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TERRITORY OF ECO-CHANCE

Co-benefits of Nature-based adaptation for
future development of the Rhine-Meuse-Scheldt Delta

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MSc Urbanism
Graduation Project

Colophon

Territories of Eco-chance:
Co-benefits of Nature-based adaptation for
future development of the Rhine-Meuse-Scheldt Delta

MSc Thesis P5 report

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Transitional Territories Studio
North Sea: landscapes of Coexistence

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future development of the Rhine-Meuse-Scheldt Delta

The accelerated rate of climate change questions the capacity of current infrastructures to adapt to altered future climate conditions, specifically in areas prone to floods, such as the Rhine-Meuse-Scheldt delta. Simultaneously the unforeseen effects of 'hard' engineering approaches (such as dams, storm surge barriers, defensive coastal management) have been affecting biophysical as well as ecological systems, resulting in increased vulnerability to floods and loss of estuarine habitats. Therefore there appears to be a need to rethink coastal (protection) strategies.

The project relates to the temporal and spatial distributions of socio-economic as well as ecological vulnerabilities under the influence of increased flood probability and climatic stressors in the Rhine-Meuse-Scheldt delta, questioning how a nature-based approach can be used to support the adaptive capacity of the delta and mitigation of altered future climate conditions. It specifically explores the development of critical land-water zones adjacent to the Eastern Scheldt, and construction of a framework for decision making in which nature-based solutions are prioritized based on initial stressing factors as well as space availability, indicating solutions both landwards and seawards over the consolidation of the existing line. As means to structure proposals an adaptive framework has been developed on the scale of Schouwen Duiveland to maintain the existing qualities of the island, as well as selecting and excluding a solution pathway based on the systemic functioning of the island. The approach stands closely to the the notion that humans are an intrinsic part of nature. Therefore developments related to water safety, fresh water supply and critical infrastructures should act in accordance to the acceptance of dynamics as apposed to the idea of presumed stability.

Content

1. Introduction

The Waker, The Sleeper and the Dreamer

1.1 Context studio

Related to territories in risk between land and water, the studio of transitional territories corresponds to both spatio-ecological, as well as socio-economic challenges posed by climate change. The studio offers an approach of research by design that can test different performances of the environment related to livelihood as well as biodiversity in areas that are challenged by natural processes (such as erosion, inundation etc.). The project relates to the inquiry of 'flux, erasure, and terraforming', through which the North Sea can be perceived as a dynamic shaper of the coast. This dynamism interacts with the static human made environment, creating certain vulnerabilities of floodrisk as well as environmental degradation. Secondly the project adresses the inquiry of 'the dual nature of externalities', in which the performance of the environment and the negative externalities are adressed.

In order to understand this complexity of the problems as well as the solution field in which this thesis is approached, this report will inform about the motivation, the urgencies and first methodology setup of the project. First of all the personal background and motivation for the project frames the notions through which the project is perceived. Secondly the urgencies will be adressed, describing the perceived problematization. This results in the aims and research questions for the project, and informs the bodies of knowledge, leading to the framework of the project.

1.2 Personal motivation

It is often said that people should live where it is 'high and dry'. And with the uncertainty of climate change, flood risk management can be perceived as an urgent theme. A majority of the Netherlands is below sea level, leading to a great dependency on a system consisting out of dunes, dikes, and barriers to secure safety. But 'the waker, the sleeper and the dreamer' might not be enough to guarantee our safety in the future.

With a background in both landscape architecture and urbanism comes a fascination for the dynamic land-water interface and its relation with the static built environment. Simply based on mappings, the existing 'scape' can be perceived as a static element. However looking at its development over time shows the forces of nature, and the rules through which both nature and people have shaped the 'scape' that is inhabited today. With this also comes an interest in the narrative of inhabitation over time, understanding the story about reclamation and struggle in a 'fight against water'.

< Static versus dynamic

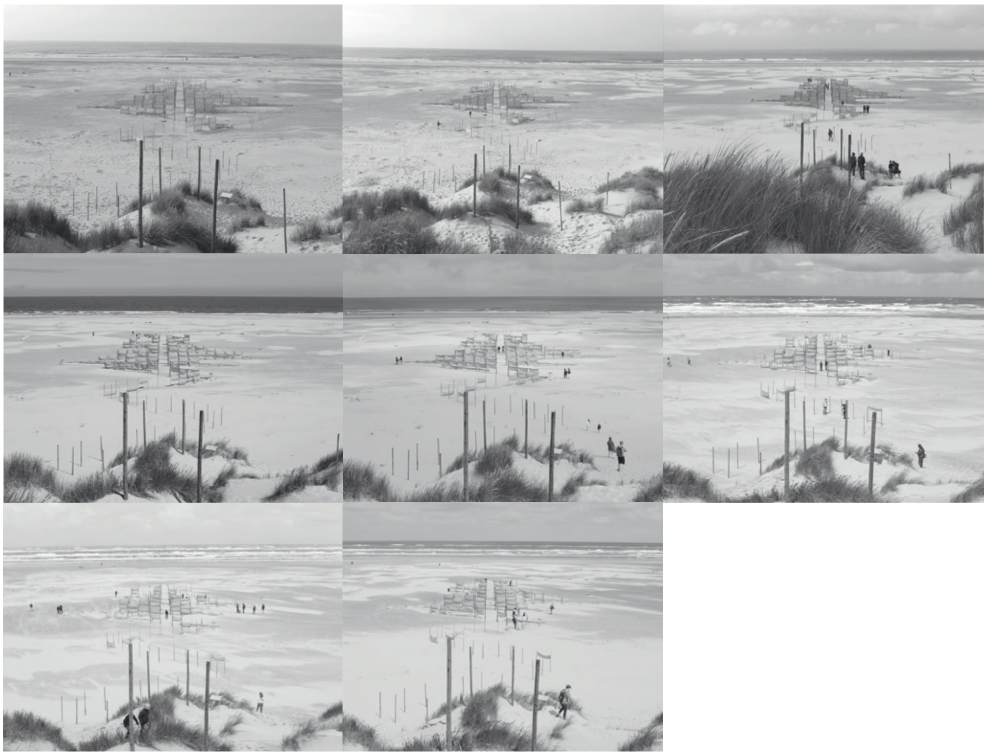
With an instalation made of hessian and wooden poles, an attempt was made to speed up the process of (embryonic) dune formation. It concerned the interaction with the static instalation and the dynamic forces of nature.

(Pictures made by group-members Aeolis - gap the border, 2018)

> Aeolis

Working on the Oerol project 'Aeolis' (2018) made clear the intrinsic relationship between the forces of nature (Aeolis-wind) and human interventions. In a timespan of ten days the installation and its environment changed.

(Pictures made by group-members Aeolis - gap the border, 2018)



1.3 Key Notions

As a means to develop a personal manifesto, three key notions were chosen to orient the core of the project on a theoretical level. The notions directly or indirectly relate to theories.

I Multi temporalities & Performance

'With its concern for improvements and with the future as its object, planning is, by definition, a temporal field, one that is concerned with transformation through time'
(Abram, S., 2014)

The notion acknowledges time as a dimension, through the progression of the past, present and future, and therefore the temporal state of a place or system. This on its turn also relates to the performance of the environment or a system, such as livelihood or biodiversity. Perfomance can be understood as: 'the system's effectiveness to maintain a certain quality level' (Estévez-Mauriz, L et all., 201, p1)

II Palimpsest

" It might be more useful to begin by viewing the landscape as a palimpsest rather than cultural strata - an analogy that at least provides the possibility for erasure and overwriting and the co-existence of several different scripts, implying not just different historical eras, but several historical and contemporary actors as well. " (Schein, 1997, p.662)

The notion of palimpsest acknowlegdes that contemporary ideas can affect the physical character of a place. Different layers are superimposed and coexisting, and together they show the dynamics over time. The notion of palimpsest also recognizes the urban cultural landscapes and their history and cultural significance.

III From nature to natures

" the awareness that humanity is an intrinsic part of the earth system is causing a fundamental shift in the way science is pursued. No longer is it sufficient to explore only the physical dynamics of the earth system... So potent is the human on the earth system that knowledge of physical processes ruling terrestrial or atmospheric change will be incomplete until scientist better understand the dimensions of that change."
(Silver & deFries, 1990, p. 46-47)

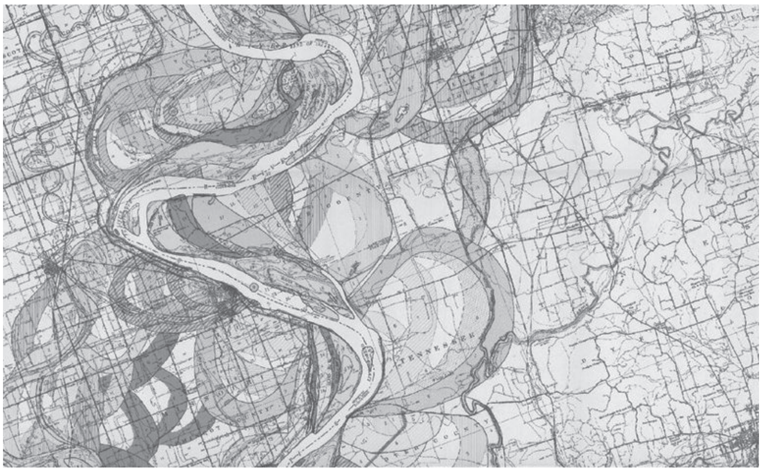
The notion acknowledges that people are part of nature. It relates to socio-ecological theories on complex adaptive systems, as well on ecosystem services on the base of ecosystem based adaptation.

Fase

Four movements to the music of Steve Reich.

Phase shifting dancing on repetitive minimalistic music representing the extra dimension of time (in planning), as well as the act of performing (environment or system) over time.

(Herman Sorgeloos, 2009)



Riverbeds Mississippi River

The map represents the dynamics of the river-bed and its sedimentation. Simply one capture over time does not capture the complexity of the system.

(Fisk, H. 1944)

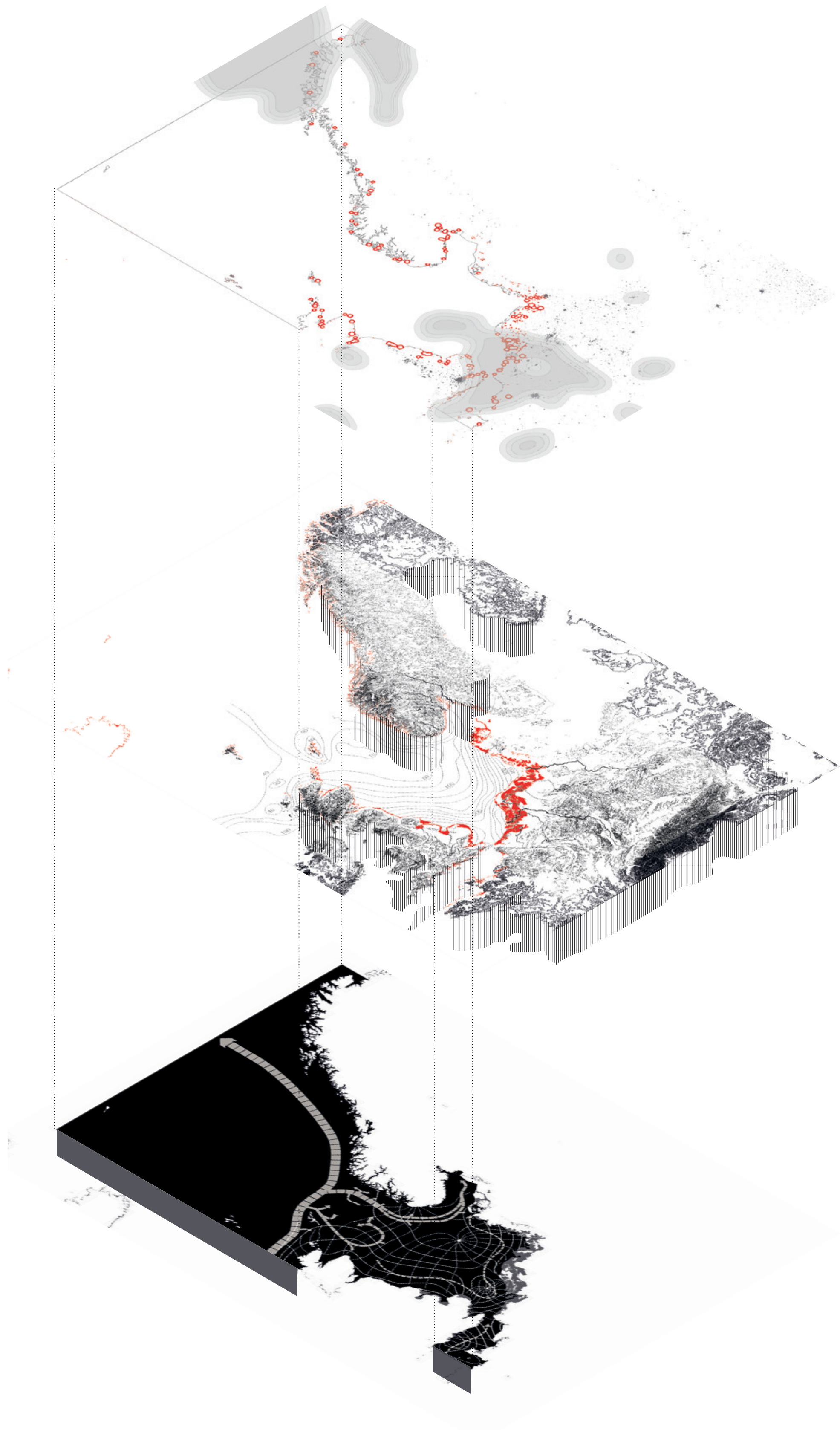
Animals

Series of picture manipulations of animals in a human form, such as the lion. It is through these manipulations thats one might reflect on the human nature.

(Meyer, C., 2013).

2. Urgency

Rethink flood management strategies in delta areas



Areas prone to floodrisk, related to the 5m elevation line.
Part of the collective work through the inquiry of Flux, Erasure and terraforming
(Isabel Recubenis, Luca Parlangeli, Anneloes van Slooten & Anne de Jong)

2.1 Issues of the North Sea territory

With a continuously changing climate comes the difficulty of predicting the New Anthropocene Water level and its effects on the spatial and systematic interface between land and water along side the North Sea. According to the synthesis report of the Intergovernmental Panel on Climate change (IPCC) estimates of global sea level rise range from 0.18 to 0.59m at the end of the 21st century (IPCC, 2007, p. 45). The Delta Committee of the Netherlands even concludes that a regional sea level rise of 0.65 to 1.3m should be taken into account by 2100, and 2 to 4m by 2200 (Deltacommisie, 2008, p.10). However the effects of sea level rise have regional differences. Whereas it's not questioned that the interface between land and water around the North Sea will change (it's simply not possible to deny the dynamic character of nature and its forces) one can still question the future shape of the delta and coastal areas and their increased vulnerability for floods.

- Image 1 shows the simplified hypsometric curve of the Netherlands, in which the proportion of land area is related to the different elevations in the country (also read relative area against the relative height). It shows that a mere half of the country is below the 3m level (about 17% below the 0m), and could therefore be affected by future sea level rise. The areas vulnerable for the risks of floods are also projected on the map.

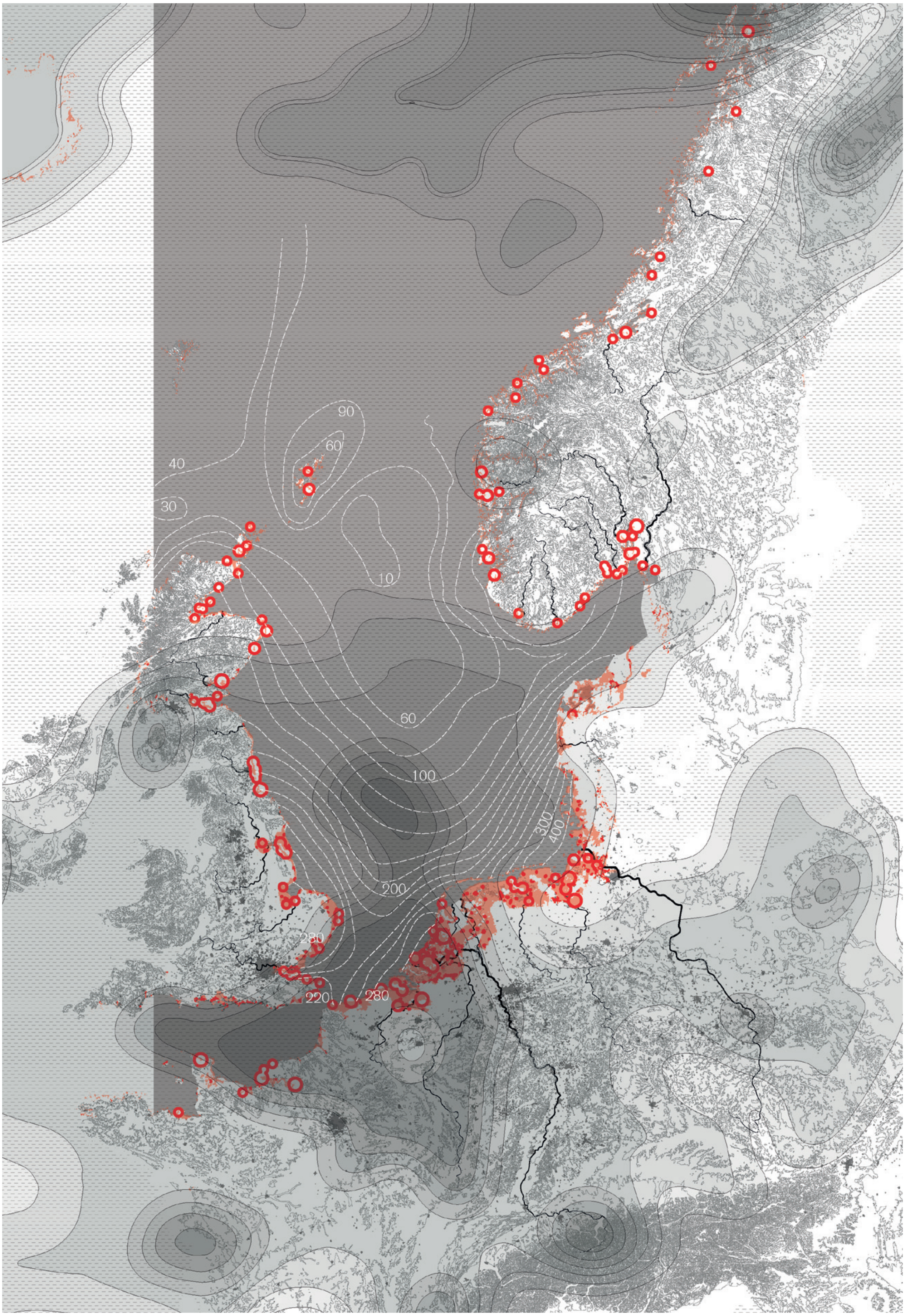
Threats of hazards alongside the coast of the North Sea, which could be aggravated by sea level rise, vary and relate to both spatio-ecological as socio-economic vulnerabilities. Aeolean and tidal processes are cause for erosion of the cliffs alongside the Eastern Coasts of the UK. In England about 28% experience erosion at rates higher than 0.1m/year (Climate Change Post, n.k.), questioning the viability of the coastal settlements. Safety assessment of primary flood defenses in the Netherlands showed that segments do not comply to the current standard (Deltacommisie, 2008, p. 20). Example is the dunes near the Westland, where a lack of natural sand nourishments and space consuming glasshouse developments pressure recovery of the dunes. However there are also threats related to the loss of biodiversity. The Waddensea area (World heritage) is an important area for migrating birds (East Atlantic bird migration routes). The area of salt marches could shrink as a result of inundation, and due to the restrained from expanding inland by defense barriers. Delta areas in particular are affected, since artificialization of waterfronts has constrained the natural processes alongside the waterfronts. Therefore there appears to be an urgency to reconsider (coastal) protection strategies, as well as the current way of inhabitation.

- 'The recent series of serious floods in in urbanized delta and coastal areas (…) addresses the need to fundamentally reconsider the relation between urban developments and the natural environment' (Meyer, 2014) -

Image 1| Simplified hypsometric curve of the Netherlands (made by author)

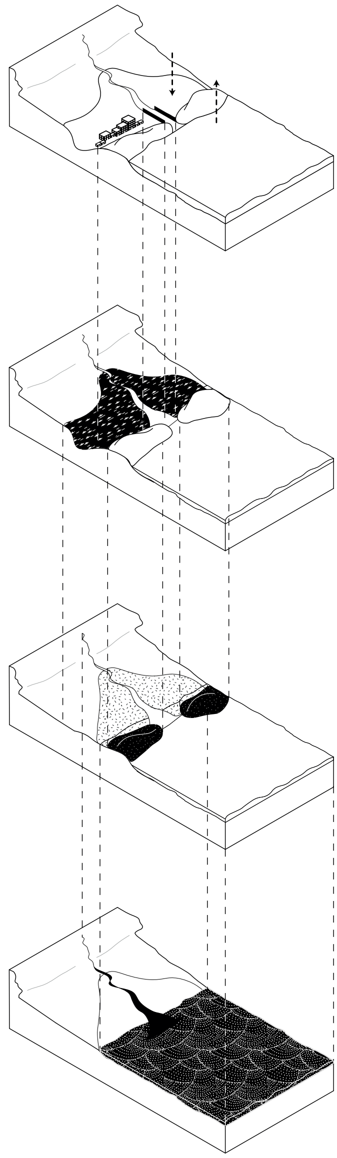
Map: Areas Prone to floodrisk
Part of the collective work through the inquiry of Flux, Erasure and terraforming
(Isabel Recubenis, Luca Parlangeli, Anneloes van Slooten & Anne de Jong)

- Current coastline
- Coastline 5m elevation
- Cities affected by 5m sea level rise or coastal erosion


90
60
40
30
10
60
100
300
400
200
280
220
280

Increased vulnerability: accelerated agents of the Anthropocene

Human interventions and actions have influenced natural conditions and systems. As a result processes related to the interchange of land and sea have been accelerated. The unforeseen environmental affects of 'hard' engineering approaches (dams, storm surge barriers, defensive coastal management) in the Netherlands resulted in increased vulnerabilities of coastal areas. For instance soil sealing in combination with water management lead to increased oxidation of peat, causing soil subsidence. This on its turn affects the vulnerability of these lands for sea level rise (relative).



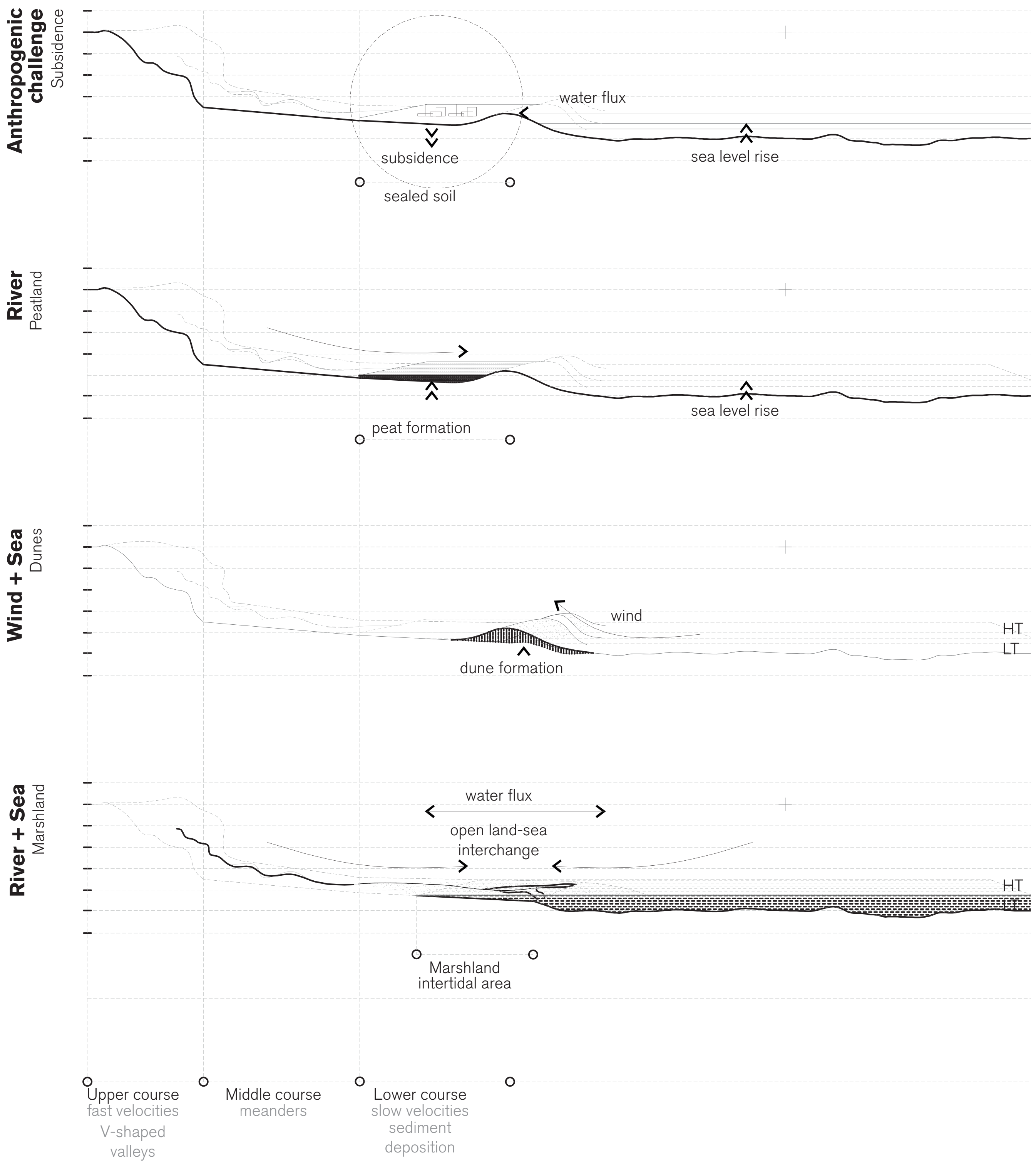
Nature to Natures: From framing Nature to Building with Nature

> 'Let us accept the proposition that nature is process, that it is interacting, that it responds to laws, representing values and opportunities for human use with certain limitations and even prohibitions to certain of these'
> (McHarg, I,I., 1971, p.7)

There appears to be a paradoxical situation in which measures to protect from the forces of Nature have actually led to increased vulnerability. The Room for the river program in the Netherlands showcased a different view on dealing with flood risk from rivers, by 'giving back space' that was once reclaimed in order to accommodate in the need to store access water from rivers. Quite frankly this way of thinking emerged out of the need to reduce possible flood risk. However it also triggered reflection on the traditional way of designing waterfronts (hard engineering), and its inability to cope with changing climate conditions. As a result more nature-based approaches for design (flood risk management) entered the field of design. An example is the concept of 'Building with Nature', that emphasizes a collaborative effort between Nature, Engineering and Society (Van Slobbe, E., De Vriend, H., Aarninkhof, S., Lulofs, K., De Vries, M., & Dircke, P., 2013). Different from hard engineering approaches the domain of Nature is incorporated in the framework. However it can still be questioned whether or not such an approach includes a certain adaptive capacity of the systems it effects. Whereas Building with Nature emphazises the use of nature for human purposes, concepts such as of ecosystem-based adaptation might emphazise a more systematic approach of using ecosystem services.

Antropogenic challenges of the Deltas relate soil subsidence as a result of watermanagement and soil sealing.

Part of the collective work through the inquiry of Flux, Erasure and terraforming (Isabel Recubenis, Luca Parlangeli, Anneloes van Slooten & Anne de Jong)



RIVER + SEA FORCE
MARSHLAND
The soil sealing and dutch water strategy management (dependent on pumping water) generates a situation of land subsidence, more and more challenging with rising sea levels

WIND + SEA FORCE
DUNES
The dunes set the conditions for fluvial sediments and organic matter to deposit on the delta. Peat is formed by the decomposition of organic matter with a rate of about 1 mm per year (Charman, 2002), which means 1 m deep peat needs 1000 years to form.x

RIVER FORCE
PEATLAND
Sea and wind dynamics, together with the low-lying nature of the delta coast set the conditions for the settling down of marine sediments in ridges, sand dunes.

ANTROPOGENIC CHALLENGE
SUBSUDENCE
For thousand of years the interchange land-sea was open and free. From that interchange, a changing state of the coast was defined.

Time and scale of change
The edge between water and land is often portrayed as a solid line, however in fact it is less well divined over the cause of time. And whereas humankind tends to fight against the dynamic nature of the coast, changes are eminently part of bigger complex systems. Although changes can be relative when considering a timeframe of thousands of years (sea levels within a glacial interval have changed with more than a 100m) they become of relevance when considering the shorter timespan of urban renewal processes. They are therefore only cause for problems in the 'modern' times (decadal timescale), since the static man-made infrastructures do not have the capacity to respond to the changing conditions in a certain speed. This questions the feasibility of (new) urban developments in vulnerable coastal areas.

The timeline represents the sea level rise on the the geological time-scales and its pace (horizontal red lines on the vertical axis represent a timeframe of 2000 years), as well as a decimal time-scale with present and future predictions of sea level rise until 2100. The geological pace becomes completly irrelevant to the decidal timescale of the present situation and future predictions, since predictions on such timescales would merely be speculative.

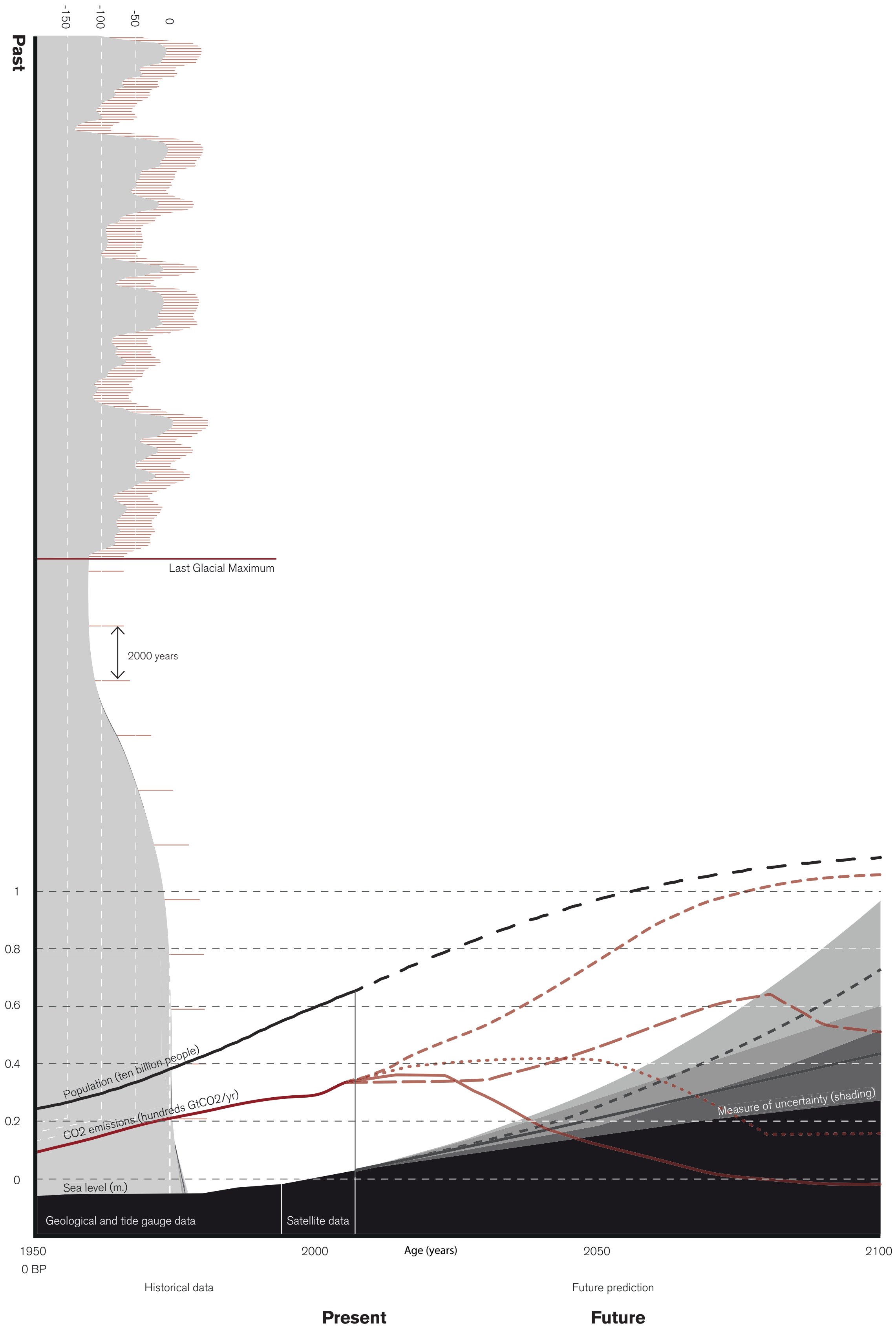
Future predictions are based on the different emission-scenarios of the IPCC synthesis report (IPCC, 2014), the so-called RCP's (Representative Concentration Pathways), decribing the development of greenhouse gasses. Every RCP includes a range depicting uncertainties. The RCP 2.6 and RCP 8,5 are the most divergent scenarios:

- RCP 2.6: ambitious climate policies, many measures to achieve low levels of green-house gas concentrations.
- RCP 8,5: few measures and technological breakthroughs.

The scenarios are compaired with different predictions of CO_2 emissions (red line), and expected (world) population growth (black) on a global level, already showing a very uncertain rate of changes. However differences on a regional level can be more diverse. Hazards can become more extreme or frequent Riverdischarges can both be high or very low. This questions the cappacity of current infrastructures to adapt to altered future climate conditions.

Uncertain rate of changes
Questioning the capacity of current infrastructures to adapt to altered future climate conditions

- CO_2 emissions (hundreds $GtCO_2/yr$)
- RCP 8.5 (hundreds $GtCO_2/yr$)
- RCP 6.0 (hundreds $GtCO_2/yr$)
- RCP 4.5 (hundreds $GtCO_2/yr$)
- RCP 2.6 (hundreds $GtCO_2/yr$)
- Global mean sea level rise 2.6 (m.)
- Global mean sea level rise 8.5 (m.)
- Population



The time and scale of change

Part of the collective work through the inquiry of Flux, Erasure and terraforming (Isabel Recubenis, Luca Parlangeli, Anneloes van Slooten & Anne de Jong)

2.2 Competing claims - Rhine Meuse Scheldt Delta

General introduction of the Rhine Meuse Scheldt Delta
The Rhine/Meuse has the largest catchment area in Europe and follows its route through Switserland, Germany, Luxembourg and the Netherlands. The mean annual discharges of the Rhine and Meuse are respectable 2300 m3/s and 230 m3/s. However large parts of the lower plain lie below the sea level. According to the Delta alliance the areas host about 40% of the Dutch population, and contains the four largest cities of the Netherlands, as well as Europe's largest seaport and fourth largest airport (Schiphol). The coastal plain is therefore protected by a system of coastal dunes as well as an extensive system of dikes and dams. Whereas the riverdikes represent a safety level of 1:1250 years, the coastal defence has safety levels of 1:10000 years (Delta Alliance, n.k.).

Marked territory
The Rhine Meuse territory is marked by former flood events. Example is the flood disaster of 1953 in which large areas in the Netherlands, as well as in England and Belgium, were affected by extreme storm surges and floods. The affected areas are shown on the map. As a reponse the delta plan was established. Barriers were build to shorten the coastline and protect from storm surges from sea. Consequence of the barriers, was a loss of tidal influene in the estuary, leading to a changing composition of flora and Fauna species. Diadrome species, that reproduce in fresh water but grow up in salt seawater or vice versa, were specifically effected due to the inability to reach the rivers or sea. Additional fishing practices, such as bottom trawling, and sand dredging have intensifely damaged the sea and riverbeds. Hydro-electric installations, such as locks and sluices, are barriers for inland migration of species.

Competing claims in the Delta
There appears to be competing socio-economic as well as ecological claims in the Rhine Meuse Delta. While the Rhine and Meuse delta is an important route for migrating fish and birds, artificualisation of the waterfronts (for instance the Port of Rotterdam, and endikements) have affected the process of delta formation. The result is a loss of wetlands and estuarine habitats. At the same time flood risk management is of great importance for the safety of large urban territories that benefited the conditions in the delta (such as Rotterdam). Saline infiltration threatens the freshwater supply (of a growing population) and affects agricultural activities. Combined with the possible impact climate induced hazards, the relience of species and ecosystems can be effected, as well as the land uses in the Delta.

Present towns
Damaged communities
Dikebreaks
Flooded areas

Rhine Meuse (and Scheldt) Delta and related scales of the project.
Image made by author based on (NOS, n.k.).

3. Methodology

This chapter presents the research and design methodology of the project related to the problem field of the Rhine-Meuse-Scheldt delta addressed in the previous chapter. Firstly, an overal research roadmap is established to present the main structure of the project. Secondly the ‘Why’ of the project will be explained through the problem statement, aims of the project and main research questions, posing a main pathway that will be explored. This leads to ‘How’ of the project, elaborating on the theoretical, and conceptual understanding of the project and the proposed methods, tools, and outcomes.

3.1 | Introduction - Overal research roadmap
3.2 | Problem statement
3.3 | Research question
3.4 | Research aims
3.5 | Explored pathway
3.6 | Conceptual & theoretical framework
3.7 | Research Methods & tools
3.8 | Design development and expected outcomes
3.9 | Overall project framework

3.1 Introduction

Current focus on climate change leads to increasing relevance of flood resilience in urban practices. However, reluctancy of floods remains to be the main driver of change in applied practices in the Netherlands, maintaining a 'hold the line' response. This driver can be questioned after 2100. Specifically related to the Rhine-Meuse-Scheldt delta in the Netherlands numerous research has already been conducted, mainly concerned with scenario planning (mostly the most extreme) on a larger scale. However, this does not entail a vision of working towards a certain allowance and acceptance of floods in the future, which might be inevitable when considering future predictions of sea level rise. There appears to exist a knowledge gap in applied practices related to the allowance of flood phenomena and the the synchronization of different subsystems, as well as the constitution of applied adaptation methods. Therefore, challenging is the identification of suitable research and design methods. This project aims to contribute to bridging the epistemological and methodological gaps between urban flood resilience and it operationalization in urban planning.

Image 3.1 |
Overall research roadmap

URGENCIES

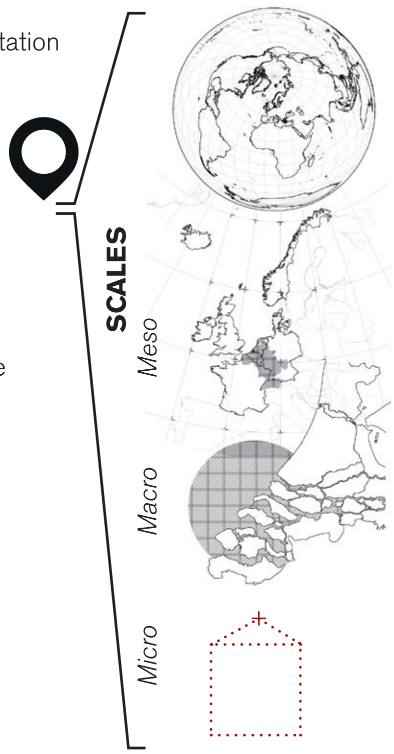
Problem field | Socio-economic/ecological vulnerabilities under the influence of (climate induced) floods and human exploitation

Key words | Uncertainty, complex adaptive systems, urban flood resilience, ecosystem based adaptation

Where? | Rhine-Meuse-Scheldt delta, NL (Oosterschelde)

Problem statement | Hard engineering measures and human exploitation caused disruption of natural systems, resulting in lower ecosystem health and increased vulnerability to the impact of flood hazards in the Rhine-Meuse-Scheldt delta.

Focus on | Ecosystem based adaptation approaches that include learning on natural systems and ecosystem services resulting in a higher ecosystem health, through which on its turn the effects of coastal phenomena can be mitigated and the vulnerability to coastal phenomena can be reduced.



FRAME

Research aim | Support a flood resilient delta

Research question | *How can ecosystem-based adaptation be used to support the adaptive capacity of the (Rhine-Meuse-Scheldt) delta and mitigation of altered future climate conditions, while meeting multiple environmental, social, and economic objectives to support its inhabitation?*

Analytical

1. What is the possible impact of floods in the delta? (in other words: which systems are affected?)

2. What vulnerabilities were created by 'hard engineering' approaches, and which spatial layers and processes were affected?

3. What are social, economic and environmental drivers for change?

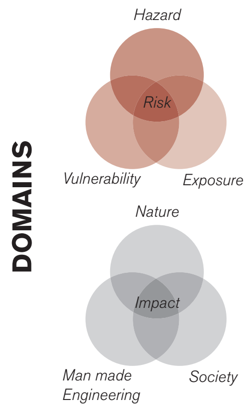
Theoretical

4. What constitutes the adaptive capacity of systems in the delta, and how can this be improved through behavioural, societal and (bio) physical adjustments?

5. What do theories on climate/flood resilience imply for applied urban practices?

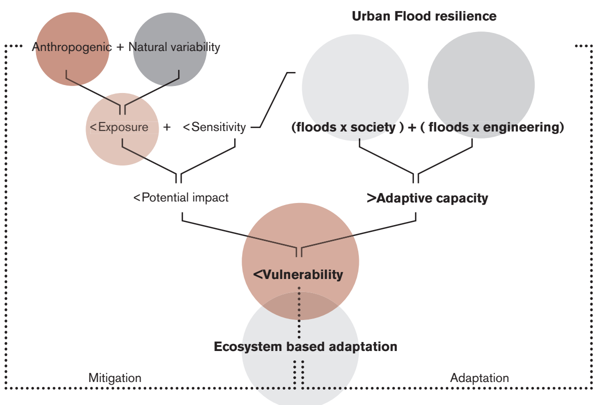
Applied

6. What are the ecosystem services of the delta related to flood phenomena and how can they be applied in order to contribute to (urban) flood resilience?



Research approach | Exploratory, quantitative, qualitative, applied

Conceptual Framework |



Methods | & tools

Literature review
Data analysis
Field work
Conversation experts
Scenario planning
Transcalar (diachronic) mapping

Expected [Design] outcomes

Manifesto
Scenario
Vision for delta
Adaptive pathways for change
Possible phasing project

Conclusion and impact assessment indicators

3.2 | Problemstatement & problemfield

It is not a question 'if', but a question of 'at which rate' sea level rise will occur. This uncertainty makes planning more difficult, since the static (human) environment is imposed on a dynamic surface. Currently the impact of flooding is perceived as an undesirable event that can negatively affect socio-economic processes (land use change, safety), as well as ecological processes. However, key constraints of current hard engineering is the relocation of existing infrastructures, and financial and technological barriers, as well as the availability of relocation space. Additionally, the unforeseen environmental effects of 'hard' engineering approaches (such as dams, storm surge barriers, defensive coastal management) have been affecting biophysical as well as ecological systems, and resulted in increased vulnerabilities of floods in the Rhine-Meuse-Scheldt delta as well as a loss of estuarine habitats. In the context of climate change it might not be a reliable long- term approach for risk management. Specifically in Rhine-Meuse-Scheldt delta there appears to be competing socio-economic (agriculture, horticulture, industry, fishing) and as well as ecological claims, that will only be stressed more by a expected increasing population and related human activities and needs. This questions the feasibility of (new urban) developments in delta areas. Therefore, there appears to be a need to rethink coastal (protection) strategies, questioning future relations between design, engineering, natural and social sciences, as well as governance.

The problem field relates to temporal and spatial distributions of socio- economic as well as ecological vulnerabilities in delta areas under the influence of intensive human exploitation as well as increased flood risk under the influence of the natural variability of climate as well as Anthropogenic climate change.

