Groundwater flow model in the karst aquifers using the Fup Finite Volume approach

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ABSTRACT

Karst aquifers are very important groundwater resources around the world as well as in coastal part of Croatia. They consist of extremely complex structure defining by slow porous medium and usually fast turbulent conduits/karst channels. In this paper novel 3-D hybrid karst flow model is developed. This model uses multiresolution meshless concept based on Fup basis functions with compact support and finite volume framework. Porous matrix is described by linear combination of 3-D Fup basis functions satisfying Darcy law and continuity equation, while conduits are described by linear combination of 1-D Fup basis functions controlling transition between laminar and turbulent flow regimes as well as pressurized or open channel flow conditions. Two sets of these basis functions are independent with own multiresolution description. Porous matrix and conduits are coupled without additional (usually unphysical) parameters satisfying flux continuity through the interface between them. Transient flow simulations are performed through the well-known concept of the method of lines separating spatial and temporal approximation. Using the Fup implicit time integration, coupled nonlinear system of equations is formed at the end of each time step with unknown Fup coefficients for 3-D porous matrix and 1-D conduits. Methodology enables control of numerical error, mass continuity and accurate velocity field that is particularly important for transport karst simulations. Particular difficulty with complex 3-D karst flow model is its verification due to lack of extensive amount of needed input data such as heterogeneity of porous matrix, position and dimensions of conduit network, rainfall and spring discharge data and many others. Therefore, we will show here possibility to verify karst flow models under the laboratory controlled conditions. Special 3-D karst flow model (5.6*3.0*2.0 m) consists of concrete construction, 2 reservoirs, 84 piezometers and other supply equipment. Model is filled by fine quartz sand (3-D porous matrix) and drainage plastic pipes (1-D conduits). This model enables knowledge of full heterogeneity structure including position of different sand layers as well as conduits location and geometry. Moreover, we know geometry of conduits perforation that enables analysis of interaction between matrix and conduits. In addition, pressure distribution and discharge flow rates from both phases can be measured very accurately. Results show verification of presented 3-D karst flow model under different experimental configurations such as different levels in reservoirs (boundary conditions), different flow regimes in conduits (laminar or turbulent flow, pressurized or free surface flow), submerge or free discharge from conduits, flow with and without precipitation, etc. Presented analysis confirms potential benefit of laboratory flow model and main properties of presented karst flow model since this is the first step toward more reliable karst flow modeling in real karst aquifers.

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