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Adapted waterways engineering towards varied hydrological conditions due to climate changes

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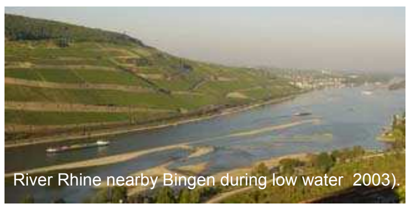
Adapted Waterways Engineering Towards Varied Hydrological Conditions due to Climate Changes

S. Wurms, P.M. Schröder, R.B. Weichert, L. Hahne


River Rhine nearby Bingen during low water 2003).

Due to the apparent climate change, the probability of extreme hydrological events, droughts as well as flood events, might be increased. In consequence, lowered water levels during droughts would result in a reduction of maximum transportation capacity of inland vessels and in the constriction of navigable fairway width. Thus, the efficiency of inland shipping would decrease as well as the safety and reliability of navigation.

Using the example of the River Rhine from Mainz to St. Goar, river training measures are analysed that focus on the maintenance of required minimum flow depths in free flowing waterways under extreme low water conditions. Especially, the potential of a width-reduced, deepened “Depth stepped fairway”, in terms of gaining flow depth during droughts is investigated.

1. Area under investigation: Rhine-km 493.0-557.5

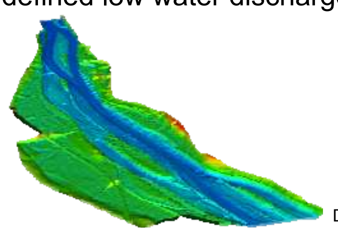
The chosen stretch from Mainz to St.Goar contains the least guaranteed fairway depth within the whole free flowing Rhine, which is only 1.90 m below GlW_{2002} between Rhine-km 508.0 and 557.0. GlW_{2002} is the water level corresponding to GlQ_{2002}, which is the discharge, that just falls below a gauge on 10 or 20 ice-free days per year in a long-time average.

Area under investigation (Rhine-km 493.0 – 557.5)

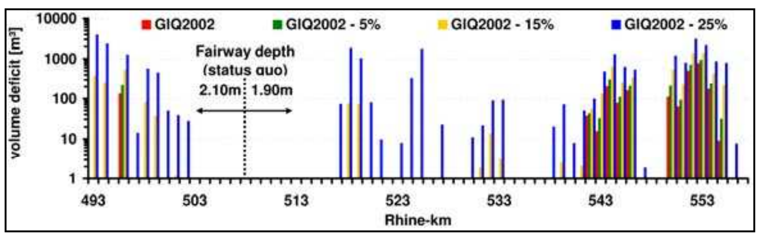
2. Identification of hydraulic bottlenecks

Projections of future discharge conditions contain uncertainties due to the climate scenarios chosen and the various possible combinations of climate and hydrological models.

Thus, potential future hydraulic bottlenecks are identified from numerical simulations with TELEMAC-2D (EdF) for a bandwidth of extreme low water discharges between the defined low water discharge GlQ_{2002} and GlQ_{2002} – 25%.


Detail of the model topography

Considering the minimum water depths and volume deficits within the fairway it can be shown that the present river training and maintenance strategies have to be adapted to guarantee minimum flow depths within the fairway in case of a reduced discharge level.



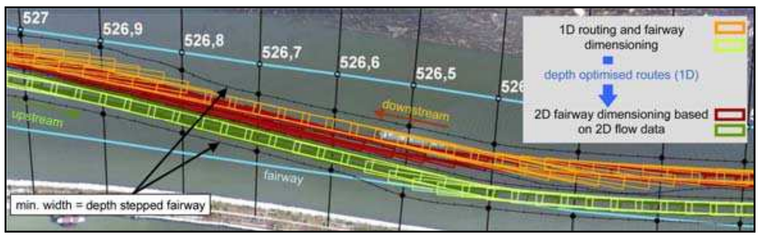
Volume deficits per kilometre within the fairway (GlQ2002 and reduced low water discharges)

3. Adaptation strategy "Depth stepped fairway"

With the objective of gaining flow depth during reduced low water conditions, a width reduced “Depth stepped fairway”, deepened to 2.10 m related to the water level corresponding to GlQ_{2002} – 25% is implemented into the model.

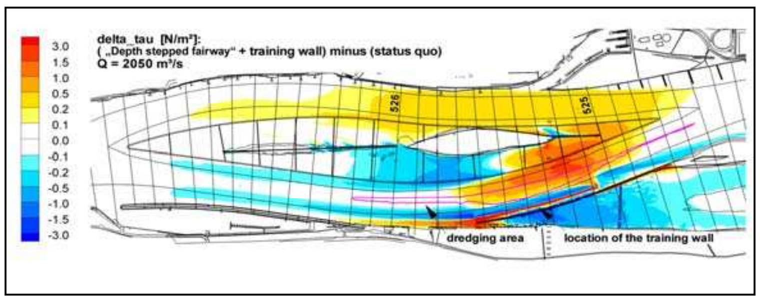
The minimum widths of the “Depth stepped fairway” result from the addition of both swept paths of upstream and downstream going one-row, one-column push tow units and common safety distances (outer: 10 m; inner: 5 m each ship).

Swept paths are determined by means of the standard BAW model PeTra1D and the higher level tool PeTra2D, which considers e.g. the explicit calculation of cross current impacts, reduced rudder forces at low under keel clearance and more realistic steering commands from an autopilot.



Swept areas from PeTra1D and PeTra2D calculations of vessels driving upstream and downstream and additional safety distances, resulting in the "Depth stepped fairway".

Implementing the "Depth stepped fairway" into the numerical model results in local decreases of calculated water levels less than 0.01 m at mean discharge. Within the areas where the bed level had to be dredged within the model, reductions of the bed shear stresses occur. As a consequence, tendencies towards aggradations rise within these areas. Additional regulation structures were designed to compensate decreased bed shear stresses in relevant locations on the basis of the hydrodynamic model. The regulation structures have to be optimised in the morphologically sense in a further step to yield a dynamic equilibrium of the river bed and to keep up the implemented "Depth stepped fairway".



Increase of bed shear stress within implementation areas of the “Depth stepped fairway” at effective discharge due to a training wall located on the left-hand side of the fairway.

4. Conclusions

Depending on the level of a possible reduction of low water discharges due to climate changes, the present river training and maintenance strategies have to be adapted to be able to guarantee required flow depths within the fairway in the future. From a technical point of view, a width reduced, deepened "Depth stepped fairway“ is a promising measure for the purpose of gaining flow depth.

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