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Exploring sediment processes in pool-riffle sequences using a simple 1D morphodynamic model.

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Many gravel bed streams have a typical bed morphology consisting of pool-riffle sequences, which provides important habitat diversity both in terms of flow and substrate. Here we use a 1D unsteady multi-fraction morphodynamic model to explain the formation, self maintenance and degradation of pool-riffle sequences. Previous research has focussed almost exclusively on understanding self-maintenance on existing pool-riffle sequences, leaving formation and degradation at a speculative level. Spontaneous formation of pools and riffles has not been attempted before, even though other similar stable bedforms have been generated numerically and in the laboratory through the interaction of flow and sediment transport, like alternate bars in meanders and central bars in braided rivers. While this previous research substantially simplified flow (constant discharge), geometry (sinusoidal description of curvature or channel width) and sediment (uniform material) it showed the forcing effects of either curvature or width on the location of bedforms. For the formation of pools and riffles we use elements of the previous approach (width forcing) but we also incorporate a much more detailed geometry, flow and sediment description, since our intent is to study driving mechanisms for both the morphology and the sediment composition of the bed in a more realistic setting. We tested two hypotheses using our model. The first hypothesis states that the dynamic interaction of 1D flow and sediment processes can not only maintain but also generate a stable pool-riffle morphology with the corresponding longitudinal sorting on a stream with a non uniform bed material, variations in width and subjected to a variable flow regime. The second hypothesis we investigated is that the two key forming sediment processes of erosion/deposition and sorting have different time scales, which interact with the flow time scales to produce a feedback mechanism that reinforces the pool-riffle morphology, including bed geometry and composition. We performed both variable flow and constant flow simulation imposing the width variations observed in an existing river reach and did experiments starting from both a flat bed (to study formation) and from a pool-riffle sequence (to study degradation). Using measured flows on a stream in which we have removed initial bedforms and sediment sorting our model spontaneously generates pools with finer substrate at narrow sections and riffles with coarser sediment at wider sections, closely resembling the natural bed morphology. Additional experiments show that under our modelling assumptions a variable flow regime is fundamental for development and self-maintenance of the longitudinal grain sorting characteristic of pool-riffle sequences, which could not be obtained or maintained with constant discharges.