INTEGRATED 1-D AND 2-D MODELS FOR FLOW AND WATER QUALITY MODELLING

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Numerical models based on solving the Navier-Stokes and solute transport equations have been widely used for predicting hydrodynamic and water quality processes in river, estuarine and coastal waters. For river and open channel problems these equations are often averaged over the cross-sectional area to give a set of one-dimensional (1-D) equations and numerical models developed based on solving these 1-D equations are called 1-D models. Similarly, for estuarine and coastal problems, depth-averaged two-dimensional (2-D) models have been developed and widely used. In many practical situations both one and two dimensional flows co-exist across different parts of the study area, thus both 1-D and 2-D models are generally used separately in these areas.

Details are given of three methods used to link 1-D and 2-D numerical models for predicting hydrodynamic and water quality processes in river and estuarine waters. In method (a) a weir equation was used to connect the 1-D and 2-D model domains, which can be used for conditions where a distinct boundary location can be identified between the 1-D and 2-D model domains. In method (b) an overlap between the 1-D and 2-D model domains was used to enable the transformation of information between the two models, which is suitable for studies that involve long rivers with many branches. In method (c) the 1-D governing equations were reformulated to enable them to be solved in the 2-D grid, this approach has advantages in terms of mass and momentum conservation.

Method (a) was developed primarily for flood prediction, where a 2-D model was linked to a 1-D model to simulate overbank flows. The 1-D model used in this study was called ISIS - a comprehensive software system developed by Halcrow and Wallingford Software for managing changes in river basins. The two models were linked through a weir equation, in which the discharge between the 1-D and the 2-D domains was determined by the water level difference either side of the weir.

The linked model was applied to the River Thames, U.K., to predict the flood wave propagation under an assumed flood flow condition. The 1-D model was setup to cover the whole tidal Thames down to the mouth of the Estuary and the 2-D model was setup for the Greenwich Embayment. The model bathymetry was generated using a GIS system, with both 10m and 5m grid size models being setup and used in the simulations. Extreme tidal and surge levels were assumed at the 1-D model seaward boundary, and it was assumed that failure of an embankment would occur at several possible locations along the river. A series of model runs were carried out to simulate the propagation of the flood wave and the corresponding water level distributions. From these predictions the routes for the flood wave to propagate can be clearly identified and the speed of the flood wave can also be estimated. A comparison of water level time series predicted by this model and that predicted by two other well known models was undertaken and it was found that the agreement between the two predictions was close.

With the second approach the 2-D model was linked to a 1-D model through a common area of the model domain and the linked model was used to assess the bathing water quality of the EC designated bathing waters located adjacent to the mouth of the Ribble Estuary. The 1-D and 2-D models were run individually at each time step and the required boundary values were exchanged between the two sub-models across the common domain. For the hydrodynamic modelling the predicted water surface elevations obtained using the 2-D model were specified as the downstream boundary condition of the 1-D model and the predicted velocities or discharges obtained from the 1-D model were specified as the upstream boundary condition of the 2-D model. For water quality modelling the predicted concentrations of a water quality indictor obtained from the 2-D model were transferred to the 1-D model when the flow across the 1-D model boundary was directed towards the head of the estuary (i.e. landwards), whereas the predicted concentrations from the 1-D model were transferred to the 2-D model when the flow across the 2-D boundary was directed seawards. The model was calibrated and verified against a large set of hydrodynamic and water quality data for various weather and tidal conditions.

The third approach used to integrate 1-D and 2-D models was to formulate the 1-D finite difference equations in a similar manner to the 2-D equations so that they could be solved as part of the 2-D solution. An extended 2-D grid system was constructed to incorporate the both the 1-D and 2-D computations. The one-dimensional grid was connected to the two-dimensional grid in either the x or y direction. To solve implicitly the 2-D and 1-D systems together, one of the grid rows in the two-dimensional grid system was chosen as a principal grid row, which was also connected to the 1-D grid system.

The integrated model was set up and applied to simulate tidal flow, and salt, sediment and trace metal concentrations in the Mersey Estuary. The model area was represented horizontally in two grid systems, i.e. the two-dimensional and one-dimensional parts. Since this method implicitly solved the 2-D and 1-D system as a whole, which eliminated the explicit exchange of data between the 2-D and 1-D models at their overlapping fictitious boundary, this approach has advantages in terms of mass and momentum conservation. The model generally showed good agreement between the predicted and measured water levels and salinity, sediment and trace metal concentration distributions.