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Impact of river regulation on potential sediment mobilization and transport in an Alpine catchment

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The upper Rhône basin (upstream of Lake Geneva) has been heavily affected by human activities during the last century. The most evident impacts are related to river regulation, specifically flow impoundement, flow abstraction and channelization. In the last century and mainly since 1960, several large dams have been built along the main tributaries of the Rhône River, resulting in the water storage of a volume equal to 20% of the total annual river flow. The dams are part of hydropower systems which abstract water from streams and transfer it through complex networks (intakes, tunnels and pumping stations) to the reservoirs. Hydropower production leads to regulated flow in the Rhône: mostly an increase of winter flows, a reduction of summer flows, and a decrease of flood peaks. The sediment supply into Lake Geneva has decreased following dam construction (Loizeau & Dominik, 2000) due to the storage of sediment in upstream reservoirs, in rivers with reduced sediment transport capacity due to flow abstraction, and due to the development of sediment mining. Our hypothesis is that streamflow regulation itself has dramatically impacted the sediment transport dynamics of the system.

We investigate the impacts of flow regulation on the sediment transport regime, by analysing the effects on potential sediment transport capacity (bedload). By the use of different bedload transport formulae (Meyer-Peter Müller, Wilcock and Crowe), the potential sediment transport capacity is computed at different cross sections within the basin. Potential sediment mobility occurs when the applied bed shear stress exceeds a critical value, $\tau > \tau c$. The applied bed shear stress is computed as τ=ghS, with water depth (h) measured from rating curves. We obtain an estimate of the energy slope (S) from the analysis of the river cross section, assuming uniform flow. The critical value of bed shear stress τc is computed using empirical formulae as a function of the grain diameter (ds). To identify the grain size-dependent effects of streamflow regulation, computations are applied to different grain sizes taken from grain size distributions of river bed sediment.

The results show that flow regulation has indeed resulted in higher potential mobility of finer grain sizes during winter due to the increased flow, but not for the coarsest fractions which are mobilized only during summer high flows. Many studies of the impacts of major flow regulation have focused upon the effects of dams and flow diversions on sediment flux. In contrast, here we focus upon the effects of flow regulation on sediment transport potential downstream of a region of major flow regulation in an Alpine catchment. We show that the seasonal changes in streamflow arising from flow regulation impact upon sediment transport potential and these may be important in terms of the seasonal dynamics of sediment production (e.g. glacier erosion, landslides, rockfalls produced by heavy seasonal rainfall). In this context we also analyse suspended sediment concentration data and turbidity data at the outlet of the basin, in order to identify specific features of fine sediment production and transport processes.

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