INTEGRATED MODELLING OF 2-D SURFACE WATER AND GROUNDWATER FLOW WITH CONTAMINANT TRANSPORT

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Groundwater and surface waters are often interconnected, and hydrologically should be regarded as a single resource. It is becoming increasingly clear that many hydrological problems require realistic linkages between surface water and groundwater in a model. For example: groundwater inputs to a river (baseflow) can be very significant when considering flood levels. In particular, the recent surface water impoundment at Cardiff Bay has significantly influenced surrounding groundwater levels and has been the focus of much hydraulic interest to engineers involved in this project.

An ongoing project within the Hydroenvironmental Research Centre at Cardiff University has been to research various methods of approaching this integrated problem. As an initial step into the field of conjunctive modelling, the DIVAST model has been extended to simulate groundwater in land horizontally adjacent to the surface water body.

DIVAST (Depth Integrated Velocities And Solute Transport) is a two-dimensional hydrodynamic and water quality model which has been developed for estuarine and coastal modelling by Cardiff University. The original model simulates two-dimensional distributions of surface water currents, elevations and various water quality parameters as functions of time. The extension to this model involves a novel approach of integrating the surface water and groundwater equations so they are solved in the same process.

Over the past 3 or more decades, both free surface and groundwater flow have been considered numerically. There are several existing models that are capable of simulating various aspects of the groundwater/surface water interface, but so far as the authors are aware, there are no widely available non-commercial codes capable of modelling contaminant transport in 2-D surface water and groundwater flows in particular. DIVAST-SG is intended to fill this gap by extending the 2-D surface water code to include groundwater flows adjacent to the surface water body, thereby allowing diffuse pollution interactions with large surface water bodies to be modelled.

The groundwater equations of flow are analogous to the surface water equations. Continuity and momentum provide the basic equations, similar to surface water models; with the groundwater momentum equation essentially being given by Darcy's law. For the surface water model, the equations are discretised for use in the Alternating Direction Implicit (ADI) method. To extend the model, the groundwater equations are discretised in a very similar fashion, with the same unknowns, but different coefficients for each part of the equation. When the solution comes to a groundwater cell in the model, it simply uses the groundwater coefficients instead of the surface water coefficients and solves the equations in the same way as normal. In effect, the program is 'flagged' into solving the groundwater equations instead of the surface water equations. This approach allows rapid solution of conjunctive surface/subsurface flow scenarios, without resorting to two separate models, and thereby allowing groundwater zones that are located immediately adjacent to surface water bodies to be simulated in an integrated structure. Problems where this situation arises in the real world include river bank storage, wetlands, and flow through man-made porous structures, such as dams and breakwaters.

The extended model was used to simulate a tidal water body influencing an unconnected water body via the groundwater. Porosity and permeability can be set and varied over the area of the model. In this case a relatively high permeability was used to allow quick interactions between the water bodies, and in order to show the model operation. The original model assumes a negligible water depth over the ground surface that is 'dry' (Fig. 1a), whereas the new model extends the flow through the groundwater and into the other water body (Fig. 1b).

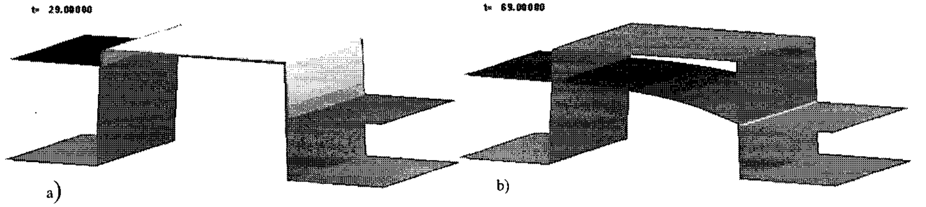

Fig. 1 a) Original Divast model with negligible depth assumed over the ground surface.and with tidal water body on left having no influence on water body on right; and b) Extended model where flow continues through the groundwater area and with tidal water body on left influencing water body on right.

A flume is currently under construction in the Hyder Hydraulics Laboratory at Cardiff University to test the model against laboratory data. A novel approach, using porous foam for the aquifer, will be used. The computer model of this flume is currently under investigation, with some initial tracer results being shown in Fig. 2.

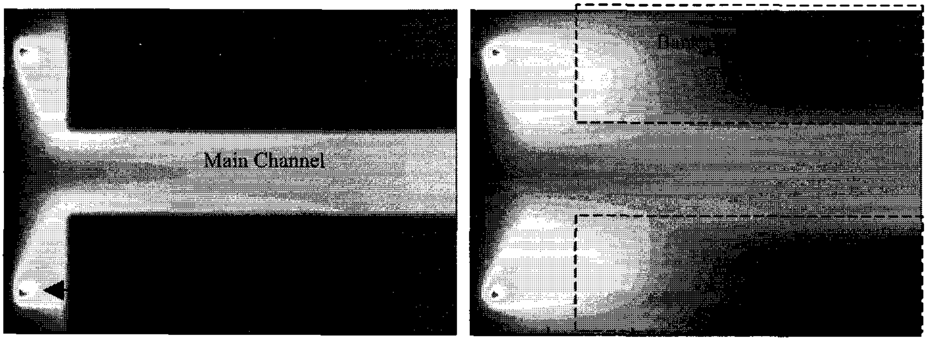

Fig. 2 Simulation of flume without (left) and with (right) groundwater interactions (high permeability). Flow is from left to right. Two outfalls are inputting a constant flow of tracer. Colours show concentration of tracer. Left boundary is constant flow. Right boundary is at constant elevation.

The model is also being set up for the area around Cardiff Bay to simulate the topical groundwater/surface-water interactions there. This extended model is very much a work in progress. Solute transport in groundwater requires some additional modifications. There are also a number of limitations of representing surface water and groundwater interactions solely in 2-D, so it is hoped to add 3-D aspects to the model, either by developing the 3-D equivalent code (namely TRIVAST) or by adding a 3-D groundwater model as an underlay.

Keywords: Hydrodynamic Modelling, Surface Water/Groundwater interactions, DIVAST