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.

TOC

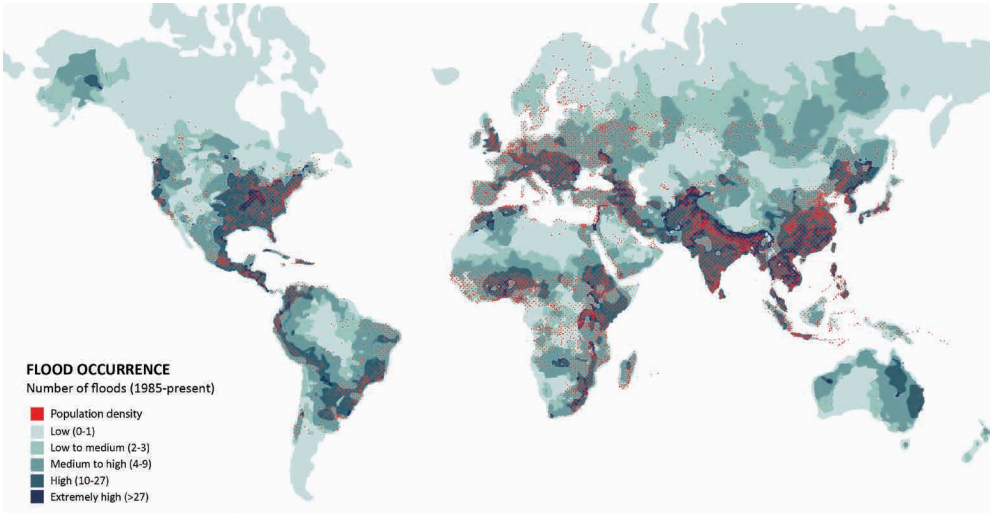

FIGURE 1.1 Many densely populated areas are positioned in places with a high flood occurrence (image by author, data source flood occurrence: World Resources Institute (WRI) Aqueduct, data source population density: Population explorer 2017)

§ 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.