3.3 Research Aims

There appears to be an emergent need to rethink how, and where urbanization can take place in consideration to the effects of sea level rise. This project aims to think about the possible future land-water interface of the North Sea related to scenarios of the New Anthropogenic Water level. It questions the current way of inhabitation, and its drivers. It opts for nature-based approaches in to improve flood resilience, and overcoming site-specific issues, but also questions the scale and impact of such an approach. Although changes might not be tangible within the timespan of a human life, the aim is to build robust for a longer timeframe. The narrative of the changing morphology will be brought into perspective, as well as a reflection on inhabitation over time in order to establish a frame through which new design strategies of deltas and coastal waterfronts can be proposed. The nature-based approaches are not seen as an ultimate solution but will be questioned throughout the process.

Concluding, the aims are:

- Relate to the uncertain future of waterfronts of the North Sea based on existing scenarios for the New Anthropocene water level (until 2100).
- Support an inclusive and integrative approach, including engineering, research, planning and design, for spatial adaptation and mitigation of climate hazards.
- Reflect on current risk management strategies as well as nature-based solutions, as a means to improve the adaptive capacity of vulnerable areas.
- Create robust design strategies that can contribute to the adaptive capacity of systems in the delta, while seeking co-benefits for corresponding site-specific issues (fresh water supply, artificialization of waterfronts, loss of estuarine habitats etc.).
- Improve the adaptive capacity of delta systems to support urban flood resilience.

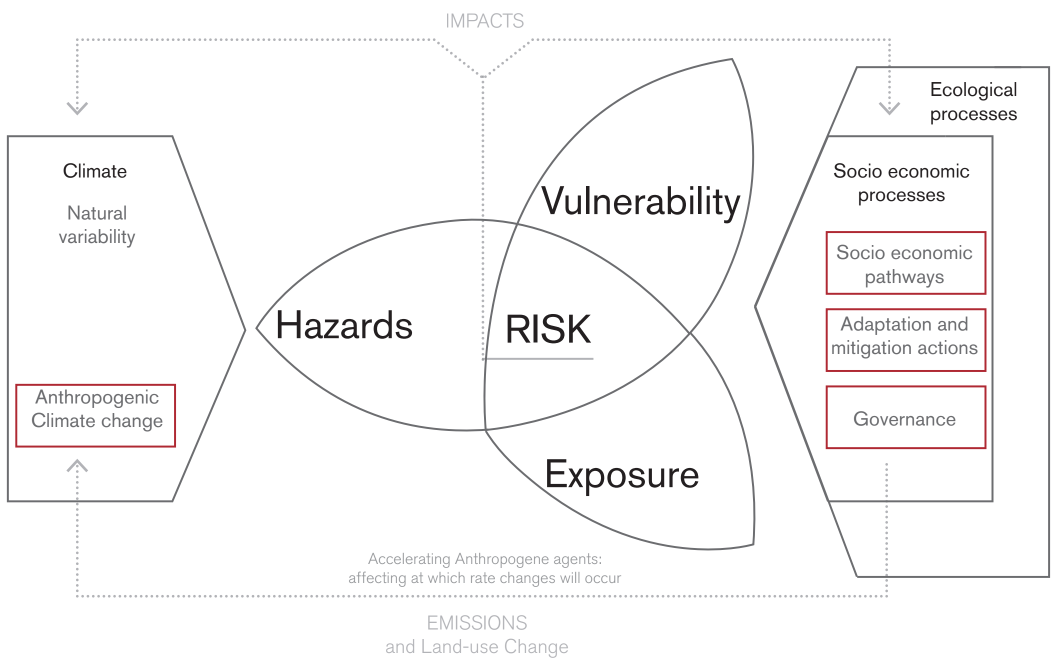


Image 3.3 Risk management strategies, adopted from the IPCC chart modified by author

3.4 Explored pathway

The project relates to the research done for the the inquiry of flux erasure and terraforming, perceiving the North Sea as a dynamic shaper of the land-water interface. The inquiry explored the idea that adaptive responses and soft engineering can benefit the living conditions (see image 2.3). Coastal hazards are currently perceived as a risk, using hard engineering measures to protect flood prone areas. This has led to disruption of natural biophysical systems and low ecosystem health, and increased vulnerability of areas to floods. On its turn this could increase impacts of new coastal hazards, informing new and larger protection measures.

However, this system is not seen as feasible on the long term, since it continuously requires new input of resources, such as sand and extra space for enlarged dike systems. When perceiving coastal phenomena as an opportunity, one can try to adapt. This can relate to 'soft engineering' approaches, such as nature-based solutions, such as ecosystem based adaptation. Eventually the objective of such an approach is to learn about ecosystem services of natural phenomena and establish a high ecosystem health. This might then help mitigate the effect of climate change and reduce the impact of new coastal phenomena as well as providing co-benefits related to the wellbeing of its inhabitants.

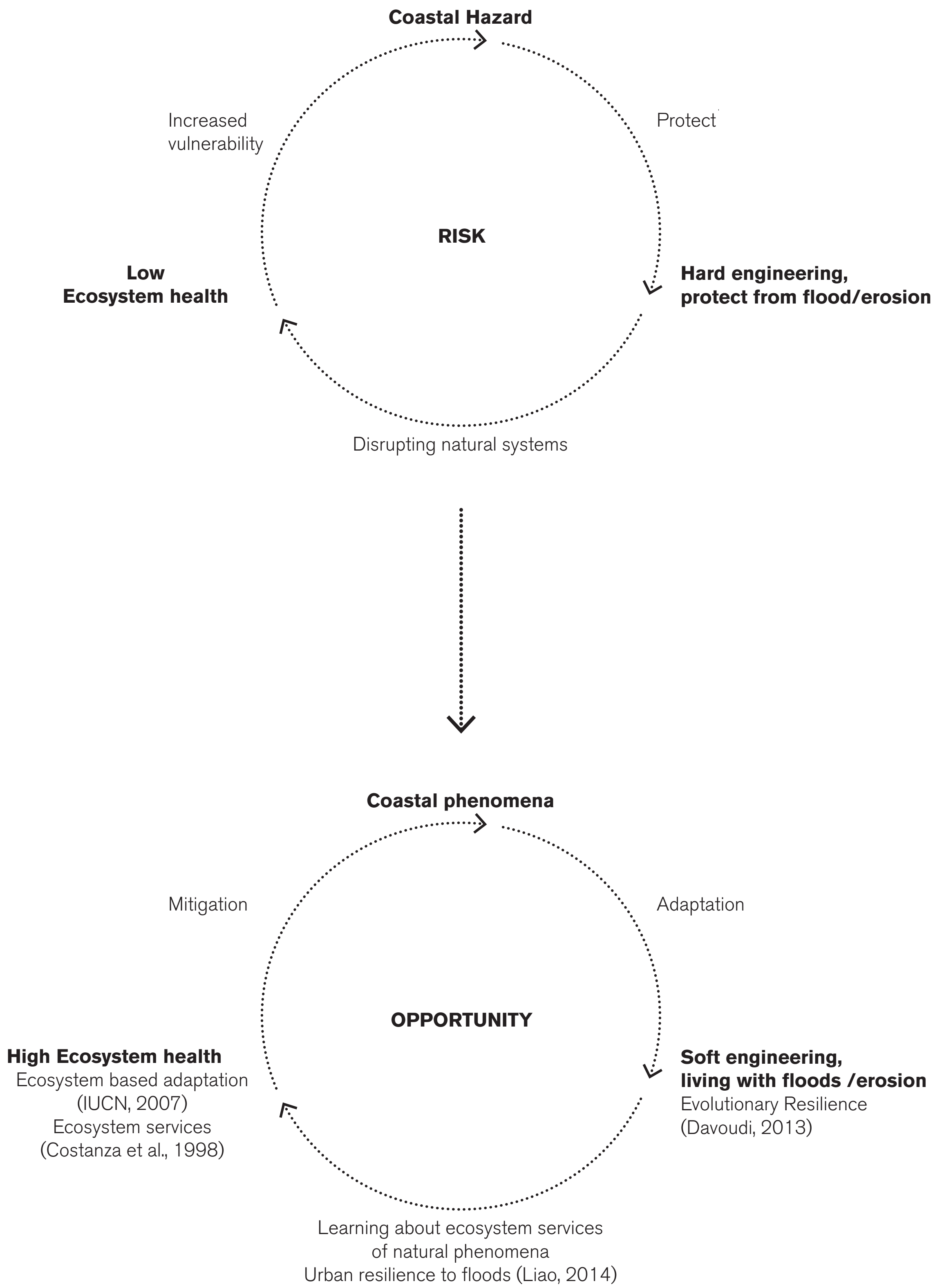


Image 3.4 | Explored approach researched through the inquiry of Flux, erasure and terraforming.

3.5 Researsh questions

The main research questions, following the problematization of the North Sea territory and Rhine-Meuse-Scheldt delta in the Netherlands are as follows:

North Sea territory
How can robust urban design strategies be developed for areas prone to floods alongside the North Sea coast, while considering its dynamic character over time?

Systems
How can a Nature-based approach be used to support the adaptive capacity of the Rhine-Meuse-Scheldt delta and mitigation of altered future climate conditions, while meeting multiple environmental, ecological, social, and economic objectives to support its inhabitation?

In other words, the project aims to illustrate how Nature-based adaptation can create a framework for (urban) flood resilience.

This will be explored through
<u>Analytical knowledge</u> on:
- The rate and magnitude of changes;
- The distinction of socio-economic as wel as ecological vulnerabilities, and affected systems;
- The spatial implications/possible impacts of floods in the delta;
- The social, economic and environmental drivers of change in the delta.

<u>Theoretical knowledge</u> on:
- Complex adaptive (socio-ecological) systems;
- Adaptive capacity of systems;.
- (urban) flood resilience and operationalizing of resilience theories;
- (valuation of) Ecosystem based adaption .

And <u>applied knowledge</u> on:
- Ecosystem services and ecosystem based adaption measures
- Biophysical systems in the delta

The sub questions support the analytical, theoretical, or applied (design related) framework of the project (see image 3.5).

Research question

How can a Nature-based approach be used to support the adaptive capacity of the Rhine-Meuse-Scheldt delta and mitigation of altered future climate conditions, while meeting multiple environmental, ecological, social, and economic objectives to support its inhabitation?

ANALYTICAL

1: What is the possible climatic impact in the Rhine-Meuse-scheldt delta? (in other words: which systems are affected?)

2. What are social, economic and environmental drivers for change?

THEORETICAL

3. What constitutes the adaptive capacity of systems in the delta, and how can this be improved through behavioural, instituational and (bio) physical adjustments?

4. What do theories on climate/flood resilience imply for applied (urban) practices?

APPLIED

5. How can nature based solutions be applied in order to contribute to (urban flood) resilience?

Image 3.5 | Summarizing the research questions of the projects (made by author)

3.6 | Conceptual and Theoretical framework

The increasing vulnerability to floods questions the current relationship between nature, society and engineering of the build environment. This demands a new approach through which these complexities can be addressed. The project proposes to adapt through the lens of evolutionary resilience, or urban flood resilience. However, there are still some knowledge gaps related to how these theories can be applied in practice effectiveness and implementation. This relates to the possible scale of interventions, as well as the impact on land use changes. Whereas ecosystem-based adaptation might be implementable in rural or natural environments there is a concern when static urban environments are involved. Additional there is the difficulty of assessing 'the adaptive capacity' of a system in a quantifiable form. Whereas soft engineering mostly relates to the use of ecological principles for shorelines, there still appears to be a lack in approaches for delta areas, in which riverine phenomena are also addressed. Concluding, the knowledge gap addressed in this research is the use and assessment of nature-based solutions for climate change adaptation related to the natural phenomena and systems in the delta. The project aims to contribute to bridging this knowledge gap.

Image 3.6 shows the conceptual framework of the project. It compresses the decomposition of risk and it elements through an approach in which theories on urban flood resilience, and applied practices in ecosystem based adaptation support the adaptive capacity of systems in the delta. The framework and its elements will be explained in the next paragraphs.

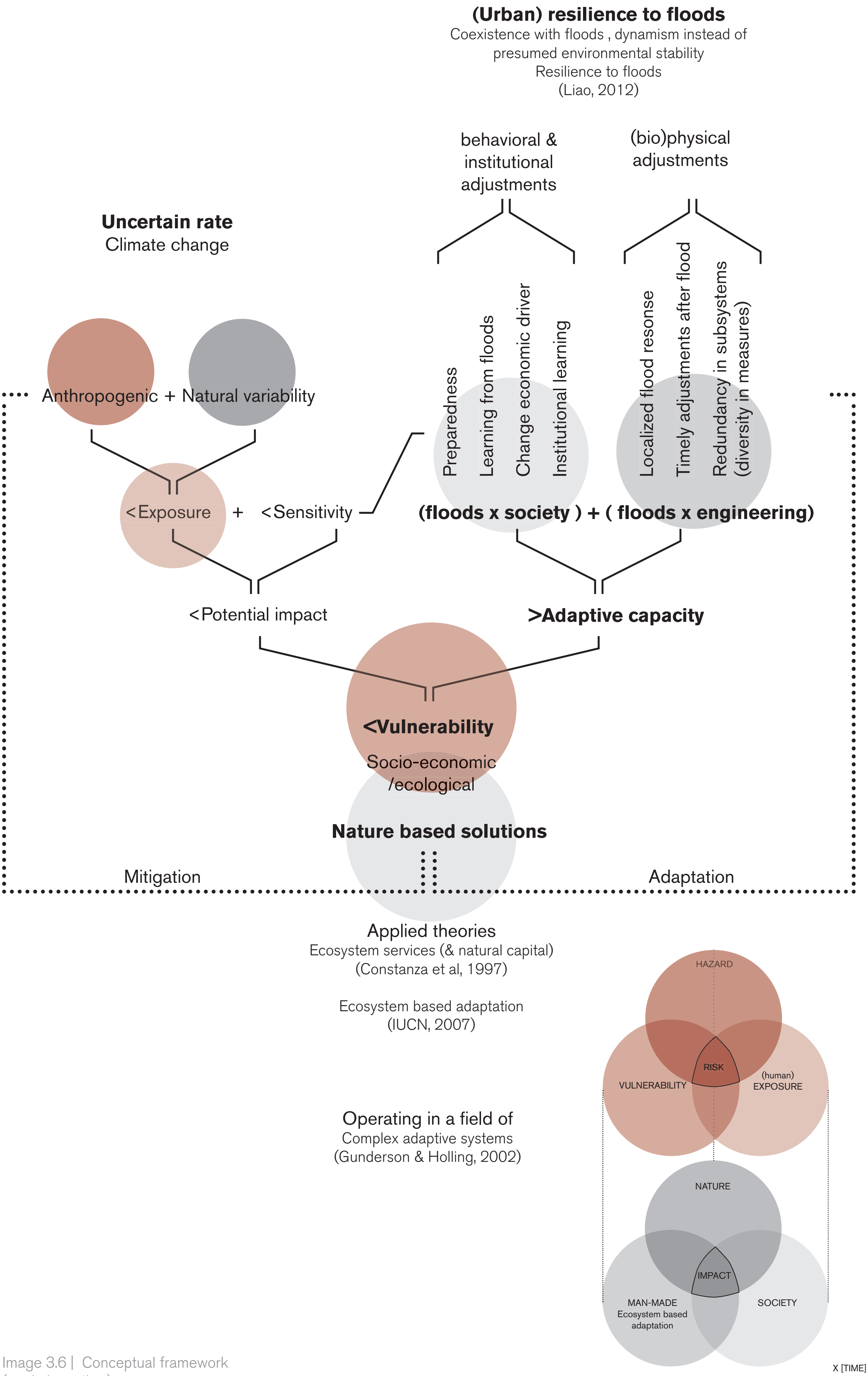


Image 3.6 | Conceptual framework
(made by author)

3.61 Decomposition of risk

Risk (to floods) is perceived as 'the potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of value', and is represented as the 'probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur' (Oppenheimer et al., 2014, p.1048). Often risk is portrayed as an equation: Risk = (Probability of Events or Trends) × Consequences. However, the parameter of this equation are quite difficult to address.

Risk management focusses on the reduction and mitigation of the risk impact by reducing the level of exposure to hazards and reducing sensitivity to a hazard. Therefore, the project perceived the problem field as a decomposition of risk and its components, namely: Hazards, (human) Exposure and Vulnerability. The definitions of the key components, as described by the IPCC (Oppenheimer et al., 2014, p.1048) are:

- Hazards: "The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources".
- Exposure: "The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected".
- Vulnerability: 'sensitivity or susceptibility to harm and lack of capacity to cope and adapt.'

These relate to the domains through which the project operates.

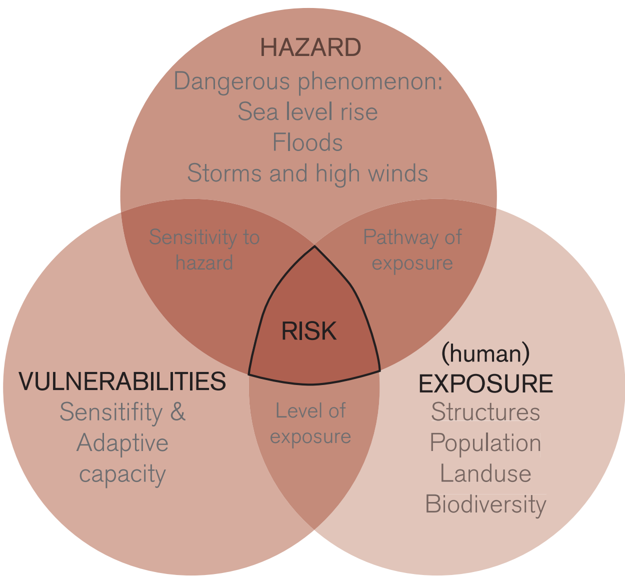


Image 3.61 | Decomposition of risk through vulnerabilities, exposure and hazards. (made by author)

3.62 Domains of the project

Informed by nature-based approaches the lenses of Nature, Man-made structures, and (Governance of) society are considered as the main domains in which the project operates. Whereas the domain of Nature aims to relate to dynamic processes and certain given biotic and abiotic conditions of a site, the domain of Man-made structures relates to the design and impact of spatial modifications. Governance of Society relates to the importance of certain environmental performances, for instance related to livability or biodiversity, but also frames the importance of the institutional level and policy making. Society is not merely seen as 'human society' but also represents 'flora and fauna' that might be affected by the risk of floods or erosion.

The domains can be translated into informative bodies of knowledge related to Sociology, Natural sciences, and practices related to the design/engineering of the build environment. Combined these notions relate to Socio-ecological theories as well as design related practices of which the main ones are represented in the scheme. On a meta level these theories can be informed by more subjective cultural narratives, to inform about past perspectives on hazard management. Within the frame, time is acknowledged as an important agency through which all domains and systems are affected. It related to the planning and execution of plans, as well as the political climate through which decisions needs to be made. Theories that have, till so far, been perceived as relevant are shortly described in the following paragraphs.

Design related practices

Nature based sollutions (IUCN, 2007)

Ecosystem services
(Constanza et al, 1997)

Ecosystem based adaptation
(IUCN, 2007)

Informing

Socio-ecological theories

Complex Adaptive Systems & Panarchy
(Gunderson & Holling, 2003)

Evolutionary resilience
(Davoudi, Brooks, & Mehmood, 2013).

Urban resilience to floods
(Liao, 2012)

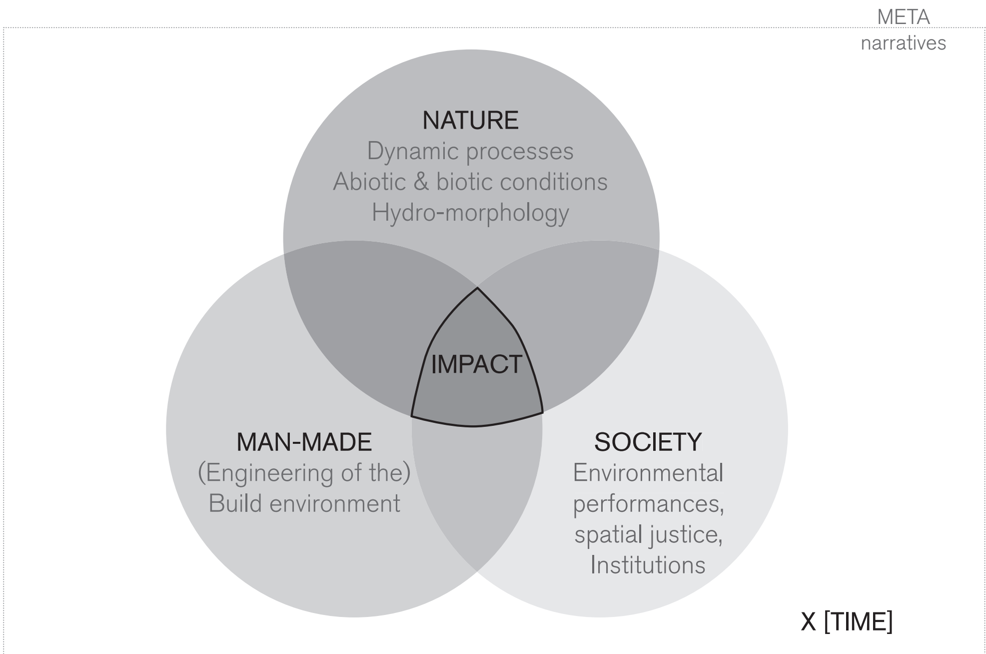


Image 3.62 | Domains through which the project operates
(made by author)

3.63 Related theories

This paragraph will shortly explain the main theories that support the framework. This chapter is supported by the theory paper (chapter 4).

Complex social and ecological systems: panarchy
Within these theories social and ecological systems can be perceived as complex integrated systems in which humans are part of nature (Berkes & Folke,1998). Addressing the multi-scalarity of systems, and the different speeds through which they can operate or inform each other is related to the theory of panarchy. Gunderson and Holling refer to panarchy as, a 'interacting set of hierarchically structured scales' (Gunderson & Holling, 2003). The panarchy theory acknowledges that a system cannot be understood or managed when focused on at a single scale single time perspective (Relience Alliance, n.k.). Systems are interlinked and can either be small and fast, or large and slow.

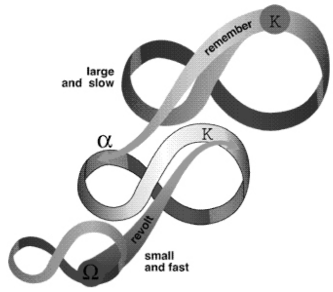


Image 3.63 |
Concept of Panarchy: linked adaptive cycles at multiple scales
(Resilience Alliance, n.k.)

Adaptive capacity and resilience
The IPCC refer to the adaptive capacity (in relation to climate change impacts) as: 'The ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.' (IPCC, 2007, p.869). According to the Resilience alliance, 'systems with high adaptive capacity are more able to re-configure without significant changes in crucial functions or declines in ecosystem services. A consequence of a loss of adaptive capacity, is loss of opportunity and constrained options during periods of reorganization and renewal.' (Resilience Alliance, n.k.)

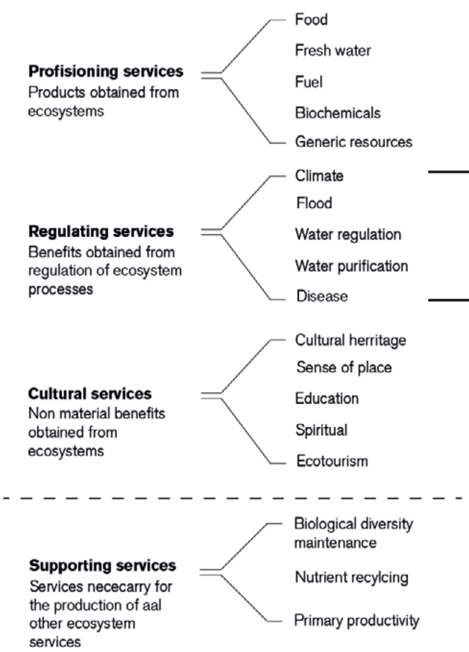
Both Ecosystems, as well as social ecological systems are represented as an 'adaptive cycle' with four phases, namely: 1: Growth or exploitation; 2: Conservation; 3: Collapse or release; 4: Reorganization. The moment a system is in distress there might occur a point of collapse or release after which reorganization can take place. Systems perform a task and can learn through remembering or can revolt.

Urban flood resilience
Future trajectories of Social-ecological systems are determined by three complementary attributes, namely: resilience, adaptability, transformability (Walker et al., 2004, p.1). The capacity of social-ecological systems to 'withstand perturbation and other stressors' whereas it remains the same regime (maintaining its structure and functions) is called resilience (Resilience alliance, 2019). It describes the degree to which the system is capable of self-organization, learning and adaptation, and is therefore capable to benefit from change (Gunderson & Holling, 2002, p.3). Building resilience can essentially be understood as a process of adaptation.

Resilience can be approached through different domains. Through Evolutionary resilience climate change adaptation is considered as 'a continuing process, which involves social and institutional learning and transformative potentials. As such, it discourages planners from putting the emphasis on rigid and fixed plans and the attempt to command and control space and time' (Davoudi, 2012). According to Liao it can be argued that "the adaptive capacity contributing to increasing urban resilience to floods" requires the ability to learn from each flood (Liao, 2012, p. 6/15). Through the learning process one can be "making timely behavioral, physical, and institutional adjustments to be better prepared for the next flood" (Liao, 2012, p. 6/15). Three key properties to urban flood resilience are mentioned by Liao, namely: localized flood-response capacity, timely adjustments after a flood, and redundancy in subsystems (Liao, 2012, p. 6/15).

Nature based design solutions & ecosystem based adaptation
Different approaches try to tackle the adaptive capacity. Often mentioned are nature-based solutions. These, as defined by the IUCN, are “actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively” (IUCN, 2007, p.1). Integrated are lessons learned from ecosystem services and natural phenomena, Nature based solutions can therefore be considered as an umbrella term for different concepts. One example is Ecosystem-based adaptation that integrates the use of biodiversity and ecosysteem services in a overal strategy in order to help adapt to the impacts of climate change, induced by the current climate variability and climate change (IUCN, 2007, p.1), and therefore reduce risk. They also pose solutions to societal as well as ecological challenges, and can meet with multiple (environmental, social and economic) objectives.

Ecosystem services
Ecosystem-based adaption is based on the use of ecosystem goods and services, which can be defined as ”the benefits human populations derive, directly or indirectly, from ecosystem functions” (Costanza et al., 1997, p. 253). And these ecosystem functions can refer variously to the habitat, biological or system properties or processes of ecosystems (Costanza et al., 1997, p. 253). Most often they are divided in four types of services, namely: provisioning services, regulating services, cultural services, and overall supporting services. Whereas regulating services are mainly related to the mitigation and regulation of climate related issues, additional services can arise as co-benefits from the conditions on the location. The project questions how ecosystem services related to the mitigation of flood phenomena can be used to support other services.



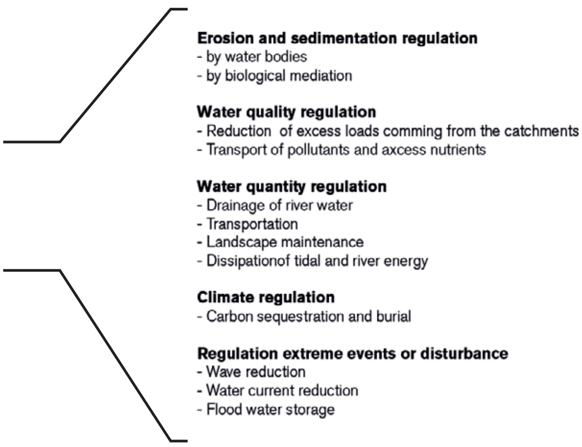


Image 3.631|
Classification of ecosystem services
(made by author)

Image 3.632|
Example of some ecosystem services related to mitigation of flood phenomena in the delta
(made by author, adopted from: Ysebaert & Meire, n.k., p.28)

3.64 Risk related to theories

The framework of the projects is based on the assessment frame of vulnerability by climate change, focussing on the improvement of the adaptive capacity of systems in both the natural physical as well as the societal environment, and incorporates ecosystem-based adaptation as a means to support the adaptive capacity. The framework will be explained through the decomposition of its elements.

Risk: hazards, exposure and vulnerability
Based on the IPCC frame (IPCC, 2007) the vulnerability of a system depends on both the adaptive capacity, as well as the potential impact of hazards. The potential impact relates to the sensitivity informed by the societal (socio-cultural context, education, institutions) and natural (physical, biotic and abiotic) environment, which influences the adaptive capacity of a system. The exposure depends on both the natural variability of climate, but the frequency and impact of climate related hazards might be accelerated due to anthropogenic influences.

Through the scheme (Image 3.641) it can be understood that the vulnerability of a system can be reduced through 1) the decrease of sensitivity 2) reducing the exposure of potential climate hazards, and 3) an increase of the adaptive capacity of a system.

The vulnerability scheme is complemented with the input of ecosystem services (as a base for ecosystem-based adaptation) as projected by the EEA. It is linked to ecological vulnerabilities, such as loss of biodiversity, as wel as socio-economic vulnerablilies that for instance relate to land use changes or deathly casualities. It recognized co-benefits of ecosystem services to improve the adaptive capacity of systems

Both mitigation as well as adaptation are considered in the scheme. Whereas mitigation focusses on the source of climate change and reduction of glass house emissions, adaptation addresses its consequences (Schneiderbauer, S., Pedoth, L., Zhang, D. et al, 2013). Mitigation of climate change could partly be tackled on a governance level, through which the reduction of emissions can be stimulated.

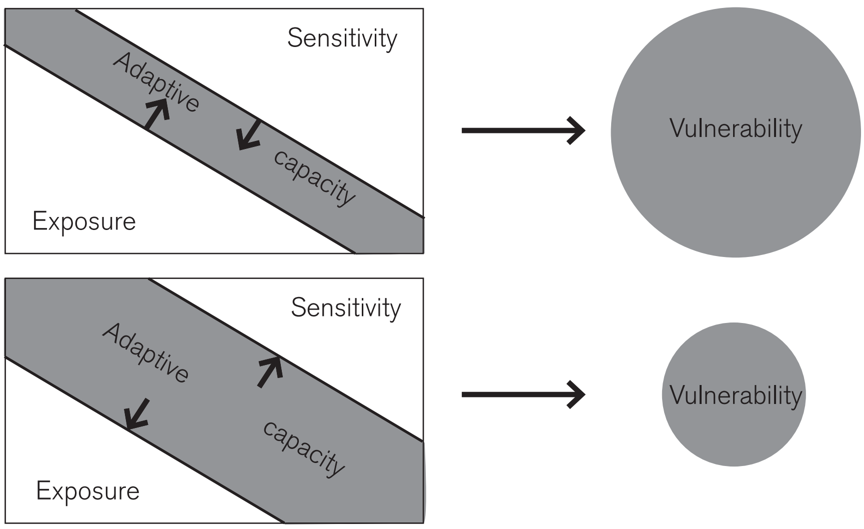
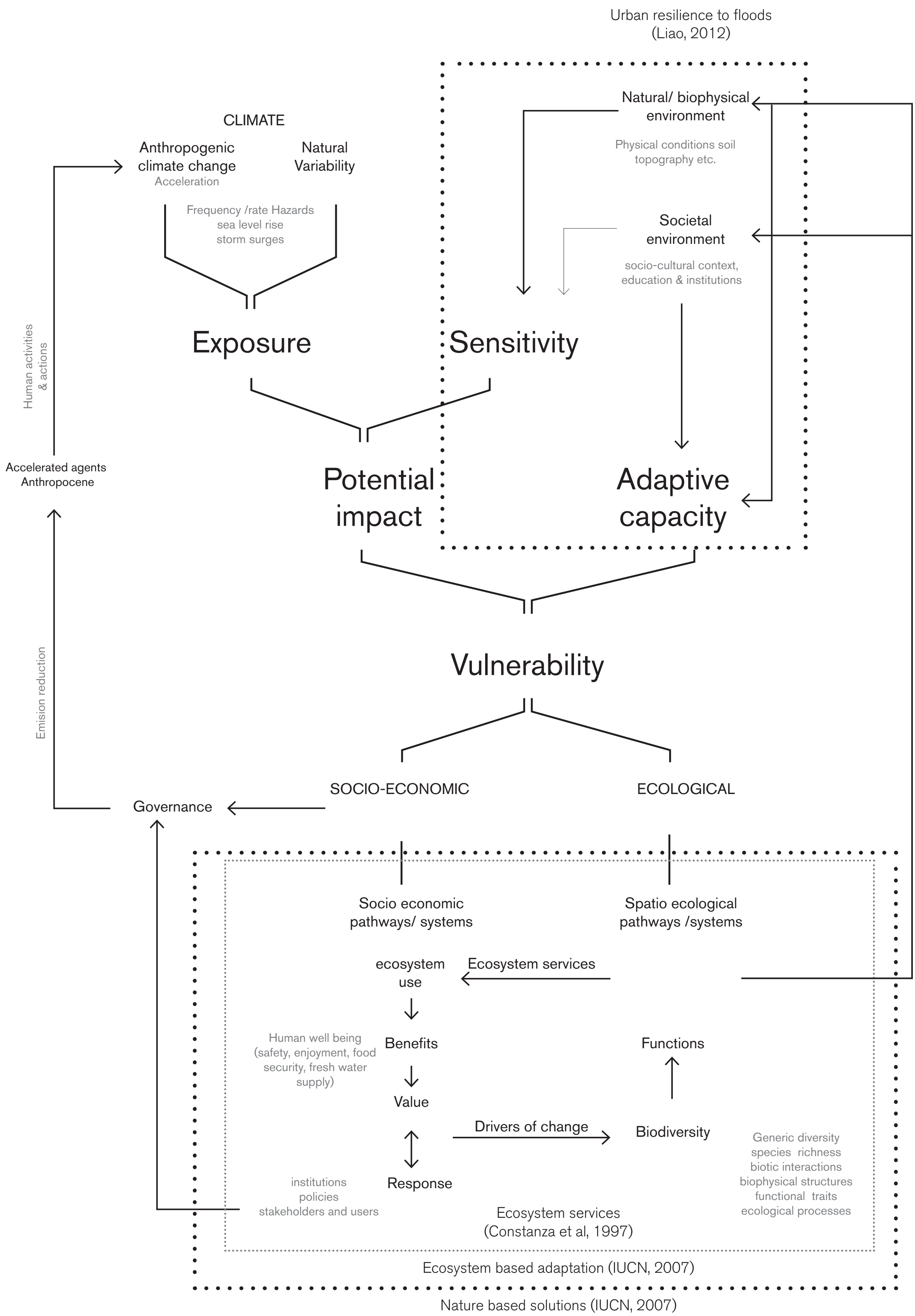


Image 3.64 | Support the Adaptive capacity of systems to reduce the vulnerability to floods (Made by author, adpted from Engle, 2011)

> Image 3.64 1 | Overal scheme implementing the components of risk with an approach of ecosystem based adaptation to tackle the adaptive capacity of social-economic and ecolgical systems. Made by author, based on IPCC framework (IPCC, 2007)


Urban resilience to floods
(Liao, 2012)
CLIMATE
Anthropogenic climate change
Acceleration
Natural Variability
Frequency /rate Hazards
sea level rise
storm surges
Natural/ biophysical environment
Physical conditions soil topography etc.
Societal environment
socio-cultural context, education & institutions
Human activities & actions
Exposure
Sensitivity
Accelerated agents Anthropocene
Potential impact
Adaptive capacity
Emision reduction
Vulnerability
SOCIO-ECONOMIC
ECOLOGICAL
Governance
Socio economic pathways/ systems
Spatio ecological pathways /systems
ecosystem use
Ecosystem services
Human well being (safety, enjoyment, food security, fresh water supply)
Benefits
Functions
Value
Drivers of change
Biodiversity
Generic diversity
species richness
biotic interactions
biophysical structures
functional traits
ecological processes
institutions
policies
stakeholders and users
Response
Ecosystem services
(Constanza et al, 1997)
Ecosystem based adaptation (IUCN, 2007)
Nature based solutions (IUCN, 2007)

3.7 Research approach

Mixed: quantitative and qualitative approach
In order to respond to societal, anthropological, and phenomenological issues of the North Sea, the approach envisioned for the project is both quantitative as qualitative. On the one hand empirical data is collected related to Anthropogenic challenges, as well as the natural variability of climate and frequency and scale of hazard events. This will inform a possible (time) scale in which the build environment can be affected by floods. However, the topic of 'risk' is also intrinsically linked with culture and the narrative of inhabitation over time. Driven by a need to create stability a certain permanence of the build environment was established, somehow discarding the forces of Nature. This 'story' will be of input on a meta level.

Starting from the general notion of a 'New Anthropocene Water Level' on the scale of the North Sea, and with the aim to test the appliance of ecosystem-based adaptation approaches, the project shows a more deductive approach. However, it is also questioned if this concept alone is enough to support the development of design strategies. It might therefore be necessary to support the approach starting from empirical observations, something a narrative based approach can support (inductive input). The project is considered as applied, since the aim is to apply knowledge for practical implications/ strategy development.

Urgencies, themes, and focus
The scheme below shows an overview of the themes and urgencies that are pressed in the project, as well as the areas of focus. The problem field relates to the risks of floods, as well as a loss in biodiversity, and the foreseen inability of settlements alongside the North Sea to deal with these issues in a more accelerated pace. Combined with the imposed themes this frames the project focus. First areas of interest were the outcome of the collective research. The analysis on the north Sea (macro scale) has lead to a focus on the Rhine-Meuse-Scheldt delta on a meso scale, with a particular focus on the Eastern Scheldt. Based on a specific analysis of ecological and socio-economic vulnerabilities, a project area will be selected.

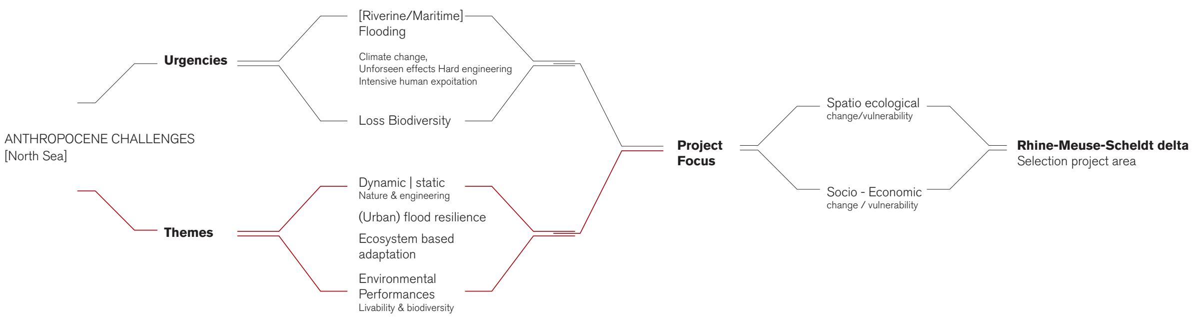
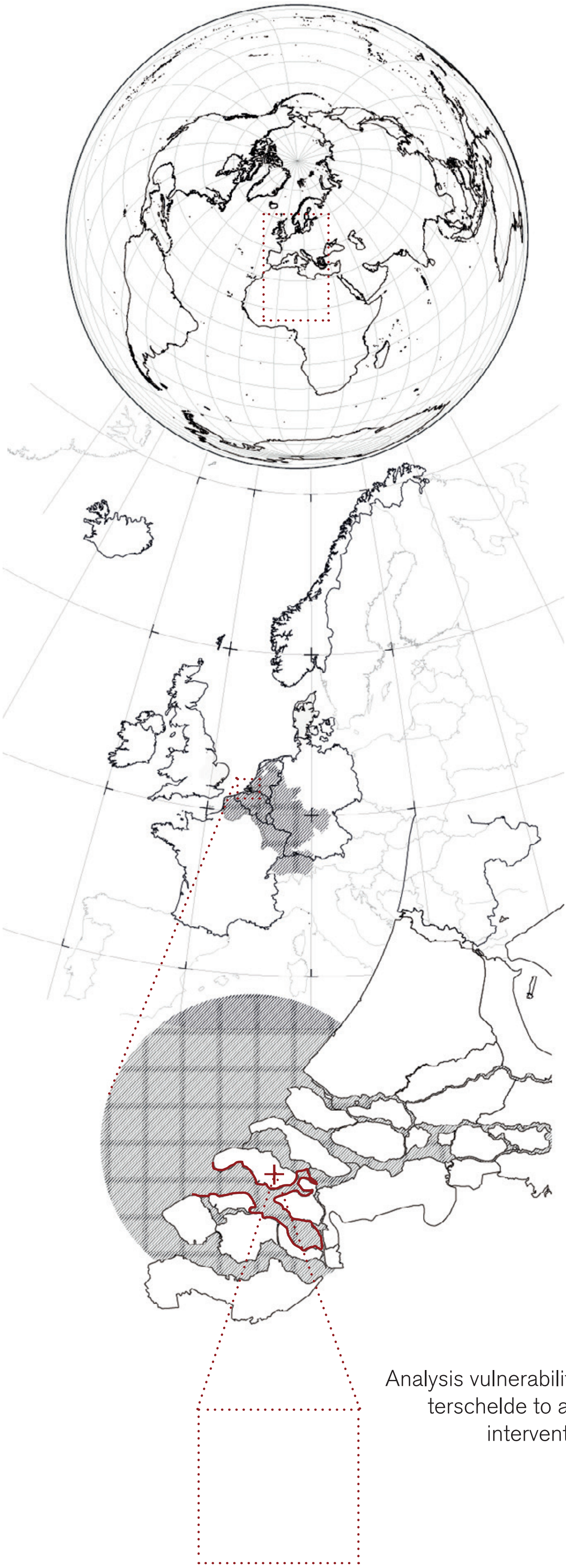


Image 3.7 | Urgencies, themes and focus in first stage of the project (made by author)

PROJECT SCALES
Scales through which the project operates



Global
Phenomena

Macro
North sea
Catchment area rivers
(collective research)

Meso
Rhine-Meuse-Scheldt delta
NL/BE

Analysis vulnerabilities in the Oosterschelde to appoint key interventions

Micro
Oosterschelde
Schouwen Duiveland

3.71 Research methods

Creative methods (informed by social learning) can be combined with research to respond to socio-ecological problems. In general, research by design is perceivedas a helpful method to explore different outcomes. Different mediums can support this, namely: sketching, cartography, narration (through film or projections/models), scenario planning, etc.. A spatial Narrative approach might help in understanding the changing land-water interface, and the different forms of inhabitation/urbanization driven by specific economic, cultural and societal drivers over time.

Since adaptation demands dynamic, long term and transitional approaches to accommodate uncertainty (and avoid future maladaption) adaptive pathways are used as a method for designing with uncertainties. Example is the use of dynamic adaptive pathway development (Haasnoot, Kwakkel, Walker & Ter Maat, 2013). A list of possible actions and decisions needs to be defined related to the issues in the project area in order to establish different possible pathways. Example is actions related to the water supply or demand in an area. This approach is mainly qualitative, in the sense that it proposes different possible spatial actions.

Several tools will be used to accommodate the main methods, namely:

- Literature review
- Data analysis
- Field work
- Scenario planning
- Assessment tools
- Conversations with experts
- Stakeholder analysis
- Transcalar mapping

The tools are linked to the different phases of the project, and will be shortly explained.

PROJECT PHASES		TOOLS: Literature review	Data analysis	Field work	Scenario planning	Assesment tools	Conversation experts	Stakeholder analysis	Transcalar mapping
Project foundation	*Collective research/Atlas*	■	■	■	■	□	■	□	■
	Motivation	■	■	□	□	□	□	□	□
	Problem statement & analysis	■	■	□	□	□	□	□	□
	Project aim	■	□	□	□	□	□	□	□
	Research question	■	□	□	□	□	□	□	□
	Research approach	■	□	□	□	□	□	□	□
Establishment Frameworks	*Analytical framework*	■	■	■	□	□	■	□	■
	Theoretical framework	■	□	□	□	□	□	□	□
	Conceptual framework	■	■	■	□	□	□	□	□
	Design framework	□	□	□	■	■	■	■	■
Analysis	*Mapping & sections*	■	■	■	■	□	□	□	□
	Field work (north sea/site)	□	□	■	□	□	□	□	□
Design & stragegies	*Scenario & vision*	■	■	□	□	□	□	□	□
	Development choice model	■	■	■	□	□	□	□	□
	Design & interventions	□	□	□	□	□	■	■	■
	Project phasing	□	□	□	□	□	□	■	■
Evaluation	*Conclusion*	□	□	□	□	□	□	■	□
	Reflection	■	□	□	□	■	□	□	□
	Limitations & recommendations	□	□	□	□	■	□	□	□

Image 3.7 1 | Proposed tools for data collection and analysis related to the main phases of the project (made by author)

3.72 Research tools

Literature review
The theoretical body of knowledge is established through literature review and relates to the key notions of the project. Literature review is also used to specify the problematization. Next to academic readings additional publications, and news articles can help framing the issues.

