



## ADAPTATION MEASURES AND PATHWAYS FOR FLOOD RISK IN DORDRECHT

B. Gersonius<sup>1&2</sup>, E. Kelder<sup>2&3</sup>, K. Anema<sup>1</sup>, S. van Herk<sup>4</sup> and C. Zevenbergen<sup>1&5</sup>

1. UNESCO-IHE Institute for Water Education, Westvest 7, Delft, 2611 AX, The Netherlands
2. Delta Programme Rhine Estuary-Drechtsteden, Boompjes 200, Rotterdam, 3011 XD, The Netherlands
3. City of Dordrecht, Spuiboulevard 300, Dordrecht, 3311 GR, The Netherlands
4. Bax & Willems Consulting Venturing, Roger de Lluria 120, Barcelona 08037, Spain
5. Delft University of Technology, Stevinweg 1, Delft 2628 CN, The Netherlands

**ABSTRACT:** In line with the Adaptive Delta Management approach of the Dutch Delta Programme, Dordrecht has developed a multi-layer safety strategy to meet the future tasking for flood risk management. This strategy puts greater emphasis on limiting the consequences of floods through spatial planning (layer 2) and emergency management (layer 3), in addition to protection from floods through dikes (layer 1). The reasoning process and measures related to the new strategy are as follows.

The proposal of the Delta Programme sub-programme Safety for updating the protection standards has made it possible to invest in strengthening specific dike segments, where it is most cost-efficient. By transforming the northeastern dike segment into an extra strong dike, Dordrecht can be safer than with an economically optimal standard for the entire dike ring -- for about the same cost. This targeted measure in layer 1 is sufficient to meet the basic safety level (chance of fatalities is not higher than 1/100,000) and reduces the risk of social disruption (large groups of casualties) to virtually none.

Economic damages and casualties due to a dike breach in the Northwest or in the South can be reduced by using regional defences as compartmentalisation (layer 2). In addition, compartmentalisation of the dike ring area enables the creation of a "safe haven" for preventive evacuation on the island itself (layer 3). This also calls for thorough preparation for floods, e.g. by robust design of critical infrastructure networks and improved risk and crisis communication.

The multi-layer safety strategy for Dordrecht ensures that the objectives for flood risk management are met in a timely and efficient manner, that opportunities for mainstreaming adaptation and for spatio-economic development are taken advantage of, and that unnecessary costs of potentially irreversible measures are avoided.

**Key Words:** Adaptation Pathways, Adaptive Delta Management, Dutch Delta Programme, Flood risk, Multi layer safety

### 1. CONTEXT: THE DUTCH DELTA PROGRAMME

In the Netherlands, the central government, water boards, provinces and municipalities are working together on a new Delta Plan on Flood Risk Management (DP, 2013). This is the implementation element of the Dutch Delta Programme and it comprises a cohesive set of measures for specific regions, like the region around the major rivers, Rhine Estuary-Drechtsteden and the IJsselmeer. The Delta Plan programmes measures for the short term (up to and including 2028), but also looks ahead to the medium term (up to 2050). This phased approach to investment decision making was driven by major uncertainties around future developments and the desirability of responsible financial investment. In this context, it was considered inappropriate to set down measures for the next 50-100 years. Rather, these should be allowed to develop along with new insights and changing circumstances.

The Dutch Delta Programme uses the Adaptive Delta Management (ADM) approach (Isoard and Winograd, 2013), which is a transparent way of including uncertainty around future developments in investment decision making. This approach is focused on identifying Adaptation Tipping Points (ATP), where the objectives of flood risk management are no longer met (Kwadijk et al., 2010). Combining the defined ATPs with climate change scenarios will provide information about the need for additional measures. The ATP analysis can, therefore, help to develop Adaptation Pathways (Haasnoot et al., 2011). These refer to a sequence of measures and potential options, which may be triggered before an ATP occurs. Adaptation pathways are commonly used in the context of long-term planning as they provide insight into the options, lock-ins and path dependencies and introduce the flexibility to adapt to a wide range of future developments.

ADM encourages an integrated approach to tasking and minimises the regret with respect to maladaptation, which results from e.g. over- or underinvestment in flood risk management. Key points of the ADM approach are (DP, 2012):

- Linking short-term decisions with long-term tasking around flood risk management;
- Incorporating flexibility in possible solution strategies (where effective);
- Working with multiple strategies that can be alternated between (i.e. Adaptation Pathways);
- Linking different investment agendas.

