INVESTIGATING THE IMPACT OF LOW-HEAD DAMS ON SEDIMENT TRANSPORT DYNAMICS IN GRAVEL-COBBLE STREAMS

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Objectives & study sites

With an estimated 16.7 million man-made barriers (dams, weirs, culverts etc.) fragmenting riverine systems worldwide there is a growing need to better understand the impact these structures have on sediment connectivity.

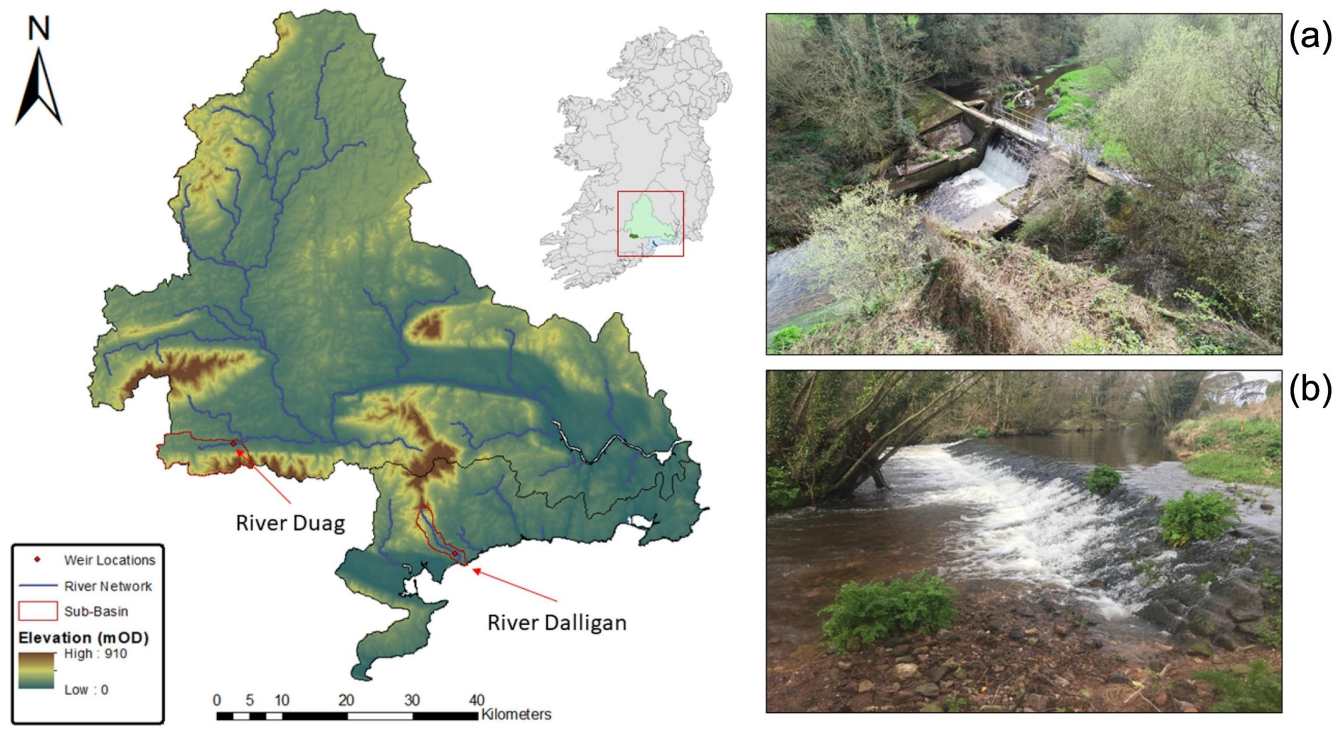

Fig. 1. Study sites located on the River Dalligan (a) and River Duag (b)

Here we present results from a sediment flux study of two gravel-cobble streams located in Ireland's South-East (Fig. 1), and how the presence of low-head dams (weirs) may potentially continue to have an impact on both suspended sediment and bedload connectivity long after storage capacity has been reached.

