

Study Title: Numerical Modeling Evaluation of the Cumulative Physical Effects of Offshore Sand Dredging for Beach Nourishment

Report Title: Numerical Modeling Evaluation of the Cumulative Physical Effects of Offshore Sand Dredging for Beach Nourishment

Contract Number: 1435-01-99-CT-30993

Sponsoring OCS Region: Headquarters - International Activities and Marine Minerals Division

Applicable Planning Area(s): Offshore Sand Borrow Sites from southern New Jersey to Cape Canaveral, Florida

Fiscal Year(s) of Project Funding: FY1999 to FY2001

Completion Date of Report: November 2001

Costs: FY 1999: \$37,074.90; FY 2000: \$ 79,059.52; FY 2001: \$ 83,806.76

Cumulative Costs: \$199,941.18

Project Manager: Mark R. Byrnes, Ph.D.

Affiliation (Project Manager): Applied Coastal Research and Engineering, Inc.

Address: 766 Falmouth Road, Suite A-1, Mashpee, MA 02649 (Applied Coastal)

Principal Investigators: Mark R. Byrnes, Ph.D., Sean W. Kelley, M.S., John S. Ramsey, M.S.

Key Words: wave modeling, sediment transport, offshore sand borrow sites, beach nourishment, cumulative impacts, dredging, Outer Continental Shelf

Background: The potential for exploitation of sand resources as a source for beach and barrier island restoration has grown rapidly in the last several years as similar resources in State waters are being depleted or polluted. Extraction of sand resources in Federal waters may be preferred relative to State waters due to concerns over changes in physical oceanographic conditions resulting from large quantities of material dredged from resource sites impacted by waves and currents. This study examines the potential for negative impacts to coastal and nearshore environments, particularly from alterations to the local wave and sediment transport regime, due to long-term dredging and significant removal of sand from shoals offshore southern New Jersey, southeastern Virginia (Sandbridge Shoal), North Carolina (north of Oregon Inlet), and Cape Canaveral, Florida.

Objectives: The most effective means of quantifying incremental and cumulative physical environmental effects of sand dredging from shoals on the continental shelf is through the use of wave transformation numerical modeling tools that recognize the random nature of incident waves as they propagate onshore. Although the interpretation of wave modeling results is relatively straightforward, evaluating the significance of predicted changes for accepting or rejecting a borrow site is more complicated. A substantial part of this study was aimed at assessing the significance of simulated changes between existing and post-dredging conditions versus natural variability in wave climate and potential sediment transport rates to determine the relative importance of predicted changes. It is expected that information generated will enable the MMS to assess potential impacts of long-term offshore dredging and to identify potential dredging alternatives aimed at minimizing or precluding adverse physical environmental impacts.

Description: The inshore portion of the continental shelf, seaward of the State-Federal OCS boundary and within the Exclusive Economic Zone (EEZ), encompasses the project study areas offshore southern New Jersey, southeastern Virginia, northeastern North Carolina, and Cape Canaveral, Florida (Figure 1). The seaward limit of all borrow sites is generally within about 30 km of the shoreline and located between the 10- and 20-m depth contours. A four-phase approach was implemented to assess the potential for negative impacts from alterations to the local wave climate and sediment transport regime associated with offshore sand mining. First, a detailed evaluation of three readily-available, project-tested spectral wave models was conducted to determine the most effective simulation routine for

predicting potential wave impacts due to dredging at offshore borrow sites. Second, a standard method was developed to qualify the significance of changes associated with borrow site excavation to determine the influence of borrow site geometry on local wave refraction and sediment transport patterns. The method developed for this study is based on historical wave climate variability, as well as local wave climate changes directly attributable to borrow site excavation. The third phase of the project focused on wave spectra development, wave transformation modeling, and coastal sediment transport calculations. Wave transformation modeling and sediment transport potential calculations were performed for existing and post-dredging bathymetric conditions within the study area. In addition, a site-specific determination of acceptable limits for borrow site impacts relative to sediment transport potential was determined for each case. The fourth phase of the project addressed potential cumulative effects of sand dredging from offshore sand borrow sites. These analyses were designed to determine how potential wave impacts at individual sites may interact to produce additive physical environmental effects along the coast.