Keywords:
- Risk: hazards, exposure & vulnerability
- Adaptive capacity of systems/resilience
- Reflection on example cases of adaptational measures.
- (Governmental) coordination strategies (policies and scales)
- Spatial planning measures

Primary databases:
Tudelft library, JSTOR, Science direct, Springerlink, Google scholar

Data analysis
Through (GIS) mapping and online databases, data can be analyzed and processed in relation to the different sub themes, such as:

- Land use & watermanagement
- Current Hard engineering measures
- Future risk projections
- Demography

Primary databases:
PDOK, European environmental agency, Waterboards

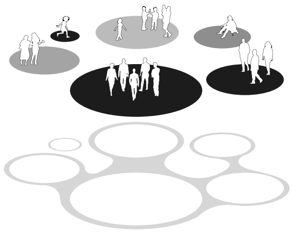
Field work
The collective field trip has been of input for the selection of the project area. Aim of the field trip is to experience different sites alongside the coast and collect empirical data.

1st field trip: North Sea excursion, final week October 2019
2nd field trip: Site visit, after the P2 presentation (20th January 2020).

Fieldwork will be conducted previous to the P1 presentation as a means to make site observations that could support a selection of a possible site. A second field trip is planned shortly after the P2 presentation. Objectives of the project will then be specified, and the final project area will be chosen. This will inform what additional empirical data is necessary from the specific site.

Site observations & documentation
Site observations are noted during the field trip. Photographs and videos will be made of current flood response measures, as well as the perceived qualities or problems related to the current performance of the site. Site observations and documentation will be included in the appendix.

Scenario planning
To consider future uncertainty scenarios can be used as a tool to relate the rate of climate change (read moderate against extreme) and socio-economic developments. These scenarios will already be briefly explored in the collective research of Flux, erasure and terraforming.



Stakeholder analysis
Acknowledge the field of actors involved, as well as their level of interest and power (crowd, subjects, context setters, key players), and indicate alternate strategies to engage various actors or stakeholder in the establishment of resilient urban flood responses. The image is an example of a diagram showing relationships between stakeholder/actors that can be specified to the context of the project.

Conversations with experts
Conversations with experts in the field of the Deltaplanning can contribute to knowledge about existing design practices. These can be linked to meeting with the OOZO group.

3.73 Transcalar [Diachronic] Mapping

Through transcalar mapping the aim is to gain spatial understanding of phenomena on different scales. The collective research focusses on mapping on the scale of the North Sea, although also addressing phenomena on a global scale, through which the initial-problem field is determined.

<u>*Scales of focus:*</u>
North Sea (Macro)
Rhine-Meuse-Scheldt delta (Meso)
Local scale, most probably the Oosterschelde (Micro)

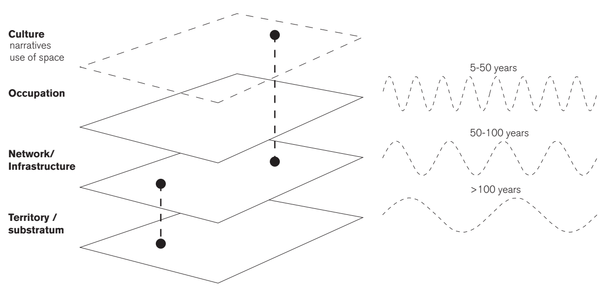
<u>*Process:*</u>
Mapping is used to support different stages of the project, namely the problem analysis, contextualization of the site and its dynamics, as well as the design phase.

Problem analysis:
Mapping is used to give innsight in key problems on different scales. Mappings on a Macro scale, also related to global processes, on the effects of sea level rise results in the understanding of the urgency of floods in the Rhine-Meuse-Scheldt delta on a meso scale. Through mappings on the Meso and Micro scale context specific issues in the delta can be pinpointed. The macro scale informs hydro morphological conditions of river catchments areas, where activities upstream and midstream can affect the lowlands, and should be considered on a transnational level.

Dynamic land-sea interface - Diachronic mapping:
Diachronic mapping is used to give in sight in the dynamics land-water interface on different timescales. Geological timescale is used to include the temporality of the physical form of North sea territory, as well as the Rhine-Meuse-Scheldt delta. In order to show the spatio - temporal character of the area, a beamer projection (of diachronic mappings) can help narrate the story.

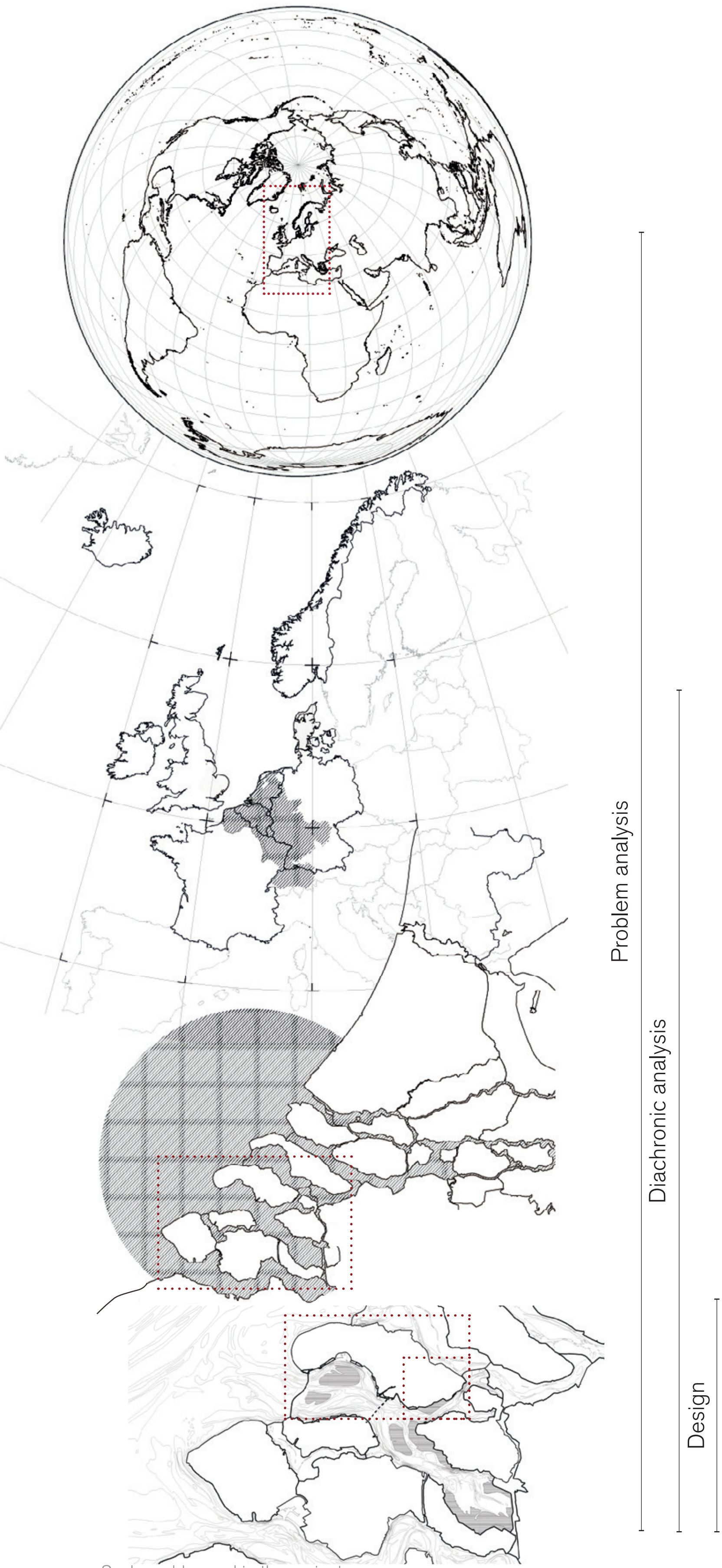
Design scale:
The design mapping mainly entails the meso and micro scale to identify and evaluate opportunities for regional and local context specific measures.

<u>*Layer approach*</u>
The Dutch layer approach (De Hoog, Sijmons & Verschuuren, 1998) can be used in order to understand spatial interrelations. Three different sublayers can be exposed, namely, occupation, networks/infrastructures, and the territory/substratum. A fourth layer is superimposed, namely cultural narratives, as a means to understand the current approach to flood related measures. The layers can be understood through different spatio-temporal dynamics. This emphasizes that changes of both the network layer as well as the substratum layer will require long term, and most probably also large scale, approaches.



Layer approach and indication of spatio temporal dynamics (made by author) based on (De Hoog, Sijmons & Verschuuren, 1998)

PROJECT SCALES



Global

NS

Macro
North sea
Catchment area rivers

D

Meso
Rhine-Meuse-Scheldt delta
NL/BE

L

Micro
Oosterschelde
& island
Schouwen Duiveland

Scales addressed in the project

3.74 Design development & expected outcomes

Several steps for the project are proposed to facilitate a spatial transition of areas in the delta concerned with floods, namely;

1: Manifesto for the design
2: Scenarios planning and development
3: Drivers of change (vision)
4: Explorative design (open ended)
5: Project phasing

Manifesto
The manifesto is a means to declare the main standpoint of the project in order to question what a resilient delta area should be like. This will be supported through the exhibition of an object during the exhibition (part of the studio of transitional territories).

Scenario building
Whereas a lot of projects reflect on the most extreme scenario, sometimes leading to large scale proposals that might be difficult to implements, scenario building is used to define the critical points of system failures (such as the limit of the Eastern Scheldt barrier, or total submergence of sand banks), and other projected systemic boundaries that are cause for actions. Projections of sea level rise from the Delta programm will be used as guideline, ranging from 0,35m till 1m in 2100 (Haasnoot, Diermanse, Kwadijk, Winter & de Winter, 2019, p.15) with additional RCP4.5 and RCP 8.5 projections. The project opts for open ended design in which different pathways can be tested.

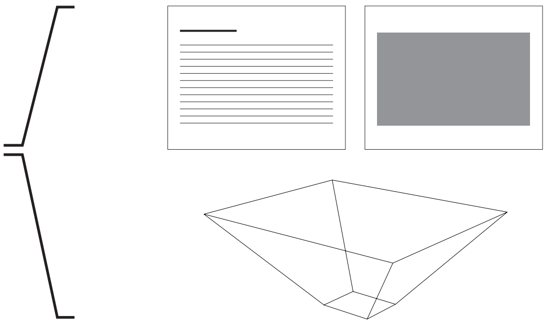
Drivers of change: Overall vision/approach for development
Based on the analysis of the area, the manifesto as well as the scenarios the drivers of change can be defined to support an overall vision.

Choice model
In the project a 'backcasting' perspective is used, in which it is questioned what needs to be done now and in the near future to accommodate future resilience (to floods). This can be linked to the different projections of sea level rise. The scope the project entails is at least until 2100. This leads to a choice model that can evoke explorative and open ended design proposals.

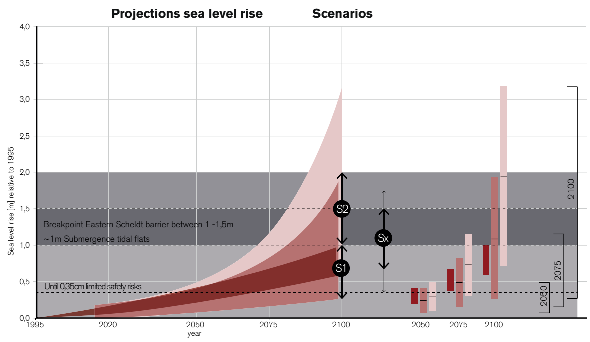
Project phasing/ adaptive pathway development
As mentioned, dynamic adaptive pathway development (Haasnoot, Kwakkel, Walker & Ter Maat, 2013) will be used as an approach for different spatial development trajectories of the project site. This consist out of a list with possible actions or decisions that can be related to a specific location or moment of intervention.

DESIGN DEVELOPMENT & EXPECTED OUTCOMES

Manifesto based on input analysis



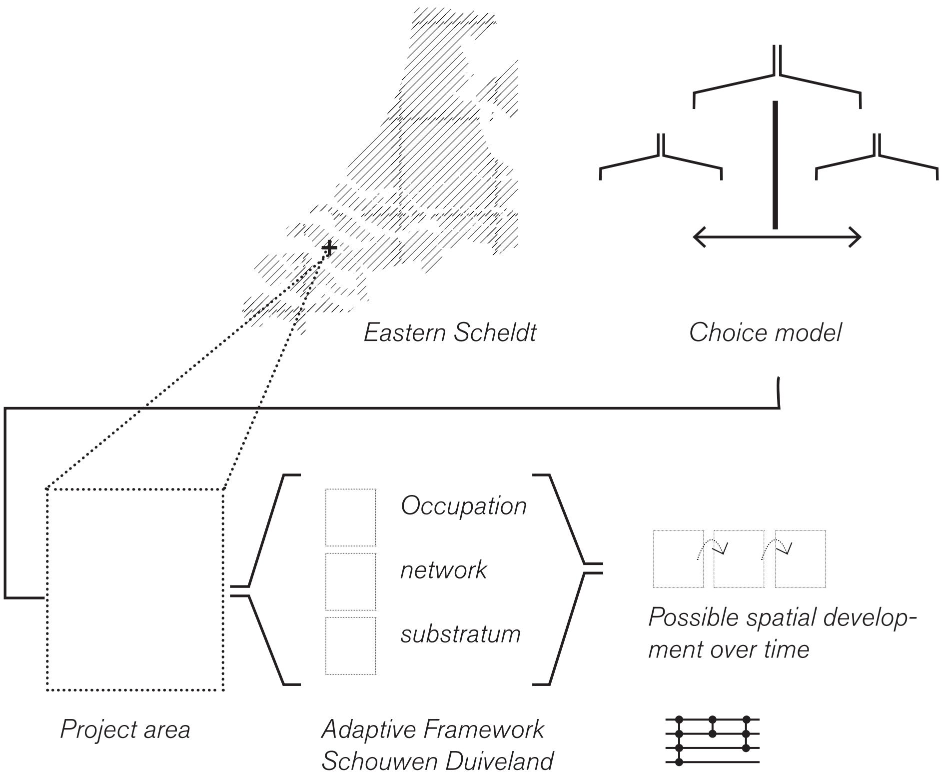
Scenario building



Drivers of change (vision) = **Manifesto + Scenario**

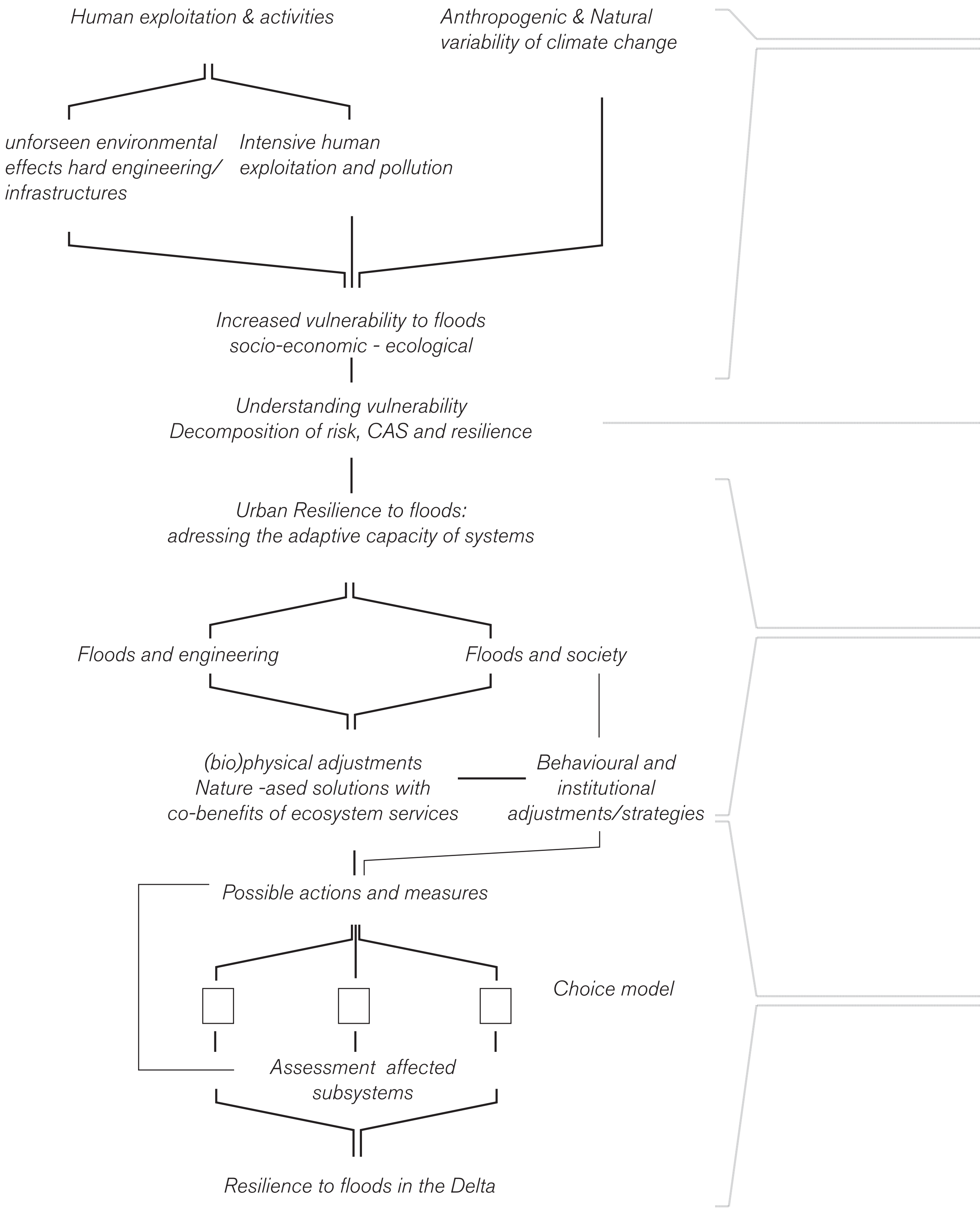
Choice model land water zones

Development



3.8 Overall methodology framework

An attempt was made to make an overall scheme of the project framework. The overal structure relates to the different frameworks and envisioned methods and tools.



Frameworks and research methods

Analytical framework

NS D L

Project foundation
Understanding existing phenomena:
Data collection
Context analysis
Externalities and impacts

1. Projections of climate change and sea level rise (scenario planning)
Quantative research: Emirical data, projections of climate change and frequency and scale of hazard events.

2. Pattern of urbanization in the delta and related phenomena
Quantitative & Qualitative research: Diachronic mapping, demographics, layer approach.

3. Affected (biophysical) systems/ negative externalities
Quantitative & Qualitative research: Assessment of socio-ecological and ecological vulnerabilities under the influence of climate change and human exploitation (such as pollution, nutrification, salinization, soil subsidence) etc. leading to a selection of main systems to address in the project.

Collective research studio

Theoretical framework

D L

Vulnerability
Literature review
Data collection

1. Risk management
Qualitative & quantitative research: literature review, data collection, flood events in the Netherlands, cultural resistance to floods.

2. Complex adaptive systems adaptive capacity
Qualitative research: literature related to systems thinking and appliance of resilience theories in applied practice.

Theory paper

Conceptual framework

D L

Drivers of change

1. Link between urgency, theory and the design space that unfolds
Schematic view of the link

2. Manifesto and model to support a view on the solution space.
Presentation with experts to question how the approach can be improved.

Exhibition studio

Planning/ Design framework

D L

Resilience (to floods)
Nature based solutions
& EBA

1. Planning for (urban) flood resilience
Qualitative and quantitative research: literature review, data collection
Guidelines to build (urban) resilience to floods, scenario building

L

Choice model &
proposal trajectory
exploration of planning with uncertainty

1. Exploration of nature-based solutions
Explorative research (design, sections, models etc.)
Possible solution trajectories based on nature-based solutions

1. Adaptive pathway
Quantitative /quantitave research: concrete list of actions/measures and design proposals.

Explorative design

L

Evaluation
delta planning for (urban) flood resilience

1. Evaluation and assessment of proposed pathways
Quantitative & qualitative research:
Assessment model to quantify the impact on affected subsystems

3.9 | Concluding

Flood resilience requires a change in the current social, economic, and cultural processes and a re-evaluation of supporting ecological (biophysical) processes. It might require different types of land use, and a different mindset towards watermanagement. This challenge is intensified in the Rhine-Meuse-Scheldt delta (NL), where risk of floods will become more evident in the context of climate change. This chapter presented the 'Why', 'What' and 'How' to elaborate on the core of the project. Through the research and design methodology, the methods were proposed. The development of the different project phases is illustrated in Image 3.9.

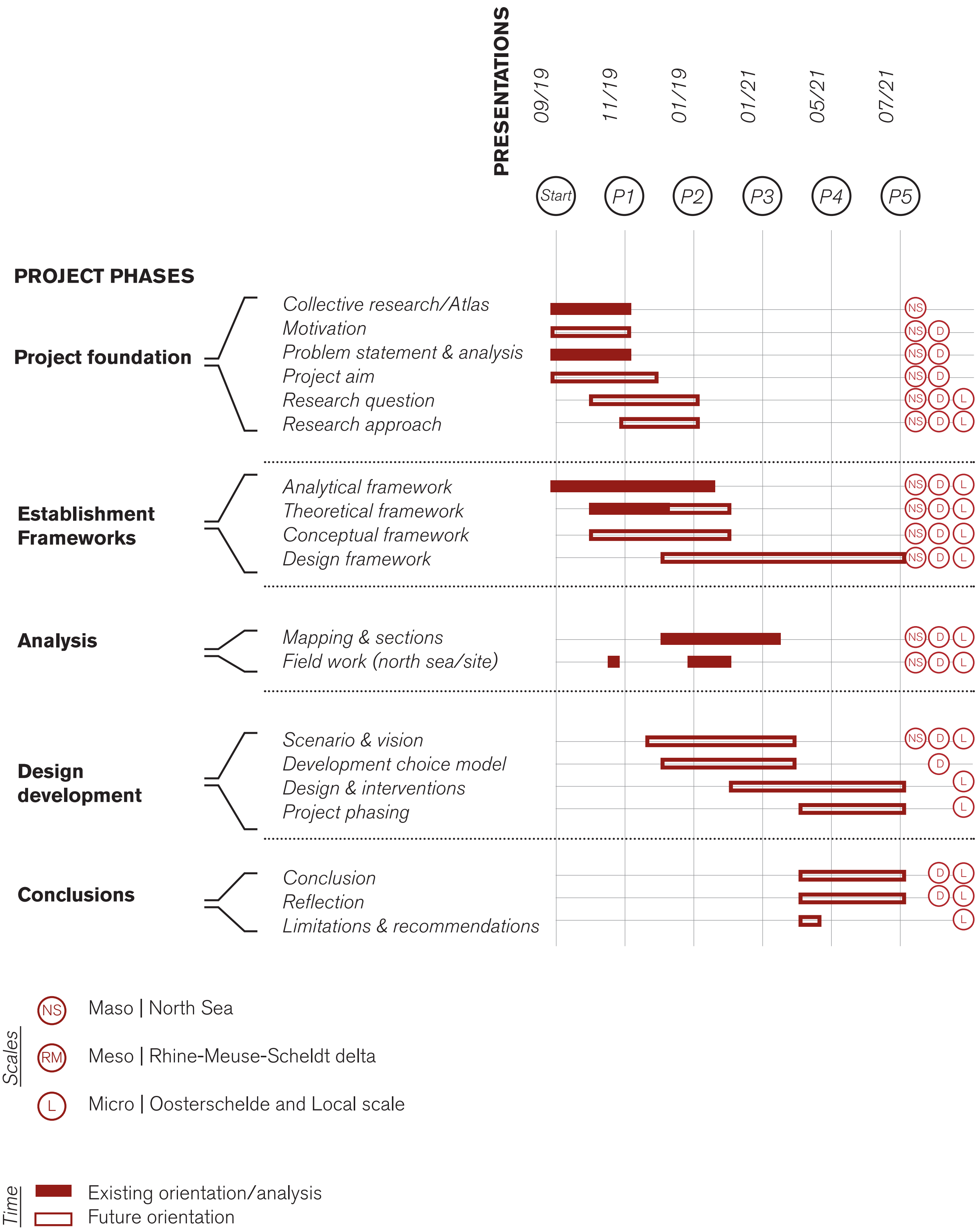


Image 3.9 | Overal timeline graduation project with main presentations

Theory paper

(Urban) flood resilience


Nieuwe waterweg
Nieuwe maas
Oude maas
Spui
Haringvliet
Grevelingenmeer
Hollands diep
Krabbemeer
Schelde-
Rijnkanaal

Re-normalization of floods in the delta
Gradual allowance of floods through ecosystem based adaptation

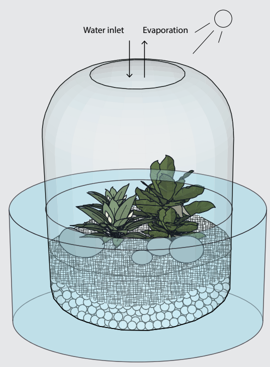
The natural variability of climate and expected climate change questions the capacities of design strategies, and the robust qualities that deltas might need in order to deal with an uncertain future. This applies on the southwestern delta in the Netherlands, where scenarios for sea level rise range from a few centimeters to a few meters until 2100, potentially leading to an increased exposure to floods. At the same time other threats, such as the loss of biodiversity, are linked to intensive human exploitation. Specifically in deltas there appear to be competing claims of biodiversity, urbanization and agricultural use. However there appears to be a shift in the approach towards design projects, where hard engineering ‘to protect against nature’ was rethought in more nature-based solutions, such as ecosystem-based adaptation approaches. This paper aims to address main urgencies in the Dutch delta, specifically the Southwestern delta. It argues the limits of hard engineering and current perception of risk, and presses re-normalization of floods through theories on resilience. It also explores local appliance of ecosystem- based adaptation strategies as a means to mitigate and adapt to the impacts of floods.

Key words
Floods
Uncertainty
Risk management
Resilience
Ecosystem-based adaptation

Introduction: Delta conditions

Deltas have been of specific interest, since their conditions, related to both sea and river have presented benefits for large scale human occupation (trade and fertility of soil). Deltas can be considered as the richest ecosystem services on the earth from an economical perspective. Due to gradual ecotones, transition areas between two biomes, deltas represent large diversities of flora and fauna that could serve different purposes (Costanza et al., 1998, p.256). However the deltas also appear to be particularly vulnerable for climate change related issues. Possible extreme discharges of rivers, as well as relative sea level rise (soil subsidence) pose threats for floods in the low-lands. Projections of sea level rise, according to the Delta programme, range from 0,35m till 1m in 2100 (Haasnoot, Diermanse, Kwadijk, Winter & de Winter, 2019, p.15). Global projections of the KNMI even give a range of 2-3m in 2100 based on stronger global warning (Le bars, Drijfhout & de Vries, 2017, p.4) after which it might still rise 5-8m till 2200 (Haasnoot et al., 2019, p.15). So how to can planning approach this uncertain rate of changes?

This paper aims to address urgencies in the delta, specifically the Southwestern delta in the Netherlands. It states the limits of hard engineering and current perception of risk, and argues the renormalisation of floods through theories on resilience. The paper is structured accordingly. Firstly the urgencies in the delta will be explored as a means to introduce the perceived problem and to address the limits of hard engineering approaches. Secondly risk and risk management will be addressed in the context of climate change in order to frame a focus on addressing the adaptive capacity of systems. Thirdly the concept of resilience will be introduced addressing different views and their differences through literature review. This will lead to a focus on urban flood resilience, in which nature based approached, such as ecosystem based adaptation, will be discussed as a means to provide design principles. Reference project will be used as a method to explain some principles.



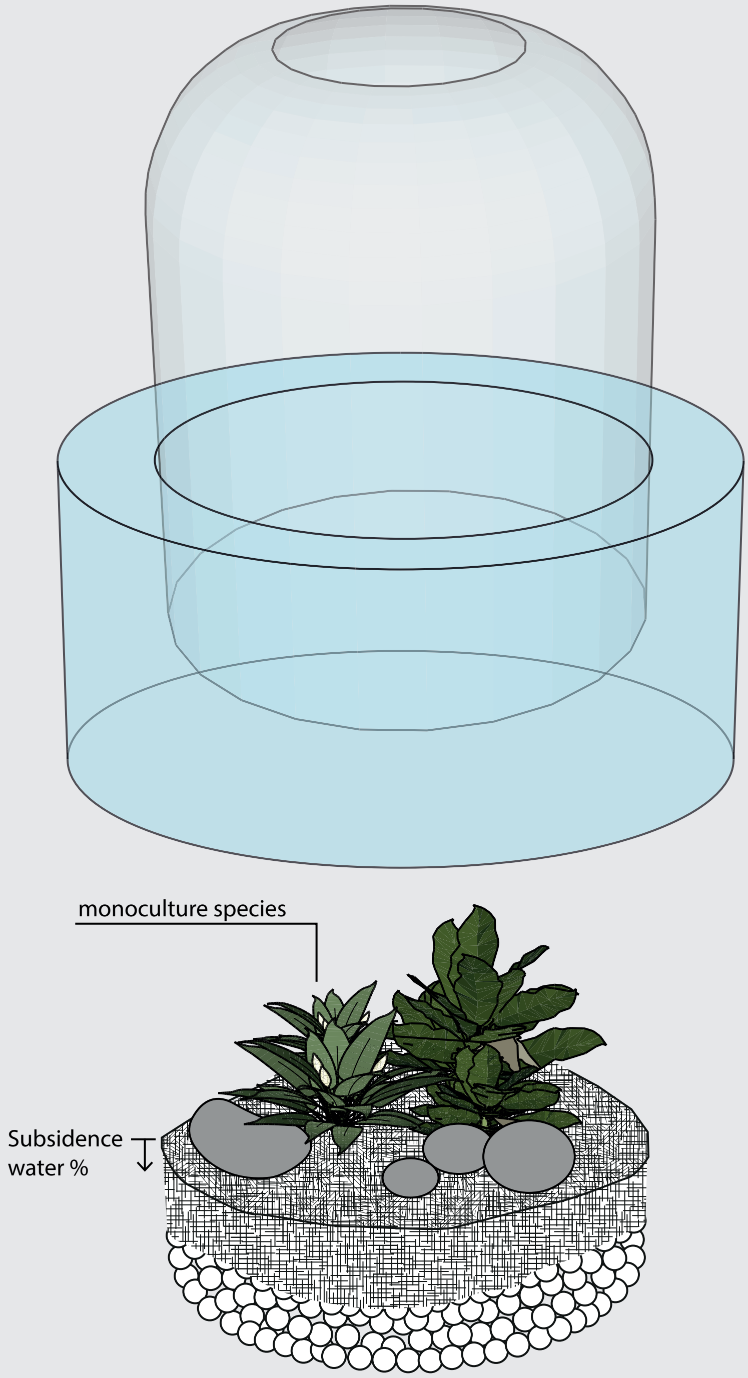


Image1| object of Inquiry showing that different biophysical processes can be affected by human interventions (such as dikes or the delta works), leading to increased vulnerability to floods.

Urgencies of Delta planning

This chapter will firstly elaborate on some main issues in the Southwestern Delta in the Netherlands. Secondly the capacity of current hard engineering approaches for future developments and flood protection is questioned in the context of climate change.

Spatio temporal dimensions of land and water, climate change, claims in the delta

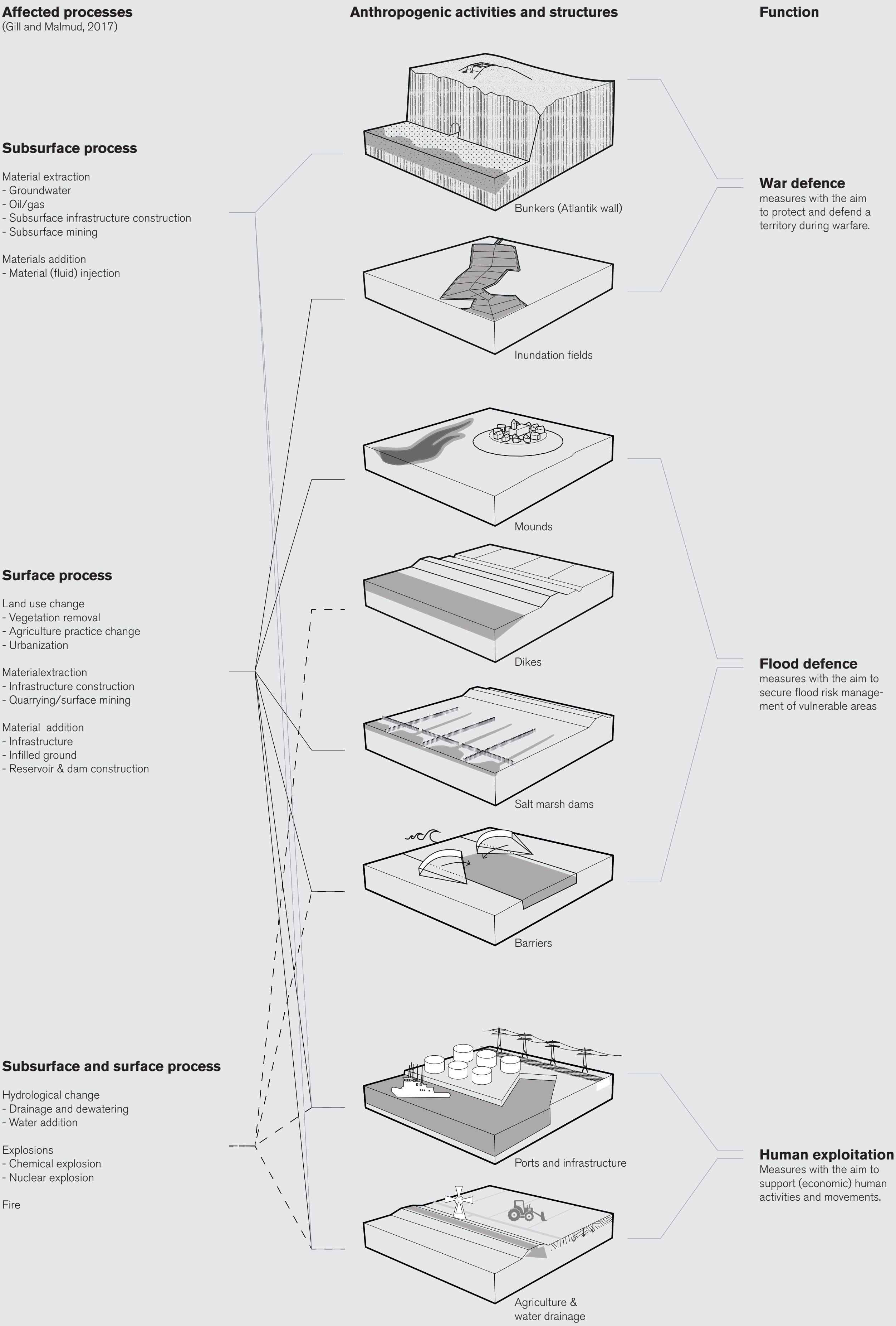
Spatio temporal rhythms of both land and water systems differ (Meyer, Born & Geodan, 2013, p.72). The natural formation of the South western delta in the Netherlands continued until 1300 when endikements and polders were introduced. This enabled more permanent conditions for inhabitation and agricultural land use. Port cities such as Rotterdam could thrive due to the open connection with the sea. This was further constituted by the 'Nieuwe waterweg' that was built in 1874 as a means to ensure an open sea connection.

However these Anthropogenic infrastructures affected different (biophysical) processes (surface, subsurface or combined). For instance water drainage resulted in soil subsidence of water containing soils (peat and clay), leading to increased relative sea level rise. The deltaworks reduced the tidal influence leading to a loss in sandbanks and related habitats. In the meantime the pace of urbanization increased from 1900, leading to a highly urbanized delta as well as intensification of land use. Therefore potential exposure to flood increased. Simultaneously Intensive human exploitation has led to degradation of soil, posing ecological threats. And areas that were once dominated by tides and mudflats have been replaced by artificialized waterfronts to support industries. It can therefore be concluded that deltas are exposed to different social, economic, as well as ecological claims.

Static versus dynamic: the limits of hard engineering

As stressed by Belanger and Williams in 'landscape as infrastructure' the long-term effects of industrialization and urbanization on the biophysical systems have often been neglected (Belanger & Williams, 2016, p.277). At the same time climate change questions the design capacity of flood protection infrastructures. Adaptation of these infrastructures to climate change requires financial, spatial (wider dikes), material (tragedy of the sand commons) and new technical resources, as well as time to develop them. Increased maintenance might be needed to support a stable coastline based on the existing infrastructures. According to Haasnoot, about three to four times as much sand is needed to support the current Dutch coastline when sea level is rising about 10mm/year (until 2050). This could even be more than 20x as much in 2100 depending on the rate of changes. (Haasnoot et al., 2019, p.15). It can be questioned if this is a sustainable long-term solution. What does this mean for (the perception of) risk management?

> Representation of different surface and subsurface processes affected by Antropogenic activities. Image made by author as part of the collective research for the inquiry of Flux, Erasure and Terraforming. Based on processes as mentioned by Gill & Malmud, 2017

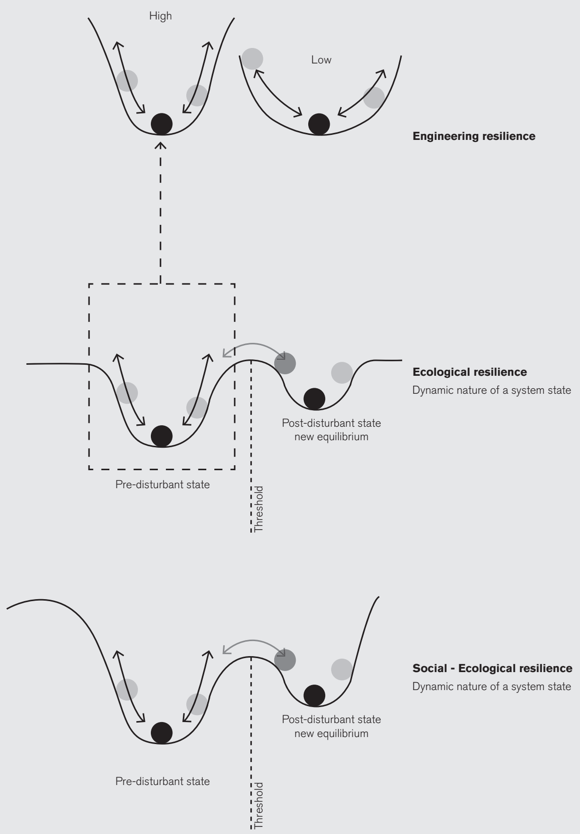

Affected processes
(Gill and Malmud, 2017)
Anthropogenic activities and structures
Function
Subsurface process
Material extraction
- Groundwater
- Oil/gas
- Subsurface infrastructure construction
- Subsurface mining
Materials addition
- Material (fluid) injection
Surface process
Land use change
- Vegetation removal
- Agriculture practice change
- Urbanization
Materialextraction
- Infrastructure construction
- Quarrying/surface mining
Material addition
- Infrastructure
- Infilled ground
- Reservoir & dam construction
Subsurface and surface process
Hydrological change
- Drainage and dewatering
- Water addition
Explosions
- Chemical explosion
- Nuclear explosion
Fire
Bunkers (Atlantik wall)
Inundation fields
Mounds
Dikes
Salt marsh dams
Barriers
Ports and infrastructure
Agriculture &
water drainage
War defence
measures with the aim
to protect and defend a
territory during warfare.
Flood defence
measures with the aim to
secure flood risk manage-
ment of vulnerable areas
Human exploitation
Measures with the aim to
support (economic) human
activities and movements.

(Flood) Risk management

The Intergovernmental Panel of Climate change (IPCC) explains risk as “the potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of value’, and is represented as the ‘probability of occurrence of hazardous events (such as floods) or trends multiplied by the impacts if these events or trends occur”. (Oppenheimer et al., 2014, p.1048). Therefore often risk is portrayed as an equation: Risk = (Probability of Events or Trends) × Consequences.

The decomposition of risk to climate change leads to the components of Hazards, (human) Exposure and Vulnerability. Firstly hazards can be described as the ”potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources” (Oppenheimer et al., 2014, p.1048). This can be affected by both natural as well as Anthropogenic climate change. In the description of a hazard part of the perceived ‘value’ is mentioned that might be at stake. Secondly the exposure relates to the places and settings that can be adversely affected by an event. This concerns the presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets (Oppenheimer et al., 2014, p.1048). Finally the vulnerability can be described as the ”sensitivity or susceptibility to harm and lack of capacity to cope and adapt” (Oppenheimer et al., 2014, p.1048). ‘Risk management’ therefore focusses on the reduction and mitigation of the risk impact by reducing the level of exposure to hazards, and sensitivity to a hazard.

It might be good to consider that risk is mainly perceived from a human perspective, where dynamics interfere with the stability and perceived values. It relates to the incapacity of our structures and lifestyles to adapt to certain events (that might occur more frequently in an uncertain rate of climate change). Specifically interesting for the field of design related practices therefore is the approach of the adaptive capacity of systems through both the natural/physical as well as the societal environment. This could serve as a means to reduce the potential impact or decrease the vulnerability related to floods. However this might require a different view on flood risk.



Visualisation of resilience theories
(image made by author)

A system approach: Complex adaptive (social and ecological) systems

Before addressing the adaptive capacity of a system (related to the environment), it is necessary to understand that planning operates in a field of complex (social and ecological) systems. Social and ecological systems (SES) can be perceived as complex integrated systems in which humans are part of nature (Berkes & Folke, 1998, p.339). Addressing the multi-scalarity of systems, and the different speeds through which they can operate or inform each other can be related to the theory of panarchy. The panarchy theory states that a system cannot be understood or managed when focussed on at a single single geographic or time scale, but emphasizes the importance of relevant interactions between these scales (Gunderson & Holling, 2002, p.3). Systems are interlinked and can either be small and fast, or large and slow. So how can these complex systems adapt and withstand stressors?

<u>Resilience through different domains</u>

Future trajectories of Social-ecological systems are determined by three complementary attributes, namely: resilience, adaptability, transformability (Walker et al., 2004, p.1). The capacity of social-ecological systems to 'withstand perturbation and other stressors' whereas it remains the same regime (maintaining its structure and functions) is called resilience (Resilience alliance, 2019). It describes the degree to which the system is capable of self-organization, learning and adaptation, and is therefore capable to benefit from change (Gunderson & Holling, 2002, p.3).

Resilience can be approached through different domains. In several works Holling, a theoretical ecologist, addresses two different views on resilience, namely engineering resilience, addressed from environmental sciences (physical/engineering), and ecological resilience, which is adressed through (socio) ecological sciences. According to Holling the main difference of the views on resilience lies in difference between assumptions whether multiple states (of equilibrium of systems) exist (Holling, 1996, p.31).

Holling stresses that some key features of ecosystem structures and functions are probably not included in an engineers 'view of ecology'. For instance whereas ecosystems have moving targets and multiple potential futures (that are uncertain and unpredictable), policies and management apply fixed rules to achieve constant yields or harvest, independent of scale. This could lead to a gradual loss of resilience. Therefore a system might not be able to overcome disturbances that could previously be absorbed (Holling, 1996, p.32). This opts for more flexible and adaptive management. Davoudi addresses a third conceptualization of resilience, namely Evolutionary resilience, also referred to as socio-ecological (urban) resilience. It challenges the idea of there being a equilibrium, in this sense can, with or without external disturbance, change over time (Davoudi, 2013, p.309).

