Hydrodynamic modelling with unstructured grid using D-Flow-FM: case study Afferden-Deest

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Introduction

Accurate predictions of water levels play an important role in the management of flood safety. Nowadays, it has become common practice to use multi-dimensional numerical hydrodynamic models for such purposes. Currently, two model types are the standard tools in the Netherlands, namely WAQUA/TRIWAQ (Rijkswaterstaat, 2012) and Delft3D (Deltares, 2014). WAQUA and Delft3D are both based on a structured curvilinear grid, which can follow large-scale topographical changes and uses similar grid resolution throughout the entire computational domain. Drawbacks of the structured curvilinear grid approach are that elevation jumps in the river's topography may lead to unrealistic staircase representations in the model, and the inner bends of meandering rivers gridlines may become focussed to unnecessarily small grid cells (Kernkamp et al., 2011). To improve on these issues, Deltares is developing the unstructured-grid-based hydrodynamic model Flexible Mesh (also referred to as "D-Flow-FM"). The unstructured grid approach enables the user to use a spatially variable grid resolution. By combining curvilinear grid cells with triangular grid cells, the modeller can increase grid resolution on the locations where, because of local topographical variations, it is most desired.

In this study, modelling results of Flexible Mesh and WAQUA are presented for a selected river reach near Afferden-Deest and benefits of local grid refinements in Flexible Mesh are demonstrated.

Comparison Flexible Mesh and WAQUA

Besides the advantage of allowing local grid refinements, Flexible Mesh allows the bed level of a grid cell to be diagonal, while in WAQUA the bed level in a grid cell is always horizontal. To compare model results of Flexible Mesh and WAQUA, a schematization of 50 km of the Waal river from the Pannerdense Kop is considered. The Waal schematization is modeled for the high discharge in 1995 (Fig. 1) and for a low discharge in 1994 (Fig. 2). The water levels appear to be higher in Flexible Mesh in the high discharge simulation. The difference between WAQUA and Flexible Mesh is largely caused by a difference in the treatment of energy losses at weirs. In the low discharge simulation, the modeled water levels in Flexible Mesh and WAQUA are closer, because in the low discharge simulation the water is mainly flowing through the main channel of the Waal, where less weirs are effecting the flow.

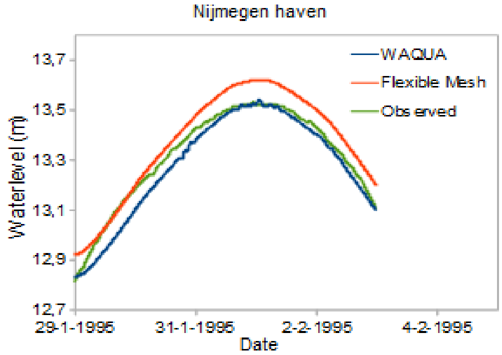

Figure 1. Observed and modeled water levels at location Nijmegen haven for the high discharges of 1995.

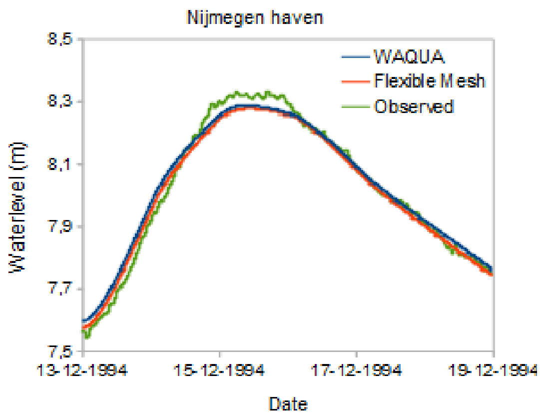

Figure 2. Observed and modeled water levels at location Nijmegen haven for the low discharges in 1994.

Grid Refinements

Next, the impact of local grid refinements of the Flexible Mesh model is investigated. The grid is refined at the side channel at Afferden-Deest along the Waal, located between Tiel and Nijmegen. This side-channel is of particular interest, because the scale of the side channel is relatively small compared to the scale of the main channel of the Waal and cannot be properly represented by the structured curvilinear grid in WAQUA.

The flexibility of the unstructured grid is used in Flexible Mesh to increase the grid resolution at location of the side channel. Fig. 3 shows the grid refinement at the side channel. Preliminary results show that the refined Flexible Mesh model gives significantly different water levels and a different discharge and flow pattern in the side channel at Afferden-Deest. Fig. 4 shows the discharge for the original grid and the refined grid, with especially large difference during peak discharge in the Waal (difference +30%). These and other results are discussed in the context of Room for the River design studies.

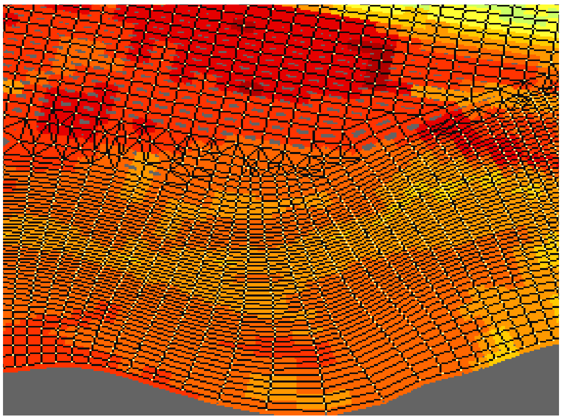

Figure 3. Grid refinement of side channel Afferden-Deest.

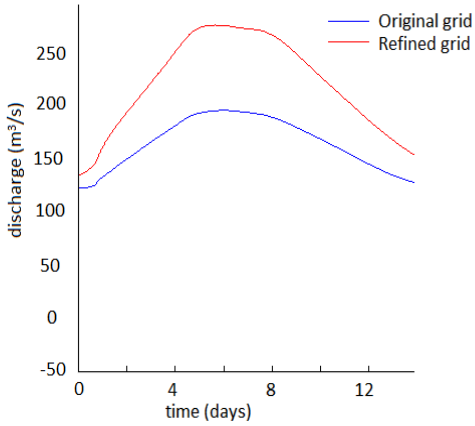

Figure 4. Discharge in side channel at Afferden and Deest for original and refined grid.

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