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Book of abstracts

Rivers in an uncertain future

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Jord J. Warmink, Anouk Bomers,
Vasileios Kitsikoudis, R. Pepijn van
Denderen & Fredrik Huthoff (eds.)

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Numerical study on the transition between river bar regimes due to varying discharge

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Introduction

River bars are large-scale bedforms, formed by the local deposition of sediments. They create suitable habitats for aquatic fauna and riparian vegetation, which makes them valuable in river restoration projects. Understanding the dynamics of river bars is required for a proper design of the restoration project and for the development of a sustainable management scheme.

The channel width-to-depth ratio is the key controlling parameter for the formation of bars. Based on early described stability analyses, a resonance point and critical width-to-depth ratio have been defined, which mark the transition between different types of bar regimes (Colombini et al., 1987). By widening a river section to a width-to-depth ratio above its critical value, migrating bars develop. When they are fixed to a local perturbation, the bars show a pattern subcritically damped in downstream direction. By further increasing the width-to-depth ratio towards its resonance point, the celerity of the migrating bars becomes zero. This results in a pattern of steady bars, which are referred to as an unstable bar regime.

Due to the natural variability of river discharge, the width-to-depth ratio varies over time. The objective of this research is to give insights into the transition between river bar regimes due to a varying discharge. Therefore, insight in the timescale of adaptation to new flow conditions is necessary.

Methodology

A straight river channel is modelled in Delft3D, with non-erodible banks, starting with a flat bed. The geometry and the discharge hydrograph are roughly based on the Dutch river 'Grensmaas'. A fixed perturbation by means of a groyne is applied, which obstructs 20% of the channel width. A relatively small sediment size is applied to model morphological changes in the total discharge regime.

In the uniform analysis, the upstream boundary condition is a steady discharge, with magnitudes between 50 and 1250 m^3/s. The damping length and wavelength of the river bars are compared with theoretically obtained values to validate the numerical model and to determine the resonance point of the river model. Furthermore, the time to develop the river bars from a flat bed is assessed. This value is compared to existing morphodynamic timescales.

The transition between the river bar regimes around the resonance point (unstable to subcritically damped and vice versa) is modelled by means of a steady increasing and decreasing discharge, starting with a fully developed bed. The response of the river bars to the varying discharge is coupled to the timescale of development based on the uniform analysis.

Results

Three types of river bars are shown in Figure 1, being a. Unstable, b. Subcritically damped, and c. Supercritically damped. The corresponding discharge is 100, 150, and 1000 m^3/s, equivalent to width-to-depth ratios of 42, 32 and 9 respectively. The damping length and wavelength show good agreement with the values determined by the theory of Crosato and Mosselman (2009), which is based on the theory developed by Struiksma et al. (1985). The resonance point is at a width-to-depth ratio of 37-38.

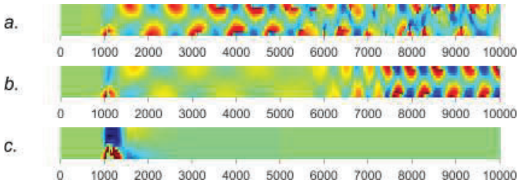

Figure 1: Unstable (a), subcritically damped (b), and supercritically damped (c) river bar regimes.

From the numerical simulations, two timescales have been defined. First, the development of migrating bars towards their final amplitude (Figure 2a). Secondly, the time

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to reach the final bed topography, which is in the unstable and subcritically damped bar regime a pattern of steady bars. The timescale of the development of migrating bars shows good agreement to the timescale defined by Taal (1989), which is inversely proportional to the sediment transport rate. The timescale to the final bed topography is 4-6 times greater.

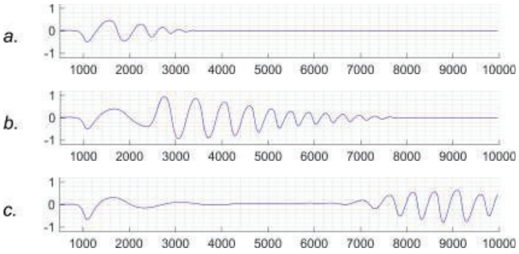

Figure 2: Bed levels along river bank, starting from a flat bed. a. Migrating bars develop from the fixed perturbation (t = 20 days). b. & c. A pattern of steady bars, damped in downstream direction, develops (t = 2 & 8 months).

The transition between an unstable to a subcritically damped bar regime is shown in Figure 3; vice versa in Figure 4. In both figures, bed levels are plotted for the width-to-depth ratios between 35 to 41, which captures the resonance point of the river. The same colour in the two figures corresponds to the same width-to-depth ratio. A qualitative description of the transition is given.

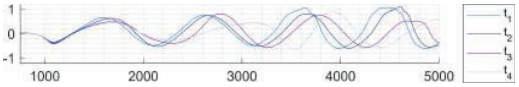

Figure 3: Bed levels along river bank, in the transition from an unstable to a subcritically damped bar regime.

From unstable to subcritically damped (Figure 3): The amplitude of the bars decreases towards a constant amplitude in downstream direction, and in this process the river bars are slowly migrating. Starting from the fixed perturbation, a new pattern of steady bars with a damped character develops (t_4). The bars migrate faster than the development of steady bars starting from the perturbation. Therefore, new migrating bars develop at the tail of the steady bars.

From subcritically damped towards unstable (Figure 4): At the tail of the subcritically damped steady bars, migrating bars develop. This bed instability slowly moves upstream. The pattern of steady bars becomes steeper with shorter wavelengths.

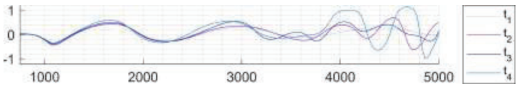

Figure 4: Bed levels along river bank, in the transition from a subcritically damped to an unstable bar regime.

Conclusion and recommendations

Based on the uniform analysis, a distinction in timescales of development of migrating and steady bars is made, with a shorter (4-6 times) timescale of development for migrating bars. This results in a different response of migrating and steady bars to a varying discharge. When the bed becomes unstable due to an increasing width-to-depth ratio, migrating bars develop. A pattern of steady bars follows, developing in downstream direction from the fixed perturbation.

The development of migrating bars in the idealized case of a straight river limits the validity of the results for real rivers, as their migration can be limited by other local perturbations, like a local widening or curvature.

Recommendations for further research are towards the effect of varying sediment sizes on the timescale of development and response of river bars to varying discharge.

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References

Struiksma, N., Olesen, K., Flokstra, C., de Vriend, H., 1985. Bed deformation in curved alluvial channels. Journal of Hydraulic Research 23, 57–79.

Crosato, A., Mosselman, E., 2009. Simple physics-based predictor for the number of river bars and the transition between meandering and braiding. Water Resources Research 45

Taal, M.C., 1989. Time-dependent near-bank bed-deformation in meandering rivers. (MSc Thesis). Delft University of Technology

Colombini, M., Seminara, G., Tubino, M., 1987. Finiamplitude alternate bars. Journal of Fluid Mechanics 181, 213-232.