To isolate the impact dam emplacement has on bedload transport and RFID tracer mobility, monitoring sites were sub-divided into distinct reaches (Fig. 2).

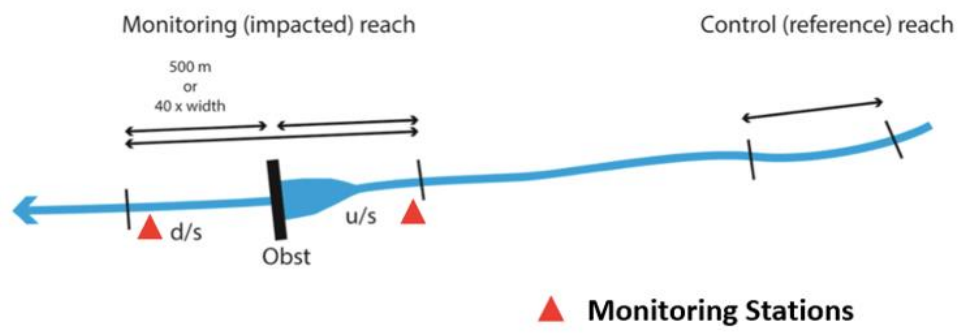

Fig. 2. Experimental design indicating sub-division of sites into distinct reaches

Suspended sediment connectivity

Suspended sediment transport at each site was monitored using a turbidity probe, auto-sampler and water-level recorder located above and below each structure (Fig. 3). Differences between sediment inputs and outputs reveal periodically elevated sediment concentrations downstream of the weir structures compared to what is coming into the reach (Fig. 4). This pattern was observed over a range of flow conditions (above baseflow) at both sites and is indicative of a local source of sediment between monitoring sites. Results suggest that as sediment inputs (from above the dam) became exhausted before peak discharge, the weir's impounded zone (which is typically thought of as a depositional area) becomes the dominant source of sediment to the downstream reach (Fig. 5). If sediment trapped behind the weir is available for transportation during elevated streamflow, the system must be trapping sediment under lower flows, which is consistent with field observations. These results are currently being prepared for publication.

Fig. 3 Monitoring stations at each site are instrumented with auto-samplers, turbidity probes and water-level recorders.