Significant Conclusions: Potentially rapid and significant changes in bathymetry due to sand extraction from the OCS may have substantial impact on wave propagation patterns on the continental shelf and at the shoreline. As such, significant effort was spent understanding existing wave propagation patterns relative to those resulting from potential sand extraction scenarios. Overall, post-dredging wave model output for the four study sites illustrates reduced wave heights landward of borrow sites and increased wave heights at the longshore limits of the borrow site. This effect is more pronounced for cases with larger wave heights and longer periods. As waves propagate across a borrow site (deeper water than the surrounding area), wave refraction bends waves away from the center of the borrow site and toward the shallower edges. The net effect is to create a shadow zone of reduced wave energy immediately landward of the borrow site and a zone of increased wave energy updrift and downdrift of the borrow site. This shadowing effect is apparent in model results for offshore southern New Jersey. In the immediate vicinity of the borrow site, wave heights increased by a maximum of 0.20 m at the northern and southern edges of the borrow site and decreased by a maximum of 0.19 m behind the borrow site.

A predominant condition for simulating wave propagation across the southeastern Virginia continental shelf was a 1.8 m high, 10 sec peak period wave, approaching from the southeast. Maximum increased wave heights near Rudee Inlet are 0.5 m above the offshore condition. This zone of increased wave heights extends approximately 10 km on either side of Rudee Inlet. As a result of wave focusing by Sandbridge Shoal, there is a corresponding decrease in wave heights south of the shoals, shoreward to Sandbridge. An area of maximum decrease in wave height is indicated just seaward of Sandbridge, where wave heights are approximately 0.8 m less than at the offshore boundary. Modeled wave height changes relative to post-dredging conditions range between 0.2 and -0.35 m. The zone of influence along the shoreline for the two sites extends approximately 12 km, from just north of Rudee Inlet to Sandbridge.

For offshore North Carolina, the predominant wave condition has a significantly longer period than the New Jersey condition ($H_s=1.5$ m, $T_{peak}=12.8$ sec, $\theta_{peak}=71$ deg), and as a result, waves respond more rapidly to offshore bathymetry gradients. At the offshore shoals directly east of Oregon Inlet, wave heights increase approximately 0.7 m over offshore conditions. Wave height change from existing and post-dredging conditions at the two borrow sites illustrates an overlapping region of influence, as site 3 West is located directly landward of the site 3 East along the direction of wave propagation (Figure 1). The area of maximum increased wave heights for post-

dredging conditions is located at the northern corner site 3 West, where wave heights increase 0.06 m over existing conditions. Similar to the southeastern Virginia examples, wave height increase is the result of the combined influence of the two sites. The area of maximum wave height decrease is located landward of site 3 West, where wave heights are reduced by 0.07 m from existing conditions.

Canaveral Shoals, the complex of ridges and troughs that extend southeast from Cape Canaveral, cause significant increases in wave heights as waves propagate over this area. The predominant offshore wave condition is a 1.6 m, 14.3 sec wave propagating from the east-northeast. Vectors indicating wave direction illustrate that for some nearshore regions adjacent to the Cape, the direction of wave propagation changes more than 45 degrees, following the gradient in bathymetric contours. The largest waves in the model domain occur at the shoals north of Cape Canaveral, and are 1.3 m higher than offshore waves. At shoals in the vicinity of the borrow site, wave heights increase to a maximum of 2.8 m, 1.2 m above offshore conditions. Shoals tend to refract wave energy and focus it near the cusp of the Cape. Wave energy is focused away from the coast south of Cape Canaveral, and an area of reduced wave heights is created. Maximum changes in post-dredging wave heights were ± 0.7 m, which are substantially greater than changes observed at previous sites. The area of greatest wave height increase occurs at the northwest corner of the site. The alongshore extent of influence extends approximately 13 km north of the Cape to about 5 km south of Port Canaveral.

To establish useful criteria for estimating impacts of sand mining on the nearshore littoral system, a comparison of sediment transport potential and long-term shoreline change was performed at each of the four sand borrow sites. For the southern New Jersey shoreline, erosion and accretion trends are predicted well at all locations, including in the vicinity of tidal inlets. Along the southeastern Virginia coast, model results predict similar trends as observed long-term shoreline change, where much of the coastline is stable or slightly erosional. Overall agreement between modeled trends and measured shoreline change also was achieved for the North Carolina coast. Discrepancies between predicted and measured results likely are a result of the significant historical migration of Oregon Inlet. Along the Cape Canaveral coast, STWAVE modeling was not capable of evaluating changes in wave climate resulting from wave diffraction processes across Canaveral Shoals. In addition, these shoals likely serve as a sediment source to the beach in this region. South of Port Canaveral, away from the influence of the Cape's topographic and bathymetric features, the trends predicted by the sediment transport potential model match well with historical shoreline change.

