Safe and Dynamic Rijnmond-Drechtsteden
Rebalance the Natural Processes and Human Interventions
Through Integrated Flood Risk Management

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Safe and Dynamic Rijnmond-Drechtsteden
Rebalance the natural processes and human interventions through
integrated flood risk management
MSc thesis

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Fascination

Even the most "simple" flood-resistant method could be made into a legendary story...

Hans Brinker
from the dike-plugging tale
image source:
http://katieandbas.blogspot.nl/2011/01/madurodam.html
Summary

“The social, economic, ecological and cultural values of flood risk management measures should be considered and pursued (MARE Toolbox, 2011).”

• TASK DEFINITION

This project combines the tasks of flood risk management and spatial planning together to test the hypothesis of “the linkages between flood management, urban design, planning and management, and climate change initiatives are beneficial (Abhas K Jha et al., 2011. P47).”

The task is to devise strategies that will not only make the area safer, but also have extended benefits on ecological, spatial and economic aspects. It explores the way to deal with the relationship between human interventions and natural processes “on a wide variety of scales that will transform and strengthen the identity of the Delta”. The products include “Integrated flood risk management toolbox (IFRM Toolbox)”, strategies for Rijnmond-Drechtsteden region on 4 levels (Delta level, Dike-ring level, Local level and building level), and a small scale design of Numansdorp. The IFRM toolbox, the multi-scales’ strategy and the research method could be adopted to other Delta regions as design guidelines or case studies.

Rijnmond-Drechtsteden area has been selected since it is not only the transition zone which influenced by geological influences and human activities, but also both hazardous and vulnerable to floods, as can be seen from figure 2. In the past, the flood defense could be regarded as flood resistant structures, including dikes and dams. In recent years, increasing urban development pressure and the corresponding interests on living environment have caused a discernible change in attitude. As the sea level rises and safety standards are tightened, the current flood management will require new interventions. Particularly in this transition zone and urban-rural fringe, traditional flood resistant measures on Delta and dike-ring levels lead to an undesirable influence on ecosystem and spatial quality, as well as high expenses on maintenance. Climate change and the resulting rising water levels increase urgency to the task. All this can hardly indicate anything else than the necessity for a change in water management (Rijkswaterstaat, 2011). Therefore the issue of integrated flood risk management is a recurring topic of debate.

Under this circumstance, the project explores the way of close collaboration in the field of flood management and spatial development. Therefore the main research question in this thesis is “How can the integrated flood risk management improve the estuarine and agricultural ecosystem, and the spatial quality for the urban-rural fringe area of Dutch delta? “

• OBJECTIVES AND RESEARCH APPROACH

The project is the design-driven research. The main objective of the present study is to develop and test the integrated flood risk management
toolbox (IFRM toolbox). A large part of the study is devoted to the development of the IFRM toolbox that will help to balance the various interests from the flood risk management and spatial development angle. The development of the IFRM toolbox is based on the literature review and comparative study of the current theories and projects. It reflects on what it means to use flood risk management on a wide variety of scales, and what the impacts will be brought to spatial, environmental and ecological aspects.

A second objective concerns about testing the IFRM toolbox through the design study on specific location. The study area is the urban-rural fringe of the Dutch delta, Rijnmond-Drechtsteden region, where different safety standards and development requirements come together. The concrete elaboration of the design study on specific location will help to identify and discuss the possibilities and impossibilities of the toolbox. For the selected location, different solutions were devised, and the most preferable one was studied in further detail and tested to assess its performance in terms of safety, environmental impacts, and technical feasibility.

This thesis uses design-driven research as main method and it includes two parts: design research and research-by-design. The graduation project is motivated by the analysis of the specific topics and locations. On this basis, the general research question triggers the design research process, in order to describe, review and evaluate the existing situation and methods. The knowledge obtained from the design research will be summarized into the IFRM Toolbox. Then, in order to in depth study the effectiveness of the toolbox and to receive realistic responses, the IFRM Toolbox is evaluated and visualized under concrete situation in the research-by-design process. As a result, the design-driven research has resulted in a vision that transforms Rijnmond-Drechtsteden region from the far side of Randstad into an attractive delta new frontier with complete river estuary, robust agro-ecosystems and sustainable urban development. And the key intervention of Numansdorp shows how does the tools and multi-scales work together.

- **MAIN CONCLUSIONS**
  - Rapid urbanization requires the integration of flood risk management into regular urban planning and governance.
  - A totally open delta is not preferable for the dense-populated Dutch delta;
  - The decisions on larger levels will result in water hazards on smaller levels, but with smartly use of the water, such kind of challenges will be transformed into development opportunities;
  - The engineering structure can be transformed into benefits by relating them with other functions, such as residential, recreational, and ecological functions.
  - An integrated strategy requires the use of both structural and non-structural measures and good metrics for “getting the balance right”.
  - The IFRM Toolbox will not only benefit the researchers and designers, but local people could also make use of the tools.
Figure 3. Main structure of the report  
Source: Author, 2013

Literature:


1. Introduction

1.1 Rethinking

1.2 Problem statement

1.3 Aim

1.4 Relevance
1.1 Rethinking the current flood risk management

Rijnmond-Drechtsteden region is a product of natural processes and human engineering in the past hundreds of years.

1.1.1 Definition of flood risks and flood risk management

In this project, flood risk is defined as the expected yearly flood impact, and it can be mathematically calculated as the product of hazard, exposure and vulnerability (Hooijer et al., 2002), as can be seen from figure 5. Generally speaking, flood hazard could be reduced by structural measures, such as dam and dikes. The exposure and vulnerability can be alleviated by non-structural measures such as changing land-use typology and spatial planning (Gouldby and Samuels, 2005).

1.1.2 Before Deltaworks: Defend on local and dike-ring level

When the development and technical levels were low in the past and retreat to higher ground is unthinkable due to that most of the country area is below sea level (Kundzewicz, 2003), people have to attack natural challenges by constructing embankments. The clay and sand continuously silted up outside the dikes, which formulated the unique delta landscape, and the delta branches was part of a large nature reserve together with the tidal channels, polder lakes and creeks. For years, it is the important habitat for thousands pairs of birds to raise their young there year in, year out. “In wintertime, tens of thousands of wild geese would sit along the banks of the Haringvliet. The rich benthic life of the uncovered mudflats and sandbars provided plenty of food for the birds (Rijswaterstaat, 2010).”

During this period, the dikes was built on the local level. Moreover, they were mentained by the local landlords. The poor mentainance of the dikes and sluices, in company with the peat-cutting activities, aggravated the flood hazard and vulnerability.

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Figure 4. Changing relationship between human interventions and natural processes

Source: Author, 2013

Data used: Based on information from the books Atlas of Dutch Water Cities, Dutch Lowlands, Man-made lowland. And digital maps from EduGIS and watwaswaar.nl

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1.1.3 After Deltaworks: Resist on Delta level

After the 1953 flood disaster, the flood defences structure quickly jumped up to the delta level. The Deltaworks has closed all the estuaries of the southwest Delta with dams or storm-surge barriers except Nieuwe Waterweg. As one of the consequences, the urban area and industrial facilities quickly take place of the former floodplain. However, as can be seen from figure 4, there is a big gap between natural processes and human interventions after the Deltaworks, which calls for rethinking the current flood risk management and exploring other possibilities, which not only “keep our feet dry”, but also bring dynamics back to this region.

( * Please see Appendix 1 for the complete diagram).

1.1.4 Current flood risk management: Dominated by structural measures

According to historical analysis and relative researches, the current flood risk management of this region could be regarded as regional structural resistant strategy (De Bruijn, 2005), due to the fact that in the past hundreds of years people merely rely on structural measures to reduce the flood probability, such as dams, dikes, river training works and reservoirs. But little efforts were paid to mitigate the flood consequences by combining flood risk management together with more resilient spatial planning.

The recent flooding in the Rhine River is a serious warning, which has aroused the current resistant strategy to be a very heated discussion recently. It is time to change our insight and research into alternative management.

Flood risk= Probability * Consequences

Exposure  Vulnerability (flood prone areas)

Hazard

Key words
Flood risks, Flood risk management Structural measures, Non-structural measures
Indeed, the Deltaworks ensured a freshwater supply and protection against flooding. However, it has its disadvantages on natural, spatial and environmental aspects, as can be seen from the two diagrams on the right side.

The long and short-term problems concerning water management, socio-economic status and landscape qualities have been uncovered gradually (Kundzewicz, 2000), such as the disappearance of the salt- and freshwater transitional area with its characteristic flora and fauna, the virtual disappearance of the tidal effects, which has resulted in banks caving in, and the urban vitality of Drechtssteden cities has been weakened due to the closure of Haringvliet sluices. Besides, although currently the flood risk is quite small, potential probability and consequences of a flood are very high. Whenever there is an unpredictable disaster, the consequence is deadly; especially when we take into account this region is highly urbanized and populated.

The problems could be summarized as follow:

**(1) Loss of Dynamics:**
- **Land-Water**
- **Life-Water**

**(2) Flood Hazard and Vulnerability**

### 1.2.1 Land-Water: Loss of dynamics

**• Disappearance of the saltwater-freshwater interface**

Before the dam and sluices were constructed in the Haringvliet, this region was part of a natural transitional area between the sea and the major rivers with large area of mud flats, sandbars and creeks. Twice a day, the sea could flow in and out freely. The tide and the changing discharge of freshwater from the rivers resulted in a continually changing and unique transitional area between saltwater and freshwater. It was also part of a large nature reserve together with the mouth of the Haringvliet, where the biggest pied avocet nesting ground could be founded (Rijkswaterstaat, 2010), tens of thousands of wild geese would sit along the banks of the river, and the mudflats provided sufficient food for the birds.

**• Barely any tidal effects**

the tidal difference has decreased from 1.8 – 2.3 m to 0.3m (Kees Storm et al.). The wash, which now hits the banks at approximately the same height every time causes the banks to cave in. The mudflats and salt marshes in areas outside the dykes that were created by tidal effects are gradually disappearing under water (figure 7). Many birds have lost their nutrient-rich habitat, special plants have disappeared and reed borders have turned into fields of nettles (Rijkswaterstaat, 2010). The disappearance of a
large area of natural buffer zone has further reduced the resilience of the whole systems to cope with the future uncertainties.

- **Disappeared fish migration**
  Closing off the estuary has resulted in the natural saltwater-freshwater interface largely disappearing. The sluices are only open at low tide to drain surplus river water. The sluices’ barriers prevents migratory fish such as salmon, sea trout, allis shad and twaite shad from swimming up the Rhine to the spawning grounds. Although there are six fish sluices on the dam, which operate like locks to facilitate fish migration. Research has shown that fish hardly use the “fish sluices”. Research by the Rhine Commission shows that further opening the Haringvliet sluices is the only possible way of achieving free fish migration for salmon (Kees Storm et al.).

- **Loss of the quality of eco-structure in the large agricultural landscape**
  The landscape has lost much of their original character and quality. In the past, the creeks are the tidal channels with natural levees. Gradually, it has been enclosed by dikes. Nowadays, the creeks have embarked by steep dikes, and some of the creeks are taken place by more “productive” farmland. Besides, Rijnmond-Drechtsteden region is the urban-rural fringe, a large area is dominated by mono-species agricultural land, without robust eco-structure (also called the buffer zone), it is very vulnerable to pests. Therefore, it is important to establish the robust eco-structure to enhance the quality and identity of this region.

Figure 7. Disappeared foreshore wetland
Source: Author, 2013
Data used: (Kees Storm et al.)
1.2.2 Life-Water: Loss of spatial quality

Historically there are several types of dwellings: the dike town with ribbon development, the harbour town with canals and sluices, the water town built largely upon the land reclaimed from marsh or lake, and the dike and dam town with creeks and small harbours (Burke, 1956). As can be seen, the urban pattern has strong relationship with the water. The hydraulic system, polder patterns, harbours and urban functions were mixed together as a whole. Traditionally life was focussed on and around the water with plenty of interesting path along the intertidal zone of land and water, while the small creeks interweave with the polder landscape and the water can be experienced almost everywhere.

However, in recent years, the expansion of port-related industrial site and the following heavy infrastructure along the river, the vanishing of former water system and more “stronger” dikes have kept people away from the water (Bosch Slabbers Landscape Architects. 2012, p.54-61). As illustrated in figure 8, the dike area has reverted to be a barrier between the water and our daily life in such a way that the spatial quality and accessibility of the waterfront is poor. In the future, if we continually increase the height of the embankments to cope with the conflicts between water hazards and urban development, the mono-functional water infrastructure will become a hard barrier between life and water, instead of an attractive place in between of the delta landscape and the built-up areas.

Figure 8. Barriers between life and water
Source: Author, 2013
1.2.3 Flood Hazard and Vulnerable: “Lull before Storm”

- **The potential failure of the structural measures**
  The flood risks include the potential failure of flood resistant structures and the likelihood of flooding elsewhere. Firstly, if an embankment fails, the unexpected high water level will suddenly occur in an area that was supposed to be protected. But for inhabitants, it is always unclear which risk they are facing. In recent years, within the “strong” protections, the port-related industry and dwellings quickly built on the former floodplain. However, the quick economic development further increases its flood hazard and vulnerability. What is more, the disappeared buffer zone and the accelerated land subsidence also increase the flood probability. Moreover, the flood threats may turn back to the upstream or low-lying areas and cause catastrophic floods there.

It is impossible to entirely eliminate the risk of flooding. Hard-engineered measures are designed to defend to a pre-determined level. Until a decade ago little efforts were paid to mitigate the flood consequences (De Bruijn, 2005). While in fact, with the help of smart land-use or spatial strategies, we may not need to prevent floods everywhere. “As both urbanization and climate change accelerate, there may well be the need to move away from what is often today an overreliance on hard-engineered defenses towards more adaptable and incremental non-structural solutions (Abhas K Jha et al., 2011. P32).”

“A new strategy should not only focus on reaching a ‘safe’ situation by technical solutions.” (De Bruijn, 2005).

- **High hazard and vulnerability delta cities**
  Although currently the flood risk is quite small, potential consequences of a flood are very high. Whenever there is an unpredictable disaster, the consequence is deadly.

