REMR TECHNICAL NOTE HY-N-1.2

CHANNEL MAINTENANCE CONTROL THROUGH OPTIMUM STRUCTURAL REHABILITATION

PURPOSE: To describe methods and tools available for determining the optimum structural configuration within a channel reach.

PROBLEM: Determining the optimum rehabilitation level of training structures to minimize navigation channel shoaling.

DESCRIPTION: Structures used to stabilize navigation channels and to minimize required maintenance dredging can often benefit from field experience in selection of the optimum level of rehabilitation of a deteriorated structure. Generally, predictions of the dredging requirements for the various levels of rehabilitation are needed. These predictions can help determine whether a structure should be rehabilitated, and what the payback would be for various levels of rehabilitation.

CAUSES: Channels through movable sediment beds are inherently unstable. Attempts to stabilize them with structures may only reduce the degree of instability of the channel geomorphology. Littoral transport trapped by flood currents, riverborne sediments, and a natural tendency for migration make natural channels difficult to confine and maintain. Accurate estimates of channel sedimentation rates for structural modifications require an understanding of the relationships between these sources and the hydrodynamics of the system. Prediction accuracy also depends on the extent of the deviation of the proposed configuration from the existing conditions from which the field data base is developed. Therefore, often an accurate, detailed, and optimum structural configuration cannot be developed until the field data base includes some experience with some form of the structure in place. The structure can then be rehabilitated to its optimum level.

METHODS FOR OPTIMIZATION: To predict the optimum structural configuration within a channel reach requires modeling of both hydrodynamics and sedimentation. The current state of the art in sedimentation modeling has been developed in the TABS-2 modeling system, a collection of two-dimensional (2-D), finite element modeling codes and their appropriate preprocessing and postprocessing codes. The system has the flexibility to be applied over a wide range of complexity, from tidal inlet channels to riverine problems.

The following steps summarize the basic approach in applying the TABS-2 system for a specific problem:

a. A site evaluation should be made to assess the nature of the shoaling problem, defining the probable sources and character of sediment causing the problem. The problem should be identified as either a cohesive, noncohesive, or combined shoaling problem. Field data should be obtained to assist in defining sediment properties.

b. The transport processes should be evaluated to identify those mechanisms contributing to the shoaling problem and the relative frequency of significant energy levels for these processes. Wave energy, tidal currents, wind-induced flows, and river-discharge-induced currents should be evaluated. This evaluation should include field data collection whenever feasible.

c. From the evaluation of the processes and the sources of sediment and energy for transport, a general modeling area can be determined. Over that area, a numerical computational grid is developed with appropriate resolution in the area of the shoaling problem. The grid resolution should also reflect the anticipated location to which the shoaling problem may be shifted by the proposed structural measures.

d. The transport processes of significance must be categorized into representative discrete events, with their frequencies of occurrence. Usually, this must be accomplished for both a particular period of time being used for modeling verification and for subsequent typical events that are drawn from a more protracted prototype period to be used in structural performance evaluation. The events defined may be steady-state or perhaps a tidal cycle of specified tidal range, or be a composite of a steady-state condition for one process and other varying processes. But each event is related to some frequency of occurrence.

e. Once the simulation period has been discretized, the model boundary conditions for each of the events must be defined, either from field data, other model data, or synthesized analytically. Often, physical models are utilized to provide the required numerical model boundary conditions. This method has been termed the "hybrid" modeling approach.

