The effect of a constant hydraulic roughness on the migration of mid-channel bars

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Introduction

Worldwide, floods are one of the main hazards causing damage and life-floss each year. Sophisticated two dimensional horizontal (2DH) hydrodynamic models can help to get a detailed representation of water levels and discharges during flood events. These models can be extended towards a morphodynamic model which is, besides of simulating hydrodynamic properties, also capable of predicting erosion and sedimentation patterns. The morphological development of a river is of high importance since it may influence flood propagation and characteristics.

In a river, the main physical forces that control the flow are: inertia, pressure, gravity and friction. These forces are all influenced by the geometry and hydraulic roughness of the river. Much data of the geometry of a river is generally known using satellite images and in-situ measurements. The estimation of the bank roughness, and specifically, the main channel roughness are much more complex (*Kim*, 2010). Therefore, hydrodynamic model calibration is generally done by changing the main channel roughness until simulated water levels are close to measurements (*Bomers*, 2019). Consequently, the hydraulic roughness is typically not changing within a simulation neglecting the dynamic character of the migration of river bars such as alternate bars and mid-channel bars. However, in a morphodynamic model accurate estimation of the hydraulic roughness in time and space is important since it affects the transport of sediments and geomorphological development (*Baptist*, 2005; *Liu*, 2018). Therefore, the objective of this study is to identify the effect of a constant hydraulic roughness in time and space on morphodynamic model results.

Case study and model set-up

A schematizated model is set up based on a section of the Ayeryarwady river in Myanmar close to the city of Nyuangdon. The Ayeryarwady river has a large mid-channel bar which is highly active and dynamic. The dimensions of the river and the mid-channel bar are highly simplified to a straight river with oval-shaped mid-channel bar including floodplains (Fig. 1). A highly schematized morphodynamic model is set up to be able to better interpret the physical processes that influence erosion and sedimentation patterns. The software Delft3D is used to perform the computations. The grid has a resolution of 25 m. The mid-channel bar is positioned exactly in the middle of the main channel and has a length and width of 600 and 300 m respectively (Fig. 1). It has a height of seven m above the main channel bed which gradually diminishes towards the main channel bed with a slope of 1/15 m/m in cross-channel direction and a slope of 1/30 m/m in long-channel direction.

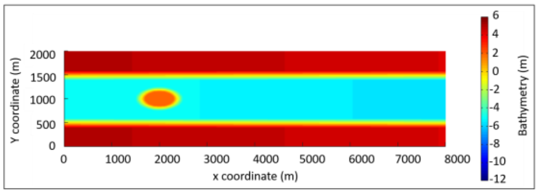

Figure 1: Schematized model set-up

A discharge wave is used as upstream boundary conditions and downstream a water level boundary condition is implemented. Furthermore, a median grain size of 0.35 mm is used throughout the model domain and a morphological factor of 15 is used to speed up the computations. Two different scenarios are run with this model:

- A constant Manning's roughness coefficient of 0.03 throughout the model domain is used.
- A Manning's roughness coefficient of 0.03 is used for the floodplains and main channel. The mid-channel bar has a Manning's hydraulic roughness coefficient of 0.1.

First results

Both hydraulic roughness scenarios are run for one year. The results are presented in Fig. 2. We find that if a constant hydraulic

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roughness is used throughout the model domain (Fig. 2A), the mid-channel bar migrates in downstream direction. The evolution and final shape of the mid-channel bar is in line with literature and observations in the field. Fig. 2B shows the results of the mid-channel bar has a higher Manning's roughness coefficient than the main channel and floodplains. At the initial location of the mid-channel bar, erosion occurs caused by the high Manning's roughness coefficient. Although the mid-channel bar migrates in downstream direction, its higher roughness is not updated and remains at the same location. This results in too high bed shear stresses at the initial location of the mid-channel bar and hence erosion. We can conclude that the latter scenario, in which the mid-channel bar has its own Manning's roughness coefficient, is not capable of reproducing the physical processes as seen in a natural river system.

