# Uncertain amount of impact of a river intervention in a bifurcating river system

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## Introduction

In the past decade, the conveyance capacities of the main Dutch rivers have been increased by large-scale river interventions under the Room for the River programme. The impact of the projects on water levels along a branch were determined using model simulations. Berends et al. (2019) have shown that under the influence of uncertain roughness parameters in the hydraulic model, the amount of water level reduction of an intervention is uncertain.

Also in the vicinity of the bifurcation points of the river Rhine, several interventions were implemented, e.g. the dike relocation at Nijmegen-Lent and floodplain excavation at the Millingerwaard. Without counteracting measures, these projects are expected to influence the distribution of discharge at the bifurcation points. Gensen et al. (2020) have shown that a river bifurcation provides a self-regulating mechanism for water levels throughout the river system. For example, a high water level in a branch is counteracted by a decrease in discharge towards this branch.

In this study, we assess the uncertainty of the impact of a river intervention along a branch in the bifurcating Dutch river Rhine system. Here, impact is the change in water levels along the branch after the intervention is done. The uncertainty of the impact of an intervention scales with the amount of impact itself (Berends et al. 2019). Therefore, we hypothesize that under the self-regulating mechanism in a bifurcating river system the impact of an intervention reduces as well as its uncertainty.

## Methods

An idealised model of the Dutch Rhine branches is set up (Fig.1). Every branch has a uniform compound channel cross-section geometry with dimensions based on the Rhine branches. The Manning's roughness values of the main

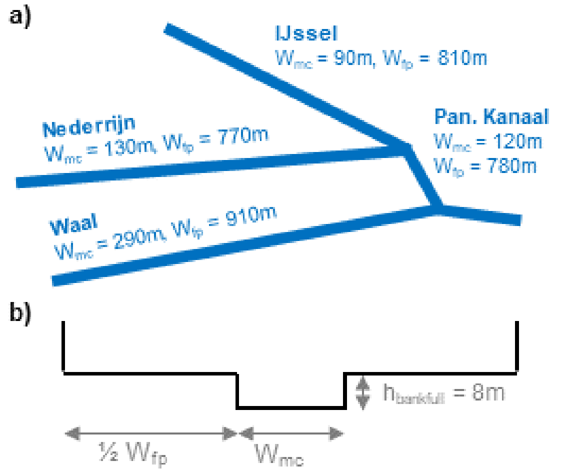


*Figure 1. a) Schematization of Dutch Rhine branches and b) the geometry of the compound cross-sections. $W_{mc}$ and $W_{fp}$ are the width of main channel and floodplain respectively.*

channel and floodplain are set as stochastic variables, normally distributed, for every branch independently. The boundary conditions are a constant upstream discharge and downstream stage-discharge relationships. For both a fixed and a free discharge distribution, we run a quasi-random Monte Carlo Simulation.

We assess the impact of a water-level lowering intervention in the upper reach of the Waal branch. Over a length of 10 kilometers the floodplain is widened with 500 meters (i.e. dike set-back). The roughness of the widened area is equal to the floodplain's roughness. We run the MCS for the intervention model (both fixed and free discharge distribution) and attain the impact of the intervention by subtracting the set of water levels from the 'intervention model' from the set of water levels from the reference model. We quantify the uncertainty by its 90% confidence interval and using the metric 'relative uncertainty' as defined by Berends et al. (2019):

$$U_r = \frac{Width\ 90\%\ confidence\ interval}{Mean\ impact\ of\ intervention} * 100\%$$

## Results

A free discharge distribution reduces the uncertainties in water levels compared to a fixed discharge distribution (red vs blue lines in Fig.2), as observed by Gensen et al. (2020). The width of the 90% confidence interval is reduced for both the reference as the intervention model. Also, as expected, the free discharge

