Book of abstracts

# Rivers in an uncertain future

NCR days 2021| Enschede, February 11-12

Jord J. Warmink, Anouk Bomers,
Vasileios Kitsikoudis, R. Pepijn van
Denderen & Fredrik Huthoff (eds.)

NCR publication: 46-2021

Netherlands
Centre for
River studies

# NCR Days 2021

*Rivers in an uncertain future*

Jord J. Warmink, Anouk Bomers, Vasileios Kitsikoudis, R. Pepijn van Denderen & Fredrik Huthoff (eds.)

**Organising partner:**

UNIVERSITY OF TWENTE.

**Co-sponsored by:**

NWO
Nederlandse Organisatie voor Wetenschappelijk Onderzoek

J.M. Burgerscentrum


**Organising partner**

| | | |
|---|---|---|
| University of Twente | telephone: | +31 53 489 35 46 |
| P.O. 217 | e-mail: | secretariat-mfs-et@utwente.nl |
| 7500 AE Enschede | www: | https://www.utwente.nl |
| The Netherlands | | |

**Contact NCR**

| | | |
|---|---|---|
| dr. ir. K.D. Berends (programme Secretary) | telephone: | +31 6 21 28 74 61 |
| Netherlands Centre for River Studies | e-mail: | secretary@ncr-web.org |
| c/o Deltares | www: | https://www.ncr-web.org |
| P.O. 177 | | |
| 2600 MH Delft | | |
| The Netherlands | | |



**Cite as:** Warmink, J.J., Bomers, A., Kitsikoudis, V., van Denderen, R.P., Huthoff, F. (2021), *Rivers in an uncertain future: NCR Days proceedings*. Netherlands Centre for River Studies, publication 46-2021

**Photo credits cover:** IJssel river from Bureau Beeldtaal Filmmakers (2018)

# Probabilistic flood risk approaches along rivers

Matthijs Kok,
*Delft University of Technology, Faculty of Civil Engineering and Geosciences*
*Postal Address: Postbus 5048, 2600 GA Delft*
*Matthijs.Kok@TUDelft.nl*

**Keywords —** Flood protection, Flood Risk

## Introduction

Probabilistic risk analysis is an international well known research area. The standard handbook of this approach is written by (Bedford and Cooke, 2001). In this book it is made clear that "probabilistic risk analysis differs from other areas of applied science because it attempts to model events that (almost) never occur. When such an event does occur then the underlying systems and organizations are often changed so that the event cannot occur in the same way again". The risk methodology are applied to assess risk in many sectors, for example the chemical and nuclear sector. However, the assessment of risk in flood protection systems differ from other technological systems, because these risks are partly driven by extreme natural events, like for example extreme storms, hurricanes or rainfall. Also, infrastructure is made of natural materials like clay and sand (think of levees and dunes), which means often a high variability and therefore larger uncertainties compared with man-made materials like concrete or steel.
In this keynote lecture I will handle the approaches which are followed to deal with these uncertainties.

## Uncertainties

There are 2 interpretations of uncertainty: the frequentist and the Bayesian. According to the frequentist interpretation, a probability is the average number of times that a certain result is obtained in a long series of identical independent experiments. In this view, a probability is thus a relative frequency. According to the Bayesian interpretation, the probability of flooding is a measure of the likelihood that a flood will occur, given the knowledge at our disposal. The difference between *inherent* and *knowledge* uncertainty is irrelevant in the Bayesian interpretation, according to which the probability that a flood will occur is not uncertain; the probability is a measure of uncertainty. The probability is no longer, therefore, a physical property (which could be measured) but a subjective 'degree of belief'.

## Flood Risk

A risk analysis tries to answer the flowing questions:

a. What can happen?
b. How likely is it to happen?
c. Give that it occurs, what are the consequences?

Often, risk is defined by a set of scenarios $s_i$, with probability $p_i$ and consequences $d_i$.
There are, however, many different definitions of risk. In hydraulic engineering, flood risk is a concept that concerns both the possible impact of flooding and the probability that it will occur. It indicates the consequences, and also the probability of these consequences. Risk is often expressed as probability x economic damage. Risk is more than that, however. Flood risk can also be expressed in terms of other risk measures, such as societal risk (the probability that a large group of people will lose their lives) and individual risk (the probability that an individual will die). Which risk measure is preferable depends on the factors that determine how serious an imminent event is perceived to be. The Dutch policy towards flood risk considers three measures of risk: the annual expected damage, the individual risk and the societal risk, see Kok et al (2017).

## Flood risk Reduction

A clear idea of flood risks and the extent to which measures can be taken to reduce them can support decision-making on flood risk management. Levee reinforcements, providing extra room for rivers, spatial interventions and crisis management and public readiness measures all impact on flood risk, albeit in different ways. By showing the impact of such diverse measures on the flood risk, it is possible to make consistent and comparable decisions. Which individual measures or combinations of measures are ultimately the most appropriate will not only depend on the effect on the flood risk, but also on the costs, and any benefits apart from flood risk management.
Flood risk can help with decisions as to whether the level of safety provided is adequate: whether it is an *acceptable* risk, in other words. The first Delta Commission assessed the acceptability of flood risks on the basis of cost-benefit analysis (economic risk).

