Moving Sediment Management Forward

River basin case studies

The Rhine

The river Rhine originates in the Swiss Alps, reaches the North Sea in the Netherlands and is the most abundant river in terms of river flow to the North Sea. The Rhine catchment area is distributed between nine countries (Switzerland, Austria, Germany, Netherlands, Liechtenstein, France, Belgium, Italy and Luxembourg) . More than half of the catchment area belongs to Germany. Switzerland, France and The Netherlands have nearly the same shares in the catchment. At 1,230 km, the Rhine is the sixth largest river in terms of length and as a shipping route it is one of the busiest in the world. More than 58 million people live in the catchment area. Some areas are very densely populated: relevant cities in the basin are Basel, Zürich and Bern (CH), Mulhouse, Strasbourg (F), Ludwigshafen, Cologne, Düsseldorf (D), Arnhem, Nijmegen and the ports of Amsterdam and Rotterdam (NL).

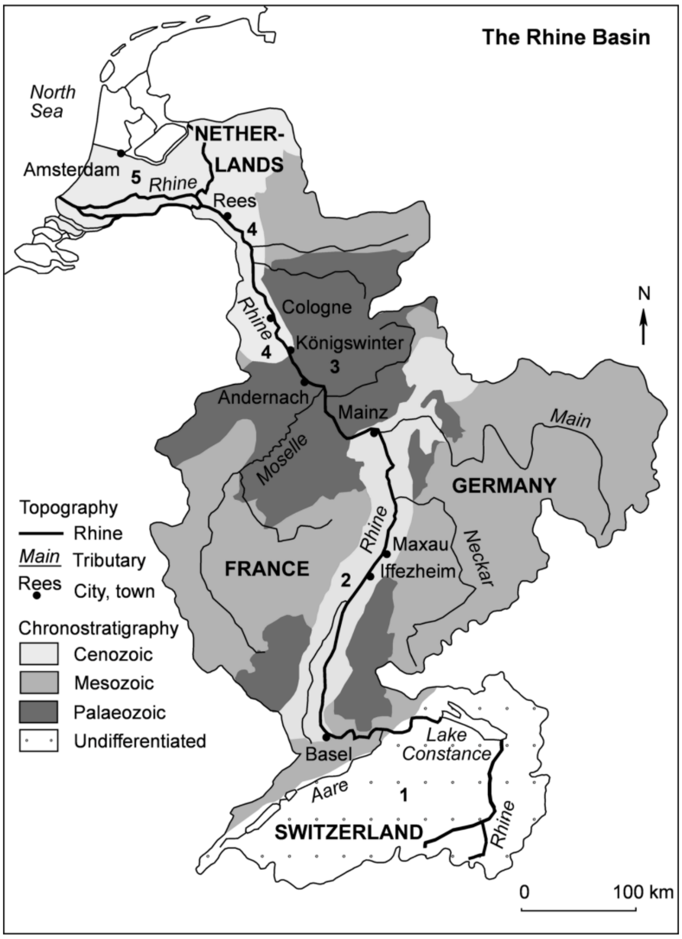

Fig. 1: Topography and geology of the Rhine basin (Frings et al, in prep, modified from CHR, 1976). Major tectonic units: 1. Alps with Molasse, 2. Upper Rhine Graben, 3. Rhenish Massif, 4. Lower Rhine Embayment, 5. North Sea Basin[1].

The Rhine has been subject to pollution from industrial activities over many decades (e.g. hexachlorobenzene (HCB) discharge with waste water in 1970-1980). Local contamination also causes problems in the aquatic environment in many tributaries (e.g. the rivers Neckar, Main and Ruhr).