Conclusions

Mid-channel bars have a different hydraulic roughness than the surrounding main chan- nel. However, up till now, as mid-channel bars migrate in downstream direction its hydraulic roughness coefficient is generally not updated during the morphodynamic simulation. The preliminary results of this study show that a constant (in time and place) hydraulic roughness results in inaccurate model outcomes. Due to the higher roughness at the initial location of the mid-channel bar, bed shear stresses are overestimated resulting in too much erosion at that location.

As a next step, we will develop a new modelling approach in which the hydraulic roughness of mid-channel bars are updated as it migrates. The schematized model set-up is expanded such that it captures the actual Ayeryarwady river dimensions. Consequently, model results can be compared with field observations.

Acknowledgements

References

Baptist, M.J., 2005. Modelling floodplain bio-geomorphology. Phd dissertation. Delft University of Technology.

Bomers, A., Schielen, R.M.J., Hulscher, S.J.M.H., 2019. The influence of grid shape and grid size on river modelling performance.Environmental Fluid Mechanics 19, 1273–1294. doi:10.1007/s10652-019-09670-4.

Kim, J.S., Lee, C.J., Kim, W., Kim, Y.J., 2010. Roughness coefficient and its uncertainty in gravel-bed river. Water Science and Engineering 3, 217–232. doi:10.3882/j.issn.1674-2370.2010.02.010.

Liu, Z., Merwade, V., Jafarzadegan, K., 2018. Investigating the role of model structure and surface roughness in generating flood inundation extents using one- and two-dimensional hydraulic models. Journal of Flood Risk Management 12, 1–19. doi:10.1111/jfr3.12347.

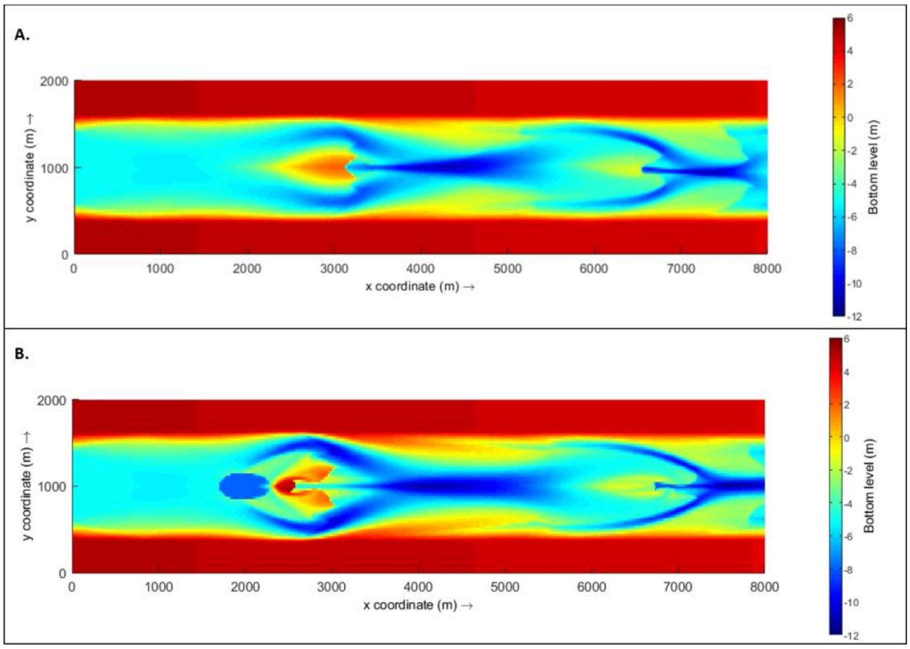

Figure 2: Model results of the two different roughness scenarios in which Fig. 2A shows the results for a constant Manning's roughness coefficient of 0.03 throughout the model domain and Fig. 2B shows the results for the scenario in which the mid-channel bar has a higher Manning's roughness coefficient (0.1) compared to the floodplains and main channel (0.03).