domain of the RSM GIS near Mobile Pass, Alabama. Visible in the domain are the shoreline and navigation channels in this area. The dredging event highlighted in the dredge data reporting tool (shown blacked out here) is linked to the channel section highlighted in the main window of Figure 8a (denoted by arrows here). The dredge data reporting tool then uses data extracted from the dredge material database to fill a dredging report. A portion of a dredging report is shown in Figure 8b.





Dredging Report - Historical Record - Regional Sediment GIS

Project Key: ML004 Printed: 30-Mar-200

Project Data:

Project	Start Station Location	Disposal Area
Mobile Lower Bay Channel	0939+00	
Dredge Name	**End Station Location**	**Contractor**
Bucket Dredge 54	0970+00	Great Lakes Dredge & Dock Co.

Dredging Statistics:

Diesel Horsepower	Pipeline Size In	Gross Hourly Digging CYDS	Avg Daily Digging Hours
		1,333.80	13
Cubic Yards Gross	**Net CYDS Per FT**	**Total Operating Time Hours**	**Total Dredge Advance Ft**
254,972	15.71	1,161	34,670
Cubic Yards Net	**Gross CYDS Per FT**	**Total Digging Time**	
173,759	23.55		
Max Swim Pipe Ft	**Max Floating Pipe Ft**	**Max Shore**	
Min Swim Pipe Ft	**Min Floating Pipe Ft**	**Min Shore**	

Remarks

Figure 8 Dredging Report tool created for RSM GIS. Figure 8a shows the RSM GIS spatial domain near Mobile Pass, Alabama. This view includes the shoreline and navigation channels in this area. Figure 8b shows a portion of the dredging report filled with data from the dredge material database.

5.4.3 Profile Tool. Beach profiles have been collected as part of the coastal monitoring for the State of Florida for many years. Part of the baselining effort for the RSM Demonstration Program included the collection of beach profiles along the entire coast of Alabama. To compare this data with higher-density data sets, like SHOALS or multibeam data sets, users must be able to view profiles extracted from the higher density data sets at locations where historical profiles were collected.

The profile tool allows the user to extract profiles from the higher density data sets. The profiles may be extracted along hand drawn line objects. The profile tool creates a set of elevations along a line based on the grid surfaces included in the GIS.

An example profile tool is shown in Figure 9. Figure 9a shows the spatial domain of the RSM GIS near East Pass, Florida. Visible in the domain are the shoreline in this area, the grid surface for a SHOALS data set collected in at East Pass in 1996, and a solid line for which a profile will be extracted. Figure 9b shows the profileviewing window, where a profile is shown for both the November 1995 SHOALS data set and the 1996 SHOALS data set.

5.4.4 Compute Volumes Tool. The compute volumes tool gives RSM engineers and scientists the capability to compute volumes between data sets. The volumes are computed based on the grids created from the original data sets. The user may compute a volume by drawing an area (polygon) for which a volume is desired. At each grid point, an elevation difference is calculated between the two data sets. The volume is determined by integrating the differences over the areas they represent. The volume for the designated area is reported in a pop-up window. The differences are stored as a data layer in the RSM GIS.

