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Spatial Quality as a decisive criterion in flood risk strategies

An integrated approach for flood risk management strategy development,
with spatial quality as an ex-ante criterion

Anne Loes Nillesen

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**An integrated approach for flood risk management strategy
development, with spatial quality as an ex-ante criterion**

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"If we knew what it was we were doing, it would not be called research, would it?"
Albert Einstein

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Abstract

The role of the designer in flood risk management strategy development is currently often restricted to the important but limited task of optimally embedding technical interventions, which are themselves derivatives of system level flood risk strategies that are developed at an earlier stage, in their local surroundings. During this thesis research, an integrated approach is developed in which spatial quality can already be included in the regional flood risk management strategy development, and thus can become a decisive 'ex-ante' aspect of flood risk management strategy development.

The key principle to this approach is the inclusion of a range of interchangeable (effective) flood risk reduction interventions at varying locations, so that the criterion of spatial quality can become decisive in flood risk management strategy development. As part of the methodology development, an assessment framework is developed, allowing for the assessment of the impact of the different interventions on spatial quality; research-by-design is employed to systematically evaluate different interventions at different locations. The Rijnmond-Drechtsteden area in The Netherlands is used as a case study area for this research.

Samenvatting

De rol van de ontwerper is bij het opstellen van waterveiligheidsstrategieën vaak beperkt tot de belangrijke maar beperkte taak van het op lokale schaal optimaal inpassen van technische ingrepen; die ingrepen zelf worden geformuleerd is een eerder stadium waarin de waterveiligheidsstrategie wordt ontwikkeld. In dit PhD onderzoek is een geïntegreerde aanpak ontwikkeld waarmee ruimtelijke kwaliteit reeds aan het begin van de ontwikkeling van een regionale waterveiligheidsstrategie kan worden meegenomen als 'ex-ante' criterium bij selecteren van waterveiligheidsmaatregelen.

Het belangrijkste principe wat ten grondslag ligt aan deze aanpak is het formuleren van een reeks van verschillende maatregelen op verschillende locaties, die vanuit een waterveiligheids oogpunt gelijkwaardig zijn, en daarmee uitwisselbaar. Zodra er meerdere effectieve waterveiligheidsmaatregelen zijn waaruit kan worden gekozen wordt het mogelijk om andere criteria, zoals bijvoorbeeld ruimtelijke kwaliteit doorslaggevend te laten zijn. Als onderdeel van de methode is een ruimtelijk toetsingskader ontwikkeld, waarmee het mogelijk is de effecten van de verschillende interventies voor wat betreft ruimtelijke kwaliteit te beoordelen; ontwerpend onderzoek is ingezet om de verschillende ingrepen op verschillende locaties ontwerpend te verkennen. De Rijnmond-Drechtsteden regio in Nederland is gebruikt als case study gebied voor dit onderzoek.

1 Introduction

This thesis report is paper based, and as such contains a series of 7 journal and book chapter publications published as part of my PhD research. Each paper has its own problem statement, research question, theoretical framework, and methods section, which are not repeated in this introduction.

Due to the paper-based setup of the dissertation, this introductory section is of a different nature than the traditional introduction found in many thesis books at the Faculty of Architecture. The goal of this introduction is not to give a comprehensive introduction to aspects of the research, but to explain the relation between the different publications, which are subsequently included as chapters.

§ 1.1 The Importance of an Integrated Approach for Flood Risk and Spatial Quality

§ 1.1.1 The Generic Settlement Paradox of Urban Deltas

Delta regions throughout the world are highly populated and make a significant contribution to GDP; approximately 50 percent of the world's urbanised areas are located in deltas (UN-Habitat 2006). The position of deltas at the transition zone between the open sea and the rivers, which provide sea ports, inland water connections, and fresh water, results in them being favourable locations for trade and settlement. However, the urbanised delta areas in the often-low-lying deltaic plains also face severe flood risks. Subsidence and climate change (sea level rise and increased river discharges), as well as some man-made interventions (such as draining, impermeable surfaces, and removing natural discharge canals), further increase the flood risk challenge.

The rapidly increasing urban development and population growth of many Delta regions result in high urbanisation and population densities in areas that are prone to floods (see Fig. 1.1) and flood risk. The often-rapid urban growth also creates challenges with regard to a healthy and qualitative living environment and sustainable urban and economic development (UN Habitat 2006). This results in a growing awareness of the importance of ecological and spatial quality of urbanised areas. Spatial quality can be summarised as a combination of three qualitative parameters: utility, attractiveness, and robustness (Ruimtexmilieu.nl 2012).

Flood risk can be defined as the product of probability and consequences of flooding (Hall et al. 2003). Flood risk management strategies in effect aim to reduce the probability and/or consequences of flooding events. Countries such as the Netherlands, Bangladesh, Vietnam and Myanmar, and cities such as Jakarta, New Orleans, Houston and New York, are developing flood protection strategies to protect inhabitants and economic centres against flooding.

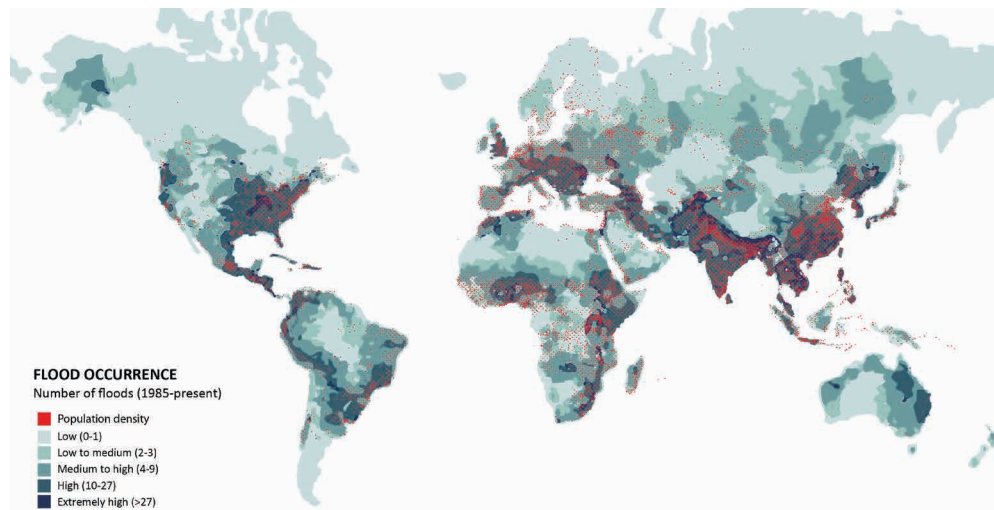


FIGURE 1.1 Many densely populated areas are positioned in places with a high flood occurrence (image by author, data source flood occurrence: World Resources Institute (WRI) Aqueduct, data source population density: Population explorer 2017)

§ 1.1.2 Current practice: A flood risk management strategy for The Netherlands

This research concentrates on the Netherlands, where, almost, 60% of the country is subject to (significant) flood risks from the North Sea, lakes and rivers (Netherlands Environmental Assessment Agency), as can be seen in Fig. 1.2. Next to The Netherlands' position on the edge of the delta, ongoing subsidence, climate change, the growing economic value of low-lying parts of the country, and new insights with regard to failure mechanisms of dikes have contributed to a significant long-term flood risk challenge (Delta Committee 2008).

In recent flood risk management projects facing this challenge, we see a paradigm shift, including:

- A shift from a probability-based to risk-based flood risk standards ¹.
- The context in which flood risk reduction strategies are currently being developed and changed.
- Nowadays, there is greater emphasis on spatial quality and ecology.

The growing emphasis on spatial quality and ecology manifested itself in the public protest against flood risk structures that disregard these values. Examples of such are the protest in the 1970s against the initial design for the 'Oosterschelde' sea barrier which would have had a severe ecological impact (Bosch & Van der Ham 1998), and the protest against the dike elevations that comprised the demolition of historical dike patterns (Klijn et al. 2013). Currently spatial quality and ecology receive a prominent position in policies and development strategies (Ministry of VROM 2008; World Wildlife Fund 2010).

1 (1) Note: Flood risk can be defined as the probability of a flood multiplied by the consequence of a flood. The Dutch flood risk policy used to be focussed on probability-based standards and subsequently on measures that relate to probability reduction. Recently, the standard shifted to a risk-based standard (Kok et al. 2016). This potentially increases the number of potential flood risk management interventions as, in addition to probability reduction measures, consequence reduction measures can also be applied.

These factors have led to new approaches to flood risk reduction with an emphasis on integral design and the so-called 'risk based' approaches in flood risk reduction strategies.

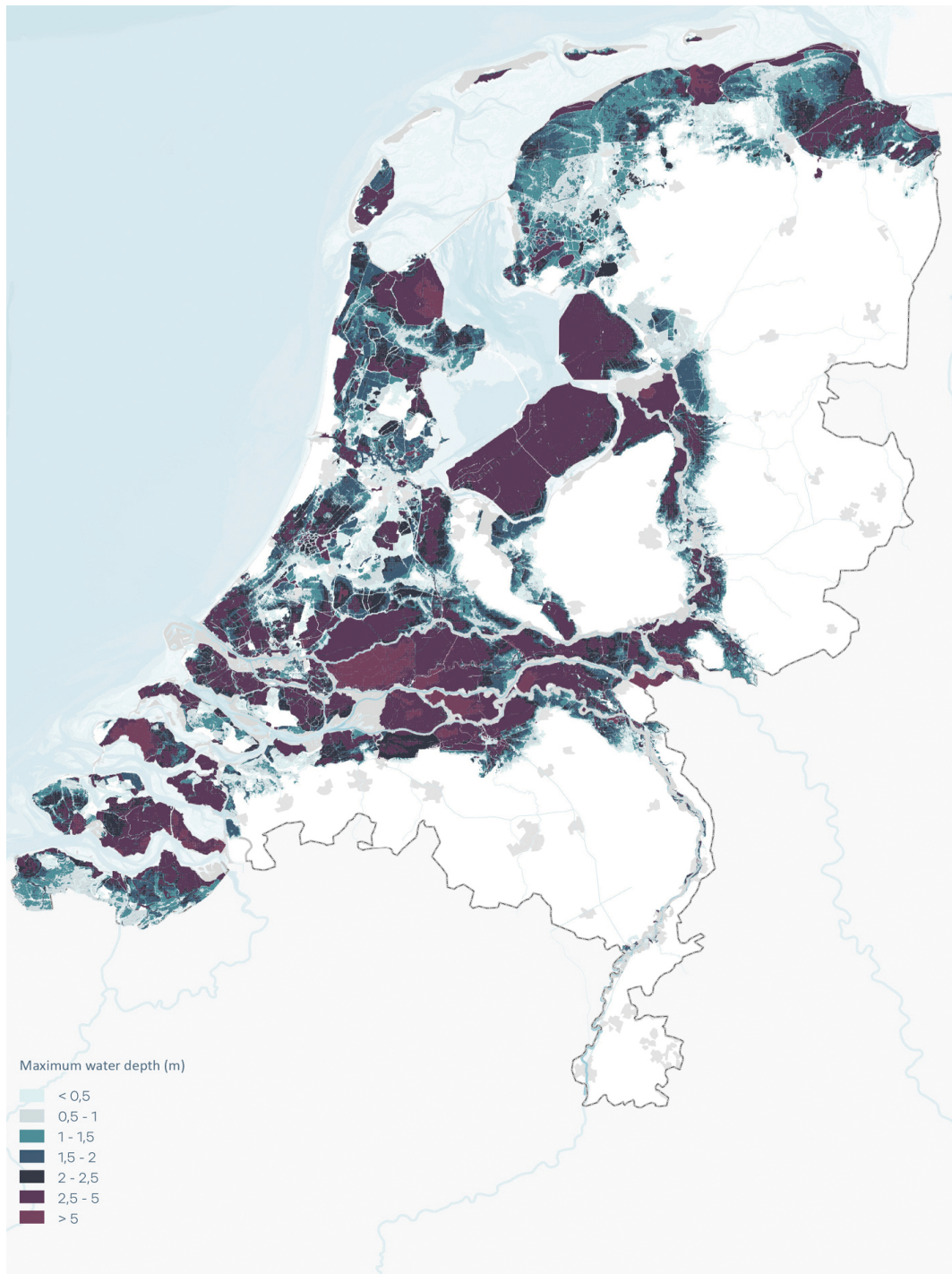


FIGURE 1.2 Map showing the 60% of the Netherlands that is liable to flooding from the North Sea, lakes, and major rivers. Potential water depths may locally exceed five metres (taken and processed from Kok et al. 2016).

§ 1.1.3 Importance of an Integrated Approach: Strong Relation Between Flood Risk Strategies and Spatial Quality

The strong relation between flood risk management interventions and the regional and local scale spatial composition and quality is clearly visible in the Dutch landscape (Meyer 2006).

When we look at, for instance, the Rijnmond- Drechtsteden region of The Netherlands, we see that previous interventions strongly influenced the current spatial composition. It is expected that interventions that will be necessary to address the current and future flood risk will also have a substantial impact on the spatial quality and spatial potential of this region. This underlines the importance for an integrated approach for flood risk and spatial quality.

The new emphasis on spatial quality in relation to flood risk reduction strategies demands integrated approaches for flood risk and spatial quality.

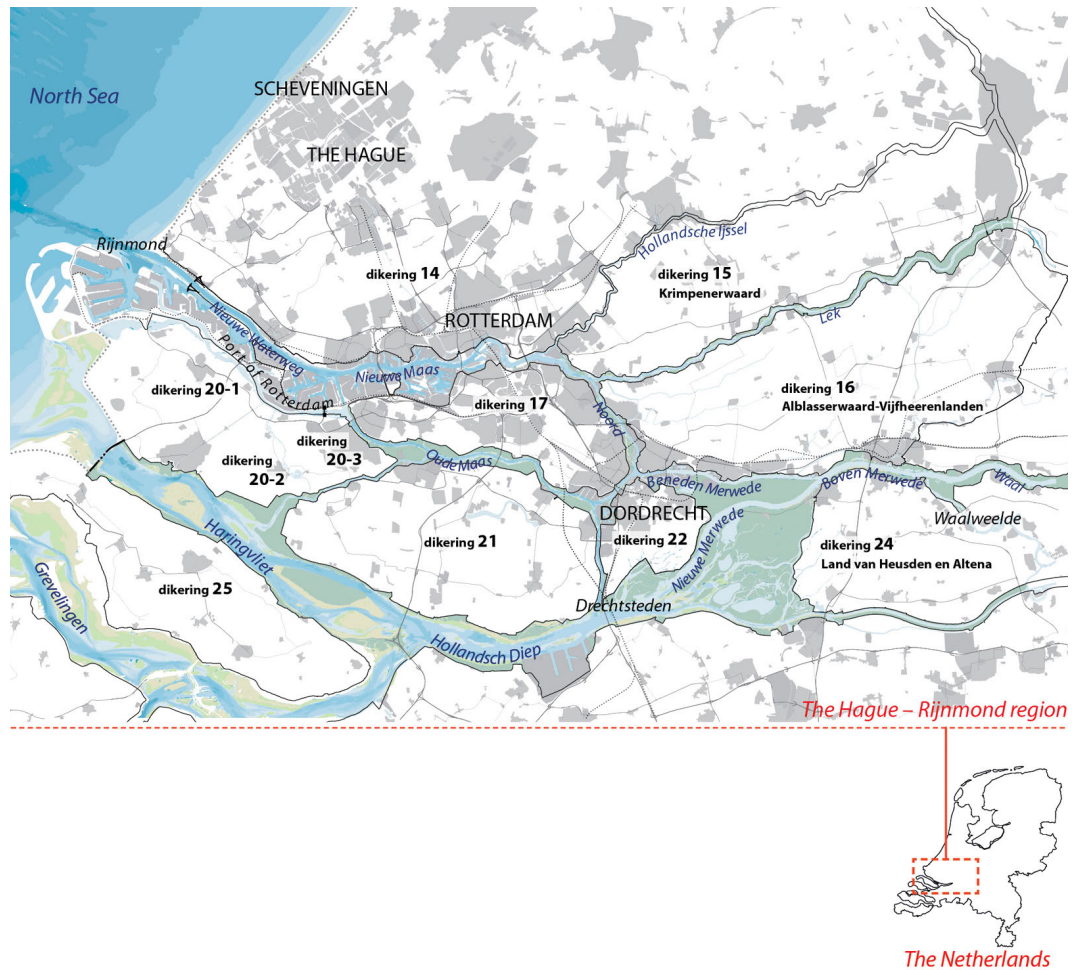


FIGURE 1.3 Map of The Netherlands' Rijnmond-Drechtsteden region, showing the waterways, dike-ring system, and the built-up areas.

§ 1.2 Knowledge gap in existing approaches for spatial quality enhancement and flood risk management strategy development: Spatial quality as an 'ex-ante' aspect of strategy development

Now that there is a higher societal emphasis on the spatial impact of flood risk management strategies, designers are gradually becoming more involved in flood risk reduction projects. As a result, combined approaches for flood risk management and spatial quality enhancement are deployed in many contemporary projects. Below, some relevant projects and developments, inventoried at the start of this research, are described.

Long tradition regarding the integral notion of functionality (water management) and aesthetics

Historically, the integral notion of functionality regarding, amongst others, water management, and aesthetic aspects of designs has been inherent in urban plans. We can already see this in 16th and 17th century designs for fortifications of, for instance, Stevin, the urban extension plans for the cities of Amsterdam, Leiden, Utrecht, and Haarlem, and in the plan for the reclamation of the Beemster (van den Heuvel 2007).

Increasing awareness of the importance on liveable cities

The awareness of the importance of liveable and qualitative cities increased in proportion to the rise of rapid urban expansions during the industrial revolution. From the 1900s onward, the amount of policies to regulate the quality of living environments and urban developments continuously increased. The Netherlands Institute for Social Housing and Urbanism [Nederlands Instituut voor Volkshuisvesting en Stedenbouw] was established around the 1920s to focus on regional plans with, as an apotheosis, the ideal of combining those regional plans into a national plan (Andela & Bosma 2007).

The 1953 Flood and the First Delta Committee

From the process of deciding between two alternative flood risk strategies from the first Delta Committee in 1953, we see that spatial aspects had already been included in the decision-making debate. Two different flood protection models were considered: the reinforcement of all existing dike-rings and the larger-scale protection network of the so-called Delta Plan, which involved damming off the estuaries that connected the rivers with the North Sea to shorten the coastline, through which rain the main flood defence line. The Delta Plan was preferred since it was expected to have positive side-effects, among which was connecting the previously isolated islands to the Randstad metropolitan area, thereby increasing their (recreational) potential (Tinbergen, 1961). The report 'Randstad en Delta' from the Province of South Holland's planning department describes, eagerly, how the Delta Plan could contribute to an improved liveability of the increasingly pressured urban centres of the Province of South Holland (Provinciale Planologische dienst in Zuid-Holland 1956).

Resistance Against Flood Risk Structures With Severe Ecological and Spatial Impact

As mentioned in 1.1.2, from the 1960s onwards the public protest against major flood risk structures that interfered with and damaged ecology and spatial quality (especially cultural heritage) increased. This manifested itself in the public resistance against the Oosterschelde sea barrier (Bosch & Van der Ham 1998) as well in the resistance against the river dike reinforcements recommended in 1977 by the so-called Becht Commission. The resistance against the dike reinforcements were so severe that a

new commission 'Commission Boertien' was established to investigate how the impact on landscape, natural and cultural values could be reduced by optimised dike designs (Walker et al. 1994).

Embedment of spatial quality in policies

The increasing pressure on the urban areas resulted in an explicit inclusion of spatial quality in governmental policies, the inclusion of 'quality teams' and supervisors in project teams, and the appointment of governmental advisors on spatial quality. The role of water as an inclusive part of the national spatial planning policy was established in the fourth National Policy Document on Spatial Planning in 1990 and was extended in the studies for the fifth National Policy Document on Spatial Planning. This coincided with the publication of the fourth national policy document on water management in 1998, in which the inclusion of spatial planning was an important focus point (van Buuren 2009).

'Room for the River' Approach

The Netherlands 'room for the river' program, which started in 2006, is an inspiring reference and starting point for including spatial quality as a decisive criterion in flood risk reduction strategies. After an increase of the design discharge of the river, the room for the river programme focussed on compensating this increase by creating more discharge capacity for the river. Resulting in the introduction of load reducing measures, such as widening the riverbed by creating bypasses. Due to the potential spatial impact of this program spatial quality was set to be a prominent second objective in the flood risk strategy development. At locations where, alternative measures are available from a flood risk perspective, this allows for selection based on the secondary criterion, being spatial quality. To achieve and supervise goals with respect to spatial quality, a 'Quality Team' was established (Klijn et al. 2013).

Regional Integral Delta Design and the Second Delta Committee

In recent design studies that explore the spatial opportunities relating to different strategic flood risk protection approaches, such as 'blauw bloed' [blue blood] by Kuiper Compagnons and the 'afsluitbaar open Rijnmond' [Rhine estuary closeable but open] project (de Hoog et al. 2010), it becomes apparent that different strategic approaches (such as the four directions defined by the second Delta Committee, discussed in Chapter 3) offer opportunities for different regional spatial visions. Although each of these different future perspectives has its own distinguishing qualities and offers the opportunity to provide feedback for decision-making, they are not yet deployed to systematically explore the impact of the strategies, and therefore have not become part of the decision-making process regarding the different flood risk strategies.

Regional Scale Integral Design Methodologies

Regarding regional integral design methodologies, the Delta Urbanism book series aims to deliver methods for establishing urbanization in a delta. However, these publications concentrate primarily on the history of the complex relationship between the delta and urban development. In a publication on the Netherlands by Meyer, Bobbink, and Nijhuis (2010), inspiring examples of designs and visions for the delta are shown and the need for interdisciplinary approaches is expressed. However, the strategic steps for such a method remain undefined.

Local Scale Integral Design Studies

Many studies exist that elaborate on typologies and design principles that are integral to flood risk management and spatial design at a local scale: the spatial integration of dikes in its direct surroundings is addressed by the Internationale Bauausstellung (IBA) or International Architecture Exhibition (Stokman et al. 2008) and the City of Rotterdam (Veelen et al. 2010). The 'river.space.design' project contains case studies and design principles for interdisciplinary design in the course of revitalising river fronts (Prominski et al. 2012). The Life Project shows design studies that demonstrate how extra space for water can be obtained with multifunctional design solutions (Baca Architects et al. 2009). The Netherlands' national environmental agency published an overview of civil engineering, architectural, and governmental flood risk measures (Ruimtelijk planbureau et al 2007). And the book 'Amphibious Housing in the Netherlands' presents typologies of flood proof houses and associated parcelling principles (Nillesen & Singelenberg 2011).

Multidisciplinary Design Workshops

At the local scale (including the urban or landscape region), the flood risk challenge is often approached in an integrated way by interdisciplinary teams of spatial designers and civil engineers. The 'Dutch Dialogues' project has been especially successful in the set-up of workshop series in which designers and experts from different disciplines work together on flood risk protection strategies, resulting in integrated design proposals for New Orleans (Meyer, Wagonner & Morris 2009).

Knowledge Gap in Existing Approaches

Regarding the integrated approaches, the commonly accepted practice of integrating flood risk and spatial assignments is to: (1) study effects and potentials of alternative interventions on the surroundings to formulate a preference; (2) embed necessary flood risk management interventions in a qualitative way, or; (3) exploit possibilities for synergy at locations where flood risk assignment and spatial assignment overlap.

The role of the designer is often restricted to the important but limited task of optimally embedding technical interventions (which are derivatives of system level flood risk strategies that are developed at an earlier stage) in its local surroundings. This research aims to develop an integrated approach in which spatial quality enhancement is already included as an objective in the regional flood risk management strategy development, therefore becoming an 'ex-ante' aspect of flood risk management strategy development.

§ 1.3 Research Question

The goal of this research is to develop an integrated approach for flood risk and spatial quality, in which spatial quality is a decisive ex-ante criterion in flood risk management strategy development.

How can an integrated approach for flood risk and spatial quality, in which spatial quality is a decisive ex-ante criterion in flood risk management strategy development, be developed, and what elements and steps would be included in such a method?

In order to answer this question, this dissertation investigates and describes:

- How flood risk management interventions and spatial development influence each other
- How spatial quality can become an ex-ante aspect of flood risk management strategy development
- How research-by-design can be used as a basis for the intended integrated approach
- How interchangeable measures for flood risk management interventions can be determined
- How the location of the necessary flood risk intervention can be shifted by selecting measures at other scale levels or flood risk layers
- How a spatial assessment framework can be developed to assess the impact of different technical interventions for flood risk management, for spatial quality enhancement at the local scale
- How the developed method can be deployed for the Rijnmond Drechtsteden case study area

§ 1.4 Case Study Area: The Netherlands, Greater Rijnmond - Drechtsteden Region

As a case study location, the Netherlands' wider Rijnmond Drechtsteden region is explored. This urban region contains the greater Rotterdam area, including the Port of Rotterdam, which is an important economic driver in this region. The area faces a double danger of flood: it is threatened by storm surges at sea and, potentially simultaneous, peak river discharges. Within this region, more detailed research through design exercises are deployed at The Hague's urban seaside area of Scheveningen and the more rural polder area, Alblasserwaard-Vijfheerenlanden.



FIGURE 1.4 Map of the Rijnmond-Drechtsteden case study area.

The Rijnmond-Drechtsteden case study area is described in Chapter 3 and Chapter 5. The The Hague case study area is described in Chapter 4. The Alblasserwaard-Vijfheerenlanden case study area is described in Chapter 6 and Chapter 7. The flood risk challenge for the area is described in intermezzo 1.

§ 1.5 Research Approach

The research can be divided into three main phases (which, during the research period, partly interfered with each other and overlapped):

1. Combining and testing existing approaches for flood risk and spatial quality
2. Identifying essential elements for developing an integral method for flood risk and spatial quality
3. Developing and testing an integrated approach for flood risk and spatial quality, in which spatial quality is a decisive ex-ante criterion in flood risk management strategy development.

The phases are described briefly here and then further elaborated upon in Sections 1.6, 1.7, and 1.8. During the PhD research, intermediate results were published as journal or book publications.

In the first phase, the literature study explored the case study area, existing methodologies for integrated flood risk and spatial design, and the spatial and flood risk challenges for the case study region of Rijnmond Drechtsteden.

Resulting publications:

- 1 Flood Risk and Spatial Quality: A Paradigm Shift in Dutch Flood Risk Reduction Strategies.
- 2 Rotterdam: A City and a Mainport on the Edge of a Delta.

Based on this literature study, an attempt is made to combine two successful existing methods (the 'Room for the River' approach which has a dual flood risk management and spatial quality enhancement objective, and the research-by-design approach) into an integrated approach to flood risk management and spatial quality. This combined approach was subsequently tested and applied on the The Hague case study area.

Resulting publication:

- 3 The Synergy Between Flood Risk Reduction and Spatial Quality Enhancement in Coastal Cities.

From both the literature study and from applying the The Hague case study, new insights were developed regarding the essential elements for developing an integrated method for flood risk and spatial quality. These elements included: Increasing the amount of interchangeable flood risk management interventions, redefining the definition of research-by-design, and developing a spatial assessment framework. In the second phase of the research, those elements are specified and developed further, based on the literature study and case study application.

Resulting publication:

- 4 Water-safety Strategies and Local-scale Spatial Quality.

The elements from the second phase are combined in a new, proposed integrated method for flood risk and spatial quality, in which spatial quality is a decisive ex-ante criterion in flood risk management strategy development. The method is subsequently tested by applying it to the Alblasserwaard- Vijfheerenlanden case study area. After the first application, the method is updated and reapplied to the same case study area.

Resulting publications:

- 5 Improving the Allocation of Flood-risk Interventions from a Spatial Quality Perspective.
- 6 An Integrated Approach to Flood-risk Management and Spatial Quality Enhancement for a Netherlands' River Polder Area.

7 Integrated Design for Flood Risk and Spatial Quality Enhancement - Examples from the Dutch Delta Programme

Some of the papers were written in the midst of the process of developing and exploring the strategy. Since the different steps in the research led to new insights that (re)directed the research process (which was therefore not linearly defined from the beginning), together the papers describe a consecutive process.

Therefore, the following description of the relationship between the different papers in the next sections partly includes a description of the chronological steps taken that led to intermediate conclusions and insights, which led to the developed integrated approach.

§ 1.6 First Research Phase: Combining Existing Approaches for Flood Risk and Spatial Quality

In the development of a combined approach for flood risk and spatial quality, a method, based on the successful principles from existing integrated design approaches, is first deployed. This first method includes the dual flood risk and spatial assignment (from the 'Room for the River' approach) combined with a design study in which the potential spatial integration of different alternative solutions for flood risk protection are explored. Formats of work from the successful multidisciplinary design workshops from the Dutch Dialogues are used. The method is applied to the Netherlands case study area of The Hague. Based on the results of this research-by-design exercise, the method is subsequently developed further.

§ 1.6.1 Research by Design as a Means for Verifiability and Reproducibility

To make sure the design research is verifiable and reproducible, which are standards for scientific research (KNAW, 2010), a research-by-design method is employed. Many different definitions of research-by-design exist (source). In general, research-by-design refers to the use of design as a tool to generate new knowledge, insights, and possibilities (De Jonge 2009: 93). Within this approach, a form of research-by-design is initially applied in which a single parameter is systematically varied (the flood risk intervention) while other parameters are fixed (such as the context and the objectives from a spatial and flood risk perspective). Later, the approach is adjusted to a research-by-design form in which both the flood risk intervention as well as the location are varied (see also paragraph 1.7.2).

§ 1.6.2 Application of the First Phase Method to the The Hague Case Study

A test is undertaken to determine whether the use of a combined research-by-design approach, which (like the 'Room for the River' programme) includes a dual flood risk and spatial quality objective, and considers different alternative flood risk management interventions, can serve as 'a combined

approach for spatial quality enhancement and flood risk reduction with spatial quality as a decisive ex-ante criterion’.

The research was performed as part of the ‘Atelier for Coastal Quality’, in which The Hague’s seaside area of Scheveningen was selected as a case study location. Here the future reinforcement of the sea barrier could be combined with addressing spatial challenges regarding identity, vitality, connectivity, and quality.

A research-by-design approach was undertaken, in which a single parameter (the flood risk intervention) was systematically varied while fixing other parameters (such as the context and the objectives from a spatial and flood risk perspective). After exploring and defining both the flood risk and spatial objectives for the area, three alternative flood risk reduction strategies (based on three alternative interventions: a boulevard, dunes, and a perpendicular dam) for Scheveningen were developed. In order to facilitate the integrated design process ‘Delta Ateliers’, in which multidisciplinary experts and stakeholders interactively worked together, were successfully established.

§ 1.6.3 Case Study Results: The Key to Defining Spatial Quality as an Ex-ante Criterion

By performing a research-by-design exercise for the The Hague seaside, it became apparent that the secondary spatial objective is, though important, not the main key to including spatial quality as an ex-ante criterion. The three alternative flood risk reduction interventions for the Scheveningen boulevard area had all been successfully embedded in terms of meeting the prescribed spatial criteria for the same location, thereby disqualifying the spatial aspects as decisive selection criteria for the flood risk intervention.

However, as part of the study, a supporting research-by-design exercise was performed in which three different locations for the positioning of the perpendicular dam were examined from a spatial perspective. Here, it seemed that providing interchangeable (similarly effective) interventions at different locations did result in very different potentials for spatial quality, thus allowing spatial quality to become a decisive selection criterion.

As a result, the ‘Room for the River’ principle that appears to be essential is the provision of interchangeable interventions for flood risk reduction at different locations. In the ‘Room for the River’ programme, the additional option of creating extra space for the river that was provided offered an alternative to necessarily elevating the dikes. Being able to consider several interchangeable interventions at various locations, which are equally effective from a flood risk perspective, creates the opportunity to select options based on additional criteria, such as spatial quality. This allows for spatial quality to become an ex-ante criterion in flood risk management strategy development.

The secondary spatial objective, as deployed in the ‘Room for the River’ programme is, though important, not the main key to including spatial quality as an ex-ante criterion. The key is being able to consider several interchangeable interventions at various locations, equally effective from a flood risk perspective. This creates the opportunity to select options based on additional criteria, such as spatial quality, thus allowing spatial quality to become an ex-ante criterion in flood risk management strategy development.

§ 1.7 Second Research Phase: Identifying Essential Elements for Developing an Integrated Method for Flood Risk and Spatial Quality

From the case study application, important lessons could be drawn with regard to essential elements for developing 'an integrated approach for spatial quality enhancement and flood risk reduction with spatial quality as a decisive ex-ante criterion'.

§ 1.7.1 Increasing the Number of Interchangeable Flood Risk Management Interventions

The way of creating alternatives from 'Room for the River' (dike reinforcement or expanding allowable space for the river) only offers a small amount of interchangeable options and has limited applicability for the Rijnmond region (which is only partially situated in the area in which river water levels dominate the flood risk challenge).

To increase the range of interchangeable flood risk management interventions (and thereby allowing spatial quality to become a decisive criterion), alternative interventions at different scale levels and different flood risk layers are systematically included.

The principle of including interventions at different scales is based on the possibility to either deal with increasing water levels where they appear locally (by, for instance, reinforcing dikes or protecting flood plains) or applying larger scale system interventions that reduce the local water levels (such as barriers, diverting river flows, or creating more space for the river). For instance, a sea barrier can, in the event of storm surges, prevent heightened water levels upstream, which reduces the degree of local interventions necessary behind the barrier.

The principle of including interventions at different 'flood risk reduction layers' is based on the so-called 'multi-layer safety' approach (Ministry of Infrastructure and Environment 2009; Expertise Netwerk Waterveiligheid 2012). Since flood risk can be defined as the probability of a flood multiplied by the consequence, interventions can be taken to both address the probability of a flood (such as levees, barriers, and lowering water levels) as well as the consequences of a flood (such as flood proofing buildings, elevating areas, protecting vital functions, or improving evacuation). For instance, you can either protect a building by creating a dike around it to reduce the probability of flooding or elevate it by positioning it on a mound to prevent damage in the event of a flood.

For the Netherlands, the recent policy shift from a probability-based flood risk approach (with uniform dike-ring safety standards) to a risk-based approach conceptually increased the range of potential interchangeable flood risk management interventions. Although, in practice, this resulted in the continuation of a probability-based defence system, a risk-based target does offer the opportunity to include flood risk management interventions that address the risk by consequence reduction. In addition, it makes it possible to conceptually break down the previously uniform dike-ring into segments, each of which conceptually can have (and by now has) its own probability reduction standard, increasing the flexibility of locations at which probability interventions or potential alternatives can be considered.

For a description of the method that includes interventions at different scales and flood risk layers, and its application on the Rijnmond Drechtsteden case study area, see Chapter 5 (complete method) and Chapter 6 (elaborating on the layer of the intervention).

§ 1.7.2 Research by Design (or Study by Design), as Defined by Teake de Jong

The principle that appeared to be essential in order to include spatial quality as a decisive ex-ante criterion is the creation of alternative exchangeable options for flood risk reduction interventions at different locations. Based on these findings, the employed research-by-design approach is extended to not

only systematically test different interventions, but to also systematically vary the location of the intervention. This coincides with the description of research-by-design by Teake de Jong, who uses the term ‘Study by design’ and characterises this as: ‘generating knowledge and understanding by studying the

effects of actively and systematically varying both design solutions and their context’(De Jong & Van der Voordt 2002). The Delta Atelier multidisciplinary work form is continued in the remaining research.

		OBJECT	
		determined	variable
CONTEXT	determined	Design research	Design study
	variable	Typological research	Study by design

FIGURE 1.5 Diagram based on classification from ‘Ways to study and research’ (de Jong & van der Voordt 2002). This diagram indicates that, according to the classification by de Jong, the method previously applied within the The Hague case study would qualify as design study.

§ 1.7.3 Spatial Assessment Framework

As stated, having a wide range of exchangeable interventions from a flood risk perspective offers the opportunity to select additional criteria such as spatial quality. In order to do so, an assessment is necessary to establish which interventions are preferred from a spatial quality perspective. In order to assess this in a verifiable and reproducible way, a spatial assessment framework is developed.

The framework is based on the 'Room for the River' assessment framework in which a checklist with criteria is combined with expert judgement. The 'Room for the River' method was developed to test elaborate design proposals in a rural setting. For the purposes of this research, the framework is adjusted and extended to test more conceptual interventions, and criteria are altered to fit the more urban setting of the Rijnmond-Drechtsteden area.

The assessment is undertaken by comparing the existing situation with the proposed situation, including a potential flood risk intervention. In the research, the criteria on the checklist (which are based on the perception of spatial quality in terms of a combination of functionality, attractiveness, and robustness) only weigh in when deemed relevant by the experts. The checklist supports the expert judgement in two valuable ways: Firstly, as a tool during consecutive assessments to provide the experts with a coherent and wide-ranging view of the criteria and, secondly, to make the assessment verifiable and open to discussion.

In this research, the assessment framework is designed to assess the impact of both regional and local-scale flood risk management interventions on the local-scale spatial quality. As described in the 'Conclusions and Discussion' section, in order to apply the developed method for assessing the impact of flood risk management interventions at regional and national scale spatial quality aspects, the framework should be further extended.

§ 1.8 Third Research Phase: Developing and Testing an Integrated Approach for Flood Risk and Spatial Quality, in Which Spatial Quality is a Decisive Ex-ante Criterion in Flood Risk Management Strategy Development.

By applying a research-by-design approach in which interventions are systematically applied at different scales and flood risk layers, while their spatial impact is assessed. Through the subsequent selection of the combinations of measures that address the flood risk target while also having the preferred effect on spatial quality, a method is developed that makes it possible to include spatial quality (as an ex-ante decisive criterion) in flood risk management strategy development.

The method is applied, developed further, and reapplied to the Alblasserwaard-Vijfheerenlanden case study area.

The developed method contains the following steps:

- An inventory of the current and potential flood risk protection strategies
- An inventory of the spatial characteristics, challenges, and potentials of the region
- A qualitative assessment of the existing situation and (if available) of the spatial impact of a reference flood risk management strategy

- Systematic research-by-design on how flood risk management interventions at different scales can shift the location of the flood risk intervention (including qualitative assessments of the intervention at the various locations)
- Systematic research-by-design on how flood risk management interventions in different flood risk layers can shift the location of the flood risk task (including qualitative assessments of the intervention at the various locations)
- Selection of the combination of interventions most preferable from a spatial quality enhancement objective.

§ 1.9 Context of the Research

The research was performed at the Technical University of Delft, Department of Urbanism, as part of the Dutch Knowledge for Climate Research Programme.

§ 1.9.1 Relation to Practice

This research was performed alongside practice, maintaining a strong link to the Dutch Delta Programme, which, in recent years, developed a flood risk reduction strategy for the Rijnmond-Drechtsteden area. The data sets developed within this programme, which were used over the course of this research (such as the data sets regarding the flood risk task in the Rijnmond-Drechtsteden region), were continuously progressed and updated. The reader will notice that, as a consequence of such updates, different papers are based on different data sets.

Projects performed in practice by Anne Loes Nillesen at her design firm, Defacto Architecture & Urbanism, were used to gain additional knowledge relating to the research topic and develop, test, and apply aspects of the developed methodologies.

§ 1.9.2 Paper-based Dissertation

This dissertation is based on seven (journal and book chapter) publications. For this dissertation, the papers are, with the exception of some small additions, included as published. Preceding each paper, a cover page is included that reflects on the role of the paper in the context of the overall research and describes the conclusions and findings that are relevant for the development of the intended integrated approach.

The different publications have the following position within the overall research:

- 1 Flood Risk and Spatial Quality: A Paradigm Shift in Dutch Flood Risk Reduction Strategies
This book chapter describes the current trends in flood risk reduction approaches in the Netherlands and therefore represents a good introduction to the current practice.

- 2 **Rotterdam: A City and a Mainport on the Edge of a Delta**
This paper can be seen as the overall introduction, in which the Rijnmond-Drechtsteden case study region and its spatial and flood risk challenge are described. The strong link between the flood risk interventions and spatial composition and quality of the region is described, supporting the urgency of approaching the future flood risk reduction task in an integrated and comprehensive way.
- 3 **The Synergy Between Flood Risk Reduction and Spatial Quality Enhancement in Coastal Cities**
In this paper, the approach and results of an interdisciplinary research-by-design exercise with a dual flood risk reduction and spatial quality enhancement objective is described. For the case study location of the The Hague seaside area, different design proposals are made based on three alternative flood risk management interventions. Within this research, the Delta Atelier work format is used to support the multidisciplinary design process. Based on the findings of this research, the research-by-design approach deployed and is extended to not only systematically test different interventions, but to also systematically vary the location of the intervention.
- 4 **Water-safety Strategies and Local-scale Spatial Quality**
This paper describes the development of a spatial quality assessment framework, which is based on a framework used in the 'Room for the River' project. The framework, which combines a criteria checklist with expert judgement, is altered for, and tested on, the Rijnmond-Drechtsteden case study area. More specifically, the impact of different regional flood risk system interventions (defined by the Dutch Delta Programme) on local-scale spatial quality is tested, thereby allowing the local-scale spatial quality to, if desired, function as a selection criterion for selecting a regional flood risk management strategy.
- 5 **Improving the Allocation of Flood-risk Interventions From a Spatial Quality Perspective**
In this paper, the steps of the developed research-by-design method are described and tested for the Alblasserwaard-Vijfheerenlanden case study area, within the Rijnmond-Drechtsteden region. A range of interchangeable flood risk reduction measures that can be applied at different locations are assessed on their spatial impact. Based on the outcomes, a combination of measures with the most favourable impact on spatial quality are selected. The case study application demonstrates that the developed method, compared to the business-as-usual reference strategy, allows for the formulation of a flood risk management strategy with an improved impact on spatial quality.
- 6 **An Integrated Approach to Flood-risk Management and Spatial Quality Enhancement for a Netherlands' River Polder Area**
In this paper, the method's aspect of including interventions from different flood risk layers, is further elaborated. The paper demonstrates how a risk-based Approach to Flood Risk Management allows for a wide range of interchangeable measures in varying locations. By applying this enhanced part of the developed method on the Alblasserwaard-Vijfheerenlanden case study area, the paper demonstrates how the Netherlands' recent shift from a probability-based target towards a risk-based target, increases the amount of interchangeable flood risk management interventions in the case study area. This contributes to the developed method in which providing sufficient interchangeable options for interventions are crucial to making spatial quality an ex-ante criterion.
- 7 **Integrated Design for Flood Risk and Spatial Quality Enhancement- Examples From the Dutch Delta Programme**
This paper is added to the publication list to show more of the research-by-design work that was performed during the course of this research. Though the Scheveningen case study described earlier (publication #3) was the most essential in terms of the methodology development for this research, further applications have been performed in case studies from practice. The case studies were used to apply the method of testing different flood risk management interventions at the local scale. As concluded, this method is

very successful for embedding the flood risk intervention in the most spatially optimal way, as well as for exploring the local-scale spatial impact and opportunities to consequently formulate a spatial assessment.

Fig. 1.6 shows an overview of the specific aspects of the research, methods, and case study locations that are addressed in the different publications.

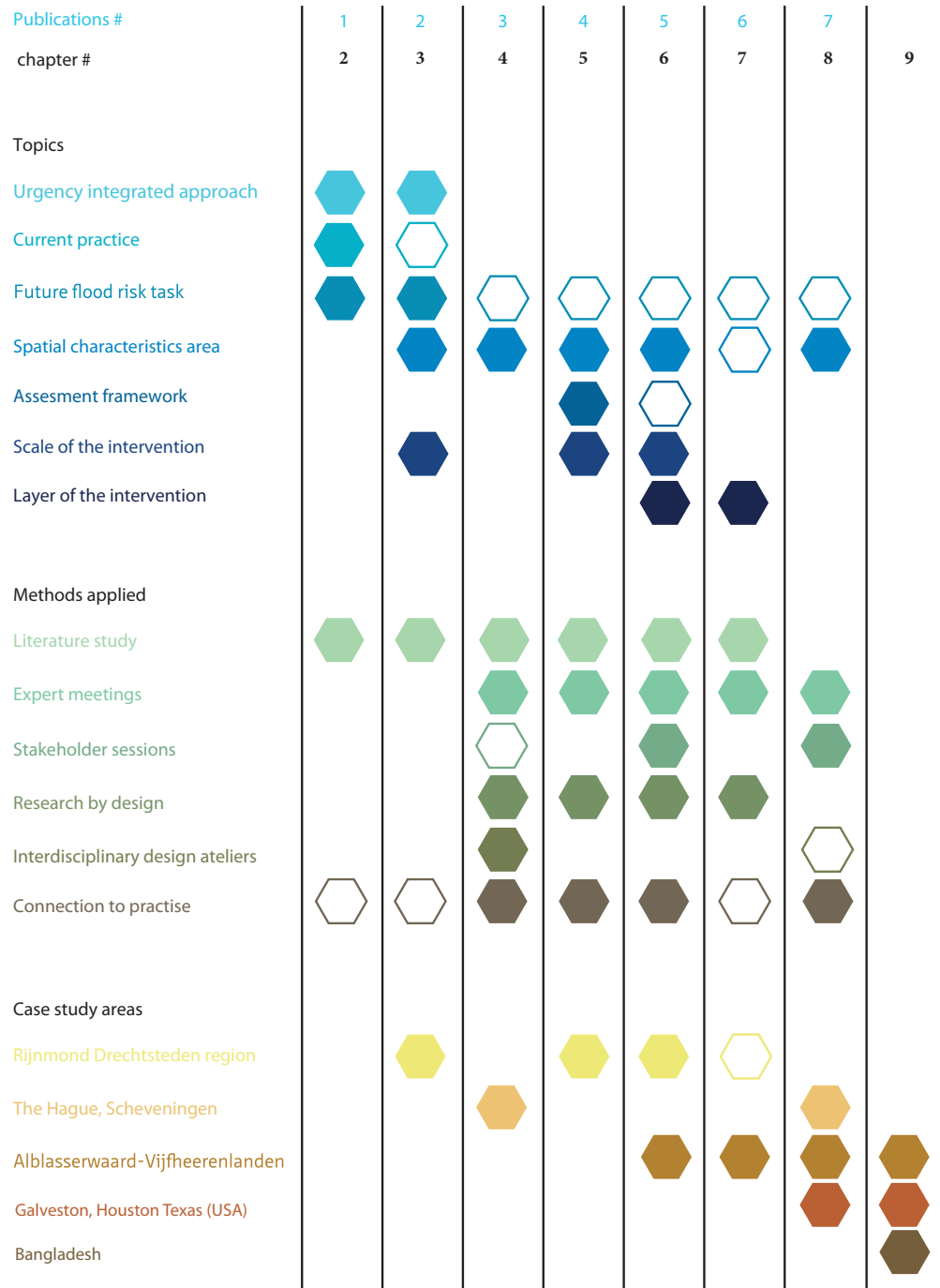


FIGURE 1.6 Overview of topics, methods and case study areas deployed in different chapters

Intermezzo 1: The Dutch Flood Risk Reduction System

The Netherlands is located in the Rhine-Meuse-Scheldt delta. The country faces a significant flood risk reduction challenge as a result of storm surges from the North Sea, peak river discharges, and a high population density and economic value throughout low-lying parts of the country.

The Growth of the Current Flood Risk Reduction System

Natural flood risk protection in the Netherlands is provided by the sandy dunes along the coast in the west and the higher grounds in the east. The Rhine-Meuse-Scheldt delta, like many other deltas worldwide, transformed from a natural and sparsely inhabited area into a densely occupied delta. Protection of private properties was initially provided by mounds; with the growing occupation of the delta, from the 12th century onwards, the mounds gradually became obsolete as a result of the continuous construction of dikes and polders. At the end of this centuries-long process, the original system of dynamic rivers and flood plains, ever-changing through sedimentation, was contained within an extensive system of dike-rings (dijkkringen).

The 1953 Delta plan

Following the 1953 North Sea flood, the first Delta Commissie (Delta Committee) was established and given the task to propose measures to reduce the chances of such a disaster reoccurring. Two different flood protection models were considered: the reinforcement of all existing dike-rings and the larger-scale protection network of the so-called Delta Plan, damming off the estuaries connecting the rivers with the North Sea to shorten the coastline, through which runs the main flood defence line. As also described in 1.2, the awareness of the strong interrelation between flood risk management interventions and the water and occupation layers is apparent in a report on those two models by Tinbergen (1961). The Delta Plan was selected and a network of fixed (closed) storm surge barriers with two further flexible storm surge barriers, was realised under the umbrella name Deltawerken (Delta Works), ensuring access to shipping lanes and harbours. The barriers are closed as soon as water levels rise to a certain level, preventing the water levels within the delta from rising further, thereby reducing the hydraulic load on dikes and protecting outer dike areas from flooding.

At the same time, the safety levels of different dike-rings were increased and enshrined into Dutch law. The flood risk standard of the dike-rings (up to January 2017) varied from 1 in 10,000 to 1 in 1,250 (the normative water level that can occur with a chance of a 1 in 10,000 to 1 in 1,250 years occurrence), based on the impact of flooding for a given area and determined by aspects such as the economic value of the area, the presence of either salt or fresh water, and the possibility for the timely evacuation of inhabitants (Slomp 2012; Brinke & Jonkman 2009). The highest safety standard of 1 in 10,000 was applied for the Randstad dike-ring, which contains the densely-built metropolitan area that includes the cities of Rotterdam, Amsterdam, The Hague, and Utrecht.

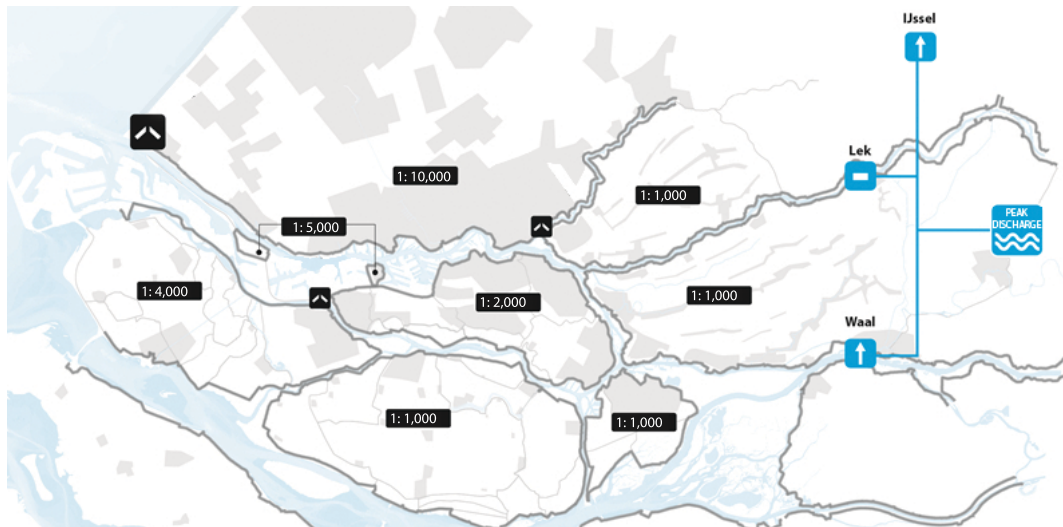


FIGURE 1.7 Rijnmond-Drechsteden flood risk reduction standards in 2015

Current Flood Risk Reduction System

Over time, the Dutch developed an extensive flood risk reduction system that utilises dams and dike-rings to reduce the likelihood of flooding. Fig. 1.7 shows the current Dutch dike-ring system. Dikes are inspected every 6 years by independent government agencies, the so-called Water Boards (waterschappen); if necessary, reinforcement and maintenance works are carried out to ensure that they conform to the safety levels defined by Dutch authorities.

In the Netherlands, ongoing subsidence, climate change, the growing economic value of low-lying parts of the country, and new insights with regard to failure mechanisms of dikes have contributed to a significant, long-term flood risk challenge. The second Delta Programme was established to develop strategies that address the long-term flood risk challenges (Delta Committee 2008). As a result, in 2017, the Dutch government set new updated standards (Helpdesk Water 2017).

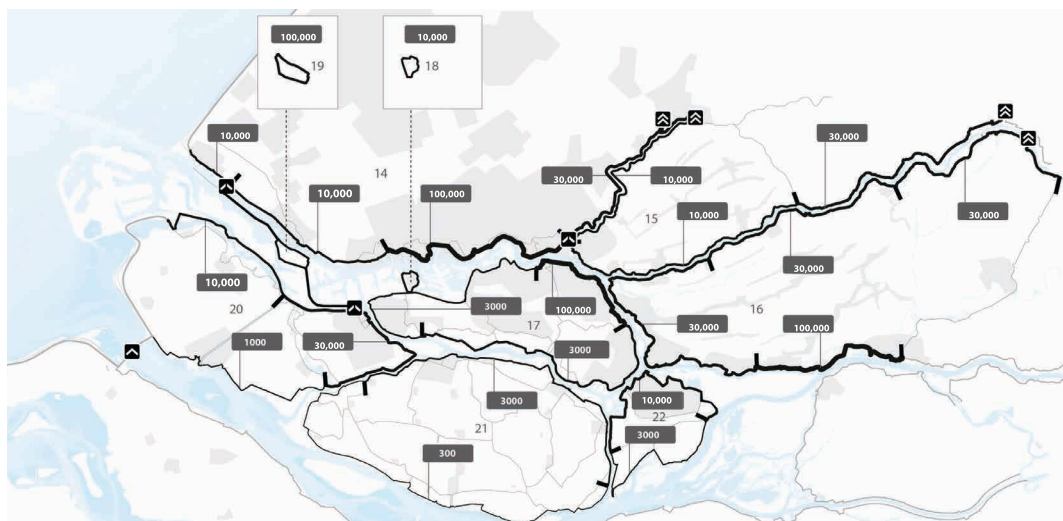


FIGURE 1.8 Updated Rijnmond-Drechsteden flood risk reduction standards, 2017

2 Flood Risk and Spatial Quality: A Paradigm Shift in Dutch Flood Risk Reduction Strategies

Anne Loes Nillesen

This paper (a version edited by Jean-Jacques Terrin) is published in: Villes inondables Prévention, résilience, adaptation, by Parentheses (2014). Some changes were made, mainly to improve consistency and readability throughout this thesis.

