



Flood risks and climate change

Threats or opportunities for the design of multifunctional flood defences?

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Large parts of the Netherlands are prone to flooding. What is the level of flood risk in our country and how will it be affected by climate change? What do we do to prevent water of getting “Carte Blanche”? This article addresses these questions. In addition, insight is given in strategies for flood risk reduction and it is argued that especially in densely populated areas there is a need for the further development of multifunctional flood defence zones..

Large parts of the Netherlands are below sea level or the high water levels of rivers and lakes. Without the protection of dikes, dunes, and hydraulic structures (such as storm surge barriers) approximately 60% of the country would be flooded regularly. Due to this situation, the Netherlands has a long history of flood disasters. Until the 13th century protection against flooding in the Netherlands was mainly example achieved by living on dwelling mounds (in Dutch: *terpen*) or on higher grounds. In the 13th century a more active approach was taken in this field. The first flood defences (dikes) were constructed and the organisational structures to maintain these dikes, the so-called water boards, were introduced. Nevertheless, major catastrophes occurred in the country throughout the centuries, such as the St. Felix flood in the year 1570 that led to ten thousands of fatalities in the Southwestern part of the country. The last disastrous flood in the Netherlands occurred in 1953. A storm surge from the North

Sea flooded large parts of the southwest of the country. Apart from enormous economic damage, more than 1,800 people drowned during this disaster. As a response to this disaster the (first) Delta Committee new safety standards for flood defences in the Netherlands that were based on a cost benefit analysis¹. For example, for South Holland an optimal level of protection of one in 10,000 years was proposed, implying that the flood defences around the area have to be designed to safely withstand a storm surge that occurs (on average) once in 10,000 years. For other areas the same type of safety standards were derived (see figure 1) and the protection level varied between areas depending on the potential level of damage. This Delta committee also made proposals for the improvement of the flood defence system and proposed to close off the open estuaries in the province of Zeeland that were vulnerable to coastal flooding by means of a series of gates and dams. Throughout the last

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2 Dike ring areas and safety standards in the Netherlands (Source: Rijkswaterstaat)

3 Fatalities by neighbourhood and flooded area for the scenario with breaches at Den Haag and Ter Heijde (Jonkman, 2007)



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decades of the 20th century, these so-called Delta Works have been constructed.

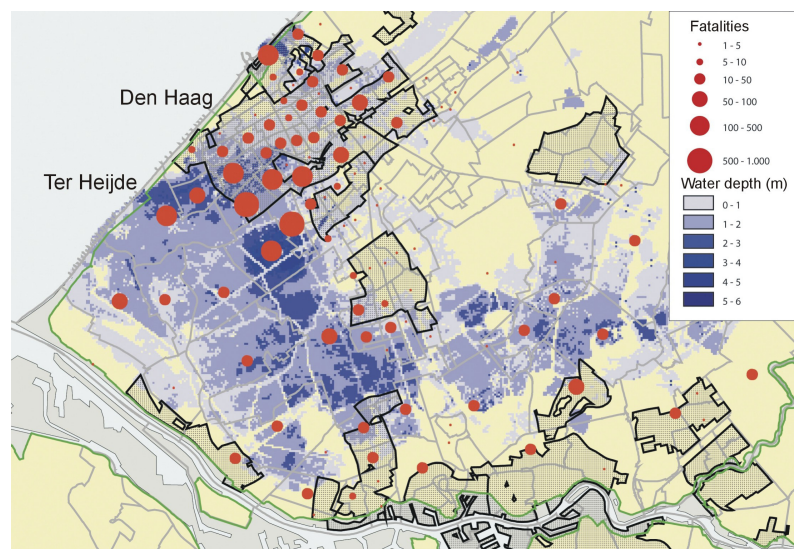
Although the level of protection in the Netherlands is "better than ever before" and relatively high in comparison with other countries it still can be questioned whether the current level of flood risk in the Netherlands is acceptable. The concept of risk concerns the combination of the probability of flooding and the consequences of flooding. These consequences can be expressed amongst others in terms of economic damage and loss of life. Since the work of the (first) Deltacommittee in the 1960's the potential damage and the number of inhabitants in the flood prone has drastically increased².

