Some Benchmark Simulations for Flash Flood Modeling

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Introduction

Flash floods are sudden and mostly destructive rushes of water down narrow gullies or over sloping surfaces. They are mostly caused by heavy rainfall in the upstream watershed. They may also appear as result of catastrophic events as dam or levee breaks, mudslides or debris flow .

Simulation of flash floods has thus become an increasingly used tool. In urban planning flood modelling is utilized to delineate flood risk maps. Moreover it is applied in early warning systems, in order to predict the rush of a fluid front as reaction of a certain rainfall event.

In order to achieve and ensure most accurate results of such models, several benchmark cases have been defined and discussed in the concerned literature and projects [2]. Classical benchmarks are dam break models. The most simple setting in 1D is shown in Figure 1.

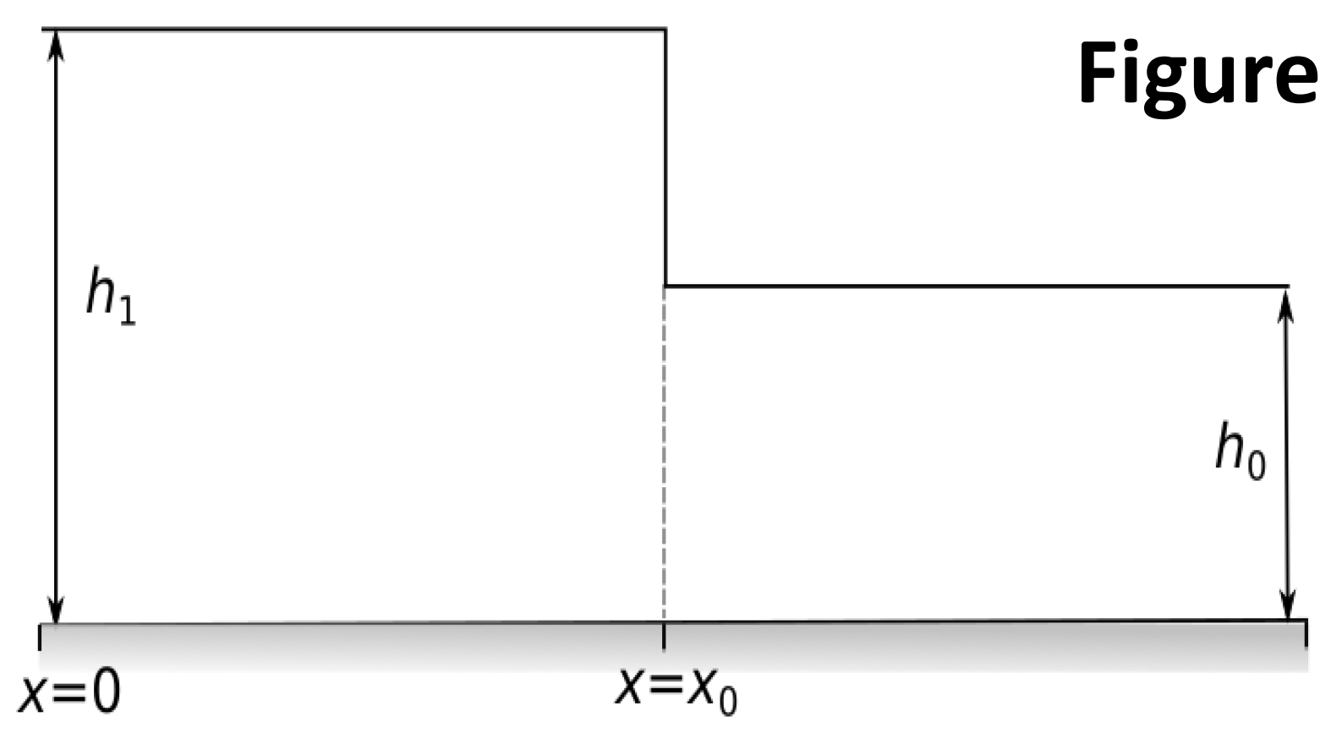

Figure 1. Sketch of 1D dam break model set-up

Computational Methods

Flash floods are mainly modeled by the Shallow Water Equations (SWE), used for open channel flow (see: [1])

$$\frac{\partial \eta}{\partial t} + \nabla \cdot \left(H\mathbf{u} \right) = 0$$

$$\frac{\partial \mathbf{u}}{\partial t} + \left(\mathbf{u} \cdot \nabla \right)\mathbf{u} + g\nabla H - \mathbf{F} = 0$$

with total water depth H, water height above reference height, velocity vector $\mathbf{u}$, and acceleration due to gravity g and vector $\mathbf{F}$ of imposed forces. For our modeling we use the shweq physics interface for COMSOL Multiphysics® [3]. The ad-/disadvantages with different numerical approaches are shown in Figure 2.

