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The 2021 summer floods in the Netherlands: some findings and lessons

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The heavy precipitation along with the floods of July 2021 in the Netherlands and surrounding countries was an extreme and exceptional event. In the Netherlands, the event had major societal impacts in the south, particularly in the province of Limburg. Commissioned by the Dutch Expertise Network for Flood Protection (ENW), a broad consortium of knowledge institutes, led by Delft University of Technology and Deltares, has performed an exploratory fact finding study (Jonkman et al., 2021). Several All-Risk researchers have contributed, focussing on topics such as dike performance, damage and river systems. As a flood affects the whole society, a broad range of topics has been assessed: meteorology, civil engineering, societal and health impacts, and emergency management. This contribution summarises preliminary findings and lessons for the future.

Damage larger than for the 1993 and 1995 floods

The measured amounts of precipitation and river discharges have never been so large, particularly during summer. It is estimated that the event of July 2021 occurs only once every 100 to 1,000 years. The peak discharge (3,280 m^3/s) on the Meuse River near Maastricht in Eijsden (at the Dutch border with Belgium) and on a number of tributaries such as the river Geul (north of Maastricht) were the highest discharges ever measured. Water levels further downstream the river (past Roermond) were lower due to attenuation of the discharge peak.

In total 2,500 homes and 600 business were flooded. The estimated total damage due to flooding amounted 350 to 600 million euros and took place to a large extent in the river Geul valley. The damage was therefore greater than during the floods along the Meuse river in 1993 and 1995.

The primary flood defences along the Meuse withstood the exceptionally high loads well. However, incidents such as piping (erosion of the sand under the dike) and local height deficiencies did occur in some places. Temporary measures such as sandbags were therefore used on a large scale. During the event, the first floods occurred along the river Geul. A warning was given, but no guidance for citizens to evacuate (out of the area). Along the river Meuse, 50,000 people were evacuated and multiple hospitals and care facilities.

Insight has been given in health impacts. Two thirds of the surveyed doctors reported an increase of psychological conditions. In addition, drinking water intake was stopped due to pollution. During the same period, severe flooding caused billions in damage and hundreds of deaths in Germany and Belgium. There, the situation was more catastrophic than

Inhabitants are evacuating from the flooded area in Limburg. Photo © Marcel van den Bergh.

in the Netherlands, also because of the greater precipitation amounts and the steeper – faster flowing – rivers.

Lessons learned

The findings from the fact finding study can be used for follow-up research, evaluation and for future-proofing the system. Although this study was an initial exploration, some lessons and recommendations can be formulated:

- **Improve the predictions, flood warnings and crisis management and their interfaces.** Predictions of rainfall and flooding changed during event and the severity of the floods was therefore not anticipated, and insufficiently addressed in warnings and emergency response.
- **Knowledge of river floods:** Evaluate (the likelihood of) the occurrence of river floods in summer, including the effects of climate change. Improve the understanding of the combination of floods in the river Meuse and its tributaries. Develop an integrated model for this entire river system, including rainfall, runoff, and use this for river management and flood warning. Implement observation stations that will remain functioning during extreme floods.
- **Impacts:** Collect and analyse data for damages and compensations, in order to improve damage modelling and the understanding of the effect of interventions. Evaluate and monitor the longer-term economic and health impacts in the affected area.
- **Flood defences**: Evaluate the effects of the measures that were in place before the floods – i.e. room for rivers and dike reinforcements. Analyse the performance of the defences along the river Meuse under the extreme loads (including "proven strength"). Use the outcomes to update the safety assessment of the defences. Improve the knowledge and modelling of failure mechanisms, by evaluating incidents, such as observed cases of piping. Also evaluate the performance of structures such as weirs.
- **Risk management and risk reduction:** Evaluate for the smaller rivers whether there is a need to adapt the safety standards[1], based on a cost-benefit analysis. Consider the performance of the system for scenarios higher than the design scenario. What would be the effects of the rainfall observed in Germany and Belgium, would it have occurred in the Netherlands? Particularly the smaller rivers require attention: elaborate engineering, spatial and organisational measures to reduce the risk (through a "multiple lines of defence" approach), to prepare emergency management and inform decision-makers. In these flood risk reduction plans, include other needs, such as drought, ecology, housing and climate adaptation.

[1] Many of the populated areas in Limburg, e.g. along the river Geul, had a safety standard of 1/25 per year. This is smaller than the safety standard that is normally applied for such water systems in the Netherlands (1/100 per year).

