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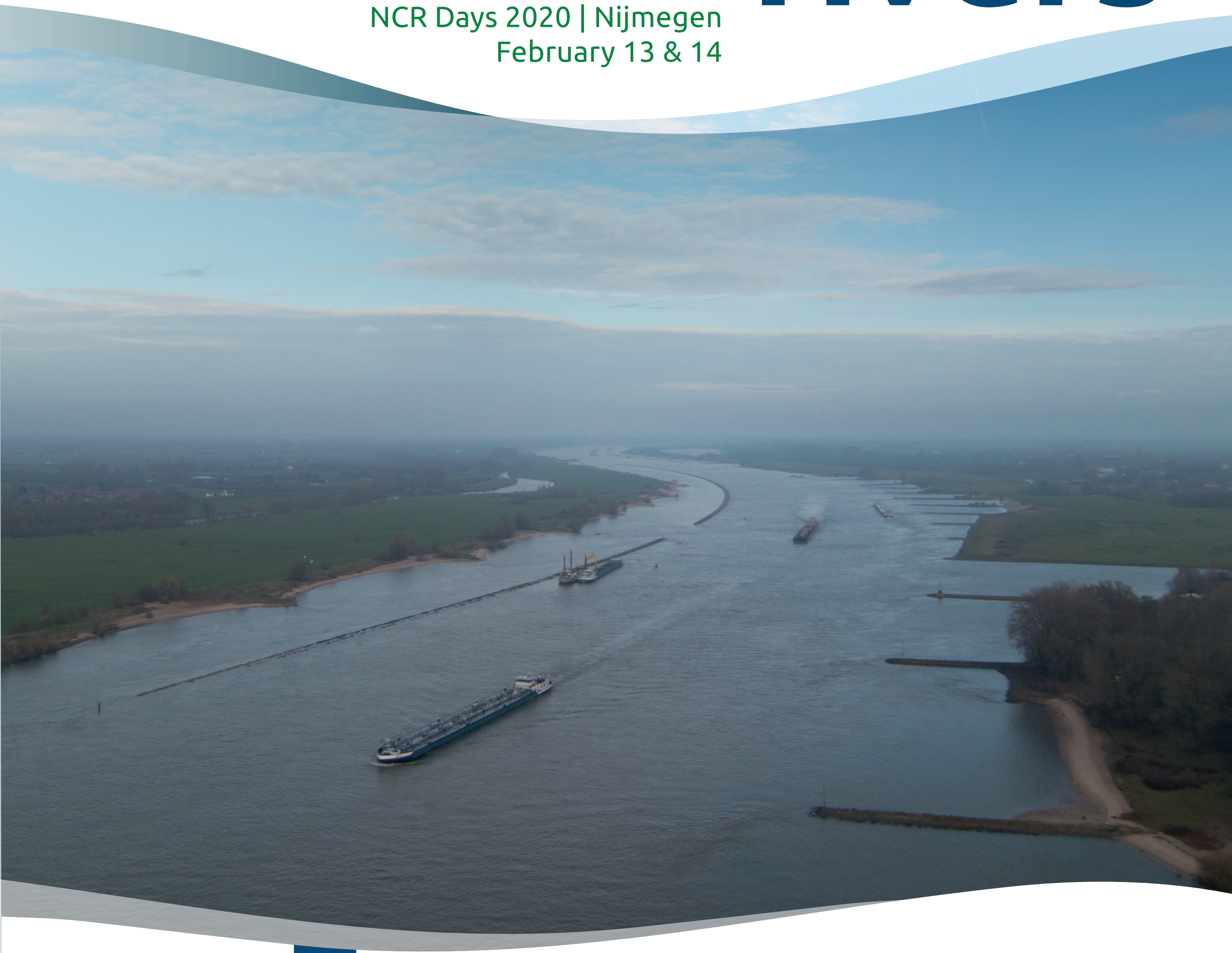

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Using expert opinion to quantify the uncertainty in the discharge distribution at the Pannerdense Kop

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Introduction

The discharge distribution at bifurcation points is a crucial aspect for flood protection in the Netherlands. The discharge distribution is controlled by the water levels of the downstream branches and the water levels in turn depend on the amount of discharge flowing into the branch (Gensen et al., 2020). In a bifurcating river system, the uncertainty of the discharge distribution over the downstream branches is therefore a result of river water level uncertainty.

The most important sources of uncertainty for flood protection are the upstream discharge and the roughness of the main channel (Warmink et al, 2011). The upstream discharge is uncertain because of the discharge distribution upstream. The hydraulic roughness of the main channel is uncertain because of the formation of bedforms increasing the hydraulic roughness.

The aim of this research is to quantify the sources of uncertainty individually using expert elicitation. These expert judgements are combined to find a total probability distribution of the discharge distribution at the Pannerdense Kop during a 16,000 m^3/s flood wave at Lobith. This flood wave is the old norm for flood protection in the Netherlands before the new norm was adopted in 2017. The experts interviewed for this study have experience with this flood wave and therefore have a better ability to give a quantification of the uncertainty compared to flood waves that are not commonly used.

Identified sources of uncertainty

Many sources of uncertainty contribute to the uncertainty in water levels and discharge distribution (Table 1.). Firstly, the wind can result in set-up close to the bifurcation point, possibly causing a change in the discharge distribution (Ogink, 2006). Secondly, the geometry is a source of uncertainty. Erosion before and during the flood wave can affect water levels substantially (Paarlberg et al., 2010). Furthermore, the failure of levees in the river profile are possibly prone to failure or erosion and thus changing the geometry. Thirdly, the roughness of the main channel is uncertain due to the creation and heightening of bedforms or flattening of bedforms during the flood wave (Paarlberg et al., 2010). Fourthly, the roughness of the floodplain is uncertain because of the vegetation (Warmink et al., 2011). Fifthly, during a flood wave the primary defense can be subject to failure (Ogink, 2006). And finally, the regulation structures have to maintain the policy discharge distribution by steering the discharge. The regulation structures have been adjusted using a model study which creates uncertainty.