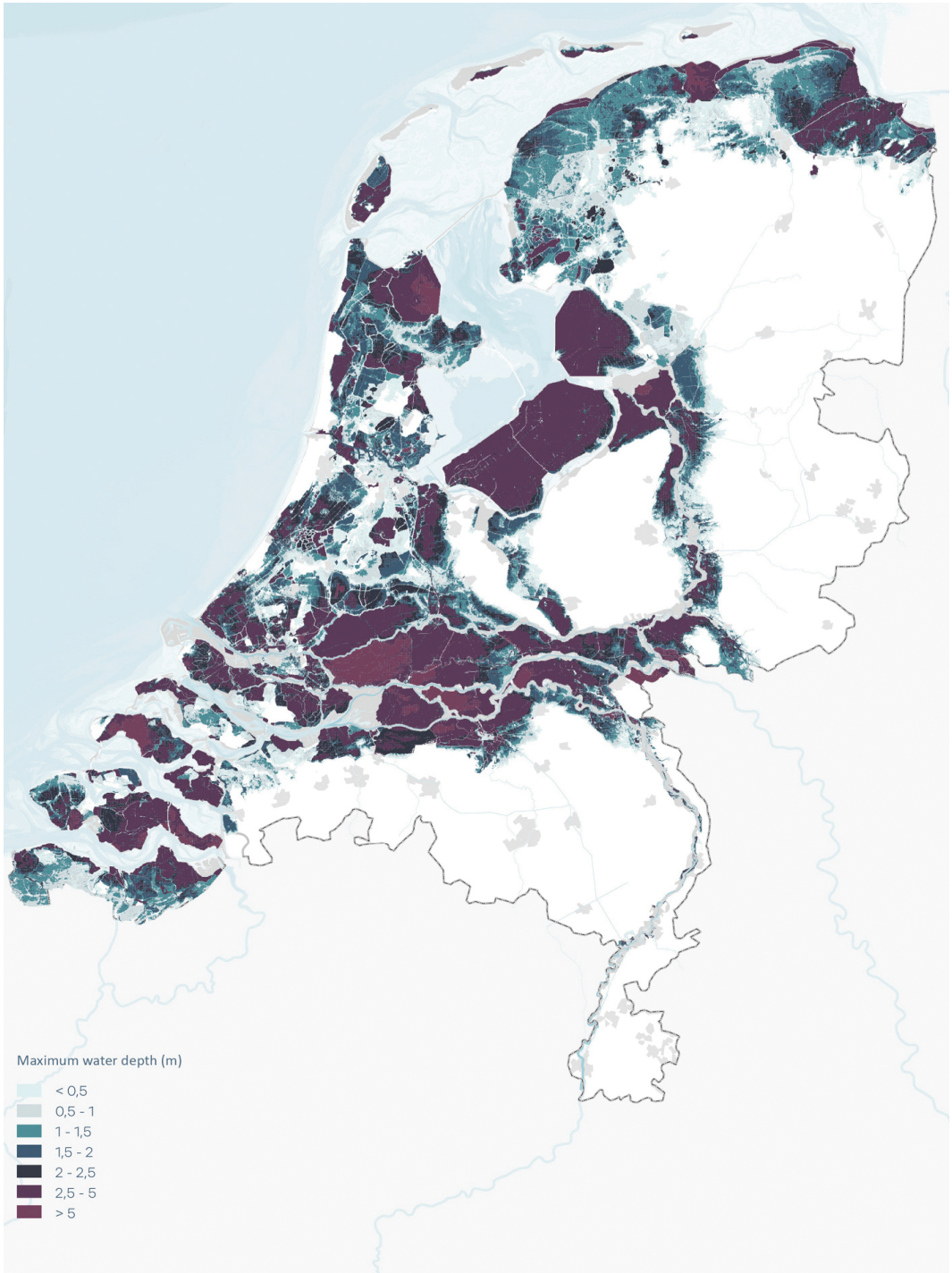

FIGURE 1.2 Map showing the 60% of the Netherlands that is liable to flooding from the North Sea, lakes, and major rivers. Potential water depths may locally exceed five metres (taken and processed from Kok et al. 2016).

TOC

§ 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.