- **Governance and knowledge:** Evaluate the effectiveness of the current governance for the river Meuse and tributaries (with involvement of the federal government, province, regional water authority, municipality and citizens) and the funding arrangements. The crisis in Limburg has shown the importance of knowledge and expertise within the organisations. During crises, decision-makers can insufficiently rely on models only. Consider the implications for the required expertise in water management organisations and the utilisation of this expertise during crises.
- **Implications for other regions in the Netherlands.** The extreme rainfall and flooding in Limburg has surprised experts, water managers and citizens. Assess what the effects of such extreme events would be for other areas in the Netherlands, and whether there is a need to implement additional measures.

Many of these topics need to assessed in an international perspective – with Germany and Belgium – as the water systems in this region are transboundary.

Parties involved

The study was carried out by a broad consortium: Deltares, Delft University of Technology, HKV consultants, VU University Amsterdam, Utrecht University, KNMI, WUR, Erasmus MC and the University of Twente, commissioned by the Expertise Network for flood protection (ENW) and with the full support of the Limburg Regional Water Authority and Rijkswaterstaat.

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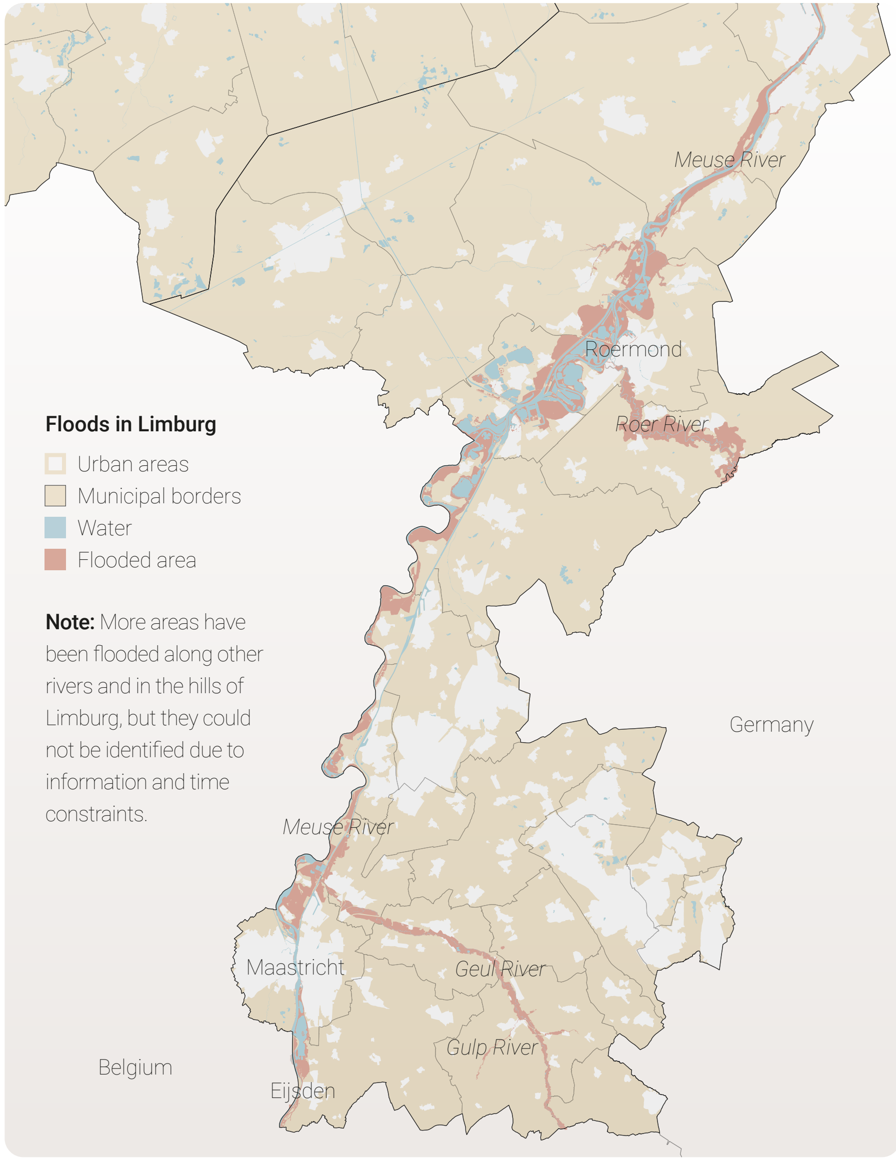
Task Force Fact Finding Hoogwater (2021). *Hoogwater 2021: feiten en duiding.* Doi: 10.4233/uuid:06b03772-ebe0-4949-9c4d-7c1593fb094e



Map of the 2021 floods in Limburg, the Netherlands, as a result of the fact-finding study for the Meuse river and the tributaries Geul, Gulp and Roer. Base map data from PDOK. Flood extents data by Slager et al. (2021). Illustration by Martijn Vos.