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A novel flood risk model for The Netherlands

Even though significant parts of the Netherlands are susceptible to flooding or even lie below sea level, it is one of the safest deltas globally due to an extensive system of flood defenses. As of now, about two-thirds of levees comply with the Dutch Water Act. Despite the high level of protection against flood in The Netherlands, the financial sector requires adequate means to assess and quantify the remnant flood risk.

A probabilistic catastrophe model – if well designed – provides reliable flood risk insights on both local and national level that come forward to the needs of (re-)insurers, brokers and banks alike. Applications of such a model extend to CSRD/EU Taxonomy reporting, EIOPA regulatory standards, and financial stability stress-testing, etc. Aon Impact Forecasting and HKV Consultants have developed and released a catastrophe model to assess flood risk across the Netherlands. The model has been approved by the Institute for Environmental Studies at VU Amsterdam. It has already been deployed for most of the applications outlined above. In this article we describe the major challenges faced and design choices made during the development of this model.

FLOOD HAZARD

Using the current available Dutch flood risk data easily leads to an overestimation of the probability of primary defense failures. This is based on three assumptions that are made:

1. Failure events of levee sections are typically assumed to be independent. Hydraulic loads are interdependent though, and breaches in levees can significantly affect water flow, particularly as the discharge wave is altered. This results in lower flood probabilities down the water system. Furthermore, multiple breach events across multiple sections are usually not considered.

2. Emergency measures, such as ringing boils with sandbags to create counter-pressure and heightening the dike by placing sandbags, are not taken into account when determining the failure probabilities of flood defenses. However emergency measures can reduce the flood probability by a factor 1.5-4 (Lendering et al 2015).

3. The failure definition which is used in flood risk assessments and levee design is conservative. Generally, it only captures the initial stages of the failure process and does not encompass the entire failure mechanism. That is, several components of the failure process are excluded due to the lack of quantitative models.

The overestimation can result in undesired consequences like high costs for insurance and decreased willingness to invest in the Netherlands. Hence, Kolen and Nicolai (2024) have developed a novel method to more realistically estimate the probability of flooding in the Netherlands. It builds upon publicly available flood risk information, and adds statistical methods and expert judgment tailored to delta areas with hydraulic interdependencies and flood defenses. The method allows for multiple breaches. The approximately 1,900 available flood scenarios for the primary defenses are expanded into five million unique flood events, which can be incorporated into catastrophe models. Consequently, it offers local flood hazard profiles at every single location in The Netherlands.

f.l.t.r.:

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FLOOD EXPOSURE AND VULNERABILITY

From modelled exposure perspective, the following information is passed into the catastrophe model in the form of portfolio:

- The description of the exposure, both quantitative (sums insured) and qualitative, including occupancy (building type) and coverage (building, contents, business interruption). Optional details like construction material, basement presence, building height, age, and area can improve loss estimation accuracy.
- Exposure location, most often in form of coordinates or postal code, which is then compared with the flood extents stored in the catastrophe model.

Modelling motor hull portfolios includes additional challenges like fluctuating vehicle values and vehicles changing locations not only on regular basis but also due to evacuation effects in case of flood warning.

Once the specifications are set, the catastrophe model translates flood depths affecting individual risks in individual flooding scenarios into monetary loss by applying loss ratio defined by appropriate damage functions to the sum insured. The SSM2024 model described in (De Bruijn et al. 2015) provides a wide range of damage functions for various occupancies. This set was enhanced to allow for building height- and construction material-specific curves using Impact Forecasting's methodologies. Moreover, the functions were adjusted with input from the QFLAT model (created by the University of Leuven and Probabilitas), which is fed with a significant database of validated loss claims including the ones after the July 2021 floods in Western Europe.

OUTPUTS AND RESULTS

The main output of a catastrophe model is a table detailing flood events (each specified by a flood depth map, breach location and probability) and corresponding loss. For any single local exposure it is straightforward to browse through the list and extract a flood risk profile, describing the exceedance probability of flood depths at the location. Subsequently, once flood depths are translated into monetary loss, the loss profile (PML) as well as annual average loss (AAL) can be obtained. Additionally, mapping tools can provide quick access to model results, offering visual overviews and risk specifications for selected locations.

The significant added value of our catastrophe model is that it can calculate AALs and PMLs for whole portfolios of exposures, not only single locations, reflecting on their geographical proximity and potential concurrent flooding as specified by the flood events.