Over the past years, the Delta Programme sub-programmes have examined which measures are needed, in the short term and future, for continued compliance with the objectives for flood risk management. ADM has been used in a number of area-based sub-programmes. The Rhine Estuary-Drechtsteden sub-programme, for example, has developed Adaptation Pathways and explicitly outlined at what times adaptation measures are required (i.e. ATPs). This article illustrates the application of the ADM approach for flood risk in Dordrecht, which is an area of the Rhine Estuary-Drechtsteden region.

## **2. ADAPTIVE DELTA MANAGEMENT APPROACH**

Decision-making on flood risk management measures needs to take account of a medium to long-term planning horizon. A range of future developments could influence the efficiency of these measures, for example in terms of use of space. Some developments may lead to higher costs, e.g. building-over spaces that could later have been more usefully deployed for adaptation measures. While other developments could lead to cost reductions, e.g. combining river widening with the replacement of sluices approaching end-of-life. Therefore, decisions on short-term measures should be taken in such a way as to avoid the unnecessary mounting of long-term costs, while agreements should be made on actions that could be linked efficiently (DP, 2011).

The ADM approach aims to ensure that any short- to medium-term adaptation decision is set within a framework that will not be maladaptive, if future developments (e.g. sea level rise) are different from what is currently predicted to be 'the most probable' (Reeder and Ranger, 2011). It sets out to develop a schematic overview of Adaptation Pathways that will address the tasking for flood risk management (or other policy domains, like freshwater supply) in a specific area. This approach assumes a bandwidth of plausible future developments (i.e. scenarios). Starting with the current situation, the schematic overview charts out the short-term adaptation measures. It then looks at possible amending or adaptive strategies in the medium- to long-term, including conditions under which it would be wise to shift to an alternative strategy. Furthermore, it focuses on possibilities for linking the implementation of strategies for flood risk management with other investment agendas (DP, 2011).

There are four crucial steps when pursuing ADM (Bloemen, 2013), and these are summarised below.

## **2.1 Step 1: Short-term (current strategy)**

- Description of the current strategy, together with the reasoning process (ambitions, objectives and direction of action);
- Translation of ambitions and objectives related to the current strategy into short-term tasking;
- Identification of the measures that could contribute to meeting the short-term tasking;

## **2.2 Step 2: Medium-term (uncertainties, tipping points and alternative strategy)**

- Clarification of the key uncertainties from future developments influencing the tasking, such as climate change and socio-economic development;
- Definition of the metrics (parameters) that describe the future developments, such as the magnitude of sea level rise in cm/year;
- Modelling different future developments to provide insight into the occurrence of ATPs, where the current strategy will no longer be able to meet its objectives. Scenarios may be used to transform the boundary conditions (e.g. the magnitude of sea level rise) under which an ATP will occur into an estimate of when it is likely to occur. The time at which an ATP may occur defines the moment that a new strategy will be needed;
- Development of the reasoning process related to the new strategy;
- Identification of alternative measures and potential options that might alter the timing of ATPs and assessment of the efficiency (costs and effects) for the different scenarios;
- Identification of the opportunities for mainstreaming adaptation with other planned investments in the area, such as the renewal of the urban fabric and infrastructure;

## **2.3 Step 3: Long-term (Adaptation Pathways)**

- Design of multiple Adaptation Pathways based on the efficiency of the individual measures and potential options (identified in step 2). Adaptation Pathways show the timing of implementation of measures and the points at which decision should be made on the selection of potential options that can be called upon. These pathways also generate insight into the consequences of decisions in terms of lock-ins and possible options that are still open (Haasnoot et al., 2011). Opportunities for mainstreaming adaptation may be considered to adjust timing of implementation of measures;
- In addition, it is necessary to identify critical values (triggers) beyond which adjustments in the strategy will need to be made;

## **2.4 Step 4: Linking short-term to long-term (anticipative actions)**

- Identification of anticipative actions that are necessary in the short term to enable the Adaptation Pathways. This comprises the initiation of:
  - Potential adjustments in legislation, rules and procedures;
  - Innovation and research;
  - Spatial reservations;

- Securing of funds.

