The impacts of floods: considering the estimation of direct economic damage and loss of life

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Introduction

Large parts of the Netherlands lie below sea level and are threatened by river floods. Without the protection of dunes, dikes and hydraulic structures more than half of the country would be almost permanently flooded, as is shown in figure 1.
The last disastrous flood occurred in 1953. A storm surge from the North Sea inundated large parts of the Southwest of the country. Apart from immense economic damage, about 1800 persons drowned during this disaster. After the 1953 flood the Delta Committee was installed to investigate the possibilities for a new safety approach. In an econometric analysis (Van Danzig, 1956) the optimal safety level was determined for the largest flood prone area, Central Holland. This work laid the foundations for the new safety approach, in which dikes are dimensioned based on a design water level with a certain probability of occurrence.
Since the work of the Delta Committee, carried out in the late 1950's the economic value situated in the flood prone areas has grown rapidly. It can be questioned if the protection standards as derived by the Delta Committee still provide enough protection when the current economic value is considered. In 1993 and 1995 extremely high river discharges occurred in the river system, which made large scale evacuations necessary. Also other recent disasters, such as the crash of the El Al Boeing in Amsterdam in 1993 and the explosion of the fire works storage in Enschede in 2000, have lead to increasing awareness of risks that face society and it's citizens. In the future climate change, the accompanying sea level rise and higher river discharges will lead to an increase of flooding probabilities for the Netherlands.

Figure 1. The Netherlands without flood protection (the dark area would be flooded due to sea and river floods and the city Amersfoort would be localised on sea).

Background of the project

In the last decade of the 20th century methods have been developed to determine the probability of flooding and the consequences of a flood. These methods form the basis for the risk-based approach of flood protection. In this approach the probabilities and consequences of flooding have to be considered together and in coherence. The developed methods have been applied in a case study (TAW, 2000), in which the flood risks were determined for four areas in the Netherlands. Based on the outcomes of these case studies a project has been initiated to assess the safety of all flood prone areas in the Netherlands. The FLORIS (flood risk) project is carried out by the

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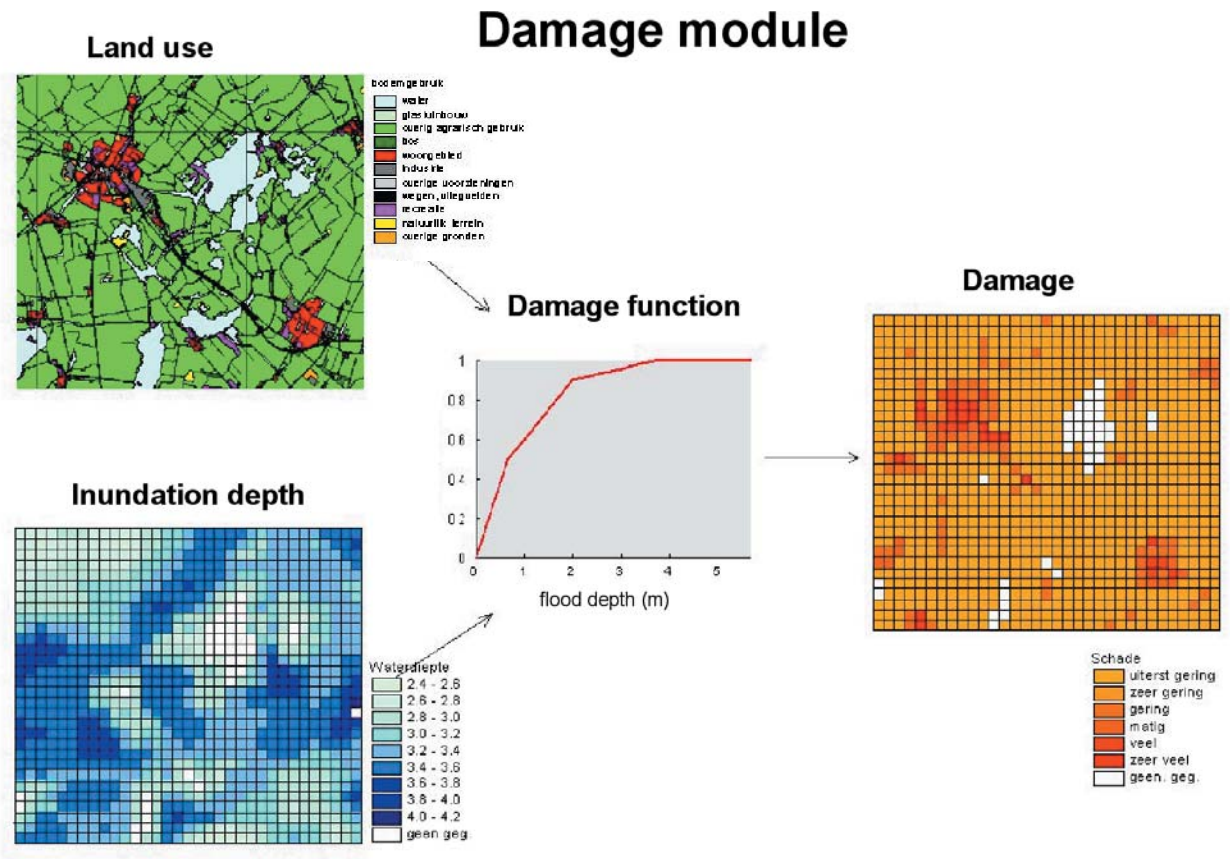

