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2D Numerical Modeling of Hydrodynamics and Contaminant Dispersion in Shallow Waters in Curvilinear Coordinates

ABSTRACT

This paper is concerned with development of a two-dimensional (2D) depth-averaged curvilinear model of hydrodynamics and transport of contamination in shallow waterways. The model is a numerical hydrodynamic-advection-dispersion model which can handle rivers with variable width, depth, and path and is capable of grid generation, input data preparation, and processing of output results. The model is formulated in curvilinear coordinates. The governing two-dimensional unsteady depth-average Navier-Stokes equations are solved numerically using an implicit finite difference technique. The numerical scheme used is a second order accurate in time and space and its stability is controlled by Courant number. The model is verified with hydraulic problems, including flow modeling in a converging channel and a 90 degree bend, and flow and pollutant dispersion in a simple bend.

***Keywords**: Hydrodynamics, Pollutant Dispersion, Numerical Modeling, Shallow Waters*

INTRODUCTION

2D-depth-averaged numerical models have been frequently used in problems of rivers and shallow waterways in recent years. Rivers, estuaries, and waterways are generally characterized by large aspect ratios (i.e., length/width or width/depth), allowing effective 2D modeling of large-scale flow dynamics [1]. For river bends with a mean radius-to-width ratio of bigger than 3.0 ($\frac{R}{W} > 3.0$), we can suppose flow exhibits 2D characteristics [2]. Several researchers have developed 2D, depth-averaged models for hydrodynamic modeling of river flow [2-11]. Their simulations show capability and performance of 2D-depth-averaged models in the variety of hydraulic problems.

Simulation of contaminant dispersion in rivers and waterways is also one of the interesting research topics recently. Duan (2004) developed a hydrodynamic and contaminant dispersion model [11]. She used a Cartesian grid for her model. The main drawback of using Cartesian mesh is its shortcoming in modeling of perimeters accurately in curved waterways. Some Cartesian models require extra storage and trivial computations for the ''dry'' cells in the system which may increase cell counts in meandering systems by an order of magnitude. In contrast to the Cartesian approach, boundary-fitted curvilinear methods align the mesh with streamwise and cross-stream flow, allowing use of grid cells with large aspect ratios [1].

This paper reports development of an integrated curvilinear 2D-depth-averaged numerical model for hydrodynamic and pollutant dispersion for rivers and shallow waterways. We first describe the formulation of the model and numerical approach, and then illustrative examples, including flow modeling in a converging channel and a 90 degree bend, and flow and pollutant dispersion in a simple bend are worked out.