- **Increasing river discharge task**
  KNMI scenarios forecast that all scenarios envisage that the average discharge of the Rhine will increase in winter (up to +12 percent and decrease in summer (up to –23 percent). The same applies for the Meuse, with a maximum increase of 5 percent in winter and a maximum decrease of 20 percent in summer. As the consequence of the sea level rise together with the increasing river discharge, part of the dike rings are needed to be heightened or reinforced in the long run. It is time to explore more resilient flood risk management and spatial planning for the future.

![Figure 9. Flood hazard and vulnerability map](image)

Source: Author, 2013
Data used: Programmateam Rijnmond-Drechtsteden, 2013
1.3 Aim
“Using the integrated flood risk management as opportunities to establish a safe and dynamic delta new frontier”

The task is to devise strategies that will not only make the area safer, but will also improve the ecological quality and transform the area into an attractive place to live and to work.

In other words, the integrated flood risk management will not only work, but also have added values on social, ecological, spatial aspects. In specifically, the research and design processes including two parts: Design Research, and Research-by-Design

- **Design Research**
  - Understanding the relationship between urban, rural and delta branches.
  
  - Figure out what is integrated flood risk management (IFRM) and how does it works.

- **Research-by-Design**
  - Turn the flood risk management into benefit to bring together the hydraulic infrastructure, estuarine ecosystem, cultural landscape and spatial planning on different levels;

  - Test the IFRM Toolbox and explore the relationship between different levels

Notable mention is that, the collaboration of strategies on different levels is very important. For example, strategies like the small-scale retention ponds could also bring benefits to the the dike ring level or even the delta level in such a way that they help to enhance the resilience of the whole system.

Figure 10. 3 layers and 4 levels work together
Source: Author, 2013
1.4 Relevance

Urbanized delta: Safer, and more attractive place to live, to work and to stay...

1.4.1 Societal relevance

Half of the world population lives in delta regions that are under increasing threats, all of which is under further pressure from global warming. “It is important to consider the wider social and ecological consequences of flood management spending. While costs and benefits can be defined in purely economic terms, decisions are rarely based on economics alone (Abhas K Jha et al., 2011. P47).” The social and ecological consequences such as loss of local identities and buffer zones also need to be taken into account by city managers, urban planners and civil engineers on these broader issues. Indeed we need hard engineering structures to protect the built-up areas, However, long and short-term problems related with the use of structural resistant measures are evident today (Kundzewicz, 2000). There is now an opportunity to re-evaluate the important role of integrated flood risk management in creating a new harmonious relationship between natural processes and human interventions. The Drechtsteden area was selected, since it comprises several of the riskiest places in the Netherlands, and it is lies at the transition from open delta landscape to the compact urban areas. With grand challenges and great possibilities, major changes need to take place as to how society and the natural environment interact.

1.4.2 Academic relevance

Many researches have been done into the flood control system of the Rhine-Meuse Delta, as well as the economic and spatial strategies for the Randstad region. Most of them focus on the civil engineering or the metropolitan strategy, little connection has been made between flood risk management, the natural environment and the urban development. But through the historical analysis, we can see that the urban development of the delta cities have been greatly influenced by the water infrastructure. Especially after 1953, when people started to construct the regional flood control system. This research and design project will contribute to the current philosophies of “integrated flood risk management strategy” (Findings from FLOODsite, MARE project, IPDD principles, LIFE project, Multilayered safety policy, Kennis voor Klimaat), which aiming to reduce both of the flood probability and its consequences, and make the system more resilient in an uncertain future. Currently, little has been show as how does such kind of strategy will influence the ecological, social and spatial qualities on different scales, and how to develop a balanced combination of various aspects for planning and design in urbanized delta areas, such as water management, urban development, economic development, natural environment, and recreation. This project will provide opportunities to explore the hypothesis of “turn the flood risk management into benefit” within Rijnmond-Drechtsteden region based on existing theories and projects. It will also lead to physical design proposals that help to evaluate the effectiveness of the integrated flood risk management. The strategy, methodology and design toolbox can be also applied to other delta regions around. Especially for the urban-rural fringe areas which are facing conflicts between human interventions and natural processes.
Literature:


KEES STORM, BACKX, J. & BREUKELAAR., A. Benefits and consequences of managing the Haringvliet sluices for fish migration.


2. Methodology

2.1 Knowledge-based design
2.2 Graduation planning
2.1 Knowledge-based design

2.1.1 Relationship between design and research

What is a scientific research?
Research is a systematic inquiry to describe, explain, predict and control the observed phenomenon. The most important thing of research is actually the thinking behind the research: What we really want to find out? How we build arguments about ideas and concepts? (Anglin, Ross, and Morrison, 1995).

Design as research
Gall, Borg and Gall (1996) proposed four types of knowledge that research contributed to education, including: Description, Prediction, Improvement, and Explanation (The last type research subsumes the other three). From this point of view, the knowledge-based design could be regarded as research, and the reasons could be listed as follow:

• Firstly, it is the goal-oriented interdisciplinary approach. It is stimulated by the general research questions which based upon design study;
• Secondly, it describes the phenomenon, predicts the consequences that “will occur at time Y from information at an earlier time X (Gall, Borg and Gall, 1996)”, and identifies the general principles (“Design research”);
• Thirdly, it explores the effectiveness of intervention. The research approach includes experimental design and evaluation research (“Research-by-design”).

2.1.2 The graduation project as a form of research combining research inquiry and design thinking

The general research question
“How can the integrated flood risk management improve the estuarine and agricultural ecosystem, and the spatial quality for the urban-rural fringe area of Dutch delta? “

Design research: Reliable scientific work
“Design research describes and analyses existing designs with a known context (De Jong and Van der Voordt, 2002).”
• Modes of research:
  - Literature review and comparative study in order to generate design tools, and it is also a way to evaluate study of the existing theories and project.
  - Aims:
    - Understanding the relationship between urban, rural and delta branches;
    - Figure out what is the problem of the current flood risk management and what is the integrated flood risk management (IFRM).

The design research is based on the existing theories and practices. It provides a generic knowledge which could be used to other situation as well. In this graduation project, the generic knowledge is the integrated flood risk management toolbox(IFRM Toolbox), which has been developed based on documented, examined and evaluated existing theories and projects, such as “room for the river” program, LIFE project, the Deltaworks, etc. The Toolbox will work as the design tools for the next step to guide the spatial planning and to enhance the water safety. With different combinations of the tools based on the concrete situations, the toolbox could provide new opportunities for further research and design activities. Take the regional structural measures (such as Concrete Dam) for example, although it has not been developed a lot in this graduation project, but we could further test and imply such kind of tools in other deltas which are facing situations much more complex and urgent. Therefore, the Toolbox is like a laboratory rather than a concrete design solution. It contains thousands of probabilities, which should be examined and evaluated in a broader context.

Research-by-design: Creative design and evaluation
“Research-by-design is about study through design using knowledge acquired by design research (Nijhuis, S. and Bobbink, 2012).”

The “Research-by-design” is useful for testing whether scientific theories and models actually work in the real world. It is also a method used to narrow down a very broad field of research into one
easily researchable topic.

- Modes of research: Experimental design study by using the IFRM Toolbox; Design study to visualize and evaluate the interventions.
- Aims:
  - Test the IFRM Toolbox under concrete requirements and situations;
  - Turn the flood risk management into benefit to bring together the hydraulic infrastructure, ecosystems, and spatial planning on different levels.

In order to test the effectiveness of the generic knowledge that got from the previous design research, various types of tools will be involved into the experimental design study according to the concrete requirements and situations of the specific location. For Rijnmond-Drechtsteden region, three alternatives have been considered. They range from storm surge barriers option to super dike option and the most preferable alternative will be further explored in the next step (design study). As can be seen from the diagram on the right side, the design study involves diverse types of techniques, including case study, mapping, modelling, etc. It tries to visualize and evaluate the preferable alternative on different levels: Delta level, dike-ring level, local level and building level. And the co-relationship between these four levels will be further explored through the key intervention of the village – Numansdorp. The key intervention also shows the probability of strengthening the relation between occupation layer and landscape layer with the help of water infrastructure layer.

2.1.3 Techniques

In figure 11, the methods and techniques are shown in relation to the products. The techniques will be involved to answer the sub questions, as explained further below.

Figure 11. Approach, methods and techniques used for this graduation project
Source: Author, 2013
• Integrated flood risk management
- What are the negatively impacts of existing flood risk management strategies on the natural processes and why?
  • Domain(s): Urban design & Ecology
  • Method(s): Design Research. Including Layers Approach, Literature Review.
  • Implementation: Diagram shows the relationship between natural processes (Landscape layer) and Human interventions (Infrastructure layer and Occupation layer);

- What are the core principles and beliefs behind such theories as “Integrated flood risk management” and “More resilient system”?
  • Domain(s): Urban theory
  • Method(s): Design Research. Including Literature Review & Project Study
  • Implementation: Literature review paper on "Integrated flood risk management"; Chatagory the existing structural and non-structural measures into a “integrated flood risk management Toolbox” based on the core principles of the integrated flood risk management.

- What are the flood hazard and vulnerability of this region in the long term with a time horizon of 50-100 years?
  • Domain(s): Cross-disciplinary study, engineering
  • Method(s): Design Research. Including Literature Review & Expert Interview
  • Implementation: Mapping and sketching based on the current researches.

• Water hazards
When the Haringvliet sluices need to be closed temporarily,
- How to cope with the unexpected water level along the Haringvliet- Hollandsch Diep-Biesbosch?
  • Domain(s): Urban design, Ecology & landscape planning
  • Method(s): Site Analysis & Literature Review, Sketching
  • Implementation: Mapping, testing the toolbox, project study.

- How to retain and store the storm water while it cannot discharge into the river due to the high river water level?
  • Domain(s): Urban design, Ecology & landscape design
  • Method(s): Site Analysis & Literature Review, Sketching
  • Implementation: Mapping, testing different combination of the toolbox, project study. This research will provide design inspiration by discovering the requirements of the water safety tasks. And in the design process, these knowledge could be used as the urban design tools to influence the natural, cultural and spatial aspects.

• Delta level & Dike ring level: Estuarine dynamics
- How did the Foreshore area function historically as an ecological system?
  • Domain(s): Landscape design & Ecology
  • Method(s): Historical Analysis (before deltaworks), Spatial analysis (foreshore area), Mapping, Sketching.
  • Implementation: Research on the intertidal wetland, including the tidal range, typical fauna/flora and their preferred habitats. Explore the changing situation of the foreshore areas with the help of models and sections.
- In order to restore the estuarine dynamics, what kind of alternatives could be tested? and how does it works?
  - Domain(s): Landscape design, Civil engineering & Ecology
  - Method(s): Literature review, Modelling, Mapping.
  - Implementation: Comparing the existing 4 alternatives of the Haringvliet sluices management. The research results will form a basis and spatial framework for design on the dike ring level, namely estuary restoration.

- Building level: Spatial quality
  - How to deal with the relationship between urban and rural, natural areas? and Which chances can be addressed from the point of view of the (potential) spatial and functional quality of the region?
  - Domain(s): Urban design & landscape design
  - Method(s): Site Analysis & Literature Review, Sketching, Modelling.
  - Implementation: Research on the theoretical model of the relationship between landscape and urban areas. Based on the spatial analysis and the green-blue structure, the theoretical model will be further developed into spatial strategies.

- Local level: Eco-structure
  - What are the typical identities of the agro-ecosystem in the past?
    - Domain(s): Urban design, Ecology & landscape planning
    - Method(s): Site Analysis, Literature study, Mapping,
    - Implementation: Through historical analysis and spatial analysis, the typical identities of the cultural landscape will be summarized. As well as the existing problems.

- How to enhance the quality of agro-ecosystem in such a way that it could benefit the ecostructure, recreational functions, and spatial quality?
  - Domain(s): Urban design, Ecology & landscape planning
  - Method(s): Site Analysis, Literature study, Mapping, Case study.
  - Implementation: Cross-discipline study on the requirements of the robust agro-ecosystem and the creek networks. Then combine the knowledge with the stormwater management and urban design to enhance the safety and dynamics of the cultural landscape.

- The relationship of different levels: Tested district
  - How does different levels work together to establish a safe and dynamic Delta New Frontier?
    - Domain(s): Urban design, Ecology, Civil Engineering, Architecture & landscape design
    - Method(s): Site Analysis, Case study, Modelling, Sketching.
    - Implementation: It is also the knowledge-based design. The knowledge of historical development, survey, and spatial analysis will work as the basis for the design proposals. The draft concept will be improved by experimental design study and case study.

- What can we learn from the specific location when testing the IFRM Toolbox and using the strategies gain from the previous research and design?
  - Domain(s): Urban design, Ecology, Civil Engineering, Architecture & landscape design
  - Method(s): Sketching, Reflection.
  - Implementation: Actually this subquestions will be raised and addressed, raised and addressed...all the time, even after finishing the graduation project. It could help to gradually update the IFRM toolbox, and to test the other possibilities under different context.
2.1.4 Dilemma: Evaluation research in a design proposal

“Objectivity” is the foundation for academic research since it aims to explain and improve the objective phenomenon. In the traditional thinking, design is more intuitive which is based on personal experiences and emotions. But “in a University of Technology, designs are made not only intuitively, but based upon study, documented, examined and evaluated” (De Jong and Van der Voordt, 2002). Therefore, the “Knowledge-based design” could be regarded as “Scientific work”. As for scientific work, the evaluation research is an important component part in order to make the research reliable and convincible to the public. However, as for a design intervention, there are still difficulties in the evaluation research, especially taking into account that there are hundreds of other probabilities of the design proposals. There are mainly two types of questions: the first one is “How to evaluate a design proposal?”, and the second one is strongly related to the first one and it is “How to figure out the best option? Or, perhaps the intention to ‘figure out the best solution’ is just an illusion? “

Possible answers to question one: Evaluation research runs through the whole project (figure 12)
- Evaluate study of the existing knowledge: “plan analysis” & “comparative study”;
- Evaluation by design in a context: “site analysis”, “experimental design” & “design study”;
- Evaluation by public: the design proposal, research approach and design tools will be judged scientifically by the public. And the IFRM toolbox could be examined in other deltas as well, in order to continually improve its effectiveness under different circumstances.

