THREE-DIMENSIONAL NUMERICAL MODELING OF SEDIMENT TRANSPORT NEAR COASTAL INLETS

Weiming Wu, Clarkson University, NY, USA, wwu@clarkson.edu

Simulation of the hydro- and morphodynamic processes near coastal inlets is important but challenging, due to multiple interacting forces (waves, wind, tides, river flows, density currents, etc.) on a wide range of spatial and temporal scales. A number of 2-D models have been used in the past, but recently 3-D models have gained more and more attentions because better accuracy and reliability are desired. A 3-D model has been developed in this study to simulate the complex flow, sediment transport and bed change near coastal inlets.

The flow model uses the 3-D phase-averaged shallow water flow equations with wave radiation stresses. The flow model is coupled with the horizontal 2-D wave spectral transformation model CMS-Wave (Lin et al., 2008), which calculates the wave properties, such as wave height, period, direction and radiation stresses. Multiple-sized sediment transport and the resulting bed change are simulated using the non-equilibrium total-load transport model. The governing equations are solved using an implicit finite-volume method based on a multiple-level quadtree (telescoping) rectangular mesh on the horizontal plane and the sigma coordinate in the vertical direction (Wu and Lin, 2015). The SIMPLEC algorithm with under-relaxation is used to handle the coupling of water level and velocity on the non-staggered grid used. Fluxes at cell faces are determined using Rhie and Chow's momentum interpolation method. The vertical eddy viscosity is determined using a modified mixing length model, and the horizontal eddy viscosity considers the effects of current, wave propagation, and wave breaking. The flow and sediment calculations are decoupled, but the three components of the sediment model: fractional sediment transport, bed change and bed-material sorting are solved in a coupled form.

The model has been tested using measurement data of tide flow, waves and channel infilling at the Shark River Inlet, NJ. The inlet is stabilized by two parallel rubble stone jetties. The model domain covers a local scale of approximately 11 km centrally located around the inlet. A telescoping grid is used, which has the smallest 8-m cell size in the main throat of the inlet and the largest 128-m cell size in the ocean. The total of active ocean cells is approximately 20,000 in the horizontal (Figure 1). In the vertical (z-) direction, 6 layers are used.

The measurement of morphology change over a 4-month period from January to April 2009 is used to validate the model. Figure 2 compares the measured and calculated bathymetry along two transects after the 4-month simulation period. The transect in Figure 2(a) is long the direction of ebb tide currents in the inlet channel, extending from the bridge pilings eastward toward the ocean, while the transect in Figure 2(b) is along the direction normal to the inlet channel, starting near the south jetty tip. The model predicts well the channel infilling patterns. The calculated bed morphology changes along the two transects are in a generally good agreement with the measured data.

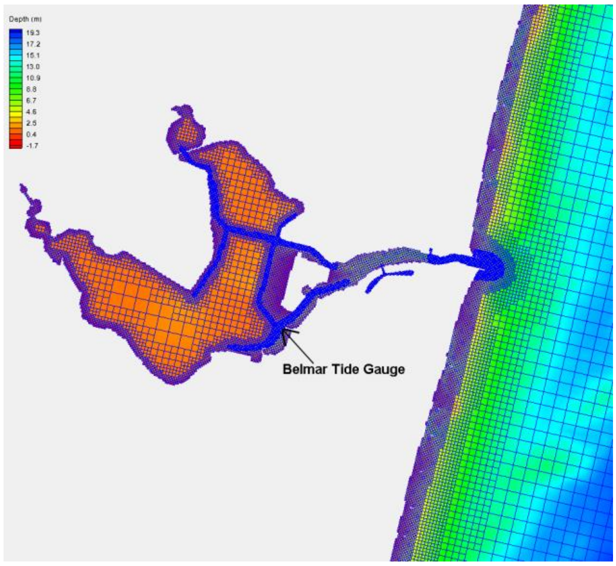

Figure 1 - Computational Mesh for the Shark River Inlet

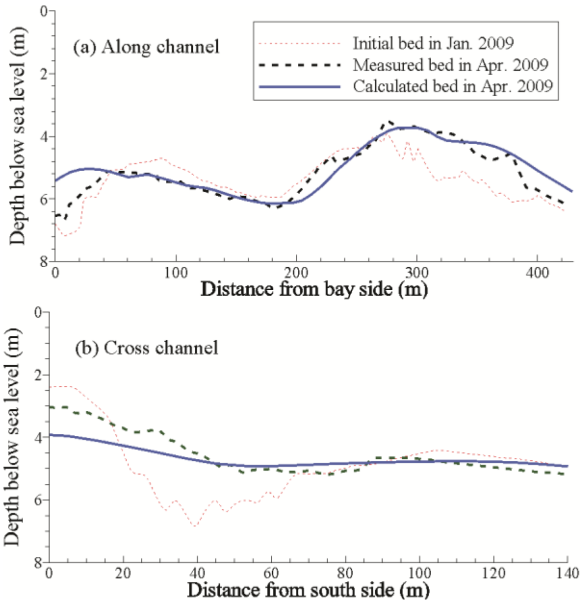

Figure 2 - Measured vs. Calculated Bed Levels

REFERENCES
Lin, Demirbilek, Mase, Zheng, Yamada (2008): CMS-Wave: a nearshore spectral wave processes model for coastal inlets and navigation projects. Technical Report ERDC/CHL TR-08-13. U.S. Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory, Vicksburg, Mississippi.
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