Figure 2. Principle of the method for assessment of economic damage.

Road and Hydraulic Engineering Division of the Directorate General of Public Works and Water Management (Ministry of Transport, Public Works and Water Management) together with the responsible provinces and water boards. FLORIS is divided into the following four subprojects:

1 Assessment of the probability of flooding of dikes and dunes;
2 Assessment of the probability of flooding of hydraulic structures;
3 Determination of the impacts of floods;
4 Development of methods to take into account uncertainties in subprojects one to three (Wehrung, 2003).

The project is scheduled to be finished in 2004 and it's outcomes will give insight in the current flood risks in the Netherlands and provide the basis for an informed discussion on the desired level of flood protection. This paper focuses further on the activities within the third subproject of FLORIS, namely the assessment of the impacts of floods.

Flood risks and the impacts of floods

Insight in the impacts of floods is an essential element in the approach mentioned above. The new insights will make it possible to develop a better view of the costs and benefits of high-water protection measures. These measures might be in the field of reinforcement and elevation of water defences, the lowering of water levels as well as the restriction of the consequences of floods due to technical and governmental measures. Examples of the latter type are measures in the field of spatial planning, which reduce flood damage (potential).

The consequences of floods can be of various nature: loss of life can occur, as well as economic damage, social disruption and damage to landscape, environment and cultural values. Within the flood impacts subproject several studies have been initiated which focus on the various types of consequences. Knowledge from disciplines such as economics, environmental planning, agricultural sciences, psychology, cultural history and nature conservation is hereby

used. The remainder of this paper will focus on methods developed for estimation of economic damage, loss of life and the effect of evacuation.

Estimation of economic damage

Statistics on natural disasters show the immense economic damage caused by floods all over the world (see for example Münich Re Group, 2000). Moreover, the statistics indicate a growing amount of floods as well as an increase of the damages per event. An inundation of one of the densely populated, highly economically developed areas in the Netherlands will undoubtedly cause enormous economic damage. The extent of this damage depends on the nature of the flood, for example from sea or river, and the properties of the area, for example terrain height and land use. A method has been developed for estimation of the economic damage due to flooding (Vrisou van Eck *et al.*, 2001). The procedure for damage estimation is schematically shown in figure 2.

Information on land use is combined with flood data (water depth). Damage relations have been developed for different types of land use, which estimate (part of maximum) damage as a function of water depth. The result of the damage assessment is the total economic damage that can be expected, given that particular scenario.

The method as outlined above provides insight for decision makers in the effects of several measures, for example the damage prevention obtained by spatial planning. The method has proven a useful tool in some major projects in river engineering in the Netherlands, including the room for rivers study and the study on the use of emergency retention areas. While the described method focuses mainly on estimation of the direct economic damage, ongoing research (van der Veen *et al.*, 2001) is carried out to gain more insight in the indirect effects of floods on the national economy.

Estimation of loss of life and the effect of evacuation

Floods cause harm all over the world and are the leading cause of death for natural disasters as can be concluded from worldwide statistics (www.cred.be). Although most major floods of the last decades have occurred in Asia, Africa and South America, recent floods in Central Europe and "near floods" in 1993 and 1995 in the Netherlands have raised the awareness on this matter.