Possible answers to question two: Acquiring knowledge through goal-oriented design
De Jong (2012) explains that: “It is the task of empirical research to find probabilities, but it is the task of design to find improbable possibilities.”(De Jong, 2012. p6). In this graduation project, with the help of in-depth analysis and experimental design study, several “improbable” possibilities have been discovered, and the one of the probabilities has been studied thoroughly. Under such circumstances, the graduation project is not aiming to figure out “what is the best solution for Rijnmond-Drechtssteden region”, but the thinking behind the design is more important: It aims to explore the probabilities to “turn the flood risk management into benefit to balance the relationship between human interventions and natural processes”. Although the design proposal is based on specific location and requirements, some of the discoveries could add to a more general body of knowledge: Firstly, the design proposal makes it possible to test the hypothesis, and in this case, the hypothesis is “the flood risk management can be turned into benefit” (chapter 1), which has been testified and visualized by design proposals (chapter3-5); Secondly, the creative design thinking could arise new research topics. For example, in chapter 5, the mutual benefit relationship between agro-ecosystem and local storm water management has been discovered, and the effectiveness of such kind of strategy could be further studied by doing small-scale experiments.
2.2 Graduation planning

Motivation

Design Research

Research -by -Design

- Literature Review; Thesis Plan
- Comparative Study
- Field Trip
- Site Analysis
- Project Position, Concept
- Strategies on different levels
- Tested District
- Report
- Master Thesis
- Reflection

My Experience...
Literature:


Describe, explain and evaluate the existing knowledge

3. Design Research

3.1 Theory & 3.2 Comparative study

3.3 Spatial analysis

3.4 Theoretical model

3.5 Concept
3.1 Theory

3.1.1 Literature review

**Water as Foe, Water as Friend:**
Reviewing Long-term strategies for flood risk management of lowland river systems

**Key words**
- lowland
- flood risk management
- delta cite
- structural resistant measure
- non-structural mitigation measure
- resilience

**Abstract** – For the past hundreds of years, flood risk management has mainly focused on reduction of flood probability with the help of structural resistant measures. While recently policy makers propose to increase the resilience of systems, since scientists expect resilient systems to better cope with the flood consequences in the face of urbanization, growing populations and long-term climate change trends (Waterstaat, 1999, Gouldby and Samuels, 2005, Deltares, 2010, Hooijer et al., 2002).

In this review paper this advantage of more resilient flood risk management was verified based on the current theories and projects. The objective was to explore comprehensive strategies for flood risk management which not only better reduce the flood probability but also mitigate the flood consequences in the long run.

This literature review will look into the first section the traditional structural resistant measures and the non-structural mitigation measures in view of sustainable development. Then it will conclude the character of long-term strategies for flood risk management. The following section will further explain the key elements in the continuing cycle of flood risk management measures. Finally it will work as the theoretic framework of the graduation project.

**Key conclusions:**
- “Instead of a foe - that should be tamed and conquered - water is becoming more and more a friend for the planners and water managers...that water and flood protection measures create opportunities for spatial development, such as nature, recreation and housing.” (Sokolewicza et al., 2011, p.143).
- Smartly using the water in Landscape planning and urban design;
- It is the combinations of structural and non-structural measures on different scales (de Bruijn et al., 2009).
3.1.2 Definition of integrated flood risk management

More resilient! “Turn the flood risk management into benefit.”
-- MARE Toolbox

Based on the current flood risk management, more resilient strategies related to regional and local differentiations are needed to be developed in such a way that the future flood risk management could be transformed into benefit for sustainable development. Therefore the Dutch policy makers suggest making water systems more resilient for the long-term scenarios with a time horizon of 50–100 years. “Rapid urbanization requires the integration of flood risk management into regular urban planning and governance. and many flood management measures have multiple co-benefits over and above their flood management role (Abhas K Jha et al., 2011. P46).” For example, the retention pond has amenity value, enhances biodiversity, provide food production, evacuation space, and it can also reduce flood impacts.

Flood management measures are typically described as either structural or non-structural. Structural measures aim to reduce flood risks by controlling the flow of water with (visible) engineering structures. They are complementary to non-structural measures that intend to keep people safe from flooding through better planning (Abhas K Jha et al., 2011). A comprehensive integrated strategy should be linked to the concrete requirements for now, and for the future. Structural and non-structural measures do not preclude each other, and most successful strategies will combine both types (De Bruijn et al. 2009, p.76).

As can be seen from figure 13 & 14, there are four types of measures (* based on the research from FLOODsite and Deltaras): At the Delta level, there are structural load reduction and non-structural load reduction measures, such as dam, storm surge barriers, and flood-plain management; At the dike-ring level, there is structural flood protection, mainly focus on the primary dike ring system; At the community and building level, there are diverse non-structural mitigation measures to reduce the consequence of a flood disaster, such as spatial planning, evacuation plan, and adaptive houses.

![Figure 13. Integrated flood risk management](source: Author, 2013)
Data used: (Nathalie Asselman et al., 2012)
3.1.3 Rethinking: Human intervention & Natural process

<table>
<thead>
<tr>
<th>Human interventions</th>
<th>Natural process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regional level: Reduce the hydraulic loads, including water levels and waves through the engineering structures.</td>
<td>Dike ring level: Unbreachable flood defences</td>
</tr>
<tr>
<td>Load reduction (structural)</td>
<td>Flood protection</td>
</tr>
<tr>
<td>Load reduction (non-structural)</td>
<td>Consequence reduction</td>
</tr>
</tbody>
</table>

Figure 14. 4 types of Integrated flood risk management
Source: Author, 2013
3.1.3 Four elements of “integrated flood risk management”

• Load Reduction: Structural and non-structural measures

Measures which may reduce the hydraulic loads include all technical and non-structural measures that may reduce either the flood levels (whether design flood levels or all flood levels), or the wave height, wave volume or wave impact. This is especially relevant when the hydraulic loads are expected to increase as a consequence of climate change and sea level rise. (Nathalie Asselman et al., 2012, p7-9).

The structural measures comprises flood resistant measures such as barriers, and dams along the coast or the estuaries. These technical measure are efficient ways of controlling the flood levels. However, they can also fail, take Maeslantkering for example, the probability of failure of the Maeslantkering is equal to approximately 1/110 per closing demand (Nathalie Asselman et al., 2012). And if they fail, the water levels may become too high and the damage is unacceptable, because the dam or barrier are usually been used to protect the dense-populated big cities.

In the 1990s the Netherlands experienced two major river floods, which triggered an exploration of more resilient measures, known as non-structural measures to reduce the hydraulic loads. For example, “room-for-river” program aims to lower water levels, the use of vegetation (salt-marsh vegetation, willow coppice and forest) is effective to reduce wave height, and wetlands in the transition zones between land and water is useful to break waves and to reduce the energy.

• Flood Protection: embankments and dunes

Traditionally, flood protection is mainly rely on natural levees, dike rings, and dune. A robust flood protection is a broad, elevated area, subdivided in subzones which are appointed for other functions in front, behind, or on top of the embankment, as explained in figure 15. The broad profile forms a deliberately over-dimensioned flood defence, which requires no regular adjustments because of changing boundary conditions, or a revision of protection standards. Thus, the concept is robust and future-proof.

The multifunctional use of the flood protection zone involves elements such as transportation, housing development and businesses, vegetated foreland, agriculture, landscape values, cultural heritage, recreational functions and energy production. Indeed, the initial costs of a integrated flood defence are considerably higher than a traditional dike. However, it saves space and investment in the long run.

Figure 15. Scheme of embankment,
Source: (Nathalie Asselman et al., 2012, p13.)
• Consequence reduce: Exposure Reduction

Measures to reduce the exposure to floods aim to reduce the extent of the flooding and/or its depth. Compartmentalisation, local defences around vulnerable facilities, unbreakable dike, and other measures that may reduce the inflow can be classified as Exposure Reduction.

Compartmentalisation literally means: splitting up into smaller portions. The primary objective of compartmentalisation is to diminish the surface area which can be flooded due to one single flood event resulting from the failure of an embankment.

Unbreachable embankments are often regarded to classify as flood protection only, but they also have significant influence on the exposure characteristics and thus reduce a flood’s consequences. Past and recent floods worldwide reveal that the breaching of embankments may result in flood disasters with many fatalities.

The temporary flood defence and local defences around the vulnerable facilities are mostly been applied to the historical centers, where the spatial and cultural qualities require special protection.

• Consequence Reduce: Vulnerability reduction

The common denominator between measures that reduce vulnerability is that they concern actions that do not affect the floodwater, but rather aim to reduce the adverse effects of a given flood.

The measures that reduce vulnerability including spatial planning (building elsewhere), insusceptible construction (building otherwise), building relocation, retention ponds, elevated ground, private flood mitigation measures (early warning system, evacuation plan and shelters), insurance arrangements, and so on. As in common, the hazard zoning is the foundation for the vulnerability reduction.

• Conclusion

As for the long-term scenarios with a time horizon of 50-100 years, the Dutch policy makers suggest making water systems more resilient (De Bruijn, 2005). The design of a flood risk management strategy involves combining measures including both structural resistant measures and non-structural mitigation measures. Together, they “will not only make the area safer, but will make it a more interesting place in which to live, work and stay” (Deltaprogramme, 2012).

Getting the balance right between structural and non-structural measures is also a challenge. Policy makers and planners need a clear vision of the alternatives, methods and tools to assist them in making choices. Therefore, A toolbox which including the existing tools and techniques is very important. It can help to illustrate the cost-benefit analyses, predict the outcome of decisions, and communicate risk and create linkages between stakeholders.

The graduation project is devoted to the development and evaluation of the IFRM toolbox (Table 2.) and the visualization of several selected tools.
3.2 Comparative Study

Based on the 4 elements explained before: Load reduction (structural and non-structural measures), Exposure reduction, and Consequence reduction, the existing tools have been elaborated by a wider research of the current theories and projects.

The involved main theories including: Toolbox from the book “River.Space. Design: Planning Strategies, Methods and Projects for Urban Rivers”; Urban Flood Protection (UFP) Matrix; Eco-shape design guidelines; Tools for integrated flood management (ASSOCIATED PROGRAMME ON FLOOD MANAGEMENT, APFM); Multilayered Safety policy; The report from Kennis voor Klimaat--Towards climate-change proof flood risk management.

The major involved projects including: Ruimte voor de rivier (“Room for the river”) program; Balance-island project outside the Haringvliet sluices; MARE project in Dordrecht; LIFE project; Toolkit on Blue Infrastructure in Hackbridge; Tokyo’s Super-dikes; Flood risk management in Elba island; Scenarios for the Rhine-Meuse Delta, and so on.

Examples

<table>
<thead>
<tr>
<th>Delta level ← Nature</th>
<th>Rural</th>
<th>Urban</th>
<th>Building level →</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room for the river</td>
<td></td>
<td></td>
<td>River. Space. Design</td>
</tr>
<tr>
<td>Kennis voor Klimaat</td>
<td></td>
<td></td>
<td>MARE</td>
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<tr>
<td>Multi-layered safety</td>
<td></td>
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<td>UFP Matrix</td>
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<td>APFM</td>
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</tr>
<tr>
<td>Nature</td>
<td></td>
<td></td>
<td>Eco-shape</td>
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<tr>
<td></td>
<td>Islands</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ecoshape</td>
<td>Building</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Comparative study
Source: Author, 2013
# 3.3 Result: IFRM Toolbox

## Load Reduction

### Structural measures
- Concrete dam
- Earth dam
- Fixed dam
- Fixed dam (with sluices)
- Fixed dam (with shipping capacity)
- Storm surge barrier
- River training works (canalisation or normalisation)
- Reservoirs

### Non-structural measures
- Balance island
- Sand engion
- Floodplain management (Room for the river)
- Shellfish reef
- Buffer zone: Wetland, Marshflat
- Reforestation
- Rehabilitation
- Retention polders (with controlled inlets and outlets)
- Adapted agricultural practice

## Flood Protection

### Structural measures
- Super dike/Delta dike
- House dike
- Dam/Sluice
- Elevated road/railway
- Unbreachable dike
- Flood defence stairs

### Non-structural measures
- Quay wall
- Temporary defences
- Fortification
- Park dike
- Grass dike
- Rich revetment

## Consequence Reduction

### Structural measures
- Compartmenatalisation
- Unbreachable dike
- Former military defense line
- Intersection (eg. the Dief dike and A2)
- Small-scale retention
- Creek
- Pump
- Temporary defences
- Dune/Natural levee

### Non-structural measures
- Exposure reduction
- Vulnerable reduction
- Spatial planning
- Relocation
- Sealing of openings
- Elevated ground
- Surrounding defences
- Insusceptible construction
- Early warning
- Evacuation plan & Shelters
- Insurance

---

Table 2. Result table of the comparative study  
Source: Author, 2013  
Data used: Literature and project review
"All strategic alternatives should consist of combinations of structural and non-structural measures, and all the alternatives should aim at both hazard control and vulnerability reduction (Meerlaagsveiligheid, 2011)." As can be seen from figure 16, since the flood risk management will not only deal with the flood hazard, but also the flood vulnerability, we need to take into account the differentiation of the spatial characters as well.

As shown with the diagram below, with the joint effort of these two elements: Flood risk management and spatial planning, “Instead of a foe - that should be tamed and conquered - water is becoming more and more a friend for the planners and water managers. (and) water and flood protection measures will create opportunities for spatial development.” (Sokolewicz et al., 2011).

For the next step, in order to evaluate the effectiveness of the toolbox and visualize the tools in the real world, Rijnmond-Drechtsteden delta has been selected to do the in-depth design study. This kind of design-oriented research could provide more realistic responses than pure theoretical research.

Figure 16. Differentiation of flood hazard and vulnerability
Source: (Meerlaagsveiligheid, 2011)
3.4 Site analysis

3.4.1 Differentiation of spatial character

- Extensively urbanized;
- Rely on the primary dike ring.

- The secondary dikes may partly be used, but they play a minor role for spatial coherence;

- The buildings, road infrastructure, industry, and urban landscape dominant the spatial structure;

- The port-related industry along the river push people away from the water.

Figure 17. Typical spatial character of IJsselmonde
Source: Author, 2012
Data used: TOP10NL (2011)
- Dike and dam village, mound village.
- Original cultural landscape.

- The secondary dikes are combined with the local road system. **Dike compartments dominate the spatial structure**, eg. ribbon development;

- **Canals and creeks** enable people experience the water everywhere.

Figure 18. Typical spatial character of Hoeksche Waard
Source: Author, 2012
Data used: TOP10NL (2011)
- Half-Half: The north part is dominated by compact urban area and port-related industry; The south part is dominated by the open rural landscape with creek network, polders and nature reserves.

