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Formation and degradation of pool-riffle sequences

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Research on the formation and self-maintenance of pool-riffle sequences has strongly focused on the identification of 2 and 3-D flow characteristics (e.g. jet flow and separation, macro-scale turbulent flow structure) influencing the observed morphodynamic behaviour. In most studies of this type, the identified flow characteristics were used to infer morphological changes without explicitly quantifying sediment transport or accounting for complex intermediate sediment transport features and the interactions among different mechanisms.

Recent studies on forced bar formation have carried out detailed analysis of the influence of channel width variations on the bed profile within a theoretical framework of sinusoidally varying widths and vertical banks. The results of these studies demonstrate a strong influence of width variations on the bed longitudinal profile. In spite of the close relation between the generation of these forced bars (both mathematically and in the laboratory) and the formation of pool-riffle sequences in streams, extrapolating the results obtained under this theoretical framework to the reach-scale is not straightforward, especially due to the presence and interaction among different mechanisms operating in the field. In particular, some of the effects that complicate the analysis of pool-riffle morphodynamics in natural streams include the inherent flow unsteadiness associated with the natural flow regime, fractional sediment transport and grain sorting mechanisms, transient alterations on the bed profile during floods, as well as different feedbacks among these individual processes.

The present study tests the importance of longitudinal width variations on the formation of pool-riffle sequences on a reach-scale. A numerical model integrating 1-D unsteady flow, fractional sediment transport, morphodynamics and grain sorting was applied to a well-defined pool-riffle reach where field data is available. Firstly, the topographic data has been simplified to eliminate the pool-riffle patterns in the longitudinal profile (thus creating a uniform slope bed profile) and complexities in the shape of the cross-sections, while keeping the longitudinal differences in the channel widths observed in the studied reach. The model was then run using these initial conditions and measured discharge time series on a continuous basis during one year. Results show that a sequence of pools and riffles was formed which remarkably resembles that observed in the field. The fact that the model does not incorporate any 2 and 3D flow mechanics provides strong evidences that these processes, although inherently present in any natural stream, are not strictly needed for the formation of pool-riffle sequences under the described circumstances.

The model was then used to investigate the influence of flow discharges on the long-term morphological response of the pool-riffle sequence. The basic hypothesis tested here is the possibility of a partial disruption of the pool-riffle morphology by the long-term action of low or medium flow discharges. Understanding the discharge-morphological response is of paramount importance to anticipate the consequences of flow regime alterations on reach-scale morphology. A series of 10-year long steady-flow simulations was carried out beginning with the pool-riffle morphology formed in the 1-year long unsteady flow simulation. Results show different patterns of bed evolution over time as a function of the flow discharge. Namely, flows above a certain threshold tend to increase the differences between pool and riffle elevations, while those under the threshold gradually flatten the reach. These results indicate that flow regulation strategies that increase the duration of low and medium discharges at the expenses of a reduction in peak flows may cause significant changes in the channel morphology and the associated processes.