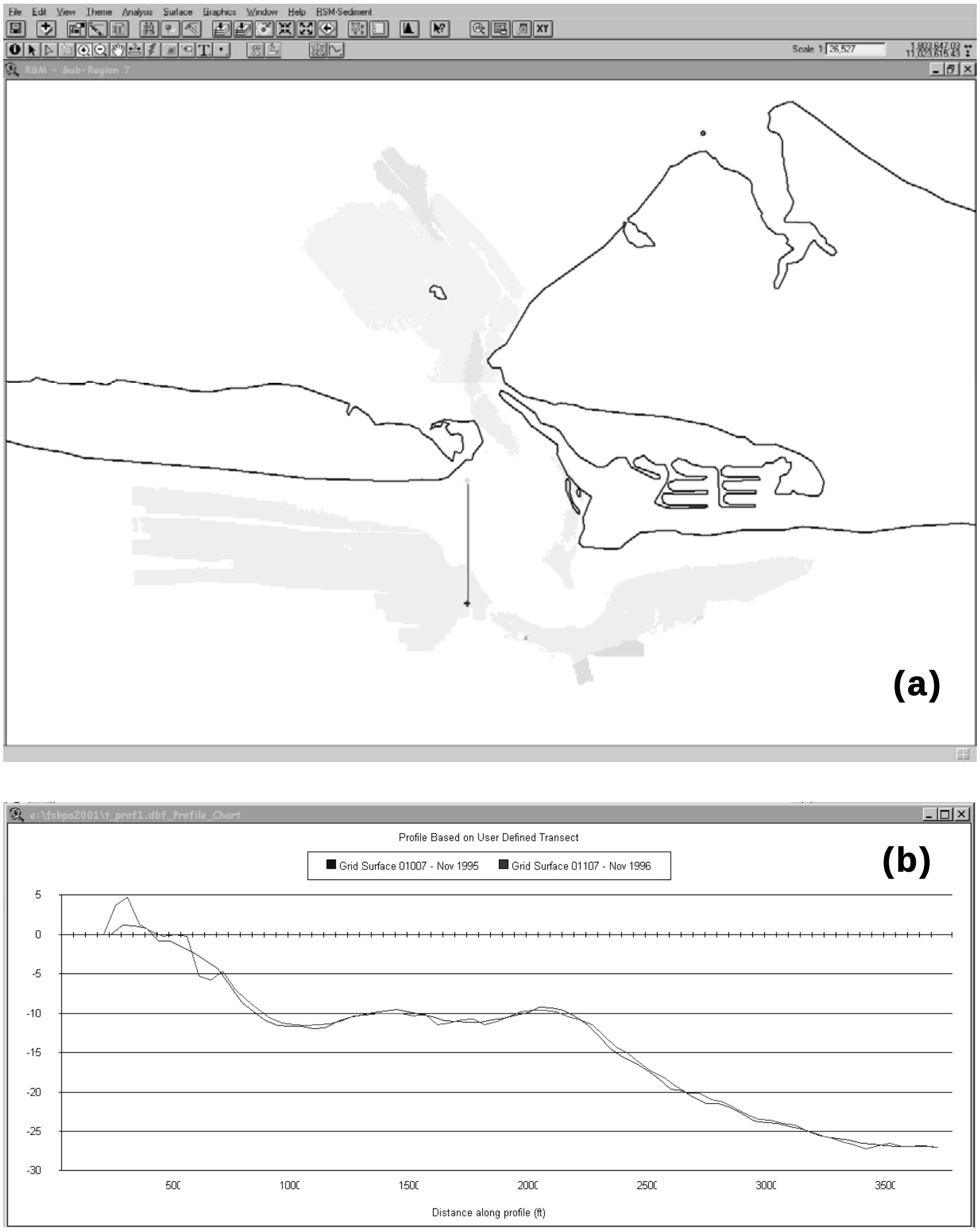


Figure 9. Profile tool created for RSM GIS. Figure 9a shows the spatial domain of the RSM GIS near East Pass, Florida. This view includes the shoreline in this area, the grid created for the 1996 SHOALS data set, and a line where a profile is desired. Figure 9b shows the profile viewing window, where a profile is displayed for the November 1995 SHOALS survey and the 1996 SHOALS survey.

An example showing the computed differences is shown in Figure 10. This view shows the spatial domain for the RSM GIS near East Pass, Florida. Visible in the domain are the shoreline and the difference grid computed during a volume calculation. The difference grid is shown in the lower central portion of the view. The black and dark gray grid cells are areas of positive difference, or accretion. The lighter gray areas are areas of negative difference, or erosion.

5.4.5 Additional RSM Tools. Five additional tools created specifically for the RSM are the RSM theme tool, a dynamic search tool, a coordinate conversion tool, and two printing tools. The theme tool allows users to select a group of themes, or data layers, to add to a view at a single time. For instance, all the themes in the area surrounding East Pass, Florida may be added as a single group. The dynamic search tool allows the user to search for a specific feature within a single theme. The coordinate conversion tool allows the user to convert between UTM and geographic coordinates. The printing tools allow the user to automatically print the current view or select feature attributes to output to the printer.

5.5 Conclusions. The RSM GIS provides engineers and scientists with tools to both visualize spatial data and perform engineering analyses. Data visualization improves understanding of potential sediment transport pathways. Engineering analyses provide exact quantities of change in shoreline position and sand volumes. These two pieces of information are required by RSM engineers and scientists to calibrate the numerical models upon which regional sediment management concepts depend.

