Numerical River Laboratory: platform for long term development of river systems

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Keywords — Long term river morphology, platform, community, D-Flow FM

Introduction

The Dutch rivers have a clear distinction between navigation channel and the floodplains and are almost completely confined within levees and groynes. However, this does not mean that the river bed does not change anymore. During high discharge the bed of the navigation channel rapidly changes and part of the sediment is deposited in the floodplains. Adaptation to river training works and Room for the River projects takes place on the scale of years to decades. Other changes have an even longer time scale, such as changes in sediment input from upstream, adaptation to sea level rise, and changes in discharge regime due to climate change.

The challenge is to guarantee that the Dutch river system remains stable for the next 50-150 years. Not only for safety against flooding, but also navigation and nature have to profit in an optimal way. Therefore, Rijkswaterstaat has initiated a research program on lowland rivers within the program National Knowledge and Innovation Program on Water and Climate (NKWK) which focusses on the long term development of rivers. The goal of this program is to gain knowledge about the behaviour of rivers that will lead to sustainable measures for the future, which will be applied to the Dutch rivers and abroad. The new concept 'Building with Nature' might help in achieving this.

The NKWK program requires both numerical models that are able to accurately predict long term morphological changes as well as the ability to apply new research results for policy making. Therefore the Numerical River Laboratory ('RiverLab') is set up as a platform where these numerical models and the accompanying software can be shared and further developed within the river community.

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Software functionality

The RiverLab focusses on large spatial scales and long term morphology. With these requirements a 1D modelling approach, with 2D and 3D parts where needed, appears to be the best choice. For this purpose, the RiverLab utilizes the Delft3D FM Software Suite that integrates these multi-dimensional approaches in one package. The key component of Delft3D FM is the D-Flow Flexible Mesh (D-Flow FM) engine for hydrodynamical and morphological simulations on unstructured grids in 1D-2D-3D. Until recently, only the 2D (morphological) functionality was fully validated and supported. Within NKWK, also basic 1D (morphological) functionality is added and validated. It is now possible to import existing 1D SOBEK3-models within D-Flow FM.

The Delft3D FM Software Suite is open source, which means that it is freely available under AGPL-licence. Separate branches for dedicated research can be generated and proven methods can be merged to the main version, such that they become available to all users.

The advantage of using one integrated software suite is that functionalities developed by other parties, such as universities or engineering companies, can be easily used and combined (e.g. new numerical schemes, friction formulations due to dune evolution, other processes such as water quality, bank erosion and waves). It is also possible to add functionalities via Python-scripting, without having to change the code itself. This allows researchers in the NKWK program (as well as other researchers) to adjust and extend the tools to suit their needs.

Numerical (pilot) models

The RiverLab not only provides the software for evaluating long-term morphological developments, but also aims to provide the model(schematisation) for the River Rhine branches such that they can be used for studies in the Dutch rivers. Other rivers may be added in the future.

Within the RiverLab, also several 1D standard test cases are available that are used to test all the software functionalities (hydrodynamic and morphological). These test cases are preferably based on analytical solutions or a comparison with available 2D results and can be used by the research community to test new functionalities that are implemented. An example of the results for a moving shoal is shown in Fig. 1, where the results for D-Flow FM 1D are compared with SOBEK3.

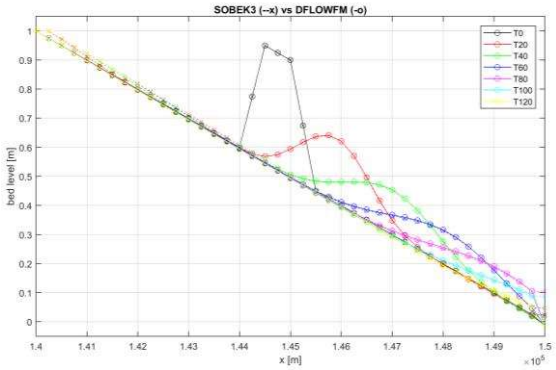

Figure 1. Bed level at different time steps for a moving shoal with Engelund-Hanssen transport formulation (o = D-Flow FM, x = SOBEK3).

In the first phase of the RiverLab project a pilot community model of the Waal is set up. This model is based on a recent hydrodynamic 1D (SOBEK3)-model (sobek-rijn-j11_5-v1) of Rijkswaterstaat (see Fig. 2). The SOBEK3-model is converted to D-Flow FM 1D and morphological information and boundary conditions are added based on the SOBEK-RE model that was used in an earlier pilot within NKWK (Sloff, 2006; Giri and Spruyt, 2017).

Platform and community

The ambition is to create a community of users, contributors and river managers (extending beyond the research community) that is stimulated to utilise the RiverLab as a communication and discussion platform.
To facilitate this, a web-based infrastructure is set up from which you can download the numerical models and software and which can be used as discussion platform. Third parties are allowed to download and adapt the RiverLab models for own use. Preferably, new versions of the models are uploaded again to this website for use by other parties. Third parties may develop a version of the model for own purposes. It should then be made publicly available according to conditions of the Creative Commons Attribution-ShareAlike 4.0 International License.

Future work

The Delft3D FM Software Suite is constantly improved and new features become available regularly. The 1D-functionality within D-Flow FM will be further developed and coupling with 2D (and even 3D) models will be made possible.
Universities, knowledge institutes and engineering companies are encouraged to test their new ideas within the RiverLab, both by improving and extending the models as well as adding new functionalities to the software.

Acknowledgments

The Riverlab is made possible by contributions of the ministry of Infrastructure and Water Management, Deltares, HKV Consultants and Royal HaskoningDHV.

References

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Figure 2. Structure of the 1D-model of the Rhine branches.