



## **Unwanted scour holes in morphodynamic experiments: seeking necessary and sufficient conditions**

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Morphodynamic landscape experiments of river reaches, deltas and estuaries often feature unrealistically large scour holes, which are on average 2 cm deep and 5 cm long. Such scours occur under similar conditions as current ripples (as opposed to other bedforms such as dunes). It has long been suspected that they form on hydraulically smooth boundaries, which occur at low boundary Reynolds numbers, typically induced in fine sand and under relatively low sediment mobility. Until now three strategies exist to prevent the unwanted scour holes. The first is to use coarser sand to disrupt the laminar sublayer, but this means low or no mobility. The second is to use fine but poorly sorted sand where the coarser material disrupts the laminar sublayer and the small caliber causes higher mobility, and the third is to use coarse granular material which has a low-density that increases mobility. However, we lack systematic study to determine causes of the scour holes, on which to base experimental design and material choice. Here we present experiments in which we systematically varied sediment types and used various methods to provoke scour holes or removal thereof. We also conducted model runs of Computational Fluid Dynamics and sediment transport in which bedforms automatically emerge. All model runs and most experiments confirm that ripples and scour holes both form in hydraulic smooth conditions induced by low boundary Reynolds numbers. On the other hand, they are absent in coarser sediment and poorly sorted sediment. The experiments also show that scours can be provoked by perturbations even below generalised sediment motion. However, granular material of intermediate density and poor sorting deviated in behaviour: this formed scours despite the addition of coarser fractions that were sufficient to prevent scours in the case of sand. We observed this unexplained behaviour also in channelisation experiments, where peculiar, sharp bends with unrealistically deep outer-bend scour holes formed. With this presentation we hope to initiate debate and data exchange to solve the scale issue of scour hole formation in morphodynamic experiments.