principles to generate QUALITY LANDSCAPES impacted by UNCERTAIN SEA LEVEL RISE

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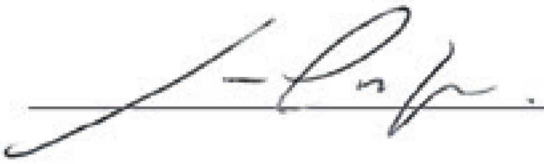

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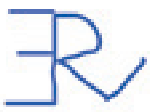

ABSTRACT

Sea level rise (SLR) is a serious consequence of climate change. SLR can cause severe impacts which endanger landscape qualities. Yet, few landscape architecture studies focus on the integration of landscape quality and SLR adaptations. Therefore, the research aim is to generate effective principles which combine landscape quality and SLR adaptation to understand how SLR adaptation can sustain or enhance existing landscape qualities. The Research For Design approach identified current and future landscape qualities and bottlenecks. This resulted in goals to increase the water safety, to conserve tidal nature, and to reduce salinization and increase the freshwater availability. The Research Through Design approach consisted of designing and testing, being reiterated until a final design and four final principles were created. To conclude, these principles are the super dike, the tidal protection grid, the silt motor, and the new landward tidal nature. They are relevant due to the integration of SLR adaptation and landscape quality, the focus on different goals, the applicability for multiple fields of knowledge, and by the applicability to similar world-wide coastal locations. General findings are that the design was determined by: the substratum, the type of used measures, the spatial layout of the landscape, the land use, and the landscape identity. To conclude, studying local landscape qualities and bottlenecks is important when adapting to SLR. The next aspects need to be combined to enhance or sustain landscape qualities: relevant disciplines, technical design requirements and a thorough understanding of existing and future landscape qualities and bottlenecks. Such insights help to select types of measures, to determine the locations of measures, and to know which measures to combine. Altogether, this contributes to ensuring the landscape quality while adapting to SLR.

Keywords: Climate adaptation, sea level rise adaptation, landscape quality, Schouwen-Duiveland, design principles.

PREFACE

This thesis is part of the Master Landscape architecture at Wageningen University. During this master, my motivation to contribute to sea level rise adaptation has grown. Therefore, this thesis was an excellent opportunity to contribute to this relevant issue.

During this thesis, I had the great opportunity to get in touch with the Oosterschelde knowledge community, and to contribute to the project 'Research by design concerning extreme sea level rise in the Oosterschelde'. This increased my motivation to achieve useful results and the project contributed to the relevance of my work.

First, I am grateful for the help and support of my friends and family. Furthermore, I want to thank the many experts which wanted to help with the assessment of the designs. A special thanks to Peter van Veelen who contributed multiple times in testing the designs. Furthermore, I want to thank Leo Adriaanse, Frans van Zijderveld, Marjan Sommeijer, Erik van Zanten, Adriaan Haartsen, Maurice Buuron, Pieter de Ruyter, Marcel van den Berge, Cockie de Wilde, and Miranda van der Neut.

Last but not least, I would like to thank my supervisors João Cortesão and Mark Zandvoort for their great support and their intelligent insights.

Emmelie van Ommen,

March 16, 2021

Wageningen

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1 INTRODUCTION

1.1 LANDSCAPE QUALITY AT RISK

Climate change will have major impacts on humanity and nature. However, climate change is accompanied with a high degree of uncertainty. The intensity and the timing of climate change effects are uncertain, due to the complex global climate system (Hallegatte, Shah, Lempert, Brown, & Gill, 2012; IPCC, 2014). This uncertainty forces countries to prepare for divergent climate scenarios to reduce the possible climate change impacts on our environment. Climate change causes various impacts all over the world, such as temperature increase, increasing intensity of precipitation, and accelerating sea level rise (SLR) (Klein Tank, Beersma, Bessembinder, van den Hurk, & Lenderink, 2015).

Accelerated SLR is projected to be one of the severest impacts of climate change (Nicholls & Cazenave, 2010). Global sea levels rose on average with one to two millimetre (mm) per year in the past century, and the pace has increased to 4.3 mm per year in the past decade. Moreover, this acceleration will increase in the coming centuries (Le Bars, de Vries, & Drijfhout, 2019).

However, the timing and magnitude of SLR are uncertain (Hallegatte et al., 2012), partly due to a probable increasing contribution of the melting ice from Antarctica and Greenland (Le Bars et al., 2019). Therefore, different degrees of SLR need to be considered. Diverse impacts are projected to be the result of accelerating SLR (Oppenheimer & Glavovic, 2019), such as: increased flood risk, erosion, damaging of habitats (Thorarinsdottir, Guttorp, Drews, Skougaard Kaspersen, & de Bruin, 2017), salinization of freshwater systems, and reduction of sedimentation (Song, Fu, & Wang, 2018; Tai, 2018).

These SLR impacts can pose a risk for the landscape quality (Klijn, de Bruin, de Hoog, Jansen, & Sijmons, 2013; Nillesen, 2019; van Veelen, Voorendt, & van der Zwet, 2015). This requires spatial adaptations to SLR impacts which simultaneously guarantee the overall landscape quality (Klijn et al., 2013; Nicholls & Cazenave, 2010; Nillesen, 2019; van Veelen et al., 2015).

The Oosterschelde in Zeeland is an exemplar of a region where landscape quality might become under pressure due to SLR impacts. Projected impacts are an increased flood risk, erosion, damaging of habitats, salinization of freshwater systems, and a reduction of sedimentation (Zandvoort, van der Zee, & Vuik, 2019; Zanten & Adriaanse, 2008). The statements mentioned above are illustrated in Figure 1.

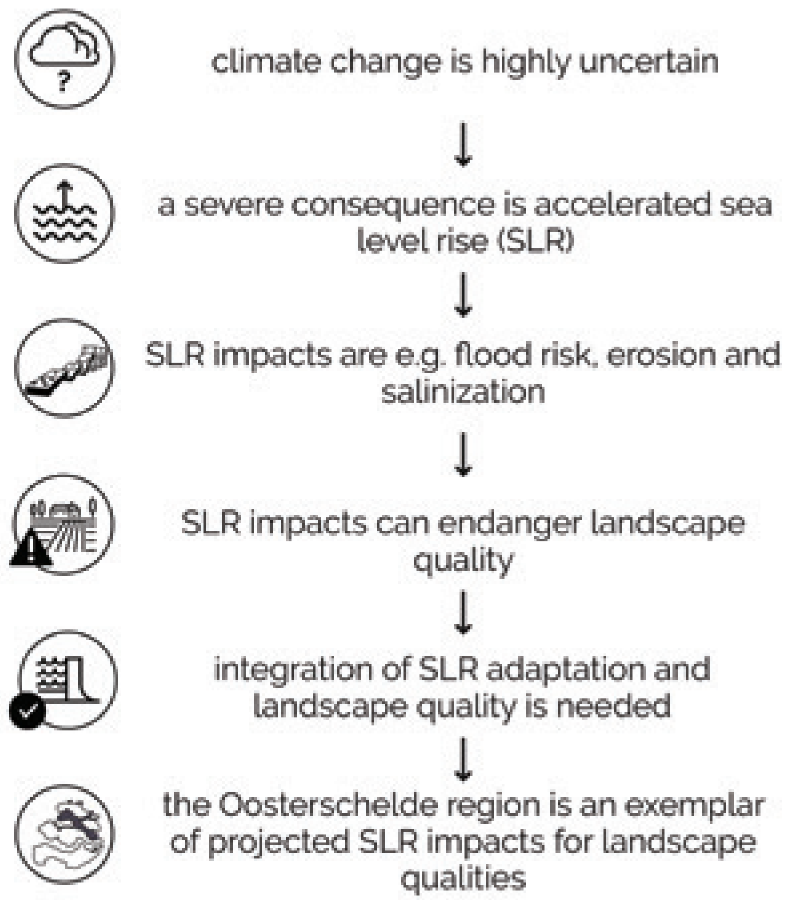


Fig. 1. Climate change, SLR and impacts, landscape quality, and the Oosterschelde region as an exemplar.

1.2 PROBLEM STATEMENT & KNOWLEDGE GAP

There is a lack of research on landscape quality as part of adaptation strategies in coastal areas (Busscher, Verweij, & van den Brink, 2018; Djagiri, 2018; Nillesen, 2019). The Oosterschelde region is no exception to this. Therefore, it is necessary to investigate SLR adaptation strategies that are required to guarantee landscape quality. This means that adapting to SLR results in prevention of negative effects of SLR on the landscape quality, or even enhances the landscape quality. The conclusions of these investigations need to be replicable to other locations suffering from similar problems.

Currently, the role of the designer is mainly limited to implementing technical solutions in landscape designs (Nillesen, 2019). However, the design of coastal areas is not only technical, but should also involve landscape quality (Hajer, Sijmons, & Feddes, 2006). By making landscape quality part of the design objective, SLR adaptions can be designed while sustaining or even enhancing existing landscape qualities. This way, it is possible to address challenges which are strongly connected, such as realizing flood defences, accommodating urban development, handling environmental issues and supporting economies (Meyer, Nijhuis, & Broesi, 2014).

Thus, the current problem is a technical approach on adaptations, lacking sufficient understanding of landscape quality. Also, the related challenges due to projected SLR in coastal areas need an integrated approach which includes landscape quality as part of the landscape design objective.

Knowledge gap

Taking the problem statement above into account, the knowledge gap addressed in this thesis is the lack of understanding to combine technical adaptation measures with landscape quality to cope with uncertain SLR impacts.

1.3 RESEARCH GOAL AND RESEARCH QUESTIONS

The objective of this research is to generate effective design principles which combine landscape quality and SLR adaptation to understand how SLR adaptation can sustain or enhance existing landscape qualities. To achieve this objective, different adaptation strategies, measures, and concepts are studied. The southeast coast of Schouwen-Duiveland (S-D) was used as a case study. To meet the objective, the following main research question (MRQ) is formulated:

What are effective principles for sea level rise adaptation which sustain or enhance landscape qualities?

To study how to sustain or enhance landscape quality when adapting to SLR, different steps are required. The first step is to identify the most important current landscape qualities. However, current landscape qualities can be threatened by existing bottlenecks. Therefore, existing bottlenecks need to be understood concerning their effect on landscape quality. The second step is to study future landscape qualities and future bottlenecks arising due to SLR. By knowing which bottlenecks affect current and future landscape qualities, SLR adaptation goals can be established. Thirdly, these goals enable development of SLR adaptation strategies and measures which consider landscape quality. The final step is to study which SLR adaptation strategies and measures are the most effective to ensure landscape quality. To structure these four steps, the following four sub research questions (SRQ's) are formulated:

1. What are the most important current landscape qualities and bottlenecks?

2. What is the effect of sea level rise on future landscape qualities and bottlenecks?

3. Which sea level rise adaptation strategies and measures are available to sustain or enhance landscape quality?

4. What are effective sea level rise adaptation strategies and measures to sustain or enhance landscape quality?

2 RESEARCH APPROACH

In this chapter, theories and concepts are described in 2.1 to focus the research and select methods. The overall methodology is described in 2.2, followed by the explanation of the single-unit case study in 2.3. In paragraph 2.4, landscape quality analysis methods are described. In the next paragraphs, each step of the research is described (2.5, 2.6, 2.7, 2.8).

2.1 THEORIES AND CONCEPTS

Several concepts arise from the research goal and the research questions which were studied to focus the research and select the methods. Firstly, SLR adaptation was studied. Secondly, SLR projections were studied. Thirdly, landscape quality was defined and approaches were studied that enable the analyse landscape quality. Finally, the concept concerning design principles was studied.

2.1.1 SEA LEVEL RISE ADAPTATION

SLR adaptation means to change human behaviour to decrease SLR consequences. Such actions can vary from individual house alterations to large-scale coastal defences (Dronkers et al., 1990; Nicholls, 2018). The more sea level rises, the fewer adaptation options are possible. Therefore, the selection of adaptation options is urgent (Haasnoot, Brown, et al., 2019). The adaptations to SLR should be specifically selected based on the local impacts of SLR, and the vulnerability of the region (Thorarinsdottir et al., 2017). Based on this, adaptation to SLR can be specified.

However, selection of SLR adaptation can be difficult due to scientific uncertainty. Therefore, three aspects of SLR adaptation should be considered. Firstly, adaptation to SLR should acknowledge the relevant uncertainties of SLR. Secondly, adaptations should be focused on long-term goals, without excluding future changes in adaptations (Walker, Haasnoot, & Kwakkel, 2013).

2.1.2 SEA LEVEL RISE PROJECTIONS

Different degrees of SLR have been projected, due to climate change uncertainty. This uncertainty mainly originates from the uncertain future human behaviour. This human behaviour determines the amount of greenhouse gas emissions. Subsequently, the amount of greenhouse gas emissions determines the degree of global warming. This means humanity can influence climate change by mitigation: taking actions to reduce emissions. However, human climate mitigation can follow different paths, creating uncertainty. Therefore, different scenarios are based on different degrees of climate mitigation (van Vuuren et al., 2011).

Four divergent projections of global SLR have been made by the Intergovernmental Panel on Climate Change (IPCC). These projections are based on different emission scenarios, called representative concentration pathways (RCP's) (van Vuuren et al., 2011). The two most divergent projections are shown in Figure 2. These two projections are based on the extreme (RCP8.5) and the moderate (RCP2.6) scenario. To explain, the moderate scenario (RCP 2.6) reflects a high degree of mitigation, resulting in a low amount of greenhouse gas emissions. The extreme scenario (RCP 8.5) reflects a low degree of mitigation with a high amount of greenhouse gas emissions. The moderate scenario projects about 0.43 meter (m) of SLR where the extreme scenario projects about 0.84 m of SLR in 2100. The moderate scenario has an uncertainty range of 0.29-0.59 m, and the extreme scenario has an uncertainty range of 0.61-1.10 m. Sea levels could continue to rise after 2100 up to about 3.6 m in 2300 in the extreme scenario, with a range of 2,3-5,4 m uncertainty. In contrast, a rise of only about 1 m is projected for 2300 in the moderate scenario, with an uncertainty range of 0,6-1,07 m (IPCC, 2019).

Note that these average global SLR projections cannot be used directly on a local scale (Le Bars et al., 2019). Therefore, a translation from global to local SLR projections for the Dutch coast is required.

The Royal Dutch Meteorological Institute (KNMI) have made local projections of absolute SLR (disregarding subsidence) for the Dutch coast, including the uncertainty concerning Antarctica's melting ice sheet. These projections are shown in Figure 3. With a moderate global warming, a SLR of 0,3 to 2,0 m at the Dutch coast is plausible. With an extreme global warming

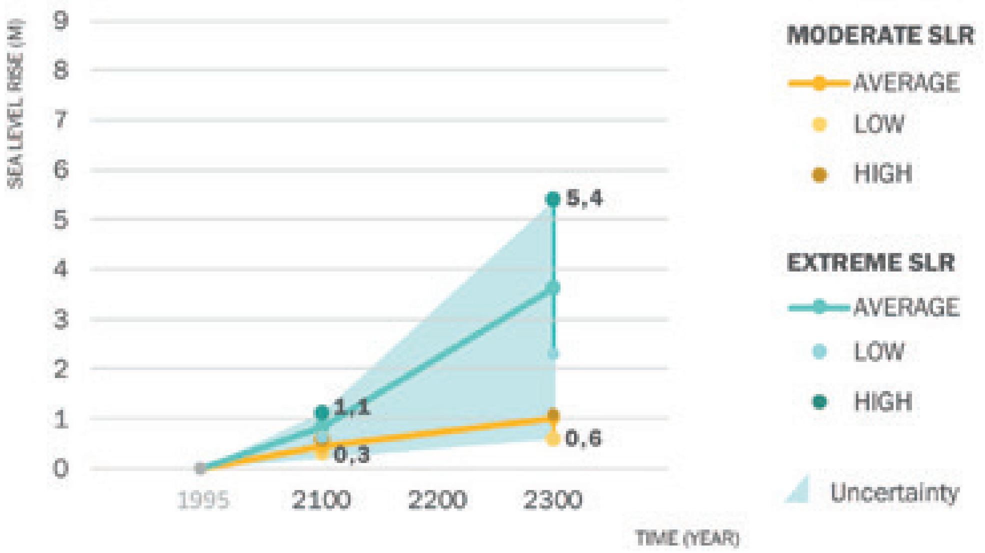


Fig. 2. Uncertainty IPCC projections of global mean SLR. Adapted from IPCC (2019).

(4˚C in 2100), a SLR of 2,0 to a maximum of 3,0 m could be reached. This extreme accelerated SLR could proceed to 5 or 8 m in 2200 (DeConto & Pollard, 2016; Haasnoot et al., 2018; Le Bars, Drijfhout, & De Vries, 2017). It becomes clear that uncertainty in projections of SLR becomes larger over time.

However, the average sea level has increased to 4,3 mm annually between 2009 and 2019 (Le Bars et al., 2019). Therefore, it is uncertain if these extreme projections will be achieved so fast.

Taking the above into account, a large range of uncertainty is found between the projections as the IPCC projections are more recent than the KNMI projections. While the KNMI projections are more accurate as they are specific projections for the Dutch coast, they also encompass a greater uncertainty between the projections for moderate and extreme SLR. Nevertheless, as global mean SLR cannot be used locally, the KNMI projections are used in this study.

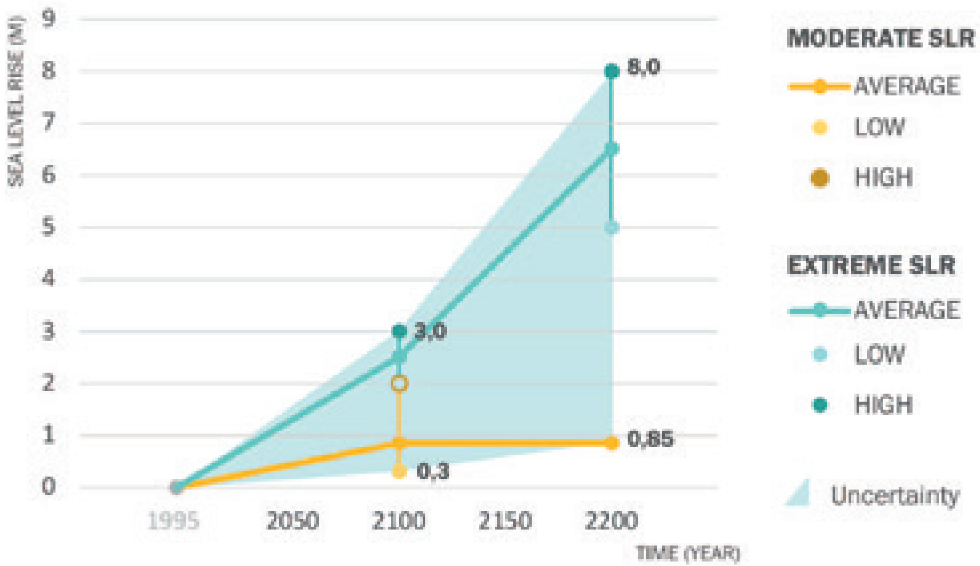


Fig. 3. Uncertainty KNMI projections SLR for the Dutch coast. Adapted from Haasnoot et al. (2018).

2.1.3 DESIGN PRINCIPLES

A design principle is a guideline which directs an action to address a general prevailing situation. This principle represents the best advice concerning this situation (van den Brink, Bruns, Tobi, & Bell, 2017). In the context of Research Through Design (RTD) methodologies, a design principle includes generalizable knowledge, which applies to a common situation or problem (Cortesão, Lenzholzer, Klok, Jacobs, & Kluck, 2019). The advantage of such a principle is that these are only directional and leave space open for creativity. This is needed because too specific principles would result in designs which are not unique and unrelated to the site (van den Brink et al., 2017). Therefore, a principle should be abstract, but still include new detailed knowledge.

2.1.4. A FOCUS ON 3-METER SLR TO DEVELOP EFFECTIVE AND DETAILED PRINCIPLES

As SLR adaptation requires focus on long-term goals, and principles require detail, a specific SLR goal to adapt to is required. The extreme projection of 3 m was set as a goal for the development of the principles. The projection of 3-m SLR was selected because this is a long-term goal. Furthermore, focusing on one specific SLR projection allows to include detailed new knowledge within the available time of the research. Finally, the 3-m SLR makes the principles applicable for an extreme situation which requires the most adaptations. This makes the principles more relevant.

As it is uncertain whether these extreme projections will come true in 2100, different time steps were considered in the last phase of the development of the principles. This way, the SLR adaptions could be implemented later than for the year 2100, based on new and more certain projections.

2.1.5 LANDSCAPE QUALITY

Landscape quality is an often used concept which lacks a clear definition (Bouma et al., 2008; Koomen, Gerritsen, Kersten, Nieuwenhuizen, & Weijschede, 2006). Without a clear definition, different interpretations are possible. To ensure a clear interpretation of landscape quality, studying the concepts landscape and quality separately is helpful (Bouma et al., 2008). Additionally, existing landscape quality definitions were studied.

Several definitions of landscape were found. A definition of the concept landscape is: “an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors” (Council of Europe, 2000, p. 2). Another definition is: a landscape is the perceptible part of the earth determined by the interrelated and mutual influence of the factors climate, topography, water, soil, flora and fauna, and human actions (Ministerie van Landbouw Natuurbeheer en Visserij & Directie Natuur Bos Landschap en Fauna, 1992). Based on these definitions, landscape was defined as an area which is the result of interaction between nature and humanity, perceived by people.

One clear definition of quality was found. The concept quality can mean how good or bad something is, a high standard, a characteristic of someone or something (Cambridge University Press, 2020). In other words, ‘a quality’ can be the degree of how good or bad a characteristic is. Furthermore, ‘quality’ can mean an overall high standard.

Several definitions of landscape quality were found. Firstly, landscape quality can be explained as the result of the value which people give to a landscape (Marinaro, 2017). Secondly, landscape quality can be defined as a personal quality experience, which could be interpreted as subjective in this sense (Bouma et al., 2008). Thirdly, landscape quality can be the sum of high landscape values and functions for the environment, the society, and the economy (Wascher, 2004). Fourthly, landscape quality can be defined as the condition of the spatial, functional and visible landscape at a specific moment (Sowińska-Wierkosz & Michalik-Nieek, 2020).

Based on the definitions mentioned above, landscape quality was defined as the valuation of perceptible characteristics and functions, given by people to an area at a certain time.

Landscape quality approaches

Two landscape quality approaches were defined: the holistic approach and the fragmented approach.

The holistic approach views the landscape as inherently connected and only explainable by reviewing the whole. This approach often uses multisensory experiences, considering the attendance of the reviewer in the landscape. It is important to consider this holistic approach, as the experience and aesthetic valuation of the visitor of the whole landscape is easy to neglect.

In the fragmented approach, the landscape is reviewed by analysing separate aspects, such as: physical and visual aspects. However, the fragmented approach is an incomplete assessment of the landscape (Davoudi & Brooks, 2019). Firstly, the overall quality and the aesthetic quality cannot be assessed. Furthermore, the spatial experience, the cultural identity, and the everyday experience are neglected (Swanwick, 2009; Wascher, 2004).

Therefore, both the fragmented and the holistic approach should be considered when analysing landscape quality.

As the landscape is perceived as a whole, the landscape quality requires analysis as a whole (van Herwaarden & Koedoot, 2011). A useful concept to capture the full landscape quality is the landscape identity, as it considers the landscape as a whole (Kerkstra, Struik, & Vrijlandt, 1976; van Herwaarden & Koedoot, 2011). Furthermore, Stobbelaar & Pedroli (2011) define landscape identity as the perceived uniqueness of a place. Therefore, the landscape identity is defined as the complete and unique perception of a place.

The landscape identity consists of three aspects. These are: the spatial, personal, and cultural identity. The spatial identity reflects the visible, touchable, hearable, testable, and smellable aspects of the landscape (Stobbelaar & Hendriks, 2006). The cultural identity includes all cultural aspects of a landscape. These aspects can be commonly recognized objects, memories, or meanings. The personal identity is a personal translation of the landscape identity by people. To clarify, people construct their own identity partly based on the landscape identity to their own identity (Stobbelaar & Pedroli, 2011). This personal identity is left out of the research, as it goes beyond the perceivable characteristics of an area.

Therefore, this study focused on the two aspects of the landscape identity: spatial and cultural landscape identity.

2.1.6 INSIGHTS FROM THEORIES AND CONCEPTS FOR THE METHODS

SLR adaptation should start as soon as possible, should be specified to local impacts and vulnerabilities, should be focused on long-term goals, and should keep future adaptation options open. Furthermore, the SLR adaptation principles should be generic, but should also include sufficient new knowledge on a detailed level. The goal of 3-m SLR was set to be able to develop effective and detailed principles. This 3-m adaptation goal is not only bound to the year 2100, because the adaptation principles can be implemented when they are needed. This way, SLR adaptation acknowledges the uncertainty. Landscape quality was defined as the valuation of perceptible characteristics and functions, given by people to an area at a certain time. This quality was viewed both from a fragmented as a holistic approach. The holistic approach is reflected by the concept landscape identity. The landscape identity was defined as the complete and the unique perception of a place. Two different aspects of landscape identity were considered: the spatial, and the cultural landscape identity.

2.2 OVERALL METHODOLOGICAL STRUCTURE: RESEARCH FOR DESIGN AND RESEARCH THROUGH DESIGN

This research was divided in a Research For Design (RFD) part, and a Research Through Design (RTD) part (Figure 4). Through these methods, solutions can be explored to address multiple complex consequences of SLR at the same time (Meyer, 2014; Meyer et al., 2014; van der Meulen et al., 2020).

RFD was used to study information which supports RTD (Nijhuis & Bobbink, 2012). RTD is a repetitive sequence of testing and designing to achieve the research goal. Also, RTD can result in general applicable principles (Cortesão et al., 2019), fitting the objective of this study: to generate effective principles which combine landscape quality and SLR adaptation.

RFD was executed in the two phases A and B (Figure 4). In part A, SRQ 1 and 2 were answered by studying the most important landscape qualities and landscape bottlenecks. Based on the most important qualities and bottlenecks, the goals were specified. Additionally, a landscape analysis and a SLR analysis were done to further clarify the goals. In part B, adaptation strategies and adaptation measures were studied which could help achieving the goals. This way, SRQ 3 was answered.

RTD was used in phase C to answer SRQ 4. Firstly, different concepts were developed and tested. Secondly, the most effective concepts were improved and tested again. Subsequently, the most effective concept was further improved in the preliminary design, and principles were created. This was followed by further testing and refining the design and the principles. Based on the test results, a final design with final principles was the final improvement.

Based on this process, general applicable principles and insight in the combination of landscape quality and SLR adaptation were retrieved to answer the MRQ.

Worldview

Within the RTD methodology part, this thesis employed the pragmatism research approach or worldview, as posited by Cortesão et al. (2019). In the pragmatism worldview is aimed to retrieve practical knowledge for a complex problem by mixing different research methods to solve this complexity (Lenzholzer, Duchhart, & Koh, 2013; van den Brink et al., 2017). The pragmatism perspective was the most suitable RTD perspective for this thesis. This is because integrating landscape quality and SLR adaptation is a complex topic which calls for different research approaches and methods.

The different types of methods of the pragmatist worldview of this research can be categorized in observing, modelling, and experimenting (Nijhuis & de Vries, 2019). Firstly, observing was done by a field survey. Furthermore, modelling was done by creating different spatial models to study the design. Finally, experimenting was done by testing the designs in the case study. This resulted in a methodology where both quantitative and qualitative methods were used.

Fig. 4. Scheme of the research setup.

2.3 SINGLE-UNIT CASE STUDY: SOUTHEAST COAST OF SCHOUWEN-DUIVELAND

To answer the MRQ, a single-unit case study was used. This enabled comparison of different design options where the case was the testbed (van den Brink et al., 2017). The case was selected based on information-oriented selection (Flyvbjerg, 2006). As a criterion, the case had to be a coastal region vulnerable to SLR impacts. The biggest issues were found in the eastern part of the Oosterschelde (Stuurgroep Zuidwestelijke Delta, 2014). The South-East coast of S-D (Figure 5) was selected, as the area is very sensitive to SLR impacts.

The dike zone 26-3 (indicated by the black rectangle in (Figure 6) in S-D is vulnerable to SLR impacts for multiple reasons. In comparison to the whole of Zeeland, S-D contains the largest surface below sea level, making the former island more vulnerable to flooding. Also, the dike zone does currently not meet the flood risk safety standards, resulting in a major assignment at the south-east border of S-D (Slabbers, 2014; Zandvoort, van der Zee, et al., 2019). Much research on the area has been done, but practical solutions are lacking.

Fig. 5. Location of the single-unit case study: The South-East coast of Schouwen-Duiveland, adjacent to the Oosterschelde. Adapted from Kadaster (2020).

Therefore, a design study was initiated called 'Designing strategies and new opportunities for adapting to extreme SLR of the Oosterschelde', in short, 'design study Oosterschelde'. This initiative was taken by Rijkswaterstaat Sea and Delta, the province of Zeeland, the municipalities of Noord-Beveland and S-D, and the knowledge community Oosterschelde. Participating in this project offers easy access to data, knowledge, and a network of experts (Personal communication Peter van Veelen, November 26, 2019). As this thesis can contribute to this research project, the case becomes increasingly relevant.

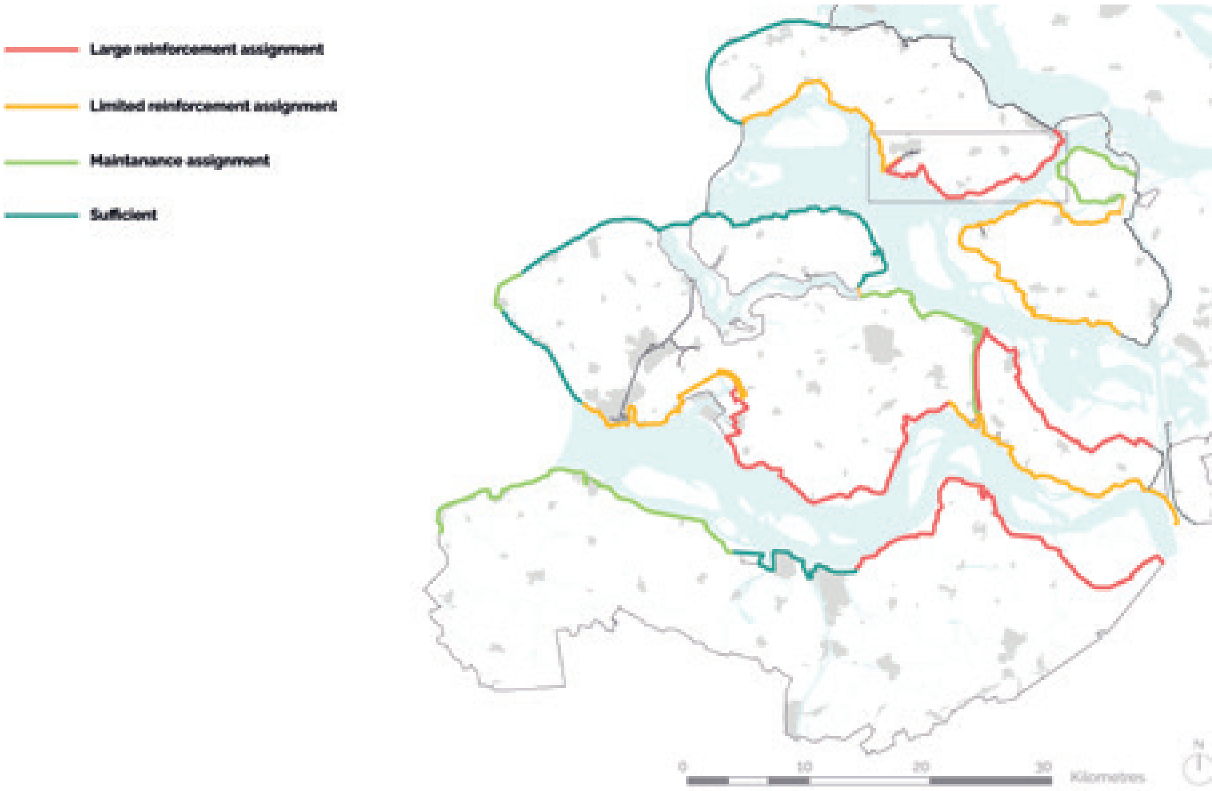


Fig. 6. Reinforcement assignment for the south-western delta on basis of the new norms. Adapted from Slabbers (2014).

2.4 SELECTION OF LANDSCAPE QUALITY ANALYSIS METHODS

Two landscape quality analysis methods were selected to find the landscape qualities and bottlenecks, because assessing landscape quality requires different research methods and divergent types of data (Sowińska-Wierkosz & Michalik-Nieek, 2020). Landscape quality parameters were studied, which led to the selection of the complex-system approach and landscape identity variables. This complex-system approach fitted to the fragmented approach and the parameters. Additionally, the landscape identity variables were selected according to the holistic approach.

Assessing different values and perspectives of landscape quality resulted in the complex-system approach as analysis tool

Different landscape quality values are mentioned in literature. Firstly, in the nature policy plan, geological, cultural-historical, and experience values are counted together as landscape values (Ministerie van Landbouw Natuurbeheer en Visserij, 1990). Secondly, in the Note Landscape, landscape values as ecological, aesthetical, and economic-functional values are mentioned (Ministerie van Landbouw Natuurbeheer en Visserij & Directie Natuur Bos Landschap en Fauna, 1992).

It is important to consider different perspectives to assess landscape quality (Moulaert, van Dyck, Khan, & Schreurs, 2013), because different disciplines have an interest in landscape quality, such as economy, society, ecology, and culture (Hooimeijer, Kroon, & Luttik, 2001).

Based on these statements, different perspectives and values of the landscape needed to be considered to assess landscape quality. Therefore, the selected analysis tool needed to include these values and perspectives.

The complex-systems approach is a sufficient tool to assess landscape quality as it explains the landscape as a system consisting of three layers (RPD, 2001; Van Buuren, 2003), which include the mentioned perspectives and values. The three layers are the substratum, the networks, and the occupation layer. The substratum layer consists of the sub layers: soil and water, geomorphology, and ecosystems. The networks layer consists of the sub layers: transport, energy, and water management. The occupation layer consists of the sub layers: urban patterns, industry and ports, and tourism and leisure (Meyer & Nijhuis, 2013).

Note that the layer cultural history was not yet included in the complex layer approach, therefore, this layer was added to assess this perspective as well.

Landscape identity to analyse landscape quality

Additional to the landscape quality layer analysis, the landscape identity was analysed relating to the following variables: characteristic landscape elements; degree of internal cohesion; orientation in time; and connectedness to the landscape.

Characteristic landscape elements can be large geographic units such as large rivers or old sea beds, or small units like region specific plants and animals. Important are the distinctiveness of a landscape element for a specific landscape and the historic connection. These landscape elements can be green, blur, or cultural historic elements. Shrubs, hedges, and hedgerows are examples of green elements. Ditches and creek ridges are examples of blue elements. Finally, farms, mills, mounds are examples of cultural historic elements. The internal cohesion of a landscape is the relation between abiotic, biotic, and human behavior. This is assessed by a visible relation between characteristic land use related to the substratum. Each landscape has a characteristic space and mass ration, and a specific combination of patterns and structures of landscape elements. For example, the internal cohesion in Zeeland is visible by broad parcels, low water levels and arable farming.

The orientation in time is determined by recognizability of the landscape history. For example, the degree of the recognizability of the ecological, archaeological, cultural-historical, and social past.

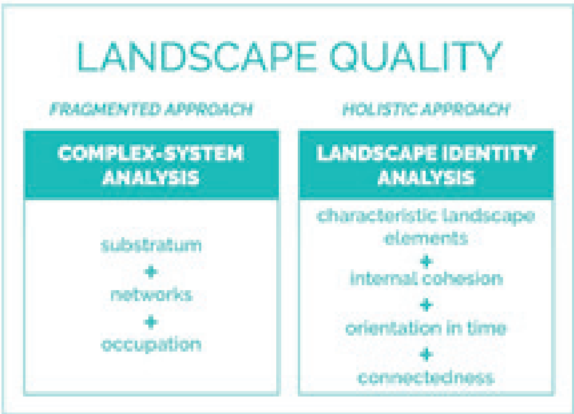


Fig. 7. Analysis of landscape quality using the complex layer analysis and the concept landscape identity.

The connectedness to the landscape is the result of the relationship of people with their surroundings. This relationship is different for each type of user, for example: inhabitants, recreants, or entrepreneurs (van Herwaarden & Koedoot, 2011).

Summary landscape quality methods

The landscape quality was assessed using the complex-layer analysis and the landscape identity analysis (Figure 7). The complex-layer approach was used to analyse the landscape in layers, and the landscape identity reflected the landscape as a whole.

2.5 STEP 1 & 2 – STUDYING LANDSCAPE QUALITIES, BOTTLENECKS, AND SETTING GOALS

To guarantee future landscape quality while adapting to SLR, the most important current and future qualities and bottlenecks were studied. This provided insight into what should be preserved or changed to guarantee the landscape quality while adapting to SLR. Also, this supported focus in the study, and allowed generation of design goals. The complex-system approach formed the basis for the analysis (as described in the previous paragraph). In this approach, the landscape was divided in layers and sublayers. Subsequently, each sublayer was separately studied using expert judgements, being a sufficient tool to assess landscape quality (Klijn et al., 2013). Experts from several perspectives fitting the sublayers were approached to ensure a complete and valuable analysis (Figure 8).

SUB LAYERS	EXPERTISE	EXPERT
SUBSTRATUM		
SOIL & WATER	HYDROLOGIST	MARJAN SOMMEIJER
GEOMORPHOLOGY	GEOMORPHOLOGIST	ERIC VAN ZANTEN
ECOSYSTEMS	ECOLOGIST GREEN EXPERT	FRANS VAN ZIJDERVELD COCKIE DE WILDE
NETWORKS		
TRANSPORT	INFRASTRUCTURE EXPERT	MAURICE BUIJRON
WATER MANAGEMENT	WATER & SAFETY EXPERT	LEO ADRIAANSE
ENERGY	ENERGY EXPERT	*DUE TO TIME MANAGEMENT NOT SELECTED*
OCCUPATION		
URBAN PATTERNS	URBANIST	MIRANDA VAN DER NEUT
INDUSTRY & PORTS	ECONOMY EXPERT	MARCEL VAN DEN BERGE
TOURISM & LEISURE	TOURIST/RECREATION EXPERT	MARCEL VAN DEN BERGE
AGRICULTURE	FARMER	PIETER DE RUIJTER
CULTURAL-HISTORY		
	CULTURE-HISTORIAN	ADRIAAN HAARTSEN

Fig. 8. The selected experts based on the complex system approach.

Assessing the importance of landscape qualities and bottlenecks

The importance of the qualities and bottlenecks (Q&B's) was studied by asking the experts open questions and by letting the experts rate their own given Q&B's. This was based on the study of Klijn et al. (2013) where the experts list their own criteria, and judge the quality using these criteria. In this study, the Q&B's were the criteria for landscape quality. Using open questions is advantageous as it allows various answers, which can result in new insights (Hyman & Sierra, 2016; Singer & Couper, 2017). Closed questions were not used as these might induce a specific answer, increasing the possibility of a biased answer (Hyman & Sierra, 2016).

Furthermore, the Q&B's require analysis of the regional occurrence (Fagerholm, Käyhkö, & Van Eetvelde, 2013). Therefore, both the Q&B's of S-D and Zeeland were studied. Besides open questions, the experts were asked to give a rating per quality and bottleneck to determine the importance. The parameters for these ratings are described in the next sections, and an overview of the questions and parameters is given in Figure 9.

OPEN QUESTIONS	PARAMETERS
PRESENT QUALITIES AND BOTTLENECKS	
What do you consider as current *qualities* concerning (topic) in **Zeeland**?	RARITY INDISPENSABILITY VULNERABILITY CHARACTERISTIC
What do you consider as current *qualities* concerning (topic) in **schouwen-duiveland**?	
What do you consider as current *bottlenecks* concerning (topic) in **zeeland**?	OCCURENCE IMPACT
What do you consider as current *bottlenecks* concerning (topic) in **schouwen-duiveland**?	
FUTURE QUALITIES AND BOTTLENECKS DUE TO SLR	
What *qualities* do you expect to arise in **Zeeland** concerning (topic) due to sea level rise?	RARITY INDISPENSABILITY VULNERABILITY CERTAINTY
What *qualities* do you expect to arise in **Schouwen-Duiveland** concerning (topic) due to sea level rise?	
What *bottlenecks* do you expect to arise in **Zeeland** concerning (topic) due to sea level rise?	OCCURENCE IMPACT CERTAINTY
What *bottlenecks* do you expect to arise in **Schouwen-Duiveland** concerning (topic) due to sea level rise?	

Fig. 9. Open questions and assessment parameters.

Assessment parameters of landscape qualities

The assessment of current landscape qualities was done by four parameters: *indispensability, vulnerability, rarity, and characteristic.* Firstly, *indispensability* is based on the concept importance (Alkema, van der Veen, & Dauvellier, 2004; Ministerie van Landbouw Natuurbeheer en Visserij, 1990). *Indispensability* was used to find out which important qualities were essential and should be preserved. Secondly, the variable *vulnerability* was rated as it represented the risk of the quality to be impacted by a bottleneck (Klijn, de Bruijn, Knoop, & Kwadijk, 2012). The more vulnerable a quality is, the more attention a quality requires, influencing the approach of the design (Alkema et al., 2004). Lastly, uniqueness was an important indicator for landscape quality (Alkema et al., 2004; Ministerie van VROM, LNV, VenW, & EZ, 2004). The uniqueness was measured by the aspects *rarity* and *characteristic* (van Herwaarden & Koedoot, 2011).

As no literature was found on assessing future landscape quality, this was rated partly through the same aspects: *occurrence, rarity,* and *vulnerability*, and additionally by the aspect *certainty*. Characteristic was excluded from this assessment, because indicating the characteristic of a new quality seemed too difficult to produce reliable results. However, *certainty* is a relevant concept, because it is useful to know how probable it is that new qualities will arise due to SLR. The more probable it is that a quality will develop, the more relevant the quality becomes.

In short, the current landscape qualities were rated on *indispensability*, *vulnerability, rarity,* and *characteristic.* Future landscape qualities were rated on *occurrence, rarity, vulnerability,* and *certainty.*

Assessment parameters of landscape bottlenecks

Different parameters were used to study the most important future and current bottlenecks.

Future bottlenecks can originate from future SLR consequences, which could set a risk for landscape qualities. Therefore, the bottlenecks were rated on risk to determine the most important bottlenecks. Risk is the result of the probability of the incident, the exposure, and the degree of vulnerability to the effect (Klijn et al., 2012; Renn, 2008). Subsequently, the probability was measured by the *certainty* of the bottleneck. Secondly, the exposure was measured by *occurrence* of the bottleneck. Thirdly, the *impact* of the bottleneck was measured to help understanding the vulnerability to the effect. The *occurrence* means the prevalence of the bottleneck. The *impact* means the intensity of the bottleneck for the area. The *certainty* means the degree of confidence that the bottleneck would occur.

Thus, future bottlenecks are rated on *occurrence, impact,* and *certainty.*

The current bottlenecks were only rated on the *occurrence* and *impact* of the bottleneck, as measuring certainty is not needed, because the bottlenecks already currently occur.

Rating of bottlenecks and qualities

The experts were asked to give a score for different parameters. The five-point Likert scale was used as a rating scale to express the intensity of their position towards the mentioned matter (Kumar, 2011) (Figure 10). The different values for the parameters were: significantly high degree (5), high degree (4), average degree (3), low degree (2), significantly low degree (1), and I do not know (0). Valuation of the parameters resulted in an average score per quality or bottleneck. The qualities and bottlenecks which scored highest (5) on average were considered the most important. The score 'five' was used as a threshold for importance, as it reflected a significantly high degree of agreement to all the parameters. When a field was left open, or a '0' rating was given, this factor was excluded from the average score. Some qualities or bottlenecks (Q&B) were fully unrated, so the importance could not have been established. However, the unrated Q&B's could possibly be important. Therefore, an additional indicator of importance was used. When Q&B's were mentioned multiple times by different experts, these Q&B's were integrated into goals.

FIVE-POINT LIKERT SCALE	EXPLANATION
0	I do not know
1	significantly low degree
2	low degree
3	average degree
4	high degree
5	significantly high degree

Fig. 10. Explanation of the five-point Likert scale.

Prevention of biases during data processing of expert judgements

The two rating factors vulnerability and certainty could possibly have influenced the outcome of the results. When a quality was rated to be highly vulnerable, this required extra attention to prevent the loss of the quality. However, a quality could also have been very important when the value for vulnerability was low, and other factors scored high. Therefore, the average score was also calculated without inclusion of vulnerability: Average-V. This way, the effect of vulnerability was controlled. It appeared that without inclusion of vulnerability, mostly the same qualities were most important.

The factor certainty was used as a rating factor for the future qualities and future bottlenecks. The factor concerns the probability of the quality to occur. But, if the probability is low, the quality can still be very relevant. However, when the quality scored high on all factors, the chance that the quality would occur, increased the required attention for the quality. Therefore, the average score was also calculated without inclusion of certainty: Average-C. It appeared that without inclusion of certainty, mostly the same qualities were most important.

Thus, the factors vulnerability and certainty alone do not indicate importance. However, when other factors are rated high, the factors vulnerability and certainty do increase the importance. Therefore, for future qualities, the average score was also calculated without inclusion of vulnerability: Average-V. For future qualities, the average score was also calculated without certainty and vulnerability: Average-CV. For future bottlenecks, the average score was also calculated without certainty: Average-C.

Selection of experts

The experts were mainly selected using the network of Peter van Veelen, organiser of the research project Oosterschelde. The infrastructure expert was selected by using the website of the province of Zeeland where provincial managers and their expertise were described. The culture-historian was selected based on his involvement in research about Zeeland, which became clear through literature study.

The experts were required to have expertise regarding the topic, and to have knowledge of Zeeland and S-D. A person was considered an expert when being educated, and experienced regarding the topic (Pill, 1971). Therefore, the experts should have gained expert knowledge by years of experience, or by education. Also, the experts should have knowledge of the area by having lived there or having been involved through work concerning the area (Figure 11).

To select the right experts, a short list of general questions was asked via email:

1. Could you describe your expertise?
2. What is your current position (title), and where do you work?
3. Could you describe your knowledge of

Schouwen-Duiveland and Zeeland?
- Schouwen-Duiveland:
- Zeeland:

4. Could you describe your relationship with Schouwen-Duiveland and Zeeland?
For example: I spent a large part of my life in Schouwen-Duiveland. Or: I have been involved in a project in Zeeland.
- Schouwen-Duiveland:
- Zeeland:

The process resulted in the selection of ten experts (Figure 8). Only for the layer 'energy', no expert could be selected as the asked experts could not be reached. For the sake of time management, this layer was excluded from the research. In appendix I, the selected experts are described in detail.

Practical execution of expert judgements

The next steps were identified for structured expert judgement, based on the protocol of Cooke & Goossens (2000). Differences in the steps of this thesis and the protocol are explained in the discussion of this thesis. Due to time and budget limitations, only the indispensable steps were undertaken:

a. Provision of documentation of the topic regarding the expert judgements
b. Definition of variables
c. Determination of possible experts
d. Appointment of experts
e. Establishment of document to collect judgements
f. Expert elicitation session: the actual practice of expert judgements
g. Assembling expert judgements using equal weighing
h. Documentation of the outcome

The experts received a document by email which explained the setup of the research and invited them to participate in the study. Next, the variables were explained. By sending general questions via email, the experts were tested on suitability. This resulted in the appointment of the right experts.

An Excel document was established to collect the expert judgements. This was done as no survey program was suitable to collect the open answers and to rate the open answers. The excel sheet is displayed in Appendix II. The excel sheet was emailed to the experts. They could download the file, answer the questions, rate their answers, save the file, and email the file back. In the email to the experts that it was optional to do the expert judgements via an online meeting, if they preferred to. The expert judgements were done individually as this was the most simple to organize and does not influence the results in comparison to a group judgement (Pill, 1971). Finally, the expert judgements were collected and assembled with equal weighing and documented.

Fig. 11. Criteria for selecting the experts.

2.6 STEP 3, 4, 5 & 6 – LANDSCAPE AND SLR ANALYSIS & ADAPTATION STRATEGIES AND MEASURES

Step 3 – landscape analysis
The landscape analysis clarified the most important bottlenecks and qualities, and consisted of three parts: a map study, a literature study, and a field survey. The map study and the literature study aimed to gain in-depth understanding of where, when, and how the most important bottlenecks and qualities occurred. The field survey was used to study the landscape identity to create a vision, to retrieve design inspiration, and to spatially understand the most important qualities and bottlenecks.

Map study
The map study was used to understand the location and magnitude of the bottlenecks or qualities. The data for the maps was collected using the program Geographic Information System (GIS) and Quantum GIS (QGIS). The data was analysed on different scale levels to understand the landscape (Meyer & Nijhuis, 2013).

Literature study
The literature study was used to gather and analyse scientific research (Baumeister & Leary, 1997; Tranfield, Denyer, & Smart, 2003), focusing on when and how the most important landscape qualities and bottlenecks occurred. Also, insights from the literature study were used for the map study.

Field survey
During the field survey (Francis, 2001; Swaffield & Deming, 2011), the landscape identity was analysed, being an important indicator of landscape quality. Additionally, the field survey supported visual understanding of the most important landscape qualities and bottlenecks. Focused was on three aspects of the landscape identity during the field survey: characteristic landscape elements, degree of internal cohesion, orientation in time. The field survey consisted of site observations. The observations were captured by taking notes and pictures. The results from the field survey were used as a basis for the design vision.

Step 4 – SLR impact analysis
A literature study was done to understand the SLR impacts on the main bottlenecks and qualities. The focus was on finding thresholds and turning points to specify the goals for designing as much as possible.

Step 5 & 6 – SLR adaptation strategies & adaptation measures
Generic long-term regional-scale SLR adaptation strategies and adaptation measures were extracted from existing literature. The adaptation strategies were the basis for the development of the different concepts. The measures were selected according to the design goals from step two and categorised according to the different adaptation strategies. Also, measures were studied using (landscape) architecture websites as literature (Dezeen, Landezine, Topos, and Asla), as measures are often used in practical designs and are not always present in academic literature. The used searching terms were: sea level rise, flood protection, water safety, coastal erosion, and coastal design.

2.7 STEP 7 UP TO AND INCLUDING STEP 13 – DESIGNING AND TESTING

Step 7 – Sixteen concepts

Sixteen different concepts were developed: four concepts for each of the four different strategies. Each concept aimed to achieve the goals in a different way. The designs were created through 'extreme thinking', including inspiration from the field survey. 'Extreme thinking' was deployed by thinking of a counter idea when an idea for a concept came up. After the idea for a concept was generated, measures were selected which matched the idea of the concept. The purpose of the concepts was to generate creative and effective ideas. Therefore, sketching was done on the scale 1:75.000, on A3 size to avoid falling into too much detail. For some concepts, simple explanatory sections were required.

Step 8 – Test 1

The testing of the design was done by expert judgement. Only one expert was selected, as the concepts were general and not detailed. This way, other experts could still be selected in later testing moments, when detailed-scale judgements were required. An external expert was approached to test the design to enhance expert validity (Nijhuis & de Vries, 2019).

The expert judgement consisted of two parts. First, the concepts were explained in an online meeting with the expert. This improved the comprehensibility of the concepts, as it allowed the expert to ask questions. Subsequently, a digital survey was used as a testing tool where the expert answered the questions and filled in ratings per concept. This allowed the expert to fill in the answers at his own pace.

The digital survey consisted of three parts. Firstly, the purpose of the expert judgement was explained. Secondly, each concept was textually described and explained by drawings and sections if required. Finally, for each concept, questions were asked which could be answered with a grade (Figure 12). The concepts were tested on the degree of achieving a goal. Therefore, each question reflected a goal. The questions started in the same way to increase the comprehensibility. The start of each question was: to what extent could the concept be an improvement regarding: (goal)? The main design goals were counted twice, the sub design goals and the design guideline were counted once. This was done because the main design goals were the most important, but to still include the effects on the other goals. Finally, an open question left room to mention any other remarks on the concepts to consider other important positive or negative aspects of the concepts.

A rating scale was used to express the intensity of the agreement of the expert towards the question (Kumar, 2011). The five-point Likert scale (Figure 13) was used, because this allowed more options than yes or no and would be an easy number of options to understand. The different values for the answers were: significantly high degree (5), high degree (4), average degree (3), low degree (2), significantly low degree (1), and I do not know (0).

		TO WHAT EXTENT COULD THE CONCEPT BE AN IMPROVEMENT REGARDING:	RATING 0-1-2-3-4-5
MAIN DESIGN GOALS (2x)	1	water safety?	
	2	the drowning of tidal nature?	
	3	the effects of the shortage of sediment? (e.g. erosion)	
	4	nature threatened by a shorter period of low tide?	
SUB DESIGN GOALS	5	nature disturbed by the factors: eutrophication (nitrogen), dessication, fragmentation, and lighting?	
	6	consequences of salinization and fresh water shortage? (considering nature and agriculture)	
DESIGN GUIDE-LINES	7	the integration of 'Karrenvelden'	

Fig. 12. *Questions to test the concepts, based on the design goals.*

FIVE-POINT LIKERT SCALE	EXPLANATION
0	I do not know
1	significantly low degree
2	low degree
3	average degree
4	high degree
5	significantly high degree

Fig. 13. *Rating scale to indicate the improvement of the concepts regarding the goals.*

Step 9 - creating 3 designs

The highest scoring concepts per strategy were selected to be integrated in the new designs. The new designs were more detailed and included the required improvements based on the test results. Both the ratings as well as the answers to the open questions were considered.

The setup of improving the concepts

The new concepts were based on the highest scoring concepts. From the test results became clear on which criteria the concept needed to be improved. Only the criteria based on the main goals were improved, allowing focus in this study. The concepts were considered effective if the scores reflected a high improvement or a significantly high improvement. A score on a criterion required improvements if it scored lower than 4. This threshold was set as the score 4 indicated a high degree of improvement, and the score 3 indicated an average degree of improvement. Parts from other concepts from the same strategy were used to improve the specific criterion. These concepts were selected based on four aspects. Firstly, the concepts had to score the highest on the specific criterion. Secondly, if multiple concepts scored equal on the criterion, the concept was selected which scored the highest on average on all criteria. Thirdly, the considered concept was not selected if it resulted in deterioration. Finally, all the comments of the experts were considered during the selection.