This book chapter describes the current practice with regard to combined approaches for flood risk management and spatial quality enhancement in the Netherlands. Currently, there is a requirement to extend the current flood risk system because of increased flood risk (caused by climate change and increased investments in the protected area) and new insights with regard to acceptable risks. Flood risk measures nowadays need to be implemented in a context in which local stakeholders emphasise aspects such as spatial quality and ecology.

In this contemporary context, we see interesting developments with regard to combined approaches for flood risk protection, such as, for instance, the experimental flood proof building programme, the 'building with nature' concept (in which natural principles are employed for flood risk protection), the atelier for coastal quality (that as part of the Delta Programme developed integrated designs for coastal protection and quality) and the 'Room for the River' project (in which, as an alternative to dike reinforcement, the water load is reduced by creating extra space for the river to expand).

For this research, the 'Room for the River' project is an important reference. Within the project, which aims to address more extreme river discharges, spatial quality is an important secondary objective. Next to the availability of extra budgets, a 'Quality Team' was established to supervise the inclusion of spatial quality objectives. The project addressed the growing resistance against the elevation of traditionally-built levees, by offering an alternative option of lowering the water levels by improving the flow capacity of the river (for example, by creating a bypass to widen the river).

Within the development of the combined method for flood risk and spatial quality, different aspects have been inspired or based on the 'Room for the River' approach. Among such aspects are the dual flood risk and spatial quality objective, the principle of providing alternative options for flood risk management interventions, and the inclusion of a spatial quality assessment.

Key aspects: Current practice, Urgency integrated approach, future flood risk task.

§ 2.1 Introduction

Existing Dutch flood risk reduction policies are under debate as a result of two important trends:

- New insights with regard to the expected effects of climate change and a debate regarding the recalibration of protection levels in relation to increases in economic value drive a review and improvement of the current flood risk reduction system. At the same time, there is a better conceptual and technical understanding of flood risk, for instance, with regard to the failure mechanism of piping and the flood patterns caused by dike breaches, as well as regarding the conceptual understanding of (the impact of) infrastructural interventions within a Delta system.
- The context in which new flood risk reduction strategies are being developed and changed Nowadays, there is greater emphasis on spatial quality and ecology (Ministry of Housing, Spatial Planning and the environment 2008; World Wildlife Fund 2010). The political environment changed, moving from a national, top-down approach towards a process in which local stakeholders and ownership are essential..

These factors have contributed to a paradigm shift and led to new approaches to flood risk reduction. The emphasis is now on integrated design, stakeholder participation, regional holistic long-term visions, and the use of natural processes and the so-called ‘risk-based’ approaches in flood risk reduction strategies. The following sections describe recent developments in flood risk approaches in the Netherlands in the light of distinctive projects such as ‘Room for the River’ and the ‘experimental adaptive building’ programme, the ‘Delta Programme’, and ‘Building with Nature’.

§ 2.2 Room for the River

Climate change is expected to lead to larger peak river discharges (Delta Programme 2008) and with that higher water levels. This increases the loads exerted on dikes and as a result, the probability of failure. With flood risk defined as the probability of a flood multiplied by its consequences (Jonkman, Kok & Vrijling 2008), climate change thus leads to an increased flood risk. If applying the traditional Dutch flood risk approach, this would mean that dikes have to be reinforced in order to maintain the same safety levels.

There are however two important arguments against dike reinforcements. From a flood risk perspective, the consequences of flooding grow proportionally in relation to the severity of the inundation; polders are subsiding while water levels in rivers are increasing (Delta Commissie 2008). From a spatial perspective, the increasing value placed on nature and cultural heritage has led to resistance against dike reinforcements, as these usually have a large impact on spatial quality (Klijn et al. 2013).

This led to a new policy and approach in which the reduction of the load by creating extra space for the river was favoured over dike reinforcements (Alberts 2009). This paradigm shift ends a long history of narrowing riverbeds. The key aspect here is an increased discharge capacity; this can be achieved in several ways, such as: through the removal of obstacles; lowering of the floodplains, riverbed, or groins; increasing the riverbed by moving a dike or creating a river bypass or; through the creation of retention areas in polders adjacent to the river (Rijke et al. 2012).

This new policy resulted in the 'Room for the River' programme, in which the improvement of spatial quality is a prominent second objective (Ministerie van Verkeer en Waterstaat 2007). In order to achieve and supervise goals with respect to spatial quality, a 'Quality Team' was established (Klijn et al. 2013).

Currently, several 'Room for the River' projects are under construction. One example is a dike relocation in Lent, near Nijmegen (Fig. 2.1), where a new stream channel is combined with urban development on the northern river bank of the city. Another example is the Biesbosch 'de-poldering' where the existing 'Noordwaard' polder has been changed into a flood plain and recreational area (Fig. 2.2).



FIGURE 2.1 River bypass in Lent, near Nijmegen (<https://beeldbank.rws.nl>, Rijkswaterstaat, Ruimte voor de Rivier / PDR)



FIGURE 2.2 De-poldering of the Noordwaard (Biesbosch) (<http://combinatie-noordwaard.nl/>)

§ 2.3 Flood-Proof Houses

The Netherlands has a long tradition in flood-proof housing. As a result of the gradual extension of the regional and national flood risk reduction system, consisting of dams and dikes, small-scale flood risk management interventions have become obsolete. The 'Room for the River' programme required land reservations for riverbed extensions, thereby reducing availability of land for housing development. This resulted in a demand for the multifunctional use of riverbeds.

This demand was addressed through a Dutch government programme, 'EMAB', short for Experimenteren Met Aangepast Bouwen (Experimenting with Adapted Building). The programme defined 15 riverbed locations where it would be allowed to construct houses provided that certain conditions were met: the houses should be safe in the event of high water levels, contribute to the spatial quality of the area, and increase the space for the river. Several different types of flood-proof houses were developed, among which were pole houses, floating houses, and a new innovative housing type: amphibious houses.

An amphibious house is a house that is normally situated on dry land but will float in the event of high water levels. In order to accommodate floods, the houses are built upon a floating base, have flexible service connections to the main land, and are attached to mooring poles to ensure the houses stay at their location. The houses are positioned within the riverbed; a well-known example is the group of amphibious houses in Maasbommel where the water fluctuation can be up to 7 metres (Fig. 2.3). These houses can also be used in water retention areas, or in situations where a second layer of safety is desirable, such as in deep polders that inundate quickly in case of a dike breach (Fig. 2.4).



FIGURE 2.3 Amphibious houses of Maasbommel, developed by Dura Vermeer



FIGURE 2.4 Design for a lightweight composite amphibious house for retention areas.

§ 2.4 Dutch Delta Programme

Following the 1953 North Sea flood, in which large parts of the Netherlands were flooded, Dutch authorities established the so-called Delta Committee. This commission created a plan to minimise the chance of a similarly catastrophic flood event occurring in the future. Construction of the Delta Works was initiated, a system of closed and open-but-closable flood barriers that closes off the Rhine-Meuse-Scheldt estuary and protects against storm surges from the sea. Safety standards for existing dike-rings were improved and enshrined in law (Brinke & Jonkman 2009).

The present-day Dutch Delta Programme was established in order to define suitable long-term strategies and interventions to answer future flood risk challenges brought about by erosion, sea level rise, and subsidence; at the same time, the programme needs to ensure that the Dutch delta remains an attractive place in which to live, work, recreate, and invest (Delta Programme, 2008). In the Delta Programme, a variety of activities is performed, such as problem analysis, development of integrated long-term strategies, scenario development, assessment of alternative strategies, and the formation of regional strategies through extensive stakeholder consultation processes.

The Delta Programme will report to the Dutch government on a preferable flood risk reduction strategy for the country. This section presents some interesting studies that have been conducted over the course of the development of this strategy.

§ 2.4.1 Cornerstones

In an early phase of the Delta Programme, a sub-programme for Rijnmond-Drechtsteden, an interesting ‘out of the box’ design research was undertaken. Four extreme flood risk reduction strategies, so-called

'cornerstones', were defined; these were not considered realistic strategies but extremes that could widen the scope and allow for reflection on the effects and opportunities of certain high-level choices regarding flood risk protection. In addition to the current ('as is') situation, the cornerstones included a variation on a completely open delta (with no dams, but rather an emphasis on reinforcing dikes), a completely closed delta (with an emphasis on dams), and an open-but-closable delta (with an emphasis on closable barriers).

Interdisciplinary teams worked together on exploring the opportunities and consequences of the cornerstones. This resulted in a research-by-design study in which the relationship between flood risk management interventions and other essential aspects of the complex system of a delta such as shipping, ecology, economics, fresh water supply, and spatial development, were explored.

One of the strategies was the continuation of the current flood risk reduction system. Six urban and landscape design offices were invited to investigate and visualise the spatial consequences and opportunities of the current system, if extended to address the future flood risk reduction task up to 2100. This led to a wide range of projects varying from grand regional visions to small-scale investigations of the effects of dike elevations (Delta Programme 2011). Fig. 2.5 shows a vision for the reinforcement of old sea-dikes along the Haringvliet into a recreational dune landscape (by the urban and landscape design office Bosch and Slabbers). Fig. 2.6 shows the results of a research-by-design study by urban design office, Defacto, into the spatial effect of dike reinforcements along the historical dike ribbon of the Albasserwaard polder. Local stakeholders and governments were involved in the spatial assessment of the necessary interventions.



FIGURE 2.5 Design for a recreational dune landscape by Bosch Slabbers Landscape + Urban Design

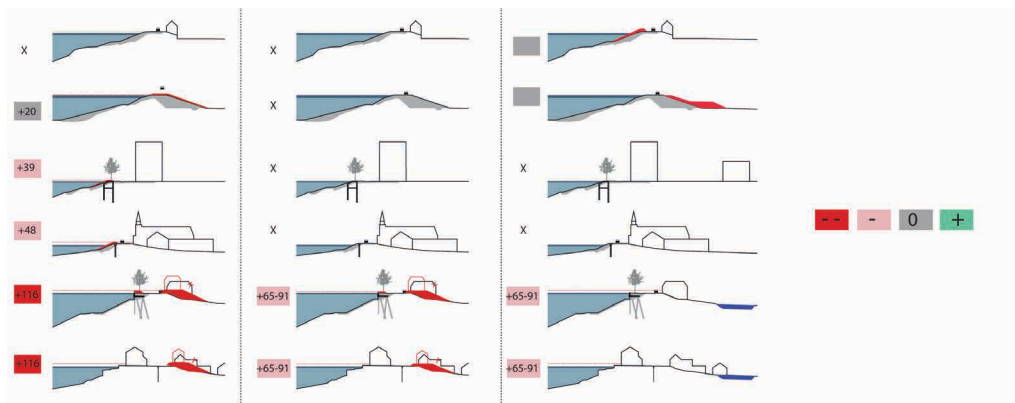


FIGURE 2.6 Assessment of the spatial impact of dike elevations for the Alblasserwaard area, in relation to different regional strategies.

§ 2.5 The Hague - City by the Sea

One of the studies that stands out for its interdisciplinary approach to flood risk and spatial design, is a research-by-design study for the development of the beach resort of Scheveningen (City of The Hague). The study was performed within the creative setting of the 'Atelier for Coastal Quality'. Sketches were made of holistic, long-term perspectives based on three different flood risk reduction strategies: a flexible dune extension, a hard quay extension, and a perpendicular dam. The goal of this study was to address long-term flood risk reduction (2100) while also improving the identity, accessibility, vitality, spatial quality, and identity of the area.

The working method of the Atelier for Coastal Quality consisted of interdisciplinary studio and workshop sessions in which civil engineers, spatial designers, and local stakeholders cooperated. These experts worked together in integrated sessions to explore and evaluate different options. The designers deemed it essential to understand the essence of the flood risk reduction task and interventions, in order to properly embed these in an integrated design. In the end, three strategies were developed, each of which had a different guiding design theme in relation to the type of flood risk intervention (Fig. 2.7). In the design for a seaward extension, the focus was on the flexibility of the solution and possibility for it to be developed in phases.

In the design featuring the hard quay, the focus was on creating proximity of the city to the water. The design for the perpendicular dam concentrated on a research-by-design approach in order to optimally position the dam. Here, the interdisciplinary way of working was essential to the research-by-design process, performed to explore the hydraulic, as well as the spatial, suitability of different possible locations for the dam.

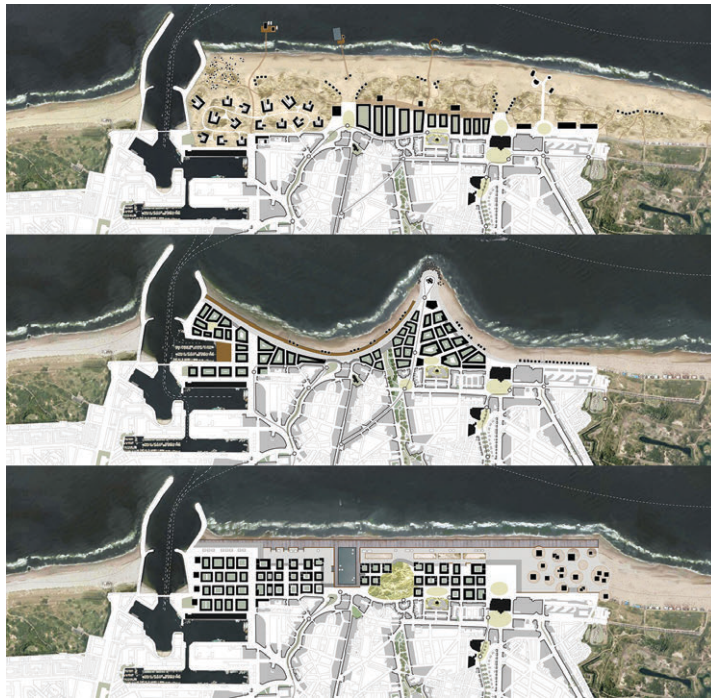


FIGURE 2.7 Three alternatives for the future development of The Hague.

§ 2.5.1 Risk-based Approach & Multi-layered Safety

A more recent development is the so-called risk-based approach. Potential failure mechanisms of dikes and the associated consequences, such as flood patterns, are studied with the use of new insights and models. This provides valuable information with respect to the contribution of specific dike segments to the potential amount of fatalities and economic damage. Dike segments that contribute significantly to risk can be held against stricter safety standards. In the Netherlands, some dike segments are being considered for construction as so-called 'delta dikes', which have a very small probability of failure, thus increasing the level of safety of an area. Generally, this results in a bigger footprint, which serves as an incentive for multifunctional use and design of such dikes.

In addition to reducing flood risk by reducing the probability of flooding, there is also renewed attention to impact (consequence) reduction. The so-called 'multi layered safety approach' aims to provide flood risk reduction, not just from a first layer of probability reduction (such as dikes and dams), but also from a second layer of spatial interventions that reduces the consequences (such as mound, compartmentations of areas, flood proof houses) and a third layer of evacuation and recovery (Ministry of Infrastructure and Environment, 2009). In particular, the interventions in the second layer appeal to designers and many imaginative design studies are made; however, it appears to be difficult to make a feasible business case for investment in flood risk reduction by means of consequence reduction in the protected areas. Nevertheless, more awareness of the flood risk in certain areas could contribute to a reduction of the risk by applying modest measures such as placing vital functions (power generation, healthcare) in higher areas, providing roofs with a rooftop to serve as an emergency escape route, or placing power sockets in houses at a height sufficient to prevent damage.

§ 2.6 Building with Nature

The 'Building with Nature' programme aims to facilitate 'a paradigm shift from building in nature to building with nature, to ensure a sustainable future' (Ecoshape 2014). New concepts and trials are developed in which the natural system is put to optimal use to provide, or contribute to, flood risk protection. Interdisciplinary cooperation is essential to developing new eco-dynamic spatial approaches that anticipate the dynamics of the natural system (Ministry of Infrastructure and Environment 2008). In the programme, engineering companies, universities, governments, and natural advocacy organisations cooperate to develop sustainable, effective, and affordable flood risk management interventions.

§ 2.6.1 Sand Engine

One of the pilots is the 'Sand Engine': an imaginative alternative to conventional sand replenishments along the Dutch coast (Fig. 2.8). Whenever, due to erosion or climate change, there is a severe inland deviation from a so-called base coastline, as defined in 1990 by Dutch authorities, Rijkswaterstaat will interfere with sand replenishments (Ministry of Public Housing, Spatial Planning and Environment 2006). Usually, this is done every 5 years, thereby temporarily disturbing ecology and recreation. The Sand Engine breaks with this strategy by providing a large-scale concentrated replenishment of 21.5 million cubic metres of sand along the coast of the Delfland region (Province of Zuid-Holland and Rijkswaterstaat, 2015). From this location, the replenishment is continued by the natural forces of wind and currents that distribute the sand gradually along the Dutch coast, thus limiting the disturbance of ecosystems and tourism. While it exists, the Sand Engine itself serves as a temporal location for nature and recreation.

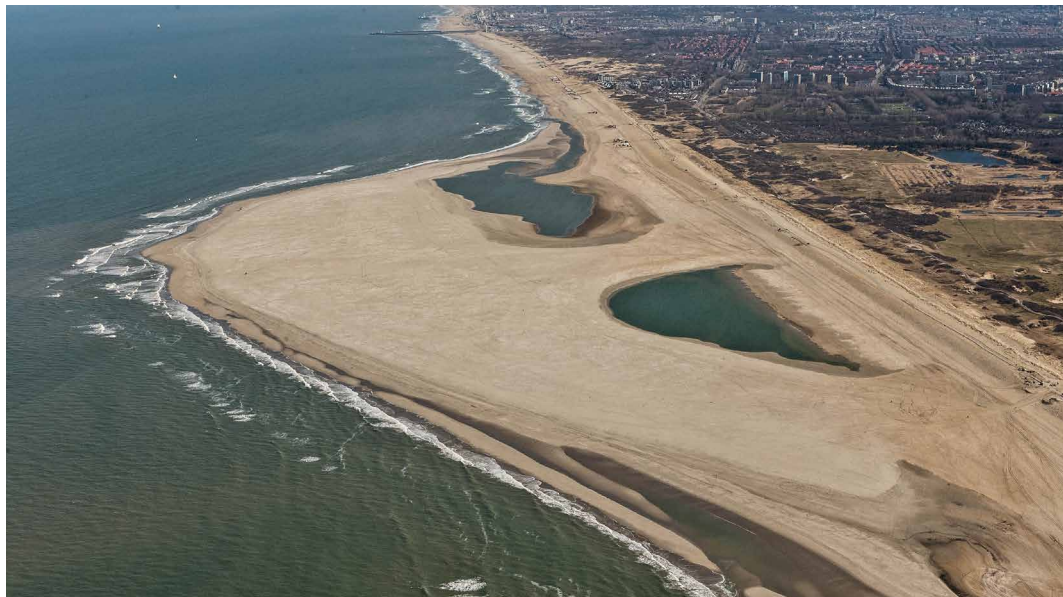


FIGURE 2.8 The Sand Engine along the Dutch Delfland coast (<https://beeldbank.rws.nl>, Rijkswaterstaat / Joop van Houdt)

§ 2.6.2 Vegetation as Wave Reduction

Another concept is the use of vegetation to break waves in the flood plain and thus reduce the loads exerted on dikes behind the vegetation. The necessary height and strength of a dike is linked to the expected water levels under extreme circumstances; the height of waves is included in calculations and may be severe due to strong winds combined with large fetches. In areas where vegetation within the flood bed does not compromise the discharge capacity of the river, vegetation such as willows can successfully lower the wave energy and height. In Dordrecht, a study was performed to combine the development of a landscape design for a recreational and ecological park with a flood risk reduction function (Fig. 2.9). Engineers and spatial designers worked together on the design of a park with willow vegetation that, in case of high water levels, is part of the flood risk reduction system.

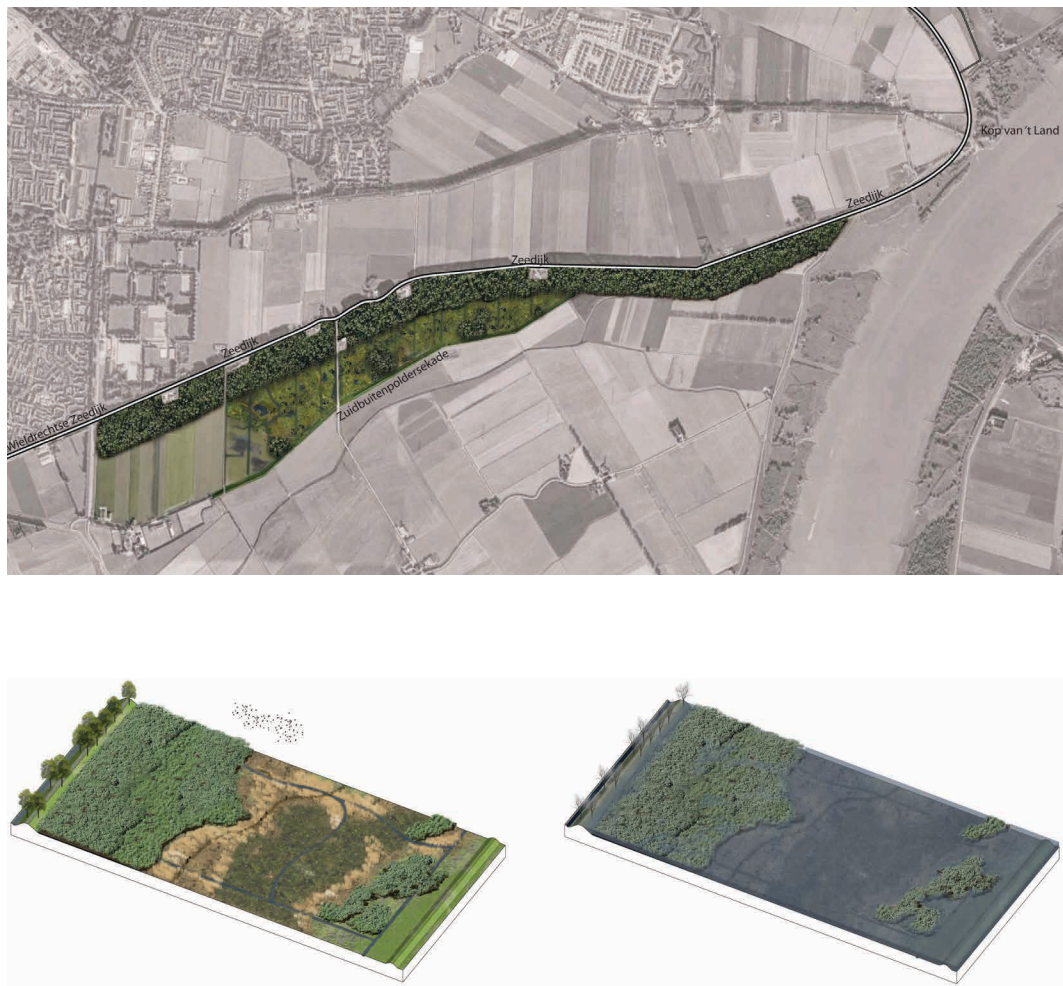


FIGURE 2.9 Dordrecht, willows as flood risk protection.

§ 2.7 Conclusion

A new emphasis on spatial quality in relation to flood risk reduction provides promising opportunities. Designers are gradually becoming more involved in flood risk reduction projects: initially, to embed interventions in a qualitative way, but, gradually, also to develop innovative and outside-the-box approaches to flood risk protection. This development is very interesting from both an urban and landscape perspective as well as from a flood risk perspective. New approaches are developed by breaking paradigms and consensus, and viewing flood risk from new angles. The 'Room for the River' and 'Experimenting with Adapted Buildings' programmes have already changed the approach to, and perception of, flood risk reduction in a permanent way. Projects such as 'Building with Nature' and the 'multi-layered safety approach' are still in the early stages but are expected to further change and develop the consensus about flood risk protection.

The outcomes of the Delta Programme and the final strategy will probably not deviate much from the current flood risk reduction strategies; changes and optimisations have been made to the current system. However, the undertaken studies that resulted in those strategies embody the new paradigm of flood risk in direct relation to spatial design, on local as well as regional scales.

Local stakeholder participation and local ownership have become important elements in the formulation, development, and implementation of flood risk reduction programmes. This leads to an important role for the designer and the design atelier approach, in order to communicate the challenges and opportunities and facilitate the stakeholder process. The role and relevance of the designer as a facilitator in the formulation of complex long-term holistic visions appears to be recognised and furthered. More and more international projects dealing with major infrastructural interventions invite spatial designers to be part of the development team, based on their skills in connecting different scale levels, work in an interdisciplinary manner, and thinking in terms of opportunities.

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Intermezzo 2: Rotterdam Rijnmond Photographs

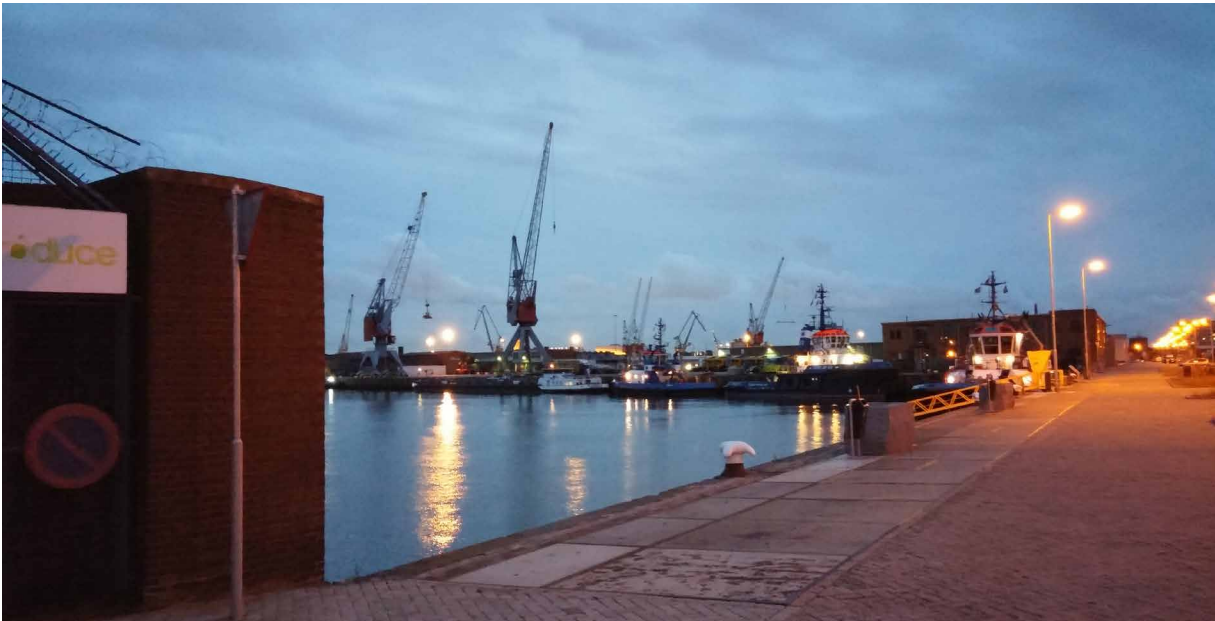


FIGURE 2.10 Photograph of the 'city-harbours' that are positioned close to the urban centre of Rotterdam and are currently transformed into mixed use areas

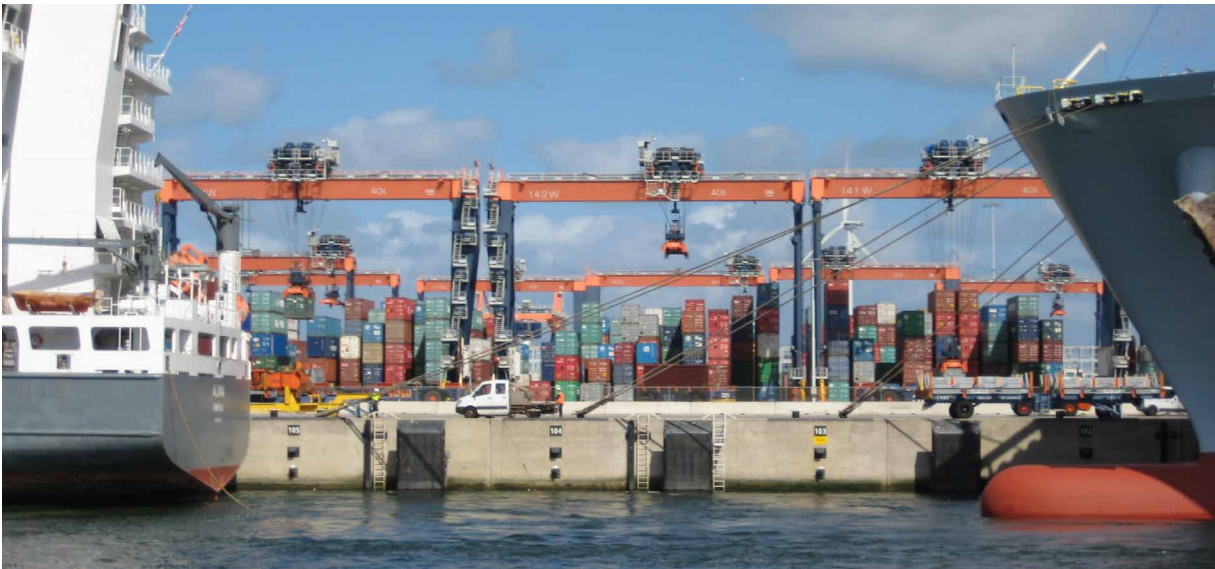


FIGURE 2.11 Photograph of the second Maasvlakte, a recent harbour extension that allows for large sea vessels to enter the harbour and unload



FIGURE 2.12 Part of the unembanked residential area 'Noordereiland' in the city centre of Rotterdam, during high water levels



FIGURE 2.13 Photograph of the Rotterdam riverfront, including the Erasmus bridge, the 'Boompjes' city quays, and the unembanked 'Noordereiland'

3 Rotterdam: A City and a Mainport on the Edge of a Delta

Han Meyer, Anne Loes Nillesen & Wil Zonneveld

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This paper can be seen as the overall introduction in which the Rotterdam Rijnmond case study region and its spatial and flood risk challenge are introduced. It describes the strong historical relation between flood risk management interventions and the spatial development of the region. The region is protected against floods by an extensive system of (sea)barriers and dike-rings. Positioned on the edge of the Rhine-Meuse delta, the region developed as a port area and is part of the so-called Randstad area: the most densified area of the Netherlands.

Due to climate change, increasing sea levels and peak river discharges are expected in the future, resulting in an increased flood risk. In order to address this future flood risk challenge, the second Delta Committee was established - the first Delta Committee was established after the 1953 flood that flooded part of the Netherlands. This Delta Committee develops regional strategies for flood risk reduction for the long-term period, up to 2100. As part of the strategy development process, four conceptual regional flood risk reduction strategies are developed, which can be perceived as cornerstones of the playing field of possible flood risk reduction strategies for the region.

Those cornerstone strategies vary from the complete damming of the delta (thus lowering the extreme water levels behind the barrier) to opening up the delta and dealing with the expectedly high water levels by elevating the region's dike-rings. The different cornerstones offer different potentials and threats for the spatial development of the region. In addition, at a local scale, the different cornerstones impact the spatial quality of the dike zones and flood plains in different ways.

This strong relation between the flood risk management interventions and spatial composition and quality of the region supports the urgency of approaching the future flood risk reduction task in a comprehensive way.

Key aspects: urgency-integrated approach, future flood risk task, and spatial characteristics of the Rijnmond-Drechtsteden case study area, scale of flood risk management interventions.

ABSTRACT

Within Europe, Rotterdam is by far the largest port and supplier of fossil energy sources. City and port have a 'sandwich' position in the low lands between a sea with a rising level and rivers with increasing peak discharges. It is certainly no exaggeration to say that sustainability raises a matter of life or death for Rotterdam as a delta city. The question of whether Rotterdam is sustainable or not is related to the following issues: (1) water management (preventing hazards, the restoration of the estuary, salinisation); (2) urban renewal; (3) the spatial and climate footprint of the ever-growing port and; (4) energy transition. Currently, all these issues are dealt with largely independently of one another. For a genuinely sustainable future, links have to be made between strategies, projects, and actors.

§ 3.1 Introduction

The city of Rotterdam can ascribe its economic 'raison d'être' and power, as well as its increasing vulnerability, to the same source: its position in the Rhine-Meuse delta, at the edge of the north-western European 'megapolis'. Being the largest European port and supplier of fossil energy sources and, struggling with its 'sandwich' position in the low lands between a sea with a rising level and rivers with increasing peak discharges, 'sustainability' is a far from meaningless term in this city. We distinguish four main topics that can be regarded as questions of life or death for this city.

The first topic concerns how the city and the port can survive during changing conditions of sea, rivers, and rainfall. With a dense concentration of people, capital and economic activities (the Rotterdam region is responsible for 8% of the GDP of the Netherlands), the first question is how the risk of flooding can be reduced to a minimum. The central water problem in this delta region is the danger of flooding, but similarly, questions about salinisation, soil subsidence, and rainwater management need to be taken into account.

The second topic concerns the strategic position of the city as a European mainport in relation to energy transition. If the city aims to continue exploiting this strategic position, the port policy should consider how the port can anticipate the future transition of energy sources. Future scenarios concerning this energy transition should result in new visions and strategies concerning land use, accessibility, networks, supporting economies, etc. Moreover, being one of the most important contributors to CO₂ emissions, the port is being forced to look for possibilities to substantially reduce these emissions.

Third, the development of a new flood risk management strategy, combined with a substantial transformation of the port, will result in new possibilities for the urbanisation of docklands and riverfronts. Altogether, we are talking about huge areas of hundreds of hectares that will be available for urbanisation in the future. This provides an opportunity for the city to develop an urban design policy, emphasising new spatial and functional qualities which might be important to the stimulation of specific social and economic processes.

The fourth topic explores the fact that, until recently, neither flood risk management nor the port economy was considered to be very good for nature and ecology. Land reclamations, the construction of many dikes and dams, and the expansion of the port industry resulted in the disappearance of wetlands and estuaries, a radical change in the ecosystem of the delta and a dramatic loss of bio-

diversity. A new awareness of the importance of ecological sustainability, embodied in European rules and civic pressure groups, has forced the city and the port authorities to develop new strategies concerning flood risk management and port development, contributing to the repair of the natural deltaic system.

Certain issues that are important for Rotterdam and Rijnmond and could be considered as part of a wider interpretation of sustainability are not considered here. For example, the socio-economic problems in the greater Rotterdam area are greater than anywhere else in the Netherlands. The economic (industrial) history has left a legacy of problems: a relatively one-sided economy, high concentrations of social and economic deprivation, and a massive urban renewal problem. Since 2006, the Rotterdam South area has been one of the main targets of a national government programme to improve social and economic conditions in problematic urban areas (van den Brink 2007).

The city administration of Rotterdam is quite aware of the importance of the development of an effective policy concerning the aforementioned aspects of sustainability. Because of this, the Rotterdam Climate Initiative (RCI) programme was started in 2008. The aim of this programme is for the city to become a 'worldwide benchmark' for dealing with climate change and to make the city 'climate-proof' by 2025¹. Water and water management, as well as energy transition and the reduction of CO₂ emissions, play an important role in this programme. An important question that remains is whether we can really expect an innovative and comprehensive approach to be taken by the city administrators.

This paper starts with a general introduction to the origins of the delta city of Rotterdam and the wider area in which it is situated referred to as the Rijnmond region; we intermittently use these two names, in most cases referring to the wider Rotterdam area: the city and the dozen or so municipalities on either side of the Nieuwe Waterweg. Section 3 looks at the way in which the Rijnmond mainport system has evolved and the often non-critical—from a present-day perspective—political decisions that were made in order to achieve a continuous and almost endless expansion of Rotterdam harbour. We focus on the primary sustainability and climate change issues facing the Rijnmond delta city, independent from the water system. In Section 4, we look at the latest expansion of the Rotterdam port and how the Maasvlakte 2 project—the name given to the new port area—has become immersed in discourses about sustainability, delta nature, and climate change. In Section 5, we redirect our perspective towards the water-related problems that the Rotterdam delta faces. Section 6 focuses on the possibilities of new types of urban environments resulting from new strategies concerning flood management and port policy. In Section 7, we focus on the possibility of developing comprehensive strategies, based upon scenarios concerning flood management and port development. We round off with conclusions and discuss some of the future key sustainability and climate change issues related to delta and (main)port development.

§ 3.2 One Delta City with Two Faces

The spatial development of the city of Rotterdam has been strongly determined by its position at the edge of the southwest delta area of the Netherlands: this position defines its economic position and spatial structure and has influenced the social diversification of the city. This 'edge position' means that Rotterdam is settled on two different ground structures, separated by the Nieuwe Maas river.

North of this river, the ground structure is mainly peat, part of the 'peat continent' of central Holland (the area that covers the two western provinces with 'Holland' in their names), which stretches from the river Maas to the banks of the IJ, north of the historical core of Amsterdam. This peat area was the first area to be surrounded by dikes in the thirteenth century, and since then has been relatively safe for human settlement (Van de Ven 2004). This enclosure still plays an important role in the water management and flood control of Holland as 'Dike-ring 14', a part of the system of dike-rings that is the basis of water management and flood control in the Netherlands (Fig. 3.1). Dike-ring 14 surrounds the area with the highest safety standard and created the condition for a process of intensive urbanisation (De Vries & Van de Woude 1997), resulting in what we call the 'Randstad' today.

South of the river Nieuwe Maas, we find the actual delta, composed of a number of estuaries, islands, and peninsulas, with a ground structure that is mainly clay. Until the nineteenth century, the city of Rotterdam was built on the north bank of the river, in the peat area, and mainly safely behind the dike. Part of the city, the port area in particular, was built on raised areas outside the dikes. From the mid-nineteenth century, two important spatial developments took place.

First, the accessibility of the Port of Rotterdam was improved by digging the 'Nieuwe Waterweg', which started in 1863. The Port of Rotterdam struggled with increasing inaccessibility due to sedimentation processes in the main channels of the delta. This sedimentation was caused by the rivers as well as by the tidal currents of the sea. By digging a new channel from Rotterdam to the sea, parallel to the southern dike of Dike-ring 14, a new main discharge channel for the river was created. This channel resulted in a faster river currents and consequently in an increased discharge of sediments and cleaning of the river bed. The new channel combined two goals: it contributed to the control of the water levels of the principal rivers in the Netherlands, and it created a new deep-water access to the Port of Rotterdam. However, it also resulted in the sea becoming increasingly influential in the Rotterdam region itself, in terms of bigger tidal differences in the river water levels and a greater vulnerability to storm surges, as well as in terms of the increased salinisation of the whole region (Van de Ven, 2004).



FIGURE 3.1 Dike-rings in the western part of the Netherlands.

The second important spatial development concerns the extension of the city and port on the left banks of the river. During the nineteenth and twentieth centuries, the two parts of the city on both sides of the river banks developed in two different ways. The north bank, with the historical city, maintained its role as the city centre and developed some prosperous urban districts. The south bank is still part of the deltaic landscape and shows a more fragmented character; the former structure of the area as a conglomeration of small islands is still recognisable in the urban pattern of this part of the city (Palmboom 1987) (Figs. 3.2 and 3.3). The first generations of residents of this part of the city worked mostly in port-related industries (Bouman & Bouman 1952). For a large part, this was related to the fact that the left, southern riverbank became the main territory of port development of the nineteenth and twentieth centuries.

At the moment, the municipal territory of Rotterdam covers 314 km², with ca. 600,000 inhabitants. The metropolitan region has ca. 1.2 million inhabitants. The city territory includes a port area of 105 km² (Fig. 4), which is in the unembanked areas. Several urban districts, most of them built on former port areas, can also be found in unembanked areas.

§ 3.3 Conflicts about the Growing Territorial Footprint of Rotterdam Mainport

The open connection between the sea, the port, and its hinterland has been a crucial factor in the development of the Port of Rotterdam. It is generally accepted that the Rotterdam port owes its present position to its favourable location in northwest Europe in general and the excellent water connections to Germany in particular.

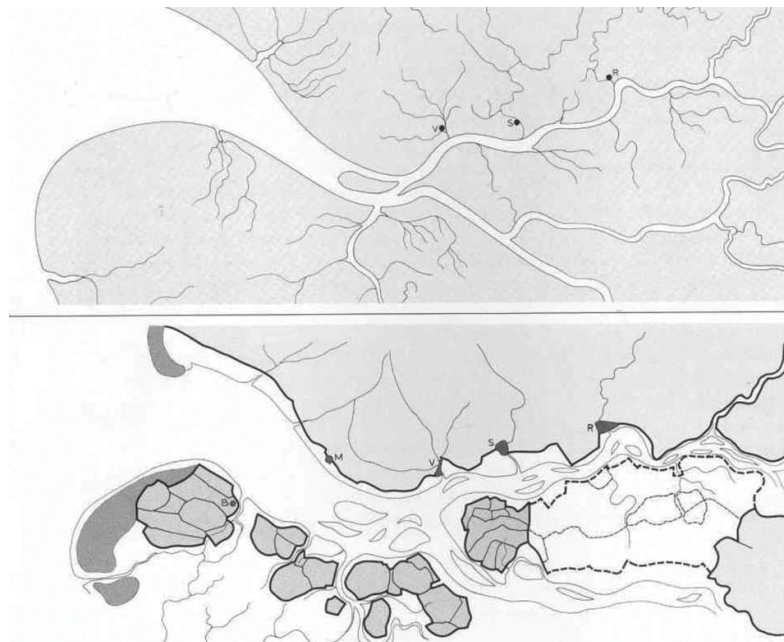


FIGURE 3.2 The Rotterdam region before 1100, dominated by rivers and creeks (top); and around 1400, with a dike along the north bank of the river and islands with dike-rings in the south (bottom) Source: Palmboom (1987).



FIGURE 3.3 The spatial structure of Rotterdam: north of the river, it is defined by long lines of dikes and quays, and south of the river it is dominated by ring polders. Source: Palmboom (1987)

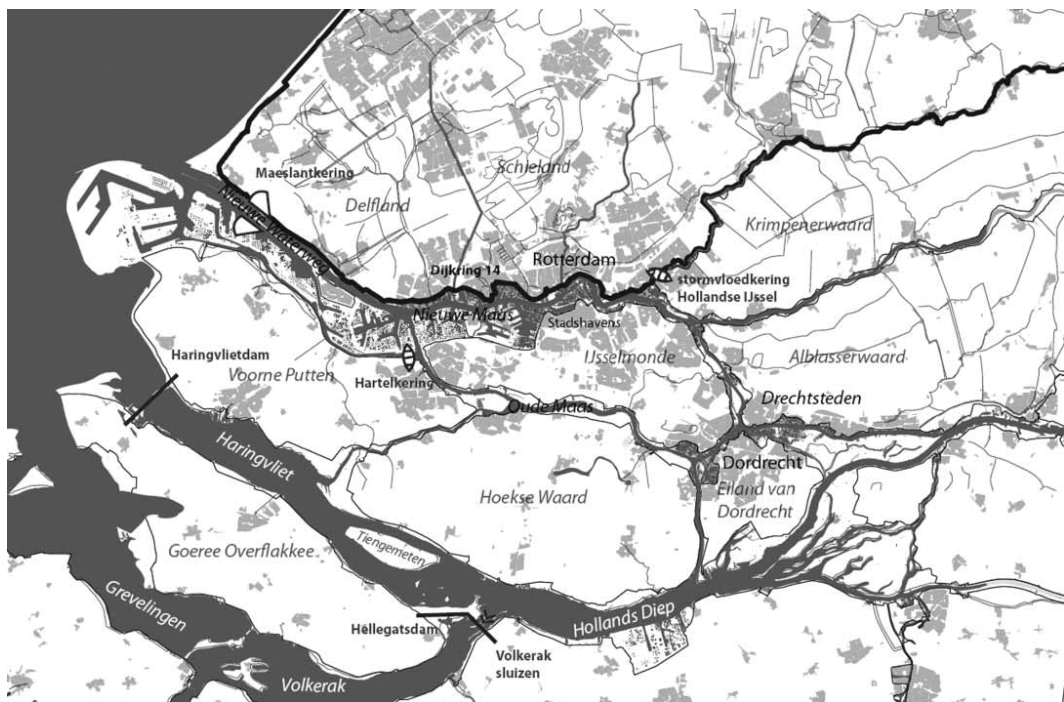


FIGURE 3.4 Rotterdam region ('Rijnmond') with unembanked and port areas.

§ 3.3.1 A Transportation Hub

Although no longer the largest seaport in the world—this position has been taken by Asian seaports—figures on the volume of flows at Rotterdam Mainport are still extremely impressive. The latest available figures for 2009 show that Rotterdam, in terms of transshipment, is more than twice the size of the second port of Europe, Antwerp: 387 million metric tonnes compared with 157.6 for Antwerp. Most of this volume, about 71%, goes into the harbour; 29% is transferred to other sea vessels (transshipment). When it comes to the number of containers, the differences with its main competitors are fewer. Rotterdam handles 9,743,000 TEUs (Twenty-Foot Equivalent Units) while the figure for Antwerp—the second European harbour in this respect as well—is 7,310,000 TEUs. Hamburg is close on the heels of Antwerp with 7,008,000 TEUs (Port of Rotterdam 2009). Although the market position of Rotterdam in the so-called Le Havre-Hamburg range—the range of harbours catering for the same hinterland—is gradually diminishing, the volume of goods and, consequently, the number of transportation units are enormous. In 2009, no fewer than 29,000 sea vessels entered the Rotterdam harbour areas to deliver or pick up goods and containers.

From the perspective of the ecological footprint of the harbour, it is interesting to look at other figures: what does the mainport position of the Rotterdam harbour area mean in terms of flows running through the metropolitan region: trains, lorries, and inland vessels? Although the number of inland vessels entering the mainport is rather impressive—about 110,000 in 2009 approximately—the modal split of the harbour results in a heavy environmental burden on the Rijnmond metropolitan region and the country as a whole. Although one should not overlook the fact that emissions from inland vessels are an important polluting factor, the overall majority of container transshipment does not take place via waterways but via roads. Of the 4132 million containers going to or coming from the hinterland, no less than 56% is transported via lorries, 33% via inland vessels, and only 11% via rail².

From the late 1960s onwards, the attention given to environmental issues increased and the development of the Rotterdam mainport attracted the attention of environmentalists who started to voice opposition. In the late 1980s, the debate entered a new period because of plans to build a dedicated freight railway line from Rotterdam to Germany as well as (again) a new, large-scale extension of the harbour area: the Maasvlakte 2. Both projects would have serious environmental repercussions. Environmentalists were joined by—at least some—economists claiming that more development space and improved accessibility were outdated strategies for strengthening a mainport. For instance, Boelens and Atzema (2006) claimed that instead of focusing on volumes of transported goods, a network-oriented strategy would make far more sense.

The concept of a mainport approach was born in Rotterdam as Van Duinen (2004, p. 64ff) explains. Two professors of Erasmus University of Rotterdam—Poeth and Van Dongen—published several reports in the early 1980s on port development. They highlighted the global trend to concentrate on specific activities in huge, centrally located ports, a trend resulting from worldwide shipping processes. For the sake of efficiency, shipping companies would direct their ever-bulkier vessels to a small number of ports: from ‘multi-ports’ to ‘main ports’.

This signal was rapidly picked up by the Rotterdam Port Authority but, in doing so, part of the story was overlooked. Instead of just concentrating on the qualities of the ports itself, Poeth and Van Dongen emphasised the crucial importance of looking at entire international transport chains: advanced logistical systems, hinterland connections, inland terminals, automation, etc. (Van Duinen 2004, pp. 65 – 66). According to Van Duinen, this was a bridge too far. Rotterdam port authority stayed within

its span of control: a (main)port is a physical entity that needs excellent external connections via all relevant modes. The institutional position of an organisation and its internal doctrine and (spatial) planning concepts determine how the world looks (see, for instance, Throgmorton 1992).

At first, public opposition was small. An obvious explanation is that, at that stage, the mainport concept was just an idea on paper. The full effect only became visible later when the mainport concept was used to substantiate plans to build Maasvlakte 2, the Betuwe freight route to Germany, and also Schiphol's fifth runway. All these projects have been heavily contested with judicial fights in the highest courts in the Netherlands. Environmental concerns including the effects on the landscape—which were of particular importance in relation to the Betuwe line—were at the top of the opponents' agenda.

Ultimately, all three projects have gone ahead, although two of them are still under public and political discussion. Schiphol is the object of ongoing rows about noise pollution (on the whole, only NGOs and the GreenLeft party emphasise the negative effects of air transport on CO2 emissions). A principal issue of the Betuwe route was the dramatic increase in the estimated costs. This eventually led to an official parliamentary investigation, which included public hearings. Moreover, the line—which started to operate in 2007—is still not properly connected to the German railway system. The original plans foresaw a connection in 2003. The present indication from Germany is that this is not likely to happen before 2020.

It was several years after the birth of the mainport concept that the Port of Rotterdam developed a strategy focused on wider transport 'chains' rather than just focusing on the port area itself. The port authorities started negotiations with inland ports in the region and the hinterland with the aim of better controlling the quality of hinterland connections, which were of vital importance for the position of the port itself. This resulted in the port of Dordrecht being managed by the Port of Rotterdam from July 2011 onwards, with further plans of it becoming a shareholder—together with Antwerp—in the port of Duisburg (Germany), the largest inland port in Europe. These latter plans have, however, been heavily opposed by the Port of Hamburg³. In addition, negotiations concerning collaboration and coordination with the ports of Amsterdam and Antwerp have recently started. What will come out of such negotiations is highly uncertain: these three ports have always competed with each other. Moreover, the port authorities of Amsterdam and Antwerp are still municipal services, while the Port of Rotterdam is privatised, its shares owned by Rotterdam municipality and the national government. In the case of Antwerp and Amsterdam, perceptions of territorial interest and the competition of municipal councils might still tip the balance.

§ 3.3.2 Maasvlakte 2: Sustainability Conflicts

During the 1970s, it became clear that due to the changing port economy and transport technology the inner-city port areas would be abandoned. The port concentrated its activity in the large-scale post-war port areas of Botlek, Europoort, and Maasvlakte (Meyer, 1999). As a result, large sections of the inner-city harbour areas became available for urban transformation. The second half of the 1980s turned out to be a period of economic recovery; growth figures for the Rotterdam port were rising, resulting in a new plan for the port: the 2010 Port Plan. The plan was officially adopted by the municipal council late in 1993, although there was some opposition due to environmental concerns. The main proposal therein was to create a new major port immediately west of the latest Maasvlakte 1 extension.

The role of environmental groups became powerful when the realisation grew that the future development of the Port of Rotterdam not only fell under Dutch law, but also under European law: the

1992 EU Habitat Directive. In 2000, this directive had still not been properly transposed into Dutch law as required under the EU treaties. But that does not change the working of an EU directive: in the absence of a (proper) transposition, a European directive takes effect directly. This strengthened the position of environmentalists opposing the plan to build the new port area.

Eventually, a compromise was reached between the various actors and arenas. Of particular importance was an agreement between the municipality of Rotterdam and three large environmental groups laid down in a memorandum of understanding in 2000 called 'Vision and Courage'. In this document, both parties agreed that the objectives to further develop the Rotterdam mainport were equally important to the improvement of liveability in the Rijnmond areas. A second Maasvlakte could be realised and compensated by various measures. Moreover, several projects to develop new nature and outdoor recreation areas up to a total of 750 hectares had to be realised (this would eventually lead to four projects in Rotterdam). Within the existing port area, the available space would be more intensively used, and measures would be taken to improve the environmental impact of industrial and harbour-related activities. Easterly port areas that were no longer needed would acquire new urban functions. At the time of writing, work has already started; their progress can be followed through a webcam ⁴.

§ 3.4 The Ecological Footprint of Rotterdam Mainport and its Possible Future

§ 3.4.1 The RCI

The debate about Maasvlakte 2 and the making and future use of Maasvlakte over time have become increasingly framed within the perspective of climate change. As Rotterdam is a major transport hub as well as a (very) highly concentrated area for industry and, in particular, the petrochemical industry, environmental policies are becoming increasingly intertwined with climate change mitigation policies and energy transition strategies. In both these areas, 'Rotterdam'—that is, a coalition of various stakeholders—is striving to become a world leader and a benchmark for many other port and delta cities.

The major vehicle for this ambition is the RCI (Rotterdam Climate Initiative), in which energy transition and the reduction of CO₂ emissions play an important role in the aim to make the city 'climate proof' by 2025. The RCI is a cooperative body with four members: Rotterdam municipality, Port of Rotterdam, DCMR Environmental Protection Agency Rijnmond, and Deltalinqs. The latter is a regional NGO which— according to its website— "[..]represents the common interests of all the logistical and industrial companies in the Rotterdam port and industrial area. The organization is considered to be the focal point and spokesman for more than 600 registered companies and associations."⁵

Almost always publicly represented by its ambassador, former prime minister and UN's High Commissioner for Refugees Ruud Lubbers, the RCI has a very simple slogan: 100% climate-proof.