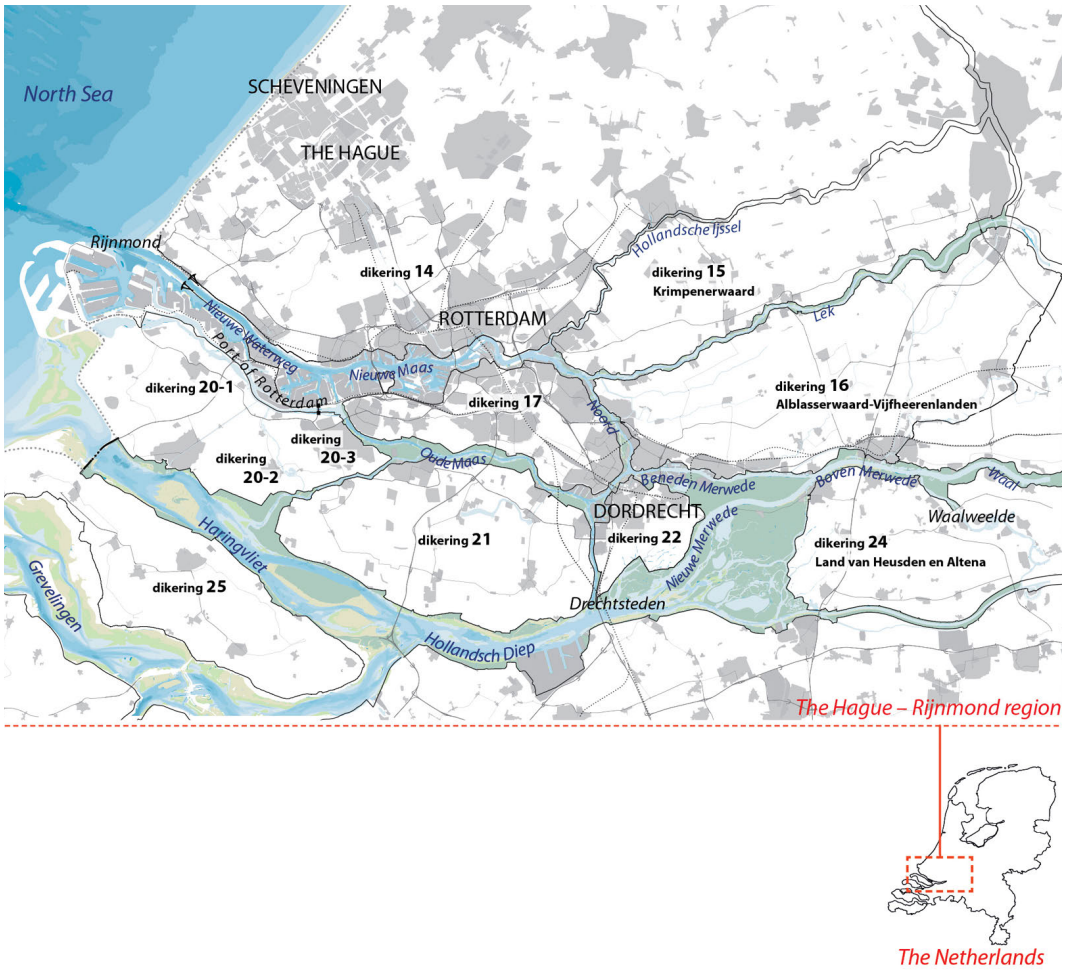

FIGURE 1.3 Map of The Netherlands' Rijnmond-Drechsteden region, showing the waterways, dike-ring system, and the built-up areas.

TOC

§ 1.2 Knowledge gap in existing approaches for spatial quality enhancementand 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 enhancementis 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 enhancementat 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 enhancementobjective, and the research-by-design approach) into an integrated approach to flood rsk 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 Enhancementfor 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 enhancementand 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 enhancementand 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.

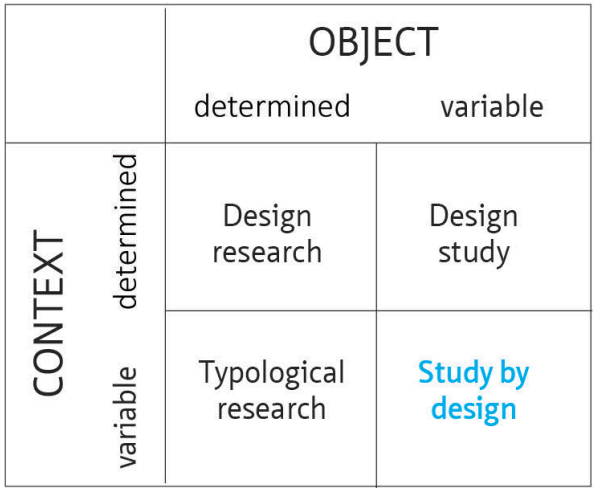

FIGURE 1.5 Diagram based on classification from 'Ways to study and research' (de Jong & van der Voordt 2002). This diagram indicates that, according to the classification by de Jong, the method previously applied within the The Hague case study would qualify as design study.

TOC

§ 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 enhancementobjective 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 Enhancementfor 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 Albasserwaard-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.