The designing: design map, sections, and interventions

Sketching was done on the scale 1:20.000, allowing new details to study the implementation of the improvements. The design maps were made on the same scale as in the first design step (1:75.000). The sections varied from scales between 1:4000, and 1:500. This depended on the size of the section, and the required level of detail. Additionally, specific interventions were developed to make the changes more specific. The designing consisted of different design activities, such as drawing, mapping, visualising, representing, and modelling (van den Brink et al., 2017). Design tools for these activities were sketching paper, pencils, and markers. Besides that, design programs were used as computer-aided design (CAD), and Adobe programs as Illustrator and Photoshop.

Step 10 – test 2

Only testing the main goals

The interventions of the three concepts were assessed on different criteria (Figure 14). The criteria were also based on the goals from step 2. However, instead of including the sub design goals, only the main design goals were tested. This was done as there was nearly no effect of the concepts on the sub design goals in test 1. Also, this allowed focusing on the important goals. However, the goal concerning salinization issues and freshwater shortage appeared to be more important than was considered in test 1. This became clear from the comments of the expert in test 1. Therefore, this goal was included as a main design goal.

The expert judgements

As the established criteria concerned multiple knowledge fields, multiple experts were approached. For each knowledge field one expert was selected, resulting in three different experts (Figure 14). Assessed was through separate online meetings in Microsoft Teams. Open questions were prepared for each expert. The first question being: 'Could this intervention work?'. Followed up by the second question: 'Why could this intervention work?'. The third question was: 'What could be improved concerning this intervention?'. The final question was, 'how could this be improvement be achieved?'
Subsequently, the interventions were rated by the experts. The expert could mention the rating, which was documented by the researcher to

		TO WHAT EXTENT COULD THE MEASURE BE AN IMPROVEMENT REGARDING:	RATING 0-1-2-3-4-5	EXPERT	CATEGORY
MAIN DESIGN GOALS	1	water safety?		Leo Adriaanse	W&S
	2	the drowning of tidal nature?		Frans van Zijderveld	N&E
	3	the effects of the shortage of sediment? (e.g. erosion)		Frans van Zijderveld	N&E
	4	nature threatened by a shorter period of low tide?		Frans van Zijderveld	N&E
	5	consequences of salinization and fresh water shortage? (considering nature and agriculture)		Marjan Sommeijer	S&W

Fig. 14. The tested criteria by experts from different perspectives. W&S: water safety, N&E: nature & ecology, S&W: soil & water.

facilitate the process for the expert. Finally, the expert was asked about the motivation behind the scoring of each intervention, resulting in understanding of what could be improved and why.

Step 11 – Preliminary design + principles

Based on the results of test 2, the preliminary design and the principles were created. The preliminary design and principles were improvements of the three concepts with the highest scoring interventions. The highest scoring interventions were selected for each design goal (Figure 14) as the aim of this study was to find effective principles. Based on these interventions, the principles were generated and implemented in the preliminary design. An intervention was assumed effective if it scored a 4 or 5 on a certain criterion, because it was an improvement to a high or significantly high degree. If a selected intervention scored lower than 4 on another criterion, it had to be improved. The way of improving the design and the principles was based on the mentioned improvements by the experts. Smaller scales were used to study the implementation of the improvements in more detail. The scales varied between 1:3000 and 1:100. However, the design map was made on the same scale as the three concepts: scale 1:75.000.

Step 12 – Test 3

The preliminary design and the principles were assessed in test 3 using expert judgements. This was done by a meeting with a group of experts related to the knowledge community Oosterschelde. The experts came from relevant knowledge fields such as: landscape architecture, water safety, nature development, aquatic ecology, farming, and sustainable development. The preliminary design and the principles were presented and followed by a group discussion where the experts could give feedback. The effectivity of the principles and the recommendations for improvements were discussed. Due to time limitations, a rating was not included. After the group meeting, an extra meeting with the landscape architect was held to discuss each principle in more detail. The focus was on the effectiveness of the principles and on the required improvements. The meeting with the group of experts was organized by the knowledge community Oosterschelde and was held in Microsoft Teams. The extra meeting was also held in Microsoft Teams, as the program proved to be a properly working tool. Both meetings were recorded and transcribed. Based on these transcriptions, a list of required improvements was established.

Step 13 – Final design + principles
Based on the list of required improvements, the final design and the principles were created. The final design included a detailed design map of a location where all the developed principles were present. This map was made on the scale 1:5000, allowing a new level of detail. More sections were made on a smaller scale, such as 1:200.

From this step, the effective principles which combined SLR adaptation and landscape quality became clear. These principles were used to answer the main research question.

3 RESULTS: RESEARCH FOR DESIGN

This chapter represents the Research For design Phase. First, the most important landscape qualities and bottlenecks are described which resulted in design goals (3.1). Thereafter, the landscape identity results are described which resulted in a vision for the design (3.2). To clarify the design goals, the landscape and SLR analysis was done (3.3). Finally, strategies and measures were studied (3.4) as a basis for the Research Through Design phase in chapter 4.

3.1 MOST IMPORTANT LANDSCAPE QUALITIES AND BOTTLENECKS

The full results of the landscape qualities and bottlenecks analysis can be found in appendix III, including the answers of the experts to the open questions.

3.1.1 CURRENT LANDSCAPE QUALITY

The current qualities of Zeeland and S-D according to the experts are displayed in Figure 15 and Figure 16. Several landscape qualities were present in S-D and Zeeland. The transition of sea-beach-dune in Zeeland and S-D, and the 'Karrenvelden', and 'Schurvelingen' in S-D were considered most important and had the maximal score. The second most important qualities in S-D were the habitat coastal breeding and migratory birds, dikes 'welen' and 'inlagen', 'Vroonland', and ring fortresses and mounds. The third most important qualities were the system of dikes, dams, and the storm surge barrier, the variation of islands & water, the climate, the high amount of sun and wind, and the 'Meestovens'. The fourth most important were the front street villages and ring villages. The fifth most important qualities were the silty nature, the transition salt-fresh, the high service level, the commitment of sectors, the unique nature areas, the fertile soils, the estate forest around Schuddebeurs, the soil quality for agriculture, and the reclamation history and legibility in the landscape.

To conclude, the most important qualities for S-D were the transition of sea-beach-dune, the 'Karrenvelden', and the 'Schurvelingen'.

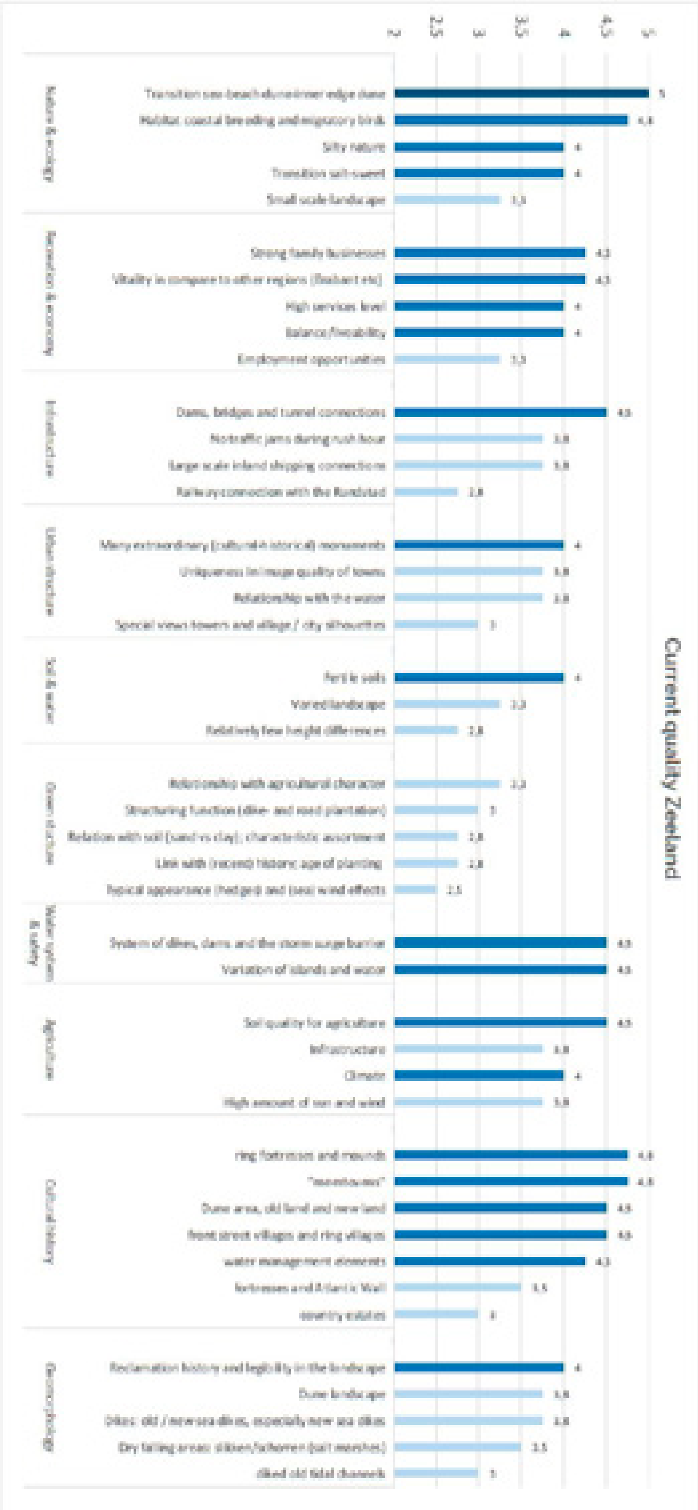


Fig. 15. *Current qualities in Zeeland.*

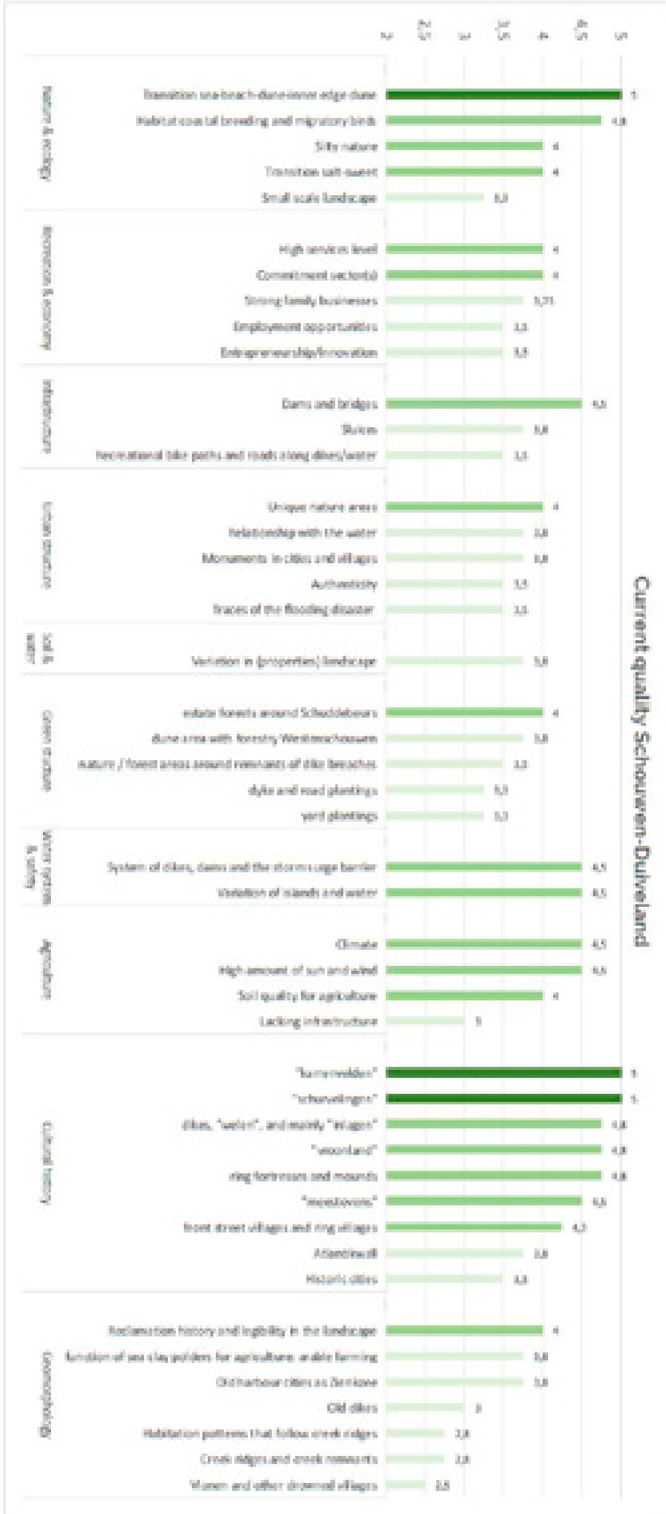


Fig. 16. *Current qualities in Schouwen-Duiveland.*

3.1.2 CURRENT LANDSCAPE BOTTLENECKS

The current bottlenecks of Zeeland and S-D according to the experts are displayed in Figure 17 and Figure 18. The most important current bottlenecks for Zeeland and S-D were the disruption of nature and the limited freshwater availability, having the maximum score. The second most important bottlenecks in S-D were the pressure on rural area for more recreation; the lack of freshwater and retained rainwater; and the urbanization of the inner dune edge. The third most important bottlenecks were the buyout by big concerns; the limited public transport to the Randstad; limited accessibility through roads, bridges, and dams; the few possibilities of external water supply; the insufficiency of choices in policy and management; the lack of freshwater between Bruinisse and Zierikzee and the development of nature.

To conclude, the most important current bottlenecks for S-D were the disruption of nature and the limited freshwater availability.

3.1.3 FUTURE LANDSCAPE QUALITIES DUE TO SLR

The potential future qualities as a consequence of SLR in Zeeland and S-D are displayed in Figure 20 and Figure 19. In comparison to the other domains, future landscape qualities had a lower score. Many experts mentioned that it was hard to predict future qualities, which could explain the lower ratings. Therefore, the qualities with the highest score were considered most important.

Only a few future qualities were mentioned, and these almost all applied both for Zeeland as well as for S-D. The most important future quality was the silty nature. The second most important quality was the transition of salt to fresh. Thirdly, more innovation could develop. Fourthly, an increase in salty seepage pressure was mentioned. The fifth most important quality was the plausible seaward extension of territory for. The other fifth quality was the use of saline crops, also mentioned by another expert for Zeeland: opportunities for saline nature and plants.

The unrated future landscape qualities overlapped with the rated landscape qualities. Firstly, water safety measures could be combined with access routes. Secondly, new salt marshes could be reclaimed. Thirdly, a double dikes system could be introduced. To continue, the double dikes system could be an example of innovation. Salinity as a quality was also often mentioned.

To conclude, silty nature was the most important future quality for S-D.

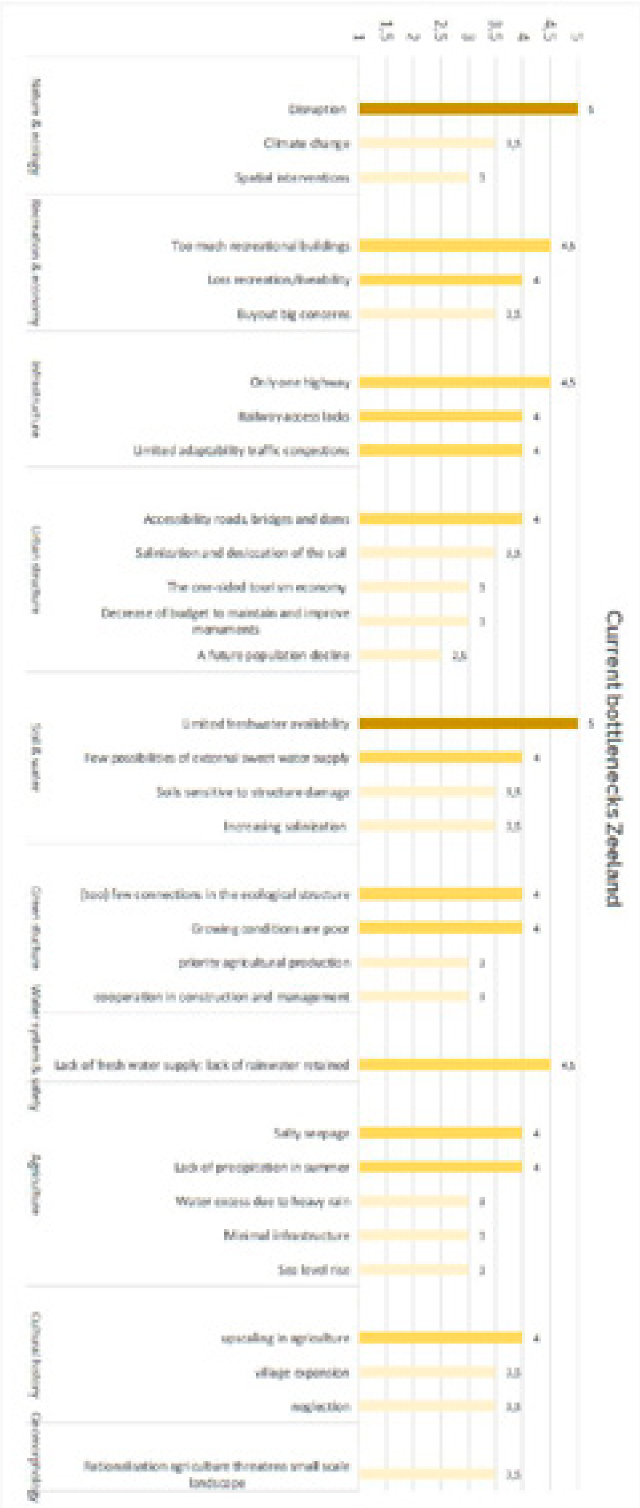


Fig. 17. *Current bottlenecks in Zeeland.*

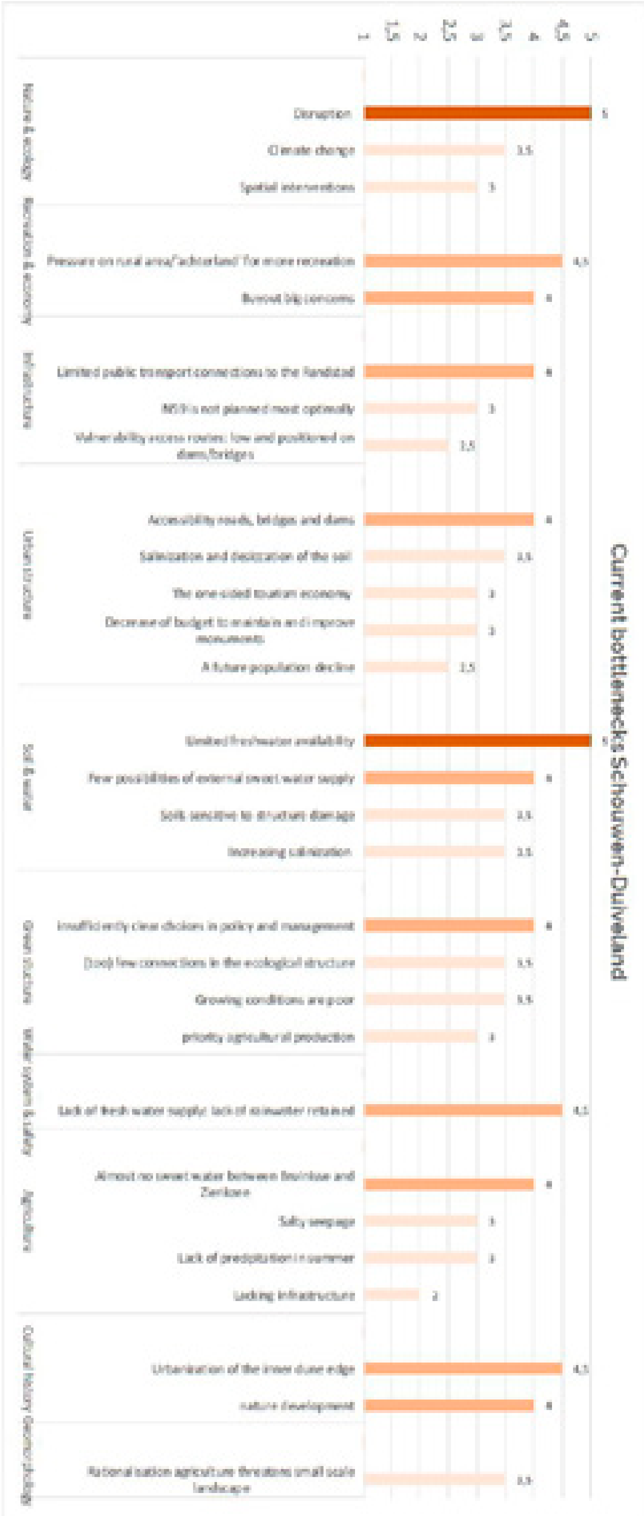


Fig. 18. *Current bottlenecks in Schouwen-Duiveland*

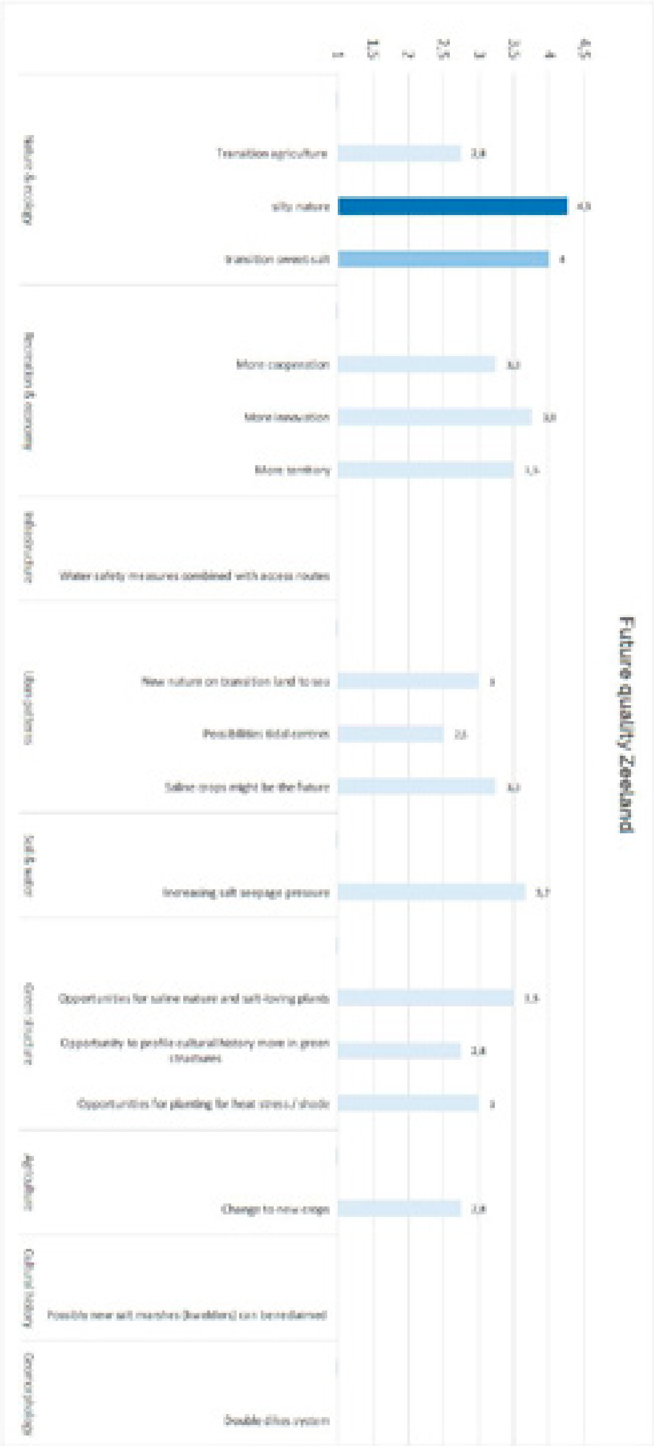


Fig. 19. *Future qualities in Zeeland*

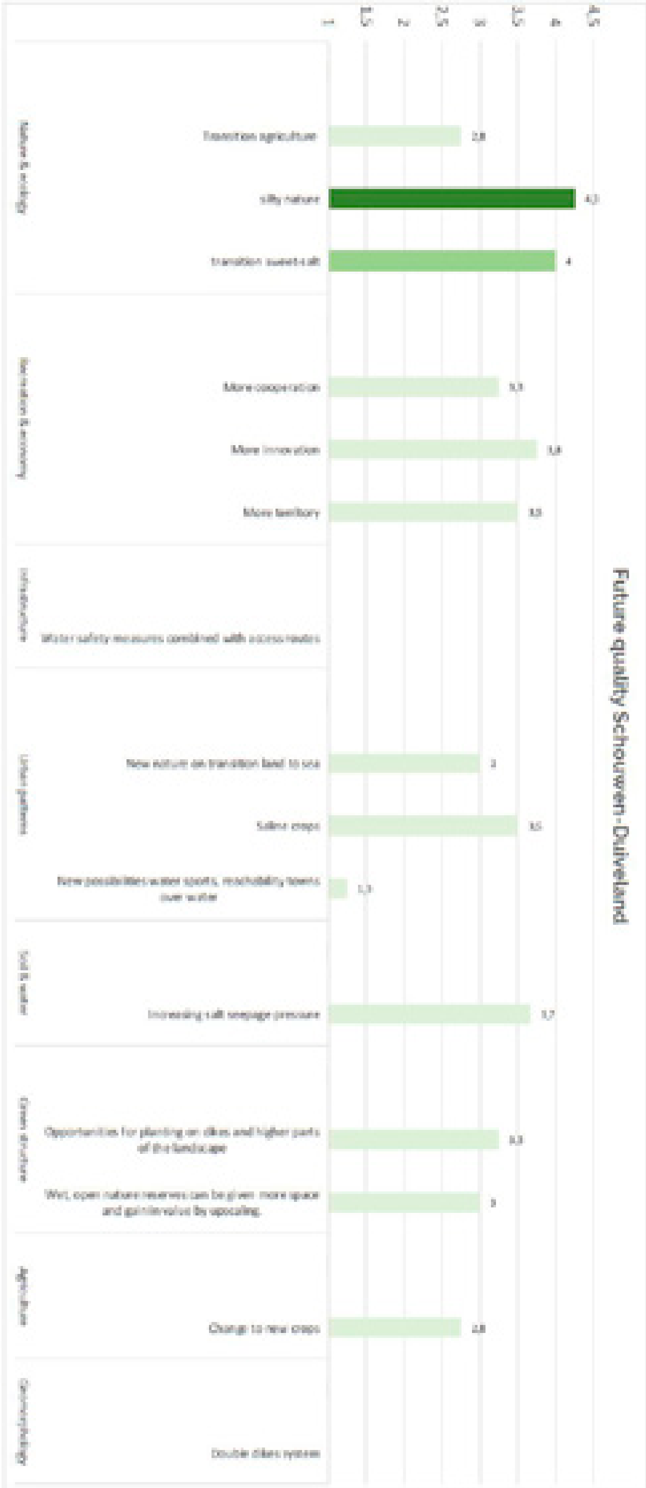


Fig. 20. *Future qualities in Schouwen-Duiveland*

3.1.4 FUTURE LANDSCAPE BOTTLENECKS DUE TO SLR

The future bottlenecks as a consequence of SLR in Zeeland and S-D are displayed Figure 21 and 22. Several important future bottlenecks in Zeeland and S-D were found. Notably was the high number of future bottlenecks in comparison to the current bottlenecks. The most important future bottlenecks were similar for S-D and Zeeland. These potential bottlenecks were: inundation of land outside the dikes; the storm surge barrier will not be suitable anymore; sediment shortage; and decrease of dry periods intertidal areas. The experts regarded the consequences of tidal changes as severe problems. The second most important bottleneck was the lack of freshwater. Thirdly, the drowning tidal areas were important. The fourth most important bottlenecks were flood defences; bridges & dams; salty seepage; lack of precipitation in summer; and processing capacity of rain showers. The fifth most important were: the pressure on ground- and freshwater; nature being robust nor connected; freshwater shortage; water management; more salinization of the soil; increasing salt seepage pressure; salinization and desiccation.

To conclude, the most important future bottlenecks for S-D were; inundation of land outside the dikes; the finite functioning of the storm surge barrier; sediment shortage; and decrease of dry periods for intertidal areas. Especially, the consequences of tidal changes were considered severe.

3.1.5 CONCLUSION ON THE MOST IMPORTANT QUALITIES AND BOTTLENECKS AND DEFINITION OF GOALS

Most important qualities and bottlenecks

Several important qualities and bottlenecks were found in S-D and Zeeland. The goals were formulated based on the most important qualities and bottlenecks from S-D; as this was the study area. However, a comparison with the most important qualities and bottlenecks in Zeeland was made to determine whether certain qualities or bottlenecks were extra relevant. When a quality or bottleneck was the most important in both regions, it gained more relevance because it was widespread.

Firstly, the most important current qualities were the transition of sea-beach-dune, the 'Karrenvelden', and the 'Schurvelingen'. For Zeeland, this transition was also the most important quality, stressing the relevance of this quality.

Secondly, the most important current bottlenecks in S-D were the disruption of nature and the limited freshwater availability. For Zeeland, these bottlenecks were also the most important, emphasizing the relevance of these bottlenecks.

Thirdly, the most important future quality in S-D was silty nature. This quality was also the most important in Zeeland, stressing the relevance of this quality.

Finally, the most important future bottlenecks in S-D were inundation of land outside the dikes; the storm surge barrier will not be suitable anymore; sediment shortage; and decrease of dry periods intertidal areas. These bottlenecks were also the most important in Zeeland, stressing the relevance of these bottlenecks.

To summarize, it became clear from the qualities that transitionary and silty nature areas were very important. Also, cultural elements as 'Karrenvelden' and 'Schurvelingen' were specifically important in S-D. From the bottlenecks became clear that impacts regarding the tidal nature, and freshwater availability were important to address.

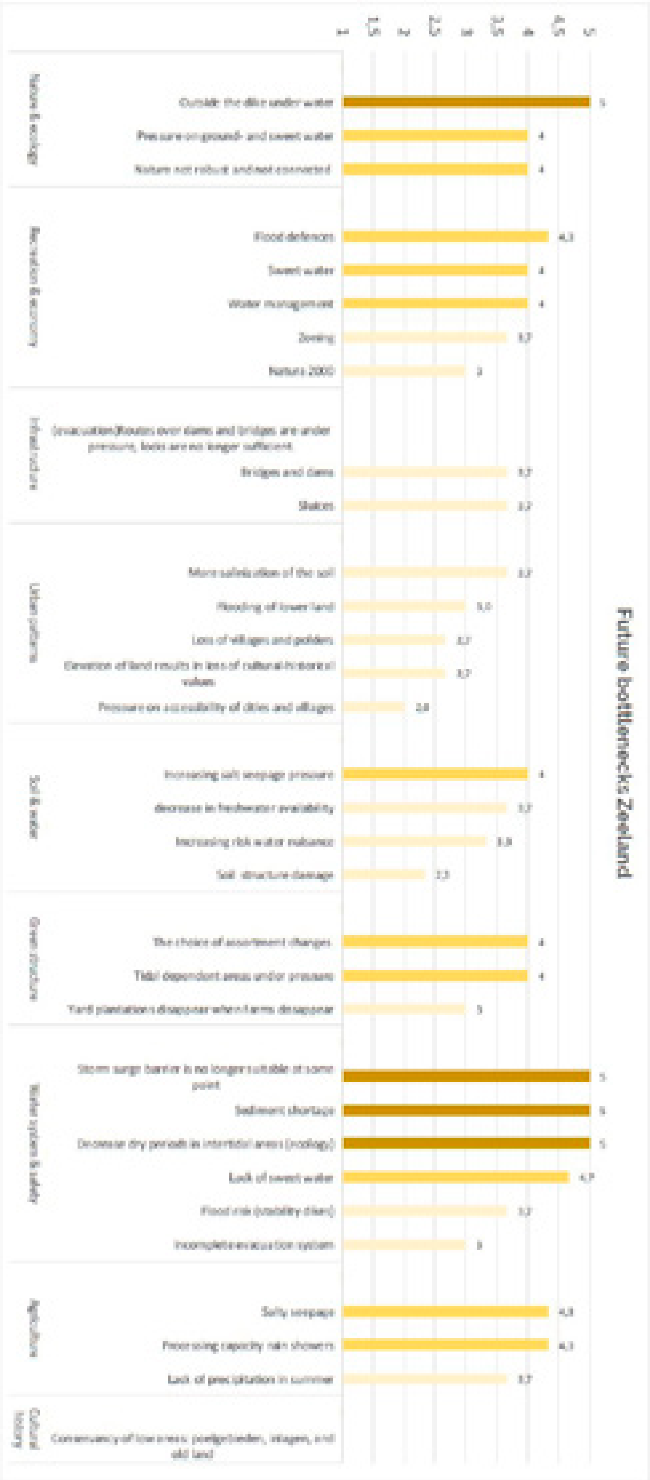


Fig. 21. *Future bottlenecks in Zeeland.*

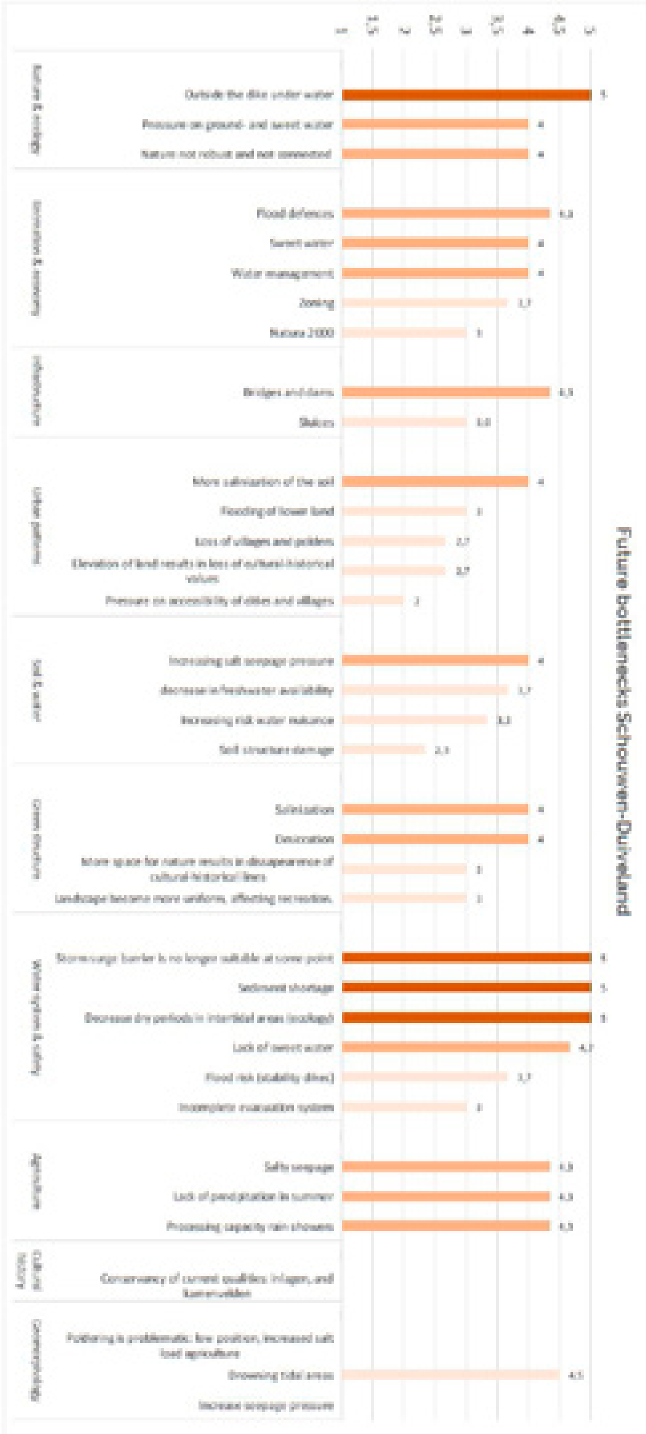


Fig. 22. *Future bottlenecks in Schouwen-Duiveland.*

Defining the goals

Based on these identified most important qualities and bottlenecks, goals were established to conduct the RTD. These goals were divided in main design goals, sub design goals and design guidelines (Figure 23). No goals were based on future qualities, because these scored too low on importance.

The main design goals were based on the future bottlenecks, because this study is focused on adapting to the future impacts of SLR. Also, these bottlenecks were selected as main goals because these were related and could therefore be solved in an integrative way. The sub design goals were based on current bottlenecks, as these endanger the landscape quality. Furthermore, design guidelines were established, based on the current qualities.

The first main goal was based on the bottleneck that the storm surge barrier would not offer sufficient protection anymore. The expert clarified that this endangered the water safety of the inhabitants. Therefore, the goal was to study solutions for water safety and to explore alternatives concerning the storm surge barrier.

The second main design goal was based on the bottleneck that land outside the dike would inundate. This bottleneck was very relevant because three different experts mentioned that this bottleneck was significantly important. Therefore, the goal was to study solutions for the impacts of tidal changes on nature, such as drowning of land outside the dikes.

In the third goal, solutions were studied for impacts of sediment shortage. The expert mentioned that sediment shortage was an immense problem, where solutions are lacking. Therefore, solutions to reduce erosion were studied, which is the result of sediment shortage.

Finally, solutions for the impacts of a decrease of dry periods on tidal nature were studied.

The fifth goal: 'salinization & freshwater regarding nature and agriculture' was considered as a sub goal, as the previously mentioned future bottlenecks were considered more important. However, subgoals could be met when they fitted in the design.

Finally, preservation and integration of the "karrenvelden" was formulated as the design goal. This guideline was based on the current qualities, which simply had to be preserved. Therefore, assumed was that this quality demanded the least attention. Two other qualities were the most important, but were not part of the guidelines, as these were not present in the project area. These neglected qualities were the transition sea-beach-dune and the 'Schurvelingen'.

The bottlenecks were further analysed to specify the goals, in paragraph 3.3.

	MAIN DESIGN GOALS	BASED ON FUTURE BOTTLENECKS	LAYER
1	Study solutions for ***water safety*** and explore new options regarding the storm surge barrier	STORM SURGE BARRIER WILL NOT BE SUITABLE ANYMORE	W&S
2	Study solutions for ***impacts of tidal changes*** on nature, such as drowning of land	INUNDATION OF LAND OUTSIDE THE DIKES	N&E
3	Study solutions for impacts of ***sediment shortage, such as erosion***	SEDIMENT SHORTAGE: EROSION	W&S
4	Study solutions for impacts of a ***decrease of tidal dry periods*** on nature	DECREASE DRY PERIODS INTERTIDAL AREAS	W&S

	SUB DESIGN GOALS	BASED ON CURRENT BOTTLENECKS	LAYER
5	Strengthen/protect nature against ***disruption*** factors	DISRUPTION FACTORS	N&W
6	Find solutions to deal with the ***lack of fresh water*** and the ***increase of salinization*** regarding nature and agriculture	LIMITED FRESHWATER AVAILABILITY	S&W

	DESIGN GUIDELINES	BASED ON CURRENT QUALITY	LAYER
7	Integrate the ***'Karrenvelden'*** as best as possible in the design	'KARRENVELDEN'	CH

Fig. 23. Overview of the design goals based on the most important future and current bottlenecks and qualities.

3.2 RESULTS: LANDSCAPE IDENTITY

The landscape identity vision was the second basis for the design, mostly analysed through a field survey. During the field survey, observations were recorded by taking notes and photos from aspects representing the landscape identity (page 49). These four aspects were the characteristic landscape elements, the degree of internal cohesion, and the orientation in time. The connectedness to the landscape was analysed through expert discussions.

Characteristic landscape elements
The geographic units were: old seabed, polders, and sea erosion channels (D) from the 'watersnoodramp (1953)'. The main region-specific flora and fauna were: mussels, cockles, and oysters (A), wader birds, and salt tolerant plants. The green elements were: hedges, hedgerows, and tree rows. Only a few green elements were present, the region was mostly open (H). Blue elements comprised creek remains and creek ridges, ditches with a low water level (B), dikes and dams, and 'inlagen'. (G) Cultural historic elements were found to be historic and modern windmills (F), historic farms, historic harbours, 'muralt' walls (E) at dikes, drowned villages, a 'meestoven', caissons (G) from the storm surge in 1953, 'karrenvelden', and old tidal harbours (J).

The internal cohesion
The open landscape with large parcels was related to the agricultural land use (H). This land use is related to the fertile permeable soil, which resulted in low water levels (B). Furthermore, the dikes illustrated the human behavior to reclaim and protect the land. The irregular patterns of roads and ditches were based on creek patterns. Also, the edges of the reclaimed land as Duiven and Dreischor were visible by the secondary dikes (C), being the former edges of these polders. However, reallotment after the super storm in 1953 resulted in more rectangular and large-scale parcels. Thus, a strong internal cohesion is present, however, the endless fight against the water has changed the original irregular, small scale landscape in a larger, rectangular shaped landscape.

The orientation in time
The orientation in time is visible, due to the recognizability of the landscape history. Old dikes are still present and show the gradual reclamation of the former island S-D. Mainly the old dikes (C) display the edges of the polders being a recognizable structure in the landscape. Furthermore, information panels display the location of drowned villages (I). The old historic town Zierikzee includes many monuments and contributes to the orientation in time. Overall, the orientation in time has decreased, as the small scale and irregular landscape has changed into a large(r) scale and rational landscape.

The connectedness to the landscape
The connectedness to the landscape is the result of the relationship of people with their surroundings. This relationship is different for each type of user, for example: inhabitants, recreants, or entrepreneurs (van Herwaarden & Koedoot, 2011). Experts originating from Zeeland are strongly connected to their landscape (appendix I).

Landscape identity vision

The landscape identity included several characteristics and was related to the substratum, however, land consolidation resulted in a large scale and more open landscape than originally was present. The vision for the design was to preserve the landscape identity and strengthen it where possible. To elaborate, five main guidelines were established to this end (Figure 24):

1. To relate the substratum to the land use;
2. To preserve or replace the analysed landscape characteristics;
3. To make the history readable;
4. To keep the mass / space balance as it is;
5. To avoid forcing inhabitants to leave their homes

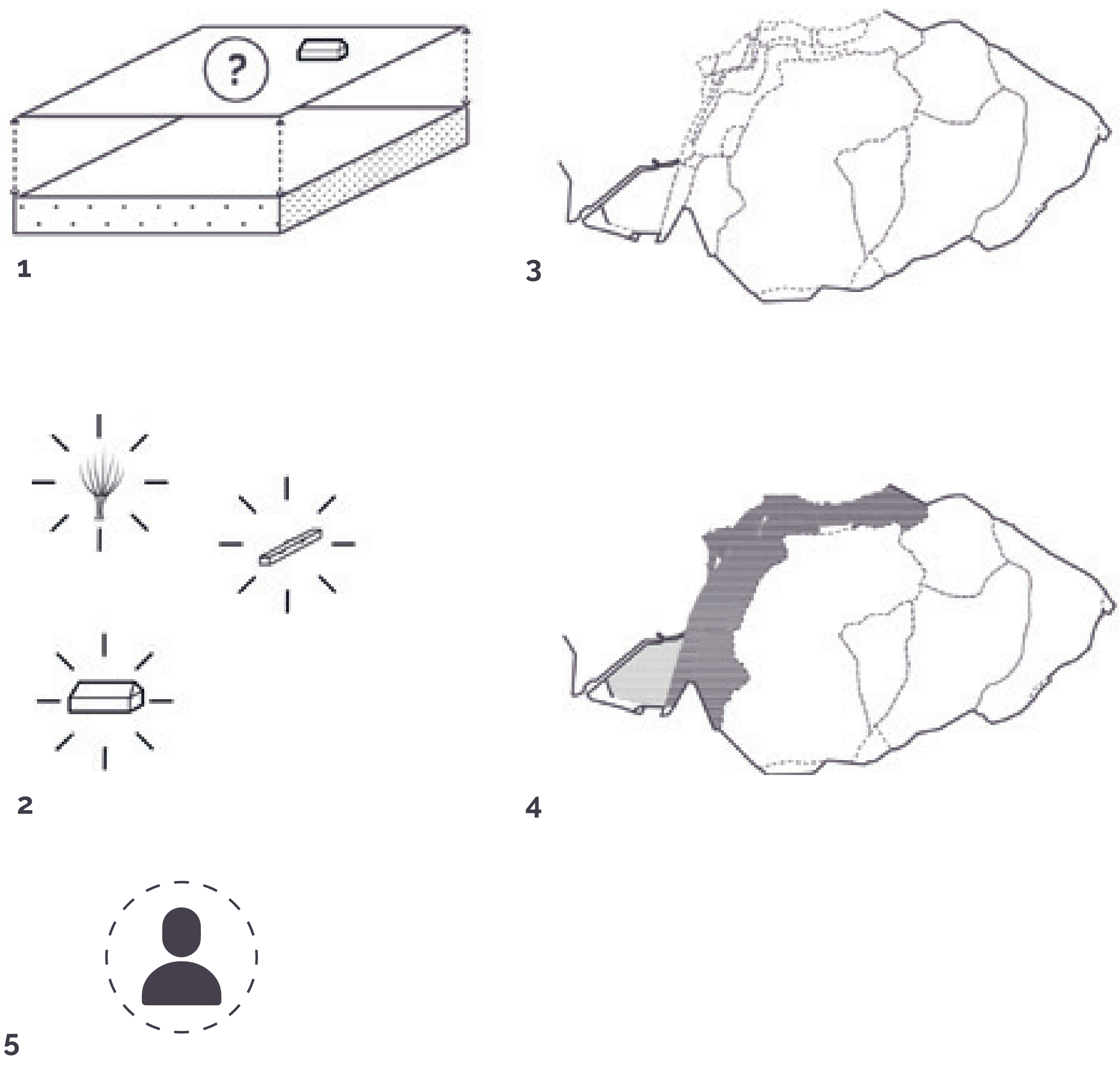
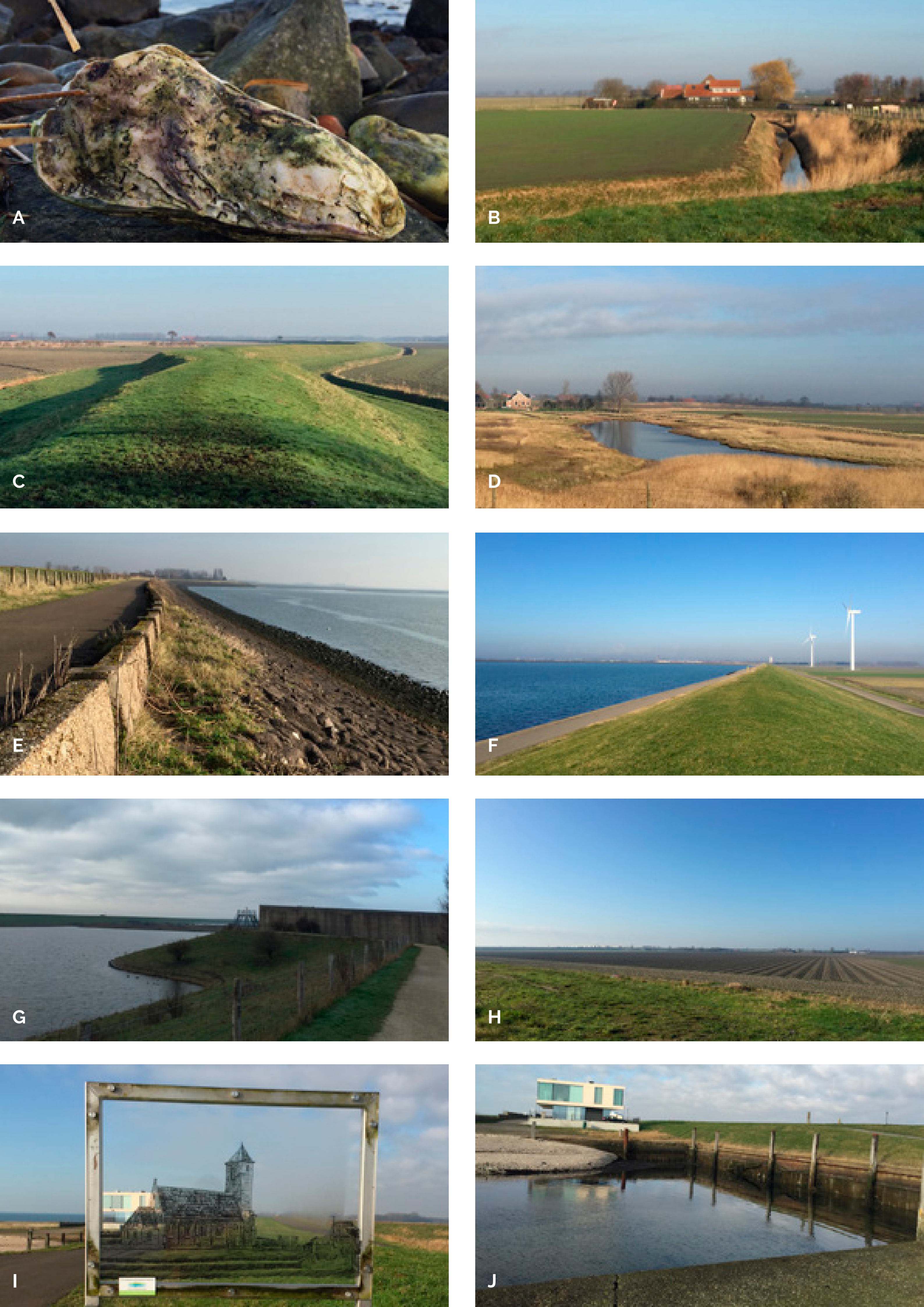


Fig. 24. Vision illustrated in schemes.


A
B
C
D
E
F
G
H
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J

3.3 RESULTS: LANDSCAPE AND SEA LEVEL RISE ANALYSIS

The first main goal was to design solutions for water safety and explore options regarding the storm surge barrier. Therefore, altitude, subsidence, flood defence types, safety standards and flood chance were studied. Subsidence was studied as this contributes to the total relative sea level rise (Sayol & Marcos, 2018). The second main goal was to study solutions for impacts of tidal changes on nature, such as drowning of land. The third main goal was to study solutions for impacts of sediment shortage: erosion. The fourth main goal was to study solutions for impacts of a decrease of tidal dry periods. On basis of these goals, the tidal system and the SLR impacts on nature were analysed.

3.3.1 ALTITUDE

Altitude Zeeland

The west positioned dunes (yellow-orange and encircled in Figure 25) are the highest elements in Zeeland. The other higher positioned parts of the landscape are the creek beds. The most southern part of Zeeland is positioned the highest on average, and S-D is positioned the lowest on average, in comparison to the rest of Zeeland. The dikes at the edges of the islands are also higher. Finally, the east positioned salt marshes outside the dikes in Zeeuws-Vlaanderen are significantly higher, because these silt up due to tidal processes (also encircled).

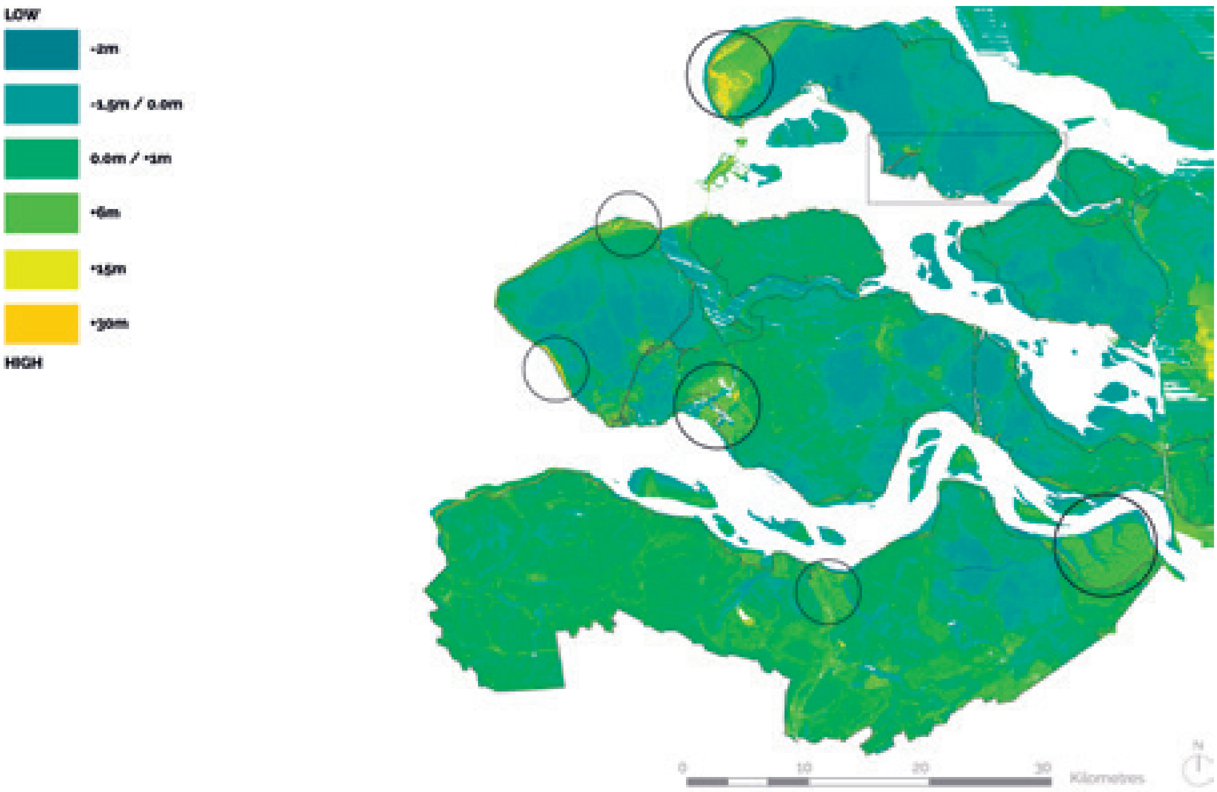


Fig. 25. Altitude Zeeland. Adapted from Beheer PDOK (2014).