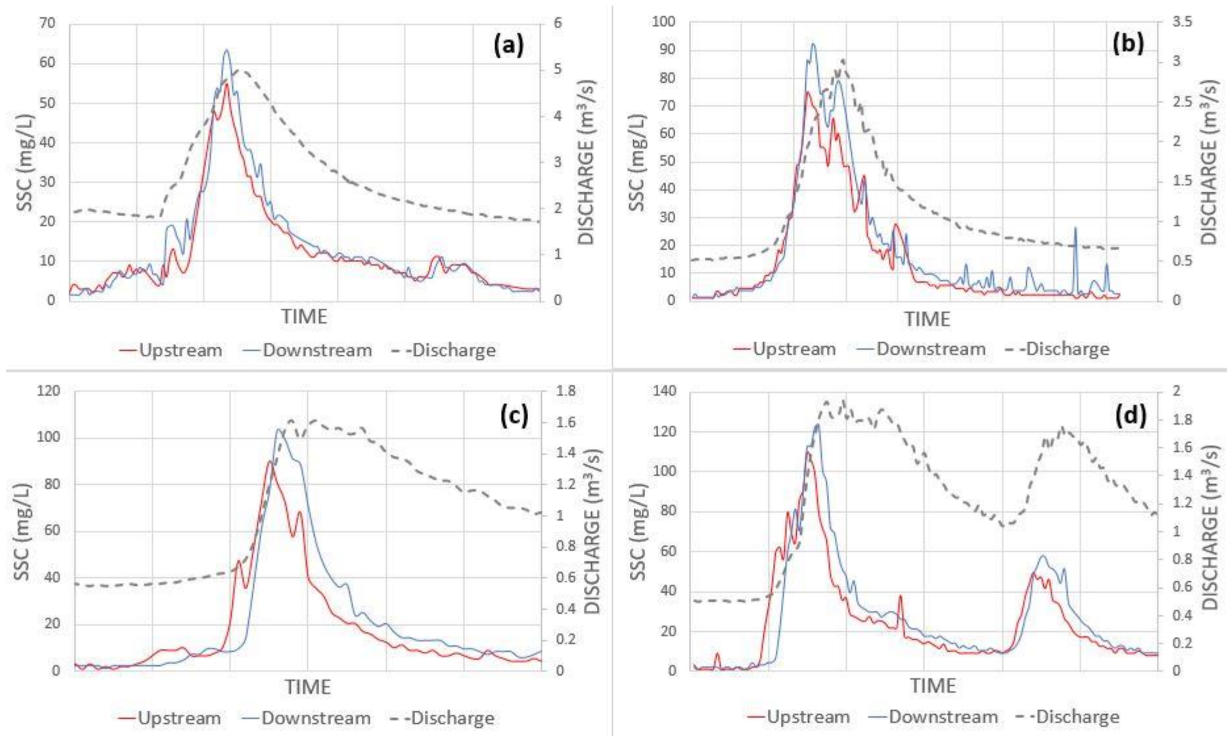

Fig. 4. Event scale comparison of sediment concentrations at the River Duag (a) and River Dalligan (b-d)

