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RISK ASSESSMENT IN TRANSBOUNDARY COOPERATION BETWEEN THE NETHERLANDS AND GERMANY

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ABSTRACT: Floods are part of the natural hydrological cycle and do not stop at country boundaries. Based on this realization a group of both German and Dutch governmental institutes has decided to start a study towards identification and mitigation of flood risks in the transboundary area of the river Rhine. On both riverbanks the areas of interest lie in Germany and in the Netherlands and are enclosed by either flood defenses or higher grounds. Regardless of the location of a dike breach, in case of a flood both countries are probably affected. In this study German and Dutch experts work together carrying out a risk assessment for two dike-ring areas using a joint Dutch-German method. This method has been developed during the first year of the project, where knowledge from both countries has been used.

The joint method in the risk assessment consists of five different stages:

1. investigation of the failure mechanisms and the corresponding failure probabilities,
2. conducting flood and breach simulations,
3. calculation of the (economic) damage for each of the flood simulations,
4. computation of the flood risk by combining probabilities and consequences, and
5. cost-benefit analysis for various risk-reducing measures.

During the first phase of the project the complexity of a transboundary study became obvious, not just because of the different models that both countries use, but also with regard to the legislative state and the flood protection policies of both countries. The available models in both countries have been compared in each of the five stages. By combining the advantages of each of the models a joint German-Dutch-Method has yielded. Due to the participation of various institutes an environment has been achieved in which the methods have been questioned and verified critically on a scientific basis, but still within a realistic, policy-oriented framework.

Key Words: flood-risk assessment, transboundary cooperation, river dikes, cost-benefit analysis

1. INTRODUCTION

Rivers do not stop at boundaries between countries, and neither do floods. The river Rhine is a prime example of this, as it crosses the German-Dutch border in an area where transboundary dike rings are located on both banks of the river (Figure 1). These areas are enclosed by either flood defenses or higher grounds, and are situated on both Dutch and German soil. Regardless of the location of a dike breach, in case of a flood both countries are probably affected.

A very successful cooperation between German and Dutch partners exists In the border area . The involved parties are the „Ministerium für Umwelt und Naturschutz, Landwirtschaft und Verbraucherschutz“ of the German federal state North Rhine-Westphalia and the Dutch province of Gelderland and Rijkwaterstaat. Together they form the Working Group High Water, which coordinates studies and research developments to improve the flood protection in the transboundary area. In the summer of 2005 this work group decided to initiate a study towards the identification and reduction of flood risks in this area.

The main goal of this study has been to identify the flood risks for the two dike-ring areas in the transboundary area, using a joint Dutch-German method based on existing models and technology. Besides identifying the flood risks it should be possible to weigh various risk-reduction measures in a cost-benefit analysis. The project is carried out by a consortium of various German and Dutch partners.

2. PROJECT OVERVIEW

The project has been split into three phases:

- Phase I has mostly been a communication and identification phase in which the already existing methods to determine flood risks in both countries have been compared and analyzed. After a critical evaluation of the methods, a joint approach has been chosen. With this selection one of the main goals of the project has been fulfilled: the identification of a joint approach, which provides the best of both countries in a mixture of both Dutch and German methods. This phase has been completed last year, resulting in the report “Risikoanalyse für die grenzüberschreitenden Deichringe am Niederrhein” (Silva et al., 2006). This paper is a brief summary of that report.

- In Phase II the joint method developed in the first phase of the project has been used to determine the flood risk for dike ring 48, located on the right riverbank of the river Rhine. A cost-benefit analysis will be performed as well.

- The third and final phase is very similar to the second phase, except the flood risk and the cost-benefit analysis will be performed for dike ring 42, located on the left riverbank.