It seeks to create “[...] a movement in which government, organizations, companies, knowledge institutes, and citizens collaborate to achieve a fifty per cent reduction in CO2 emissions, adapt to climate change, and promote the economy in the Rotterdam region.”⁶

The RCI CO2 reduction targets are ambitious when compared with those set by others. The region of Rotterdam for instance—a statutory cooperative body in which the municipality of Rotterdam participates — is seeking a reduction of 40%. The province of South Holland is following general EU policy targets: a reduction of 20% (OBR, 2010, p. 97). This figure also stands for the present centre-right national government, which explicitly does not strive to move beyond the ambitions of the EU. What is more interesting is the way in which the government would like to reduce CO2 emissions, namely through large-scale carbon capture and storage (CCS), and nuclear energy. The latter is unprecedented when compared with a number of previous government coalitions: the present government explicitly sees nuclear energy as a climate friendly technology.

CCS is a primary component of the RCI strategy. CCS has become urgent because there are plans to build two new coal-fired power plants in the port area. However, the CCS strategy of the RCI received a major blow in November 2010. A major project to store CO2 in a depleted gas-field under the city of Barendrecht has officially been abandoned after heavy protests by the local community, who were afraid of certain risks such as leaks from the installations or from deep underneath the soil. The North Sea is now fully in the picture. Plans to store CO2 in the continental shelf are already being carried out. As is the case with offshore wind farms, potential opponents are literally over the horizon.

§ 3.4.2 To Maintain Mainport Status in an Age of Energy Transition

We can say that port areas at present are indeed hubs in the global and continental flows of energy. In this respect, no other European port has the same status as Rotterdam. To maintain this position within the perspective of energy transition is part of the survival strategy of the Port of Rotterdam and other major stakeholders involved in the port area.

Being an energy hub is currently almost exclusively related to fossil fuels: oil, coal, and—in the near future—liquefied natural gas (LNG). The throughput of oil at the port is quite stable at the moment, at around 100 million metric tons annually. About half of this is transported through pipelines to Vlissingen in the southwest of the country, as well as to Antwerp and Germany. The other half is processed in the port area itself; together with Singapore and Houston, Rotterdam belongs to the top three global petrochemical clusters. Throughput of coal has steadily risen over the years and now stands at about 25 million metric tons. Transported by belt (in the Rotterdam port itself), barge, and rail, about 20% is used in steel mills, the remainder going to power plants, mainly in Germany.⁷ A main goal is that a third energy flow will be added to the two traditional fuel sources, oil and coal: LNG. This is part of a wider, national strategy to diversify the importation of natural gas to improve the security of the supply. But Rotterdam is also striving to play a major role in the European transshipment of LNG, as well as building an industrial cluster around LNG in the port area itself.

At present, the port is also developing a strategy to become a hub in the transshipment and use of biofuels and biomass. With this in mind, the so-called Rotterdam Biomass Commodities Network (RBCN) has been set up as an offshoot of RCI, and is formed by a large number of companies.⁸ As biofuels have come under heavy attack by environmentalists and NGOs—driven by the cutting down of (rain)forests and pushing aside food production—RBCN supports the certification of biofuels mainly

through the Dutch NTA8080 standard.⁹ As with other fuels, biofuels are supposed to play a role in energy production within the port area itself (there are plans to build several energy plants), as well as becoming the core of industrial clusters. This is called co-siting by the Port of Rotterdam Authority; new facilities link up directly with adjacent tank terminals and factories.

What the effects could be of the future energy transition—the general heading for the period during which, according to many, fossil fuels will be gradually phased out—for Rotterdam is the object of discussion and scenario building. At the time of writing—early Spring 2011—the port authority is preparing its new 10-year vision, its horizon 2030. The full effects of energy transition, according to many, will be felt later. At present, the harbour is still developing in a mainstream fashion, as has been outlined above. For years to come, fossil fuels will continue to be fundamental to the harbour, their negative effects being overcome by CCS. Although the overall objective is to maintain the position of being an energy hub on the continent, during and after a possible period of energy transition, one can only speculate on whether this will indeed be the case. There are many unknown factors and quantities. Bio fuels form an entirely different sort of commodity compared with oil and coal; in particular, the concentration of production and transport of these traditional fuels are totally different when compared with biofuels. Rotterdam’s position as one of the world’s top three petrochemical clusters is largely due to its location: in the centre of a mega-region, connected to a major mass-transport axis (the Rhine), and accessible for the largest vessels on the planet. If the future pattern of biofuel and (sustainable) energy production is to become much less concentrated, which seems to be becoming the case, transport patterns could change radically. More spatial inertia could stem from the spatial pattern of chemical complexes. If the Rotterdam petrochemical complex is to gradually turn into a biochemical complex, the sheer scale of investment needed would lead to some form of stability in the transport chains of biofuels and the biological replacements of (crude) oil and their (semi-) manufactured product.

§ 3.5 Sustainability of the Delta City

Besides energy transition and the reduction of CO₂ emissions, water and water management play an important and multi-faceted role in the RCI programme. This means that policies concerning sustainability necessarily need to consider the different aspects of water in the city. These are:

- groundwater control and soil subsidence;
- rainstorm management;
- rises in sea level;
- increasing river discharges;
- environmental quality and bio-diversity;
- salinisation.

§ 3.5.1 Groundwater Control and Soil Subsidence

Like many other delta cities, Rotterdam is dealing with a difficult dilemma concerning groundwater control. Originally the peat areas were very wet and unsuitable for human living and building. Draining these areas had already started in the twelfth century and continued over the following centuries, supported by improving technology. A result of draining peat, however, is that the dried peat starts

to oxidise, thereby resulting in shrinkage. As a consequence, the ground level subsides by about 1 m each century, resulting in ground levels varying from 1 to 6 m below average sea level (referred to as Normaal Amsterdams Peil (NAP)). This subsidence means that the consequences of flooding as a result of a broken dike would be disastrous. Considering a storm surge with a sea level of 4 m above NAP, the result of dikes being broken would be that the water level in the flooded city would be 5 – 10 m above ground level.

Stopping the process of soil subsidence is crucial in order to make the city less vulnerable to flooding. It means that the groundwater level needs to be maintained at as high a level as possible, which conflicts (especially in the older parts of the city) with the interests of people who own houses with basements that are vulnerable to high groundwater.

§ 3.5.2 Rainstorm Management

Because of climate change, northwest Europe is confronted with an increasing frequency of heavy rainstorms, delivering much more water in a short time than was usual in the past. During the last 100 years, the average rainfall has been 790 mm per year, but this is increasing rapidly. It is estimated that the increase will be 20%, while the intensity of rainstorms is also increasing (Gemeente Rotterdam et al., 2007).

During the nineteenth and twentieth centuries, many of the original canals in the city of Rotterdam were filled in. They not only lost their function as transport routes, but new drainage technology focused on the construction of underground draining systems. As a result, the amount of surface water decreased from its original level of 16% to less than 6% of the built-up area. Because of this decrease, sewage systems are frequently over-loaded during periods of heavy rainfall. Pumping stations are not able to pump the water from the sewage system into open water (river or sea) fast enough, resulting in flooded streets and an overspill of sewage water in what is left of the canal and open water system in the city.

Rather than increasing the capacity of the sewage systems and pumping stations, the focus of water management in Rotterdam (and other Dutch cities) has shifted to increasing the storage capacity for water in the city. This means making new surface water areas as well as the creation of public spaces that can play a role in the temporary storage of water. This policy is linked to a more sustainable groundwater management: an increased amount of surface water supports a higher groundwater level (Gemeente Rotterdam et al., 2007).

§ 3.5.3 Rising Sea Levels and Increasing River Discharges

Rising sea levels and increasing river discharges are two different things. However, the combined effect creates new problems for the city. Rising sea levels are nothing new, and this has already been taking place for thousands of years. During the twentieth century, the sea level rose by ca. 17 cm. The 'speed' of the rise in sea level, however, is expected to increase due to climate change. The various calculations and estimations of, for instance, the Intergovernmental Panel on Climate Change do not give any certainty about the exact situation in the future. The second Delta Committee installed by

national government—the first Delta Committee was installed after the disastrous 1953 flood that killed about 2000 people—assumes a considerable increase in sea level over the coming decades. The Delta Committee bases its advice on the scenario of a maximum 130 cm rise in sea level by the end of this century (Delta Commissie 2008). Apart from the question of whether this scenario is realistic, it is generally assumed that a structural rise in the sea level will take place.

At present, the dike system runs right across the urban fabric of Rotterdam. The unembanked areas, directly adjacent to the river, were raised to a level of 3.20 – 4.00 m above NAP over the course of the nineteenth and twentieth centuries. These levels were supposed to be sufficient to avoid regular flooding, but they are likely to become increasingly vulnerable to flooding in the future. To prevent flooding, a storm barrier in the mouth of Nieuwe Maas has been built: the Maeslant Storm Surge Barrier.¹⁰, which closes when the sea level is expected to rise by more than 3 m above NAP. Without this barrier, a large proportion of the areas outside the dikes would be flooded by several centimetres of water during serious storm surges.

With the expected rise in sea levels, it is anticipated that the Maeslant barrier will have to close more frequently in the future, thereby creating substantial problems for the port. The barrier is currently closed at a frequency of approximately once every 10 years which is regarded as acceptable for the continuity of the port economy. However, a substantial increase in the frequency of closing, as well as uncertainty about when the barrier will be closed, combine to produce an unacceptable decrease in the reliability of the open entrance. We will come back to this later.

Increasing river discharges have been a reality since the mid-1990s, when the river area in the Netherlands was confronted several times with either serious floods or near-floods. According to the Delta Committee, river discharges could increase by 150% over the coming decades. The extreme river discharges of the Rhine, which enter the Netherlands at the eastern border, currently deliver 12,000 m³ per second, but are expected to increase to 18,000 m³ per second in the future (Delta Commissie 2008). For the Rotterdam region, this means that the flood hazards come from two directions: from the sea and from the rivers. A worst-case scenario would be a coincidence of an extreme storm surge and extreme river discharges.

In the Delta Committee's report, the Rotterdam region is defined as a special case, which makes extraordinary solutions necessary. In 2010, a high-level Delta Commissioner was appointed by the government, alongside the establishment of a special programme committee for the Rotterdam region. Supported by several research initiatives,¹¹ this committee investigates different scenarios and options to increase safety, varying from raising the existing dikes to closing the whole region by a system of locks or storm surge barriers and directing the river water to the delta south of Rotterdam.

Technically, all these different options are possible; the big question concerns the effects of each type of solution on the port economy, the city structure, and the environment. An important issue concerning city structure is that the dike system runs right across the urban fabric of Rotterdam. As already mentioned, the unembanked areas were raised to a level of 3.20 – 4.00 m above NAP over the course of the nineteenth and twentieth centuries. The ground levels behind the dikes are much lower, due to subsidence resulting from continuous drainage, as explained above. Therefore, a now-typical situation has occurred in which the area 'outside the dike' is much higher than the area inside the dike. In between, the dike itself has an average height of 5.5 m and is experienced as a barrier between the floodplain areas and the areas behind the dikes.

§ 3.5.4 Environmental Quality and Bio-diversity

Since the 1980s, interest in the environmental value of estuaries has increased substantially, in particular because of their function in the complex ecosystems of connecting the seas, oceans, and rivers (see, for instance, Saeijs, 2006). Several (Dutch) environmental groups, large NGOs (World Wildlife Fund, 2008), landscape architects (Sijmons, 2002; Sijmons & Venema, 1998), scientists (Tjallingii, 1996), as well as governmental institutions, are paying increasing attention to the environmental effects of large-scale hydraulic works in the southwest of the country; damming the estuaries resulted in dramatic changes to their bio-diversity and produced a concentration of pollutants, river sediments, and toxins from agriculture (see, for instance, Adriaanse & Blauw, 2007). The title of the report of Delta Committee, 'Working Together with Water', is a recognition of the attention paid to environmental issues in official flood-control politics. It has resulted in a serious reconsideration of the future position of the Delta Works, the series of dams and storm surge barriers in the delta in the southwest of the country. NGOs like the World Wildlife Fund put a lot of energy into their pleas to maintain or restore the openness of the large estuaries worldwide. They have chosen the Dutch delta as an important test case and developed a plan for this delta, showing a complete reopening of all the estuaries (WWF, 2008).

For the Rotterdam region, this means that the combination of flood defence, port installations, and environmental issues has been placed high on the political agenda here also. The clearest example so far is (as described in Section 3) the layout of a series of new natural areas in the Rotterdam region to compensate for the loss of natural environment resulting from the construction the new Maasvlakte 2. The construction of this new area of land reclaimed from the sea will change the environmental system of the coast; the new natural areas are supposed to compensate for this loss to a greater extent than required by the EU Habitat Directive (see below). However, this solution can be regarded as a rather artificial and incidental approach; for future challenges, a more comprehensive approach will be expected.

§ 3.5.5 Salinisation

The changing climate results not only in more rainfall and intensified rainstorms, but also in longer periods of drought. Combined with rising sea levels, this phenomenon leads to a shortage of fresh water and the increasing influence of salt water in the peat and clay areas of Holland. This process has a damaging effect on agriculture in the Rotterdam region. Due to the Delta Works, the estuaries Haringvliet and Brielse Meer have been transformed into large suppliers of fresh water. This guaranteed fresh water supply on a large scale (a unique condition for a sea port) was a main motivation for the establishment of the petrochemical industries in Rotterdam in the 1960s, resulting in the second largest petrochemical complex in the world. Today, the port's industrial complex uses more than 36 million m³ of fresh water each year (Stuurgroep Zuidwestelijke Delta, 2009).

A supply of fresh water is also essential for agriculture. The clay polders south of Rotterdam have become one of the most productive agricultural areas in Europe (Ruimtelijk Planbureau, 2005) and the 'Westland' area just northwest of Rotterdam has been developed into the most intensive complex of greenhouses in Europe. This agricultural and horticultural area is also dependent on the availability of fresh water on a large scale and is connected, via a pipeline, to the Brielsemeer.

§ 3.6 Promises and Problems of New Urban Waterfronts

The recent increase in interest in the effects of climate change on water management and flood defence, and the increased attention to competitiveness and identity, have created perspectives and opportunities for a new interweaving of hydraulic engineering targets and concerning urban and economic regeneration targets.

As a result of its historical development, the city of Rotterdam is split by the river into two very different sides: Rotterdam Centre and Rotterdam South. Both sides are different in the sense of spatial structures, economic activities, and social and cultural structures. Currently, the two parts of the city have different safety standards concerning flooding. The northern dike-ring 14 area (Fig. 3.1) is given the highest safety standard, with a chance of flooding once in 10,000 years. Rotterdam South is part of a dike-ring with a greater chance of flooding: once in 4000 years.

With the departure of port-related industries during the 1980s and 1990s, Rotterdam South became one of the most problematic urban areas of the Netherlands, characterised by high rates of unemployment, poverty, low degrees of education, racial tensions, etc. Since the 1980s, the city administration has tried to change the one-sided economical focus on the port to a more diverse urban economy. Approximately 15,000 residential units, mixed with offices and amenities, have been built on approximately 250 hectares of former port areas, like, for instance, in the Kop van Zuid area on the left bank of the river. All of these developments took place in unembanked areas.

During the planning and construction of the first generation of transformation projects, the city of Rotterdam agreed upon a provisional rule with the provincial and national authorities: the entrances and floors of new houses in unembanked areas should be raised to a level of 4 m above NAP. This rule was regarded as sufficient, considering the new 'Maeslant' Storm Surge Barrier that was constructed close to the mouth of the Nieuwe Waterweg during the 1990s, which is intended to close whenever the sea level rises more than 3 m above NAP, as explained in the previous section. However, the growing danger of high water levels because of increasing peak discharges of the rivers that feed the delta, as also described in the Section 5, has forced the city to develop new strategies.

The need for a comprehensive strategy is becoming increasingly more important, as a huge unembanked port area will shortly become available for urban (re)development: the so-called city ports area that covers 1000 hectares. The city ports provide great potential in terms of new urban districts in attractive environments and creating more spatial coherence between the two parts of the city on both river banks (Meyer 1999); at the same time, they are part of the most flood-prone areas in the urban territory. One of the main aims of Rotterdam's urban policy will be solving this paradox.

§ 3.6.1 Perspectives for Solutions

In general, there are three basic principles that can be used to protect the unembanked areas against flood damage (De Hoog & Nillesen, 2010). The first is to dam the water off by creating dikes, barriers, or dams that keep the water out. This can happen on a regional scale (see next section), but also on a local scale, at the site of a building. This method, however, creates a similar barrier between the built-up areas and the water, as is nowadays found to be problematic in Rotterdam's city centre. There are

new options for designing dikes in such a way that they become part of the waterfront, by integrating urban space, nature, and built functions within the body of the dike (Stalenberg, 2010).

A second option for making the unembanked area flood-proof would be to elevate either the whole area or the building grounds. This method is one of the oldest water defence mechanisms used in the Netherlands. Farmers from the northern provinces built their houses on artificial mounds called 'terpen', to protect themselves from floods. Elevation is also used frequently in the Rotterdam harbours when creating harbour sites, such as, for instance, the Maasvlakte. This is the same principle that is successfully used in Hamburg's Hafencity, an old harbour in Germany that is being transformed into a flood-proof residential and business area. In the former port area, a partial elevation has been created. Next to the elevation, buildings are placed on flood-proof plinths that simultaneously serve as parking garages. In case of high water levels in the river Elbe, the garages are locked and the lower parts of the streets, the original quays, are flooded. A secondary network of pedestrian evacuation roads connects the buildings with the elevated main street. In the Hafencity project, the construction of a dike around the building site was considered but was also rejected as the relationship with the water would have been compromised and a large upfront investment in water safety would have been needed. By flood-proofing each building block separately, the investment in flood protection grew in line with the pace of development, reducing the economic risk in case of stagnating development. The public space is brought close to the water and designed with multiple layers to optimise the experience of the fluctuation and natural force of the water.

The third principle is to make buildings flood-proof by, for instance, placing them on poles, using floating or amphibious houses or by making the interior of houses water-proof. The latter options are still at an experimental stage and in urban developments, these are often considered as small-scale solutions rather than as extensive urban flood strategies. Floating houses and functions are very popular with designers, even though they occupy water instead of land. Therefore, the amount of floating functions the water can hold without losing its openness—an invaluable quality offered by the river to the city of Rotterdam—should be studied carefully.

Since the Rotterdam city ports aim to be an experimental site for water-proof innovations, a wide range of flood-proof measures for buildings and public spaces could be applied within the area, creating new urban typologies that deal with the water in ways that are distinct from existing practices. One of the essential questions will be how to create highly functioning connections between the harbour areas being transformed and the rest of the city. Apart from the existing industrial transportation network, the sites are poorly connected to their surroundings and the city centre. Socially and economically poor neighbourhoods, combined with a large amount of infrastructure, form a barrier that creates a separation, especially between the southern harbour sites and the city centre. Transportation over the water is now intended to better connect the transformation areas.

§ 3.7 Flood Protection: Crux of a Comprehensive Strategy

The Delta Programme proposes four flood risk strategies that define the corners of a 'playing field' of possible safety solutions for the Rijnmond region. Many different aspects of sustainable development in Rotterdam (port development, safety against flooding, possibilities for new forms of urbanisation in the former dockland and waterfront areas, and care for the environmental quality of the delta) are strongly interlinked with the choice for a regional flood defence strategy.

The four strategies are based on the principle that a storm surge barrier reduces the amount of inland dike reinforcements, by closing the front entrance to the sea and thus protecting the region against high water threats. The same basic principle led to the construction of the existing Maeslant Storm Surge Barrier that currently protects the Rijnmond region against high water levels in the case of a storm surge.

The first water safety strategy is based on a ‘business as usual’ approach, protecting the Rijnmond region with the existing, closable Maeslant barrier at the sea-bound side of the region (Fig. 3.5). Barriers which can be closed carry with them a chance of failure, however, meaning that the dikes behind the barriers have to be strong enough to protect against rising water levels in the case of barrier failure, or in the case of high river discharges (which are expected to become more extreme and increase from 12,000 to 18,000 m³ per second at peak discharge) occurring simultaneously with a storm surge. Due to rising sea levels, this might (as mentioned in Section 5) in the future result in more frequent closure of the barrier. In an extreme scenario put forward by the Delta Committee (Delta Commissie 2008), the sea water level might have risen 1.30 m by 2100. The barrier would then have to close up to 30 times a year—unacceptable for the Rotterdam port authority, since the accessibility, and with that the reliability, of the port depend on the open connection with the sea. Besides that, the chance of the Maeslant barrier failing to close is estimated to be one in every 100 closures. More frequent closing of the barrier would lead to a greater risk of failure in the future. Therefore, the Delta Programme (Deltaprogramma Rijnmond Drechtsteden, 2010) proposes that the barrier, when the time comes for it to be replaced, should be upgraded to a barrier with an improved chance of failure of 1 in every 1000 closures. It is also proposed that the barrier should not be closed more frequently than once a year, even if this results in closing the barrier at a higher water level than the currently prescribed +3 m NAP. With some of the unembanked areas starting at a height of 3.2 m above NAP, this means that additional measures would be needed to protect these areas against flooding.

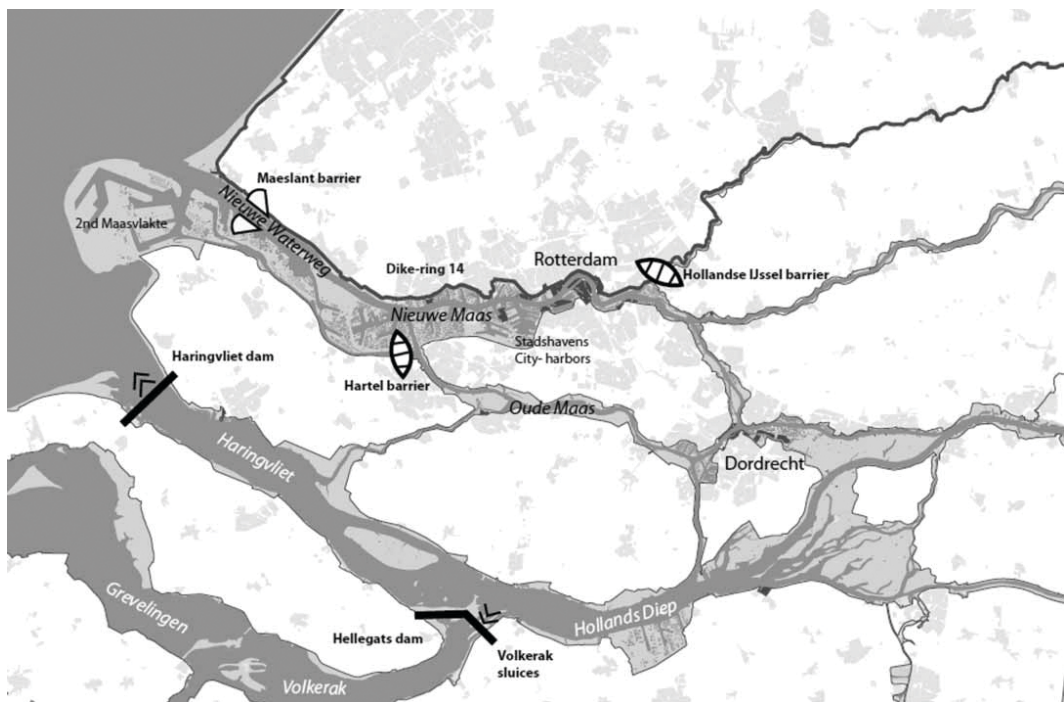


FIGURE 3.5 Rijnmond open/closable interventions at the seaside, with storm surge barriers in the sea gates.

The second water safety strategy comes in response to the extra flood risk caused by simultaneous storm surge and peak river discharges by placing additional closable barriers on the river side of the region (Fig. 3.6). In the case of peak discharges, the barriers could then be closed, and the water redirected towards the Haringvliet, which directs it towards the sea. An extra advantage of the placement of barriers is the possibility to use them to improve the infrastructural network of the region. However, the small-scale 'business as usual' interventions between the barriers that are related to this strategy hardly create a catalyst for new urban transformations of a scale that could redefine the relationship between the northern and southern parts of Rotterdam.

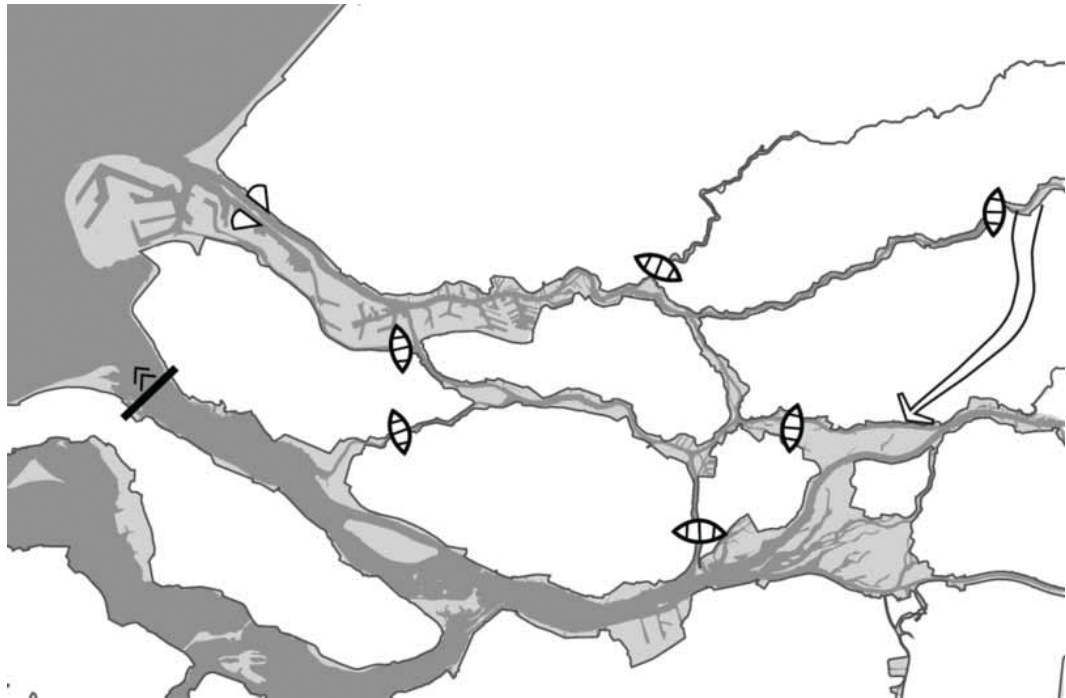


FIGURE 3.6 Rijnmond open/closable interventions at the seaside and riversides—with storm surge barriers in all waterways to the urban territory.

The third strategy, 'closed Rijnmond', provides a solution to the problem of the chance of failure related to the closable barriers by damming off part of the Rijnmond region— leading to a similar situation to that of Amsterdam (Fig. 3.7). The new barrier would disturb the natural, open connection of the river to the sea. The Port of Rotterdam would lose its big competitive advantage: open access to both the North Sea and its European hinterland. Ships would have to pass locks to access the port or use hinterland connections. However, between the barriers a controlled water level would create many possibilities for urban redevelopment and would allow for the transformation of the central riverside part of the city, which now divides the city into two parts. Because of the controlled water level, the dikes that form a barrier between the city and the river could be partly removed or lowered in order to strengthen the connection between the city and the water. By gaining a more recreational and urban function, water could become part of the city itself and connect the two halves of the city. The closed system makes it possible to connect the river Maas with the canals and creeks within the dike-rings, creating possibilities for transportation over water as well as ecological connections. In this scenario, the river has the potential to develop into a central spine. Depending on the development of the port and the need for growth or shrinking of the city, new urban environments could be created that include mixed urban areas, port-related functions, or green recreation or nature areas.

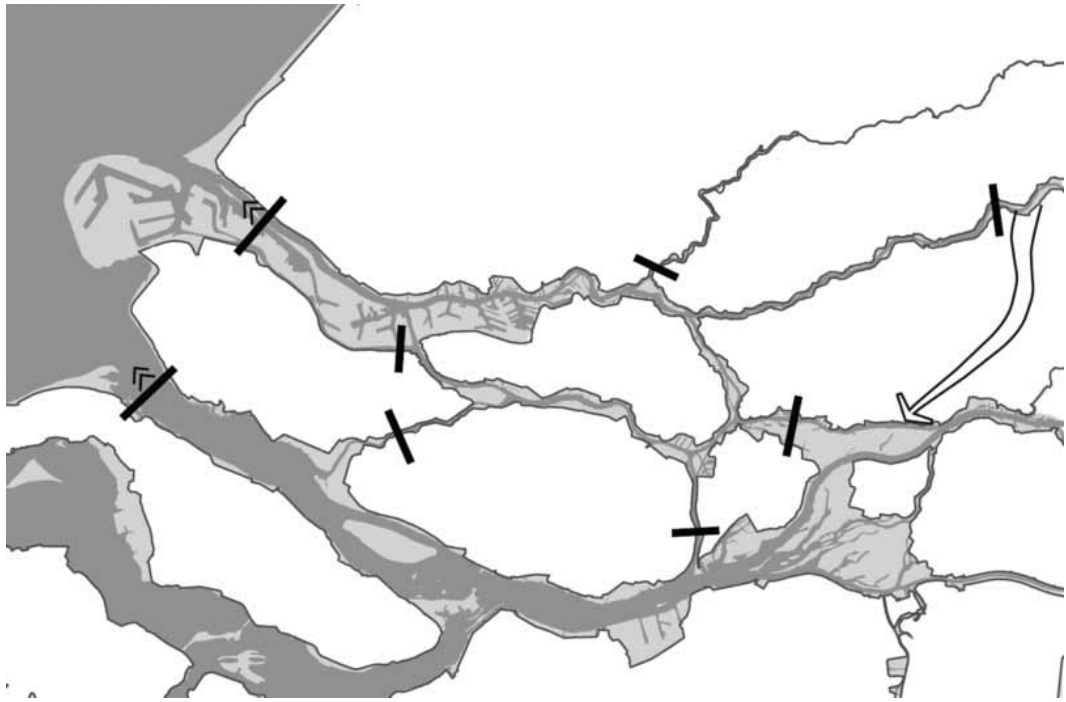


FIGURE 3.7 Closed Rijnmond, with locks and dams in all waterways to the urban territory.

The fourth safety strategy is referred to as open Rijnmond. In this strategy, all storm surge barriers including the Grevelingendam would be removed, creating an open relationship between the rivers and the sea (Fig. 3.8). The natural tide, sedimentation processes, and the fresh and salt gradient of the water would be re-established, resulting in a more natural estuarine delta area. For the shipping traffic, this open connection guarantees accessibility to the port and the hinterland. The unembanked areas would come under tidal influence and flood on a more regular basis. Any areas containing buildings, polluted grounds or industries vulnerable to floods would have to be protected by additional small-scale dikes or barriers. The regeneration projects within the unembanked area can be designed as flood-proof areas, strengthening the relationship between the river and the city. To reach the safety levels prescribed for the dike-rings, most dikes would have to be reinforced in a radical way. New forms of delta dikes could be used to strengthen the dike while at the same time making the dike itself become part of the urban waterfront. From this perspective, the open Rijnmond strategy offers opportunities that are comparable to those of the closed Rijnmond strategy—to give the river a more central and binding position within the city of Rotterdam.

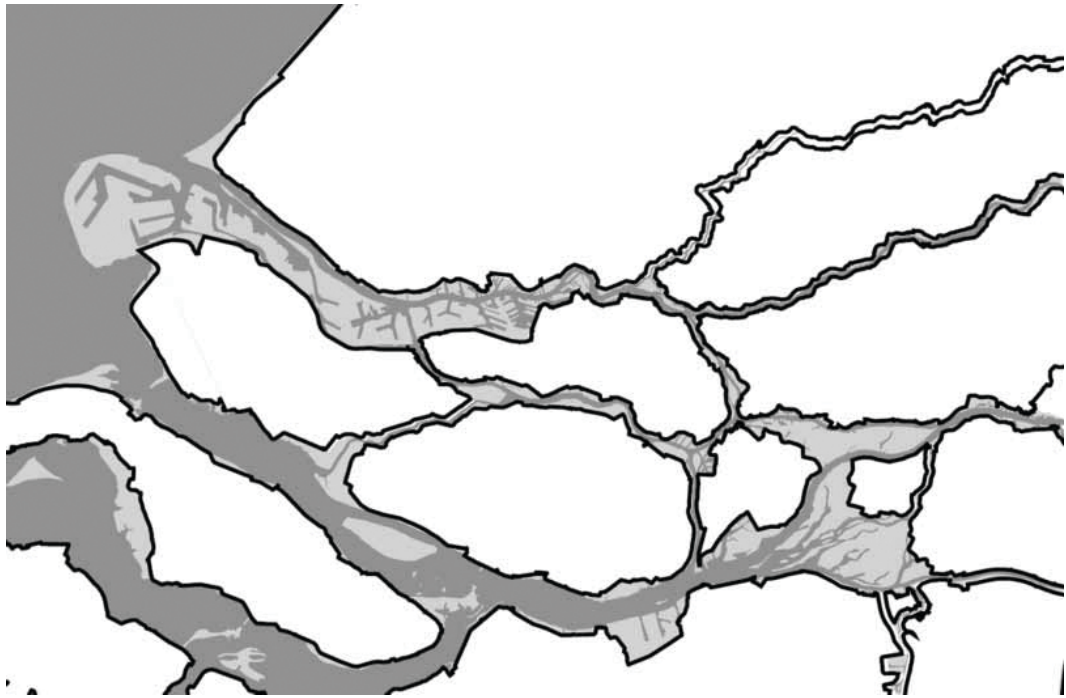


FIGURE 3.8 Open Rijnmond, with enforced and heightened dikes.

The range of possible water safety strategies defined by these four 'corner positions' creates possibilities to compare them and distinguish their characteristics, effects, and opportunities. The four options ('corner positions') result in different conditions for water levels in the unembanked areas, as shown in Fig. 3.9, and thus propose different conditions and possibilities for the urban environment.

In addition, the future of the port will be seriously influenced by the type of flood-protection strategy. However, the interests of the port are not unambiguous. Considered from the perspective of the importance of accessibility of the port area, the option of an 'open Rijnmond' seems to be the best one. However, considering the importance of the availability of fresh water supply to the process industry, the closed option delivers the best conditions. And considering the long-term perspectives, with a possible transformation from petrochemical industry to other types of production and storage of energy, the question is whether the port will need the total amount of the present-day 10,500 hectares of port area in the future. The answer to this question will be important in the context of making a decision regarding the location of a new storm surge barrier or lock system.

Finally, the environmental quality of the rivers in and around the Rotterdam region will be dependent on the final solution concerning flood protection. An open system will mean that the estuaries will be repaired as transition zones between salt and fresh water; a closed system will mean that also the river Nieuwe Maas will be transformed into a fresh water body. Recently, the World Wildlife Fund (WWF, 2010) presented its report 'Met Open Armen' ('With Open Arms'), as a plea for an abolishment of the dams in the southwest delta and for the repair of estuarine wetland systems in the river mouths. The WWF states that the repair of an open system will contribute to a new balance of nature, safety, and economy, but does not say what the safety consequences would be in this concept: the heightening of many kilometres of dikes in the region.

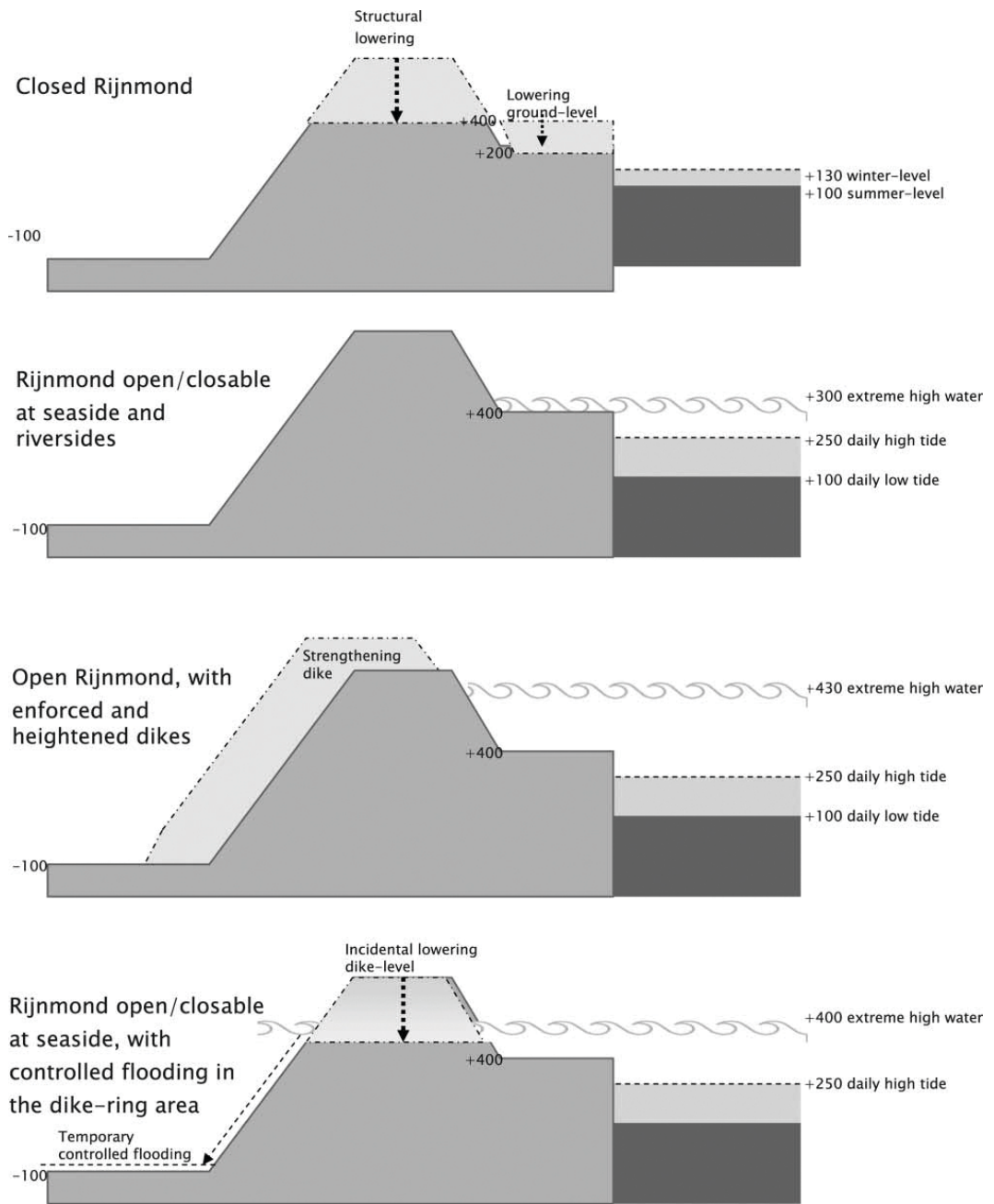


FIGURE 3.9 Dike sections showing the effects of the different regional water management options for the local situations of unembanked areas and dikes.

§ 3.8 Conclusion and Discussion

The Rotterdam region plays a central role in two main issues concerning sustainability in the Netherlands: water management and energy transition. These two issues are directly linked to each other because of the central role of the port as a global energy hub and as a central element in any new water management strategy. Furthermore, the decisions concerning these issues directly influence other sustainability issues, such as the environmental quality of the delta waters and the chance to provide the city of Rotterdam with new attractive urban waterfronts which might play a role in the strategy to attract innovative industries and medium- and high-income groups.

The future of Rotterdam mainport is intrinsically connected to changes in the Dutch delta system and therefore to one of the main effects of climate change: the rise in the sea level. The first major step on the road to the present status of Rotterdam as a global mainport—the realisation of the Nieuwe Waterweg in the nineteenth century—created an open port, accessible directly from the sea without the necessity of passing a lock barrier, an advantage in comparison to other ports in the Hamburg—Le Havre range. It remains to be seen whether this system can be maintained long term. Worst-case scenarios will make it necessary to surround the Rotterdam region with a system of locks or storm surge barriers, but also in the case of a system of storm surge barriers, these barriers will have to close so often that the shipping connection to the hinterland will become unreliable, and will result in ‘unacceptable’ financial damage to the shipping sector.

The paper shows that altogether, ‘water’ refers several different issues, which touch and overlap with each other. Moreover, many of these issues touch spatial, economic, social, and environmental questions in the city and harbour area. The question remains as to how a planning approach and policy can be developed which considers the linkages between the different issues of water and the linkages of water with spatial, economic, and social issues as a possibility to develop comprehensive plans.

In summary, to answer the question of whether Rotterdam really is a global benchmark in terms of water and port management: perhaps, yes, in the sense of ambitions and intentions; in the sense of real practice, there is still a long way to go.

On the positive side, it is clear that many initiatives are underway at this moment in time, several of which have been discussed in this paper. The main challenge though is to link the various individual initiatives, strategies, studies, and projects, and the actors and coalitions behind them. There is, for instance, the process which should lead to a new strategy for the port (Port Vision 2030) and which—among other things—will deal with an issue totally new to the port authority: climate change. It does not yet seem to be the case that thinking about the future of the port has been linked to the issue of a long-term hazard-proof system of flood control. The question of how water management could be linked to urban renewal and the revitalisation of Rotterdam South is yet another example of how linkages can be made between issues, but which is still in its infancy.

At first sight, this seems to be a call for comprehensive planning. This is not what we mean. Comprehensive planning presumes—among other things—the presence of decisive actors. These actors are simply not there, have never been there, and nor will they ever be. What we would like to see is the making of linkages. One way of achieving this is to give a key role to the water system because this system is so closely linked to the way the city and the port is developing, and could, or even should, develop in the future. One example of this close relationship, as we have already highlighted above: the dependence of the petrochemical complex of Rotterdam—as one of the largest in the world—on a reliable and large supply of fresh water.

A water system is a territorial network in itself and based on these characteristics networks can be developed at the level of strategies, programmes, projects, and actors. A serious handicap for such a network approach is the extremely complex system of government in the Rotterdam region and the south wing of the Randstad at large. What is needed is what Bob Jessop calls 'metagovernance'. But it is very difficult to see which actor(s) could take the lead to create some kind of metagovernance capacity. Some kind of administrative restructuring appears to be an obvious strategy. There is doubt in the literature (see, for instance, Salet, 2006) about whether this would be the right way forward, especially in the case of the Randstad and its sub-regions, such as the north (centred around Amsterdam) and the south wing (centred around Rotterdam and The Hague): the territorial organisation of government will never perfectly match territorial relationships. Moreover, every new design of this organisation is likely to become outdated in the future thanks to processes of spatial rescaling. Nevertheless, one could, or should, ask at what point a certain territorial arrangement becomes unworkable. This seems to be the case in the Rotterdam region. Starting a discussion on the territorial structure of government in the Netherlands is like opening Pandora's box, as has been proven by decades of such discussion. At present there is, yet again, talk of rearranging the governmental structure of the Randstad. A genuine political pandemonium is the result: provinces, municipalities, and their umbrella organisations take different positions, as has always been the case. However, some administrative reorganisation seems necessary: the use-by date of the present organisation has long since passed.

Notes

- 1 www.rotterdamclimateinitiative.nl (accessed February 2011).
- 2 Of the 5.9 million containers transported via the Rotterdam harbour nearly 30% is called sea – sea trans- port (Port of Rotterdam, 2009).
- 3 <http://www.rnw.nl/english/bulletin/germans-reject-dutch-purchase-port-duisburg-share> (accessed February 2011).
- 4 <http://www.maasvlakte2.com/nl/index/> (accessed February 2011).
- 5 http://www.deltalinqs.nl/index.php?option=com_content&task=view&id=54&Itemid=4 (accessed 8 February 2011).
- 6 http://www.rotterdamclimateinitiative.nl/en/about_rotterdam_climate_initiative/rotterdam_climate_initiative/mission_ambition (accessed 7 February 2011).
- 7 All figures collected from the website of the Port of Rotterdam.
- 8 Biomass is a wider concept than biofuels. Biomass is of particular importance for the Netherlands: according to some (for instance, Hetsen & Hidding, 1991), the large-scale, very intensive cattle breeding which forms a major pillar in the Dutch agri-business industry owes its existence mainly to cheap and reliable imports of biofood through the Rotterdam port.
- 9 NTA is the Dutch acronym for Dutch Technical Agreement (see <http://www.sustainable-biomass.org>; accessed February 2011).
- 10 See http://www.keringhuis.nl/engels/home_noflash.html (accessed February 2011).
- 11 Especially the programme ‘Knowledge for Climate’, supported by NWO, the Dutch research council (see <http://knowledgeforclimate.climateresearchnetherlands.nl>; accessed October 2010).

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Intermezzo 3: Historical Development in the Rijnmond Region

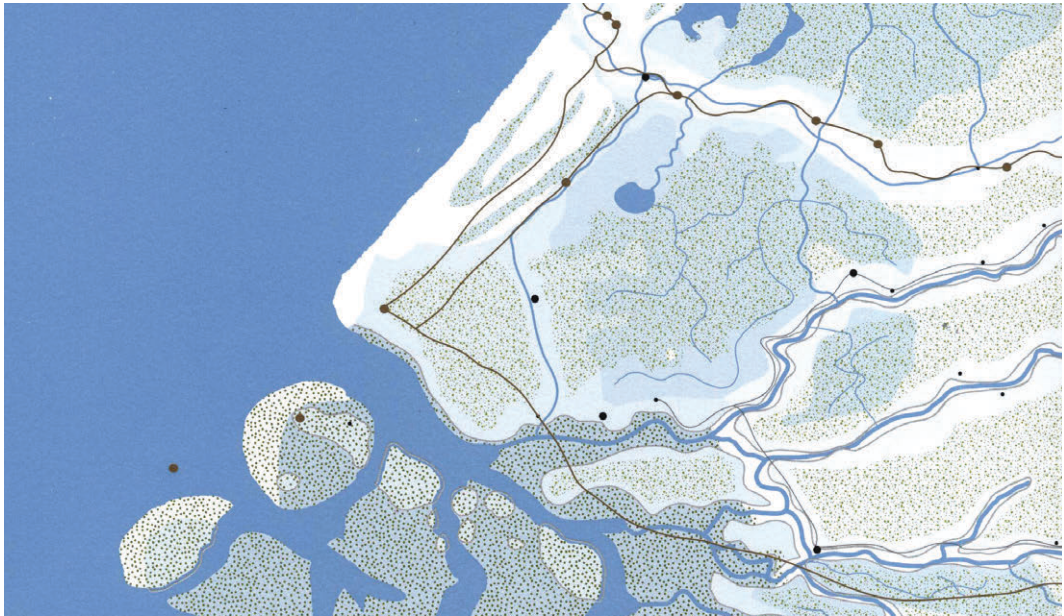


FIGURE 3.10 Map of the Rijnmond region in 1200AD. Source: Limes atlas (Colenbrander, MUST 2005, 010 Publishers)

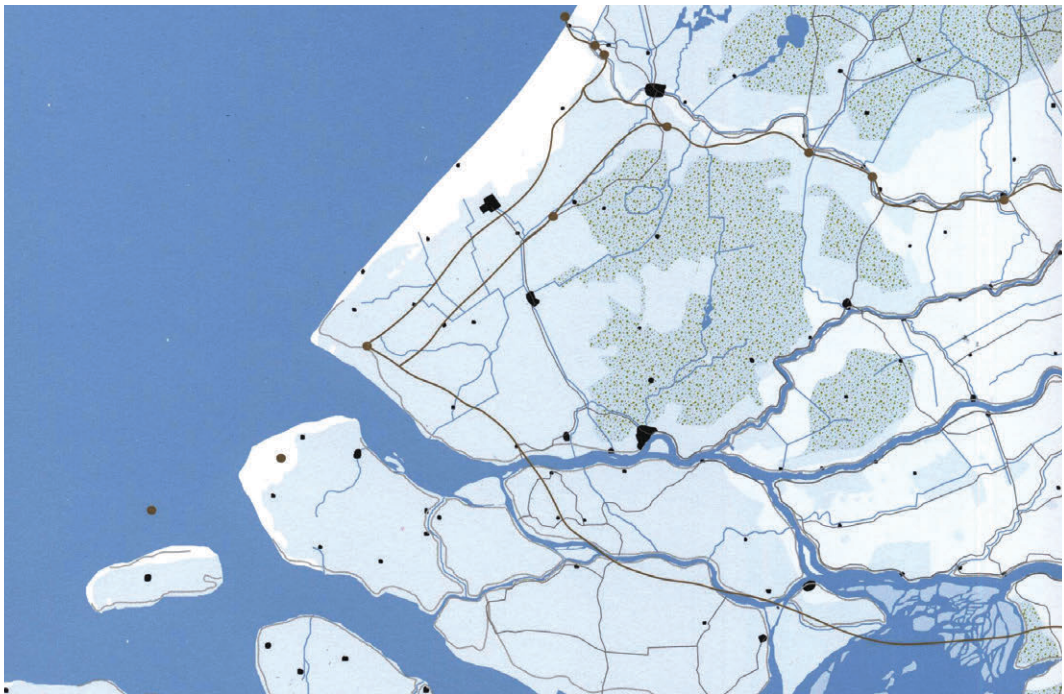


FIGURE 3.11 Map of the Rijnmond region in 1650AD. Source: Limes atlas (Colenbrander, MUST 2005, 010 Publishers)

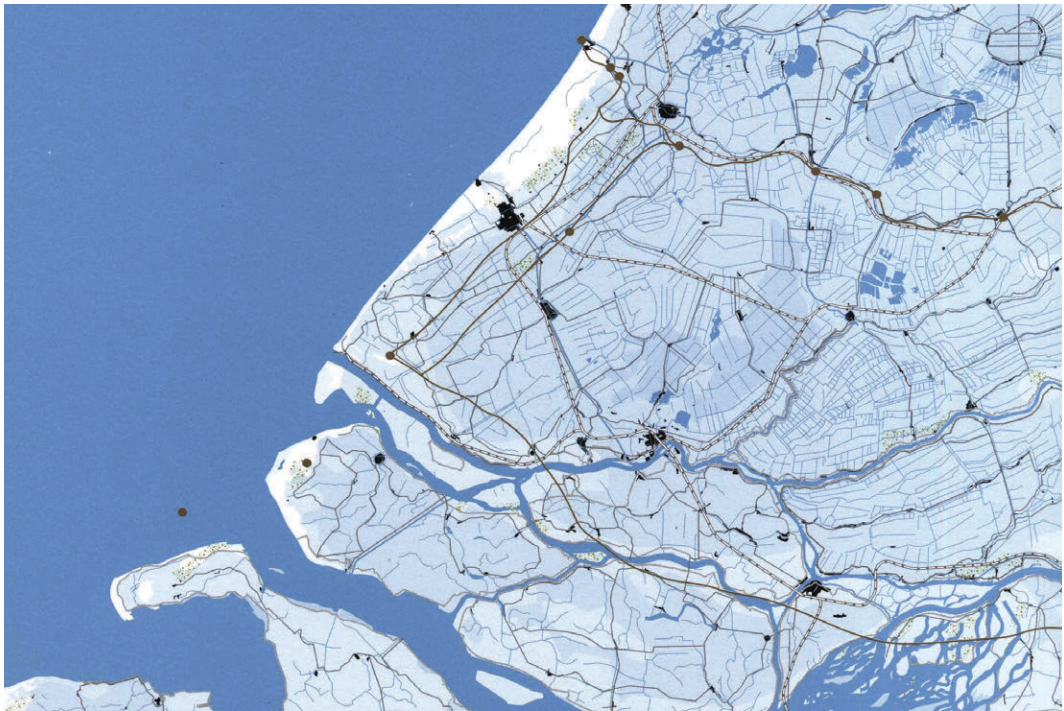


FIGURE 3.12 Map of the Rijnmond region in 1900. Source: Limes atlas (Colenbrander, MUST 2005, 010 Publishers)

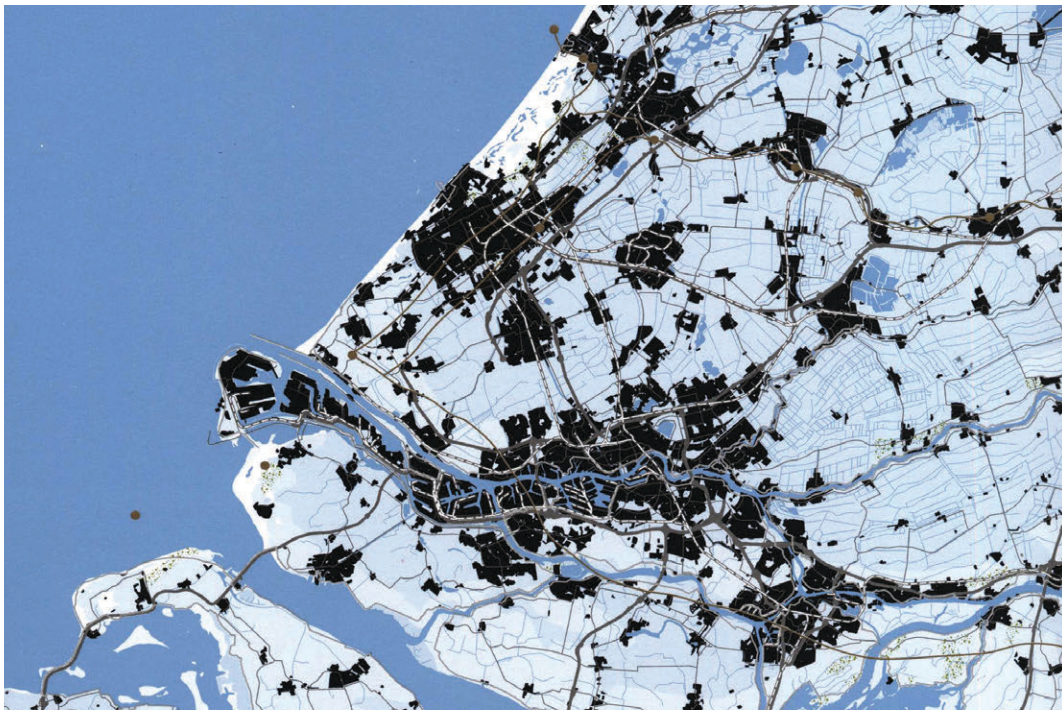


FIGURE 3.13 Map of the Rijnmond region in 2000. Source: Limes atlas (Colenbrander, MUST 2005, 010 Publishers)

4 The Synergy Between Flood Risk Reduction and Spatial Quality in Coastal Cities

Anne Loes Nillesen

Originally published in: RiUS – Research in Urbanism Series Vol. III (2014), IOS Press. Some changes were made, mainly to improve consistency and readability throughout this thesis.

