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Ecosystem impacts of Alpine water intakes for hydropower: the challenge of sediment management

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Natural Alpine flow regimes are strongly modified by anthropogenic activities, notably water abstraction or impoundment for hydroelectric power production, which impacts upon both river discharge and sediment transfer systems, and in turn upon flora and fauna downstream. These kinds of impacts are well studied where rivers are regulated by dams, with sediment retained in the associated reservoirs although occasional flushing may be required (a frequency typically of many years). Such impacts may be managed by environmental flows or e-flows, whose restoration value has been shown in a number of research publications.

However, there has been less attention in relation to the e-flows needed at water intakes which in Alpine environments may be associated with serious sediment-related problems. Water intakes have a very smaller sediment storage capacity than dams and thus may need to be flushed of accumulated sediment more regularly. In an Alpine setting, because rates of erosion are naturally higher, sediment is flushed in 'purges' with a frequency that may even be sub-daily at certain times of the year. Purges feed the river with solid material, but as the means of transporting it, the water, is being abstracted, sediment transport capacity is reduced. In theory, this does not eliminate sediment connectivity, but rather reduces it: the sediment is still delivered, but it can only be transported for a reduced duration; and the results may be profound hydrogeomorphic and ecosystem impacts, including downstream aggradation.

In this study, we present results from a combined study of fluvial geomorphology, hydrology and ecosystem impacts of flow abstraction at water intakes. Using hydrodynamic modelling, we show that because the duration of remobilisation of purges and the peak discharge are much shorter than under natural flows, this causes the formation of a zone of sediment aggradation that moves progressively downstream as a sediment wave, leading to sedimentation rates that are greater than the speed with which the ecosystem can adjust to them. The results is a clear ecological productivity and diversity decline. However, we also show that it is very difficult to design e-flows that can counter this process, because whilst sediment transport is a threshold-dependent non-linear transport process, in these kinds of streams, sediment transport under natural flows is almost continual during the summer months. The sediment transport capacity of the system is reduced in almost direct proportion to the volume of water abstracted, such that e-flows cannot be redesigned to manage sediment without completely undermining hydroelectric power production. This, we argue that managing the sediment regime in this kind of system needs a very different approach.