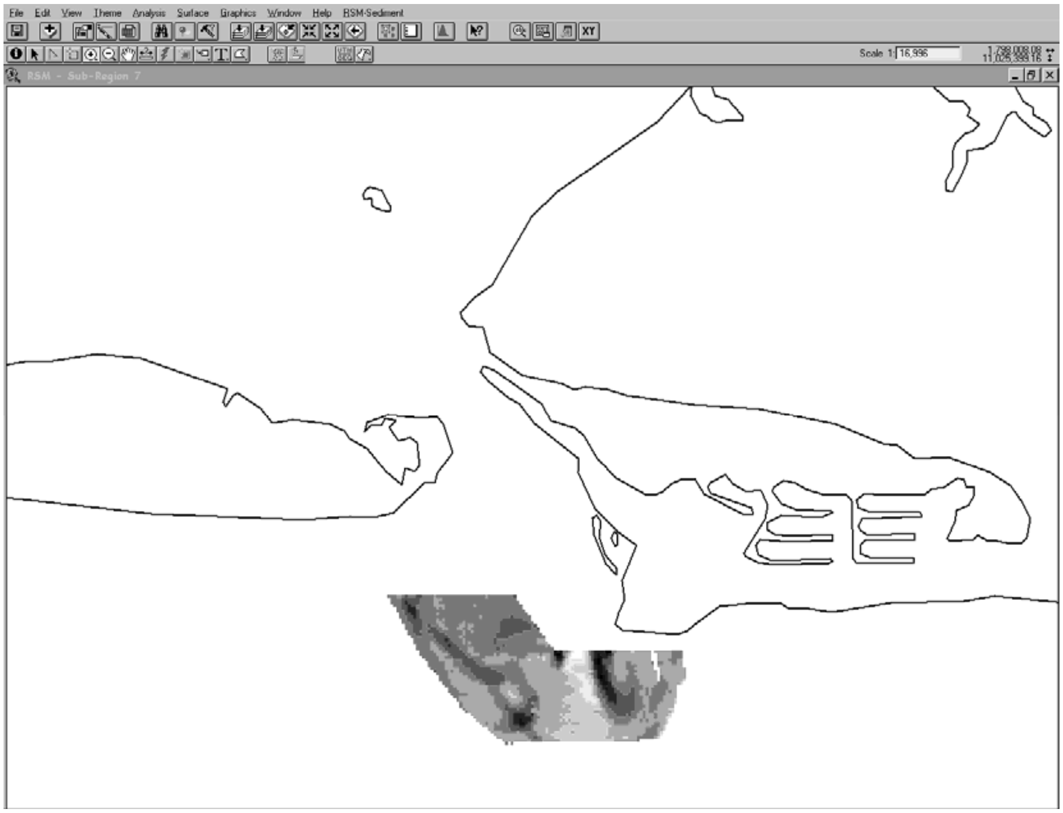


Figure 10. Volume tool created for RSM GIS. This figure shows the spatial domain for the RSM GIS near East Pass, Florida. The view includes the shoreline and the difference grid computed during a volume calculation. The black and dark gray grid cells are areas of positive difference, or accretion. The lighter gray grid cells are areas of negative difference, or erosion.

6.0 NUMERICAL MODELS FOR RSM

Regional sediment management concerns identifying and quantifying pathways and patterns of sediment movement, and using best management practices to preserve littoral and financial resources. Regional numerical models are tools to aid decision-makers in alternative selection for future activities to minimize or improve impacts on all pieces of the littoral system. Only through modern numerical models and innovative data measurement procedures are we now able to technically support the development of answers to regional sediment pathways questions.

This section gives a general overview of the regional setting on the south shore of Long Island, New York, and of the numerical models that can be used in the evaluation of regional sediment management. Examples of how we are using these models at the New York District Corps of Engineers will be discussed.

The south shore of Long Island faces the Atlantic Ocean. Net transport of material is to the west, toward New York Harbor, but there are strong seasonal and localized reversals of transport, especially at the inlets. The Long Island south shoreline consists of 95 miles of barrier island, eroding headlands on the eastern 30 miles, and productive estuarine bays. There are six federal navigation inlets on the south shore. The area has farms and parklands, and the cities of Long Beach and New York. The shoreline over the last 100 years has been impacted by both storms, which caused barrier island breaching and overwash, and human activities such as inlet stabilization and groin construction.