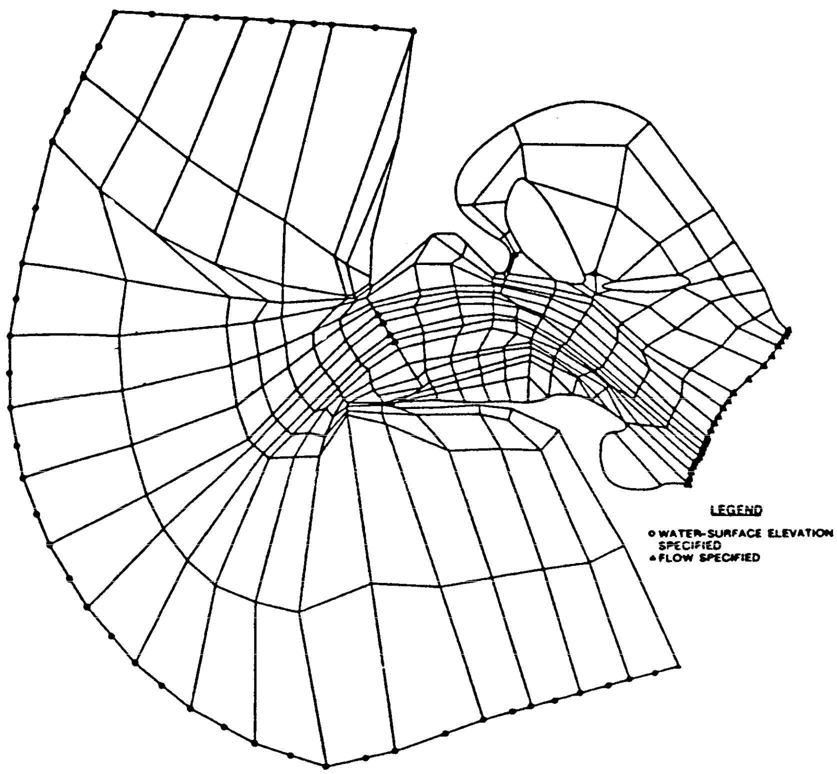
f. The actual modeling of the problem consists of running the numerical 2-D hydrodynamic model for the period of the discretized events.

Then, for each event, the sediment transport model is driven by the predicted hydrodynamic conditions and the resulting rates of bed change determined.

g. The long-term sedimentation rates are synthesized by linearly combining the deposition or erosion rates for each event, weighted by the defined frequency of occurrence assigned to the event. The dredging requirements are then determined from the shoaling estimates within the navigation channel.

h. The impacts of the proposed structural modifications to the system are determined by altering the geometry of the models and performing steps f and g above for comparison for the purposes of optimization.

CASE STUDY: The application of the TABS-2 system in a hybrid modeling case is presented here for the Columbia River entrance channel. The mouth of the Columbia River has a navigation channel authorized to 2640 ft wide by 55 ft deep that experiences severe shoaling in an extreme wave climate with high tidal energy and river discharge conditions.



Boundary condition nodes in the computational grid

a. Shoaling in the entrance channel of the Columbia River is dominated by noncohesive sands (D50 = 0.2 mm) derived from the river, but with intermediate storage in sand banks within the estuary and on the adjacent beaches. With the high energy levels for transport of the sediment, it is very difficult to identify a specific source that dominates the sediments in the channel shoals. Therefore, none of the sediment sources can be overlooked.

b. The transport of sediments in the entrance channel area is dominated by tidal and density currents, with river discharge and wave energy affecting the supply of sediments to the entrance area. The wave energy also impacts on the erodibility of deposits previously shoaled in the channel, and the greatest bed changes occur during extreme wave conditions. Three field data collection efforts were mounted, two during the spring freshets of 1977 and 1978, and a winter deployment in 1978. From these the impact of wind stress on circulation was identified as of little consequence. Long-term wave statistics were obtained from the National Weather Service in the form of hindcasts for deep-water stations off the Oregon coast.

c. The numerical grid was developed for the entrance area from approximately 10 miles upstream of the ends of the jetties to about 10 miles each offshore, north, and south of the entrance channel. The grid has the greatest resolution in the throat of the entrance channel and the least resolution in the extreme limits of the ocean area.