Study Results: Based on site-specific analyses for each of the four sites, the impacts associated with offshore dredging were deemed acceptable. For the southern New Jersey coastline, the significance criterion envelope was typically ± 10 to 15% of the modeled annualized net transport potential, with values of about $\pm 30\%$ close to Great Egg Harbor Inlet. Overall, the significance criterion envelope (representing plus or minus one standard deviation about the mean) for New Jersey was relatively narrow compared with the other three modeled areas. This results from limited variability in inter-annual wave climate along the southern New Jersey coast.

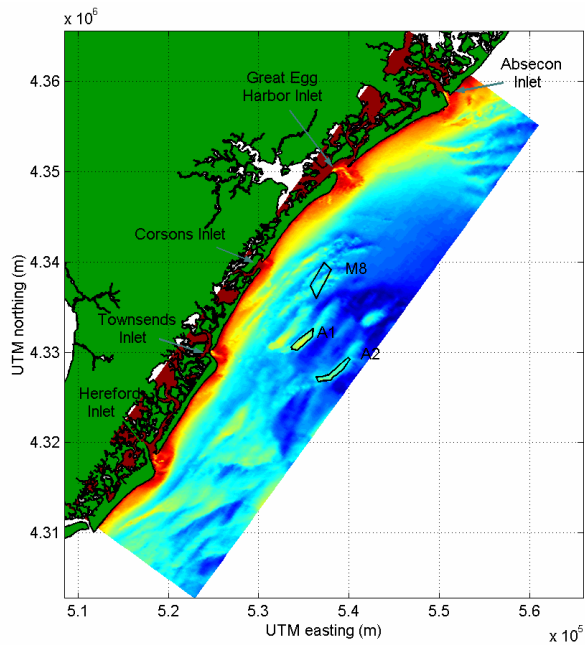
For southeastern Virginia and North Carolina coastal regions, the dredging significance criterion envelope generally falls within ± 20 to 40% of the computed net transport values. For the modeled sand excavation conditions, post-dredging model results fall within the significance criterion envelope for both cases, so again the modeled dredging plan would be acceptable. Model output for the region south of Port Canaveral, Florida

illustrates that in the area of greatest impact from the borrow site, the significance envelope is approximately $\pm 20\%$ of the mean computed net transport potential. Again, the modeled impacts in this region associated with potential offshore dredging are well within the significance envelope. However, due to limitations with the wave modeling effort, further analyses would be required to accurately assess impacts caused by dredging for the shoreline north of Port Canaveral.

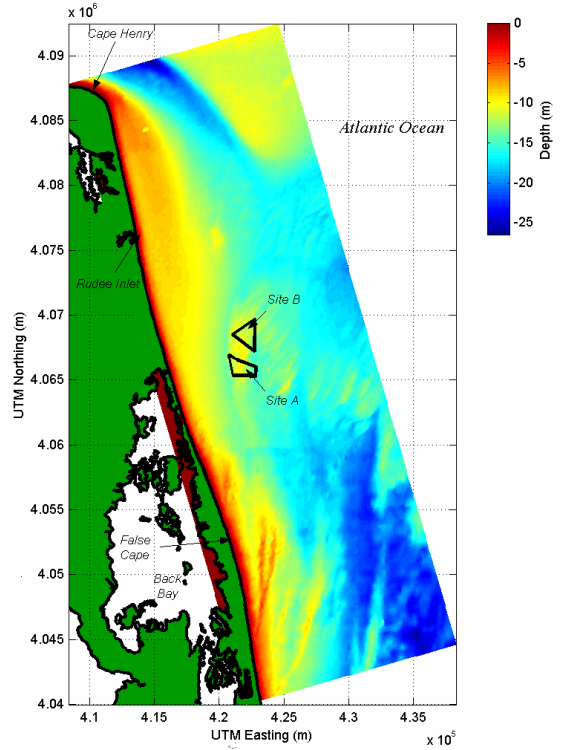
To evaluate cumulative impacts associated with incremental dredging of a single site and/or the combined effects of dredging borrow sites in the same region, two types of borrow site configurations were investigated. The first involves the interaction of multiple sites in close proximity, such that they have overlapping areas of shoreline impact. The second involves multiple dredging events at a single site. At Sandbridge Shoal, the two borrow sites are oriented side-by-side and parallel to the shoreline. For offshore North Carolina, sites 3 East and 3 West are oriented front-to-back in a line perpendicular to the shoreline. To evaluate the influence of individual borrow sites relative to the combined influence of both borrow site excavations, wave model runs were performed for cases where each borrow site was excavated individually and both borrow sites were excavated in a single event. Annual sediment transport calculations were then performed for each wave modeling scenario. Superimposing the effects of individual borrow site excavations onto the sediment transport potential curve developed from the combined excavation model run was used as the basis for comparison. The results from these two cases (Virginia and North Carolina) suggest that borrow sites located in close proximity illustrate additive impacts. Therefore, the influence of multiple sites on sediment transport along a coastline is a simple additive effect, rather than a more complicated non-linear effect or amplification.