### 3. CASE STUDY: FLOOD RISK IN DORDRECHT

The application of the ADM approach is illustrated for the management of flood risk in Dordrecht. Surrounded by a series of rivers and canals – the Oude Maas, Beneden Merwede, Wantij, Nieuwe Merwede, Dordtse Kil – the city of Dordrecht is located on an island. Its population consists of around 120,000 inhabitants. Most residential, industrial and agricultural areas are located in a single polder area of about 7 ha, which is protected by a 37 km long dike-ring. Part of Dordrecht is situated outside the dikes: the unembanked areas. These areas are positioned at relatively high elevations, in addition to being protected by the Maeslant barrier and Hartel barrier. The historic port area is the lowest-lying unembanked area. The Island of Dordrecht lies in the transition zone between the tidal reach and the river regime reach, where the extreme water stages are influenced by both the high river runoff and storm surges from the sea. Together with the city of Rotterdam, a number of other municipalities and the surrounding industrial, agricultural and nature areas, it is located in the Rhine Estuary-Drechtsteden region.

#### 3.1 Step 1: Short-term (current strategy)

Under the current strategy, flood risk management in Dordrecht is ensured by dike improvements and by replacing the storm surge barriers. Without these barriers the dikes would need to be 0.5m higher in Dordrecht. The protection standard for the dike ring has been established by national law (VenW, 2010) as the average exceedance frequency of the design water level that the dikes must withstand. This has been set at 1/2,000 per year.

The short-term tasking in Dordrecht has been inventoried in the second and third Statutory Assessment of primary flood defences. These were based on the defined protection standard and the corresponding design water levels. Findings of the Statutory Assessment (Figure 1) indicated that 28% of the dikes were below standards (due to, among other, changes in hydraulic peak conditions) and require improvement (PZH, 2011). These dike improvements are incorporated, or will be incorporated, into the implementation programme for flood protection measures (IenM, 2011).

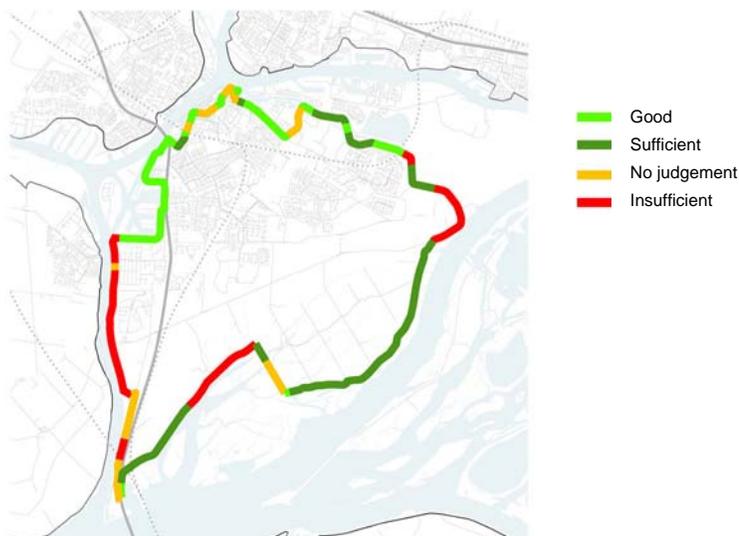


Figure 1: Short-term tasking (required improvements) in Dordrecht

There are no legal protection standards for the unembanked areas. According to the National Water Plan (VenW, 2009), the residents and users of these areas are responsible for taking consequence-reducing measures (where there is an unacceptable risk). This could include using elevated ground floor levels, dry proofing and wet proofing ground floors. Dry proofing may involve shielding, where the floodwater is kept out of the building by installing temporary barriers. Wet proofing, on the other hand, is based on the acceptance of water entering the building and involves using materials that will minimize the impact of floodwater on fabric and fixtures.

### 3.2 Step 2: Medium-term (uncertainties, tipping points and alternative strategy)

Uncertainty arises from a range of external factors, and these include future developments in sea level, river discharges and soil subsidence. These developments generate additional tasking, particularly in the transitional areas of the Rhine Estuary-Drechtsteden region. The Delta Scenarios were used in analysing the tasking following from these developments. These scenarios combine the existing KNMI-2006 climate scenarios and socio-economic scenarios from the collaborating planning bureaus (WLO-2006 scenarios).