In the project three different moments in time have been identified for which the flood risk is determined. Each moment in time corresponds to a different hydraulic situation as well as a different state of the flood defense system. The situation in the year 2015 is considered the reference situation, and corresponds to the situation in which already planned measures to the river and flood defenses have been finished. Basically this means the system is "in order", and both countries fulfill the safety conditions as required by law (RBSO, 2005). For comparison the present situation (2006) is considered as well, in order to link the project with already ongoing risk-assessment studies and placing the study in perspective. The results from the present situation can also be compared to existing dike-assessment methods in both countries for verification. The third snapshot in time that is considered is called the 2015+ situation. In the project various risk-reducing measures will be defined. The 2015+ situation is set in a somewhat arbitrary future year in which these measures will have been implemented, so that their effects on the probabilities, consequences, costs and the overall flood risk can be evaluated.

3. DESCRIPTION OF THE JOINT METHOD

3.1 Failure probabilities

One of the major research programs in the Netherlands in which failure probabilities are determined with the aid of a probabilistic model is called “Flood risk and Safety in the Netherlands (FLORIS)”. The main purpose of the FLORIS-project is to gain insight into the consequences and probabilities of floods for the current state of the Dutch water system. Besides the exceedance probabilities of water levels, used to assess the Dutch dikes at present, failure probabilities of other mechanisms are investigated as well, such as bursting of the soil, piping and failure of structures.

The probabilistic models are also used extensively in the assessment of the Dutch flood defenses. For this purpose the Hydra-models have been developed which are used to assess the required integrity of the dikes according to the Dutch law.

In Germany the MC-DikeFail model has been developed at the Institute of Hydraulic Engineering and Water Resources Management (IWW) of RWTH Aachen University to compute failure probabilities of river dikes and dams. The program is a research model based on a fault tree for river dikes and dams that are required in a risk analysis. So far the model has been used in several risk analyses for regions along the Lower Rhine in North Rhine-Westphalia as well as for dams.

Each of these models provides failure probabilities. However, this is done differently in each model, with different goals, but also with various data, computational methods and possibilities. As mentioned before, the goal of the first phase of the project has been to determine a joint German-Dutch method based on existing models and techniques. In the project the joint method for the failure probabilities consists of three steps:

1. A deterministic method is used for the assessment of the flood defenses, to determine the potential weak points in the dike-ring area. These weak points are locations where the actual strength of the flood defense is less than required according to the design safety norm. Both failure mechanisms with respect to hydraulics (height) and geo-technics (strength) of the dikes are considered. However, the assessment method does not provide the required failure probabilities for a risk analysis. The results are used to identify dominating failure mechanisms at certain locations beforehand (“weak spots”). Since it is impossible to predict these weak spots for the 2015 situation, the present situation has been used for the identification. Based on the Dutch assessment in combination with knowledge from local experts 10 weak spots have been defined in each of the two dike-ring areas, on both Dutch and German soil.

2. The probabilistic Hydra-model is used to determine the required crest levels of the dikes, based on the wave-overtopping and overflow calculations. This approach is used because it will be able to give a very detailed overview of the differences between the required crest levels (by law) and the actual crest levels. The model computes failure probabilities for each location in each dike ring (every 100 meter), based on overflow and wave-overtopping.

3. The probabilistic model from the FLORIS-project has been used to determine the overall failure probabilities for the 10 weak points identified for each dike ring in step 1. Besides considering failures of the dike due to wave-overtopping, also bursting of the soil, piping and sliding of the inner slope are considered. Advantages of the model are the model-specific options, the possibility to compute an overall dike-ring failure probability, the large amount of practical experience with the model and the already available Dutch data.

