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Assessing longitudinal bed load continuity in a large river following a century and a half of human management: the Rhône river in France

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Human management of large rivers worldwide during the second half of the XXth century has been dominated by the construction of hydropower dams. Consequently, dams have been a major driver of channel change, due to the imbalances between sediment supply and water flow caused by disruption of longitudinal sediment fluxes. The upstream and downstream impacts of large dams are well documented in the scientific literature. However, previous studies are mainly focused on the effects of individual dam and do not consider the combined effects of successive reservoirs along a river. Moreover, in many large European rivers, hydropower schemes were implemented on systems previously affected by other human interventions such as river training and gravel mining. The influence of successive dams in combination with these other influences has not been adequately considered.

The Rhône river in France represents an ideal case to study hydro-sedimentary functioning along a river corridor disrupted by a series of dams on a channel already perturbed by a long history of human regulation. The present-day Rhône River owes its geomorphic character to several major periods of human modifications carried out in the main channel over the past 150 years. The first, in the late 1900s, consisted of classic river training aimed at improving navigation. The second, starting in 1948, involved the construction of a series of canals that bypass the main channel, diverting flow to dams for hydroelectric production. Finally, gravel mining was widespread from the 1950s until the 1990s.

The overarching objective of this study is to provide a quantitative overview of present-day bedload transport capacities along the Rhône and assess the impact of different periods of management. Mean annual transport capacities were estimated by coupling a 1D hydraulic model (MAGE) with empirical bedload transport equations using grain size characteristics obtained from measurements carried out along the channel over 512 km. In a first step, transport capacities and flow competence were calculated for a range of discharges under the present-day flow regime. We compared these to transport conditions under an unimpeded flow regime representing the pre-dam hydraulics. In addition, we calculated transport capacities for characteristic grain sizes measured on gravel bars (surface and subsurface) in order to formulate hypotheses on how armouring might have contributed to the low mobilities that characterise the present-day system.

The results of the study highlight the variables controlling bed load transport on a reach-by reach basis and large-scale sediment continuity. It sheds light on the relative influences of various periods of human modification on a large river characterised by a series of successive dams superimposed on a system with a a long history of human management.