- The eastside part of the dike is the weakest link which are needed to be reinforced in the near future, as shown in the diagram below.
3.4.2 Conclusion: Two systems confront in the urban-rural fringe area

As a conclusion of the spatial analysis, there are two systems meet together at the edge of the “Green-blue Heart”: one is dominated by the landscape layer, including delta branches, creek network, polder landscape, dike compartments, historical dwellings with linear character; The other one is dominated by urbanization processes, including port-related industry, heavy infrastructure, and urban areas with compact character.

“How to deal with the relationship between the unique landscape and the built-up areas?”

Figure 20. Two systems
Source: Author, 2013
In order to understand the relationship between compact built-up areas and the surrounding open landscape, a review study was undertaken.

In the book “Oorden van onthouding– Nieuwe natuur in verstedelijkend Nederland” (1998), Eric Lutes and Dirk Sijmons introduced three so-called “Potential mutual benefit zones” between urban settlement and the open landscape: Contact zone, contrast zone and contract zone. In the project “Gebiedsvisie Deltapoort 2025”, the three zones have been further explained and distinguished as the front (contrast), the contact and overlapping area (contract). In this graduation project, this theoretical model will be applied to improve the identity and spatial quality of the urban-rural fringe, see figure 22. This results in the concept of this region. In the next chapter, the theoretical spatial model will be combined with the flood risk management through integrated planning and design.

- **The front (“contrast”)**

It is focus on the sharp edge between settlement and landscape. We could find this quality in places where the settlement along the coast or along the arms of delta branches, or in districts which developed in the dunes or along a polder. For the contrast model, the cities and the landscape could both express their own specific characteristics. Therefore it calls for extra attention to the relationship between settlement and landscape, such as physical connections or visual connections.

For these “sharp edge” areas, project “Safe and Dynamic Rijnmond-Drechtsteden” will on one hand restore the contrast identities of delta branches and the built-up areas, on another hand, the physical and visual connections will be enhanced. As a result, the “hard edge” between life and water will be transformed into a mutual benefit system.

- **The overlap (“contract”)**

It is a gradual transition between built-up areas and landscape where urban and rural functions penetrate into each other. It is suitable for the integrated development of living, working, production and leisure facilities, which rely on the spatial qualities of the surrounding landscape and the recreational trails. Such as sports fields, allotments, golf courses, folk gardens, country parks, and so on.

For these overlapping area, the project try to develop an integrated plan that combine the recreational functions with the eco-structure of the polder landscape, in order to enhance the attractiveness of the rural areas where people could experience the landscape everywhere, and establish a robust eco-structure.

Figure 21. three types of qualities
Source: Google Earth, 2013; Bing map, 2013.
Connections ("Contact")

The “contact” consists of the visual and physical connections between built-up areas and landscape, such as roads, trails, dikes, avenues or even the watercourses. This type of transition is typical for villages or suburbs, where the urban functions grafted to the vast landscape pattern. It is based on the experience that the exchange between urban and rural areas is very important (in economic, ecological and aesthetic aspects). The mutual contact depends on urban pattern, landscape and heritage structures.

Contact Quality in the project reflects on the idea of better connection between urban, rural and natural areas, such as cycling and walking paths, the development of leisure facilities and housing program with a linear character.

Figure 22. Theoretical model for Rijnmond-Drechtsteden
Source: Author, 2013
3.6 Concept

Two systems work together hand in hand!

For the urbanized delta areas, integrated flood risk management strategies are naturally designed to fit in with water-related planning issues and can be part of urban design, eco recovery or climate change adaptation.

The concept of the project is to establish a mutual benefit relationship between the landscape and the built-up areas with the help of integrated flood risk management, in such a way that the unique landscape and the delta cities could both express their own identities while working closely together hand in hand.

As shown in figure 23, the unique delta landscape penetrate into the urban areas and transform it into an attractive place. On the other hand, with new programs within the green-blue structure, the urban functions bring new opportunities to the rural areas. For example, currently, the small cities along Hollandsch Diep are considered as the far side of Randstad which hardly attract any private investment, but with the identity of this region as the Delta new frontier and new attractions along the river, it will become the gateway to the Dutch delta, the key intervention of Numansdorp (Chapter 5) shows an example of the detailed design.

The new identities, the safer living environment, the unique landscape and the coherent relationship between urban and rural areas will bring new opportunities for its sustainable development.

Figure 23. Concept “Hand in Hand”
Source: Author, 2013
Basemap: (Deltaprogramma, 2010)
Literature:


BACA ARCHITECTS 2010. Toolkit on Blue Infrastructure: Designing for Climate Change and Flood-risk Environments in Hackbridge.


KARIN DE BRUIJN, FRANS KLIJN, ALFRED OLFERT & EDMUND PENNING-ROWSELL 2009. Flood risk assessment and flood risk management: An introduction and guidance based on experiences and findings of FLOODsite (an EU-funded Integrated project) In: KLIJN, F. (ed.).


4. Thinking hand

Concept & IFRM Toolbox

4.1 Way of working
4.2 Three alternatives

Design experiment

Concept improvement
The concept is improved with the help of integrated flood risk management, based on the following design guidelines:

- An integrated strategy usually requires the use of both structural and non-structural solutions on different levels, including Delta level, Dike ring level, Local level and building level. This has been discussed in Chapter 5;

- Turn the flood risk management into benefit to enhance the spatial quality and eco-dynamics;

- In depth analysis should be focus on specific flood risks, social and spatial qualities, and the environmental problems.

Figure 24. Way of working
Source: Author, 2013
4.2 Three alternatives

Three alternatives were considered for the Rijnmond-Drechtsteden site, which ranged from storm surge barrier around the vital urban areas, to the dike strengthening along the Haringvlie-Hollandsche Diep (the detailed design could be found in Appendix 3).

The “Alternative 3- Combination” takes the advantages of the other two alternatives (Safe / Dynamic), and it is an improvement which based on the current water management methods. As a result, it was thought to provide a wider benefits to the regional development and the local identities by creating a clear sense of “Delta new frontier”, improving connections between urban and rural areas, and opening links to the delta branches and the polder landscape.

Figure 25. Experimental design study
Source: Author, 2013
5. Research-by-Design

5.1 Strategies on four levels

5.2 Levels work together

5.3 Tested District

Test the Toolbox Effectiveness: Applying the generic knowledge in specific context
5.1 Concept improvement

Delta level
According to the research from Delta Commissie, the Haringvliet sluices need to be further opened in order to establish the complete river estuarine dynamics, and to preserve the contrast characteristics.

Therefore, on the Delta level, the aim is to bring the tidal different back to this region and bring benefits to the smaller scales on natural, spatial, social and economic aspects.

Dike ring level
This principle focus on improvement of the contact zone (“The front”). After the closure of Haringvliet, more than 40 years the wave hit almost the similar level and washed away the entire foreshore wetland, which has destroyed the esturine eco-system. Thousands of birds and fishes have disappeared since they lost the food place and breeding ground. Besides, traditional life was towards to the water, with dike houses and harbour villages, but now The dike ring has changed into hard edges between water and the daily life behind the dikes.

The aim on the dike-ring level is the restoration of foreshore wetland and eco-dynamics.

Local level
This principle focus on improvement of the contact zone (“Overlapping”). A large area of this region is agricultural landscape, which is dominated by dense creek network and ancient polders. In 2010, it has been nominated as the National Landscape.

However, currently the creeks with steep slopes are polluted by blue-green algal, and the mono-species agro-ecosystem is very vulnerable to pests. The eco-structure of the urban-rural “overlapping” area has been weakened during these years.

The aim on the local level is establishing the robust eco-structure.

Building level
This principle focus on the contact zone (“Connection”). The aim of the Building level is strengthening the physical, functional and visual connections between urban area and rural area. Together with the green-blue structure, the built-up areas will be transformed into an attractive place to live, work and stay.

Image source:
http://www.nationaaldorp.nl/nationaal-landschap/
Overview of the strategies

Figure 26. Overall picture of strategies
Source: Author, 2013
5.1.1 Delta level

Further open Haringvliet sluices to bring tidal influence back

The traditional flood risk management with many long and short-term problems related with the use of structural resistant measures are evident today (Kundzewicz, 2000). Therefore, four options for opening up the Haringvliet sluices were reviewed, as shown in figure 27. These options ranged from “sluice Ajar” to managing the complex as a storm surge barrier.

• Current: “Sluices Ajar”

Since 2010, “the sluice gates were left slightly ajar, but the flow opening will be a few hundred square metres. That’s tiny, compared to what it used to be.”

Evaluation of ‘Sluices Ajar” after 5 years (2013) shows that the salt water gradient is acceptable, but the influences of “sluices ajar” on the estuarine restoration and migratory fish route are not satisfied. Therefore, It is time to consider further open Haringvliet sluices to involve the tidal range and saltwater-freshwater interface back to this region (Kees Storm et al.2003, Martin Platteeuw and Cornelissen, 2005).
Two options for the sluices management

(1) Fully open system
The fully open system is too risky and the cost-efficient is relatively low. It has already been denied by the local municipalities as explained in the report: “Een volledig open Haringvliet wordt niet meegenomen als uit te werken strategie. De mildere variant wordt wel onderzocht” (Deltaprogramma, 2012).

(2) Preferred Option: Alternative “Controlled tide” (“Getemd Getij”)
According to the relevant researches, the “Sluise ajar” is just the ‘transitional’ measure on the way towards to a more open Hollandsch Delta. The ‘Controlled Tide’ option was the preferred option. The effects of the “controlled tide” alternative are so much larger, such as water currents, tidal range and salt intrusion. This option’s cost-benefit ratio for society and ecology is the most favourable. The costs relate to the required compensatory measures (especially preserving the freshwater supply) while the benefits relate to nature being restored. Controlling the tide would require that some of the sluices stay open for most of the time, thereby resulting in a 1 metre tidal difference and restoration of the tidal effects in the Hollandsch Diep (Rijkswaterstaat, 2010).

Impacts: Clear identity as “a complete river estuary”
The new management of the Haringvliet sluices will lead to a significant change in the flow patterns and will further influence the ecosystem. The impacts could be summarized as follow:

- The barrier-free migration route of fish species will be restored;
- The tidal influence and salt-freshwater interface will return to Rhine-Meuse Delta. By increasing the tidal volumes, the dynamic exchange between land and water will help to restore the unique identity of the whole region as a complete river estuary;
- Bring new opportunities to natural, rural and urban areas, including potential recreational facilities, ecological functions, and better environment for living and working.
5.1.2 Water hazards on smaller levels

Water storage capacity need to be enhanced on smaller levels

The decisions on the Delta level will surely influence the water hazards of the smaller levels. At time when there is a heavy storm at the seaside, in company with a peak river discharge, the Haringvliet sluices, Maeslantkering dam and the Hartelkering vlood gates are closes, the river water has to be temporarily stored in Haringvliet and Hollandsch Diep. It means that the river water along the Hollandsche Diep-Haringvliet will increase to an unexpectable high level. Especially taking into account that the sea level is rising, and the river discharge will increase from 15.000m3/s to 16.000m3/s in the future (Deltaprogramme, 2012), the dams will need to be closed more frequently and the duration be even longer.

As a result, more water will need to be retained and stored in the future, including the storm water inside the dike rings, as well as the river water outside the dike rings. As shown in figure 29.

However, it is also a good chance to examine the effectiveness of the IFRM Toolbox on different levels, and to explore the co-relationship between those measures. Through the in depth design study under specific context, the integrated planning and design method will be visualized and developed, and the lessons learnt from the design process will be summarized in chapter 6 (Discussions and conclusions). The hypothesis of “the flood risk management can be transformed into benefits to natural dynamics, eco-structure and spatial quality” will receive realistic responses rather than pure theoretical statistics and models.

2. Local & building level: Stormwater store & retain

1. Dike ring level: Extra river storage plain

Figure 29. Water Hazards
Source: Author, 2013
Data used: (Deltaprogramme, 2012)
5.1.3 Dike ring level

Peak river discharge + Foreshore wetland restoration
KNMI scenarios forecast that all scenarios envisage that the average discharge of the Rhine will increase in winter (up to +12 percent and decrease in summer (up to –23 percent). The same applies for the Meuse, with a maximum increase of 5 percent in winter and a maximum decrease of 20 percent in summer. If the climate develops according to the scenarios, the normative conditions for the Rhine (16,000 m³/s) and the Meuse (3,800 m³/s) have actually been exceeded already, at least according to the 2008 study entitled Climate Change Resilience of Water Land the Netherlands (Rijkswaterstaat. 2011).

Therefore, in the long term (from 2030), the storage must be increased. Except the option of draining the water into the Volkerak-Zoommeer lake and the Grevelingen, there are other two options based on the current water management, as can be seen from figure 30:

**Option one: raising the dikes along the Hollandsche Diep-Haringvliet;**
**Option two: increase the surface of the storage plains by relocating the dike.**

This research and design study will explore the second option since it has a wider benefits to the spatial, environmental, social and economic aspects (Deltaprogramme, 2012).
Analysis: Weakened Delta landscape during the past 40 years

After the construction of Deltaworks, the tidal range has decreased from 2-3m to only 20cm. For more than 40 years the wave hit the banks at approximately the same height every time and causes the banks to cave in. Hundreds of acres of sand and wetland have been washed away and the unique foreshore wetland has vanished almost completely. Besides, as can be seen from the several sections of the riverfront, traditionally life is along the water, but now the primary dike ring has transformed into visual and physical barriers between life and large rivers. The continuous exchange between land and water has been weakened, and there are hardly any attractions of the delta branches.

The new sluices management on the delta level is an opportunity to bring the tidal influence back to this region and restore the estuarine dynamics. And the integrated planning and design methods on dike-ring level could draw people back to their riverfronts with successful waterfront projects.
The strategy is to involve the water and tidal influence back into this area to restore the wetland, tidal channels and eco-system.

The strategy aims to provide extra water storage basin for the peak river water (> 20km², Haringvliet-Hollandsch Diep, see figure 39), as well as to make it more interesting place to live. Besides, it will also improve the ecological quality by opening links to the river and wildlife corridor.