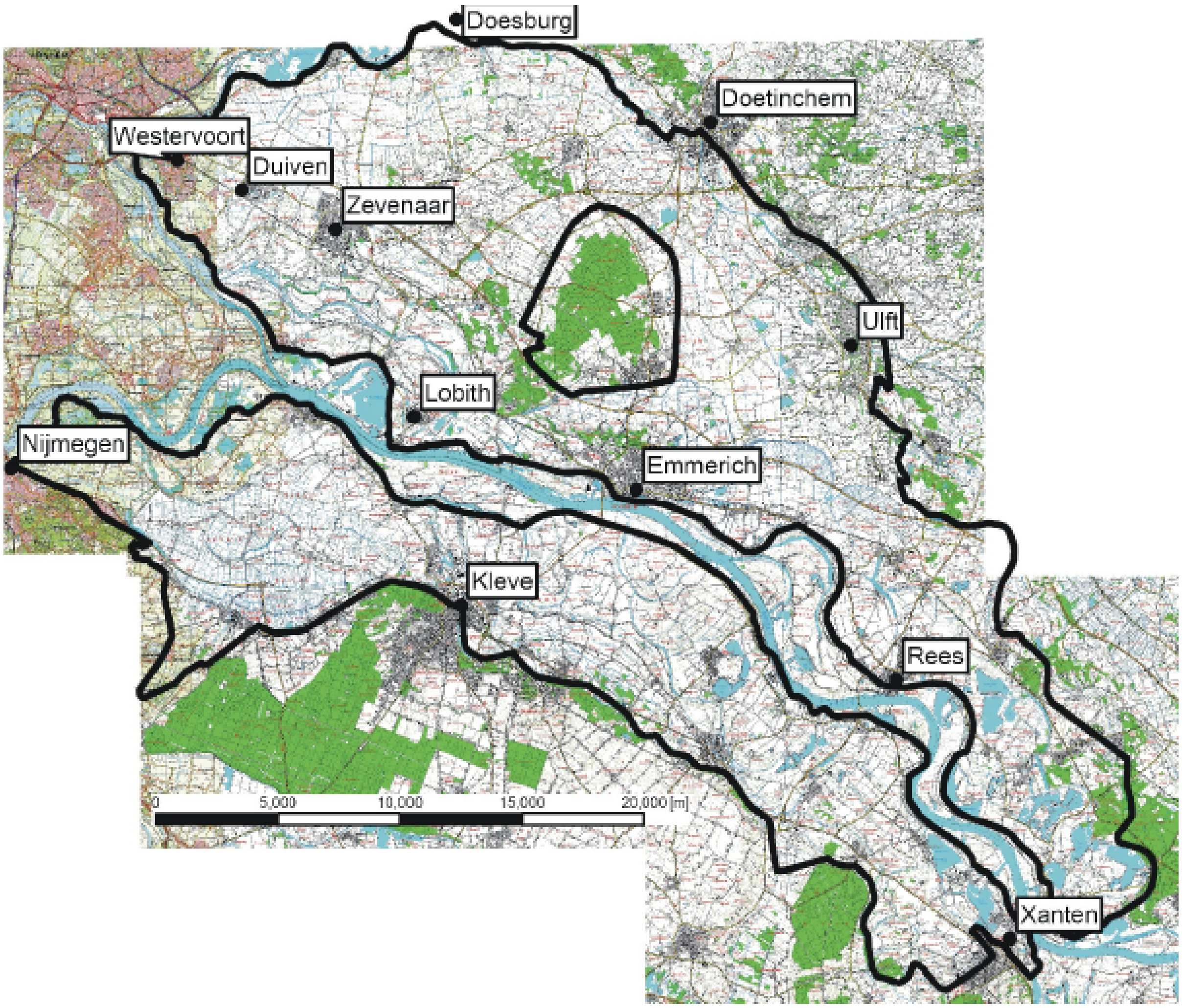

Figure 1: Project area with the considered weak spots

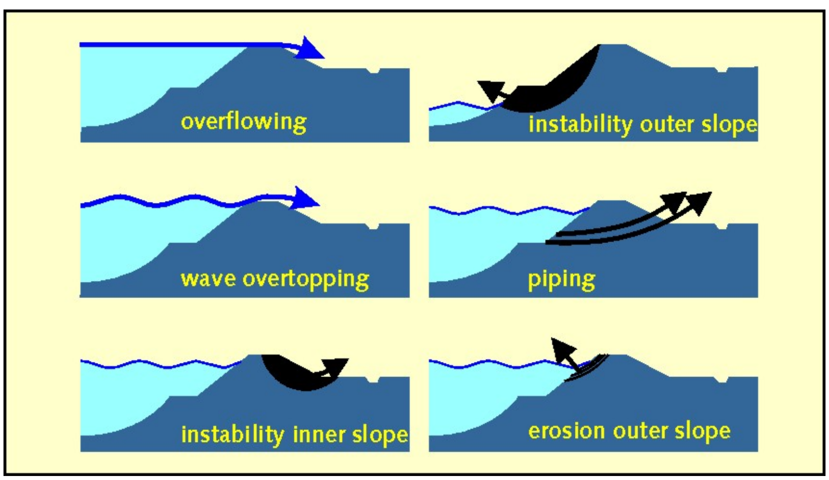

Figure 2: Failure mechanisms [source: VNK, 2005]

In the probabilistic model from the FLORIS-project the failure mechanisms are simulated in detail (Figure 2). However, there are still some simplifications in the model, in particular with respect to the geo-technical failure mechanisms. The consequences of these simplifications are investigated by using the M-RWTH model, which was modified based on expert knowledge from the “Division of Embankment Dams and Landfill Technology” of the Institute of Soil Mechanics and Rock Mechanics of the University of Karlsruhe, Germany. New failure mechanisms have been developed and tested, such as the collapse of the "pipes" that occur in the piping process, which is beneficial to the failure probabilities.

All three methods require detailed data from the dikes and the river, e.g. information about the dike cross-section, the soil characteristics of the dike, the river discharge, waves, discharge water-level relationships, and statistics of discharges and wind.

3.2 Flood and breach simulations

Besides failure probabilities the consequences of a flood need to be determined as well in order to identify the flood risk. To identify the damage caused by a flood, simulations are required of the breach growth and the flood itself. When the hydraulic load on a dike exceeds the existing strength of the dike, it will fail. The resulting breach ultimately leads to flooding of the hinterland. The maximum flooded area, the maximum flood depth and the flow velocities are determined. This information is then used for the damage computations (see next paragraph).

