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Effects of bed material grain-size distribution on bed morphology at a river confluence - numerical study

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River confluences play an important role in the drainage of a catchment and transport of sediments and pollutants within this area. Riverbed morphology at these important nodes of the river drainage network might be very complex as shown by numerous laboratory studies in movable bed models and scarce bathymetric surveys in the field. Different parameters were varied in laboratory confluences to infer which of them control morphodynamic processes at the confluence. It was shown that the development of three characteristic morphological elements, i.e. a bar with an avalanche face at the entrance of a tributary channel to the confluence, a scour hole and a separation zone bar in the confluence hydrodynamics zone, depended on: 1) the confluence plan-view (symmetrical or asymmetrical), 2) the junction angle, 3) the channel width ratio, 4) discharge and momentum-flux ratios of the combining flows, 5) sediment loads supplied into one or both upstream channels and 6) the sediment size of the bed material and of supplied sediments. However, most of studies were conducted with uniform sediments. There are only a few laboratory and numerical studies on the effect of bed material gradation on the erosion and deposition patterns in the confluence hydrodynamics zone (CHZ).

This study, thus, focuses on effects that bed material grain-size distribution (GSD) has on these patterns at a river confluence. A layout of a 60^o laboratory confluence of two straight channels with channel width ratio B_T/B_R=0.71 (where B_T and B_R are widths of tributary and main channels, respectively) is chosen for this numerical study. The laboratory confluence was created to study sediment transport and bed morphology at the confluence whose bed is filled with uniform sediments of D = 1.95 mm size. The experimental data from this confluence are selected for validation of a 3D finite-volume based model SSIIM1 that is used in the present study. Effects of GSD are analysed for four materials having the same D_{50} as the uniform sediment (1.95 mm), but different values of standard deviation ($\sigma \in$(1.5, 2.9)).

It is shown that the scour hole is extended further downstream from the separation zone with the increasing non-uniformity of the bed material (increasing σ). However, the zone of maximum scour and its inclination angle with respect to the main channel axis are reduced and moved towards the downstream junction corner. There is pronounced self-armouring of a riverbed within the CHZ. The self-armouring accelerates both bed scouring and the deposition of coarse particles in the flow separation zone. However, it has an adverse effect on the scouring and deposition – the scouring is reduced, while the height of the separation zone bar is increased. Additionally, it is observed that the water surface and bed profiles are out of phase. The maximal water surface elevation is located above the bottom of the scour hole. Water surface longitudinal gradients increase with the increase in the σ-value due to reduction of the scour-hole size and the upstream shift of the bar crest. The possible corridor of sediment movement in the CHZ is a narrow strip which skirts the separation zone bar.