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The effect of bed defects on bedform generation – A new approach using the SPH simulation technique

Gerhard Bartzke, Lina Podszun , and Katrin Huhn
MARUM, Universität Bremen, Leobener Straße, D-28359 Bremen, Germany (gbartzke@marum.de)

Various researchers investigated the initiation of bed forms from a flat sediment bed in aquatic environments using analogue techniques, such as wave tanks or in situ field investigations. Nevertheless, this process particularly the role of major controlling factors is still not fully understood. Prior work has highlighted that the existence of bed defects has the potential to influence the erosion pattern at the surface of sediment beds. In such cases, artificial defects were manufactured in a flat bed and tested under various flow speeds, which resulted in the generation of various bed forms. As bed defects impinge on the in the interior of sediment beds, their effects on fluid flow conditions are difficult to quantify with analogue techniques.

To investigate the fluid flow conditions occurring at the direct vicinity and in the interior of a sediment bed, a new 3D-SPH (Smooth Particle Hydrodynamics) numerical ‘wave tank’, as an alternative to the difficult task of in situ measurement, was used.

The model geometry was chosen to mimic typical wave tank dimensions, i.e. X = 2.5 m, Y = 0.35 m, Z = 0.8 m. In order to generate a sediment bed 0.2 m in height, each grain (D50 = 4000 μm) was generated as a fixed particle. Afterwards, the numerical wave tank was flooded with fluid particles. A wave was generated using a vertical paddle accelerated to 0.8 m/s perpendicular to the bed. Six sets of experiments were undertaken with an increasing depth range of bed defects (0.04 – 0.2 m). High resolution flow conditions inside the bed defects as a function of the wave activity were constantly monitored. For estimation of sediment erosion, all measured flow speeds were compared to the Yalin (1972) curve describing transport initiation.

The results showed that the fluid velocities in the bed defect increased with increasing bed defect size depth, which was accompanied by an increase of the flow velocities into the pore spaces along the flanks of the defect. With increasing wave propagation time, the direction of the flow field changed from downstream to upstream resulting in vortexes within the defects. This study quantifies the flow field within and around bed defects and also the importance of the role of pore space infiltration along the flanks for bed form initiation.

Consequently, the existence of even minor defects causes an increase in the inflow into the interior of a sediment bed. Furthermore, bed defects significantly reduce the stream-wise velocity near the bed and increase turbulence at the lee-side of the defect, which provides the turbulent energy to scour. Furthermore, due to the increasing inflow velocities into the shallow bed, the erosion potential along the flanks of the defect is also increased. This might, in turn, result in a deepening of bed defects.