Altitude Schouwen-Duiveland

The larger, lower areas (green) represent the lower old land ('oudland'), and the more high areas represent the higher new land ('nieuwland') (Boon, 2012) (Figure 26). In the old land, height differences of two m were found due to creek ridges and lower positioned tidal plains ('poelgronden') (van der Sluijs, Steur, & Ovaa, 1965). The new land silted up higher than the old land, and the soil subsided less than old land polders. However, less height differences were found within the new land (Boon, 2012). In the east of the project area, some irregular patterns in height differences are visible, which originate from tidal creek beds. Lastly, land outside the dikes silt up higher due to tidal processes.

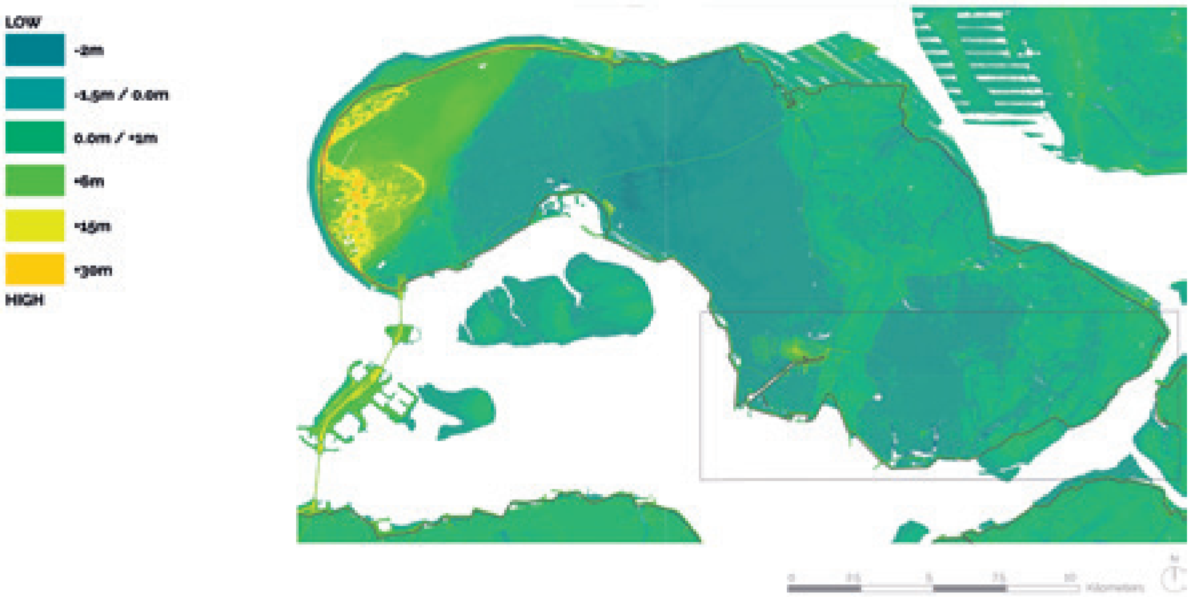


Fig. 26. Altitude Schouwen-Duiveland. Adapted from Beheer PDOK (2014).

3.3.2 SUBSIDENCE

Soil subsidence

Different projections for subsidence in 2050 are shown enlarged on the scale of S-D (Figure 27 and Figure 28). Three uncertainties were found: variations between the projections, uncertainty within the projections, and the uncertainty created by downscaling the projections. The projection of 1997 in Figure 27 continues equally to the year 2100 (Haasnoot, Vermulst, & Middelkoop, 1999). The uncertainty of the projected subsidence should be considered, as well as the strong variations locally.

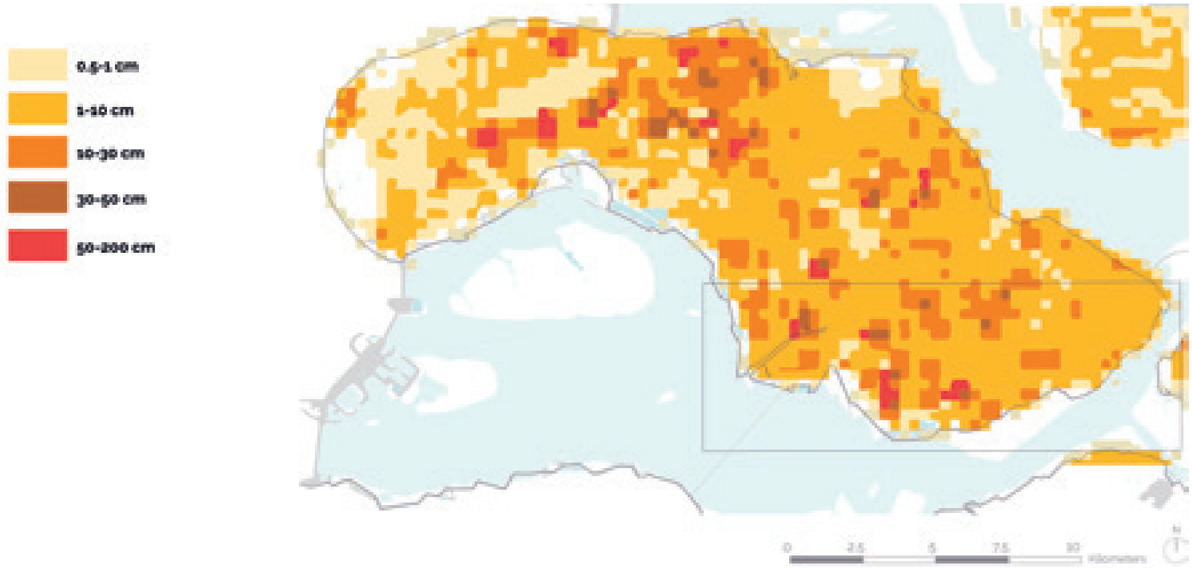


Fig. 27. Expected natural and anthropogenic subsidence in 2050 in centimetres (cm). Adapted from Muntendam-Bos, Kroon, Fokker, & de Lange (2006).

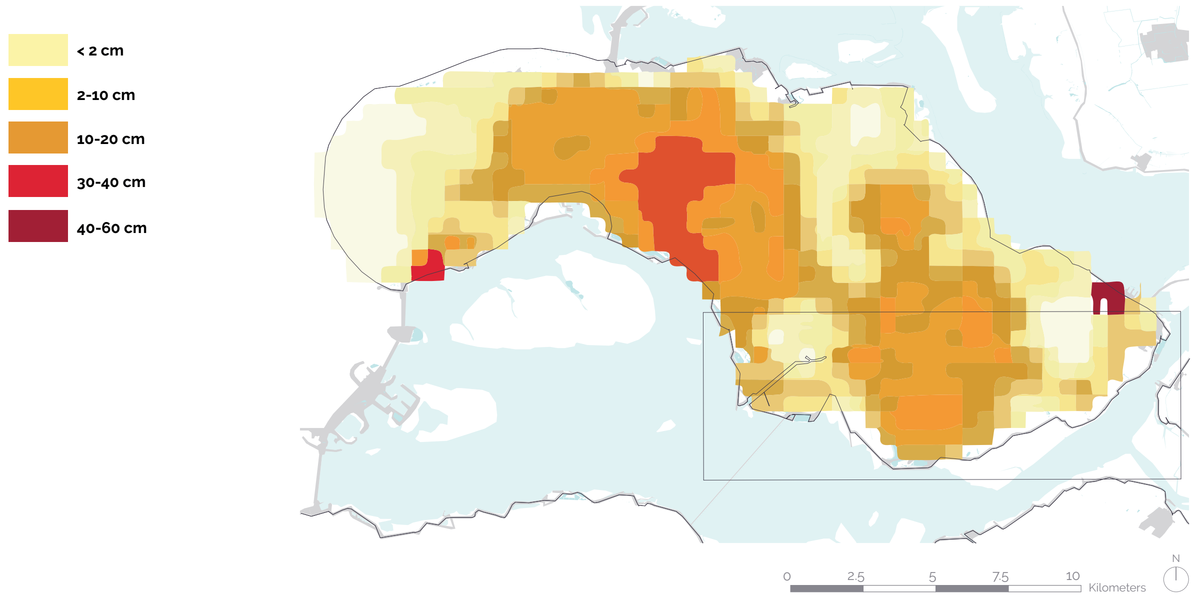


Fig. 28. Expected natural and anthropogenic subsidence in 2050 in centimetres (cm). Adapted from Bolleboom, Erkens, Kinneging, & van der Meulen (2017).

3.3.3 FLOOD DEFENCE TYPES AND SAFETY STANDARDS

The whole border of S-D (dike ring 26), is uninterrupted connected by dikes, dunes, and artificial barriers (Figure 29). Primary dikes protect the land from floods (STOWA, 2017). The regional dikes limit the flood magnitude, delay the water, and form escape routes (Team deltacommissaris, 2019).

Different dike norms per dike segment

The dikes in Zeeland are divided in different dike segments. These have their own norms, depending on local circumstances that affect the dikes and the accompanying flood risk (STOWA, 2017). For instance, the natural foreland of the tidal flats breaks the waves, which reduces the pressure on the dikes. The subsidence of the polders increases the pressure on the dikes as well as the risk on piping and dike bursts (von Meijenfeldt et al., 2017).

Lower limit and signal value

Dike safety standards are expressed in a lower limit, and a signal value (Figure 30 and Figure 31). The lower limit ('ondergrens') is the maximum acceptable flood chance. The signal value indicates the reinforcement of the barrier, when the flood chance exceeds this value, reinforcement needs to be planned. The lower limit is based on a chance of death from flooding of 1/100.000 persons per year. The signal value is based on a flood having a chance to occur once per 200.000 years (Slootjes & van der Most, 2016).

Dike segment 26-3

The dike norm of the trajectory between Zierikzee and Bruinisse has a signal value of 1/10.000 and a lower limit of 1/3.000. The predicted water level occurring once every 10.000 year determined the height of the dike (Slootjes & van der Most, 2016), which is generally + 6 m above the 'Normaal Amsterdams Peil' (NAP), being the Normal Amsterdam Level (Hillen, Haselen, Brader, & Kolen, 2011).

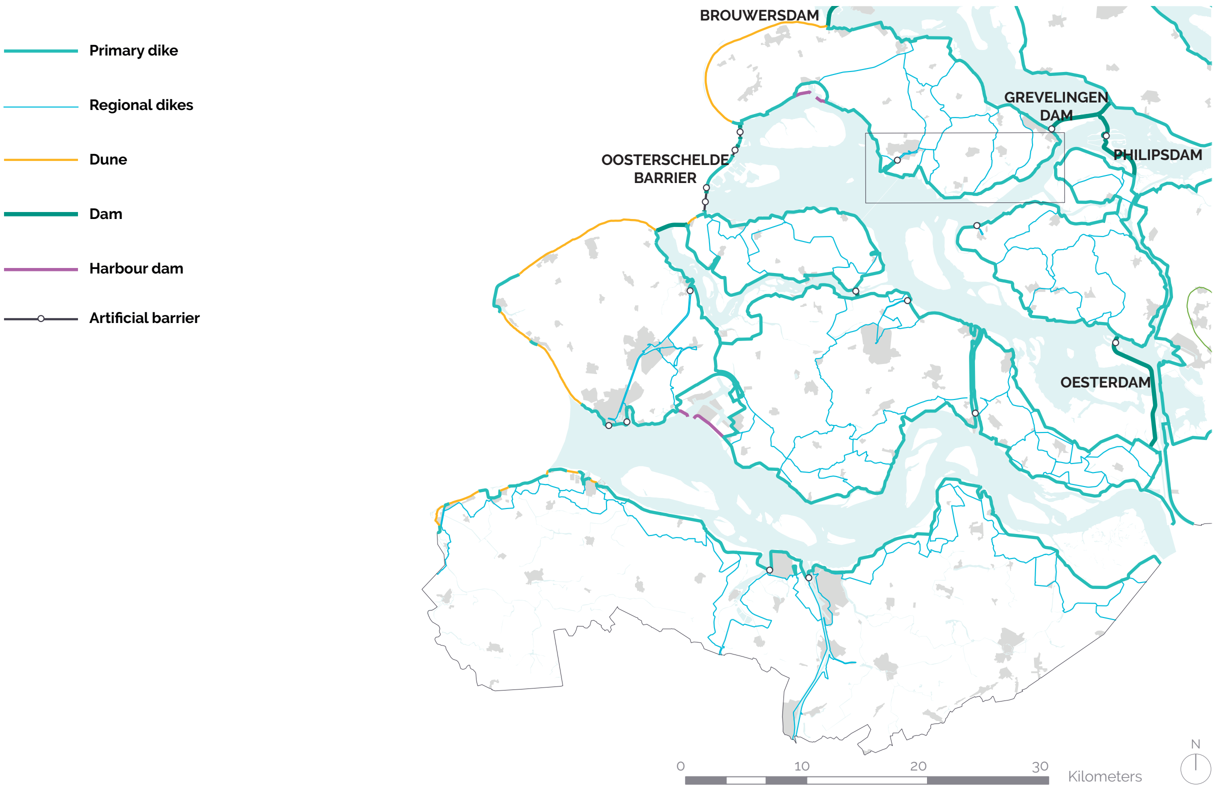


Fig. 29. Flood defence types. Adapted from Provincie Zeeland (2019a, 2019b).

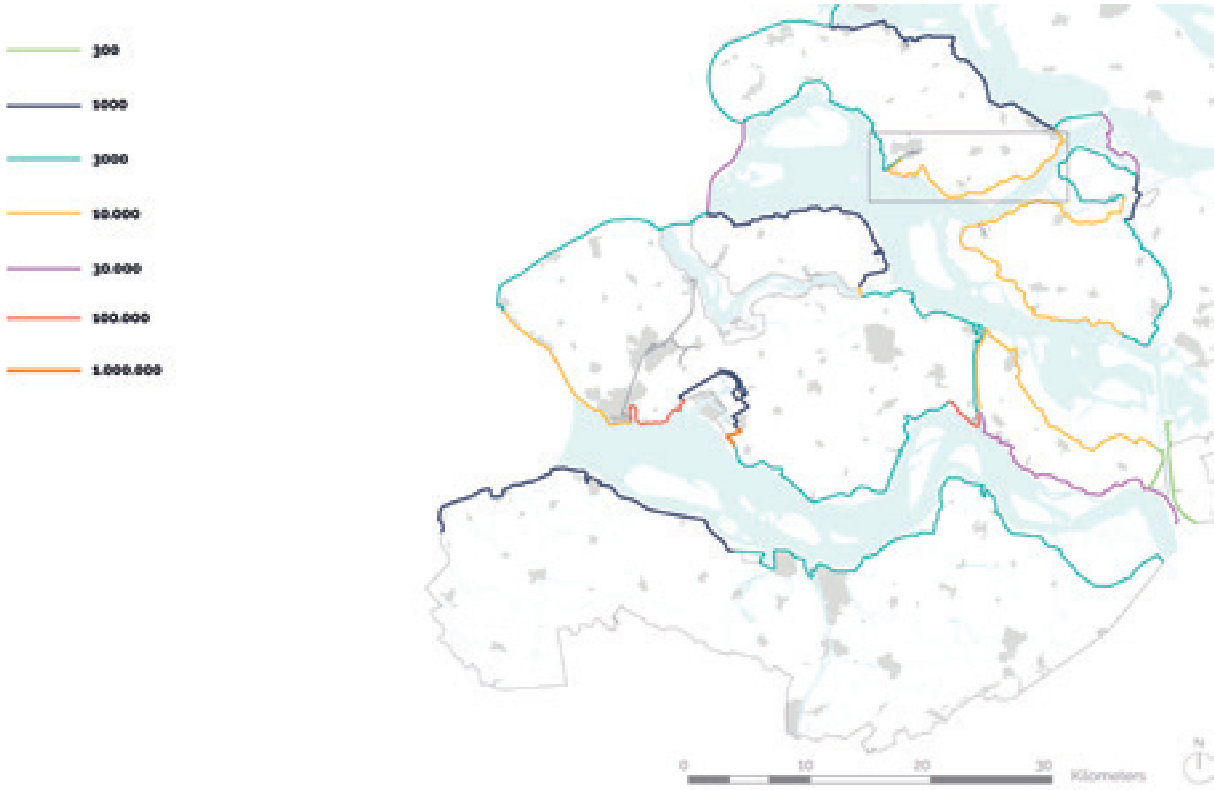


Fig. 30. *Protection standards (signal value). Adapted from Slootjes & van der Most (2016).*

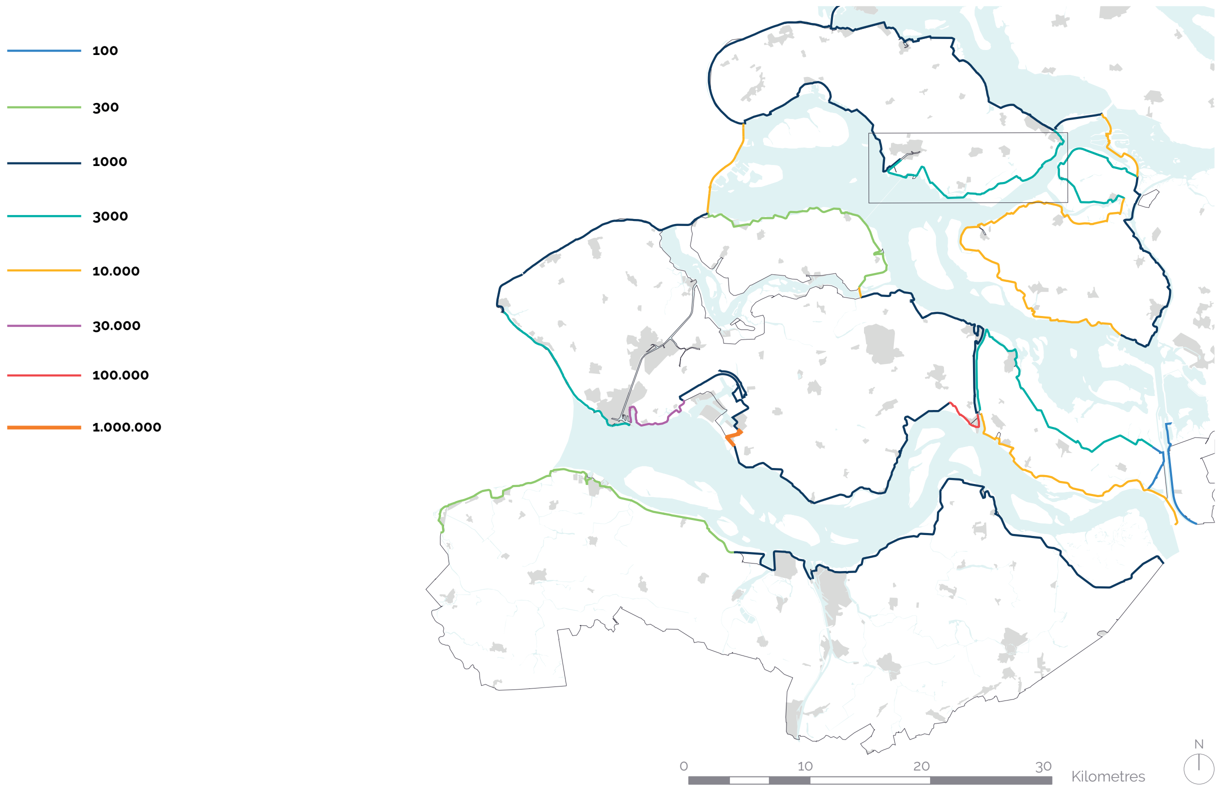


Fig. 31. *Protection standards (lower limit). Adapted from Slootjes & van der Most (2016).*

Flood chance

The expected flood chances for 2020 per dike trajectory, after realisation of planned projects, are shown in Figure 32. The flood chance of the east dike segment (23-6) of S-D was 1/300 years. The lower limit for the dike segment was 1/3000 years (Slootjes & van der Most, 2016). This meant that the flood chance is 10 times larger than acceptable.

Fig. 32. Flood chances per dike trajectory, after completion of projects in 2020. Adapted from Slootjes & van der Most (2016).

3.3.5 THE OOSTERSCHELDE BARRIER

The Oosterschelde barrier and erosion

The Oosterschelde used to be an open connection between the sea and the rivers the Rhine, the Meuse, and the Scheldt, with large tidal differences. In 1986, the Oosterschelde was locked by the Oosterschelde barrier (OSB). The Philipsdam, the Grevelingendam and the Oesterdam locked the river side of the Oosterschelde. The OSB was a key in the safety plan of the region. This storm surge barrier can close to protect from storm surges (von Meijenfeldt et al., 2017).

The Delta Works changed the estuary into a sea arm. This resulted in erosion, which threatens the dams and dikes, by making them unstable (Meyer, Bregt, Dammers, & Edelenbos, 2015).

Water levels in the Oosterschelde

The water level in the Oosterschelde naturally differs due to the tides. The water level is given in m above (+) or below (-) the NAP. This tidal difference is 2,5 or 2,7 m near the barrier, and 3,0 or 3,7 m in the back part of the Oosterschelde. The barrier is theoretical resistant to +5,5 m NAP (von Meijenfeldt et al., 2017).

SLR effect on the closing time of the Oosterschelde barrier

It appeared that that the OSB will not offer enough protection in the future. Therefore, the current and future functioning of the barrier and the impact of SLR are discussed.

With the current closing regime based on 3 m + NAP, the OSB would close 85 times per year at a SLR of 1 m. At 2-m SLR, the barrier would close 662 times per year. After a SLR of 1,5 m, the barrier would be closed more than 30% of the time.

In a scenario with a new closing regime based on wave overtopping rate, a SLR of 2 m results in a closing of 63 times per year, which would be 5% of the time. Based on the normative high-water level, 1 m of SLR will result in a closing frequency of 10 times per year. At 2-m SLR, the barrier would close 522 times per year, which results in a 40% closed barrier of the time. However, this depends on the closing regime. Basing the closing regime on the wave load or normative high water can lead to a lower increase of the closing time (Zandvoort, van der Zee, et al., 2019).

Hence, the OSB would close more often with a current closing regime as well as with a new closing regime due to SLR.

3.3.6 TIDAL SYSTEM

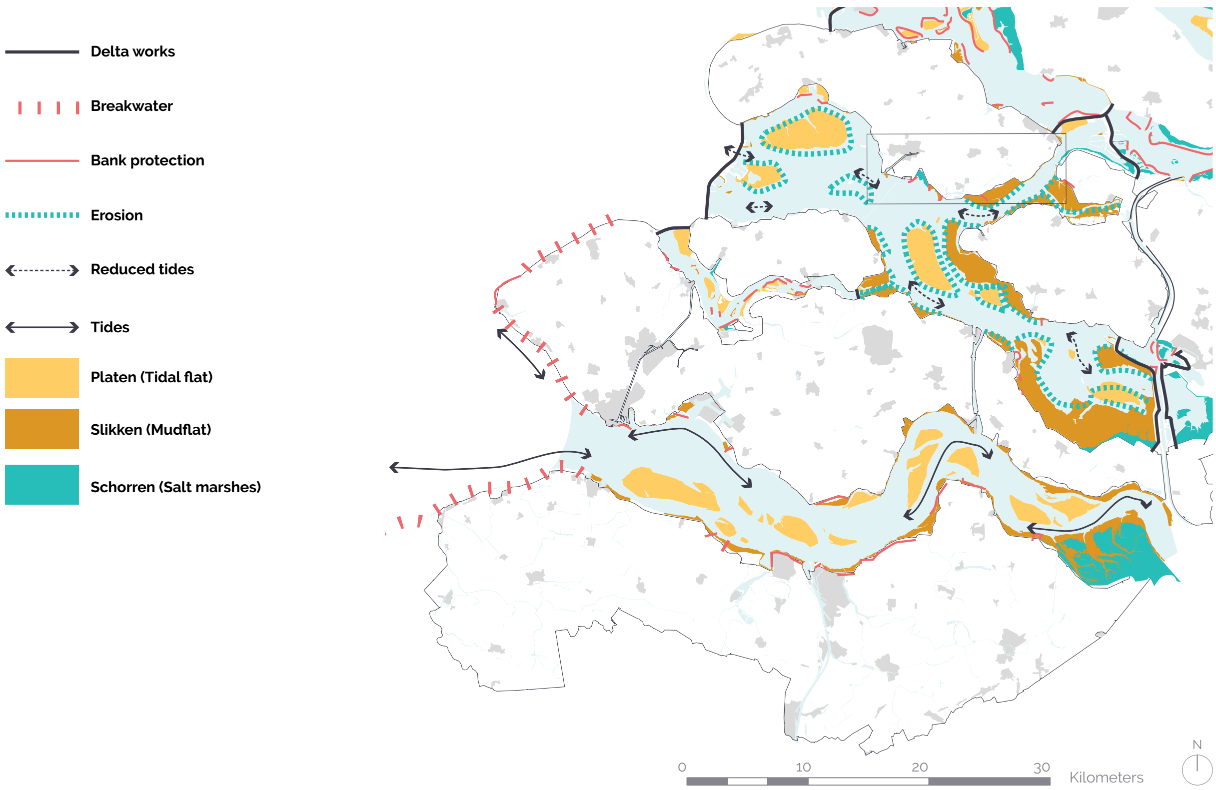


Fig. 33. Erosion and tidal changes in the morphological system caused by the Delta Works. Adapted from Meyer, Bregt, Dammers, & Edelenbos, (2015); Provincie Zeeland (2019).

Sand shortage

Since the OSB was placed, sand exchange became almost impossible, which means that the morphological system is out of balance (Figure 33). In the natural situation, the sand would originate from the front part of the delta (Geurts van Kessel, 2004).

The combination of reduced water flow capacity though the OSB with large tidal channels resulted in a decrease of flow velocity and tide volume. This resulted in almost no sediment movement from the channels to the intertidal area (Figure 34) (von Meijenfeldt et al., 2017; Vroon, 1994). Due to the reduced difference between high and low tide, and fewer sediment supply, erosion of tidal flats is continuing (Vroon, 1994). This problem is called sand shortage (Zanten & Adriaanse, 2008).

Loss of intertidal areas due to SLR and current closing regime Oosterschelde barrier

The tipping point for loss of intertidal areas is already reached, as the areal of tidal nature has decreased due to sand shortage. A SLR of 0,5 m resulted in a strong decrease of dry falling intertidal areas. A SLR of 1 m could lead to largely disappeared tidal flats (Zandvoort, van der Zee, et al., 2019).

Loss of intertidal areas

About 1.100 ha of tidal flats already inundated and the average height of the flats has decreased by 25 cm (Witteveen+Bos & Bureau Waardenburg, 2013). From the original 'schorren' surface, only a quarter was present, and this area would diminish with 3 hectare per year independently from SLR.

The tidal difference reduced 10%, and the tidal volume decreased with 30% before the establishment of the OSB in 1986 (De Ronde, Mulder, Van Duren, & Ysebaert, 2013). The tidal difference was 3,70 m, which changed to 3,25 m. The maximum flow velocity was 1.5 m per second (m/s), which changed to 1.0 m/s. The tidal volume decreased from 1230 to 880 (106 m3) (Geurts van Kessel, 2004).

The delta works led to disruption of the tidal dynamics. Therefore, human interventions are necessary to conserve tidal flats and to protect the flood defences. The biggest issues are found in the eastern part of the Oosterschelde (Stuurgroep Zuidwestelijke Delta, 2014).

Future decrease tidal flats

The inundation of tidal flats would accelerate due to SLR, which is an almost irreversible impact (Geurts van Kessel, 2004; von Meijenfeldt et al., 2017). A SLR of 2 m could increase the tidal range. This could result in too much exportation of sand; setting risk to the shoreline. Under 2 m SLR, the Oosterschelde could change from a mix of high tide and low tide to mainly low tide (Jiang, Gerkema, Idier, Slangen, & Soetaert, 2020). SLR rise would then barely directly affect

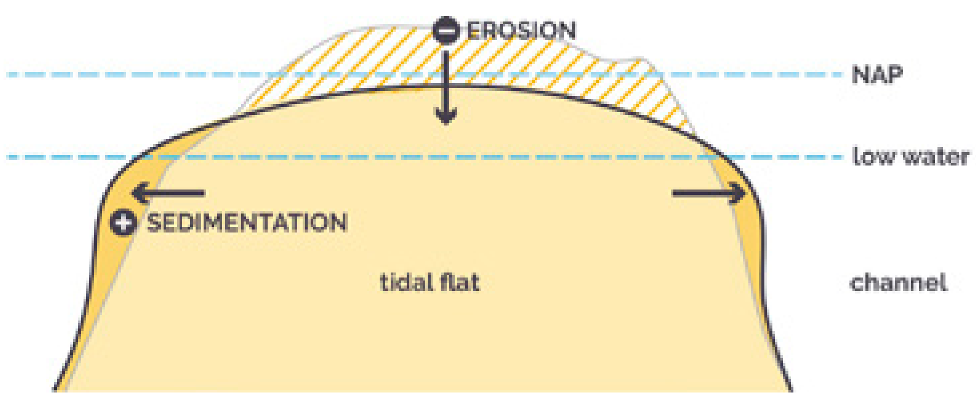


Fig. 34. The main problem caused by the OSB: erosion of the tidal flats, due to decreased flow velocity in the channels, and decreased tidal volumes. Adapted from: (Zanten & Adriaanse, 2008).

the sand shortage (Geurts van Kessel, 2004). A future SLR larger than 1 cm per year, would be problematic for intertidal nature.

In total, 1200 hectare of intertidal area will be lost in 2045, based on 60 cm SLR. (Figure 35 & Figure 36). Another 5100 hectare will be lost due to 'sand shortage' (Zanten & Adriaanse, 2008). This stresses the urgency of need to adapt fast to SLR.

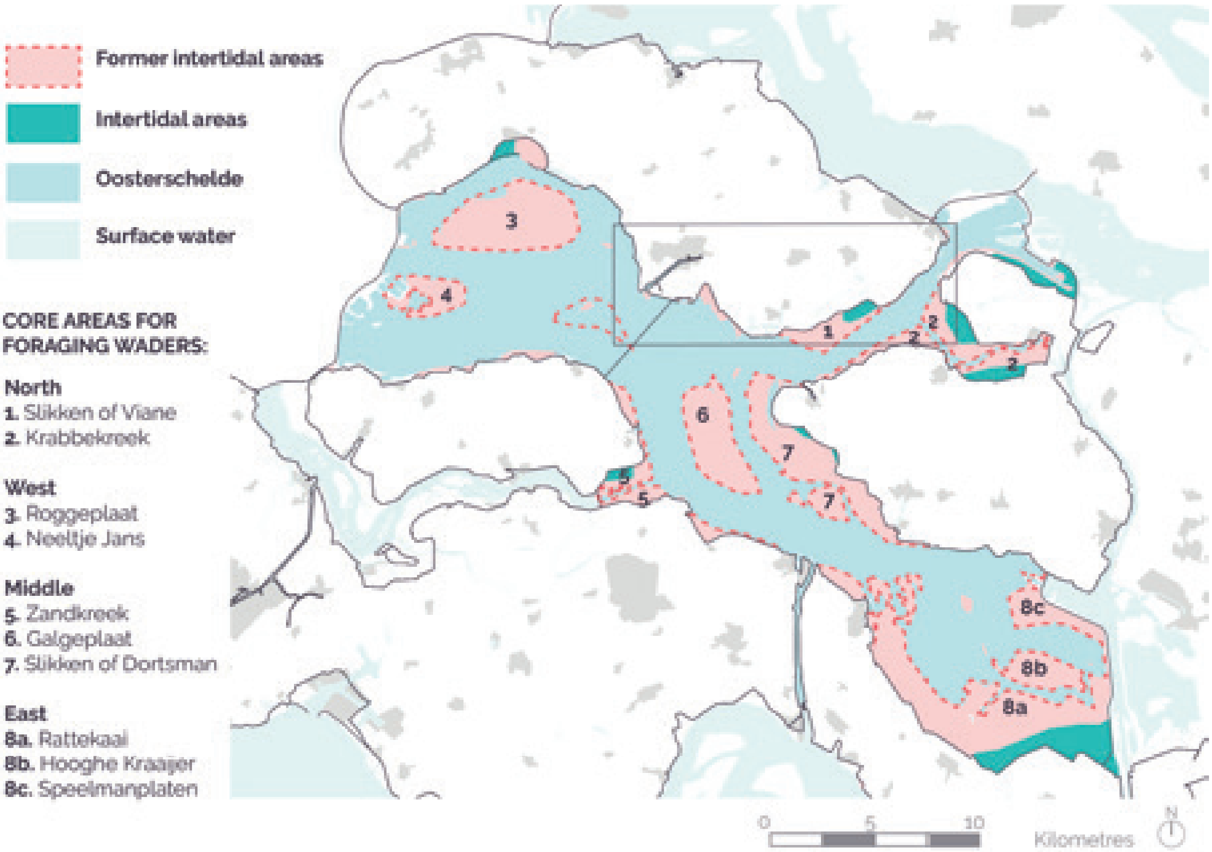


Fig. 35. Projected end situation of intertidal areas between 2050 and 2100. Adapted from Zanten & Adriaanse (2008) & De Ronde et al. (2013).

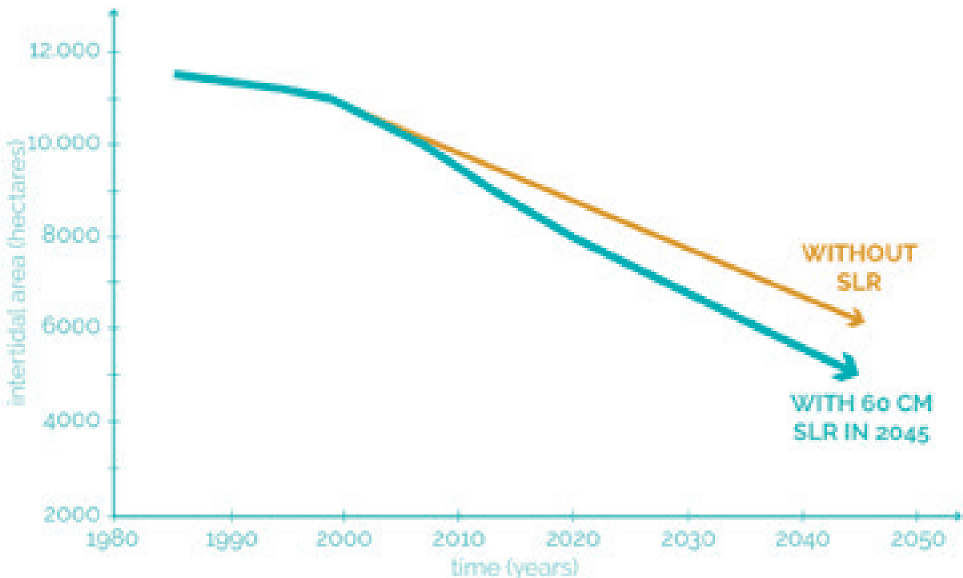


Fig. 36. Historical and projected development of intertidal area from 1986 to 2050. Adapted from Zanten & Adriaanse (2008).

3.3.7 VALUES AND DANGERS OF THE TIDAL NATURE AREAS IN THE OOSTERSCHELDE

The value and the endangerment of the tidal nature areas

The tidal nature areas in the Oosterschelde belong to the most important tidal nature of the southwestern part of the Netherlands. Note that the Oosterschelde is of international importance for migratory birds, as some species use the Oosterschelde for resting in the winter. Different valuable functions are present for different types of birds. These functions are resting, breeding, and finding food. The different dry falling periods due to the tides and the height differences of the tidal areas determine these values.

Three types of tidal nature areas exist in the Oosterschelde, being 'schorren', 'slikken' and 'platen'. 'Schorren' are vegetated tidal nature areas, which only flood during storm surges. The 'slikken' are unvegetated silty tidal nature areas, attached to the coast, which daily fall dry during low tide. The 'platen' are similar but are not attached to the coast. During low tide, food is collected by wader birds on the dry falling 'slikken' and 'platen' The 'schorren' mainly serve as breeding habitats for birds.

However, SLR and sand shortage can shorten the dry falling periods of the tidal nature areas. This results in difficulties for birds to find food. Without adaptations, the ecological value of the Oosterschelde is endangered (Atelier Oosterschelde, Bosch Slabbers Landschapsarchitecten, Slabbers, Brader, & Sorée, 2018; De Ronde et al., 2013; Programmadirectie Natura 2000, 2009; Slabbers, 2014; von Meijenfeldt et al., 2017; Zandvoort, van der Zee, et al., 2019).

Mitigating erosion by supplementations

In the existing strategy to protect the tidal nature areas, supplementation is done to mitigate the erosion. With each suppletion, one of the eight core tidal nature areas is heightened (Figure 35). After a sediment suppletion, the soil life has to recover for minimal 4 years (Zandvoort, van der Zee, et al., 2019). The other seven core areas would offer enough space for waders to rest, breed and find food (Witteveen+Bos & Bureau Waardenburg, 2013). This way of supplementation would be sufficient until a yearly SLR of 1cm.

The magnitude of such a suppletion aimed for a specific dry falling period of the plates. This dry falling period is the yearly average percentage of the time that an intertidal area falls dry within the tidal cycle (Osté, de Groot, & van Dam, 2013). The tidal cycle takes twelve hours and 25 minutes in the Netherlands (Rijkswaterstaat, 2021). In the Oosterschelde was aimed for a dry falling period of 50-80%, having the most ecological value (Zandvoort, van der Zee, et al., 2019).

3.3.8 SUMMARY SEA LEVEL RISE IMPACTS AND LANDSCAPE QUALITY ANALYSIS

To summarize, some parts of S-D were already positioned below sea level. Furthermore, different degrees of subsidence were projected for the region. S-D is already protected by primary and regional dikes, dunes, dams, and artificial barriers. The maximum acceptable flood chance of the dike trajectory in the project area is defined as 1/3.000 (the lower limit). However, the flood chance is currently 1/300 years, being ten times larger than the lower limit. This means that interventions are urgently needed.

A key in the defence system is the OSB, which closes when the water level at sea would be +3 m NAP. This level will be reached more often due to SLR. With or without adjustment of the closing time, the barrier will close more often when SLR increases. A sand shortage in the Oosterschelde is already present due to the barrier, resulting in erosion of the tidal nature. Increased closing of the barrier would enhance these problems. Insufficient sedimentation rates would result in permanent inundation of the tidal nature, as the water level in the Oosterschelde will increase due to SLR. This results in a decrease of the internationally important ecological values of the Oosterschelde. Especially the wader birds are strongly dependent on the tidal nature areas.

3.4 RESULTS: STRATEGIES & MEASURES

3.4.1 STRATEGIES

Existing adaptation strategies

Several existing adaptation strategies to SLR were studied to develop the concepts in the RTD phase.

The IPCC distinguished three adaptation strategies to SLR: retreat, accommodate, and protect. The strategy retreat concerns no protection of land, but suggests a landward movement to higher areas. This comprises to prohibit expansions near the coast, or permit expansions which can be moved quickly. Accommodation means remaining and adapting at the current position. The land is not protected from flooding, but mitigation measures such as flood proofing agriculture are undertaken to be resilient to SLR. Protecting includes the use of measures against SLR impacts to preserve the existing way of living (Dronkers et al., 1990).

The research institute Deltares translated these three strategies into four strategies for The Netherlands: protecting closed, protecting open, move along, and going seaward. The strategy 'protecting closed' protects the coast against SLR impacts with hard or soft measures, and rivers are being closed off from the sea. The strategy 'protection open' implies the same protection, but the rivers continue to have an open connection to the sea. The 'move along' strategy implies a reduced vulnerability to the impacts of SLR, by changing the landscape and the connected land use. The seaward strategy implies creation of new and higher positioned land to protect the coast from flooding (Haasnoot, Diermanse, Kwadijk, De Winter, & Winter, 2019).

To summarize, the protecting strategies focused on remaining at and defending the current position. The moving along strategy concerned remaining at position including accommodating. The seaward strategy focused at reclaiming new and safe positions at sea.

Translation into four adaptation strategies

The strategies of the IPCC and Deltares depended on two choices: defending or accommodating and moving landwards or seawards. Defending concerned the reduction of the probability of SLR impacts such as flooding. Accommodating concerned the reduction of the vulnerability by changing behavior due to the consequences of SLR. Retreat was a form of accommodating. Defending meant to preserve the current way of living, by taking measures to protect the land from the SLR impacts. Four adaptation strategies were constructed based on the studied strategies: defend seaward, defend landward, accommodate seaward, and accommodate landward (Figure 37).

Strategic choices connected to accommodating and defending

As Haasnoot et al. (2019) state, multiple strategic choices regarding SLR adaptation had to be made. These options related to the different strategies: defending or accommodating. Firstly, to choose for an open or closed sea connection of the Oosterschelde. Secondly, to allow or prevent salinization. Thirdly, as Dronkers et al. (1990) state, the strategies differ in having a temporary or permanent base.

The strategy 'defend on sea' implied that seaward adaptations were used to reduce the SLR impacts including protecting the current landscape. The connected decisions were to close the Oosterschelde of from the sea to preserve or maximally increase the freshwater, and to aim for a permanent situation.

The strategy 'defend on land' implied that landward adaptations reduced the SLR impacts. The current landscape was preserved as much as possible including the related land use. The connected decisions were to close the Oosterschelde of from the sea to preserve or maximally increase the freshwater, and to aim for a permanent situation.

The strategy 'accommodate on sea' implied that the sea was given space, and adaptations were used to be less vulnerable to the SLR impacts. These accommodations were undertaken seaward or retreated was to the sea. The connected decisions were: the Oosterschelde was in open connection to the sea, salinization was allowed, and temporality was considered.

The strategy 'accommodate on land' implied that the sea was given space, and adaptations were used to be less vulnerable to the SLR impacts. These accommodations were undertaken landward. The connected decisions were: the Oosterschelde was in open connection to the sea, salinization was allowed, and temporality was considered.

Fig. 37. Four adaptation strategies based on defending or accommodating, and moving seaward or landward.

3.4.2 MEASURES

Different measures were studied to achieve the four main goals. The first goal was to study solutions for water safety and to explore new options regarding the storm surge barrier. The second goal was to study solutions for impacts of tidal changes on nature, such as drowning of land. The third goal was to study solutions for the impacts of sediment shortage, such as erosion. The fourth goal was to study solutions for the impacts of a decrease of tidal dry periods on nature. The measures were divided in accommodating and defending measures. The measures were gathered through a literature study focused on finding measures to break waves, reduce erosion, and to deal with permanent or temporary flooding.

Accommodating measures

Eight accommodation measures were found (Figure 38). Four types of managed retreat measures were found, being abandonment, relocation, setbacks, and avoidance.

Firstly, planned abandonment accommodated to permanent flooding and erosion and could be done by different actions. For example, the 'not act' approach. Built up areas endured until their lifetime would be over, or until they were flooded. The buildings could be destroyed before or after the flood.

Secondly, a landward setback line could be modified after a flood, which could stimulate abandonment and landward relocation (Neal et al., 2019). Two types of setbacks were defined: a static and a dynamic setback. Both types aimed to accommodate to temporary flooding and erosion. The static setback comprised that buildings were established at a safe distance from a reference line, this border would not be adjusted. In contrast, the dynamic setback was a reference line which moved landward according to the threat. The unsafe area could be defined as a no-construction zone in both setbacks (Haasnoot, Brown, et al., 2019; Neal et al., 2019).

Thirdly, relocation aimed to accommodate to permanent flooding and erosion. Relocation could be active or passive or could be planned on the long-term. Active relocation would be done before a threat, or before the flood event occurs. Passive relocation comprised rebuilding elsewhere after the flood. Long-term relocation meant a strategic relocation plan for areas which would be impacted by flooding or erosion (Haasnoot, Brown, et al., 2019; Neal et al., 2019).

Fourthly, avoidance aimed to accommodate to temporary and permanent flooding, and erosion. Avoidance comprised to avoid locating inhabitants and relevant functions in flood prone areas. These areas were selected as no-construction areas (Neal et al., 2019).

The fifth measure, flood proofing, accommodated to permanent and temporary flooding. Flood proofing comprised to protect infrastructure and buildings from flooding. For example, to establish housing on elevations (Haasnoot, Brown, et al., 2019; Klijn & Maarse, 2015).

Sixthly, changing to flood tolerant land use aimed to accommodate to the impacts permanent and temporary flooding, rising groundwater levels, and salt water intrusion (Auerbach et al., 2015).

Seventhly, drainage systems and pumps could deal with the impacts temporary flooding, rising ground water levels and salinization (Haasnoot, Brown, et al., 2019).

The eighth measure was to use floating islands (Frearson, 2020) or floating land use (Mairs, 2015) to deal with permanent and temporary flooding.

Accommodate		Source	Counteracts the effect of:
1.	Planned abandonment	(Neal, Bush, & Pilkey, 2019)	Permanent flooding, erosion
2.	Setbacks	(Haasnoot, Brown, et al., 2019, Neal et al., 2019)	Temporary flooding, erosion
3.	Relocation	(Haasnoot, Brown, et al., 2019, Neal et al., 2019)	Permanent flooding, erosion
4.	Avoidance	(Neal et al., 2019)	Temporary flooding, permanent flooding, erosion
5.	Flood proofing	(Haasnoot, Brown, et al., 2019) (Klijn & Maarse, 2015)	Permanent & temporary flooding
6.	Flood tolerant land use (food production)	(Auerbach et al., 2015)	Permanent & temporary flooding, saltwater intrusion, rising ground water levels
7.	Drainage systems and pumps	(Haasnoot, Brown, et al., 2019)	Temporary flooding, rising ground water levels, salinization
8.	Floating land use / islands	(Mairs, 2015) (Frearson, 2020)	Permanent & temporary flooding

Fig. 38. Overview of the studied measures fitting the accommodating strategies.

Defending measures

Twelve defence options were available (Figure 39).

Firstly, the use of wave breaking structures aimed to address temporary flooding and erosion (Haasnoot, Brown, et al., 2019).

The second solution was a floodgate, which could regulate water levels, and could be opened and closed to protect an area from flooding. This aimed to reduce permanent and temporary flooding (Al, 2018).

Thirdly, dikes and sea walls defended from permanent and temporary flooding (Al, 2018; Haasnoot, Brown, et al., 2019). The difference was that dikes are man-made elevations from a natural or artificial matter and sea walls are upright constructions made from artificial materials. A downside was that sea walls could increase erosion, and could require sand supplementations (Al, 2018).

Fourthly, storm surge or tidal barriers could protect from permanent and temporary flooding (Haasnoot, Brown, et al., 2019). A surge barrier is a solid construction and has gates which can be closed (Al, 2018).

The fifth measure was land raising. This aimed to prevent from permanent flooding (Haasnoot, Brown, et al., 2019).

Sixthly, revetment could reduce wave energy and prevent erosion, but could also create erosion problems elsewhere. The revetment structure would be placed on embankments, and can be made of various materials (Al, 2018).

The seventh measure was a living shoreline, aiming to reduce wave power and erosion. The shoreline had a gentle slope, and could consist of plants and sand (Al, 2018).

The eighth selected measure was a sediment suppletion, aiming to reduce permanent and temporary flooding, and erosion (Witteveen+Bos & Bureau Waardenburg, 2013).

Ninthly, silt buffers reduced erosion and wave power. These buffers were made of brushwood dams, positioned parallel to the coast (Prinsen, 2020).

The tenth solution was to use mussel banks to reduce erosion and to break waves (Schotanus et al., 2020).

The eleventh measure was to use artificial or self-growing islands to reduce permanent and temporary flooding, and erosion (Sabina Aouf, 2019).

The final selected measure was to make use of retaining walls to reduce erosion and temporary flooding (VEGA Landskab, 2018).

Defend		Source	Counteracts the effect of:
1.	Wave breaking structure	(Haasnoot, Brown, et al., 2019)	Temporary flooding, erosion
2.	Floodgate	(AL 2018)	Permanent & temporary flooding
3.	Dikes and sea walls	(AL 2018)	Permanent & temporary flooding
4.	Storm surge or tidal barriers	(AL 2018)	Permanent & temporary flooding
5.	Land raising	(Haasnoot, Brown, et al., 2019)	Permanent flooding
6.	Revetment	(AL 2018)	Temporary flooding, erosion
7.	Living shoreline	(AL 2018)	Permanent & temporary flooding, erosion
8.	Sediment suppletion	(Witteveen+Bos & Bureau Waardenburg, 2013)	Permanent & temporary flooding, erosion
9.	Silt buffers	(Prinsen, 2020)	Temporary flooding, erosion
10.	Mussel banks	(Schotanus et al., 2020)	Erosion, reduce wave
11.	Islands: self-growing/artificial	(Sabina Aouf, 2019)	Permanent & temporary flooding, erosion
12.	Retaining wall	(VEGA Landskab, 2018)	Erosion, temporary flooding

Fig. 39. Overview of the studied measures fitting the defend strategies.

3.4.3 TOOLBOX OF STRATEGIES AND CONNECTED MEASURES

The accommodating and defensive measures were linked to the strategies based on applicability at sea or at land. This resulted in a toolbox of measures for each strategy (Figure 40). Firstly, the measures for defend seaward were: wave breaking structure, floodgate, dikes and sea walls, storm surge, revetment, living shoreline, sediment suppletion, silt buffers, mussel banks, islands, and retaining walls. Secondly, the measures for defend landward were: floodgate, dikes and sea walls, storm surge, land raising, revetment, and living shoreline. Thirdly, the measures for accommodate seaward were: relocation, floating land use / islands, sediment suppletion, flood tolerant land use, and flood proofing. Finally, the measures for accommodate landward were: planned abandonment, setbacks, relocation, avoidance, flood proofing, flood tolerant land use, and drainage systems and pumps.

Fig. 40. Strategies and measures.

4 RESULTS RTD: DESIGNING & TESTING

4.1 DESIGNING AND TESTING SIXTEEN CONCEPTS

Development of the concepts
In the next paragraph, the sixteen developed concepts are described. Four concepts were developed for each of the four different strategies: defend seawards, defend on landwards, accommodate seawards, and accommodate landwards. The studied measures in the previous chapter were used as design ingredients. In Figure 41, an overview of the strategies, concepts and the used measures is given. The drawings of the concepts are displayed in appendix IV.

4.1.1 THE SIXTEEN CONCEPTS

1. Modern 'Karrenvelden' - Strategy defend seaward
In the concept modern 'Karrenvelden', retaining walls were used which reduce erosion and function as wave breakers. The current OSB was replaced by a more often closing OSB, placed in a seaward direction. The concept was inspired on the pattern of 'Karrenvelden', which are cultural-historical elements of the region. These 'Karrenvelden' reflect a linear pattern of ditches which was created in the past when clay was mined to create dikes. This pattern was reflected by placing mussel banks perpendicular to the dike. This way, the mussel banks would work as silt buffers.

2. Tidal dike - Strategy defend seaward
The used measures in the tidal dike concept were the flood gate, dikes / sea walls, revetment, and a living shoreline. The current OSB would close more often. The tidal dike was inspired on the historical 'inlaag' system, where an extra dike was established behind the water-retaining dike, the area in between was called an 'inlaag'. In the tidal dike concept, a new dike was also established in front of the current dike. This new dike could also be a sea wall when no space for a dike was available. The new dike contained flood gates (inlets) which could artificially regulate the tidal level in the 'inlaag'. This way, the areal of tidal nature was conserved

DEFEND SEA	wave breaking	flood gate	dikes / sea walls	storm surge	revetment	living shoreline	sand supplementation	slik buffers	mussel banks	Islands	retaining wall
'Karrenvelden' system	x			x				x	x		x
Tidal dike		x	x		x	x					
Foreland first	x					x					x
Island machine			x		x		x			x	

DEFEND LAND	flood gate	dikes / sea walls	storm surge	land raising	revetment	living shoreline
Super dike	x	x		x	x	x
Double dike		x			x	x
Unbreachable		x			x	
Broad foreland		x	x		x	x

ACCOMODATE SEA	flood proofing	relocation	floating land use / islands	sand supplementation	flood tolerant land use
Drowned villages	x	x		x	
Schelde islands	x	x	x		x
Inlaag system			x		x
Safe haven	x	x	x		x

ACCOMODATE LAND	planned abandonment	setbacks	relocation	avoidance	flood proofing	flood tolerant land use	drainage systems / pumps
Higher level	x		x		x	x	x
Saved by old dikes			x	x	x		
Flood proof			x	x	x		x
Temporary living		x	x			x	x

Fig. 41. Overview of the four strategies with the connected four concepts and the used measures.

and the water safety was increased. The flood gates could also function as fish passages and boat connections.

3. Foreland first - Strategy defend seaward
This concept was also inspired on the 'inlaag' system, but only on the patterns. Erosion was prevented by placing multiple retaining walls parallel to the coast. This could create different levels for development of tidal nature habitats. The foreland could increase, which breaks waves, additionally to the retaining walls. Finally, the current OSB closed more often.

4. Island machine - Strategy defend seaward
This concept connected to the original landscape identity of the estuary: a dynamic Oosterschelde, where nature rules. Sand supplementations were planned at locations without deep channels, and without boat traffic. Expected was that the sand would be transported over time by the tidal dynamics. Aimed was to prevent erosion of tidal nature as the tidal flats could become higher over time. Additionally, planned was to close the current OSB more often, for water safety.

5. Super dike - Strategy defend landward
The aim of the super dike was to increase the landscape identity by enhancing the spatial contrast between the dike edge and the open land. The dike aimed to protect from flooding and could not break. A gentle slope at the Oosterschelde side aimed to generate a living shoreline, and new tidal nature aimed to 'replace' the current tidal nature. The super dike was designed extremely broad and high, which could result in a freshwater bubble under the dike. This could support conservation of the current agricultural practices. Additionally, the current OSB needed to close more often, for the sake of water safety.

6. Double dike - Strategy defend landward
This concept consisted of a double dike which was a literal translation of the 'inlaag' system. This meant that an extra dike was placed behind the current dike. The old dikes from landscape were used in the new dike if possible and would have a different spatial design. In the zone between the two dikes (the 'inlaag') was room for salty nature and aquaculture. This concept was copied to the zone behind the storm surge barrier if possible. The intention was that the OSB would close more often.

7. Unbreachable - Strategy defend landward
The concept unbreachable focused on keeping the landscape simple, and to avoid damaging the landscape identity. By strengthening the dike and making it unbreachable, S-D would be safe from flooding. The intention was that the OSB would close more often.

8. Broad foreland - Strategy defend landward
The concept was inspired on using nature to increase water safety. Aimed was to remove the current dike, and to establish a new strong dike landward. This would give room to create a gentle slope with a living shoreline. The foreland would reduce wave power, and new dikes were designed to further increase the water safety. Planned was to move the OSB back, creating a foreland which reduced wave power and increased the nature habitat. Additionally, this OSB was planned to close more often.