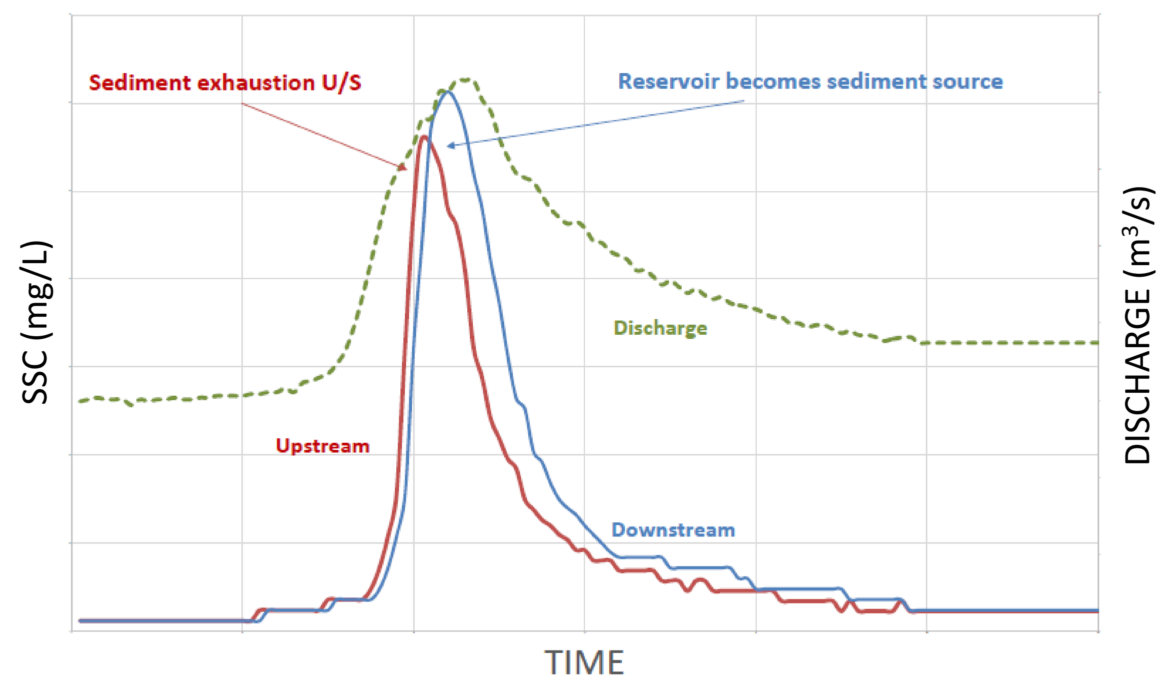

Fig. 5. Conceptual model illustrating the pattern observed at both sites

Bedload connectivity

Bedload connectivity, mobility rates and tracer transport over each structure was captured using RFID-tagged tracers. Observations show that sediment exceeding the reach-averaged D_{90} particle size can be carried over both structures (Fig. 6). However, in addition to coarser particle size distributions seen downstream, when reinterpreted as fractional transport rates (Eq. 1) using a workflow based on existing empirical relations (Fig. 7-9), the tracer data indicate patterns consistent with supply-limited transport conditions downstream; indicating more sediment entered the system than was observed leaving it over the monitoring period. A detailed exposition of these results is reported by Casserly *et al*. (2020).

$$Q_b = \frac{L}{t} \cdot w_s \cdot d_s \cdot (1-p) \cdot \rho_s \cdot P_m$$

Eq. (1) Adapted from Haschenburger and Church, 1998

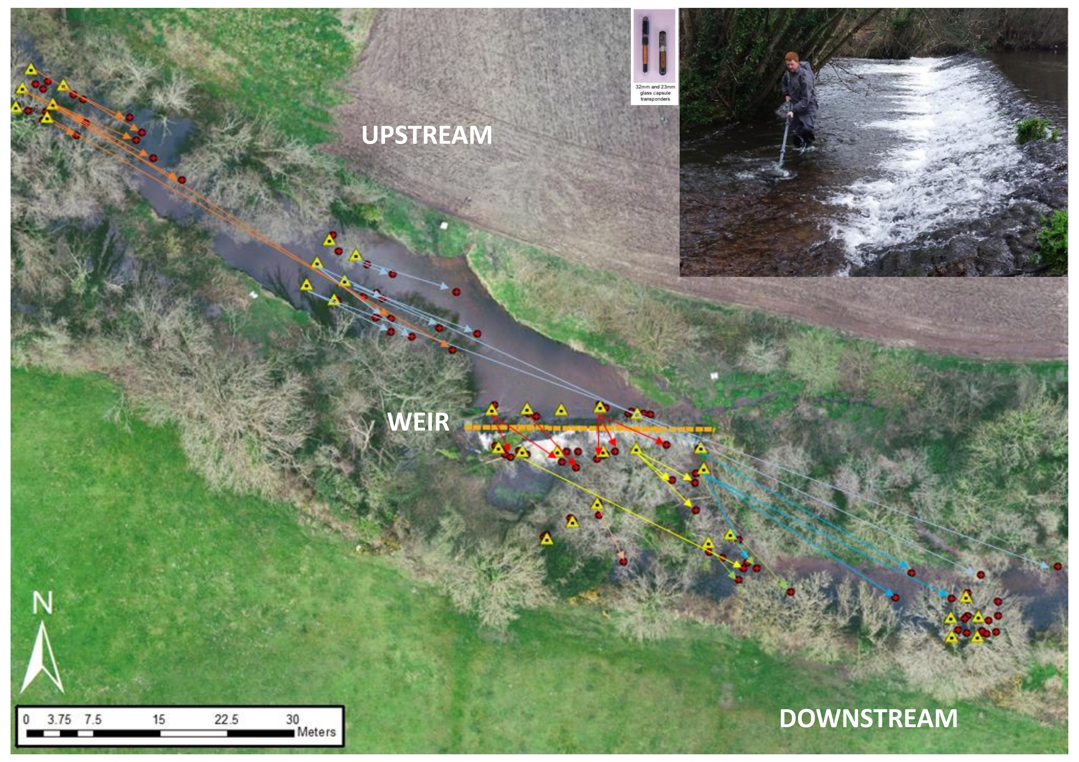

Fig. 6. Tracer mobility and transport through and over the Shanrahan Weir (River Duag). Initial seeding positions (yellow triangles), transport distances (arrows) and final resting positions on recovery date (red circles).