In addition to these external factors, there are also internal influences on the tasking. At the launch of the Delta Programme, it was found that population and economic values in the region have increased considerably since the first Delta Committee issued its recommendations, on which the current protection standards are largely based. To this end, the Delta Programme sub-programme Safety has examined whether the current levels of protection (protection standards) are still sufficient. This was based on a social cost-benefit analysis, an analysis of individual casualty risks and an analysis of group risks. These analyses have shown that the Island of Dordrecht, among other parts of the Rhine Estuary-Drechtsteden region, has to increase its level of protection (these are 'areas of attention'). The Delta Programme 2015 will present a proposal for updating the protection standards, as part of the Delta Decisions. This will lead to another safety task for the Island of Dordrecht.

Figure 2 shows the future tasking following from both external factors (sea level rise, shifts in river discharges and soil subsidence up to 2050) and internal influences (updating of the protection standards).

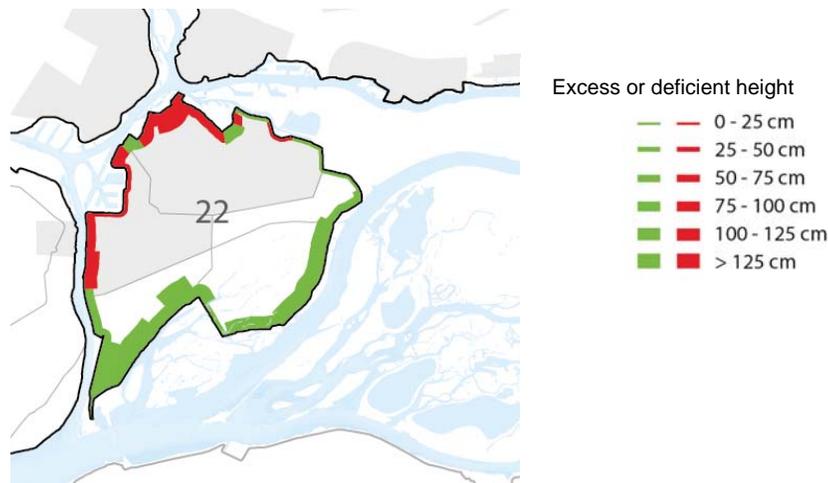


Figure 2: Future tasking (required improvements) following from both external factors and internal influences

In spatial terms, the Island of Dordrecht is faced with a considerable tasking that underscores the importance of a comprehensive view on and strategy for flood risk management. The question arises as to whether the current strategy of dike improvements is adequate to meet the future tasking or whether there needs to be a shift in strategy.

As such, an alternative strategy has developed been for Dordrecht that addresses the three layers of multi-layer safety, as outlined in the National Water Plan (VenW, 2009):

- Layer 1: Protection from floods through dikes;
- Layer 2: Limiting the consequences of floods through spatial planning;
- Layer 3: Limiting the consequences of floods through emergency management.

In the new strategy for flood risk management, measures in layer 2 and 3 are combined with protection measures in order to achieve the required level of protection (Figure 3). The reasoning process and measures related to the new strategy are summarised below.

The proposal for updating the protection standards has made it possible to invest in strengthening specific dike segments, where it is most cost-efficient. By transforming the dike northeastern segment into an extra strong, Dordrecht can be safer than with an economically optimal standard for the entire dike ring -- for about the same cost. This targeted measure in layer 1 is sufficient to meet the basic safety level (chance of fatalities is not higher than 1/100,000) and reduces the risk of social disruption (large groups of casualties) to virtually none. Economic damages and casualties due to a dike breach in the Northwest or in the South can be reduced by using regional defences as compartmentalisation (layer 2). In addition, compartmentalisation of the dike ring area enables the creation of a "safe haven" for preventive evacuation on the island itself (layer 3). This also calls for thorough preparation for floods, e.g. by robust design of critical infrastructure networks and improved risk and crisis communication.