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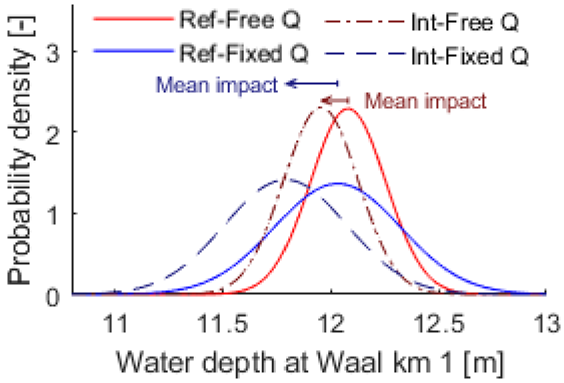


*Figure 2. Probability density functions for the water depth at Waal km 1 in the reference and in the intervention model for both a free and a fixed discharge distribution (Q). The upstream end of the intervention is at km 1.*

distribution reduces the impact of the intervention (smaller shift in Fig.2) due to an increased Waal discharge.

The typical impact of an intervention is a water level lowering generated over the length of the intervention with a maximum at the upstream end of the intervention (Fig.3). Upstream from the intervention the impact diminishes via a typical backwater curve.

With a free discharge distribution the uncertainty of the impact decreases along with the impact itself (Fig.3). In other words, a larger impact also causes a larger uncertainty of the impact. Evidently, the further away from the bifurcation point the intervention is implemented, the smaller the differences in impact and uncertainty of the impact between a free and a fixed discharge distribution become.

As the uncertainty of the impact appears proportional to the impact itself, we could expect that the relative uncertainty $U_r$ is fairly constant along the river, as found by Berends et al. 2019.

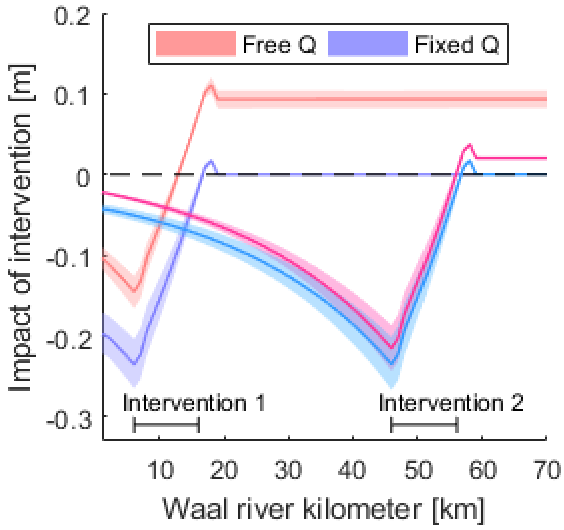


*Figure 3. The impact on water levels along the Waal branch of interventions with upstream kilometres 6 (intervention 1) and 46 (intervention 2) if the discharge distribution (Q) is free (red) or fixed (blue). The bifurcation point is at km 0. The continuous line gives the mean impact, while the shaded area indicates the 90% confidence interval.*

This is indeed so if the discharge distribution is fixed (~25% for both Intervention 1 and 2). In case of a free discharge distribution we again find a $U_r$ of roughly 25% at the upstream end of the intervention. However, now the relative uncertainty decreases in upstream direction, meaning that the confidence interval narrows faster than the impact diminishes. This could indicate a self-regulating mechanism in which the changes in discharge distribution partly counteract the uncertainty in the impact of an intervention. This is supported by the fact that with Intervention 2 we find the same relative uncertainty (~18%) at the bifurcation point as we find downstream of the intervention as well as in the other three branches of the system.

## Conclusion

We conclude that in a bifurcating river system, the impact of an intervention is strongly reduced by a self-regulating mechanism. The uncertainty of the impact scales along with the impact, such that a higher impact is also more uncertain. Furthermore, the relative uncertainty of the amount of impact close to the intervention is equal irrespective of location of the intervention or of having a free or fixed discharge distribution. However, in the case of a free discharge distribution the relative uncertainty decreases in upstream direction. This indicates that not only uncertainties in water levels are affected by self-regulation, also the impact of an intervention is affected by self-regulation.

## Future work

Next, we will use the idealised model to assess the impacts and uncertainties of two compensating interventions. Those are designed, such that deterministically the discharge distribution is equal to the pre-intervention discharge distribution. Then, we will quantify the uncertainty of the impacts and assess if it is reduced by self-regulation.


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