This paper describes the application of a research-by-design approach that aims for a combined approach for spatial quality enhancement and flood risk reduction, with spatial quality as a decisive ex-ante criterion. In order to achieve this, as in the 'Room for the River' programme, a dual flood risk and spatial quality objective is set. This research was performed as part of the 'Atelier for Coastal Quality', in which The Hague's seaside area of 'Scheveningen' was selected as a case study location. Here, the future reinforcement of the sea barrier could be combined with addressing the challenges of improving spatial quality, among which are: identity, vitality, attractiveness, and connectivity.

A research-by-design approach was deployed in which a single parameter was systematically varied (the flood risk intervention) while fixing other parameters (such as the context and the objectives from a spatial and flood risk perspective). After exploring and defining both the flood risk and spatial objectives for the area, three alternative flood risk reduction strategies (based on three alternative interventions: a boulevard, dunes, and a perpendicular dam) for Scheveningen were developed. In order to facilitate the integrated design process, 'Delta Ateliers', in which multidisciplinary experts and stakeholders interactively worked together, were successfully deployed.

As a result, it became apparent that the inclusion of a prominent spatial objective is not the main key to including spatial quality as an ex-ante decisive criterion in defining flood risk strategies. The three proposed flood risk reduction interventions had all been successfully embedded with regard to meeting the prescribed spatial criteria, thereby disqualifying the spatial aspects as selection criteria for the flood risk intervention. However, as part of the study, a supporting research-by-design exercise was performed in which three different locations for the positioning of the perpendicular dam, were explored from a spatial perspective. Here, it seemed that providing interchangeable (similarly effective) interventions at different locations did result in very different potentials for spatial quality, thus allowing spatial quality to become a decisive selection criterion.

The 'Room for the River' principle, which appeared essential in order to include spatial quality as a decisive ex-ante criterion, is the creation of alternative exchangeable options for the flood risk reduction interventions at different locations. Based on these findings, the research-by-design approach deployed is extended to not only systematically test different interventions, but to also systematically vary the location of the intervention. The 'Delta Atelier' multidisciplinary workshop approach is continued within the remaining research.

Key aspects: Research-by-design, the power of an integrated approach, spatial characteristics, future flood risk reduction task, interdisciplinary design sessions, stakeholder sessions, expert meetings, case study area The Hague.

Abstract

Coastal regions throughout the world are subject to flood risk challenges. This paper concentrates on the Netherlands; its coastline fulfils an important role in the protection of the Dutch delta. Due to the expected sea level rise, part of the Dutch coastline will have to be reinforced. Along most of the sparsely occupied coastline, the space needed for the reinforcement of the flood risk reduction infrastructure can be found easily, either on the seaside or inland. However, some segments of the coastline have been built upon and are difficult to reinforce; buildings have limited the adaptability of the originally flexible coast. One such location is Scheveningen, a borough of the city The Hague and a seaside mass-tourism resort operating at a national scale. It is difficult to reinforce the borough's flood risk infrastructure without significant restructuring. In addition to water-safety issues, Scheveningen faces socio-economic challenges and needs a qualitative programmatic and spatial stimulus. An integrated approach to spatial and flood risk design is essential to come to a qualitatively, as well as functionally, acceptable solution for multifunctional flood defences. This paper describes and demonstrates the approach and application of an integral 'research-by-design' study for flood risk management and spatial quality enhancement in Scheveningen. It is the result of a collaborative effort between spatial designers and flood risk engineers, who worked together in so-called 'Delta Ateliers'. Three different flood risk strategies ('a sandy shore', 'a hard protection body', and 'a perpendicular dam') are used as leading principles for integral designs in which both the spatial assignment as well as the long-term flood risk reduction assignment are addressed. This results in three different designs that are discussed in relation to their spatial potential and hydraulic efficiency. This applied research-by-design approach was considered very valuable—even essential—in feeding the debate regarding the choice of a flood risk intervention. As a result, this approach will be continued throughout the Dutch National 'Delta Programme' that focusses on long term flood risk protection.

Keywords: flood risk protection; seaside; waterfront; spatial quality; integrated design; Delta Programme; research-by-design; Dutch delta; Scheveningen

§ 4.1 Introduction

Coastal regions throughout the world are subject to flood risks challenges (IPCC, 2007). This paper concentrates on the Netherlands, where the coastline plays an important role in the protection of the Dutch delta. Erosion, climate change and the growing economic value of low-lying parts of the country create significant long-term flood risk challenges. The Delta Programme was established in order to define suitable strategies and interventions to answer these challenges (Delta Committee 2008). Through several projects, the programme is orientated towards specific regions, such as the south-west delta and the Wadden region, and specific topics, such as freshwater supply. One of the regional sub- projects concentrates on the Dutch coast.

In this project, a series of expected short-term (2050) and long-term (2100) weak spots in the Dutch coastal defence system were identified and addressed. The short-term weak spots have been strengthened through regular maintenance of existing flood risk reduction infrastructure works. In the long term, regular maintenance will have to be carried out continuously to compensate for erosion. In addition to erosion, rising sea water levels will also contribute to the creation of new long-term weak spots. In these coastal sites, the flood risk reduction infrastructure will have to be reinforced.

This infrastructure consists of a combination of natural stretches of sandy dunes or barrier islands and elements such as dikes, barriers, and dams (Hidding & Van der Vlist, 2009).

Given the sparse occupation of most of the Dutch coastline, the extra space needed for the reinforcement of the flood risk reduction infrastructure can easily be found either at the seaside or inland. However, some settlements are located in close proximity to, or even directly on the coastal defence line. One of these is the former fishing village of Scheveningen that dates from the Middle Ages. Nowadays, Scheveningen is a relatively densely populated borough of The Hague and a seaside mass-tourism resort operating on a national scale. For such a location, it is difficult to reinforce the flood risk infrastructure without significant restructuring, which is controversial and costly given the private ownership of most of the properties. In addition to water-safety issues, Scheveningen faces socio-economic challenges. The old town centre has degraded and needs qualitative programmatic and spatial improvement (Municipality of The Hague 2009).

An integrated approach to spatial and flood risk design is essential to come to a qualitatively and functionally acceptable solution for multifunctional flood defences. Such an integrated approach becomes even more relevant if the flood risk reduction task coincides with a complex spatial assignment. The latter is the case in Scheveningen. Given the dual requirements of socio-economic and flood risk improvements, an opportunity for synergy arises (Nillesen 2014).

This paper describes an integrated research-by-design study that is conducted in order to develop designs for flood risk management interventions that are effective from both the perspectives of flood risk management and spatial quality. It is the result of a collaborative effort between spatial designers and flood risk engineers, who worked together in so-called 'Delta Ateliers'. In this study, three different types of interventions for Scheveningen were developed and evaluated. The interventions are referred to in this document as 'a sandy shore', 'a hard protection-body', and 'a perpendicular dam'.

The methods paragraph starts with a brief introduction on the concepts of the Delta Ateliers and the research-by-design approach. Subsequently, the flood risk assignment and spatial assignment for Scheveningen are described, as well as specific choices regarding design goals that serve as starting points for the development of the aforementioned designs. Then, the designs for flood risk management and spatial quality enhancement themselves are described. The paper concludes with a reflection on the methodology.

§ 4.2 Methodology

Atelier sessions and research-by-design are approaches that are often referred to in contemporary design related studies. The exact meaning of these terms often remains vague or undefined, therefore this paragraph will start with the description on how such approaches are used within this research. The use of the layer model as a conceptual framework to describe and understand the essence behind the flood risk assignment in Scheveningen is then set forth.

§ 4.2.1 Delta Ateliers

Workshops or design ateliers that bring together different stakeholders and multidisciplinary experts are successful work formats in the process of reaching an integrated design (Prominski et al, 2012). Atelier work sessions in which stakeholders and designers work together to develop a holistic plan are often referred to as 'charettes' (Girling, Kellett, & Johnstone 2006). However, this term is typically used to describe interactive sessions for community participation (Sanof 2000; Girling, Kellett, & Johnstone 2006), whereas this research focuses on integrated design and participation among professionals. Because of the community participation connotation, the term 'charettes' in this study is deliberately avoided and the design sessions are referred to as 'Delta Ateliers'.

During this research, two types of Delta Ateliers have been applied: 'interactive stakeholder sessions' and 'expert sessions'. Interactive stakeholder sessions are workshops in which professional stakeholders and experts interact. The goal is to share knowledge, to establish joint fact-finding, to identify relevant topics and assignments, and to create understanding and agreement on different standpoints and visions. An interactive stakeholder session consists of a general presentation to bring participants up to date and the actual interactive workshop, for which the participants are divided in small groups that discuss topics under guidance of a team leader. At the end of the workshop session, there is a feedback round followed by a discussion under the direction of the atelier leader and agreement is reached on standpoints and visions.

Expert sessions focus on collecting, sharing, and creating knowledge. During sessions with a core team of multidisciplinary experts (urban designers, landscape architects, and civil engineers) insights are created and shared, knowledge gaps are identified, and measures and strategies are proposed, integrated, or assessed. In instances in which a knowledge gap is identified, experts are requested to undertake additional research. The urban design office Defacto Urbanism supported the Delta Ateliers by preparing the sessions, performing additional in-depth analysis, and further developing, integrating, and visualising the conceptual visions and design proposals as formulated during the ateliers. The outcomes of the Delta Ateliers and the additional research and design proposals were combined in a research report, De Stad aan Zee (Atelier Kustkwaliteit 2011).

Over the course of this research, three interactive stakeholder sessions were organised. The first session focussed on the problem definition, the sharing of knowledge regarding flood risk reduction, and spatial tasks and ambitions. Agreement was reached on the long-term goals and the future development scenarios that will be applied.

As preparation for the second interactive stakeholder session, a spatial analysis of the area was performed by the urban design office based on the information shared during the first session. An expert session was conducted in order to formulate and select three flood risk management interventions that were effective from a hydraulic point of view. During the second session, three effective interventions, from a flood risk point of view, were confronted with spatial considerations of the area. Opportunities and threats were identified and discussed. The outcomes of the first and second sessions were used as building blocks in the preparation of the third session.

Based on the building blocks as described above, the design office performed a research-by-design exercise in which integrated designs were made that address both flood risk and spatial considerations. The development of the integrated design was done in cooperation with the multidisciplinary expert team that provided detailed information on the flood risk related aspects of the design alternatives. During the third interactive stakeholder session, the outcomes of the research-by-design exercise were presented and discussed among experts and stakeholders.

§ 4.2.2 Research-by-design

Different definitions of research-by-design exist (Geldof & Janssens 2013). The research-by-design method used during this research assumes a definition in which a single parameter is systematically varied (the type of flood risk intervention), while other parameters are fixed (such as the location, the expected scenarios for climate change and economic development, and the spatial design component). The different flood risk management interventions are used as a leading principle for an integrated design in which both the spatial considerations and long-term flood risk reduction are addressed.

In the case of Scheveningen, this results in three different designs that are discussed in relation to their spatial potential and hydraulic efficiency. The aim of this research-by-design study is not to develop and select the most favourable alternative, but to feed and support the ongoing debate regarding flood risk management interventions for Scheveningen by exploring strategic opportunities for flood risk protection ¹.

§ 4.2.3 Layer Analyses and Complex Systems

In this study, the 'layer model' is used as a conceptual framework to describe and understand the essence of the flood risk assignment in Scheveningen. The layer model was documented by the Dutch Ministry of Infrastructure and Environment (VROM 2001) and based on the triple layer model by Ian McHarg (1969). The layer model contains three conceptual layers: the substratum (the natural layer of the subsoil in which changes take place over the course of centuries), the network (the layer of the infrastructural networks, changing over the course of 50-100 years), and the occupation layer (the layer of the human occupation, changing over the course of 25-50 years) (Meyer & Nijhuis 2013).

In the current research context, these layers are interpreted as the three layers of water, flood risk infrastructure, and occupation.

§ 4.3 The Flood Risk Reduction Task

The coastline is part of the Dutch flood risk reduction system, protecting low-lying parts of the Netherlands against floods in the event of a storm surge. The Dutch coastline used to be a dynamic landscape that transformed over time due to erosion, sedimentation, and varying water levels. However, in 1990, the Dutch government decided to define a base coastline (basiskustlijn) to prevent further erosion of the coastline. The main goal of this measure was twofold: to protect both the sea defence line and the functions in the coastal zone. The coastline is maintained by Dutch water boards and if, at some point, the dunes no longer meet the flood risk reduction standards or there is a severe deviation from the base coastline, action is taken to reinforce the coastline. When it comes to reinforcing the coastline, different landward and seaward interventions are possible, varying from more natural sandy reinforcements to hard structures such as dams, quays, and barriers to hold back the seawater.

The Dutch erosion management policy is referred to as 'dynamic preservation' (VROM, 1990) and prescribes a sequential preference of measures. Preservation and free transport of sand along the coast is encouraged. If an intervention is necessary, this is done with sandy (or 'soft') measures, only using hard measures such as constructions when they are unavoidable (VROM, 2006).

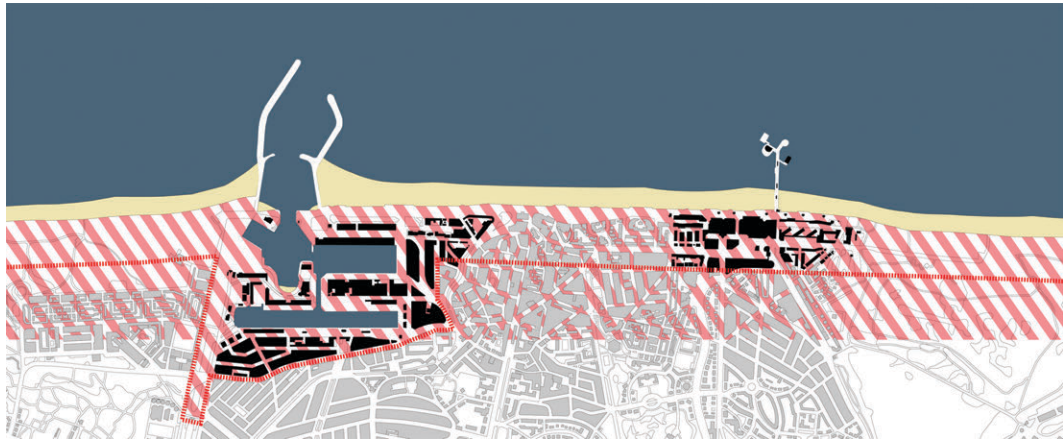


FIGURE 4.1 Scheveningen coastal protection zone

Scheveningen is part of the sandy coastal stretch referred to as the 'Holland coast' (Mulder, Hommes, & Horstman, 2011) which protects the core economic and urban centre of the Netherlands (the Randstad) from flooding. In Fig. 4.1, the coastal protection zone of Scheveningen is visualised.

The coastal protection zone consists of both the actual flood protection body as well as a reservation zone, anticipating future land or seaward extensions of the flood risk reduction body. When the flood risk reduction body is a dune (as is the case in Scheveningen) the possibility of that part of the dune eroding during a storm surge is taken into account. The dune is designed to be wide enough to still function as a flood protection body after a partial collapse. The line that should still be able to shield the water under all circumstances (within the range of the flood risk reduction standard) is referred to as the 'water shielding line'. In Scheveningen, the water shielding line is positioned in the densely built centre. This complicates the reinforcement of the sea defence line, since the flood risk reduction body as well as most of the reservation zone are built on it and are, therefore, fixed.

When following the layer model theory, the occupation layer is regarded to be the most flexible layer. In this case, the occupation layer has actually become the fixed layer. The dynamics of sedimentation and erosion on a local scale have already caused changes to the base coastline and protection standard over the course of decades. This asks for the involvement of the infrastructural layer. However, the occupation layer on top of the infrastructure layer consists of buildings that do not match the theoretical life span from the layer model of 25-50 years, for example, the famous Kurhaus building, a hotel along the beach promenade that was built in 1887 and many heritage protected houses that date from around the year 1900. Of course, such monuments can be regarded as exceptions, but even the 'modern' privately owned seaside apartments date from the 1970s and are expected to last at least some more decades. In other words, the necessary dynamic of the infrastructural and occupation layer to adapt to natural processes is, in practice, limited by the built tissue of the occupation layer.

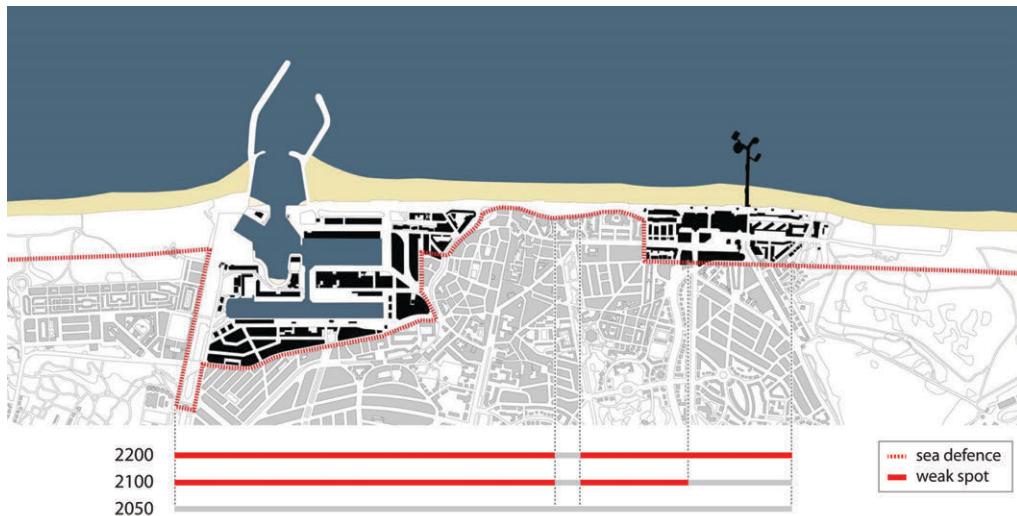


FIGURE 4.2 Indication of expected weak spots of the sea defence (in red) over time

When considering the maintenance of the flood risk reduction standards in the short term (up until the year 2050), a weak spot was identified in the old village of Scheveningen (Fig. 4.2). This weak spot has already been resolved with the realisation of a higher boulevard. With that addition, the coastal protection is extended seaward by the construction of a hard structure. Fig. 4.3 indicates the new extension movement of the water-shielding line seaward. This new extension by Spanish architect, de Sola-Morales, has been praised for the added spatial value that the enforced boulevards offer Scheveningen. In the long term (2100) the whole sea defence of Scheveningen, including the new extension, is expected to need reinforcement.

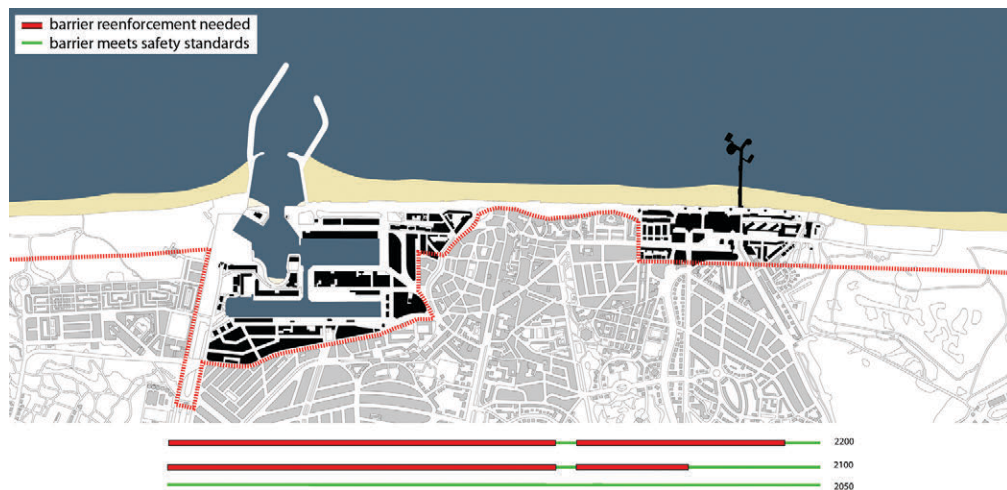


FIGURE 4.3 The extensions of the boulevards shift the water-shielding line seawards

During the first interactive stakeholder meeting, the position was taken that restructuring the complete sea defence line at its current location, or further inland, is neither feasible nor desirable. This means that the focus of this research is a seaward extension. During the first expert meeting, three main principles for extending the sea defence line were decided upon: a sandy dune extension, a hard protection body, and a perpendicular dam. An important starting point was that the dimensions of the proposed flood risk reduction bodies should be viable from a flood risk reduction point of view until 2200.

§ 4.4 The Spatial Assignment

Two important positions with respect to long-term scenarios were taken during the first stakeholder sessions: in the long term, the city of The Hague will still grow regarding both economics and population, and the borough of Scheveningen will remain an important part of the city of The Hague and should reinforce the identity of The Hague as a city by the sea.

During the first interactive stakeholder session, the governmental vision and ambition for Scheveningen were presented. The findings were later supplemented with the outcomes of a spatial analyses performed by the urban design office. The spatial tasks that were identified concerned the identity, accessibility, spatial quality, and vitality of Scheveningen.

§ 4.4.1 Identity

Within Scheveningen, three different coexisting identities can be distinguished: that of Scheveningen harbour, Scheveningen village, and Scheveningen resort. The harbour in the south of Scheveningen has a rough character and offers potential for redevelopment now that many businesses have relocated. The adjacent part of Scheveningen is the authentic centre of the historic fishermen's village of Scheveningen. Here we find small-scale residential buildings. The central axis of the village is directly connected to the seaside. North of the village, the futuristic seaside resort can be found, characterised by the faded glory of the boulevard, the Kurhaus hotel, and the pier.

The different seaside towns along the Dutch coast all have their own distinctive character and identity. The wish to contain and strengthen this difference of identities is expressed in a regional vision (Provincie Zuid-Holland 2009). Scheveningen stands out as the only seaside town with a metropolitan identity. However, the city centre of The Hague is not well connected to the borough of Scheveningen. You could say currently Scheveningen is a village by the sea, instead of The Hague being a city by the sea. In order to reinforce the identity of it as city by the sea, the ambition is to develop Scheveningen to become a mixed-use urban sub-centre of The Hague (Municipality of The Hague 2009).

§ 4.4.2 Connectivity

At both the city scale and the local scale, Scheveningen is poorly connected to the seaside. From the The Hague train station it is a 40-minute tram ride to reach the seaside. On sunny days, regular car traffic is hampered by traffic jams. Both directions of travel bring you to either tram stops or parking garages. At these points, although you are very close to the seaside, the seaside is not experienced. The sections in figure 4.4 show how the barrier formed by the dune top separates the arrival point and the tissue of Scheveningen from the actual seaside.

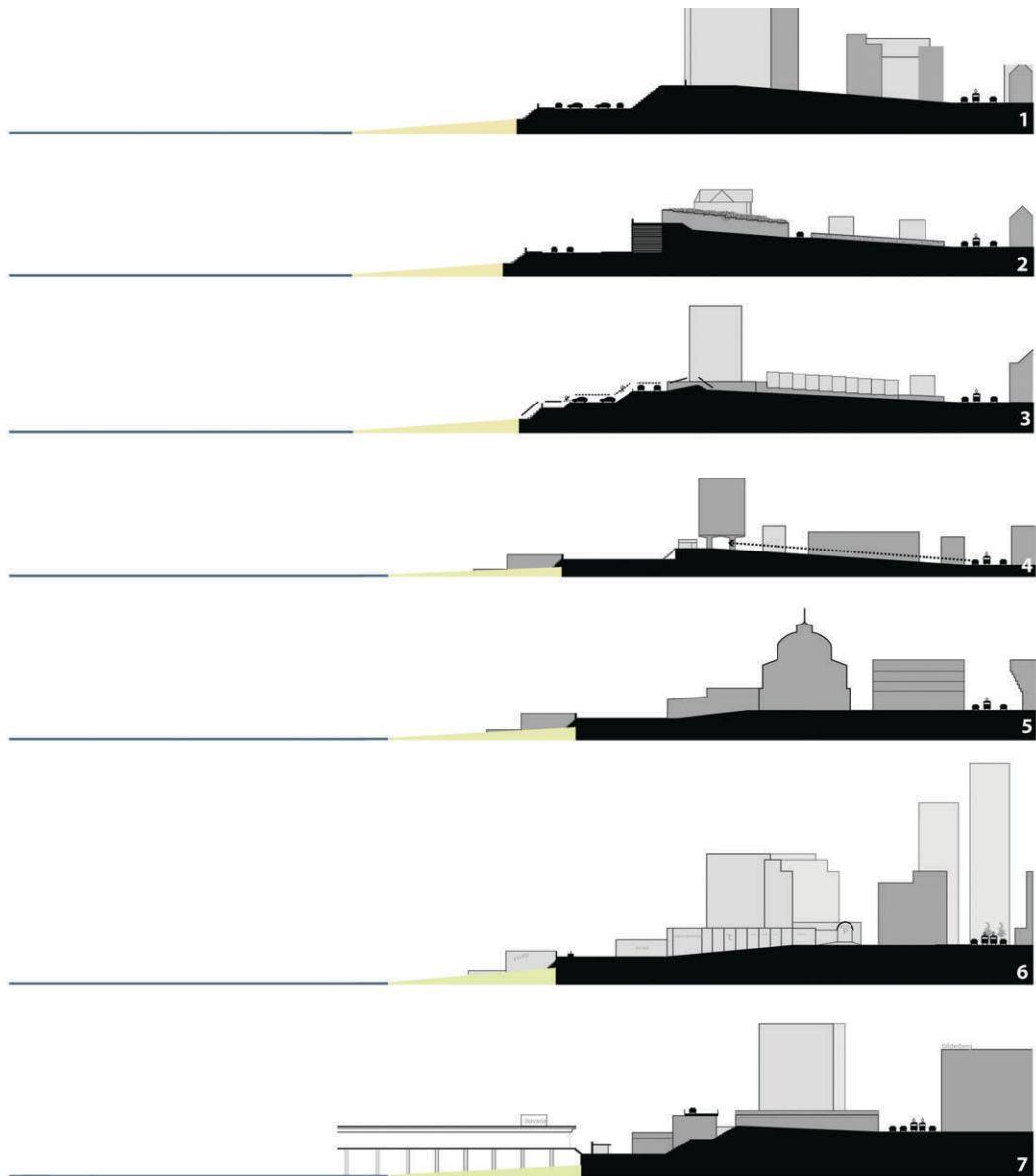


FIGURE 4.4 Scheveningen sections, from its entry points to the shoreline

§ 4.4.3 Spatial Quality

During the first interactive design session, the experts and stakeholders were asked to name the qualitative aspects of Scheveningen (Fig. 4.5). The participants constructed a map, indicating the challenges from a spatial point of view (Fig. 4.6). In general, the spatial quality in Scheveningen was considered to be poor. Buildings alongside the boulevard are oriented towards the sea only, and many streets have blind façades or parking garages at street level. The streets close to the sea lack any trees or any quality public green space due to the strong salty wind. Additionally, many buildings are due for renovation and the partly abandoned harbour is fenced off. The proximity of the sea and some of the majestic buildings along the boulevard offer great potential, as do the characteristic 1920s and 1930s neighbourhoods. The character offered by the old harbour offers potential as well.



FIGURE 4.5 Qualitative elements in Scheveningen



FIGURE 4.6 Scheveningen's poor quality areas

§ 4.4.4 Vitality

Tourism is an important economic contributor for Scheveningen. The seaside now mainly attracts day-trippers who do not spend much on average. Such tourism is seasonal and only pays off for part of the year. The goal for Scheveningen would be to create a mixed programme that is interesting for both tourist and business visitors, and to secure a year-round programme to attract more long-stay visitors. The faded glory of the boulevard could be supplemented with a new contemporary identity to attract a wealthier group of tourists.

§ 4.5 Three integrated designs for a safe and vital city by the sea

To integrate the three different flood risk reduction interventions with the spatial considerations and the ambition of Scheveningen, three design concepts for the long-term have been made. The three research-by-design studies resulted in different designs: the first design concept, with a hard flood risk reduction body, is labelled 'the city at the sea'; the second concept, with a sandy flood risk reduction body, is labelled 'the city behind the dunes'; and finally, the third variation based on the perpendicular dam led to the design for 'the city in the sea'.

Within the three designs, we can both find generic interventions applied in all three of the design variations to address part of the spatial issues of Scheveningen, as well as specific spatial interventions that are unique for one design variation and relate directly to the choice for a certain type of flood risk intervention. First, the generic spatial interventions are described and, subsequently, the unique qualities of the three design variations in relation to the applied flood risk intervention are described.

In all of the designs, a new seaward city extension is used to connect the three parts of Scheveningen: Scheveningen harbour, Scheveningen village, and Scheveningen resort. The different identities and characteristics of the three parts of the town are reflected in the new design of the boulevard. The extension offers space for new economic functions and brings a new identity to the Scheveningen seaside. There are two essential historical points connecting the existing tissue and the sea: the endpoint of the central street of Scheveningen village and the Kurhaus. At both locations the direct visual and functional relationship between the existing tissue and the sea is retained and reinforced. The monumental square in front of the Kurhaus is restored, allowing the Kurhaus to become a landmark that marks the transition of one of the main entrance roads to the sea. The tramline is diverted seaward and a direct view of the sea is established at all stops.

§ 4.5.1 Hard Seaward Extension: City at the Sea

The hard seaward extension brings the boulevard and the water-shielding line seaward (Fig. 4.7). This gives space for an additional permanent programme resulting in a metropolitan city by the sea. A reference project for this identity is the new business and living district of Hafencity in Hamburg, Germany.

The height of the water shielding part of the boulevard must be +14 metres NAP in 2200 (Arcadis & Alkyon 2005). The current boulevard is +6.7 metres NAP. This new height of the boulevard can lead to an undesirable detachment between the boulevard and the sea. Therefore, maintaining a strong relationship between the new boulevard and the sea was an important design theme. The choice was made to create a stepped boulevard with three different flood risk reduction levels. Moving from the water-shielding line towards the sea, an unembanked area at the height of +7 metres can be found, which will flood in extreme weather conditions during the winter months. In this unembanked area, additional flood risk reduction is achieved by flood proofing the ground floors of individual buildings and applying functional uses that are less vulnerable to flooding, such as car parking. The third element is a timber boulevard in close proximity to the sea. This part of the boulevard brings visitors close to the sea (as does the beach area currently) and will flood regularly during the winter season. The functions positioned along this low-lying boulevard are seasonal functions such as surf rental shops and beach bars that are disassembled in winter.

The flood risk reduction body is designed in a way that it can be hinged on a complete floor level, which makes it robust. However, working with a hard construction in the natural surroundings of the dunes creates lots of erosion; sand will have to be supplemented repeatedly under the water level.

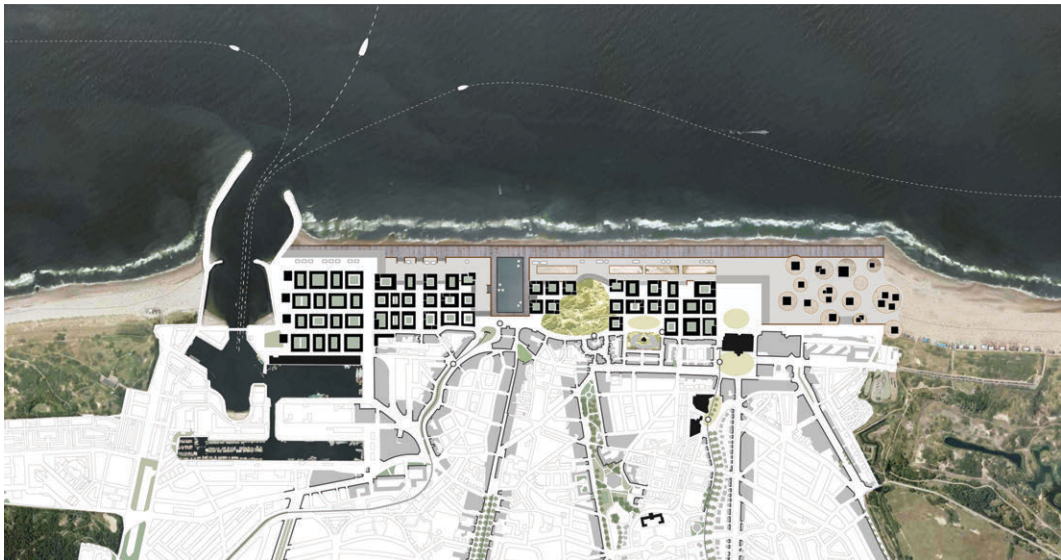


FIGURE 4.7 City at the Sea design plan

§ 4.5.2 City Behind the Dunes

To extend the dunes seaward, sand is supplemented in front of the current boulevard (Fig. 4.8). Depending on the desired proportions of the dune, this extends the current beach with tens of metres and heightens it to approximately 12 metres above NAP (Arcadis & Alkyon 2005). The water-shielding zone covers the part of the dune that could collapse in case of a storm. This section should be extended in case of sea level rise or erosion. Therefore, it is essential that this zone of the flood risk reduction body remains flexible and will not be fixed by the infrastructural layer.



FIGURE 4.8 City Behind the Dunes design plan

The necessary flexibility of the dune is the main design theme of the City Behind the Dunes. Only flexible or seasonal buildings can be positioned in the water-shielding zone. In this zone, flexible artist residences and tourist apartments could be located. On the beach itself, which is subject to seasonal tides, seasonal pavilions can be realised. There is also potential for pavilions and pools to be located in the sea. When the dune is extended far enough inland of the water shielding zone, the opportunity arises to build permanent buildings. Permanent apartment blocks are proposed within the dune near Scheveningen harbour. Along the current boulevard, a new neighbourhood is designed, referring to the majestic residential neighbourhoods of the thirties (Fig. 4.9). The character of Scheveningen will be that of a city with grandeur positioned along the beach.



FIGURE 4.9 Dwellings amongst the sand dunes

Lots of sand will have to be supplemented to create these new dunes and since the dune is positioned seaward it will erode. The erosion does not have to be problematic; the sand gets transported along the coast and Scheveningen will function as a sand engine, supplementing Holland's northern beaches (this principle is currently being tested near Hook of Holland), but ongoing maintenance will be necessary.

§ 4.5.3 City in the Sea

The third design variation is the city in the sea. Here, a perpendicular dam extends Scheveningen into the sea and protects the coast from eroding (Fig. 4.10). If a perpendicular dam is applied, additional erosion and sedimentation will affect the beaches nearby. The rule of the thumb given by the

participating engineers is that along a stretch of beach of approximately 1.5 times the length of the dam, sedimentation will take place. Beyond that part of the beach, extra strong erosion will occur.

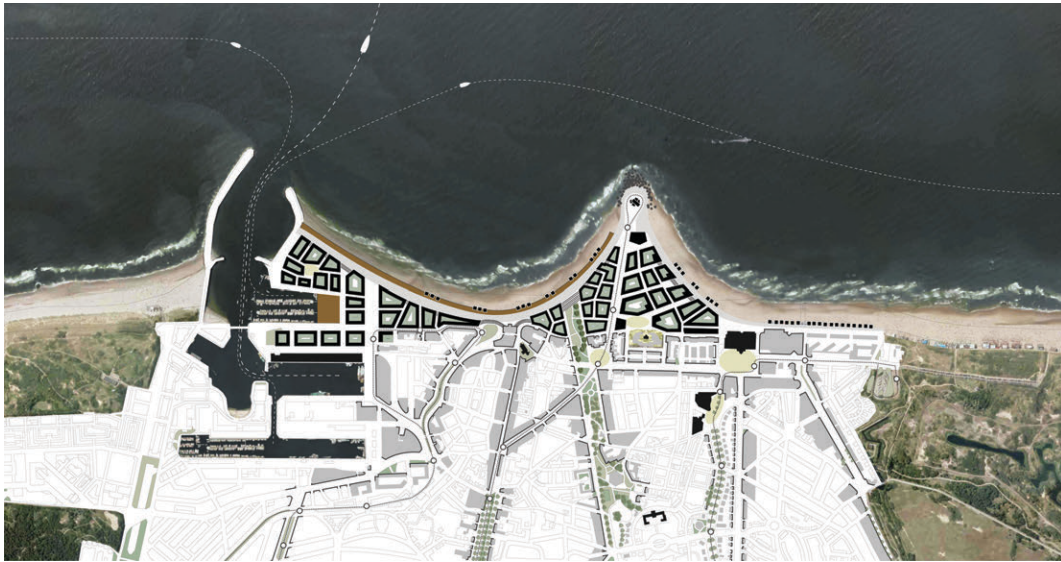


FIGURE 4.10 City at the Sea design plan

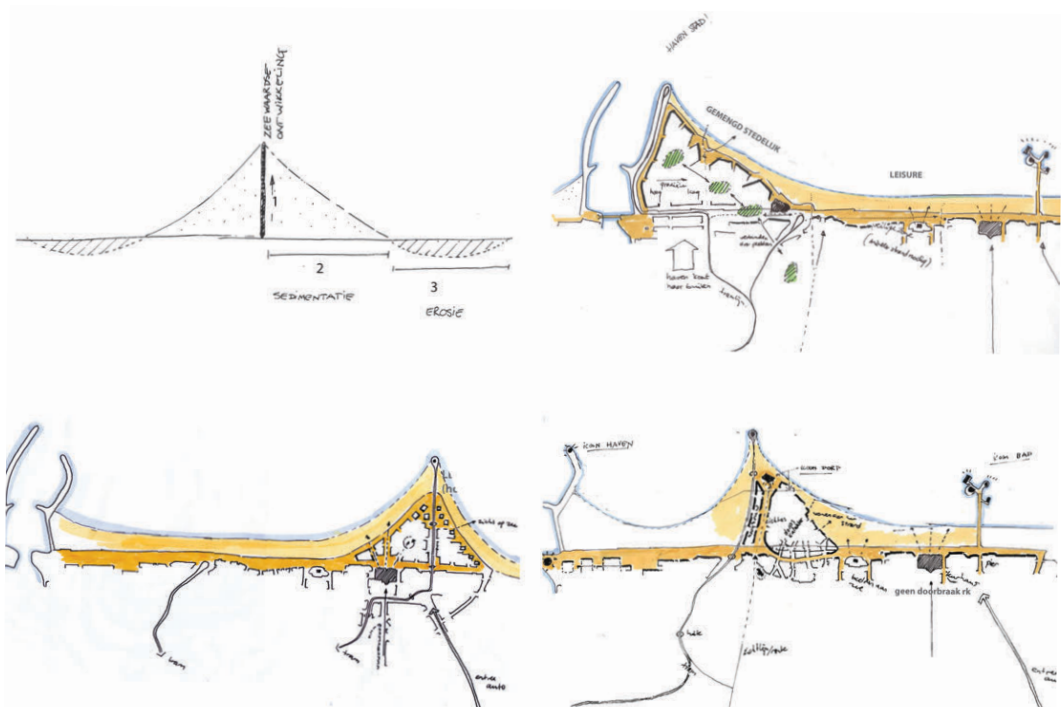


FIGURE 4.11 Dam placement evaluations

The main design theme of this design variation was finding the optimal positioning of the dam. An optimal placement would be beneficial to both the flood risk assignment and the spatial quality assignment. The design has been formulated by testing multiple locations for the dam and then evaluating these locations (Fig. 4.11). Finally, the dam was positioned in between Scheveningen village and Scheveningen beach. The dam divides the current seaside in two parts: on the south the calmer beach for the local inhabitants and on the north the touristic resort. The tramline can be extended to the end of the dam and thus bring tourists close to the beach. The type of beach town emerging on the elevated dam with a gradual slope can be best compared with Mediterranean seaside towns.

After placing the dam, the natural sedimentation will already take care of some of the needed supplementation. However, a big supplementation is necessary to extend the beach to its maximal volume. The dam protects the sand from eroding, so less maintenance will be necessary compared to the other design variations.

§ 4.6 Conclusions

This paper described the outcome of an integrated research-by-design study that was conducted in order to develop designs for flood risk management interventions that are effective from both the perspectives of flood risk management and spatial quality. Using different options for flood risk management interventions as design themes, three different designs were created, each demonstrating different options for The Hague as a city by the sea. Although similar spatial interventions and concepts were used to address the spatial considerations as prescribed (the improvement of the accessibility, vitality, spatial quality, and identity of Scheveningen), the three designs show completely different types of beach resorts with different identities. This relates to the choice of different flood risk management interventions. The various flood risk management interventions lead to different main design themes and, as a result, a different design focus for each of the three design variations. Additionally, the physical requirements and characteristics of the flood risk management interventions (for instance the difference between a hard quay or sandy dune) directly relate to specific conditions and thus different possibilities for, and atmospheres of, seaward development. Using this approach, the spatial characteristics and consequences directly related to different choices regarding flood risk management interventions could be explored. This was considered very valuable – even essential – to feed the debate regarding the choice of a flood risk intervention. As a result, this approach will be continued throughout the Delta Programme.

This design study qualifies as research-by-design, as the influence of varying a single parameter in the flood risk intervention on the design outcome is transparent, understandable, and replicable. The design variations could be assessed from a flood risk perspective in relation to the robustness and necessary maintenance of the design solution. However, there are no objective assessment criteria available to evaluate the different alternatives from a spatial quality perspective; the different designs were mainly judged based on personal preference. In that sense, the sub-study was performed to identify the most profitable location for the perpendicular dam, both from a flood risk as well as a spatial perspective. This could be considered a purer form of research-by-design since the different options are assessed both from a functional perspective and a spatial perspective, resulting in the preference for an alternative. This sub-study also fits the definition of De Jong and Van der Voordt (2005) for research-by-design as not only systematically testing different options but also testing them on different locations.

The use of the layer model as a conceptual framework was very useful. It helped to clarify that, in the case of Scheveningen, the occupation layer, which is usually considered the most flexible layer, is in fact a fixed layer. This is essential in order to understand the problems related to the current flood risk task. The relationship between the layer model and the current flood risk assignment in the Netherlands is subject to a continued research effort.

Endnotes

see <http://www.deltacommissaris.nl/onderwerpen/delta-atelier/>

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5 Water Safety Strategies and Local-scale Spatial Quality

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Originally published in Municipal Engineer, Proceedings of the Institution of Civil Engineers (ICE). Some changes were made, mainly to improve consistency and readability throughout this thesis.

In this paper, the development of a method to assess the impact of a flood risk intervention on spatial quality is described. In order to make spatial quality a decisive criterion for the selection of flood risk management interventions, the assessment of the impact of an intervention on spatial quality should be assessed in a verifiable and reproducible way. As described in the first publication, the Delta Programme defined four alternative system strategies for the reduction of flood risk in the Rijnmond Drechtsteden area. In this research, the developed method is deployed to assess the impact of those alternative system scale interventions on local scale spatial quality.

The developed method is based on the 'Room for the River' assessment framework for spatial quality, which is based on a combination of a criteria checklist and expert judgement. The Room for the

River method is developed to test elaborate design proposals in a rural setting. In this research, the framework is adjusted and extended to test more conceptual interventions, and criteria are altered to fit the more urban setting of the Rijnmond Drechtsteden area. In the research, the criteria on the

checklist (which are based on the perception of spatial quality of a combination of utility, attractiveness, and robustness) are only considered when deemed relevant by the experts. The checklist supports the expert judgement in two valuable ways: firstly, as a tool to during consecutive assessments provide the experts with a coherent and wide view of criteria, and secondly, to make the assessment verifiable and open to discussion.

The method contains the following steps:

- Adapt the spatial assessment framework to specific conditions for a case study area. Visualise the various (local-scale) locations that need to be evaluated in a consistent and neutral fashion.
- Assess the current situation as a reference, using an expert team and relevant criteria from the framework
- Assess the new situation related to the flood risk protection strategy, using an expert team and relevant criteria from the framework.

Though time-consuming, the assessment framework works well in achieving verifiable assessments regarding the impact of regional and local flood risk management interventions on spatial quality at a local scale, in this particular case study, by allowing the local scale spatial quality to function as a selection criterion for selecting a regional flood risk management strategy. In this dissertation research, spatial quality is aimed to be a criterion in strategy development and not just in selecting already composed strategies. In order to achieve this, in an earlier research stage, different measures will have to be assessed, and, based on the assessment, be selected or omitted as components of a regional flood risk management strategy.

Key aspects: assessment framework, spatial characteristics, future flood risk reduction task, expert meetings, research-by-design, Rijnmond Drechtsteden case study area.

Background

Delta regions throughout the world are subject to increasing flood risks. For protection, regional water-safety strategies are being developed. Local-scale spatial qualities should be included in their evaluation. An experimental methodology has been developed for this purpose. This paper concentrates on water safety in The Netherlands. The Delta Programme aims to ensure the country's water safety until 2100. A sub-programme, Rhine Estuary–Drechtsteden, defines scenarios for water-safety interventions that use combinations of permanent or flexible, opening or closing of connections between the Dutch delta, North Sea, and river systems. Cross-sections show water levels throughout the urbanised Rhine Estuary region, based on forecasts for each of the scenarios, and local-scale interventions, such as dikes or flood barriers. The interventions are rated using existing and new criteria for the evaluation of spatial quality. Dominant criteria for each area have been used to define design criteria. The choice of a solution on a regional scale is shown to have a significant impact on the spatial quality at a local scale. In particular, water-safety interventions that result in extreme water levels have a negative impact. The methodology is suitable for estimating the impact of a regional water-safety strategy on a local scale and provides valuable design criteria.

§ 5.1 Introduction

Approximately 50% of the world's urbanised areas are located in delta regions (UN Habitat 2006), characterised by high population numbers and a representing a significant contribution to the economic output of regions and countries. Climate change is expected to lead to a rise in sea levels (Pachauri & Reisinger 2007) and, as a result, an increasing risk of flooding for many delta regions. Suitable strategies need to be developed, and measures implemented; some of these may find applicability in multiple regions because of similarities between the geographies of different deltas.

The Netherlands has a long history in the development of water-safety strategies. Government authorities and academics actively engage in the Delta Programme (Delta Committee 2008) to analyse the impact of a rising sea level, increasing fluctuations in river discharges, and subsidence on the country. The Programme aims to provide solutions that ensure water safety until at least 2100; water safety in this context is concerned with limiting both the probability and consequences of flooding (Delta Committee 2008). The western part of The Netherlands is a highly urbanised region with port cities that are significantly exposed to rising sea levels (UN Habitat 2008). Within the Delta Programme, the sub-programme of Rhine Estuary–Drechtsteden (DP RD) concentrates on the port cities of Rotterdam and Dordrecht. Located along the estuaries of the Rhine and Meuse rivers, this region requires protection against storm surges from the North Sea and, potentially concurrent, high water discharges from the rivers (Delta Committee 2008).

In the sub-programme DP RD, water-safety interventions are defined through four extreme, large-scale strategies – so-called cornerstones (Delta Committee of Rijnmond – Drechtsteden, 2010). These are based on the basic principle that the water level in an area protected by sea and river barriers is reduced, and hence the amount of dike reinforcements required for protection is minimised. Each

of the strategies has a different impact on: flooding risks in inner and outer dike areas, fresh water supply, shipping traffic, nature, and spatial quality at both regional and local scales. Until recently, the emphasis in the assessment of the strategies was on water safety, fresh water supply, nature, and economic activity; little attention was paid to the concept of spatial quality, which can be summarised as a combination of three qualitative parameters: utility, attractiveness, and robustness (Ruimtexmilieu.nl 2012).

Improved spatial quality is deemed an important factor for the solution of socio-economic problems (Ritsema et al. 2006); the latter frequently occur in the Rhine Estuary–Drechtsteden area, where commercial activity in old sections of its ports is in decline. The city of Rotterdam, in the centre of this vulnerable region, is preparing for urban transformation and strives to strengthen its image as a water city (Gemeente Rotterdam 2007); improving spatial quality is an important aspect of its plans.

In a study that identifies and quantifies the (dis)advantages of the four strategies (Jeuken, Kind, & Gauderis 2011), local-scale spatial quality was determined to be an important assessment criterion. However, the effects on spatial quality are not easily quantifiable. For conceptual water-safety strategies that are defined on a national and regional scale, much uncertainty remains about suitable measures that can be taken at a local scale. A clear need for qualitative analysis of the effects on nature and spatial quality arises, and hence the need for a methodology for the analysis of spatial effects at a local scale.

Several methods exist for the evaluation of spatial quality. One approach uses a check list or questionnaire that contains qualitative criteria – an example is the so-called Habiforummatrix (Hooimeijer et al. 2001); another approach is based on the involvement of a quality team (Sijmons, 2008). The Ruimtelijke Kwaliteits Toets (RKT, spatial quality assessment framework) is a hybrid of these two approaches and was developed and utilised as part of the Dutch ‘Room for the River’ (Ruimte voor de Rivier) programme in 2006 (Bos et al. 2004). In this method, the spatial quality of concrete design proposals for flood risk management interventions in a regional landscape is evaluated by an expert team, using a set of criteria that is based on the description of spatial quality as a combination of utility, attractiveness, and robustness.

Check lists or questionnaires with qualitative criteria are considered incapable of grasping all subjective aspects of spatial quality (Sijmons 2008); on the other hand, expert panels are not always verifiable. The RKT is found to be usable (Ruimte voor de rivier 2006). However, the criteria included in this methodology can be hard to interpret and is irrelevant in a particular context – the criteria have been defined towards a rural rather than urban setting, with regional scales and short-term design proposals in mind. It was advised to continue development of the set of criteria and to use them as guidelines rather than as a formal set of questions to be answered.

In order to meet the need for a suitable methodology for use in the sub-programme Rhine Estuary–Drechtsteden, the research presented in this paper describes an attempt to extend the existing hybrid methodology of the RKT. The goal is to design a methodology that allows the estimation of the impact on spatial quality of conceptual large-scale regional water-safety strategies rather than design proposals, at a local rather than a regional scale and in a more complex urban as opposed to rural context. The proposed methodology is subsequently used to analyse the impact of the four regional water-safety strategies (cornerstones) defined for the Rijnmond–Drechtsteden area.

§ 5.2 Materials and Methods

Water-safety interventions for the protection of the Rijnmond–Drechtsteden region are defined through four extreme, large-scale strategies – so-called cornerstones (Delta Programme of Rijnmond–Drechtsteden, 2010). These are all based on the basic principle that the water level in an area protected by sea and river barriers is reduced, and hence the amount of dike reinforcements necessary for protection is minimised. The choice of water-safety strategy at a large, regional scale has an impact on water levels throughout that region. Depending on the strategy chosen, additional water-safety interventions are required at a local scale, which affect spatial quality.

The four cornerstones (strategies) are listed below.

- Improved closable – A continuation of present-day Dutch water-safety strategy. The safety-level of the Maeslantkering, a large, flexible, storm surge barrier near Rotterdam, is increased; peaks in high water-levels in the region are reduced, with some dike reinforcements remaining necessary.
- Closable but open – An extension of the current strategy with flexible river barriers to prevent flooding in case high river discharges coincide with a storm surge from the North Sea. High-water levels in the protected area can be kept at an acceptable level and require relatively few local-scale interventions. Water levels upstream of the barriers rise, resulting in the need for additional water-safety measures in areas beyond the barriers.
- Closed – Eliminates the risk of failure inherent in flexible barriers of the closable but open type by using closed dams and locks. Water levels in the urban area within the barrier system can be fully controlled and lowered.
- Open – Restores the naturally open connections between the North Sea, rivers, and waterways in the Rhine Estuary–Drechtsteden; in case of a storm surge, any existing dams or flexible barriers are no longer used. This scenario leads to more extreme water-level fluctuations throughout the area and requires the strongest local-scale interventions.

Several different local-scale location types that frequently occur throughout the area were identified; together, these are representative of the spatial composition in this complex and diverse region. The location types are: a levee in a rural setting adjacent to the Haringvliet river, with buildings located behind it; a levee with buildings on top of it; a levee with historical buildings behind it; a levee as part of an urban river front; an outer dike urban transformation zone; an outer dike area with historical buildings; and an outer dike area with buildings that are approximately 20–30 years old.

For each of the cornerstones, the effects on spatial quality at a local scale have been assessed in two work group sessions with an expert panel composed of the following: two urban designers, one landscape architect, one architect, and one ecologist. Involving two urban designers allows the evaluation of judgements and arguments for consistency; it may also give an indication of the level of subjectivity involved. Involving experts from multiple disciplines increases the chance of identifying aspects that are relevant to the evaluation of spatial quality (Janssen-Jansen et al. 2009). All of the experts were familiar, at least to some extent, with the locations used in the sessions.

The selected locations have been visualised as cross-sections in a consistent and neutral fashion (Fig. 5.1). Each cross-section includes projected water levels, based on a probability of an occurrence of 1 in 100 and a 1 in 1000 years, possibly varying for each cornerstone (Huizinga 2011). Based on the water levels occurring at a specific location as a result of the regional-scale strategy, choices can be made regarding local-scale water-safety interventions.