Figure 32. Land reclamation
Source: Author, 2013
Data used: Historical maps from watwaaswaar.nl

Strategy: Wetland recovery within the extra river storage basin

As can be seen from the map below, in the past the riverfront is dominated by wetland, mudflat, polder landscape and very dense creek network. Some part of the polders were enclosed by relatively lower summer dikes or ‘kade’, which could easily be transformed into extra floodplain during the winter season. However, after the Deltaworks, more “stronger” dike rings have taken place of the summer dikes to protect the settlement away from water threats. Along with more powerful water infrastructure (such as steam pump station) and more efficient farming methods, the estuarine wetland, former floodplain and water network have gradually disappeared.

Tested tools of dike-ring level
New opportunities:

- Restore the unique delta landscape: Intertidal wetland and mudflat;
- Habitats for thousands of birds;
- Improve the local socio-economic status: housing program, adaptive agriculture, recreational facilities;
- Improve the spatial quality and accessibility of the riverfront;
- Establish the identity of the delta branches;
- Improve the water safety of the river basin to cope with the future uncertainties.

Strategy:
Dike relocation, Wetland & Creeks restoration
Implementation: Dike relocation

Figure 34. Possible place of dike relocation
Source: Author, 2013
Data used: Top 10 vector map, 2012; AHN map, 2013
Implementation: Intertidal wetland restoration

- Levee
- Grass dike

Dominated species in a tidal freshwater wetland (Based on the report of Leck et al. 1988)

- Stream Channel
- High marsh
- Pond
- Pond-like
- Shrub forest
- Forest
- Grass dike
- Polder

Figure 35. Possible location of the tidal wetland restoration
Source: Author, 2013
Data used: Historical maps from Tudelft library

> 20 km²

Figure 36. Typical biocenosis of a tidal freshwater wetland
Source: Author, 2013
Data used: Leck et al. 1988
5.1.4 Local level
Stormwater retain and store & Robust eco-structure

* GEERTSEMA, W., STEINGR VER, E., WINGERDEN, W. V., SPIJKER, J. & DIRKSEN, J. 2006. KWALITEITSIMPULS GROENBLAUWE DOORADERING VOOR PLAAGONDERDRUKKING IN DE HOEKSCHWAARD.
"When there is a storm, the river is already too high and the water cannot be carried away to the sea. So we have to retain the water temporarily as far as possible where it falls. This means we need extra space." (Arie van der Vlies et al., 2006)

Heavy rainfall occurs mostly between September and March. This is also the period when the rivers carry more water. Excess of water that occurs as a combined effect usually affects low-lying areas, where the water gathers and from where it is difficult to pump out because of high water levels.

According to relevant research, more than 400,000m$^3$ extra retention capacity is needed to store and retain the storm water (Broersma et al., 2004).
**Analysis: Vulnerable agro-ecosystem**

The **creek network and polder landscape** are the typical historical-cultural elements of the region. Historically, the creeks were tidal channels with important functions, such as water transportation, habitats for animals, water infrastructure, etc.

Enclosed creeks
Steep slope, mono-species, polluted...

Large part of the urban-rural fringe area is farmland, which is dominated by mono-species crops which is very vulnerable to pest, such as potato and beet (see figure 39). Currently the creeks have been narrowed down and bounded by steep slopes, which can no longer provide the suitable habitat for wildlife with food, water, shelter and space, especially for those beneficial insects and birds. The eco-structure of this region has been therefore weakened.

Figure 38. sections
Source: Author, 2013
“The large area of continuous farmland need natural pest control system, which is known as the buffer zone or robust eco-structure.”

(Geertsema et al., 2006)

The grass strip in the farmland cannot provide habitat for natural enemies of insect pests, because it lacks nectar source plants.

The creek with steep slopes also cannot provide sufficient habitat for natural enemies of insect pests.

Figure 39. Existing situation
Source: Geertsema et al., (2006)
Strategy: Stormwater management for robust eco-structure

The strategy aims to transform the stormwater management into benefit to create the robust eco-structure for the urban-rural overlapping area.

Tested tools of local level

The benefits are:
- Extra water store capacity to reduces flood risk;
- Improve water quality by plant filtration;
- Create eco-corridors between riverfront and the built-up area;
- Enhance the quality of cultural landscape, such as creek network and ancient polder landscape;
- The built-up area will be transformed into an attractive living environment. The eco-structure has amenity value, enhances biodiversity, protects against urban heat island and can provide fire breaks, urban food production and evacuation space.

>400,000 m$^3$ extra water retention space (*NBW standard), which is more than120ha additional open water.


Figure 40. Stormwater retention and storage
Source: Author, 2013
We can make use of the existing creek network and stormwater management as an opportunity to establish robust eco-system for the urban-rural fringe area. It consists of three components: Creeks with natural levee, retention ponds, and flower strips in the farmland.

Firstly, they help to enhance the local storm water management capacity by increasing more space for the water. Secondly, they help to establish a robust eco-structure for the mono-species’ agro-ecosystem, as can be seen from figure 42. Thirdly, vegetation in and around the retention basin helps filter runoff and attract wildlife and plants. And fresh water supply will also be guaranteed during the dry season.

What is more, the green-blue network will penetrate into the dense-populated urban area, and improve the quality of the living environment with public space, improved connections and recreational programs.

Figure 41. Strategy
Source: Author, 2013
Implementation: Guidelines for robust eco-structure

The large area of continuous farmland needs a natural pest control system, which is known as the buffer zone or eco-structure. The source area habitat should be at least 25m width, >1ha, and 150m in length. The habitat strip should be >3.5m width, and the overall length should be >3.5m. Natural enemies of pests are essential to control pest populations.

Figure 42. Strategy
Source: Author, 2013
Data used: Geertsema et al., (2006)
Cultural Landscape: Creek restoration

I. Creek widening
Slope ratio $< 1:3$
Approximate additional open water surface: 80ha

II. Extra open water surface
Goudswaard & Piershil return to harbour villages

Figure 43. Creek restoration
Source: Author, 2013
Data used: Geertsema et al., (2006)
Figure 44. Impression of creek restoration
Source: Author, 2013
The existing grassland is the preferable location for water retention:
- Lowest flood vulnerability (* NBW standard);
- Located on the lowest ground;
- Close to creeks and farmland.

> 40ha extra open water surface

Implementation: “Fun polders”

Figure 45. Existing grassland
Source: Author, 2013

Figure 46. Project Strype
Source: Arie van der Vlies et al., (2006)
The local farmers create the “fun polders” by themselves. They could gain rewards and benefits from this program. As a result, the local identity could be established by local people, just as they did hundreds of years ago...
5.1.4 Building level
Flood adaptation & Urban-rural penetration
Analysis: urban-rural typology

Figure 48. Typology
Source: Author, 2013
Analysis: Disconnected local road network

As can be seen from fig 49, the urban area of IJsselmonde and the vast rural area of Hoeksche Waard is only connected by the international highway A29.

The physical and visual connections between urban and rural areas need to be improved.

Figure 49. Road network
Source: Author, 2013
Strategy: Linear development along the eco-structure

N217 as the edge of the city; Compact urban expansion on the north side.

Figure 50. Urban development
Source: Author, 2013

In recent years, many young people (19-44 yr.) of this region tend to move away from the rural area to big cities for working and studying. On the other hand, the elderly people (>65 yr.) in the rural area will increase from 14% in 2007 to 28% in 2030 (source: Woningbehoeftenonderzoek HoekscheWaard “woonwensen in beeld”).

The strategy on the building level aims to:
• Enhance the relationship between urban and rural areas by good accessibilities and visual connections;
• Attract younger households and elderly people by the unique landscape, coherent urban and rural relationship, good accessibility, and diverse characters of the site.

Tested tools of building level
Implementation: Landscape living

**Urban area**
- Public space: park, playground, community garden, etc;
- Small-scale retention basin to filter runoff and attract wildlife;
- Improved living environment of the dense-populated urban area.

**Rural area**
- Farms along the creeks;
- New attractions and recreational facilities: playground, orchard, natural reserve, etc;
- Improved physical and visual connections between urban and rural areas.

**Delta branch**
- Adaptive houses;
- Recreational facilities and services;
- Natural reserve.

*Figure 51. Different types of landscape living*
*Source: Author, 2013*
5.2 Four levels work together

Experiencing...Delta New Frontier

Figure 52. Regional plan
Source: Author, 2013
5.2.2 Recreational nodes

* Source: Based on the report "Gebiedsvisie Deltapoort 2025"
5.2.3 Recreational route

Figure 54. Recreational routes and experiences
Source: Author, 2013
5.2.4 Conclusions

**TESTED TOOLS**

- Building
- Local
- Dike-Ring
- Delta Level

**DELTA NEW FRONTIER**

- Living with water
- Robust eco-structure
- Foreshore wetland
- Tidal influence & fish migration routes
### Safe

<table>
<thead>
<tr>
<th>(1) Delta level</th>
<th>(2) Dike ring level</th>
<th>(3) Local level</th>
<th>(4) Building level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Threats from the sea</td>
<td>higher peak water level</td>
<td>stormwater management</td>
<td>flood adaptation</td>
</tr>
</tbody>
</table>

*When the Haringvlietsluizen sluices, Maeslantkering dam and the Hartelkering flood gates are closed, more water will need to be stored in the long term (from 2030)*

### Dynamic

<table>
<thead>
<tr>
<th>(1) Delta level</th>
<th>(2) Dike ring level</th>
<th>(3) Local level</th>
<th>(4) Building level</th>
</tr>
</thead>
<tbody>
<tr>
<td>More resilient system</td>
<td>River estuary</td>
<td>Robust eco-structure</td>
<td>Landscape living</td>
</tr>
</tbody>
</table>

### FRM Toolbox

- "controlled tide" option

### DELTA NEW FRONTIER

#### Strategies on 4 levels

<table>
<thead>
<tr>
<th>(1) Delta level</th>
<th>(2) Dike ring level</th>
<th>(3) Local level</th>
<th>(4) Building level</th>
</tr>
</thead>
<tbody>
<tr>
<td>sea-river</td>
<td>land-delta branches contract zone</td>
<td>rural-urban contract zone</td>
<td>urban-rural-delta branches contract zone</td>
</tr>
</tbody>
</table>

- Bring back the tidal effects
- Dike relocation & strengthening;
- Intertidal wetland.
- Creeks restoration;
- “Fun polder” program.
- Linear development along the green-blue structure

Tested District: Numansdorp
Literature:

ARIE VAN DER VLIES, KEES STOUTJESDIJK & WAALS, H. 2006. EFFECTS OF CLIMATE CHANGE ON WATER MANAGEMENT IN THE NETHERLANDS.


DELTAPROGRAMMA 2012. Uitkomsten 'Bestuurlijke consultatieronde gemeenten' voorjaar


GEERTSEMA, W., STEINGR VER, E., WINGERDEN, W. V., SPIJKER, J. & DIRKSEN, J. 2006. KWALITEITSIMPULS GROENBLAUWE DOORADERING VOOR PLAAGONDERDRUKKING IN DE HOEKSCHWAARD.


Southwest Delta Programme Office, 2011. Past present future: A pictorial history to bring together the history, present situation and possible future perspectives for the Southwest Delta.


RIJKSWATERSTAAT 2010. The Haringvliet Sluices ajar.

5.3 Tested District: Numansdorp

Basic information:

This village was built in the Polder Numan ("Nobody Polder") in 1642
Gemeente: Cromstrijen
Planning Area: 700ha
Current land-use: residential, commercial, agricultural and industrial.

CONTENT

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- Spatial analysis 91
- Initial Concept 95
- Experimental design study 97
- Mater plan 101
- Layers 102
- Experiencing... 109
- Phasing 113

Figure 58 the relationship between tested district and the region
Source: Author, 2013
5.3.1 Context

Numansdorp as the transition zone

- **Motivation**

In order to examine how to bring the motto “Turn the flood risk management into benefit” into reality, **Numansdorp has been chosen as the tested district, due to it is the transition zone of the delta branch, vast polder landscape and compact settlements.**

- **Aims**

Test the IFRM Toolbox and the strategies of the 4 levels on a specific location. Specifically speaking,

- Solving the water hazards tasks, including higher peaks river discharge, and local stormwater management by providing more space for the water;

- Transforming this area into an attractive delta frontier area with new programs along the riverfront;

- Exploring the co-relationship between strategies on different levels that range from delta level to building level;

- Visualizing the strategies and tools under concrete spatial and social context.

- **Relevance**

- The strategies and knowledge obtained from this key intervention will not only test the feasibility of the IFRM Toolbox, but also introduce new and unexpected results during its course.

- The tested district works as a laboratory to test and inspire new ideas, which can be applied to other locations as well, especially those fringe areas, see figure 55.

Key words:

- Estuarine dynamics;
- Eco-structure;
- New frontier;
- Local identity;
- Spatial quality.
Current situation

Figure 56. Existing situation
Source: Author, 2013

Image source: Google
Q: “What do the local people want (USP, 2010)?”

<table>
<thead>
<tr>
<th>Facilities</th>
<th>Percent of population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green recreation</td>
<td>17%</td>
</tr>
<tr>
<td>Public transport/ Bus stop</td>
<td>12%</td>
</tr>
<tr>
<td>ATM</td>
<td>12%</td>
</tr>
<tr>
<td>Shop</td>
<td>10%</td>
</tr>
<tr>
<td>Health care</td>
<td>9%</td>
</tr>
<tr>
<td>Rental houses / Senior apartment</td>
<td>*</td>
</tr>
</tbody>
</table>

* The population of elderly people will double in size in 2030. According to the report “Verslechterings- en verstoringstoets Numansdorp-Zuid” (bureau Schenkeveld, 2007), there is a need for new housing program, including 1550 permanent homes and 150 care homes.

Figure 57. Site bird’s eye view
5.3.2 Historical analysis

**< 1700: Slowly silted up**

**Landscape**
- Natural landscape: **Clay & Sand Slowly Silted Up** outside the dikes;
- Cultural landscape: **Creeks** connected to the open water and functioned as tidal channels and the local transportation network.

**Settlement**

**Harbour canal.** Almost all villages in the region have an access to the open water, even Klaaswaal. As a result of continually reclamation, the harbour channel has been extended several times to connect to the Hollandsch Diep.

**Dike houses and unpaved roads**

**Dike houses:** The farms were originally built on the seaward side of a former dike. Because of that the seaward side of the former sea defenses dike was the highest part of the new polders. Later on, with the improved technique and water management, farmers could settled in the lower parts of the polders.

