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A NUMERICAL SIMULATION APPROACH TO ESTIMATING DISPOSAL SITE STABILITY

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ABSTRACT

A systematic methodology is described for estimating the long-term response of a dredged material site to local environmental forcings. The methodology is based on the development of user-accessible data bases of wave and current time series and the subsequent application of these boundary conditions to coupled hydrodynamic, sediment transport, and bathymetry change models. The approach was developed to provide an estimate of long-term material fate for use in determining whether an existing or proposed disposal site will be dispersive or nondispersive over periods of time on the order of months to years.

INTRODUCTION

The U.S. Army Corps of Engineers is responsible for maintaining operational depths in essentially all navigable waterways in the United States. Over 450 million cubic yards of material are dredged each year by the Corps in support of this mission. Annual costs are on the order of half a billion dollars.

Dredged material is often placed in locations referred to as Ocean Dredged Material Disposal Sites (ODMDS). The Corps is seeking new or enlarged ODMDS in many locations because existing sites are becoming filled to capacity. Approval of new sites requires a rigorous demonstration of the environmental impact of the disposal operation to areas adjacent to the disposal site. This material fate projection must often be based on field data and subjective opinions concerning the probable impact of the disposal operation on areas adjacent to the designated site. This process can require years and considerable cost.

In 1988, a 7-year Dredging Research Program (DRP) was initiated with a goal of decreasing costs associated with all phases of dredging. The substantial costs associated with locating and gaining approval of new disposal sites could be greatly decreased by the development of a systematic methodology for analyzing the dispersive or nondispersive characteristics of proposed or existing ODMDS.

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Long-term predictions of sediment transport and associated bathymetry change are difficult to verify because the processes of erosion and movement of sediment are functions of not only the local bathymetry and sediment composition but also of the local time-varying wave and current conditions. This paper briefly describes the development of a comprehensive approach to estimating the fate and stability of a disposal site as a function of local environmental conditions. The basis of the approach is twofold. First, a data base of user accessible local wave and current information was developed. Data include the means of generating site specific time series of waves and tidal elevations and currents as well as frequency indexed storm surge hydrographs. These data are used as boundary condition input to the second component of the analysis approach; a coupled hydrodynamic, sediment transport, and bathymetry change numerical model. The boundary condition and modeling components are described in the following sections.

BOUNDARY CONDITIONS

The data base of environmental forcings were developed to provide a means of defining realistic boundary conditions at a proposed or existing disposal site without the requirement of gathering prototype data. Although all possible sources of waves and currents which contribute to erosion and transport of sediment cannot be included in the data base, the intent is to identify the most significant contributions. These components include time series of wave height, period and direction; time series of tidal elevations and currents; and frequency indexed time series hydrographs for both tropical and extratropical storm events.

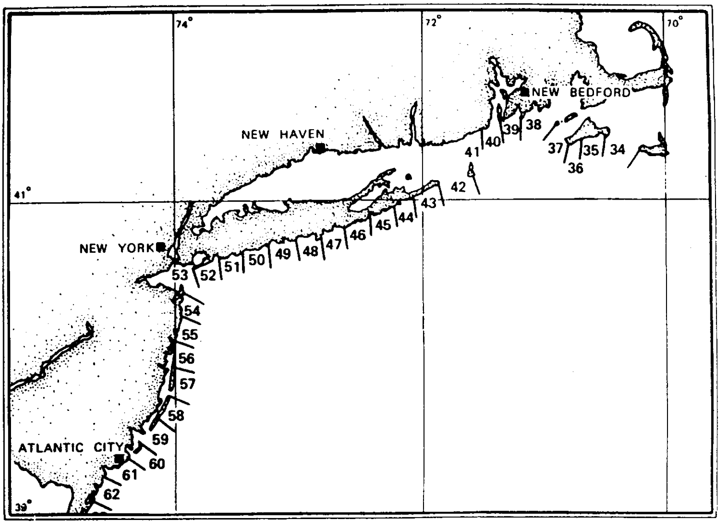

Figure 1 Phase III WIS data base density in the New York Bight

Waves

A stochastic procedure for generating simulated time series of wave height, period, and direction was developed for this project (Borgman and Scheffner 1991). The methodology is based on the pre-computed intercorrelation matrix of an existing time series of data. Therefore, the simulated wave series contains all of the primary statistical properties of the entire original time series, including wave sequencing and seasonality.

The Wave Information Study (WIS, Jensen 1983) Phase III 20-year hindcast data base was used for the site stability analysis application. This data base contains time series of wave height, period, and direction at a 3-hour time increment and spatial density of approximately 10 miles along all coasts of the United States. Figure 1 demonstrates the Phase III density for the Middle Atlantic Shelf region. A similar density continues down the east coast. Additional WIS hindcasts include the Gulf of Mexico, the West Coast, and the Great Lakes. An example simulation is shown in Figure 2 comparing simulated and hindcast data for a WIS station located in the Gulf of Mexico, just offshore of the entrance to Mobile Harbor, AL.