For most of its length up to the ocean - including the branches Waal, Ijssel and Lower Rhine - the Rhine is considered as heavily modified. Regulation works were necessary to protect the population from the harmful effects of floods and to realize a water management regime that optimizes water use. Some of the most important measures have been: bed fixation, river-bend cut-offs to increase discharge capacity, dyke building to protect against flooding, and expansion or stabilizing works in shipping channels (groynes, bank and bed fixations, short-cuts, widening and dredging of the channel). Other complex construction works include weirs, large canals, diversions of water courses and impounding reservoirs.

Besides revenues as mentioned above the measures for regulation also had negative effects:

- Deterioration of aquatic ecology. These constructions have led to the disappearance of the gradual, shallow water transitions between land and the river, and fish migration has been affected by obstructions which have also led to a decline of habitats for fish, macro fauna and water plants.
- Degradation of the river bed. Regulation of the river often implies a narrowing of the channel leading to an increase in flow velocities and rates of bed erosion. A second cause is a shortage of sediment due to: sand extraction in the past from dredging for navigation; and a reduction in inputs of sediment from upstream.
- Increase of flood levels. Confinement of the river bed by the construction of dikes leads to higher flood levels.

In order to be prepared for more extreme river discharges in the future due to climate change, programmes to reinforce dikes are continuing, but there are limits in heightening river dikes. In case that a flood occurs the impacts will be larger. An effective approach to reduce high water levels is providing more space for water, where this is feasible. The Dutch Room for the River programme is in full progress. Examples of measures are deepening or widening of riverbeds, construction of secondary channels, relocation of dikes inland and lowering of groynes. Dredging and dredged material management is a crucial aspect for realisation of the programme. Nearly all excavated sediments and soils have been used as a construction material and for ecological enhancement.

Sediment balance

The Rhine covers five geological zones (Fig. 1). Its discharge regime is partly snow-melt and partly rain dominated. Due to impounding in the upper course and the large tributaries, the sediment flow of the main river has been drastically disturbed.

It is obvious from Figure 2 that:

- the first substantial input of sediment into the system via the suspended load is made by the Aare River,
- part of the suspended load is lost in the impoundment chain of the Upper Rhine and,
- the most important input comes from the River Moselle (Fig.2).