Through the adoption of the term 'Resilience' in urban practices 'planning for resilience' appears to have become a concern. Yet it can be argued that some of these terms of are potentially contradictory (Alexander, 2013, p.1), or not as well defined, and can therefore be somewhat problematic when operationalizing it in an urban context (Doyle, 2016, p. 101). Therefore maybe more importantly is how the approach towards design practices is affected through these notions.

Through evolutionary resilience, design practices should be based on dynamism instead of presumed environmental stability. However this dynamism appears to be limited by a current view in which cities and floods cannot coexist. As Liao states, "Building urban resilience to floods is essentially a process of adaptation" (Liao, 2012, p. 9/15). This would require a change in applied practices, and will be a process of learning by doing (Liao, 2012, p. 6/15).

Adaptive capacity

As mentioned, building resilience can essentially be understood as a process of adaptation.However what is the adaptive capacity of a system? The IPCC refers to the adaptive capacity (in relation to climate change impacts) as: 'The ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences" (IPCC, 2007, p.869). According to the Resilience alliance, "systems with high adaptive capacity are more able to re-configure without significant changes in crucial functions or declines in ecosystem services" (Resilience Alliance, n.k.).

Social- ecological systems, as well as ecosystems, can be represented as an 'adaptive cycle' with four phases, namely, 1: Growth or exploitation, 2: Conservation, 3: Collapse or release, 4: Reorganization. The moment a system is in distress, there might occur a point of collapse or release after which reorganization can take place. Systems perform a task and can learn through remembering, or can revolt. A loss of adaptive capacity is seen as a loss of opportunity and could constrain options during periods of reorganization and renewal (Gunderson & Holling, 2002, p.5-7).But what does this entail for design practices?

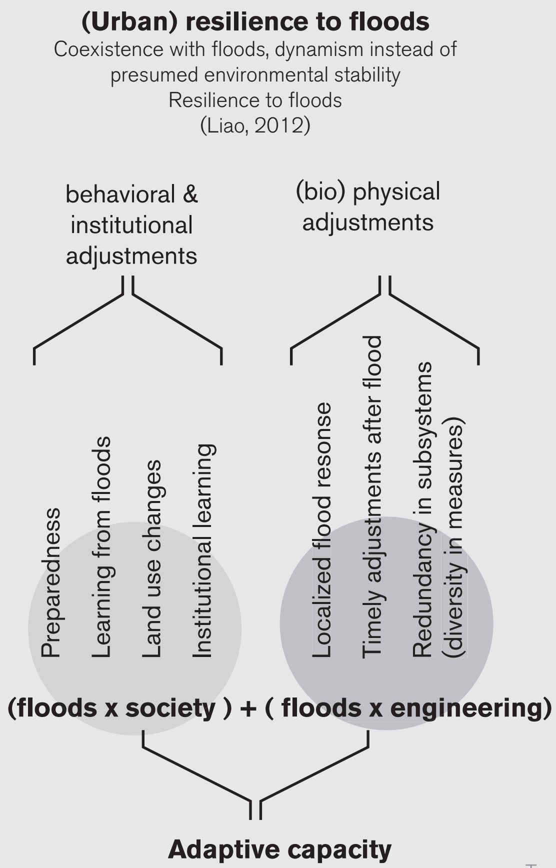
Climate change adaptation and the properties of urban flood resilience

Climate change adaptation can be considered as "a continuing process, which involves social and institutional learning and transformative potentials'. This should discourage planners to put an emphasis on rigid or fixed plans. (Davoudi, 2012, p. 314). According to Liao it can be argued that "the adaptive capacity contributing to increasing urban resilience to floods" requires the ability to learn from each flood (Liao, 2012, p. 6/15). This refers to the notion that socio-ecological resilience to a disturbance, arises from learning from that very disturbance (Berkes, Colding, & Folke, 2003, p.20). Through the learning process one can be "making timely behavioral, physical, and institutional adjustments to be better prepared for the next flood" (Liao, 2012, p. 6/15).

Three key properties to urban flood resilience are mentioned by Liao, namely: localized flood-response capacity, timely adjustments after a flood, and redundancy in subsystems (Liao, 2012, p. 6/15). Firstly, localized flood-response. When authorities are trusted with the mitigation of flood hazards people might not feel the need to take any measures themselves. As mentioned by Pielke in the 'Nine fallacies of floods', flood control infrastructures can offer a false sense of security (Pielke, 1999, p.419). When centralized measures fail, floods can indeed become 'disastrous', mainly due to in ill preparedness to such an event. It is therefore argued that by reducing flood risk awareness resilience is reduced (Colten & Sumper, 2009, p.356).

Secondly Liao mentions timely adjustments after every flood. By understanding the phenomena and making necessary adjustments Liao argues that the flood ability of a city could incrementally increase (Liao, 2012, p. 6/15). This can include timely reinforcements or elevation of housing before a flood season or expected event. When applying flood hazard mitigation measures at a property level, timely, system-wide adjustments are more likely. However some households might have limited financial resources. Through subsidies or new requirements of for developments in flood prone areas, governance can still contribute to actions on property level. However in order to create a willingness for measures at property level flood risk awareness is something to address firstly.

Thirdly redundancy in subsystems is mentioned, in which a flood hazard management system would comprise diversity in measures for mitigation, preparedness, response and re-organization. Through this diversity Liao mentions that the flood response capacity is distributed across different levels (individuals, communities, and municipality), that can benefit from each other when one level is overwhelmed (Liao, 2012, p. 6/15). Advantage of a diversity in measures is also that one can learn from different cases, and search for more context specific measures.



Translation of key properties to flood resilience as mentioned by Liao (made by author)

Re-normalization of floods in a flood resistant culture

As said by van Dam, "A river does not flood, a river flows"(van Dam, 2012, p.2). Floods merely got a negative connotation from a human perspective. Although this paper does not aim to fully elaborate on the 'cultural dimension' of floods, it is relevant to have a general understanding of the perception of floods in the Netherlands over time. Flood events over time, both riverine as well as maritime, resulted in local, regional and national strategies for both the survival and mitigation of floods, shaping the perception of causality. Therefore, this chapter will address the the ideology to prevent floods by addressing some former events, as well as some former flood coping strategies in the Netherlands, that can contribute to knowledge about a lost amphibious culture of living with floods.

Ideology to prevent floods

Several floods have affected the Netherlands over time. Examples are the St. Elizabeth flood in 1421 in which the Grote Waard polder was flooded, or the flood 'disaster' of 1953 in the southern delta of the Netherlands (as well as Belgium and part of the UK). These events resulted in alerted risk management on a governance level. For instance the deltaworks were initiated after the flood event in 1953. Quite unique is the fact that the normation of the primary flood defenses is even included in the Dutch water law, stating that the maximum risk of flooding can't exceed more than one casualty per 100.000 inhabitant per year (Ministerie van Infrastructuur en Milleu, 2016, p.29).

Therefore there still appears to be an ideology that floods must be prevented, as flooding is assumed to be disastrous. The response to sea level rise remains to be to 'hold the line', reinforcing the existing coastline. It might be necessary to denote this ideology and question if there is a need for an opportunistic view on flood as a phenomena. As written by van Dam, the concept of risk has a connotation of predictability and choice (van Dam, 2012, p.5), but this predictability and choice can be questioned when considering the uncertain rate of climate change. There might not be a choice to not allow floods, therefore pressing a need to, gradually, re-normalize floods. This would question the form and shape of the physical environment and a gradual change in its use. As mentioned by Liao many physical systems (on which we depend) can only operate in dry conditions and become dysfunctional when the environment turns (Liao et al., 2016, p.75). So how did we deal with this in former times?

Former coping strategies: Netherlands

According to van Dam three interaction strategies have been specifically important in the Netherlands to cope with floods, namely: Compartmentalization of the landscape by dikes, living on elevated areas (mounds), and thirdly transport by water (van Dam, 2012, p.6). Firstly the compartment of dikes served as a secondary safety system. It gained time for people to evacuate. Although some of these secondary dike structures have been neglected after the introduction of one primary system, they might still be of use as a tool to re-introduce floods. Current plans with double dike systems are tested, and might inspire the reformation of locations in the southwestern delta as well.

Secondly people mainly lived on elevated areas in the landscape. This included natural elevated areas, such a river levees, (river) dunes, or creek ridges, as well as man-made structure (van Dam, 2012, p.6), such as the mounds that were predominantly present in the Northern part of the Netherlands, as well as Germany and Denmark. This simply allowed people to continue living during floods (although with additional food supplies and other necessities). Centres of larger cities were, in most cases, also built on higher grounds, and therefore served as coordination centres during a flood events for surrounding villages. Current problem is that new developments have not necessarily been built on the higher grounds.

Thirdly van Dam mentiones the local transport of goods. The 'farmer boat' was specifically mentioned as a condition for amphibious behaviour, since it provided safe and easy commuting between wet and dry parts of the landscape, also related to commuting on flooded lands during events (van Dam, 2012, p.7). Water transport could also help the reconstruction after such an event.

In current planning some of these strategies have been reintroduced. Example is the depoldering of the Noordwaard as part of the Room for the river programme. The plan was initiated alongside the Nieuwe Merwede as a means to reduce high river discharges. It includes the reintroduction of floods in both natural as well as arable lands (Image 1). Depending on the height of the water different endiked compartments can flood. Mounds have been reintroduced to ensure that the farmers could remain in the area. A safety route allows them to evacuate during more extreme events. Parties involved were the Directorate-General for Public Works and Water Management (In dutch: Rijkswaterstaat), the Waterboard, as well as the municipality. However such a project could not have succeeded without adjustments of its residents and required land use changes.

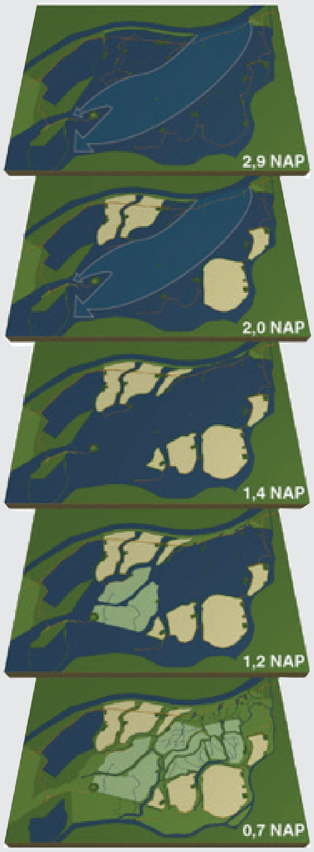


Image 1: Depoldering of the Noordwaard: the sequence of flooded areas based on height (de Ingenieur, 2015).

Delta planning and urban design principles

Knowing that planning can contribute to the adaptive capacity, through both the physical as well as the social environment, and arguing for the re-normalization floods, it is necessary to translate a systematic approach into urban design principles. Several planning strategies have emerged in an attempt to correspond to adaptive planning in deltas related to climate change. Examples are 'Urbanized deltas in transition' (Meyer & Nijhuis, 2014), and 'New perspectives for an urbanized delta' (Meyer, Born & Geodan, 2014). Although these present a systemic analysis of several delta areas, it can be argued that they do not present an approach for applied local solutions. Therefore there still appears to be a need for more concise applied strategies and design principles on a local scale. This chapter will explore the use of ecosystem based adaptation approaches as resilient pathways in delta areas, the ecosystem services of flood phenomena, and finally some main urban design principles that can support proposals for the delta.

<u>Ecosystem based adaptation approaches</u>

Different approaches try to tackle the adaptive capacity. Often mentioned are nature based solutions. These, as defined by the IUCN, are "actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively" (IUCN, 2007, p.1). Integrated are lessons learned from ecosystem services and natural phenomena. One example is Ecosystem-based adaptation that integrates the use of biodiversity and ecosysteem services in a overal strategy in order to help adapt to the impacts of climate change, induced by the current climate variability and climate change (IUCN, 2007, p.1), and therefore reduce risk. They also pose solutions to societal as well as ecological challenges, and can meet with multiple (environmental, social and economic) objectives.

In order to apply this, it is necessary to learn about the ecological structures, functions and services. It can therefore be hypothesized that, whereas hard engineering approaches generally resulted in disruption of natural systems, low ecosystem health, and increased vulnerability for the impact of hazards, Ecosystem based adaptation approaches include learning on natural systems and ecosystem services resulting in a higher ecosystem health, through which in turn the effects of flood phenomena can be mitigated and the vulnerability to flood phenomena can be reduced. As mentioned by Liao, "Resilience-based management supports the recovery of river health because the ability of the river to provide ecosystem services promotes urban resilience to floods." (Liao, 2012, p.10/15).

So what are the ecosystem services of flood phenomena that could provide benefits and support resilience?

<u>Ecosystem services of flood phenomena</u>

Ecosystem-based adaption is based on the use of ecosystem goods and services, which can be defined as "the benefits human populations derive, directly or indirectly, from ecosystem functions" (Costanza et al., 1997, p. 253). And these ecosystem functions can refer variously to the habitat, biological or system properties or processes of ecosystems (Costanza et al., 1997, p. 253). Most often they are divided in four types of services, namely: provisioning services, regulating services, cultural services, and overall supporting services (Image 1). Whereas regulating services are mainly related to the mitigation and regulation of climate related issues, additional services can arise as co-benefits from the conditions on the location.
But what are examples of ecosystems services in the delta related to the mitigation of flood phenomena in the delta? Some examples of ecosystem services in the

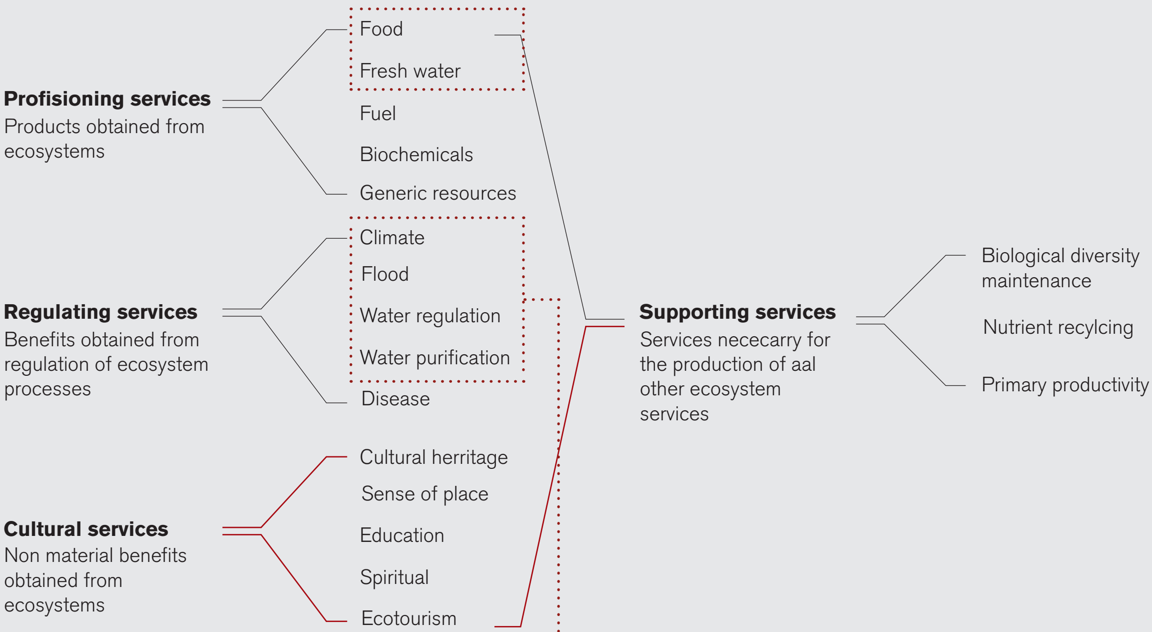


Image 2: Classification of ecosystem services (made by author)

Erosion and sedimentation regulation
- by water bodies
- by biological mediation

Water quality regulation
- Reduction of excess loads comming from the catchments
- Transport of pollutants and axcess nutrients

Water quantity regulation
- Drainage of river water
- Transportation
- Landscape maintenance
- Dissipationof tidal and river energy

Climate regulation
- Carbon sequestration and burial

Regulation extreme events or disturbance
- Wave reduction
- Water current reduction
- Flood water storage

Image 3: Example of some ecosystem services related to mitigation of flood phenomena in the delta (made by author, adopted from: Ysebaert & Meire, n.k., p.28)

delta are mentioned in image 3. Through a qualitative approach, (such as the Ecosystem service habitat matrix),
present or potential habitats can be linked to ecosystem services to underpin their delivery (Geange, Townsend, Clark, Ellis & Lohrer, 2019, p.150). Liao mentions that, in a natural state, floodplains (of rivers) convey and store the share of high flows and sediments that spill overbank (Liao, 2012, p.8/15). Important is the floodplain vegetation that creates hydraulic roughness, exerting significant impacts of the flood process since it reduces the flood wave, but also speeds up the sedimentation proces during minor floods (Liao, 2012, p.8-15). Therefore the (time) scale impact of floods related to the flood magnitude, floodwater velocity and depth as well as the timing could be reduced during extreme weather events. Another example are mudflats are storage for CO2 they can also support climate regulation. Shellfish reefs for instance can stabilize eroding coastal zones. This service can also be linked to an economic driver in the delta, like food production.

Urban design principles

Related to the concept of 'Ecological wisdom' Liao mentions three urban design principles, additional to already existing urban design concepts, namely : anticipate and accommodate flooding, incorporate the ecological process of flooding, and reveal the flood dynamics to the public (Liao et al., 2016, p.7). Example mentioned of the first is pilotis architecture in which new developments are high-rise accommodation on 'stilts'. This requires an open ground floor space, and waterproof flooring, walls, and furnishing. It might be necessary to integrate such measures in new urban developments. An example of a measure in already existing urban environments is the installation of small flood barriers in front of houses, as is the case in the center of Dordrecht (NL) where floods occur more frequently. In this context such a local measure might therefore be the best (short term) solution, since there is often no space.

Secondly, urban design should incorporate the ecological process of flood, such as the re-naturalization of river fronts (as river parks) or the sand engine as part of the 'building with nature' programme in the Netherlands. It can be argued that this often relates to the development of non-urban areas. This whereas urban areas appear to be more incompatible with the flood dynamics

Thirdly, reveal the flood dynamics to the public. It can be argued that people merely perceive a seemingly stable state of nature (due to flow regulation). This leads to "little public concern with river health and a low awareness of riverine dynamics, including the failure to appreciate flooding as a natural phenomenon" (Liao, 2016, p.76-77). Therefore it is proposed to support the interaction between the water fronts and people through the accommodation of harmless (controlled) floods. This would support the education in flood ecology, as well as the awareness of floods as phenomena. Whereas governance might become a tool to establish guidelines for new developments, this would also require more responsibility from public owners and developers who need to anticipate.

Concluding

Delta areas in particular are affected by climate change, however hard engineering approaches don't appear to be sustainable long-term approaches to adapt to these uncertainties.

Through the understanding of evolutionary resilience it can be argued that planning should be based on dynamism instead of presumed environmental stability, and that (urban flood) resilience to a disturbance arises from learning of that disturbance. This can be linked to three design principles, namely : anticipate and accommodate flooding, incorporate the ecological process of flooding, and reveal the flood dynamics to the public (Liao et al., 2016, p.7). Therefore whereas centralized flood response has lead to increased vulnerability to the effects of floods, it might be necessary to gradually re-normalize floods, and include more diversity of measures on a local scale. By slowly renormalizing floods, the awareness of the phenomena, as well as the co-benefits of it, can be better understood. This might on its turn also lead to an understanding that on the long-term change will be evident, and that some areas might need to be given back to the sea.

Former strategies of dealing with floods, such as the compartmentation of the landscape by dikes, living on elevated areas (mounds), and transport by water (van Dam, 2012, p.6), might give some inspiration for initial adaptation strategies in the Southwestern delta in the Netherlands. Nature based approaches, such as ecosystem-based adaptation are of specific interest for future developments since they promote the recovery of an ecosystems health that can promote urban flood resilience. So by linking ecosystem services to the specific habitats in the delta their delivery can be underpinned (Geange et al., 2019, p.150), and co-benefits can be found supporting the overal well being of people. Through ecosystem based adaptation floods can be gradually introduced.

Discussion

Not very much touched upon is the assessment of ecosystem-based adaptation, and the valuation of ecosystem services. Problem in the valuation of services is that it can't always be expressed in the same currency. For instance whereas livelihood of the environment can be expressed in the amount of income, as well as a certain quality of the environment for recreation, the value of specific types of agriculture can be perceived through the productivity/ha of land or the profit of crops. For context specific measures it might therefore be of relevance to examine the existing values of stakeholders.

Although discussed lightly, the renormalisation of floods is evidently cause for resistance since it provokes land use changes as well as a change in mindset. The renormalisation of floods is now mainly based on the perceived incapacity of current flood defense to cope with changes over a longer time, and therefore the expected situation that floods will become part of future deltas.

References

Berkes F. and C. Folke, eds. (1998). *Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience*. Cambridge, UK: Cambridge Univ. Press.

Chicharo L., Müller F., Fohrer N. (2015). *Introduction. In: Chicharo L., Müller F., Fohrer N. (eds) Ecosystem Services and River Basin Ecohydrology.* Springer, Dordrecht

D'Antonio, W., Sasaki, M., Yonebayashi, Y., & Cramer, L. (1995). Ecology, society and the quality of social life. Social Forces, 73(3), 1155.

Delta alliance. (n.k.). *Rhine-Meuse Delta.* Retreived: 18-10-2019, from:http://www.delta-alliance.org/deltas/rhine-meuse-delta

Gunderson, L., & Holling, C. (2002). *Panarchy : Understanding transformations in human and natural systems.* Washington, DC: Island Press. (2002). Retrieved Oktober, 2019, from INSERT-MISSING-DATABASE-NAME.

Haasnoot, M., Diermanse, F., Kwadijk, J., de Winter, R., Winter, G. (2019). *Strategieën voor adaptatie aan hoge en versnelde zeespiegelstijging. Een verkenning.* Deltares rapport 11203724-004 Retrieved, from: https://publications.deltares.nl/11203724_004.pdf

IPCC. (2007). *Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 104 pp.

IPCC. (2007). *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 976pp. Retrieved 26-10-2019, from: https://www.ipcc.ch/site/assets/uploads/2018/03/ar4_wg2_full_report.pdf

Lefebvre, H. (1991). *The production of space.* Oxford, England: Blackwell.

McHarg, I. L., & American Museum of Natural History. (1971). *Design with nature.*

Meyer, H., & Nijhuis, S. (Eds.). (2014). *Urbanized deltas in transition.* Amsterdam: Techne Press. Meyer, H., Born, G., & Geodan. (2013). *Nieuwe perspectieven voor een verstedelijkte delta : Naar een methode van planvorming en ontwerp* (Ipdd cahier, december 2013). Delft: S.n.

Meyer, H., & Bouma, T. (2017). *The state of the delta : Engineering, urban development and nation building in the Netherlands.* Nijmegen: Vantilt.

Neumann, B., Vafeidis, A., Zimmermann, J., Nicholls, R., & Kumar, L. (2015). *Future coastal population growth and exposure to sea-level rise and coastal flooding - a global assessment.* Plos One, 10(3), 0118571. doi:10.1371/journal.pone.0118571

Pranzini, E., & Williams, A. (2013). *Coastal erosion and protection in europe*. London: Earthscan.

Ritzema, H., & Loon-Steensma, V. (2018). *Coping with climate change in a densely populated delta : A paradigm shift in flood and water management in the netherlands.* Irrigation and Drainage, 67(S1), 52-65.

Schneiderbauer, S., Pedoth, L., Zhang, D. et al. Nat Hazards. (2013). *Assessing adaptive capacity within regional climate change vulnerability studies—an Alpine example*. 67: 1059. https://doi.org/10.1007/s11069-011-9919-0

Sulivan, R. (2011). *Geography Speaks: Performative Aspects of Geography.* Ashgate Publishing Company, Burlington, VT, USA, 2011. 189 pp. ISBN 9781409420095

Van Slobbe, E., De Vriend, H., Aarninkhof, S., Lulofs, K., De Vries, M., & Dircke, P. (2013). *Building with nature: In search of resilient storm surge protection strategies.* Natural Hazards : Journal of the International Society for the Prevention and Mitigation of Natural Hazards,66(3), 1461-1480. doi:10.1007/s11069-013-0612-3

ELECTRONIC SOURCES
Cambridge dictionary. (2019). *Performance.* Retrieved 26-10-19, from: https://dictionary.cambridge.org/dictionary/english/performance

Climate Change Post (n.d.) *Coastal erosion united Kingdom.* Retrieved 13 September 2019, from: https://www.climatechangepost.com/united-kingdom/coastal-erosion/

Deltacommissie. (2008). *Working together with water: A Living land builds for its future*. Retrieved 13 September 2019, from: http://www.deltacommissie.com/doc/deltareport_full.pdf

IUCN. (n.k.). *Nature-based Solutions.* Retrieved 10-10-19, from: https://www.iucn.org/commissions/commission-ecosystem-management/our-work/nature-based-solutions

Science for Environment Policy (2015) *Ecosystem Services and the Environment. In-depth Report 11 produced for the European Commission, DG Environment by the Science Communication Unit*, UWE, Bristol. Retrieved 14-10-2019 from: http://ec.europa.eu/science-environment-policy

IMAGES
Image | Simplified hypsometric curve, image based on: Pawe S. (5 May 2013). Hypsometric curve of the Netherlands.svg. Retrieved, 13 September 2019, from: https://commons.wikimedia.org/wiki/File:Hypsometric_curve_of_the_Netherlands.svg

Image | Plan B by LOLA: Possible future of the Netherlands in 2200
Retrieved, 13 September 2019, from: https://www.blauwekamer.nl/2019/06/07/oproep-schetsen-voor-nederland-in-2300/

Image | Concept of panarchy
Resilience alliance. (n.k.). Panarchy. Retrieved 20-10-2019,from: https://www.resalliance.org/panarchy

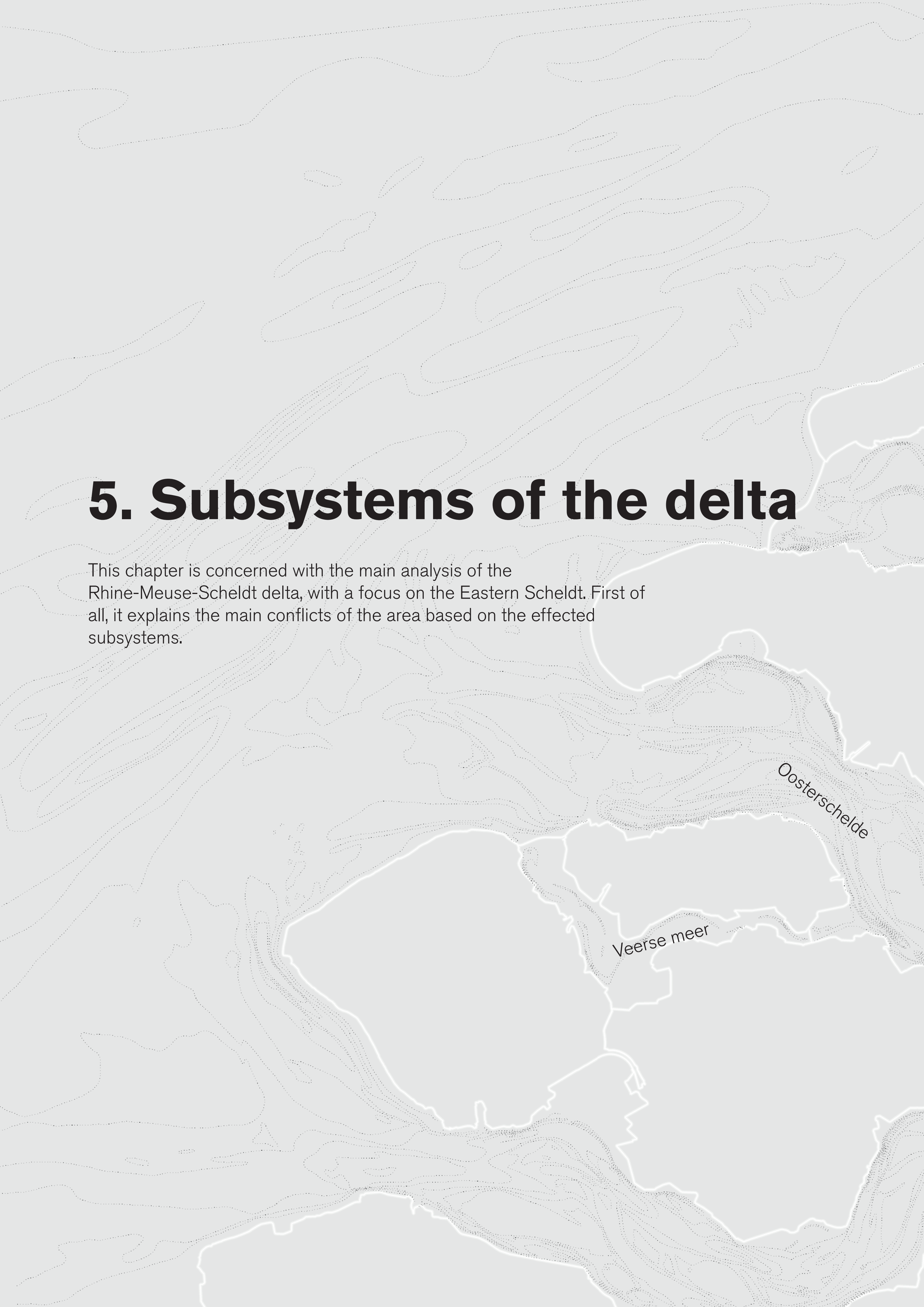
Image | Risk management strategies, adopted from the IPCC chart
Retrieved 18-10-2019, from: https://www.ipcc.ch/report/ar5/wg2/emergent-risks-and-key-vulnerabilities/

Image | Waterflood 1953
NOS. (n.k.). *Dijkdoorbraak - Rijkswaterstaat*
Retrieved 23-10-2019, from: https://lab.nos.nl/projects/waternood/index.html

Map | Waterflood 1953
Nederland Waterland. (n.k.). *Watersnoodramp 1953*
Retrieved 23-10-2019, from: https://sites.google.com/site/nederwaterlandje/pakketten

5. Subsystems of the delta

This chapter is concerned with the main analysis of the Rhine-Meuse-Scheldt delta, with a focus on the Eastern Scheldt. First of all, it explains the main conflicts of the area based on the effected subsystems.




Nieuwe waterweg
Nieuwe maas
Oude maas
Spui
Haringvliet
Grevelingenmeer
Hollands diep
Krabbemeer
Schelde-
Rijnkanaal
Westerschelde

5.1 Relevant subsystems

Relevant subsystems of the delta
According to Meyer et al. nine relevant subsystems can be distinguished in the Southwestern delta (Meyer et al, 2013, p.122). These are shown in Image 5.1. To establish a focus for the research a selection of main and secondary subsystems has been made. This does not exclude the relevance of the other subsystems but shapes the focus of the project after which other subsystems will be informed.

Different scales will be addressed, namely the Rhine-Meuse-Scheldt delta (concerning national or cross-border phenomena), secondly the Oosterschelde will be analyzed, leading to a first spatial framework that might support future developments of areas prone to floods.

Analysis of the Rhine-Meuse-Scheldt delta
The layer-approach will be used to address the base of the area, through the mapping of the occupation layer, network layer, and substratum layer. Additional diachronic mapping will help in understanding the dynamics of the delta. Other maps will focus on the major subsystems mentioned.

Analysis of the Eastern Scheldt
As a means to structure the analysis of the relevant subsystems in the Eastern Scheldt, the Saltmarsh conceptual ecological model (Allen et al, n.k., p. 39) was used as a reference to structure the different drivers, ecological factors and major ecosystem services. Although the model was specifically structured based on the salt marsh ecosystem, the scheme appears to be of relevance for other delta related ecosystems. Additional information was added to the scheme.

Supporting
Habitat
Specialist birds, and (fish) species

Livability and economic welvare

RHINE-MEUSE-SCHELDT DELTA

Main subsystems

1. *Harbours and industry*
2. *Energy*
3. *Agriculture & fishery*
4. *Traffic and transport*
5. *Ecosystems*
6. *Soil and water*
7. *Water works*
8. *Urban patterns*
9. *Recreation*

Main subsystems Rhine-Meuse-Scheldt delta (Meyer et al, 2013, p.122)

Focus on

Ecosystems
Soil and water
Water works
Agriculture & fishery
Recreation
Urban patterns

Selection of main subsystems addressed

OOSTERSCHELDE

Environmental drivers	**Climatic drivers** *CO2* *Disturbance* *Sea level rise* *Temperature* *Precipitation*	**Hydrogeomorphic drivers** *Hydrological setting* *Current and wave energy* *Compaction* *Faulting* *Tidal flooding*	**Antropogenic drivers** *Agriculture* *Aquaculture* *Pollution* *Restoration/Management* *Hydrologic modification* *Development / infrastructure* *Cultural/ recreational activities*
Major ecological factors	**Abiotic factors** *Hydrological regime:* *flood depth / duration / frequency* *Soil physicochemistry* *- Salinization* *Waterquality* *Eutrophication* *(total suspended solids TSS, nutrient load)*	**Biotic factors** *(Marsh) Morphology* *land aggregation, lateral migration* *Plant community structure* *Microbial Community structure*	**Ecosystem function** *Elevation change* *Submergence vulnerability* *1st production* *Above ground & below ground* *Decomposition* *2nd production* *Specialist birds and fish species*
Major ecosystem services	**Profisioning** *Fresh water supply* *Food (production)*	**Regulating** *Coastal protection* *Wave attenuation* *Water quality* *Eutrophication/ salinization* *Carbon sequestration* *Soil carbon density*	**Cultural** *Aestetics - recreational opportunities* *Recreational fisheriy/cycling and walking*

Image 5.1 | (Salt marsh) conceptual ecological model, based on Allen et al , adjusted by author.
(Allen et al, n.k., p. 39)

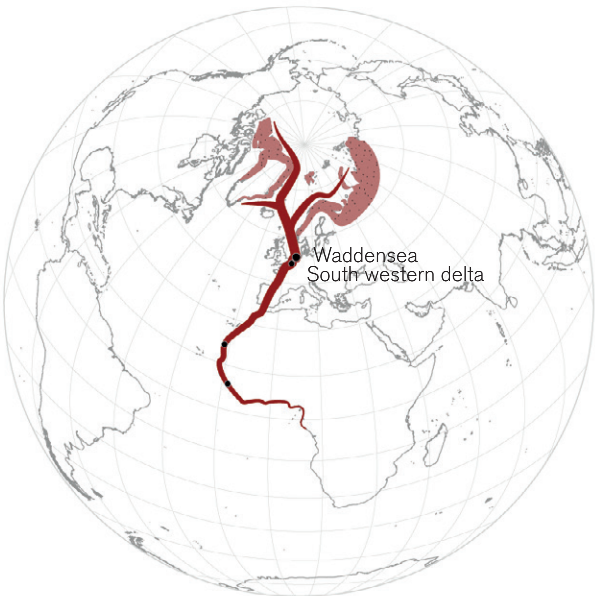
5.2 Rhine-Meuse-Scheldt delta - Introduction

Occupation and land use
The Rhine-Meuse-Scheldt delta (or southwestern delta) is globally located in the area between Rotterdam, Antwerp, the North Sea, Dordrecht and Bergen op Zoom. According to Meyer et al, the four main activities located in deltas are agriculture, fishery, transfer of goods and processing of transferred goods (Meyer et al. , 2013, p12).

Natura 2000
The Natura 2000 is a European network of protected nature areas focusing on conservation goals of habitats and species. The areas are protected by areas that are specifically indicated through guidelines for birds and habitats. When looking at the Natura 2000 areas, quite pressing are the boundaries. Areas supporting large scale economic activities, such as the port of Rotterdam and the agricultural areas, appear to be excluded from the protected status. This leaves the question of whether or not these natural areas are merely based on the potential natural value or the exclusion of main supporting human functions. The southwestern delta is, next to the Waddensea area, an important stop on the East Atlantic bird flyway from Afrika towards the northern breeding locations. The area is therefore particularly important for wadding birds.

Breeding bird species under the protection regulations in the Eastern Scheldt are Marsh harrier, Avocet, Ringed plover, Beach plover, Great Tern Fish Thief, Nordic tern, Little Tern. Examples of protected mammals are the Northern vole and the Common seal.

Substratum layer
Land use is specifically related to the substratum layer. Fluvisol depositions (alluvial, river-related), such as calcareous clay, and to a lesser extent lime-free clay, are suitable for agricultural purposes. Alongside the coast, Arenosols (wind) can be found related to the dunes and beaches.



East Atlantic bird flyway, (image made by author)

Areas affected by Water disaster 1953
Map made by author

- flooded
- Affected cities
- dikebreaks

Land use and occupation
Map made by author

On water
- Aglomerations
- Railway
- Ports
- Arable lands

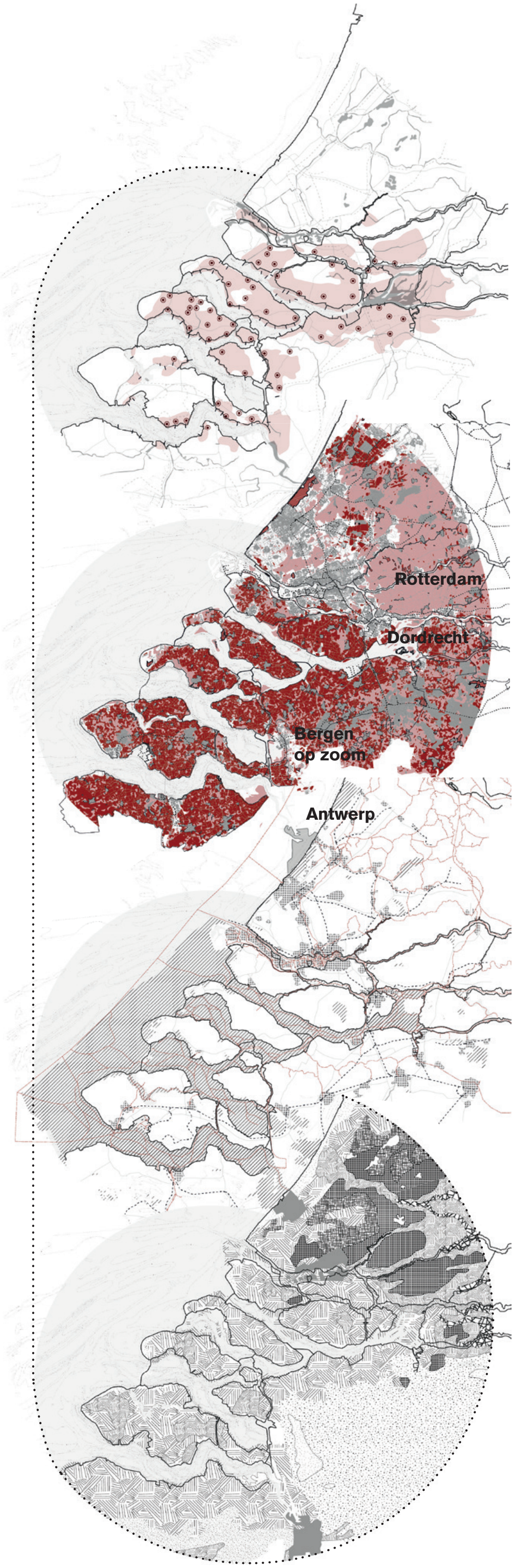
Natura 2000 (year 2018)
(EEA, 2018).
Map adjusted by author

On water
- Natura 2000
- Naviable water
- Ports

East Atlantic migration route
- Breeding areas
- Staging and wintering

Soil types (substratum)
(National Georegister, 2017).
Map adjusted by author

Soiltypes
- Technosol
- Fluvisol
- Podzol
- Histosols
- Gleysols
- Cambisols
- Arenosols


Rotterdam
Dordrecht
Bergen
op zoom
Antwerp

5.3 Climatic drivers of change

Next to sea level rise, other climatic stressors will most probably affect the delta. Although predictions are relatively uncertain an indication of possible changes is shown to address some key issues that might occur. Based on the climate effect atlas the current and possible future developments in 2050 are shown (based on the WH scenario of the KNMI 14). The maps are merely used as an indication of possible changes.

Precipitation shortage and peak storage:
Based on the climate effect atlas the expected precipitation shortage in the delta will most likely increase due to increased evaporation. This might lead to increased seepage of saline water.

Although a precipitation shortage is expected (more evaporation), the annual precipitation is most likely to increase as well as the number of days with more than 25mm per day. More extreme events, therefore lead to a need for more peak water storage. Shallow rooting crops that depend on a thin freshwater lens might therefore be quite vulnerable.