Until early 20th century, the agricultural roads were unpaved. During raining period, the clay roads became inaccessible. Therefore, the farmers built their farms along a creek or ditch so that the water transport was possible.

**Water infrastructure**

Focus on the local level: Poor maintainance of the dikes and sluices.

Dikes were maintained by different landlords. For some parts, the dikes were lack of sufficient maintainance, which increased the hazard and vulnerability of flood risks.

---

Figure 58. Situation before 1700
Source: Author
Data used: Oerlemans (1992).
1850: Harbour village

Landscape
• Natural landscape: The intertidal foreshore area consists of marshflat, mudflat, tidal wetland, it is the important winter area and resting place for birds, such as Grauwe gans, Lepelaar, Brandgans, Kolgans, Kuifeend, etc. (* source: Bureau schenkeveld. Verslechterings-en verstoringstoets Numansdorp-zuid.)
• Cultural landscape: Kade, summer polder and grassland. Firstly, areas('gorzen') were surrounded with relatively low and cheap dykes, so-called kade or summer dykes, that were allowed to be overtopped during winter floods. This resulted in new land that could be used as pasture.

Settlement
Harbours & Linear development. Starting from 17th century, Numansdorp and surrounding dike houses developed due to the rise of the harbours along the large river.

The first settlements were usually founded along the old dikes and at the junction with a creek.

Water infrastructure
The flood defences is mainly focus on the local level. The villages were protected by polder dike compartments and sluices, and connected to the river through the harbour canal. The outer dike areas were dominated by summer polders (zomerpolder), which was protected by ‘kade’ (about 1.2 metres) to preventing the summer polders to flood if it rains more than usual. While in winter, water level is much higher. The Dutch found a better solution. They use the summer polders as spare capacity for the river. The high polder dyke protects the land (Ven, 1994).

Figure 59. Situation around 1850
Source: Author
1980: From harbour activities to “Efficient” farming

Landscape
- Natural landscape: Disappeared foreshore wetland. After the closure of Haringvliet, decades of years, the wave hit the similar level. As a result, the foreshore wetland has been washed away almost completely and the ecological dynamics has been destroyed.

- Cultural landscape: Vanished creek and ditch network. Because of the powerful steam pumps and more “efficient” farming method, many creeks and ditches have disappeared during this period. The mono-species agroecosystems is very vulnerable to pests.

Settlement
Weakened competitiveness of the harbours. The importance of the harbours has been reduced due to the construction of the Nieuwe Waterweg and the closure of the Haringvliet. Therefore, the local economical structure has transformed from harbour-related activities to agricultural activities. Along with the weakening of the old harbour, life behind the dike becomes away from the large river.

Water infrastructure
Stronger “winter dykes” were created to protect the land against winter floods. The drainage system was dominated by powerful steam pumps instead of creek and ditch network. Within the strong protection, the former “summer polder” areas now allowed more profitable crops instead of pasture (Henk Nijland and Menke, 2005).

Figure 60. Situation around 1980
Source: Author
Current: New development of the waterfront

Landscape
- Nature Landscape: Nature reserve outside the dike ring, namely **Nature 2000**.
- Cultural landscape: Traditionally, the development of Numansdorp mainly focus on the north side of the Middelsluis which behind the dike. While for a long time, the polders on the other side of the dike were dominated by private farmland. Only recently, some other **recreational functions** start to locate on the waterfront, such as summer houses, recreational vehicle parking garage, boat harbour and a natural reserve.

Settlement
Rural area are suffering from a shrinking population. More and more younger families are moving to the big cities for living and working. While the percentage of elderly will increase from 17% today to 34% in 2030.

Water infrastructure
Flood resistant structures on **delta level and dike ring level**: Delta works and Dike ring 21.

Figure 61. Current situation
Source: Author
Data used: Google Earth.
The characteristics of the frontier in the past

- **Tidal wetland**: The development of the village Numansdorp is strongly connected to the history of the whole region. Once it was part of a large nature reserve, but after the deltaworks, the alluvial flats and marshes at the edge of the existing polders were gradually washed away, and the raising primary dike further transformed into barriers instead of green connectors between life and water.

- **Summerpolder and creeks**: Before the closure of the Haringvlietsluices, the area outside the polder dike was dominated by grassland and dense creeks. The creeks play a very important role in the ecosystem and the local transportation network. The summer polders were used as spare capacity for the river during the winter and spring time.

- **Harbour village**: Numansdorp located at the intersection between a dike and a vertical watercourse: the historical development axis running from north to south along the watercourse through out Hoeksche Waard. The watercourse, harbour and adjacent road formed the backbone of the village. The watercourse was an important harbour in 18-19th century, but after the closure of Haringvlietsluices, the importance has greatly decreased and the local economic activities has to transformed from port-related activities to agricultural activities. However, the important role of the watercourse and the historical route are still maintained. For this reason, the direct relationship between the large river and Numansdorp could be restored. What is more, the towns along the watercourse could also gain benefits.

Figure 62. Schematic representation of the urbanization of Numansdorp
Source: Author, 2013
5.3.3 Spatial analysis

Dead-end road and Poor physical connection

Figure 63. Dead-end and fragmented recreational facilities
Source: Author, 2013
Data used: Google street view
Poor visual connection

Figure 64. “Rooms”: dominated by poplar and hedge rows along the dikes
Source: Author, 2013
Data used: Google street view
By-pass highway & spatial fragments

Figure 65. Recreational routes stopped by forest, semi-private space and by-pass highway
Source: Author, 2013
Diagnosis: Spatial problems

Routing
- Dead ends
- No continuous recreational route

Barrier
- Physical
- Visual

Lack of recreational green space nearby
- Potential green spaces along the creeks.

* Survey results from the report: Woningbehoeft en onderzoek Hoeksche Waard "Woonwensen in beeld"
5.3.4 Experimental design study

The strategy is making use of the extra river storage basin to let the water flow back into this area. As a result, the barrier to the riverfront will be transformed into an attractive frontier area. Three options were considered based on the historical characteristics of this area before the Deltaworks, including “Foreshore wetland”, “Harbour village” and “Summer polder”. By using the design experimental study, several flood risk management tools will be tested and visualized, such as the floodplain management, elevated ground, buffer zone, etc. The different alternatives show the probabilities of these tools under different design intentions. One can also get a clue on what kind of programs can be chosen for the design intervention.

• Alternative I. “Foreshore wetland”
  - The mudflat, islands and ponds formulate **diverse types of habitats** for plants and animals, including ponds, island, creeks, river, mudflat, and so on;
  - The different characters of the landscape could provide **interesting experience** for tourists;
  - The estuarine dynamics will bring new opportunities to the local recreational, social, spatial and economic qualities.

Figure 68. Tidal wetland with ponds, islands, creeks and large area of open water
Source: Author, 2013
• **Alternative II. “Habour village”**

- **Enlarged harbours**, mixed use: commercial, housing, recreational facilities...;
- Enhanced shipping route;
- The **neighborhood growth towards to the large river**;
- Houses are located on islands, they become very close to the water.

![Image](image.png)

**Living on higher ground**

- Living close to the water;
- Enlarged harbour area;
- Shipping route;
- Better accessibility to the riverfront.

![Image](image.png)

Figure 69. Mixed-use development with enlarged harbour, green space and dwellings on the water

Source: Author, 2013

95
• Alternative III. “Summer polder”

- Historical summer polder pattern with adaptive agriculture;
- Linear development: Houses along the creeks and dike, and the surrounding landscape could penetrate into the neighborhood;
- Creek restoration transform the edge of the village into more attractive place to live and to stay.

Figure 70. Creeks restoration, and adaptive agriculture on the gentle slope of the primary dike
Source: Author, 2013
5.3.5 Results of the experimental design study: Strategies on different levels

As a conclusion of the experimental design study, when relating the regional strategies with the specific identities and spatial qualities of the site, the design principles for Numansdorp can be summarized as:
- Living on higher ground;
- Temporary floodable area;
- More gradients at wetland interfaces.

Source: Author, 2013
Concept improvement
New frontier: “Embracing the water”
5.3.6 Master plan

Figure 72. Master Plan
Source: Author, 2013
Basemap: Google earth, 2013;
Cad document from TUdelft Library, 2013
Urban design: Water system

In order to cope with the increasing river discharge and local stormwater store and retain, the water storage capacity of this area need to be enhanced;
- As can be seen from the historical analysis of the site, in the past, large area of the farmland is dominated by summer polder. During the summer period, the summer polder is structured by dense creek network, while during the winter, these summer polder areas can be transformed into extra floodplain;
- The strategy is to involve the river water back to this region in order to restore the wetland dynamics. it will not only benefit the ecosystem and spatial quality of the frontier area, but also bring new opportunities to local socio-economic status. After the construction of the Deltaworks, especially due to the closure of Haringvliet sluices, the vitality of the historical harbour has been greatly weakened, and currently the harbour is only used as storage place which is fenced in to restrict access. In the strategy, the existing harbour will be enlarged and moving closer to the village and transform the village back into a harbour village with closer relationship with the open water.
- Extra floodable area: 1.8 km².

Figure 73. Water network
Source: Author, 2013

Map legend:
- inlet with bridge
- dike improvement
- removed dike / reduce the height of the dike
- dike
- flow
- international highway
- ‘new goal’ planning area

Figure 74. Case study: Water inlets
Source: “Room for the river” program, 2013

Case study: “Room for the river” program (source: http://www.ruimtevoorderivier.nl/)
**Location 1: Harbour area**

In this design study, option 3 has been further tested and visualized since it has the best cost-efficiency. As can be seen from the images below, part of the dike will be transformed into a water channel to involve the water flow into this area.

Programs:
- Enlarged harbour area with improved accessibility;
- Living on higher ground (“islands”);
- Water channels;
- Recreational facilities and continuous public space;
- Better connection between town center and the riverfront.

Figure 75. Schematic perspective showing the transformation of the historical harbour area
Source: Author, 2013
Adaptation to flooding

As is shown in the (schematic) section below, there are several depths created in this area outside the primary dike. The dwellings are located on higher ground with NAP +3.5. Other part of the outer dike area can be temporary under the water. It will not only increase the surface of the floodplain during the high tide, but also improve the exchange between land and water, which is the key element to restore the mudflats and wetland. Besides, different surfaces provide diverse nutrient-rich habitat for the plants and animals. And the different depth can also accommodate different kinds of recreation that enable people to experience the water. For example, the shallow water is suitable for swimming and sunbathing on the beach. The deeper water (>1.5m) is suitable for boating.

Figure 75. Schematic section showing the new depths of the harbour area in relation to recreational facilities
Source: Author, 2013
Location 2: Wetland area

New programs:
- Estuarine restoration;
- Adaptive agriculture;
- Dwellings along the creek network;
- Floating gardens;
- Better connections;
- Recreational functions;
- Wetland education.

Part of the existing dike will be lowered in order to “let the water in”, and the existing polder dike will be strengthened as the primary dike with gentle slope. The sloping banks make the tidal effects visible. In the summer, when the water level is relatively low, the flood plain is occupied by adaptive agriculture, recreational activities and inter-tidal wetland; While during the winter, the peak river water will easily flows through the dike and runs into the former farmland. The whole area will become new water storage basin and breeding ground for thousands of birds.

Figure 75. Schematic perspective showing the transformation of the wetland area
Source: Author, 2013
Adaptation to flooding

Figure 77. Schematic section showing the new depths of the harbour area in relation to recreational facilities
Source: Author, 2013
Urban design: Recreational network

Figure 78. Open space and road network
Source: Author, 2013
Urban design: Cultural-Historical elements & Path structure

Figure 79. Elements and path structure
Source: Author, 2013
Building Typology: Existing situation

Figure 80. Existing building typology
Source: Author, 2013
Building Typology: Existing situation

Figure 81. Form analysis
Source: Author, 2013
Building Typology and Density: Strategy

Figure 82. Form and Density Analysis
Source: Author, 2013
5.3.7 Impressions

Harbour area

* The design is based on the case study “living outside the dike”, see Appendix 5.
Neighborhood on the water

old harbour  public facilities  free plots  senior apartment  park

Creek  Dwelling  Park  Adaptable house  Camping site  Adaptable house

Figure 85. Section of the neighborhood area
Source: Author, 2013
Floating gardens

Figure 86. Section of the Floating garden area
Source: Author, 2013
Wetland wandering

Figure 87. Section of the tidal wetland
Source: Author, 2013
5.3.8 Phasing

- **Phase 1**

  + A continuous path along the riverfront;
  + Small-scale wetland restoration with several retention ponds (see the example of project “Oosterse Bekade Gorzen”), the rain will partially filled the basin with fresh water:
    1. Herbaceous community;
    2. Change the micro topography and replant native species to re-habitat the diversity of planting.

- **Phase 2**

  + Connections from the town center to the waterfront;
  + Polder dike strengthening;
  + Inlets & outlets, water channels (‘geul’);
  + Large-scale wetland restoration:
    1. Reed bed & shrub forest;
    2. A complete inter-tidal wetland.

Example of the small-scale’s retention ponds
Source: Project “Oosterse Bekade Gorzen”.
*The case study is in Appendix 4 “let the water in”

Example of the inlets
Source: Project “Lippenbroek”.
*The case study is in Appendix 4 “let the water in”
- **Phase 3**
  - Event: “New Frontier Expo” (to attract attention and investments);
  - Public facilities: Nature center, tourist center, hotel, shops, summer houses...;
  - Public space: Park, floating gardens, squares;
  - Path structure.

- **Phase 4**
  - Public facilities: Senior apartment, health care center;
  - Eco-structure restoration further inland: Creek restoration, “Fun polder” program.

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Figure 88. Phasing  
Source: Author, 2013
Literature:


BUREAUSCHENKEVELD 2007. verslechterings- en verstoringstoets NUMANSDORP-ZUID


USP 2010. Woningbehoeftenonderzoek Hoeksche Waard “woonwensen in beeld”.

What can we learn from this research?