On south shore of Long Island, the Army Corps has six maintained navigation channels that are each dredged every two to three years, from 200,000 cubic yards per operation at Rockaway Inlet to 1 million cubic yards at Fire Island Inlet. There are a number of storm protection projects, including the 83-mile Fire Island Inlet to Montauk Point study. The entire shoreline is covered by Federally authorized storm protection projects. Over the last six years we have had intensive data collection efforts, and we have an Ecosystem Restoration program for the bays. As an indication of the amount of sediment placed on the beach in the area between Fire Island Inlet and Montauk Point, over the last 40 years, an average of approximately 300,000 cubic yards of material has been placed annually by the Corps and others. For these Long Island projects, over the last 10 years we have extensively used numerical modeling for the individual project areas.

Within the last three years, the district was forced by the geography and coastal processes of Long Island, its' continuous sediment transport path along the headlands and barrier islands, and the need for material for storm damage protection projects, to start to think regionally, as the navigation inlets, shoreline protection projects and the ecosystem concerns are interconnected. Other agencies are concerned about regional impacts also. The EPA and U.S. Fish and Wildlife Service have asked us to examine the cumulative impacts of the beachfill placement and dredging activities. There are also concerns about endangered species and prevention of overwash fan development. The task now facing the New York District is to connect the project areas into a regional system using the coastal processes tools and models available.

For regional numerical modeling on Long Island, we have initiated regional sediment budgets, a regional ocean circulation model, regional shoreline change models, circulation models for inlets and bays, and a regional wave model, with nested grids at the inlets. A requirement for the validity of the regional models is accurate input data. We have been fortunate to be able to collect repeated high quality bathymetry of some of the inlets, long-range profiles and aerial photography. Through an authorized data collection program and the support of the Coastal Inlets Research Program (CIRP), we have collected a very large data set of wave, wind, current and water level data. Again, through CIRP support, we have assembled a long-term history of the shoreline and the bays, which is used to check the reasonableness of the models. Regional does not always mean a large spatial area. It can also mean the understanding of all the features of a location, such as ebb and flood shoals, bay hydrodynamics, and wave and current interaction. Models are needed to answer the questions of wave energy and height, shoreline evolution, ocean and bay hydrodynamics, inlet sedimentation patterns and effects on adjacent beaches, and the stability of the barrier islands.

The District has used the following numerical models to develop regional understanding of natural processes, and as tools for evaluating engineering alternatives: sediment budgets and the Sediment Budget Analysis System (SBAS), STWAVE, GENESIS, ADCIRC, a multiple inlet stability model, MIKE21, the Reservoir Model, and the Cascade model. A discussion of each of the models follows.

6.1 Sediment Budgets and SBAS. A regional sediment budget is an accounting of gains and losses within a littoral system for a specific period of time, over both local and regional scales. Sediment budgets can range from conceptual to very detailed, depending on the quantity and quality of the littoral system change data available. Sediment budgets can be used to measure the impacts of engineering actions along a regional coastal area, and well as measure the effects of natural processes such as long-term erosion and barrier island breaching.

Rosati and Gravens (1999) developed a regional sediment budget for the Fire Island Inlet to Montauk Point study area. The area was divided into five morphologic zones, and evaluated over a number of time periods. Through the sediment budget, the net longshore transport rates for various conditions, such as the uncertainties in contributors such as bluff erosion, the historical and existing conditions, and various time periods, were developed, along with the potential longshore transport rate developed from adjusted Wave Information Study (WIS) hindcast data. In the near future we will develop a regional sediment budget for all of Long Island as an RSM demonstration project. This Fire Island to Montauk Point sediment budget will be used to evaluate storm protection alternatives for that project. The Sediment Budget Analysis System (SBAS) is a PC-based system for formulating sediment budgets, has been applied at Shinnecock Inlet, including all the sources and sinks and the sediment pathways. SBAS can be as general or specific as needed.

