Estimating the amount of erodible contaminated sediments within the groyne fields of the Elbe River

Hillebrand G., P. Heininger, T. Krämer, C. Möhlenkamp, J. Pelzer, D. Schwandt and E. Claus

Federal Institute of Hydrology (BfG), Am Mainzer Tor 1
56068 Koblenz, Germany
E-mail: hillebrand@bafg.de

The International Commission for the Protection of the Elbe River (ICPER) aims at establishing a sediment management concept both in terms of quantity and quality. To this aim, key processes of sediment transport and budget had to be defined under regular and under extreme conditions. Sediment budgets in regulated rivers are strongly influenced by lateral exchange processes. This study focused on the function of groyne fields acting as source and sink for cohesive sediments and particle-bound contaminants along the Elbe River. One specific aim was to assess the amount of erodible contaminated sediments within the groyne fields as basis for establishing a sediment management plan.

The contamination level of fine sediments within the Elbe catchment is generally high and following a precautionary principle, all fine-grained material in the Elbe groyne fields should be considered potentially contaminated, even though there are known local hot spots, and patterns of contaminants differ regionally resulting from tributaries and smaller sub-basins.

The German inland Elbe River has about 6600 groyne fields. In order to assess the number of groyne fields with deposits of fine sediments, about 270 groyne fields were probed in several field campaigns in 2010 and 2011 by sounding rods, push core samplers and Van Veen grabs along a river reach of about 450 kilometres. The bed sediments of the groyne fields were subjectively classified on site as 'gravel', 'sand' or 'mud'. The total amount of mud per investigated groyne field was categorized as 'high', 'low' or 'none'. Mud content of 73 groyne fields was considered high, low in 59, no mud was found in 128 groyne fields.

To enable extrapolation of these classifications, a number of variables, deemed to influence fine sediment deposition in groyne fields, were determined for all groyne fields following a literature research. These variables included parameters describing groyne field geometry, river alignment, grain size distribution of the main channel and other characteristics of the near and far field of the groyne fields. For all Elbe groyne fields, the values of these variables were determined. Using uni- and multivariate statistics, they were checked for correlation to observed mud contents. As an example, strong interdependency was found for groyne fields with high mud content between conventional groyne structures when they were connected to backwaters and exhibited longitudinal ridges within the groyne field (cf. Fig. 1). Observed mud contents were best reproduced (correct prediction of 2 out of 3 groyne fields in the categories 'high', 'low' and 'no' mud content) using a multinomial logistic regression with the following variables: river kilometre index, alignment of the groyne field (interior/exterior bank), aspect ratio, wetted area at low water, connection to backwater areas, existence of ridges within the groyne field or existence of incised groynes.

The multinomial logistic regression model was then used to extrapolate mud content to all groyne fields. 10% of all groyne fields were classified by the statistical model as having a high mud content, 4% as low mud content and 83% were classified as mud-free. 3% could not be classified due to missing values. From the results of the field campaigns and additional investigations of sedimentological and chemical properties of the sediments in muddy groyne fields, we estimate that the depth of fine sediments which are regularly mobilized and reworked is of the order of 0.5m. Using two thirds of the wetted area during low water conditions as an estimate for the size of the groyne fields and the area on which fine sediments may be found, the overall amount of fine sediments in the groyne fields of the River Elbe is of the order of 1 million m³.

In order to prioritize potential remediation measures, groups of contaminated groyne fields in close proximity to each other have to be determined, as remediation of single groyne fields is not feasible. From the extrapolated classification, it was estimated that 10 groups of 20 or more such groyne fields in close proximity can be identified along the whole river reach. Remediation of those groyne fields is estimated to remove about 30% of the total volume of erodible contaminated sediments within the groyne fields of the Elbe.
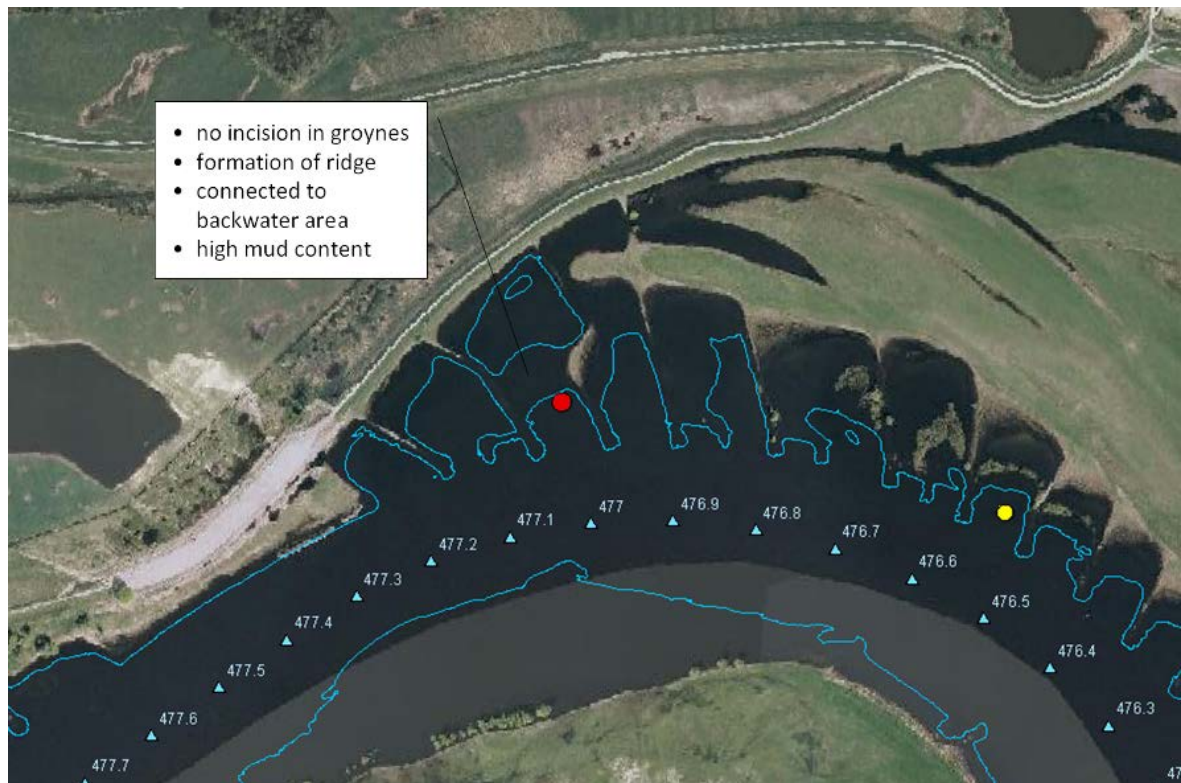
Fig. 1. Illustrative example of groyne field with high mud content (groyne field at km 477.0). The light-coloured dot within the groyne field at km 476.55 indicates a groyne field with low observed mud content. The wetted area during low water conditions is depicted by the light-coloured line.