6 Discussions and conclusions
Generic lessons

The project is goal-oriented research, which is triggered by the general research question: “How can the integrated flood risk management benefit the natural dynamics, agro-ecosystem, and spatial quality?” As a result, the following conclusions could be drawn:

• The linkages between flood risk management, biodiversity, urban design and climate change initiatives are beneficial. Integrated flood risk management strategies are naturally designed to fit in with water-related planning issues and can be part of a wider agenda such as urban expansion, eco-recovery or climate change adaptation. Specifically speaking, On the delta level, the new sluices management could bring the tidal range back into the whole region and enhance the unique identity of the green and blue heart; On the dike ring level, with the help of dike strengthening work and floodplain management, the natural dynamics could be restored; On the local level, the eco-structure will further develop inland with the creeks transform from hard edged landscape into a natural embedded elements providing (fresh) water storage and robust agro-ecosystem; On the building level, the settlement also gain benefits from the flood risk management on spatial, social and economic aspects. With all the levels working closely together, the transition zone (urban-rural—nature) could be transformed into a “SAFE and DYNAMIC Delta New Frontier”, with the unique delta landscape penetrates into the urban area, while the urban functions bring new opportunities to the rural areas as well.

• A totally open delta is not preferable for the dense-populated Dutch delta. Since it is too risky for the economic sector, and the cost-efficiency is relatively very low, therefore the totally opened Delta has been denied by the local municipalities. This project explores a more preferable option, “Controlled Tide”, which is partly open Haringvliet sluices even during the high tide. Through the design study one can see that, with the help of integrated flood risk management on different levels, it could also restore the foreshore wetland and enhance the eco-structure further inland, and at the same time, the water safety could also be guaranteed for the dense-populated urbanized delta.

• The decisions on larger levels will result in water hazards on smaller levels, but if we could smartly use the water in spatial planning, such kind of challenges will be transformed into development opportunities. The graduation project shows the important role of water infrastructure for urbanized delta. Instead of traditional flood risk management, which is “one standard for the entire area”, appropriate strategies should be applied on different levels based on the specific flood risks and spatial development requirements.

• The engineering structure can be transformed into benefits by relating them with other functions, such as residential, recreational, and ecological functions. The project aims to turn the flood risk management into benefit, especially on the ecological and spatial aspects. The design research explores the probabilities of water infrastructure, and the design proposal visualized the theoretical models.

• An integrated strategy requires the combination of structural and non-structural measures and good metrics for “getting the balance right”. The two types of measure should not be thought of as distinct from each other. Rather, they are complementary. The most effective strategies will usually combine several measures.

• The IFRM Toolbox will not only benefit the researchers and designers, but local people could also make use of the tools. For example, on the local level, the communities could design and build the retention ponds by themselves under the guidance of experts, as explained in 5.1.4.

• The IFRM Toolbox should be evaluated within a broader context by peer review. And strategies should be carried out through a participatory process involving all those stakeholders that have an interest in flood management, including those people at risk or directly impacted by flooding.

Research approach: Design as research?

To sum up, this graduation project is:

• Goal-oriented research;
• Reliable: Based on the description, evaluation and comparison of the existing theories and practices;
• Flexible and creative: The feasibility and effectiveness of the generic knowledge are tested and visualized by in depth design study under a concrete situation;
• Evaluation research runs through all the process. Further research should involve peer review and stakeholder participation.

Design could be regarded as research because of that we could use (one-case) design to test and visualize the scientific model. However, some argue that the design is such a narrow field that
they show only one narrow example and its results cannot be extrapolated to fit an entire question. On the other hand, some people argue that the design could provide more realistic responses than pure statistical method. Besides, design could bring flexibility to the research. Whilst a pure scientific research is trying to prove or disprove a hypothesis, the design might “introduce new and unexpected results during its course, and lead to research taking new directions”. What is more, perhaps one design cannot be extrapolated to fit an entire question, but it could provoke reasoned debate in in broader context. The approaches and results of (one-case) design could be evaluated and Developed by piers and the public. For example, other researchers could apply the IFRM toolbox into their design. As a result the effectiveness of the toolbox will be gradually improved with the help of collective knowledge.

**Recommendations**

- The integrated flood risk management aims to combine the water infrastructure with spatial planning, so it highly rely on the water hazard and vulnerability map. The project explains the probabilities of the toolbox on the specific location, but in order to make the project more reliable, more precise and latest data should be involved into the research process, and planner should work closely together with experts from other disciplines.

- Test the IFRM Toolbox under more complex context to figure out its probabilities and limitations. In this graduation project, Rijnmond-Drechtsteden region has been chosen for the in-depth research. In order to evaluate the IFRM Toolbox in a more scientific way, the toolbox should be tested in a broader context, especially for those areas which are facing severe conflicts between flood risks and rapid urban expansion, such as the Pearl River Delta in China.

- **When the sea level rise more than a meter by 2100, in addition to closable Haringvliet sluices, several barriers around the greater Rotterdam are needed.** If that happened, local water management and non-structural measures will become even more important in coping with the longer period of high water, the potential failure of engineering structures, and the longer dry season. From this point of view, the strategies explored in the design study is not a concrete “plan” for the future, it is more like a framework which is resilient for future uncertainties and new techniques, and that is also the reason why developing the IFRM Toolbox is so important, for it could provide numerous probabilities for different areas, and for diverse future scenarios. Just as mentioned before, “the heart of the research is not on the final products, but the thinking behind the research.”

- **Design as scientific work**
  The design study is unlike a scientific report due to that it is more creative and intuitive, and there is no strict set of rules. It is very easy getting lost into a lot of irrelevant information. So the most important thing is making sure that the research is focused and concise.
Looking back...

7 Reflection
The theme of the studio

“(it is) an interdisciplinary studio in which architects, civil engineers, urban and landscape designers will collaborate. Within this studio the students will be challenged to find innovative and endurable build interventions, on a wide variety of scales that will transform and strengthen the identity of the Delta.” (Delta Interventions Graduation Studio, 2013).

My graduation project is motivated by the triple layers analysis we made in the beginning few weeks of the studio. Through this research practice, the gap between natural processes and human interventions after the construction Deltaworks has been discovered. Later on, I was inspired by the ideas from the research program “Integrated Planning and Design in the Delta” (IPDD), and quickly started my research on the integrated relationship of flood risk management, ecology, urban design and landscape planning. As can be imagined, the research tasks involve diverse disciplines and scales, but thanks to the lectures that held by the studio, I had chance to get close to the experts from other disciplines, which makes me further convinced that these disciplines are indeed overlapping with each other. So my research and design project try to involve different disciplines and to explore “on a wide variety of scales that will transform and strengthen the identity of the Delta”.

Research and design

When looking back the whole project, it can be concluded that design could be regarded as research (chapter 2). The research consists of 4 parts, as listed:

1. Basic research & General research question: The starting point of research;
2. Design research: Based on the existing knowledge and practices to figure out the generic knowledge;
3. Research-by-design: Narrow down the research topics through in depth study of a particular situation. The generic knowledge is tested and visualized under concrete requirements and situations;
4. Conclusions/ Reflections: Answer the research question and it will allow further elaboration or hypothesis creation on a subject.

The wider social context

The research and design project relates to the social context in different aspects. This project has showed how ecological and spatial conditions could be improved with the help of integrated flood risk management. Take the interventions of Numansdorp as an example. The intervention is based on the survey results of the local residents, and the strategy is contributing to provide sufficient senior apartment and health care to the increasing population of elderly people. Besides, after the construction of Deltaworks, the urban-rural fringe has become the far side of Randstad which hardly attract any private investment. Today more and more young people have left the rural areas to the big cities for better life. The graduation project provides a new possibility for this region. With integrated planning and design, the whole region will be transformed into the gateway to the hinterland. The unique delta landscape, creek network and polder landscape, together with the robust agriculture, housing program and recreational facilities, will help to improve the socio-economic status, and transform the region into an attractive and safe place to live, to work and to stay.

Furthermore, the mutual benefit system between urban and rural could also be used for urbanized delta areas worldwide, because it could on one hand protect the unique delta landscape, and on another hand guarantee the sustainable urban development.

The wider academic context

The graduation project is combining the flood risk management together with urban planning. This research can add to the research of “integrated planning and design” as one case study. The IFRM Toolbox is based on the existing theories, such as multi-layered safety, “Room for the river” program, etc. But this project is also an evaluation research, which shows the common features and
differentiation of these theories and practices. Besides, by narrowing down the topics during the design study, the effectiveness of several tools has been further developed and visualized under concrete requirements and situations. With the design interventions, the generic knowledge of integrated flood risk management received realistic responses. Since there are numerous possibilities of the IFRM Toolbox, it could be applied to other areas as well in coping with the relationship between water management and spatial planning. And the IFRM Toolbox is really like a “Box”, new techniques, theories and approaches could be gradually added to the toolbox, since it is both reliable and flexible.
Word of thanks

I would like to thank: my tutors Anne Loes Nillesen, Steffen Nijhuis for guiding me through the graduation research and design process. My external examiner Ivan Nevzgodin for the good suggestions. My fellow students at Delta Interventions Studio for your feedback and support. My friends and family for the encouragements.

Thank you so much!

NaiLi Zhao
Appendix 1. Layers approach

**Human vs. Nature**

- **1421...** Clay silted up
- **1953** 1993, 1995
- **1990-2001** Reducing the Maas to rapid drainage
- **Clay silted up** Peat
- **Maas moved eastwards** Large tidal range
- **Hollandsch Diep and Haringvliet became the main estuaries.**

**Energy vs. Nature**

- **Human force**
- **Natural strength**

**0**

- **12-16th century**
- **17-19th century**
- **20th century**
- **21th century**

**OCCUPATION**

- Industrialization
- Urban sprawl

**INFRASTRUCTURE**

- Dike and Sluices
- 16th century-wind mills
- Widen and deepen the river
- Deltaworks 1950-80s
- Closure of Haringvliet

**Source:** Ecology as industry project, www.delta-alliance.nl
Water as Foe, Water as Friend
Reviewing Long-term strategies for flood risk management of lowland river systems

Abstract – For the past hundreds of years, flood risk management has mainly focused on reduction of flood probability with the help of structural resistant measures. While recently policy makers propose to increase the resilience of systems, since scientists expect resilient systems to better cope with the flood consequences in the face of urbanization, growing populations and long-term climate change trends (Waterstaat, 1999, Gouldby and Samuels, 2005, Deltares, 2010, Hooijer et al., 2002).

In this review paper this advantage of more resilient flood risk management was verified based on the current theories and projects. The objective was to explore comprehensive strategies for flood risk management which not only better reduce the flood probability but also mitigate the flood consequences in the long run. This literature review will look into the first section the traditional structural resistant measures and the non-structural mitigation measures in view of sustainable development. Then it will conclude the character of long-term strategies for flood risk management. The following section will further explain the key elements in the continuing cycle of flood risk management measures. Finally it will work as the theoretic framework of the graduation project.

Key words - lowland, flood risk management, delta cities, structural resistant measure, non-structural mitigation measure, resilience

1. Introduction
As a geographically low-lying country, the Netherlands has been greatly influenced by the annually returning flood water. On one hand, the flood water brings sedimentation which enable large area of land reclamation. On another hand, along with the rapidly increasing population and urbanization, the floods has become into larger disasters. In this paper, flood risk is defined as the expected yearly flood impact, and it can be mathematically calculated as the product of hazard, exposure and vulnerability (Hooijer et al., 2002). Generally speaking, flood hazard may be reduced through structural measures, which alter the frequency (i.e. the probability) of flood levels. The exposure and vulnerability can be limited by non-structural measures such as changing land use (Gouldby and Samuels, 2005). The term ‘flood risk management’ is used here to emphasize that not only flood probabilities but also flood consequences that related to the socio-economic system can be managed (De Bruijn, 2005).

The current flood risk management of the Rhine River could be regarded a resistant strategy (De Bruijn, 2005). Because of that until recent years, the flood risk management of the Netherlands has been merely focusing on reducing the flood probability with structural measures, such as dams, dikes, river training works and reservoirs. Specifically, in the past, the development and technical levels were low and retreat to higher ground is unthinkable because of that most of the country area is below the sea level (Kundzewicz, 2003). Thus from the start of the civilization, people have started to attacking natural challenges by constructing embankments. Later on, along with the construction of large and impressive engineering structures such as the Deltaworks, the disadvantages of floods increased because of the exploded urban development and industrial sites have taken place on the former floodplain (Rossi et al., 1994). As a consequence, long and short-term problems related with the use of structural resistant measures are evident today (Kundzewicz, 2000), which will be elaborated in the next chapter.

Maybe the recent flood disaster of 1993 and 1995 could be seen as a wake-up call. The climate change has accelerated sea-level rise with elevated tidal inundation, which result in higher hazard and vulnerability of delta cities. The traditional flood resistant strategy is based on “we know it could work”, but there are so many complex and interacting variables that the future is very uncertain (Evans et al., 2004). According to Deltares, there are mainly four different delta scenarios which combine socio-economic growth or shrinkage with a fast or slow climate change (Deltares, 2011). This requires a change of perspective. Instead of traditionally only focusing on the river itself to reduce flood probability, now we need to consider the whole area threatened by floods in order to mitigate flood impact as well. Developing a long-term flood risk management vision (with a time horizon of 50-100 years) could therefore help to better motivate short- and middle term decisions and to prevent future regret (Bruijn et al., 2008, De Bruijn, 2005, Lyle, 2001).

In this context this paper’s main research questions are: What is the long-term flood risk management for lowland rivers? How to reduce flood hazard and societal vulnerability of flood-prone areas?

After examine the advantages and disadvantages of the structural resistant measures, it will look into the non-structural mitigation measures which start to receive more attention recently. Then, it will answer the first question based on different theories and projects. The following section will answer the second research question with key elements in the continuing cycle of flood risk management, and finally it will explain the role of this theoretic framework in the graduation project ‘Safe and Dynamic Drechtsteden’.

2. Rethinking the current flood risk management strategy
2.1 Discussions on the structural measures
As described in the previous section, the Netherlands, a lowland country where most of the areas are flood-prone, the commonly applied
flood risk management strategy is based on flood resistance, which aiming at raising and strengthening embankments. However, the flood event of 1993 and 1995 in the Rhine River is a serious warning, which has aroused the structural measures to be a very heated discussion recently. It has been puzzling our major that for how long does it still work for protecting us from floods?

On one hand, the hydraulic structures have advantages of flood attenuation and downstream discharge control (B.Petry, 2002). These measures focus on resisting floods, such as concrete dam. They have been largely used in areas with rapid pace of industrialization and urban sprawl, such as Pearl River Delta and Mekong Delta.