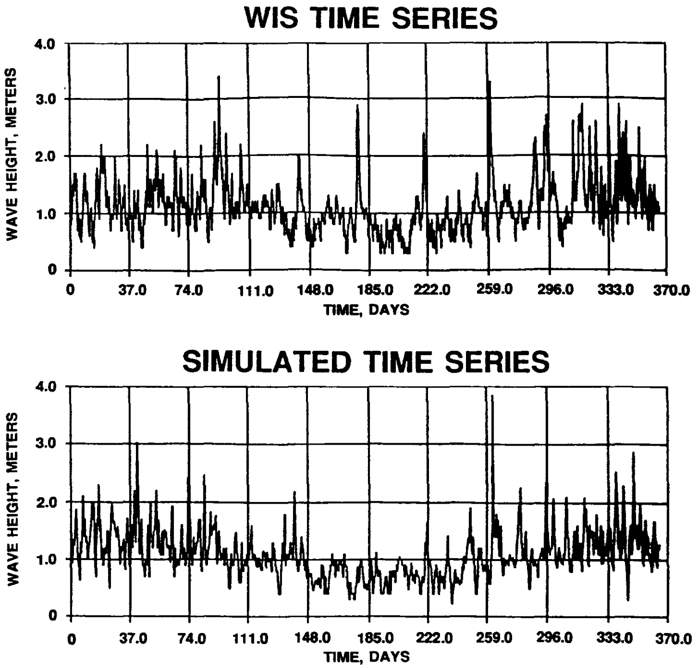

Figure 2 Simulated and hindcast wave comparison, Mobile, AL

Tides and storm events

The second component of the data base represents tide and storm induced current and water level elevation data. Both are computed with a generalized wave equation-continuity equation based finite element model (Luettich, Westerink, and Scheffner 1992). The model was developed specifically to have the flexibility to model global sized domains yet be capable of detailed nearshore resolution on the order of 10 miles along both east and west coasts of the United States. The east coast model has been completed. Accuracy of the computation is maintained by placing the computational boundaries beyond the continental shelf, while extending the grid from Nova Scotia, down the East Coast, Gulf of Mexico, and Caribbean Sea to the eastern edge of Venezuela. Thus, minimizing nearshore lateral boundary conditions as well as eliminating the problem of specifying water surface elevation boundaries across the continental shelf. The computational grid for the east coast model is shown in Figure 3. The model contains approximately 50,000 elements with 25,000 nodes. Flexibility of the grid is demonstrated by a ratio of the largest cell area to the smallest of approximately 5,000.

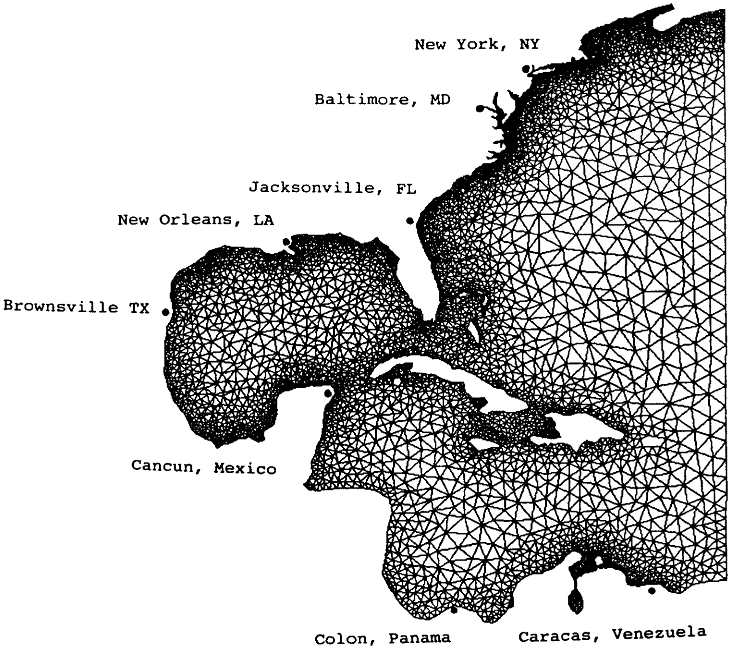

Figure 3 East Coast Computational Grid

The tidal component of the data base is computed by first driving the model with a water surface elevation time series computed according to globally defined harmonic constituents (Schwiderski, 1980). Time series at each grid location are then input to a standard harmonic analysis program to compute constituent amplitude and equilibrium argument data for both surface elevations and currents. In this manner, time series of tides can be reconstructed at virtually any grid point in the domain for any time or duration.

The storm event component is developed by reconstructing frequency-indexed storm events according to their global pressure and wind field distribution. This boundary condition data is used as input to the global hydrodynamic model to compute nearshore surge height and current hydrographs. Each hydrograph will be contained in the data base for use in investigating storm related erosion. All boundary condition components such as waves, water surface elevations, and currents are finally input to the coupled numerical models to investigate the fate and stability of an existing or proposed ODMDS.

SITE STABILITY MODEL

The disposal site stability analysis program is composed of coupled hydrodynamic, sediment transport, and bathymetry change models. The constructed boundary condition time series of waves and tidal and/or storm induced currents and elevations are input to the program. Computations predict the time change in the geometric configuration of a user specified disposal site feature such as a mound to the local environmental conditions. Computations on the order of months to years are used to indicate the dispersive characteristics of the site.

The numerical sequence of events is performed at a 3-hour time step, equivalent to that of the simulated WIS hindcast data base. Waves, currents, and water surface elevations are then used to compute the velocity distribution around the specified disposal feature. This distribution is used to compute the associated distribution of sediment transport and the resulting patterns of erosion and deposition. Currently, the noncohesive sediment transport component of the model is based on the equations of Ackers and White (1973) and modified for the presence of waves according to Bijker (1967). Successful applications of the general approach have been made to several locations, including Humboldt Bay, CA (Scheffner, 1992) and Charleston, SC (Scheffner and Tallent, 1992).

CONCLUSIONS

The numerical simulation methodology presented in this paper represents a systematic approach to disposal site analysis. Site specific predictions are based on wave and current data which are representative of the area in which the disposal site is located. Accurate predictions of site stability are therefore possible through the use of coupled hydrodynamic, sediment transport, and bathymetry change numerical model simulations. This site stability procedure has been shown to produce accurate estimates of site behavior which can be used in the selection and operation phase of ocean dredged material disposal sites.

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APPENDIX - REFERENCES

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