Flood-simulation models have been developed both in the Netherlands and in Germany. In the project the Dutch flood-simulation model Delft-FLS has been used. In order to determine the flooded areas the following data has been used: a digital terrain model of the project area, hydrographs, dike and area characteristics (geometry and geo-technical aspects) and the failure probabilities. Four existing terrain models have been available which cover the project area (Figure 3).

In Germany a detailed breach-simulation model has been developed, called BreFlow. In this model the development of a breach in a flood defense is simulated in great detail by using a numerical 1D model of the area near the breach, coupled with a 2D-hydraulic flow simulation model (Niemeyer et al., 2007). The results form the BreFlow-model are coupled with the Delft-FLS model and replace the default breach formula in the model. In a test scenario the breach discharge and the flooded area of the different models using the same geometrical formation of the breach have been compared. Figure 3 shows the results of the development of the breach discharge over the time. With the default breach formulation of the Delft-FLS model the discharge is approximately 30% higher than the one calculated with BreFlow.

The joint Dutch-German method for the breach and flood simulations is as follows:

- For the flood simulation of the hinterland the flood-simulation model Delft-FLS is used. The models for both dike-ring areas are available and have already been used and calibrated in existing projects for both the situation in 2006 and in 2015.

- For a maximum of four weak points detailed breach simulations are made with BreFlow. For all other weak points a default breach formula is used in the flood-simulation model. If relevant, the results from the detailed breach simulations are incorporated into the flood simulations.