In recent years Rijkswaterstaat has worked on a project that aimed to give insight into flood risk levels in the Netherlands by determining the probabilities and consequences of flooding due to failure of primary flood defenses (dikes, dunes)³. As part of these risk studies assessments have been made of the potential consequences of flooding of several areas in the Netherlands. One of the largest flood prone areas is South Holland. The area has 3.6 million inhabitants and it is also the most densely populated area in the country and includes major cities such as Amsterdam, Rotterdam and Den Haag. Flooding of this area can occur due to breaches at various locations both along the coast and the river. The consequences for various flood scenarios have been assessed by means of a method has been developed to estimate the loss of life due to

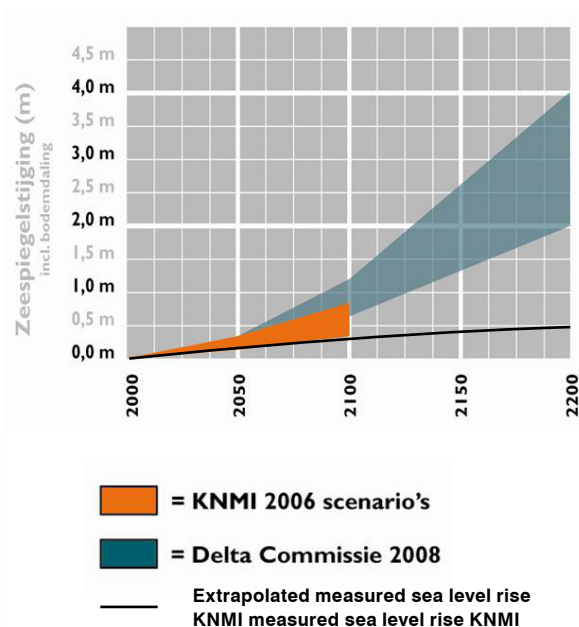
flooding⁴. As an example the output for a more severe coastal flood scenario with breaches at two locations (Den Haag and Ter Heijde) is considered. In this case an area of approximately 230 km² could be flooded with more than 700,000 inhabitants. It is expected that the possibilities for evacuation of this area are limited because the time available for evacuation (approximately one day) is insufficient for a large-scale evacuation of this densely populated area. Eventually it is calculated that this flood scenario could lead to more than 3000 fatalities. Figure 2 shows the flooded area and the spatial distribution of the number of fatalities. Although the probability of this scenario is expected to be relatively small (approximately once per million years), the consequences could be enormous.

From these studies it appears that the probability of death for an individual in the Netherlands due to flooding, the so-called individual risk, is small. However, the probability of a flood disaster with many fatalities, the so-called societal risk, is relatively large in comparison with the societal risks in other sectors in the Netherlands, such as the chemical sector and aviation⁵.

In the future it is expected that the effects of climate change, subsidence and economic and population growth could lead to an increase of the level of risk if no measures are taken. In the year 2008 the report of the (second) Deltacommittee (also named the Veerman committee) has been published⁶. This committee investigated the possible strategies for flood protection, looking 100 to even 200 years ahead. As part of their analyses the Deltacommittee used predictions of the sea level rise. In their most extreme scenario the sea level could rise 1.3m in the year 2100 and 4m in the year 2200 (figure 3). This raised a lot of public discussion as this scenario was considered very conservative



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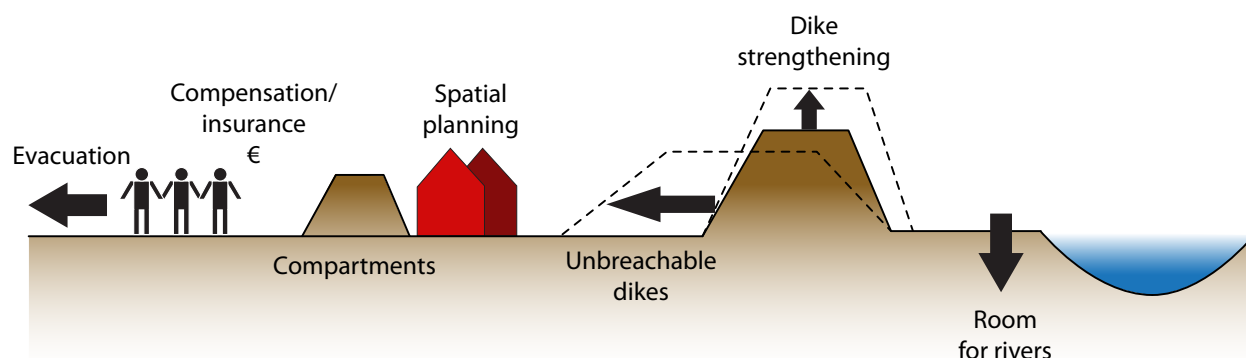
and an inappropriate basis for decision-making. To stimulate further discussion it is interesting to compare the prediction of sea level rise by Deltacommittee with the extrapolated trend of the observed sea level rise over the last decade, which is a sea level rise of approximately 30 cm per century.