Yearly annual precipitation
(klimaateffectatlas, 2019)
Maps adjusted by author

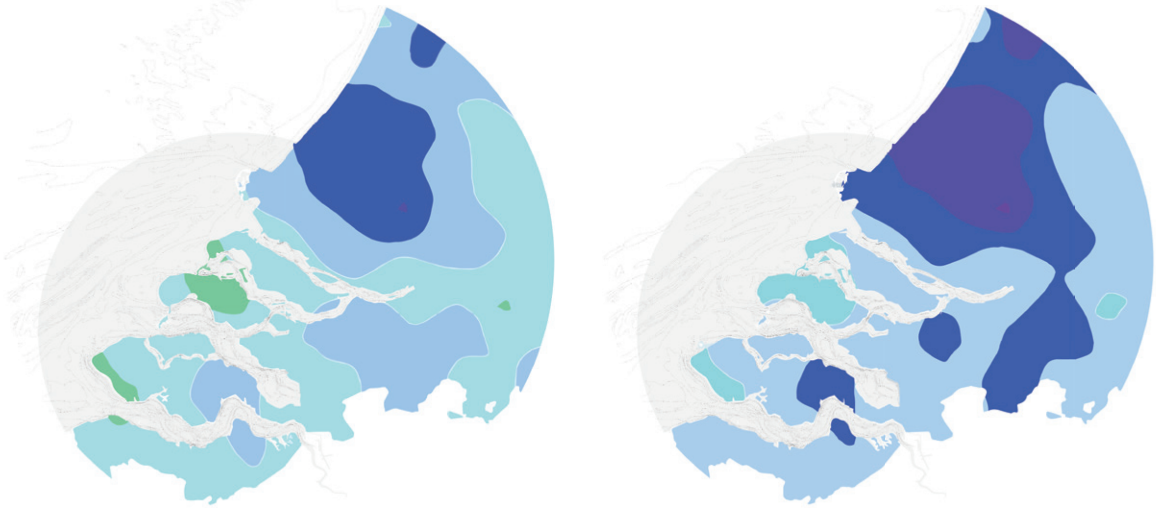
- 750 - 800mm
- 800 - 850mm
- 850 - 900mm
- 900 - 950mm
- 950 - 1000mm
- 1000 -1050mm

Potential maximum precipitation shortage
(klimaateffectatlas, 2019)
Maps adjusted by author

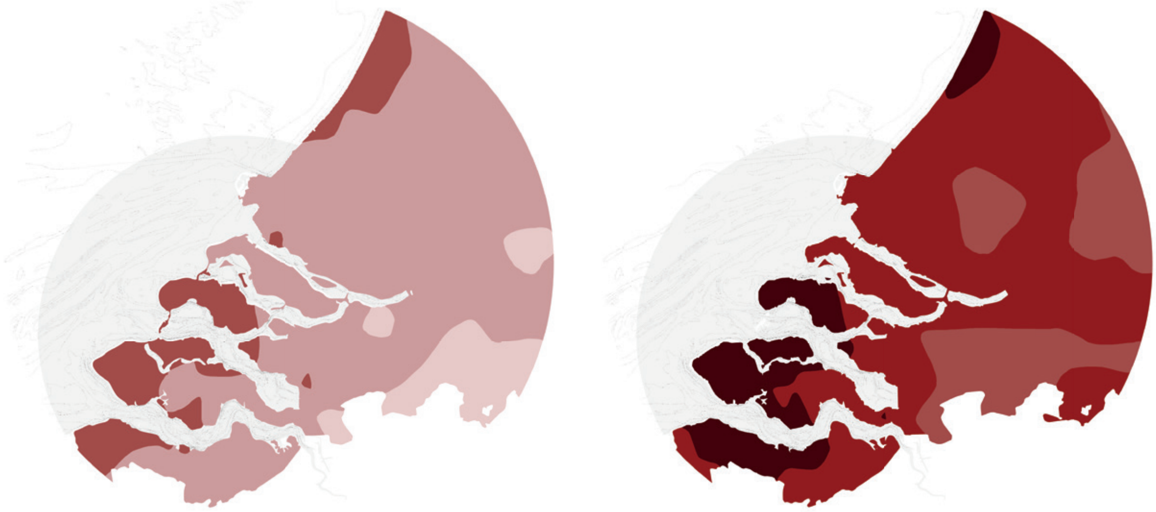
- 120 -150mm
- 150 -180mm
- 180 - 210mm
- 210 - 240mm
- 240 - 270mm

Yearly reference evaporation
(klimaateffectatlas, 2019)
Maps adjusted by author

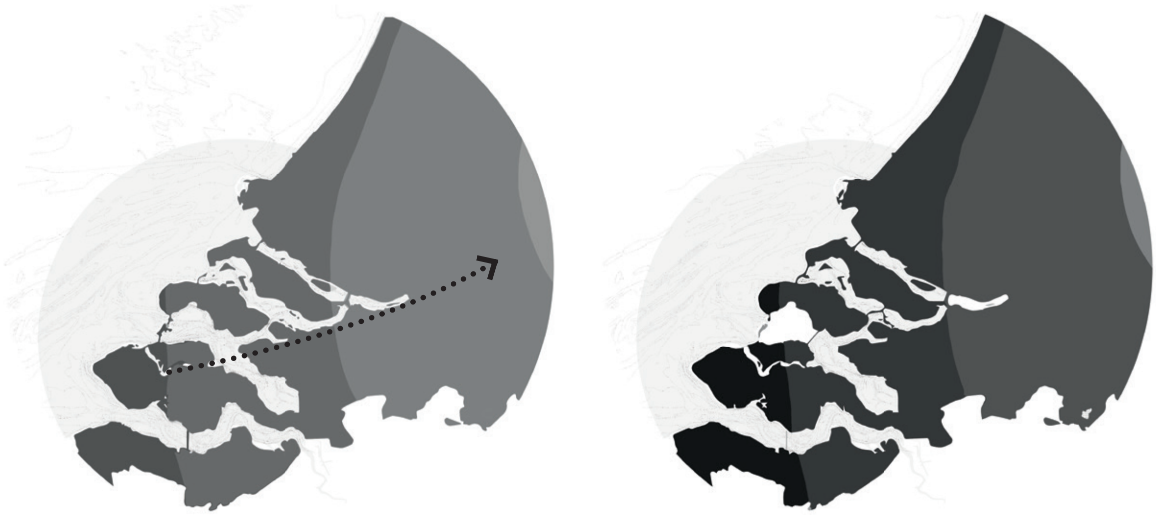
- 550 - 570mm
- 570 - 590mm
- 590 - 610mm
- 610 - 630mm
- 630 - 650mm
- 650 - 670mm



Yearly anual precipitation current situation (left) and projections of 2050 (right)



Potential maximum precipitation shortage current situation (left) and projections of 2050 (right)



Yearly reference evaporation current situation (left) and projections of 2050 (right)

5.4 Changing delta morphology

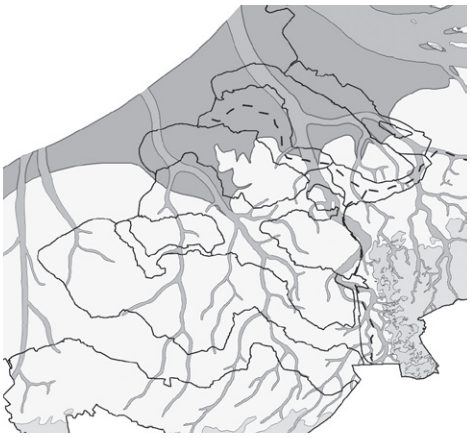
A range of Palegeographical maps of the Southwestern delta enables an initial understanding of formation processes and biophysical adjustments and in the delta. From 9000BC- 7000BC the delta was in a continental phase. The progression of sea-level rise led to the inundation of the area between 7000- 3100 BC after which regressive coastal development dominated. The higher accretion of sand and clay led to the formation of peat. Around 1500 BC the area was covered by a peat layer (Holland veen). Initial agricultural drainage practices led to subsidence of peat after which tidal ranges could again affect the area. This led to rapid degradation of peat. Around 800 AD the area was therefore covered with thick layers of clay with vast salt marshes intersected by large tidal channels and smaller creeks.

To make the area, inhabitable polders were reclaimed from 1300 onwards using the higher marshlands. The fertile clay led to the exploitation of these lands for large scale agricultural purposes. However, the stabilized conditions led to a dependence on flood defenses. Intertidal areas reduced as a result of modified hydrological conditions (delta works).

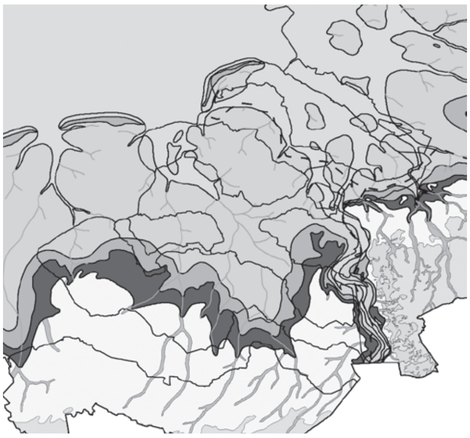
Palegeographical maps of the Southwestern delta
(Vos & de Vries, 2013)
Maps adjusted by author

Paleogeograpical layers
- Inner water (fresh - brakisch)
- Open water (salt)
- Pleistocene sand 16-0m -NAP
- Pleistocene sand > 0m NAP
- High dunes
- Tidal flats
- River surfaces & salt marshes
- Peat
- Endiked area
- Build environment

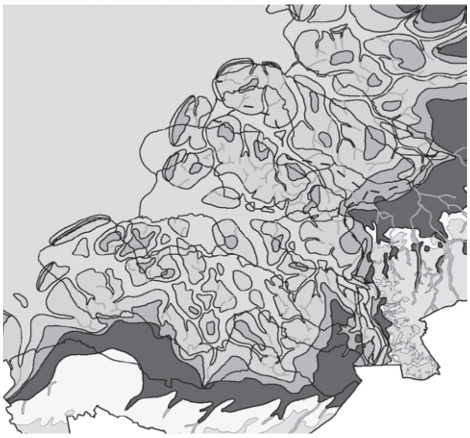
9000 BC



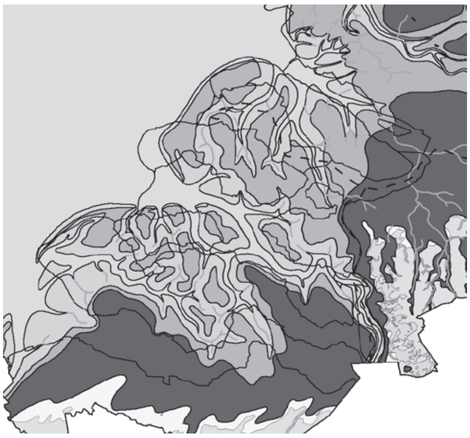
5500 BC



3850 BC



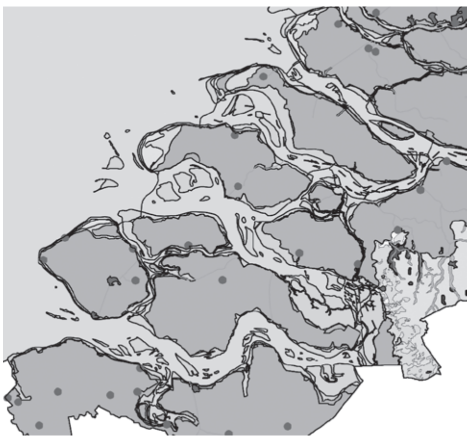
2750 BC



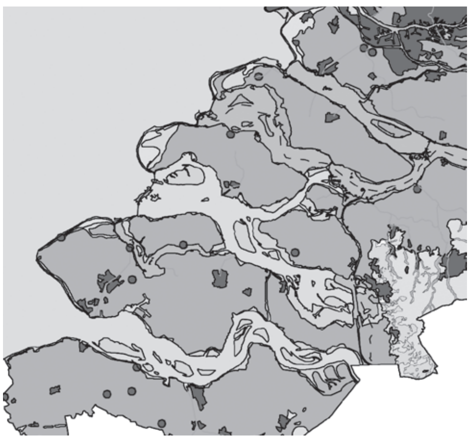
1500 BC

800 AD

1850 AD



2000 AD



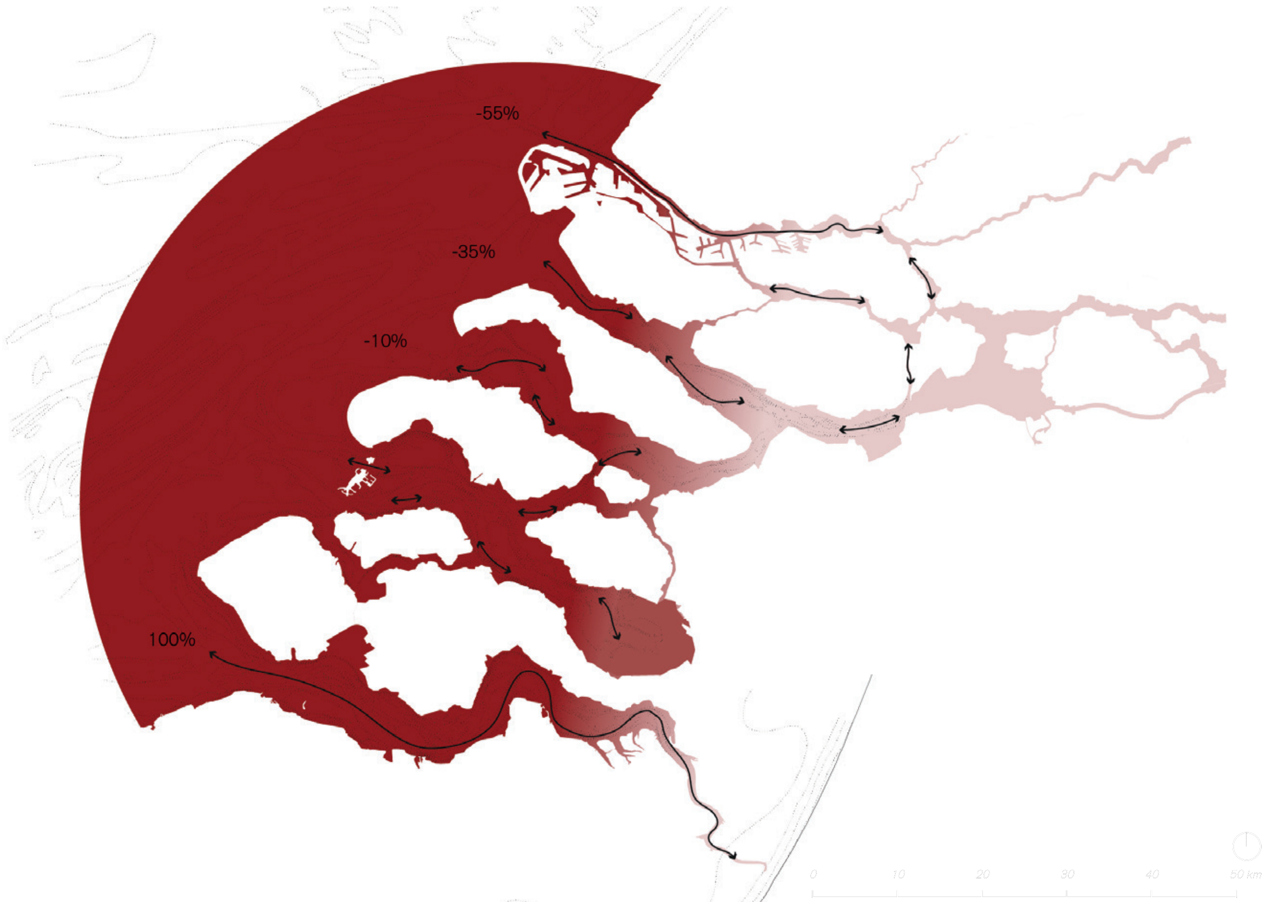
5.5 Hydrogeomorphic drivers

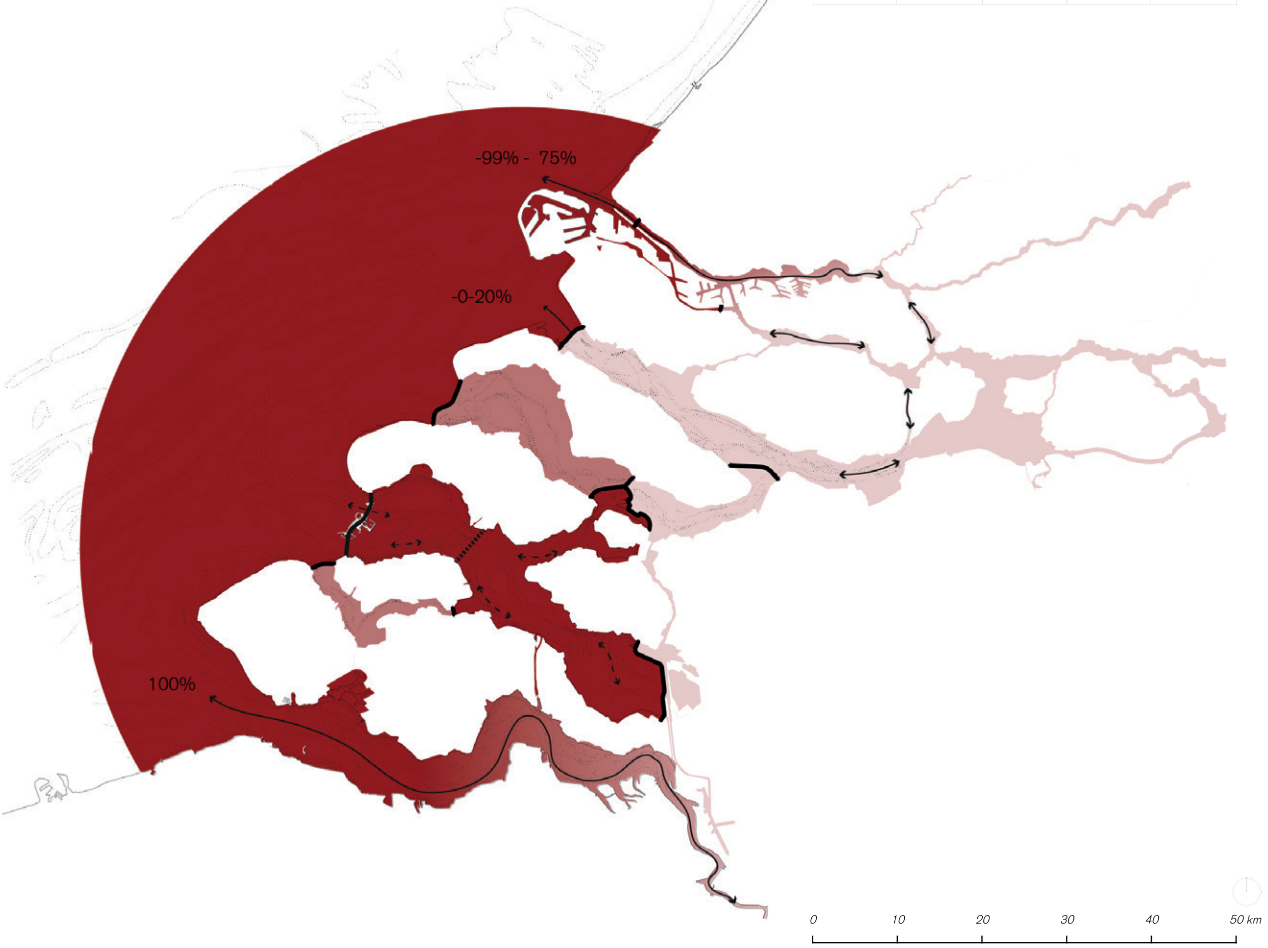
The delta works were initiated in 1953 to reduce the coastline, as a response to large scale floods. The interventions led to changes in the water regime and natural sand accretion. Before the delta works it was a turbid estuary. Transitions of salt (sea) and freshwater (river) was gradual due to the flux between rivers (discharge) and tidal range of the North Sea. The delta works led to a compartmentation of the system. River discharges were redistributed. Dams and barriers led to areas with stagnant water bodies and reduced tidal ranges. The Westerschelde en Oosterschelde maintain open sea connections, dominated by industrial zones of Antwerp and Rotterdam. The Eastern Scheldt became a closed saline sea arm with reduced tidal ranges.

Situation before (around 1850) and after the Delta works (around 2010)
made by author based on (Meyer et al, 2013)

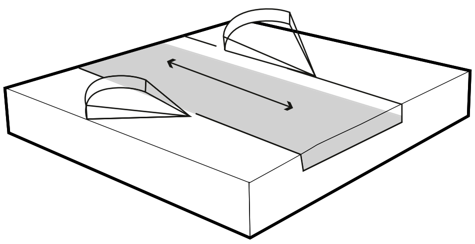
↔ Reduced tide
↔ Tides
▬ Delta works
20% percentage riverdischarge

Indication salinity
Fresh water
Salt water

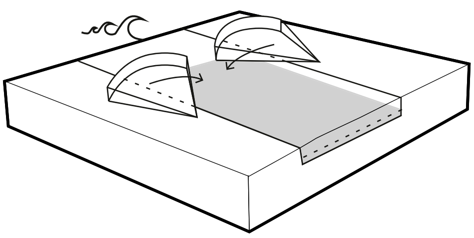

-55%
-35%
-10%
100%
0 10 20 30 40 50 km


-99% - 75%
-0-20%
100%
0 10 20 30 40 50 km

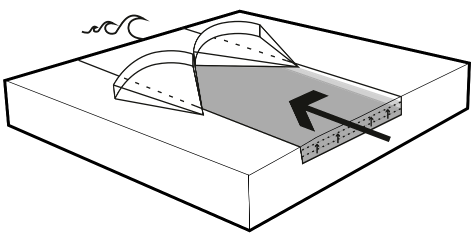
Open or closed barriers:
During storm surges the storm surge barriers close. However, with the continuation of rivers discharging, and specifically during peak discharges there is a need for extra water storage in the lower plains. Several room for the river projects anticipates extra water storage during peak events. However, it is questioned whether or not this will be sufficient enough.



Storm surge barriers are
open,
tidal influence



Storm surge barriers close

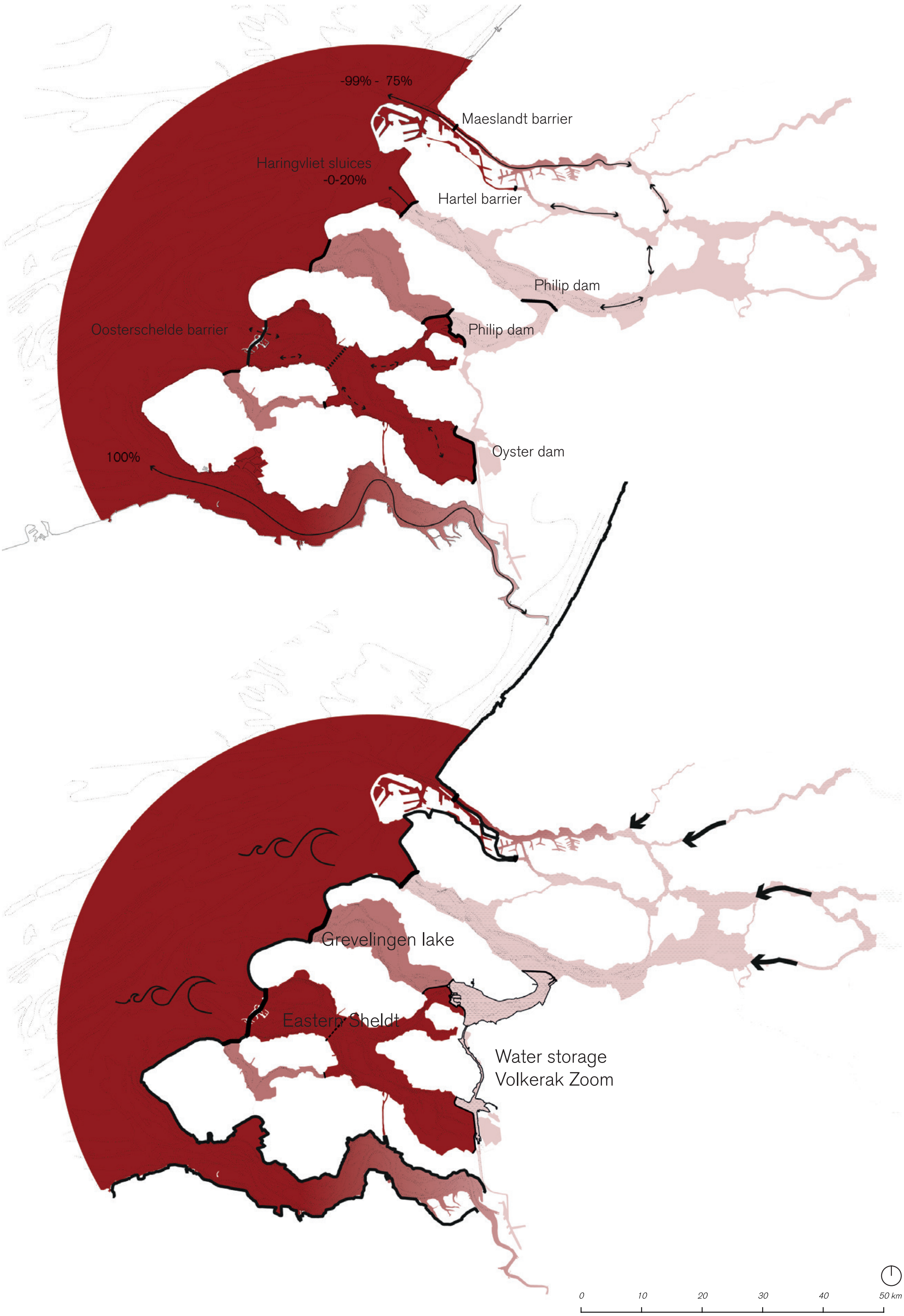


Discharge of rivers continues
Extra water storage in lower
plains

Situation before (around 1850) and after the Delta works (around 2010)
made by author based on
(Meyer et al, 2013)

Appointed area water storage
River discharge (low or high)
Storm surge
Reduced tide
Tides
Delta works
20% percentage riverdischarge

Indication salinity
Fresh water
Salt water


-99% - 75%
Maeslandt barrier
Haringvliet sluices
-0-20%
Hartel barrier
Philip dam
Philip dam
Oosterschelde barrier
Oyster dam
100%
Grevelingen lake
Eastern Sheldt
Water storage
Volkerak Zoom
0
10
20
30
40
50 km

5.6 Dike trajectories

Norms relate to the dike trajectories in the delta and are based on calculations on flood probabilities and risks. Trajectories are distinguished by a lower limit norm (OG) and signaling value (SW). Highest values can be found around Rotterdam as well as areas around the Eastern Scheldt.

Dike trajectories
(National Georegister, 2017)
Map adjusted by author

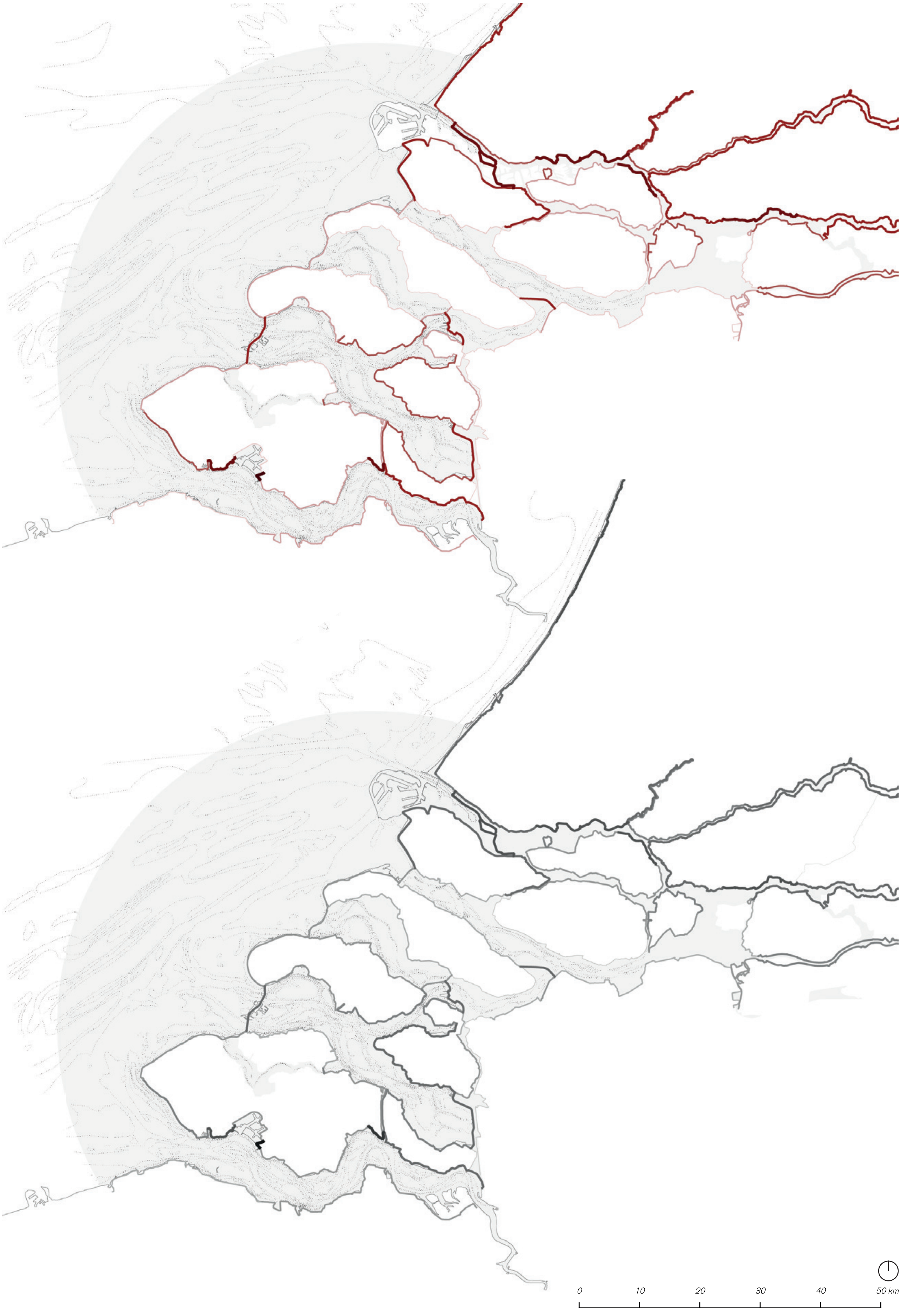
Dike trajectory signaling value (SW)
flood probability per year

1000000
100000
30000
10000
3000
1000
300

Dike trajectory lower limit (OG)
flood probability per year

1000000
100000
30000
10000
3000
1000
300
100
10

Primairy


0
10
20
30
40
50 km

5.7 Conditions dikes and Flood probability

Condition dikes and flood probability

The probability of floods was mapped as a means to indicate possible vulnerable areas to floods, using the risk map viewer (Risicokaart, 2019). Areas with a high probability of floods can be related to the outer dike tidal flats and marshes, and areas with a surface below the current NAP. Additional the third inspection of the dike trajectories indicates dike trajectories that did not suffice according to the national guidelines (Inspectie Verkeer en Waterstaat , 2011, p.16). Trajectories alongside the Eastern Scheldt, as well as the Boven Merwede, the Lek and Hollandsche IJssel, were indicated as insufficient.

This project will focus on the Eastern Scheldt and affected tidal flats, as well as the effects on the main economic drivers (arable lands and aquaculture and recreation).

Although the fourth examination should determine the new indications (based on more recent guidelines), the data was not yet availible. Therefore the project will use the third examination as a means to indicate possible key trajectories.

Condition dikes
(Inspectie Verkeer en Waterstaat , 2011, p.16)
Map adjusted by author

Does not suffice
Research nececarry

Dike trajectory satisfied (SW)
flood probability per year

1000000
100000
30000
10000
3000
1000
300

Probability of floods
(Risicokaart, 2019)
Map adjusted by author

Large change
Mid large change
Low change
Extrordinairy event
Primairy dikes


Hollandsche IJssel, Lek and
Boven Merwede
Eastern Scheldt
0
10
20
30
40
50 km

5.8 Anthropogenic drivers of change

Main agricultural land uses are found in alongside the coast, due to fertile chalk containing clay soils. Around € 90.3 billion agricultural goods were exported from the Netherlands in 2018, making the Netherlands the second-largest agricultural exporter in the world after the United States (Dolman, M., Jukema, G. & Ramaekers, P., 2019, p.5). However, it can be questioned whether or not this concerns production or related agricultural services.

The province of Sealand contains the largest surface of agricultural lands relative to other land uses, about 76% (based on numbers CBS, 2018). The main products that are grown and processed are onions, potatoes, legumes, sugar beets, wheat, grain, and flax. The saltwater conditions of the Eastern Scheldt lead to the establishment of aquaculture in the delta (mussel and oyster, seaweed, algae, and worms).

Whereas only 2% works in the industry of agriculture, forestry and fishing in the province of Sealand the agricultural land use (without water) represents a large percentage of the land use cover. Due to the large cover percentage farmers are a particularly vulnerable group for climate change-related issues, such as salinization and reduced fresh water supply, in the province of Sealand. Morphological changes in the Eastern Scheldt affects the oyster and mussel industry. This questions the future economic viability of these two sectors on the long term.

Note: The data was restricted to the province of Sealand. Although it does not fully represent the Rhine-Meuse-Scheldt delta, it represents the main concern relevant to the Eastern Scheldt case.

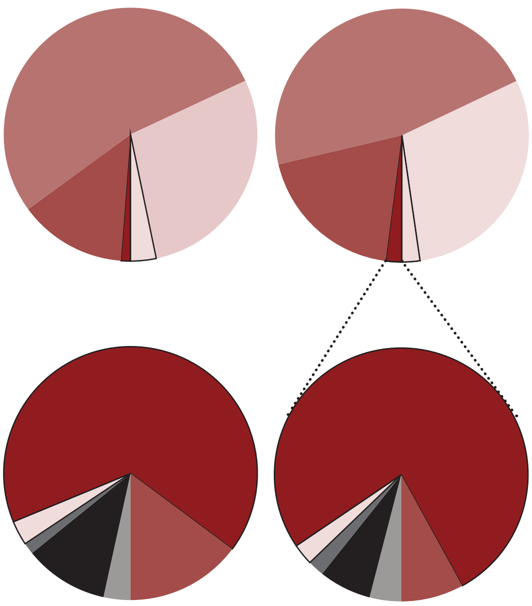
Jobs of employees (december) related to industries 2018
(CBS, 2019).
Adjusted by author

Land use type percentage 2018 (minus water)
(CBS, 2019).
Adjusted by author

Land use
(Nationaal georegister, 2019).
Map adjusted by author

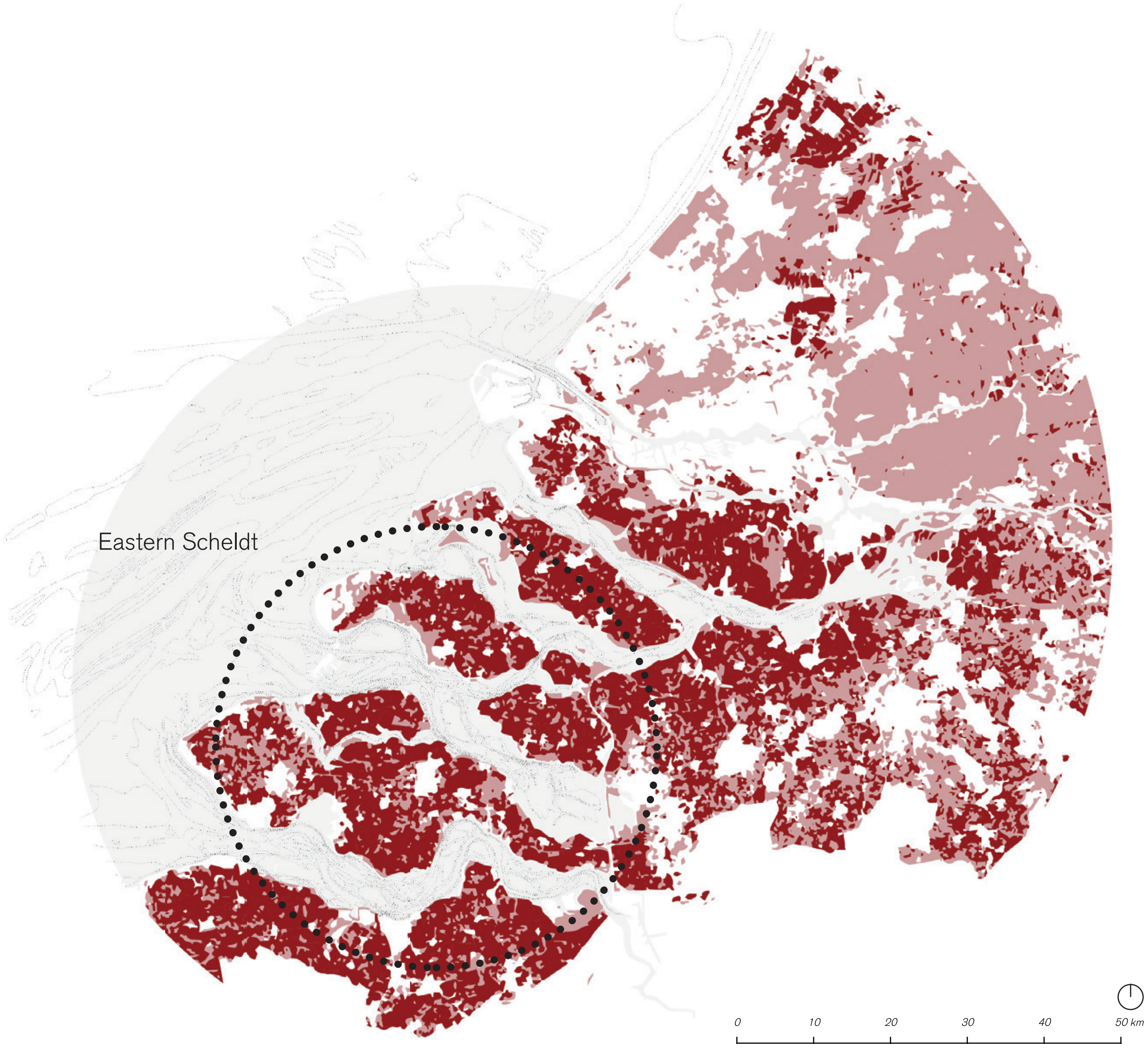
- Agriculture
- Forest
- Graslands
- Other

Netherlands **Province Sealand**



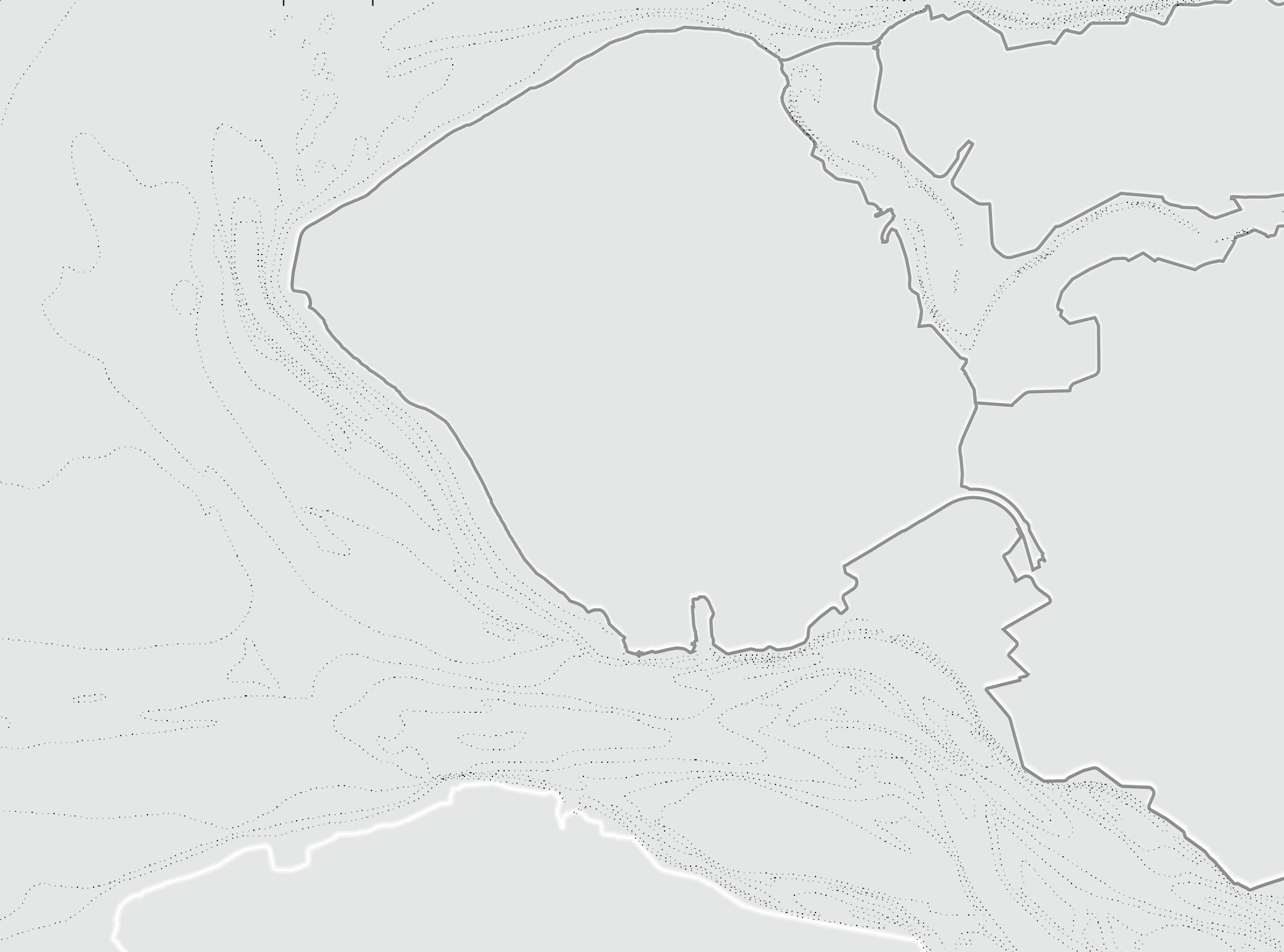
	NL %	Province Sealand %
A: Agriculture, forestry & fishing	1,2	**2,0**
B-F: Industry and energy	13,7	19,3
G-N: Commercial services	53,1	46,6
O-Q: Government and care	28,7	29,8
R-U: Culture, recreation, other services	3,3	2,3

		ha minus water
	3367098	*178213*
	NL %	Province Sealand %
Agriculture	66,4	**76,5**
Forest and open terrain	10,7	6,7
Recreation	14,8	8,0
Build	1,5	2,1
Semi Build	3,1	2,7
Infrastructure (traffic)	3,4	4,0



6. Eastern Scheldt

This chapter is concerned with the main analysis and initial planning development of the Eastern Scheldt. The analysis highlights possible opportunities based on the specific spatial framework of the area.

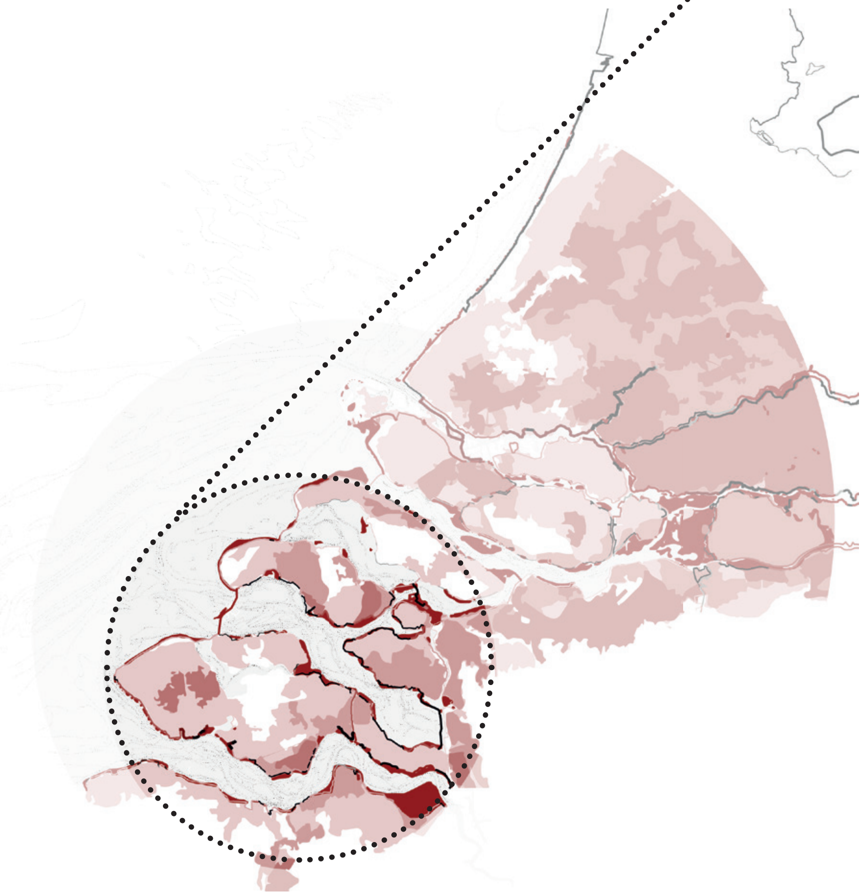


Eastern Scheldt

6.1 Eastern Scheldt - Introduction

The Eastern Scheldt is selected as main focus area. Since the introduction of the Eastern Scheldt barrier, Philipsdam and Oysterdam the area has been functioning as an enclosed sea arm with reduced tidal volume. Primary land use in the area is agriculture. The Eastern Scheldt is used for the Shellfish industry that profits from the saltwater conditions. Main cities in the area concern Middelburg Vlissingen and Goes. The map shows an indication of several villages that have been lost as a result of flooding. Although the map projects a static situation, the lost villages stress that the project concerns a highly dynamic surface.

The following paragraphs concern the analysis of several stressors in the area, in a search for a spatial solution framework in which the project can operate.



Drowned cities
(Provincie Zeeland, 2018)
Map adjusted by author

Villages
Roads
Railway
Villages lost by floods
Bathymetry


Bergen op zoom
Steenbergen
Markiezaatsmeer
Philipsdam 1987
Tholen
Oysterdam
Bergen op Zoom (NB)
Bruinisse
Yerseke
Zierikzee
Sealand bridge (1965)
Goes
Schouwen Duiveland
Eastern Scheldt
Noord Beveland
Zuid Beveland
Eastern Scheldt barrier (1986)
Middelburg
Wester Scheldt
Vlissingen
Walcheren
o
5
10km

6.2 Salt intrusion & fresh water supply

Salinization is an increase in the salt content of water and soil. Specifically affecting low-lying areas where there is no external freshwater supply (such as Schouwen-Duiveland). From 1500mg of Chloride per Liter water is considered as salt. Freshem (2015) distinguished the depth of this edge for the province of Sealand. The surface water has primarily turned brackish due to upwelling brackish or salt groundwater. It is expected that the areas adjacent to the Eastern Scheldt, such as Schouwen-Duiveland and Noord Beveland, will face increasing salinization of groundwater and surface water, due to increased upwelling of saltwater (sea level rise) and will have to retain more water.

