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CFD Modeling of Local Scour under Complex Free Surface Flow

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In the present study the open-source three-dimensional numerical model REEF3D is used to calculate the complex free surface flow over a spillway, the corresponding hydraulic jump downstream of the spillway and the resulting local scour. The numerical results are compared with experimental data. The transcritical flow changes from supercritical to subcritical after the hydraulic structure, which results in the hydraulic jump. The flow of the hydraulic jump is characterised by the its violent nature and the large amount of turbulence production. While the downstream area of a spillway is typically protected by a concrete apron, scour can still occur downstream of this protection. REEF3D has advanced interface capturing capabilities, with which it is possible to simulate the complex free surface dynamics. With the level set method free surface is modeled as the zero level set of a scalar signed distance function. The flow velocities are calculated together with the pressure on a staggered grid, ensuring a tight velocity-pressure coupling. Complex geometries are modeled with a ghost cell immersed boundary method. The convective terms of the momentum equations, the level set function and the equations of the k-ω turbulence model are discretized with the fifth-order finite difference WENO scheme. Parallelization of the numerical scheme is achieved by using the domain decomposition framework together with the MPI library. The topography of the sediment bed is implicitly described by a level set function. Based on bedload and suspended load transport formulations, the sediment continuity defect in the bed cells is converted into the rate of change of the vertical bed elevation. This strategy has two major advantages: the topology is a well defined surface when calculating the incipient motion on the sloping bed and the sand avalanche. In addition, the numerically error prone re-meshing can be avoided, because the complex boundary surface is accounted for by the immersed boundary method.