Building on piles in floodplains

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Introduction
Last year in the Netherlands 15 locations were allocated along the Rhine branches where – under strong restrictions - it was allowed to build in floodplains. Building in floodplains may lead to a water level rise during floods and moreover, the river bed morphology may be disturbed (erosion/sedimentation). A potential building location on a floodplain of the river IJssel near Deventer (Wilpische Klei) is used as a fictitious case to investigate these processes (Fig. 1).

Method
Hydraulic and morphological calculations are carried out with a simple analytical model and with a 1D SOBEK model. Hydraulic calculations are also carried out with a 2D WAQUA model. The flow obstruction of the piles in the floodplain is represented as an additional roughness in the floodplain. The change in roughness is calculated using a force balance taking into account the gravity force, the bottom friction and the drag force of the pile elements on the water. The following expression for the representative Chezy coefficient, Cr, is applied:

\[
C_r = \frac{1}{\left[ C_0 + \left( \frac{C_D D h N}{2gA_p} \right) \right]^{\frac{1}{2}}}
\]  

in which \(C_0\) is the Chezy coefficient of the floodplain bed roughness (without piles) estimated with the White-Colebrook relation based on Nikuradse roughness, \(k_n\), \(N\) the number of piles, \(D\) the diameter of the piles (0.5 m), \(h\) the water depth, \(g\) the acceleration of gravity, \(A_p\) the area in which piles are placed, and \(C_D\) the drag coefficient (Van Velzen et al., 2003; Huthoff et al., 2006).

Results
In the building region, the river shows a maximum water level rise of several centimetres during the design discharge (Fig. 2; Ribberink and Hulscher, 2003). The maximum water level rise calculated with the simple analytical model is about 3.0 cm and about 3.2 cm calculated with the 1D model. 2D model calculations show a maximum water level rise of 1.3 cm in the middle of the river to 2.8 cm in the floodplain.

The influence of a number of parameters such as the number of piles, the diameter of the piles, the roughness between the piles and the drag coefficient of the piles (Fox and McDonald, 1994) on the water level rise is investigated using the analytical model and SOBEK (Fig. 3). The calculated water level rise ranges between 1 and 5 cm.

Simple analytical calculations show that, due to a shift of the river discharge from the floodplain...
to the main channel in the region where the buildings are planned, the main channel shows a bed level erosion of ca. ½ cm per day during a flood (Ribberink, 2004). Upstream sedimentation due to backwater effects is not significant.

SOBEK computations show that the riverbed in the main channel recovers from this erosion during the longer dry periods between the floods when the flow is confined again to the main channel. In the long term there is erosion as well as sedimentation of the river bed along the river.

Model comparison
In general, the hydraulic results obtained with the simple analytical model and SOBEK show a good correspondence. The water level rise as computed with the 2D WAQUA model is slightly smaller. This difference is probably due to 2D flow effects, which are very relevant in the river area considered and cannot be represented in the other 1D approaches. Further investigations with WAQAU are required.

The morphological calculations, as carried out with the analytical model and SOBEK, should be considered as indicative. The SOBEK computations show a dominant influence of long sand waves which interfere with the morphological effects caused by the floodplain intervention. Further investigation with a 2D morphological model is recommended for more reliable predictions.

Recommendation
Although the present feasibility study provides a good first impression of the possible hydraulic-morphological impacts of building on piles in floodplains, it is recommended to investigate other locations with different riverbed slopes and floodplain levels / widths in order to get more insight in the effects of piles in floodplains.

References