6.2 Steady Wave (STWAVE). STWAVE is a steady-state spectral wave model. It is a nearshore wave transformation model used to describe changes in wave parameters such as wave height, period, direction and spectral shape, between the offshore and the nearshore. STWAVE simulates many wave transformation characteristics, including refraction and shoaling, diffraction and wave growth due to wind input. The nearshore wave output from STWAVE is used to develop estimates of sediment transport, and then with subsequent models, shoreline change. An STWAVE wave grid has been developed for the 83-mile Fire Island Inlet to Montauk Point reformulation study (Gravens, 1999). The wave grid was developed from recent bathymetry, the use of the WIS waves, and verified using nearshore and offshore wave gage data. Three computational grids were used for this nearshore model. Accounting for changes in bathymetry and coastal features, variations of net sediment transport over the domain were developed. The model was applied to evaluate the changes in transport caused by dredging offshore borrow sites.

The LISHORE project has implemented STWAVE regionally along the Long Island coast (Grosskopf, 2001). LISHORE is supporting wave gauges that provide validation data for numerical modeling and real time documentation of wave conditions. The model is configured on a coarse resolution grid (1 nautical mile) along the entire island that provides boundary wave spectra for the finer, nested grids with resolution of 50 to 100 meters at Shinnecock and Jones Inlet. The application of STWAVE along the entire regional domain provides insight into wave-driven processes at a variety of spatial scales, which are critical to defining the regional sediment budget and impacts of engineering on that budget.

6.3 Generalized Model for Simulation of Shoreline Change (GENESIS). GENESIS is a one-contour-line beach evolution model. GENESIS calculates longshore sand transport rates and resulting planform shape of the modeled coast at short time intervals over a proscribed simulation period. The effects of coastal structures and other planform changes to the beach can be evaluated by the model. For the Fire Island to Montauk Point study, the GENESIS model was configured for application to three analysis reaches within the study area, from 15 to 30 miles long. The area includes three inlets, as well as a field of 16 groins at Westhampton. Project alternatives for the Fire Island to Montauk Point study, such as widened beaches, and the addition or removal of coastal structures, will be evaluated in the near future, based on the configured GENESIS model. Having a regional shoreline change model will provide answer to questions of the regional impacts of the project alternatives.

6.4 Advanced Circulation Model. ADCIRC is a two-dimensional, depth integrated finite-element hydrodynamic model developed with the capability of operating over a wide range of grid element sizes. Fine resolution can be defined for accurate calculation of flow through channels and around coastal structures. ADCIRC has been applied by the New York District in large- and small-scale applications. A regional tidal circulation model has been developed that includes the Atlantic Ocean, Long Island Sound and New York Harbor, and the six inlets and the associated bays located on the south shore of Long Island. Resolution is increased from the ocean toward the coast, with greatest node density in the bays and inlets. The regional propagation of the tidal wave around Long Island was modeled using ADCIRC. Differences in water surface elevations play a key role in the circulation of water through the south shore estuary system, which in turn impacts inlet hydrodynamics and inlet sediment transport patterns.

Due to concerns regarding borrow area sources for a shoreline protection project just west of Shinnecock Inlet, we asked for assistance from the Coastal Inlet Research Program to develop a model which could predict impacts of using the flood shoal as a borrow source (Militello and Kraus 2001). Fine detail was implemented in the ADCIRC model mesh for the Shinnecock study area, for resolution of the channels, jetties and shoals. Over 15 alternative configuration of flood shoal mining were modeled. ADCIRC has a robust wetting and drying algorithms to simulate the inundation and exposure of the flood shoal. Based on the impacts calculated by the model, a final recommended plan for the flood shoal mining was developed. By having this tool, we were able to show the local land trustees how changes in the bathymetry would change the current patterns. Without this tool we would have never been able to recommend using the flood shoal as a borrow source.

6.5 Stability Analysis. A multiple inlet stability analysis was used for the evaluation of barrier island breaching, to determine whether a stabilized inlet or a newly formed inlet would remain open after a breaching event (Headland, 1999). The condition of the inlet/bay system can have great impacts on local and regional sediment transport, including displacement of barrier island sediments, burial of bay habitat, interruption of littoral drift, and increased shoaling or closure of inlet navigation channels. The analysis was based on the methods of Escoffier and van de Kreeke. For each of the barrier-bay systems, closure surfaces considering the areas of the inlet and the breach, and corresponding flow velocities were developed. The overlapping of the two equilibrium flow curves, is plotted separately to determine if both the inlet and the breach will close, if the inlet will close, if the breach will close or both will remain open. Empirical data of historical breaches on Long Island, especially breach cross-sectional area, was very important to this analysis.

