3D Non-Hydrostatic Modeling of Bottom and Bank Stability Subjected by Ship Propeller Jets

V. Maderich[(1)], Yu. Kanarska[(2)], S. Fenical[(3)], K. Terletska[(1)], I. Brovchenko[(1)]

[(1)]Ukrainian Center of Environmental and Water Projects, Glushkov av. 42 Kiev 03187 Ukraine
Tel. (38044)5266187, Fax: (38044)5263615, email: vlad@env.kiev.ua
[(2)]Institute of Geophysics and Planetary Physics UCLA 405 Hilgard Ave. Los Angeles, CA 90095
[(3)]Coast & Harbor Engineering, Inc., 388 Market Street, Suite 500 San Francisco, CA 94111, Tel. 415.296.3822, Fax: 415.276.3784, email: scott@coastharboreng.com

In coastal engineering practice, strong currents generated by ship propellers/jets are known to affect biological resources, sediment quality in marine industrial areas, and in some cases are the design condition for bank/slope protection near marine terminals. The Ukrainian Center of Environmental and Water Projects (UCEWP) and Coast & Harbor Engineering (CHE) have developed new tools for evaluation of propeller/jet wash and other vessel hydrodynamic effects as part of a grant from the U.S. Civilian Research and Development Foundation.

The Vessel Hydrodynamics Propwash Unsteady (VH-PU) model is a 3-D, non-hydrostatic free-surface model that has been recently developed, verified and applied on numerous coastal engineering projects. Unlike previous propeller wash models, it describes three-dimensional fields of velocities generated by ship propellers, turbulence intensity and length scale in the given domain of arbitrary bottom and coastal topography. The time and space varying bottom shear stresses that caused bottom erosion and damage for bottom habitat are calculated, as well as forces due to pressures on submerged boundaries. The initial version of the model allows calculation of hydrodynamic fields caused by propeller jets for stationary vessels.

The model was developed based on the non-hydrostatic model of Kanarska and Maderich (2003) that was a non-hydrostatic extension of the well-known Princeton Ocean Model (Blumberg and Mellor 1987). In the VH-PU model, the 3-D Reynolds-Averaged Navier-Stokes equations are used. The Reynolds stresses were modeled using the eddy viscosity approach where the eddy viscosity coefficient is related with kinetic energy of turbulence $q^2/2$ and length scale l. The model of turbulence is a q-q^2l model that is the 3-D extension of the model of Mellor and Yamada (1982). The momentum theory description by Blaauw and Van de Kaa (1978) is used to calculate the initial velocity generated by the propeller/jet.

The model uses the terrain-following sigma vertical coordinate system and orthogonal curvilinear horizontal coordinate system. Finite difference semi-implicit methods were used to solve 2-D equations for surface elevation and depth-averaged velocities (external mode) and 3-D equations for velocity and pressure (internal mode). The free surface elevation, hydrostatic and non-hydrostatic components of pressure and velocity are calculated at sequential stages. The model was validated using data from the experiment of Schokking (2002) with a free propeller jet impacting on an inclined laboratory tank bottom. The simulations agree well with the vertical distribution of mean velocities along the jet axis (Figure 1). The model was also validated using a set of measured field current data from tug boat propwash testing. For testing runs where the tug position was well-controlled the simulations agree well with the vertical distribution of mean velocities along the jet axis (Figure 2). The hydrodynamics model was also dynamically coupled with a 3-D Lagrangian model for simulation of sediment transport and erosion under propeller/jet wash velocities. The model has been applied for evaluation of impacts to biological resources, most notably eelgrass.

Figure 1. Vertical distribution of mean velocities along the jet axis at distance 0.1 (a) and 0.7 (b) m from propeller. Curves are VH-PU model computations, symbols are lab measurements (Schokking 2002).

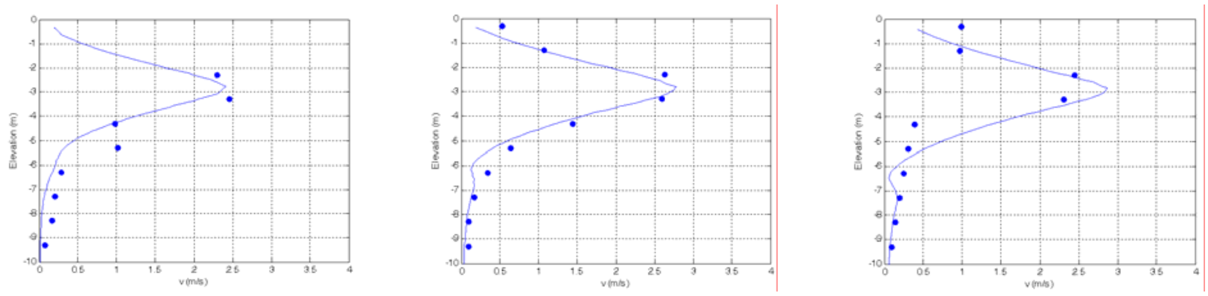

Figure 2. Vertical distribution of velocities along the jet axis at time 1.0 (a), 3.0 (b) and 5.0 (c) seconds. Curves are VH-PU model computations, symbols are field measurements (2-second averages).

Figure 3 shows bottom velocities predicted by the model for an Issaquah-class ferry landing at the Port Townsend Ferry Terminal, Puget Sound, WA. The model has also been used to evaluate stability of contaminated sediment caps and armor rock for slope protection at marine terminals.

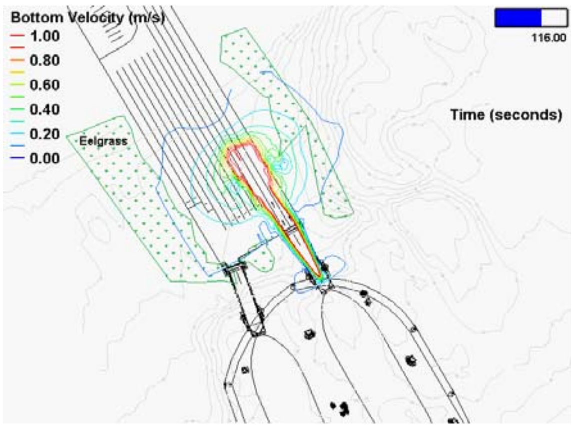

Figure 3. Bottom velocities generated by Issaquah-class ferry during landing at Port Townsend ferry terminal, Puget Sound, WA at simulation time = 116 sec. Also shown are bottom elevation contours, eelgrass locations and terminal and vessel locations.

References:

Blaauw, H.G. and E.J. van de Kaa. 1978. Erosion of Bottom and Sloping Banks Caused by the Screw-Race of Manoeuvring Ships. *International Harbour Congress*. Antwerp, Belgium.

Kanarska Y, Maderich V. 2003. A non-hydrostatic numerical model for calculating free-surface stratified flows. *Ocean Dynamics*, 53, 176-185.

Mellor G., Yamada T. 1982. *Reviews of geophysics and space physics*, 20, N 4, 851-875.

Schokking L. 2002. Bowthruster-Induced Damage. MS thesis, TUDelft 143 p.