Can floodplain excavation help to mitigate bed erosion?

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Introduction

In October 2018, the water level in the Dutch Rhine reached an all time low-record. At Lobith, a water level of 6.50 m.+MSL was measured, which was approximately 3.5 meters lower than the average water level and more than 10 meters lower than the all-time high water level (16.93m.+MSL, recorded in 1926). This situation of low water levels lasted from May 2018 until December 2018, which is very exceptional. Due to this, shipping on the Rhine was seriously hindered. Low water levels by itself hinder navigation, but along the Waal River this hindrance was increased because ships encountered obstacles in the navigation channel: apart from natural rock formations in Germany, there are man-made training works in some of the outer bends, fixating the bed level by boulders. As a result, the bed level in the inner bend gets lower and the navigational width is increased. This so called 'fixed layer' is stable, while the surrounding stretches experience bed erosion of several cm's per year. It is kind of ironic that a measure which was intentionally meant to help navigation, now has an opposite effect.

At this moment, bed erosion is one of the most serious problems that Rijkswaterstaat (the executive organization of the Ministry of Infrastructure and Water Management) encounters. Besides its negative impact on navigability, it has also severe consequences for biodiversity and ecosystems in the floodplains due to lower ground water levels, it endangers the stability of sluices and bridges, cables and pipelines might get exposed, it interrupts the intake from fresh water during low flows and finally, the entrance to harbours (which is often provided by sills) becomes more difficult. Therefore, it is obvious that Rijkswaterstaat is interested in mitigating measures to counteract this bed erosion. As erosion and sedimentation is basically caused by an imbalance between the sediment supply and the transport capacity of the river, there are essentially two ways to counteract erosion: increase the supply (e.g. sediment nourishments) or lower the transport capacity of the river. As the transport capacity of the river is a function of the slope, width, sediment properties and flow velocity, those are the parameters that one might try to alter to decrease the transport capacity and reduce or stop the erosion (see also Lane, 1955).

The World Wide Fund for Nature (WWF) is the founding father of the Living Rivers concept, which was an important source of inspiration for the Room for the River program. Now that Room for the River is almost finished, WWF wants to further explore the Living River concept, and introduced Room for *Living* Rivers. Their vision is to create more space for climate-proof rivers, where nature can flourish and people live, work and recreate safely.. A way to do this is to reconnect the floodplains to the main river, for instance by creating a chain of side channels along long river stretches. This means that essentially, the river is widened. Hence, the same measure serves multiple goals: nature development and floodplain restoration, as well as sediment management to create a sustainable river system.

Recently, Rijkswaterstaat also adopted the concept of Integral River Management. This means that apart from creating and maintaining a safe river system, also other functions in the river system (e.g. nature, navigation, agriculture, extraction of drinking and industry water) play an essential role. That is where RWS and WWF meet and work jointly on a more sustainable river.

Method

To test the hypotheses whether large floodplain widening indeed reduces bed erosion, we use a 1D-SOBEK model of the Waal, in which we implement a 2-meter integral excavation of the floodplain. We assume that every section of the floodplain is lowered, side channels and objects within the floodplain included. Only a small zone at the toe of the dike is excluded for dike-

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stability reasons and a small levee-like structure at the boundary of the navigational channel and the floodplain is maintained, such that there is still a threshold discharge before the floodplains get inundated. As upstream hydrodynamic boundary condition, we assume a historically averaged annual regime, which we repeat every year. We assume a sediment supply from Germany such that the annual bed erosion of 2cm/a continues for the next 100 years. We model a sediment mixture with 17 sediment classes.

Results

In Figure 1, we plotted the mean bed level for the reference situation after 100 years of simulation. The bed erosion in the most upstream reach is approximately 2 meters. In downstream direction, the erosion decreases. Approximately 35-50 km downstream, there is a stretch where there is almost no erosion or sedimentation. Going further downstream, we see increased sedimentation, up to 3 m at the downstream end with respect to the initial situation. This simulation is in accordance with present erosion and sedimentation trends in the Waal River.

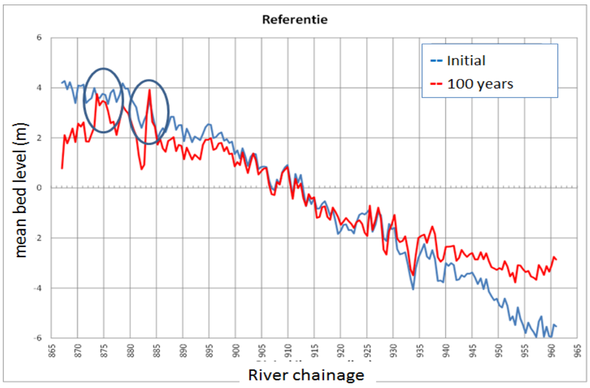

Figure 1. Mean bed level for the reference, as initial state and after 100 years. The two ellipses indicate the location of the bottom groynes and the man made fixed layer at Nijmegen

Note also that at the locations where the bed is fixed by human interventions there is no erosion (see blue ellipses in Figure 1).

We also calculated the reduction in water level for the highest discharges, which appears to be more than 2 m. at the upstream boundary. In Figure 2, we plotted the effects of the variant with respect to the reference. Note that in the most upstream part of the river stretch, it seems that the bed erosion continues at a rate which is even larger compared to the reference. This might be due to the effect that in that part, also the reduction in the flood water level is the most. Apparently, the water level is reduced to such an extent that at moderate discharges, the floodplains no longer inundate and erosion in the main channel is even increased. Further downstream, we indeed see reduction of the erosion trends. As in this variant all floodplains are lowered uniformly by 2 meters, existing irregularities in discharge distribution between main channel and floodplains may be maintained or increased, depending on the reduction in water level. Alternating local erosion and sedimentation is the result.

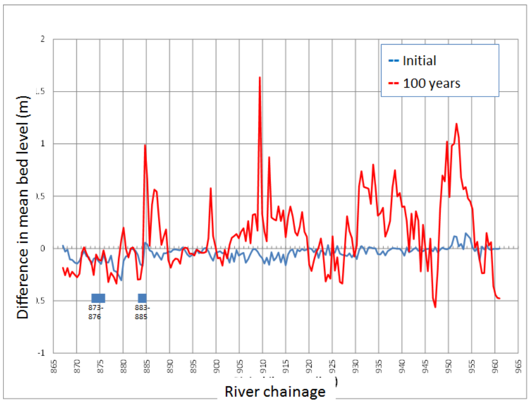

Figure 2. Difference in mean bed level between the reference and the variant. Positive values mean that there is less erosion in the variant. The two blue rectangles indicate the location of the non-erodible stretches.

Conclusion

We studied the effect of large scale floodplain excavation on the reduction of erosion in the upstream part of the Waal River. Simulations with a 1D numerical morphological model indicate that this measure indeed has the potential to reduce the erosion. However, applying the measure uniformly on the whole stretch does not give clear results. This might be due to the large reduction of flood water levels, because of which the effects of the excavation are not everywhere evenly effective. This means that the measure should be designed tailor made to have maximal effect. The results can also be used to get insight in the necessary sediment supply at the upstream boundary for stabilizing the river bed.

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