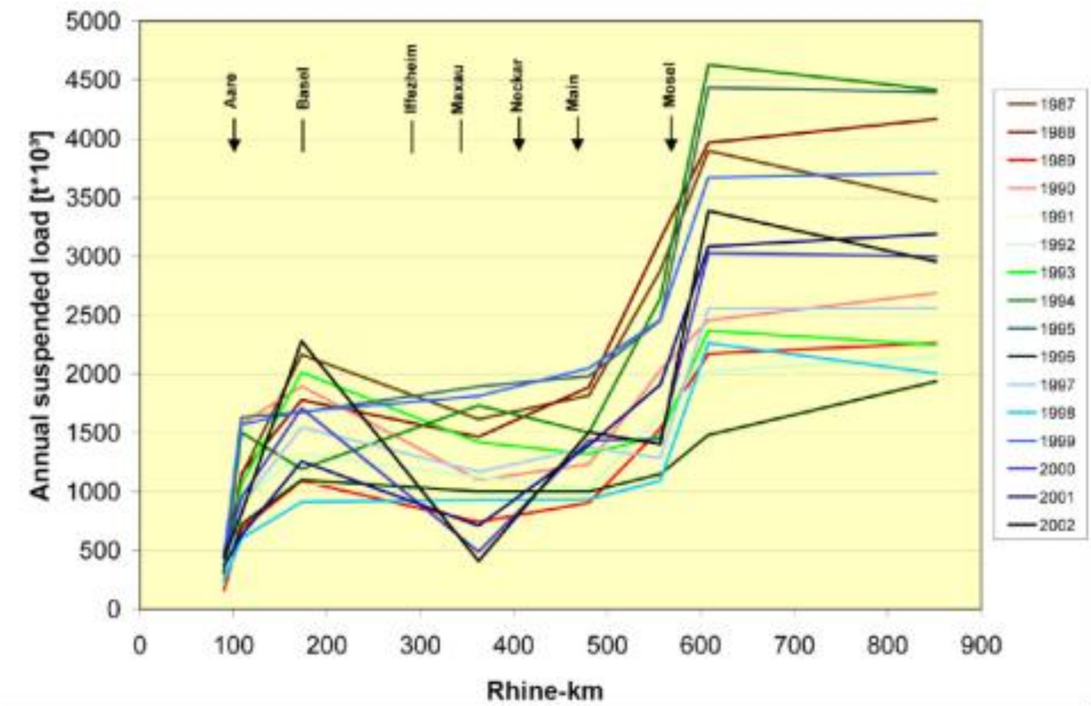

Fig. 2: Longitudinal section of the annual suspended load along the River Rhine[2]

In the impounded section there is little net transport of coarser grain size fractions. The free-flowing section of the river is characterized by a severe bed load deficit leading to bed degradation and falling water levels. This bed degradation represents a major fraction of the sediment in the overall sediment budget (Fig. 3).

Negative consequences of this fall in water levels also extend to ecological damage in the flood plains, to navigation problems, and to economic disadvantages for water management and agriculture.

To reduce bed degradation, bed load management measures need to be combined with conventional river training measures. This involves balancing the bed load budget of the river by artificial bed load supply as well as by dredging and re-distributing bed sediment. The amount of material and its grain size distribution is mainly dependent on the transport capacity of the reach to be stabilized and the grain size of the natural bed load there.

To date, a sediment budget analysis has been carried out for the German Lower Rhine, a 225 km long reach of the Rhine (area 4 in Fig. 1), focusing on gravel and sand. Echo-soundings indicate an average bed degradation of 3 mm annually between 1991 and 2010. Sediment sources are the sediment supply from upstream and the artificial feeding of sediment (mostly gravel) by river managers to reduce bed degradation. Coarse sediment inputs by tributaries and bank erosion are assumed to be negligible. Sediment sinks include net dredging activities, abrasion and the sediment output to the downstream area. Although no data on floodplain deposition exist, a significant deposition of sand on the floodplains and in the groyne fields has to be assumed in order to close the budget (Fig. 3).

The causes of bed degradation in the study area include historic river training works, an insufficient sediment supply from upstream and subsurface sediments consisting of fine Tertiary sand. The erosion of sand leads to bed coarsening or armouring, which is likely to reduce erosion rates in future. The sediment budget analysis shows that although the Rhine is a gravel bed river, sand is the dominant morphological agent. This implies a high morphological process rate. The analysis also shows that the sediment exchange between the river bed, floodplains and groyne fields - which is usually neglected by river managers - is highly relevant. Such budget analyses provide new insights into the Rhine system.

