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Effects of Numerical and Physical Parameters on SPH Models Using LiDAR-Based Dam-Break Flood Simulations

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Abstract

Flooding, characterized as a free surface flow where water inundates typically dry areas, poses significant risks when triggered by dam failures. Such events, often resulting from the sudden release of large volumes of water, can lead to catastrophic consequences for downstream regions, including loss of life, extensive property damage, and severe environmental impacts. This study investigates the influence of a numerical parameter, the CFL number, and two physical parameters, the dam height and the gate-opening position, on the ability of the Smoothed Particle Hydrodynamics (SPH) method to predict water surface elevation (WSE) over time. The analysis focuses on a specific location (X = 80 m downstream of the dam), a critical point in the floodplain with a population at risk. The study employs the SPH approach, implemented within the DualSPHysics framework, to simulate the failure of the Cleveland Dam located in North Vancouver. With the recent availability of publicly accessible high-resolution Light Detection and Ranging (LiDAR) data, the SPH model utilizes this data to capture the topography of the case study.

Dynamic boundary condition is implemented, with the dam and river's geometry modeled as a solid boundary to represent the influence of the river's topography and boundary interactions on the flow dynamics. Within the SPH framework, boundary particles are dynamically assigned to interact with fluid particles near the edges of the domain. A sensitivity analysis is conducted to investigate the influence of the CFL number, dam height, and gate-opening position on the results of the SPH method. The analysis involves sampling the CFL number within the range [0.1, 1.0], as this range ensures numerical stability for unsteady simulations. The CFL number is chosen because it directly affects the time step size, influencing both the accuracy and computational cost of the SPH model. Additionally, the dam height and gate-opening position are included as physical parameters due to their significant impact on the water surface elevation (WSE). For each combination of these parameters, the SPH model is run to extract the average WSE. The sensitivity of the WSE to the CFL number, dam height, and gate-opening position is then quantified using Sobol' indices, which decompose the variance of the WSE into contributions from each parameter and their interactions. This approach highlights the influence of these parameters on the behavior of the SPH model and provides a quantitative measure of their impact on simulation outcomes.