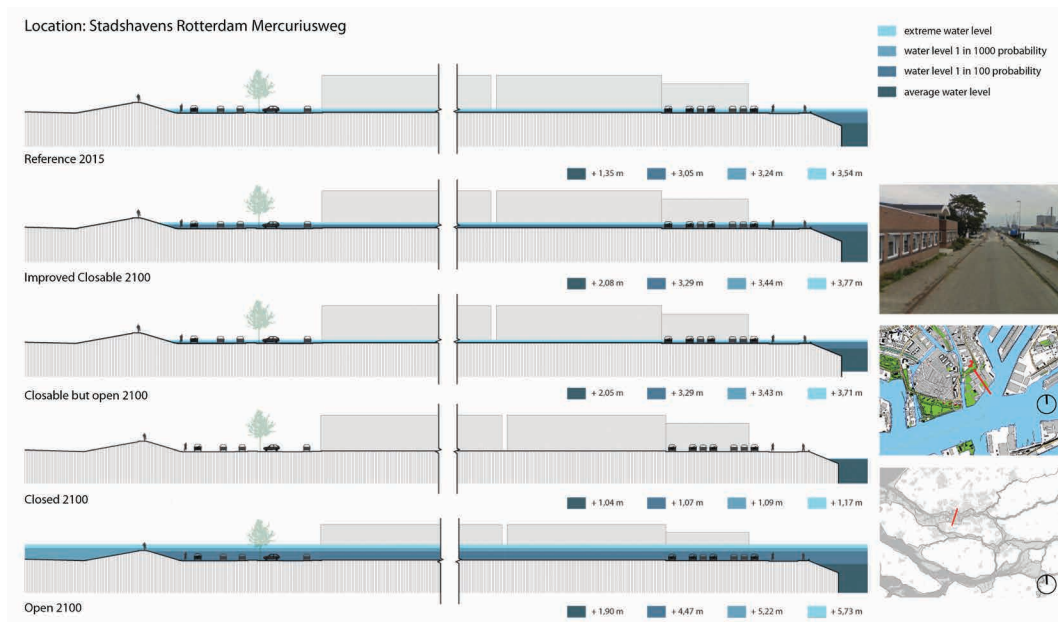


FIGURE 5.1 Cross-sections of the urban transformation zone location, showing the current water levels (2015 reference) and the projected water levels for the different cornerstones in 2100

In the first work group session, the expert panel identified suitable local-scale water-safety interventions for each location and water level. A civil engineer assisted the panel with this selection process. The selection was limited to conventional, widely accepted interventions, such as the construction of new, or reinforcement of existing, levees, quays, dams, locks (Waterschap Hollandse Delta 2012), land elevations, and flood-proof buildings (Fig. 5.2). Water safety, technical requirements, and spatial quality aspects were taken into account, while assuming the continued validity of current water-safety norms.

In addition to establishing suitable local-scale interventions, one of the interventions was evaluated using the existing RKT in order to identify specific issues in the existing methodology – and to be able to design an improved model for use in the second work group session. The expert panel found the criteria to be unsuitable for the evaluation of spatial quality in an urban environment. In addition, the criteria were considered unclear and difficult to interpret, the structure of the questionnaire was considered too rigid, and some criteria were too suggestive with regard to the interpretation of the qualitative aspect.

In order to improve the applicability of the methodology, both the working principle of the questionnaire and the formulation of the criteria were changed. Whereas the original RKT questionnaire assumes all criteria are evaluated and rated for any given location, the adjusted methodology provides more flexibility to the expert panel in describing their judgement, in choosing criteria deemed relevant and to allow for inclusion of specific criteria that were not foreseen beforehand. Criteria not relevant for a location need not be evaluated. For example, some criteria may be relevant in an urban setting, while others are relevant in a rural context.

The set of criteria was modified and extended based on literature (Gehl et al. 2006; Hooimeijer et al. 2001) and in consultation with the expert panel. Some of the original RKT criteria were removed or combined, such as economic vitality and urban aspects. Other RKT criteria were reused: functioning as residential, commercial, recreational, or public space; accessibility and routing; ecological functioning; maintainability; identity of the location/surroundings; recognition of structures; cultural recognition;

spatial recognition; diversity/ alteration; uniqueness; logic of spatial arrangement; image; water-safety experience; attractiveness; intervention versus location scale; relation to the water; reversibility; development opportunities; multifunctional space utilisation; robustness; flexibility and durability. Ten new criteria were added: future value; feasibility of gradual development; experience value; colour palette; uniqueness; the logic of the spatial arrangement; lines of sight; identity; scale of the local intervention; and seasonal attractiveness.

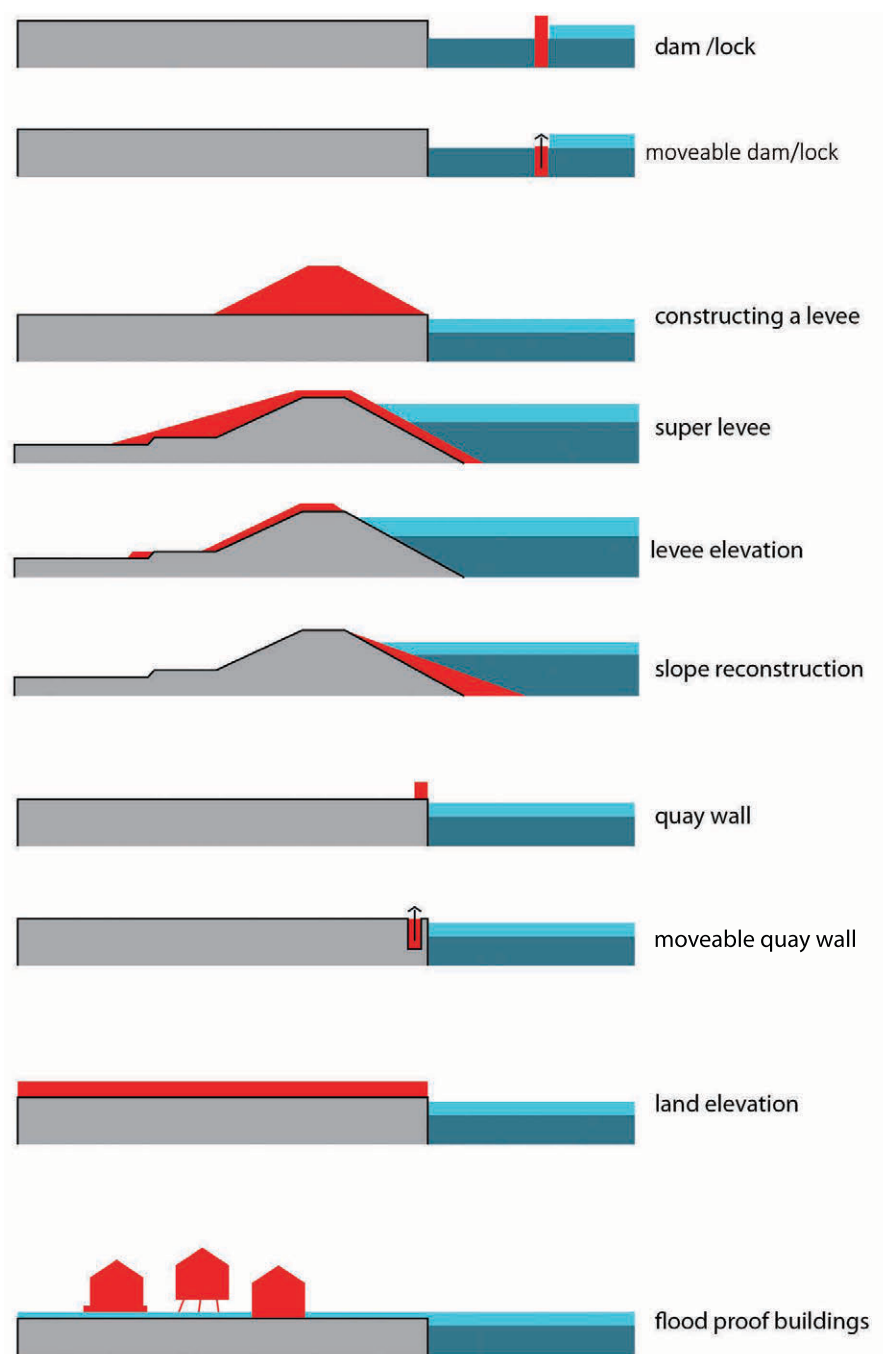


FIGURE 5.2 Conventional, widely accepted water-safety interventions to be selected for the locations based on the occurring water levels

Location: Stadshavens Rotterdam Mercuriusweg

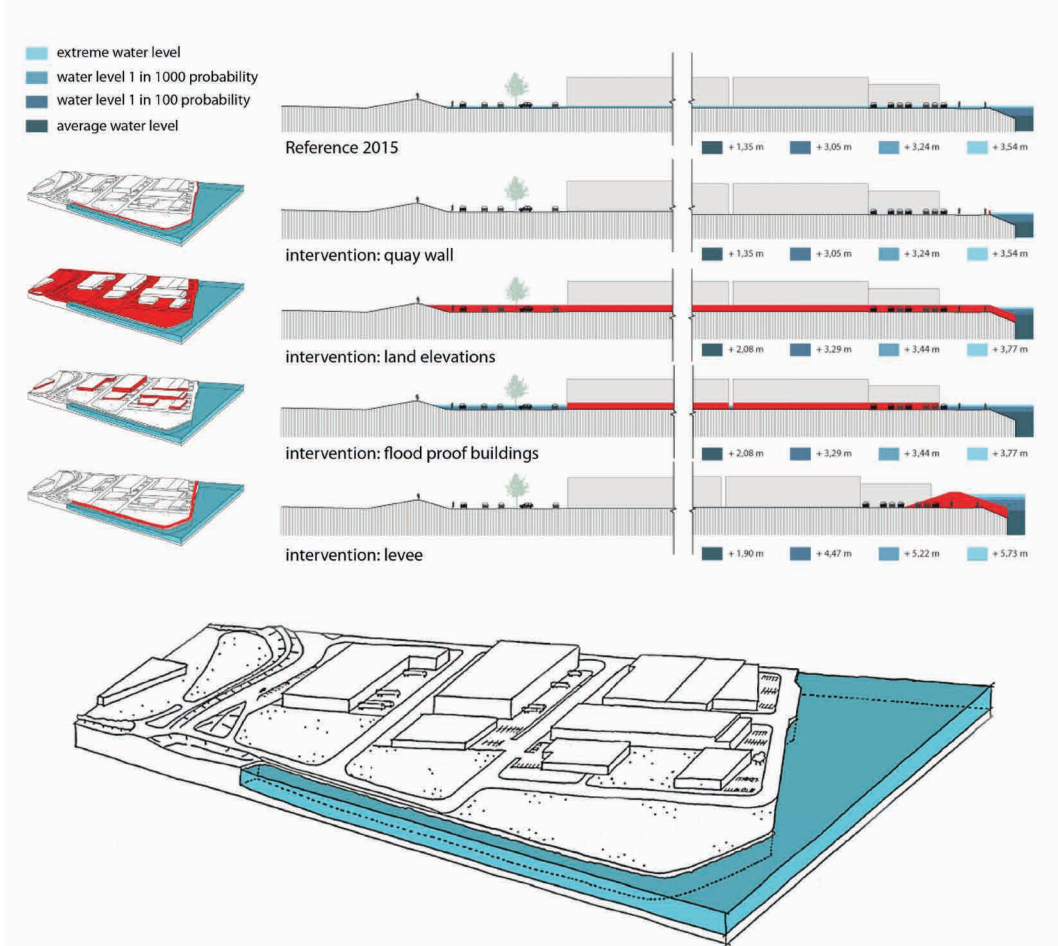
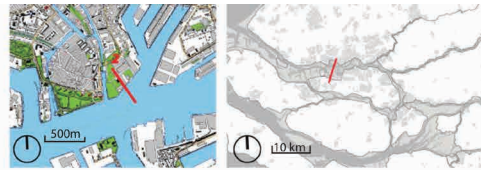


FIGURE 5.3 Selected water-safety interventions projected within the location, in this case the outer dike redevelopment area

In the second expert panel meeting, the local-scale water-safety interventions were assessed for their impact on spatial quality using the improved methodology. The current situation was described using a map of the area, a neutral three-dimensional sketch (Fig. 5.3) and impressions from Google Street View. Differences between the current situation and the situation based on the combination of

regional (cornerstone) and local intervention were described. Local interventions were visualised in the cross-sections of the locations.

The members of the expert panel had the opportunity to share and explain their choice of relevant criteria and subsequent evaluation before giving a final judgement. This allowed learning from others' arguments and, possibly, revising choices and judgements. At the end of the evaluation of each location, the expert panel was asked to reach a consensus on the effects of each local water-safety intervention (Fig. 5.4).

In a follow-up workshop after the two expert panel work group sessions, a group of graduate students from Delft University of Technology, Faculty of Architecture, investigated which criteria had negative scores; an attempt was made to neutralise the negative effects by optimising designs.

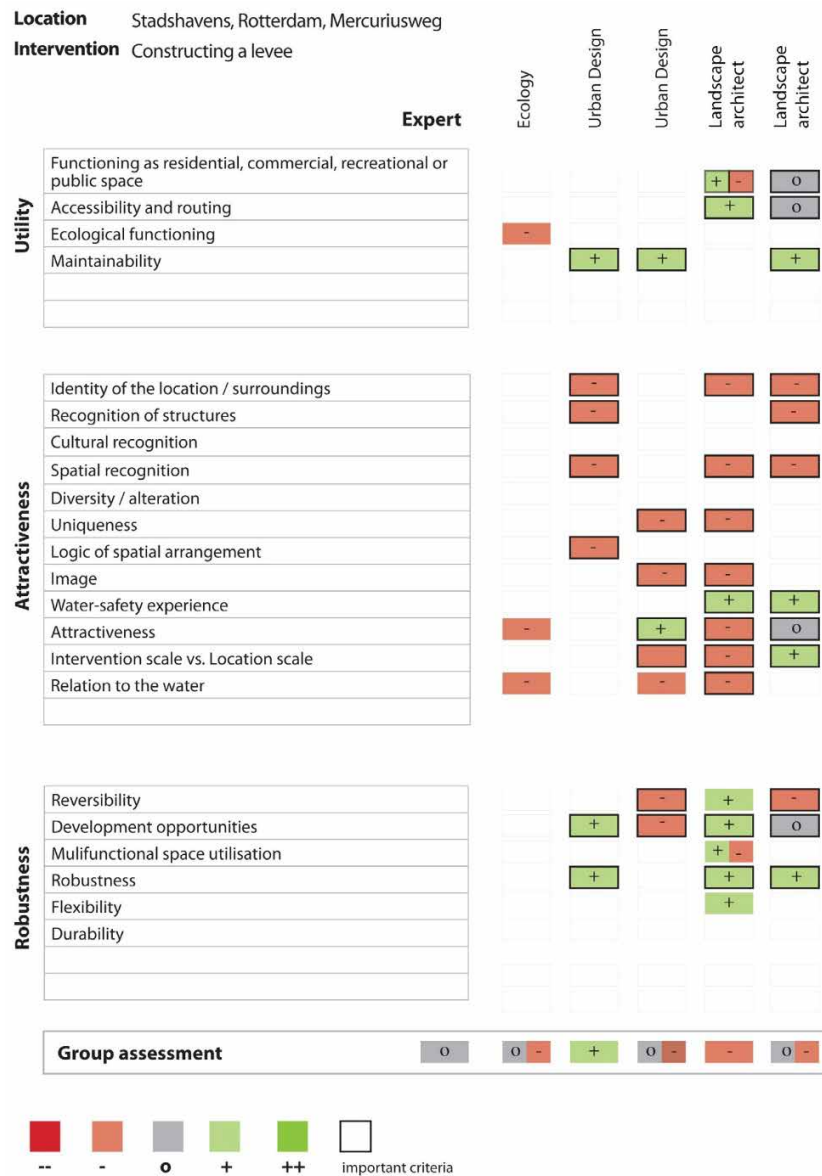


FIGURE 5.4 Assessment of the impact of constructing a levee as a water-safety intervention in the outer dike redevelopment area

§ 5.3 Results and Discussion

The methodology for the assessment of spatial quality was developed throughout the research period and focused on applicability in an urban setting. The list of criteria was modified to reflect usage in an urban context. Criteria frequently mentioned as being relevant to the Rijnmond–Drechtsteden area were: direct ‘view’ relationship to water, opportunities for new water living environments, logic of an intervention, and the scale of an intervention versus the scale of the surroundings. The new visual tools offered in the two work group sessions were valuable additions.

Generally, new or additional water-safety interventions are judged to be positive in areas that require restructuring; this offers chances for the creation of distinguishable and unique water-related environments. During the assessments, the identity of the open water and the view towards it proved to be important criteria for spatial quality of the locations. For the cornerstones that resulted in water-safety interventions up to approximately 0.7–1.0 m in height in existing built areas, that is ‘Closable but open’ and ‘Improved closable’, these criteria frequently received a positive rating from the panel members. In the case of the extreme water levels that occur outside the barriers for the cornerstones ‘Closable but open’ and ‘Closed’, the reinforcement of existing levees, which have a strong relationship with the built environment, is required. Those reinforcements received a negative assessment, as the scale of the intervention does not seem to fit in well with the human scale of the built environment. However, large-scale interventions at a local scale did not always receive a negative evaluation; in the case of the ‘rugged’ levees along the Haringvliet, reinforcements of the levees deemed necessary for the ‘Open’ cornerstone were of the same scale and character as the surrounding landscape and received a positive assessment. The drastic interventions required in the case of the ‘Open’ cornerstone in the built area received negative feedback from the expert panel.

During the work group sessions, the two urban designers provided different judgements, demonstrating the challenges of obtaining reliable, consistent, and objective results that are independent of individual, subjective opinions.

As the criteria to measure spatial quality became starting points for the design assignment, the students succeeded in making designs that had a better score with respect to spatial quality. It may be worthwhile to add such a design optimisation approach to the assessment framework in a next phase; this ‘research-by-design’ may help to identify which negative aspects of an intervention can be neutralised by integration into a design, and which negative aspects are impossible to mitigate and are therefore unacceptable.

§ 5.4 Conclusion

A methodology for spatial quality assessment was presented that builds on the RKT – a similar and existing methodology that is applicable for assessing the impact of concrete design proposals on spatial quality in a landscape setting, at a regional scale. The revised methodology has been changed to be suitable for assessing the impact of large-scale water-safety interventions on spatial quality at a local-scale in an urban delta region. Where existing methods require concrete design proposals for evaluation, the new approach allows the evaluation of large-scale water-safety interventions in an earlier stage of the development.

Supported by positive results achieved with this method, it is deemed suitable for use in follow-up phases of the Delta Programme. In order to improve its accuracy and applicability, it is recommended that a larger number of cross-sections in any future research programmes be evaluated. A map should be made that shows the occurrence of specific types of locations throughout the region so as to clarify what the locations and cross-sections actually represent. Locations should be compared during the evaluation of cornerstones; a decrease in spatial quality may be a bigger problem in one location than in another.

The methodology is well suited for application in regions beyond The Netherlands. However, several boundary conditions need to be met. Sufficient data are required regarding the expected changes in water levels throughout an area of interest as a result of a specific regional intervention. Considering that international engineering companies are often involved in large-scale water-safety interventions, the required knowledge may well be available in developed as well as less developed countries. In addition, the availability of a team of experts that is both familiar with the phenomenon of spatial quality and has sufficient knowledge of a region is key to the successful application of this method. A well-balanced selection of experts will contribute to the outcome, as will the availability of knowledge from domains such as civil engineering.

The results from the assessment of spatial quality may differ between regions as the methodology contains both objective and subjective qualitative criteria. In other deltas, the same criteria might be assessed or interpreted differently, since the assessment is subject to location, zeitgeist, and culture (Janssen- Jansen et al. 2009).

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Intermezzo 4 : Rotterdam Rijnmond Photographs



FIGURE 5.5 Photo of the Sliedrecht levee along the Merwede, incidental built constructions and trees on the riverside have been removed for dike reinforcements



FIGURE 5.6 Photo of the monumental house of the water board on the polder site of the river Lek dike, within the Kinderdijk UNESCO area



FIGURE 5.7 Photo of a previous levee elevation on a two-sided built levee along the river Lek near Everdingen



FIGURE 5.8 Photo of the Hardinxveld riverfront along the Merwede, with large scale maritime buildings and small scale dike houses in close proximity

6 Improving the Allocation of Flood risk management interventions From a Spatial Quality Perspective

Anne Loes Nillesen

Originally published in : *Journal of Landscape Architecture*, Taylor and Francis. Some changes were made, mainly to improve consistency and readability throughout this thesis.

In this publication, the developed integrated method for including spatial quality as an ex-ante criterion in flood risk management strategy development is presented in detail and tested. Based on the results of the earlier research-by-design exercise, as described in the third publication, it is concluded that the key to making spatial quality an ex-ante criterion is to make sure sufficient interchangeable flood risk management interventions, with varying locations, are available, since having multiple effective measures from a flood risk perspective makes selection based on other criteria, such as spatial quality, possible.

In this paper, the ways in which a range of interchangeable measures can be included by considering flood risk management interventions at different scale levels (varying from system scale to local scale interventions) and at different flood risk layers (including both flood risk reduction and consequence reduction measures) is described.

As a base reference situation, the impact on spatial quality of the 'business as usual' flood risk management strategy for this region is assessed. Subsequently, the ways that the flood risk management interventions can be shifted away from the locations in which they have a negative effect on spatial quality, by considering alternatives with a better (preferably neutral or positive) impact on spatial quality is tested. This is done by systematically deploying interventions at different scale levels and safety layers, while assessing their impact on spatial quality. Based on this assessment, the combinations of measures that result in an optimal impact on spatial quality, can be selected for the regional flood risk management strategy.

This case study research demonstrates that the developed method, compared to the business as usual reference strategy, allows for spatial quality to become an ex-ante criterion, resulting in the formulation of a flood risk management strategy with an improved impact on spatial quality. The approach includes the following steps:

- An inventory of the current and potential flood risk protection strategies
- An inventory of the spatial characteristics, ambition, and potentials of the region
- A qualitative assessment of the existing situation and (if available) of a reference flood risk management strategy
- Systematic research-by-design on how flood risk management interventions at different scales can shift the local flood risk management interventions (and a qualitative assessment of this shift)
- Systematic research-by-design on how interventions in different flood risk intervention layers can shift the flood risk intervention (and a qualitative assessment of this shift)

Key aspects: research-by-design, layer of the interventions, scale of the intervention, Rijnmond Drechtsteden and Alblasserwaard Vijfheerenlanden case study area, expert meetings, stakeholder meetings, spatial characteristics of the area.

Abstract

This paper describes an integrated Approach to flood risk management protection and spatial design that allows for the active involvement of landscape architects and urban designers in the allocation of flood risk management interventions within the Dutch delta. The Dutch Rijnmond–Drechtsteden area is used as a case study to demonstrate how choices regarding the scale and layer of a flood risk intervention can shift the location of that intervention. A spatial assessment framework is used to test the spatial impact of different flood risk management interventions at different locations and to determine where the intervention is most required from a spatial point of view.

§ 6.1 Introduction

Delta regions throughout the world are subject to increasing flood risks. These regions often have high population numbers and make a significant contribution to GDP; approximately 50 % of the world's urbanised areas are located in deltas (UN-Habitat 2006). Countries such as the Netherlands, Bangladesh, and Vietnam, and cities such as Jakarta and New York, are developing flood protection strategies to protect inhabitants and economic centres against flooding.

This paper concentrates on the Netherlands, where ongoing subsidence, climate change, the growing economic value of low-lying parts of the country, and the discovery of new failure mechanisms of dikes have created a significant long-term flood risk challenges. In response to this, the Dutch government established the Delta Programme. The aim of this programme is to develop long-term strategies to provide protection against flooding. Its main focus is on developing high-level choices with respect to the scale and type of interventions that are required. At the same time, the programme needs to ensure that the Dutch Delta remains an attractive place in which to live, work, recreate, and invest (Delta Committee 2008: 11). In order to develop sustainable urban deltas, there is a need for interdisciplinary approaches in which urban designers and civil engineers can collaborate (Meyer 2009: 385).

Several studies present typologies and design principles for integrated design at a local scale to integrate dikes in its surroundings (Stokman et al. 2008; Veelen et al. 2010), revitalise river fronts (Prominski et al. 2012), obtain extra space for water (Baca Architects et al. 2009), and design flood-proof houses (Nillesen & Singelenberg 2011). The Delta Urbanism book series aims to deliver methods for urban design at the scale of the delta. The publications stress the need for interdisciplinary approaches (Meyer 2009: 97) and show interesting examples of regional design and scenario studies addressing flood risk protection, but the contours of such approaches remain undefined. Both the Dutch Dialogues project and the Atelier for Coastal Quality have been successful in setting up workshop series in which designers and experts from other disciplines worked together (Atelier Kustkwaliteit et al. 2013; Meyer, Morris, & Waggoner 2009). The recent flood protection project, 'Room for the River', introduces Quality Teams, consisting of experts in the field, established to ensure the enhancement of spatial quality in relation to flood risk protection measures (Klijn et al. 2013).

The existing approaches to integrate flood risk protection and spatial design either study the effects on or potentials of alternative interventions for the surroundings to formulate a preference, embed necessary flood risk management interventions in a qualitative way, or exploit the potential for synergy at locations where flood risk and spatial assignments overlap. On a local scale, a flood risk assignment is often approached by interdisciplinary teams of spatial designers and civil engineers; the assignment itself, however, remains a given fact and is defined in an earlier research stage by civil engineers. Landscape architects and urban designers only get involved in such studies in the later stages (Prominski et al. 2012: 16), limiting their role to the task of optimally embedding a flood risk intervention at a given location, in order to achieve the best possible spatial quality.

This paper presents the first contours of a method that combines the perspectives of flood risk protection and spatial quality enhancement in an early analysis stage in which choices with respect to different scales and types of interventions within a delta are addressed. Flood risk management interventions can be implemented at different spatial scales and flood risk layers, resulting in different locations of those interventions. As this paper demonstrates, this mechanism offers the potential to allocate interventions to locations in a delta that are most suitable from a spatial point of view, and thus enables a more prominent role for the spatial assignment of an area in the development of flood risk strategies.

First, the method and its underlying concepts are explained. Then the main characteristics of the Rijnmond–Drechtsteden case study area in the Netherlands are described from a spatial and flood risk point of view. Next, the results from the application of the method in that case study area are described. The paper ends with conclusions and recommendations.

§ 6.2 Methodology

In this section, the underlying principles of the scale and layer of the flood risk intervention are explained, as well as the research-by-design and spatial assessment method that are applied to shift the flood risk intervention to a more favourable location.

§ 6.3 Research-by-design

Research-by-design can be defined as a study in which knowledge and understanding are generated by studying the effects of actively varying design solutions as well as their context (De Jong & van der Voordt 2005: 21). As will be demonstrated in the next sections, systematically applying flood risk management interventions at different scales and flood risk layers will lead to different design solutions and interventions at different locations. In this study, research-by-design is used to visualise and study the spatial impact of those varying design solutions and shifting contexts. This creates understanding about the spatial impact of high-level choices regarding the scale and layer of the flood risk intervention. Once the impact is understood, the knowledge gathered can be used to select or create the most favourable flood risk intervention strategy from a spatial point of view.

§ 6.4 The Scale of a Flood Risk Intervention

Flood risk management interventions can be implemented at different scales, varying from large (such as an entire delta system) and medium scales (such as polders and river branches), to local (such as a stretch of land or section of dike within the delta) and small scales (such as a single building).

As shown in Fig. 6.1, interventions at the scale of a delta system and the medium scale of river branches and dike-rings can influence water levels throughout the entire delta. As a result, the local flood risk protection assignment can be changed and thus, so can the need for specific local interventions. In order to demonstrate how this mechanism can be actively used to allow the shifting of local-scale interventions to the most suitable locations the following steps have to be taken:

- Identify the relevant flood risk strategies on the medium and large scale that are effective from a hydraulic point of view;
- Visualise the impact on the local normative water levels;
- Let civil engineers describe appropriate flood risk management interventions at specific local sites, based on normative water levels; and
- Let an expert team assess the impact of the flood risk intervention on the spatial quality.

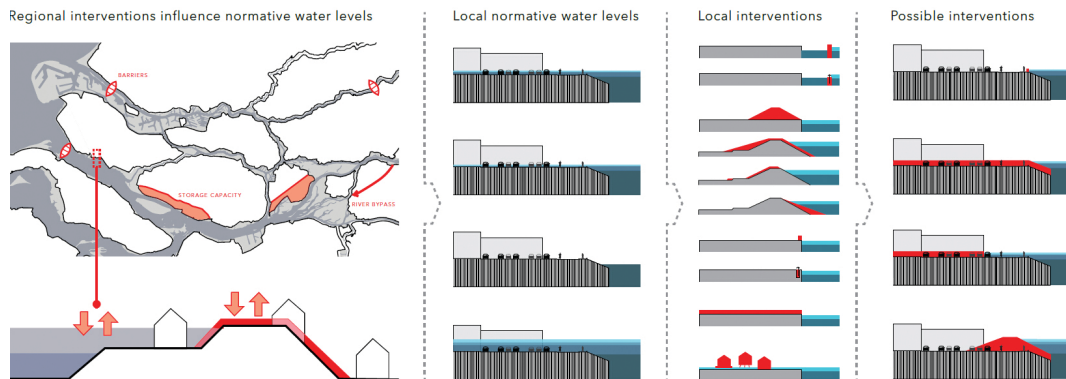


FIGURE 6.1 Schematic representation of the impact of regional flood risk management interventions on local flood risk management interventions. Regional interventions influence the local water levels and flood risk assignments and, with that, the probable local flood risk management interventions.

§ 6.5 The Layers of a Flood Risk Intervention

Flood risk is defined as the probability of a flood multiplied by the consequences of a flood. Therefore, interventions that reduce the probability of a flood are, at least to some degree, interchangeable with interventions that reduce detrimental consequences. Flood risk management interventions can be implemented on different 'flood-risk layers'. A first layer, the layer of (1) probability, includes prevention measures such as dikes and barriers, and interventions that reduce the normative water level. Two others are related to consequences, namely (2) exposure, which includes interventions such as flood-proof buildings, the protection of vital infrastructures, compartmentalisation, and restrictive building policies, and (3) vulnerability, which includes interventions that allow people to evacuate an area safely and allow rapid recovery after a flood (Expertise Netwerk Waterveiligheid 2012).

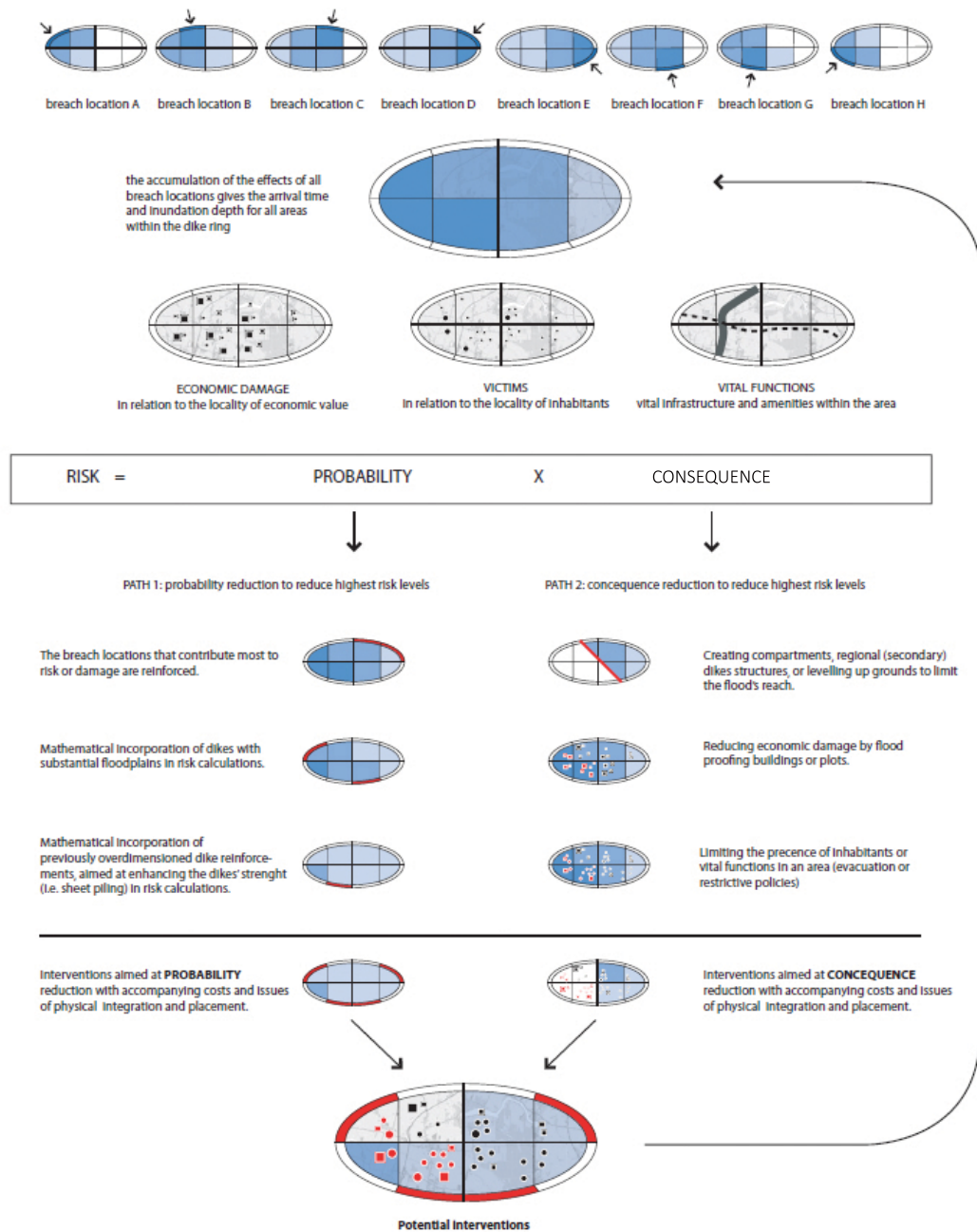


FIGURE 6.2 Schematic representation of the multi-layer safety approach showing the data as they were developed by the engineering company, as well as the proposed research-by-design method

The proposed method is closely linked to the concept of flood risk maps, such as those used in the Dutch Delta Programme. A flood risk map shows how deeply and within what time period areas will flood, and what the estimated number of fatalities and the economic damage suffered will be. As Fig. 6.2 visualises, the map is an overlay of the consequences for several dike breaks at different locations. This means that the flood risk in a random area within a dike-ring can either be targeted by local interventions that reduce potential damage or by reducing the probability of a dike break at a certain place that contributes to the flood risk at that location.

A differentiated design approach is proposed here in which flood risk management interventions at different layers work together. Specific locations that are preferred from a spatial point of view are used as a starting point for the flood risk management strategy. The design approach is cyclical: two parallel tracks for interventions that can reduce the probability, or the consequences, are investigated.

The following steps are taken to shift the flood risk assignments to the most suitable locations:

- 1 Selection of flood risk management interventions that either have:
 - a A positive effect on spatial quality and a considerable contribution to flood risk reduction, or
 - b A neutral impact on spatial quality and a major contribution to flood risk reduction flood risk management interventions
- 2 Update the risk map so that the new or remaining focus points of the risk assignment are defined.
- 3 Address the remaining problematic risk areas with a second round of flood risk management interventions while using design optimisation to embed the necessary interventions.
- 4 Update the risk map and, if necessary, repeat steps 3 and 4.

§ 6.6 Spatial Assessment Framework

The spatial assessment framework used in this study builds on the 'Ruimtelijke Kwaliteits Toets' (Spatial Assessment Framework) that was used by the Dutch 'Room for the River' project (Bos, Lagendijk & Beusekom 2004). The assessment criteria are based on the definition of spatial quality as a combination of utility, attractiveness, and robustness. They are derived from previous studies on qualitative criteria (Hooimeijer, Kroon & Luttik 2001; Gehl et al. 2006), and contain factors such as ecological functioning, maintainability, identity of the surroundings, recognition of structures, cultural recognition, alteration, logic of spatial arrangement, relation to the water, reversibility, development opportunities, and uniqueness.

In order to assess the impact of a flood risk management strategy, the following steps have to be taken:

- Adapt the spatial assessment framework to specific conditions for a case study area;
- Visualise the various (local-scale) locations that need to be evaluated in a consistent and neutral fashion;
- Assess the current situation as a reference, using an expert team and relevant criteria from the framework;
- Assess the new situation related to the flood risk protection strategy, using an expert team and relevant criteria from the framework.

Fig. 6.3 shows an example of the assessment list used in the Rijnmond– Drechtsteden area. Assessments can be judged as positive, negative, or neutral. A positive assessment indicates that the flood risk intervention may improve the spatial quality, or that synergy with the spatial assignment or ambition of the area is expected. A negative assessment indicates a negative impact on the existing spatial quality; it would be preferable to shift the necessary flood risk intervention away from this specific location.

UTILITY	EXPERT	EXPERT					
		Ecologist	Urban designer	Urban designer	Landscape archi	Landscape archi	
Functioning as residential, commercial, recreational, or public space					+	-	○
Accessibility and routing					+		○
Ecologic functioning		-					
Maintainability			+	+			+
ATTRACTIVENESS							
Identity of the location /surroundings			-		-		-
Recognition of structures			-				-
Cultural recognition							
Spatial recognition			-		-		-
Diversity/alteration							
Uniqueness				-	-		
Logic of spatial arrangement			-				
Image				-	-		
Water-safety experience					+	+	+
Attractiveness		-		+	-		○
Scale of intervention vs. local scale				-	-		+
Relation to the water		-		-	-		
ROBUSTNESS							
Reversibility				-	+		-
Development potential			+	-	+		○
Multi-functional use of space					+	-	
Robustness			+		+		+
Flexibility					+		
Durability							

ASSESSMENT

- - -
- -
-
- +
- ++
- Dominant argument

GROUP ASSESSMENT

-
- -
- +
-
-
- -

FIGURE 6.3 The spatial criteria list used in the expert session on spatial assessment

§ 6.7 The Rijnmond–Drechtsteden and Alblasserwaard Areas

The Rijnmond–Drechtsteden area is shown in Fig 6.4 and contains the greater Rotterdam area including the Port of Rotterdam, which is an important economic driver in this region. The area faces a twofold danger of flood: it is threatened by storm surges at sea and, potentially simultaneous, peak river discharges. A system of dike-rings combined with a network of storm surge barriers protect the Netherlands against floods (Jonkman, Kok, & Vrijling 2008).

The Netherlands will have to extend its flood risk protection system in order to maintain the current flood risk standards with regard to the expected long-term flood risk challenge. Currently the location of flood risk management interventions, as well as the timescale for their implementation, are determined by the Dutch water boards, which are government bodies charged with a wide range of water management responsibilities. They test the strength of dikes every six years and act to heighten or strengthen them if current flood risk standards are no longer met (Waterschap Hollandse Delta). Fig 6.5 shows, in red, the dike raises that will be required for the year 2100, also referred to as the ‘business-as-usual’ flood risk protection strategy. We see an attention point around the subsiding peat polders of dike-rings 15 and 16. The Alblasserwaard (dike-ring 16) was selected as a case study area at the medium-scale level; the area and its dike raising task are shown in more detail in Fig. 6.6.

In the Alblasserwaard, two main types of landscape can be distinguished: riverfronts and polders (Steenbergen et al. 2009: 251). The riverfronts are relatively densely built, while the open peatland polder mainly consists of grasslands, with the exception of some built-up ribbons along drainage canals. The polder has an extensive drainage system that includes the windmills of Kinderdijk, a world heritage site.

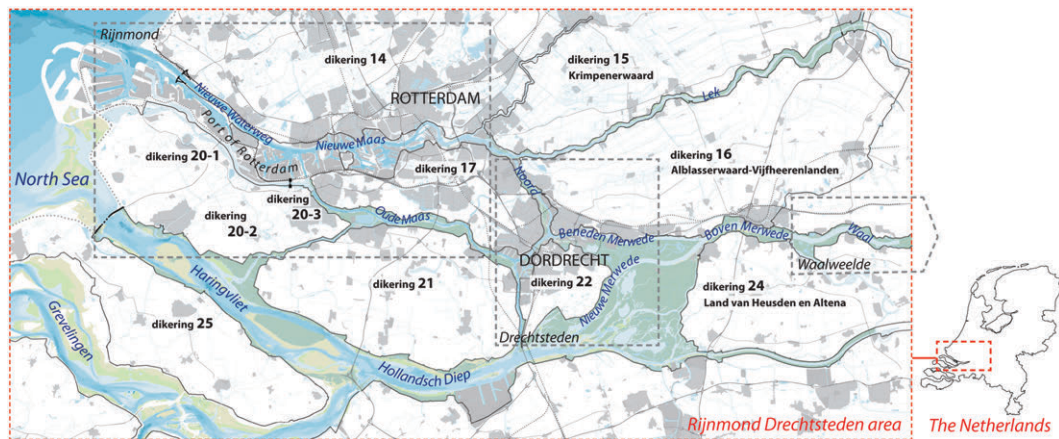


FIGURE 6.4 Map of the Rijnmond–Drechtsteden area

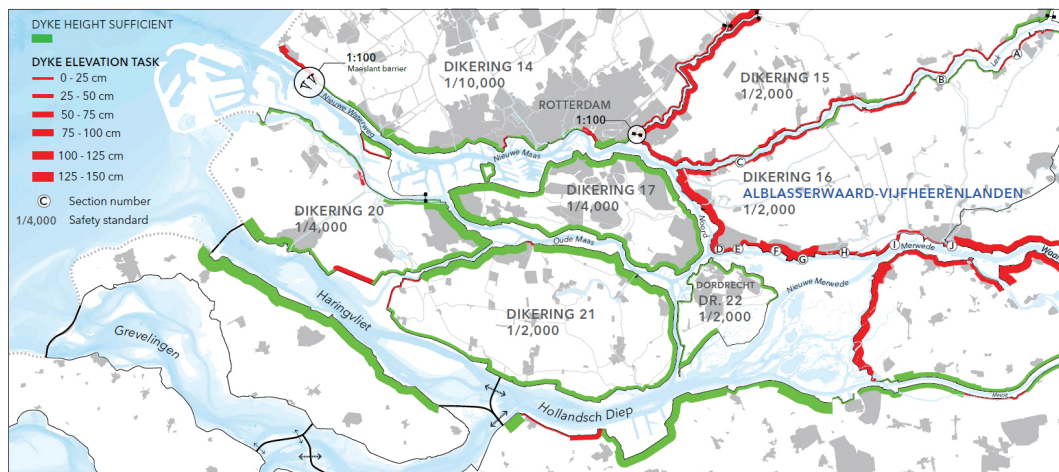


FIGURE 6.5 Indication of the regular dike raisings planned according to the 'business-as-usual' flood risk management strategy for 2100, including land subsidence and climate change (Data: vd Kraan 2012)

The pictures and sketches of the area in Fig. 6.7 show that the three rivers along Alblasserwaard have their own distinctive characteristics. The steep Lek dikes form a clear separation between the polder and the river. Along the Lek we find ribbons of individual houses and some villages inside the dike-ring. Dikes that were reinforced over time now almost absorb some of the dike houses. The unembanked areas are used for extensive water-related industries, for recreation, or as floodplains. Along the Noord, we find ribbons of small terraced houses, opposite a changing sequence of large industrial sheds, flood plains, and picturesque river views. The southern edge of the polder is most densely urbanised. The south-western edge of the Alblasserwaard polder is part of the Drechtsteden: an urban cluster positioned along the intersections of the rivers Merwede, Noord, and Oude Maas. The unembanked areas of this economic sub-centre have been raised and are mainly used for harbour-related activities, which obstruct the view of the river. Along both sides of the dike are ribbons of terraced or detached houses positioned close to each other. The shrinkage of the population that is expected from 2030 onwards makes the liveability and identity of the area an important focus point in the regional vision of the Alblasserwaard area (Provincie Zuid-Holland 2012).

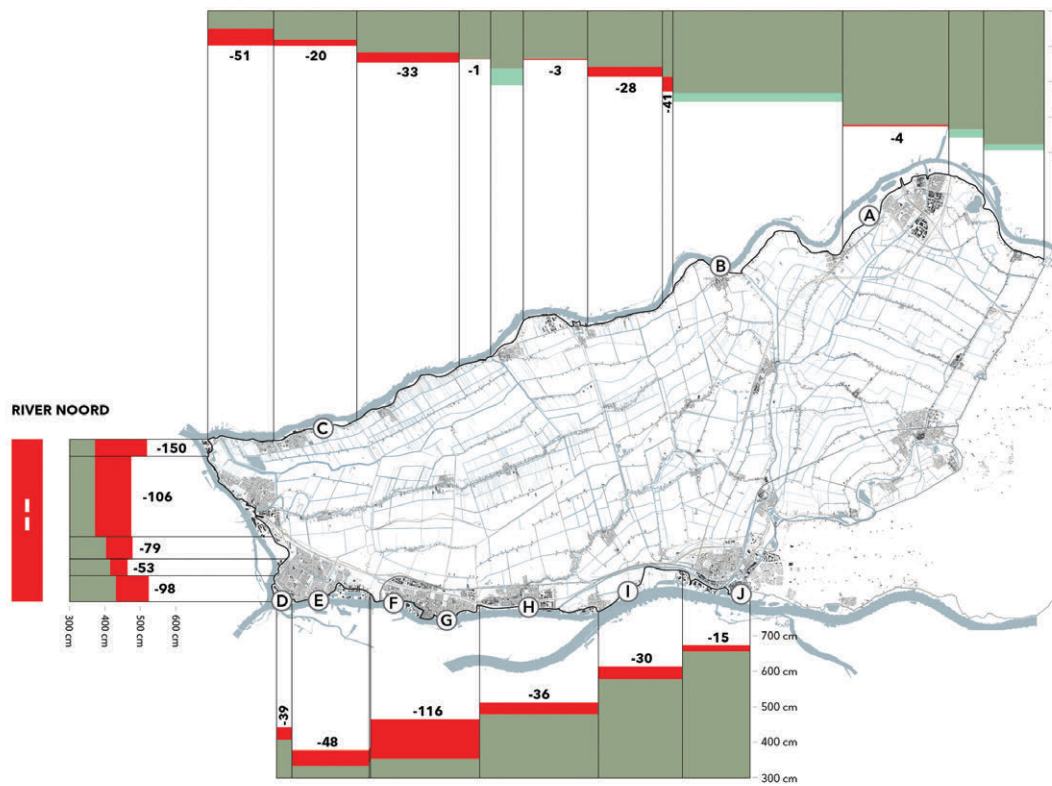


FIGURE 6.6 Map of the Alblasserwaard, including the dike raising tasks for 2100 (Data: vd Kraan 2012)



FIGURE 6.7 Sketch and pictures of the three rivers surrounding the Alblasserwaard

§ 6.8 Applying the Spatial Assessment Framework

The first step in the research was to apply the spatial assessment framework to the 'business-as-usual' flood risk protection strategy in order to describe the effects of the strategy shown in Fig. 6.5. The spatial assessment framework, as described previously, was adapted to the specific situation of the Rijnmond–Drechtsteden area; criteria like future value, feasibility of gradual development, logic of the spatial arrangement, and seasonal attractiveness were added by the expert team, which consisted of two urban designers, two landscape architects, and an ecologist.

The spatial assessment method is described in detail in an article by Anne Loes Nillesen in *Municipal Engineer* (2013). Here, some exemplary assessments are briefly described. A selection of the sections assessed is shown in the left column of Fig. 6.8. We see that, according to the water levels predicted, the dike in section E would have to be heightened by 48 centimetres. According to the civil engineering expert, this requires either a quay wall or an elevation of the dike along the waterside. Both options are shown in more detail in Fig. 6.9. As the expert panel concluded, the first option would be an inappropriate element in this area and would interrupt the continuous flow of space from the square to the river; the second option would cause the same interruption and change the historical character of the dike as a result of the more gradual slope. Both options scored negatively. However, the expert panel indicated that a dike raising of 30 centimetres would be neutral if the raise is designed as a continuous but sloping public space.

The local impact on the scale of the section is already related to a larger scale perspective. This is demonstrated by the assessment of section B, shown in detail in Fig. 6.9. The dike reinforcement blocks the view of the river from the main road, a situation that in other sections has been assessed as negative. In this case, however, on the larger scale, the reinforcement creates an interesting sequence of blocking and allowing views. The same applies to the historical buildings in sections F and G.

The demolition of incidental buildings does not harm the overall character, whereas completely restructuring the dike would eliminate its existing, distinct character. For section H, raising the dike could create the opportunity for a landscaped park and is assessed positively.

§ 6.9 Shifting the Scale of Flood risk management interventions

In order to demonstrate the impact of a large-scale flood risk intervention and its ability to shift the local flood prevention measures, the flood-risk strategies from the Delta Programme are considered, including the improvement of the Maeslant storm surge barrier, additional water storage capacity in the Grevelingenmeer, and a bypass along the River Merwede. Fig 6.10 shows the effects on the normative water levels and thus on the local assignment to raise dikes for the combined flood risk management interventions. We see that some local assignments for the Alblasserwaard have shifted. The middle column of Fig. 6.8 shows the impact of the regional flood risk management interventions on the local-scale interventions in more detail. Compared to the 'business-as-usual' strategy in the left column, some of the negatively assessed flood risk management interventions (sections D, E, and J) disappeared or reduced (sections F and G) from 116 centimetres to approximately 65 to 91 centimetres. This reduction changed the assessment to a less negative score, since the more modest dike raising task extends the timeline of the necessary intervention. In this case, a more gradual transformation of the existing characteristics of a ribbon consisting of different houses from different time periods could be achieved.

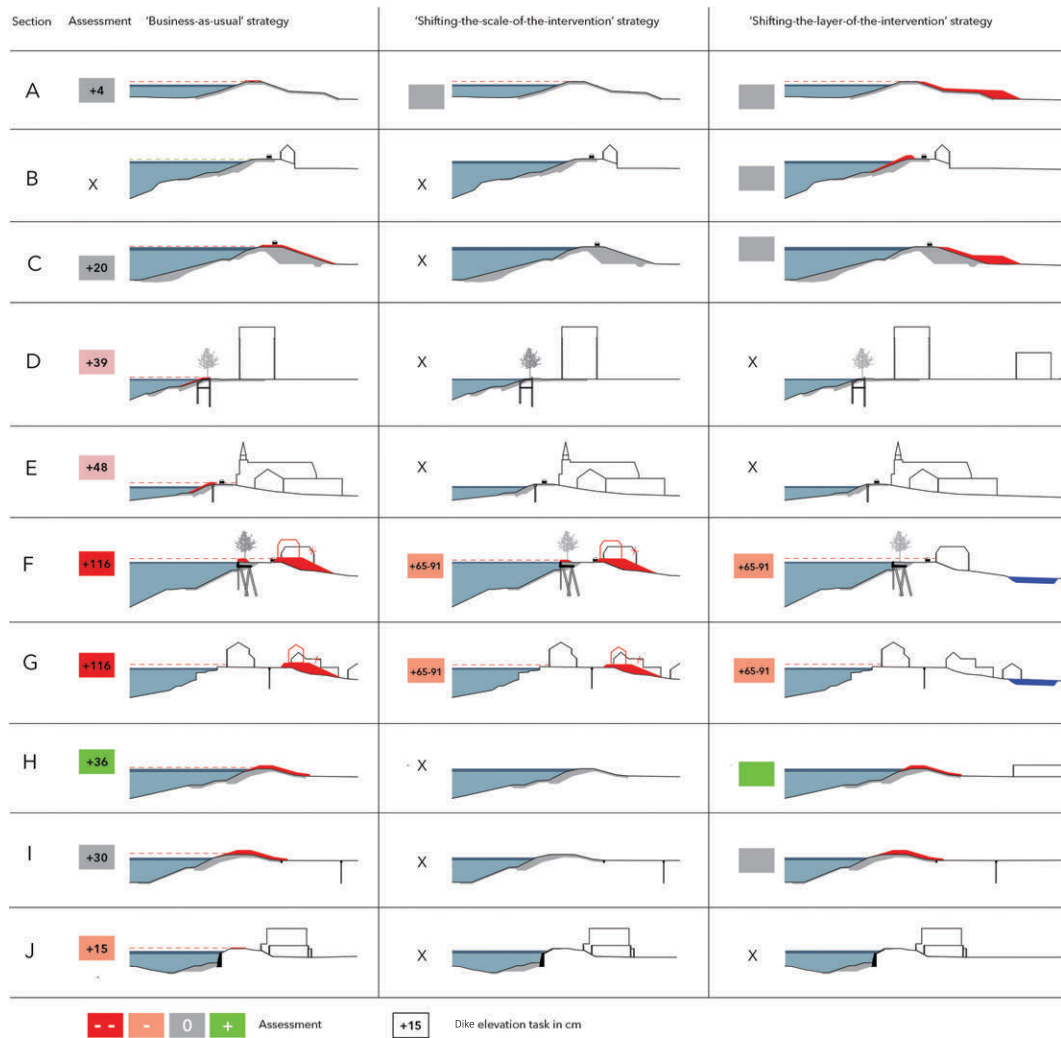


FIGURE 6.8 Example of sections used in the assessment of the impact of the different flood risk strategies on the local-scale spatial quality. (Data on section: Water Board; data on normative water levels: vd Kraan 2012)

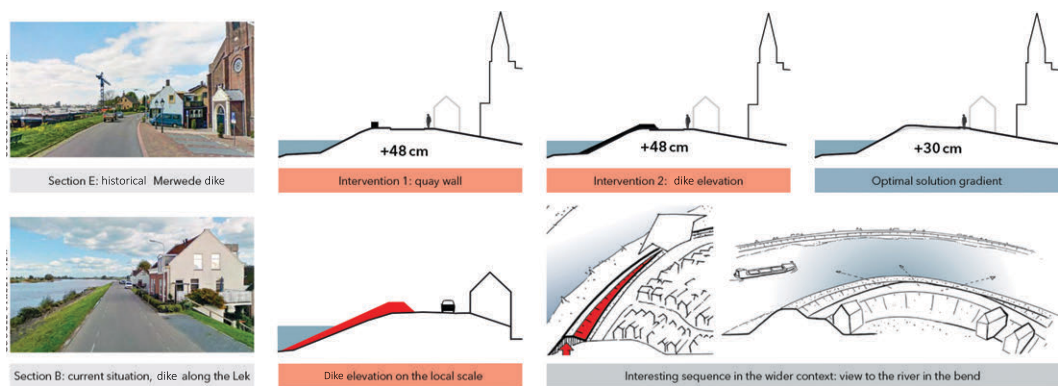


FIGURE 6.9 Detailed example of sections E (above) and B (below) used in the assessment of the impact of flood risk strategies on the spatial quality at a local-scale

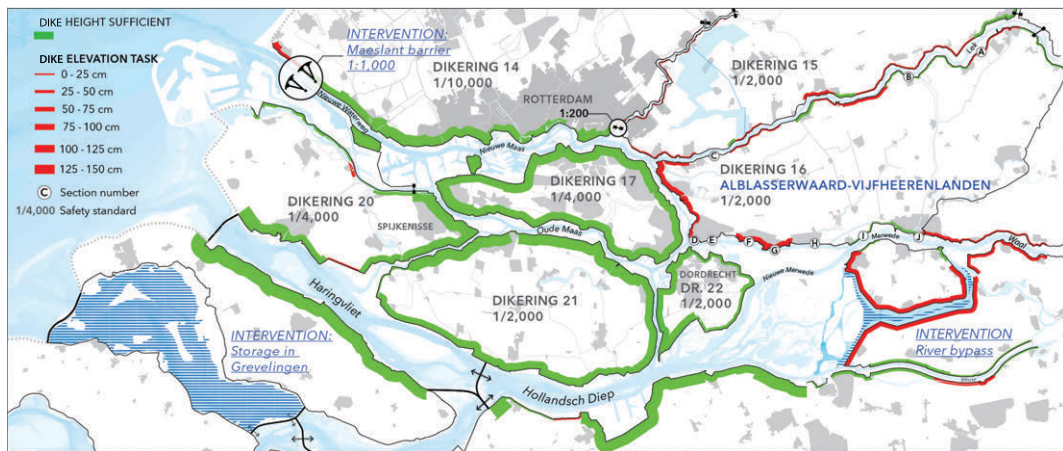


FIGURE 6.10 Indication of the regular dike raises planned up until 2100, with the flood risk protection strategy including land subsidence and climate change, an improved Maeslantkering, and a new green river and water storage at the Grevelingen Lake (Data: Deltares 2013)

§ 6.10 Shifting the Flood Risk Layer of Interventions

The western part of the Alblasserwaard is positioned 3.5 metres lower than the eastern part. In Fig. 6.11, it is shown that the eastern dikes would take a relatively large share in the potential damage caused, since a dike breach at the eastern part of the dike-ring would flood this ring in its entirety. In the first round of interventions, it is proposed to strengthen the eastern dike sections. Expert judgements performed as part of the Delta Programme indicate that the reinforcement of those sections alone to a 1:100,000 standard would reduce the number of fatalities by 60%. Possible consequences are further reduced by interventions from the second layer that focuses on local areas that suffer a large share of the economic damage or the number of fatalities. In Figs. 6.11 and 6.12, it is shown how the damage in some areas that inundate quickly and deeply can be reduced by setting up life-saving flood shelters.