The map shows the areas where freshwater bubbles occur of at least 15 meters thick or have a water-sealing layer. These areas correspond with groundwater abstraction points. The freshwater bubbles are mainly found under the dunes, sandy creek ridges and cover sand areas. The dunes are the primary source of freshwater and are exploited by Evides a water company.

Although salt surface water is not a cause for problems, problems can occur when the top groundwater layer salinizes, and the freshwater layer becomes to thin. This affects the cultivation of often shallow rooting conventional agricultural crops.

Freshwater bubble
(Provincie Zeeland, 2010)
Map adjusted by author

Ground water abstraction
(Provincie Zeeland, 2015)
Map adjusted by author

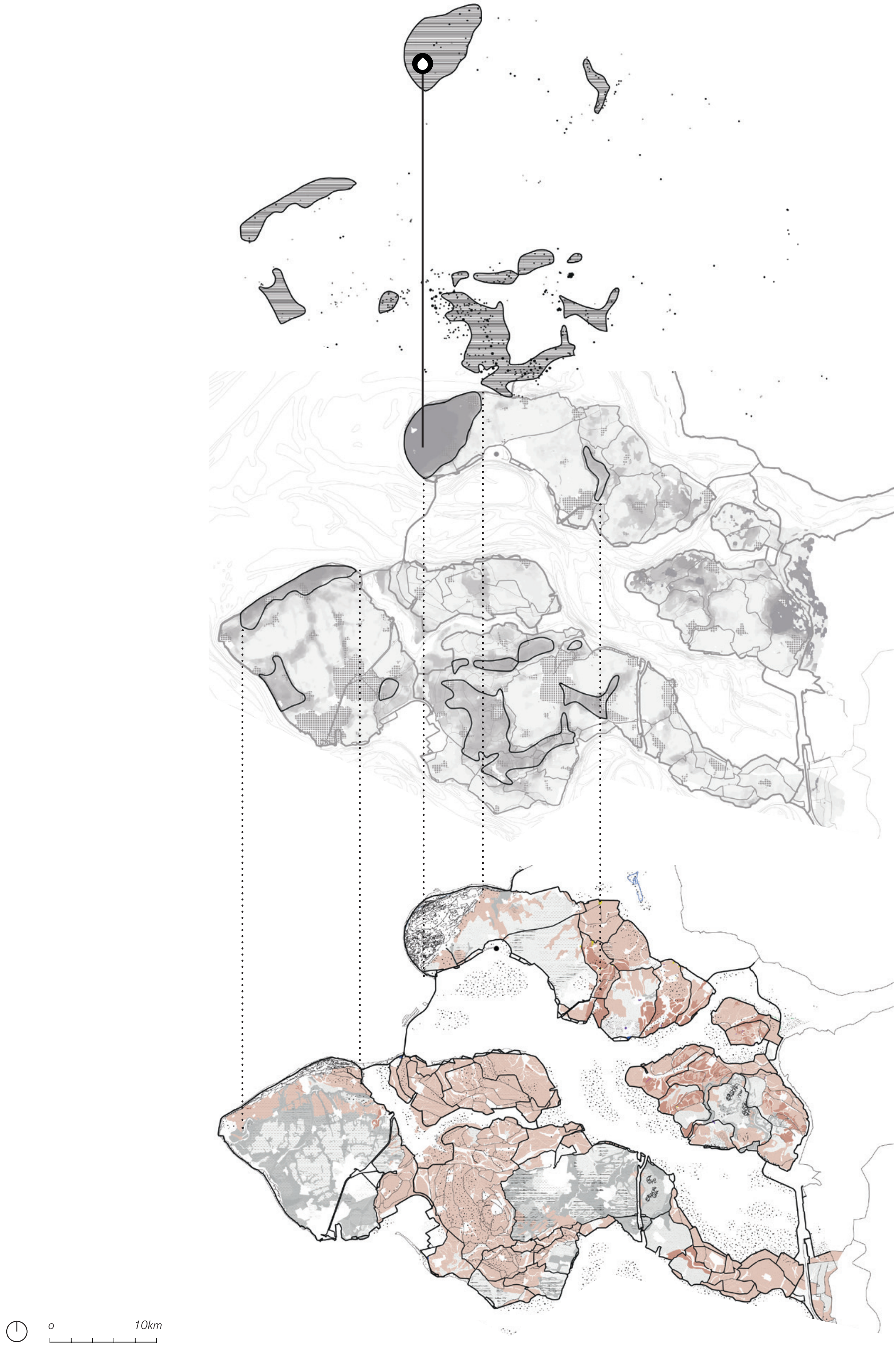
- Fresh water bubble
- Ground water abstraction

Depth 1500 mg Cl/l under surface
(Freshem, 2015)
Map adjusted by author

- 0 - 2,5m
- 2,5 - 5m
- 5 - 7,5m
- 7,5 - 10m
- 10 - 12,5m
- 12,5 - 15m
- 15 - 20m
- 20 - 25m
- 25 - 30m
- 30 - 40m
- > 40m
- no border

Geomorphology
(Provincie Zeeland, 2012)
Map adjusted by author

- Tidal bank
- Plain of tidal deposits
- Plain of locally moored tidal deposits
- Coastal dunes
- Beach flat, sandbank or mud dunes
- Tidal creek bed



o
10km

6.3 Habitats - Shell fish bottom culture

The area is quite intensively used for shellfish bottom cultures, such as oyster reefs and mussel fields, for consumption purposes. The parcels are shown on the map. Important requirements for oyster reefs relate to the size and shapes of oyster reefs, the availability of primary production, and the position of the oyster fields. As shown on the map Oyster reefs are clustered in the

Artificial (and natural) Oysters reefs (such as the Japanese oyster or Cassostreas gigas) could potentially function as breakwaters for sediment stabilization and wave attenuation. Therefore, the construction or restoration of oysters reefs (and monitoring) could be a potential measure to reduce the impacts of floods.

A possible threat to the shellfish industry is the toxic substance tetrodotoxin (TTX). The neurotoxin, most likely produced by bacteria (soil, water or food chain), that has been found in mussels and oysters in the eastern, and northern, part of the Eastern Scheldt (Poelman, van der Heuvel-Greve, Smaal & Steins, 2018).

Shellfish parcels
(Witteven+Bos, 2013, p.6)
Map traced by author

Fields
- Oyster
- Mussel
- 'Verwater' bassins

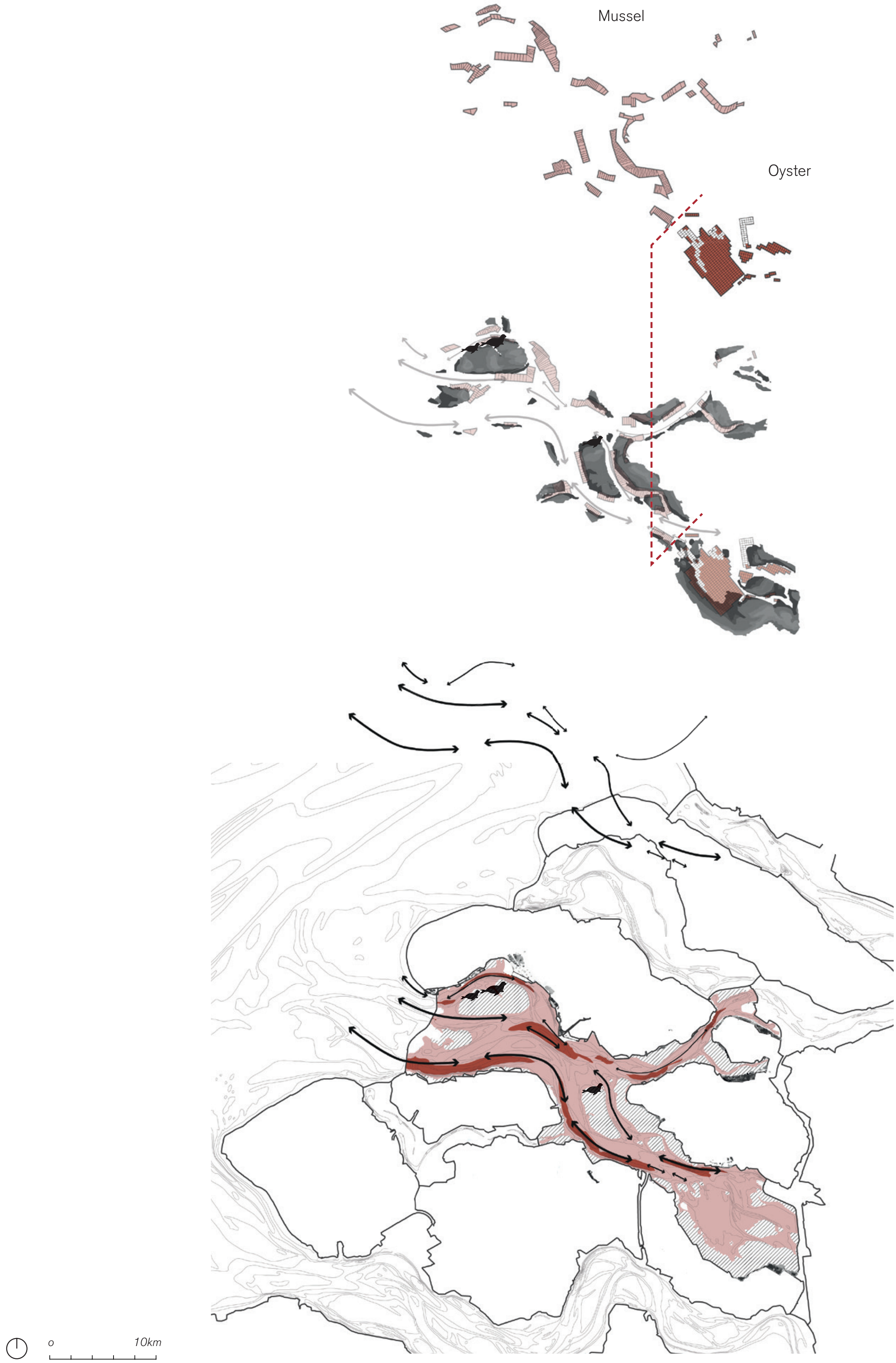
Desiccation period in percentage
(Behrens, 2008).
Map traced by author

Percentage
1-10
90-99

Indication locations higher water velocity based on bathymetry
↔

Spatial units and habitat types
(Ministerie van Infrastructuur en Milieu, Rijkswaterstaat, 2015 ,p.30)
Map traced by author

- H1310A: Salty pioneer vegetation (Salicornia)
- H1310B: Salty pioneer greenhouses (Marine wall)
- H1330A: Salt marshes and salty grasslands (outside dikes)
- H13120: Mud Grass Fields
- H1330B Salt marshes and salty grasslands (inside dykes)
- H1100: Intertidal areas
- Deeper than 20m at low tide
- Permanently flooded sandbanks
- Swallow and sandbanks
- Bird habitat (forraging stilts)
- Common Seal



Mussel
Oyster
0
10km

6.4 Spatial framework and flood depth

Interrelation water depth (height) and polders

The area consists out of former salt marshes and tidal flats that were endiked. This process started from the1300 onwards. When relating the reclamation periods with the maximum water depths of the areas, the oldest polders mainly correspond with the largest water depths. Sedimentation processes did not continue in these early reclaimed areas. Continued drainage of these areas leads to soil subsidence, making them more vulnerable to floods.

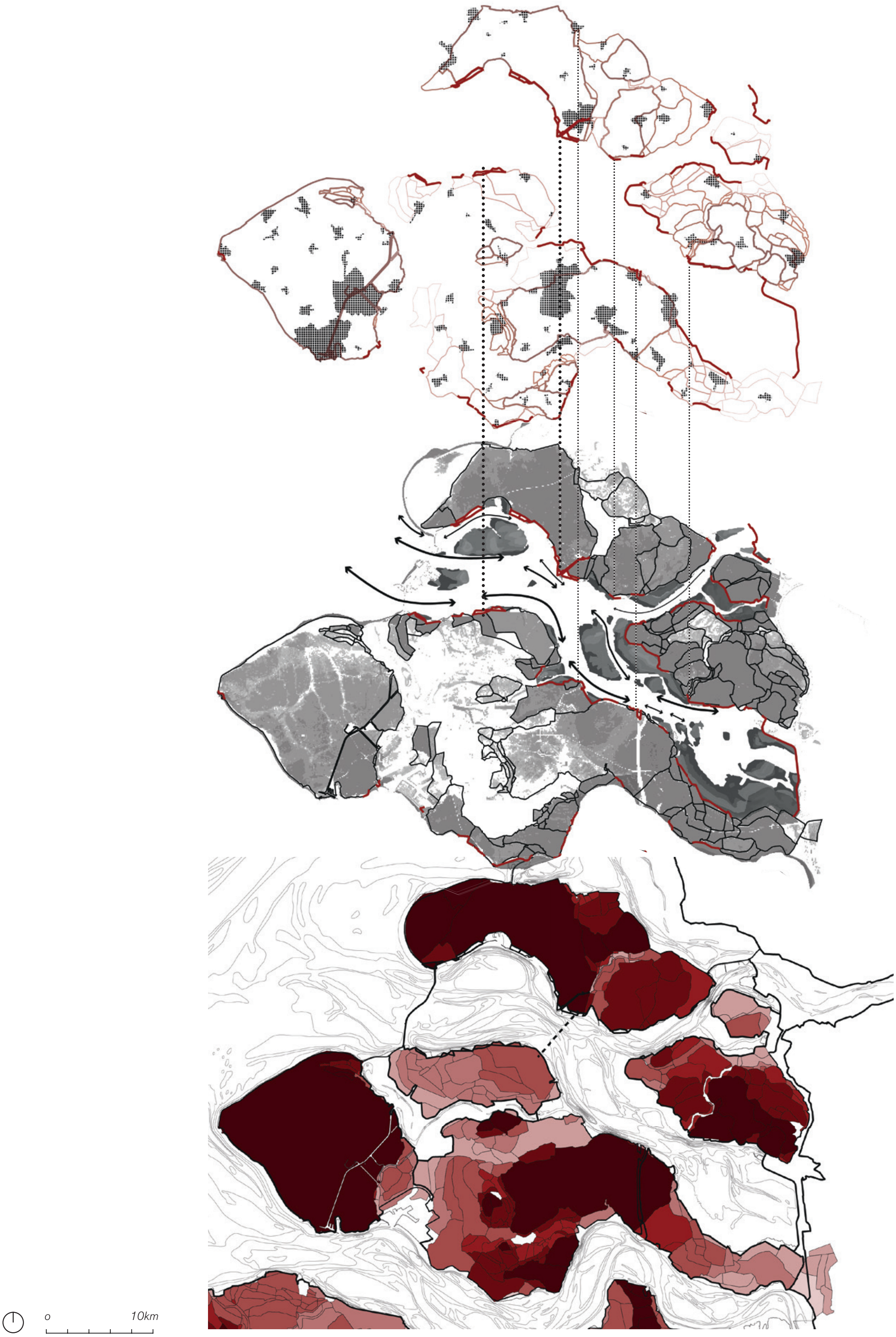
Based on the 3rd examination of the primary dikes and expected higher water velocities (based on bathymetry), and the presence or absence of a foreshore and indication of some critical areas has been made.

Maximum water depth (protected)
(Provincie Zeeland, 2016).
Map adjusted by author

- <0,2m
- 0,2-0,5m
- 0,5-0,8m
- 0,8-2,0m
- 2,0-5,0m
- >5,0
- Primairy & regional dikes
- Dikes insufficient (3rd assesment)
- Build environment

Polders and reclamation period.
(Provincie Zeeland, 2006)
Map adjusted by author

- <1300
- 1300-1421
- 1422-1532
- 1533-1648
- 1649-1808
- 1809-1953
- >1953
- Primairy dike
- Regional dike


0
10km

6.5 Sand starvation & loss intertidal flats

The delta works led to biophysical changes in the Eastern Scheldt. The Philips dam and Oysterdam cut of the Eastern Scheldt from the rivers. Therefore, the Eastern Scheldt has become a bay with a constant high salinity. The Markiezaatlake was cut of from the Eastern Scheldt making it a stagnant freshwater lake. The limited movement of the water is cause for water quality issues in the lake.

Sand starvation and loss of intertidal flats
Sand transport is limited by barriers. According to Ysebaert (Ysebaert, 2017) the tidal volume of the Eastern Scheldt has reduced with about 30%, and the tidal range has reduced about 13%. The smaller range of high and low water leads to a decrease in flow rates and turbidity of the water. The channels are too deep related to the new tidal volume. With reduced input of new sand and a decrease in flow rates, the system therefore tries to reach a new equilibrium and fill the channels.

The area of tidal flats (slabs and mudflats), the so-called intertidal area, is gradually decreasing (Ronde, Mulder, van Duren & Ysebaert, 2013, p.5). Sand starvation caused by modified water regimes (artificial barriers and dams), and drowning as a consequence of sea-level rise causes erosion of current tidal flats. About 1.100 ha of tidal flats have already submerged permanently. On average the tidal flats have lowered about 25cm since the introduction of the barrier (RWS, 2017). Due to sea-level rise, there is a loss of desiccation time. With about 1m sea-level rise they are quite likely to even disappear. This would affect the water safety of the area, the current protected natural values, but will also affect the fish and shellfish sector and the recreational value.

The migration of habitats further inland is hindered by flood defenses, resulting in coastal squeeze. The sandbanks have become smaller and shallower. During tide they are more likely to flood. These mudflats and salt marshes are feeding grounds for birds (stilts), shellfish and other exploited commercial fish in the Oosterschelde. Under the influence of the tides and sea-level rise Birds will have less foraging time. Shallow underwater areas expand. Every area in connection with the Eastern Scheldt will experience the effects of sand starvation, therefore without measures, those areas will also erode (Storm, 1999, p.48). Designated habitats are therefore threatened to be lost.

Water safety
The flood defenses are already sensitive to the combined effect of sea-level rise and erosion of the foreland due to sand hunger, which increases the water depth for many dike sections. Macro stability of the dikes (shifting ground) is therefore in jeopardy (RWS, 2017). Dike reinforcements, need to have an extra marge in the design, for more extreme conditions and therefore become more complex and expensive. It also requires adjustment to harbours and bridges.

Sea-level rise and effects:

- 0,35m: effects on high water safety will be limited (RWS, 2017)
- 1-1,5m: Limit of the functional design of Eastern Scheldt barrier (Haasnoot et al, 2019)

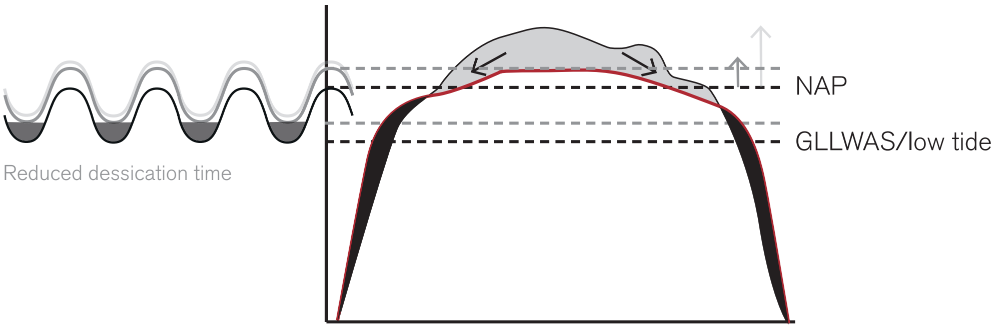
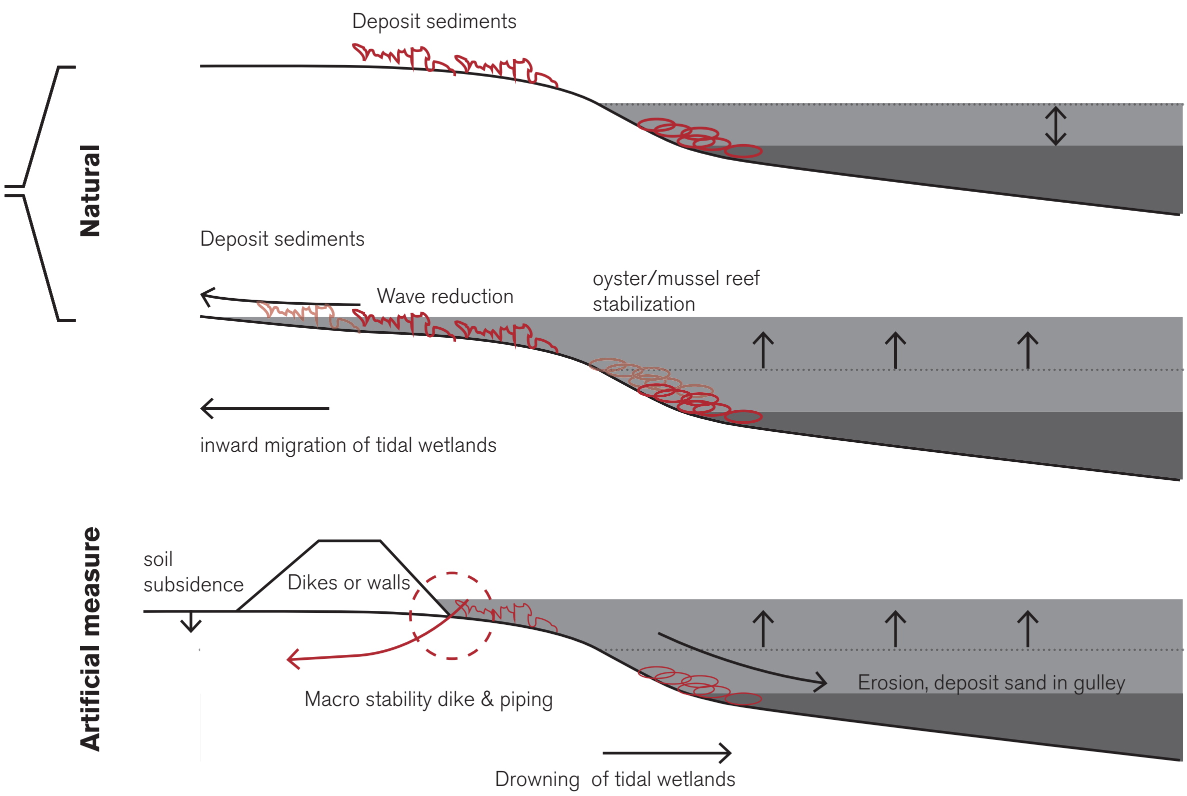


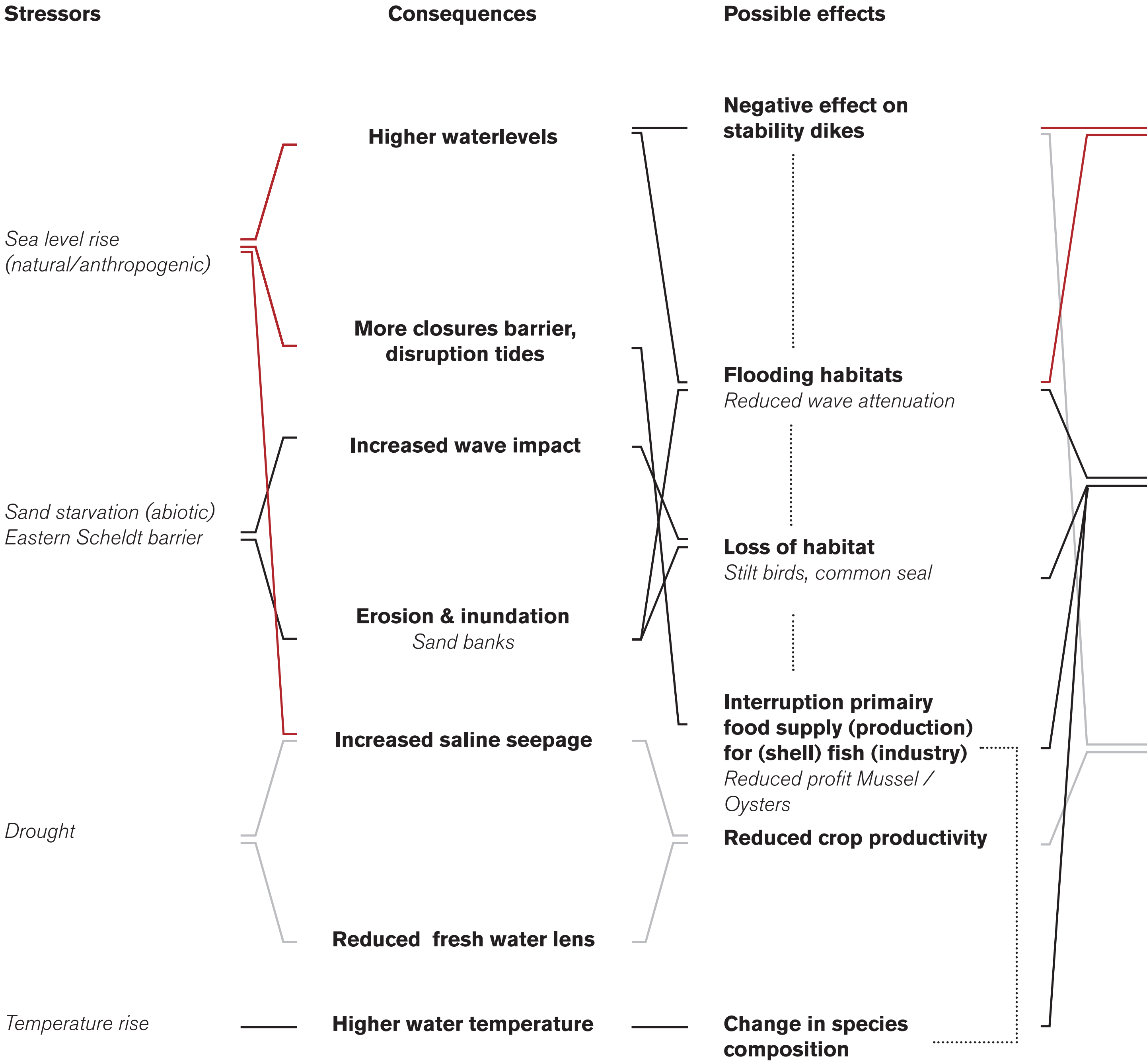
Image 6.5 Explanatory section of processes affecting the sandbanks in the Oosterschelde. More shallow mudflats as a result of sediments moving to lower part of the gulley.
Based on (Witteveen+Bos , 2011, p.7.) Image adjusted by author



Indication scheme of coastal sqeeze: articfiualized measures prevent inward migration of tidal wetlands, causing current tidal wetlands to drown.
(Burwell, H. , n.k.) Image adjusted by author

6.6 In conclusion - the affected subsystems

In conclusion, different stressors affect activities and the probability of floods in the Eastern Scheldt. The indication scheme shows the main stressors, consequences and possible effects that are of relevance for the scope of the project.



Indication scheme of main stressors related to the Eastern scheldt addessed in the project
Made by author

Main Themes

Safety
Adaptive capacity of current infrastructures

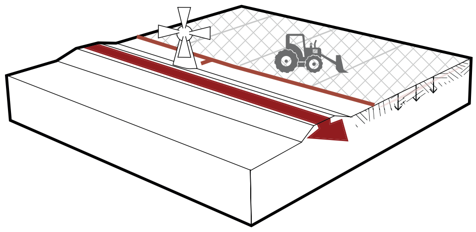
Ecosystem health
and related services

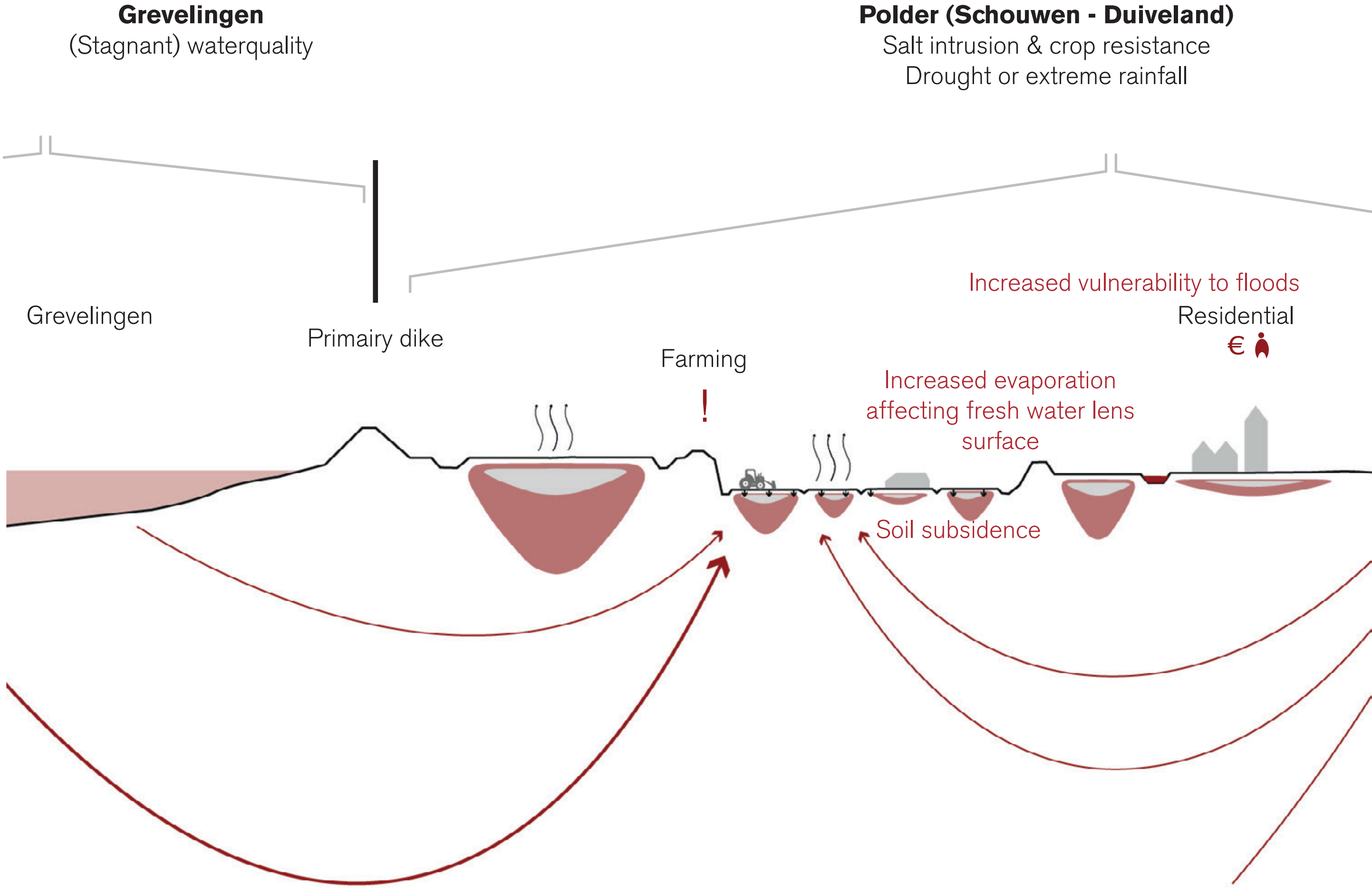
Society
Lack of preparedness
Availability of resources
fresh water

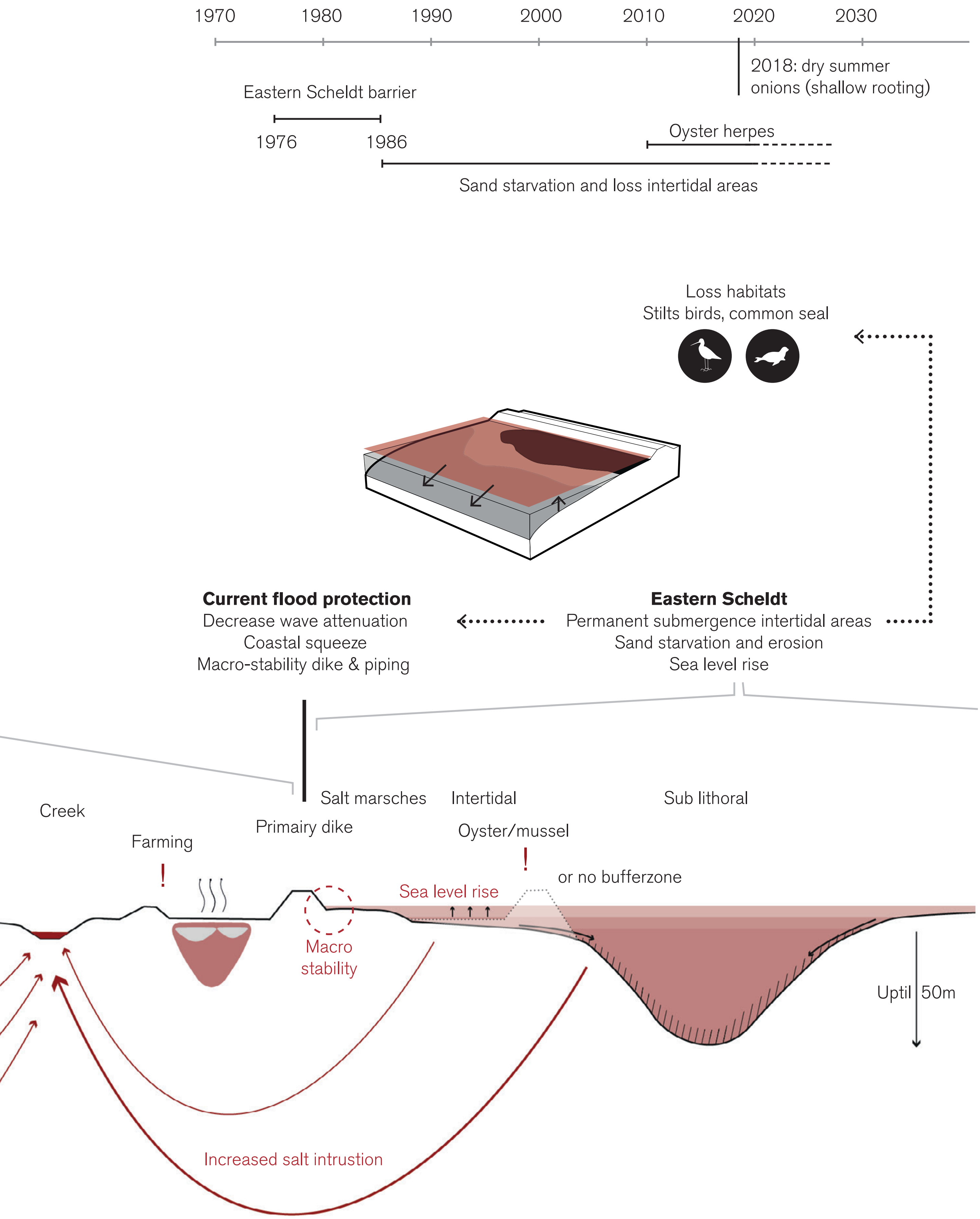
The scheme shows a spatial representation of several stressors that are affecting the area and its current uses. Possible submergence of tidal flats can cause a loss of oyster and mussels reefs (affecting the shellfish industry) as well as salt marsh vegetation. This reduced the foreshore and options for wave attenuation.

Preparedness:
Main roads in the area are not entirely elevated and could therefore not function as emergency routes. At the same time, the capacity of the roads can be questioned for the evacuation of the area. This questions the availability of high -water safety areas in villages and the preparedness of people, and how local awareness of floods can be improved.

Section indicative processes
made by author







1970
1980
1990
2000
2010
2020
2030
2018: dry summer
onions (shallow rooting)
Eastern Scheldt barrier
1976
1986
Oyster herpes
Sand starvation and loss intertidal areas
Loss habitats
Stilts birds, common seal
Current flood protection
Decrease wave attenuation
Coastal squeeze
Macro-stability dike & piping
Eastern Scheldt
Permanent submergence intertidal areas
Sand starvation and erosion
Sea level rise
Creek
Farming
Primairy dike
Salt marsches
Intertidal
Sub lithoral
Oyster/mussel
or no bufferzone
Sea level rise
Macro
stability
Uptil 50m
Increased salt intrustion

6.7 Powerfield: Involved parties Eastern Scheldt

The Sea and Delta department of the Directorate-General for Public Works and Water Management (in Dutch: Rijkswaterstaat, or the abbreviation RWS), has a concern about the consequences of extreme sea-level rise on the edges of the Eastern Scheldt and the still-waiting attitude of many stakeholders to act. Therefore, the project aims to create awareness and to develop perspectives for adaptation of the area.

Research by design:
Initiated is the OOZO (Ontwerpend Onderzoek Zeespiegelstijging Oosterschelde), a collaborative network of students (different fields) and experts and stakeholders to think about future pathways of the Oosterschelde related to sea-level rise developments. The municipalities of Schouwen-Duiveland, Noord-Beveland, the water board, and the province are involved, as well as the knowledge community Eastern Scheldt (in which various experts and local stakeholders work together to develop knowledge about the Eastern Scheldt). Through this initiative, the 'soft space' can be addressed, sharpening the spatial problem and solution field, and already explored options.

Main actors
The main actors involved in the project are related to planning, construction, management, or maintenance of water-related infrastructures, or actors with land use values such as farmers or exploitation of (eco-) tourism, or nature organizations. Vulnerable farmers (on land/water) and residents of flood-prone towns can be considered as vulnerable communities. They depend on ecosystem services such as fresh water supply. Simultaneously they are dependant on the Eastern Scheldt barrier and dikes for safety to floods.

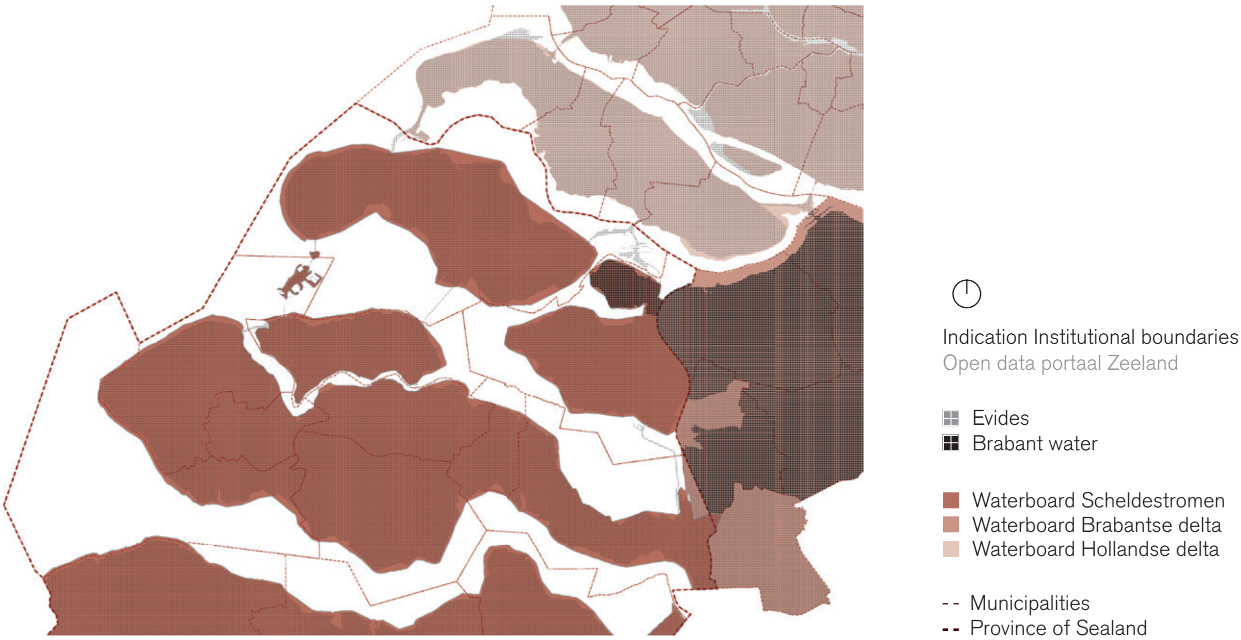


Image 6.7 - Indication of several institutional boundaries

Policy or guiding | **Scale** | **Actors**

Policy or guiding

Natura 2000
European network of protected natural areas.

Birds Directive (Special Protection Areas, SPAs) and the Habitats Directive (Sites of Community Importance, SCIs, and Special Areas of Conservation, SACs).

KRW (Kader Richtlijn Water)
Chemical and ecological quality of water

Scale

Cross national borders

National

Inter - regional

Local

Actors

European Union

Flemish government (BE)
Department mobility and public works (BE)
Agency Maritime Services and Coast (BE)
(Agentschap Maritieme Dienstverlening en Kust, MDK)

Kingdom of the Netherlands (het Rijk):
Standard for primary barriers

Ministry of Infrastructure and the Environment.:
- Departmental Crisis Management Coordination Center

Directorate-General for Public Works and Water Management
(Sea and delta department):
Construction, management and maintenance of part of the primary flood defenses and structures.
- Region

National Coordination Committee for Flood Threat;
(Landelijke Coördinatiecommissie Overstromingsdreiging)

Safety regions

Provinces: Standardization of regional defenses.
Sealand and Noord Brabant

Nature organisations
- Natuurmonumenten
- Milieu federation
- Stichting Natuur en Millieu

Water boards:
Construction, management and maintenance of (part of) the primary flood defenses, regional flood defenses and structures.
- Scheldestromen
- Hollandse Delta
- Brabantse Delta

Municipalities:
- Schouwen-Duiveland
- Noord-Beveland

Evides drinking water (& Brabant water)

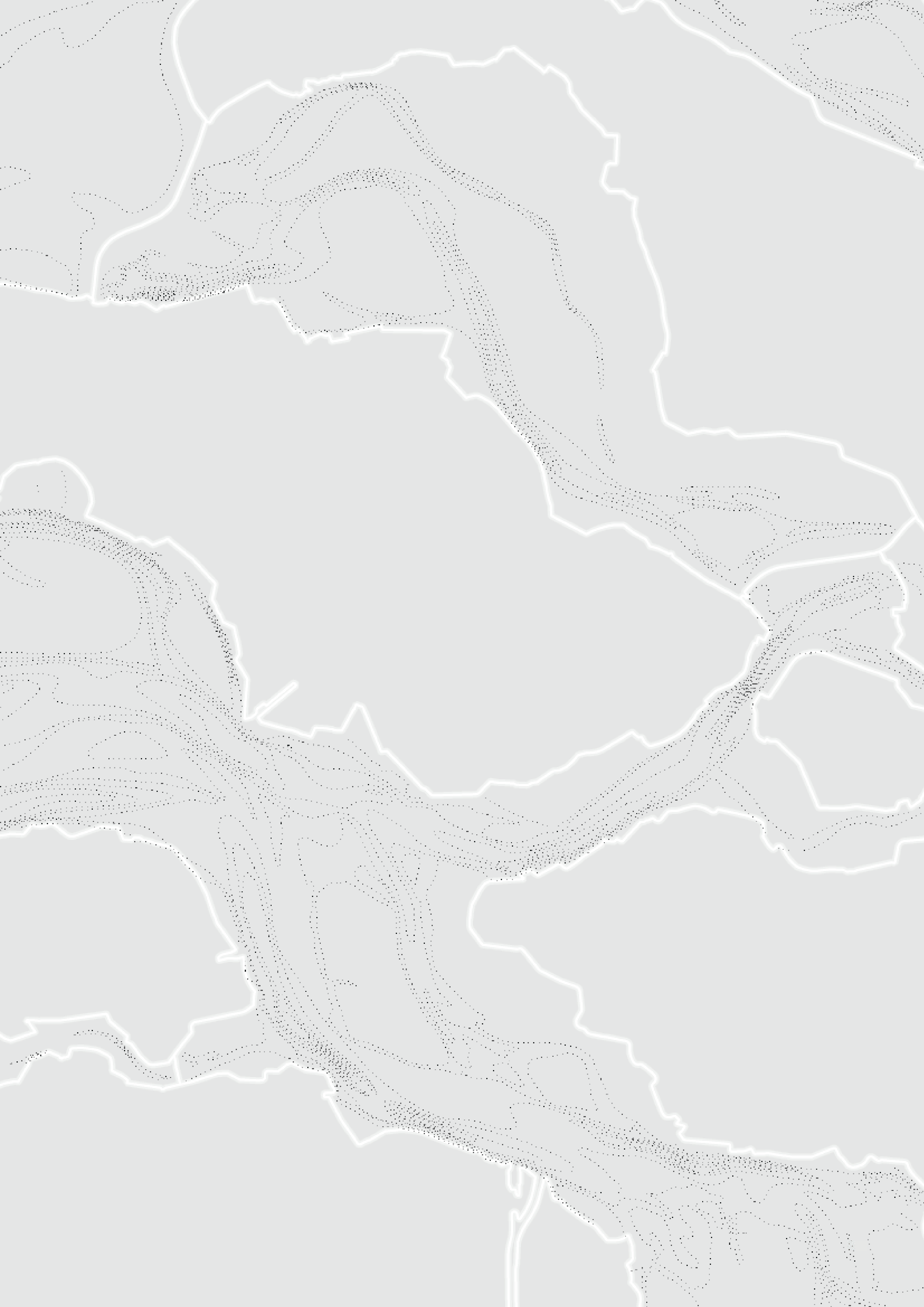
Oyster farmers and (shell)fish industry
Local harbour Authorities

Farmers
Eco-tourism (VVV)
Residents
Watersnoodmuseum

Indication of involved actors and guiding policies. Made by author

7. FUTURE PROJECTION

This chapter is concerned with the spatial strategy of land water zones alongside the Eastern Scheldt, with particular concern for the island of Schouwen-Duiveland.