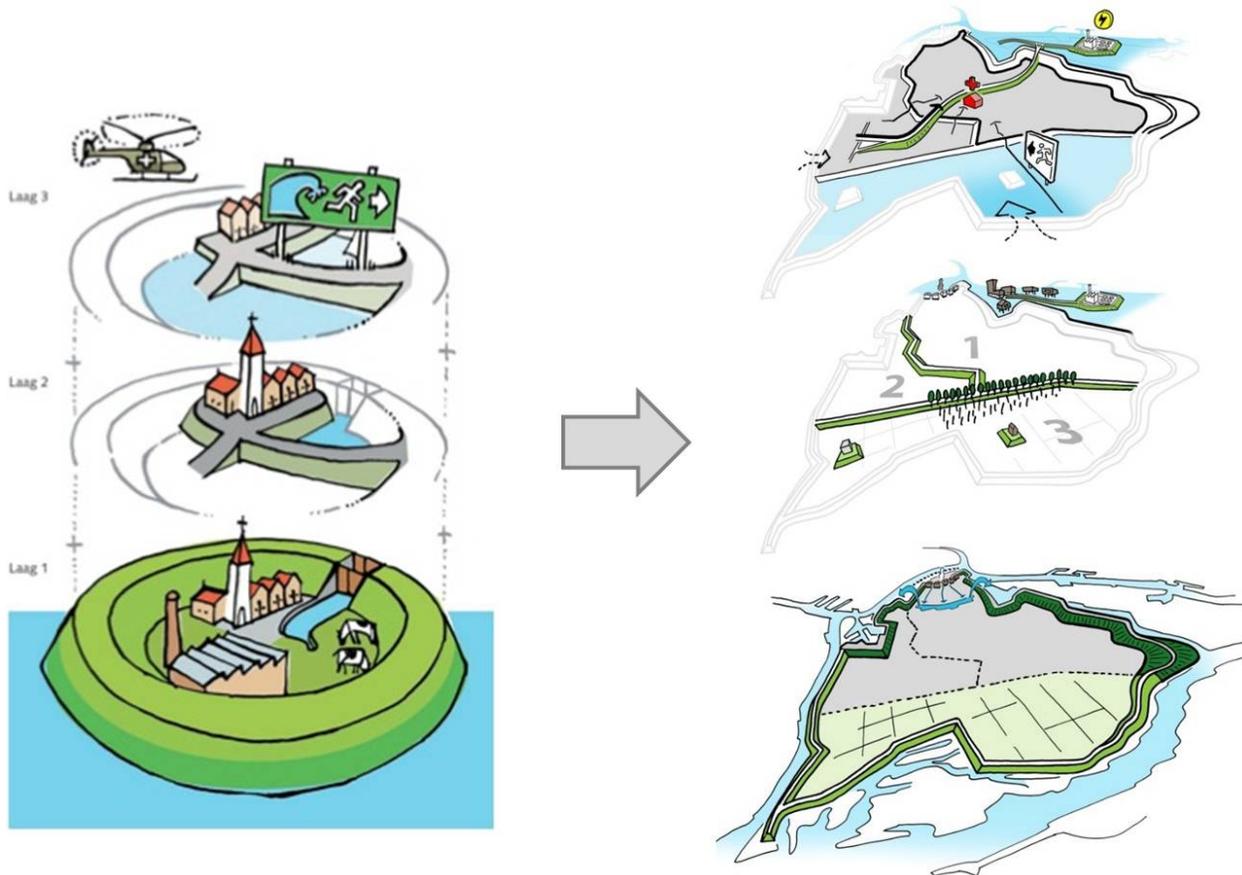


Figure 3: Multi-layer safety for the Island of Dordrecht

As part of the strategy development, it has been considered how the implementation of the required measures for the short- and medium-term can be linked with other spatio-economic developments and ambitions. The following opportunities for mainstreaming adaptation have been identified:

- A possible alternative to dike improvement of the Voorstraat is to build a new flood defence along the river Oude Maas to replace the existing dike (Hinborch, 2010). This new flood defence will consist of a floating barrier in the quays. Because this barrier will not be visible under normal circumstances, it will have little impact on the historical town centre. The barrier will provide considerable synergistic benefits by protecting the unembanked part of the historical town centre against flooding, against only slightly higher investment costs. As such, it provides the opportunity to link the tasking for the unembanked areas with the required dike improvements.
- The water board Hollandse Delta has made an extra investment in safety with the regular improvement of the dike section Kop van 't Land (northeastern dike segment), as part of the Second Flood Protection Programme. This excess safety allows for the adoption of an extra stringent protection standard, without increasing the future tasking (up to 2050). This has made it possible to link the short-term tasking with the future tasking.
- The Ecoshape consortium, which is a collaborative body comprising the business community, knowledge institutions and government bodies, is conducting a study into the potential of green adaptation measures (building with nature) in Dordrecht. These measures could be implemented as alternative measures to address the safety tasking, such as for the maintenance and management of the foreland. Green adaptation measures can deliver added value through a combination of nature development and safety (Figure 4).