9. Drowned villages – Strategy accommodate seaward
This concept was inspired on drowned villages. In the past, several villages drowned by floods. In the concept, these old villages would become temporary flood proof living locations in the Oosterschelde. Inhabitants who lived in the low positioned countryside, would be relocated for the long term. The countryside would be abandoned and creek ridges would develop

here. These creek ridges could raise the land naturally over many years. Therefore, the OSB was planned to be permanent open to enhance the water dynamics, allowing creek ridges to develop on the land. Sand supplementations would be naturally distributed by the water dynamics and would prevent erosion. Infrastructure would be raised to a safe height, and existing urban areas were flood proofed. Over time, moving back to the land was planned when the land was at safe height.

10. Schelde islands – Strategy accommodate seaward
In this concept, the consequences of SLR were accepted. This meant that the OSB would be removed or permanently open. This concept explored the functional opportunities of the Oosterschelde. The endangered functions on land were moved towards the Oosterschelde as the natural values would be gone. New floating agriculture was designed on the water, and tidal nature was turned into safe islands with sand supplementations, offering flood proof living and recreation.

11. Floating 'inlagen' – Strategy accommodate seaward
In this concept, the consequences of SLR were accepted, and the OSB would be permanently open. This concept focused on floating land use, inspired on 'inlaag' shapes. The floating elements were aimed to break waves and served as aquaculture locations.

12. Safe haven – Strategy accommodate seaward
In this concept, the consequences of SLR were accepted, resulting in an open OSB. Safe floating 'harbours' could be used as safe locations during floods. This was inspired on the many small harbours of the past. The tidal flats were designed to become islands with flood proof land use and flood proof living.

13. Higher level – Strategy accommodate landward
In this concept, the consequences of SLR were accepted, resulting in an open OSB. This concept was inspired on living high and dry. The lower positioned areas would consist of flood tolerant land use. The inhabitants living on risky locations would be moved to higher positioned areas. The infrastructure was designed flood proof.

14. Saved by old dikes – Strategy accommodate landward
In this concept, the consequences of SLR were accepted, resulting in an open OSB. This concept used the old dikes in the landscape. The inhabitants of risky low-laying areas would be relocated to safer heights. This way, the old dikes gained more attention in the landscape.

15. Flood proof – Strategy accommodate landward
In this concept, the consequences of SLR were accepted, resulting in an open OSB. This concept created a flood proof S-D. The inhabitants of the countryside were stimulated to make their own property flood proof, including flood tolerant land use. It was also possible to actively relocate inhabitants of the countryside to safe urban areas. After the floods, the inhabitants could move back to their homes.

16. Temporary living – Strategy accommodate landward
In this concept, the consequences of SLR were accepted, resulting in an open OSB temporality was the focus, such as temporary functions as recreation (camping). Inhabitants of risky areas would move to safe areas when a flood came.

4.1.2 THE RESULTS OF TEST 1

From the score results, the most outstanding scores are described. Furthermore, comments and answers of the experts on the open questions are summarized. The full transcript of the answers of the expert judgement is displayed in appendix V.

The concept Modern 'Karrenvelden' scored low on reducing impacts on tidal nature, because the catchment of silt by mussel banks would probably be too slow (50-100 years), and the mussel banks could drown, but could possibly reduce erosion. Doubtable was the applicability of the measures, as deep channels in the Oosterschelde could increase the construction costs and the complexity. Positive effects of this concept were the reduction of dike shear and breach risk. This could be reduced by the 'schorren', as the foreshore is strengthened, and could reduce wave power.

The concept Tidal dike scored high on water safety and scored average on dealing with salinization and freshwater consequences. The expert commented that the zone between the new and current dike could generate a new salty nature landscape. However, the natural dynamics would be disturbed, and this led to tidal nature loss. It was uncertain if the new salty landscape would be just as unique as the lost tidal nature.

The test results of the concept Foreland first indicated that this concept did not score high on any goals. The highest score was a 3 on water safety. The expert commented that the retaining walls would capture some sand, but extra measures were needed. Also, the retaining wall was normally a connected element, so these were break waters. Furthermore, the number of walls needed to be studied. Finally, it was suggested to explore natural types of these walls such as sand, braided willow twigs, or mussel banks.

The results of the concept Island machine indicated possible reduction of sediment shortage issues and drowning of nature as it scored a 4 on these criteria. The expert expected that nature had the time to slowly adapt. Another comment was to determine where supplementation was necessary, depending on the hydrodynamics in the Oosterschelde. Research was needed if the sediment would silt up fast enough or if the tidal nature still would drown. A final suggestion was to create new landscapes with new functions, such as sustainable recreation.

The Super dike scored a 4 on water safety, and a 3 on drowning of tidal nature, and a 3 on the reduction of nature threatened by a shorter duration of low tide. The comments indicated the relevance to consider the local variation between fresh and salt groundwater. An advantage of this concept was that the freshwater amount could increase. Furthermore, when the super dike would be positioned landward, a broad foreshore could enhance development of tidal nature.

The Double dike concept scored a 4 on water safety, a 3 on drowning of tidal nature, and a 3 on the reduction of nature threatened by a shorter duration of low tide. The expert indicated that the soil and the fresh and saltwater system was complex. Suggested was to separate the fresh and salt water to conserve the freshwater. Another advise was to shift the focus to salt tolerant crops such as potatoes or onions, because less demand for aquaculture was present. Suggested was to place the extra dike significantly landwards being advantageous for the nature. Finally, an inlet for the salty zone between the two dikes was suggested.

The concept 'Unbreachable' scored a 5 on water safety, but scored a 1 on all other criteria, except for the salinization issues as it scored a 2 on this criterion. The expert indicated that the solution was cheap. However, the tidal nature would drown, and salinization problems were not addressed.

The concept Broad foreland scored the highest of all concepts on average. It scored a 4 on the prevention of drowning of tidal nature, and a 4 on the reduction of nature threatened by a shorter duration of low tide. The concept scored a 3 on water safety and on the consequences of sediment shortage. The expert advised to consider the time to let the land silt up, but expected that nature would profit a lot from the interventions. However, the concept was disadvantageous for agriculture. Also, moving the OSB could be expensive.

The concept Drowned villages scored a 4 on the consequences of sediment shortage, the drowning of tidal nature, and on nature threatened by a shorter duration of low tide. The concept scored low on the other criteria. The expert indicated that only the unusable low laying soil should be given for development of creek ridges. Suggested was to use the sand for dune expansion to enlarge the freshwater bubble. Furthermore, advised was to preserve the current creek ridges, and to locate inhabitants to these safe heights. Overall, the concept increased problems instead of reducing them.

The concept Schelde islands scored a 1 on all criteria, being one of the two lowest scoring concepts. The expert indicated that too much quality would go lost and suggested to increase the height of the land.

The concept Floating 'inlagen' scored a 1 on most of the criteria. A 2 was scored on the criterion water safety and on the criterion nature threatened by a shorter duration of low tide. From the test results became clear that too much quality would go lost. The only advantages of the concept were the increase of water safety and the space for aquaculture. Advised was to only use the floating elements where deep channels were present to reduce wave run-up. Furthermore, the floating elements could be interesting for nature and (diving) recreation.

The concept Safe haven scored a 1 on most criteria being one of the two lowest scoring concepts. The expert indicated that too much natural value would go lost and the concept required too many investments.

The concept higher level scored a 4 on water safety. Also, it was the only concept which scored a 4 on the consequences of salinization and freshwater shortage. The expert firstly suggested to separate the fresh and saltwater systems. Secondly, to combine this concept with the concept 'saved by old dikes'. Thirdly, to expand the dune edge, or to use the creek ridges to ensure flood proof infrastructure. Fourthly, to move the water barriers landward, where low laying land was present to develop tidal. Finally, the expert commented that the effect on salinization was positive, as the land use was adapted to the salty circumstances.

The concept Saved by old dikes scored a 4 on water safety, and a 1 on most other criteria. The expert suggested to combine this concept with the concept 'higher level'. Furthermore, the design of the old dikes required attention for cultural history.

The concept flood Proof scored a 4 on water safety, and a 1 on most other criteria, except that it scored a 3 on the consequences of salinization and freshwater shortage. The expert suggested to create living mounds, and to integrate this concept with the concept 'higher level'.

This concept Temporary living scored a 4 on water safety and a 1 on most other criteria, except that it scored a 3 on the consequences of salinization and freshwater shortage. The expert suggested to relocate farmers to living mounds. Furthermore, this concept could be integrated with the concept 'higher level'.

4.1.3 IMPROVING THE HIGHEST SCORING CONCEPTS PER STRATEGY

The test results (Figure 42) indicated that the on average highest scoring concepts were part of different strategies. Therefore, assumed was that focusing on one strategy in this phase would not lead to the most effective integration of landscape quality and SLR adaptation. Thus, focused was on improving the highest scoring concept per strategy.

From the strategy 'defend seawards', the highest scoring concept was concept 4 island machine, scoring 2,6. From the strategy 'defend landwards', the highest scoring concept was concept 8 broad foreland, scoring 3,3. From the strategy 'accommodate seawards', concept 9 drowned villages scored the highest, being 3,0. Finally, the highest scoring concept of the strategy 'accommodate seawards' was concept 13 higher level, with a score of 2,5.

The concepts needed to be improved, because the selected concepts did not score high on all criteria. In the next section, the general setup of improving the concepts is explained.

		MAIN CRITERIA				SUB CRITERIA		GUIDELINES	
STRATEGIES	CONCEPTS	water safety (2)	consequences sedimentation shortage (2)	drowning tidal nature (2)	nature threatened by shorter duration of low tide (2)	nature threatened by disruption factors	consequences of salinization and freshwater shortage	integration of Karrenvelden	AVERAGE SCORE
DEFEND SEAWARD	1 Modern 'Karrenvelden'	3	1	1	2	1	1	0	1,6
	2 Tidal dike	4	1	2	2	1	3	0	2,2
	3 Foreland first	3	1	2	2	1	1	0	1,8
	4 Island machine	1	4	4	3	1	1	0	2,6
DEFEND LANDWARD	5 Super dike	4	1	3	3	1	2	0	2,5
	6 Double dike	4	2	3	3	1	3	0	2,8
	7 Unbreachable	5	1	1	1	1	2	0	1,9
	8 Broad foreland	3	3	4	4	0	2	0	3,3
ACCOMMODATE SEAWARD	9 Drowned villages	1	4	4	4	0	1	0	3,0
	10 Schelde islands	1	1	1	1	1	1	1	1,0
	11 Floating 'inlagen'	2	1	1	2	1	1	0	1,4
	12 Safe haven	1	1	1	1	1	1	0	1,0
ACCOMMODATE LANDWARD	13 Higher level	4	2	2	2	1	4	0	2,5
	14 Saved by old dikes	4	1	1	1	1	1	0	1,6
	15 Flood proof	4	1	1	1	1	3	0	1,8
	16 Temporary living	4	1	1	1	1	3	0	1,8

Fig. 42. Scores of the concepts, the criteria of the main goals were counted twice (2), and the other criteria were counted once.

4.1.4 REQUIRED IMPROVEMENTS CONCEPT 4 – ISLAND MACHINE, STRATEGY DEFEND SEAWARD

Improvements based on the test scores: the criterion water safety

Concept 4, island machine was the highest scoring concept from the strategy defend seawards. However, it scored a 1 on the criterion water safety. Therefore, other concepts which scored higher on water safety of this strategy were used to improve this concept. The tidal dike (concept 2) scored a 4 on water safety. However, the comments of the expert indicated that this concept would enhance erosion, as it could interrupt the natural dynamics. Therefore, concept 2 was not used to improve concept 4. Therefore, the next highest scoring concept was selected to improve the criteria water safety. Two concepts both scored a 3 on water safety, being concept 1 and 3. However, concept 3 was selected, because it scored the highest on average on all criteria. The breakwaters in this concept could reduce wave attack, and capture sediment, according to the expert.

Improvements based on the comments of the expert: concept 4

The comments of the expert on concept 4 indicated that the location of the suppletion determined if it would be successful. Therefore, the tidal movements in relation to a suppletion required studying. Furthermore, a suggestion was to develop new landscapes which could serve multiple functions as sustainable recreation, this was also thought through in the new design.

Improvements based on comments of the expert: concept 3

A suggested improvement for the breakwaters of concept 3 was to use a natural material instead of an artificial breakwater, such as sand, braided willow twigs, or mussel banks. However, the expert commented that the setup of mussel banks in concept 1 would not contribute much to water safety, as these would drown and would not break waves. Also, the number of breakwaters was doubtable, according to the expert. Therefore, principles for the setup of breakwaters and a natural material needed to be studied.

Summary required improvements

To summarize, concept 4 was improved on the criterion water safety by using concept 3. However, two improvements required studying: the material and setup for the breakwaters, and the location of suppletion.

4.1.5 REQUIRED IMPROVEMENTS CONCEPT 8 – BROAD FORELAND, STRATEGY DEFEND LANDWARD

Improvements based on test scores: the criteria water safety and effects of sediment shortage

The concept broad foreland was the highest scoring concept of the strategy defend landwards. Concept 8 scored a 4 both on the criteria 'drowning of tidal nature' as well as 'nature threatened by a shorter duration of low tide'. Furthermore, concept 8 scored a 3 on both the criteria 'water safety' and 'consequences of sediment shortage'. Therefore, interventions of other concepts were needed to improve concept 8.

Concept 7 scored the highest on water safety within this strategy. However, the expert indicated that the foreland would drown, and that salinization would increase. Therefore, concept 7 was not selected as the only improvement, due to deteriorating effects. Concept 6 scored a 4 on water safety as well as concept 5. However, concept 6 scored a 2,8 on average based on all criteria, where concept 5 scored 2,5. These average scores would indicate to select concept 6 as improvement. However, from the comments of the expert on concept 6 became clear that a separated fresh and saltwater system was required to conserve the landscape quality. As the double dike in concept 6 would only fit in a saltwater system, another concept was needed to improve the water safety criterion. Therefore, concept 5 super dike was selected to improve concept 8, fitting in the freshwater system. To summarize, all the three concepts 5,6, and 7 were needed to improve concept 8.

Concept 8 - broad foreland scored the highest on the criterion 'consequences of sediment shortage'. Therefore, no other concept within this strategy was available to improve concept 8. Therefore, principles had to be studied which reduced consequences of sediment shortage.

Improvements based on the comments of the expert: concept 5 – super dike

Based on the comments of the expert, the super dike had to be positioned significantly landward to stimulate the tidal nature development. Furthermore, if impermeable layers were present in the substratum, the freshwater bubble in the dike would remain small. This required studying the soil and groundwater situation to determine the optimal location for the super dikes.

Improvements based on the comments of the expert: concept 6

Based on the comments of the expert, the double dike had to be significantly positioned landward to stimulate nature development. Furthermore, the double dike would be combined with a separated freshwater and saltwater system. Moreover, the soil and groundwater system required studying to determine the best locations for the double dikes. An inlet had to be added to develop salty nature. Finally, the land use between the dikes had to be focused on salt tolerant products such as potatoes and onions.

Improvements based on the comments of the expert: concept 7

Based on the comments of the expert, the unbreachable dike was only implemented if space was lacking to implement the more valuable dike types such as the super dike and the double dike.

Improvements based on the comments of the expert: concept 8

The pace of the growth of the foreland had to be studied in concept 8. Additionally, the loss of farmland due to creating new foreland had to be considered.

Summary of improvements

Concept 8 required improvements concerning the criteria water safety and effects of sediment shortage. Therefore, parts of the concepts 5, 6, and 7 were used. The improvements were: the landward position and a soil-based location of the super dikes, the landward position and a soil-based location of the double dike, addition of inlets, a focus on salt tolerant products, a separated freshwater and saltwater system, the unbreachable dike was only implemented if space was lacking for other dike types, and finally to ensure a fast enough growth of foreland.

4.1.6 REQUIRED IMPROVEMENTS CONCEPT 9– DROWNED VILLAGES, STRATEGY ACCOMMODATE SEAWARD

Improvements based on test scores: water safety

Concept 9, drowned villages, was the highest scoring concept of the strategy accommodate seawards. The concept scored a 1 on the criterion water safety, and thus required improvements. No concept scored high on this criterion within this strategy, as all concepts scored a 1, except that the concept floating 'inlagen' scored a 2. However, these did not improve the concept significantly. Therefore, the concepts of another strategy were used to improve this concept. The strategy accommodate landward was the most similar strategy. Within this strategy, all concepts scored a 4 on water safety. However, the highest scoring concept on average was concept 13 'higher level' and was therefore used to improve concept 14.

Improvements based on comments: concept 9

The first improvement was that only the untenable low laying grounds were invested for tidal nature if these were endangered by salinization. Next, the sand was used to increase the height of existing creek ridges, instead of creating islands of sand. This way was intended to increase the freshwater bubbles under the creek ridges. The creek ridges could function as safe living locations.

Improvements based on comments: concept 13

Concept 13 was used to improve concept 9 on the criterion water safety. But, concept 13 also required improvements. Based on the comments, a separated salt and freshwater system was added to the concept. Furthermore, the creek ridges would also function as safe and dry connections, as suggested by the expert.

Exclusion of strategy accommodate seaward

Based on the improvements, concept 9 was no longer part of the strategy accommodate seaward. As the improvements were focused on land, no interventions were undertaken seaward anymore, and the concept became part of the strategy accommodate landwards.

Development of the strategy accommodate landward

As concept 13 was already integrated in concept 9, concept 13 was not developed further as a new concept on itself. Assumed was that this would not lead to new principles. Another reason for this choice was to prevent that two concepts within the same strategy would be developed. This would lay too much focus on one strategy.

Summary of improvements

Based on the test results, concept 9 was improved on the criterion water safety using concept 13. Furthermore, an improvement was that only the untenable low laying soils were invested for tidal nature. Next, the height of existing creek ridges was increased. Also, a separated salt and freshwater system was added to the concept. Furthermore, the creek ridges were intended as dry and safe connections.

4.2 DESIGNING AND TESTING THREE NEW CONCEPTS

The new concepts

The improvements of the concepts resulted in three new concepts: A - sand machine (strategy defend seawards), B - dike landscape (strategy defend landwards), and C - creek landscape (strategy accommodate landwards). Concept A, sand machine, was an improvement of concept 4, island machine, combined with concept 3. Concept B, dike landscape, was an improvement of concept 8, broad foreland; combined with concept 5, super dike; concept 6, double dike; and concept 7, unbreachable. Finally, concept C, creek landscape, was an improvement of concept 9, drowned villages, combined with concept 13, higher level.

Before the improvements could be incorporated in the design, further research was necessary, described in the next paragraphs.

Vision of landscape identity

Some spatial rules were implemented in the new concepts, these rules were based on the landscape identity analysis. The first rule was to ensure a simple landscape language, which was done by creating the shortest dike length as possible, and not to avoid creation of too many bends. Secondly, characteristic landscape elements had to be preserved. When possible, old dikes were used to create new dikes, or new dikes would connect to old dikes. When an old dike had to be removed, it was brought back in a spatial recognizable structure. Thirdly, 'inlagen' were kept as these were characteristic landscape elements. Finally, to deal with the connectedness of the inhabitants, a dike was only placed landward when no buildings needed to be moved.

4.2.1 DESIGN A: SAND MACHINE – STRATEGY DEFEND SEAWARD

The material and the setup of the breakwaters to reduce erosion and enhance sedimentation had to be studied, as the expert suggested. Also, the location of the suppletion was studied. Finally, studied was what could be improved concerning the current way of recreation.

Studied intervention: The setup of the breakwaters

In the North of the Netherlands, a system to enhance sedimentation to increase salt marshes was found. This was studied by analysing topographical maps over time in Groningen and Friesland. Based on this, simplified maps were created to show the system over time (Figure 43). This started with natural sedimentation (1820). Next, ditches were excavated perpendicular to the dike (1850), resulting in a stimulated growth of the salt marshes. When a salt marsh silted up high enough for agricultural purposes, the area was diked. Later, brushwood dams ('rijshoutdammen') were added in 1930 (Figure 44), resulting in better circumstances for sedimentation and salt marsh vegetation. Each time an area silted up higher, new brushwood dams were placed perpendicular to the coast. This way, the brushwood dams were found on the transition of heights. From 1969, the goals for the salt marsh works shifted from agricultural use to preservation of tidal nature and coastal protection.

Recently, it has been found that ditches support a dry vegetation, and a wet vegetation is supported without ditches. Moreover, the ground dams were not required anymore with the new goals. Therefore, ditches and dams made of soil are generally not maintained anymore.

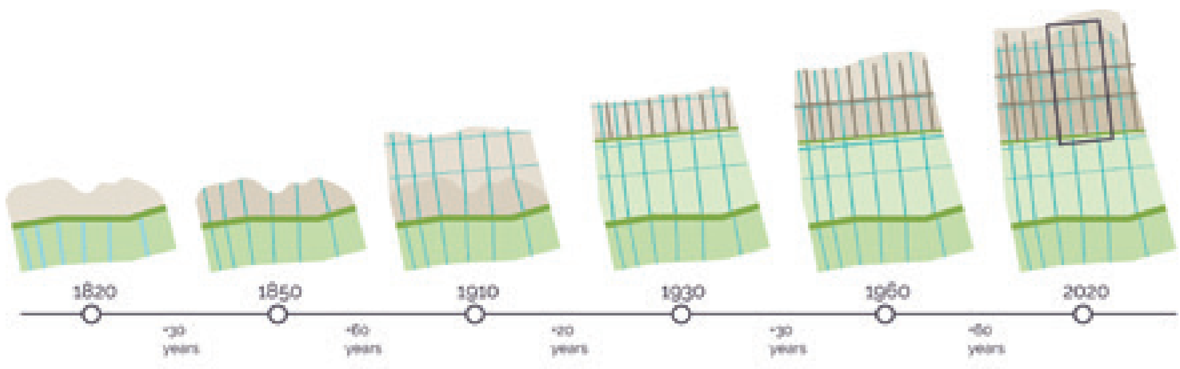


Fig. 43. Enhancing sedimentation using the salt marsh works system ('kwelderwerken'), as found in the North of the Netherlands. Adapted from Kadaster (2019).

In Figure 45, a detail of the system is shown. The distance between the perpendicular to the dike placed brushwood dams, was 200 m. The distance between the brushwood dams placed parallel to the dike was 400 m (van Duin et al., 2016). The brushwood dams consisted of a row of poles filled with a bunch of branches. The dam is filled with branches until 10 cm lower than the height of the poles. The branches had a diameter between 3 and 6 centimetres. The distance between the poles was 0,35 m (S. de Vries & de Jong, 2000). The height of the poles was 1,5 m (van Duin et al., 2016).

The ground dams and the ditches were not used as they were not required anymore. Therefore, only the principle of the perpendicular and the parallel dams were used in the new concept. The perpendicular dams were designed at 200 m from each other to create calm areas to support sedimentation. The parallel dams were designed at different height levels, as was done in the studied principle.

Studied intervention: the material of the dams; braided willow twigs, mussel banks, and oyster banks

The expert suggested three types of materials for the dams: sand, braided willow twigs, and mussel banks.

The willow was a region-specific type of vegetation and would enhance the landscape identity. Furthermore, the willow was a fast-

Fig. 44. Reference image of brushwood dams (de Vries, 2012)

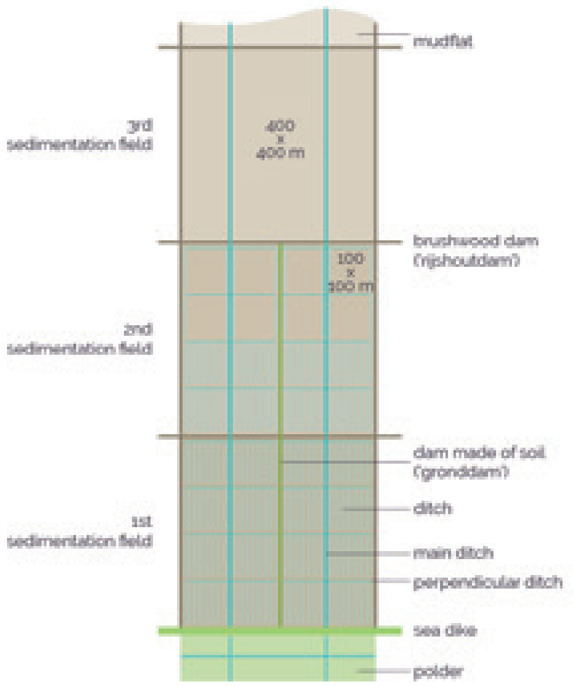


Fig. 45. Detailed principle of salt marsh works ('kwelderwerken'), m = meter. Adapted from van Duin et al. (2016).

growing tree, making it a practical material to use. For these reasons, the braided willow twigs were a good material for the brushwood dams.

Mussels were also characteristic to the region and would thus enhance the landscape identity. Also, they had value for the shellfish industry and for waders. This made the mussel banks even more interesting than the brushwood dams.

There were two types of mussel banks: littoral and sublittoral banks. Littoral banks fall dry during low tide, and sublittoral banks remain under water. Since the nineties, mussel parcels were moved from the littoral to the sublittoral level. Due to lack of harvesting and maintenance, littoral mussel banks were colonized by oysters (Wijsman, 2007). However, the oyster was not suitable as prey for birds. Therefore, littoral mussel banks were more valuable (Wijsman, 2007; Zanten & Adriaanse, 2008). Oysters were found in the deeper littoral level, being 1 m under NAP (-1 m NAP) (Zanten & Adriaanse, 2008) until the sublittoral level (-42 m NAP) (Dankers et al., 2006).

To prevent oysters from colonizing the mussels, littoral mussel banks were used above -1 m NAP, and sublittoral oyster banks were used from -1-m NAP and deeper.

Based on the studied materials, three materials were selected for the design of the dams: braided willow twigs, mussel banks, and oyster banks. All three materials were selected to generate diversity and liveliness in the design. As the braided willow twigs were the least valuable, they were used as parallel retaining walls, because in this direction the least dams were needed. The mussel banks and oyster banks were used perpendicular to the coast, where more breakwaters were required.

Studied intervention: strategic located supplementation based on erosion and sedimentation in the tidal system

The principle of erosion and sedimentation in the tidal system were studied to find a strategic location for the sand suppletion. The curve effect was the most important influencer of the tidal system. The strongest flows were found in the outside of the curve, resulting in a higher water level (Figure 46). Generally, this resulted in erosion of the outer bend, and sedimentation in the inner bend (Kohsiek, Mulder, Louters, & Berben, 1987).

Based on this principle, the selected suppletion location was the outer bend of the channel, opposing the area where the suppletion was needed.

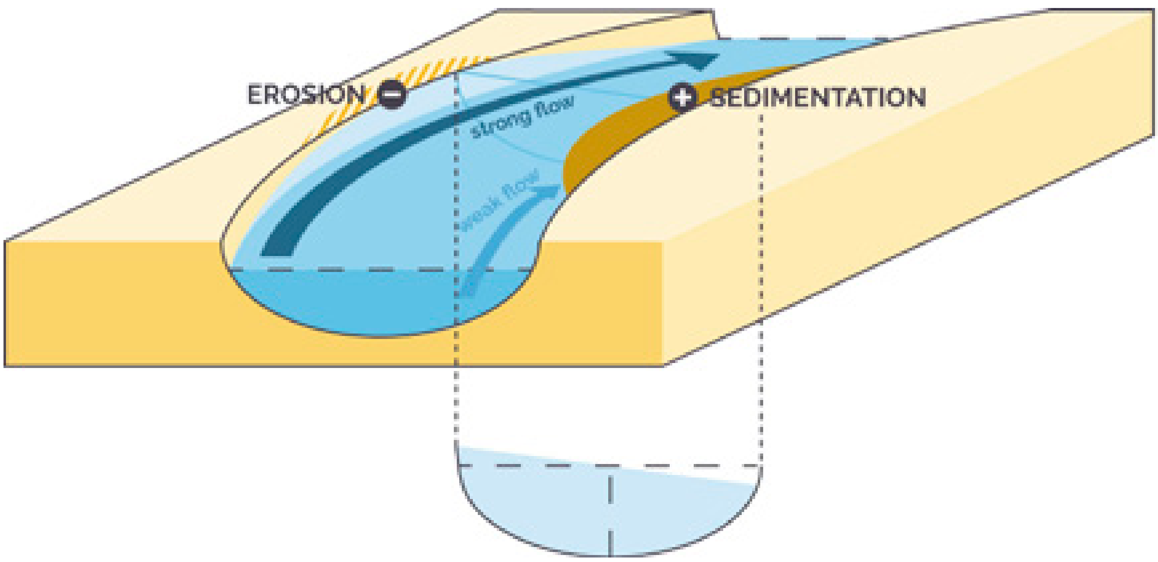


Fig. 46. Principle of erosion and sedimentation in the bend of a tidal channel. Adapted from Kohsiek et al. (1987).

Studied intervention: sustainable recreation

Tidal nature is sensitive to disruption as the recreation along the dikes could disturb the nature (Atelier Oosterschelde et al., 2018). Based on this, the next improvements were developed. Firstly, to prevent recreants from to accessing the tidal nature directly, but to allow visiting of the tidal nature by generating elevated structures. Secondly, to create new recreation loops connecting to the existing recreation rout. These loops were made on the land side of the dike. The recreants could be attracted to other side of the dike, by displaying the agricultural side of the landscape.

The improved concept A: sand machine

Based on the studied interventions, the new concept was created (Figure 47 & Figure 48). The first intervention enhanced sedimentation by using perpendicular placed mussel and oyster banks. The mussel banks would be placed between 0 and -1 m relative to the NAP. The oysters would grow until -1 m NAP. The mussels were valuable as food for stilt-waders and would ensure a higher biodiversity. The banks would become 0.5-1 m high (Zanten & Adriaanse, 2008).

The second intervention was the parallel placed brushwood dams made from braided willow twigs which reduced erosion.

The third intervention consisted of a sand suppletion in the outer bend of the channel. Finally, a sustainable way of recreation was integrated. This was done by releasing pressure of the current recreation route by making new loops. Some elevated structures were added to prevent disturbing the nature. As the structures were elevated, these were SLR proof.

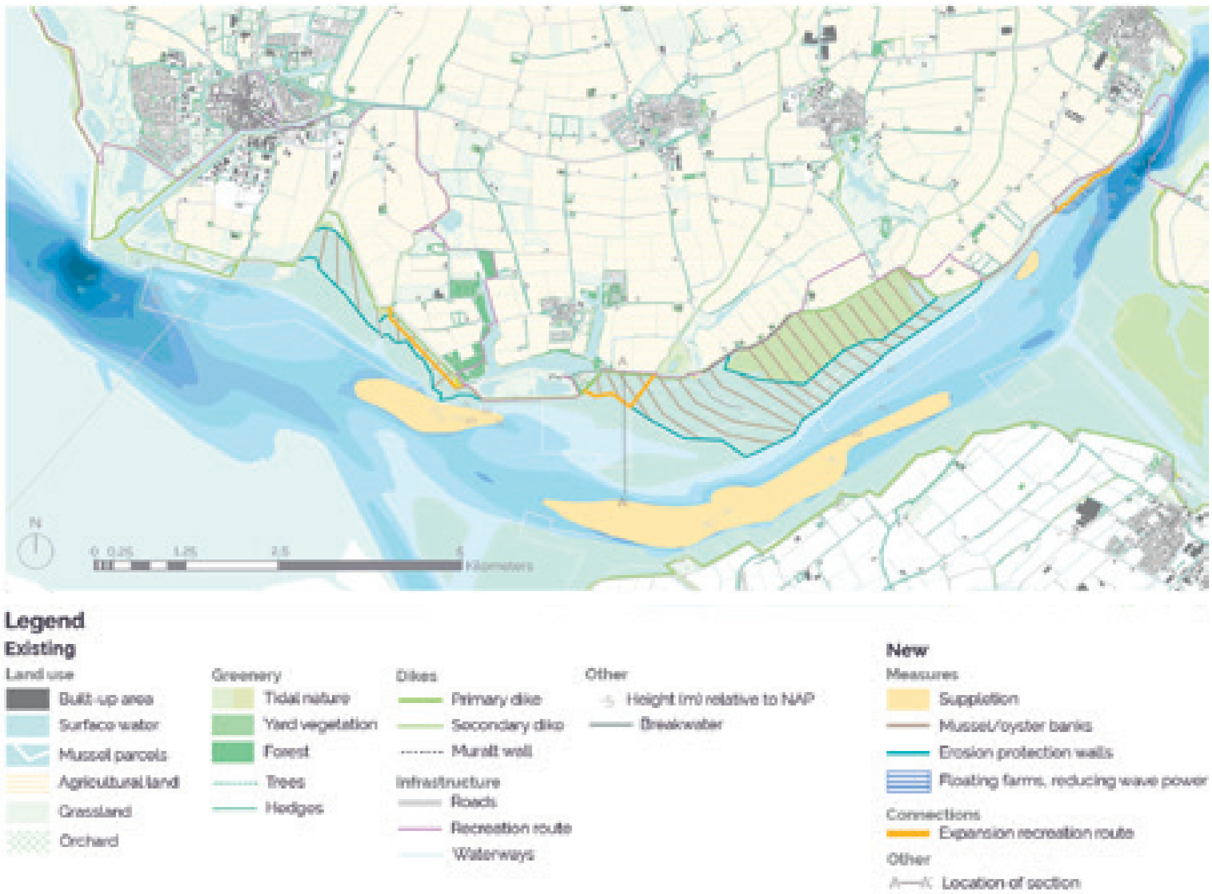


Fig. 47. The improved concept A: Sand machine – strategy defend seawards.

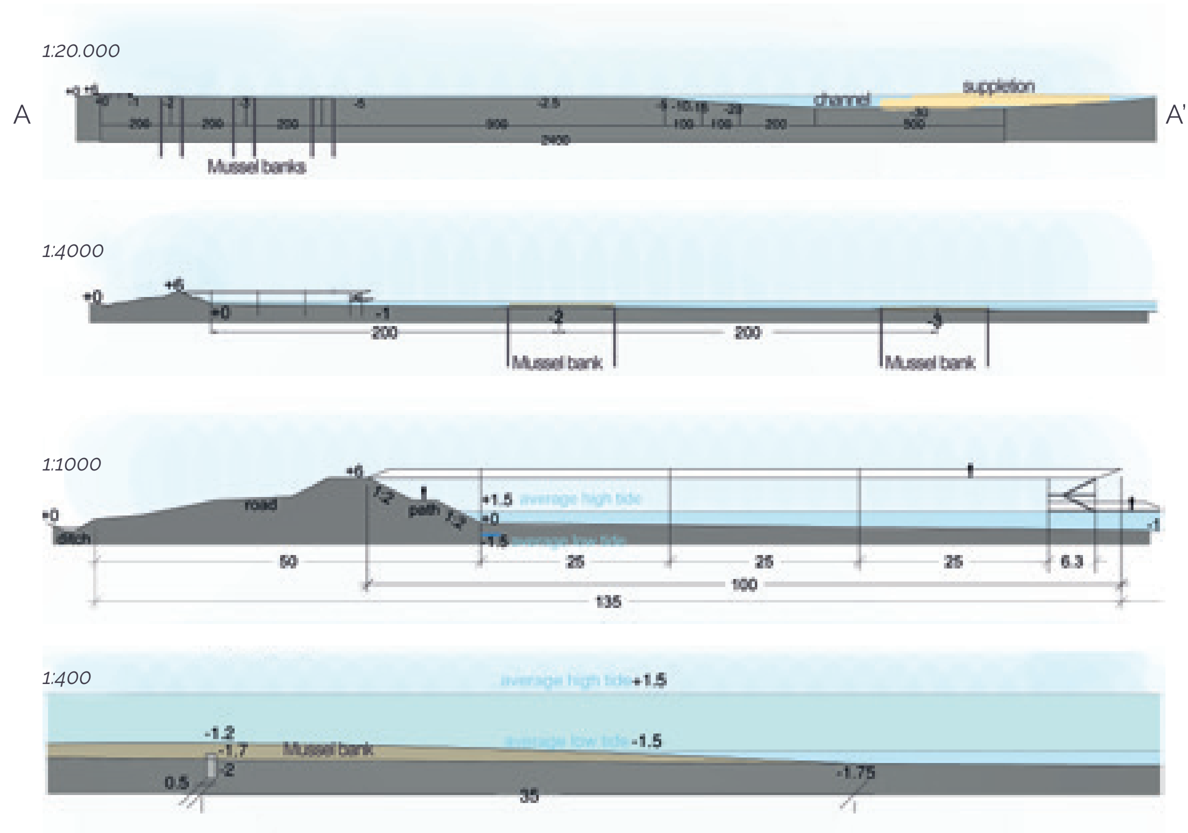


Fig. 48. The sections show the interventions: the elevated recreation element, the mussel banks, and the suppletion. Dimensions in m, heights relative to NAP.

4.2.2 DESIGN B DIKE LANDSCAPE – STRATEGY DEFEND LANDWARD

Based on the test results, five interventions required studying. Firstly, the double dike intervention required studying concerning land use and inlets. Secondly, the principle of the super dike required studying regarding the soil-based location. Thirdly, the growth of foreland required studying. Therefore, the salt marsh works principle was studied to ensure growth of foreland. Fourthly, the inlet width of tidal nature areas was studied to ensure growth of foreland. Fifthly, a soil salinity-based principle was developed to implement the interventions in the separated fresh and saltwater system.

Studied intervention: double dike type and land use

Two types of double dikes focused on salt tolerant products (Figure 49). Type one had an overtopping proof dike at the Oosterschelde side, followed by a zone for salt tolerant agriculture, and a flood proof dike. This zone aimed to collect the surplus of overtopping water during a storm surge. The zone would be rarely flooded. The flood proof dike would never flood and kept the land behind the dike always safe. Type two consisted of a floodable dike, followed by an agriculture zone and a flood proof dike. The aquaculture zone would flood two times a day during high tide and fall dry during low tide, due to the lower floodable dike in the front. The dike behind this zone would never overflow and kept the land behind the dike always safe (Dieker & Veendorp, 2020).

These two types indicated that no inlet was needed to develop the intended land use.

Studied intervention: the super dike to increase the freshwater bubble

The best location of the super dike was on the edge of a freshwater bubble and salt groundwater (Figure 50), where a creek ridge was present and freshwater bubble existed. The super dike was designed between the Oosterschelde and the creek ridge. This way, the salty seepage would reduce, and the freshwater bubble would increase. The super dike was constructed on the landward side of the old dike, as advised by the expert.

Studied intervention: salt marsh works

The system of the salt marsh works was used to ensure the growth of new foreland, as described in the previous paragraph. However, in concept B, the parallel brushwood dams would be placed 400 m from each other to stimulate development of new tidal nature.

Studied intervention: inlet width tidal nature

Existing examples of tidal nature inlets were studied as the inlet width could influence the success of the new tidal nature area. Two examples were selected based on the knowledge of the secondary supervisor. The Perk Polder was found during doing research about polders turned into tidal nature. From the three examples became clear that the minimal inlet width had to be 360 m (Figure 51).

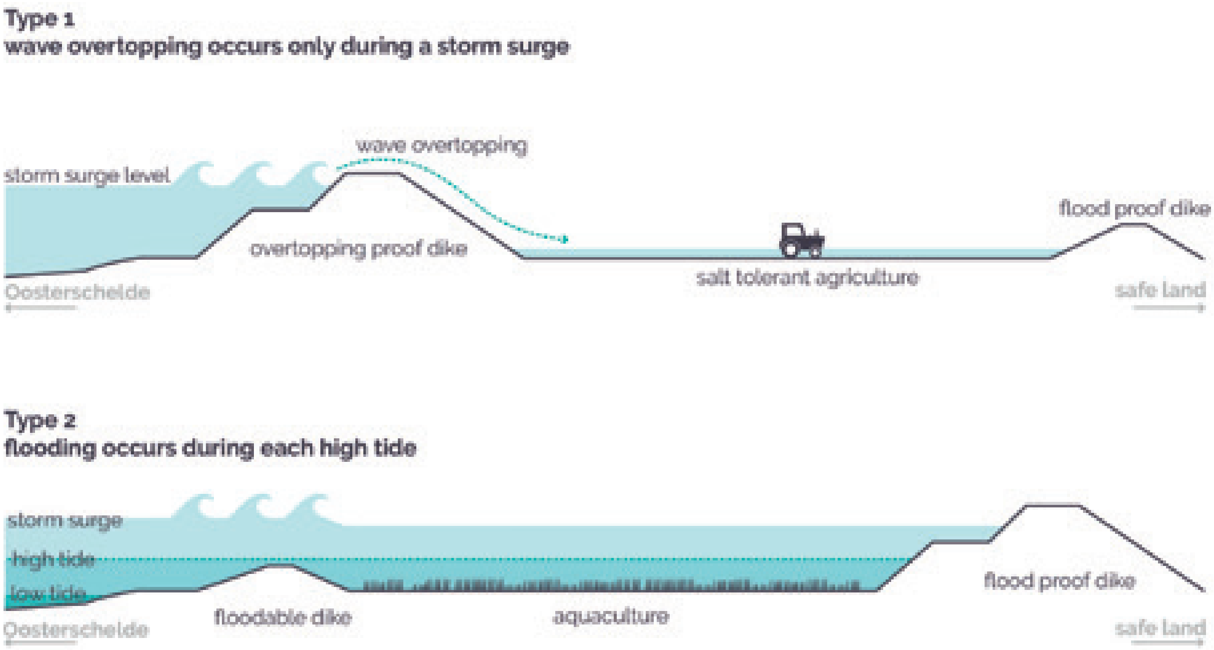


Fig. 49. Two types of double dikes resulting in a different type of land use. Adapted from Dieker & Veendorp (2020).

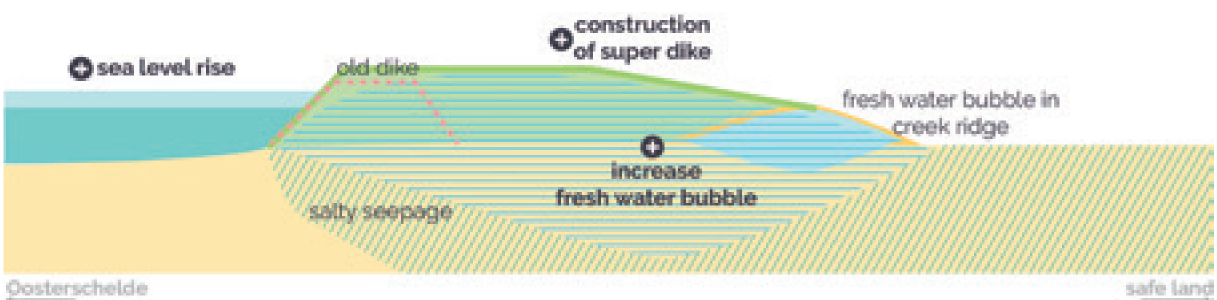


Fig. 50. Developed intervention: super dike situated on the edge of a freshwater bubble and salt groundwater.

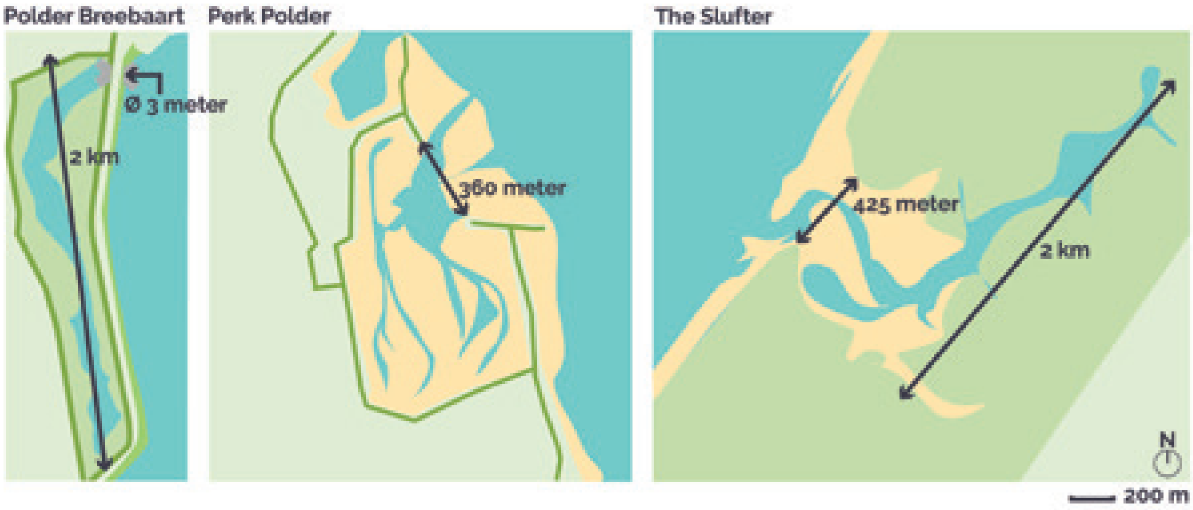


Fig. 51. *Studied inlet widths for the development of a new tidal nature area landward. Km: kilometre.*

Studied intervention: groundwater based principle

As suggested, the concept was based on a separated salt and freshwater system, resulting in interventions based on the different salinities (Figure 52). Firstly, the intervention tidal nature was applied where an extremely saline soil was present, as traditional agriculture would not be profitable there. Secondly, the intervention double dike applied where salt soil was present, focusing on salt tolerant products. Thirdly, the super dike intervention applied on the borders of salt and freshwater. This increased the freshwater bubble and preserved freshwater based farming.

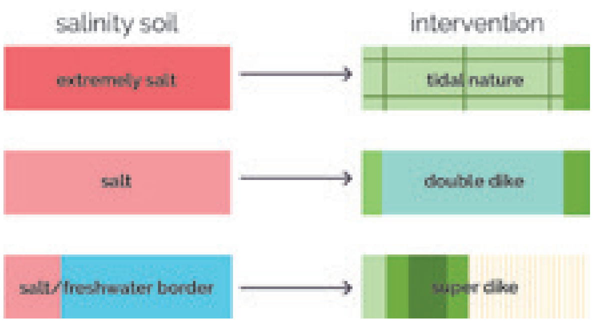


Fig. 52. *Interventions based on the salinity of the soil.*

The improved concept B: dike landscape

The dike landscape concept (Figure 53) was based on the studied interventions. The interventions were implemented based on the salinity of the soil, as previously described in the section: the groundwater-based principle. Furthermore, the unbreachable dike was only implemented without available space for the other interventions, as this dike was the least valuable.

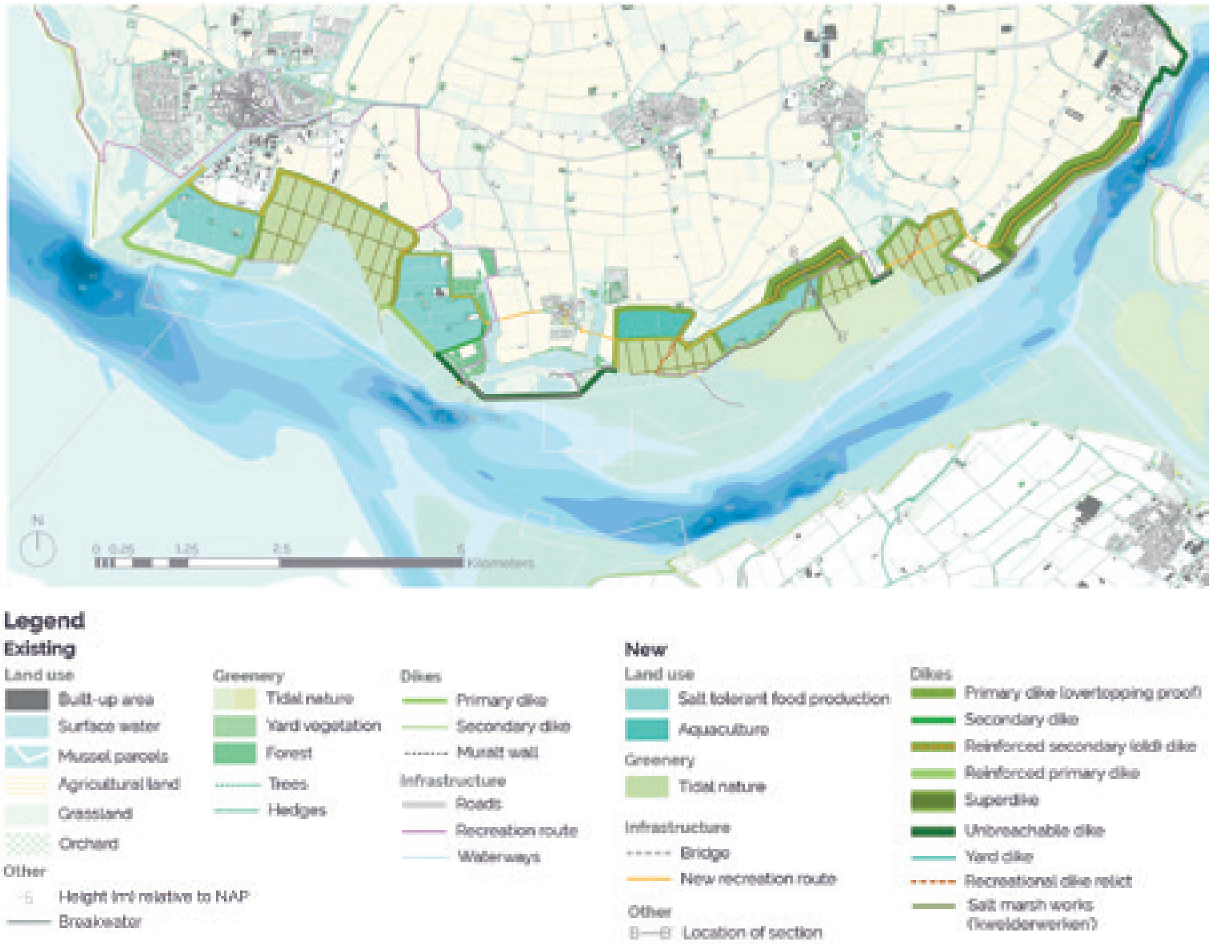


Fig. 53. *The improved concept B dike landscape, with the improved interventions - strategy defend landwards.*

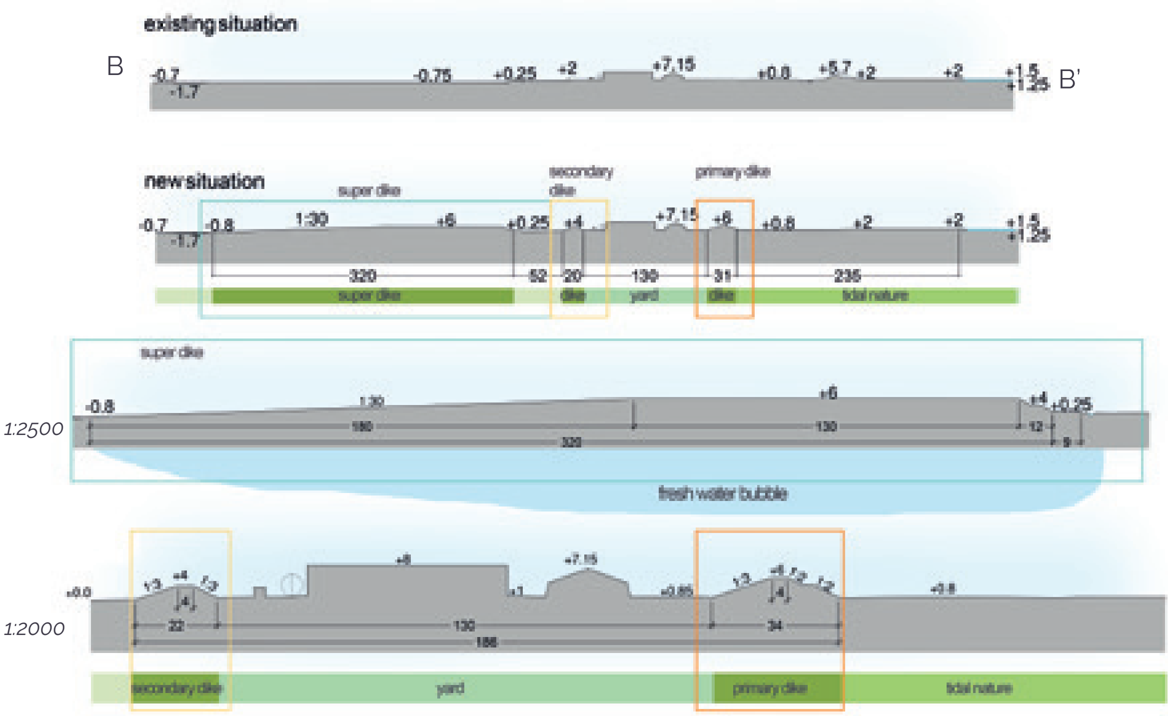


Fig. 54. *Sections displaying the super dike, and the double dike zone. Dimensions in m, heights relative to NAP.*

4.2.3 DESIGN C CREEK LANDSCAPE – STRATEGY ACCOMMODATE LANDWARD

Three interventions required studying based on the test results. Firstly, the width of the inlet to develop tidal nature was studied. Also, studied was how natural creek ridges would develop. Thirdly, studied was how the existing creek ridges had to be designed to generate freshwater bubbles underneath them.

Studied intervention: inlet width for tidal nature

The inlet size could have influenced the development of the new tidal nature area. Therefore, the studied 360 m inlet width of tidal nature in concept B was used as an improvement in concept C as well.

Studied intervention: development of natural creek ridges

The studied development of a creek ridge is illustrated in Figure 55. First, the creek eroded through the substratum. Later, the edges of the creek started to silt up. This process continued until the creek would become narrow. When the creek dried up, a freshwater bubble would develop as the creek ridge mainly consisted of permeable sand (Bennema & van der Meer, 1952). This knowledge was used to envision a long-term development of freshwater bubbles in creek ridges.