Some decisions may reduce the risk only marginal, but some decisions may reduce the risk a lot. If the (societal) costs of these risk are equal, than it would be rational to implement only measures which reduce risk a lot. This is the challenge of the probabilistic flood risk approach, since measures may not only reduce the probability, but may also reduce the consequences. From a flood risk point a view, both type of measures can be efficient. However, we often seen that it is relatively easy to reduce the probability with a factor 10, but it is often quite difficult to reduce the consequences with 10%. This means that we also have to take into count the economic, ecological and other cost when discussing about decisions. For example, evacuation plans can reduce the risk, and might be very cheap.
In figure 1 the possible measures are shown which can be taken in Room for the River programs.

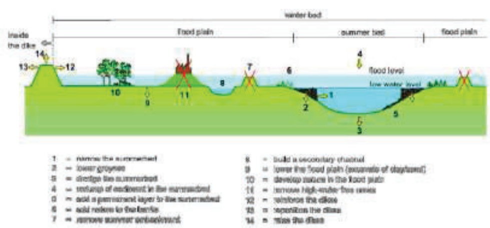


*Figure 1 Room for the River measures (Kok et al, 2017)*

Also other type of measures can be taken into account, for example strengthening of flood defences. Because flood defences might fail because of multiple failure mechanisms, we all have to take into account. In figure 2, a design to handle three different failure mechanism of river levees are shown.

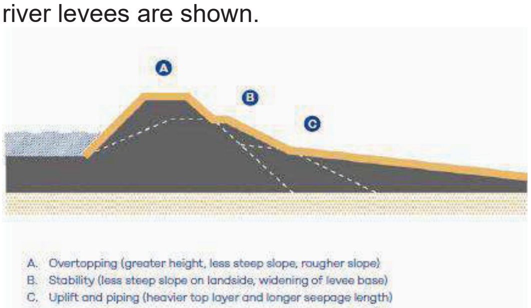


*Figure 2. Example of the design of the levee profile based on three failure mechanisms. The thick orange line envelopes the solutions to the three failure mechanisms, and shows the design profile.(Kok et al, 2017)*

## Systems approach

Often, risk is assessed for only one part of the river system, a 'dijkring' or a dijktraject'. However, risk does not limit itself to these boundaries. In my opinion, we have to look at the interactions within the river system, and the uncertainties associated with it. In a recent thesis (Curran, 2020) the systems approach was followed. It was shown the flood risk of an area can be assessed taking account possible overflow and breaches of flood defences upstream this area. In the thesis, so called fragility curves are used to assess the flooding probability. These curves represent the conditional probability of failure, given the hydraulic load, for example the waterlevel. In figure 3 an example is given.

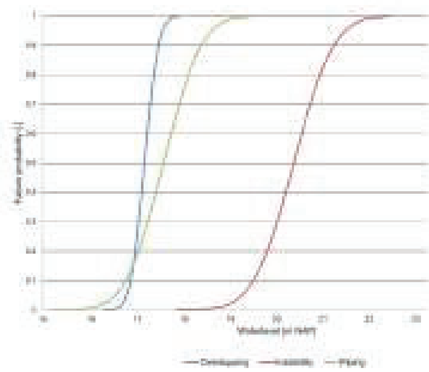

*Figure 3 Example of a fragility curve.*

Together with the probability density function of water levels, the flood probability can be relatively easy assessed. However, it is still relatively difficult to predict breaches at specific locations, so the systems approach in rivers still needs further development. Predicting overtopping seems more easy, and that is why in the Grade system for the river Rhine upstream Lobith, only possible breaches due to overtopping are included (Hegnauer et al, 2014).

## Conclusion

The probabilistic flood risk approach is capable to include uncertainties which can be identified within river systems. However, a full probabilistic systems approach including all failure mechanisms of levees needs data which are not yet available.

## References

Bedford, Tim and Roger Cooke (2001) Probabilistic Risk Analysis: Foundations and Methods., Cambridge Press, 414 p

Curran, A. (2020). Flood risk analysis of embanked river systems. Probabilistic systems approaches for the Rhine and Po river. Deft University of Technology.

Hegnauer, M. J.J. Beersma, H.F.P. van den Boogaard, T.A. Buishand, and R.H. Passchier (2014). Generator of Rainfall and Discharge Extremes (GRADE) for the Rhine and Meuse basins - Final report of GRADE 2.0

Kok, M., R. Jongejan, M. Nieuwjaar and I. Tanczos (2017). Fundamentals of Flood Protection, Expertise Network of Flood Protection.