Although loss of life is seen as one of the major impacts of floods relatively little research has been done on prediction of the numbers of fatalities for floods. In the Netherlands a method for estimation of life loss has been developed, which is based on data from the 1953 flood disaster, which inundated large parts of the Southwest of the Netherlands and caused 1800 fatalities. In this method the probability of drowning is a function of the local water depth and the rate of rising of the water. It can be questioned whether the circumstances during the 1953 flood and the characteristics of the area during that time still represent the current situation in the Netherlands. For example building strength and warning systems may have undergone many changes since 1953. Furthermore, the function does not take into account the effect of an evacuation. It can thus be expected that the current "standard method" does not give a reliable estimation of loss of life caused by floods. Therefore a special project on loss of life modelling and evacuation simulation has been set up as part of the "impacts of floods" research. Within the suggested framework loss of life should be predicted as a function of flood characteristics and the effect of an evacuation should be taken into account. The following research activities are carried out.

General data from about 1300 worldwide floods, as is included in the international disaster database for floods that occurred between 1975 and 2002, has been analysed (The database is maintained by the Centre for the Research on the Epidemiology of Disasters: www.cred.be). It is investigated whether differences in mortality (fraction of the inhabitants that does not survive a flood) for different types of floods (for example flash flood or coastal flood) and different regions can be found. The outcomes of this study show that flood mortality is mainly determined by the type of flood (flash, river or coastal flood or drainage problems). Striking is the fact that the mortality rates are relatively constant for river floods, regardless the location of the flood. However, the results of the database analysis provide a general impression of flood losses and are not suitable for a more detailed estimation of loss of life for certain flood scenarios.

Therefore data from specific floods is analysed

more in detail to gain insight in the relation between drownings and the hydraulic circumstances of the flood. As a special case study a project is carried out together with the local authorities to analyse loss of life caused by the floods of the Odra in Poland in 1997. This study is at the moment in the data collection phase. Results will be reported in a future paper.

For evacuation a conceptual method has been developed to simulate an evacuation of a flood prone area (Barendregt *et al.*, 2002). The model takes into account various factors, such as the time needed for decision making, predictability of the flood, the required reaction time, infrastructure capacity, traffic management, etc. A typical outcome of the method is shown in figure 3.

The figure shows the percentage of the inhabitants evacuated as a function of time. At a certain point in time the dike breaches and the flood occurs (in the figure after available time). A certain fraction of the inhabitants (f_e) will still be present in the area and these persons will be exposed to the flooding conditions.

The methods developed within the loss of life and evacuation research can provide information on the reduction of impacts and the effectiveness of various measures. Decision makers can benefit from the evacuation model as a tool in their disaster management planning. Moreover, knowledge and methods developed will be important instruments in the risk-based approach of flood protection. The knowledge obtained offers the possibility to quantify flood risks with risk measures such as FN curves and individual risk contours, which are used in other sectors such as chemical engineering and airport safety to assess and limit risks (Jonkman *et al.*, 2003).

Concluding remarks

A risk-based approach of flood protection requires insight in the probabilities and consequences of floods and the accompanying uncertainties. The results of the FLORIS (flood risk) project will provide more insight in the current levels of flood protection in the Netherlands. In this paper an overview has been given of the research within FLORIS on the impacts of floods, specifically considering the estimation of direct economic damage and loss of life. Since this article describes ongoing research activities, no final conclusions can be given yet. However, some

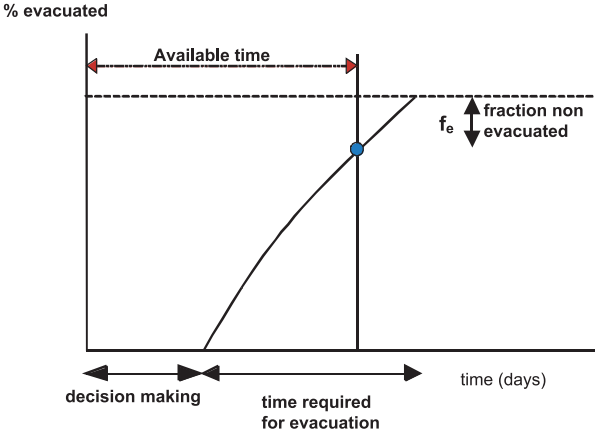

Figure 3. Development of evacuation as a function of time (Barendregt *et al.*, 2002).

concluding remarks are made here. International cooperation is necessary for the improvement of insight in flood impacts. "Learning from each other's mistakes" should be the basis for an improvement of the current methodology. Finally, the discussion on the desired level of flood protection should be based on open and objective information, in which the costs and benefits of various alternatives should be clearly put into perspective, without the exclusion of any type of measure. The methods outlined in this paper can provide a valuable contribution to this discussion.

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