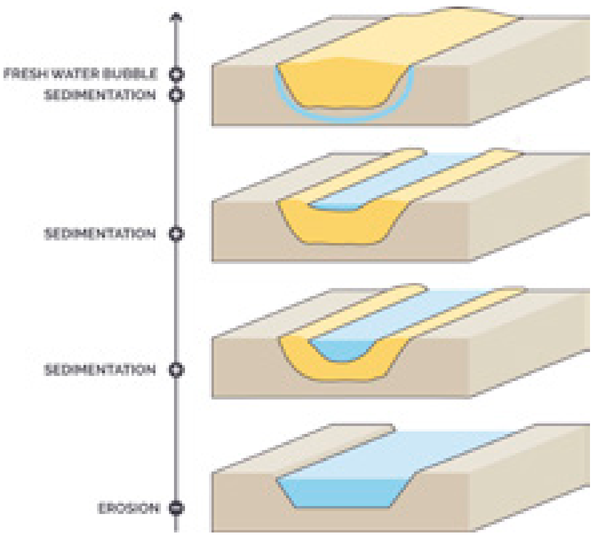


Fig. 55. The development of a creek ridge. Adapted from Bennema & van der Meer (1952).

Studied intervention: enlarging freshwater bubbles of existing creek ridges

The first insight was that existing ditches had to be removed or filled up to increase existing freshwater bubbles. Water drainage would decrease and the groundwater level would increase, resulting in a deeper freshwater bubble after some decades (figure 56).

Secondly, a deep and broad salt seepage canal had to be created. This was needed at a distance from the freshwater bubble. This way, the salt pressure would concentrate in the seepage canal, and the freshwater bubble would increase in the horizontal direction. The zone between the creek ridge and the canal would become moist, being beneficial for nature, aquaculture, and recreation (Dedert, Tangelder, & Troost, 2012).

Thirdly, the height of the creek ridges would be increased until +9 m NAP. On top of the previously safe height of +6 m NAP, a SLR of 3 m had to be incorporated, resulting in new safe height of +9 m NAP. Raising the creek ridges would increase the freshwater bubble according to the Badon-Ghyben-Herzberg principle (Carlston, 1963). For each extra vertical meter, the freshwater bubble would increase 40 m. Three assumptions were: the permeability of the sand was 8 m per day, the groundwater recharge was 0,7 mm per day, and the seepage pressure was 0,2 mm per day (Dedert et al., 2012).

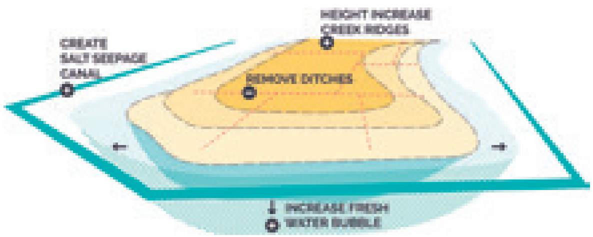


Fig. 56. Designing the creek ridge to enlarging the freshwater bubble.

The improved concept C: Creek landscape

The creek landscape concept was based on the studied interventions (Figure 57 & Figure 58). These interventions were: the inlet for tidal nature, the natural development of creek ridges, and the increase of existing creek ridges (Figure 59). The creek ridges would be redesigned after the soil was raised. To preserve the landscape identity, the original tree rows would be planted, and ditch patterns would be brought back.

Furthermore, safe farm hubs were designed. By creating tidal nature landward, some farms had to move. The farms would be relocated to an existing location with several farms. After addition of dikes, this became the safe farm hub (Figure 60).

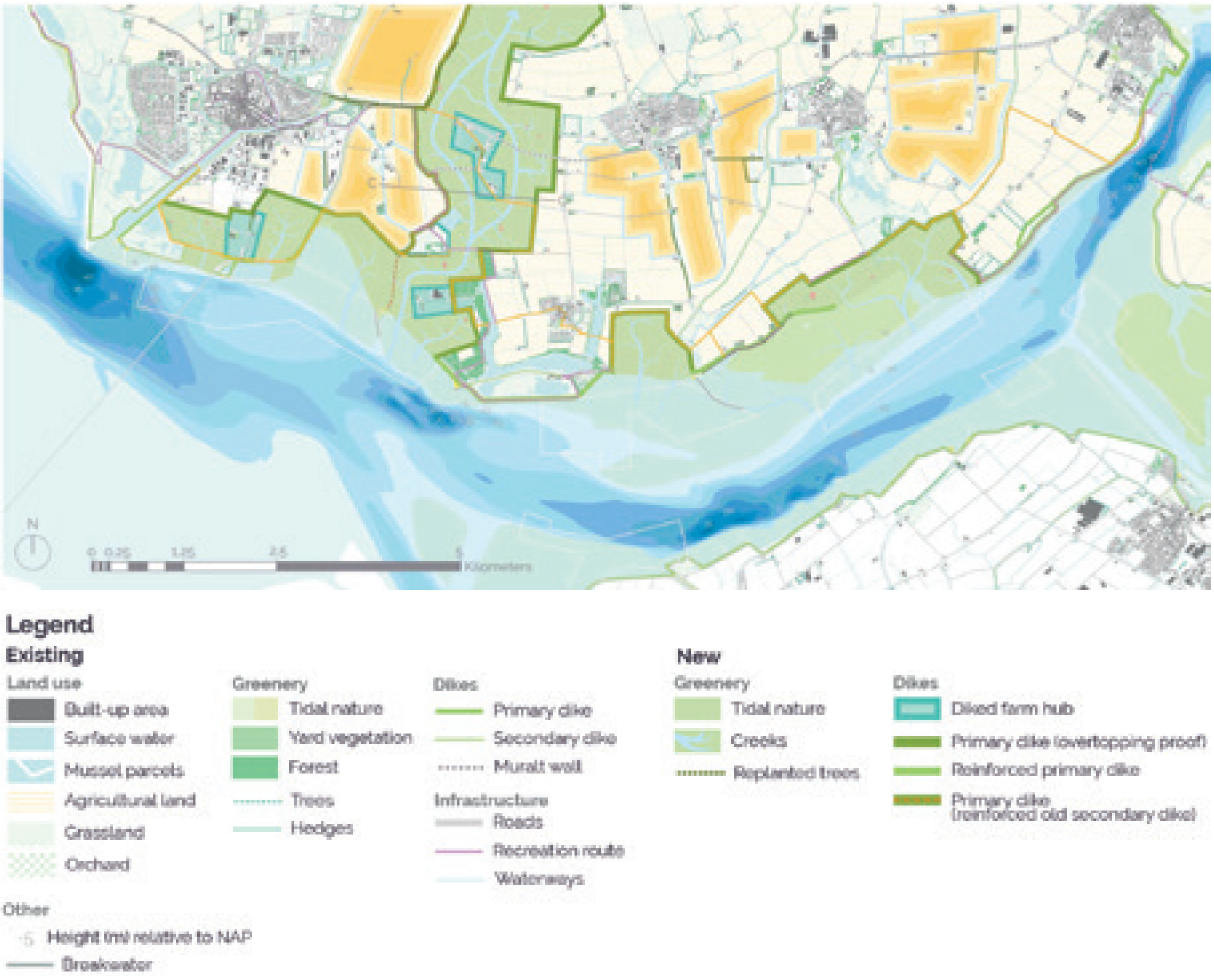


Fig. 57. The improved concept C: Creek landscape - strategy accommodate landward.

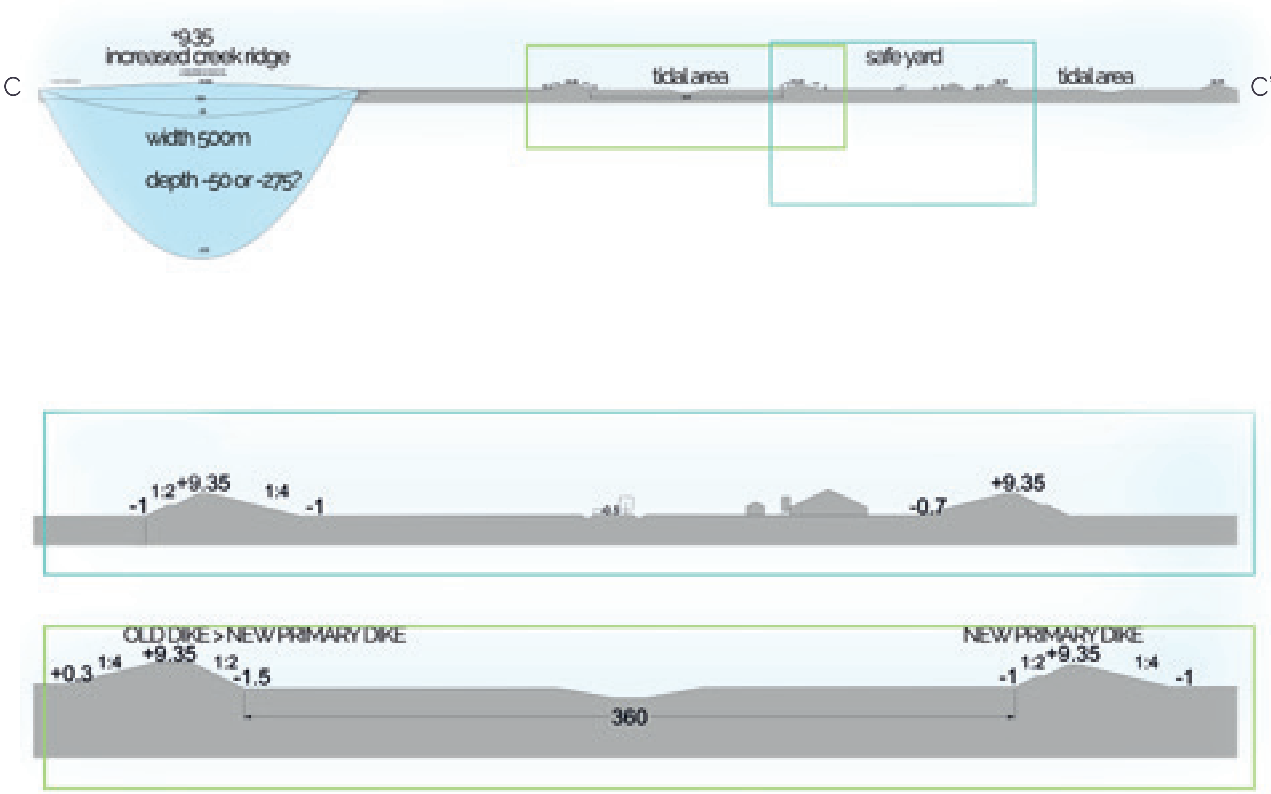


Fig. 58. *Sections illustrating the new freshwater bubble, the new tidal nature, and the safe yard. Dimensions in m, heights relative to NAP.*

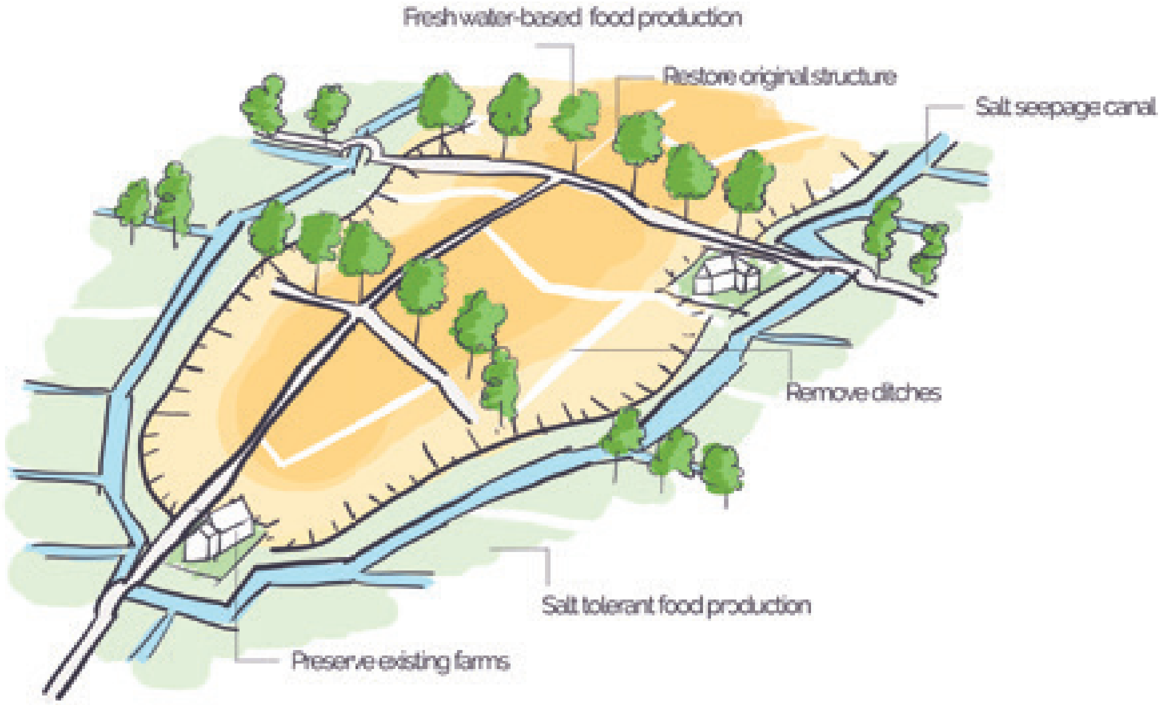


Fig. 59. *Illustration of the increased creek ridges.*

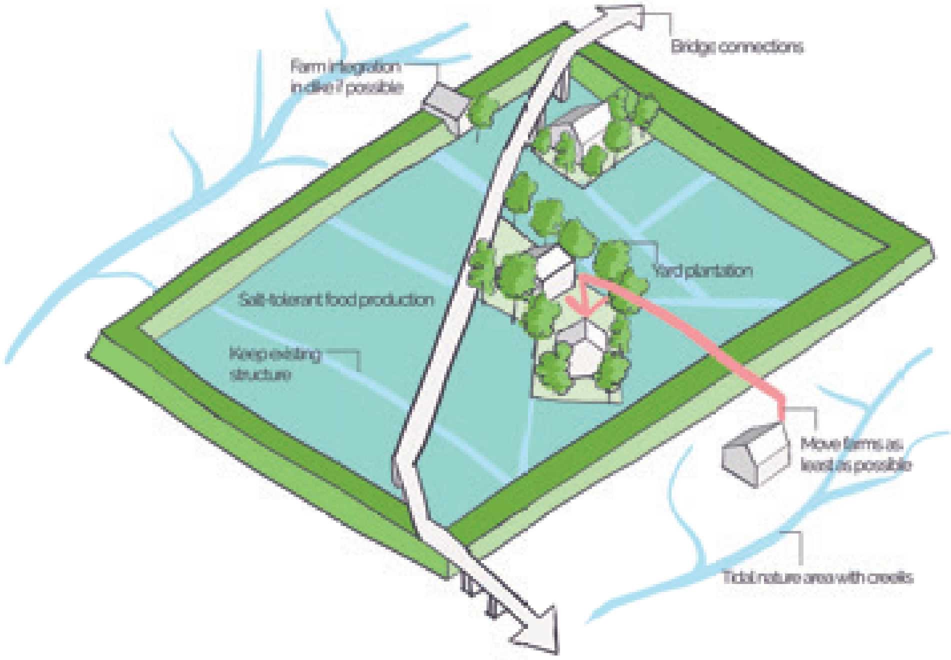


Fig. 60. Illustration of the safe farm hubs.

4.2.4 THE RESULTS OF TEST 2

Selecting the highest scoring interventions

Multiple interventions were selected to achieve the goals as the results indicated that no intervention scored the highest on all criteria (Figure 61).

Three measures scored the highest on the criterion water safety. The measure 'creation of tidal nature landward' was selected as it scored the highest on average (Figure 62). Two measures scored the highest on the criterion sediment shortage and erosion, being 'creation of tidal nature landward' and 'new tidal nature'. These measures scored equally high on average. Both measures were selected as they could easily be integrated in one principle due to their similarity. The measure 'new tidal nature' was selected as it scored the highest on the criterion drowning of tidal nature. The measure 'mussel and oyster banks, and bank protection banks' was selected as it scored the highest on the criterion nature threatened by a shorter duration of low tide. The measure 'super dike' was selected as it scored the highest on the criterion freshwater shortage and salinization.

The intervention sediment supplementation was selected as this measure was always required in combination with other interventions to protect existing tidal nature and to generate new tidal nature, according to multiple experts.

To summarize, this resulted in five interventions to be transformed into principles: the creation of tidal nature landward; new tidal nature; mussel and oyster banks; bank protection walls; and the super dike.

Prevention of errors in data

Dividing the criterion salinization and freshwater into sub criteria has led to an average number for this criterion (Figure 63). This resulted in a final average based on one decimal number, and four non decimal numbers. Also, the average value was lower in comparison to other values. An interim average was calculated with and without the average value of salinization and freshwater criterion to ensure that these two issues would not affect the results. It became clear that dividing the criterion into sub criteria did not influence the selection of the interventions.

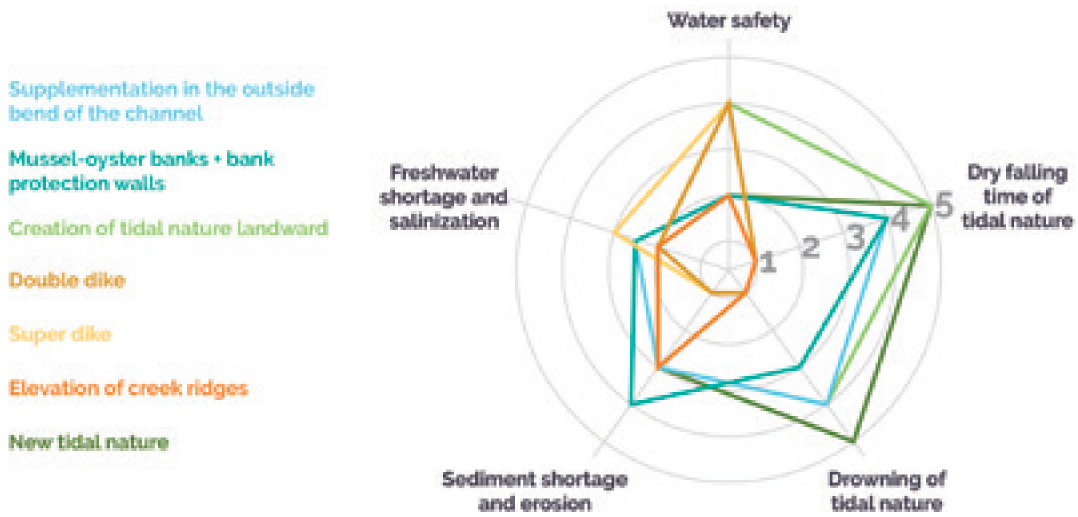


Fig. 61. Overview of the measures and their scores on the criteria.

STR.	CONCEPTS	MEASURES	Water safety	consequences sedimentation shortage	drowning tidal nature	nature threatened by shorter duration of low tide	INTERIM AVERAGE	consequences of salinization and freshwater shortage	AVERAGE SCORE
DS	Concept A	Supplementation in outside bend of channel	2	4	4	3	3.3	2.5	3.1
		Mussel-oyster banks + bank protection walls	2	4	3	4	3.3	2.5	3.1
DL	Concept B	Creation of tidal nature landward	4	5	4	3	4.0	1.8	3.6
		Double dike	4	1	1	1	1.8	2.0	1.8
		Super dike	4	1	1	1	1.8	2.8	2.0
AL	Concept C	Elevation creek ridges	2	1	1	3	1.8	2.0	1.8
		New tidal nature	3	5	5	3	4.0	2.0	3.6

Fig. 62. Complete overview of the scores of test 2.

SUB CRITERIA
CONSEQUENCES OF SALINIZATION AND FRESHWATER SHORTAGE

STR.	CONCEPTS	MEASURE	increase fresh water	decrease salinization	improvement agriculture	improvement nature	AVERAGE SCORE
DS	Concept A	Supplementation in outside bend of channel	1	3	1	5	2,5
		Mussel-oyster banks + bank protection walls	1	3	1	5	2,5
DL	Concept B	Creation of tidal nature landward	1	1	1	4	1,8
		Double dike	1	1	4	2	2,0
		Super dike	4	3	3	1	2,8
AL	Concept C	Elevation creek ridges	5	1	1	1	2,0
		New tidal nature	1	1	1	5	2,0

Fig. 63. Sub criteria of the criterion consequences of salinization and freshwater shortage.

4.2.5 IMPROVEMENTS FOR THE SELECTED INTERVENTIONS

Creation of tidal nature landward

The measure creation of tidal nature landward was improved on the criterion sediment shortage: erosion, was improved as it scored a 3, and on the criterion salinization and freshwater. Namely, on the aspects 'increase freshwater, decrease salinization, and improvement agriculture', as it scored a 1 on these three aspects.

Besides improvements based on the ratings, the intervention could be improved based on the answers of the experts (appendix VI). Firstly, aimed was for the optimal dry falling time for the birds: 50-80%. Secondly, the grid was removed as this was not required. Instead, a general creek pattern was designed to enhance the tidal nature development. Thirdly, to ensure that enough silt was available, dredging silt from harbours was suggested and integrated as an improvement. Fourthly, disruption of nature by recreation was prevented. Finally, considered was that the sediment shortage could increase as the tidal system became larger.

New tidal nature

The intervention new tidal nature could be improved on the criterion water safety as it scored a 2. Furthermore, this intervention could be improved on the criterion effect of sediment shortage: erosion. The criterion salinization and freshwater could be improved on the aspects: increase freshwater, decrease salinization, and improvement agriculture, as it scored a 1 on these aspects.

Based on the comments of the experts, the next improvements were made. Firstly, the dike length was reduced. Secondly, the need of enough silt supply was incorporated. Thirdly, the width of the inlets of the tidal areas was changed to 100 m wide. Finally, farm hubs would not lay in the middle of tidal areas.

Mussel-oyster banks + bank protection walls

Based on the scores, the criterion water safety could be improved as it scored a 2. Also, the criterion effect of sediment shortage: erosion could be improved as it scored a 3. Finally, the criterion salinization and freshwater could also be improved as it scored a 2,5. To elaborate, the aspects increase freshwater (score 1), decrease salinization (score 3), and improvement agriculture (score 1) could be improved.

Based on the comments of the experts, gabions were used to let the mussel and oyster banks grow.

Super dike

This intervention was improved on the criteria tidal nature threatened by a shorter period of low tide, drowning of tidal nature, and effect of sediment shortage: erosion as it scored a 1 on all three criteria. Furthermore, the criteria salinization and freshwater could be improved, because it scored a 2,8. To elaborate, the aspects decrease salinization, improvement agriculture, and improvement nature could be improved.

Based on the comments of the experts, the stability of the soil had to be considered. Secondly, a natural slope was added at the Oosterschelde to enhance tidal nature development. Thirdly, a seepage canal or wet area was added behind the super dike to catch away the salt, this canal would also have nature value. Fourthly, the material of the dike had to include an impermeable layer for water safety as well as a permeable layer for the infiltration of rainwater for the freshwater bubble. Fifthly, the soil of the super dike required permeability and needed to be close to a deeper freshwater bubble. Therefore, the soil conditions were studied in more detail.

Suppletion in the outside bend of the channel
The intervention, suppletion in the outside bend of the channel, was improved on the criteria water safety as it scored a 2. Also, this measure was improved regarding the effect of sediment shortage: erosion as it scored a 3. The criterion salinization and freshwater could be improved as it scored a 2,5. The intervention scored a 1 on freshwater increase, a 3 on salinization decrease, and a 1 on the improvement of agriculture.

Based on the comments of the experts, further improvements were made. Firstly, the suppletion was placed on the edge of the plate. Note that the silting up process would maximally raise the land with 10 mm per year and a faster SLR would create problems. Secondly, removing or opening the Oosterschelde barrier could be an improvement as dynamics would increase, but it was uncertain if this would lead to a low tide dominated system. Thirdly, sand could be actively moved from the channels to the plates. Fourthly, the sediment shortage would only be solved if the sediment came outside of the Oosterschelde system. Fifthly, the effect of creating higher land in front of the dikes on the salt and freshwater system was unclear.

4.3 DESIGNING AND TESTING THE PRELIMINARY DESIGN AND PRINCIPLES

Four principles (4.3.1) and an improved preliminary design (4.3.2) were developed based on the selected interventions and their improvements mentioned in the previous chapter, The next four principles were developed based on the improved highest scoring interventions: the super dike, the tidal protection grid, the silt motor, and the new tidal nature landward (Figure 64).

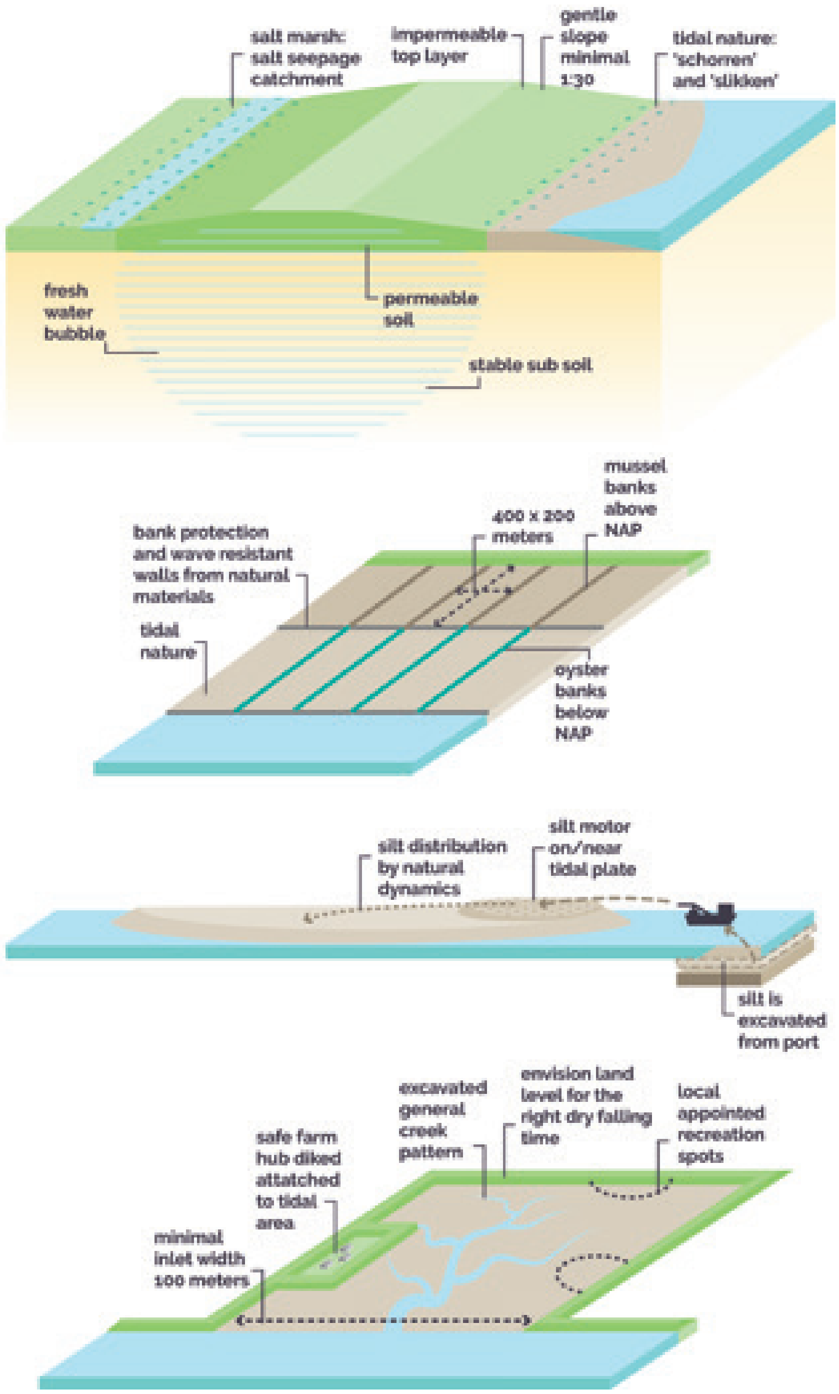


Fig. 64. The principles based on the selected interventions, from top to down: super dike, tidal grid, silt motor, and new tidal nature landward.

4.3.1 THE PRINCIPLES

1 The super dike

Three extra analyses were done to ensure the development of a freshwater bubble at the location of the super dike. The depth of the salt and freshwater border was studied, the soil types were studied, and the seepage and infiltration were studied (Figure 65). A deep freshwater bubble would develop partly underneath the super dike. These were the parts where two aspects occurred: being a freshwater border deeper than 7.5 m and a permeable soil which allowed infiltration. Thus, the location of the super dike proved suitable.

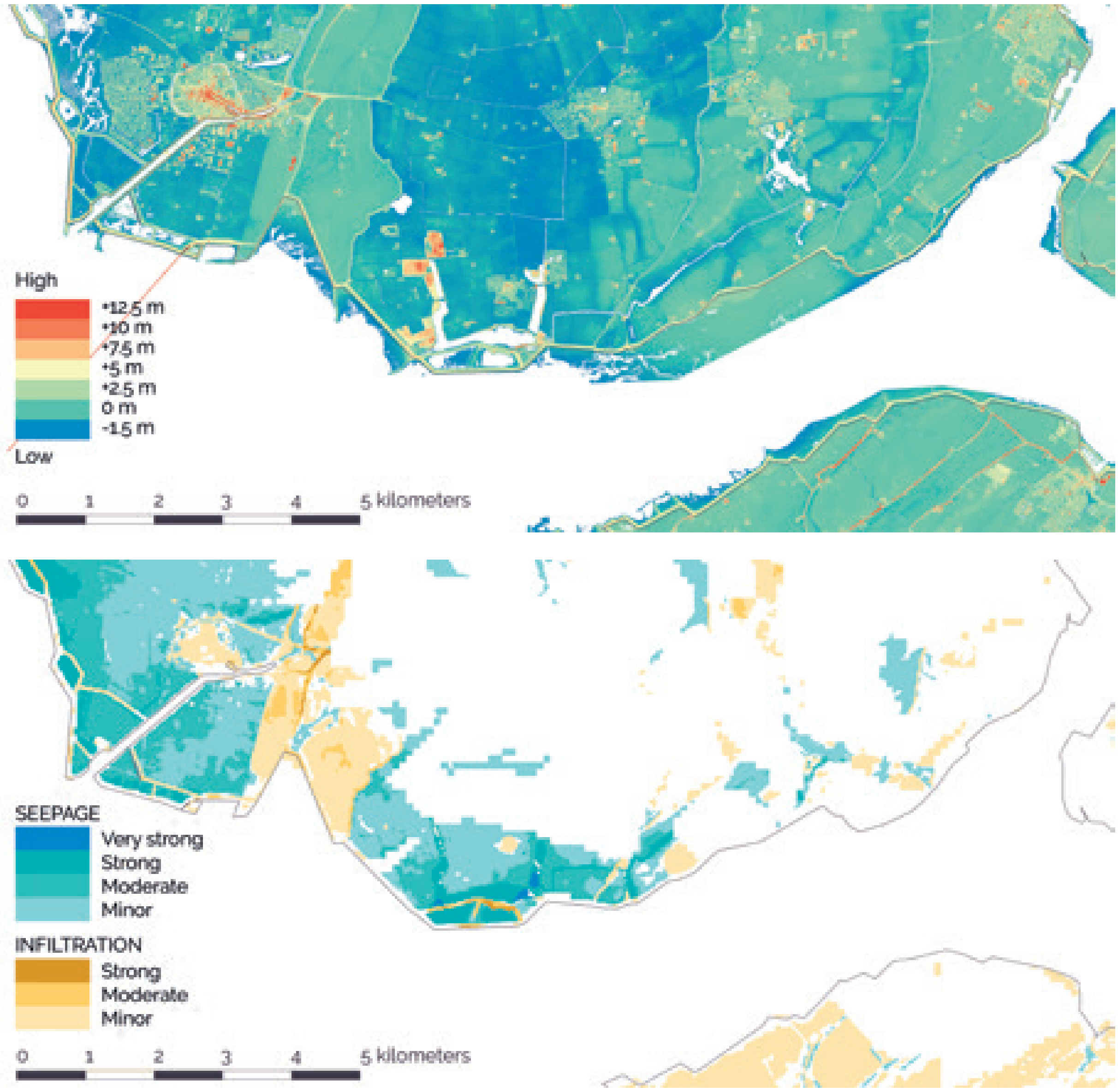


Fig. 65. A - Detailed analysis of the altitude (top) and seepage and infiltration (below). Adapted from (Esri Nederland & Wageningen Environmental Research (Alterra), 2019; Provincie Zeeland, 2021).

The improved principle was based on the intervention 'super dike' and mainly reduced freshwater shortage and salinization consequences. The super dike aimed to increase an existing freshwater bubble to increase water safety and to add new tidal nature (Figure 66). To generate the freshwater bubble, the dike had an impermeable top layer, with a permeable core. A seepage canal was placed behind the super dike to catch away salt seepage. To increase water safety, the inside slope of the dike was gentle (1:10), the dike was raised in height, and the outside slope of the dike was very gentle (1:30). This very gentle slope would also enhance tidal nature development.

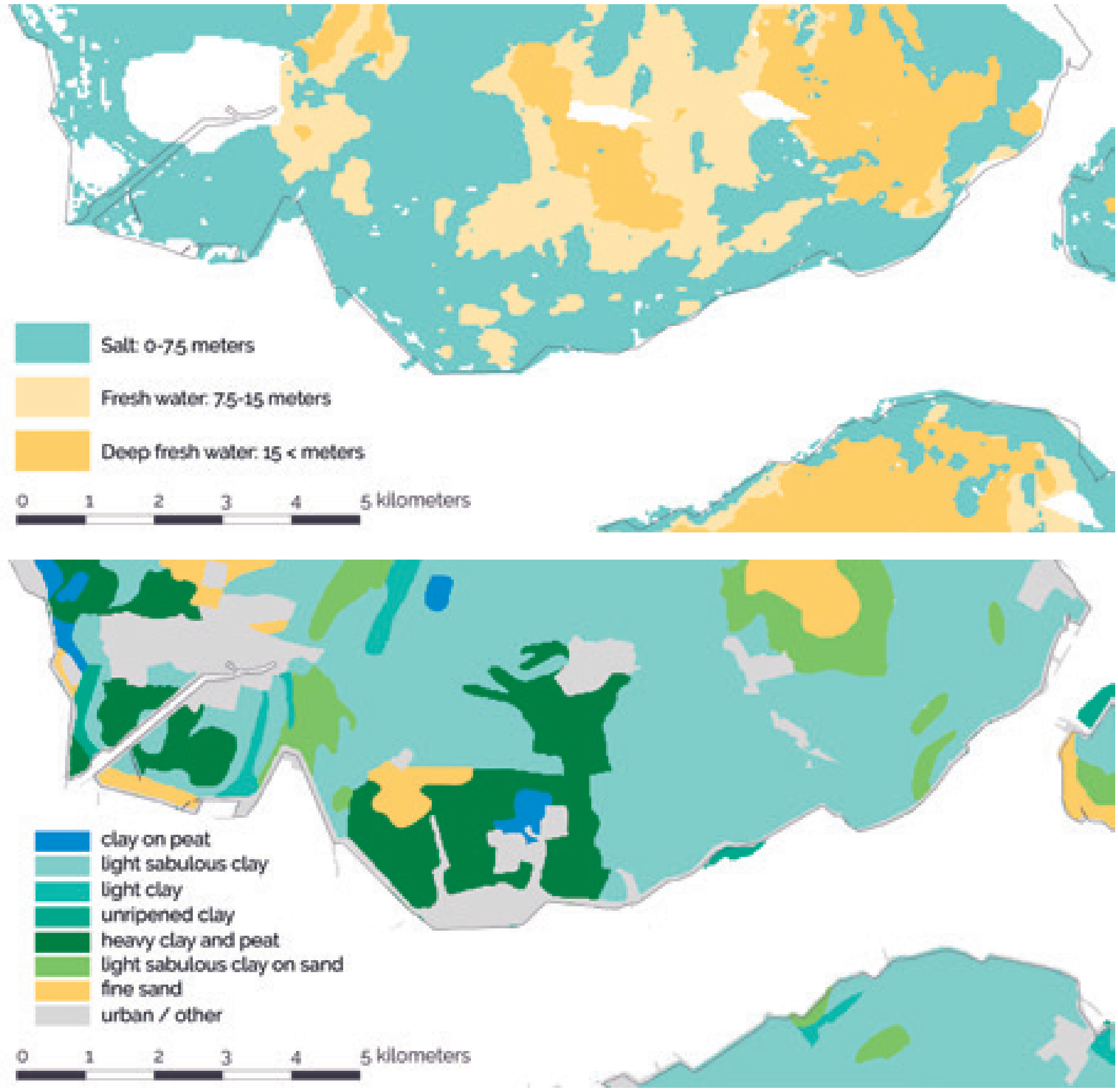


Figure 65. B - Detailed analysis of the salinity (top) and soil types (below). Adapted from (Esri Nederland & Wageningen Environmental Research (Alterra), 2019; Provincie Zeeland, 2021).

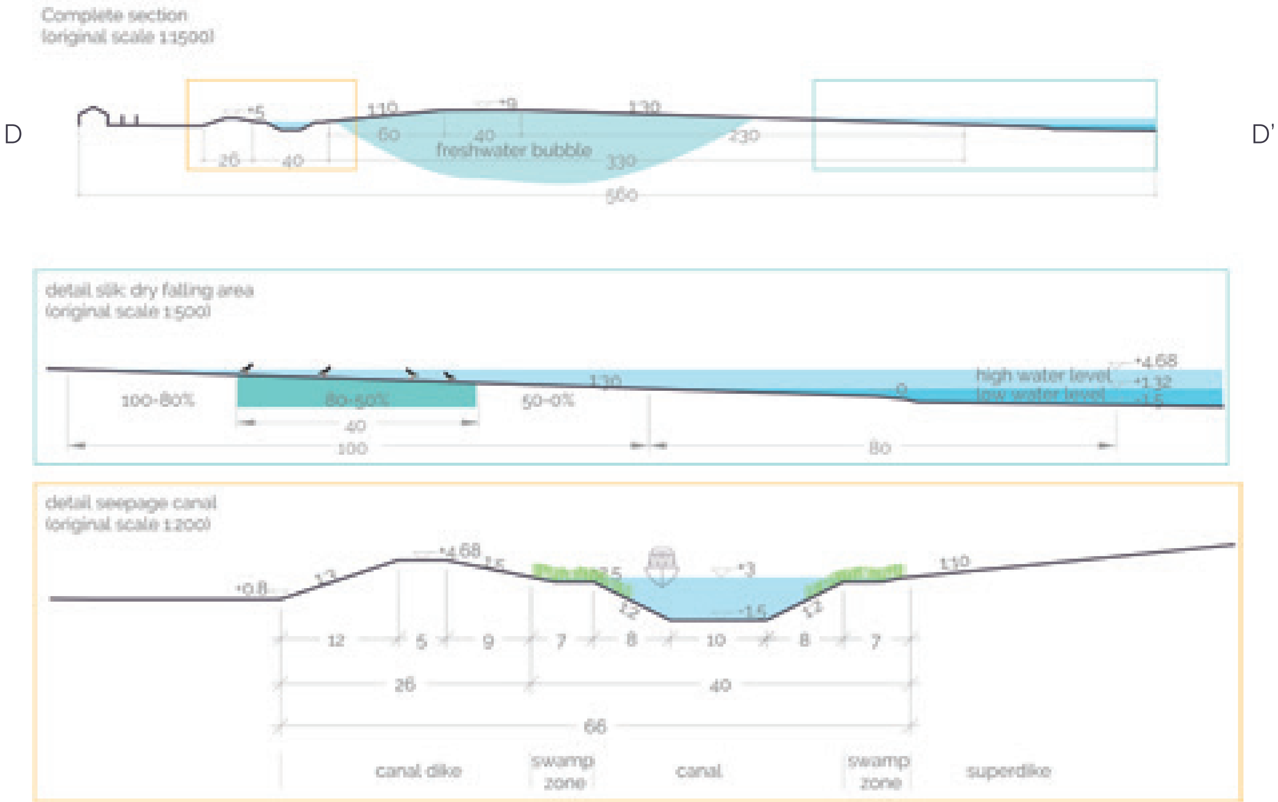


Fig. 66. The section of the super dike illustrates the freshwater bubble, the tidal nature, and the seepage canal, dimensions in m, heights in relation to NAP.

2 The tidal protection grid

The principle tidal protection grid mainly offered solutions regarding the effect of sediment shortage: erosion. This principle was based on the intervention 'mussel-oyster banks + bank protection walls'. The grid consisted of brushwood dams made of willow twigs, placed parallel to the coast following the height of the tidal nature. Secondly, mussel banks were placed perpendicular to the coast, above -1 m NAP. Thirdly, oyster banks were placed perpendicular to the coast, below -1 m NAP. This way, erosion would be reduced, and sedimentation enhanced. The mussel and oyster banks were created by placing gabions with the shellfish. Most of the time, the banks would be inaccessible to recreants, but shellfish harvesting was allowed once a year. This way, nature and recreation were balanced.

3 The silt motor

The principle silt motor mainly offered solutions regarding the effect of sediment shortage: erosion. The principle was based on the intervention 'suppletion in the outside bend of the channel'. The silt motor consisted of a suppletion of silt on the edge of a tidal area. This silt could be excavated from the channels, or from ports. After the supplementation, the silt would be naturally distributed over the tidal area. This way, erosion would be reduced, and sedimentation enhanced.

4 The new tidal nature landward

This principle mainly offered solutions regarding the water safety, the tidal nature threatened by a shorter dry falling time, and the drowning of tidal nature. This principle was based on two interventions: 'the creation of tidal nature landward' and 'new tidal nature'. These interventions were combined as they both were the highest scoring interventions for the criteria. Firstly, a low laying saline area was invested for tidal nature development. Secondly, a general creek pattern was excavated. Thirdly, an inlet of 100 m wide was created. If needed, a safe farm hub could be attached to the dike. Finally, only some spots adjacent to the tidal area were appointed for recreants to reduce disruption of the birds.

4.3.2 THE PRELIMINARY DESIGN

Implementation of the principles and starting points for the design

In test 1 of the three concepts became clear that the design had to be advantageous for nature as well as for agriculture. Furthermore, SLR is uncertain as stated in the theories and concepts section. Based on these two starting points, a changing landscape was designed in three steps. This allowed to implement steps when there was more certainty about SLR to prevent that unnecessary interventions were implemented.

Step 1

Part of the first step was to permanently open or remove the OSB to bring back the natural dynamics (Figure 67). The super dike was placed at the coast where a small freshwater bubble was present to increase this bubble. The tidal protection grid was designed on the existing tidal nature area which was endangered by the sediment shortage and SLR. The silt motor was applied on the transition from dike to channel at the edges of the tidal nature areas to stimulate growth of the new and existing tidal nature areas. The new tidal nature landward was created on uninhabited low laying salt land. This was done because the landscape identity analysis pointed out that the inhabitants were strongly connected to their landscape. This way, the inhabitants could first stay where they lived, and get used to the changing landscape.

Step 2

The second step was to invest inhabited low laying salt land for new tidal nature (Figure 68). Also, the newly generated tidal nature from step 1 was cut off from the Oosterschelde. These higher silted up areas would be retransformed into farmland, being less vulnerable to salinization. This way, the inhabitants could switch from their problematic land to the new silted up land. In short, one nature area would be transformed in agricultural land per five years to prevent ecological damage. Note that some areas would permanently remain nature, because these had no practical position to make the switch. This would be a stable factor for nature.

Step 3

The third step was to switch from agricultural land to nature and vice versa (Figure 69). After this step, no new areas had to be invested. After step 3 could be continuously switched between agricultural land and nature.

Fig. 67. Step 1: Open/no Oosterschelde barrier and investing in uninhabited problematic areas.

Fig. 68. Step 2: Silted up nature becomes farmland and investing in inhabited problematic areas.

Fig. 69. Step 3: Switching silted up nature into farmland and vice versa.

Dike relics

Because the principles led to a change of the coastline, some dikes were removed. When this was a secondary dike, this was brought back as a relic of the past to conserve the landscape identity (Figure 70 A&B). This dike relict functioned as a bird watching dike, being the first dike relic type. The second dike relic type was a closable water retaining element.

Adjustment of the recreational route

As the coastline has changed, alterations to the existing recreation route had to be made. This was a chance to make the recreation route less disruptive for the new nature. The first alteration was to prevent recreants from accessing the tidal nature directly, but also to allow visiting of the tidal nature by generating elevated structures. Secondly, to create new recreation loops connecting to the existing recreation route. These loops were made on the land side of the dike. This way, the recreants could be attracted the agricultural side of the landscape. Furthermore, the path would be adjacent to the nature area at some spots, allowing recreants to enjoy the tidal nature.

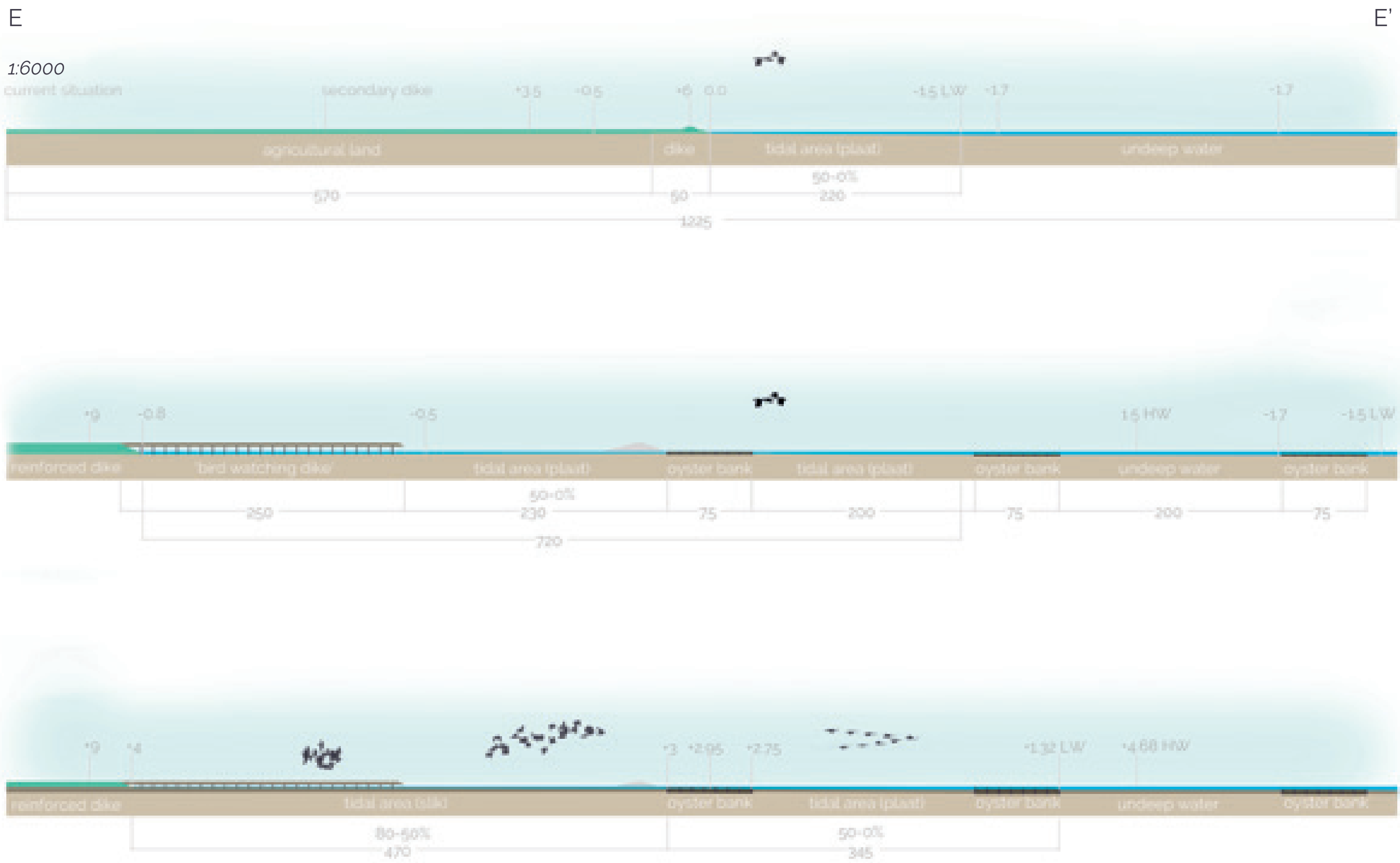
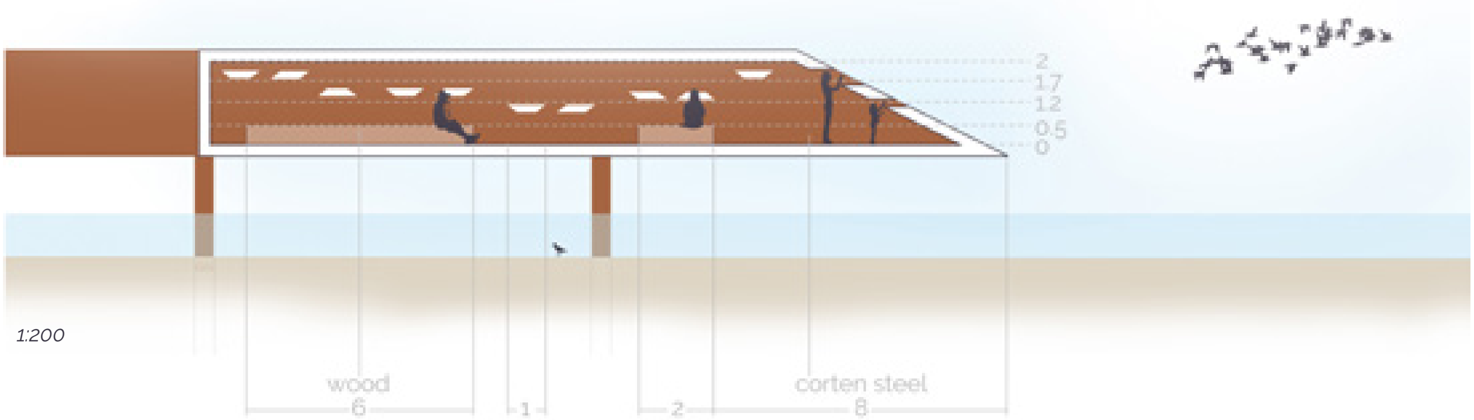


Fig. 70. A - Transition from the existing situation (top), the intervention (middle), and the 'final' situation (down). By silt suppletions, the tidal area silts up heigher and oyster banks grow with SLR. Dimensions in m, heights in relation to NAP. HW: high water level, LW: low water level..

1:1000



1:200

1:400

Fig. 70. B - Detailed sections show the dike relic which represents the removed dike as a bird watching dike. The v-shape of migratory birds is reflected in the viewing windows, which also reflect the shapes of dikes. These windows are on sitting and standing heights. The ending of the dike relic is a dry bird watching hut, offering perfect circumstances for bird watching. Below, the section of the oyster bank is shown. Once a year, the banks are accessible for harvesting.

4.3.3 TEST RESULTS 3 OF THE EXPERT JUDGEMENTS

The third test results were gathered in two parts. In part one, a presentation was given to a group of experts. Afterwards, general comments of the group were gathered. In the second part, more specific comments of the landscape architect were gathered during a separate meeting.

Test results part 1: expert judgements from relevant field

The first suggestion was to use the freshwater from the super dike for surrounding salty farmland. Secondly, a suggestion was to include retention basins in the super dike to reduce desiccation of the dike. Thirdly, the super dike could be combined with the 'freshmaker' project. Freshwater would be pumped up from the super dike during the summer for irrigation, and freshwater would be injected in the super dike in the winter to enlarge the freshwater bubble.

Test results part 2: landscape architecture expert judgement

The first suggestion was to show the added value of the land use, such as the harvesting of the oyster and mussel banks and freshwater dependant agriculture on the super dike. Secondly, a suggestion was to add the existing dike situation to the new principle or section to explain how the old dike could be integrated in the new dike. Thirdly, the profile of the super dike could be more valuable for farming as the gentle slope could be applied to the land side. Fourth, a suggestion was to explain the calculation of the dike heights, including uncertainties such as soil subsidence and wave run-up. Fifthly, it was unclear that all principles had to include supplementation. Sixthly, the freshwater was required to be injected in the aquifer instead of in the super dike, when combining the super dike principle with the 'freshmaker' project. Seventhly, the opening of the OSB had to be extremely clear as this was not clear enough yet. Also, the uncertain consequences of opening the OSB had to be mentioned, such as erosion. Finally, the soil types in the subsurface had to be studied when locating the super dike to ensure that the principle would really work.

4.4 THE FINAL DETAILED DESIGN AND PRINCIPLES

4.4.1 THE PRINCIPLES

The improved principles include clear design guidelines (blue) and landscape idenity guidelines (yellow) (Figure 71 A, B, C & D). Especially the super dike principle was improved based on the results of test three. For all the other principles, except the silt motor, the required combination with the silt motor was clarified. The land use type was specified for all principles.

The first improvement of the super dike was to clarify that freshwater dependant farming was guaranteed. Secondly, it was clarified that the super dike would be placed behind the start of the old dike at the coast side to develop tidal nature. Thirdly, the surplus of freshwater in the ditches in the winter would be injected in the aquifer. Fourthly, the profile of the super dike became more flexible. Without spatial constraints, the gentle slope could be designed on both sides of the super dike. With spatial constraints, the gentle slope would be designed on the most profitable side. This means that the coastal side of the dike would have a gentle slope when a large increase of tidal nature could be created. The land side of the dike would have a gentle slope when a large increase in freshwater could be created. Thus, the consideration about the gentle slope should be made separately for each location.

