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Effects of Suspended Sediment Transport on Bar Characteristics

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Introduction

Bars are large sediment formations in rivers that emerge at low flow (Figure 1). Bars can be forced, free, or hybrid (Duró, et al., 2016). Free and hybrid bars form due to morphodynamic instability of the river bed. Hybrid bars are stabilized by hydrodynamic forcing and are thus steady. Most bar instability analyses are based on bedload transport, which implies quick adaption of sediment transport to the local flow conditions (Engelund, 1970). However, the transport of sediment in suspension does not immediately adapt to the local flow conditions since it presents time and space lags in its response. It is therefore believed that this influences the characteristics of the river bars. Theoretical work on the effects of sediment suspension on free alternate bars is based on linear simplifications of the equations and has led to opposite conclusions.

Figure 1 Alternate bars: Rhine River (Left), Experimental flume of Tewolde (2015) (Right)

The goal of this research is to investigate the effects of suspended sediment on bar formation, distinguishing hybrid bars from free bars, using a 2D numerical model. The study is complementary to the experimental work of Tewolde (2015) who studied hybrid alternate bar formation in the laboratory with two sediments having the same granulometry but different density to obtain either bedload or suspended load. Tewolde (2015) found that hybrid bars are damped if suspended load transport is dominant, but their wavelength seems unaffected by the transport mechanism. To fulfil the study's goal, a virtual alluvial straight channel with constant width and non-erodible banks is set up using the Delft3D code. Starting with a flatbed and different boundary conditions, the flat channel bed develops into a train of alternate bars. The characteristics of the virtual channel are an upscaled version of the experiments. The numerical results are then compared to the experimental ones.

Methods

The water depths in the experimental flume of Tewolde (2015) had the order of centimeter, which makes it difficult to reproduce them numerically. For this, it was necessary to upscale the experimental channel by keeping the same flow characteristics (Froude number), bedload mobility (Shields parameter), degree of suspension (Rouse number), and 2D morphodynamic response (bar mode and interaction parameter). Suspended sediment transport is affected by the spiral flow that forms around bars. For bedload, it is important to include the effects of gravity on sediment transport direction. The model is set up to include all this, at the scale of a real river. Calibration is carried out by modifying the bed slope effect (bedload) and the spiral flow effect (suspended load) on Run 1. Validation is carried out on Runs 2 and 3 (Table 1), reproducing the first 6 laboratory tests of Tewolde (2015).

Research scenarios

The investigation scenarios simulate bar formation with different percentages of bed and suspended load to complement the laboratory experiments of Tewolde (2015). For each scenario, the simulation is carried out either by imposing a groyne near the upstream boundary to generate hybrid bars or without a groyne and with a random inflow perturbation to generate free bars.

Table 1 Research scenarios. Each run includes the simulation of either hybrid or free alternate bars

Simulations	Discharge (m^3/s)	Width (m)	Sediment Type
Run1 bedload	155	50	Gravel (1cm)
Run2 bedload	179	50	Gravel (1cm)
Run3 bedload	205	50	Gravel (1cm)
Run1 sus. load	155	50	Sand (0.4mm)
Run2 sus. load	179	50	Sand (0.4mm)
Run3 sus. load	205	50	Sand (0.4mm)
50%bed+50%sus	155	50	Gravel +Sand
33%bed+67%sus	155	50	Gravel +Sand

Preliminary Results

The upscaling procedure allowed establishing the size and the discharge of the virtual channel (Table 1). To achieve the same sediment mobility and degree of suspension the virtual channel is made by two sediment components: gravel with a D_{50} of 1.0 cm for bedload, computed with the formula of Ashida–Michiue (1974); sand with a D_{50} of 0.4 mm for suspended load, computed either using the formula of Van Rijn (1984) or with an advection-diffusion approach.

The most important parameters to compare the results of calibration and validation with the results of the flume experiments are the bar wavelength and the bar amplitude. The advantage of the model lies in the possibility to study a longer channel minimising the effects of the boundaries, which were causing large uncertainty in the interpretation of the experimental results. The results of bedload calibration are shown in Table 2. The model is then validated on Run 2 and Run 3. The results are shown in Figure 2 and Figure 3. Figure 3 shows the entire model domain, much longer than the experimental one.

What next

The model is currently run to reproduce also the suspended sediment cases. The work is therefore still ongoing and the results of suspended sediment effects are not provided yet.

Table 2 Bar characteristics in the flume and the model (bedload cases)

Bar characteristics		Experiment	Experiment (upscaled)	Model
Run 1	Wavelength (m)	2.1	525	520.8
	Amplitude (m)	0.0123	3.075	2.24
Run 2	Wavelength (m)	2.25	562.5	562.5
	Amplitude (m)	0.0105	2.625	2.41
Run 3	Wavelength (m)	2.86	715	760.4
	Amplitude (m)	0.009	2.25	2.58

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Figure 2 Run2 (bedload). Experiment (top) and model results (bottom).

Figure 3 Results of model calibration and validation for bedload.

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