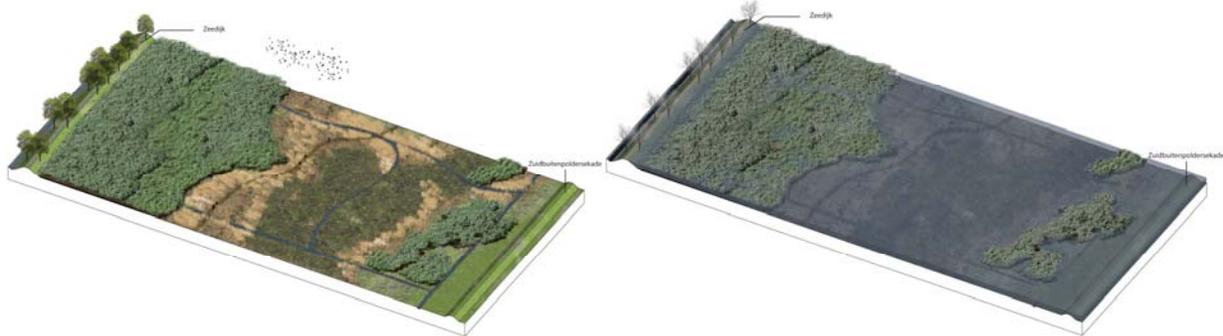


Figure 4: Impression of green adaptation measures for the North/South compartmentalisation dike, left under normal circumstances and right in case of a dike breach in the South. The nature development along the dyke has been designed to break the flood waves, in addition to enriching the landscape. (courtesy of D.EFAC.TO)

### 3.3 Step 3: Long-term (Adaptation Pathways)

In accordance with the ADM approach, an exploration of the Adaptation Pathways has been carried out for flood risk in Dordrecht. This involved specifying what is required to keep options open for the long term, so as to be able to shift from the current strategy to another in the future. The options that need to be kept open followed from the alternative strategy determined for the future (i.e. the multi level safety strategy). Based on this exploration, it appears to be possible to take no-regret decisions for the short term.

The various Adaptation Pathways for the management of flood risk in Dordrecht are given in Figure 5. These paths provide insight into which adaptation measures need to be taken when and how long-term tasking impacts upon short-term decisions.