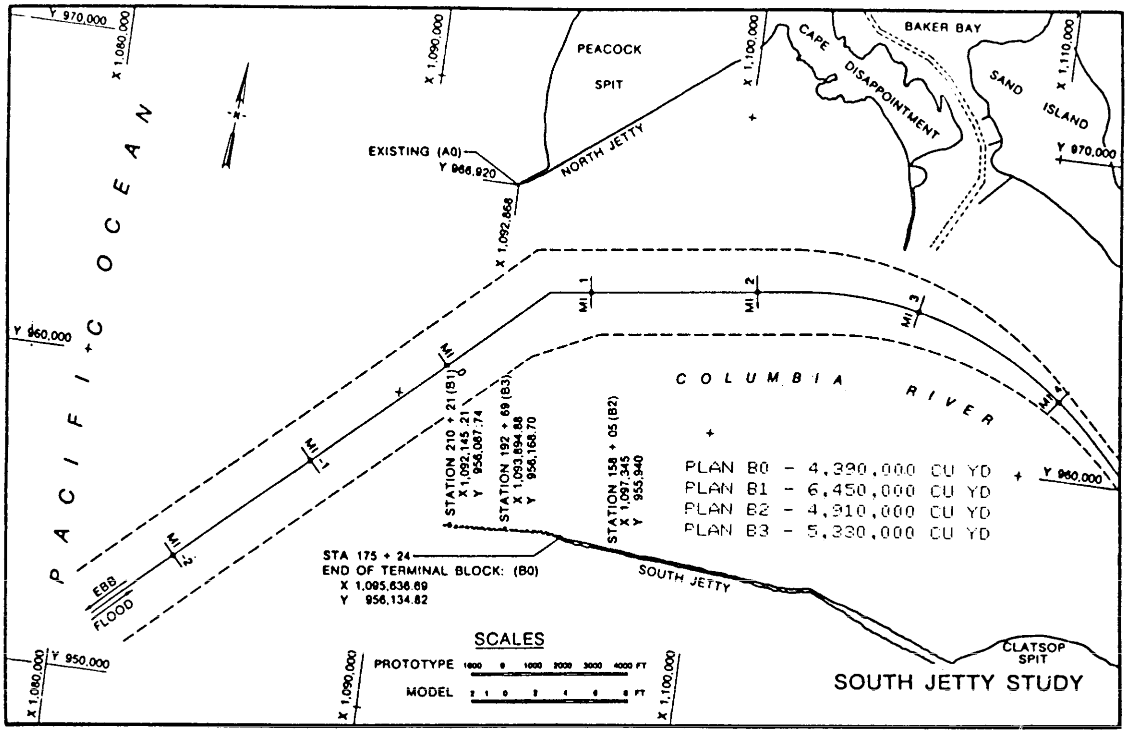
d. The energy sources for the simulation of long-term sedimentation were discretized into seventeen events. Each of these events consisted of a wave condition, river discharge, and were run in real time simulations over a mean tidal cycle. Long-term simulations revealed that the seventeen events gave comparable results to the results obtained from only five events with the 300,000-cfs discharge condition. Thereafter, all simulations were made with only five events.

e. Model boundary conditions were specified as shown in the computational grid. The ocean tidal elevation boundary conditions were synthesized from tidal data collected in the field. The flow boundary conditions were obtained from the physical model of the Columbia River Estuary, making this application a hybrid study. Wave conditions for the sediment transport model were obtained by performing a wave refraction/diffraction of deep-water wave conditions into the shoreline and entrance channel over the area defined by the limits of the numerical grid.

f. The numerical hydrodynamic and sediment transport models were run for each of the events for a tidal cycle of real-time simulation.

g. The deposition and erosion rates throughout the computational grid were then extrapolated by linear summation of the rates for each event, weighted by the duration of each event. The resulting shoaling distribution in the navigation channel required a total dredging of 4.8 million cubic yards for the model compared to 5.4 million cubic yards experienced in the prototype.

h. The modeling capability developed for the Columbia River entrance was applied to channel deepening considerations and several proposed structural modifications in the entrance to reduce channel maintenance. To illustrate the capability for optimization, the south jetty plans for incremental rehabilitation are presented. The distribution of dredging requirements is also presented, along with the total volumes for each incremental length of jetty construction. As shown, the optimum length of the plans considered with regard to dredging is plan B0, which is the end of the existing terminal block. Thus, the current length was found to be optimum.



Plans tested and dredging requirements for the south jetty study

As seen in this case study of an application of the TABS-2 modeling system, optimization of structures within a complex hydrodynamic and sedimentation setting can mean very significant savings in construction costs.

REFERENCES:

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c. Entrance channel tests. W. H. McAnally, et al. Report 4, Columbia River Estuary Hybrid Modeling Studies, US Army Engineer Waterways Experiment Station, Vicksburg, MS, Sep 1983.