In Fig. 6.12, another example of the interchangeability between interventions in the layer of the probability and consequence reduction is shown. The calculated water levels consist, to some extent, of wave heights: according to a rule of thumb, expressed during the expert session, the wave height makes up approximately 50 centimetres of the normative water level. The damage caused by the overtopping of waves, therefore, is considerably less than the damage caused by a dike break. In order to postpone problematic dike reinforcements in sections F and G, it could be decided to maintain the current dike heights and collect the water that tops over in a water retention area behind the dike. Such a retention area may coincide with current requests for extra rainwater storage.

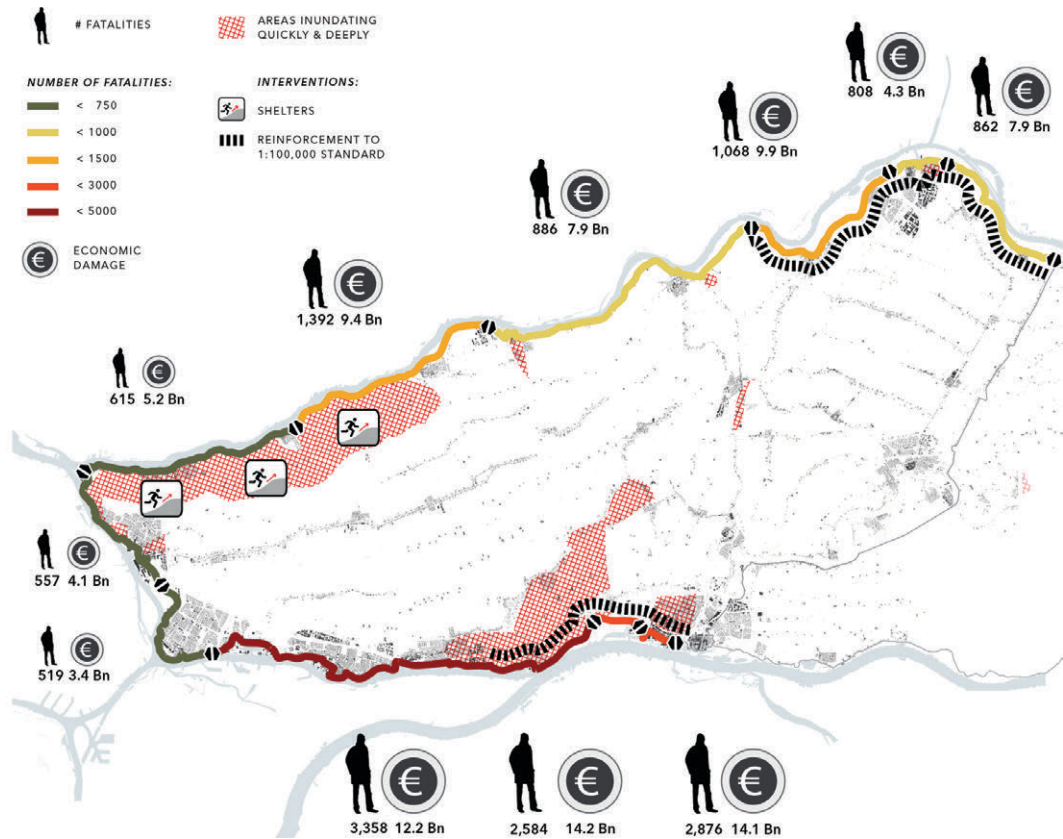


FIGURE 6.11 Schematic representation of the potential share of different dike trajectories in the amount of economic damage and number of fatalities (Data: Deltares) and the proposed flood risk management interventions on different flood risk layers.

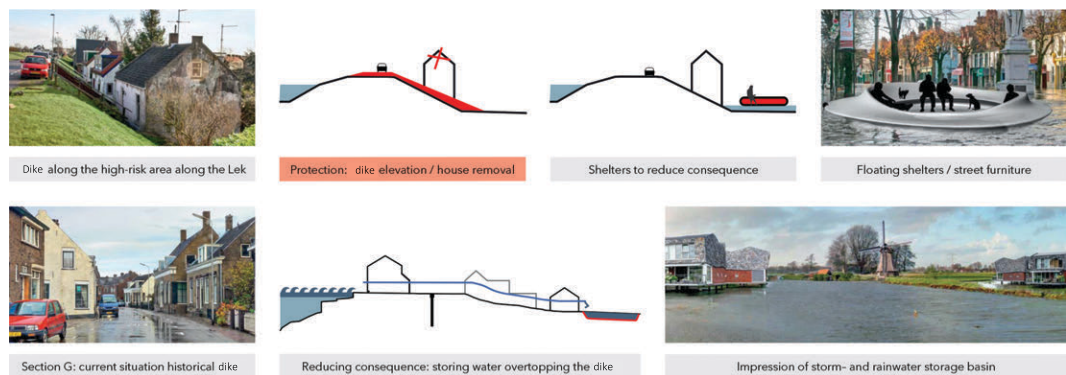


FIGURE 6.12 Raising the dike and constructing extra shelters as alternatives for risk reduction

§ 6.11 Conclusions and Recommendations

The research-by-design methodology defined and evaluated in this study demonstrates how the aspects of scale and flood risk intervention layer can be systematically employed to shift the location of a flood risk intervention to a, from a spatial point of view, more suitable location. The concept of the scale of the intervention, when applied in the dike-ring-dominated Rijnmond–Drechtsteden area, primarily facilitates shifting a flood risk assignment along a dike. The concept of the flood risk intervention layer extends the possible locations for flood risk management interventions towards the inner dike area.

The method includes:

- An inventory of the current and potential flood risk protection strategies
- An inventory of the spatial characteristics, assignments, ambition, and potentials of the region
- A qualitative assessment of the existing situation and, if available, a reference flood risk management strategy
- Systematic research-by-design on how different flood risk management interventions on different scales can shift the local flood risk assignment (and a qualitative evaluation of this shift)
- Systematic research-by-design on how interventions in different flood risk intervention layers can shift the local flood risk assignment (and a qualitative evaluation of this shift)

In order to apply the method in the manner of a spatial assessment framework for weighing up different flood risk strategies at the scale of the delta, the method should include an assessment of:

- The effects on local-scale spatial quality for the entire area that is influenced by the flood risk intervention
- The effects of interventions on a regional scale on spatial quality

The proposed methodology gives the designer the opportunity to actively participate in the debate concerning the location and scale of flood risk management interventions, resulting in a more integrated design approach. The systematic approach and the strong connection to variables and data sets makes it easier to communicate the propositions, from a spatial point of view, to engineers working on the Delta Programme.

The method can be relevant for other urbanised delta areas. Obviously, the criteria for spatial quality will have to be adjusted to the local situation, in collaboration with an expert panel. The types of data used in this research are commonly used by engineering companies throughout the world. Although different companies use different models, the type of data used to support delta decisions are often similar.

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7 An Integrated Approach to Flood Risk Management Management and Spatial Quality Enhancement for a Netherlands' River Polder Area

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In the previous paper, the aspect of including interventions from different flood risk safety layers is explained quite concisely. In this publication, an extended approach for the inclusion of interventions from different flood risk layers are described in more detail.

The paper demonstrates how the Netherlands' policy shift from a probability-based flood risk target to a risk-based flood risk target increased the range of interchangeable measures for flood risk protection. Though applying a risk-based mindset, the Netherlands' flood risk reduction targets were, until recently, defined as probability-based safety standards. This resulted in a uniform dike-ring approach in which different dike-rings have different safety standards, based on, amongst others, the perceived economic value of the area, which are applied uniformly to the whole dike-ring. Within this probability reduction based system it is possible to define interchangeable flood risk management interventions at different locations, for instance, by proposing interventions of different scales, as demonstrated in the previous publication. The 'Room for the River' project is an example of providing alternative probability reduction measures, since both dike elevation and load reduction reduce the probability of a flood.

However, applying risk-based flood risk targets conceptually considerably extends the amount of interchangeable flood risk measures. Not only does it, next to probability reduction measures, allow for the inclusion of consequence reduction measures (such as flood proofing buildings, elevating areas, and improving evacuation), but compared to the uniform dike-ring approach, it also allows for differentiations in probability standards per dike segment. This conceptually more fine-meshed perspective of the dike-ring extends the amount of variable locations for flood risk management interventions.

In the research-by-design study described in this paper, the examined method for the aspect of 'changing the layer of the flood risk intervention' is applied to the Albasserwaard case study area. The paper demonstrates how the Netherlands' recent shift from a probability standard target towards a risk-based target, by increasing the amount of interchangeable flood risk management interventions for the case study area, strengthens the possibility of deploying the developed method and the use of spatial quality as an ex-ante criterion.

Key aspects: Layer of the interventions, Research-by-design, Alblasserwaard Vijfheerenlanden case study area, expert meetings.

§ 7.1 Introduction

Deltas throughout the world are confronted with increasing flood risks. Flood risk can be defined as the product of probability and consequences of flooding (Hall et al. 2003). Flood risk management strategies in effect aim to reduce the probability and/or consequences of flooding events. These strategies evolve as flood risks increase, driven by factors such as subsidence, climate change, population growth, and economic development.

There is a strong relationship between flood risk management and spatial quality; new or improved flood defence infrastructure can have a significant impact on spatial quality, especially in urbanised deltas with (historical) built environments, such as the Netherlands (Klijn et al. 2013). Because of a growing appreciation of this relationship, spatial quality is increasingly incorporated into the objectives to be achieved in the development of flood risk management strategies.

Flood risk management strategies in the Netherlands traditionally focus on reducing the probability of flooding (Klijn et al, 2015). The country is divided into dike-ring areas, i.e. areas that are protected against flooding from rivers, major lakes, and the North Sea, through closed systems of dikes, dunes, dams, barriers, and natural high grounds.

Until recently, Dutch legislation defined protection standards for dike-rings related to the exceedance probability of flood levels. These standards were originally established in the 1960s and based on risk analysis and cost-benefit analysis, including factors such as economic output of an area and opportunities for timely evacuation of inhabitants (Ten Brinke & Jonkman 2009). Applied homogeneously to entire dike-rings, the protection standards varied between 1 in 250, i.e. designed for situations that occur once every 250 years, and 1 in 10,000 (Slomp 2012). The flood defences were evaluated periodically; if certain sections or components of a dike-ring did not meet the standard, reinforcements were implemented. This approach is referred to in this paper as the uniform dike-ring approach.

In the uniform dike-ring approach, any negative effects on spatial quality as a consequence of reinforcements are managed locally by embedding these infrastructure works in the surrounding landscape and built environment. The flood defence strategy leads the project, while the role of spatial design is limited to fitting within the flood protection measure; as a consequence, spatial quality often remains adversely affected. The interventions that were required to meet the protection standards have been facing growing opposition because of the negative effects on spatial quality and a renewed appreciation of cultural and environmental values (Klijn et al. 2013).

Within this changing context, the Dutch 'Room for the River' programme has been developed. After two major river flood events in the 1990s, the implementation programme started in 2006 and is planned to ensure that the main rivers in the Netherlands are able to safely discharge the 1 in 1250 years, as per design, river floods of 16,000 m³, as of 2015. Compared to the uniform dike-ring approach, the 'Room for the River' programme can be regarded a trend reversal from both a flood risk management perspective as well as the perspective of including spatial quality enhancement as second policy objective.

From a flood risk management perspective, the variety of alternative flood probability reduction measures has been increased by including measures that lower flood water levels by creating 'Room for the River'. This can either be achieved within the existing floodplain area by removing obstacles in the floodplain, or through deepening the riverbed or excavating the entire floodplain, or by enlarging

the floodplain area by relocating embankments, creating bypasses, or making detention areas (Alberts 2009). Although the primary objective of the 'Room for the River' approach is to comply with the same standards as applied in the uniform dike-ring approach, spatial quality enhancement is an important secondary objective (Demon & Alberts 2005). In order to address both objectives in the 'Room for the River' programme, a more integrated approach to flood risk management and spatial quality enhancement was developed.

In the 'Room for the River' approach, first, an inventory of approximately 700 possible measures was made and assessed using multiple criteria that include spatial quality (Klijn et al. 2013). The assessment was facilitated through a qualitative assessment framework for spatial quality and supervised by a quality team. The outcomes of this assessment formed an integral part in decision-making processes. Ultimately, about 40 measures were selected, which together accomplish a sufficient reduction in the water levels of a particular river branch. While the 'Room for the River' programme specifically aimed to address the spatial quality, both at the scale of entire river branches, as well as at the local scale of the intervention, the implementation by local governments shifted the focus of the integrated design to the embedment at a local scale (Hulsker et al. 2011).

Although the inclusion of spatial quality in the 'Room for the River' approach is deemed successful, the number of flood risk reduction options is limited to two: dike reinforcements and lowering the flood level using 'Room for the River' interventions, such as those already mentioned. Spatial quality enhancement and its associated economic costs only serve as evaluation criteria, provided that both options are hydraulically effective and thus valid alternatives.

Recently, the Delta Programme was established in order to define future strategies for flood risk management in the Netherlands (Delta Committee 2008). In contrast to 'Room for the River', the programme addresses flood defence strategies not only for rivers but also for coastal areas and estuaries. The programme proposed a new risk-based standard, the basic safety level, also known as local individual risk (LIR). The new standard defines a maximum yearly probability for loss of life as a direct consequence of flooding, rather than a probability standard for flood defence structures. The new safety standard is set at 1 in 100,000 and is to be complied with at any location within a dike-ring area (Delta Programme 2013). Areas that currently do not meet this standard are shown for the Netherlands' Rijnmond- Drechtsteden region in Fig. 1 and require the development of new or additional flood defence strategies or measures.

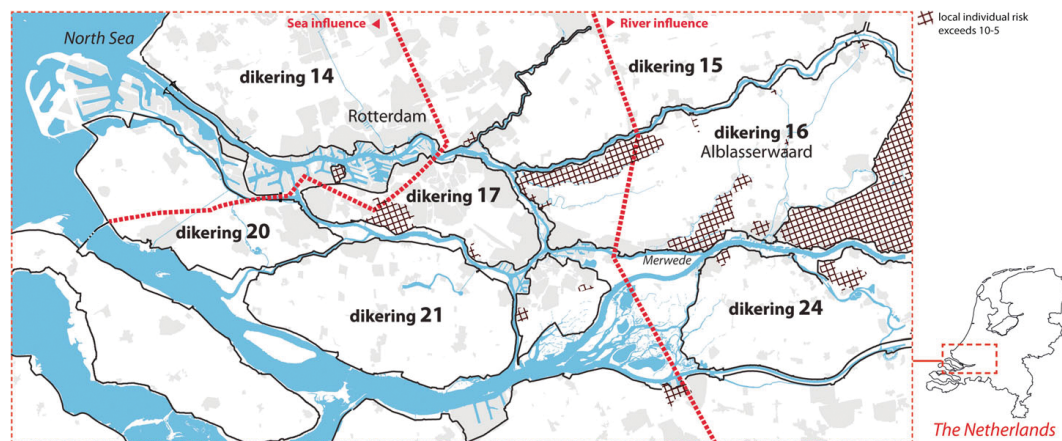


FIGURE 7.1 Dike-rings in the Netherlands' Rijnmond-Drechtsteden area. The hatches indicate the areas that do not currently comply with the standard

As this paper will argue, the new risk-based standards create the opportunity for a truly integrated approach to flood risk management while enhancing spatial quality. Compared to the conventional protection standard for flood defence structures, the risk-based standard allows for a wider variety of possible flood risk measures. The availability of a variety of measures that can effectively address flood risk allows for spatial quality to become a decisive ex-ante criterion.

First, this paper will describe how the new risk-based flood risk standard allows for an integrated method for flood risk management and the enhancement of spatial quality. Underlying concepts such as differentiated dike-rings and the basic safety level will be explained. Second, the proposed integrated approach for developing flood defence strategies while enhancing spatial quality is described. Subsequently, the results of applying the integrated approach to the case study area of one of the Dutch dike-ring areas called the Alblasserwaard will be shown and compared with results from the application of the uniform dike-ring and 'Room for the River' approaches.

§ 7.2 Materials and Methods

§ 7.2.1 Principles Underlying the Integrated Approach to Flood Risk Management and Spatial Quality

The integrated approach proposed in this paper is based on two important principles: (1) An increase in the number of alternative, exchangeable flood risk reduction measures, and (2) the ex-ante inclusion of a spatial quality assessment. First, it is explained how the introduction of the basic safety level extends the amount of applicable flood risk reduction measures. Subsequently, the different steps of applying the integrated approach, in which spatial quality is used as an ex-ante criterion, are described.

§ 7.2.2 Basic Safety Level and Opportunities for a Variety of Exchangeable Measures

Compared to the conventional flood probability standards, the new basic safety standard allows for a wider variety of possible and exchangeable flood risk reduction measures in two ways: (1) by widening the scope of potential measures by—in addition to probability reduction measures—including consequence reduction measures and by (2) by creating the possibility to define different standards per individual dike-ring segment, instead of applying one predefined standard to the complete dike-ring.

The key principle behind this is that the basic safety level addresses risk, whereas both the uniform dike-ring and 'Room for the River' approaches address probability. Risk can be defined as probability multiplied by consequence; flood risk reduction can be achieved through measures that reduce the probability and/or consequences of flooding, and consequence reduction may therefore be a substitute for probability reduction. Examples of consequence reduction measures are: improved evacuation strategies, compartmentalisation, ground elevation, adaptive building, and emergency shelters

In order to verify compliance with the basic safety level, a methodology was adopted in the Delta Programme that takes into account both the probability and consequences of failure for each dike-ring segment (Kok et al. 2016). These consequences are calculated using flow pattern simulations during normative conditions, combined with the evacuation fraction of a dike-ring (Deltares 2011). The flow pattern calculations indicate the flooding water levels in metres/h and maximum water depths during flooding; the evacuation fraction is an indication of the probability of people being present. Through this flow pattern analysis, the contribution of each individual dike-ring segment to overall flood risk can be estimated (Jongejan & Maaskant 2013). This allows for a differentiated dike-ring approach in which probability reduction measures can be evaluated and applied per individual dike segment.

Additionally, the flow pattern maps give insight into the direct geographical relationship between the failure of a certain dike segment and the dispersion of the consequential flooding. This way, insight is provided into the required location of possible probability or consequence reduction measures, supporting the gathering of a variety of possible measures.

§ 7.2.3 Integrated Approach to Flood Risk Management and Spatial Quality

This paper proposes a new approach for addressing flood risk management and spatial quality enhancement aspects in a coherent, integrated fashion. It is intended for use at the scale of a dike-ring area and is composed of four steps:

- 1 Selection of flood risk management interventions that either have:
 - a A positive effect on spatial quality and a considerable contribution to flood risk reduction, or
 - b A neutral impact on spatial quality and a major contribution to flood risk reduction
- 2 Revision of the LIR assessment of the area, resulting in the definition of new or remaining focal points
- 3 Address the remaining LIR areas with a new round of flood risk management interventions while using design optimisation to embed the necessary interventions
- 4 Repeat steps 2 and 3 (until the LIR target is achieved)

The assessments on spatial quality and hydraulic effectiveness of different measures can both take place ex-ante and can provide criteria for inclusion of specific measures in a flood risk management strategy. Both the spatial assessment framework, which evaluates the positive, neutral, or negative impact on spatial quality of an intervention, and the hydraulic effectiveness assessment, which evaluates the considerable or major contribution to flood risk protection, should always be adapted to the region of attention.

§ 7.2.4 Spatial Quality Assessment Framework

A framework for assessing spatial quality was developed in the 'Room for the River' programme, necessitated by the inclusion of spatial quality as an evaluation criterion in that programme. The framework assumes that a so-called quality team is established that evaluates flood risk management interventions for their impact on spatial quality, using a predefined set of criteria; given the background of the 'Room for the River' programme, the method is geared towards relatively rural river areas. It has been adjusted in previous research to apply to a somewhat more urban context, such as that of the Alblasserwaard and Rijnmond regions (Nillesen 2013). Derivatives of this framework are used for the evaluation of the different approaches in this paper.

§ 7.2.5 Methodology for Evaluating the Proposed New Integrated Approach

In this study, the uniform dike-ring approach, the 'Room for the River' approach, and the proposed new integrated approach are applied to a case study area, the Alblasserwaard, also known as dike-ring 16. Subsequently, it is evaluated if the latter method has a reduced negative impact on spatial quality in comparison to the first two methods.

Research steps:

- Application of the uniform dike-ring approach, based on the basic safety level, and reflection on spatial quality
- Application of the 'Room for the River' approach, based on the basic safety level, and reflection on spatial quality
- Application of the proposed new integrated approach, based on the basic safety level, and reflection on spatial quality
- Discussion of result

§ 7.2.6 Case Study Area: Alblasserwaard (dike-ring 16)

Dike-ring 16, the Alblasserwaard polder, serves as the case study area. It is located east of the Rijnmond- Drechtsteden area in the Netherlands, an urbanised and industrial region that includes the Port of Rotterdam (Meyer et al. 2012). The Diefdijk separates dike-ring 16 from the adjacent dike-ring 43, the Betuwe, and provides compartmentalisation in case of a dike breach. The rivers Lek, Noord, and Merwede form its other boundaries. Hydraulic boundary conditions are influenced by both North Sea water levels and peak river discharges towards the west; towards the east, peak river discharges are the dominant factor.

The land that is now Alblasserwaard was gradually reclaimed and embanked from the eleventh century onward. Eastern sections of the Alblasserwaard were part of the Hollandse Waterlinie; these are historical military defence works that date back to the seventeenth century and were comprised of fortresses and wide spreads of low lying land that could be inundated to prevent enemy intrusion. The polder has an extensive drainage system that is characterised by east-to-west canals that were originally drained at the north-western tip by the windmills of Kinderdijk; nowadays a major tourist attraction, their function was gradually taken over by steam pumping stations and subsequently electric and diesel pumping stations. Originally used for agriculture, the land subsided so that at present, it is mostly used as grassland and livestock management (Steenbergen and Reh 2009).

Different spatial characteristics can be found along each of the rivers. Fig 7.2 shows some characteristic images of the dikes around the Alblasserwaard. Along the river Merwede, in the south of the polder, the dikes are densely built; historical dike ribbons can be found here, with buildings on both sides of the dike. This is the economic and urban centre of the Alblasserwaard, with dredging and transshipment companies and shipyards in the unembanked areas. A clear view over the river is a rare but appreciated condition. Along the river Noord, in the west, historical ribbon development limits the view to the polder itself. Unembanked areas along the riverside of the dikes contain a mix of industrial buildings and natural reed beds. The urban and industrial areas at the confluence of Merwede and Noord rivers are part of the Drechtsteden cluster of ports. Along the Lek, in the North, individual houses and villages can be found. The riverside of the dikes along the Lek is predominantly unbuilt and consists of reed beds. The infrastructure route on the dike provides wide views to both polder and river.

The polder is characterised by built dike ribbons along the rivers that surround open polder landscapes (Steenbergen and Reh 2009), with small towns and an economy based on agriculture, livestock, and river bound activities. A restrictive building policy is applicable that aims to preserve the open character of the landscape. Dike ribbons can be found not only along the rivers but also within the polder, along some of the historical peat and drainage canals. Two important infrastructure corridors cut through the Alblasserwaard: from west to east, the A15 national highway and the international Betuwe freight train line and; from north to south the Netherlands national A27 highway. Along those national highways, clustered commercial developments occurred. The polder has a population of approximately 170,000 inhabitants, with a density of approximately 680 inhabitants/km².



FIGURE 7.2 Images characterising the Alblasserwaard riverfronts

§ 7.2.7 Application of the Uniform Dike-ring Approach

In this approach, the flood risk reduction that is required to meet the basic safety level is achieved through increasing the failure probability standard for the Alblasserwaard dike-ring. Expert judgement was involved to determine this standard. Compliance of dike-ring sections and components with the adjusted failure probability standard is evaluated; any infrastructural upgrades or reinforcements that are required to meet the adjusted standard are determined with the help of expert judgement. The impact of these infrastructure works on spatial quality is subsequently assessed.

Given the time-consuming and costly nature of fully invoking the spatial quality assessment method from the 'Room for the River' programme, in this study a similar but less elaborate expert workshop was used to determine and evaluate the effects of the necessary dike reinforcements from the uniform dike-ring approach on spatial quality. Eighteen subject matter experts, local representatives, and officials assessed the impact of potential dike reinforcements on spatial quality. The participants were assigned to one of three groups, each focussing on one of the rivers and corresponding dikes that run along the Alblasserwaard. Large printouts were available explaining the context for the Lek, Noord, and Merwede:

- A large aerial picture of each river at a scale of 1:10,000
- Photos and street view images, showing the local situation at approx. every 1000 m along the dikes
- An inventory of the proximity of buildings to the dike body. The inventory showed whether there are buildings situated on top of the dike, in the inner dike slope, on the outer dike slope, or at the foot of the dike

A hydraulic engineering/technology expert was included in each group. One group leader guided the discussion and marked the group's assessment, indicated the threshold height for the indicated spatial assessment, and the main arguments. The spatial assessment was provided and collected in a relatively simple qualitative fashion:

- "+" for a positive effect on spatial quality (the proposed intervention offers an opportunity for the improvement of spatial quality or offers opportunities for synergy)
- "0" for a neutral effect on spatial quality (the proposed intervention has neither a positive nor a negative impact on spatial quality)
- "-" for a negative effect on spatial quality (the new situation, including the proposed intervention, will be of a lower quality than the current situation, e.g. the potential intervention blocks the line of sight to the river)
- "--" for a very negative effect on spatial quality (e.g. the interventions require characteristic housing along the dike (ribbon development) to be demolished).

§ 7.2.8 Application of the 'Room for the River' Approach

The method for evaluating the impact of the 'Room for the River' approach builds upon the results from the uniform dike-ring approach. In addition to measures developed in that approach, alternative 'Room for the River' interventions are identified for the sections of the dike-ring where normative water levels are dominated by peak river discharges. This concerns the south-eastern part of the Alblasserwaard dike-ring area.

The hydraulic effectiveness of these measures was determined using expert judgement. The effectiveness of potential load-reducing measures was assessed in an expert workshop that consisted of two separate sessions:

- One session focussed on producing an inventory of potential hydraulic load reducing interventions for the Alblasserwaard dike-ring area. As preparation, measures from previous 'Room for the River' programme studies were identified through desk studies. During the workshop, these were complemented by expert judgement.
- One session, with three hydraulic engineers, focussed on the assessment of the hydraulic effectiveness of the potential load reducing measures. The measures identified in this session as being effective were subsequently verified with additional hydraulic calculations (Van Putten 2013).

A total number of 23 measures were identified and hydraulically assessed. In this paper, only those measures that are effective alternatives for dike elevation are indicated. The entire inventory and assessment can be found in a workshop report (Defacto 2013).

The spatial assessment regarding the potential load reducing measures was organised in a separate session with 20 participants, including subject matter experts and local representatives. Participants quantified the expected impact on spatial quality of an intervention as positive, neutral, negative, or very negative, and explained their reasoning.

§ 7.2.9 Application of the Integrated Approach

The first step in the application of this approach is the selection of flood risk management interventions that either:

- a Have a positive effect on spatial quality and a considerable contribution to flood risk reduction, or
- b Have a neutral impact on spatial quality and a major contribution to flood risk reduction

In order to do so, possible measures for probability or consequence reduction have to be identified, and an ex-ante analysis has to be carried out on its effectiveness from the perspectives of flood risk management and spatial quality.

Effect of Interventions on Flood Risk Reduction

In order to determine which interventions effectively reduce flood risk and to what extent, it is important that the interventions address potential failure mechanisms that contribute to flood risk: specifically, to LIR and the number of fatalities. This allows for the effects of both probability and consequence reduction measures to be considered.

Step 1 of the integrated approach involves determining the effects of possible interventions on flood risk and spatial quality. Data on the effectiveness of probability reduction measures was available, but data on consequence reduction measures in relation to flood risk reduction and spatial quality enhancement had to be obtained. The first round of the study therefore focussed on the effects of reinforcing multiple dike sections and potential load reducing interventions. Compared to the other two approaches, the number of possible interventions was increased by taking into account the opportunity to reinforce dike-ring segments in a differentiated fashion, instead of applying a homogenous standard, and through assessing their contribution to the consequences of a flood.

For the probability reduction measures related to dike reinforcements, first, the current protection levels of the dike segments are indicated by their individual failure probabilities; to this end, the preliminary results of the VNK study (Vergouwe and Van den Berg 2013) are employed (Fig. 3) To assess the share of impact that a dike breach in a single dike section has in the total consequential damage for the entire dike-ring area, we focus on the consequential damage of a flooding event as expressed in LIR and potential fatalities, and the following data is employed:

- An overview of the fatalities expected after dike failure, presented for all of the Alblasserwaard dike sections, based on hydraulic simulations of flow patterns (Fig. 3).
- An overview of the time it takes for a flood to reach the two different LIR areas (in grey) after a dike breach (listed in the remainder of the paper as arrival time). And, in black, the time in which the inundation level in the LIR area reaches 1.5 m (Fig. 4).
- The dike segments are categorised according to which potential flood risk management interventions are shown to either have a major or a relevant effect on the reduction of dike-ring area's flood risk².
- Major effect: interventions that reinforce or are load-reducing, dike segments that, in the case of a breach, would be characterised by:
 - A very short arrival time; inundation levels in one or more LIR areas are over 1.5 m within a 6-hour time span, combined with a moderate dike section failure probability greater than 1/10,000
 - Considerable number of fatalities (>1000 persons), combined with a very high dike section failure probability (over 1/1,000)

Relevant effect: interventions that reinforce or are load reducing, dike segments that, in the case of a breach, would be characterised by:

- A short arrival time (<24 hours); inundation levels in one or more LIR areas are over 1.5 m within a 24-hour time span, combined with a moderate dike section failure probability over 1/10,000
- A considerable number of fatalities (>1000 persons), combined with a considerable dike section failure probability (1/1.000 to 1/10,000)
- A high number of fatalities (>5000 persons), combined with a high dike section failure probability (1/100 to 1/1,000)

Step 2: Update the LIR assessment, which involves expert judgement by a civil engineer to estimate the remaining flood risk assignment and results in the definition of new or remaining focus points.

Step 3 of the method involves consideration of additional flood consequence reduction measures for the second round of selecting flood risk management interventions, in order to address the potential LIR areas where the basic safety level is not met. This is a creative aspect of the process, supported by indicative expert judgements, that illustrates how a wider range of interventions is included in the development of an integrated flood risk management strategy.

Effect of Interventions on Spatial Quality

The performed ex-post spatial impact assessments of the dike reinforcements in the applied uniform dike-ring approach and the load reduction measures in the applied 'Room for the River' approach were used to represent the ex-ante spatial quality assessment for the integrated approach. This helps identify which possible dike segment reinforcements have a positive, neutral, or negative impact on spatial quality.

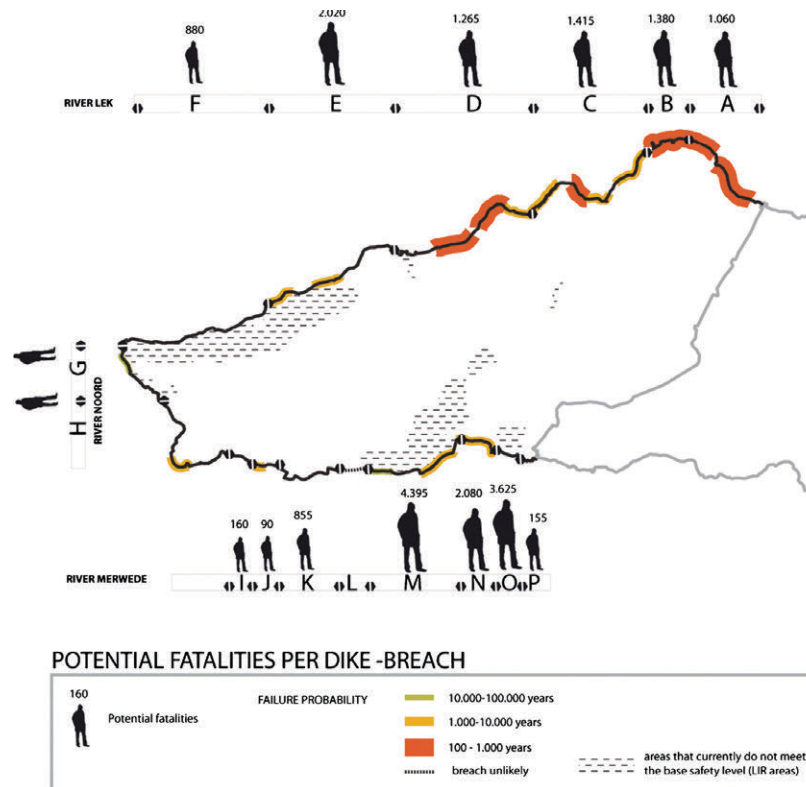


FIGURE 7.3 Failure probabilities as indicated by VNK (Vergouwe & Berg 2013), and an overview of the number of fatalities after dike failure

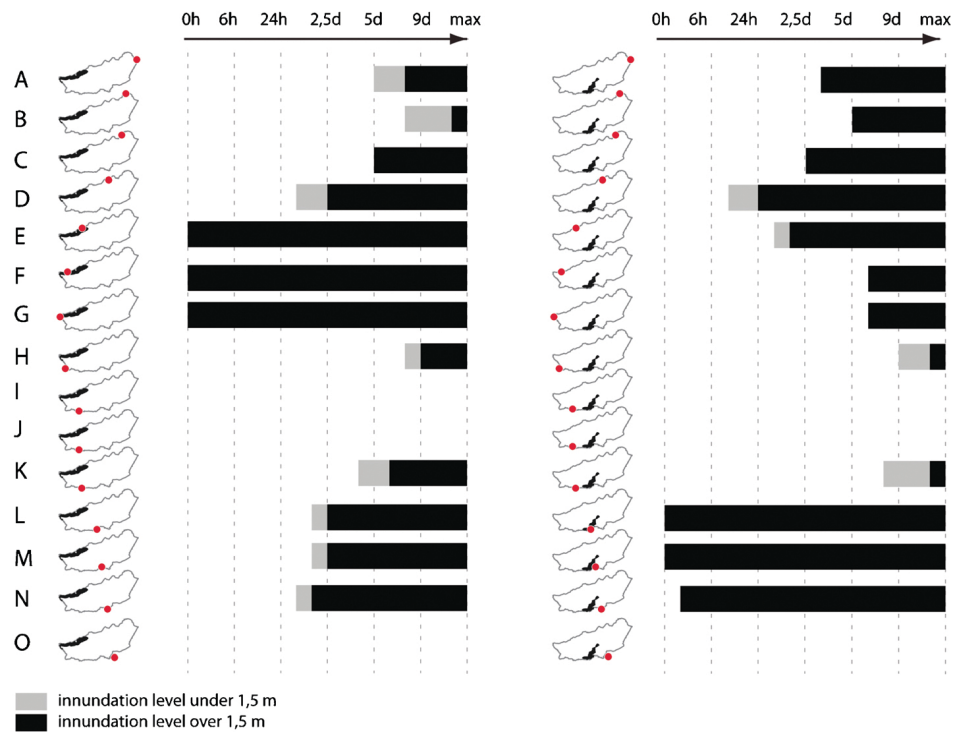


FIGURE 7.4 Overview of the time it takes for a flood to reach the main LIR areas

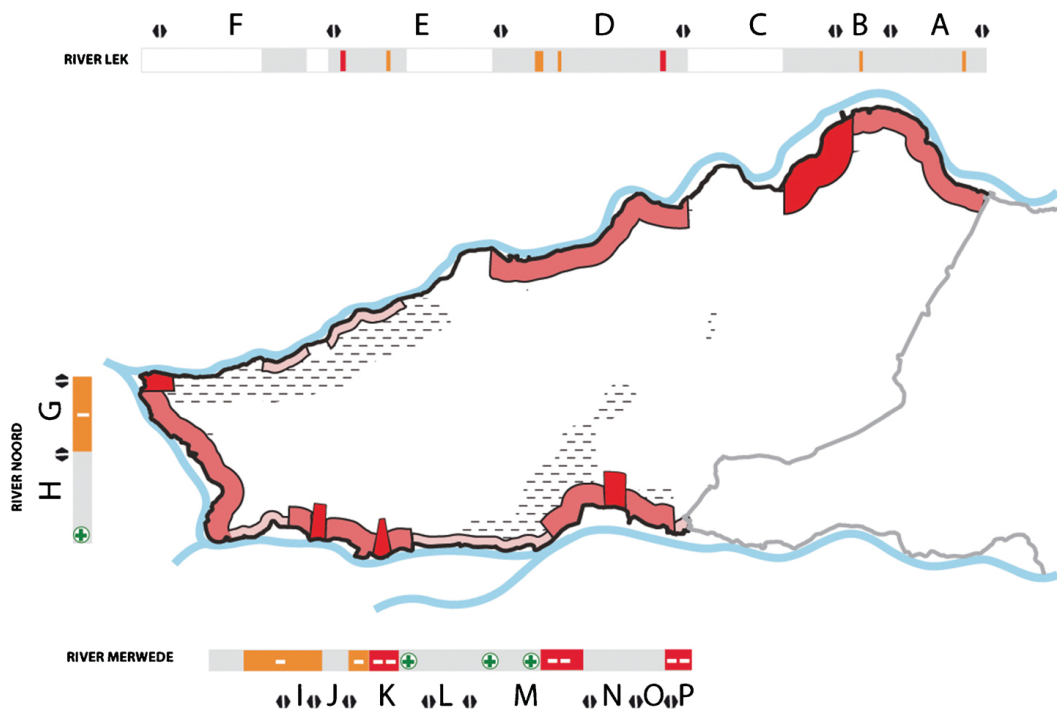
§ 7.3 Results and Discussion

Results of the uniform dike-ring approach, 'Room for the River' approach and integrated approach are explained below.

§ 7.3.1 Meeting the Basic Safety Standard with the Uniform Dike-ring Approach

Areas within the Rijnmond-Drechtsteden region that currently fail to meet the new basic safety level (LIR areas) are shown in Fig. 1. According to these estimates, the safety standard would have to be increased by 26 times for the Alblasserwaard dike-ring area in order to meet the required basic safety level (Slootjes and Jeuken 2013, p. B09). Fig. 7.5 visualises the required dike elevations (in centimetres) that would be necessary to meet the new standards for 2050 for the Alblasserwaard, based on expert judgement.

As earlier dike elevations and reinforcements to meet the previous probability-based standards were problematic, additional elevations necessary to meet the basic safety standard will not only be costly—estimates indicate € 1,520,000,000—(Slootjes & Jeuken 2013, p. B11) but will also have a major impact on spatial quality in the region. The outcome of the spatial assessment workshops regarding the impact of potential dike enforcements on spatial quality is also shown in Fig. 5. Negative effects can be found along the characteristic and historical dike ribbons along the Merwede and Noord rivers. Along the Lek, buildings with high historical-cultural value are affected. Along the Merwede river, some positive effects and possibilities for synergy were found.



UNIFORM DIKE-RING APPROACH



FIGURE 7.5 Dike elevations necessary to meet the LIR standard by following the uniform dike-ring approach

§ 7.3.2 Meeting the Basic Safety Standard with the 'Room for the River' Approach

A total of 23 (combinations of) measures were brought forward in the exploratory workshop for identifying potential load reducing measures. These measures were assessed for their hydraulic effectiveness; 19 measures were expected to have a positive hydraulic effect. The load reducing measures are concentrated along the Merwede river in the southeast of the Alblasserwaard, in the area where normative water levels are dominated by peak river discharges.

Only a few measures were found to be effective alternatives for dike reinforcement. During the qualitative assessment workshop, one of these measures (illustrated in Fig. 6) was presented as having a potentially positive effect on the area's spatial quality. This concerns the creation of a bypass through the polder south of the Alblasserwaard, in parallel to the Merwede, and can be combined with the development of a new harbour for the village of Werkendam. This measure could serve as an alternative for two dike reinforcements in dike-ring 16 that have a very negative impact on spatial quality.

§ 7.3.3 Meeting the Basic Safety Standard with the Integrated Approach

Two areas in the Alblasserwaard polder do not meet the basic safety level of 10^{-5} : an area in the north-western part of the polder along the Lek river, and a centrally located area in the south, along the Merwede river. Fig. 7.4 illustrates how a dike breach (dike failure) in each of the corresponding dike sections would contribute to flood risk in these LIR areas; these areas are under threat of flooding regardless of the location of a breach.

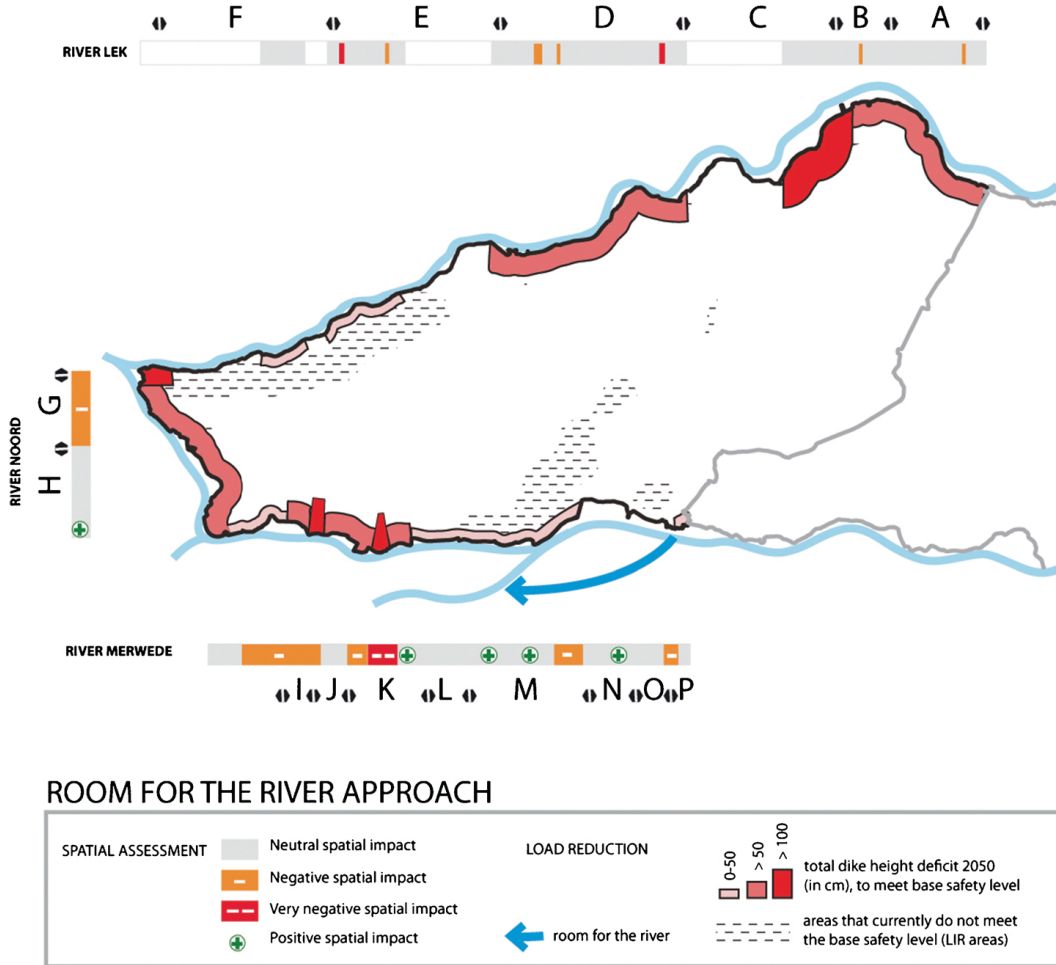


FIGURE 7.6 Probability reduction measures necessary to achieve the LIR standard by following the 'Room for the River' approach

- Six dike segments contribute to flooding instantly, to an inundation level of up to 1.5 m. These segments are therefore major contributors to the emergence of LIR areas. For the north-west LIR area, these segments include section E, F, and G. For the southern LIR area, these are the dike segments L, M, and N. These dike segments are thus said to have a very short arrival time.
- Flood waters entering the polder through a breach in dike segment D would reach the southern LIR area within approximately 16 hours and lead to an inundation level of 1.5 m within approximately 24 hours. This dike segment is therefore indicated to have a short arrival time. Many dike segments have low failure probabilities. Dike segments A and B and parts of dike segments C and D have a failure probability between $1/100$ and $1/1000$. Parts of the dike segments of

C, D, E, H, J, M, and N have a failure probability between 1/1000 and 1/10,000. So-called piping is the main failure mechanism of the dike segments.

When combining failure probabilities with potential consequences of flooding, dike reinforcements or load reducing measures is a priority for dike segments indicated in Fig. 7.

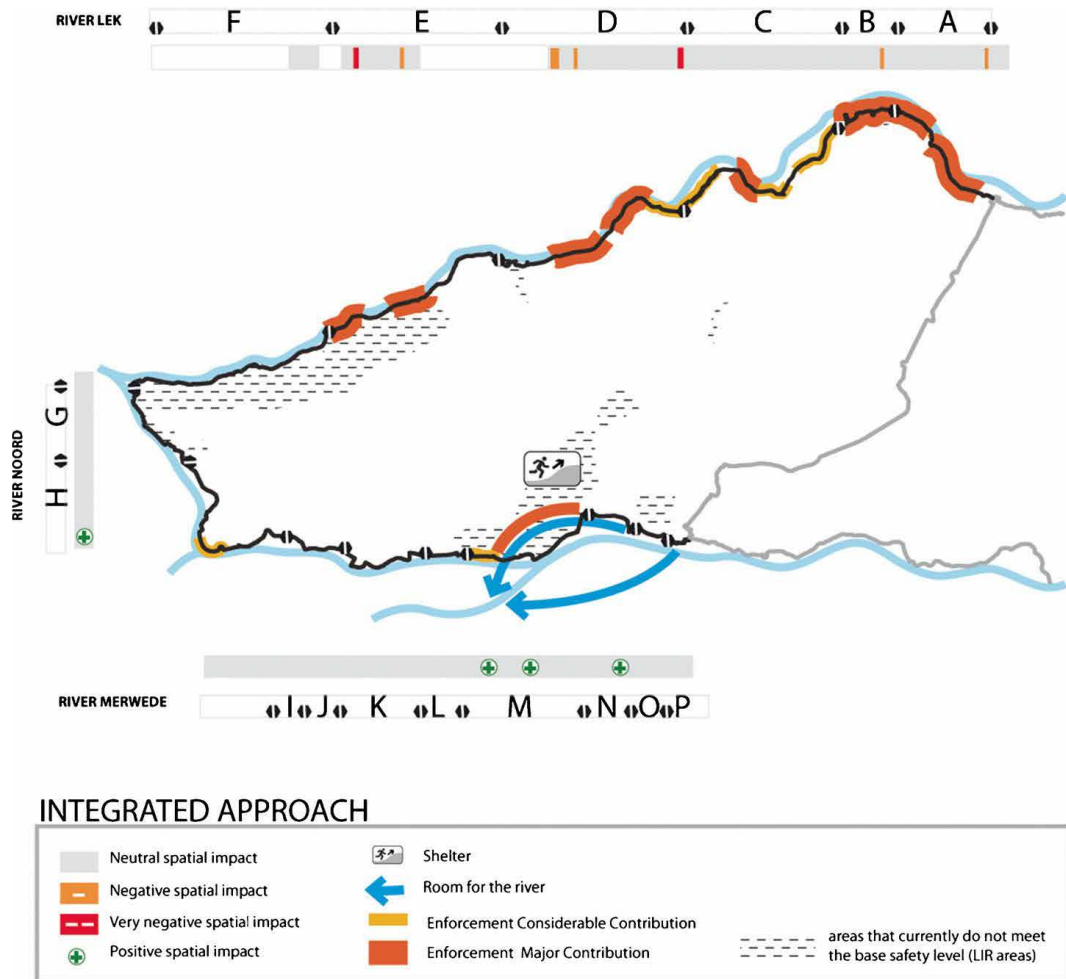


FIGURE 7.7 Probability and consequence reduction measures applied to achieve the LIR standard by use of the integral approach

For the spatial assessment, the outcome of the ex-post assessment of the dike reinforcements from the uniform dike-ring approach is used as ex-ante impact criteria of potential dike elevations. In addition, the 19 effective load reduction measures from the 'Room for the River' approach were evaluated in a similar fashion for their impact on spatial quality as an ex-ante step. One measure is selected in addition to the measure selected earlier in the 'Room for the River' application; the river bypass combined with a harbour in the dike-ring area south of the Alblasserwaard (dike-ring 24). The second spatial potential that was addressed is to combine the construction of a new river bypass along an existing canal with the necessary broadening of the highway along the canal inland of dike segment M.

§ 7.3.4 Step 1: Selection of Measures from a Flood Risk and Spatial Quality Perspective

The combination of a 'Room for the River' intervention with the construction of an additional harbour in dike-ring 24 is considered to have a positive effect on spatial quality as well as a considerable effect on flood risk reduction in the Alblasserwaard. The load reducing intervention is expected to lower the water level of the Merwede during normative conditions with approximately 40 cm near dike segment P.

Along the Lek, most dike reinforcements that have a major impact on risk reduction have a neutral impact on spatial quality, except for some locations in which individual buildings are in close proximity to the dike. In case an individual building needs to be spared from demolition, it is possible to choose a dike enforcement construction using sheet piling, thereby reducing the footprint needed for the dike reconstruction. The dike segments with a major contribution to flood risk reduction along sections A, B, and C have enough space available to bring the levee up to its standard, increase the standard by reinforcing it 26 times, and even to construct a dike with a 1/100,000 failure probability, while maintaining an acceptable level of spatial quality.

§ 7.3.5 Step 2: Revision of the LIR Map

Expert judgement indicated that the interventions as described up to this point will result in a significant reduction of flood risk in the Alblasserwaard. As a result, the LIR area in the north, along the Lek river, now complies to the required basic safety level. However, the dike segment M remains as an essential dike segment to be reinforced in order to fully address the LIR area to the south. Dike reinforcement along dike segment M is indicated to have a very negative impact on spatial quality.

The main argument is that many characteristic buildings in close proximity to the dike body are found along the dike's polder side. Dike reinforcement at this location cannot be realised towards the river side of the dike either since the dike already contributes to the existence of a critical bottleneck in the Merwede river.

§ 7.3.6 Design Optimisation

Further design optimisation is needed to handle the dike section M and the related southern LIR area. Two alternatives are put forward. The first alternative consists of the construction of a cofferdam that strongly limits the space needed for dike reinforcement. A cofferdam is a large construction and can be designed to match a failure probability of 1/100,000. The rough cost indication of this type of dike is €18,700 per metre (Deltares 2013), excluding the potential costs for the demolition of houses along the dike. This would result in a cost estimation of €43 million for the reinforcement of the 2.3 km long dike segment.

