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From source to mouth: the sediment budget of the river Rhine

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The Rhine River is one of the most important waterways in Europe, but its river bed is not stable morphologically: long reaches of the river are subject to erosion or sedimentation, causing problems for navigation, infrastructure, ecology, water supply and flood safety. Commonly techniques to investigate erosion and sedimentation processes are echosoundings and sediment transport measurements. Unfortunately, these measurements fail to provide answers to essential questions such as: “Where are the sediments transported by the river coming from?”, “Where are the eroded sediments going to?” and “How are the morphological processes in the upstream and downstream parts of the Rhine basin linked to each other?” This kind of information is crucial for optimizing dredging strategies and sediment supply strategies, and can only be obtained through the construction of a sediment budget, i.e. the balance between the amount of sediment entering a study area, the amount of sediment leaving the study area and the amount of sediment stored in the study area.

The objective of this ongoing research project is to establish a sediment budget that starts at the source of the river Rhine in Switzerland and extends to its mouth in the Netherland. This implies quantification of the downstream fluxes of clay, silt, sand, gravel, cobbles and boulders through the river Rhine and identification and quantification of their sources and sinks. This is done by actualisation of existing sediment budgets, and by collection of essential, but hitherto missing data on the sediment input from tributaries and the exchange of channel sediment with floodplains and groyne fields. International cooperation is a prerequisite for success in this project.

Up to now, budget calculations have been carried out for the German Upper, Middle and Lower Rhine. These calculations show that sand transport rates increase in the downstream direction, whereas gravel transport rates decrease, implying a net erosion of sand from the river bed and a net deposition of gravel. This is remarkable because ongoing erosion of sand in a gravel-bed river leads to bed coarsening (armouring), protecting the bed against further erosion. Part of the eroded sand travels as bed-load, but most is washed away in suspension, which implies that sand transport must be considered to be supply-limited, just as the transport of silt and clay; and that sand can be much faster supplied towards the river delta than is often assumed by river managers and geologists. Abrupt changes in sediment fluxes were observed to occur in the so-called gravel-sand transition zone close to the German-Dutch border.

These preliminary calculations illustrate that sediment budget analysis does provide new insights into the Rhine system. In future more insight into the sedimentary coupling of the several Rhine reaches, as well as a better understanding of the long-term (climate change) and short-term (floods) river development are expected. Catchment-scale sediment budgets, such as the one aimed at in this study, also fulfil the requirements of recent legislation (e.g. the EU Water Framework Directive) which prescribes a catchment-scale analysis of hydrology, river morphology and ecology.