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Book of abstracts

Rivers in an uncertain future

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Vasileios Kitsikoudis, R. Pepijn van
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University of Twente	telephone:	+31 53 489 35 46
P.O. 217	e-mail:	secretariat-mfs-et@utwente.nl
7500 AE Enschede	www:	https://www.utwente.nl
The Netherlands		

Contact NCR

dr. ir. K.D. Berends (programme Secretary)	telephone:	+31 6 21 28 74 61
Netherlands Centre for River Studies	e-mail:	secretary@ncr-web.org
c/o Deltares	www:	https://www.ncr-web.org
P.O. 177		
2600 MH Delft		
The Netherlands		

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Numerical and physical modelling of the effect of groynes lowering

Johan Harms[a*], Victor Chavarrias[b], Mohamed Yossef[b], Jeremy Bricker[a], Wim Uijttewaal[a], Burhan Yildiz[a,b,c]
[a] *Dept. of Hydraulic Engineering, Faculty of Civil Engineering and Geosciences, Delft University of Technology, P.O. Box 5048, 2600 GA, Delft, the Netherlands*
[b] *Deltares, Boussinesqweg 1, 2629 HV Delft, the Netherlands*
[c]*Mugla Sitki Kocman University, Department of Civil Engineering, 48000, Mugla, Turkey*

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Introduction

Groynes are a common sight in Dutch rivers, giving multiple advantages. They decrease the conveyance flow area, increasing the flow velocity in the main channel, inhibiting the formation of ice dams and deepening the main channel, which allows larges vessels to travel the river. They furthermore decrease the flow velocity at the bank, which protects the dikes. Groynes have some drawbacks however. One of those drawbacks is that during high-flow events, groynes hinder the river flow, increasing the overall friction and the water levels during flood events.

To increase safety against flooding *Rijkswaterstaat* is considering the lowering or streamlining of groynes. As a legal requirement the impact of such groyne adaptions have to be studied using WAQUA, a two-dimensional river model. In that model the groynes are modelled as fixed weirs, causing energy loss due to the constriction and subsequent expansion of the flow passing over the groynes. In contrast to weirs, groynes only obstruct part of the river however, allowing bypassing of water around a groyne. Furthermore there are mixing layers between the main channel, groyne fields and floodplains, which induce an extra momentum exchange in the river. The magnitude of this interaction depends on the difference in flow velocity in the different parts of the river and depends thus on the proper modelling of the groynes (Ambagts, 2019).

Current practice to compensate for these differences in flow physics is by calibration with measured water levels, applying a friction factor on the weir formulas. With such a method one cannot be certain about the effects of changing the groyne geometry (Yossef & Visser, 2018).

* Corresponding author
Email address: j.m.harms-1@student.tudelft.nl (J.M. Harms)

Therefore a numerical and a physical model are set up to determine modelling coefficients for groyne schematization. The numerical modelling includes 3D modelling with the groynes included in the bathymetry, as well as 2D sub-grid modelling with groynes included as (a combination of) weirs (Chavarrias, 2020).

These numerical simulations are calibrated on the results of physical modelling of groynes. The physical model is a 1:30 scale model of a representative section of the Waal. For this model different water levels with different discharges are modelled in the physical model, as well as the numerical model. The modelled situation includes the situation of emerged groynes, submerged groynes with emerged floodplain and high water conditions with submerged groynes and floodplain.

The measured quantities in the physical model are water levels and flow velocities. From these quantities the friction in the flume with and without groynes can be determined.

Physical groyne modelling

The physical model consists of a 36 m long, 5 m wide straight flume consisting of a main channel, groyne field and floodplain. For these dimensions 6 groynes fit in the experiment. Water levels and velocity profiles are measured up- and downstream of each groyne and within the third groyne field, in which also the surface velocities are measured using particle tracking velocimetry. Current physical modelling results without the groynes as reference case are preliminary and show a large influence of the upstream inflow boundary (Fig. 1).

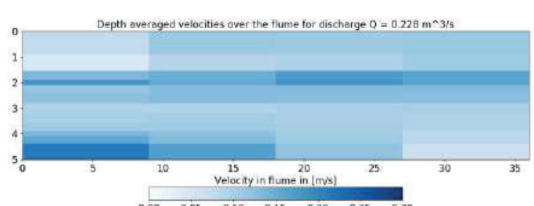

Figure 1. Mean flow velocity in the physical model, with the main channel at Y=0. The mean flow velocity increases in the main channel and decreases in the floodplain over the whole domain.