Apart from the somewhat distracting discussion on the sea level rise scenarios, the Delta committee also concluded that the current level of flood protection was insufficient, especially if the potential risks to people is taken into account (see above). Overall, these findings indicate the necessity of a further investigation of measures and plans to reduce the level of risk.

Strategies for flood risk reduction

There are several strategies and measures to reduce the flood risk. These focus either on prevention (i.e. the reduction of the probability of flooding) or the reduction of the consequences. Figure 4 presents a schematic overview of these measures. Traditionally, prevention in the Netherlands has been mainly achieved by means of dunes, dikes and storm surge barriers. Nowadays the concept of preventing flooding without raising the dikes is adopted for the river system. By giving more "Room for rivers" with riverbed widening and deepening, the discharge capacity of the river will be increased. Several strategies could contribute to a reduction of the consequences of flooding. Compartment dikes in a flood prone area could stop the flood propagation after breach of the main dike, can prevent flooding of valuable areas. As part of the spatial planning policy important economic values in flood prone areas can be moved to higher grounds. Guidelines for the construction of buildings can limit the vulnerability of buildings for flooding conditions and therefore reduce economic damage. As a mitigating measure the occurred economic damage can be compensated, either by government or by an insurance company. These two options mean in fact a financial reallocation of the flood damage. Finally, emergency management and evacuation can reduce the risks to people and loss of life during a threatening flood event.

One strategy that has received a lot of attention recently is the concept of unbreachable dikes. These are wide and very strong dikes that will only overflow during a flood situation and this concept has already been proposed after the 1953 storm surge disaster⁷. Thereby catastrophic breaching will be prevented and the amount of flood water that enters the area and thereby the consequences will be limited. This measure is thereby a combination of prevention and consequence reduction.



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- 4** Sea level rise scenarios used by the Deltacommittee [6]. A trendline has been added that shows the extrapolated trend of the observations of the last decades.
- 5** Strategies for flood risk reduction.
- 6** A house in New Orleans that was raised after the flooding of the city due to hurricane Katrina.

As part of the recent policy document⁸ the ministry of Transport, Public Works and Water Management has adopted a so-called three-layered strategy. In this strategy the layers are prevention by means of flood defences, spatial measures and emergency management. Although the ministry has also indicated that the first layer (prevention by means of flood defences) remains the cornerstone of the policy, one important question remains: how to balance the amount of attention and the investments in these three layers? This discussion can be supported by a cost benefit analysis that compares the investments in certain strategies with the reduction of the flood risk. Then, it also becomes clear that the effectiveness of a measure in one layer will depend on the level of protection that is provided by the other layer. For example, the risk reduction that could be achieved by means of compartment dikes will depend on the level of protection of the area that is provided by the primary flood defences. In general one could say that the system is at least as strong as its strongest layer and it is a misconception that all layers have to be completely filled to achieve sufficient safety⁹.

One interesting and related observation comes from the city of New Orleans. It is recovering after it was severely flooded due to hurricane Katrina in the year 2005. In New Orleans the government is repairing and improving the flood protection system to a 100 year level of protection. In addition homeowners are able to buy flood insurance and they have the choice to make adaptations to their homes to make them more flood resistant. After the poor performance of the flood defences during hurricane Katrina many citizens have limited trust and confidence in the level of protection that the flood defences will provide. Therefore some of them decide to raise their homes by several meters. Figure 6 shows a home that was raised about 4 meters in one of the lower lying areas of New Orleans. This clearly illustrates the interdependency between the different layers and strategies for protection.

