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MODELING GATED SPILLWAYS, WEIRS, DROP STRUCTURES AND PUMP OPERATIONS BY A TWO-DIMENSIONAL MODEL DSS-WISE[TM]

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The software package DSS-WISE[TM] developed at the National Center for Computational Hydroscience and Engineering has been equipped with new capabilities to model hydraulic structures such as gated spillways, overflow weirs, drop and bridge structures, and pump operations. The depth-averaged equations of mass and momentum conservation in two-dimensions, subject to the incompressibility and hydrostatic pressure approximations, typically form the basis of the existing model. The governing equations are discretized by a conservative finite volume method. The convective fluxes are computed by solving local Riemann problems at each cell interface of a Cartesian cell using HLLC solver and the solution is advanced explicitly with respect to time. The model can be used to simulate dam/levee breach floods, fluvial floods, landslide waves and to evaluate their consequences. The model is packaged in a GIS based graphical user interface that guides and assists users in preparing and maintaining a database, defining input parameters, running the model and interpreting the results in the form of plots and maps.

In the present study, the existing model is enhanced by adding new capabilities to model various hydraulic structures and pump operations in the form of linked source and sink pairs. This version of DSS-WISE[TM] models flow through weirs, radial gates, vertical gates, overflow gates, bridges and pump operations. The model can handle Broad-crested, Sharp-crested and Ogee-crested weirs, submerged, unsubmerged and full opening conditions at the inlet and outlet of a gate. The operation of the gated structures is controlled either with hydraulic equations based on different parameters specific to the structure or by defining a rating curve based on gate opening, headwater and flows. The pump operation is also simulated using source and sink pair option which defines pumping to and pumping from an area. The flow through a structure or from a pump is assumed to be represented by mass flux in the continuity equation and added as a source or sink term depending upon the flow direction. The mass flux associated with a structure/pump is calculated using the equations as suggested in HEC-RAS. However, though these structures play a role in momentum change but is neglected considering the complexity in adopting and solving the physics of the phenomenon.

In the model, the topography is defined by simply importing the Digital Elevation Model (DEM) and surface roughness can be prescribed based on land cover and land use pattern. The upgraded GIS interface enables users to define each structure on the DEM. A suitable data format

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is maintained for each type of structure and the data feeding style is kept intentionally similar to that of HEC-RAS so that the model can easily be used by the engineers from state and federal agencies and engineers from private agencies who are accustomed to work with the widely used package. A group of computational cells on both sides of a structure along with a representative trigger point for each side are selected through the interface. The two connecting trigger points define the source and sink pair. The discharge between the two trigger points is calculated based on the type of structure and is distributed among the cells so that the effect will be reflected in the two-dimensional system. At each time step the water surface elevations at the two trigger points are compared to decide which is upstream and which is downstream. Water is removed from the upstream area and added to the downstream area. if the upstream area cannot contribute enough water to satisfy the calculated discharge, then the area is emptied and that amount of water is passed to the downstream area in order to maintain mass conservation. In Figure 1, flow though a structure is computed. The flow domain is separated by a structure with 10 m water level to the left and no water to the right of the structure. It is assumed that the flow through the structure is governed by an orifice. A group of cells on the upstream and downstream sides are selected to define source and sink pair. The flow is simulated over the time and snapshots are taken at different times (Figure 1). This simple test case proves that the source-sink combination can be used to calculate flow through different types of structures.

Finally, the performance of DSS-WISE^{TM} is verified by solving analytical and experimental tests. The new capabilities of the model are validated with the HEC-RAS and then the model is successfully applied to a field test.
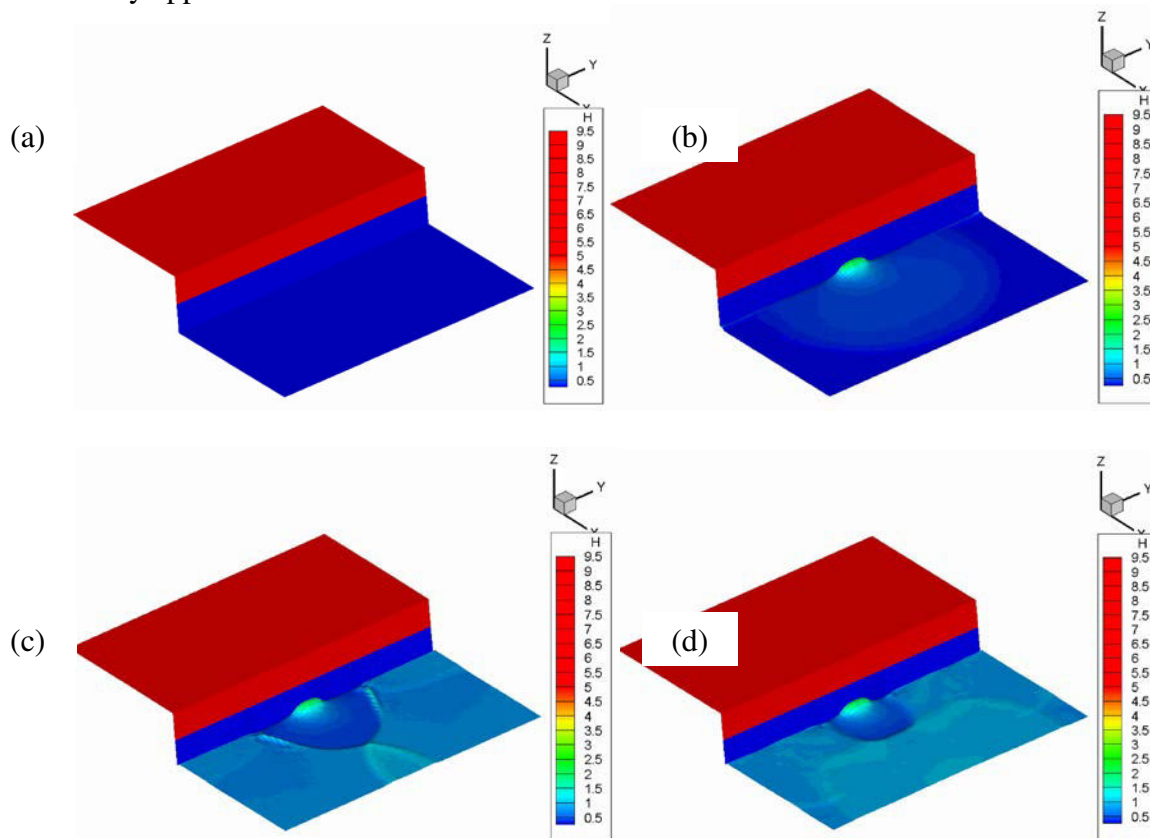

Figure 1 Flow through a structure guided by orifice: (a) 0.0 s, (b) 0.4 s, (c) 1.7 s and (d) 2.0 s