Wetland restoration impact on streamflow in the Rhine River basin.

Natural sponge effects in the German Middle Mountains

M.J. Waterloo [a], A. Gevaert [a], *A. Kersbergen* [b], S.A.W. de Roover [b], *M. Hegnauer* [c], *E. Silver* [d], *B. Roels* [e], *J.J. de Bijl* [f] *

[a] *Acacia Water, Van Hogendorpplein 4, 2805 BM Gouda, the Netherlands*
[b] *HydroLogic, Stadsring 57, 3811 HN Amersfoort*
[c] *Deltrares, Boussinesqweg 1, 2629 HV Delft*
[d] *Wetland International, Horapark 9, 6717 LZ Ede*
[e] *Wereld Natuur Fonds, Driebergseweg 10, 3708 JB Zeist*
[f] *Stroming, P.O. Box 31070, 6503 CB Nijmegen, the Netherlands*

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Introduction

In the German Middle Mountains (Mittelgebirge), historic construction of drainage networks in wetland areas along the water courses in the valley floors led to changes in the surface water flow regime. Quickflow amounts and peak flows were most likely increased as water running off the hillslopes, mainly as throughflow, could be transported in the drainage channels at a much faster rate. These changes in the uplands of the Middle Mountains may have resulted in higher peak flows in downstream areas, potentially increasing flooding risk in downstream areas, as well as lower baseflow amounts in dry periods.

Restoration of valley bottoms in the low mountain ranges, where the population density is low, to their natural wetland state may increase storage, retain water and slow down the discharge of these areas, leading to lower peak flows (van Winden et al., 2004; van Deursen et al., 2013). The German Middle Mountains show potential for flood management through wetland restoration measures with potential local reductions in peak flows which, when applied at larger scales, may impact peak flows in the Rhine River Basin (Otterman et al., 2017). Wetlands International, World Wide Fund for Nature – Netherlands and Stroming BV have initiated a project to assess the effectiveness and feasibility of enhancing the natural sponge effect of wetlands in the German Middle Mountains by restoring wetlands in the upper reaches of the tributaries of the Rhine River. Underlying goal is to explore the possibilities to combine positive effect on water quality, river ecology and river hydrology.

* Corresponding author
Email address: jos.debijl@stroming.nl (Jos de Bijl)

Method

A modelling study was performed to quantify the potential for wetland restoration in the German Middle Mountains to reduce flooding risk in downstream areas, including the Mosel and Rhine basins. The SWAT+ model was used to calculate the impact of wetland restoration on streamflow in three micro-catchments of Kylldal catchment in the German Middle Mountains, focusing on winter peak flows in particular. The analysis was based on two scenarios: a reference model representing the current situation and a wetland scenario. Wetland restoration was simulated by changing the land cover in the valley floor to natural wetland vegetation and by changing the characteristics of the streams to better match a situation in which there is no clear channel.

The indicative large-scale effects of wetland restoration in the Mosel basin and the Rhine Basin were simulated with WFLOW. Daily average discharges were simulated between January 1st, 1998 and December 31st, 2015. Three scenarios were used to describe different extents to which wetlands were restored in the German Middle Mountains, being 5%, 25% and 50% restoration. Wetland restoration is simulated by increasing the roughness (described by the Manning roughness coefficient) in a selection of cells in the existing Deltares base models. Cells are selected for parameter change when these occupy an area fit for wetland restoration and have a Strahler stream order of 2. This selection of cells is then filtered further by selecting cells at random. With this filtering, the small area in the basin that is occupied by suitable locations for wetland restoration is imitated. The factor (3.0) with which the roughness is increased and the method for cell selection were validated by reproducing the results of the SWAT+ model with the WFLOW model in the Kylldal.

Effects on (micro)catchment

Results showed that the median average daily discharge from all three micro-catchments increased after wetland restoration, especially in summer and fall. In addition, the variability in daily flow decreased substantially, by as much as 30%. The response of streamflow to extreme rainfall events was attenuated, as peaks were lower but broader after wetland restoration. In this way, the maximum annual peak discharge decreased by an average of 20 – 30% in the three micro-catchments. At the next scale-level, the Steinebrück catchment, maximum annual winter peak flows were 13% lower after wetland restoration. The dampened effect at catchment scale compared to the micro- catchment scale is a result of the fact that the micro-catchments where wetland restoration is simulated cover only about 45% of the total catchment area.

The result of wetland restoration can be summarized as reducing peak flows during extreme precipitation events as the flow is delayed by the changes in channel geometry leading to higher roughness and broader and shallower channels. This means that flooding risk in the catchment, and potentially in downstream areas, decreases. The delay in flow after extreme precipitation events also causes a higher baseflow recession after wet periods. The change to lower peak discharges and higher water availability in drier periods can be viewed as a positive impact on the hydrological regime of these areas.

The difference between modelled and measured discharges at Steinebrück suggested that the SWAT+ model could be improved through the use of better soil data, calibration and validation.

Effects on Mosel and Rhine catchment

In the scenario of 50% restoration of potential wetland areas in the Mosel basin, the reduction of maximum peak discharge is 4%. At the same time, the standard deviation of daily average discharges lowers up to 3% and low flow discharges increase up to 2%. The effects of wetland restoration in the complete Rhine catchment is similar, although relatively smaller: 1.8% maximum peak discharge reduction and up to 1% reduction of the standard deviation of daily average flow. The difference is explained by the small percentage of the total basin area affected by the wetland restoration; in the Mosel basin suitable wetland locations cover relatively more ground in the basin than they do in the complete Rhine basin.

The results correspond to the results of the SWAT+ model, in the sense that both a peak discharge reduction and an increased baseflow recession after wet periods are observed. Note that while the relative effect of wetland restoration on peak flows at macro-scale is smaller than at local scale, the reduction of peak flows in terms of total volume is substantial at the scale of the Mosel or Rhine.

References

Van Winden, A., Overmars, W., Braakhekke, W. (2004) Storing water near the source. Stroming B.V., 18 p.

Van Deursen, W., Van Winden, A., Braakhekke, W. (2013) Possibilities for storage? Stores of possibilities! Carthago Consultancy and Stroming BV. 25 p.

Otterman, E., Braakhekke, W., van Winden, A., van Deursen, W., Zeitler, F., Silver, E., Roels, B., Schoch, D. (2017). Restoration of the marshes in the valleys of the middle mountains of the Rhine basin for flood and drought risk reduction – 'the sponges approach'.

Waterloo, M.J., Gevaert, A., Kersbergen, A., Hegnauer, M., Becker, B., De Roover, S.A.W. (2019). Wetland restoration impact on the Rhine river basin. Acacia