Figure 1 shows the flooding probabilities of each location in The Netherlands resulting from the model. The local probability of flooding is highest in some parts of the river area. Along the coastal areas with very large and high dunes, the flood probabilities are smallest.

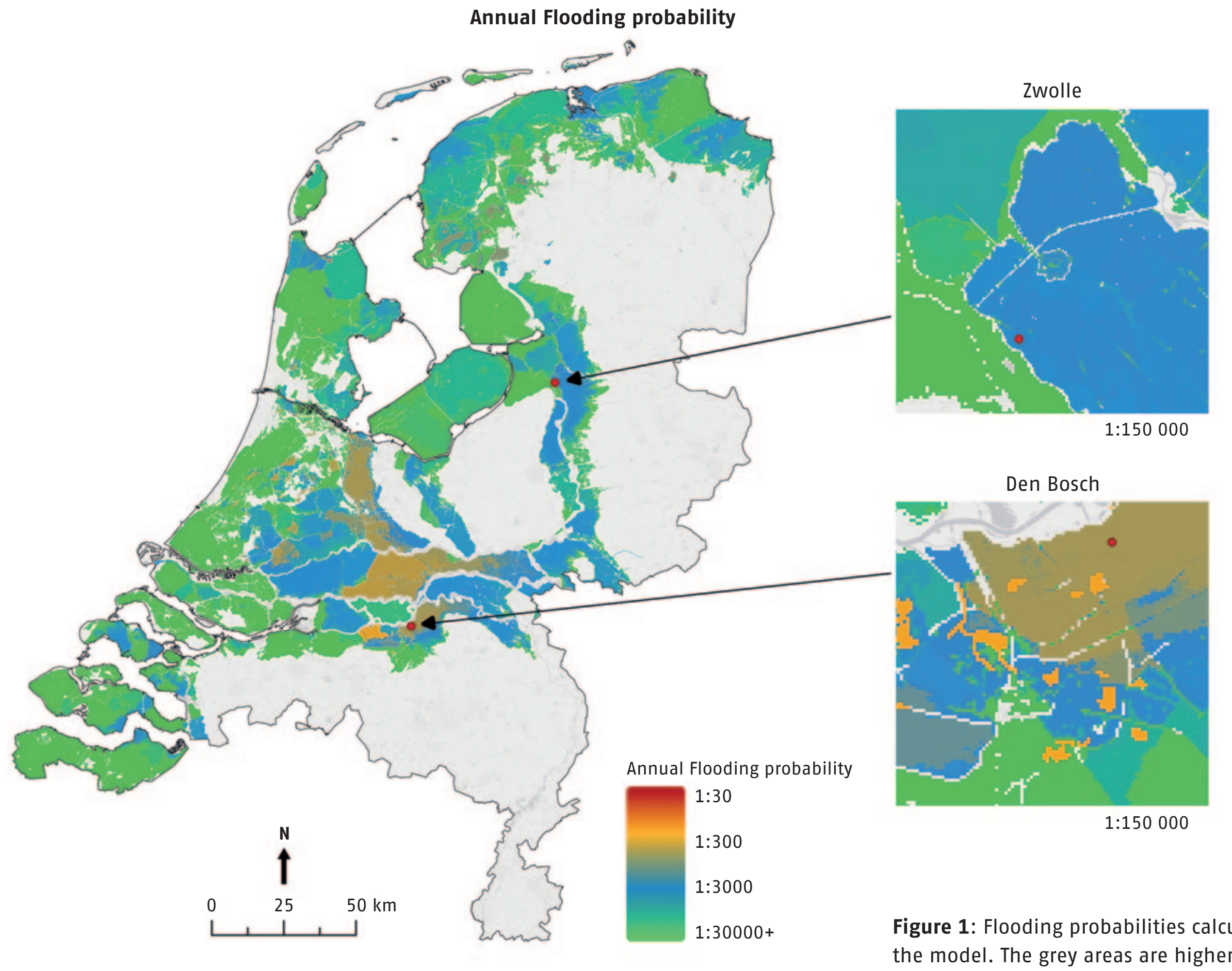

Figure 1: Flooding probabilities calculated from the model. The grey areas are higher grounds, which are not susceptible to flood risk due to primary dyke failure. Source: Impact Forecasting

Charts in Figure 2 compare flood loss profiles for two selected locations: one in Den Bosch and one in Zwolle. The annual probability of flooding for these locations is similar; it is just below 1 / 1,000. However, Den Bosch has a much higher probability of water depth exceeding 3 m. Loss profiles correspond to flood hazard profiles, but the monetary effects of flood depth increments are non-linear, yet the probability of observing loss matches the probability of flooding. The modelled building AAL for the two locations are EUR 134 and EUR 19 assuming the value of the building to be EUR 500,000.