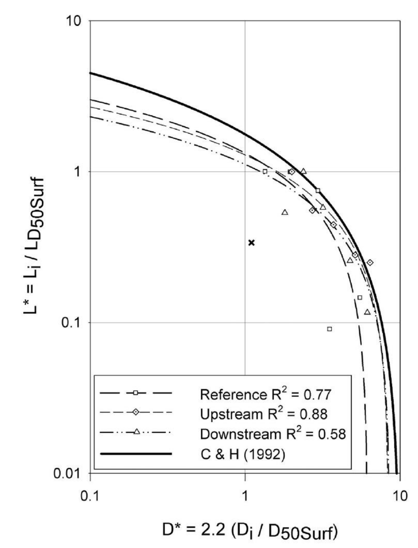

Fig. 7. Estimating transport distances of fractions not represented by tracers (Church and Hassan, 1992)

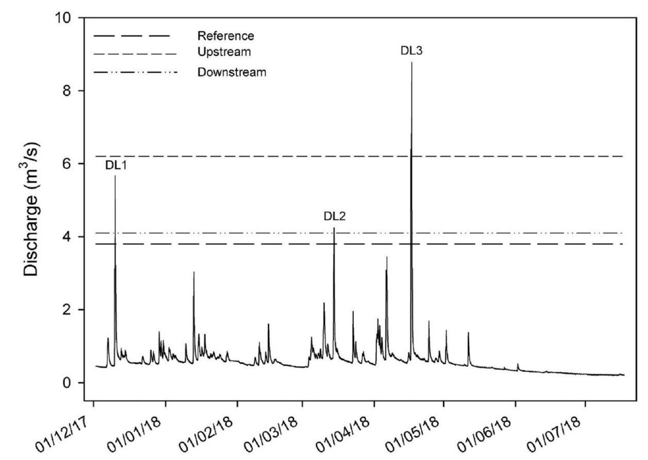

Fig. 8. Use of critical stream power to estimate time duration of competent flows (*sensu* Bagnold, 1980).

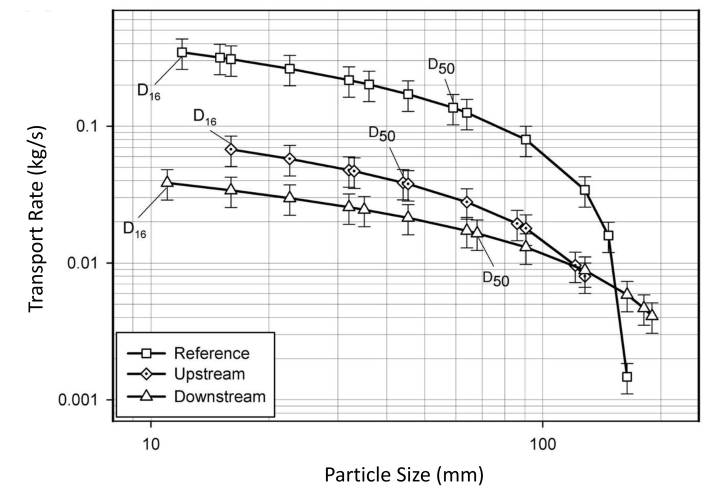

Fig. 9. Fractional transport rates for each monitoring reach at the Dalligan using Eq. (1)

Conceptual model & stationary RFID antenna

Building on existing conceptual models and mechanisms, we hypothesize how a system may continue to exhibit supply-limited conditions downstream without the need for a net attenuation of sediment to occur indefinitely. Once a transient storage capacity has been reached, the system then enters a state of dynamic dysconnectivity, where the long-term average sediment flux equals that under reference conditions, only now amplitude and wavelength of these fluctuations have increased (Fig. 10). We hypothesize that the time-lag associated with the reduced frequency accounts for the time duration necessary to complete the 'fill' phase of the transient storage dynamic before conditions for the 'scour' phase are again met. This model, though operating on a different temporal scale, can also be used to explain the unique patterns seen in the suspended sediment study (Fig. 4 & 5).

