The influence of mesh structure on simulated water levels and flow velocities in meander rivers

E. Bilgili[a,b,*], A. Bomers[a], J. van Lente[b], F. Huthoff[a,b], S. J. M. H. Hulscher[a]
[a] *University of Twente, Enschede, the Netherlands*
[b] *HKV lijn in water, Lelystad, the Netherlands*

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Introduction

A detailed insight in flow patterns in rivers is essential to evaluate the efficacy and impact of river interventions. To investigate such processes, a common approach is by making use of hydrodynamic simulations, which solve the (depth-averaged) shallow water equations. Fully triangular and fully curvilinear meshes are commonly applied in these models to discretise study areas. It is also possible to combine curvilinear and triangular mesh cells, which is known as a hybrid mesh (see Fig. 3). In *Bomers et al.* (2019), it is shown that the accuracy and computation time of depth-averaged models are substantially influenced by the mesh structure.

In *Caviedes-Voullième et al.* (2012) and *Bomers et al.* (2019), it is highlighted that in river models, poor alignment between mesh and the direction of the flow and mesh coarsening cause a smoothed hydrograph, resulting in a lower depth-averaged flow velocities and hence higher water levels. These numerical errors by a mesh are known as respectively false diffusion and numerical diffusion. Nonetheless, in *Caviedes-Voullième et al.* (2012) and *Bomers et al.* (2019), the numerical errors are interrelated with how well the bathymetry is captured by a mesh. Therefore, it is unclear to what extent numerical errors affect hydraulic river modelling outcomes, especially in river bends. Therefore, the objective of this study is to understand under which conditions numerical errors influence the outcomes of a hydraulic model in schematised meander bends with a flat bed.

Method

The characteristics of the Grensmaas river, which is a section of the Meuse River in the Netherlands, is used to set up the schematised rivers. In the Grensmaas river, both mild and sharp bends are present, with local variations in floodplain width. In order to capture the extremes of these geometrical characteristics in the Grensmaas river, four idealised river schematisations are set up which can be differentiated by a mild or sharp bend and the presence or absence of floodplains (Fig. 1 and 2).

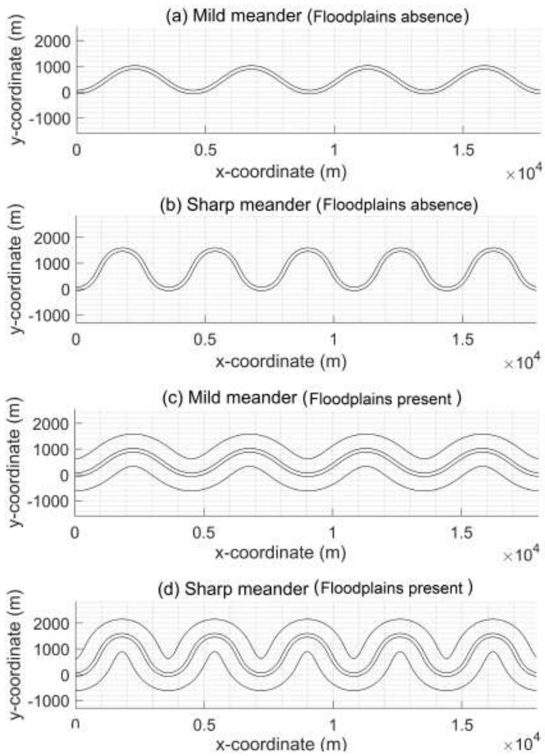

Figure 1: In (a-d) a top-view of a section of the four schematised rivers.

A floodplain height of 6 m is considered with respect to the bed level of the main channel for the cases with floodplains (Fig. 2). A valley slope of 4.49×10^{-4} m/m is applied for all idealised models, which is the slope along a straight line through the meanders bends. A constant bed level in transverse flow direction is used, except for the transition between main channel and floodplains. At $x = 0$, all four rivers are forced with a constant discharge until similar water levels are obtained between the cases. Three flow scenarios are simulated with each lasting 10 days: (i) low; (ii) mid and (iii) high discharge range. The downstream boundary conditions are set by predefined rat-

*Corresponding author
Email address: eray.bilgili10@gmail.com (E. Bilgili)

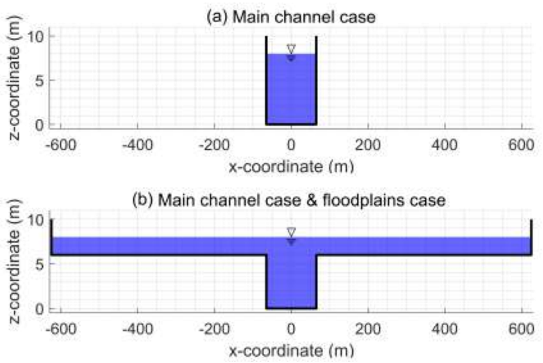

Figure 2: In (a-b) the applied cross-sections in the absence/presence of floodplains respectively.

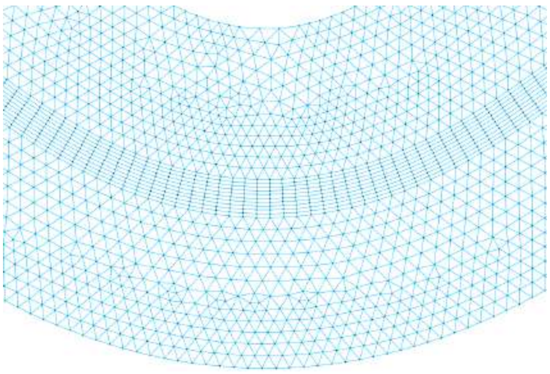

Figure 3: Medium resolution hybrid mesh for the schematised mild river meander with floodplains.

ing curves based on steady uniform flow considerations.

In cases a and b (Fig. 1), triangular and curvilinear meshes are considered with three different mesh resolutions (low, medium and high). In terms of the resolution in the main channel of the triangular meshes, 3, 4 and 8 cells are placed in the transverse flow direction for respectively the low, medium and high resolution. For the curvilinear meshes, 5, 10 and 20 mesh cells are placed in the transverse flow direction for respectively the low, medium and high resolution. In cases c and d (Fig. 1), curvilinear and triangular meshes, as well as hybrid meshes are used with only a medium and high mesh resolution (Fig. 3). To perform the computations, D-Flow FM is used as the modelling software.

Results

The analysis showed that in the schematised river meanders in the absence of floodplains, lower depth-averaged flow velocities and hence higher water depths are obtained with coarser meshes. In the sharper bend larger deviations are simulated since rapid flow changes have to be captured by the meshes, which eventually leads to a greater numerical diffusion. At higher discharges, these differences become more evident. Regarding the differences between mesh shapes, a lower false diffusion is obtained with triangular meshes at lower resolutions than curvilinear meshes. In contrast to the former, the low resolution curvilinear meshes are less capable of capturing the flow changes in the river bends due to their highly stretched cells. For the highest resolution of both meshes, the opposite is observed.

In terms of the water level in cases c and d (Fig. 1), negligible deviations are obtained, which is in contrast to the cases without floodplains. This is a consequence of relatively less deviations in depth-averaged flow velocity differences in the floodplains even though considerable differences are observed in the main channel.

Conclusion

The results showed that the generated false diffusion and numerical diffusion become larger in the case of higher discharges and hence higher depth-averaged flow velocities, and under circumstances in which rapid flow changes occur (i.e. for cases with sharp river bends). The influence of the generated numerical diffusion and false diffusion is dampened by the presence of floodplains. This suggest that the numerical errors are proportional to the discharge per unit width.

References

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