Multifunctional flood defences

Apart from the selection of measures and strategies there is the issue of the design of measures. If the sea level of water levels in the rivers rise (e.g. due to the effects climate change) the dikes could be heightened as a response. A recent study has shown that this is feasible for the coming two centuries from a technical and economic point of view, even for the most extreme sea level rise scenario¹⁰. However, especially in densely populated areas the strengthening of dikes could lead to spatial and societal bottlenecks as heightening also means widening of dikes. Therefore there has been a lot of recent attention for the



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concept of multifunctional flood defences that combine a water retaining function with other uses.

Traditionally the function of a flood defence has been combined with infrastructure. Our river dikes also function as roads and the dams in Zeeland and the Afsluitdijk provide, besides their water retaining function, a useful transport route. In recent plans by the second Delta committee an extension of the sandy coast along North and South Holland by means of foreshore nourishments has been proposed. In this "building with nature" approach the width of the coastal sand dunes is proposed to be extended as this will offer better protection and possibilities for ecological development. Also for other parts of the coastline the concept of a wider coastal flood defence zone has been investigated in the European Comcoast project.

Other function combinations are of interest for urbanized areas. One proposal from the report of the Delta Committee is the development of so-called delta dikes. Although the concept has not been defined specifically in the report it refers to failure proof flood defences that are also used for other functions such as housing. One elaboration of the delta dike is the wide "unbreachable" dike (see before) that is used to develop housing on top of the dike. In Japan, these are known as super levees and these have been already in place there for decades. They offer opportunities in areas where flood defence and urbanization could be combined, for example for Rotterdam and the new



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parts of Almere. But these delta dikes can only be developed in areas where there is sufficient space available to develop a wide dike zone. In general it will not be feasible to protect a whole dike ring system by means of unbreachable dikes due to interference with other existing functions. The contribution of these wide dikes to safety would also have to be evaluated from a systems perspective. A local widening of the flood defence reduces the risks locally. However, for a larger flood prone area (polder) it would not significantly reduce the risk, as it could still severely be flooded from other parts of the system that could not have been strengthened in this way.

One plan that can also be characterized as a multifunctional proposal is the "open-closed" solution that has been proposed for the Rijnmond area (see textbox 1). It combines the improvement of flood protection and creation of economic opportunities for waterfront development. At a lower scale level there are also possibilities to design multifunctional flood defences for densely populated area, for example a building which also functions as a flood defence¹¹.

Eventually, such multifunctional designs would also have to be evaluated from a cost-benefit perspective. Adding other functions could add value to the design, but will likely also require more investments. In some cases a leverage or synergy

effect could be achieved when multiple functions are combined, because the functions become more attractive when they are combined. For example, it is likely that houses that will be developed on a delta dike will be relatively valuable because they have a nice view.


Nevertheless, for decision-making and public discussion it is preferable to clearly assign investments and benefits to certain categories. For example, if it could be proposed to widen the coastal zone with 1000m by beach and foreshore nourishments. A widening of 100m could be sufficient for reasons of safety, but the remaining 900m widening would only be made to improve the ecological quality of the coastal zone. In this case 90% of the costs would have to be labeled as an investment in ecological and recreational values and this part of the investment could not be assigned to the flood defence budget of e.g. water boards or Rijkswaterstaat. Experiences from a past multifunctional project, the room for rivers program, show that a lot of confusion and discussion arose about which part of the total project cost (about 2.2 billion euro) could be assigned to flood defence function and which part can be assigned to ecological functions.

Threat or challenge?

The level of flood risk in the Netherlands is substantial, especially if the risks to people are taken into account. In recent years the general public and decision- and policy makers have become

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7 Concept for the Rhine Delta - 'usually open, occasionally closed'
Four new river flood barriers in addition to the existing storm surge barriers protect the highly urbanised region around Rotterdam. In the cities flood risks decrease and waterfront development becomes easier. In rural areas river water is directed south and creates new nature and recreation zones. Climate change as an opportunity for spatial quality

more aware of the importance of the protection of our low-lying country. The flood risks can increase further due to climate change and population growth, but only if no measures are taken. Throughout the centuries the a sophisticated flood defence system has been developed and it has been adapted continuously to the ever-changing natural and societal conditions. This is also the challenge for the future. Especially for urbanized areas this offers opportunities for the design of multifunctional flood defences. 

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