The second type of cumulative impact analysis evaluated the effect of multiple dredging events at a single site. As a borrow site is excavated to greater depths, the impact that it has on sediment transport along the shoreline will increase. Site M8, offshore southern New Jersey, was used to evaluate a range of excavation depths for identifying the point where changes in sediment transport potential become significant relative to natural transport variability because the site is positioned close to shore, and it has a relatively large perimeter. Deep excavations at this location would have pronounced (and therefore easily observable) effects on modeled sediment transport patterns at the shoreline. From the five model runs, change in transport potential varied linearly with excavation depth and did not exceed the impact significance criterion until an excavation depth > 5 m.

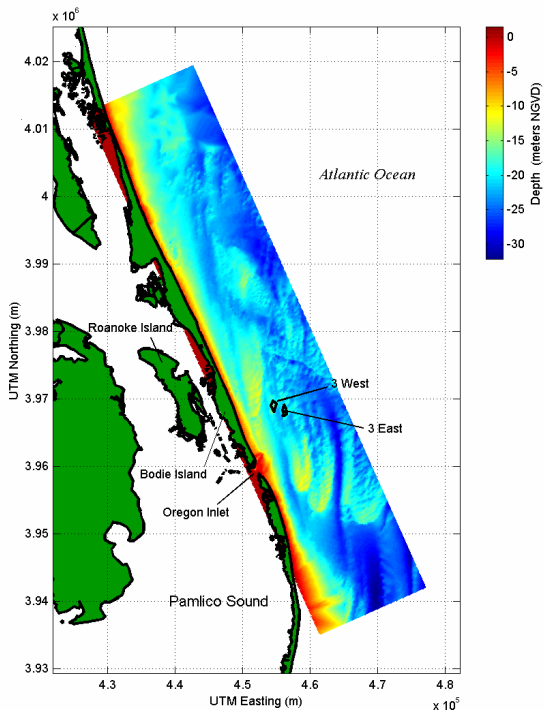
Study Products: Kelley, S.W., J.S. Ramsey, M.R. Byrnes, 2001. Numerical Modeling Evaluation of the Cumulative Physical Effects of Offshore Sand Dredging for Beach Nourishment. U.S. Department of the Interior, Minerals Management Service, International Activities and Marine Minerals Division (INTERMAR), Herndon, VA. OCS Report MMS 2001-098, 95 pp + 106 pp appendices.



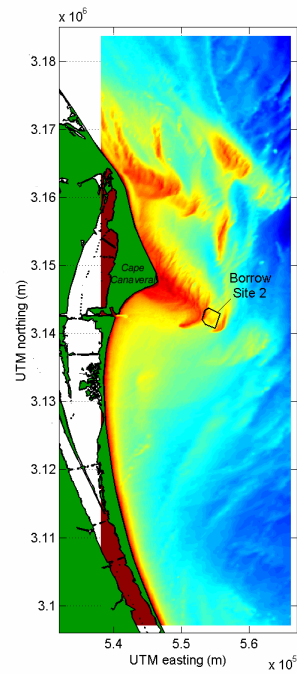
a. Offshore southern New Jersey.



b. Offshore southeastern Virginia.



c. Offshore North Carolina.



d. Offshore Cape Canaveral, Florida.

Figure 1. Location diagram illustrating potential offshore sand borrow sites in the U.S. East Coast study area.