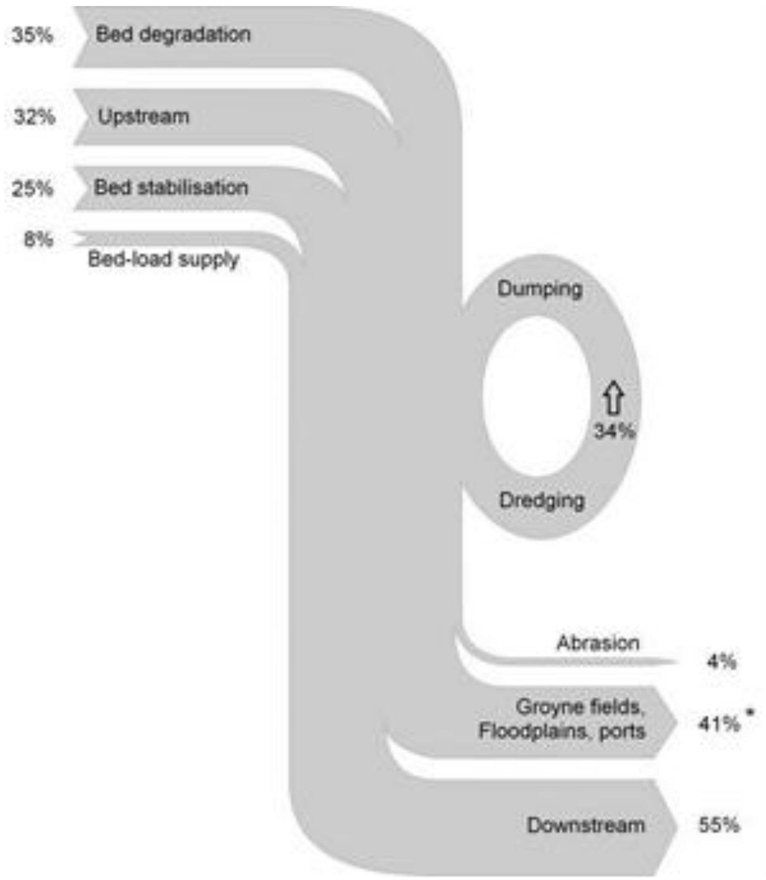

Fig. 3: Sediment budget for gravel and sand for the studied part of the Rhine (the German Lower Rhine) for the Period 1991-2010. 100% equals 1.30 Mt/a.[1]

In future, more insight into the relationships between different Rhine reaches, as well as a better understanding of the long-term (climate change) and short-term (floods) river development are expected.

Sediment quality - Addressing the challenges with respect to the WFD

Fine-grained sediments are deposited in the impounded section of the Upper Rhine. To maintain high flood discharge capacity and to ensure the security of the dykes, these sediments have to be removed from time to time. Dredging and disposal activities are problematic however, because in places the sediments are contaminated by HCB. Potential remobilization of highly contaminated sediments due to flood events or dredging activities could increase and influence the environment downstream with high risk. The development of strategies (to remove contaminated sediments, to reduce dredging of sediments and to dispose them in an ecologically friendly and economically acceptable manner) is an important sediment management task for the Rhine waterway. The sediment management plan of the International Commission for the Protection of the Rhine, which was launched in 2009, identifies 16 areas as risk Type A (where considerable contamination (e.g. due to HCB) and large amounts of sediments liable to remobilisation coincide) and 18 areas of concern (sediment amounts of more than 1000 m^3 with values which exceed national criteria for chemical pollution even though internationally determined criteria or not exceeded).

All these areas need to be examined with respect to possible rehabilitation measures. These measures must balance the interests of navigation and ecology while guaranteeing safety against flooding and achieving the objectives of the EU WFD. Measures include improving the aquatic ecology by creating habitats for fish, water plants and macro fauna as well as removing contaminated sediments as a source of risk for the environment. The chemical and ecological targets of the WFD have to be achieved in two phases ending in 2015 and 2017.

The Rhine case study describes some of the links between sediment quantity and hydro morphological modifications as well as highlighting some of the issues associated with sediment quality and remobilisation. The case study

- stresses the importance of understanding cause-effect relationships in a situation where a lack of significant new sediment input compounds the problems associated with historic physical modifications
- illustrates how dredging and disposal can be especially challenging when sediments in some parts of the River Basin have significant levels of contamination
- demonstrates how, to be effective, measures will need to balance multiple interests (navigation, ecology and flood risk management) whilst also meeting WFD objectives

Literature

[1] Frings, R. et al., (2012), From Source to mouth: the sediment budget of the river Rhine, Poster-presentation; EGU General Assembly 2012, 22-27 April 2012, Vienna

[2] KHR (2009), Erosion, Transport and Deposition of Sediment - Case Study Rhine - Report no II-20

Hakstege, A.L. (2013) Dredging for flood management and navigation in river systems: opportunities and dilemmas. Proceedings WODCON, 2013, Brussels

Links

International Commission for the Protection of the Rhine (ICPR) - www.iksr.org

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