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FORM DRAG OF SUBAQUEOUS DUNE CONFIGURATIONS

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ABSTRACT

In hydrodynamic modeling of river flows a key model parameter is the hydraulic roughness of the river bed, which is related to grain characteristics of the bed and the geometries and spatial distribution of bed forms. This parameter is commonly used for model calibration, where stationary roughness coefficients are chosen such that an accurate match between modeled and empirical flow data is achieved. However, from existing bathymetric measurements it is known that bed forms take on different shapes during the passing of a discharge wave. These observations of changing bed forms therefore indicate that bed roughness is not a stationary variable (as assumed in many hydrodynamic river models), but rather that bed roughness responds to hydrodynamics. It appears that during the rise of a discharge wave the bed forms tend to grow in height and length, and that bed forms tend to merge and decay during the falling stage of a discharge wave. Using a numerical Reynolds-averaged 2DV flow model we investigate how typical dune configurations (changes in shape, size and placements) affect the form drag, and, therefore, how dune evolution under passing of a discharge wave manifests itself as a dynamic bed roughness. The results of this research provide insight in the roughness-variability during passing of flood waves and indicate potential for improved flood modeling if non-steady roughness parameters were used.

Keywords: hydraulic roughness; dunes; bed forms; numerical flow simulation

1. METHOD

In this study, detailed non-hydrostatic 2DV free-surface flow simulations are carried out to explore the dynamics of river bed roughness that may exist under varying hydrological conditions in a river. For this purpose, we used the OpenFOAM modelling environment and applied the Reynolds-averaged flow equations with k-epsilon turbulence closure. We investigated flow over three idealized river dune configurations:

- Case 1: small secondary dunes
- Case 2: large-scale primary dunes (Figure 1)
- Case 3: primary dunes with superimposed secondary dunes (Figure 2)

These configurations are loosely based on typical river dune characteristics that may be observed in the field before, during and after passing of a flood wave (e.g. Warmink et al. 2012).

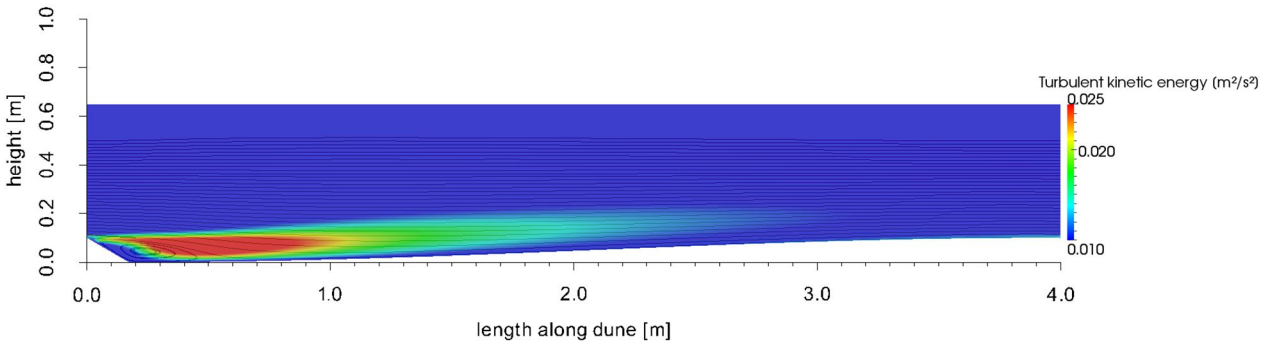

Figure 1. Case 2 - modelled flow field over a primary dune (turbulent kinetic energy).