7.1 Urbanism in the context of the Delta

The project focusses on the impact on climate change in predominantly rural areas alongside the Eastern Scheldt, and aims to enhance the goals as mentioned in the Deltaprogramm, namely:

- Watersafety: Protect from floods now and in the future;
- Freshwater:
    - Water availability: Provide suficient fresh water;
    - Added: Seasonal storage of water/peak water storage
- Spatial adaptation: Make sure that landscaping/(urban) developments are climate proof.

The project opts for multi-functional adaptive measures that can provide (short term) value for nature, recreation, aquaculture, and innovative agriculture and improved livability of residential areas, while anticipating on increased risks for water safety until 2100 through a nature-based approach. This questions how an adaptive territory can be developed and what programmatic input can be of used that contributes to the spatial performance of the area (ecological, social and economic) within the given scenarios of sea level rise. As apposed to earlier mindsets to reclaim or consolidate, the project proposes a dynamic approach.

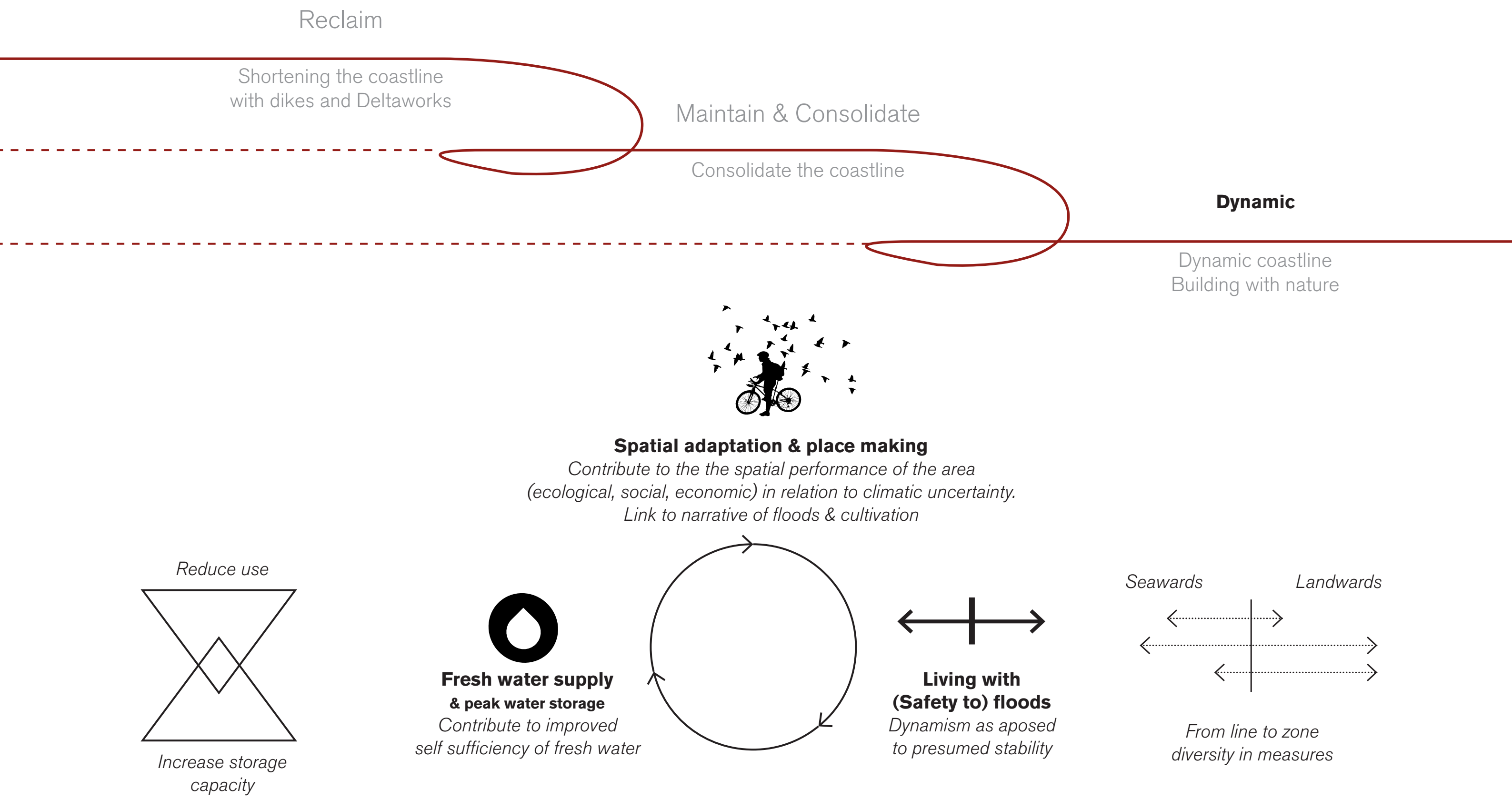
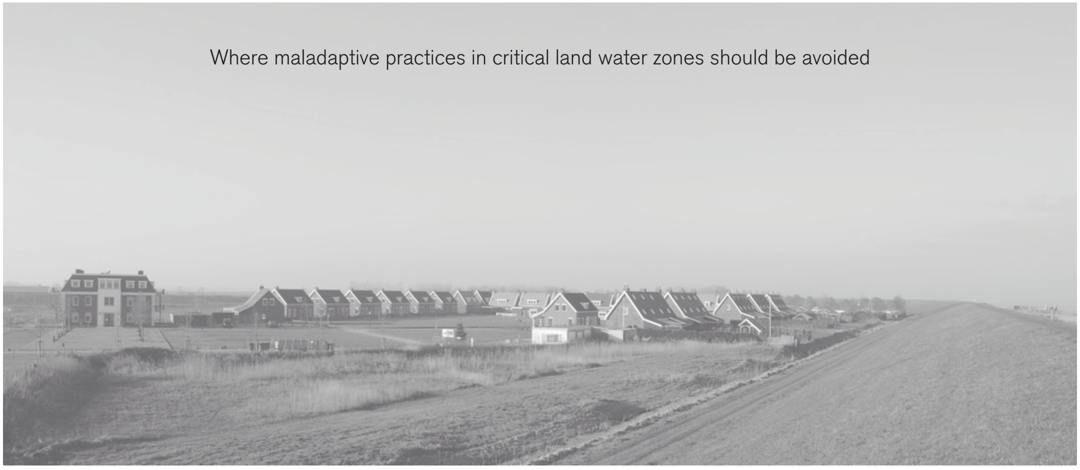


Image 7.1 | Urbanism in the context of the delta as perceived by the author based on general themes of the Delta programm

Where there is space, but limited (urban) developments and financial resources.



Where maladaptive practices in critical land water zones should be avoided

Where different interests need to be alligned

Pictures made by by author

7.2 Scenario building

To build a scenario in which the project aims to operate some critical system points were indicated and projected on current predictions of sea-level rise as mentioned by Haasnoot et al. (2019). This initially concerns the capacity of the Eastern Scheldt barrier and submergence of tidal flats.

Critical points: Eastern Scheldt barrier
It is assumed that the breakpoint of the Eastern Scheldt barrier is somewhere between 1.0 and 1.5 m sea-level rise after which the barrier must close too often and will not function anymore (Haasnoot et al., 2018, p.51). This range is therefore projected as critical zone on the projections of sea level rise. Through adjustment to the closing regime of the barrier, the life span of the barrier might be extended, but this would require reinforcements of the water defenses of the backlands, and pressures the intertidal areas, by higher water levels, and the continuing sand starvation. Therefore, it is assumed that an open system will be initiated.

Critical points: Tidal flats
The second critical process is the loss of intertidal areas and salt marshes as a result of erosion and sea-level rise. Accelerated sea-level rise after 2050 might result in increased loss of intertidal areas. As mentioned earlier with about 1m sea-level rise tidal flats are quite likely to even disappear. According to de Ronde et al. (2013) restoring the morphological balance in the Eastern Scheldt would be the most sustainable solution to tackle the problem. However, they also indicate that the theoretically required measures, either the removal of flood defenses and dams, or the import of 400 - 600 million m3 (assumed based on 60 cm sea-level rise) from the North Sea, are unrealistic within the time horizon of 2060 (de Ronde, J.G., Mulder, J.P.M., van Duren, L.A., Ysebaert, T., 2013, p.2).

Scenarios
The different critical points have been appointed as guides for scenario development. They are addressed based on scale of impact as well as flexibility and shortly explained in image 7.2.1. The project assumes scenario X in which short term measures focus on maintenance and nourishment of intertidal flats and the long-term development of initial critical land zones. The breakpoint of 1m is considered with more weight considering that the breakpoint of the Eastern Scheldt barrier has a ranging limit starting from1m. Assuming the worst scenario this breakpoint can be reached from 2070 onwards.

Timeline
Based on the projections of sea level rise a timeline has been constructed through which periods of interveniation can be determined. In the initial period from 2020 until 2040-2050 there are limited safety risks however this period already anticipates on the short-term maintenance and nourishment of intertidal flats. Specifically areas with limited amounts of forelands can be prioritized with absence of landwards buffer zones. Simultaneously planning of landward developments will be initiated prioritizing areas with limited to no buffer zones both landwards and seawards. Due to complex ownership patterns, these developments might require more time for planning and research.

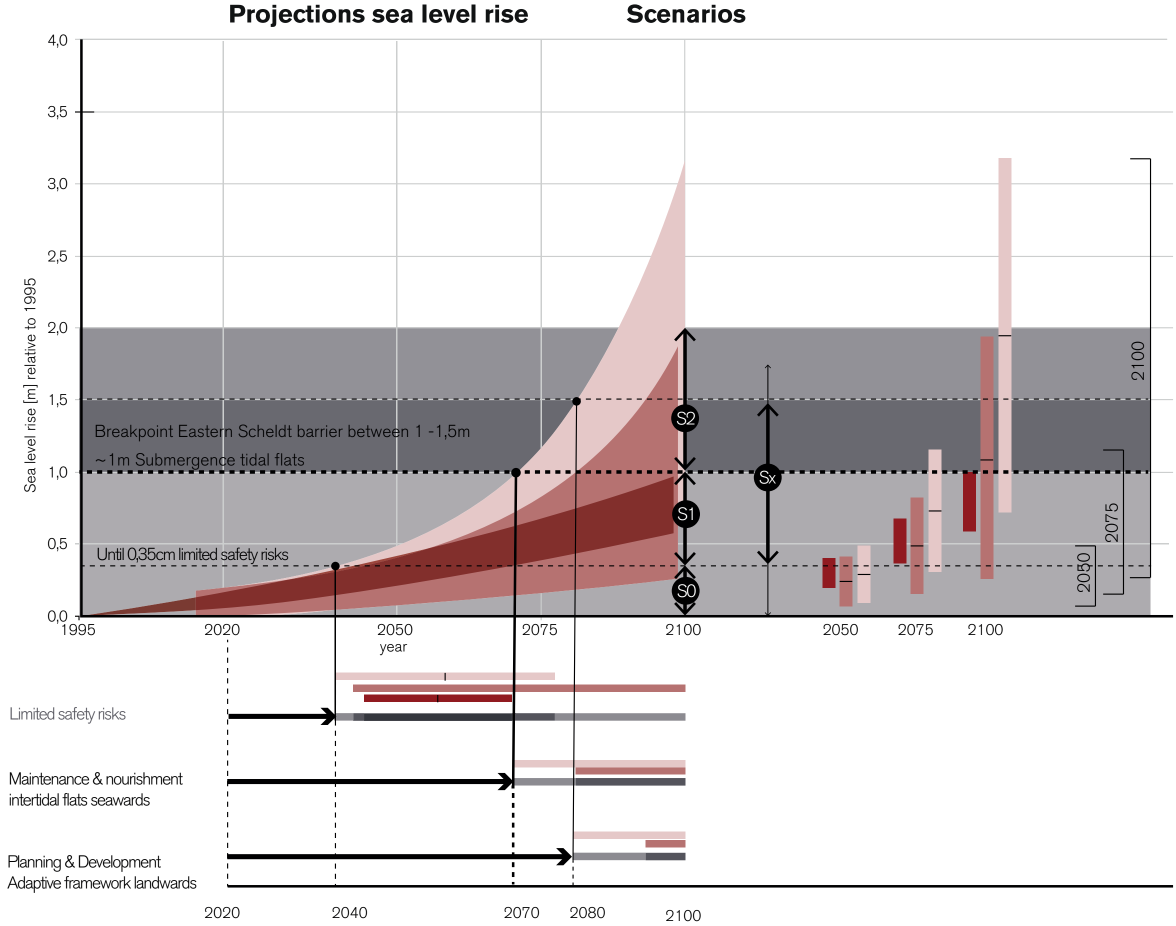
Image 7.2 | Projections sea level rise
(Haasnoot et al., 2019, p.15)
Image adjusted by author to show critical points and support scenario building

- Accelerated sea level rise RCP 8.5
- Accelerated sea level rise RCP 4.5
- Delta scenario's
- Median
- Indication of critical points
- Range scenarios

Constructed timeline with critial breakpoints based on projections
And periods of interveniation.

➔ Interventions in critical zones due before extreme projection SLR

Image 7.2.1| Scenarios
Made by author



Scenario 0: Denial
It assumes limited measures since there will be limited safety risks.

Scenario 2: Postponed denial
Assuming larger impact implies bigger implications for agricultural land-use since stressors (salt intrusion) become more apparent. The limit of the Eastern Scheldt barrier will be exceeded. The scenario, therefore, assumes removal of the barrier, after which the morphological balance will naturally be restored. This might require large scale measures in a smaller time horizon.

Impact

Scenario 1: Mitigation
The first scenario includes the maintenance of the Eastern Scheldt barrier until its critical point around 1-1,5m of sea-level rise. Measures relate to optimizing the existing system by ‘using what you got’, and mitigation of initial stressors.

Scenario X: Anticipation
Scenario X is proposed as a means to optimize the existing system, while already anticipating on critical breakpoints of systems an initiation of an open eastern Scheldt. This requires short term maintenance and nourishment of intertidal flats while initiating managed retreat landwards as a means to facilitate circular land use.

Activity

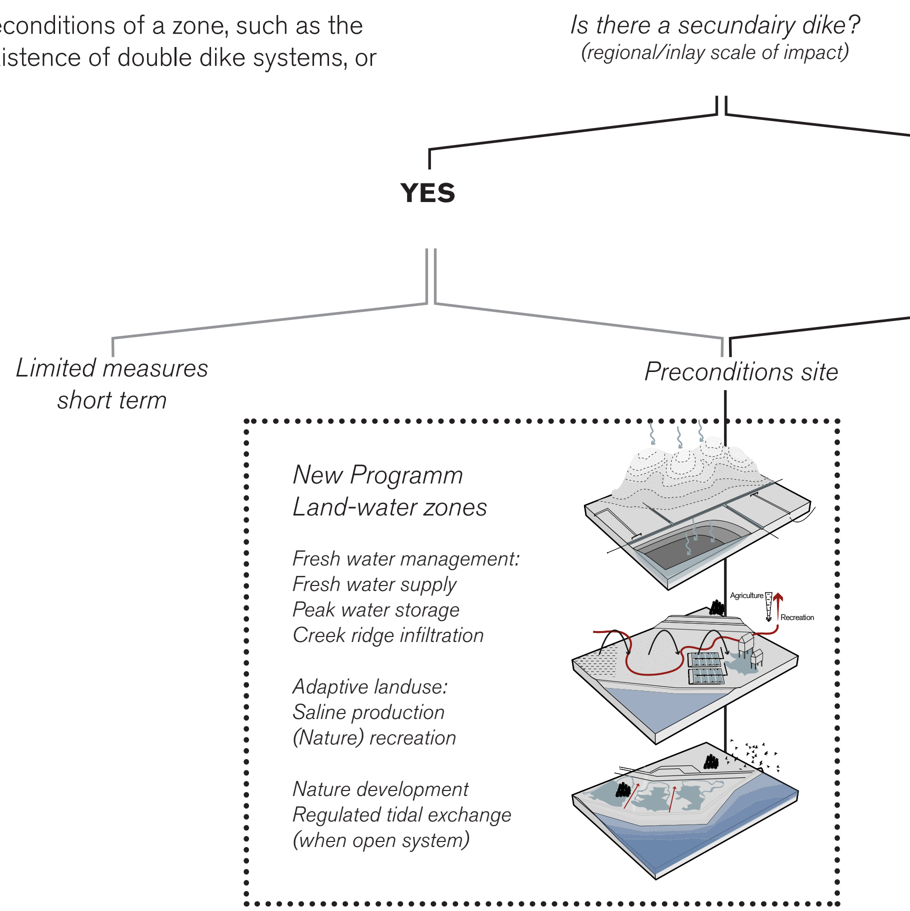
7.3 Nature-based choice model

In order to support a robust adaptive spatial framework choices need to be made concerned with the positioning of measures either landwards, seawards or by consolidating the line. This will be done through a nature based choice model.

Natural scenario:
Deltares set an initial indication of possible scenarios in which BwN principles can be included (on different levels), namely: Defensive, Offensive & Natural (Abma, R., Brouwer, J., Tangelder, M., Wiersma, A., 2014, p.24). Different from a defensive scenario in which the present configuration of the delta is largely kept intact, or an offensive scenario in which de the configuration is modified reinforcing the coastline outwards with nourishments and reinforcements of hydraulic infrastructure (Abma, R. et al., 2014, p.25), the natural scenario anticipates on the disappearance of the Deltawork dams, regaining estuarine dynamics and allowing open connections between the Rhine rivers (Abma, R. et al., 2014, p.26). The project will anticipate on a natural scenario preferring nature based solutions over consolidation of the existing line. The model from Deltares was adopted and adjusted accordingly.

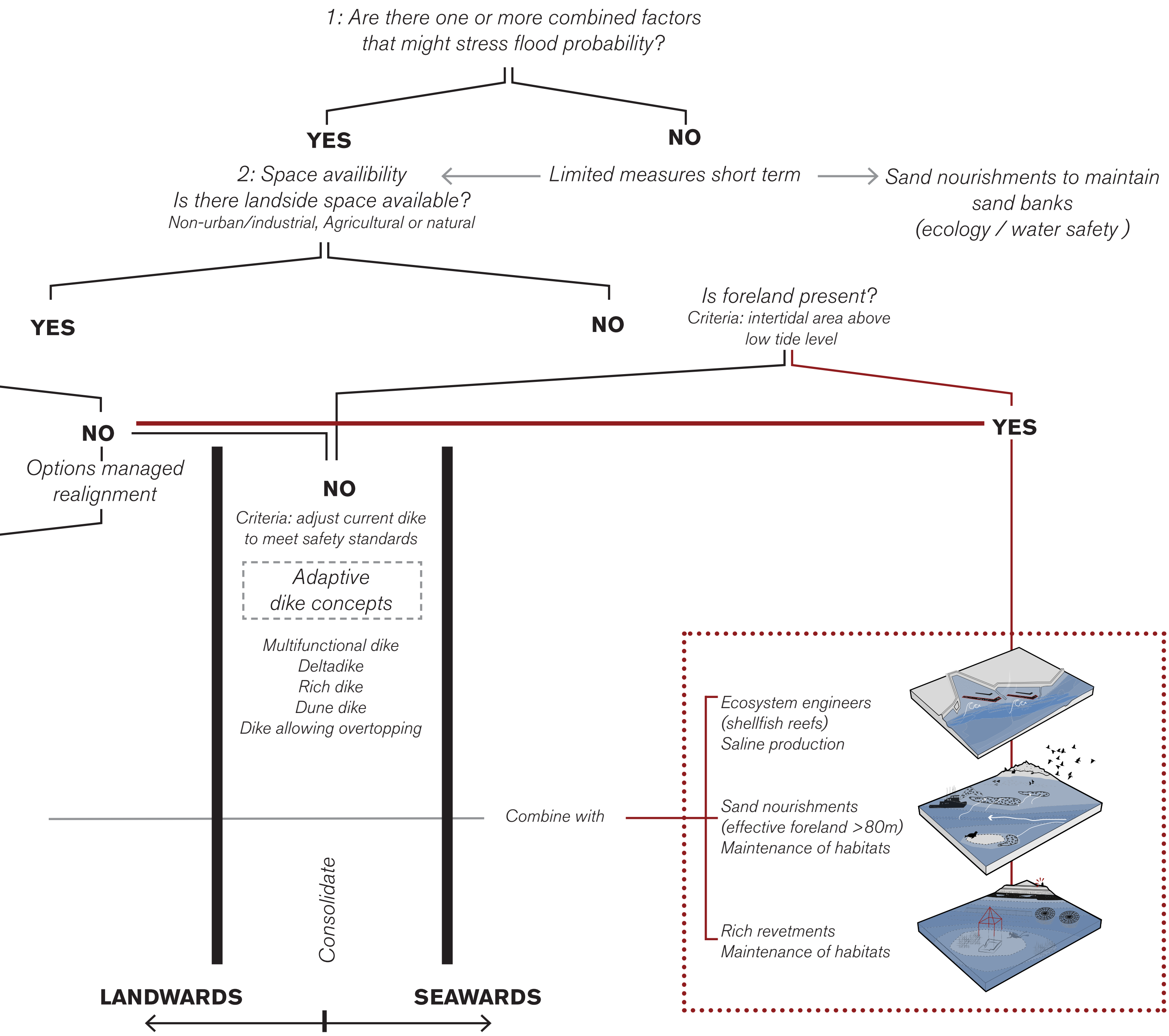
Towards a nature-based choice model
The choice model is meant to serve as a guiding tool to question urgent trajectories (question 1) as well as the available solution space (question 2) through changing conditions over time. The first question is related to flood probability and issue of water safety assuming that assignments must be borne from the water safety issue to raise public support.

The strategies can be applied depending on preconditions of a zone, such as the presence of a foreshore, water velocity, wind, existence of double dike systems, or concerns about salinization.



Nature based choice model for adaptive practices in the South-western Delta based on preconditions of the territory

Based on (Abma, R., Brouwer, J., Tangelder, M., Wiersma, A., 2014, p. 26) adjusted by author.


1: Are there one or more combined factors
that might stress flood probability?
YES
NO
2: Space availibility
Is there landside space available?
Non-urban/industrial, Agricultural or natural
Limited measures short term
Sand nourishments to maintain
sand banks
(ecology / water safety)
YES
NO
Is foreland present?
Criteria: intertidal area above
low tide level
NO
Options managed
realignment
YES
NO
Criteria: adjust current dike
to meet safety standards
Adaptive
dike concepts
Multifunctional dike
Deltadike
Rich dike
Dune dike
Dike allowing overtopping
Combine with
Ecosystem engineers
(shellfish reefs)
Saline production
Sand nourishments
(effective foreland >80m)
Maintenance of habitats
Rich revetments
Maintenance of habitats
Consolidate
LANDWARDS
SEAWARDS

7.4 Preconditions territory

A selection of critical land-water zones can be determined based on preconditions of the territory. This relates to the initial question: *Are there one or more combined factors that might stress flood probability? Stressing locations where short-term measures might be necessary.* To establish the selection several dictating forces are taken into consideration, namely:

- Wave heights
- Abrasive channels
- Water run up

A combination of stressing factors is used as an initial indication of urgent trajectories. The phenomenon will be shortly explained:

<u>Wave heights:</u>
Wave heights correlate with the average windspeeds and direction and can increase with a longer fetch (stoke length). A predominant South-Western wind direction appears to affect the dikes oriented to this direction. Storms, correlating with higher windspeeds, appear to have a West to South-West orientation. Specifically near the area of Zierikzee and Ouwerkerk this can cause increased wave heights.

<u>Abrasive channels:</u>
Abrasive channels have higher water speeds and therefore a more erosive nature. Specifically near existing dikes these channels can be a threat causing land instability, for instance the northern part of Noord Beveland.

<u>Water run up:</u>
In an closed bay water will be pushed into the system. Therefore high water levels increase further into the Eastern Scheldt system.

Piping:
Additional to the first three factors but not as explisitly shown in a map is piping. Piping is a phenomenon caused by increased rise height and therefore possible water movement underneath a dike. This can possibly weaken the dike structure. Due to sea level rise in the Eastern Scheldt, and soil subsidence in the polders, there is an increased difference in rise height that might affect the impact of piping.

One or more combined factors that might stress flood probability
Indicative, made by author based on initial mappings of stressing factors

- 1 factor
- 2 factors
- 3 factors

Wave heights
indicative pattern 1:10.000
based on (den Biemand, J., Groeneweg, J., 2017, p 31)

0,5m
4,5m

Average windspeed/direction
Province of Zeeland
based on Meteoblue

Normative high water
indicative pattern 1:10.000
Made by author,
based on (den Biemand, J., Groeneweg, J., 2017, p.61)

3,6m
4,3m

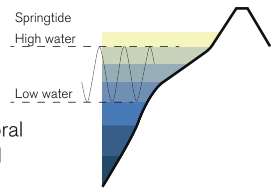
Abrasive channels
indicative pattern
Made by author,
based on bathymetry

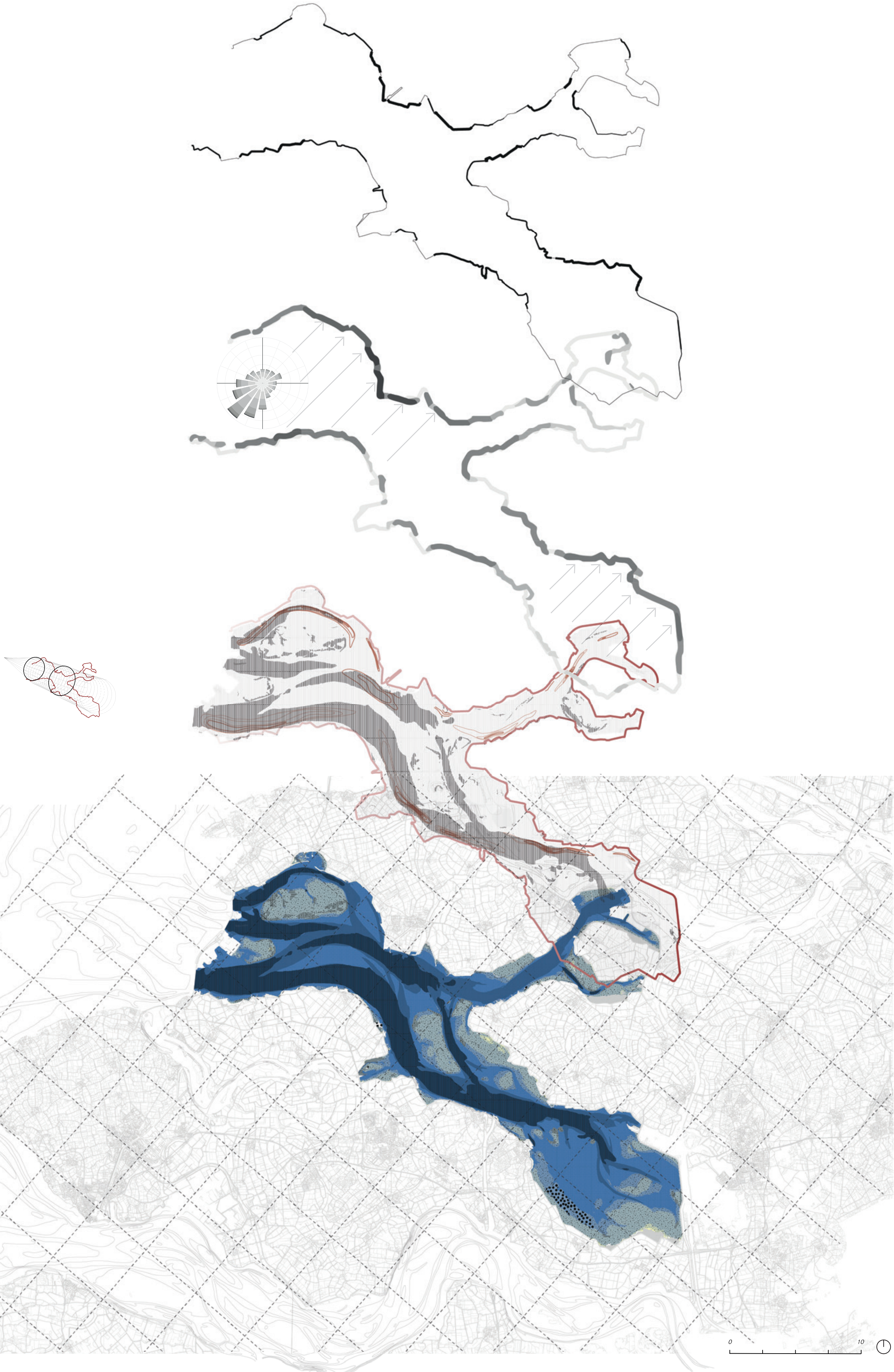
Deep channels adjacent to primary dikes

Dynamics
High dynamic
Low dynamic

Substrate
Hard: Hard peat/clay
Stone
Soft: Soft Substrate
Silty
Coarse sand

Lithoral
Salt marsh
Supralithoral
High lithoral
Middle lithoral
Low lithoral
Shallow sublithoral
Deep sublithoral
Sublithoral

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7.5 Space availability

Second question relates to the space availability, namely: *Is there landside space available? (Non-urban/industrial, Agricultural or natural).* It questions where the solution space can be found either landwards (presence of secondary dike), or seawards (presence of foreland). It also questions whether there are zones that can initially limit the impact of floods. For this study these areas have been described as buffer zones.

Landwards: inlaypolders and regional compartmentdikes
Examples of existing buffer zones landwards are inlay polders or regional compartment dikes. Inlay polders are areas between a main dike and a secondary dike, often made to serve as a reserve dike due to instability of the earlier dike. Often the second dike has been made with soil from the polder leading to brackish nature areas. Althought these double dike systems have been considerd as initial buffer zones, it can be concluded that not all of the inlay polders will suffice for water safety on the long term. Instability for instance due to piping can be of concern when observed on a local scale.

Secondly existing regional compartment dikes can be of use limiting the area of impact during a dike breach. Although not studied in this map the current conditions of these dikes (height, presence of weak spots and hydraulic elements) need to be examined on a smaller scale to conclude whether or not they need improvements. However, re-use or upgrading of these infrastructures is considered a preferred option to limit development of new infrastructures as well as maintaining the cultural narrative and stages of development in these areas.

Although regional dikes can be present it still does not determine the scale of impact in terms of economic damage (loss of crops, infrastructure and property damage) or deathly casualties. Some polders are substantially larger increasing the surface of impact.

Seawards: Marshes, foreland and sandbanks
Existing buffer zones seawards such as salt marshes, foreland and sandbanks have a regulating service such as wave attenuation and can therefore be part of the solution space. Criteria is that areas need to have an intertidal area above the low tide level.

Presence bufferzones
Indicative, made by author based on initial mappings of bufferzones landwards and seawards

— No direct bufferzone
-- Limited bufferzone

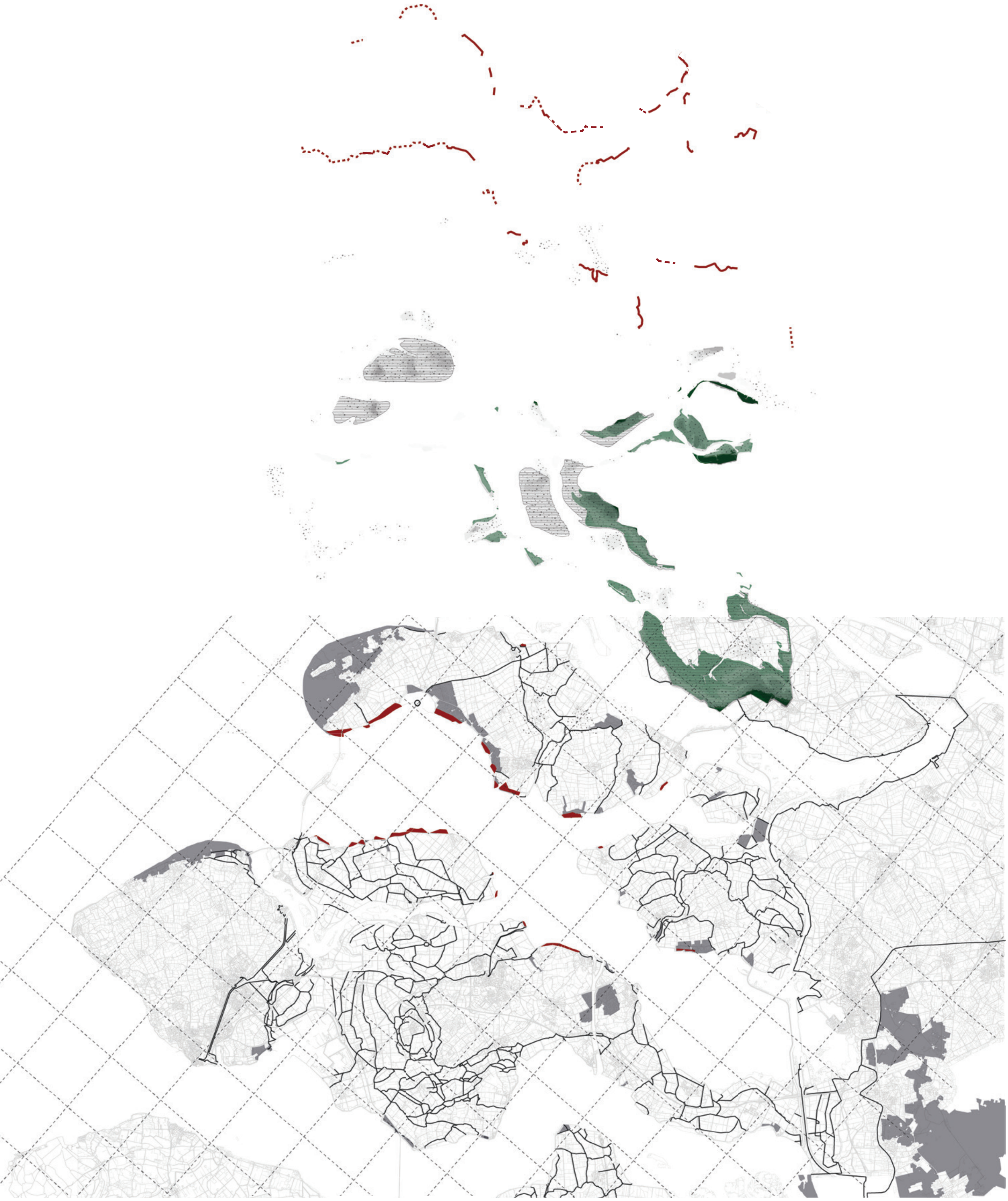
Salt Marsches & presence of foreland
Made by author, based on bathymetry

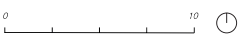
- Salt marsch
- Salt marsch sub
- Sand plates

Existing inland bufferzones cultural
(Provincie Zeeland)

- Inlay dikes
- Inland dikes / regional dikes

- Nature areas not endiked

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7.6 Urgent short-term trajectories

The combination of stressing factors and Limited or no availability of buffer zones indicates some trajectories that might need interventions on the short term (~20 years).

The island Schouwen Duiveland has been selected as a case area. The island has an autonomous freshwater system and is therefore dependent on the improvement of freshwater availability. Increased salt seapage is affecting the current land use, as it has some of the lowest polders. The island might also be representive for different solutions.

Schouwen Duiveland case island

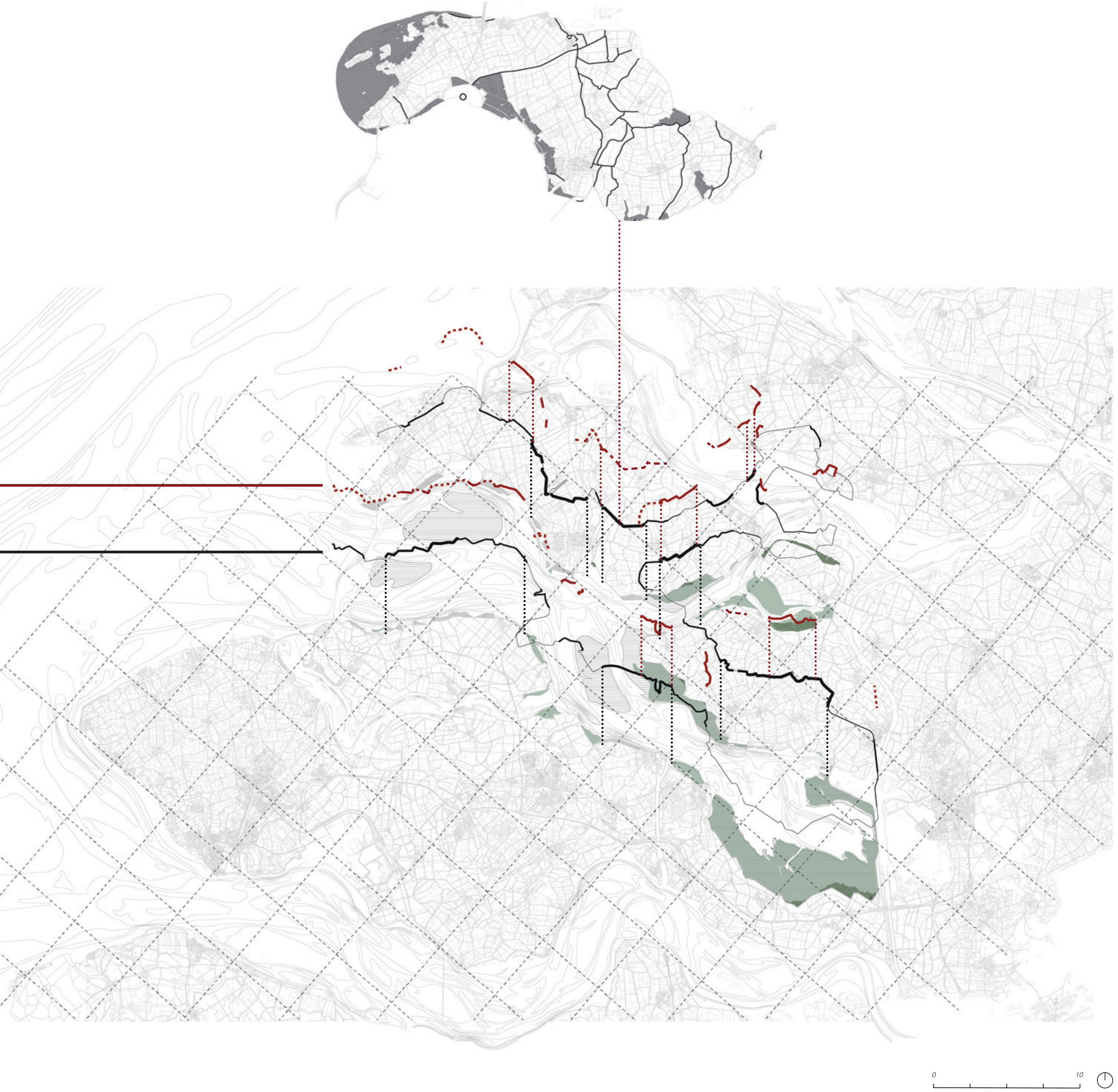
Limited availability bufferzones

— No direct bufferzone
-- Limited bufferzone

Factors stressing flood probabiliy

Existing Bufferzones
Landwards and seawards
(maps made by author)

- Salt marsch
- Salt marsch sub
- Sand plates
- Inlay dikes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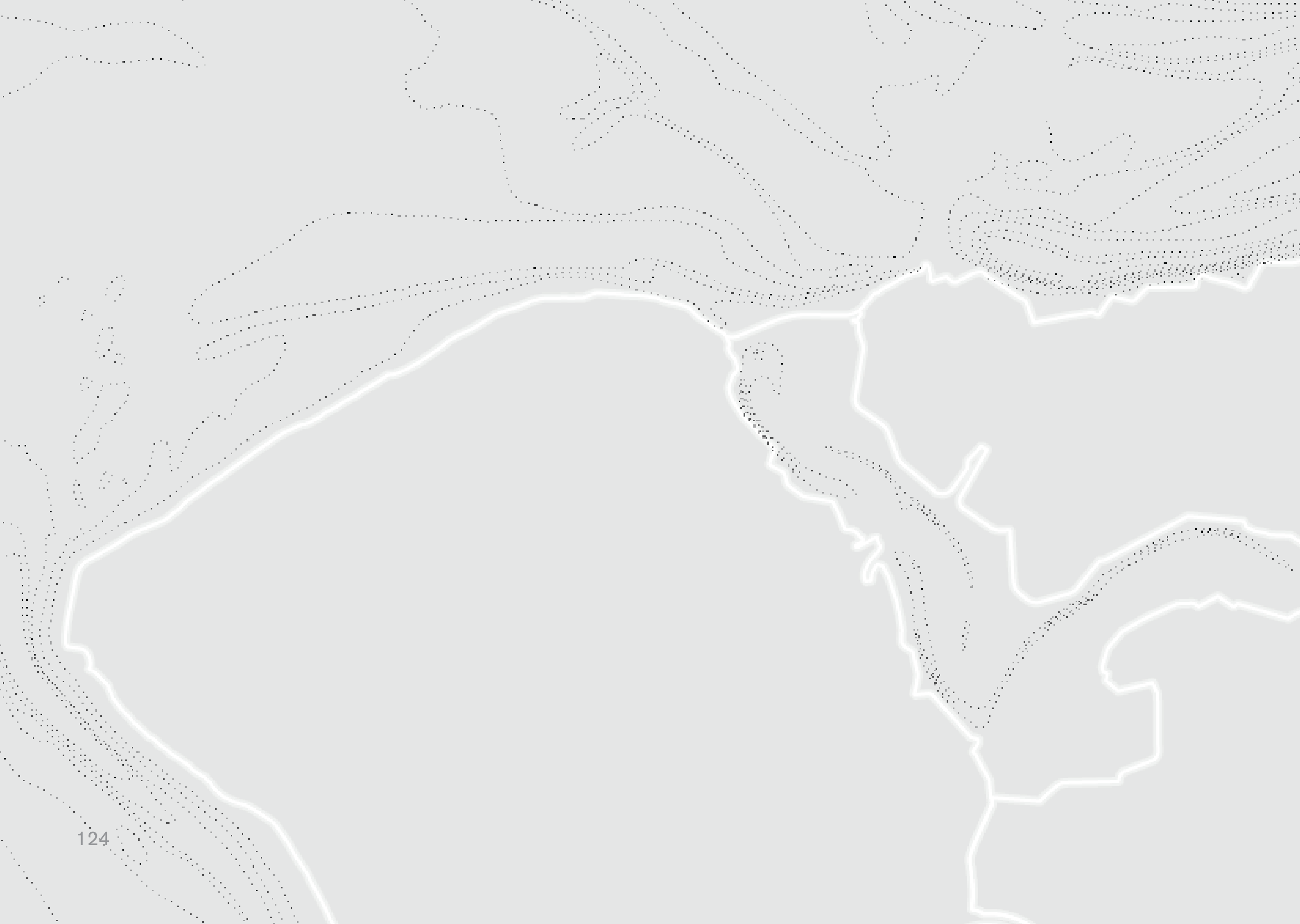
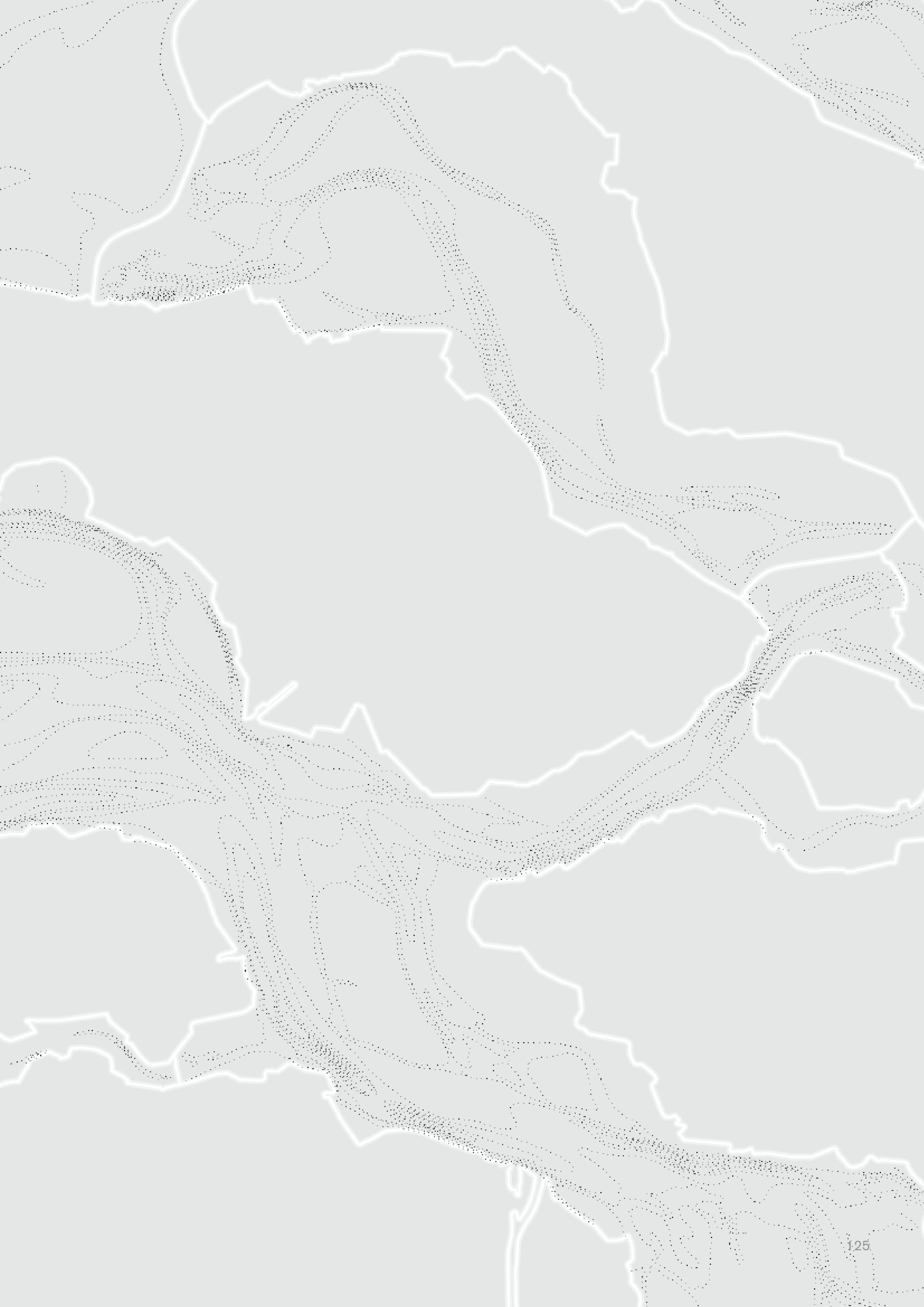
8. FRAMEWORK

This chapter is concerned with the development of the spatial frame-workfor the island/municipality of Schouwen Duiveland, abstucting initial principles that can be used to for spatial developments of the island and implementation of the nature based choice model.