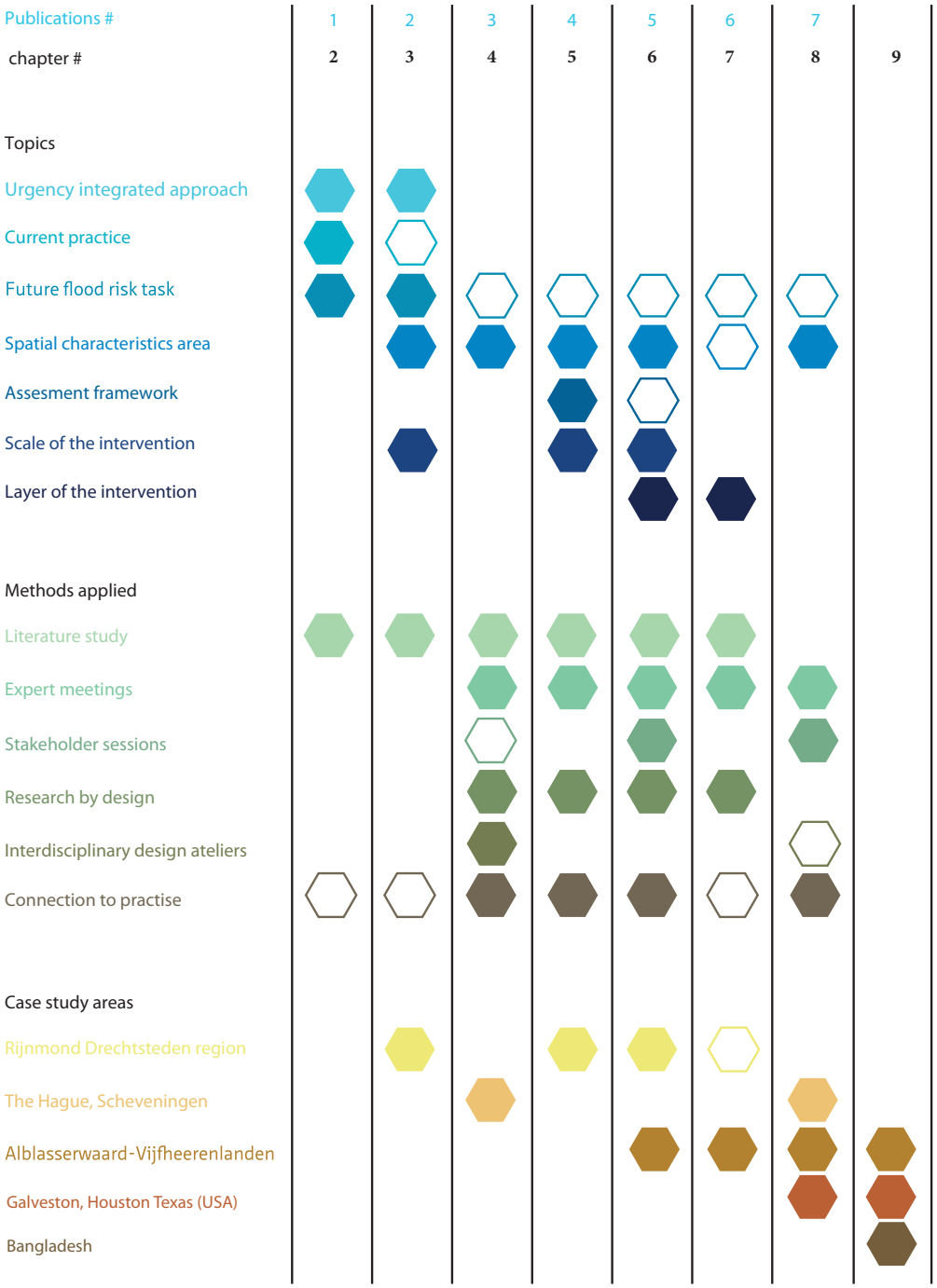

FIGURE 1.6 Overview of topics, methods and case study areas deployed in different chapters

TOC

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 (dijkringen).

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 1250 (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.