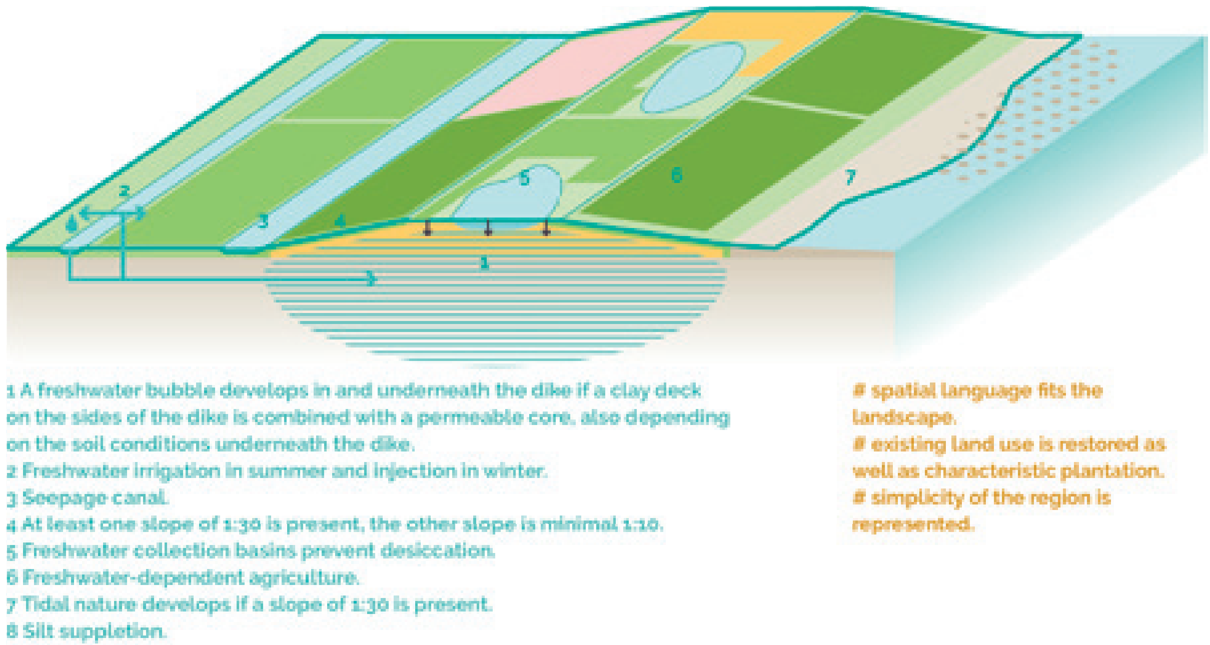
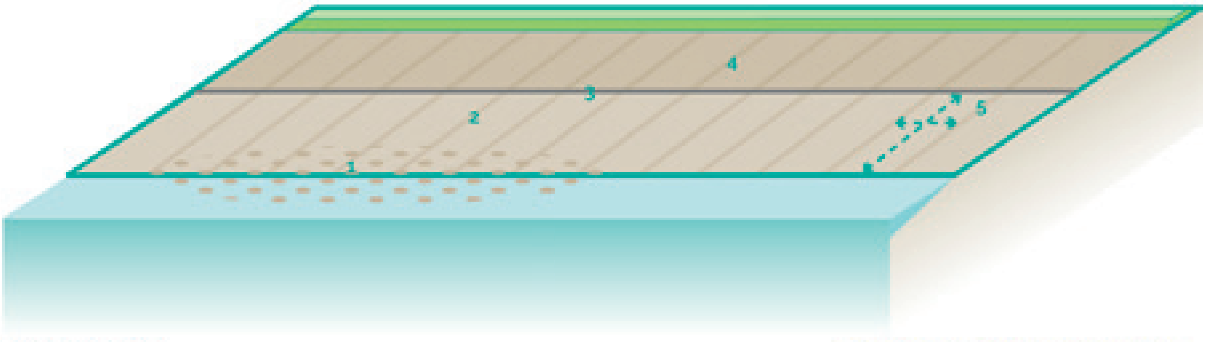


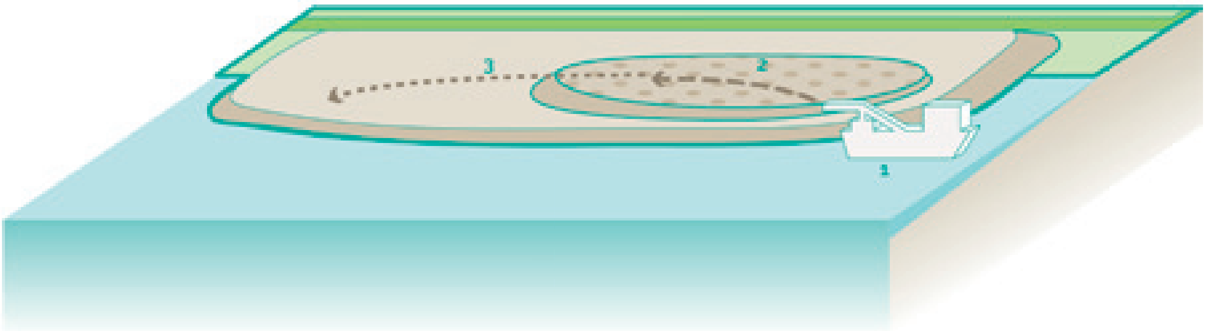
Fig. 71. A- The improved super dike principle. Goal: freshwater increase and decrease salinization



1 Silt suppletion.
2 Oyster banks below average water level
3 Wave resistant dams from natural materials offer bank protection.
4 Mussel banks above average water level.
5 Optimal distances: 400 x 200 meter.

region specific flora and fauna is used to protect the tidal nature.
spatial language fits the landscape.
shapes are inspired on historic landscape patterns.
new dike types represent the original dike types.

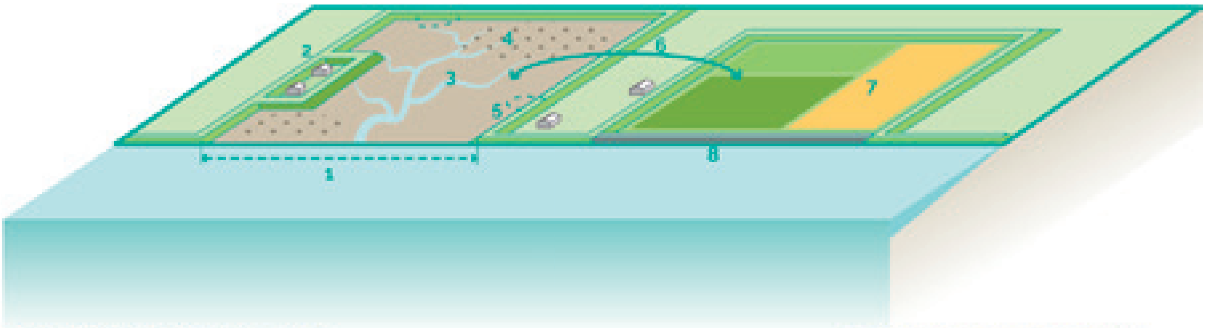
Figure 71. B - The improved tidal protection grid. Goal: decrease erosion and sediment shortage



1 Silt is retrieved from outside the system, or from channels or harbours inside the system.
2 A silt suppletion is done on the edge of the tidal area.
3 The silt is distributed by tidal dynamics.

general dynamics of the region are represented.

Figure 71. C - The improved principle silt motor. Goal: decrease erosion and sediment shortage.



1 Inlet width of minimal 100 meter.
2 Safe farm hub attached to the mainland.
3 General excavated creek pattern.
4 Suppletion depends on original land height.
5 Local appointed recreation spots.
6 After land has silted up high enough, the tidal nature is invested for agriculture and vice versa.
7 The silted up land can be used for freshwater-dependent agriculture.
8 The area is protected from floods by a sea wall which can be removed and reused for other areas during switches.

new dike types represent the original dike types.
new designed dike relics replace removed historic dikes.
existing land use is restored.

Figure 71. D - The new landward tidal nature. Goals: decrease threat short period low tide, decrease drowning tidal nature, improvement water safety.

4.4.2 THE FINAL DETAILED DESIGN

The final design was an improvement of the preliminary design based on the results of test three. The final design was a smaller scale design, requiring a new level of detail. All the principles were implemented in the detailed design. The landscape would transform in three steps (Figure 72, Figure 73 & Figure 74) and would continuously adapt to SLR. The recreational route would take the visitor through the different parts of the landscape. In the existing situation, the route mainly showed the Oosterschelde. However, this could disrupt the nature, and did not show the agricultural landscape. Therefore, the route was moved and expanded towards the farmlands. Multiple principles for the route were developed, as described in 4.3.1. Four different dike types were developed, being the upgraded secondary dike, the primary dike, the agricultural super dike, and the tidal super dike. The design of the route and the dike types are explained in the following sub paragraphs.

Fig. 72. Step 1: Investing uninhabited problematic land for nature and agriculture on the long term.

Fig. 73. *Step 2: Inhabitants move to the new silted up land available for agriculture, other areas will be invested for nature and agriculture for the long term.*

Fig. 74. *Step 3: The new silted up land is made available for agriculture, the too low positioned agricultural land is again invested for nature to let the land again silt up higher.*

Fig. 75. **Visualization of harvesting mussels, and changes over time.**
A. The first step: investing the former agricultural land for tidal nature and height increase. Location: Figure 73.

B. The second step: investing tidal nature for agriculture and investing other farmlands for tidal nature and height increase. Location: Figure 74.

The recreational route

The existing recreation route was redesigned with three new typologies (Figure 76). The secondary dike path was narrow, without benches, mainly meant as a connection to move along. The path was positioned in the centre of the dike to enhance the symmetry. The primary dike path included some benches and picknick tables at the side of the path which was the most far away from the nature side. The path itself was positioned on the coastal side of the top of the dike. This was done to prevent disruption of the nature and to include recreational value. The path on the super dike was a broad path with benches, like a boulevard. As the path was a bit winding it would create a park-like environment, pleasant to take a break and enjoy the landscape.

The recreational route was partly positioned on the closable dike relict. This dike relict included a bird watching screen with a mussel pattern, subtly indicating where mussel banks were placed, allowed views for kids as well. During high tide, the mussel banks would be under water, but the decoration on the fence would still indicate their presence (Figure 75 and Figure 77).

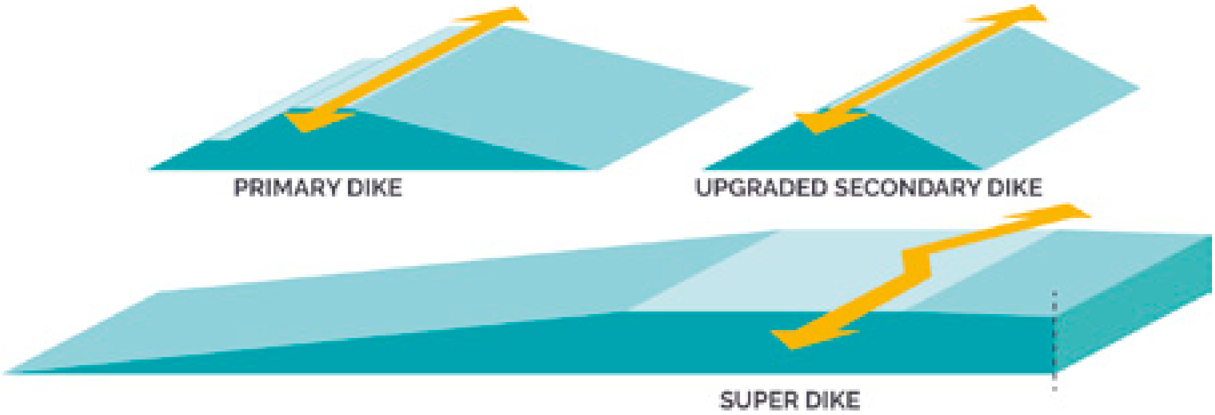


Fig. 76. Three dike types with a different recreational path.

Fig. 77. The recreational route on top of the closable dike relict, overviewing the mussel and oyster banks. Location of image is shown in Figure 75.

4.4.3 THE SUPER DIKE

Analysis of the subsurface of at the location of the new super dike

The soil characteristics of the subsurface had to be studied, based on the test results. Therefore, a section of the existing situation was made to study the soil characteristics and the effect on the freshwater bubble (Figure 78). Several layers of different soils were present. The upper 15 m generally consisted of clayey sand, clay, some peat, and a thin layer of fine sand. The deeper subsurface consisted of a large layer of fine sand, with some presence of clayey sand and clay.

Theory on the development of the freshwater bubble

The existing profile of the freshwater bubble was based on the Badon-Ghyben-Herzberg principle. In theory, for every extra vertical meter, the freshwater bubble would increase 40 m (Carlston, 1963). However, in practice, due to the presence of impermeable layers, the freshwater bubble would increase only 15 to 25 m for each extra vertical meter. Furthermore, the freshwater bubble would only develop until the presence of a clay layer was thicker than 4 m (Meinardi, Schotten, & de Vries, 1998).

The new profile and freshwater bubble of the tidal super dike

Only one side of the dike was designed with a slope of 1:30 since there was no room for two slopes of 1:30. Therefore, the choice between an agricultural super dike and a tidal super dike had to be made. A tidal super dike was made, because the dike would still result in a large freshwater bubble. Also, a too thick clay layer was present at the coastal side of the section which would not result in a freshwater bubble at the coastal side of the section. Therefore, the newly designed dike had the most optimal profile for tidal nature, but was still advantageous for

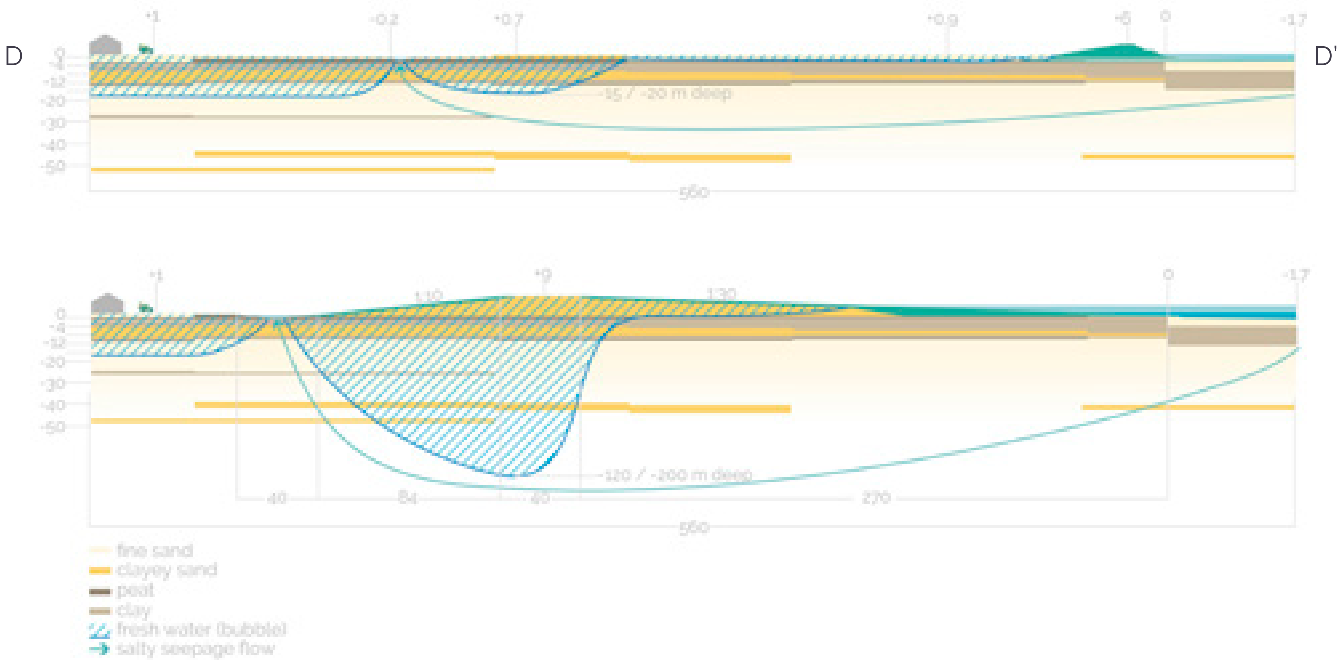


Fig. 78. Section of the existing situation (top) and the new tidal super dike (below), dimensions in meters (m), heights in relation to NAP. Adapted from (TNO, n.d.).

freshwater-dependant agriculture (Figure 78). The location of the section is shown in Figure 67. The new freshwater bubble was calculated to increase with 120 to 200 m in depth beneath the top of the dike, resulting in a maximum depth of 135 to 220 m.
The new designed tidal super dike consisted of several parts (Figure 79). The new unvegetated tidal nature part (6) is enlarged in Figure 80. The start of the new super dike was located at the same point as the start of the old dike. The intention was to preserve the existing coastline to prevent reduction of the landscape identity. However, the water comes more landward due to SLR and the gentle slope. The new unvegetated tidal nature has increased with a zone of 30 m with the most optimal dry falling time (50-80%).

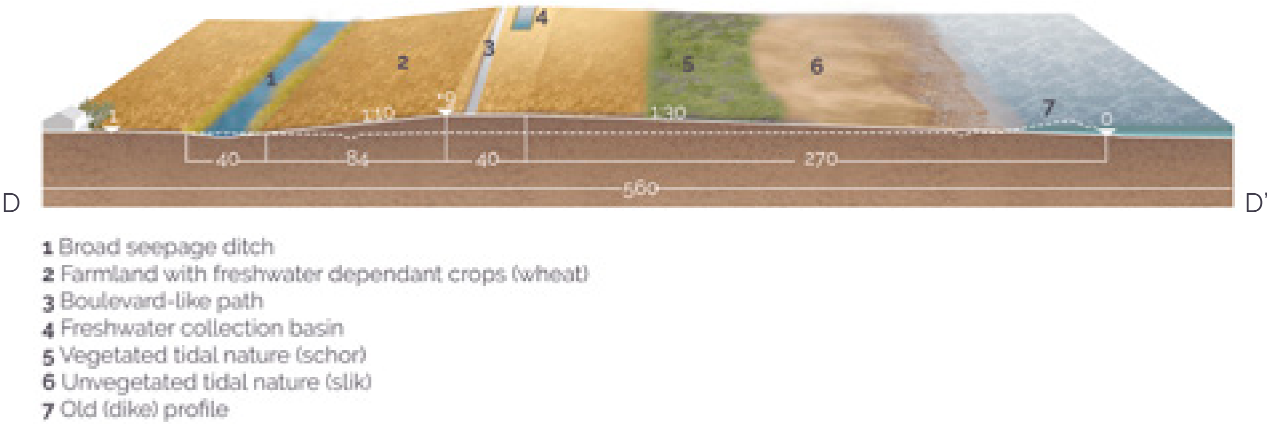


Fig. 79. Overview of the new tidal super dike and the different elements, dimensions in meters (m), heights in relation to NAP.

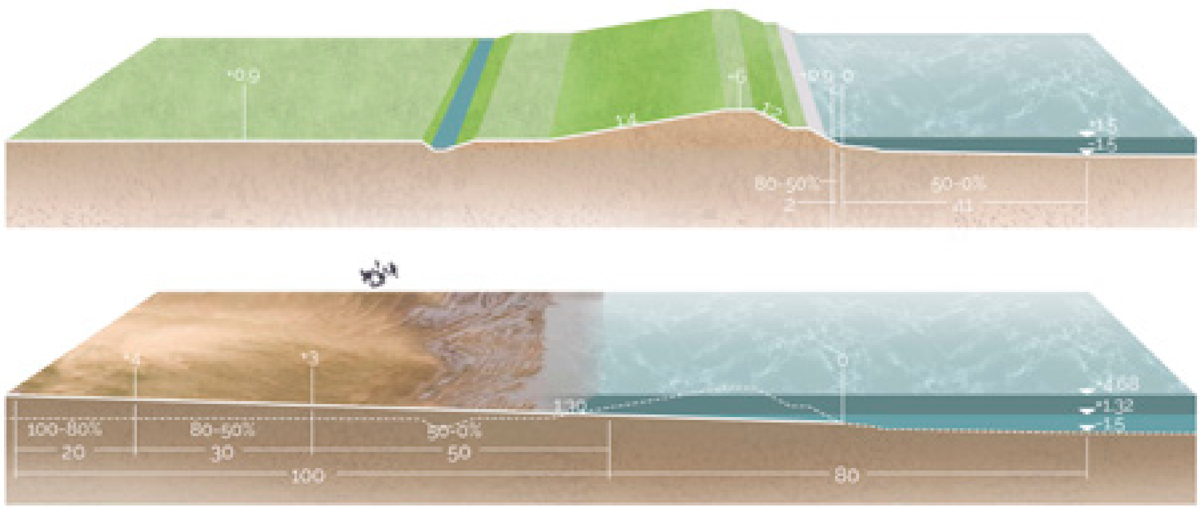


Fig. 80. The old profile (top) and the new unvegetated tidal nature at the start of the super dike (below), dimensions in meters (m), heights in relation to NAP.

The broad seepage ditch is enlarged in Figure 81. This ditch was designed to enhance the value for nature, besides the capturing of salt seepage. Different zones were designed to create different habitats. The slope of the super dike continued until the swamp zone of the ditch. A small path of 1 m was designed directly adjacent to the moist zone. This enabled visitors to enjoy the nature and the agricultural land simultaneously. Furthermore, a flower rich edge at the edges of the farmland was designed to increase the biodiversity.

The top of the dike is enlarged in Figure 82. The whole top of the dike was suitable for freshwater-based agriculture, such as wheat. Freshwater collection basins prevented desiccation. The recreational boulevard was positioned on the left side of the dike to prevent disruption of the tidal nature on the right. However, the boulevard was not positioned fully on the edge of the top of the dike, because the aim was to let the path cross through the wheat field to enhance the agricultural experience. The transition from agriculture to tidal nature was gentle to enhance the nature value. This transition included a flower edge and a zone with reed. The vegetated tidal nature continued until the unvegetated tidal nature started.

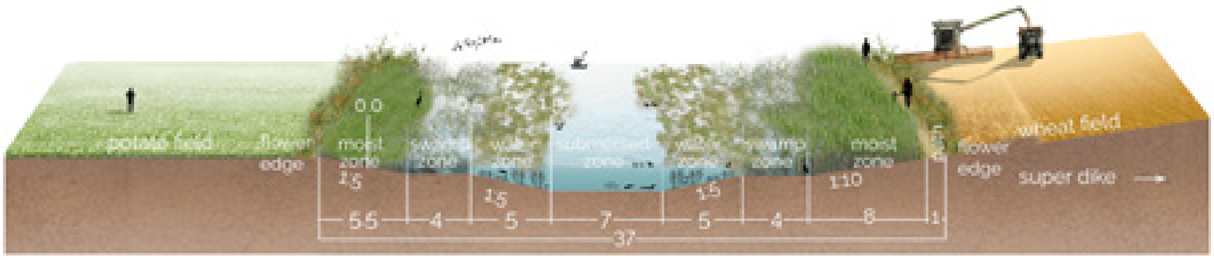


Fig. 81. *The new broad seepage ditch adds natural and recreational value, dimensions in m, heights in relation to NAP.*

Fig. 82. *The top of the tidal super dike, including freshwater dependant agricultural land use.*

The new profile and freshwater bubble of the agricultural super dike

Besides the tidal super dike, an agricultural super dike was implemented (Figure 83 & Figure 84), because an 'inlaag' was positioned in front of the planned location for the super dike. This 'inlaag' was conserved to preserve the landscape identity. It was not useful to create a gentle slope at the coastal side of the dike as the dike was not directly adjacent to the Oosterschelde. The dike had a gentle slope (1:30) at the land side of the super dike. A freshwater bubble would evolve in the dike. Also, the existing freshwater bubble would be enlarged where the subsoil was permeable. This resulted in a maximum depth of 45 to 75 m of the freshwater bubble. This combination of the freshwater and the gentle slope allowed growth of an orchard, which was also present in the original situation. The original coastal side of the new super dike was designed with the same slope (1:2) as the original 'inlaag' dike to preserve the identity of the 'inlaag'.

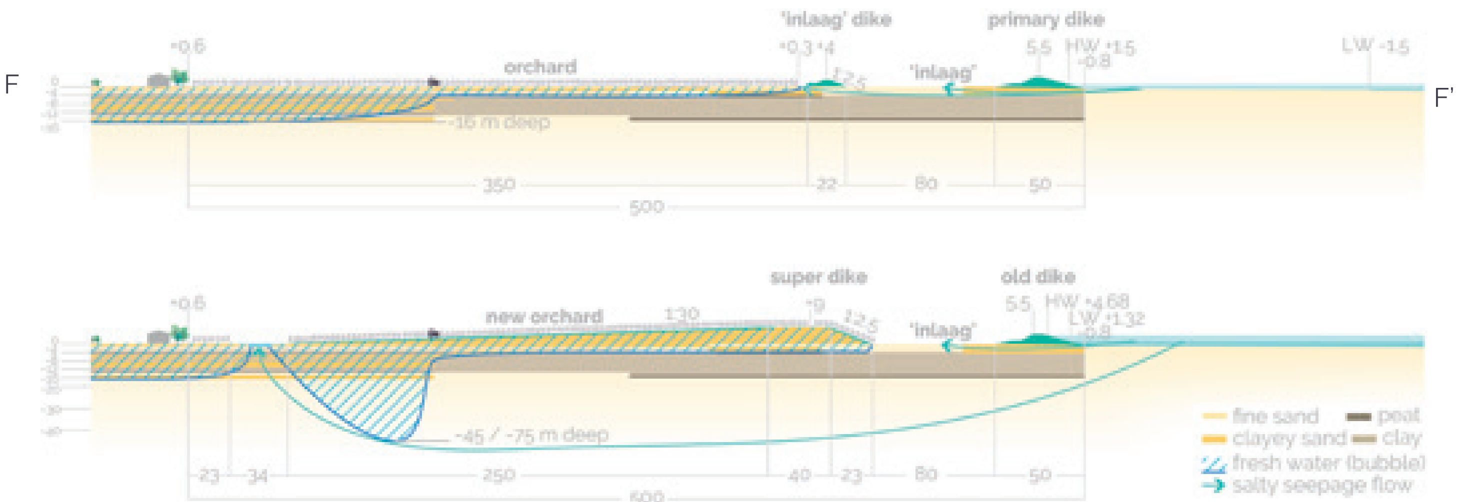
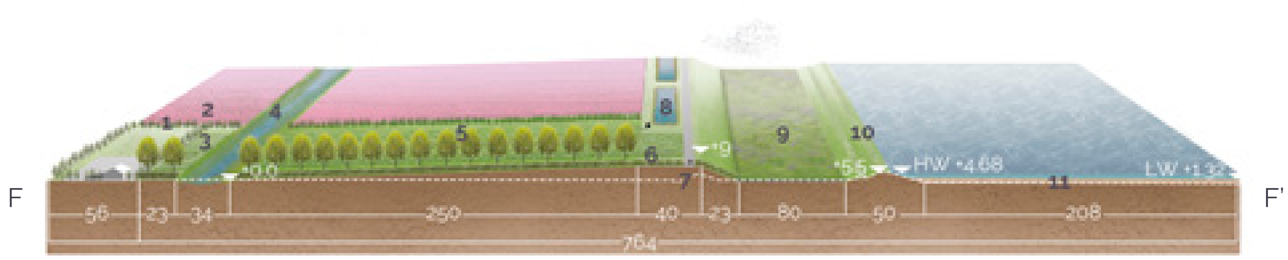


Fig. 83. Section of the existing situation (top) and the new agricultural super dike (below), dimensions in meters (m), heights in relation to NAP. HW: high water level, LW: low water level. Adapted from (TNO, n.d.). Location of section indicated in Figure 73.



1 Zeeland hedge (Zeeuwse haag)
2 Freshwater dependant flower bulb field
3 Freshwater dependant potato field
4 Seepage canal
5 Tree lane (Populus Alba)
6 Freshwater dependant low stem orchard
7 Old profile
8 Freshwater basins
9 'Inlaag', salty nature
10 Old dike
11 Silted up soil: tidal nature

Fig. 84. Section of the layout of the agricultural super dike, dimensions in m, heights in relation to NAP. HW: high water level, LW: low water level.

The design of the top of the new agricultural super dike is displayed in Figure 85. The recreational path was positioned at the right side of the top to enlarge the agricultural land maximally. The path kept 4.5 m distance from the slope to allow walking through the orchard to increase the agricultural experience. The path had a boulevard character and included benches on both sides of the path. Besides an orchard, a potato field continued on top of the super dike. This part of the field on the top of the dike could serve for education and could give the farmer some extra income. Furthermore, a row of popular trees ended on the left side of the dike. This row was originally present in the landscape and was brought back to keep the landscape identity. The final design element was the freshwater basin. These basins were designed in plain, geometrical shapes to fit in the rectangular, straightforward shaped landscape. The basins included a natural edge to increase the ecological value.

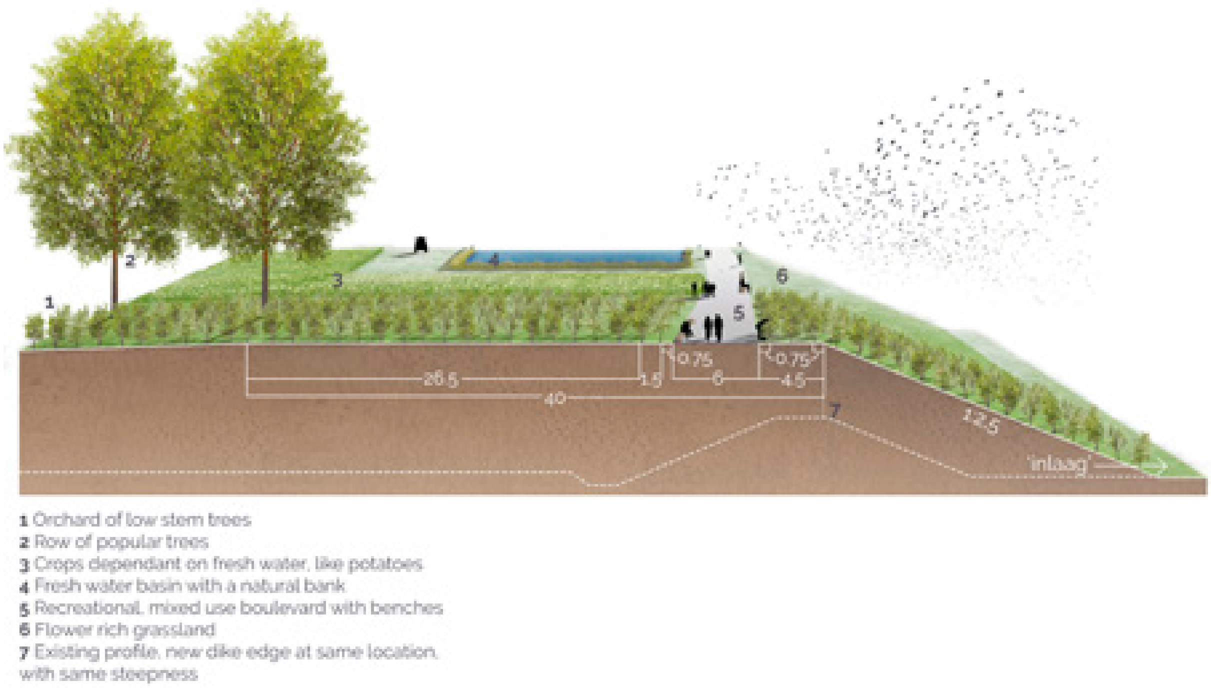


Fig. 85. The new top of the agricultural super dike. Dimensions in m.

4.4.4 THE DESIGN OF THE SECONDARY AND PRIMARY DIKES

The aim of the design of the secondary and primary dikes was to strengthen the difference between them. The dike types were developed based on the landscape identity vision. The primary dike was broad and robust designed, and the secondary dike was designed as narrow and plain as possible. The primary dike (Figure 86 & Figure 88) had a stepped slope of 1:2 and a slope of 1:4. The top of the primary dike was 3 m wider than the upgraded secondary dike. The upgraded secondary dike (Figure 87) had a slope of 1:2 on both sides.

The new primary dike was positioned landward behind the existing tidal nature. The path of the dike was positioned at the coastal side of the top of the dike as it was expected to be the least disturbing for the nature. Adjacent to the path, a zone for benches and picknick tables was designed. This zone was designed at a distance from the nature as it was expected that this zone would give more noise. Sheep would maintain the grass, as was often done in Zeeland, enhancing the nature value and adding liveliness to the dike. A fence was added, like the fences in the region to fit into the landscape. The dike path was designed 0,6 m broader than the secondary dike as a historic 'Muralt wall' was placed back on top of the dike.

The secondary dike was lined out on the centre of the old dike to preserve the original spatial setup maximally. The path was specifically designed in the middle of the dike to strengthen the symmetry. Sheep would also maintain the dike.

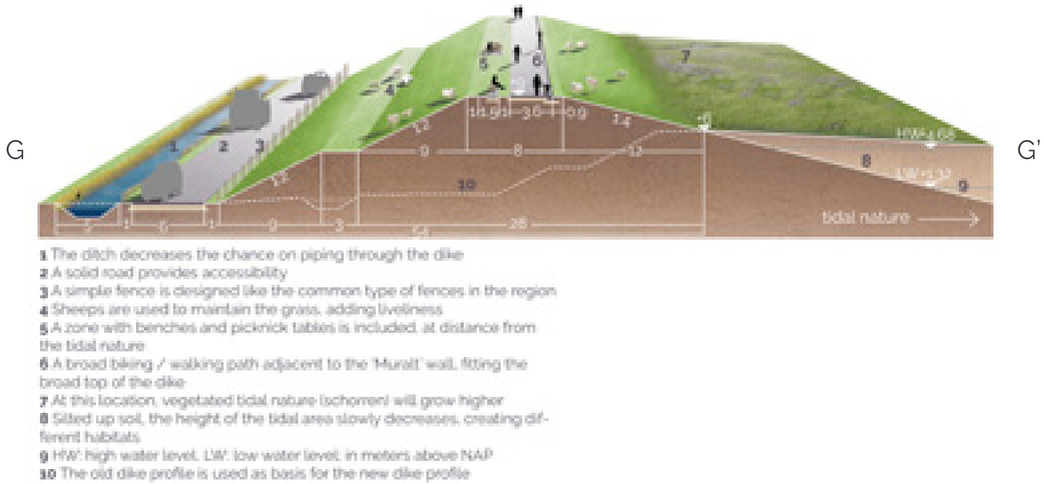


Fig. 86. Section showing the primary dike. Dimensions in m, heights relative to NAP, HW: high water level, LW: low water level. Location of section indicated in Figure 75.

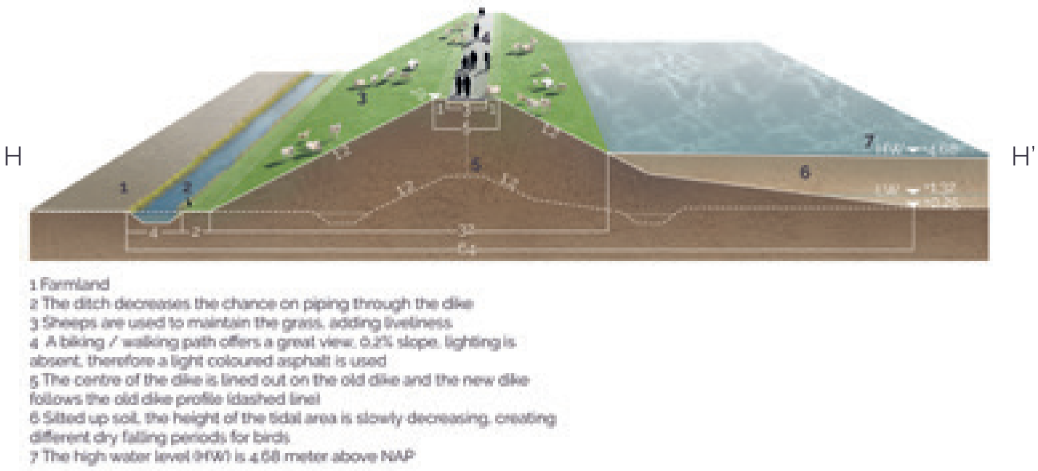


Fig. 87. Section of the upgraded secondary dike. Dimensions in m, heights relative to NAP, HW: high water level, LW: low water level. Location of section indicated in Figure 75.

Fig. 88. Visualization of the primary dike, showcasing land use changes in the steps 1 and 2 related to SLR over time. Location of image is shown in Figure 73 and 74.

5 DISCUSSION

The objective of this study is to generate effective design principles which combine landscape quality and SLR adaptation to understand how SLR adaptation can sustain or enhance existing landscape qualities.

Some studies investigate SLR adaptions while considering their effect on the landscape. Van Veelen et al. (2015) & Zandvoort, Kooijmans, et al. (2019) argue that SLR adaptation requires knowledge of the local landscape characteristics. Furthermore, Zandvoort, Kooijmans, et al. (2019) argue that SLR adaptation by spatial design offers insight in the consequences of measures. Moreover, systematically combining designing and testing the effect of adaptations can prevent landscape quality loss (Nillesen & Kok, 2015; van Veelen et al., 2015; Zandvoort, Kooijmans, et al., 2019).

Likewise, in this thesis becomes clear that studying local landscape qualities and bottlenecks is important when adapting to SLR. By using RTD to develop landscape designs, insight is gained in the effect of SLR adaptation measures on these qualities and bottlenecks. Such insights help to select types of measures to determine the locations of measures and to know which measures to combine. Altogether, this contributes to ensuring the landscape quality while adapting to SLR.

In other studies, SLR solutions lack several aspects. Firstly, most of the studies lack how the landscape quality is affected (Busscher et al., 2018; Djagiri, 2018; Nillesen, 2019). Secondly, the solutions are often focused on one goal per solution. Thirdly, the solutions lack a level of detail. Fourthly, a practical test such as a case study is often lacking. Fifthly, some of them lack adapting to the uncertainty of SLR. The study of Nillesen (2019) included too generic solutions to integrate flood risk strategies with spatial quality. The study of Al (2018) does discuss solutions in more detail, but only focuses on improving the water safety, lacks the inclusion of SLR uncertainty, and lacks the effect on landscape quality. The study of Marjolijn Haasnoot, Brown, et al. (2019) does focus on different goals, but remains very generic, and lacks a focus on landscape quality.

In comparison to the mentioned existing research, the principles of this research are relevant. They illustrate how to integrate landscape quality and SLR adaptation, include detailed requirements, and show how they practically can be applied in detail. Moreover, each principle focused on multiple goals at the same time. Finally, the uncertainty aspect is integrated in some principles. Therefore, the results of this thesis are relevant due to the new generalizable knowledge concerning adaptation of SLR resulting in landscape quality.

5.1 COMPARING THE PRINCIPLES TO EXISTING LITERATURE

The results show that the four principles effectively achieve the set goals. The first effective principle is the super dike. Based on the results, this principle mainly increases the water safety and reduces the consequences of salinization and freshwater shortage. From literature becomes clear that there is a correlation: the wider a super dike, the more resistance to storm surges. Furthermore, super dikes can be multifunctional, however, they also require a lot of space. Moreover, super dikes are suitable to be combined with natural strategies (Al, 2018). This corresponds with the super dike principle. However, the super dike principle includes new detailed knowledge. The super dike illustrates in detail how a freshwater bubble can be increased, and how a specific dry falling tidal nature zone can be created. Also, specific dimensions are included. Furthermore, the principle illustrates how the landscape identity can be conserved.

The second principle was the tidal protection grid. Based on the results, this principle mainly reduces the consequences of sediment shortage, and reduces the threat of a shorter dry falling time. According to Vuik et al. (2019), natural structures such as brushwood dams can indeed stimulate sedimentation, and thus mitigate erosion. From literature becomes clear that indeed oyster and mussel banks can catch sediment, resulting in height increase of the soil and reduction of wave run-up (Borsje et al., 2011; Salvador de Paiva, Walles, Ysebaert, & Bouma, 2018). Furthermore, Schotanus et al. (2020) state that experimental fences enhance the growth of mussel banks. This corresponds with the results of this study. However, the principle includes new detailed knowledge than what was found in literature. The principle illustrates in detail what setup of the protection grid is required to enhance sedimentation and reduce erosion. Also, specific dimensions are included. Moreover, the principle includes guidelines to enhance the landscape identity.

The third principle was the silt motor. Based on the results, this principle mainly reduces the consequences of sediment shortage, and reduces the drowning of tidal nature, if the sediment was retrieved outside of the current system. If the sediment is retrieved from inside the current system, the principle only mitigates to the problems. Indeed, according to Best et al. (2018), marshes and mudflats drown without increasing the accretion rate by sediment supplies. Thus, the results in general correspond with previous research. An integral approach for determining the location of a suppletion was developed by van der Werf et al. (2019). But it seems that they only focus on excluding locations to determine a suitable location.

However, the principle includes extra knowledge in comparison to existing literature. Being guidelines to conserve the landscape identity and guidelines for the relevant location of the suppletion. Unfortunately, this guideline remains very general. Therefore, this principle includes fewer new knowledge than the other principles. This suggests that more research is needed to specify this principle.

The fourth effective principle is the new tidal nature landward. Based on the results, the principle mainly improves the water safety, improves the consequences of sediment shortage, and reduces the drowning of tidal nature. As Vuik et al. (2019) state, salt marshes can indeed decrease wave run-up on flood defences. However, these foreshores require continuous sediment supply, which also becomes clear from the results of this thesis.

Thus, the results correspond with previous research. However, on the detailed level, the principle indicates under what conditions the new tidal nature should be created. Partly, this offers new insights. However, Brunetta, de Paiva, & Ciavola (2019) already suggest that excavation of a general creek pattern enhances development of the new landward tidal nature.

To summarize, on the general level, the results correspond with previous research. As the results correspond with previous research, but also generate new knowledge, suggested is that the selected methods were useful. The newest knowledge was generated in the super dike principle, and the least new knowledge was generated in the silt motor principle. The new insights on the detailed level of the principles increase the relevance of the results. The guidelines to preserve the landscape identity contributed to the new knowledge for all the principles.

5.3 VALIDITY & RELIABILITY

Internal validity

Firstly, the internal validity is ensured by methodological triangulation by combining qualitative and quantitative methods for data collection in the first, second and fourth research question. Secondly, theoretical triangulation is used in these questions, as the landscape quality and the design are analysed from different perspectives. Thirdly, the used methods are selected and developed based on existing literature. Fourthly, the methodology is strongly connected to all four SRQ's. Also, transparency of all the research steps and results, ensures the validity of the results (van den Brink et al., 2017). Finally, by a systematic combination of testing and designing, the internal validity is ensured (Lenzholzer et al., 2013; Nijhuis & Bobbink, 2012). This is done as the RTD methodology part includes three phases of designing and testing. Based on the test results of the design, improvements are made in each next design step. Therefore, the final principles are entirely based on the test results.

External validity

The results of this study are partly generalizable, as it focuses on a case study. The conclusions can be relevant for cases where the landscape quality is endangered by similar SLR impacts. However, the landscape identity makes it less easy to generalize the outcomes of this research to other locations. The landscape identity is different for each landscape, therefore, the way of implementing the principles should be adjusted for each location. The principles created are generic guiding principles. They are not specific for a particular landscape. Therefore, their adaptation to other situations is necessary, and this alteration could influence the true effectiveness (van den Brink et al., 2017).

Reliability

Firstly, the reliability is ensured by documenting all the steps taken in the research. Secondly, all the collected data is documented. Thirdly, the way of testing the design is standardised, as the assessed variables are mostly the same. However, the variables were slightly changed during the research, as the goals were adjusted based on the test results. This could have influenced the research, but as this was documented, the reliability was preserved. However, the first test was done on the concepts, the second test was done per intervention, and finally the test was done per principle, but without scoring the variable. Thus, the tested aspects differed per test, which could negatively influence the ability to compare the test results. However, this allowed to test in more detail, which could positively influence the quality of the results. The reliability could be improved by testing the design each time on the same level. Furthermore, only one expert was used per knowledge field. The reliability could be improved by using multiple experts per knowledge field to analyse the landscape quality and to assess the designs.

5.4 LIMITATIONS

Knowledge limitations

Several limitations in knowledge are present.

Firstly, a lack of knowledge exists concerning the sand shortage problem for the Dutch coast (Zanten & Adriaanse, 2008). Experts mentioned that solutions for the sand shortage problem are lacking. However, sediment supply is necessary for the effectiveness of the principles.

Secondly, knowledge lacks about the effect of removing the OSB. Removing this barrier is a main intervention included in all the principles to restore the balance between sedimentation and erosion. However, the effect of reopening the connection to the North Sea is uncertain. The main concern is the creation of a dominance of low tide in the Oosterschelde. On top of that, the sediment shortage remains an uncertainty. Therefore, more research is needed to predict this effect.

Thirdly, climate change and SLR already include a large degree of uncertainty. Due to changing projections, the uncertainty has consequences for this thesis. To illustrate, the most recent available projections of 'local' SLR was from 2018. New projections will be published in 2021: the new climate scenarios of the KNMI. To continue, the most recent global projections were from 2019. However, new projections will be published in 2022 in the IPCC's Sixth Assessment Report. This could decrease or increase the relevance of the results of the research. This could also result in required adjustments of the principles of this thesis, even though these aimed to include the uncertainty of SLR.

Fourthly, sufficient subsidence projections are lacking for the project area. The subsidence is relevant as it is part of the total relative SLR (Sayol & Marcos, 2018), and can largely increase SLR. However, different subsidence projections were found. Moreover, these projections vary locally, resulting in a lot of uncertainty. Due to lack of knowledge, this was left out of the research.

Analysing the most important landscape qualities and bottlenecks

In the first step of the research, the most important landscape qualities and bottlenecks were analysed for each layer of the complex-layer approach. However, no expert could be selected for the layer 'energy', therefore, this topic was neglected in the research. In a next study, this topic could be included to better analyse the landscape quality.

Only the qualities and bottlenecks which scored a 5 were selected as basis for the goals. This was done to allow focus on the most important aspects. However, other qualities and bottlenecks sometimes scored a 4.8. It was not analysed when a difference in scores was significant, due to the time limitations. This hard threshold of only selecting the 5 scoring could have influenced the results.

The way of analysing the qualities and bottlenecks was done by a digital form. However, it might be that a discussion would give more clear results, as this would give the opportunity to ask for clarifications. On the other hand, the expert could fill the form in on his or her own time, and this could have given better results.

The qualities and bottlenecks were rated on relevant parameters. These were based on literature, but little existing literature was available concerning landscape quality parameters. This limitation could be overcome by specifically studying parameters to score landscape qualities and bottlenecks.

Furthermore, landscape quality was assessed by experts. The experts had to know the region. However, by including experts originating from Zeeland, their objectiveness could be influenced. This effect could be studied by including experts from the same knowledge field, which do not come from the region, but are familiar with the region.

The landscape and SLR analysis

In the third step, a landscape analysis was conducted. This included clarifying the set goals and studying the landscape identity. A field survey was part of that study. However, the season, the daytime, and the weather conditions of the field survey could influence the concentration of the researcher. The temperature was low, but a good vision was possible due to a clear sky. However, this may have resulted in a too positive mindset of the researcher. This effect could in future studies be reduced by doing multiple field surveys with different conditions.

In the fourth step, the SLR impact analysis was only done by a literature study, due to time limitations. However, expert discussions could have increased the knowledge about these impacts.

The adaptation strategies and measures

In the fifth and sixth step, adaptation strategies and measures were studied by conducting a literature study. This offered a quick overview, but a reference study could have led to more detailed measures. However, it is not certain if this would have led to different strategies and measures and would be more time consuming.

The RTD phase: designing and testing

In the seventh and eighth step, sixteen concepts were developed and tested. The scale of the concept was large (1:75.000) to enhance 'abstract thinking'. However, this could have decreased the ability to test the concepts, as the concepts were abstract. Due to time limitations was chosen to only develop the concepts on an abstract level.

The rated goals had to be tested by a small group before doing the real expert judgements (Kumar, 2011). However, this Likert scale was not tested, due to the limited availability of time and experts. Also, there has been a deviation from the used expert judgement protocol of Cooke & Goossens (2008), being a singular focus on performance variables. Additionally, the dry run exercise is skipped, as limited experts are available. Also, an expert training session is not executed, due to the limited availability of experts and time. Also, in the expert elicitation session, no normative analyst and substantive analyst are involved, due to a limited budget, and limited analyst availability. Due to time limitations, a robustness and discrepancy analysis is not part of the process, as goes for a feedback communication, and the post-processing analyses. However, the results of the expert judgements appeared to be useful, as the results corresponded with the results in existing literature.

The best scoring concepts per strategy were selected as basis for the new designs. However, it was unclear if the difference between the highest scores and the other scores was significant. Unfortunately, no statistical analysis was done due to time limitations. Also, it could be that by improving the other concepts, other effective principles could be created. However, timewise it was the quickest to generate effective principles by focusing on the highest scoring concepts.

Another possible influential effect was that the selection of the highest scoring concepts from all test results might have given different results. Because the sub research question aimed to study the different strategies, the concepts where further developed per strategy.

In the ninth and tenth step, three designs were created and tested on the variables being the main goals. However, the salinization and freshwater shortage issue was added to the main goals, because the first test pointed out that this goal was significantly important. Focusing on this important goal may have increased the relevance of the research. The highest scoring intervention per goal was selected as basis for the principles in the next step. However, due to time limitations, it was not statistically analysed whether this difference was significant. This could have influenced the selection of the interventions, and therewith, the principles. Also, it is not certain that the lower scoring interventions could not become effective principles. However, focus was also required to be able to develop detailed new knowledge within the principles. This supports the selection of only the highest scoring principles per goal.

During the testing of this goal, it became clear that salinization be a problem, but also as a quality. An intervention could be advantageous for nature, but could be disadvantageous for agriculture. Moreover, salinization could allow exploitation of farmland for aquaculture, which be a new quality. Therefore, it should be considered that salinization can be a quality as well as a bottleneck.

In the eleventh and twelfth step, the preliminary design and principles were created and tested. These were qualitatively tested by a group of experts, without using scores. This was due to time limitations of the meeting. Unfortunately, the degree of effectiveness was not measured this way. However, the experts agreed that all the principles could work, so the principles were considered effective.

In the thirteenth step, the final design and principles were generated. This was an improvement of the previous test. However, these principles were not tested anymore due to time limitations, so the degree of effectiveness remained unclear.

To conclude, the most important weaknesses are found in the testing of the RTD phase. In the first test, only a landscape architect was approached to test the concepts. In the second test, only one expert per knowledge field was selected for testing the designs. Furthermore, the third test lacked ratings, where test one and two did included ratings. Finally, a final test was lacking, so the final made improvements were not tested. This means that no specific conclusion about the degree of effectiveness could be made.

6 CONCLUSION

6.1 ANSWERING THE MAIN AND SUB RESEARCH QUESTIONS

The research aim was to generate effective principles which combine landscape quality and SLR adaptation to understand how SLR adaptation can sustain or enhance existing landscape qualities. Therefore, a combined RFD and RTD approach was undertaken to first identify current and future landscape qualities and bottlenecks, resulting in landscape design goals. These goals were specified based on a map analysis, literature study and a field survey. Next, 16 design concepts were created which were tested through expert judgement which resulted in three landscape designs as improvements resulting from the test. This was reiterated until a final design and final principles were created.

This thesis concludes that SLR adaptation does have major influence on landscape qualities. The RTD phase showed that to sustain and enhance these qualities, the next aspects need to be combined: relevant disciplines, technical design requirements and a thorough understanding of existing and future landscape qualities and bottlenecks. A landscape design can propose feasible adaptations to SLR which ensures the overall landscape quality. The conclusions of this thesis are further explained based on the four SRQ's and the MRQ.

The first SRQ is: What are the most important current landscape qualities and bottlenecks? The most important current landscape qualities in the Oosterschelde case are: the transition of the sea to the beach to the dunes, the 'Karrenvelden', and the 'Schurvelingen'. This means that nature-related qualities, and cultural-historical landscape characteristics are the most important current qualities in this case. To conclude, this might suggest that such types of qualities are also important in similar areas. The most important current bottlenecks were the disruption of nature, and the limited freshwater availability. This means that nature-related bottlenecks, and freshwater-related bottlenecks are important in this case. To conclude, this might suggest that such type of bottlenecks is also important to similar areas.

The second SRQ is: What is the effect of sea level rise on future landscape qualities and bottlenecks? The most import important future quality for this case is silty nature. The most important future bottlenecks for this case are; inundation of land outside the dikes; the finite functioning of the storm surge barrier; sediment shortage; and decrease of dry periods intertidal areas. To conclude, the effect of SLR might be an increase of silty nature, suggesting the importance of such qualities in similar areas as well. Furthermore, SLR might result in types of bottlenecks impacting tidal nature and water safety, suggesting the importance of such bottlenecks in other areas as well.

The third SRQ is: Which sea level rise adaptation strategies and measures are available to sustain or enhance landscape quality? To conclude, four adaptation strategies are available. These strategies are: defend seawards, defend landwards, accommodate seawards, and accommodate landwards. To continue, twenty measures are available. These measures are: planned abandonment, setbacks, relocation, avoidance, flood proofing, flood tolerant land use, drainage systems and pumps, floating land use / islands, wave breaking structures, floodgates, dikes and sea walls, storm surge / tidal barriers, land raising, revetment, living shoreline, supplementations, silt buffers, mussel banks, islands, and retaining walls.

The fourth SRQ is: What are effective sea level rise adaptation strategies and measures to sustain or enhance the landscape quality? To conclude, combining all four strategies and combining specific measures is the most effective to ensure landscape quality. The next eleven measures proved to be effective in the case of the Oosterschelde: relocation, flood proofing, flood tolerant land use, drainage systems and pumps, wave breaking structures, supplementations, dikes, and sea walls, living shoreline, silt buffers, mussel banks, retaining walls. To conclude, combining these strategies and measures might sustain or enhance the landscape quality in similar areas as well. However, the measures need to be tailored to the particular landscape to enhance local landscape qualities. Effectiveness of their application is also based on the overlying type of SLR adaptation strategy.

These SRQ's were subsidiary to the MRQ of this study: what are effective principles for sea level rise adaptation which sustain or enhance landscape qualities? This research answered this question with four principles likely to be effective as these are in line with previous studies on the topic. In general, the principles proved to be effective when they scored the highest on the specific goal. This means that the principles sustain, enhance, or replace a quality, without having negative effects on existing qualities.

These principles are:

1. The super dike principle

Regarding the super dike, this thesis concludes that it increases the amount of freshwater and decreases salinization. Furthermore, the water safety is increased effectively. The super dike is divided in three types. The first type is the agricultural super dike, having a gentle slope on the land side, enabling farming on the dike. The second type is the tidal super dike, having a gentle slope on the coast side, enabling nature to develop. The third type has gentle slopes on both sides of the dike, being a combination of the latter two types.

All super dike types require a seepage canal behind the dike. The dike has at least one slope of 1:30, and if no space is available, a slope of 1:10 is added. The top of the dike is permeable and freshwater collection basins enable infiltration and prevent desiccation.