Table 1. Definitions of the Uncertainty ID's

Uncertainty ID	Definition
1	Wind
2	Geometry
3	Roughness of the main channel
4	Roughness of the floodplain
5	Primary defense
6	Regulation structures

Methodology

Seven experts were selected for a face to face interview based on their background and their experience with the topic of research. The experts were interviewed individually and were first asked to give their estimate of the mean discharge towards the Waal during a 16,000 m^3/s flood wave. Next, the experts were asked to quantify the uncertainty of the individual sources of uncertainty around the set discharge distribution. The uncertainties are quantified as the 90% confidence interval ($2*1.64\sigma$).

To cope with the different backgrounds and competences of the experts, they were asked to give themselves a weight on the scale of 1-5. Hereby, a weighted average per uncertainty source can be attained. In Table 1 the definitions are given for the uncertainty ID's that are used to visualise the results of the expert opinion study. A total amount of uncertainty is computed using a probability distribution by combining the probability distribution of each expert and their assigned weight.

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Results

Figure 1 shows that three individual sources of uncertainty are significantly larger compared to the three others. These are the uncertainty in the geometry, roughness of the main channel and the roughness of the floodplain. However, there is quite some spread in the expert opinions. For the uncertainty of the geometry, not all experts mentioned that severe erosions would occur in a branch and that it would affect the discharge distribution. Furthermore, the failure of levees in the flow profile of the river in a downstream branch was not mentioned by some of the expert. Concerning the uncertainty in the roughness of the main channel and the flood plain, all the experts agreed that the roughness is rather uncertain. However, some of the experts quantified it rather low because they thought that if we under- or overestimated the roughness, it would be the same for all branches. This would mean that the relative roughness does not change a lot and thus there is not a significant change in the discharge distribution. The other three uncertainties of wind, primary defence and the regulation structure were quantified as small by the experts which means that they have a negligible effect on the total amount of uncertainty.

The probability distribution of each expert is plotted in Fig. 2 with black lines. This weighted probability distribution is plotted with the red line. The left bound of the 90% confidence interval is equal to 9,940 m^3/s and the right bound is equal to 10,511 m^3/s. This gives a total bandwidth of the discharge distribution towards the Waal of 571 m^3/s. It is visible that the weighted probability distribution has a larger right-tale. This is caused by the experts that set their estimation of the mean discharge towards the Waal larger than the policy discharge distribution.

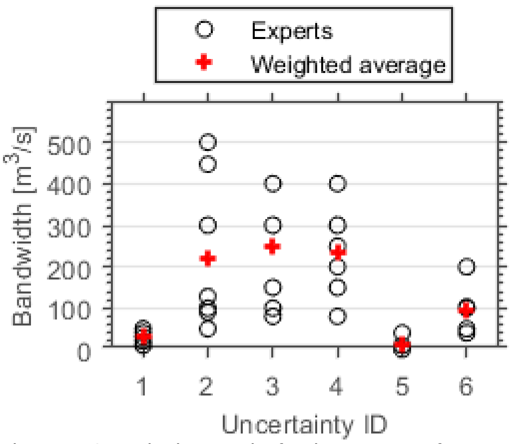

Figure 1. Quantitative results for the sources of uncertainty of the expert opinion study. Definitions of the Uncertainty ID's are given in Table 1.

Conclusions

The aim of this research was to quantify the individual sources of uncertainty and the total amount of uncertainty. The geometry, roughness of the main channel and the floodplain were found to be largest. These three uncertainties were quantified in the order of 200-250 m^3/s. The total amount of uncertainty was quantified as a bandwidth of 571 m^3/s towards the Waal.

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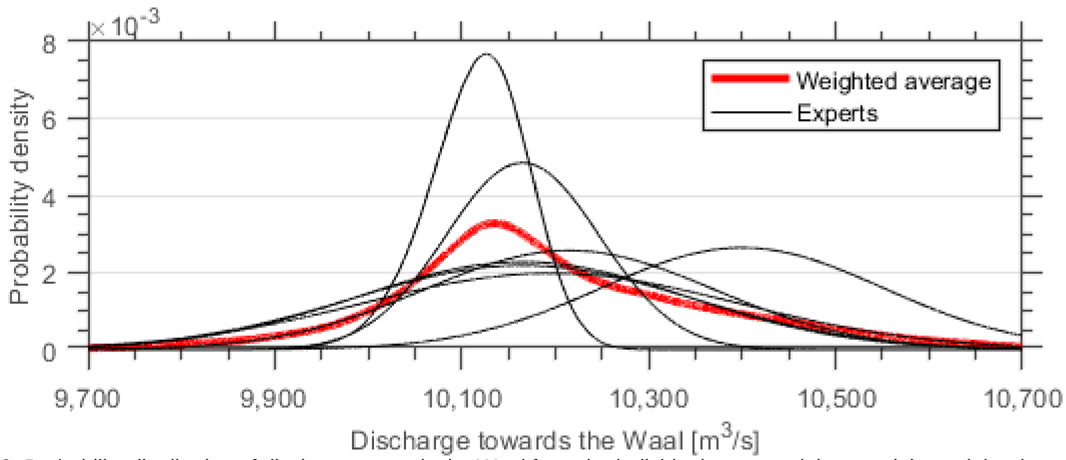

Figure 2. Probability distribution of discharge towards the Waal from the individual expert opinions and the weighted average.