Quick Scan Sustainable river bed management

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Introduction

At this moment, bed erosion is one of the most serious issues that causes problems to several river functions in both Rhine and Meuse River, mainly during low discharge. Besides its negative impact on navigability, it has also severe consequences for biodiversity and ecosystems in the floodplains, due to lower ground water levels. Furthermore it endangers the stability of sluices and bridges and cables and pipelines might get exposed. The intake from fresh water during low flows may be interrupted and finally, the entrance to harbours (which is often provided by sills) becomes more difficult. The erosion is mainly induced by human interferences in the last 200 years. River-normalisation works such as large scale construction of groynes, bend cut-offs and large scale extraction of sediment are thought to be the most important causes. The morphological response of incision is still ongoing. Within the programme Integrated River Management (IRM) the Ministry of Infrastructure and Water Management is developing policy for sustainable management of the Rhine and Meuse river bed for the year 2050. Witteveen+Bos in cooperation with HKV have been assigned by the Ministry of Infrastructure & Waterworks to carry out a Quick Scan on de impact of different river bed levels on the river functions. The project sketches the playing field for possible riverbed level options, the measures required to achieve these options, the impact thereof on the river functions, the feasibility and investment and maintenance costs.

Methodology

General

The project consists of five steps:

1. Data collection and analysis of bed level trends, climate change and discharge distribution at the bifurcation points of the Rhine;
2. Definition of four riverbed level options for riverbed management, ranging from "Do nothing" to maintain current level to restoring a historical level i.e. 10 and 20 years ago;
3. Impact assessment of the river bed level options on the river functions flood risk, navigation, nature, fresh water supply, as well as for cables and pipelines, and infrastructure and MCA;
4. Determine the dimensions of possible soft and hard measures capable of mitigating the ongoing erosion and achieving the objectives of the bed level option. For this an analytical method was develop for predicting the equilibrium morphological impact of measures;
5. Selection and assessment of realistic combinations of measures, including MCA

In this abstract we focus on the analytical method and application of the approach to the Boven-Waal (step 4). The Boven-Waal is the reach in the Rhine River suffering most of the ongoing erosion of the river bed.

Analytical model

We developed a model to assess the morphological impact of widening measures. The model calculates the change in equilibrium bed level due to river widening. The calculated parameters are the equilibrium change in bed level height and bed level gradient, according to de Vriend (2005). Using the method in an inverse mode enables the assessment of the dimensions of widening measures for achieving the required increase of the equilibrium bed level.

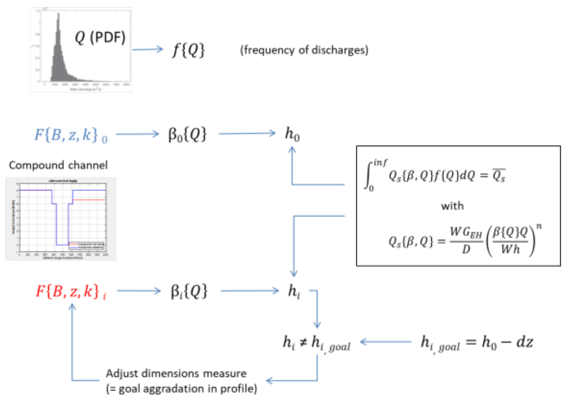

Figure 1. Flow diagram for the inverse analytical method

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Following assumptions are underlying the model:

- A compound cross-section divided into three parts: main channel, groyne field, and floodplain for (i) the reference case and (ii) situation with the intervention (Figure 2).

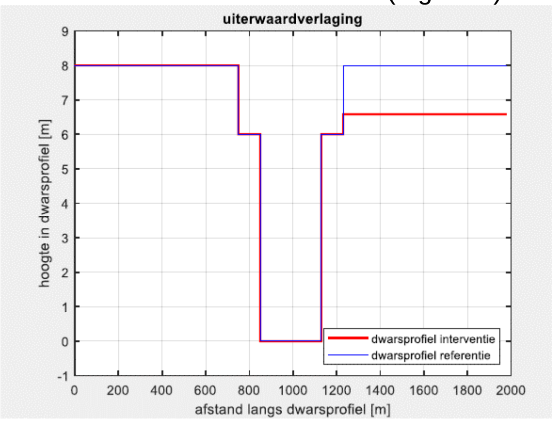

Figure 2. Example measure flood plain lowering

- The model uses the dominant or channel forming discharge Qdom. This constant discharge results in the same equilibrium depth and bed slope as the hydrograph repeated annually (e.g., De Vries 1974, Jansen et al 1979, Blom et al 2017).

$$Q_{dom} = \left[\int_0^\infty \beta(Q)\, Q^{n/A} f(Q)\, dQ\right]^{A/n} \quad (1)$$

β(Q) describes the fraction of total flow through the main channel. *n/A*=5/1 in case Engelund Hansen (n=5) is used and the equilibrium water depth is considered and 5/3 when considering the equilibrium slope.

- Sediment transport is calculated using the Engelund-Hansen (EH) or Meyer-Peter-Muller (MPM) formulas depending on the grain size of the specific river section.
- Downstream water level is unchanged and measure is applied for a long reach.
- Only sediment transport in main channel.

The model requires the following input:

- Time series of measured discharges
- Yearly average sediment load
- For all river sections:
    - Cross-sectional profile including main channel, groyne section and floodplain.
    - Hydraulic roughness
    - Grain size D50
    - Transport formula
    - Longitudinal slope
    - Length of section

With the model the equilibrium morphological impact of floodplain lowering, secondary channels, longitudinal dams, groyne lowering and river bed widening is calculated.

Application of the analytical method to the Boven-Waal

For the Boven-Waal the ongoing bed erosion is the main concern for the river manager. In the Quick Scan we assume river bed lowering of 60 cm in the year 2050. To counteract this erosion the impact of nourishments as well as widening measures large scale groyne lowering and a string of secondary channels were investigated. The maximum feasible groyne lowering of 1.5 m appears to be insufficient for solving the large erosion. It will cause an aggradation of 'only' 20 cm. Additional nourishments will thus be required. With a string of secondary channels having a cross-section of 3 m deep and 150 m wide, an equilibrium aggradation of 60 cm can be achieved. However, as is the case for groyne lowering, additional nourishments will be required as the aggradation needs time to develop (morphological time scale). Until the moment that the equilibrium bed level is reached, nourishments are required so as to reach the desired bed level. For assessing the volumes and costs of nourishments and sediment management (dredging and dumping) an additional analytical method was developed.
Finally the impacts of the measures for achieving the bed level options were qualitatively assessed for the river functions Flood risk, Navigation, Nature, Fresh water supply, as well as on the themes feasibility, flexibility, sustainability and manageability.

Conclusion

The approach provides valuable information on ongoing trends in the bed level and the impact on the river functions for different bed levels. This information can be used to define policy options on if, where and which river bed levels are interesting and feasible to manage. The analytical models gives insight in the dimensions of (combinations of) measures to achieve and maintain different river bed levels.

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