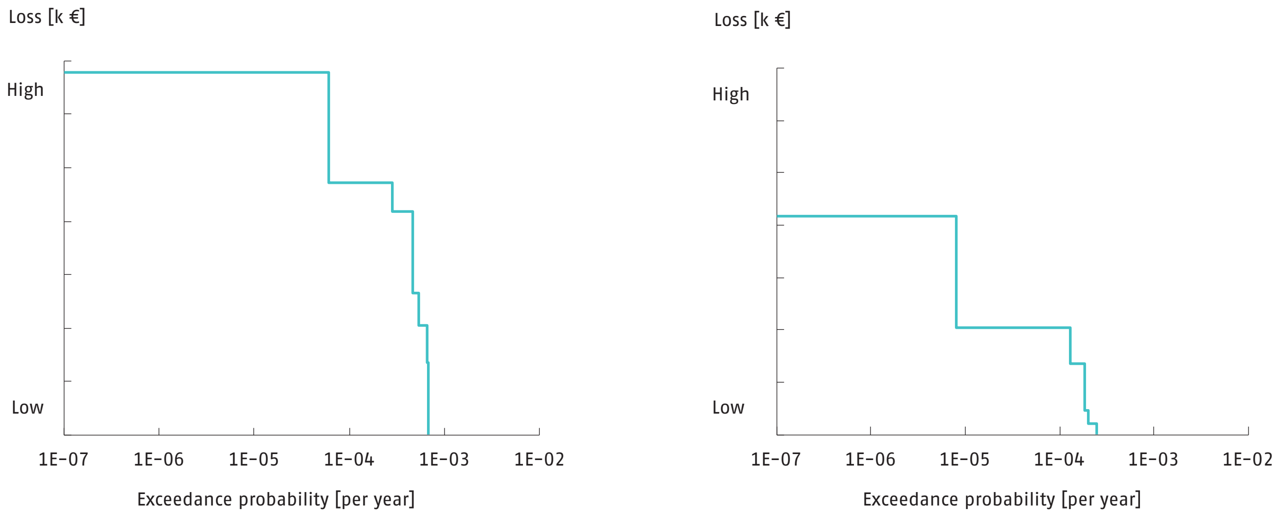

Figure 2: Flood loss profiles for two locations in The Netherlands: Den Bosch (left) and Zwolle (right).

CONCLUSIONS

Modelling flood risk in The Netherlands is a challenging endeavor. Although hydrology and defenses by themselves are well documented, the systemic risk mostly is not. Because of the difficulty to assess correlations, overestimation is a common pitfall. To correct for overestimation we have adjusted publicly available failure probabilities of flood defenses using expert judgment. Our model assesses flood damages by combining hazard, vulnerability, and exposure, producing hazard profiles, loss profiles, annual average losses (AAL), and probable maximum loss (PML) for various locations and for portfolios. Insurers are often interested in the 1 in 200 years loss. However, flood risk in The Netherlands is characterized by 'very low probability - high impact' events. Our model can be used to explore the effects of such events. Also, it can give input to the discussion how the Dutch society should divide flood risk between private and public parties. ■

References

de Bruijn et al. (2015)
Updated and improved method for flood damage assessment: SSM2015 (version 2). Karin de Bruijn, Dennis Wagenaar, Kymo Slager, Mark de Bel and Andreas Burzel. Deltares, 2015.

Kolen and Nicolai (2024)
A new framework to generate event sets for risk based spatial planning and financial decisions regarding Dutch Flood Management. Submitted for publication. Dutch version: https://www.hkv.nl/wp-content/uploads/2024/05/Overstromingsrisicomodel-voor-ruimtelijke-investeringsvraagstukken_R00917.10.pdf

Lendering et al. (2016)
Effectiveness of emergency measures. J. Flood Risk Manage, 9: 320-334. Lendering, K.T., Jonkman, S.N. and Kok, M. (2016). doi.org/10.1111/jfr3.12185