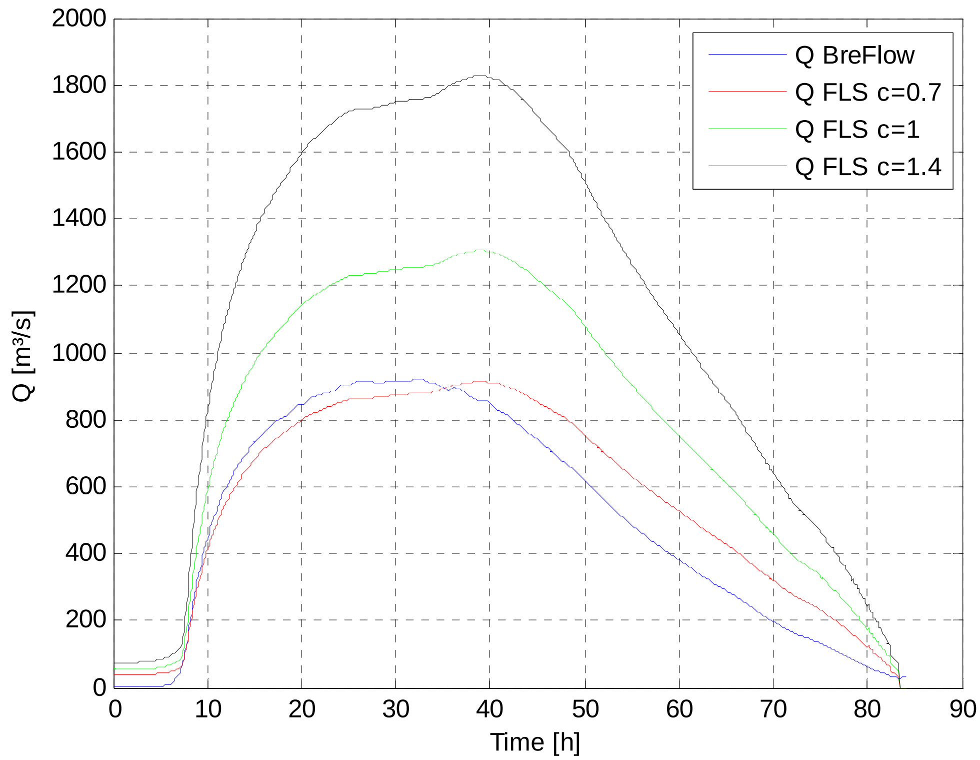

Figure 3: Comparison of breach discharges at Lower Rhine calculated with Breflow and Delft-FLS.

3.3 Damage assessment

The consequences of a flood can be determined in terms of economic value of the damage. Various types of damage can be distinguished, such as damage to houses and other goods (direct damage) and due to loss of production (direct damage caused by business loss). Besides economic damage in the flooded area itself, however, damage also occurs outside the flooded area. An example would be the damage to a factory because it runs out of supplies, or because the supplies can no longer be delivered to customers in the flooded area. This is called the indirect damage.

Loss of life is another type of damage caused by floods. In the project losses of (human) life have not been taken into account. It is assumed that all people have been evacuated before the flood occurs. However, the people living in the flooded area, the ones that are affected by the flood, have been computed.

To determine the flood damage a German and a Dutch damage model were available. The general procedure of the two models for the calculation of the direct damage is equal, differences exist in the land-use categories, the maximum damage amounts and the damage functions. As with the Dutch model HIS-SSM the business interruption and the indirect damages can be calculated, it has been decided to use that model and to modify it for the transboundary project. Another reason has been it’s ready availability for the Dutch parts of the two dike rings.

The three most important components in the HIS-SSM damage module are: the damage categories, the damage functions and the maximum damages per category. The damage categories correspond with the land use in the area, such as agriculture, roads, or housing. The damage functions link the water depths from the flood simulations to a factor between 0 and 1 indicating the damage factor. This factor is then multiplied by the maximum damage value, which results in a damage estimate at a location based on its corresponding damage category (Figure 4).