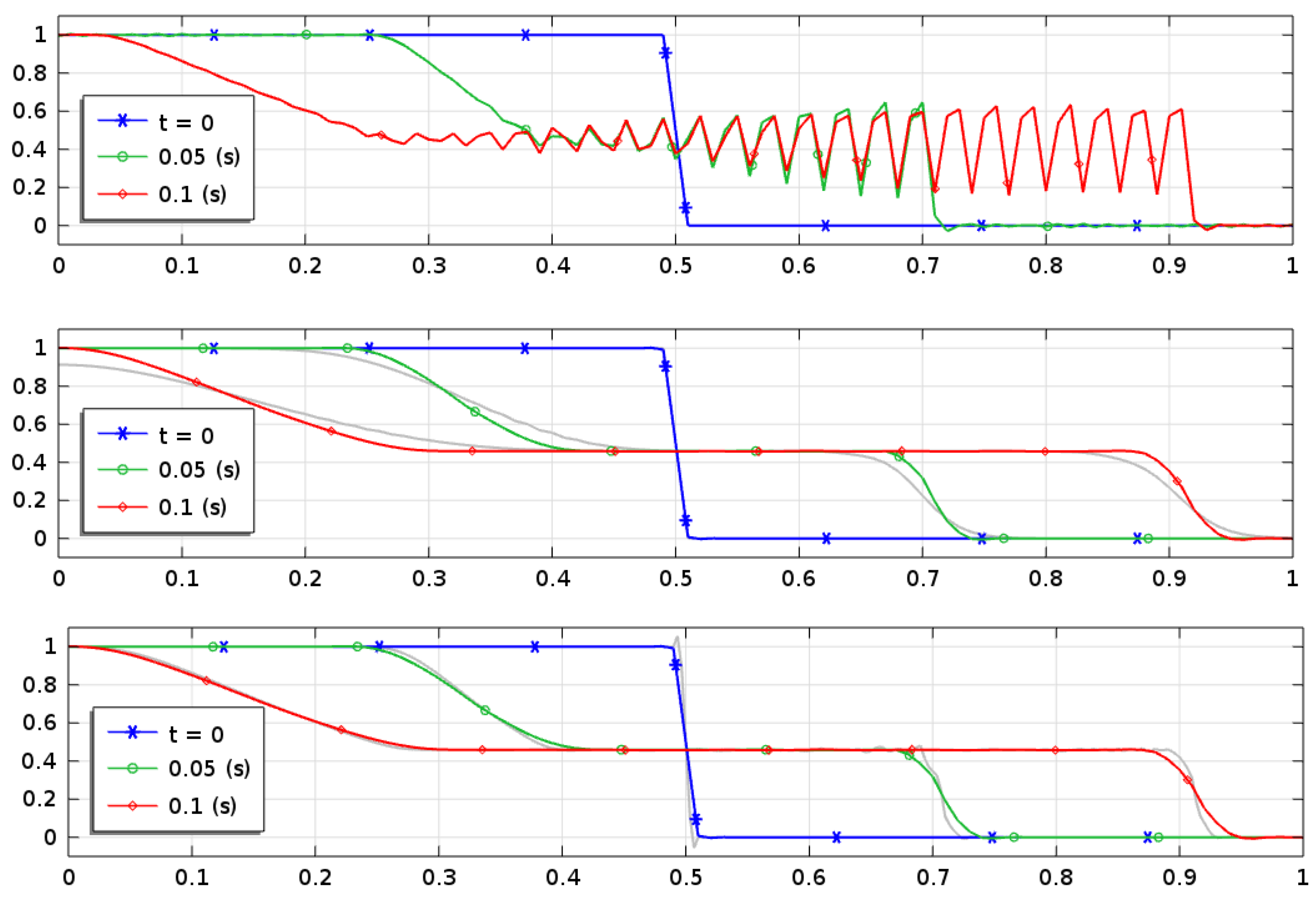

Figure 2. Height results of 1D benchmark for front propagation after dam break: (a) no stabilization, (b) comparison of consistent (with markers) and inconsistent (gray) stabilization, (c) comparison of linear (with markers) and quadratic (gray) element

Results

The IMPACT project on 'Investigation of Extreme Flood Processes & Uncertainty' was funded by the European Union during the years 2001 and 2004 [2]. Within the work-package on flood propagation flood wave propagation models were investigated. The test case which probably attracted most interest is 'the isolated building test case'. Results using COMSOL Multiphysics® are shown in Figure 3.