But on another hand, although the construction of structural measures may has higher cost benefit in the short term, it is usually being considered as “over-designed”, due to the current strategy is based on one design discharge for the entire area, but actually the damage resulting from breaches at the Betuwe area are about 10 times as high as damage resulting from a breach near Lobith. Therefore, recently more and more different sounds try to uncover the disadvantages of the current structural measures. Generally, the disadvantages can be summarized as follows:

(1) Low cost benefit for the long term. Firstly, due to the canalization of the river, large amounts of sediment have been deposited on the narrowed river basin which results in an increase of its level (De Bruijn, 2005), it causes an endless need for rising and improving the water defense structures. Secondly, we need to take into account its enormous environmental costs. For example, the construction of Deltaworks influences the sedimentation process and the tidal condition of the whole region, which leads to environmental problems like the blue algae. As a result, the excess nutrients and pollutants directly affect the shellfish reefs in Eastern Scheldt and bring a big blow to the local economic development.

(2) False sense of safety to public. It mainly includes two parts, the potential failure of flood defense structure and the increasing likelihood of flooding elsewhere. Firstly, if an embankment fails, the unexpected high water level will suddenly occur in an area that was supposed to be protected. For inhabitants living inside the embankment, it is unclear which risk they are facing. Within the “strong” protection of dike rings, urban sprawl quickly takes place of the former floodplain, like it happened on the Pearl River delta (Weng, 2007). But in fact, the quick economic development further increases the flood hazard and vulnerability. What is more, the disappeared buffer zone and the accelerated land subsidence also increase the potential of floods. Besides, the flood threats may turn back to the upstream areas or the low-lying areas and cause catastrophic floods.

(3) Little attention paid to the reduction of flood impacts: The traditional flood risk management focuses on preventing floods, until about a decade ago little efforts were paid to mitigate the potential flood consequences (De Bruijn, 2005). While in fact, with the help of smart land-use or spatial strategies, we may not need to prevent floods everywhere.

Therefore, integrative study on long-term strategies for flood risk management is needed. “A new strategy should not only focus on reaching a ‘safe’ situation by technical solutions.” (De Bruijn, 2005).

2.2. Non-structural measures that alleviate future flooding events

2.2.1 Changing attitude towards floods and flood risks

Therefore, recently we can see a shift from flood control to more holistic approaches for managing flood risk (De Bruijn, 2005) “Instead of a foe - that should be tamed and conquered - water is becoming more and more a friend for the planners and water managers. There is growing awareness among them that water and flood protection measures create opportunities for spatial development, such as nature, recreation and housing.”(Sokolewicz et al., 2011).

Figure 1 Change of perspectives (RLI, 2010).

In order to living and working with water, the flood risk management has been divided into flood prevention, protection and mitigation according to the European commission. The FLOODSite also indicate that the management of flood risks involves a wide range of actions and activities that fall within one of the following four activities: Prevention; Preparation; Response and Recovery. The Flood Risk Directive (FRD) describes the risk-based approach comprising prevention, protection, preparedness, emergency response and recovery. As can be seen in common, great effort is put on preventing and reducing flood consequences by involving more non-structural measures (Lumbroso, 2007), rather than traditionally attempts to reduce the flood risks only through reducing the flood hazard such as the frequency of flooding, as can be seen from Figure 1.

2.2.2 Involve non-structural measures to reduce flood impacts

As a result, non-structural measures started to receive more attention in recent years (Rossi et al., 1994, De Bruijn, 2005). Compare with structural measures, non-structural measures also imply physical interference in the environment, but without building obvious engineered structures and they do not rely on the introduction of large engineering structures. Instead of that, they focus on lowering flood damages by planning and regulating the way of floodplain use, flood proofing, enhancing preparedness, educating and warning the inhabitants, or by redistributing flood damages in time and space by insurance, flood relief and other financial instruments (Karin de Bruijn et al., 2009).

3. Long-term flood risk management: “More resilient”

Although the non-structural approaches have gradually been taken seriously as an effective method of risk management, without developing structural measures, they would be less effective (Heidari, 2008). As for the long-term scenarios with a time horizon of 50-100 years, the Dutch policy makers suggest making water systems more resilient (De Bruijn, 2005). The resilient systems are expected to adapt to long-term changes and unexpected events. As explained before, “uncertainty”, including climate change and socio-economic development (Deltas, 2011), is exactly one of the future challenges for delta cities. According to Karin’s definition, resistance is defined as the ability of the system to prevent floods, while resilience is defined as the ability of the system to recover from floods (De Bruijn, 2005). The difference between these two can be listed as follow: In resistance strategies structural measures tend to dominate, like dikes and dams, whereas resil-
ience strategies include more of a mix of both structural and non-structural measures (Karin de Bruijn et al., 2009).

Recently there are more and more researches and projects that try to engage more resilience strategies. The concept of multi-layer safety is a good example to show how to involve resiliency into flood risk management. In this concept, the first layer is preventing floods with dikes, dunes and barriers (structural measures). The second layer is achieving a sustainable land use planning (non-structural measures). And the third layer (non-structural measures) is emergency preparation and response. The first layer is traditionally the core measure to resist floods. The second and third layers are more resilient, and they try to limit losses and victims of the possible floods. As shown in Figure 2, these two layers have strong relationship with the spatial strategies, new technology and land-use planning. To achieve results in the second and third layers, the cooperation between local people, water managers, spatial planners and disaster managers is therefore crucial (F. Hoss et al., 2011). Another good example is the project ‘Living with floods- Green Rivers in the Lower Rhine River. It is a research projects based on long-term development, which is not only measures in the riverbed and dike relocations, but also measures with a large impact on land use planning are studied. The strategy involves structural measures such as dike relocation, sluices construction, as well as non-structural measures such as land-use planning of floodplain (De Bruijn, 2005). For example, the deep polders are used for most of the time but during periods of extreme peak flow they can be transformed into emergency flood plain to reduce the flood impacts. The area between big cities will be developed into an urban green belt that serves as a recreational area; the dikes offer possibilities for exclusive housing, and so on. With the cooperation of resistance and resilience strategies, the multi-functional variant and recovery capacity of this region are improved.

The above two examples are based on the regional or city scale, maybe we have to admit that the initial costs of resilience strategies are usually high whereas the gains and the reduction of the flood risk will only be perceivable in the long term (VIS, 2003). But from the following pilot “Oranjetoperder” we can find out that, on the smaller scale, like the community or building scale, resilience strategies could offer more opportunities for both of the short-term and long-term development. A large part of Maasdijk village is dominated by greenhouse industry (B.C. Albers et al., 2012). In order to deal with the severe flood inundations of polders, local farmers are working together with urban planner to manage the flood risks through three aspects: improve the river basin condition (widen and deepen); building retention ponds by themselves to manage storm water runoff; Increase the height of the dikes (main protection).

4. Elements of Long-term flood risk management

To summarize, the following conclusions can be drawn from the present study.

4.1 Changing attitudes of flood risks

Traditionally, attempts to reduce the flood risks have focused on reduce the flood hazard such as the frequency of flooding. Recently another factor of flood risks has been uncovered, which is the consequences of flooding (i.e. the flood vulnerability of the flood-prone area). We could lower down flood risks by “controlling flood patterns in such a way that primarily the vulnerable areas are protected by giving room to the water elsewhere” (Karin de Bruijn et al., 2009).

4.2 Changing attitudes of future uncertainty

The future uncertainty makes people full of anxiety. In the past, we have to gradually retreat to higher ground. Later on, with advanced windmills and steam pumps we could start to struggle with nature to keep “dry feet”. Nowadays, due to the changing attitude towards flood risks and the improvement of technology, we gradually try to work and live together with floods. In the future we have to continually deal with unpredictable climate change and socio-economic status, then how to guarantee the sustainable development that meets the needs of the present without compromising the ability of future generations to meet their own needs? This may be one answer: “If we can’t reduce uncertainty, then we shall have to reduce the importance of it.” (Blanksby, 2011). As explained before, making the system more resilient is a better way to reduce the importance of future uncertainty in such a way that limiting the potential flood impacts and leaving enough space for future development.

4.3 More resilience strategy: a combination of structural and non-structural measures

The traditional flood risk management is
dominated by structural measures and it might be cost-efficient in the short term, but for the long-term such kind of flood resistance strategy will cost huge ecological damage, increasing maintaining investment and it might increase the potential flood risks to elsewhere. In contrast, non-structural measures have greater flexibility and resiliency, but from the above examples one could discover that without developing structural measures, they would be less effective. Therefore, "All strategic alternatives should consist of combinations of structural and non-structural measures, and all alternatives should aim at both hazard control and vulnerability reduction – although their respective shares may deviate substantially." (Karin de Bruijn et al., 2009).

4.4 Turn the flood risk management measures into benefits

Taking into account more resilient strategies instead of just increasing the height of the dike, we could ‘make the flood risk management measures part of something that you are going to do anyway. (And) Turn the flood risk management measures into benefits.’ (Blanksby, 2011). Such as better connectivity, nature protection, new housing program, and urban green system, and so on. As shown in the above examples, compare with traditional flood resistance strategy, the long-term flood risk management involves more socio-economic activities and public participation at different scales. The process could be summarized as follow: Firstly, by working together with stakeholders, the flood risk map will work as an indicator for the flood hazard and vulnerability of different areas. According to the flood risk map and the land use patterns, appropriate strategies will be applied instead of one standard for the entire area. For example, as for urban areas with limited space for dike reinforcement, the flood defense structure could be combined with new residential areas (Blanksby, 2011). As for less vulnerable areas, we could use engineering structure and floodplain management to give more room for the river, and turns these areas into recreational green space. What is more, the information and policies should be more accessible to public, including early warning system, evacuation routes, and recovery plan. Finally, one should always bear in mind that the flood risk management is a continuing cycle of assessing, implementing and maintaining measures in order to achieve a sustainable development (Nathalie Asselman et al., 2012).

5. Recommendations

The aim of this paper was to reflect on the existing flood risk management in the Netherlands, and taking into account the challenges of future sustainable development and climate change to provide a comprehensive strategy for long-term flood risk management. In order to reduce both of flood hazards and flood vulnerability, it is therefore recommended the structural flood resistant measures and more resilient strategies should work as a whole to manage the flood patterns in such a way that primarily the vulnerable areas are protected by structural measures and by giving room to the water elsewhere.

This theoretical research will function as a base for the regional scenarios and strategic alternatives I will propose in my graduation project – Safe and Dynamic Drechtsteden. The following is recommended for further scientific research and design:
- Developing a long-term flood risk management vision could help to better motivate short and middle term programs;
- Since the flood risk management is a continuing cycle of assessing, implementing and maintaining measures, the assessment of economic, ecological, and social effects of the long-term strategic alternatives may be improved by more detailed analysis. Besides, the resilience indicators should be studied and verified through real cases;
- In systems with complex landscape and geographic typologies, such as the Rijnmond-Drechtsteden region where the sea meets the river, more detailed studies should be made to better understand the hydraulic system behavior;
- The current strategy focuses on water defenses, near the river itself. The resilient flood risk strategy will mainly take measures in the whole area threatened by floods (but with different flood hazard and flood vulnerability). Therefore thorough analysis on the land-use pattern and socio-economic status of the specific location should be made, in order to not only use water defenses but also measures to reduce the impacts of floods.
- Different from the flood resistant strategy, the resilience strategies try to involve social and economic activities to ‘turn the flood risk management measures into benefits’, the public participation is therefore very important for not only the decision-making but also the implementation of the whole strategy.
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Strategic alternative A: Storm surge barrier

Toolbox

Structural measures:
- Storm surge barrier
- Park dike

Non-structural measures:
- Floodplain management
- Room for the water
- Shellfish reef
- Buffer zone: Wetland, Marshflat
- Retention polders
- Adapted agricultural practice
- Compartmenalisation
- Small-scale retention
- Relocation
- Elevated ground
- Insusceptible construction

* Appropriate condition: sea level rise >1m (Delta commissie, 2008)

Source:
- Ontwerp2daagse zuidwestelijke Delta schetsen voor de lange termijn,p33;
- Samen werken met water, Delta commissie, 2008;
- Delta programma 2013 Probleemanalyse Rijnmond-Drechtsteden.
Strategic alternative A: Storm surge barrier
Strategic alternative B: Dike strengthening

* Raising dyke heights: > 40cm
Strategic alternative B: Dike strengthening

Before

After
Appendix 4. Case study- “Let the water in”

Lippenbroek, Hamme
Estuarine ecosystem restoration, “gecontroleerd gereduceerd getij”

The Lippenbroek is a former polder in the Belgian freshwater part of the Scheldt estuary, which now serves as a pilot project for the restoration of intertidal zone in a densely populated estuary.

The area is about 10 hectares. It was put into operation in March 2006 as a flood control area (FCA). By using a lock structure, the water could flow into the polder area and help to restore the natural tidal marshflats along the Scheldt. Besides, this project is part of the regional “Sigma” plan, which comprises of some similar plots along the Scheldt, together they could provide an extra water storage basin for the extreme spring tide.

The tidal different is about 5m (TAW 0.5-5.5m). In order to control the water level on both side of the dike, the inlet structure shall be situated sufficiently high (4.70 m), and the outlet structure is situated about 2.8m height.
Oosterse Bekade Gorzen, Numansdorp
Estuarine ecosystem restoration,
“open one section of the summer dike”

- 60ha. Former farmland (wintergraan).
- The tides in the Hollands Diep is currently limited (30 cm difference, with high and low tide of 0.70/0.40 NAP, 2007). But after the Haringvlietsluizen be further opened, the tidal different will increase from 50cm (2010), to 1m in the future;
- Only 8% of the polder (4.6 ha) are permanently dry, and the rest of the area consists of intertidal area (24%) and open water (68%);
- Inlet structure: 130m width.


Figuur Inrichtingschets Oosterse Bekade Gorzen. Bron: Groantmij
Appendix 5. Case study- “Living outside the dike”

Hellevoetsluis
“higher ground” + harbour

Flood adaptation: Higher ground 3.5m;
Program: dwellings, harbour, sand beach, water sport.

[Diagram of dike ring, marshflat, harbour, dwelling, Fort, historical center, with various elevations labeled: 4.5m, 3.5m, 8m, 1.27m]
Numangors
“Recreation house”
Flood adaptation: Higher ground 3m
Type: summer houses

Fort
“camping site”
Flood adaptation: Surrounding protection 6m
Type: Historical value, camping.
More info: http://www.deltainterventions.com/design-projects/dutch-rivers/naili-zhao/
NaiLi Zhao
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