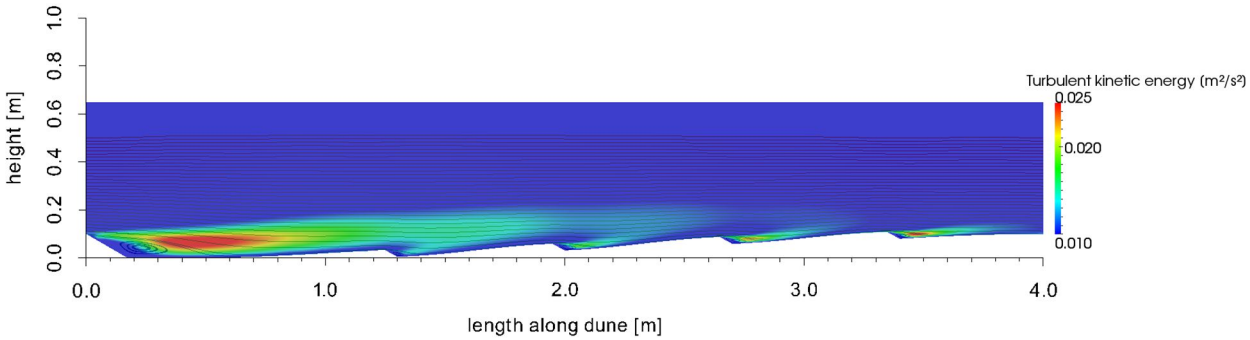

Figure 2. Case 3 - modelled flow field over a primary dune with superimposed secondary dunes (turbulent kinetic energy).

2. RESULTS

Our studies indicate that form drag of the investigated dune configurations generally increases for increasing dune length and height. Also, the form drag increases if small-scale secondary dunes develop on top of a larger primary dune. Moreover, combined primary and secondary dunes (Case 3) give even higher form drag than what would be expected from simple summation of the form drag of each separate bed form (Figure 3).

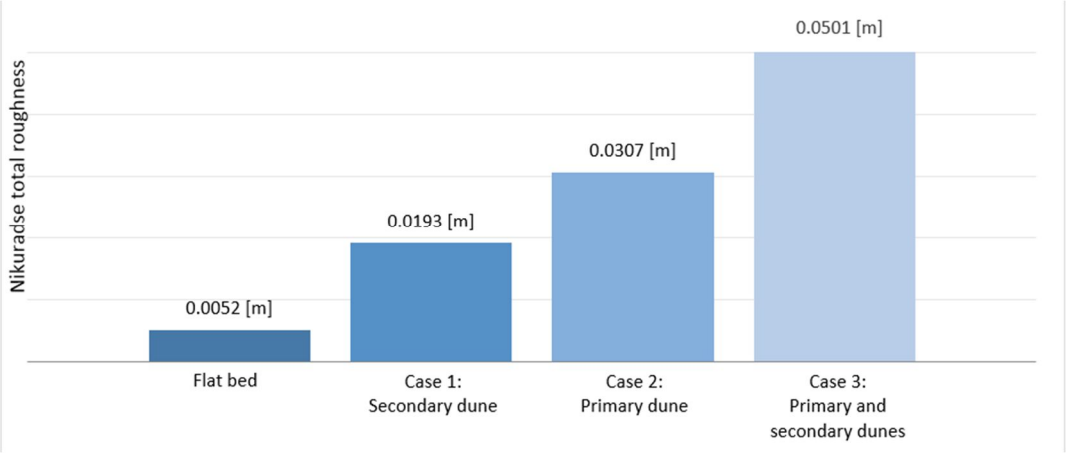

Figure 3. Overall hydraulic roughness for the investigated cases with different bed forms.

3. CONCLUSIONS

In relation to the varying bed forms during passing of a discharge wave, it is concluded that the form drag of the river bed increases during the rise of a discharge wave due to growing of primary dunes. For the falling stage of a discharge wave the form drag may still increase as secondary dunes develop on top of large primary dunes. These findings are relevant to obtain a better understanding of the underlying mechanisms of stage-discharge relations during flood events, and may guide techniques to obtain improved flood simulation tools.

ACKNOWLEDGMENTS

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