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.

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).

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 \(D_0\) 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).

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Q_b = \frac{1}{A} \int W dQ - (1 - p) A \int n dQ
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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 for 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 disconnectivity, 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 to pass material over the structure. These results are currently being prepared for publication.

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

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

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 Dalgan (b-d).

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

Fig. 6. Use of critical stream power to estimate time duration of competent flow (Bruns & Brune, 1986).

Fig. 7. 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.

Acknowledgements: The authors would like to thank the EPA for funding this project (Grant Number: 2015/1492). We would like to acknowledge the land owners whose property the study sites run through and to Inland Fisheries Ireland for facilitating access. We are also indebted to IAS laboratories for processing samples and to a great number of lab technicians, research assistants and students over the course of this study for their assistance in both the field and workshop. For more information see our website: http://www.ucd.ie/research/