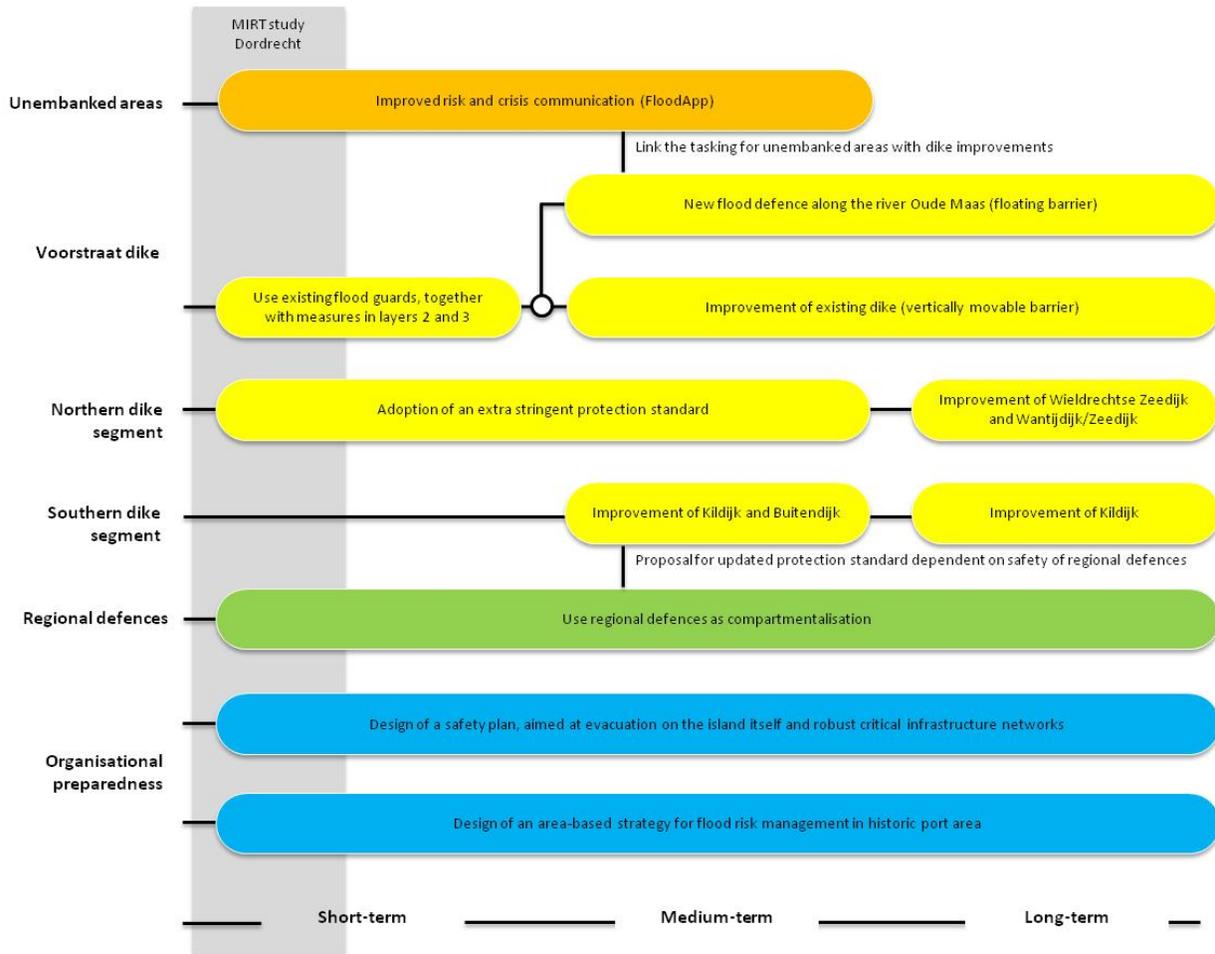


Figure 5: Adaptation measures and pathways for flood risk

### 3.4 Step 4: Linking short-term to long-term (anticipative actions)

It is not yet known how agreements on measures in layers 2 and 3 of multi-level safety can be laid down. If the protection levels are going to be based in part on measures in layers 2 and 3, then it is essential to guarantee that they will actually provide the necessary protection (DP, 2012). To this end, the central government and the regional partners (water board, province, municipality and safety region) have initiated a Multi-year Programme for Infrastructure, Spatial Planning and Transport (MIRT) study into the added value of and the possibilities for (safeguarding) measures in layer 2 and 3. The MIRT study will also look for a better connection between flood risk management and spatial planning and further develop the opportunities for mainstreaming adaptation and for spatio-economic development.

## 4. CONCLUSIONS

The multi-layer safety strategy for Dordrecht ensures that the objectives for flood risk management are met in a timely and efficient manner, that opportunities for mainstreaming adaptation and for spatio-

economic development are taken advantage of, and that unnecessary costs of potentially irreversible measures are avoided. As such, the strategy contributes to:

- **Safety:** By transforming the northeastern dike segment into an extra strong dike, Dordrecht can be safer than with an economically optimal standard for the entire dike ring -- for about the same cost. This targeted measure in layer 1 is sufficient to meet the basic safety level (chance of fatalities is not higher than 1/100,000) and reduces the risk of social disruption (large groups of casualties) to virtually none.
- **Ametity:** The strategy for flood risk management fits well to the different spatio-economic characteristics of the area. To this end, spatio-economic development perspectives have been developed, namely *strong, urbanised dikes* in the North and *robust sea clay islands* in the South.
- **Efficiency:** The present value of the strategy for flood risk management is M€ 133 in the Delta Scenario Rest and M€ 158 in the Delta Scenario Steam (Vos and Kind, 2014). In Steam, the present value of the strategy is about 38% low than for the reference strategy (without updated protection standards), meaning that it is more efficient than the reference strategy. In Rest, the strategy is less efficient than the reference strategy, partly due to the extra stringent protection standard for the northeastern segment.

## 5. ACKNOWLEDGEMENTS

The authors gratefully acknowledge the support of the EU's Interreg IVB project CAMINO and the NWO/WOTRO project Dynamic Deltas. Thanks also goes to Teun Morselt of Blueconomy for his advise on the design of Adaptation Pathways for flood risk in Dordrecht.

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