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Monitoring and Modeling of Sediment Transport Velocities

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While there are still some uncertainties about the magnitude of sediment transport in rivers, the velocity of the same is even less understood. Tracer experiments are one practical method of gathering information about the transport velocities. At the Upper Rhine downstream of Iffezheim a field experiment using 28 000 tons of granite as a petrographic tracer was performed during 1996 to 2001. The transport was quantified during six sampling campaigns using a diving bell. The sampled river stretch gradually increased during the experiment and comprised more than 60 km at the last campaign. The spacing of sampling cross-sections also increased with time from about 300 m to 7 km.

The mean transport velocities of the smallest fractions 4/8 mm and 8/16 mm was found to be equal, with a value of about 5 km/a. Larger fractions were significantly slower, with the largest fraction (45/63 mm) moving at about 2 km/a. However, two questions still remained after the field test: How large is the influence of single flood events on the average velocities? Answering this in the field would have meant to sample shortly before and after floods, which is not feasible. The other questions is about the long-term continuation of the observed tracer velocities beyond the 5 years of the experiment.

Therefore the field experiment was modeled using a 1-D model. This model comprises the free-flowing part of the German Rhine and its tributaries. It has been calibrated to reproduce the observed bed level changes and transport rates of the 1992-2004 period, but not in the view of observed transport velocities. These, however, can be shown to be well reproduced by the model. Moreover, the remaining questions can be answered using the numerical results:
1. The advection of the tracer fractions is largely influenced by single floods. Not all floods, however, have the same effect. A 1-year flood just 6 month after the tracer placement strongly increased the tracer velocities, while a flood with a return period between 10 and 50 years which occurred nearly 3 years after the beginning of the experiment showed only a minor increase. The higher exposure of the tracer material to the flow at the beginning of the experiment can explain this observation.
2. The extrapolation of the field experiment in time shows that the tracer velocities decrease over time in the long-term view. This is mainly caused by the decreasing slope of the concerned river stretch, which leads to a gradual deposition of coarse material.

Combining the results of the field experiment with the numerical simulation, the velocities and transport distances of grains in the Upper Rhine downstream of Iffezheim can be quantified. This is of high importance for the Iffezheim bed-load nourishment site, which is employed to stabilize the bed level downstream of the lowest barrage at the Rhine river.