An alternative is to combine the 'Room for the River' measure of creating a bypass out of the nearby Steenhoek channel with dike relocation. This 'Room for the River' measure decreases water levels around dike segment P with approximately 14 cm. With that, dike-ring 16 is slightly reduced in size

and the new dike, with a 1/100,000 failure probability, can be combined with the broadening of the highway further inland. This creates a new, small dike-ring area. The cost of this intervention is estimated at approximately €38 million. This dike-ring area will have a high LIR since its small surface is quickly inundated when flooding. The small dike-ring area is positioned in the river dominated area, in which high water levels can be reliably predicted some days in advance. This makes it possible to evacuate this new dike-ring area in a timely manner. In general, the evacuation fraction for dike-ring areas in the river-dominated area is 75 %, instead of the 15 % that is now used for the partly-sea-dominated flood risk rivers alongside the Alblasserwaard dike-ring area. A higher evacuation fraction reduces the consequences of a flood and, with that, the LIR.

As assessed by expert judgement, by increasing the failure probability to 1/100,000 along the dike segment M, the southern LIR area will be resolved. For the design variant that includes the dike relocation combined with a 'Room for the River' measure, it is not yet determined whether it will address the LIR area sufficiently. If necessary, consequence reduction measures, such as flood shelters, can be applied in the potentially remaining LIR areas to further reduce the risk.

§ 7.4 Conclusions and Recommendations

This paper introduced an integrated approach to flood risk management in which spatial quality is included ex-ante. Compared to the uniform dike-ring and 'Room for the River' approaches, two alternatives used in the Netherlands, this new approach offers a flood risk management strategy that reduces the negative impact on spatial quality of the interventions that are necessary to meet the basic safety standard.

In generic terms, applying a risk-based approach allows the inclusion of both probability reduction and consequence reduction measures in flood risk reduction strategies. This has two main advantages:

Firstly, in comparison with a one-sided probability reduction-based approach, as applied, for instance, in the Netherlands, Indonesia, and Thailand, the number of potentially suitable flood risk reduction measures is increased. This broader availability of effective flood risk reduction measures allows for spatial quality to be applied as an ex-ante criterion for selecting measures. The inclusion of the impact on spatial quality of interventions as an ex-ante criterion in the formation of the flood risk management strategy allows spatial planners to be involved in an earlier research stage in which the flood risk management strategy is formed, instead of solely embedding a given regional ex-post flood risk management strategy.

Secondly, the method offers a valuable framework for developing a combined probability and consequence reduction strategy. This allows the method to become a valuable decision-making tool in so-called multi-layered flood risk management approaches, in which interventions regarding the probability and the consequential damage of a flood are combined (Hoss et al. 2011). Multi-layered safety approaches have often been referred to in the flood risk management debate, but so far, consistent methods for achieving a balanced probability and consequence reduction strategy have not been in place.

In order to utilise the proposed methodology, quantitative data and/or qualitative expert guesses on both the effectiveness of probability reduction as well as consequence reduction measures should be

available. Given the Dutch setting of this study, a country with a strong focus on probability reduction and a lack of data on the effectiveness of consequence reduction measures, the consequence reduction measures were subordinate to the probability reduction.

The method would be valuable if applied in deltas with a risk-based flood risk reduction target, where the formulation for a flood risk management strategy is ongoing and both probability and consequence reduction measures can be considered in a multi-layered flood risk management approach. In order to be applied in another geographical and cultural context, the assessment of the effectiveness of flood risk reduction measures and the assessment of the impact on the spatial quality of measures should be adjusted and calibrated to fit the local values.

Notes

Similar systems can be found in the United States, Indonesia, and Thailand; the physical characteristics of such protection-centred approaches are almost identical (CIRIA, 2013).

Z A scenario in which multiple simultaneous dike segment failures occur is not discussed in this study.

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8 Integrated Design for Flood Risk and Spatial Quality Enhancement - Examples from the Dutch Delta Programme

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The assessment of the impact of a potential flood risk intervention on spatial quality at the local scale is an essential element in the research-by-design methodology developed in this thesis (and demonstrated in the previous chapters). Examples of how to explore this impact of the potential flood risk intervention on spatial quality at the local scale are shown in Chapters 5 and 6. In these research-by-design studies, applied to the Rijnmond and Alblasserwaard-Vijfheerenlanden case study areas, a conceptual representation of several business-as-usual flood risk management interventions is spatially projected on to a cross section of the location. It is mentioned in these chapters that design optimisation can mitigate the potential negative effect of a flood risk intervention on the local scale spatial quality (and thereby influence the assessment). In Chapter 6, some basic examples are shown, however, this topic is not elaborated further.

The Scheveningen case described in Chapter 4 elaborately shows a design study in which three different flood risk management interventions are optimally embedded spatially. This study also shows an elaborate analysis of the spatial characteristics, challenges, and ambitions of the area. However, this approach is too elaborate and time consuming to apply as part the research-by-design method in which the impact on the local scale spatial quality of a wide range of potential flood risk management interventions is tested.

This last publication shows an overview of some research-by-design studies, performed during this PhD research, that apply different approaches to test the impact of potential flood risk interventions on the local scale spatial quality. They vary from elaborate embedment studies (Scheveningen) to a more condensed research-by-design approach that could be included in the developed method (Sliedrecht & Houston).

In the design studies, the following method is applied to a greater or lesser extent:

- Creation of an inventory of the spatial-economic ambitions and challenges of the location
- Creation of an overview of possible (and viable) technical options for dike reinforcements
- Performing a design study for the spatial implementation of each intervention
- Reflecting on the pros and cons of the applications

The spatial ambition map developed for the Alblasserwaard-Vijfheerenlanden case study, which is included in this chapter, is a valuable example of how to inventory the spatial-economic ambitions and challenges of the location.

Key aspects: Spatial characteristics area, research-by-design, connection to practice, The Hague Scheveningen, Alblasserwaard-Vijfheerenlanden, Galveston (Houston) Texas.

Background

Due to its position on the edge of the Rhine-Meuse delta, the Netherlands faces a significant flood risk management challenge. As with many other urbanised deltas worldwide, its favourable position from an economic and trade point of view leads to urban development in areas that require continuous water management efforts (UN-Habitat 2006). The Netherlands has developed an extensive flood risk protection system consisting of dike-rings, barriers, and dunes. Nevertheless, unless additional measures are implemented, flood probability and consequences will increase due to climate change, subsidence, and the growing economic value and occupation in the areas that are protected. Thus, for the Netherlands to remain a safe and attractive country, its flood risk protection system will have to be updated (Delta Programme 2008).

§ 8.1 Introduction

The Netherlands faces a significant flood risk task. In order to remain a safe place to live, the Netherlands has to upgrade its extensive flood risk protection system. This results in an elevation and reinforcement task for many of the Netherlands' water barriers. When those barriers are positioned in an open landscape, the technical reinforcement is often especially easy to embed. However, many barriers have been built over the years making the reinforcement into a challenging spatial assignment. This article shows different case study examples of a research-by-design study (performed in the broader context of the Dutch Delta Programme that explores integrated design solutions for flood risk and spatial (re)development. The Houston Galveston Bay case study demonstrates the international applicability of the research-by-design method.

§ 8.1.1 Context

Substantial parts of the Netherlands are below sea level: 60% of the country is subject to (significant) flood risks from the North Sea, lakes, and rivers (Fig 8.1 (Kok et al. 2016)). For protection, an extensive system consisting of natural dunes, high grounds, dikes, barriers, locks, and dams has been created. Figure 8.2 shows some typical sections of land-water transitions formed by a) natural sandy dunes, b) polder dikes and c) natural high grounds. Natural high grounds are present primarily in the eastern part of the country, which is elevated above sea level and safe from flooding from the sea or rivers. Natural sandy dunes, originally formed by sedimentation processes, can be found along the coastline. Man-made additions such as dikes and barriers complement the high grounds and dunes, and can be found along the North Sea, estuaries, rivers, and lakes. Dikes played an important role in developing the polder system: polders were created by building closed systems of dikes in and around water-rich areas such as lakes and estuaries, and the subsequent draining of the enclosed areas using windmills and (steam-)pumping stations. The biggest Dutch infrastructure works related to water safety are the Delta Works; following the 1953 North Sea flood, which caused major fatalities and inundated large parts of the country, a comprehensive system of fixed and flexible barriers that provides protection against storm surges was created.

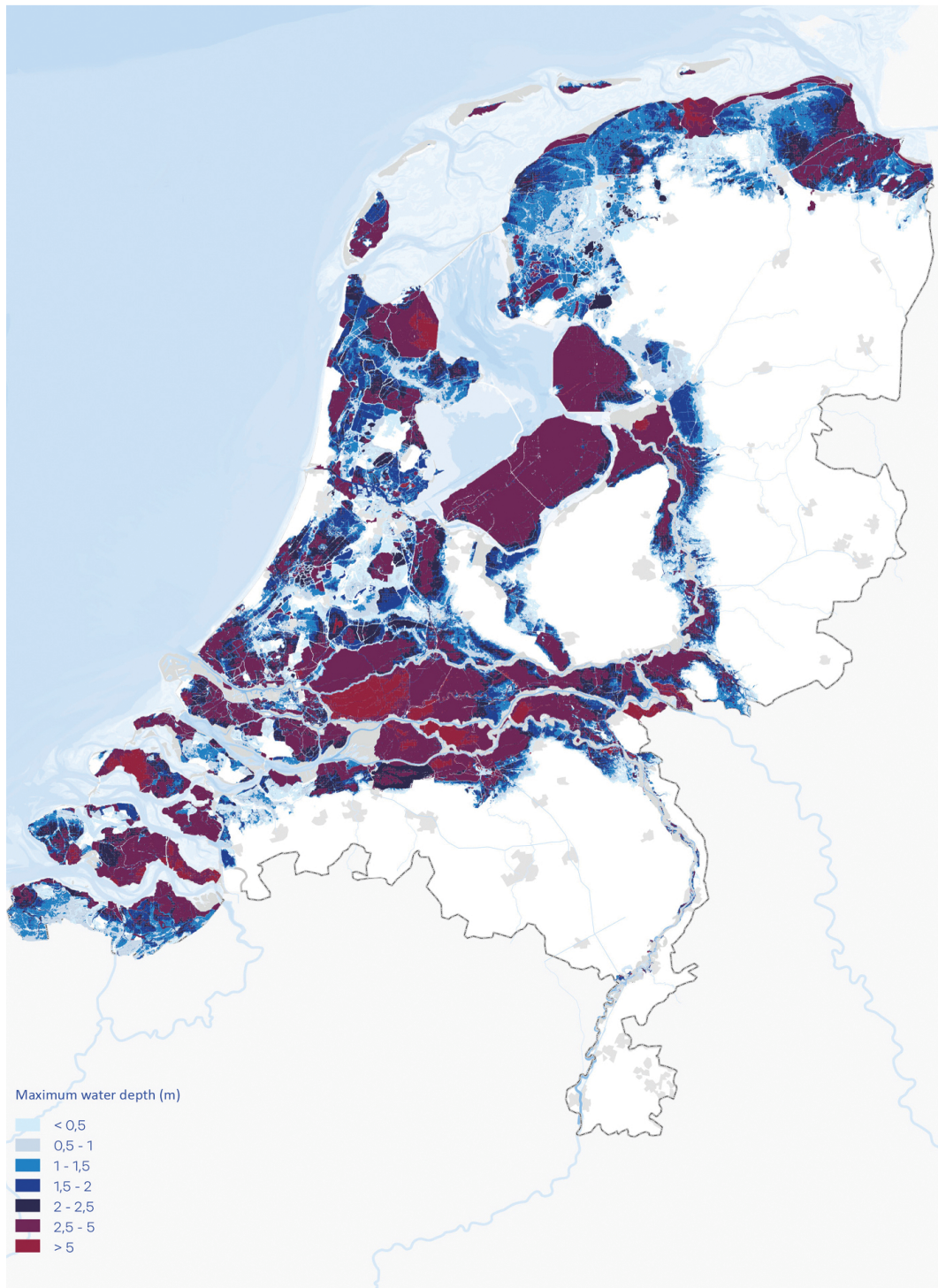


FIGURE 8.1 Map indicating the 60% of the Netherlands that is liable to flooding from the North Sea, lakes and major rivers. Potential water depths may locally exceed five metres. Source: Kok et al. (2016).



FIGURE 8.2 Photographs and diagrams of different elements of the Netherlands flood risk protection system a) natural sandy dunes, b) river dikes and c) natural high grounds. Photo of the natural high grounds of the city of Nijmegen by Rijkswaterstaat, Harry van Reeken.

§ 8.1.2 The Hague-Rijnmond Region

In this article, three integrated flood risk and spatial design studies for The Hague-Rijnmond region are described. Fig. 8.3 shows the region's flood risk protection system and spatial context. It is home to approximately 2.5 (of a total of 17 million) citizens, and includes The Hague and Rotterdam, the second and third largest cities in the country. The city of The Hague, positioned along the coast, is the seat of the Dutch national government. Rotterdam, located along the river Meuse and directly connected to the river Rhine, is a major seaport. It serves as a gateway to northwest and central Europe and contributes substantially to Dutch GDP. The dike-ring around this high-value urban cluster, dike-ring 14, is therefore assigned a high protection standard.

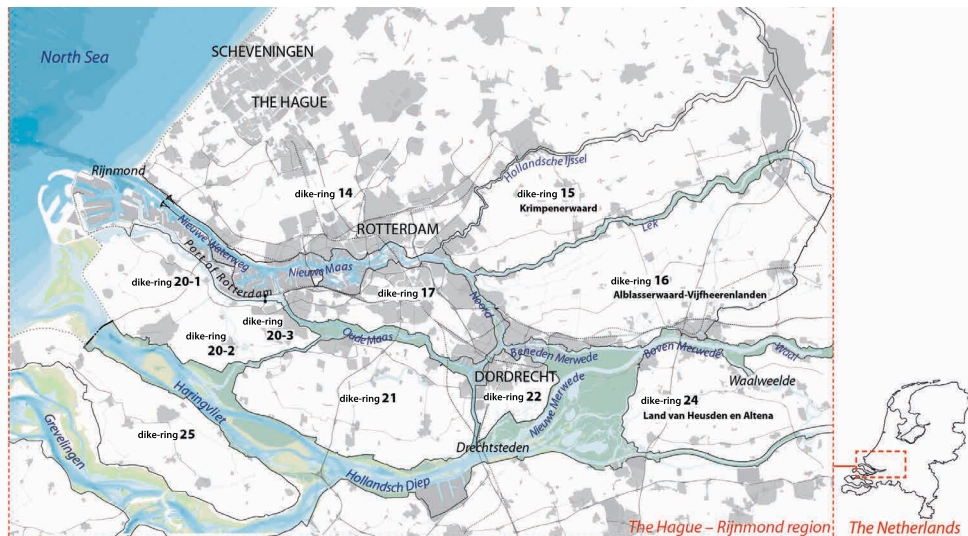


FIGURE 8.3 Map of The Hague-Rijnmond region, southwestern corner of the Netherlands. The map includes different dike-rings in this region.

The region also includes several rural polder areas among which is Alblasserwaard-Vijfheerenlanden, also referred to as dike-ring 16. This polder is largely positioned on peat soil and mostly used for agriculture (Steenbergen and Reh 2009). Unembanked areas along the polder are home to hydraulic engineering and shipbuilding companies. Dike-ring 16 has a lower economic value and density than dike-ring 14 and therefore a lower flood risk protection standard (Brinke and Jonkman 2009). However, this peat polder is subsiding; in case of flooding, it would be inundated quickly and faced with high water levels (de Vries 2014). It therefore also requires considerable protection..

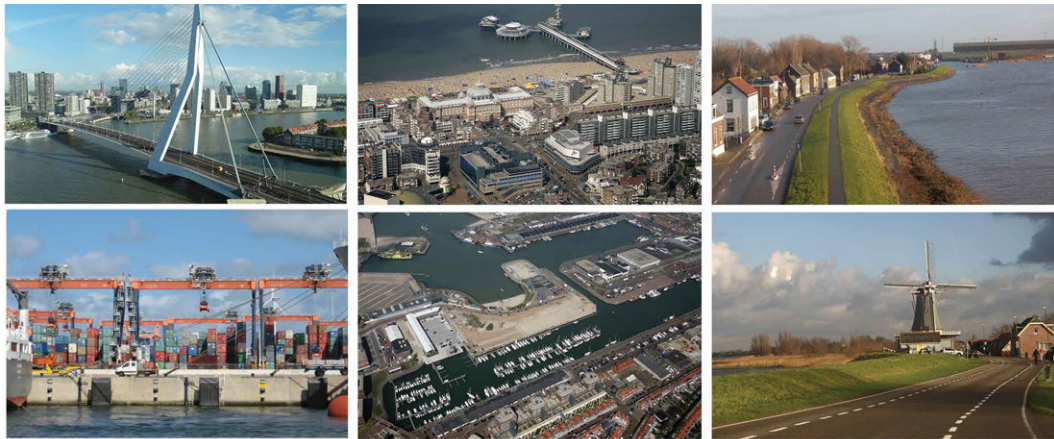


FIGURE 8.4 Characteristic photos of the ton region including Rotterdam (left), The Hague’s seaside Scheveningen (centre, source: Municipality of The Hague), and Alblasserwaard-Vijfheerenlanden polder area (right).

§ 8.1.3 Delta Programme

To proactively address future flood risks, the Delta Programme was established and tasked with developing long-term flood risk strategies, with a time frame up to the year 2100 (Delta Programme 2008). Establishing increased safety norms, to accommodate for the expected increase in flood risks, is part of the programme’s strategy. The increased safety norms may subsequently result in the need to reinforce many of the barriers, dunes, and dikes in the future. Fig. 8.5 provides an indication of the dike elevation task resulting from climate change and subsidence. The new increased flood risk standards for the The Hague-Rijnmond region will further increase the dike elevation and reinforcement task.

A dike that is constructed from sand and clay, and that is positioned in an open landscape, can be reinforced relatively easily by expanding its height and width. However, many dikes that used to be located in an open landscape have become part of urban areas; there, the implementation of reinforcements is more challenging. Fig. 8.6 shows different options for implementation. There are technical options to reinforce a dike with minimal spatial impact, using an expensive steel pile sheet or cofferdam construction. As a result of a previous iteration of reinforcing dikes—necessitated by increased flood risk standards following the 1953 North Sea flood—many houses were demolished to provide space for reinforcements (see Fig. 8.7). Future dike reinforcements must be realised in a markedly different political context: both the resistance to demolishing historical buildings and a recognition of the importance of spatial quality of the built environment (and specifically the appreciation for cultural heritage) have grown (Klijjn et al. 2013).

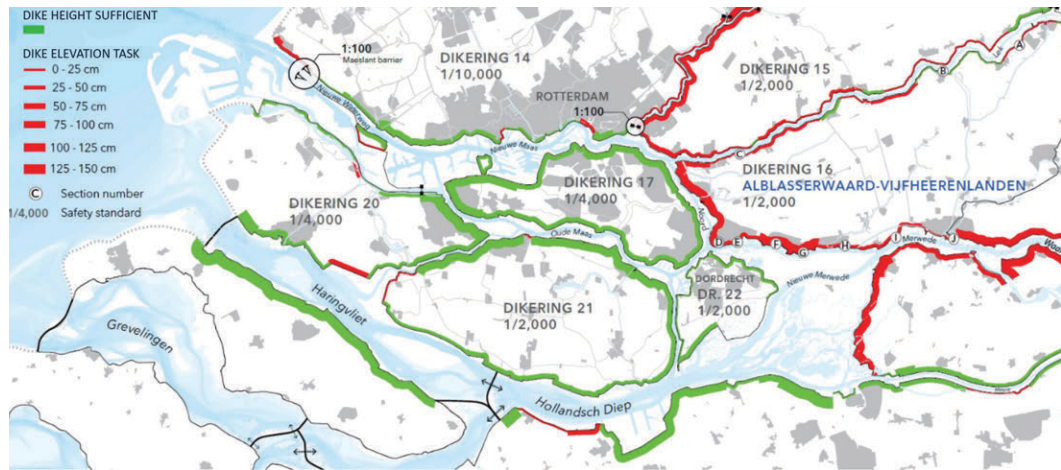


FIGURE 8.5 Dike elevation task for the different dike-rings in the The Hague-Rijnmond region, due to climate change and subsidence (based on data by vd Kraan 2013). Red indicates dikes that require reinforcement, with line thickness indicating height deficiency. The new increased flood risk standards for The Hague-Rijnmond region will further increase the dike elevation and reinforcement task.

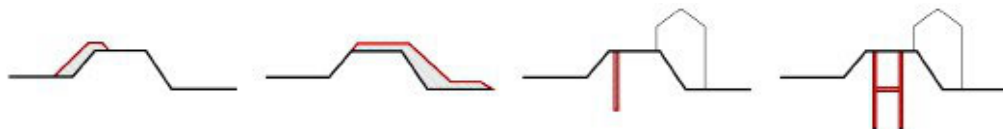


FIGURE 8.6 Different options for reinforcing a dike: on the left an inner-dike and outer-dike option for reinforcing a dike with earth; on the right two constructions: the sheet pile and a cofferdam.



FIGURE 8.7 On the left, a historic photo of the Sliedrecht dike, showing the historical presence of trees and buildings in the unbanked area along the river. The trees were removed to accommodate for dike reinforcements, changing the spatial characteristic of the dike ribbon. The picture on the right shows the current situation. Photos: Sliedrecht historic society (<http://www.historie-sliedrecht.nl>).

§ 8.2 Project

The developments described above together result in an urgency to develop integrated strategies and designs in which technical and spatial aspects are combined (Meyer, 2009). Research-by-design methodologies are used to explore the potential spatial impact and spatial economic opportunities that are associated with the necessary flood risk measures; the application of these methodologies in an early stage has become a key element of the Delta Programme. In this article, utilisation of one such methodology by urban design office Defacto is demonstrated for three locations in the The Hague- Rijnmond region: Sliedrecht, Scheveningen, and Kinderdijk.

§ 8.2.1 Case Study Selection

In the region of The Hague-Rijnmond, reinforcements will have to be implemented in multiple locations. For some of these locations, embedding these reinforcements in their environment in an acceptable way, from a spatial perspective that is, will be difficult, due to, for instance, urbanisation or specific landscape characteristics (Delta Programme 2011). An overview of these locations was created. Fig. 8.8 shows the results of a design study in which the expected impact of a standard 'business-as-usual' dike elevation on spatial quality is assessed for locations along the Alblasserwaard-Vijfheerenlanden dike-ring. In some instances, traditional dike reinforcements would have a considerable negative impact on the spatial quality of the location; in those cases, the implementation of integrated designs may possibly mitigate negative effects.

In addition to selecting locations where dike reinforcements would be difficult to embed spatially, the programme also looked for possible synergies between spatial and technical assignments. Such synergies might, for instance, result from integrating flood risk management interventions with urban (re)development projects.

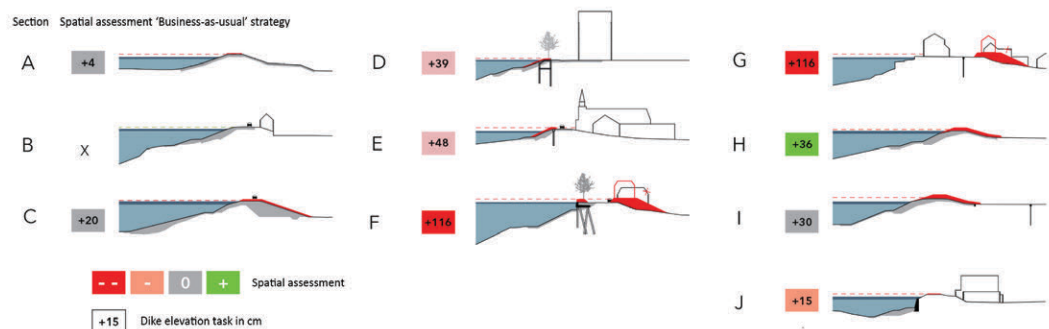


FIGURE 8.8 Results of a design study in which the impact of the expected 'business-as-usual' standard dike elevation on spatial quality is assessed. The numbers represent the expected dike elevation (in centimetres). The sections correspond to the locations indicated in Fig. 8.5. The colours indicate the assessed impact on spatial quality which can be: positive (green), neutral (grey), slightly negative (light red), or very negative (dark red). The sections represent different dike typologies along the Alblasserwaard-Vijfheerenlanden dike-ring. Section G represents the Rivierdijk in Sliedrecht. Based on a very negative assessment for implementing a standard dike reinforcement, a design optimisation study has been performed for this location (see Case Study 1: Sliedrecht).

To obtain an overview of developments that can possibly be linked to dike reinforcements, a so-called spatial economic 'opportunity map' was made. In those maps, different spatial assignments and projects are inventoried (by means of desk study and interviews) and shown in combination with the expected dike reinforcement task (Bos 2016).

Fig. 8.9 shows part of the opportunity map for Alblasserwaard-Vijfheerenlanden (dike-ring 16). Spatial assignments for this area include aspects such as preservation of cultural heritage, improved mobility and traffic safety, building and redevelopment projects, improvement of recreational routes and ecology, strengthening the (visual) relationship with the Merwede river, and improving the associated shipping channel.

Each of the three case studies selected for this article represents a different relationship between flood risk and spatial assignment (as can be seen in Fig. 8.10). In the first case study, which concerns the town Sliedrecht, the assignment is focused on embedding the flood risk management interventions so as to preserve characteristics of the existing historical dike ribbon. In the second case study, regarding the seaside section of the city of The Hague, the flood risk task coincides with the ambition for urban redevelopment and extension. The third case study concerns Kinderdijk, a UNESCO world heritage site. There, dike reinforcements are easy to embed; still, synergies can be achieved if dike reinforcements are used as a catalyst for integrated development.

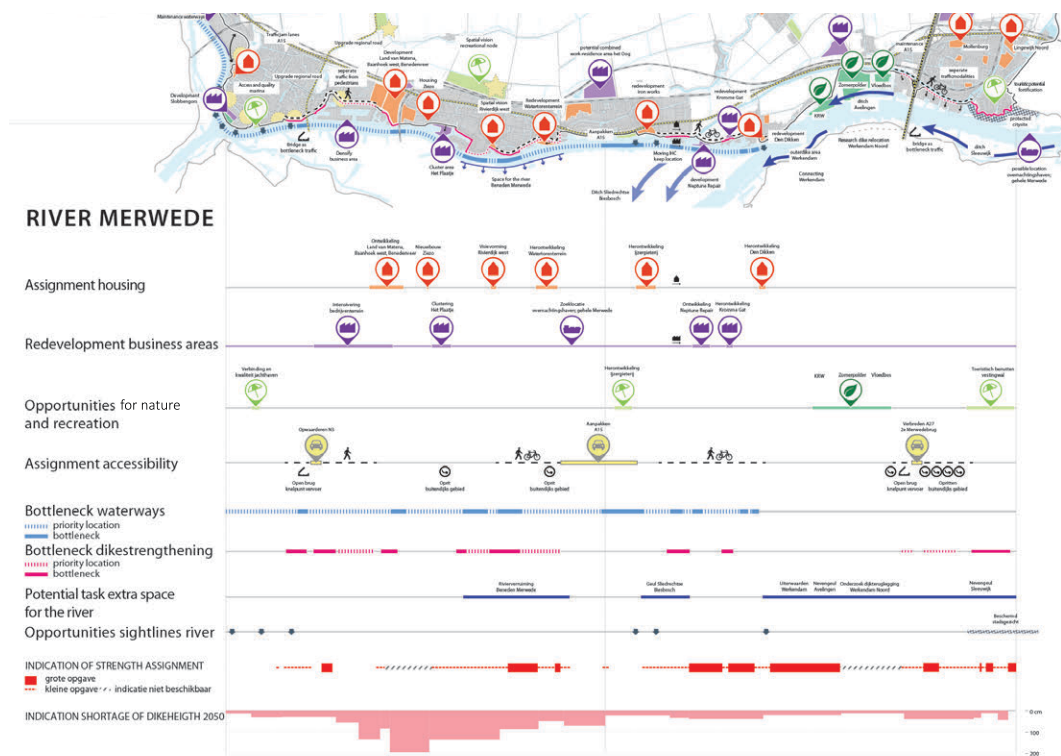


FIGURE 8.9 'Opportunity map' showing both the indicative dike reinforcement task as well as different spatial assignments and projects. This map is a cut-out of a larger map and shows the southern dike of the Alblasserwaard Vijfheerenlanden, along the Merwede river.

Case study locations	Dike reinforcement spatially difficult to embed	Opportunity for synergy with urban (re)development
1 Sliedrecht	V	x
2 Scheveningen	V	V
3 Kinderdijk	x	V
4 Galveston (USA)	V	x

FIGURE 8.10 Overview of different case study locations, selected because dike reinforcements are spatially difficult to embed and/or offer opportunities for synergy with spatial (re)development.

Often, it is questioned whether the approaches described in these case studies are applicable beyond the Netherlands. Therefore, the Houston/Galveston Bay area is included, to demonstrate applicability of research-by-design in a non-Dutch, international context.

§ 8.2.2 Research-by-design Methodology

In all case studies, research-by-design is employed to explore possibilities for combining flood risk and spatial design. The term research-by-design is widely used, and many different definitions exist (Geldof and Janssens 2013). In the research-by-design methodology used in the cases studies, multiple different 'technical' variants are tested for each location and then assessed for their spatial potential. In order to do this, teams were formed that included technical experts, local experts, and spatial designers. Although the focus of the research-by-design studies varies, in all case studies the following research-by-design steps have been applied to a greater or lesser extent:

- Creation of an inventory of the spatial-economic ambitions and challenges of the location
- Creation of an overview of possible (and viable) technical options for dike reinforcements
- Performing a design study for the spatial implementation of each intervention
- Reflecting on the pros and cons of the applications

The research-by-design studies resulted in a range of viable design variations, each with its own characteristics. It is not necessarily the objective to choose a favourable solution; rather, the aim is to identify a range of possibilities. The outcome provides insight to local municipalities with regard to the impact and opportunities related to future dike reinforcements. This allows municipalities to be activated: they can prepare budgets and seek timely cooperation with waterboards in order to reach agreement on integrated design solutions (waterboards are independent governmental bodies responsible for a range of water-management and water-safety tasks) (Kok et al., 2016, p.25). This approach provides the opportunity to realise dike reinforcements with a positive impact on the built environment.

§ 8.3 Case study 1: Sliedrecht

Sliedrecht is a town along the river Merwede with approximately 25,000 inhabitants. Its shipbuilding, hydraulic engineering and dredging companies are closely linked to the country's aquatic history and economic development. The town originated as a built dike ribbon and subsequently expanded into the polder as well as the riverbed.



FIGURE 8.11 Aerial photo of the Rivierdijk in Sliedrecht (source: PDOK). On the right, a photo of the built dike from the road (centre of the dike) and from the river.

Historically, in Sliedrecht as well as elsewhere, houses and other structures were constructed along both sides of a dike ribbon—referred to in the remainder of this article as double-sided built dikes. During previous rounds of dike reinforcements, this often left little room for expansion; dikes had to be altered or completely reconstructed, with structures being demolished on at least one side. Some stretches of double sided built dikes still exist; the longest such stretch is the 'Rivierdijk'. It is a narrow dike with separate houses on both sides along a staggered building line. It dates from the 19th century; some of the buildings are considered protected monumental heritage (Province of South Holland).

§ 8.3.1 Spatial Ambitions and Assignment

Spatial assignments mentioned for this area are the preservation of the historic dike ribbon, the improvement of traffic safety on the narrow dike road, strengthening the visual relation with the river and widening the shipping channel. For this location, the primary objective was to identify integrated solutions that would respect and, if possible, preserve the cultural value of the dike ribbon.

§ 8.3.2 Possible (and viable) Technical Options

Reinforcement of the dike ribbon is likely to be needed as a result of increasing river discharges, sea-level rise, and increased risk acceptability standards. A range of potential reinforcement options have been inventoried and assessed on their technical applicability (see Fig. 8.12).

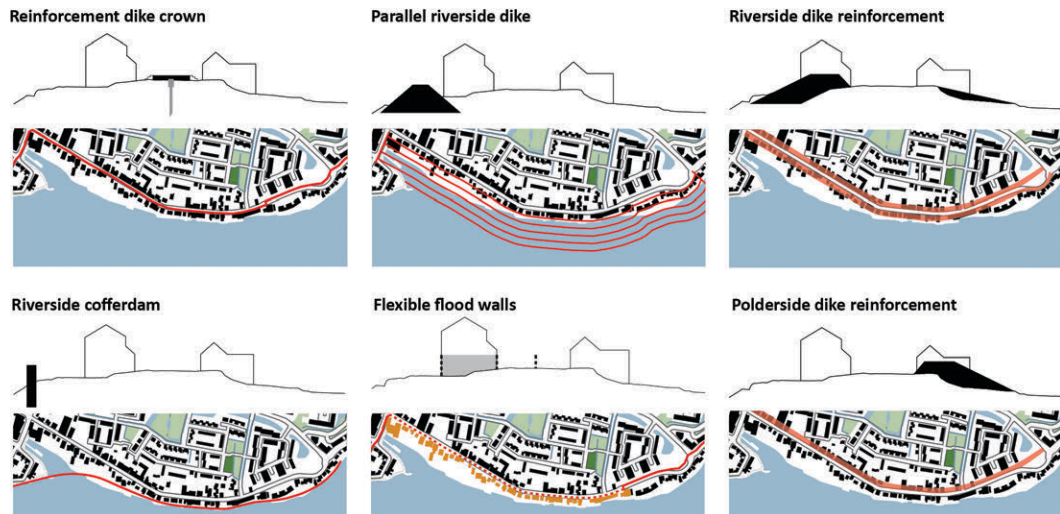


FIGURE 8.12 Overview of potential reinforcement options that have been inventoried (this is a selection from the complete overview).

Such options include: the reinforcement of the dike crest (through the use of a cofferdam or pile sheet); flexible flood walls (for instance with sand bags); reinforcement of the inner slope; reinforcement of the outer slope; the construction of a parallel dike either the riverside; or a cofferdam in the river.

During the technical applicability assessment, temporary flood walls with sand bags were dismissed because these cannot meet the protection standard; reinforcement of the outer dike slope would require reinforcement of the inner dike slope, thus not offering a viable alternative for reinforcing the inner dike slope. The inland parallel dike would result in a large new dike in another built-up and low-lying area, which was not perceived to be a viable alternative option either. Implementation of the remaining options was subsequently analysed in design studies.

§ 8.3.3 Design Study: Reinforcing the Inner Slope of the Dike

Reinforcement of the inner slope can be considered as the ‘business-as-usual’ solution for dike reinforcement of double-sided built dikes. This does not necessarily imply that all houses on the inner slope need to be demolished. In previous dike reinforcement projects, this solution was implemented leading to an adverse impact on spatial quality of the dike ribbon. Despite the intention to create a more liveable, modern street profile, the historical characteristics of the dike ribbon disappeared. Not

only does newer larger scale housing not match the remaining small-scale houses, the widened road with separate lanes for pedestrians, bikes, and cars is not in proportion to the scale of the remaining original houses. Therefore, using the same solution for the new iteration of dike reinforcement would require careful redevelopment that respects original characteristics such as: the individually built small-scale houses, the narrow road, matching low façades, and the staggered plot lines.

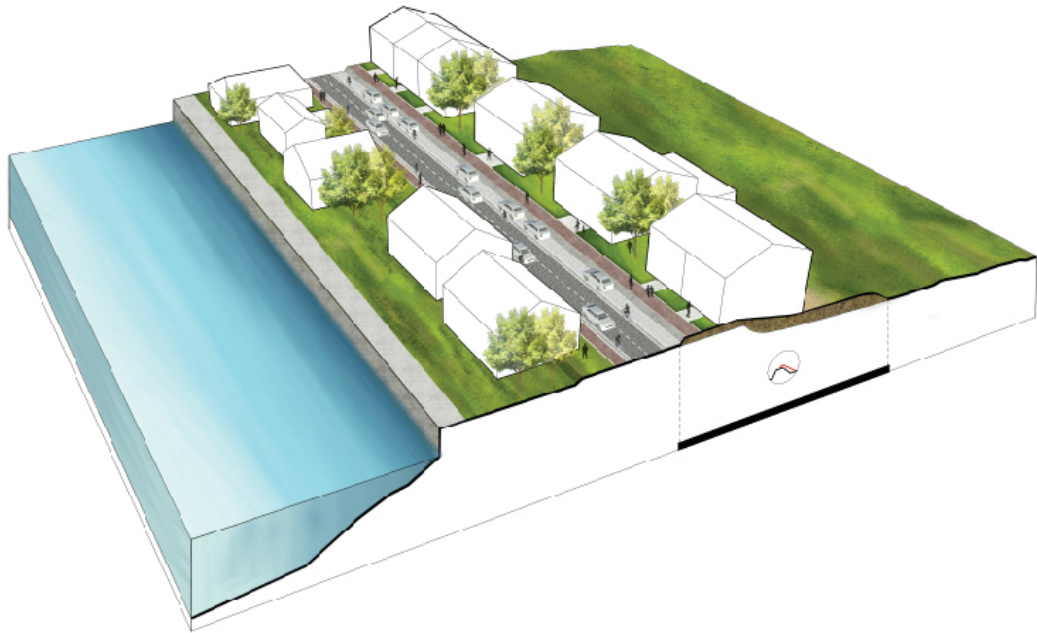


FIGURE 8.13 Visualisation of the reinforcement of the inner slope. When reinforcing the inner slope, buildings either need to be jacked up or replaced. This option is considered a ‘business-as-usual’ option, since, in previous dike reinforcement iterations, this concept was commonly practised. It is challenging, but possible, to preserve the existing characteristics of the double-sided built dike ribbon. The most challenging part of the redesign is to balance dimensions since the width of the street profile will increase and be elevated, while the small-scale houses on the outer slope remain.

§ 8.3.4 Design Study: Parallel Dike in the River

Construction of a parallel dike in the river allows for the preservation of the original dike ribbon. However, the visual relationship between the houses along the outer dike slope and the river would change dramatically. This solution was applied along other parts of the dike and therefore perceived by local stakeholders as a viable and promising option. By including a footpath along the water, the new dike can provide a new, safe route for pedestrians with spatial proximity to the water. At the same time, a parallel dike further narrows the shipping channel, making it impossible to pursue this alternative without additional compensating measures. In this location, the compensating measure would be to widen the river on the opposite side. Given that the opposite side is part of a different municipality and, most notably, of a protected natural reserve, this means that the parallel dike would require politically challenging compromises.

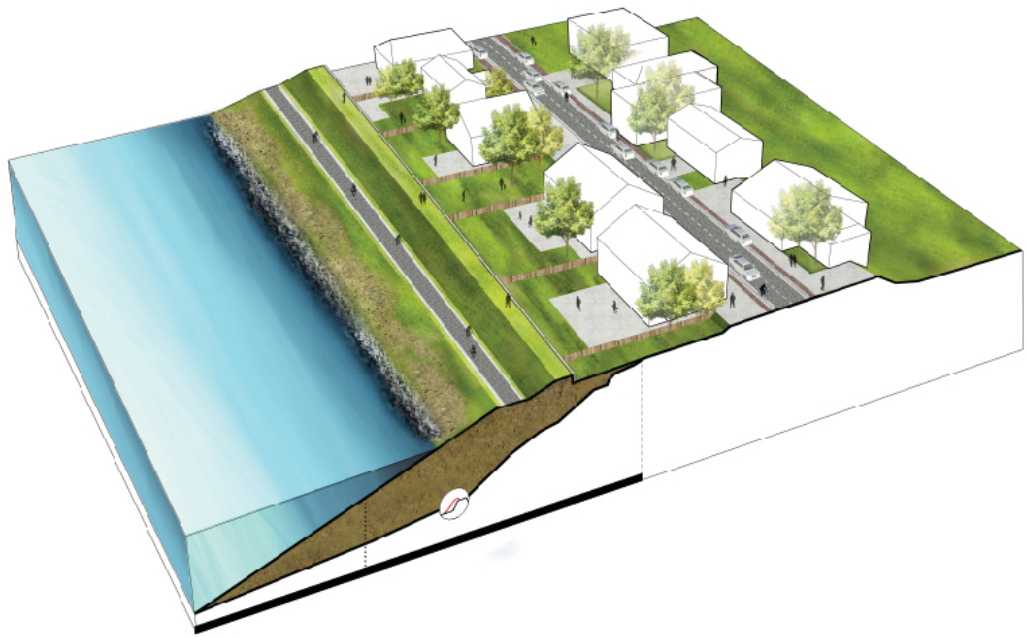


FIGURE 8.14 Visualisation of the parallel dike in the river. The footpath along the dike is positioned at a lower level. This allows for a stronger relationship with the river and preservation of privacy for the adjacent gardens.

§ 8.3.5 Design Study: Parallel Cofferdam

A derivative from the parallel dike is the parallel cofferdam. It requires less space and therefore does not compromise the shipping channel. This option results in an inspiring typology that is so far uncommon in the Netherlands. The cofferdam could include a footpath parallel to the main road that creates a safe walking route and allows pedestrians to stroll along the riverbank. The path could create a staged route with different sequences of views and proximity towards the river. Although the view from houses along the dike towards the river is obstructed in a similar fashion to the parallel dike, all buildings can be preserved. As an additional advantage, this could be an interesting pilot and showcase for the local hydraulic engineering companies.

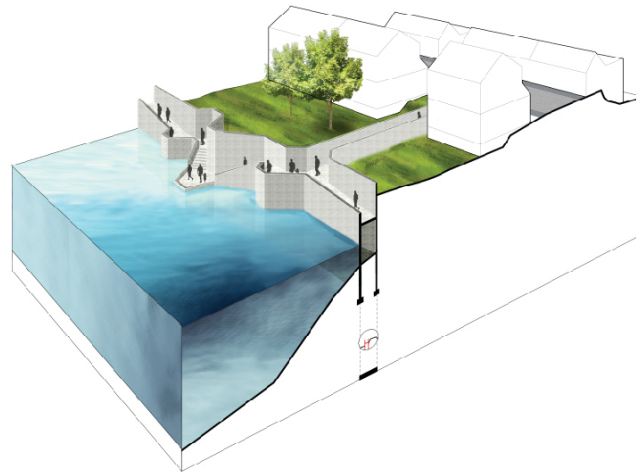


FIGURE 8.15 Visualisation of the parallel cofferdam. The coffer dam has the potential to function as a recreational pedestrian route with close proximity to the river.

§ 8.3.6 Design Study: Reinforced Dike Crown

Despite space limitations, it is possible to heighten the existing dike crown. This method was originally applied in the area to preserve the existing rows of buildings. By, again, reinforcing and elevating only the centre section of the dike, houses can be preserved. They can then be accessed through narrow walkways alongside the dike. This solution fits the characteristic of the area, where the houses have slowly been disappearing behind the dike. The road would narrow resulting in insufficient space for a two-lane road, transferring the road into a one-way vehicular road (and two-way bike lane) could, according to the experts, resolve this while also improving the traffic safety. A big advantage of this solution would be that the original relationship between the dike houses and the river would remain.

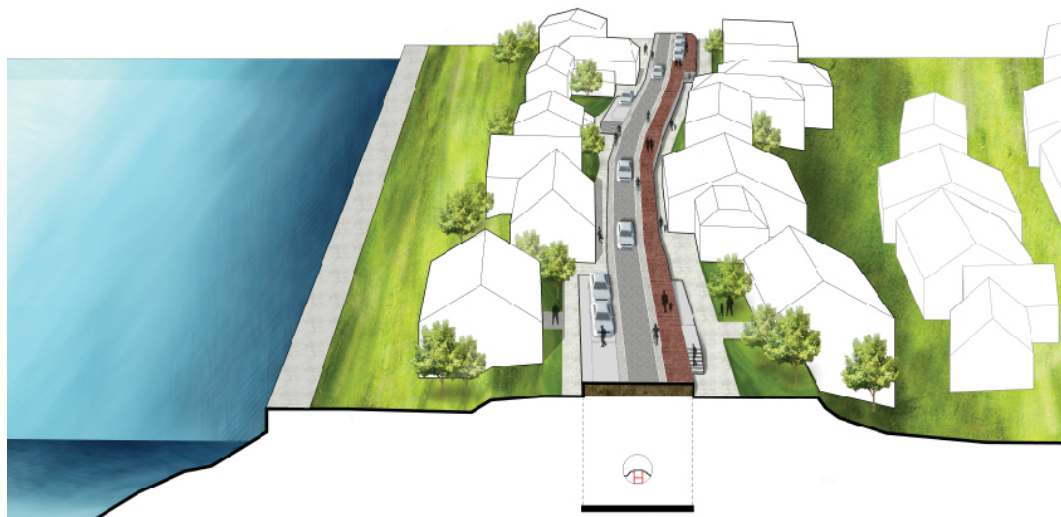


FIGURE 8.16 Visualisation of the reinforced dike crown. By creating a one-way vehicular road (instead of the current two lanes of vehicles) there is sufficient space for a continuous pedestrian path.

§ 8.4 Case Study 2: Scheveningen

Scheveningen used to be an independent fisherman's village on the coast. It has gradually become a neighbourhood of the city of The Hague. Tourism started there in the early 19th century. Nowadays, this seaside borough is known as a recreational resort with a nationwide reputation. The monumental 19th century Kurhaus and pier are reminders of the long history of tourism and recreation.

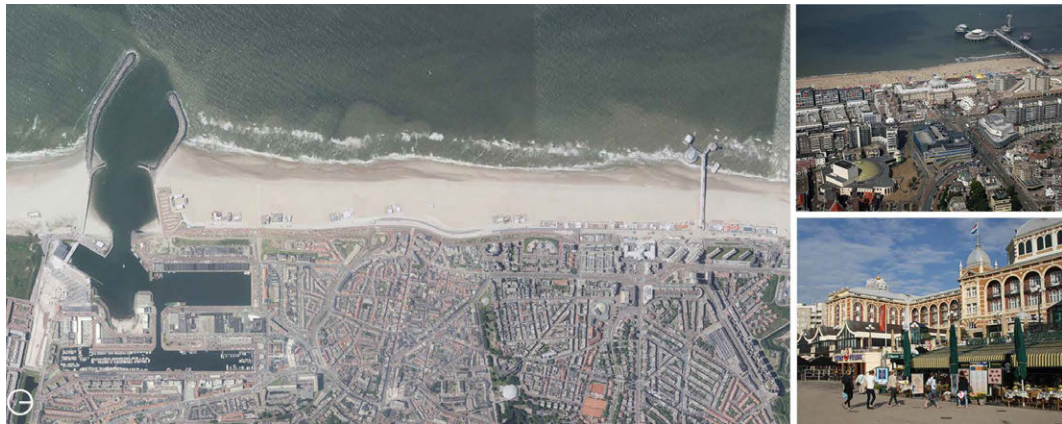


FIGURE 8.17 Aerial photo of the Scheveningen seaside (source: PDOK). On the right, an aerial photo of the Kurhaus and pier area (source: Municipality of The Hague) and, below right, a photo from the Kurhaus taken from the seaside boulevard.

§ 8.4.1 Spatial Ambitions and Assignment

The close proximity of a city to the sea is rare in the Netherlands and results in a unique identity that the municipality of The Hague would like to strengthen further. However, Scheveningen currently faces socio-economic and spatial challenges (Municipality of The Hague 2009) with regard to the vitality, identity, accessibility, and spatial quality of the area. For the harbour area, an urban transformation is envisioned in which the current fishing harbour has the potential to partly transform into a housing or business district.

An important ambition is the improvement of the spatial quality of the shore area (Municipality of The Hague 2009). Also, the accessibility of the shoreline is an important theme. Not only is the shore difficult to access by public transport or car: the urban tissue between the main traffic road and the shoreline is difficult to permeate for pedestrians. Fig. 8.18 shows the results of a GPS user study performed by the Delft University of Technology. It shows that the built tissue along the coast is mainly penetrated by pedestrians on one of the main entrance points of the boulevard. This might also relate to the fact that it's difficult to orientate: it is unclear which direction to follow towards the shoreline since there is no visual connection.

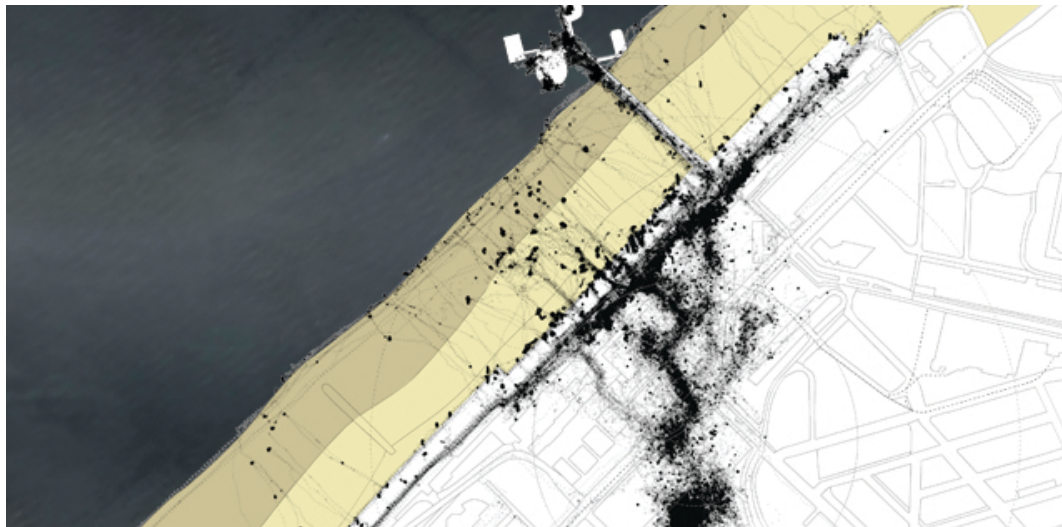


FIGURE 8.18 Results of a GPS tracking study by Delft University of Technology. Data shows people's trajectories starting from a GPS distribution point, lower-central part of the map. A lot of people visit the beach and boulevard; most of them use the main entrance route towards the beach, as the built tissue along the beach has low permeability.

§ 8.4.2 Possible (and Viable) Technical Options

The water defence line of the flood risk protection barrier, best characterised as a dune, runs through the touristic heart of Scheveningen. Reinforcing the barrier in this highly densified area is challenging. Formerly a weak spot and urgently in need of improvements, the sea defence line was recently upgraded. It was moved seaward as there was sufficient space to reinforce the dunes along the beach. The reinforcement was used as a catalyst to upgrade and improve the design of the boulevard.

In the current design study, three different viable technical options are explored: a seaward quay, a seaward dune extension, and a perpendicular dam. The exploration focusses on long-term development options, beyond the year 2050. Different technical starting points lead to multiple design concepts that are described below. In each of them, the main roads coming from the city centre of The Hague are emphasised and extended towards the coast.



FIGURE 8.19 (left) The water defence line that runs through the urbanized seafront of Scheveningen. In the middle part the water defence line has already been brought seaward, during a recent reinforcement. The landscape design was created by De Solà-Morales (photo on the right: Rijkswaterstaat, Harry van Reeken).

§ 8.4.3 Design Study - 'Hard Seaward' Extension: City by the Bay

In this option, the existing boulevard area is extended at a level of +14 metres NAP (see white extension, Fig. 8.20). Compared to the current situation, the water defence line is moved further seaward, thus creating space for a housing and business district adjacent to the sea. The new platform provides sufficient parking space. In front of the new district, a lower platform positioned at +7 metres NAP forms a zone closer to the sea with ample room for recreational functions such as a tidal pool, bars, restaurants, and surf schools. Along the shoreline, a wooden walkway provides access to the sea for swimming; it will flood during high tide.



FIGURE 8.20 Conceptual ground plan of the city at the sea proposal (with the 'hard seaward' quay extension).

From the endpoints of the roads coming from The Hague, there is an open view towards the sea at the higher +14 metres platform. The tidal swimming pool (middle left), a dune park (middle right), and a seaside square (on the right) can all be seen from there. The latter restores the connection between the historic Kurhaus and the sea. This design option emphasises the character of the high density urban area close to the sea and strengthens the identity of Scheveningen, and The Hague as 'city by the sea'.

§ 8.4.4 Design Study - 'Seaward Dune' Extension: City Behind the Dunes

In this option, the existing natural dunes are extended in a seaward direction (see Fig. 8.21). The water defence line also moves seaward and allows for new development, but in a different fashion to that of the 'hard seawall'. A sandy dune is at risk of erosion during storms. The outermost part of a dune, closest to the water, is therefore unsuitable for permanent structures. Although this limits the possibilities for development somewhat, it creates a unique natural end recreational dune landscape that connects existing natural dunes on both the southern and northern edges of Scheveningen. The

resulting beach can host seasonal pavilions used for recreation during the summer. Along the harbour, a unique living environment can be created with high-rise residential towers positioned in the dune landscape.



FIGURE 8.21 Conceptual ground plan of the 'City Behind the Dunes' proposal (with the seaward dune extension).

§ 8.4.5 Design Study - 'Perpendicular Dam': A City in the Sea

The third design study option (see Fig. 8.22) was derived from the assessment of the previous seaward extensions; it became apparent that both seaward extensions would require significant maintenance. Sand would have to be supplemented periodically to ensure the seaward extension would not erode.

The perpendicular dam was proposed to address this issue. Based on a rule of thumb, a perpendicular dam causes sedimentation along a coastal stretch of 1.5 times the length of the dam and additional erosion beyond that stretch. This information was key to positioning the dam, given the wish to protect the urban core of Scheveningen, while the adjacent natural dune park area might benefit ecologically from erosion.