To test this hypothesis directly, a stationary RFID antenna was mounted on a weir crest at a third field site (Fig. 11). This has allowed the entrainment thresholds necessary to pass bed material to be captured, the generation of Q-transport rating and the computation of the return interval for events competent enough too pass material over the structure. These results are currently being prepared for publication.

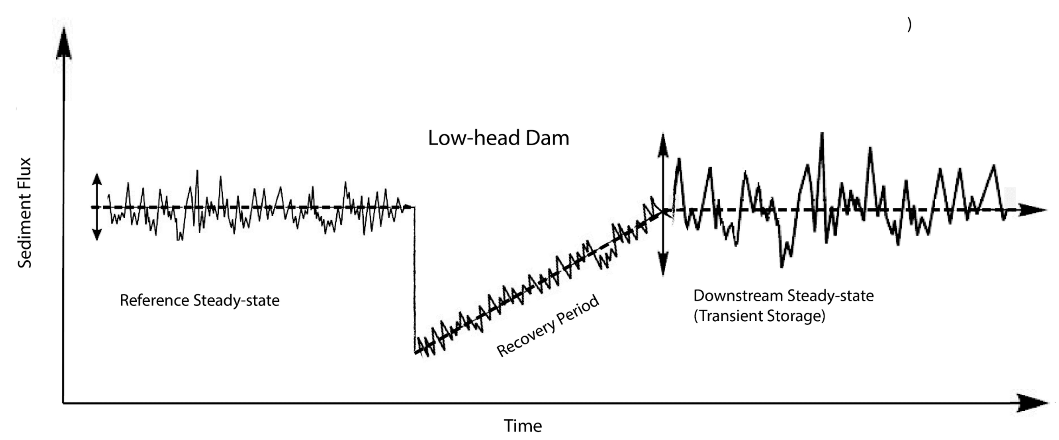

Fig. 10. Conceptual model illustrating sediment regime before (reference state) and after construction of a low-head dam. Note increase in amplitude and wavelength downstream due to transient storage.

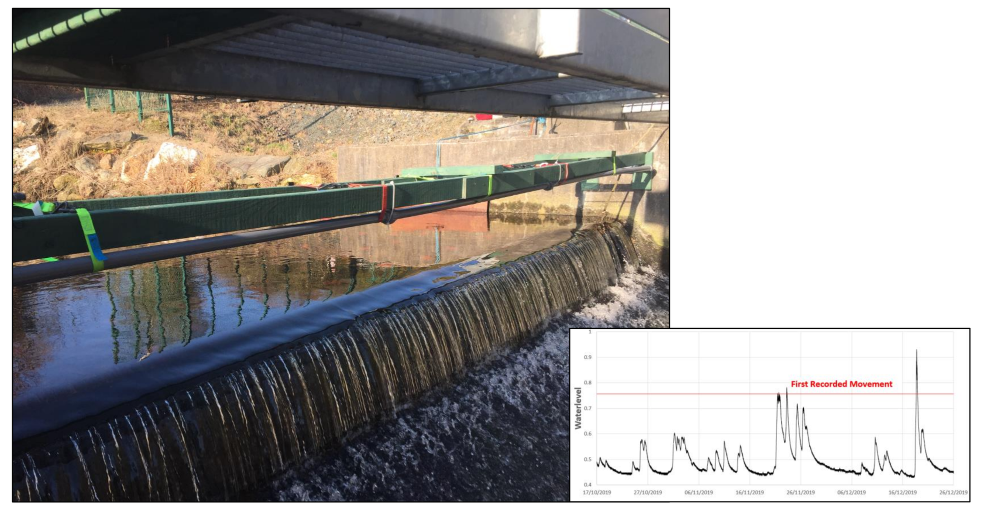

Fig. 11. Stationary antenna on the River Borough. Inset – Critical discharge for incipient motion for smallest tagged particle (26 mm)

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