Three landscape identity guidelines are set. Firstly, the existing land use should be included on the super dike. Also, existing characteristic tree rows and hedges should be included on the super dike. Furthermore, the shapes of the water basins should fit the landscape language, being geometrical and simple in this area.

2. The tidal protection grid

The tidal protection grid mitigates erosion and reduces the threat of shorter dry falling periods. This is done by placement of brushwood dams of braided willow twigs parallel to the coastline. Secondly, mussel banks are placed above -1 m relative to the average water level. Oyster banks are placed below this level. The first mussels and oysters are placed in gabions. If the sea level rises too quickly, new gabions are established with new shellfish. This way, the mussel and oyster banks will grow when sea level rises.

Also, landscape identity guidelines are established for the tidal protection grid. Firstly, region specific flora and fauna is used to protect the tidal nature. A simple, straightforward language is used. Furthermore, the pattern is a modern representation of a historic straight-lined pattern in the landscape, the 'Karrenvelden'. Finally, two dike types are generated based on present dike types in the landscape: an upgraded secondary dike, and a primary dike.

3. The silt motor

The third principle is the silt motor. This principle effectively reduces erosion as a consequence of sediment shortage. Also, drowning of tidal nature is effectively reduced. The sediment can be retrieved from ports, or from the channels in the Oosterschelde. However, these sand transportations are just mitigations to the problem of the sand shortage.

The landscape identity guideline comprises to use the natural dynamics of the region, resulting in enhancement of the natural character of the Oosterschelde.

4. The new landward tidal nature

The fourth principle is the new landward tidal nature. This principle effectively increases the water safety. On top of that, the erosion and sediment shortage are effectively reduced. Finally, the principle effectively offers a solution to the drowning of tidal nature, as it replaces endangered tidal nature.

Several guidelines were established for this principle. A general creek pattern was excavated, a minimal inlet width of 100 m was established, supplementation depended on the height of the land, and recreation spots are locally appointed. Furthermore, when a group of farms is present, these are diked as a cluster.

Finally, the landscape identity guidelines are established. The dike height must be increased. Two dike types are generated based on present dike types in the landscape: an upgraded secondary dike, and a primary dike. When a dike must be removed, the dike is replaced by a modern element reminding of the removed dike.

6.2 GENERAL INSIGHTS

After comparing the test results of the RTD phase, multiple generalizable insights became clear, which are considered as conditions to apply the principles in other landscapes:

1. The substratum determined the design, as the groundwater behaviour is determined by the (sub)soil and the altitude. These characteristics result in different degrees of seepage and infiltration, and thus determine the amount of freshwater, and the degree of salinity. The principles were applied in the landscape based on these characteristics. To conclude, the soil and water system influence the application of the principles in the landscape.

2. The type of used measures determines the type of land use. For instance, a super dike resulted in freshwater-dependent agriculture. The tidal protection grid resulted in a combination of shellfish and tidal nature. The switching system resulted in a combination of agriculture and tidal nature.

3. The spatial layout of the landscape determines the location of the principles, and vice versa. The required size of the principles determined the implementation into the existing landscape. The super dike principle required much space and can only be positioned at a broad zone of uninhabited land. Furthermore, the switching system was developed to stepwise change the uninhabited and the inhabited land into tidal nature and agricultural land.

4. The type of land use determines the design of recreation routes and elements. As tidal nature is vulnerable to disruption of recreants, the routes are altered to prevent disruption. Also, recreation elements are designed to disrupt nature as little as possible. Furthermore, agricultural land was used as a magnet to distract recreants from the tidal nature areas.

5. The landscape identity determines the design of the principles, as the made decisions in the design of the principles are based on the vision of the landscape identity.

To conclude, the substratum, the type of used measures, the spatial layout of the landscape, the land use, and the landscape identity determined the design.

6.3 ON THE RELEVANCE OF RESULTS

The four principles are significant because they contribute to closing the knowledge gap: the integration of SLR adaptation and landscape quality. Based on three tests and three steps of improvements of the design, the retrieved principles proved to effectively adapt to SLR, with landscape quality as a result.

The principles have extra value due to the focus on different goals. As SLR has different impacts on the different landscape quality in different regions, this results in different goals per region. As the principles aim to achieve different goals, the principles can be applied to multiple regions with similar goals. Above that, some principles effectively integrate multiple goals. Thus, a single principle can be used for a specific goal, but a single principle can also be used to achieve multiple goals simultaneously.

The principles are relevant for different knowledge fields. They can be used for water safety, nature development, and the agriculture and the fishing industry. Above that, the principles are the most relevant for landscape architects and planners, because they deal with different layers of the landscape in an integrative way and can determine the landscape quality (Busscher et al., 2018). When landscape architects and planners use the principles of this study, they can specifically use them to sustain and enhance landscape quality.

The principles focus on goals which are not only relevant for the south-east coast of S-D, but are also relevant for other coastal areas globally. After all, the principles focus on goals related to the most important global SLR impacts. These impacts are salinization, endangered water safety, and increased erosion. To elaborate, saltmarshes are endangered by permanent inundation, enhanced by increased erosion (Nicholls & Cazenave, 2010). The goals of this thesis are specifically focused on these impacts. This makes the principles useful, as they address goals which are focused on the global most important SLR impacts.

To summarize, the principles are of significant relevance due to the integration of SLR adaptation and landscape quality, the focus on different goals, the applicability for multiple fields of knowledge, and are relevant for world-wide coastal locations with similar problems.

6.4 RECOMMENDATIONS

From the discussion becomes clear that multiple aspects of this thesis could be further studied. The most important aspect to study is the effectiveness of the principles on a detailed level. This is needed because no existing literature was found which supported the detailed findings. Moreover, some experts mentioned that it was hard to rate some aspects of the principles, because these were unrealized ideas. Therefore, it is recommended to test the principles in more detail. This can be done by conducting a field experiment, or by digitally modelling the effects of the principles (De Ronde et al., 2013; Zanten & Adriaanse, 2008).

Besides that, other concepts, designs, and interventions which were deselected during the RTD phase could be improved further. These design products did not score high enough yet, but by improving these, other relevant and effective principles might be generated.

Some other unclarities could be studied further. For instance, it was unclear if the new landward generated tidal nature would enhance or decrease the seepage pressure in the surrounding farmlands. Furthermore, it was unclear if silted up tidal nature which is turned into agricultural land would include a freshwater bubble, and how long the development of the bubble would take.

Finally, two knowledge uncertainties require more studying. Firstly, the sand shortage problem (De Ronde et al., 2013; Zanten & Adriaanse, 2008), and secondly, the effect of removing or transforming the OSB into a bridge on the tidal system of the Oosterschelde.

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APPENDIX I DESCRIPTION SELECTED EXPERTS

Frans van Zijderveld - Ecology & nature
Frans his expertise is in nature management, -development, administrative- and policy lobby, environmental management, and stewardship ('rentmeesterij'). He is currently provincial ambassador of the Southwestern delta, and steward ('rentmeester') of Zeeland for 'Natuurmonumenten' (Nature Monuments). He has reasonable knowledge of Zeeland and S-D, concerning geography and landscape, administrative aspects, society, and history and future. Frans has worked for years in S-D and Zeeland. Also, he has lived for some years in Zuid-Beveland and has often spent holidays in S-D (personal communication Frans van Zijderveld, April 8, 2020).

Maurice Buuron – Infrastructure
Maurice has a study background in spatial planning and public administration. His current experience concerns mobility and infrastructure. He is currently task manager Smart Mobility at the Province of Zeeland. He has mainly knowledge concerning the mobility of S-D and especially concerning the future of mobility in Zeeland. Maurice has been involved in some projects focused on mobility in S-D. He lives for twelve years in Zeeland and has provincial experience with diverse projects and initiatives (personal communication Maurice Buuron, April 4, 2020).

Marcel van den Berge – Recreation & economy
Marcel has expertise regarding tourism at municipal and provincial level, and economic policy related to MKB (a network of entrepreneurs in Zeeland). Also, Maurice has expertise regarding the program Southwestern Delta. His current function is senior policy advisor recreation and economy at the municipality of S-D. He has knowledge of S-D concerning the physical characteristics and has access to a large network of entrepreneurs and groups of interest. Provincially, he has specifically knowledge relating to tourism. Marcel has been born in Zeeland, and his family originates from S-D, which means he has been raised in that region to some extent (personal communication Marcel van den Berge, March 31, 2020).

Marjan Sommeijer – Soil & water
Marjan has expertise regarding the soil and groundwater system in Zeeland, where salt and freshwater are important. She is also able to interlink this to land use and the social-economic context. She acquired this expertise because of her study background in hydrology. Currently, she is program coordinator and specialist freshwater, at the water board 'Scheldestromen' (Schelde streams). As she is involved in the Living Lab initiative in S-D. She has been raised in Zeeland and lives there as well. Also, her working area is Zeeland (Personal communication Marjan Sommeijer, April 6, 2020).

Cockie de Wilde – Green structure
Cockie de Wilde is since 2018 policy officer green and landscape at the municipality Schouwen-Duiveland. After the study Garden and landscape design ('Tuin- en landschapsinrichting') in Boskoop (currently Larenstein) she has worked for 30 years at an advice- and engineer office. Consequently, she has worked as freelancer as a policy officer at the work organization Duivenvoorde (municipality Wassenaar and Voorschoten).
She has a broad expertise regarding the green / landscape field, with specific interest in rural development. The professional, green

knowledge is a good basis for reading and appreciating the landscape.
Cockie has lived on Schouwen-Duiveland until she was 18, and still came here a lot the years afterwards, and currently the island is her working area, so she has good knowledge of the island. She knows the province of Zeeland in general, and from some cooperative projects. As municipalities of Zeeland, various contact groups consist where is worked together in the field of greenery and landscape, for example in the context of the Zeeland forest challenge. An example of a current Zeeland-wide project is the Landscape Vision for Delta Dams, where Cockie contributes to.

Miranda van der Neut – van Wagtendonk – Urban planning
Miranda has graduated as urban planner with a specialisation in urbanism. She has 25 years of experience regarding urbanism and landscape in municipalities Amsterdam, Terneuzen and S-D. She mainly was occupied with spatial visions, image quality plans ('beeldkwaliteitsplannen'), parcellation plans, restructuring plans, and public space plans. She currently works as an urban planner at the municipality of S-D. Miranda is born in and raised in S-D, she has a connection to the island and knows it well. She also has knowledge of the development history and the spatial structure (personal communication Miranda van der Neut – van Wagtendonk, April 6, 2020).

Leo Adriaanse – Water System and Safety
Leo has expertise regarding water management and water safety, ecology and nature development, area development and multi-layer safety. He is currently senior advisor water management, concerning development and vision of Rijkswaterstaat (Governmental Water Management) sea and delta. Also, he is the program coordinator of the Area Program Southwestern Delta. He has worked in Zeeland for more than 30 years and has knowledge of the region on a general level. He has knowledge of the historical development of the region and is enthusiastically committed to the area of Zeeland (personal communication Leo Adriaanse, April 14, 2020).

Pieter de Ruijter – Agriculture
Pieter de Ruijter is a dairy farmer in Schouwen-Duiveland and the chairman of Agricultural Schouwen-Duiveland (Department ZLTO). ZLTO is the Southern Agricultural and Horticultural Organization (personal communication Pieter de Ruijter, April 14, 2020).

Adriaan Haartsen – Cultural History
Adriaan is historic geographer, and author of the book 'Region descriptions province Zeeland'. He is currently director of the office 'Lantschap'. The office is specialized in physical-geographical, culture historical, and landscape aspects of the Dutch landscape. Adriaan has written 25 books and about 100 articles of the different aspects of the Dutch landscape (Bureau Lantschap, 2014). He has general knowledge of Schouwen-Duiveland, and a high amount of knowledge of the rest of Zeeland. In Zeeland, he has been involved in diverse land development projects (personal communication Adriaan Haartsen, March 31, 2020).

Eric van Zanten – Geomorphology
Eric is adviser concerning maintenance morphology Oosterschelde and is graduated as geologist. He is currently involved in the project: effects sea level rise and sand hunger Oosterschelde. He has good knowledge of Zeeland and an average degree of knowledge of Schouwen-Duiveland. He currently lives in Zeeland for a long time already. He has been involved in projects concerning the Oosterschelde and surroundings (personal communication Eric van Zanten, May 6, 2020).

APPENDIX II EXCEL SHEET EXPERT JUDGEMENTS LANDSCAPE QUALITY

Open vragenlijst

U mag bij onderstaande 6 vragen meerdere kwaliteiten/knelpunten noemen per vraag. Deel 1 gaat over de huidige situatie, deel 2 gaat over de toekomstige situatie. U kunt uw antwoord invullen in de blauwe vakken. U helpt mij het beste door een uitleg te geven bij uw antwoord.

Cijferbeoordeling

Vult u hieronder alstublieft één cijfer in de gele vakken in, u kunt kiezen uit: 1-5 en 0.

Cijferuitleg: Significant hoge mate (5), Hoge mate(4), Gemiddelde mate (3), Lage mate (2), Significant lage mate (1), Weet ik niet (0)

DEEL 1 — HUIDIGE KWALITEITEN EN KNELPUNTEN

1 Wat beschouwt u als kwaliteiten wat betreft '..........' in *Zeeland?*

Dubbelklik om uw tekst te schrijven of te bewerken

Antwoord:

	Vult u alstublieft hieronder de kwaliteiten in, zodat u deze kunt beoordelen in het gele vak met een cijfer.	*In welke mate is de kwaliteit zeldzaam?* **Zeldzaamheid**	*In welke mate is de kwaliteit onmisbaar?* **Onmisbaarheid**	*In welke mate is de kwaliteit kwetsbaar?* **Kwetsbaarheid**	*In welke mate is de kwaliteit kenmerkend voor Zeeland?* **Kenmerkendheid**
Kwaliteit a		0	0	0	0
Kwaliteit b		0	0	0	0
Kwaliteit c		0	0	0	0
Kwaliteit d		0	0	0	0
Kwaliteit e		0	0	0	0

(indien er meer kwaliteiten zijn mag u zelf extra rijen toevoegen)

2 Wat beschouwt u als kwaliteiten wat betreft '..........' in *Schouwen-Duivenland?*

Dubbelklik om uw tekst te schrijven of te bewerken

Antwoord:

	Vult u alstublieft hieronder de kwaliteiten in, zodat u deze kunt beoordelen in het gele vak met een cijfer.	*In welke mate is de kwaliteit zeldzaam?* **Zeldzaamheid**	*In welke mate is de kwaliteit onmisbaar?* **Onmisbaarheid**	*In welke mate is de kwaliteit kwetsbaar?* **Kwetsbaarheid**	*In welke mate is de kwaliteit kenmerkend voor Schouwen-Duiveland?* **Kenmerkendheid**
Kwaliteit a		0	0	0	0
Kwaliteit b		0	0	0	0
Kwaliteit c		0	0	0	0
Kwaliteit d		0	0	0	0
Kwaliteit e		0	0	0	0

(indien er meer kwaliteiten zijn mag u zelf extra rijen toevoegen)

3 Wat beschouwt u als knelpunten wat betreft '..........' in *Zeeland?*

Dubbelklik om uw tekst te schrijven of te bewerken

Antwoord:

	Vult u alstublieft hieronder de knelpunten in, zodat u deze kunt beoordelen in het gele vak met een cijfer.	*In welke mate komt het knelpunt voor in het gebied?* **Voorkomen**	*In welke mate heeft het knelpunt een grote impact?* **Impact**
Knelpunt a		0	0
Knelpunt b		0	0
Knelpunt c		0	0
Knelpunt d		0	0
Knelpunt e		0	0

(indien er meer knelpunten zijn mag u zelf extra rijen toevoegen)

4 Wat beschouwt u als knelpunten wat betreft '..........' in *Schouwen-Duiveland?*

Dubbelklik om uw tekst te schrijven of te bewerken

Antwoord:

	Vult u alstublieft hieronder de knelpunten in, zodat u deze kunt beoordelen in het gele vak met een cijfer.	*In welke mate komt het knelpunt voor in het gebied?* **Voorkomen**	*In welke mate heeft het knelpunt een grote impact?* **Impact**
Knelpunt a		0	0
Knelpunt b		0	0
Knelpunt c		0	0
Knelpunt d		0	0
Knelpunt e		0	0

(indien er meer knelpunten zijn mag u zelf extra rijen toevoegen)

DEEL 2	TOEKOMSTIGE KWALITEITEN EN KNELPUNTEN

5 Welke <u>kwaliteiten</u> verwacht u dat er ontstaan in *Zeeland* betreffende '.........' wanneer de zeespiegel stijgt?

Dubbelklik om uw tekst te schrijven of te bewerken

Antwoord:

	Vult u alstublieft hieronder de knelpunten in, zodat u deze kunt beoordelen in het gele vak met een cijfer.	*In welke mate zal de kwaliteit voorkomen?* **Voorkomen**	*In welke mate zal de kwaliteit zeldzaam zijn?* **Zeldzaamheid**	*In welke mate is het zeker dat de kwaliteit zal voorkomen?* **Zekerheid**	*In welke mate zal de kwaliteit kwetsbaar zijn?* **Kwetsbaarheid**
Knelpunt a		0	0	0	0
Knelpunt b		0	0	0	0
Knelpunt c		0	0	0	0
Knelpunt d		0	0	0	0
Knelpunt e		0	0	0	0

(indien er meer kwaliteiten zijn mag u zelf extra rijen toevoegen)

6 Welke <u>kwaliteiten</u> verwacht u dat er ontstaan in *Schouwen-Duiveland* betreffende '.........' wanneer de zeespiegel stijgt?

Dubbelklik om uw tekst te schrijven of te bewerken

Antwoord:

	Vult u alstublieft hieronder de knelpunten in, zodat u deze kunt beoordelen in het gele vak met een cijfer.	*In welke mate zal de kwaliteit voorkomen?* **Voorkomen**	*In welke mate zal de kwaliteit zeldzaam zijn?* **Zeldzaamheid**	*In welke mate is het zeker dat de kwaliteit zal voorkomen?* **Zekerheid**	*In welke mate zal de kwaliteit kwetsbaar zijn?* **Kwetsbaarheid**
Knelpunt a		0	0	0	0
Knelpunt b		0	0	0	0
Knelpunt c		0	0	0	0
Knelpunt d		0	0	0	0
Knelpunt e		0	0	0	0

(indien er meer kwaliteiten zijn mag u zelf extra rijen toevoegen)

7 Welke <u>knelpunten</u> verwacht u dat er ontstaan in *Schouwen-Duiveland* betreffende '.........' wanneer de zeespiegel stijgt?

Antwoord:

	Vult u alstublieft hieronder de knelpunten in, zodat u deze kunt beoordelen in het gele vak met een cijfer.	*In welke mate komt het knelpunt voor in het gebied?* **Voorkomen**	*In welke mate heeft het knelpunt een grote impact?* **Impact**	*In welke mate is het zeker dat het knelpunt zal voorkomen?* **Zekerheid**
Knelpunt a		0	0	0
Knelpunt b		0	0	0
Knelpunt c		0	0	0
Knelpunt d		0	0	0
Knelpunt e		0	0	0

(indien er meer knelpunten zijn mag u zelf extra rijen toevoegen)

8 Welke <u>knelpunten</u> verwacht u dat er ontstaan in *Schouwen-Duiveland* betreffende '.........' wanneer de zeespiegel stijgt?

Dubbelklik om uw tekst te schrijven of te bewerken

Antwoord:

	Vult u alstublieft hieronder de knelpunten in, zodat u deze kunt beoordelen in het gele vak met een cijfer.	*In welke mate komt het knelpunt voor in het gebied?* **Voorkomen**	*In welke mate heeft het knelpunt een grote impact?* **Impact**	*In welke mate is het zeker dat het knelpunt zal voorkomen?* **Zekerheid**
Knelpunt a		0	0	0
Knelpunt b		0	0	0
Knelpunt c		0	0	0
Knelpunt d		0	0	0
Knelpunt e		0	0	0

(indien er meer knelpunten zijn mag u zelf extra rijen toevoegen)

Hartelijk bedankt voor uw medewerking! Dit is het einde van de open vragenlijst, vergeet u niet de beoordeling in de gele vakjes in te vullen?
Als u klaar bent mag u dit document opslaan en naar mij terugmailen (emmelievanommen@hotmail.com)

APPENDIX III RESULTS EXPERT JUDGEMENTS LANDSCAPE QUALITY

Frans van Zijderveld - Ecology & nature

Current quality Zeeland/Schouwen-Duiveland	Rarity	Indispensability	Vulnerability	Characteristic	Average	Average-V
Habitat coastal breeding and migratory birds	5	4	5	5	4.75	4.7
Silty nature	4	4	4	4	4	4
Transition salt-sweet	4	4	4	4	4	4
Small scale landscape	3	3	4	3	3.25	3
Transition sea-beach-dune-inner edge dune	5	5	5	5	**5**	**5**

Current bottlenecks Zeeland/Schouwen-Duiveland	Occurrence	Impact	Average
Spatial interventions	3	3	3
Disruption themes: eutrophication (nitrogen), desiccation, fragmentation, lighting)	5	5	**5**
Climate change	3	4	3.5

Future qualities Zeeland/Schouwen-Duiveland due to SLR	Occurrence	Rarity	Certainty	Vulnerability	Average	Average-CV
Transition agriculture (more nature inclusive, less dependent on sweet water)	3	3	3	2	2.75	3
silty nature	5	4	4	4	**4.25**	**4.5**
transition sweet-salt	5	4	4	3	4	**4.5**

Future bottlenecks Zeeland/Schouwen-Duiveland due to SLR	Occurrence	Impact	Certainty	Average	Average-C
Outside the dike under water (disadvantageous for flora and fauna)	5	5	5	**5**	**5**
Pressure on ground- and sweet water	5	3	4	4	4
Nature not robust and not connected (species cannot migrate, nature cannot absorb consequences)	3	5	4	4	4

Marcel van den Berge - Recreation and economy

Current quality Zeeland	Rarity	Indispensability	Vulnerability	Characteristic	Average	Average-V
Strong family businesses	4	5	3	5	**4.25**	**4.7**
High services level (higher then without tourism)	3	5	3	5	4	4.3
Vitality in compare to other regions (Brabant etc)	4	5	4	4	**4.25**	4.3
Employment opportunities, also indirect	2	5	3	3	3.25	3.3
Balance/liveability	3	5	5	3	4	3.7

Current quality Schouwen-Duiveland	Rarity	Indispensability	Vulnerability	Characteristic	Average	Average-V
Strong family businesses	3	5	4	3	3.75	3.7
High services level	3	5	5	3	**4**	3.7
Employment opportunities	3	5	3	3	3.5	3.7
Commitment sector(s)	4	5	3	4	**4**	**4.3**
Entrepreneurship/innovation	3	5	3	3	3.5	3.7

Current bottlenecks Zeeland	Occurrence	Impact	Average
Loss recreation/liveability	4	4	4
Buyout big concerns	3	4	3.5
Too much recreational buildings	4	5	**4.5**

Current bottlenecks Schouwen-Duiveland	Occurrence	Impact	Average
Buyout big concerns	3	5	4
Pressure on rural area/'achterland' for more recreation	**4**	5	**4.5**

Future qualities Zeeland + Schouwen-Duiveland due to SLR	Occurrence	Rarity	Certainty	Vulnerability	Average	Average-CV
More cooperation	4	2	4	3	3.25	3
More innovation	4	3	4	4	**3.75**	3.5
More territory (outside the dikes/outside dunes North sea)	3	5	2	4	3.5	**4**
					3.5	

Future bottlenecks Zeeland + Schouwen-Duiveland due to SLR	Occurrence	Impact	Certainty	Average	Average-C
Sweet water	4	4	4	4	**4**
Water management	4	4	4	4	**4**
Natura 2000	3	3	3	3	3
Flood defences	4	4	5	**4.3**	**4**
Zoning	4	3	4	3.7	3.5

Maurice Buron - Infrastructure

Current quality Zeeland	Rarity	Indispensability	Vulnerability	Characteristic	Average	Average-V
No traffic jams during rush hour	5	3	3	4	3,75	4
Large scale inland shipping (binnenvaart) connections	3	5	3	4	3,75	4
Railway connection with the Randstad	1	4	5	1	2,75	2
Dams, bridges and tunnel connections	5	5	3	5	**4,5**	**5**

Current quality Schouwen-Duiveland	Rarity	Indispensability	Vulnerability	Characteristic	Average	Average-V
Sluices	3	4	4	4	3,75	4
Dams and bridges	4	5	4	5	**4,5**	**5**
Recreational bike paths and roads along dikes/water: aesthetic value	3	3	4	4	3,5	3

Current bottlenecks Zeeland	Occurrence	Impact	Average
Only one highway	5	4	**4,5**
Railway access lacks	5	3	4
Very few capacity to adapt to traffic congestions	5	3	4

Current bottlenecks Schouwen-Duiveland	Occurrence	Impact	Average
Limited public transport connections to the Randstad	4	4	**4**
N59 is not planned most optimally	3	3	3
Vulnerability access routes: low and positioned on dams/bridges	3	2	2,5

Future qualities Zeeland + Schouwen-Duiveland due to SLR	(unrated)
Additional water safety measures can be combined with access routes	

Future bottlenecks Zeeland due to SLR	Occurrence	Impact	Certainty	Average	Average-C
(evacuation)Routes over dams and bridges are under pressure, locks are no longer sufficient.					
Bridges and dams	4	5	2	3,7	**4,5**
Sluices	4	3	4	3,7	3,5

Future bottlenecks Schouwen-Duiveland due to SLR	Occurrence	Impact	Certainty	Average	Average-C
Routes over dams and bridges are under pressure, locks are no longer sufficient					
Bridges and dams	5	5	3	**4,3**	**5**
Sluices	4	2	3	3,0	3

Miranda van Neut - urban design and planning

Current quality Zeeland	Rarity	Indispensability	Vulnerability	Characteristic	Average	Average -V
Uniqueness in image quality ('beeldkwaliteit') of the villages and cities	4	4	3	4	3,75	4
Many extraordinary (cultural-historical) monuments	5	4	4	3	**4**	4
Special views with a view of towers and village / city silhouettes	2	3	4	3	3	2,7
Relationship (visible and tangible) with the water	4	4	2	5	3,75	**4,3**

Current quality Schouwen-Duiveland	Rarity	Indispensability	Vulnerability	Characteristic	Average	Average -V
Authenticity	3	3	4	4	3,5	3,3
Unique nature areas	5	4	3	4	**4**	**4,3**
Relation with water is strong, considering the magnitude and position of the island	3	5	2	5	3,75	**4,3**
Traces of the flooding disaster are still present and can be experienced on Schouwen-Duiveland	4	3	3	4	3,5	3,7
Monuments in cities and villages	4	4	4	3	3,75	3,7

Current bottlenecks Schouwen-Duiveland	Occurrence	Impact	Average
Accessibility not optimal, roads, bridges and dams	4	4	**4**
A future population decline	2	3	2,5
The economy is one-sided and mainly focused on tourism	3	3	3
Salinization and desiccation of the soil ensures that arable farming is becoming increasingly difficult	4	3	3,5
Decrease of budget to maintain monuments, and to make the buildings more sustainable	2	4	3

Current bottlenecks Zeeland	Occurrence	Impact	Average
Relative large distances due to bridges and dams	4	4	**4**
Tourism results in high peaks in the load on the environment	3	3	3
Due to the islands, the public transport is no real competitor for the car	4	4	**4**

Future quality Zeeland	Occurrence	Rarity	Certainty	Vulnerability	Average	Average -CV
New nature on transition land to sea	3	3	3	3	3	3
Possibilities tidal centres	3	3	2	2	2,5	3
Saline crops might be the future	4	3	3	3	**3,25**	**3,5**

Future quality Schouwen-Duiveland	Occurrence	Rarity	Certainty	Vulnerability	Average	Average -CV
New nature on transition land to sea	3	3	3	3	3	3
Saline crops	4	3	4	3	**3,5**	**3,5**
New possibilities water sports, reachability cities and villages over water	2	1	1	1	1,25	1,5

Future bottlenecks Zeeland	Occurrence	Impact	Certainty	Average	Average -C
More salinization of the soil	3	3	5	**3,7**	**3**
Flooding of lower land	2	3	4	3,0	2,5
Pressure on accessibility of cities and villages	2	2	2	2,0	2
Loss of villages and polders	2	4	2	2,7	3
Elevation of land results in loss of cultural-historical values	2	4	2	2,7	3

Future bottlenecks Schouwen-Duiveland	Occurrence	Impact	Certainty	Average	Average -C
More salinization of the soil	3	4	5	**4,0**	**3,5**
Flooding of lower land	2	3	4	3,0	2,5
Pressure on accessibility of cities and villages	2	2	2	2,0	2
Loss of villages and polders	2	4	2	2,7	3
Elevation of land results in loss of cultural-historical values	2	4	2	2,7	3

Marjan Sommeijer - soil & water

Current quality Zeeland	Rarity	Indispensability	Vulnerability	Characteristic	Average	Average -V
Fertile soils	0	4	4	4	**4**	**4**
Relatively few height differences	3	2	2	4	2.75	3
Varied landscape	3	3	3	4	3.25	3.3

Current quality Schouwen-Duiveland	Rarity	Indispensability	Vulnerability	Characteristic	Average	Average -V
Variation in (properties) landscape	3	4	4	4	**3.75**	**3.7**

Current bottlenecks Zeeland & Schouwen-Duiveland	Occurrence	Impact	Average
Soils sensitive to structure damage	4	3	3.5
Limited freshwater availability (groundwater+surface water)	5	5	**5**
Increasing salinization (= further decrease in freshwater availability)	3	4	3.5
Few possibilities of external sweet water supply	4	4	4

Future quality Zeeland & Schouwen-Duiveland	Occurrence	Rarity	Certainty	Vulnerability	Average	Average -CV
Increasing salt seepage pressure	3	3	5	0	**3.7**	**3**

Future bottlenecks Zeeland & Schouwen-Duiveland	Occurrence	Impact	Certainty	Average	Average -C
Increasing salt seepage pressure	4	4	4	**4**	**4**
decrease in freshwater availability	3	5	3	3.7	**4**
Soil structure damage	2	3	2	2.3	2.5
Increasing risk water nuisance	3	4	3	3.3	3.5

Cockie de Wilde - green structure

Current quality Zeeland	Rarity	Indispensability	Vulnerability	Characteristic	Average	Average -V
Structuring function (dike- and road plantation)	2	3	3	4	3	3
Relation with soil (sand vs clay); coast- and polder areas with characteristic assortment	2	3	3	3	2.8	2.7
Link with (recent) history; age of planting (in particular effect of flood and inundation)	2	2	3	4	2.8	2.7
Typical appearance (e.g. Zeeland hedges) and (sea) wind effects	2	2	2	4	2.5	2.7
Relationship with agricultural character: yard plantings (the lack of yard plantings)	3	3	3	4	**3.25**	**3.3**

Current quality Schouwen-Duiveland	Rarity	Indispensability	Vulnerability	Characteristic	Average	Average -V
dune area with forestry Westenschouwen	4	4	3	4	3.8	**4**
dyke and road plantings	3	3	3	4	3.3	3.3
yard plantings	3	3	3	4	3.3	3.3
nature / forest areas around remnants of dike breaches	4	3	3	4	3.5	3.7
estate forests around Schuddebeurs	4	4	4	4	**4**	**4**

Current bottlenecks Zeeland	Occurrence	Impact	Average
(too) few connections in the ecological structure	4	4	**4**
poor growing conditions (soil and wind, salinization)	4	4	**4**
priority agricultural production	3	3	3
cooperation in construction and management	3	3	3

Current bottlenecks Schouwen-Duiveland	Occurrence	Impact	Average
insufficiently clear choices in policy and management	4	4	**4**
(too) few connections in the ecological structure	4	3	3.5
Growing conditions are poor	4	3	3.5
priority agricultural production	3	3	3

Future quality Zeeland	Occurrence	Rarity	Certainty	Vulnerability	Average	Average -CV
Opportunities for saline nature and salt-loving plants	4	3	4	3	**3.5**	**3.5**
Preservation of islands requires more effort and therefore more appreciation; opportunity to profile cultural history even more in green structures	3	3	2	3	2.8	3.0
Opportunities for planting for heat stress / shade	3	3	3	3	3	3.0

Future quality Schouwen-Duiveland	Occurrence	Rarity	Certainty	Vulnerability	Average	Average -CV
Opportunities for planting on dikes and higher parts of the landscape.	4	3	3	3	**3.3**	**3.5**
Wet, open nature reserves can be given more space and gain in value by upscaling.	3	3	3	3	3	3.0

Future bottlenecks Zeeland	Occurrence	Impact	Certainty	Average	Average -C
Yard plantations disappear when farms are no longer viable and demolished.	3	3	3	3	3
The choice of assortment changes when sea level rise has an influence on the soil and (ground) water quality.	4	4	4	**4**	**4**
Tidal dependent areas are coming under pressure	4	4	4	**4**	**4**

Future bottlenecks Schouwen-Duiveland	Occurrence	Impact	Certainty	Average	Average -C
Salinization	4	4	4	**4**	**4**
Desiccation	4	4	4	**4**	**4**
The link to the cultural-historical lines diminishes when more space for nature is chosen.	3	3	3	3	3
When the landscape becomes more uniform, this also has consequences for recreation.	3	3	3	3	3

Leo Adriaanse - Water system and safety

Current quality Zeeland & Schouwen-Duiveland	Rarity	Indispensability	Vulnerability	Characteristic	Average	Average -V
System of dikes, dams and the storm surge barrier	5	5	3	5	4,5	5,0
Variation of islands and water (recreation/aesthetics)	5	5	3	5	4,5	5,0

Current bottlenecks Zeeland & Schouwen-Duiveland	Occurrence	Impact	Average
Lack of fresh water supply: lack of rainwater retained	4	5	4,5

Future bottlenecks Zeeland & Schouwen-Duiveland	Occurrence	Impact	Certainty	Average	Average -C
Lack of sweet water	4	5	5	4.7	4.5
Flood risk (stability dikes)	5	5	1	3.7	5
Incomplete evacuation system	4	4	1	3	4
Storm surge barrier is no longer suitable at some point	5	5	5	5	5
Sediment shortage	5	5	5	5	5
Decrease dry periods in intertidal areas (ecology)	5	5	5	5	5

Pieter de Ruijter - agriculture

Current quality Zeeland	Rarity	Indispensability	Vulnerability	Characteristic	Average	Average -V
Soil quality for agriculture	5	5	3	5	4,5	5
Infrastructure	5	4	3	3	3.75	4
Climate	5	4	3	4	4	4.3
High amount of sun and wind	5	3	3	4	3.75	4

Current quality Schouwen-Duiveland	Rarity	Indispensability	Vulnerability	Characteristic	Average	Average -V
Soil quality for agriculture	5	5	3	3	4	4.3
Lacking infrastructure	5	1	1	5	3	3.7
Climate	5	5	3	5	4,5	5
High amount of sun and wind	5	5	3	5	4,5	5

Current bottlenecks Zeeland	Occurrence	Impact	Average
Salty seepage	4	4	4
Lack of precipitation in summer	3	5	4
Water excess due to heavy rain	3	3	3
Minimal infrastructure	3	3	3
Sea level rise	1	5	3

Current bottlenecks Schouwen-Duiveland	Occurrence	Impact	Average
Almost no sweet water between Bruinisse and Zierikzee	5	3	4
Salty seepage	3	3	3
Lack of precipitation in summer	3	3	3
Lacking infrastructure	2	2	2

Future quality Zeeland	Occurrence	Rarity	Certainty	Vulnerability	Average	Average -CV
Change to new crops	1	4	2	4	2,75	2,5

Future quality Schouwen-Duiveland	Occurrence	Rarity	Certainty	Vulnerability	Average	Average -CV
Change to new crops	1	4	2	2	2,25	2,5

Future bottlenecks Zeeland	Occurrence	Impact	Certainty	Average	Average -C
Salty seepage	4	4	5	4,3	4
Lack of precipitation in summer	3	5	3	3.7	4
Processing capacity rain showers	5	5	3	4,3	5

Future bottlenecks Schouwen-Duiveland	Occurrence	Impact	Certainty	Average	Average -C
Salty seepage	5	5	3	4,3	5
Lack of precipitation in summer	5	5	3	4,3	5
Processing capacity rain showers	5	5	3	4,3	5

Adriaan Haartsen - Cultural history

Current quality Zeeland	Rarity	Indispensability	Vulnerability	Characteristic	Average	Average -V
Dune area, old land and new land	5	5	3	5	4.5	5
water management elements	3	5	4	5	4.25	4.3
ring fortresses and mounds	5	4	5	5	**4.75**	4.7
front street villages and ring villages	4	5	4	5	4.5	4.7
country estates	3	4	2	3	3	3.3
fortresses and Atlantic Wall	3	4	3	4	3.5	3.7
"meestovens"	5	5	4	5	**4.75**	5

Current quality Schouwen-Duiveland	Rarity	Indispensability	Vulnerability	Characteristic	Average	Average -V
Historic cities	3	4	3	4	3.5	3.7
front street villages and ring villages	4	5	4	4	4.25	4.3
dikes, "welen", and mainly "inlagen"	5	5	4	5	4.75	5
"vroonland"	5	4	5	5	4.75	4.7
ring fortresses and mounds	5	5	4	5	4.75	5
"karrenvelden"	5	5	5	5	**5**	5
Atlantikwall	3	4	3	5	3.75	4
"schurvelingen"	5	5	5	5	**5**	5
"meestovens"	5	5	4	4	4.5	4.7

Current bottlenecks Zeeland	Occurrence	Impact	Average
upscaling in agriculture	4	4	**4**
village expansion	3	4	3.5
neglection	3	4	3.5

Current bottlenecks Schouwen-Duiveland	Occurrence	Impact	Average
Urbanization of the inner dune edge	4	5	**4.5**
nature development	4	4	4

Future quality Zeeland

None, possibly new salt marshes (kwelders), which can be reclaimed

Future bottlenecks Zeeland

The conservancy of low laying areas as "poelgebieden, "inlagen", and old land

Future bottlenecks Schouwen Duiveland

The conservancy of current qualities as "inlagen", and "karrenvelden"

Eric van Zanten - Geomorphology

Current quality Zeeland	Rarity	Indispensability	Vulnerability	Characteristic	Average	Average -V
Dune landscape	4	5	3	3	3.75	4
Dry falling areas: slikken/schorren (salt marshes)	4	2	4	4	3.5	3.3
Dikes: old / new sea dikes, especially new sea dikes	4	5	2	4	3.75	**4.3**
Old waterways with connected old trade routes, diked-in old tidal channels, such as the Gouwe	4	2	2	4	3	3.3
Entire reclamation history and legibility in the landscape: e.g. difference in soil quality due to salinization: young polder: high location, richer farmers, old polder: low location, poorer farmers	4	5	3	4	**4**	**4.3**

Current quality Schouwen-Duiveland	Rarity	Indispensability	Vulnerability	Characteristic	Average	Average -V
function of (old) sea clay polders for agriculture: arable farming	4	5	3	3	3.75	4
Habitation patterns that follow creek ridges	3	2	3	3	2.75	2.7
Creek ridges and creek remnants	4	2	3	2	2.75	2.7
Old dikes	4	2	3	3	3	3
Old harbour cities as Zierikzee	4	4	3	4	3.75	4
Vianen and other drowned villages	4	2	1	3	2.5	3
Entire reclamation history and legibility in the landscape: e.g. difference in soil quality due to salinization: young polder: high location, richer farmers, old polder: low location, poorer farmers	4	5	3	4	**4**	**4.3**

Current bottlenecks Zeeland/Schouwen-Duiveland	Occurrence	Impact	Average
Rationalisation agriculture threatens small scale landscape (largely already happened)	4	3	**3.5**

Future quality Zeeland/Schouwen-Duiveland

Double dikes system

Future bottlenecks Zeeland/Schouwen-Duiveland	Occurrence	Impact	Certainty	Average
Poldering is problematic: low position, increased salt load agriculture				
Drowning tidal areas	5	4	0	**4.5**
Increase seepage pressure				

APPENDIX IV 16 CONCEPTS

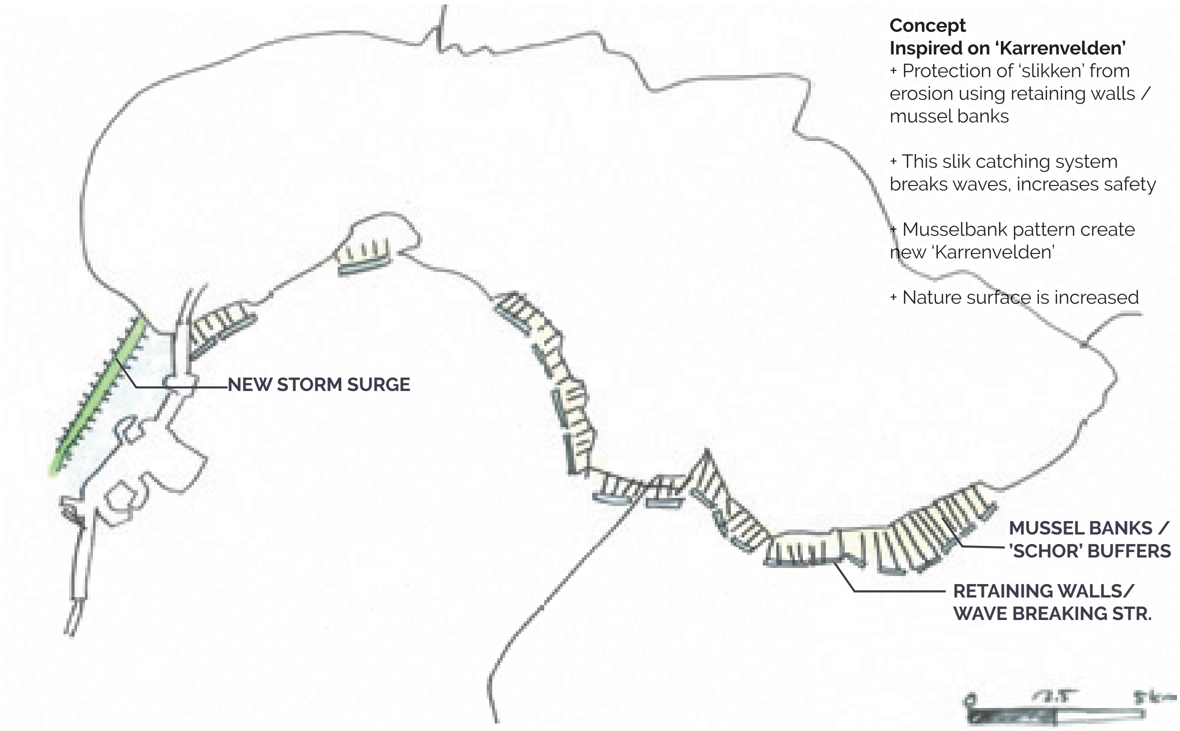
Defend sea - 'Karrenvelden' system

Concept
Inspired on 'Karrenvelden'
+ Protection of 'slikken' from erosion using retaining walls / mussel banks

+ This slik catching system breaks waves, increases safety

+ Musselbank pattern create new 'Karrenvelden'

+ Nature surface is increased



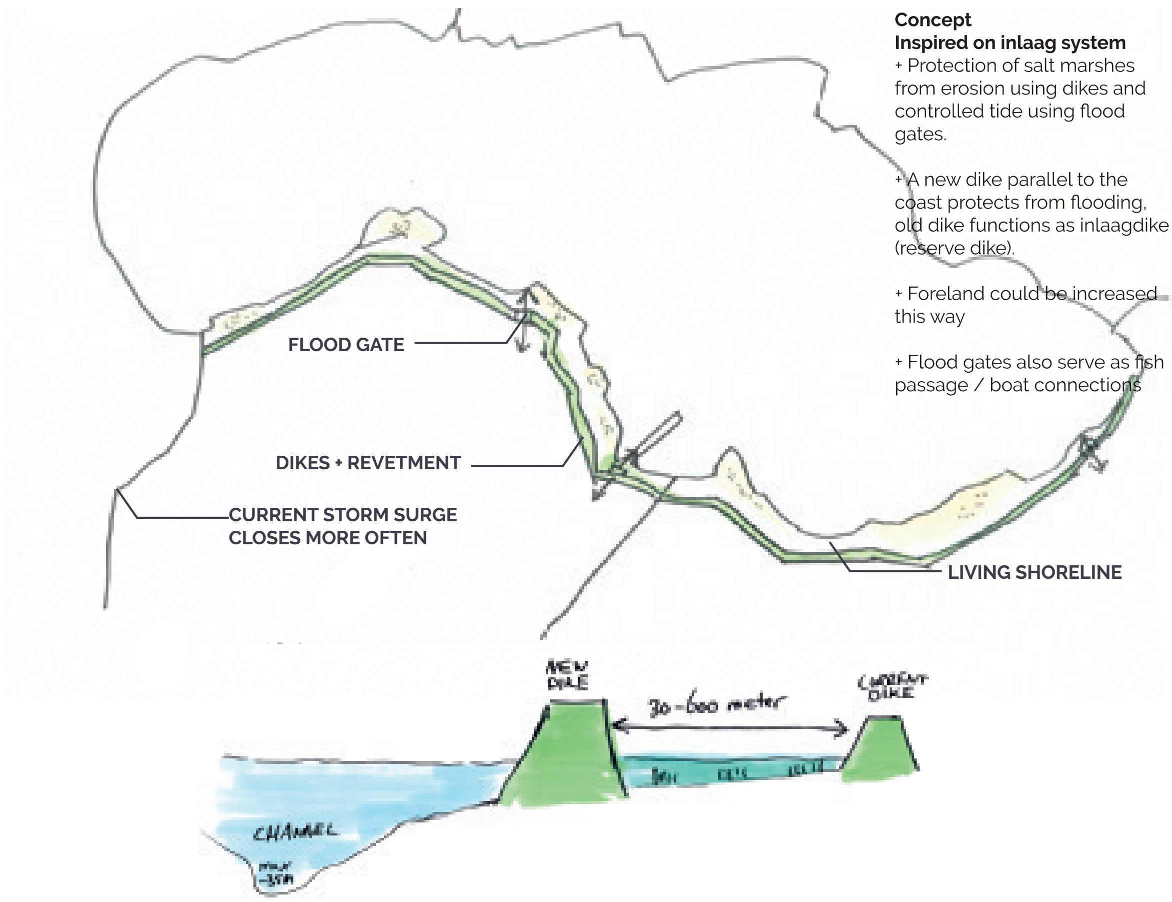
Defend sea - Tidal dike

Concept
Inspired on inlaag system
+ Protection of salt marshes from erosion using dikes and controlled tide using flood gates.

+ A new dike parallel to the coast protects from flooding, old dike functions as inlaagdike (reserve dike).