6.6 MIKE21. The New York District used MIKE21 ST at Coney Island, due to the need to better describe current actions which combine with waves to move sediment around a groin and wrap the sediment around the back side of the island (Moffatt & Nichol Engineers 1998). The model enabled the District to make conclusions about sediment transport patterns and to test alternatives at a highly eroding shoreline.

6.7 Cascade. "Cascade" is a new numerical simulation model aimed to bridge the gap between a sediment budget over a regional extent and the application of GENESIS over the individual reaches comprising the region. Sediment storage and bypassing are represented at the inlets between reaches. Cascade explicitly represents sediment-transporting motion on different spatial and temporal scales, cascading sediment transport processes to and from regional to local scale. The regional and local contours are represented, as are the ebb shoals for calculation of waves and longshore sediment transport. The Cascade model stores and bypasses sand at inlets by incorporation of elements of the Reservoir model.

6.8 Reservoir Model. The Reservoir Model (Kraus 2000) is a mathematical model for calculating the volume and sand-bypassing rate at ebb-tidal shoals. The analytical solution for volume changes and bypassing rates depends on the ratio of input longshore sand transport rates and the equilibrium volume of morphological features of the ebb shoal, the bypassing bar and the attachment bar. The model gives explicit expressions for the time delays in sand bypassing associated with creation and growth of the features. The Reservoir model was applied at Shinnecock Inlet to evaluate consequences of mining the flood shoal (Militello and Kraus 2001). An extended generalized model also includes the flood shoal, the inlet entrance channel and the exchange of sediment between these and other sand bodies.

6.9 Conclusions. In summary of this aspect of regional sediment management, numerical models are available to help define the littoral system and can be used to evaluate natural and engineering impacts to the system. Regional numerical modeling can be initiated by gathering all the available accurate data on waves, shoreline change, engineering activities, natural events such as breaching, sediment type, circulation patterns. The next step is to develop a conceptual sediment budget. From that base, SBAS can be used to develop a flexible, spatially variable sediment budget, to determine areas where more data is needed. If there are enough funding resources, and good regional data including measured wave data is available, the models describe in this section can be used to assist in regional sediment management tasks.

7.0 RESEARCH AND DEVELOPMENT NEEDS FOR RSM

Although regional concepts have engaged our attention for many decades, procedures and models for answering questions that must be addressed in RSM are not available for the large spatial and temporal scales required. Because RSM may involve the movement of sediments over large regions, and repetitive placement of material, long time periods (10 to 50 years) are necessary to evaluate the likely outcome of many RSM activities. Research at CHL in support of coastal RSM is directed towards the models discussed in the previous section, as well as other endeavors. Studies needed for RSM include:

- Large-Scale Barrier Island Processes. Processes such as barrier island dynamics, including wind-blown sand processes, overwash, and barrier island migration and shape changes are not well-understood.
- Prediction of long-term wetland and coastal land losses, and practical restoration options.
- Physics governing long-term evolution of coastal morphology (shoreline, inlets, offshore shoals, sand ridges, sandbars, etc.) expressed in terms of large temporal and spatial scales and including long term hydro-meteorological phenomena such as El Nino events, changing weather patterns, and relative sea-level rise (from Kraus 1997).

8.0 CONCLUSION

The intent of the National Regional Sediment Management Demonstration Program within the U.S. Army Corps of Engineers is to improve the Corps' management of sediment throughout the entire watershed (from the riverheads, through the estuaries, to the coasts). The program has been designed to accomplish this goal by minimizing the interruption of natural sediment transport processes or by enhancing these processes to maximize environmental and economic benefits. Implementation of RSM, both from the grass-roots level prior to implementation of the National Program, and during the past year of the National Demonstration Program has resulted in partnerships between the Corps, state, local, and other Federal offices, some of which are cost-sharing. The result of State and USACE RSM initiatives will be improved methods for managing sediment within our Nation's waterways, with advances in conceptual, analytical, and numerical models to support regional studies.

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