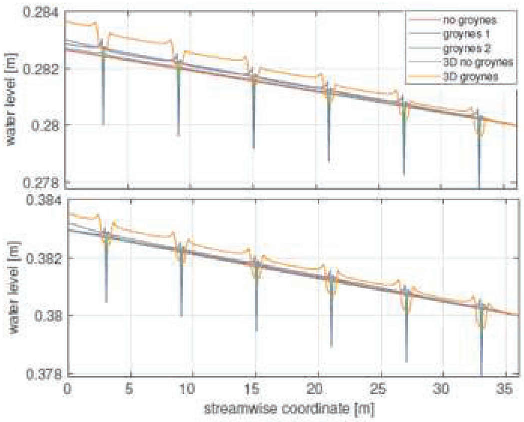

Figure 2. Water levels for different submergence levels of the groynes. On top the water levels for the case with submerged groynes. Below the case with submerged groynes and inundated floodplain. Case without groynes in 2D and 3D is modelled, as well as 2D groyne schematizations as 1 or 2 weirs and 3D modelling of groynes.

Groyne resistance modelling

Current results from numerical modelling are also preliminary. But comparing 2D and 3D modelling results shows that under high flow conditions the effect of groynes is negligible in 2D, while not in 3D (Fig. 2).

Emerged groyne modelling

For low water levels, with emerged groynes, the sub-grid modelling of weirs does produce eddies in the groyne fields (Fig. 3), and gives results which correspond well to the 3D simulation. A double gyre pattern is expected in the physical model in the groyne fields in contrast to the single gyre in the numerical models, otherwise the model correctly reproduces essential features, such as: flow unsteadiness, eddy periodicity, the role of wall friction in eddy periodicity and secondary circulation in 3D modelling (Chavarrias, 2020).

Discussion

The aim of the current research is to verify numerical models with a large flume, with few uncertainty in translating the results to the full scale. The scale (1:30) is large compared to most physical models of groynes currently build. The chosen scale does have a large drawback that the flume is relatively short, and only models 6 groynes. The influence of the inflow conditions can be large therefor, with only a few groyne fields actually representing flow conditions independent of the boundary conditions. Furthermore the accuracy of measurements is limited. The measured water level differences in the flume are in the order of millimetres, where the additions of groynes and adaptations of the groyne geometry will result in water level changes of the order of 0.1 mm, which is difficult to measure in even a controlled environment.

The current report only shows preliminary results. Future research will also include the modelling of more combinations of water levels and discharges, and of different groyne geometries, with the main goal of the overall research to find a proper modelling practice for adapted groyne geometries.

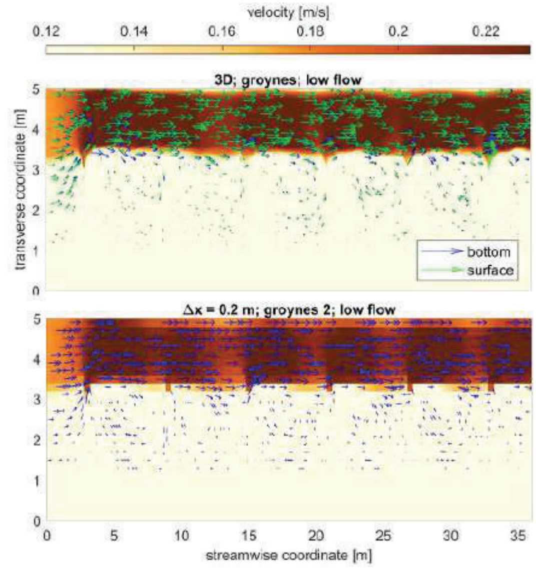

Figure 3. Flow velocities in flume for (Top) 3D modelling of groynes and (Bottom) 2D sub-grid modelling of groynes as two weirs

Conclusion

A research project is started to improve the modelling of groynes. A physical model is set up, together with a numerical model. At the moment the 2D modelling of groynes correspond well to the 3D situation, whereas for submerged groynes the 2D sub-grid modelling of groynes does give satisfactory results.

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