+ Foreland could be increased this way

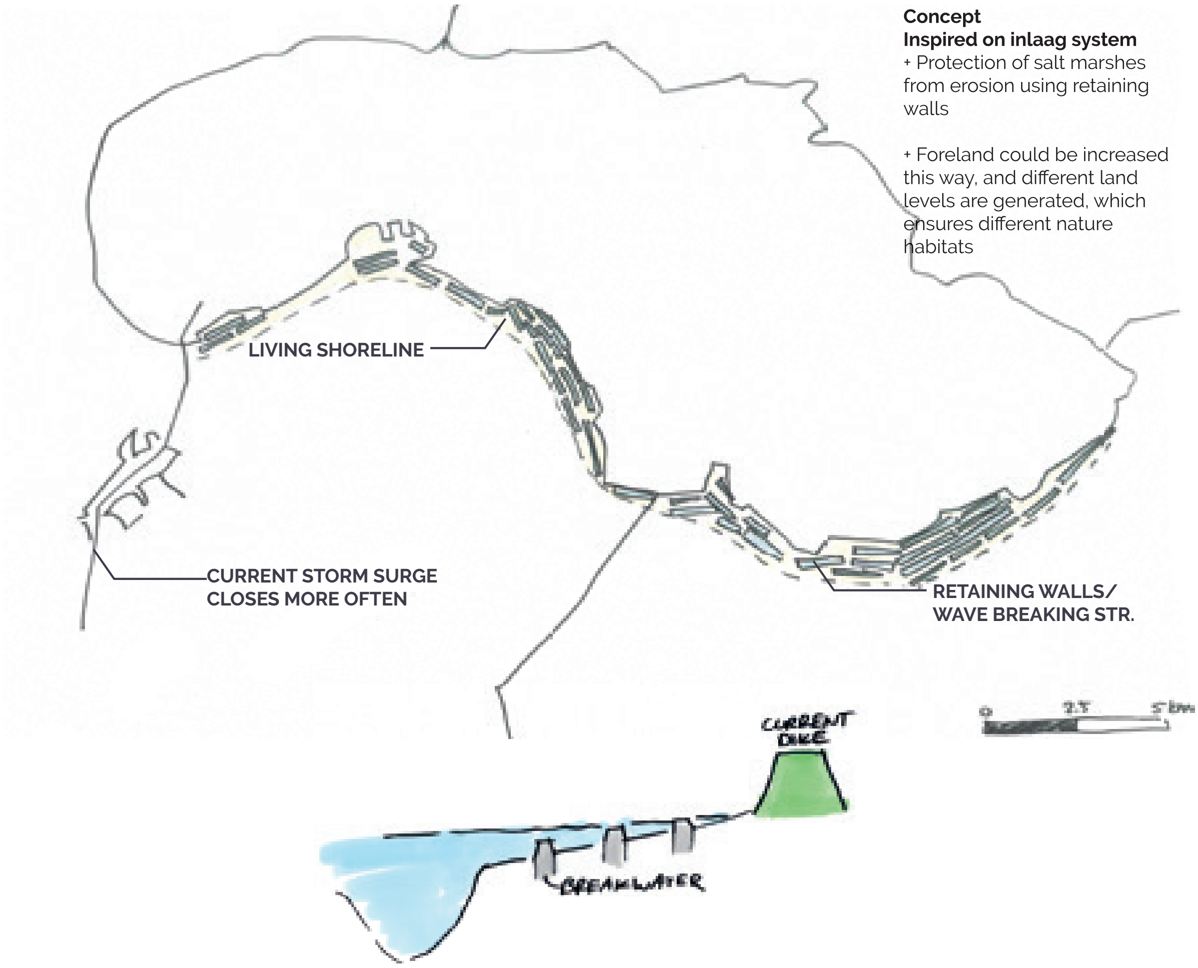
+ Flood gates also serve as fish passage / boat connections



Defend sea - Foreland first

Concept
Inspired on inlaag system
+ Protection of salt marshes from erosion using retaining walls

+ Foreland could be increased this way, and different land levels are generated, which ensures different nature habitats



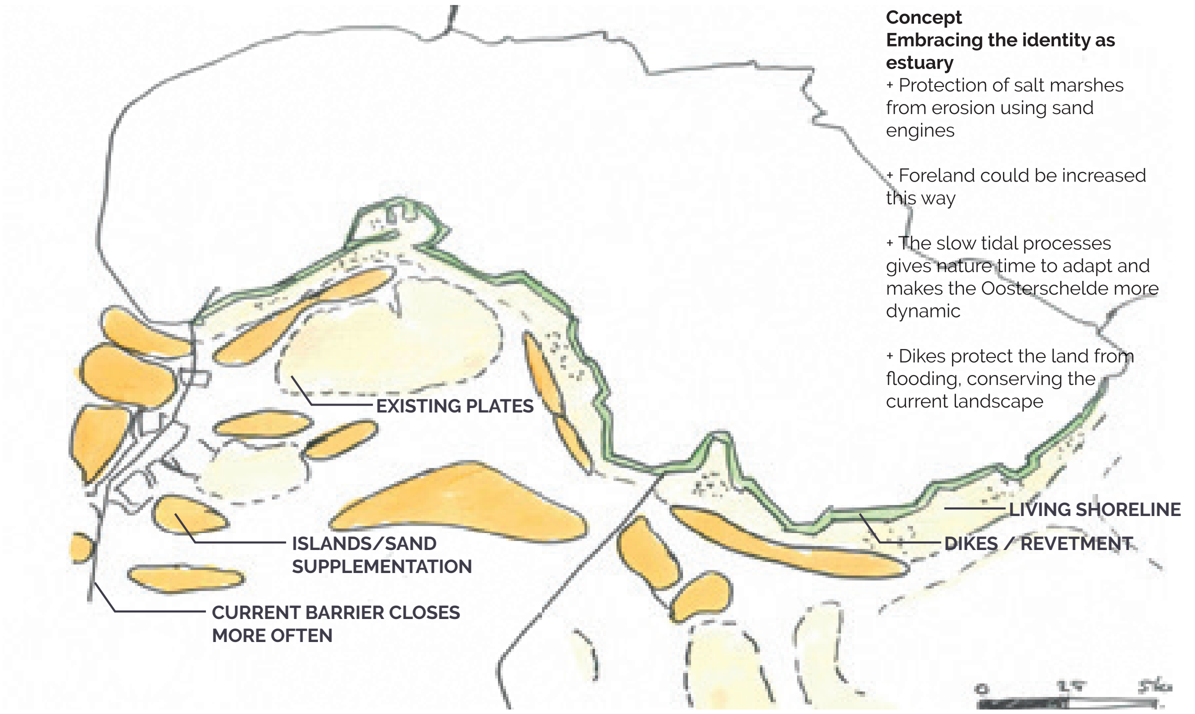
Defend sea - Island machine

Concept
Embracing the identity as estuary
+ Protection of salt marshes from erosion using sand engines

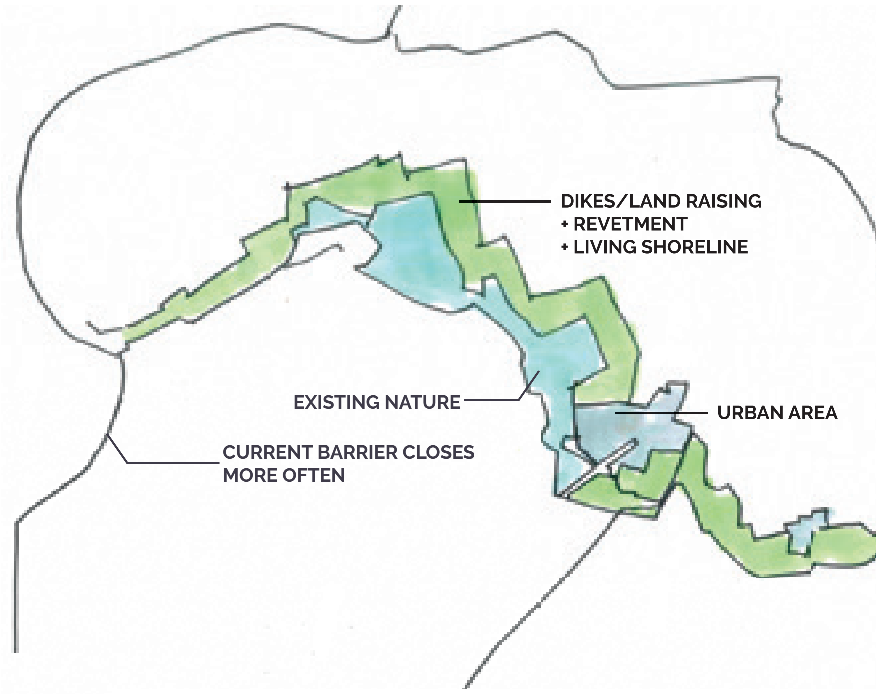
+ Foreland could be increased this way

+ The slow tidal processes gives nature time to adapt and makes the Oosterschelde more dynamic

+ Dikes protect the land from flooding, conserving the current landscape



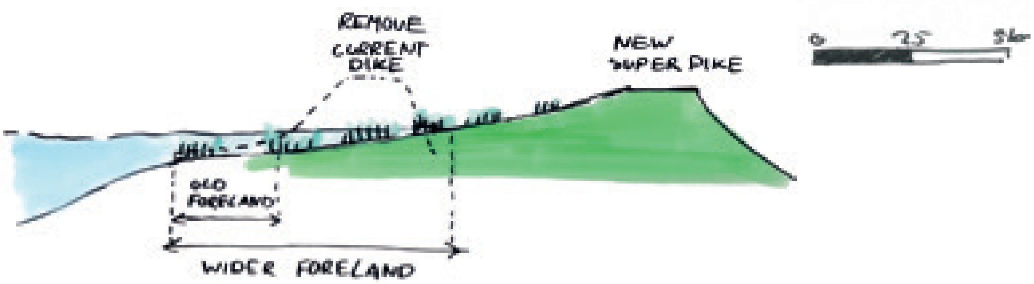
Defend land - Super dike



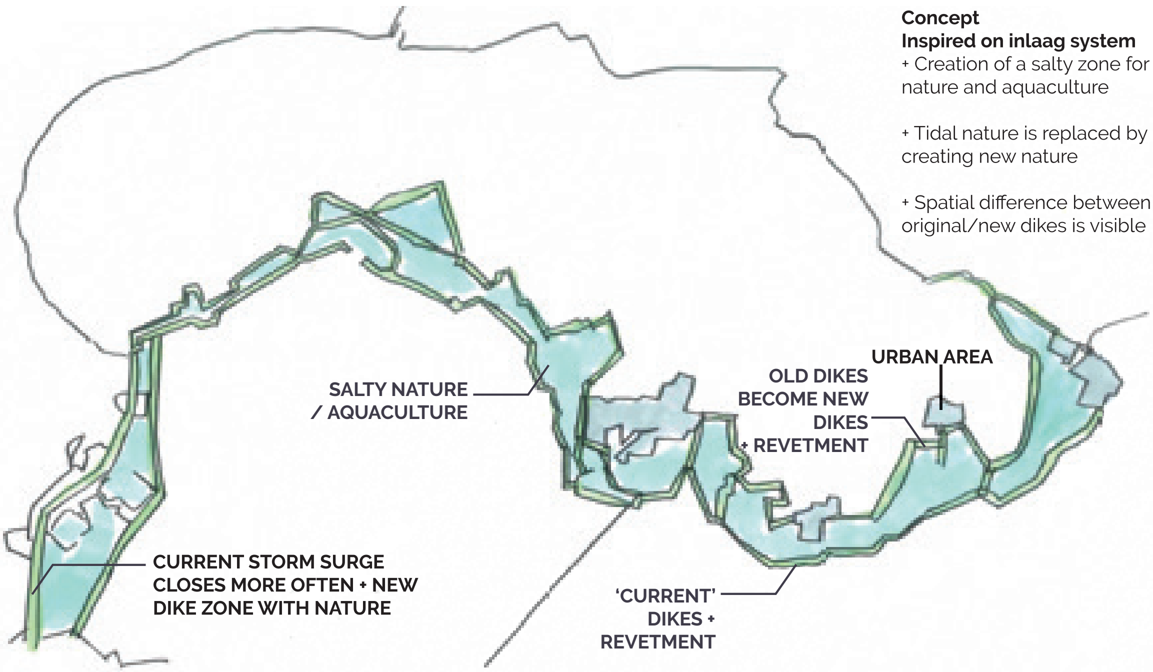
Concept
Strengthen spatial contrasts
+ Protection from flooding

+ Less salt intrusion superdike, fresh water bubble might be generated supporting agriculture

+ Gentle slope generates living shoreline, 'replaces' tidal nature



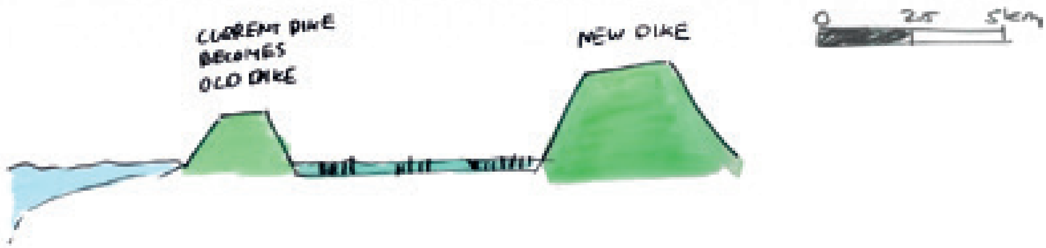
Defend land - Double dike



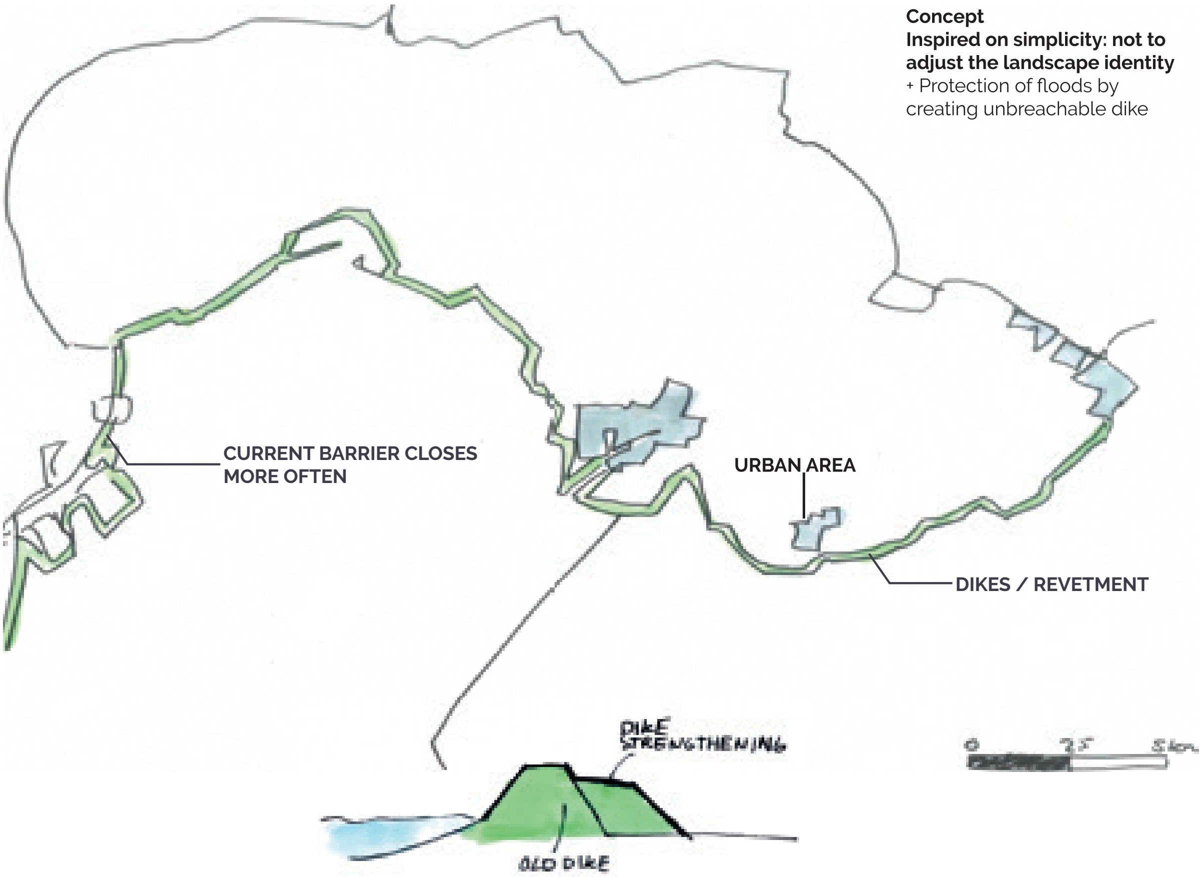
Concept
Inspired on inlaag system
+ Creation of a salty zone for nature and aquaculture

+ Tidal nature is replaced by creating new nature

+ Spatial difference between original/new dikes is visible

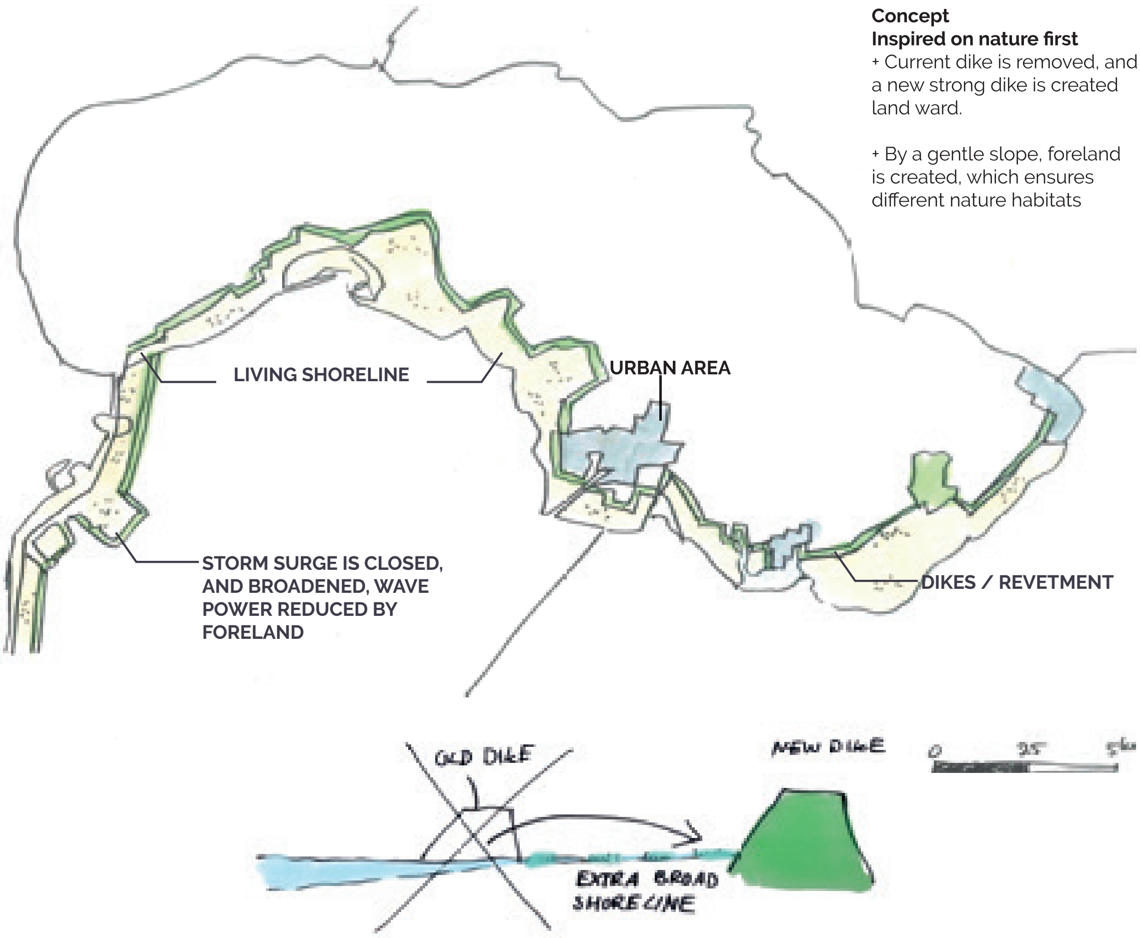


Defend land - Unbreachable



Concept
Inspired on simplicity: not to adjust the landscape identity
+ Protection of floods by creating unbreachable dike

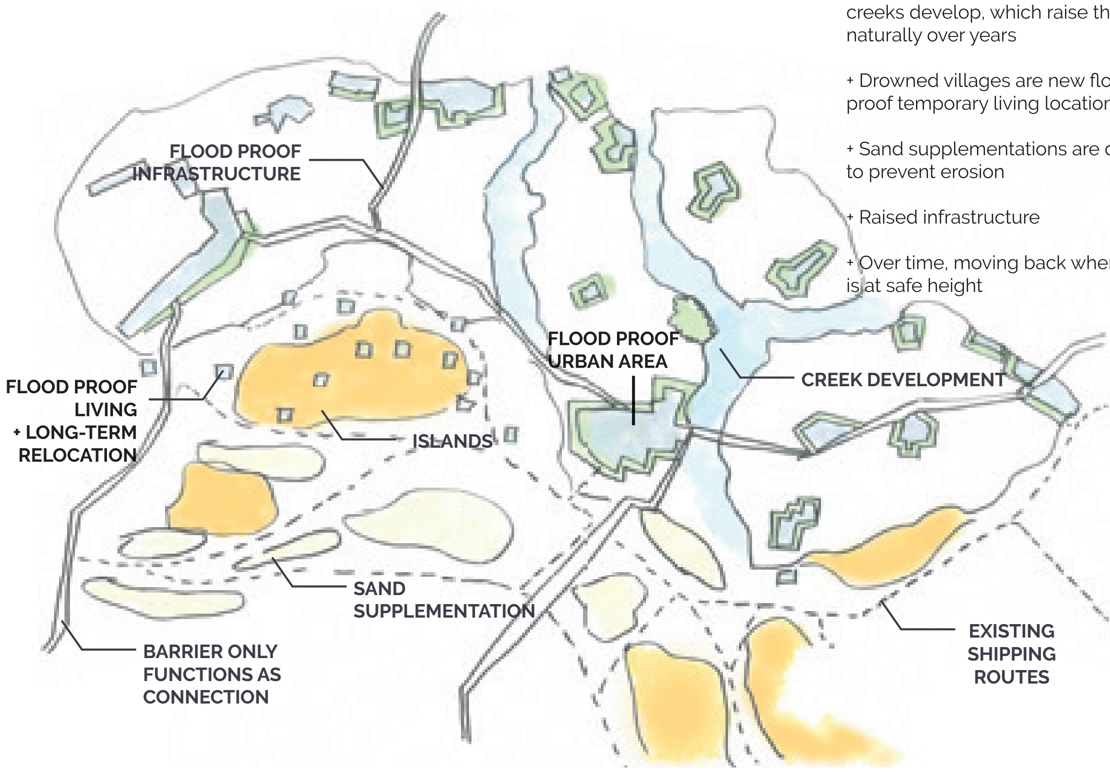
Defend land - Broad foreland



Concept
Inspired on nature first
+ Current dike is removed, and a new strong dike is created land ward.

+ By a gentle slope, foreland is created, which ensures different nature habitats

Accommodate sea - Drowned villages



Concept
Inspired on drowned villages
+ Sea level rises, land is flooded and creeks develop, which raise the land naturally over years

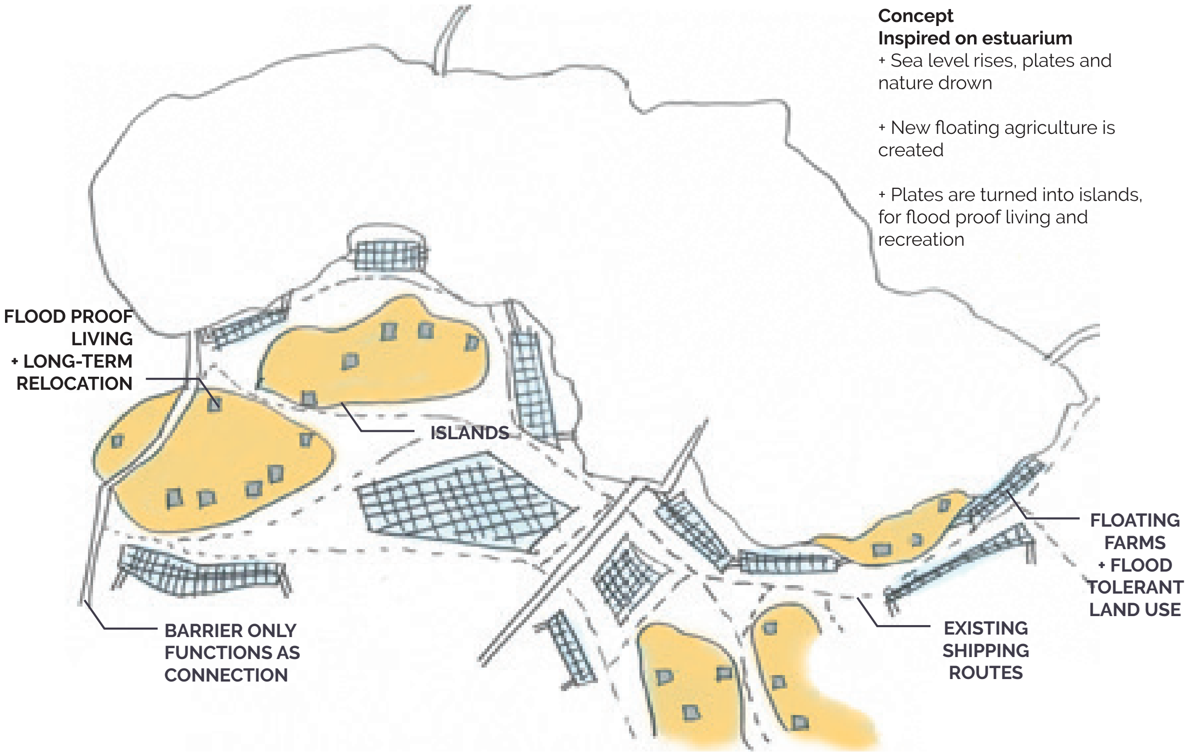
+ Drowned villages are new flood proof temporary living locations

+ Sand supplementations are done to prevent erosion

+ Raised infrastructure

+ Over time, moving back when land is at safe height

Accommodate sea - Schelde islands



Concept
Inspired on estuarium
+ Sea level rises, plates and nature drown

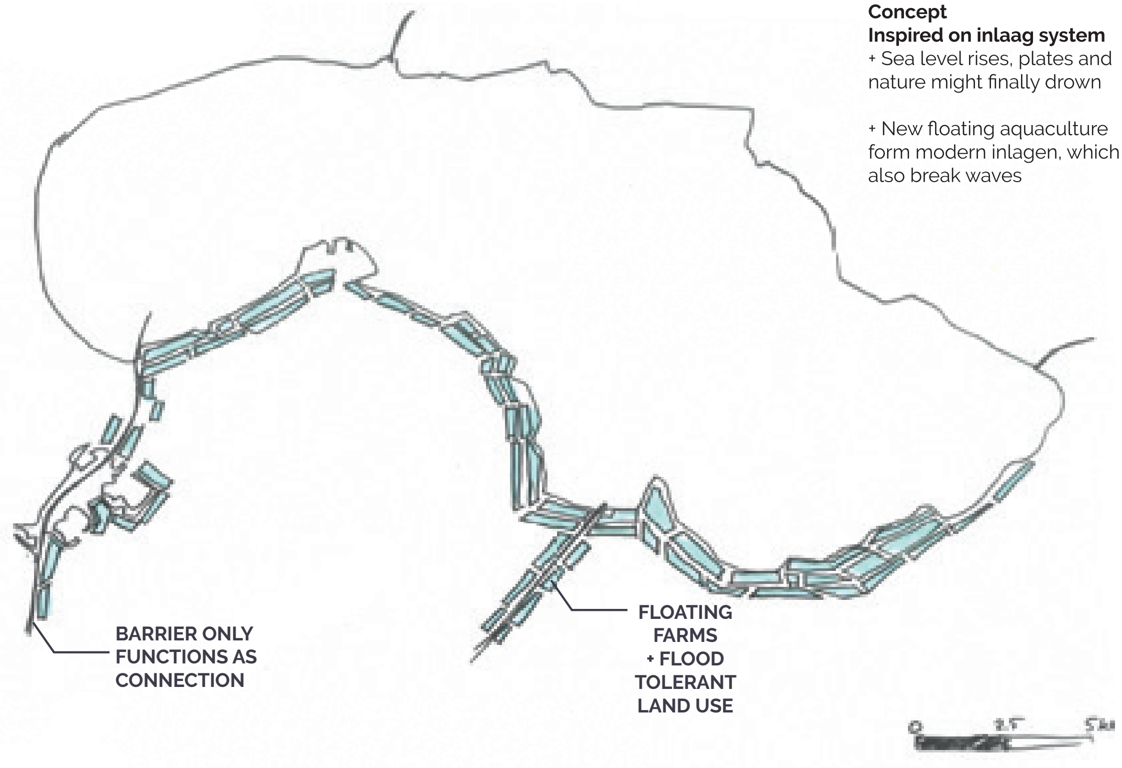
+ New floating agriculture is created

+ Plates are turned into islands, for flood proof living and recreation

Accommodate sea - Inlaag system

Concept
Inspired on inlaag system
+ Sea level rises, plates and nature might finally drown

+ New floating aquaculture form modern inlagen, which also break waves

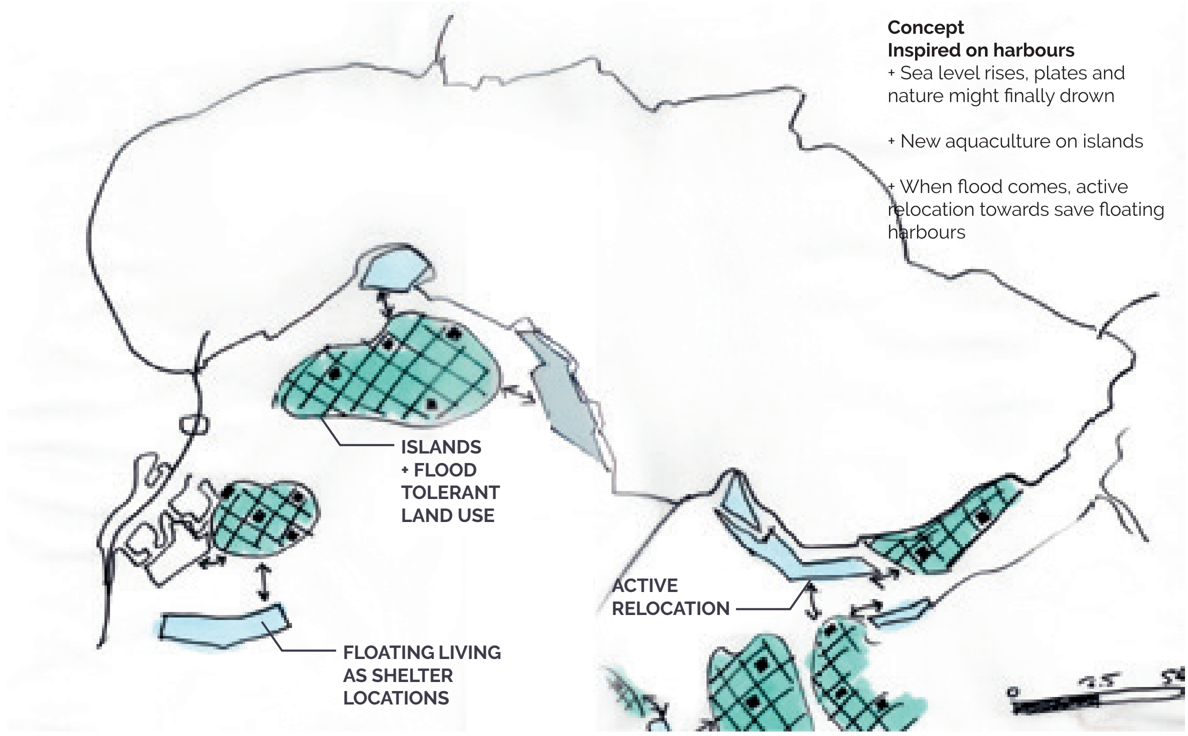


Accommodate sea - Safe haven

Concept
Inspired on harbours
+ Sea level rises, plates and nature might finally drown

+ New aquaculture on islands

+ When flood comes, active relocation towards save floating harbours

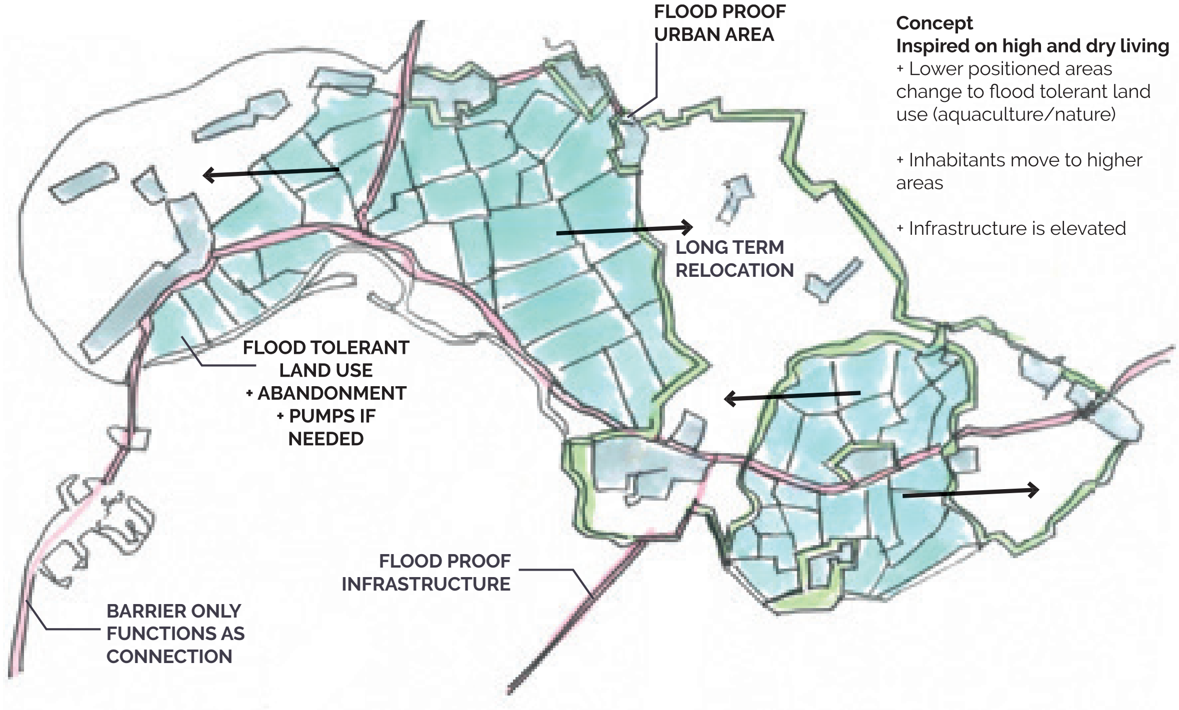


Accommodate land - Higher level

Concept
Inspired on high and dry living
+ Lower positioned areas change to flood tolerant land use (aquaculture/nature)

+ Inhabitants move to higher areas

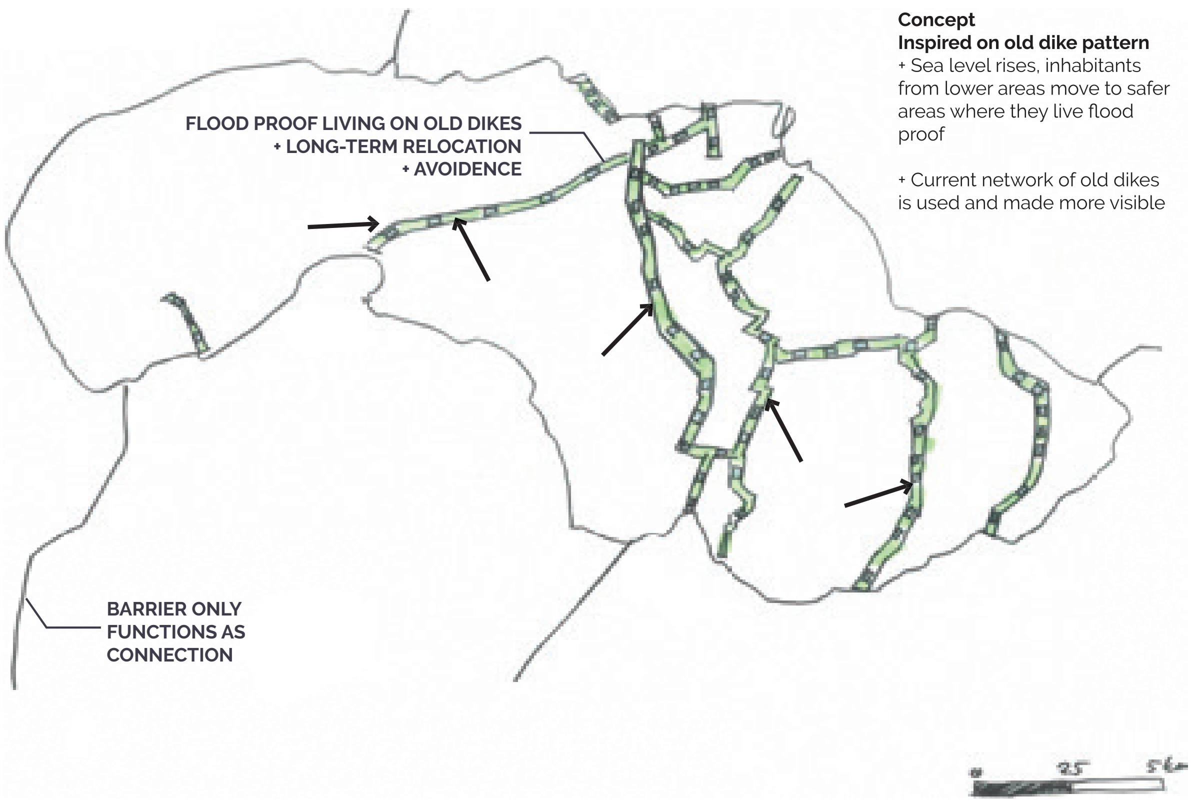
+ Infrastructure is elevated



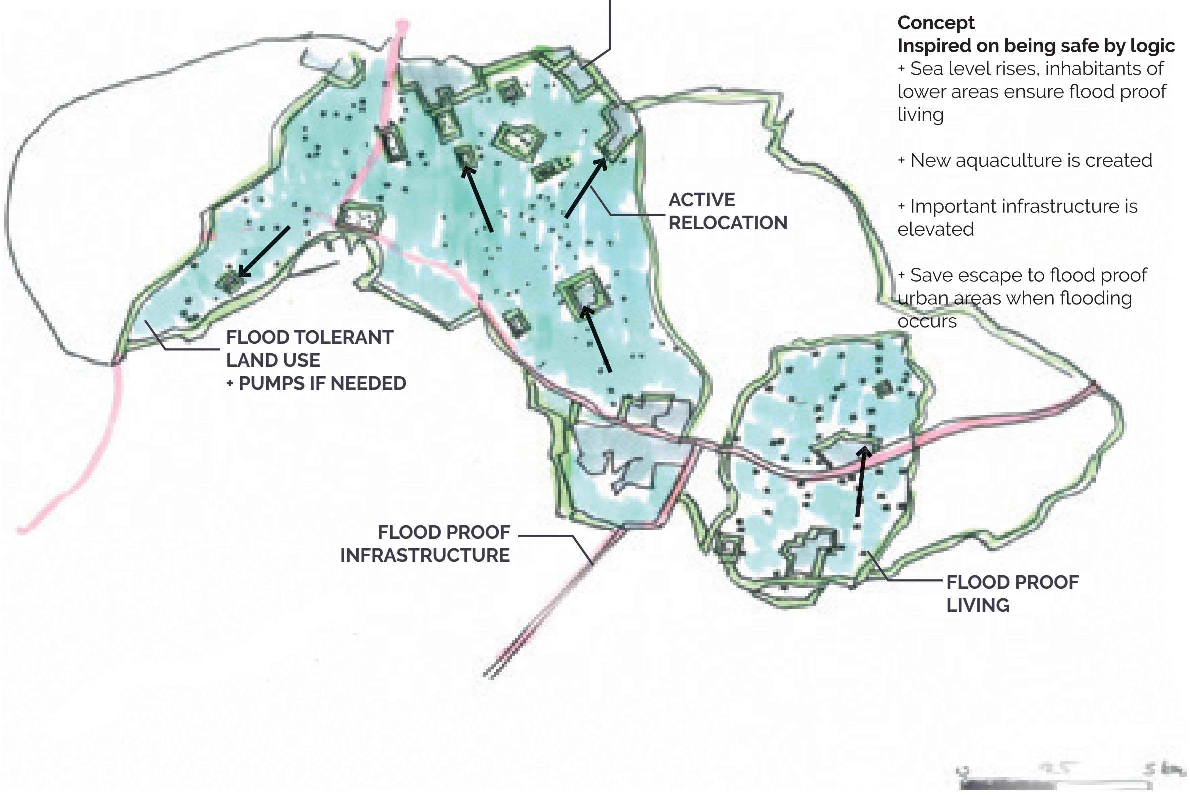
Accommodate land - Saved by old dikes

Concept
Inspired on old dike pattern
+ Sea level rises, inhabitants from lower areas move to safer areas where they live flood proof

+ Current network of old dikes is used and made more visible



Accommodate land - Flood proof



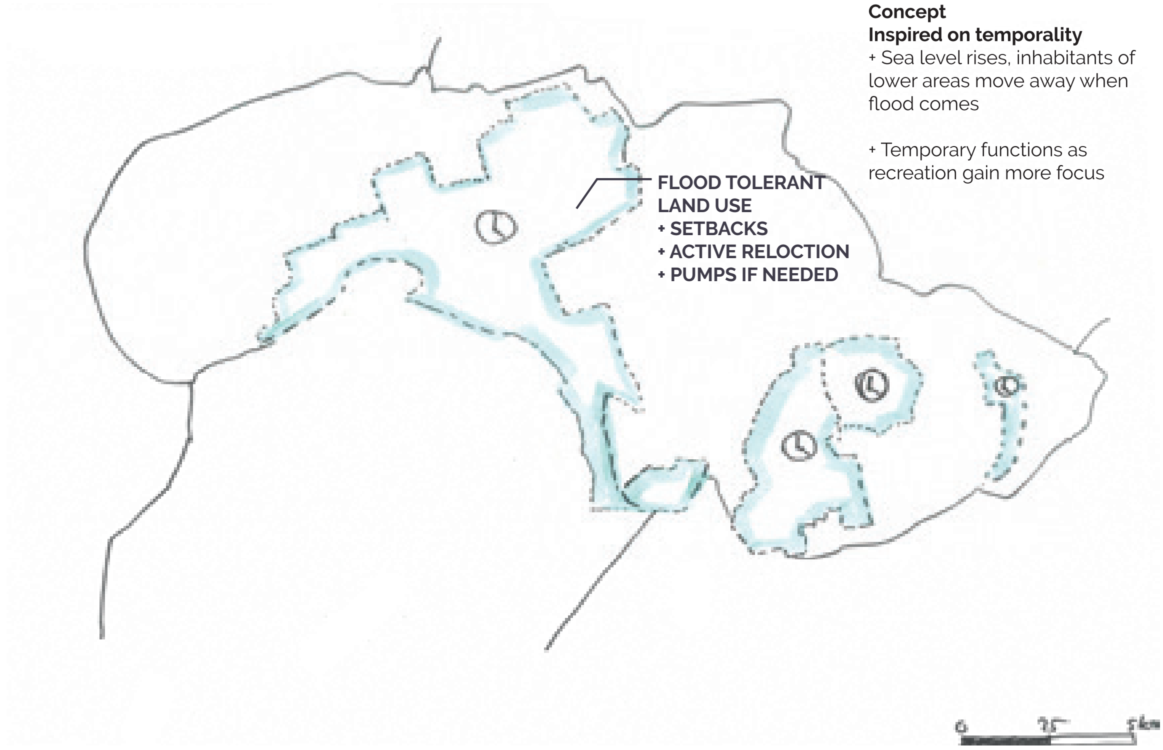
Concept
Inspired on being safe by logic
+ Sea level rises, inhabitants of lower areas ensure flood proof living

+ New aquaculture is created

+ Important infrastructure is elevated

+ Save escape to flood proof urban areas when flooding occurs

Accommodate land - Temporary living



Concept
Inspired on temporality
+ Sea level rises, inhabitants of lower areas move away when flood comes

+ Temporary functions as recreation gain more focus

APPENDIX V TEST RESULTS TEST 1

1.‘KARRENVELDEN’ SYSTEM

Opmerkingen gemaakt tijdens online gesprek

Opmerkingen

- Duurt lang voordat het land is opgeslibd, kan 50-100 jaar duren, check onderzoek Tjeerd Bouma – dubbele dijken
- Let op de diepte van de geulen, kan de maatregel hier ingepast worden?

Nadelen

- Erg complexe civiel-technische ingreep
- Erg duur
- Sediment tekort niet opgelost

Voordelen

- Breekt de golven
- Kan erosie afremmen

Heeft u nog overige opmerkingen?

Deze oplossing heeft mogelijk positieve effecten voor waterveiligheid omdat het helpt de vooroever te verstevigen en daarmee het risico op afschuiven van de dijk kan verlagen. Daarnaast is door onderzoek aangetoond dat een schor voor een dijk een positief effect heeft op het verkleinen van een dijkdoorbraak. Mogelijk kan dit concept hier ook een bijdrage aan leveren. Het concept helpt niet tegen het reduceren van de golfoploop omdat bij een hoge waterstand op de Oosterschelde de mosselbanken zijn verdronken en golven niet significant meer zullen worden geremd.

2. TIDAL DIKE

Opmerkingen gemaakt tijdens online gesprek

Opmerkingen

- Plaats de dijk niet te dicht bij de diepe geulen
- Let op de steilte van de oevers en de diepte van de geulen, waar kan wat?

Nadelen

- Verlies van huidige getijdenatuur
- Erg duur

Voordelen

- Generatie van nieuwe natuur inclusief kreekruggen
- Opslibbing van land
- Kan erosie tegengaan

Heeft u nog overige opmerkingen?

Dit concept is een beetje: "het middel is erger dan de kwaal". De natuurlijke dynamiek van zandbanken, slikken en schorren wordt onderbroken door een concept dat juist wilt helpen bij het beschermen van de natuur. De vraag is ook of een tussendijks zout waterlandschap dezelfde unieke kwaliteiten heeft als de huidige getijdennatuur. Voor waterveiligheid geldt hetzelfde: de dijk voor de dijk is heel duur vanwege de diepere waterdiepten. Met veel minder inspanning is de huidige dijk te versterken.

3. FORELAND FIRST

Opmerkingen gemaakt tijdens online gesprek

Opmerkingen
- Retaining wall is een aaneengesloten element, in dit concept is dit element eigenlijk een breakwater
- Let op de hoeveelheid muren, wat is nodig?

Voordelen
- Gaat erosie tegen
- Breekt golven

Heeft u nog overige opmerkingen?

Dit concept is eigenlijk een oplossing om erosie van het voorland tegen te gaan doordat het golfaanval remt en mogelijk sediment afvangt in de luwtes achter de muurtjes. Het is daarmee wel kansrijk als "lapmiddel" tegen de zandhonger, maar niet een duurzame oplossing. Wel interessant om te onderzoeken of het principe van "retaining walls" ook in een meer natuurlijke vorm (zand , gevlochten wilgentenen, mosselbanken) kan worden uitgevoerd.

4. ISLAND MACHINE

Opmerkingen gemaakt tijdens online gesprek

Opmerkingen
- Waar zijn de suppleties nodig: hangt af van hydrodynamiek/stromingen of het gaat werken
- Kan dit snel genoeg werken of verdrinkt de getijdenatuur alsnog
- Studenten TU Delft benaderen indien verdergaan met dit concept

Voordelen
- Zandhongerproblematiek aangepakt
- Natuur kan langzaam aanpassen

Heeft u nog overige opmerkingen?

Interessant concept om met zandmotoren gericht erosie van zandplaten tegen gaan. Gebeurt in principe la met de Roggenplaat. Zou het mogelijk zijn als landschapsarchitect om met dit principe nieuwe landschappen te ontwikkelen die meerdere functies kunnen dienen? Duurzame recreatie?

5. SUPER DIKE

Opmerkingen gemaakt tijdens online gesprek

Opmerkingen

- Bodemkundig ingewikkeld gebied zoet/zout varieert lokaal sterk

Voordelen

- Zoet water hoeveelheid kan toenemen

Heeft u nog overige opmerkingen?

Er is mogelijk een positief effect op de getijdennatuur als de superdijk ook echt fors landinwaarts wordt gelegd waardoor er een breed voorland onder invloed van getij ontstaat. Als het concept superdijk betekent dat ede bestaande dijk wordt versterkt dan zal er geen positief en misschien zelfs een negatief effect op de getijdennatuur ontstaan vanwege de bredere buitendijkse voet. Voor tegengaan van verzilting is de ondergrond en de diepteligging van de achtergelegen polders bepalend. Als er een niet homogene ondergrond is zal het zoute grondwater toch ver het lage achterland inkomen. Een zoetwaterbel in de dijk zal eveneens erg klein blijven.

6. DOUBLE DIKE

Opmerkingen gemaakt tijdens online gesprek

Opmerkingen

- Bodemkundig ingewikkeld gebied zoet/zout varieert lokaal sterk
- Polder bruinisse is nu zout, rondom oosterland is zoet water, maak gebruik van gescheiden zoet-zout systemen.
- Er is nu nog niet veel vraag naar aquacultuur, wel voor landbouw met focus op zout tolerante producten zoals aardappel en ui
- Inlaat toevoegen voor zout gebied.

Voordelen

- Mogelijkheden voor zoet/zout scheiden en zo zoet water behouden

Heeft u nog overige opmerkingen?

zie ook opmerkingen vorige concept. Alleen bij significante teruglegging van de dubbele dijk is er natuurwinst te behalen.

7. UNBREACHABLE

Opmerkingen gemaakt tijdens online gesprek

Opmerkingen

- Het voorland verdrinkt nu
- De verzilting neemt toe

Voordelen

- Waterveiligheid is hoog

Heeft u nog overige opmerkingen?

Vooral goed voor waterveiligheid. Waarschijnlijk goedkoopste oplossing zeker bij dijken die niet in de hoogte versterkt kunnen worden.

8. BROAD FORELAND

Opmerkingen gemaakt tijdens online gesprek

- Groeien met tijd kan lang duren

Heeft u nog overige opmerkingen?

Dit is in feite een terugtrekstrategie. Hiermee is veel natuurwinst te boeken, maar gaat wel ten koste van landbouwgrond en is duur vanwege het verleggen van de waterkering. Wel interessant voor gebied rond plan Tureluur.

9. DROWNED VILLAGES

Opmerkingen gemaakt tijdens online gesprek

Opmerkingen

- Alleen onhoudbare lage grond opgeven
- Als er zoveel zand wordt gebruikt, waarom niet duinen uitbreiden en zoetwaterbel vergroten?
- Kreekruggen bewaren, hier gaan wonen?

Voordelen

- Veel kansen in het concept

Heeft u nog overige opmerkingen?

Beetje middel is erger dan kwaal.

10. SCHELDE ISLANDS

Opmerkingen gemaakt tijdens online gesprek

Opmerkingen:

- Verlies van veel kwaliteit
- Waarom niet ophogen op het land

Voordelen:

- Geen

Heeft u nog overige opmerkingen?

11. INLAAG SYSTEM

Opmerkingen gemaakt tijdens online gesprek

Opmerkingen
- Verlies van kwaliteit
- Alleen waterveiligheid en aquacultuur

Voordelen
- Kan toegepast worden bij diepe geulen
- Drijvende elementen kunnen nuttig zijn bij locaties met golfgevaar

Heeft u nog overige opmerkingen?

Lokaal mogelijk interessant als combinatie van golfremmers, voedselproductie en drijvende natuur / duiksportrecreatie. Wel interessant om dit idee verder uit te werken omdat er veel kansen zijn voor kansen voor recreatie.

12. SAFE HAVEN

Opmerkingen gemaakt tijdens online gesprek

Opmerkingen
- Natuurwaarde gaat verloren
- Veel investering

Voordelen
- geen

Heeft u nog overige opmerkingen?

13. HIGHER LEVEL

Opmerkingen gemaakt tijdens online gesprek

Opmerkingen

- Zoet zout scheiden combineren
- Duinrand uitbreiden
- Infrastructuur als kreekruggen?
- Combineren met concept: saved by old dikes

Voordelen

- Kansen om zoet water te scheiden

Heeft u nog overige opmerkingen?

Heel interessante denkrichting. Graag combineren met een mogelijke teruglegging van de waterkeringen bij de laaggelegen poolgronden waardoor er ruimte ontstaat voor nieuwe getijdennatuur. Positief effect op verzilting omdat in feite het landgebruik zich aanpast aan de zoute condities.

14. SAVED BY OLD DIKES

Opmerkingen gemaakt tijdens online gesprek

Opmerkingen

- Combineren met higher level

Heeft u nog overige opmerkingen?

Interessant in combi met vorige. Wel aandacht voor cultuurhistorie nodig.

15. FLOOD PROOF

Opmerkingen gemaakt tijdens online gesprek

- Woonterpen creëren?

Heeft u nog overige opmerkingen?

integratie met concept higher level

16. TEMPORARY LIVING

Opmerkingen gemaakt tijdens online gesprek

- Boeren herplaatsen naar woonterpen

Heeft u nog overige opmerkingen?

integreren in higher level

APPENDIX VI TEST RESULTS 2: INTERVENTIONS - OPEN QUESTIONS

WATER SAFETY

Concept A

Measure: suppletion in outside bend of channel

Does the principle work?

- Probably not, because there is not enough flow velocity, and no dynamic balance.
- However, at a certain height it possibly works, but unclear at what height.

What could be improved?

- Supplementation on plate, close to dike, at edge of channel next to dike, until 10mm/year SLR, but then?
- Possibly opening up Oosterschelde, but could result in an ebb dominant system, unknown.

Measure: mussel/oyster banks + bank protection walls

Does the principle work?

- A little bit but could possibly enhance erosion at certain locations.

What could be improved?

- ?

Concept B

Measure: tidal nature

Does the principle work?

- Could work but pay attention to the start height of the land which becomes tidal nature to achieve the right time of falling dry.

What could be improved?

- Interesting to use silt motors, as sediment is lacking in the Oosterschelde, however, the best location still needs to be researched. Dredging silt from harbours, is now just thrown away.
- Check: rammegors / rattekaai
- Mind if you create vegetated schorren (zeekraal height) or slikken (roggeplaat height): birds.
- Mind disruption of recreating people (discuss with Frans)
- Is the grid necessary? (doubt) or create the basis of the creek pattern, but not to detailed, the nature follows its own pattern.

Measure: double dikes

Does the principle work?

- How low do you make the dike, how much water flows over, can the area handle it? Complex calculation. Hard to calculate if flooding over dike occurs.

What could be improved?

- Make it simpler: water or not.
- Aquaculture is more logic, or high dike in front, with inlet where water can come in. Everything under control, is socially more acceptable.
- Creating intertidal area is also an option.

Measure: super dike

Does the principle work?

-Yes, however, is the sub soil stable enough to carry the heavy dike? Is there no peat or soft clay? How much extra freshwater is generated?

What could be improved?

- Natural slope at the Oosterschelde side: full clay dike: schor, check: land of saeftinghe

Concept C
Measure: creek ridges

Does the principle work?
- For multiple layer safety, as an escape ridge, yes

What could be improved?
?

Measure: tidal nature

Does the principle work?
- Land should lay high enough in comparison to SLR: do not let it drown.
- Silt supplementation possibly needed.
- Foreland is useful.

What could be improved?
- Dike length increase is more risk, but the dikes should be at the safe height according to the norm, so no issue theoretically.

NATURE AND ECOLOGY

Concept A
Measure: suppletion in outside bend of channel

Does the principle work?
- Doubtable if it works.
- The problem is the sand hunger and too few dynamics to move the sand to the plates.
- Changing to a more often closing barrier does not help.

What could be improved?
-An open system increases the dynamics.
- Suppletion like: Galgenplaat/dortsman suppletion, Roggeplaat suppletion
- Move sand active from the channels to the plates.
- Open system: seems optimistic, but not sure if it works.
- However: Westerschelde is sediment rich
- Sediment from the Oosterschelde system is no difference for sediment shortage, if the sediment comes from other areas it does make a difference.

Measure: mussel/oyster banks + bank protection walls

Does the principle work?
- Yes, both bank protections could work.
- Perpendicular placed banks could create lee areas (luwtes) but looks more artificial.
- Width of mussel and oyster banks could become hundreds of meters.

What could be improved?
- Placing structures to get the mussel and oyster banks to grow with bio mats or baskets (schanskorven)

Concept B
Measure: tidal nature

Does the principle work?
- Very good measure to create new tidal nature, goes fast.

What could be improved?
- Dig out a global creek pattern to steer the water.
- Placing the dams is not necessary.
- Height of area is of influence, if polder is low, it takes time, the higher the better
- Effects if sediment shortage could be worse: system becomes larger, ensure enough sediment.

Measure: double dike

Does the principle work?
- Yes, area behind dikes become under influence of Oosterschelde.
What could be improved?
- Rotation system: saline agriculture switching

after 50-100 years to nature, land level has grown.
- Does currently not contribute to tidal nature.

Measure: super dike

Does the principle work?
- Yes, for safety and preventing salt water to flow over the dike.
- However, saline soil water flows under the super dike.

What could be improved?
- Add a gentle slope to create tidal nature at the Oosterschelde side.
- Create a wet saline zone, or a deep salty seepage canal, also nice nature area, behind super dike to catch away salt.
- Divide saline and freshwater.
- Pumping up freshwater increases the problem, as the bubble becomes smaller.

Concept c
Measure: increase creek ridge/ increase tidal nature

Does the principle work?
- Goes back to the situation as hundreds of years ago.
- Adds huge area of tidal nature, more ebb and flood effect far into the landscape.
- Traditional agriculture will decrease.
- Improvement regarding sediment shortage will be neutral, as area in need of sediment increases and sediment supply increases.

What could be improved?
- Using the soil from excavated dikes to elevate creek ridges?
- In comparison to super dike idea, this is very efficient for tidal nature.
- These changes are for long term, especially for farming: needs to change to saline agriculture.
- Width of tidal area inlets: could be hundred meters.
- Farm mounds could be more connected to the land instead of in the middle of the tidal nature.

Other questions
What would be a preference nature type: new tidal nature or existing nature types?
- All nature types have value, but tidal nature has preference as this is the main characteristic of the landscape.

How to combine tidal nature and recreation: how to prevent disturbing the birds?
- Nature and recreation: each bird has its own comfortable area, depends.
- Few hundreds of meter distance are necessary.
- Appoint locations for recreation, and locations for high value nature for birds with a viewpoint from the dike. Food rich area is more appropriate for birds.

SOIL AND WATER

Concept A
Measure: suppletion in outside bend of channel

Does the principle work?
- Expects it works, as the sand engine at the coast of The Hague also works: the idea of the natural spreading. Works better than the supplementation on the plate.
The more far away from the dike, the smaller the effect.

What could be improved?
- ?

What are the effects for the freshwater / saltwater system?
- Effect on salt/freshwater system is unclear: does the seepage increase or decrease. Possible prevention of salinization of freshwater.

Measure: mussel/oyster banks

Does the principle work?
- Yes, but needs enough sediment supply.

What could be improved?
- ?

What are the effects for the freshwater / saltwater system?
- Like previous intervention.

Concept B
Measure: create tidal nature landward

Does the principle work?
- Yes
What could be improved?
- ?

What are the effects for the freshwater / saltwater system?
- Behind dike more seepage, as dike is moved back, depends also how high the new tidal nature becomes. See land of Saefthinge, and the Hedwige polder. Freshwater decreases, as dike is moved back.

Measure: double dike

Does the principle work?
- Type 1: salt tolerant agriculture, soil structure will be damaged by salt, and salt tolerant crops are scarce, therefore, it is hard to practice agriculture. For instance, salt tolerant potatoes are not resistant to salt sea water.
- Type 2: Has more potential than type 1

What could be improved?
- Cattle breeding instead of agriculture.

What are the effects for the freshwater / saltwater system?
- Salinization could possibly increase in the area behind.

Measure: super dike

Does the principle work?
- Depends on material of dike: for freshwater it requires permeability, for water safety it requires an impermeable layer (probably clay)
- Freshwater bubble will probably decrease due to sea level rise and seepage increase.
- Consider the existing ditches.
- Freshwater bubble: 7,5 is already a bubble, but from 15 m deep it can pump up water.

What could be improved?
- Location 1 will work better due to the permeable soil and because it is next to a deeper freshwater bubble.
- Only the west side of location 2 will become a freshwater bubble.
- Study effect of peat layers, depends on thickness.
- Dinoloket: type schaal: meest waarschijnlijke lithoklasse
- Location 2: Between 1.2 and 1.6 km is the transition zone of green and red of the freshwater bubble border.
- Depth freshwater bubble: 1 m groundwater level increase is 40 meters of freshwater.
- Important to know how the water flows of on the side, and the permeability of the dike.

Concept C
Measure: increase height creek ridges

Does the principle work?
- Not very realistic in terms of spatial planning
- Desiccation as ground level drops in the creek ridges

What can be improved?
- Make two ridges instead of one ridge, with a water storage in between
- Or: make smaller creek ridges, use the water

for agricultural areas
- A smaller intervention: to remove ditches in existing creek ridges.

Measure: new tidal nature

Does the principle work?
- Yes, but requires enough sediment supply.

What are the effects for the freshwater / saltwater system?
- Dike is moved landwards, the salinization probably increases, depends on the created seepage.