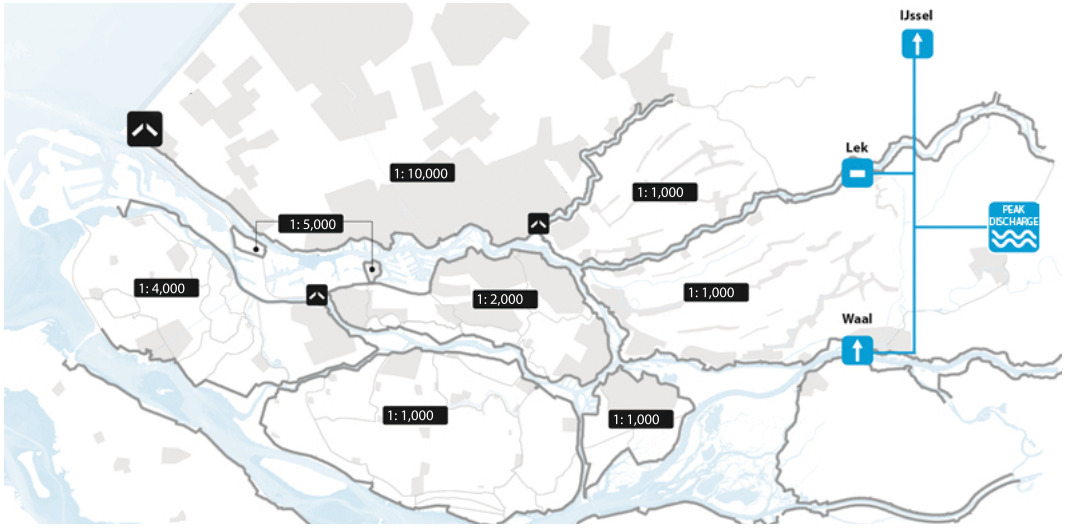

FIGURE 1.7 Rijnmond-Drechsteden flood risk reduction standards in 2015

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).

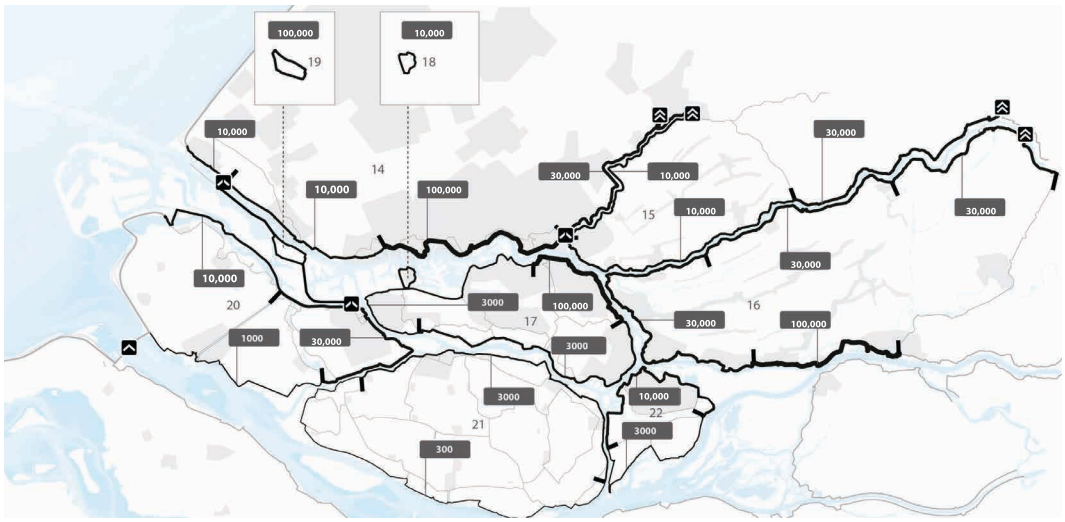

FIGURE 1.8 Updated Rijnmond-Drechsteden flood risk reduction standards, 2017

TOC

TOC