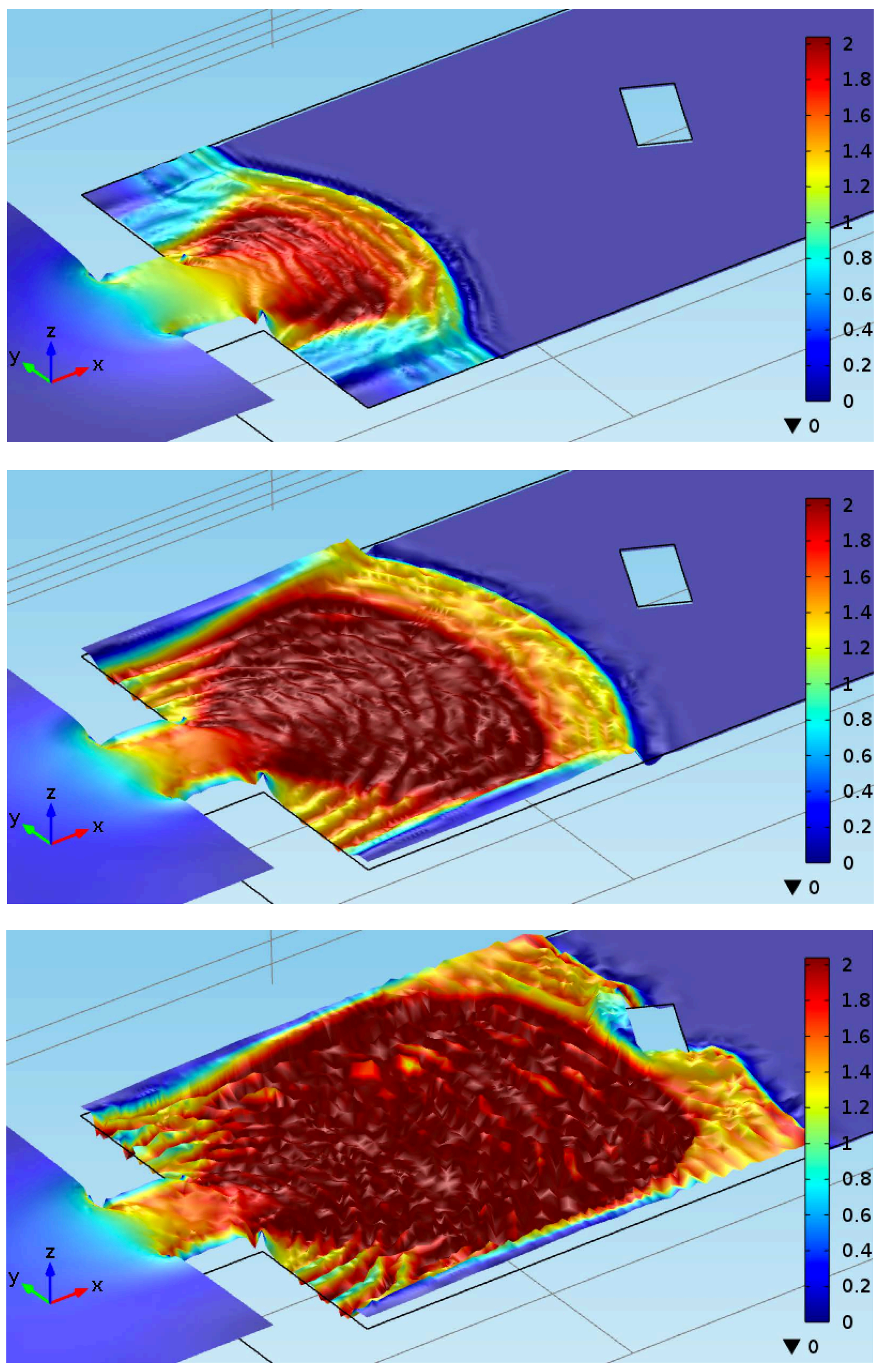

Figure 3. Water table height distribution for the IMPACT test-case with obstacle, for times t=0.66 s (top), 2 s (center) and 3 s (bottom) after dam break

Conclusions

For the 1D and 2D classical benchmarks we checked numerically computed shock waves using the analytical solution. Straight forward discretization leads to spurious oscillations. Inconsistent stabilization supresses the oscillations, but introduces a numerical viscosity error. Quadratic elements produce more accurate solutions than linear elements.

For the usual parameter range, both in 1D and 2D, adaptive meshing techniques lead to accurate solutions requiring much less computational resources than simulations on fixed meshes. In 2D adaptive meshing reduces the model size by almost one order of magnitude, and the execution time by a factor of 20.

References

1. Chaudhry M.H., Open-Channel Flow, Springer (2008)
2. IMPACT (2001), http://www.impact-project.net/impact_project_overview.htm
3. Schlegel F., Shallow water physics (shweq). COMSOL internal paper, private communication (2012)

Excerpt from the Proceedings of the 2017 COMSOL Conference in Rotterdam