FIGURE 8.22 Conceptual ground plan of the 'City in the Sea' proposal (with the perpendicular dam).

The dam makes it possible to extend the city into the sea and offers the great opportunity of extending the tramline to the end of the dam. The dam is positioned in such a way that the historical village centre and Kurhaus alongside the dam keep their direct relationship with the sea. Such a city in the sea is an uncommon typology in the Netherlands. It brings to mind built, rocky shores along the Mediterranean coast.

§ 8.4.6 Results

In this case study, joint expert sessions and design sessions with both engineers and designers proved invaluable in making integrated visions. Based on intuition, designers, for example, had incorrect assumptions about the dimensions of various types of sea defences: some of them assumed the new seaward dunes might be so high that they would form a visual barrier between the built edge of Scheveningen and the sea; they therefore favoured the 'hard seawall', which they thought to be lower (Arcadis and Alkyon, 2005). However, because the sandy dunes absorb more wave energy, they can be dimensioned somewhat lower (at +12 metres NAP) than a hard boulevard (at +14 metres NAP).

This case study did not have the objective of selecting a preferred strategy. Rather, the options are meant to support the debate on the value of an integrated approach for the long-term development of Scheveningen. The study and associated workshops made clear that any discussion on the type of flood risk protection cannot be seen isolated from the future development vision for the area; an integrated approach is a must.

§ 8.5 Case study 3: Kinderdijk

Kinderdijk is a world-renowned UNESCO heritage site. Located in the north western, low-lying corner of the Alblasserwaard polder, water from the entire polder is gathered here and discharged into the river Lek. In the past, the excess water was pumped into a discharge basin using windmills and subsequently discharged into the river during low tide. Nowadays, the windmills, from the early 18th century, serve as a tourist attraction. Electric pumping stations have taken over their original use..



FIGURE 8.23 Aerial photo of the Kinderdijk world heritage site (source: PDOK). On the right, a photo of the historical 'water board' residence and the famous windmills.

§ 8.5.1 Spatial Ambitions and Assignment

Currently, about 400,000 tourists visit Kinderdijk each year. This number is growing. Access to the site is provided by the original dike road, which is not well equipped to handle this traffic. To improve the liveability of the old village centre adjacent to the world heritage site, a visitor management strategy is being developed that encourages tourists to visit by boat. The river cruises and waterbus that provide transport services to Kinderdijk currently dock at jetties along the dike of the river Lek.

§ 8.5.2 Possible (and Viable) Technical Options

Reinforcement of this dike is relatively simple since it is freely positioned in the landscape and there are hardly any buildings. Though there is no urgency, from a spatial perspective, to develop an integrated design vision for this area. It was found that the dike reinforcement could be an interesting inducement for improving the transport infrastructure, especially for tourists arriving by boat.

§ 8.5.3 Design Study – ‘Arrival Deck’

In a design workshop, options were explored to improve the arrival route of tourists accessing the area from the jetties. They currently set foot on the ground on a priority bike path that, unbeknownst to most foreigners, functions as a cycling highway for bikes. This results in dangerous situations and annoyances. In the design vision, a public arrival deck is positioned on the riverbank (see Fig. 8.24). Visitors can first arrive, gather, and orientate themselves before they cross the public road. A local interest group is now pushing for a tunnel through the dike, to connect the deck to the heritage site without the necessity to cross the road. Establishing a tunnel in a primary water defence seems contradictory to most experts, but the interest group feels confident that local hydraulic engineering companies have the inventiveness to design and realise such an extraordinary construction safely. What is interesting in this case is that, instead of the usual hope that a local dike does not have to be reinforced, here is a situation in which reinforcements are welcomed, in order to serve as a catalyst for the redevelopment of the area.



FIGURE 8.24 Proposal for a tourist arrival platform along the dike near the UNESCO world heritage site Kinderdijk. The three jetties already exist and currently land directly on the main road. Behind the dike are two pathways leading to the famous windmills.

§ 8.6 Application Abroad: Houston-Galveston Bay

Houston is positioned along the Galveston Bay, which is separated from the Gulf of Mexico by Galveston Island and the Bolivar peninsula. The area is prone to flood risks caused by hurricanes, resulting in storm surges and extreme storm water conditions. In 2008, Hurricane Ike flooded the peninsula and nearly hit Houston’s city-centre and petrochemical industry. In 2017, hurricane Harvey caused up to \$180 billion in damage, primarily through extreme storm water conditions (Reuters 2017). These recent events emphasise the need for an integrated flood risk management strategy for the larger Houston metropolitan region. Given the high level of urbanisation in the area, this strategy should be integrated in that it includes both different technical aspects (storm surge protection and storm water management) and different disciplines (for example urban planning and ecology).

Over the past number of years, several studies explored different aspects for protection of the Houston-Galveston Bay area. One of the potential building blocks for a regional flood risk protection strategy is the creation of a coastal sea barrier along the low-lying peninsulas (SSPEED centre 2015).

Such a spine can limit the amount of storm water that enters the bay; it allows, for example, for a lower water level to be maintained in the bay in anticipation of hurricanes and other severe weather events. This increases the storage capacity for storm water that is discharged towards the bay and reduces the risk that bay water will flood Houston's city centre and port. This design study preceded Hurricane Harvey; it was performed in 2016 in close cooperation with Texas A&M and Rice University SSPEED centre.

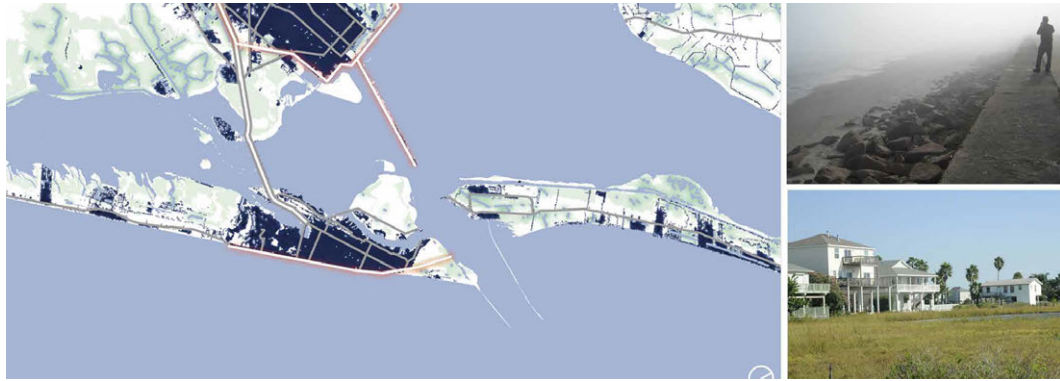


FIGURE 8.25 Map of the Houston-Galveston Bay area (source Delft University of Technology.) On the right, photos of the Galveston sea wall and one of the holiday home neighbourhoods.

§ 8.6.1 Galveston Island

Galveston Island is approximately 44 km long and mostly natural, with the city of Galveston located on the eastern end. Galveston was an important city and port in the 19th century until a major flood occurred in 1900 (Blake & Gibney 2011). Although much of the city was rebuilt, the economic centre of the area moved north towards Houston. Along the Galveston seawall, some of the hotels are reminders of 19th century grandeur. Except for the urban core of Galveston, most structures on the island are low density recreational residences, located in the open Galveston marsh and beach landscape. Although some were constructed on poles, many buildings suffered from flood damage. The aftermath of Hurricane Ike required significant rebuilding efforts, and Hurricane Harvey may indeed require similar efforts.

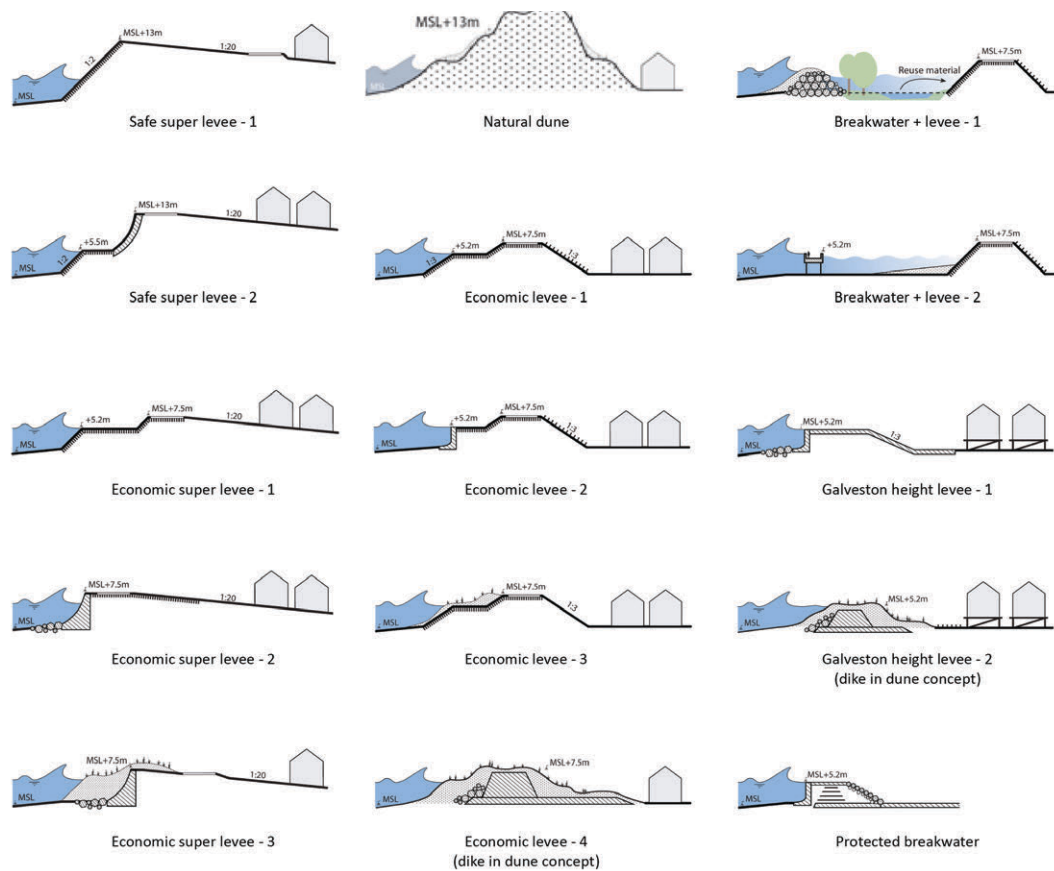


FIGURE 8.26 Overview of different technical opportunities (in section) for constructing the coastal barrier.

§ 8.6.2 Spatial Ambitions and Assignment

The main spatial ambition was the preservation of the spatial and ecological qualities of the island. Preserving the view towards the ocean from the residences as well as the road along the shoreline was an important spatial requirement.

§ 8.6.3 Possible (and Viable) Technical Options

Together with engineers, an overview was made of the different possibilities for constructing a sea barrier (van Berchem et al. 2016). This broad inventory showed a wide range of options including dikes, sandy dunes, breakwaters, and quay walls. For Galveston city, the current seawall was deemed sufficient. The study therefore focused on stretches of the island west and east of the city centre (see Fig. 8.28). A wide range of possible alternatives were assessed, resulting in the conceptual options that were studied:

- The extension of the existing Galveston seawall
- A barrier with natural appearance (a dike with a clay core covered with a natural dune layer)
- Creating a seaward breakwater combined with a levee

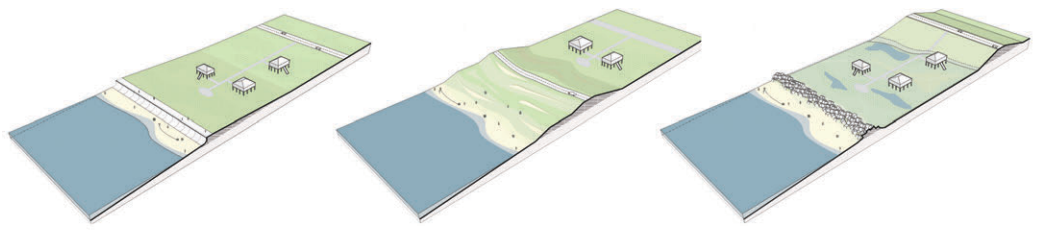


FIGURE 8.27 The three selected viable options for a barrier, being the extension of the Galveston seawall (left), a dike in dune concept with a natural appearance (centre), and a seaward breakwater combined with a levee (right).

§ 8.6.4 Design Study - 'Dike in Dune'

In the first selection of possible barriers, there was a strong preference for the barrier solution to have an appearance that would suggest a sandy dune. The disadvantage of such a solution at this location was the height that was needed to provide sufficient strength (13 metres) and the cost related to constructions that use sand (in contrast to the Netherlands, sand is not easily available in Galveston).

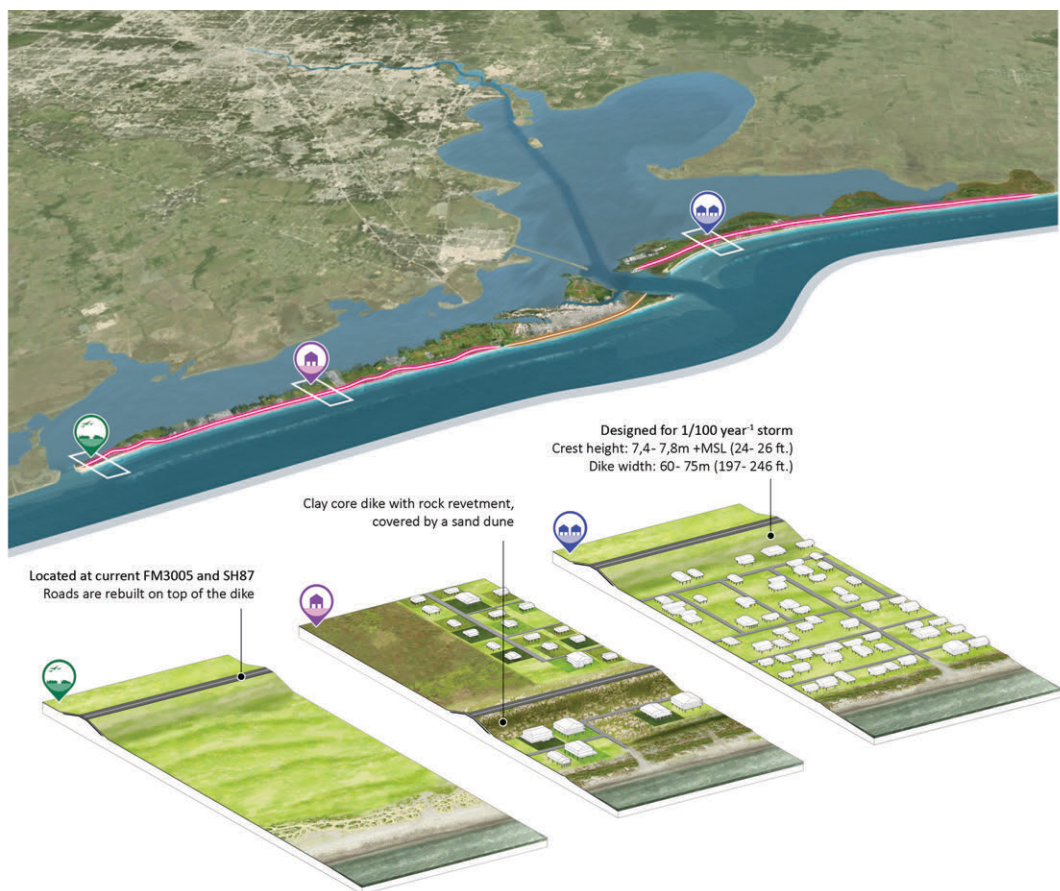


FIGURE 8.28 The preferred design option for a 'dike in dune' concept positioned under the existing road. The proximity of the road varies along the island; therefore, the technical section will vary accordingly.

Therefore, a 'dike in dune' option was proposed, in which a dune is constructed as a rigid clay core covered with a layer of sand. The height of such a dune could be limited to around 7–8 metres, whilst preserving a natural appearance. For different areas along the island, studies were undertaken to determine the best positioning for such a barrier. Taking into consideration land ownership and the requirement to preserve the seaside view towards the ocean, it was decided that the barrier would have to be positioned underneath the existing coastal road. As an extra benefit, the coastal road will thus gain ocean views.

§ 8.7 Conclusion

Two aspects of the research-by-design approach described in this article that were deemed particularly valuable are the application of research-by-design in the early design stages and the integrated (technical and spatial) work forms.

§ 8.7.1 Research-by-design in an Early Project Stage

Using a research-by-design approach in the early stages of formulating new flood risk standards, rather than in a later stage when implementing the reinforcements, is perceived to be very valuable. The design period with regard to implementing reinforcements is generally limited to four years. This has often proved to be insufficient time to set up a successful working relationship between municipalities and the water board (which implements the reinforcements), to explore potentials for synergy or optimal embedment, and to establish funds for co-investment in integrated design solutions.

By performing a research-by-design study at an early stage, stakeholders are consulted early on, allowing them to start the time-consuming integrated planning and vision development in an earlier stage and to be active partners in the integrated development. In the Kinderdijk case study, the municipalities are now eager to accelerate some of the reinforcements so that they can be combined with short-term spatial developments.

Results from the Sliedrecht case study have been shared with local inhabitants, not to inform them on a future development or vision itself, but rather to explain to them that qualitative alternatives may be possible where houses can be preserved. This eases some of the agitation that was caused by the fear that dike reinforcements would inevitably lead to the demolition of houses.

The Alblasserwaard-Vijfheerenlanden opportunity map, which provides an overview of different assignments and projects, was considered a valuable tool. The integrated information allows stakeholders from different organisations to find opportunities for synergies. Since then, the opportunity map concept has been used in many follow-up projects.

§ 8.7.2 Integrated Design Workshops

The integrated design process helped to combine technical and spatial assignments and to achieve integrated design visions. One of the aspects that seemed essential in the interdisciplinary collaboration is that designers, with the help of engineers, understand the basic principles of water management and flood risk design. Understanding those principles ultimately leads to an increased number of valid technical alternatives and hence to an increased chance that one of those alternatives can be combined with other projects or assignments in order to achieve synergies.



FIGURE 8.29 Photo of the scale model with projections and the Climate Adaptation board game (photo by Frank Auperlé).

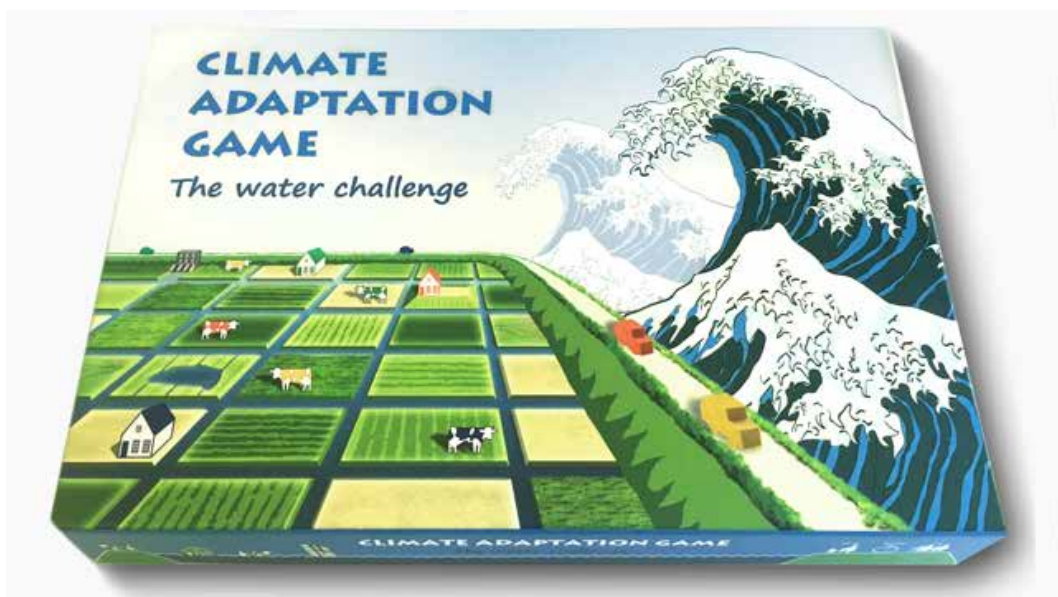


FIGURE 8.30 The Climate Adaptation board game.

For a designer, it is invaluable to be involved in the early stages of the project, when the decisions are still being made on the most suitable type of technical solution. This allows the spatial implementation, on which the designer can advise, to become a selection criterion. This leads to better results compared to an approach in which disciplines operate separately, such as when the technical design is made by engineers, and urban or landscape designers are tasked to implement this to the best of their abilities (the proverbial 'putting the lipstick on the pig'). The interactive expert and design workshop was considered a very successful work format in terms of creating interaction, allowing joint fact-finding, and facilitating integrated concept and vision development.

In order to better inform designers and stakeholders on technical principles related to water management, two special capability building tools were developed. An educational model was built in cooperation with the Delft University of Technology (Fig. 8.29); this scale model projects data, system knowledge, climate change scenarios, projects, and innovations on a physical model of the The Hague-Rijnmond area. The second is the climate adaptation game. In a playful way, this board game provides insights into complex relationships between flood risks caused by storm surges from sea, the discharge of rivers, and storm water (Fig. 8.30).

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9 Conclusions

§ 9.1 Conclusions

Main Conclusion: The Developed Approach

Is it possible to define an integrated method for strategic flood risk management and spatial quality enhancement, in which spatial quality is a decisive ex-ante criterion, and what would be the key elements and steps in such a method? This constitutes the primary research question.

The publications that together form this dissertation describe such a method and thus provide a positive answer to the primary research question. A key principle in the approach is the inclusion of multiple interchangeable (effective) flood risk reduction interventions at varying locations, so that the criteria of spatial quality can become decisive in flood risk management strategy development.

The ability to assess the impact of different interventions on spatial quality is essential. In order to do so, an assessment framework was developed; it combines the approach of a spatial quality criteria checklist with expert judgement. The checklist supports expert judgement in that it keeps a wide, open perspective while assessing the spatial quality of a conceptual intervention, and thus allows verifiable and reproducible assessments.

The method developed employs research-by-design to systematically test different interventions at different locations. It includes the following steps:

- An inventory of current and potential flood risk protection strategies
- An inventory of a region's spatial characteristics, challenges, and potentials
- A qualitative assessment of existing situations and a spatial impact assessment of reference flood risk strategies, if any exist
- Systematic research on how flood risk management interventions at different scales can shift the location of a flood risk intervention; this includes qualitative assessments of interventions at various locations
- Systematic research on how flood risk management interventions in different flood risk layers can shift the location of a flood risk assignment; this includes qualitative assessments of interventions at various locations
- Selection of a combination of interventions that are preferred from a spatial quality objective

Sub-question: How do flood risk management interventions and spatial development influence each other?

There are many sources in literature that describe the strong, influential relationship between flood risk measures and spatial development. For example, with regard to the historical development of the Rijnmond-Drechtsteden area in the Netherlands, it is apparent that the shaping and cultivation

of the landscape, and the choice of locations for urban settlement, were strongly dependent on flood risk management interventions such as dams, canals, dikes, and polders (amongst others Palmboom, 1987, Steenbergen et al., 2009, Meyer et al., 2013).

In studies undertaken by the first and second Delta Committees that reflect on the potential impact of different systems of flood risk management interventions, such as Tinbergen (1961) and 'open closable Rijnmond' (De Hoog et al., 2010), there is a strong link between options for flood risk management interventions (such as a dammed or open delta) and opportunities for regional development.

On a local scale, the link is also apparent since different flood risk management interventions have a different spatial claim and therefore bring different conditions for (local) spatial development, as demonstrated and described in Chapters 3, 4, 5, 6, 7, and 8.

Sub-question: How can spatial quality can become an ex-ante aspect of flood risk management strategy development?

The key to making spatial quality an ex-ante criterion in flood risk development strategies is to define multiple interchangeable (effective) flood risk reduction interventions. When the base requirement of providing flood risk protection can be met with multiple different flood risk management interventions, the selection of an intervention can be based on additional criteria such as its impact on spatial quality. This allows spatial quality to become decisive in flood risk management strategy development.

In order to do so, the spatial impact assessment of different flood risk management interventions has to be included in the early research stages of flood risk protection strategy development. This requires the involvement of designers, who provide feedback—from a spatial quality perspective—on the flood risk management interventions under consideration before strategic choices with regard to the flood risk management strategy are made.

Sub-question: How can research-by-design be used as a basis for the proposed integrated approach?

Research-by-design was successfully employed to systematically estimate the impact of different flood risk management interventions on spatial quality at a local scale. Compared to other less rigorously systematic design approaches, research-by-design contributes positively to the verifiability and reproducibility of the performed design studies, which are important criteria for scientific design research (KNAW, 2010).

In this study, the initially applied research-by-design definition of systematically varying a single parameter (the flood risk intervention) while fixing other parameters (such as the context and the objectives from a spatial and flood risk perspective), leads to different options for embedding, which all meet predefined spatial requirements. Therefore, this method was less suited to identifying distinguishing opportunities and impacts for spatial quality related to flood risk management interventions.

The essential principle of including spatial quality as a decisive ex-ante criterion, is to create alternative, exchangeable options for flood risk reduction interventions at different locations. Subsequently, the narrower definition of research-by-design by Taeke de Jong (de Jong & vd Voordt

2002), which includes both the systematic evaluation of different interventions (varying design solutions) as well as the systematic variation of the intervention's location (their context), is applied within the method developed.

Sub-question: How can interchangeable measures for flood risk management interventions be defined?

For flood risk management interventions to be interchangeable, there needs to be at least two possible interventions that are effective from a flood risk perspective. This principle was the basis for the 'Room for the River' approach in which, in addition to reinforcing levees, lowering water levels was introduced as a measure to reduce the likelihood of flood occurrence.

In this study, the amount of interchangeable flood risk management interventions is successfully increased by including different possible measures at different scales and different so-called 'flood risk layers'.

Flood risk is defined as the probability of a flood multiplied by its consequences (probability x consequence). Therefore, when addressing flood risk, interventions that reduce flood probability are interchangeable with interventions that reduce detrimental consequences. Potential flood risk management interventions can be formulated on different flood risk layers. The first layer of the (1) probability includes prevention measures such as dikes and barriers, and interventions that reduce the normative water level. The two other layers are related to consequences, namely (2) exposure, which includes interventions such as flood-proof buildings, the protection of vital infrastructures, compartmentalisation and restrictive building policies, and (3) vulnerability, which includes interventions that allow people to evacuate an area safely and allow for a rapid recovery after a flood (Expertise Netwerk Waterveiligheid 2012).

The approach of including interventions at different flood risk levels to shift flood risk management interventions to the most suitable locations, comprises the following steps:

- 1 Selection of flood risk management interventions, by an expert team, either having a positive effect on spatial quality and some effect on flood risk reduction, or a neutral impact on spatial quality and a considerable impact on risk reduction.
- 2 Risk map updates, defining new or remaining focus points of the risk assignment.
- 3 A second round of flood risk management interventions, addressing any remaining problematic risk areas while using design optimisation to embed the necessary interventions.
- 4 Risk map updates and, if necessary, repetition of steps 3 and 4.

Flood risk management interventions can also be implemented at different scales, varying from large scales, such as an entire delta system or region, and medium scales, such as polders and river branches, to local scales, such as a stretch of land or section of a dike within the delta, and small scales, such as a single building. When, for instance, the aim is to reduce the flood risk for a particular building, an intervention can be implemented at different scales: the building façade can be flood-proofed, a levee can be built around it (or around the region in which the building is located) or, on a larger scale, a dam or barrier can be built in the river that is causing the flood risk.

The approach of including interventions at different scale levels to shift local-scale interventions to the most suitable locations, includes the following steps:

- 1 Identification of relevant flood risk strategies on medium and large scales that are effective from a hydraulic point of view.

- 2 Visualisation of the impact on local normative water levels.
- 3 Description, by civil engineers, of appropriate flood risk management interventions at specific local sites, based on normative water levels.
- 4 Assessment, by an expert team, of the impact that interventions have on spatial quality.

Sub-question: How can the location of the necessary flood risk intervention be shifted by selecting measures on other scale levels or flood risk layers?

The interchangeable flood risk reduction measures at different scales and different flood risk layers will also (partially) affect multiple locations: by including a wide range of interventions at different scales and different flood risk layers, there will be a range of different locations where these interventions will have to be implemented. In Chapters 5 and 6, the ways in which the location of a necessary flood risk intervention can be shifted, by selecting measures at other scales or flood risk layers, are demonstrated in more detail.

Sub-question: How can a spatial assessment framework be developed to assess the impact of different technical interventions for flood risk management on spatial quality at the local scale?

The spatial assessment framework developed in this study is based on the spatial assessment framework 'Ruimtelijke Kwaliteits Toets' (RKT) as used during the 'Room for the River' project (Bos, Lagendijk & Beusekom 2004). Its approach combines a spatial quality criteria checklist and expert judgement. The original RKT method is improved and adjusted for the assessment of conceptual local scale flood risk management interventions in an urban setting.

The assessment criteria defined in this study are based on the definition of spatial quality as a combination of utility, attractiveness, and robustness. Derived from previous studies on qualitative criteria (Bos, Lagendijk & Beusekom 2004, Hooimeijer, Kroon & Luttik 2001; Gehl et al. 2006) and

an expert session, these criteria address aspects such as ecological functioning, maintainability, identity of the surroundings, recognition of structures, cultural recognition, alteration, logic of spatial arrangement, relationship to the water, reversibility, development opportunities, and uniqueness.

The assessment is performed by an expert team that uses the assessment framework as a support tool that helps to keep a wide, open perspective while assessing the spatial quality of a conceptual intervention and making the assessment verifiable and reproducible.

The developed approach for the qualitative assessment of flood risk management interventions on local scale spatial quality, as included in the combined approach for flood risk and spatial quality, includes the following steps:

- 1 Adaptation of assessment framework to specific conditions for a case study area
- 2 Visualisation, in a consistent and neutral fashion, of various (local-scale) locations that need to be evaluated
- 3 Assessment of the current situation as a reference, using an expert team and relevant criteria from the framework
- 4 Assessment of the new situation, related to the flood risk protection strategy, using an expert team and relevant criteria from the framework

Sub-question: How can the developed method be deployed for the Rijnmond Drechtsteden case study area?

Application of the method to the Rijnmond-Drechtsteden area is described in Chapters 4, 5, 6, 7, and 8. When applied to the Rijnmond-Drechtsteden case study area, the method resulted in a strategy that, compared to the reference 'business as usual' strategy, had an improved impact on spatial quality.

The method can be applied to other deltas. The spatial assessment framework must be adjusted to align with the scale of the assessment (local or regional) and to fit the local perception of spatial quality (see also Chapter 10 - Discussion & Recommendations).

10 Discussion & Recommendations

Value of the Developed Method for Practice

The proposed methodology creates opportunities for designers to actively participate in debates concerning the location, layer, and scale of flood risk management interventions, resulting in a more integrated design approach. The systematic approach and the strong connection to variables and data sets provides a framework that makes it easier to communicate designers' propositions from a spatial point of view to engineers and facilitates interdisciplinary cooperation.

The developed sub-method for evaluating interventions at different flood risk levels, to shift flood risk management interventions to the most suitable locations, offers a framework for developing a combined probability and consequence reduction strategy. This method can become a valuable tool for strategy development and decision making in so-called multi-layered flood risk management approaches, in which interventions regarding the probability and the consequential damage of a flood are combined. Multi-layered safety approaches have often been referred to in flood risk management debates in the Netherlands, but so far, consistent methods for achieving a balanced probability and consequence reduction strategy have not been put in place.

Ian McHarg's Layer Model as a Conceptual Framework

The layer model is documented by the Dutch Ministry of Infrastructure and Environment (VROM 2001) and based on the triple layer model by Ian McHarg (1969). The layer model contains three conceptual layers: the natural layer of the subsoil (in which changes take place over the course of centuries), the layer of the infrastructure networks (changing over the course of 50-100 years) and the occupation layer (changing over the course of 25-50 years) (Meyer & Nijhuis 2013). The model stacks those layers with the natural layer as a solid base on which the infrastructure networks intervene, and on top of that the more flexible occupation layer.

It is striking to notice the gap between the theoretical time periods assigned to changes in the different layers and the frequency of change observable. We see for instance that the river as part of the natural layer (indicated by the theoretical model to change over the course of centuries) due to climate change and canalisation shows relevant differences in the peak river discharges that require action over periods of decades. Additionally, the altitude of the soil (also part of the natural layer) is subsiding a rapid rate due to drainage. Both of these conditions result in the flood risk system, which is part of the infrastructure layer that was designed in the 1950s and still partly under construction, having already fallen behind. The system is in need of a major reinforcement, though the model indicates that changes are necessary over a period of 50-100 years. On the other hand, it is no exception that buildings, which, in the theoretical model, are part of the flexible occupation layer, are, in reality, being preserved for centuries.

The use of the layer model as a conceptual framework, and the awareness of this discrepancy between theory and reality was very useful. In the case study location of Scheveningen, this helped to clarify that the occupation layer, which is usually considered the most flexible layer, is in fact a fixed layer. This actual deviation from the theoretical model (which is found in several flood defences in the Rijnmond-Drechtsteden area) is essential to understanding the current combined spatial quality and flood risk

assignment. The relationship between the layer model and the current flood risk assignment (in various countries including the Netherlands), and a potential recalibration of the layer model is a valuable subject for a continued research effort.

Assessment Framework

The assessment of spatial quality based on criteria checklists can be a sensitive topic in the urban/landscape design practice, as it could suggest the opinion that spatial quality is a quantifiable sum of scores in predefined criteria. In this research method, the checklist is not deployed to provide a mathematical equation for spatial quality, but to support expert judgement. The checklist ensures a wide perspective of aspects of spatial quality with each assessment. Moreover, it makes the spatial quality assessment verifiable and open to discussion.

During expert sessions in the research described in the fourth publication, two urban designers provided different judgements, demonstrating the challenges of obtaining reliable, consistent, and objective results. Assessments are dependent on individual, subjective opinions. This is unavoidable but underlines the importance of the verifiability of the assessment.

Design Optimisation

In the design exercise that was performed by students in the research described in Chapter 5, the spatial quality assessments became a starting point for the design assignment of optimising the spatial embedment of the flood risk management interventions. Based on initial assessment results, the students succeeded in mitigating the negative scores; their optimised designs scored better on spatial quality.

As a recommendation, a design optimisation should be included in the assessment framework approach. Such additional 'research-by-design' helps in identifying locations where flood risk management interventions can be mitigated by design optimisation, making the shift of the intervention to another location superfluous.

Assessment of the Impact on Spatial Quality at the Regional Scale

At the moment, the assessment framework is designed primarily for assessing the impact of both regional and local scale flood risk management interventions on spatial quality at a local scale. In order to apply the developed method for weighing different flood risk strategies at the scale of the delta, an assessment of the impact of flood risk management interventions on spatial quality at regional and national scales should be included.

In the application of the developed method as described in the fifth publication, and the description of the impacts and potentials related to the Netherlands' Delta Programme cornerstone strategies as described in the first paper, more regional aspects of spatial quality are already included in the expert judgement. Within this research, a supporting criteria list for the regional scale spatial quality has not been developed. Such a list could still be based on the same base principles for spatial quality (being utility, attractiveness, and robustness). However, the specific criteria resulting from those principles should be adapted to fit the regional scale level, in which more strategic aspects such as connectivity and competitiveness positions and economic vitality play an important role. In particular, the assessment of robustness could become more elaborate, since, for strategic choices, it may be necessary to reflect on different future scenarios.

In Tinbergen's assessment with regard to the two potential delta plans that were developed after the 1953 flood, such a regional assessment is, in a basic way, already included as part of the decision-making process with regard to the regional flood risk management strategy. In his report on the socio-economic aspects of the delta plan, Tinbergen (1961) includes aspects such as connectivity and potential for recreation.

Potential Synergy Between the Flood Risk and Spatial Assignments

In the developed method, next to an inventory of the current and potential flood risk protection strategies, an inventory of the spatial characteristics, assignments, ambitions, and potentials of the region is included as a step. The information concerning the assignments and ambitions for the area is needed to identify potential synergy between flood risk and spatial assignments during the assessment. Different approaches have been used for this, as shown in Chapter 4 with regard to the The Hague case study and Chapters 5 and 6 with regard to the Alblasserwaard case study.

In the Scheveningen case study, the analyses of the spatial characteristics, assignments, ambitions, and potentials are done in a detailed way. In terms of the ambitions and government policies, spatial analyses, and a stakeholder workshop, the spatial assignments and ambitions are inventoried and interpreted by means of a desk study. This approach, undertaken for the local scale case study site of Scheveningen, is time consuming and it would be excessive to extend it to the full Rijnmond-Drechtsteden case study area.

To be able to identify where a flood risk intervention could create synergy with spatial economic assignments or ambitions on the regional scale, a basic overview of assignments and ambitions is needed. To illustrate this, such a map is made for the Alblasserwaard-Vijfheerenlanden case study area, based on a series of workshops and interviews. The assignments and ambitions of the province are inventoried during workshop sessions with experts from different policy fields; those of the municipalities are collected in individual interviews with the different municipalities of the region. This results in an 'opportunity map' that shows a compilation of concrete plans, ambitions, challenges, conceptual ideas, and desires for the area. When combining this information with the expected flood risk reduction task, potential areas for synergy can be identified.

The 'opportunity maps' were deemed a successful tool for practice and have, after the application for the Alblasserwaard-Vijfheerenlanden case study, as part of the Delta plan strategy development, been replicated for the Waal-Merwede rivers and for the river IJssel.

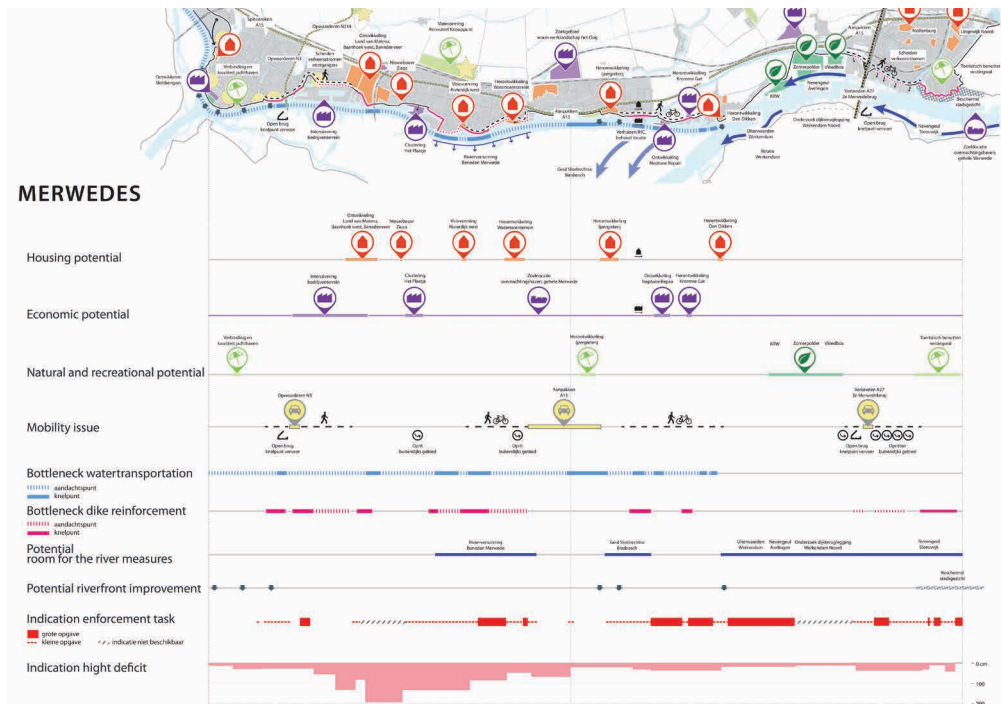


FIGURE 10.1 Zoomed-in area of the map indicating challenges and ambitions identified for the Alblasserwaard-Vijfheerenlanden area. Within the detailed image (which shows the area along the Merweede), the flood risk assignment is further elaborated by including an expert judgement from the water board with regard to the strength of the levee.

Delta Atelier Approach

The Delta Atelier work form, in which multidisciplinary experts worked together in design workshops or expert sessions, was deemed a very valuable approach for the development of integrated and innovative design proposals and strategies.

During the research period, a wide range of stakeholder and expert sessions took place. The exact approach of the sessions was not always similar; in the expert sessions described in Chapter 4 regarding the Scheveningen case study, the successful expert sessions were performed by a consistent core team of experts from different disciplines. In later expert sessions, in which there were frequent shifts within the expert team, it became apparent that having a continuous core team during a sequence of expert meetings is an important factor in the success of those sessions.

The power of the multidisciplinary expert sessions is that, gradually, a shared broad multidisciplinary understanding of the challenge is reached among multiple experts, allowing them to have a better, more holistic perspective on the challenge and with that the possible strategies. In this process there is an initial phase in which experts from different disciplines must explain to (and even educate) experts from other disciplines the basics of their profession (for instance, what 'business-as-usual' flood risk principles are available, how are future levee requirements calculated, etc.). This phase was described by some experts as feeling like a slow start, but one that pays off in a later stage where this shared foundation is a catalyst for holistic and innovative strategies.

In the expert sessions, a big fluctuation of experts meant that much time was spent on repeating this initial phase of debating the work form and explaining basic principles and the steps made in previous sessions. Experts indicated that this resulted in a tiresome work process in which the beneficiary stage of multidisciplinary understanding of a challenge was either not reached or was achieved only after a delay.

Applicability of the Method in Other Deltas

The developed method can be deployed in other urbanised delta areas. The data sets used in this research are commonly used by engineering companies throughout the world. Although different companies use different models, the type of data used to support delta decisions are often similar. If data sets are not available, they can be replaced with expert judgements. When applying the method elsewhere, the criteria for spatial quality will have to be adjusted to the local situation, in collaboration with an expert panel. The results from the assessment of spatial quality may differ between regions as the methodology contains both objective and subjective qualitative criteria. In other deltas, the same criteria might be assessed or interpreted differently, since the assessment is subject to location, zeitgeist, and culture (Janssen-Jansen et al. 2009).

The method would be most valuable when applied in deltas with a risk-based flood risk reduction target, where the formulation for a flood risk management strategy is ongoing, and both probability as well as consequence reduction measures can be considered in a multi-layered flood risk management approach.

In the next sections, two examples of deltas in which flood risk reduction strategies are being developed are briefly discussed in terms of the applicability of the developed method: The Houston Galveston Bay area and Bangladesh Ganges delta.

Houston Galveston Bay Area

As described in Chapter 8, for the Houston Galveston bay area different alternative flood risk reduction measures are currently being explored. Technical research is still ongoing to determine whether the proposed probability reduction measures are indeed interchangeable from a flood risk perspective. The spatial impact of the alternative options at the different locations is expected to become an important feasibility criterion. For instance, the integration of the sea wall along Galveston and the Bolivar highway (lines F and G) as already demonstrated in Chapter 8, will influence the current unobstructed view from the islands to the ocean. The spatial impact of this intervention could be essential in the emergence of the resistance of local stakeholders. The alternative oyster reef (intervention D), might improve the landscape and recreational potential of the area. For this area, it is interesting to apply the developed method to investigate the impact of the interventions with regard to spatial quality. Of course, next to the inclusion of spatial quality as a decisive criterion, as done in the developed approach, in this practical case additional criteria such as costs, ecological impact, and land ownership will also be decisive criteria.

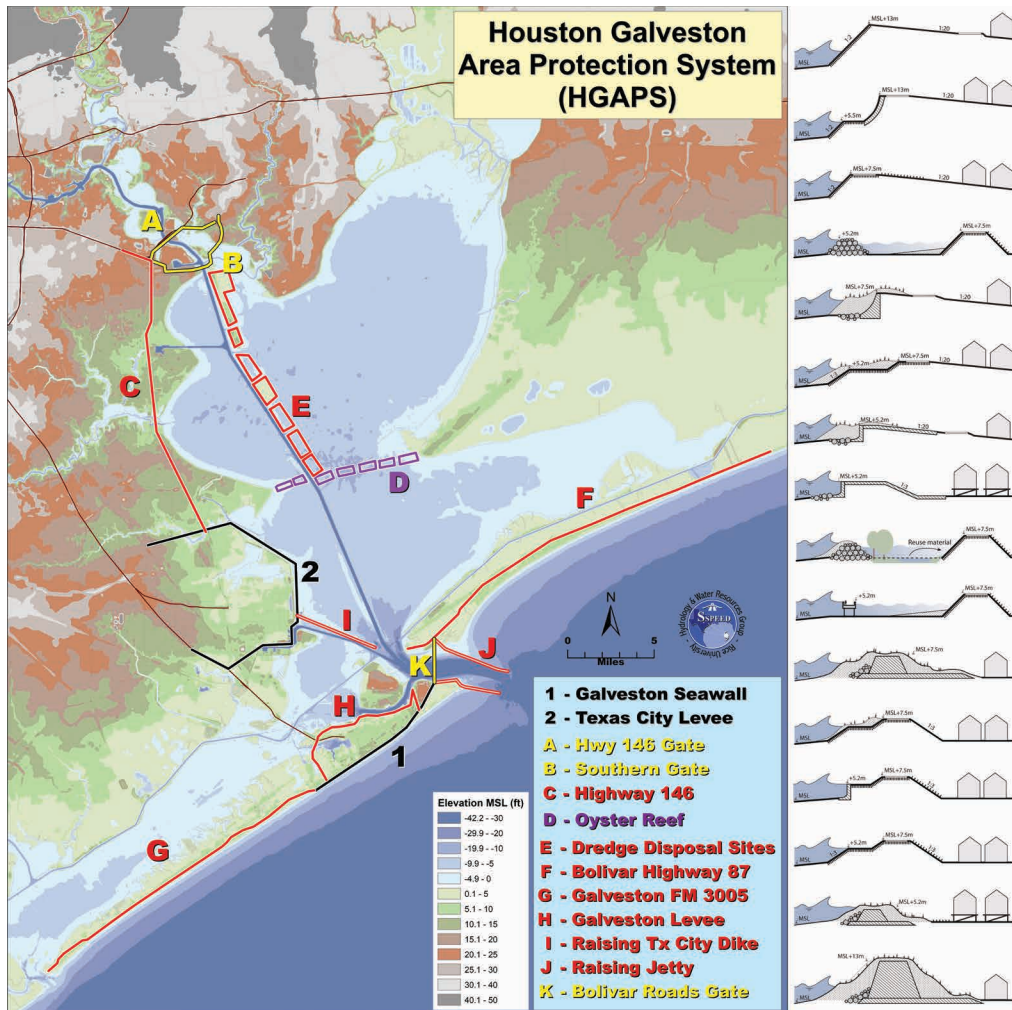


FIGURE 10.2 Above, an overview of different possibilities for flood proofing the Galveston Bay area as developed by the SPEED research centre. On the right, the first step of the developed method is applied, by making an inventory of the technical possibilities for the construction of a sea barrier along the Galveston coast and Boulevard Island (image by author. The content with regard to the technical possibilities is developed together with the Delft University of Technology and Royal-Haskoning-DHV).

Bangladesh Ganges area

For the Bangladesh Ganges delta, a national flood risk management strategy is being developed in, amongst others, the Bangladesh Delta Plan. In Bangladesh, the current flood risk reduction system is a mix of probability and consequence reduction measures. Within the strategy development, flood risk management interventions of both flood risk layers can also be considered. The developed method is very applicable here. A systematic ‘research-by-design’ process that explores different potential flood risk management interventions in relation to the spatial impact for the different regions would be valuable. However, the local spatial quality in this case will be less decisive in flood risk management strategy development. In the case study area of the Rijnmond Drechtsteden and the Houston Galveston Bay area, due to influential stakeholder opinions with regard to the impact that interventions would have on existing local scale spatial quality, such spatial quality is an important criterion. Bangladesh is still a country focussed on development. In the Bangladeshi situation, the impact on existing local scale spatial quality as a decisive criterion (with exception of the already urbanised centres) will be of limited importance. However, the regional scale impact of potential flood risk management interventions on spatial quality and the spatial composition of the country will be essential. The focus for applying the developed method for this region is on assessing the impact of alternative flood risk management interventions on the regional scale spatial quality.

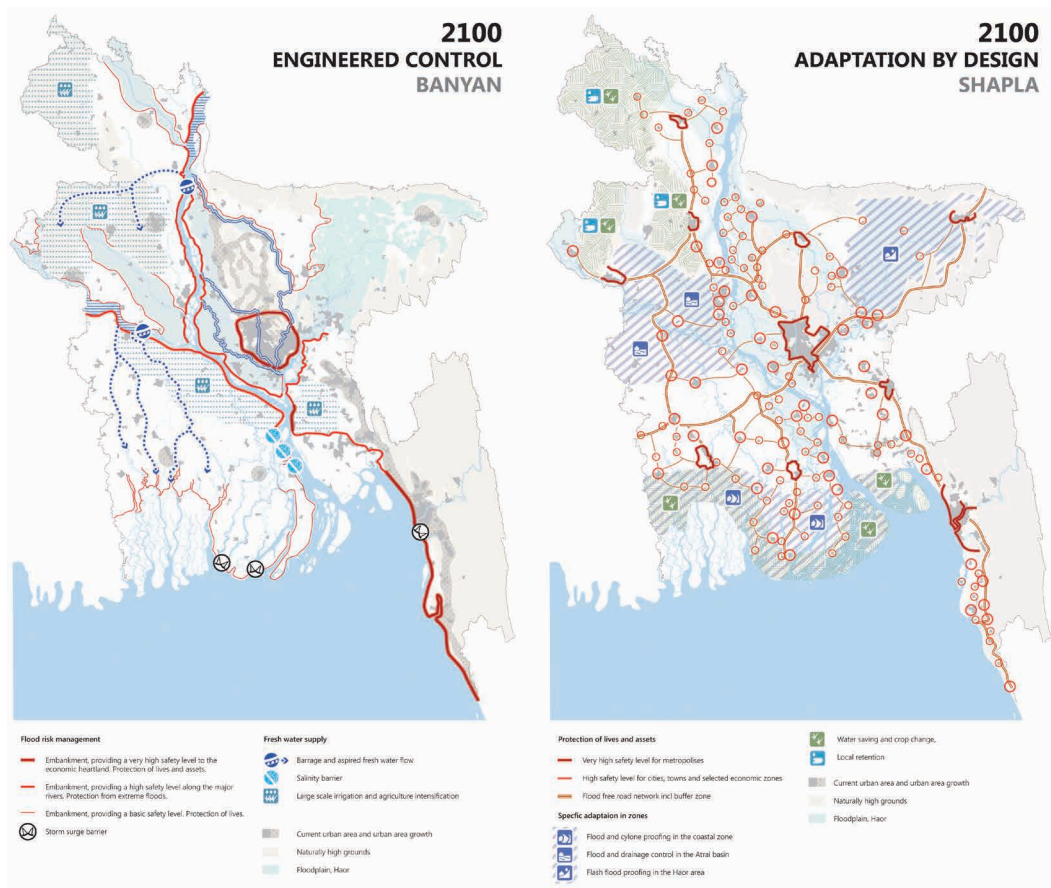


FIGURE 10.3 Above, two different potential strategies for flood risk reduction in Bangladesh. On the left, the strategy is focussed on protection by implementing dike-rings, while on the right, the strategy is based on a combined protection (around economic and urban centres) and consequence reduction approach. The proposed options will have a considerable impact on the potentials for, and characteristics of, the spatial quality and composition of the region. For instance, the dike-ring approach on the left could stimulate sprawl, while the one on the right could support a more compact township development (BDP2100 2016).

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Biography



Anne Loes Nillesen graduated with honors as an Architect and Urban designer from TU Delft and undertook postgraduate studies in Landscape Architecture and Urbanism at the Berlage Institute in Rotterdam. At the Faculty of Architecture, she founded the 'Climate Adaptation Lab' and 'Delta Interventions' multi-disciplinary MSc graduate studios.

Anne Loes is the founding director of urban design firm Defacto Architecture and Urbanism, Rotterdam, the Netherlands. Defacto specializes in urban research and design in the domain of water and flood risk management. With her office, Anne Loes worked on complex, large-scale urban design and flood risk management assignments such as the Dutch Delta Programme and Bangladesh Deltaplan, and several regional and local scale adaptation projects, amongst which a barrier design for Houston and the 'Water as Leverage for Resilient Cities Asia' project for Khulna, Bangladesh.

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- ‘Designing flood proof urban regions’ (2018) ETH Future cities Lab, Singapore
- ‘Integrated Approaches for Flood Risk Reduction & Urban Development’ (2017) Urban Flooding & Infrastructure, moving forward from Harvey, Rice University, Houston, Texas, USA
- Urban Thinkers Campus: The City We Need (2017), TU-Delft, Delft, The Netherlands
- ‘Coastal Protection and Landscape Design’, Taking action, Living on the Edge Conference, Galveston historian foundation (2016) Galveston, USA

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- ‘On design in deltas with a changing context’, Keynote, Water +, Atmosphere symposium (2016), Manitoba Canada
- ‘Temporary use as catalyst for urban development’, Sheffield University, UK (2015)
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- ‘Flood risk and spatial planning’ International Symposium on Coastal Tidal Flat Development, Hohai University, Nanjing, China (2012)
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- ‘Amphibious houses’ Building Resilience Workshops II, New Orleans, Louisiana, USA (2012)
- ‘Waterfront redevelopment’, 54th IFHP Congress, Porto Alegre, Brazil (2010)

Exhibitions (selection)

- ‘Flood risk management in the Rijnmond-Drechtsteden area’ (2017) permanent interactive maquette faculty of Civil engineering, TU Delft, Delft, The Netherlands
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- 'S-House, a flood proof prototype', Flood Biennale Rotterdam 2e IABR (2005)

