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How do sediment-laden flow events interact with braided river bed morphology?

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Alpine streams are affected by human impact both indirectly, e.g. through changes in climate and land-use, and directly, e.g. through river engineering and flow management. Their response to such external forcing mechanisms depends strongly on the internal morphodynamics of these rivers. In particular, braided rivers may show large temporal variations in bed load transport and related spatial variability in river bed storage. This is characterized by the migration of sediment units, ranging in scale from bedload sheets to entire bar complexes. Therefore, the river bed morphology, in which flow is routed and sediment is (temporarily) stored, is both indicative of and a crucial factor in downstream sediment transfer. Here, we asses both morphological change and sediment transport rates to investigate channel response to sediment-laden flows in a well-controlled field setting.

This study is set in an upstream braided reach of the Borgne d'Arolla in south-west Switzerland. The river is subject to flow abstraction for hydropower exploitation and intermittent purges which are used to evacuate accumulated sediment from the intake into the downstream river reach. Discharge and indirectly sediment supply were derived from data provided by the hydropower company (Grand Dixence). Between purge events, the channel bed downstream from the intake is more or less dry, allowing for frequent (daily), high resolution terrestrial laser scanner surveys with which we quantified bed morphology and morphological change. We performed 2D hydraulic simulations to estimate flow and sediment pathways, which we used to reconstruct event-based, spatially-distributed sediment transport rates, based on the measured morphological change. Here, we will also illustrate the practical and process-based limitations of 2D model simulations to calculate sediment transport and morphological change in this type of setting.

We show that for a series of regulated flow events (purges) the spatial distribution of sediment transport and local morphological change varies strongly within the braided reach and between successive purge events. More prominently, two large flood events (related to the near-surcharge of the hydropower intake system) lead to widespread reworking of the river bed morphology, typically causing main channel deposition and the erosion of bars. In general, the data reveals a crucial point for how we conceptualize braided river dynamics. The internal morphodynamics of the system condition their own response to external forcing by, in this case, sediment-laden flows. Thus, events with similar external forcing may lead to a different morphodynamic response and consequently sediment transfer. This point challenges simplistic notions regarding the equilibrium morphology that forms after adjustment to a flood event and emphasizes the need to factor in historic evolution and morphodynamics in order to quantify and predict future system response.