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Bottom: IJssel river from Zwolle. J.S. Huismans (2018)

Flood patterns in the Old IJssel Valley

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Introduction

To protect the Dutch hinterland from flooding, safety levels for flood defences have been established. These safety levels are based on a statistical analysis of the return period of discharges. Throughout Europe, flood frequency analyses are generally used to estimate discharges associated with different return periods (Benito et al., 2004).

In the Netherlands, it is assumed that approximately 1/3 of the design discharge at Lobith flows towards the river Waal, 2/9 towards the river Nederrijn and 1/9 towards the river IJssel. This discharge partitioning is used to determine the design discharges and hence flood protection measures along the Dutch river Rhine branches. Until 2015, a design discharge of 16.000 m^3/s at Lobith, corresponding with a return time of 1:1250 years, was the standard. After the introduction of a system of new safety standards (Dutch Ministry of Infrastructure and the Environment & Ministry of Economic Affairs, 2014) the concept of a single design discharge has changed and multiple design discharges should be taken into account, corresponding to the multiple downstream safety levels. During the determination of the design discharges, the consequences of flow patterns caused by dike breaches or overtopping are not included. This is an important prerequisite which seems obvious from protection point of view (dike breaches are unwanted and need to be provided) However as a result of the low lying area of the Old IJssel Valley, flow patterns in the embanked areas may evolve in case of a dike breach which can consequently change the discharge portioning along the Dutch river branches significantly (Figure 1). This may lead to substantially more discharge to one of the branches (and obviously to less discharge to another branch) and hence to increase (decrease) of the potential risks.

Preliminary runs with a numerical model of the found that water can potentially flow around the higher grounds of the Montferland towards the Rijnstrangen area (Figure 1). For this particular test run, the discharge wave near the city of Emmerich decreased from 11,984 to 9,531 m^3/s. The flow pattern through the Old IJssel Valley was predominant such that almost all water that left the river Rhine flowed towards the river IJssel, resulting in great inundations along this river branch.

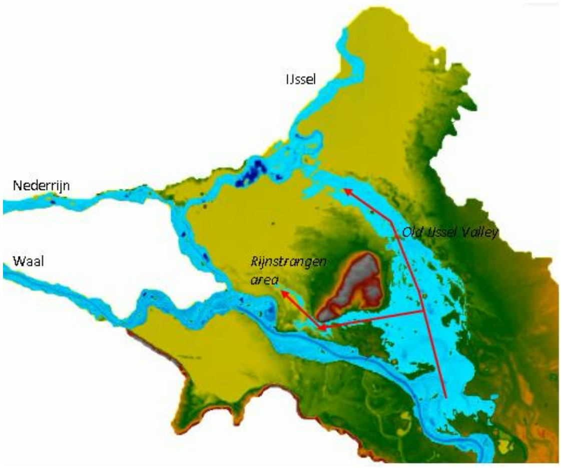

Figure 1. Flow patterns through the Old IJssel Valley as a result of a dike breach near the city of Emmerich (DE)

Method

In this study, the effect of multiple dike breaches along the river Rhine upstream of Lobith on discharge partitioning is investigated. Particularly, the maximum discharge at the river IJssel in case of dike breaches will be compared with the design discharges for which the dimensions of the flood protection measures were determined.

A coupled1D-2D model constructed in HEC-RAS will be used to perform the hydraulic simulation runs. In this model, the summer bed and its floodplains are schematized with one dimensional profiles whereas the embanked areas are discretized by a two dimensional grid (Figure 2). Both the 1D as 2D profiles are based on a high-resolution geographical database. A coupling between the 1D profiles and 2D grid cells is made with the use of a lateral structure, corresponding with the dimensions of the dikes in this study. A coupled 1D-2D model is preferred above a fully 2D model because of the relatively short

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computation time while model accuracy is still sufficient. Since computation time is relatively low, it is possible to simulate many scenarios of potential dike breaches.

A Monte Carlo analysis framework is set up in which the location and dimensions of the dike breach are randomly modelled. Typical properties of a dike breach that are included in the analysis are dike breach duration, total dike breach width and time of dike breach. Up till now, it is commonly assumed that a dike breach occurs at maximum water depth or when a water depth threshold is exceeded for a certain period of time. We will randomly sample the starting time of the dike breach such that a broad spectrum of potential scenarios is included in the analysis.

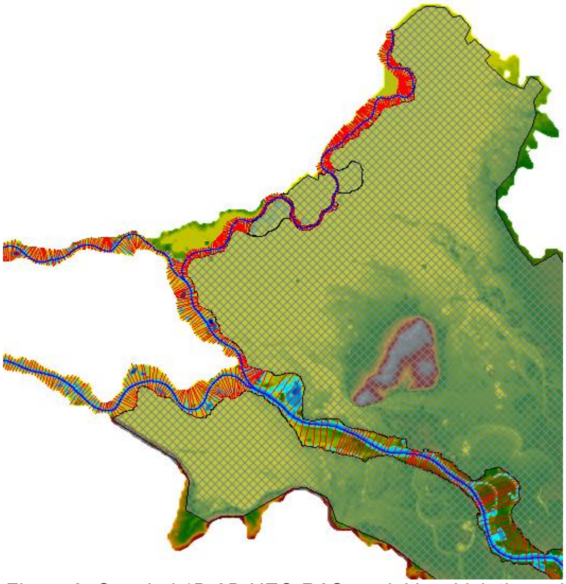

Figure 2. Coupled 1D-2D HEC-RAS model in which the red lines represent the 1D cross sections and the embanked areas are discretized by a 2D grid

Results

The Monte Carlo analysis gives insight in the sensitivity of dike breach location and dimensions on the maximum discharge at the river IJssel as a result of overland flow through the Old IJssel Valley. With this information it is possible to determine which location and under which conditions a dike breach in Germany will result in major changes of the discharge portioning along the Dutch river Rhine branches. In particular, the runs give insight in the most critical dike breach locations for which large areas will be inundated and great problems along the river IJssel evolve. Also the sensitivity of dike breach timing (e.g. at maximum water level, when certain water level threshold is exceeded) on inundation extend can be evaluated.

Besides, the model runs will show which embanked areas are flood prone in case of dike breaches. This information can be highly valuable for future design of flood measures and evacuation plans.

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