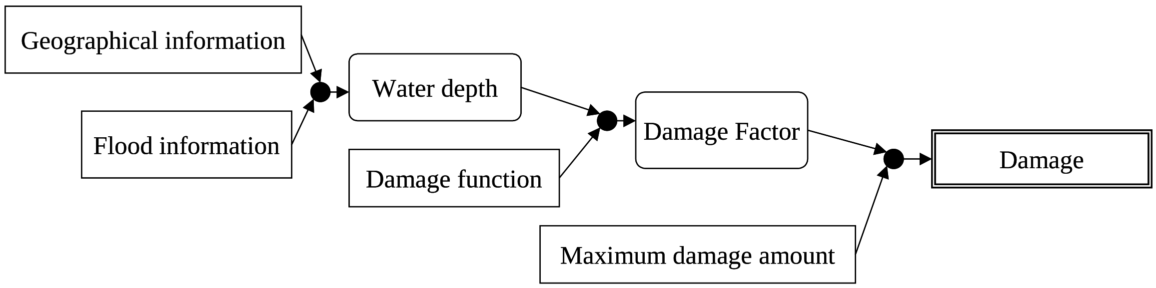

Figure 4: Computation of damages using HIS-SSM.

In the joint method German data has been implemented in the Dutch model. Depending on the damage category, either a Dutch or a German damage function has been used to provide the best knowledge of both countries. The maximum values for the categories in Germany have been developed specifically for this project, based on the Dutch values which have been corrected comparing the purchasing power parity of both countries. Within the project it is now possible to make a damage estimate for the entire dike ring, which can be displayed for the German and the Dutch part of the area.

3.4 Flood risk

The flood risk is computed as the product of the flooding probability and the corresponding consequences (damage). When determining the flooding probability it is important to consider the correlations between the failure probabilities of individual weak points. It is also relevant to consider the effects of a breach at a certain location on the failure probabilities of the other weak points. Upper and lower boundaries for the flood risk are determined as well. With the aid of the Scenario-tool, developed in the FLORIS-project [VNK, 2005], the risks of the different flood scenarios are combined into a single risk estimate for the entire dike ring. With this tool the temporal and spatial correlations of the hydraulic load and the strength of the flood defenses are taken into account.

3.5 Cost-benefit analysis of risk-reduction measures

In order to increase the safety of a dike ring with respect to high-water protection, the effects of various measures have been investigated. These measures may affect the river bed the dike itself (heightening), or the hinterland (compartment dikes). The types of measures and the measures itself are decided upon together with local experts from the project area. The costs of the various measures are based on unit-prices. Measures that focus on organizational aspects, such as dike maintenance or evacuation strategies, are not considered within the project.

Depending on the type of measure, there will be changes to the failure probabilities or damage assessment or both. As a result the flood risk changes for each measure, and therefore it needs to be recalculated. The reduction in risk due to the measure is called the societal benefit of the measure, and it should be balanced against the cost to implement the measure. This is done in a cost-benefit analysis for all measures to see which ones are the most (cost) effective.

3.6 Sensitivity analysis

The different steps in a flood-risk assessment are always based on assumptions and surrounded by uncertainties. In order to determine the sensitivity of these assumptions and uncertainties a sensitivity analysis has been carried out during the project to put things in perspective. In the sensitivity analysis attention is paid to for example the development of the breach (width, depth, time of breach with respect to the discharge wave), the flood wave (height, shape) and the correction of the damages and costs.

4. SUMMARY AND FUTURE PLANS

In the project a joint German and Dutch method has been developed which all partners in the project and policy makers in the area have accepted. By combining the best available knowledge of both countries the method has been successful in a flood-risk assessment in an area where two countries meet. It is safe to say that the transnational cooperation has provided much added value to the overall project. At the moment the first and second phase of the project are close to finishing. The third and final phase (the flood risk assessment of the dike ring on the left bank of the Rhine) has been initiated. The results of the overall assessment are expected during the summer of 2008.

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