8.1 Impact assesment

New infrastructures will determine the spatial (ecological, social, economic) performance of the area through the layers of Occupation, Networks and the Substratum. This questions which relations can be constructed or improved over time. The project anticipates on the construction or improvement of existing relating themes, through a mindset of Ecosystem based Adaptation (guided by Building with Nature principles).

As a means to describe the affected relations the IPDD model has been used as a tool to indicate the affected or activated layers and its relations with other layers over time (Meyer, van den Born & Geodan, 2013). The model is meant as a qualitative method in order to strategize measures, and indicate possible impacts (possitive or negative) according to new correlations over time.

The model will initially be used as a means to indicate existing affected layers and possibilities for activation of layers on the scale of Schouwen - Duiveland. During the development of the composition it will be used to show which relations will be improved.

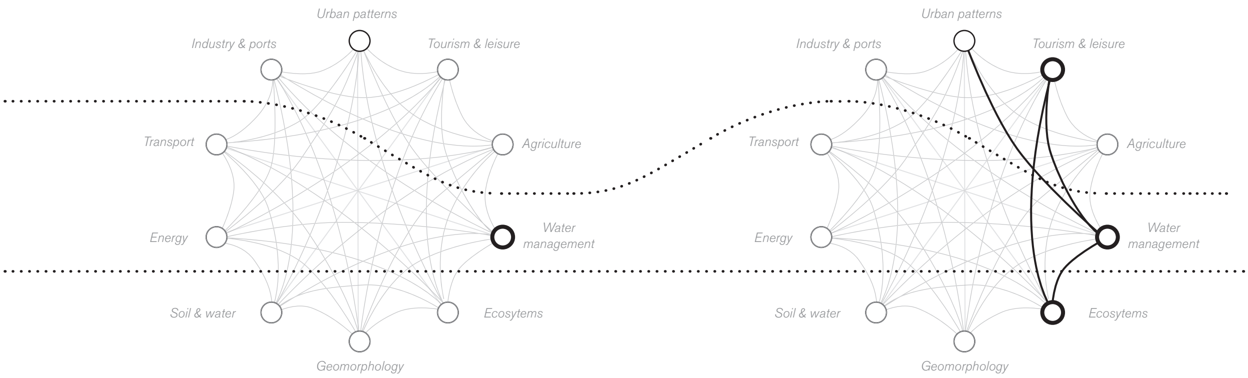
Image 8.1 Thematic relationships
Made by author, based on
(Meyer, van den Born & Geodan, 2013)

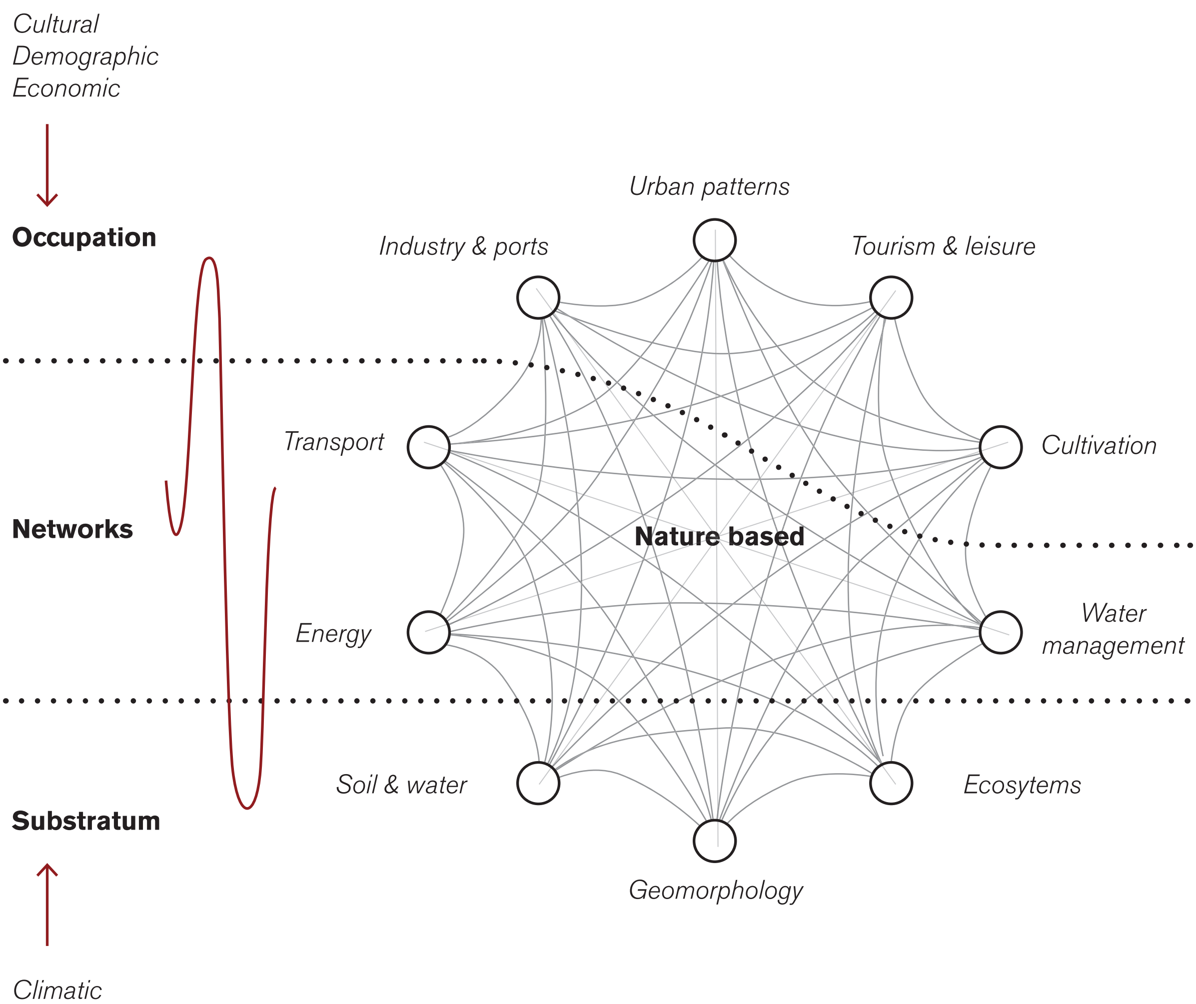
- Interaction of layers
- Negatively affected layer
- Opportunity to activate layer
- Level of impact (low- high)

Example impact assesment over time

Activation of layers or affected layers
Ex.: increase waterstorage capacity

Affected relations
Ex.: Link waterstorage to recreational network between villages

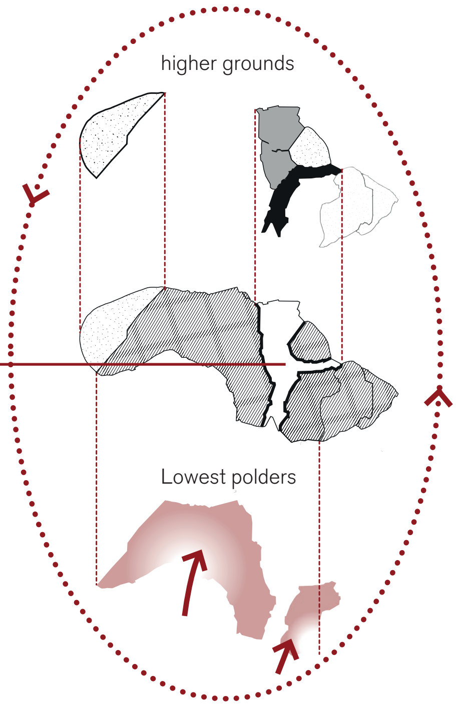




8.2 Urban patterns

Geomorphogenesis
In pre endikes times mounds (vliedbergen) were spread in the inital embanked areas, as means to escape high water levels. Polders where established from about 1200 onwards. Initially this lead to three islands, Schouwen, Duiveland and Dreischor as an embanked area. Zierikzee was firstly oriented to the Gouwe creek, obtaining welvare from fishery and trade. Elevated villages with a central church, ringvillags, were small initial agricultural clusters (Ouwerkerk, Nieuwerkerk). From 1600 onwards villages developed prependicular on the dike, often oriented to a main harbour, so called Frontstreetvillages (Bruinisse). Simultaniously the crossstreetvilllage typology developed as a cross point of roads (Oosterland). As a means to restore the the connection with the sea Zierikzee oriented a new harbour towards the Eastern Scheldt.

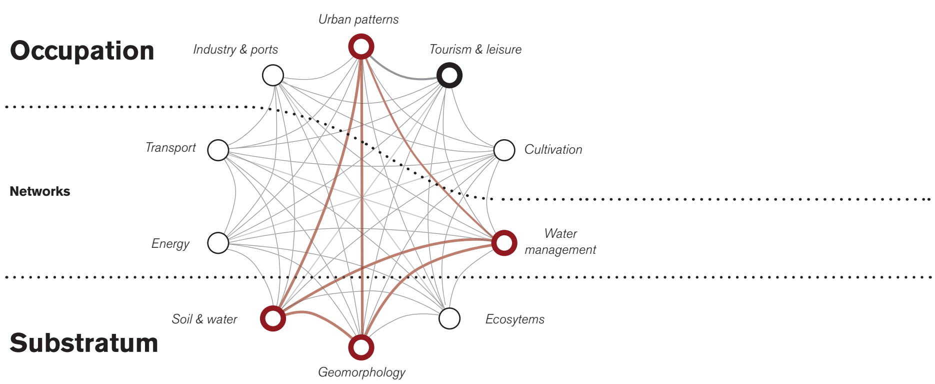
Geomorphogenesis: Circular land management
The impact of watermanagement and reclaiming on geomorphological processes as well as the impact on soil and water conditions can be observed as a circular process in which the lowest (and oldest) polders are most likely to be flooded.



Abstracted principles:

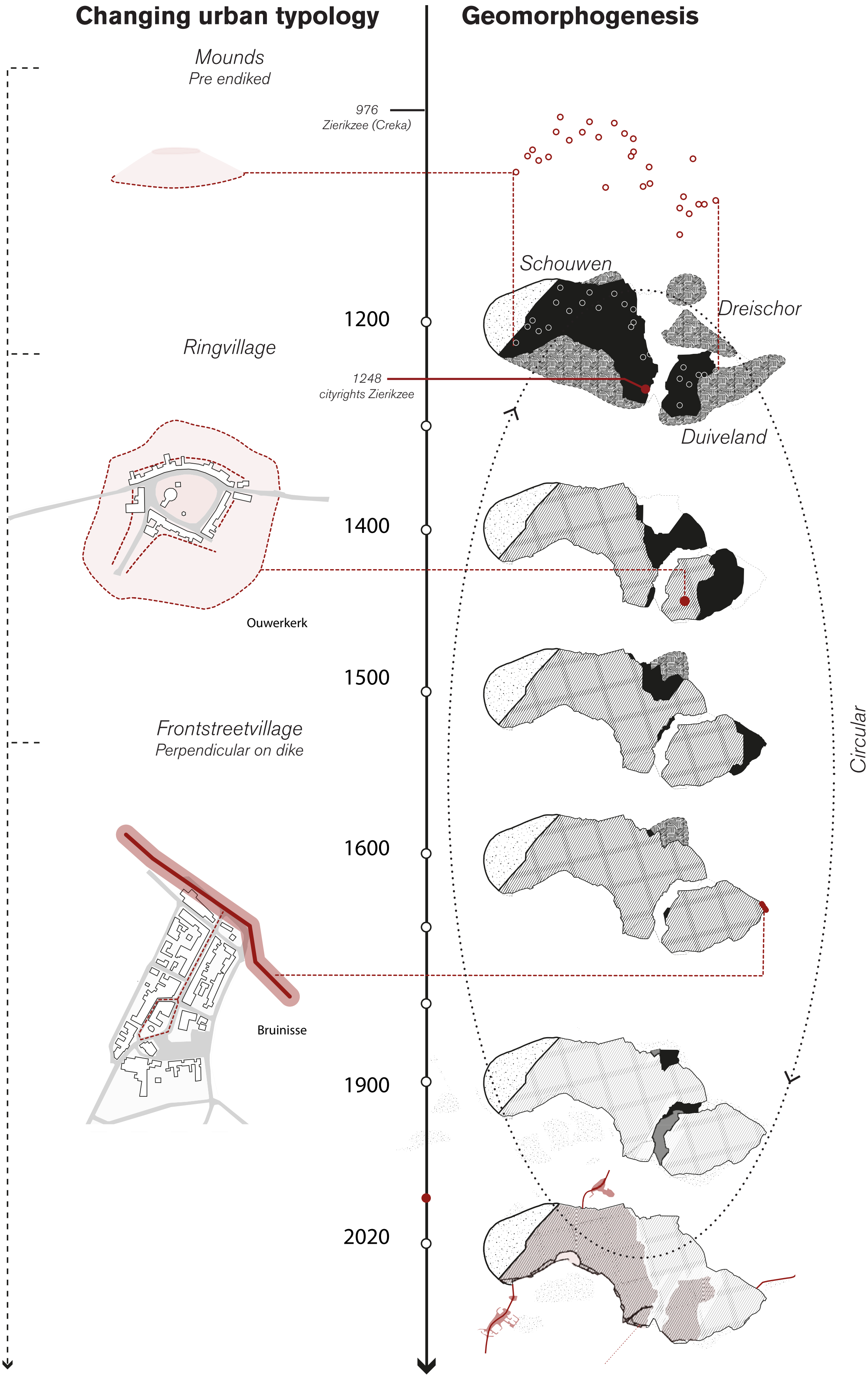
Accentuate the edges of old islands Schouwen, duiveland and Dreischor, by mainting the openess of the Gouwe creek.

Explore the possibility to adapt current typologies



Geomorphogenesis
Made by author, based on (Kuipers, S. F., 1960)

- Dunes
- New embanked nucleus (grey: earlier new embankments)
- Earlier embankments
- Probably embanked older nucleus lost
- Lowest polders
- Contour current situation
- Mounds (vliedberg)



Changing urban typology
Geomorphogenesis
Mounds
Pre endiked
976
Zierikzee (Creka)
Schouwen
Dreischor
1200
Ringvillage
1248
cityrights Zierikzee
Duiveland
1400
Ouwerkerk
1500
Frontstreetvillage
Perpendicular on dike
Circular
1600
Bruinisse
1900
2020

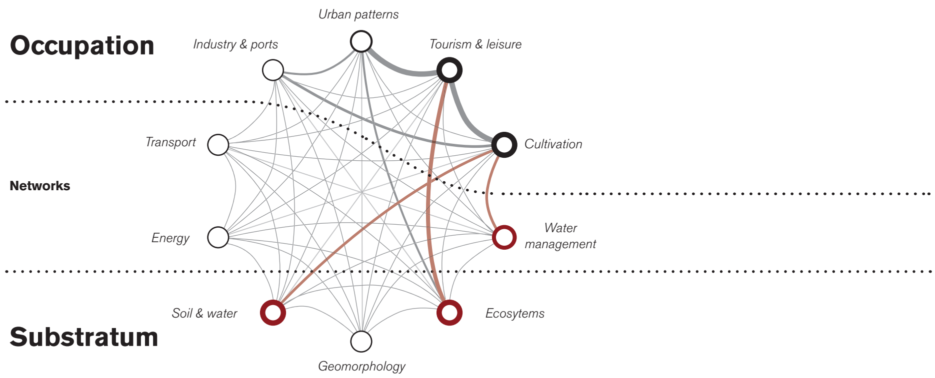
8.3 Tourism & leisure

Tourism and Leisure
According to Kenniscentrum Kusttoerisme about 14% (about 1/6) of the jobs in the municipality of Schouwen Duivland in 2018 was related to the sector of tourism, making it the main job contributing sector (Kenniscentrum Kusttoerisme, 2019, p.2). The spatial qualities of the landscapes is used as attraction for nature and water tourism, whereby a distinction can be made between the beach, dunes, forests, and polderfringe at the head of Schouwen, the open agricultural polder areas , the open Gouwe creek, the wetlands alongside the eastern scheldt coast, and the salt marsches. Surfing and sailing activities are mainly clustered alongside the Grevelingenmeer. Kiting can be found alongside the shore and barrieers. Divingspots are located around the island with exclusion of salt marsches and the beach. Public transport is limited to busconnections. Deltapark Neeltje Jans and the museum for watermanagement (caisons) have an educational purpose.

New exclusive accommodations
Main accommodations are clustered alongside the head of the island in the dunes and alongside the Grevelingenmeer adjacents to the existing mains. In the open Schouwen polders minicampings can be found as additional activity for farmers, implemented within the green casco of the farm to maintain openness.

Concern for the municipality Schouwen Duiveland is the exploration of available space for new recreational developments, since space alongside the dunes has become limited. In a survey for the municipality (Kenniscentrum recreatie, 2011, p.14) it was therefore concluded that new establishments are only allowed if:
- There is no comparable accommodation on Schouwen-Duiveland;
- The initiative focuses on a specific and/or own target group;
- Due to its unique character, the initiative does not compete directly with the available supply.

The following guidelines for can be proposed:
- Exclude Gouwe creek area, as well as existing nature reserves, from new lodging accommodations to maintain openness.
- Limited new developments in the dunes, due to space availability. Focus on the integration of existing clusters to improve spatial quality.
- Due to space availability the islands Duiveland and Dreischor can be of interest for new recreational developments in which there should be a focus on experience based accommodations. Developments should link to the themes of water safety, narrative of the island and qualities of the productive territory.



Narrative island
(Based on Minuutplan1832)

- Old centres
- Current village
- Drowned village
- Main water1832
- Remnant creek 1953

Public transport
Buslines (Provincie Zeeland, 2019)

- Main buslines
- Scholar line
- Neighborhood connection

- Cycling network

Protected nature sites excluded from developments
(PDOK, 2021)

- Beach, Dunes & Forest
- Wetlands
- Remnant creeks
- Polder Fringe

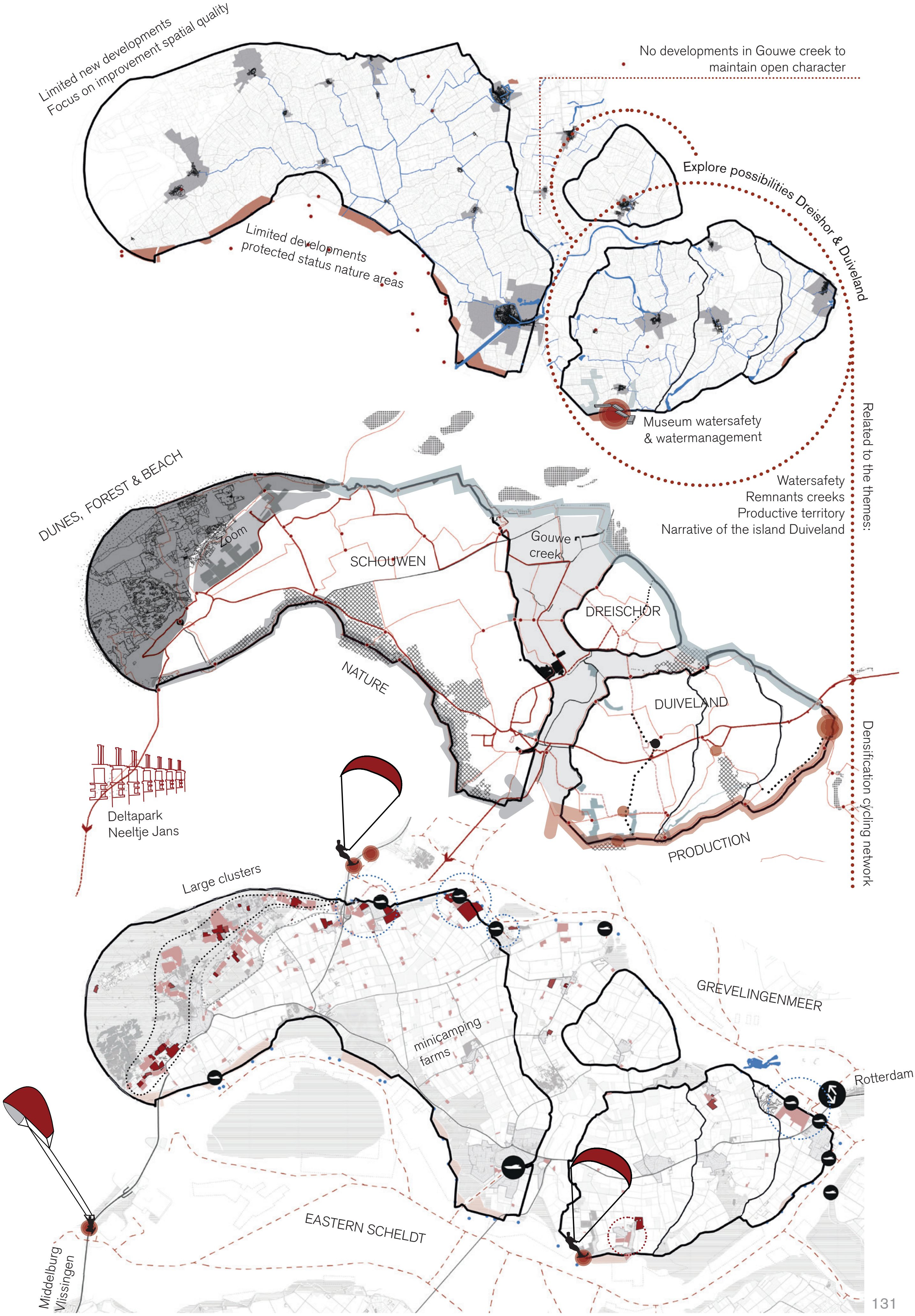
Existing accommodations
(Top 10NL, 2017)

- Recreational park
- Camping
- Estate

Accomodation clusters based on character
- Dunes & forest
- Polder fringe
- Maine/ water activities
- Creeks

Water related activities
- Kiting
- Diving locations
- Marina
- Sluice

Current landuse
(Top 10NL, 2017)


Limited new developments
Focus on improvement spatial quality
No developments in Gouwe creek to
maintain open character
Explore possibilities Dreishor & Duiveland
Limited developments
protected status nature areas
Museum watersafety
& watermanagement
Related to the themes:
Watersafety
Remnants creeks
Productive territory
Narrative of the island Duiveland
DUNES, FOREST & BEACH
Zoom
SCHOUWEN
Gouwe
creek
DREISCHOR
NATURE
DUIVELAND
PRODUCTION
Densification cycling network
Deltapark
Neeltje Jans
Large clusters
GREVELINGENMEER
minicamping
farms
Rotterdam
EASTERN SCHELDT
Middelburg
Vlissingen

8.4 Temporalities

Agriculture and recreation can be considered as main economic contributors for the island. Their seasonal character combined with issues as breeding and migration and climatic changes shape a yearly frame.

Tourism & Leisure
The period from May till September can be perceived as the range for main recreational activities. Water related recreation is also dependent on the temperature of the water and windconditions. Nature related recreation can be of disturbance during the breeding period. The high season is the summer holidays in July and August. This can also cause an increased use of freshwater, conflicting with necessary water use for agricultural purposes.

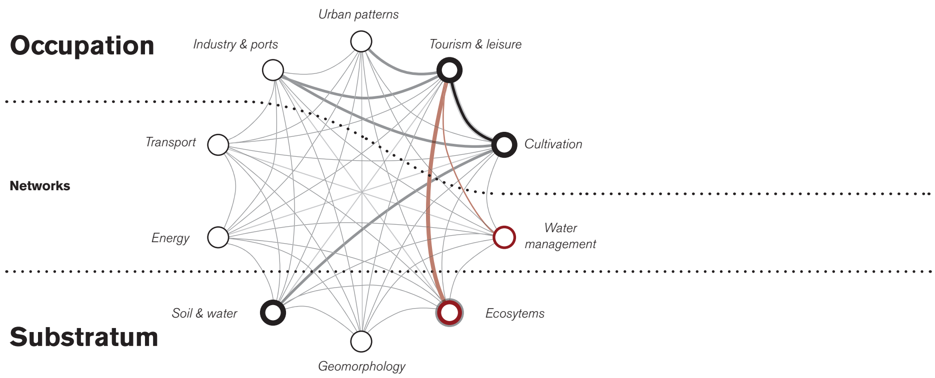
- Reduce the use of fresh water during high season and make people aware of the use.

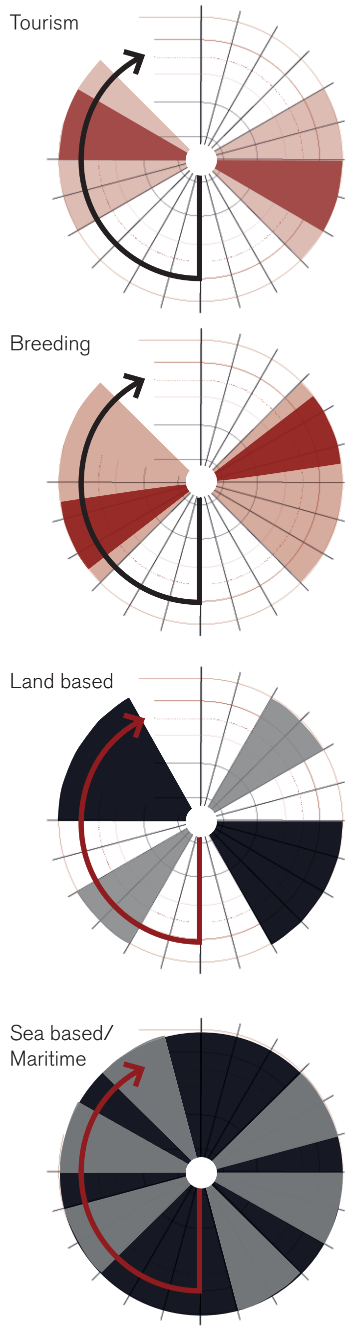
Breeding and migration
Some main species and their breeding and migration period have been projected in the scheme. Specifically the kentish plover and ringed plover appear to be vulnerable for disturbance for instance during the May holiday.

- Introduce zoning for activities to prevent disturbance during breeding seasons.
- Create excluded islands for birds.

Production: land based and sea based
Main land based crops have been projected ranging from salt resistant to low tolerant crops. While land based production is more periodically, with a clear sowing and harvesting period (exception of winter wheat) sea based production appears to be a more year round type of production. A combination of saline and maritime production and (extensive) recreation can therefore be of value. It can be argued that in practice, and most probably with less optimal and changing conditions, profitability is uncertain, and it maintains a niche market. A lot of research still needs to be done on land based saline production and necessarry requirements of water management.

- Initiate institute for research on saline and maritime production (crop testing, monitoring of hydrological conditions and trend research).
- Existing subsidies for function change and maintenance can contribute to initial developments.





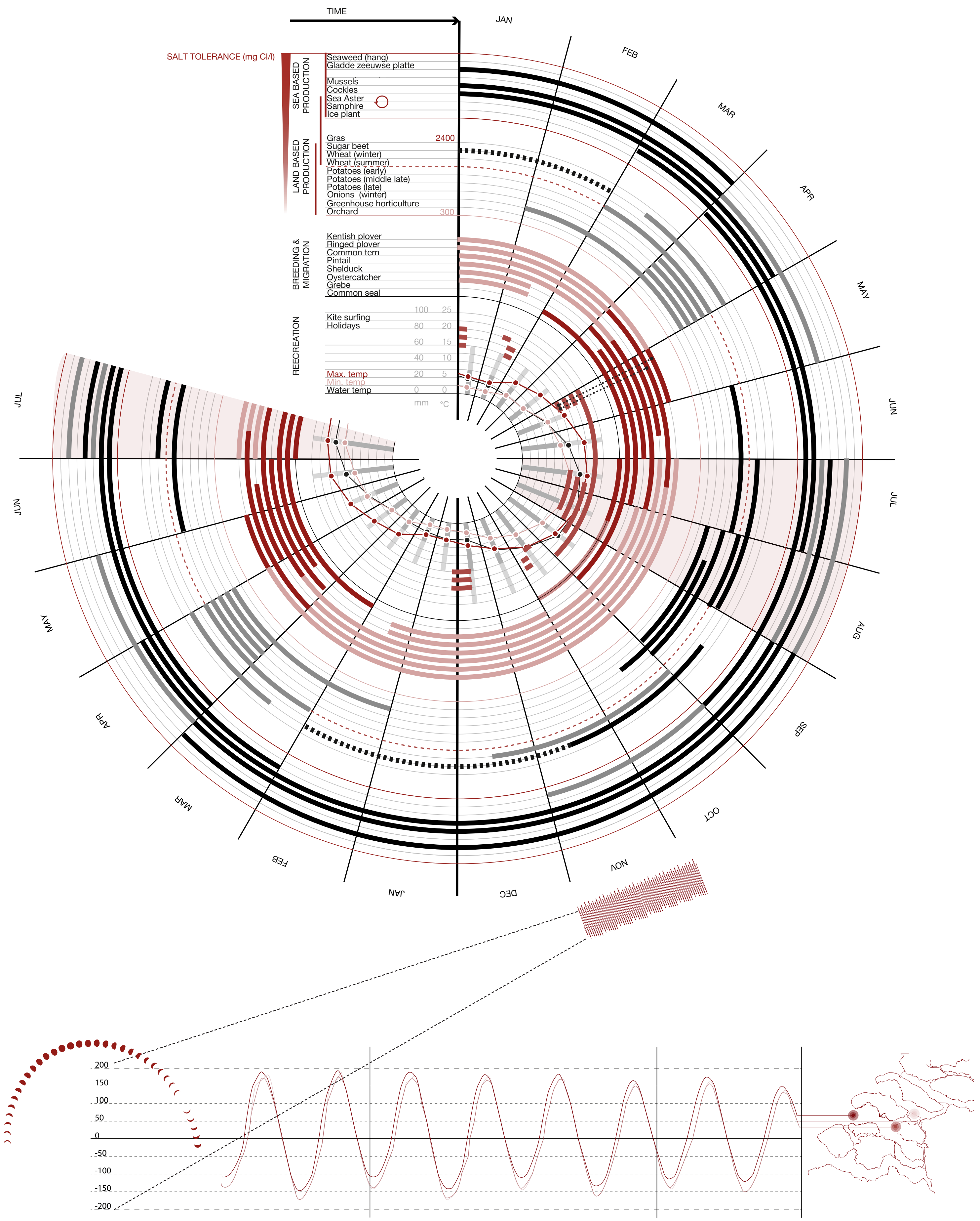
Temporalities Schouwen Duiveland
Schemes made by author

- Sow / reproduction period
- Harvest
- Production

- Migration period
- Breeding season

- Main season activities

- Average temperature
- Average precipitation


TIME
SALT TOLERANCE (mg Cl/l)
SEA BASED PRODUCTION
Seaweed (hang)
Gladde zeeuwse platte
Mussels
Cockles
Sea Aster
Samphire
Ice plant
LAND BASED PRODUCTION
Gras
2400
Sugar beet
Wheat (winter)
Wheat (summer)
Potatoes (early)
Potatoes (middle late)
Potatoes (late)
Onions (winter)
Greenhouse horticulture
Orchard
300
BREEDING & MIGRATION
Kentish plover
Ringed plover
Common tern
Pintail
Shelduck
Oystercatcher
Grebe
Common seal
REECREATION
Kite surfing
Holidays
Max. temp
Min. temp
Water temp
100 80 60 40 20 0 mm
25 20 15 10 5 0 °C
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
JAN FEB MAR APR MAY JUN JUL
200
150
100
50
0
-50
-100
-150
-200

8.5 Cultivation

Changing land based cultivation
Combined factors of hydrological circumstances (such as salt intrusion) and soil types have led to an initial indication of preferred cultivation, namely fruit cultivation, agriculture, meadows, marine cultivation (on land) and nature (Provincie Zeeland, 2015). Different from the current land use a large region has been appointed to maritime cultivation, for instance fish, shellfish, clam worms, saline crops & Algea.

This was initially the case with Plan Tureluur, the salt conditions lead to low agricultural production in the oudlandpolder of Schouwen. The government therefore purchased the land for nature development as a means to compensate for loss of intertidal area. Options for water safety with landwards retreat can focus on these zones anticipating on future loss of agricultural production capacity.

As opposed to the natural character alongside the edges of Schouwen, the island of Duiveland can distinguish itself by its productive character. The harbours of Bruinisse and partly the harbour of Zierikzee can contribute to sea based cultivation. Maritime production on land requires a few preconditions, namely:
- It is preferably in proximity to fishery related activities or existing trade/ knowledge areas for instance Bruinisse harbour;
- It is clustered for combined infrastructure such as pumps for salt water and cleansing systems;
- It has good access to the main road network, namely the N59;
- There is a presence of salt surface water/ groundwater;
- It has a shared recreational use or combination with natural extensive production;
- It can connect to existing recreational developments.

Excluding factors for maritime production are:
- Areas suitable for fresh water infiltration (Gouwe creek, edge former island);
- Areas adjacent to Nature reserves might be less suitable for intensive production but can be combined with extensive production.

Search areas managed retreat based on expected landuse
made by author

☐ Searching areas retreat
Indicative pattern for retreat
Possible future connection Grevelingenmeer

Experience
Natural edge
Productive edge

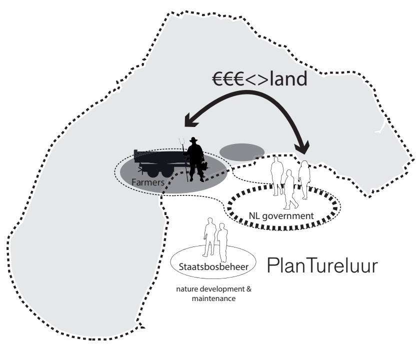
- Areas adjacent to dike
- Areas lower then 0m NAP
- Preferably meadow, martime cultivation or nature as preference

Cultivation preference based on hydrological circumstances
(Provincie Zeeland, 2015)

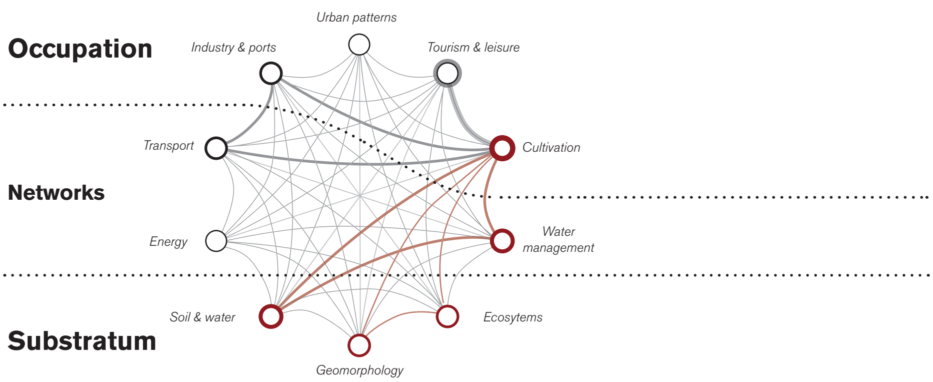
☐ Agriculture (white)

☐ Meadow
■ Maritime cultivation
Nature
Search areas

Shellfish parcels seawards

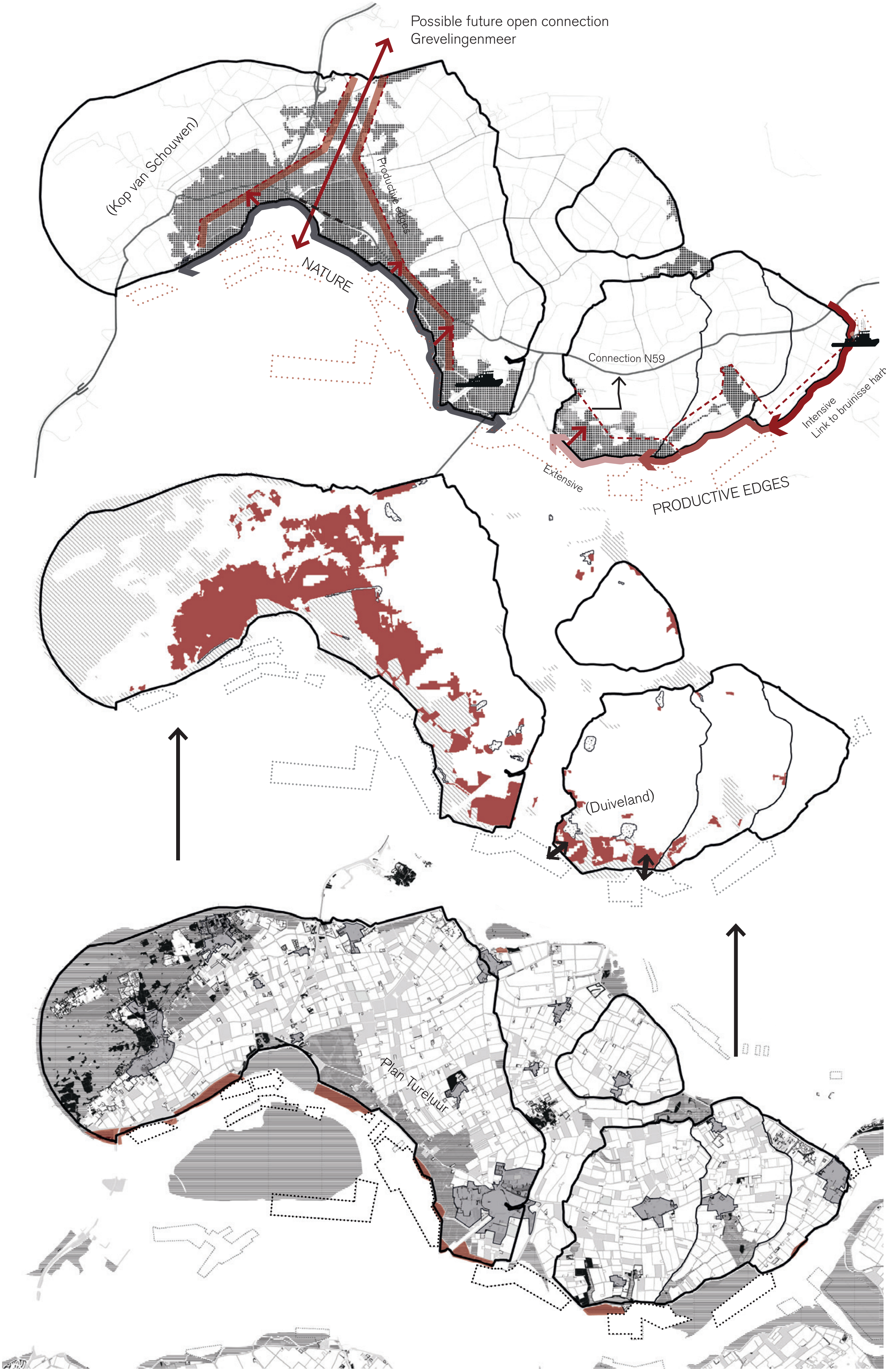


Development of Plan Tureluur in which affected farmers where bought off.



Current landuse
(Top 10NL, 2017)

☐ Build environment
■ Forest
☐ Agriculture
Meadow
Nature
Inlaypolder
Mussel /oyster parcels



Possible future open connection
Grevelingenmeer
(Kop van Schouwen)
Productive edges
NATURE
Connection N59
Intensive
Link to bruinisse harbour
Extensive
PRODUCTIVE EDGES
(Duiveland)
Plan Tureluur

8.6 Water management

In order to cope with both periods of increased precipitation in the winter, as well as more periods of drought in the summer it is necessary to optimize both the peak storage capacity as well as the use and storage of fresh water on the island. A general strategy used for rainwater in the Netherlands is the three stages strategy to collect, store and discharge.

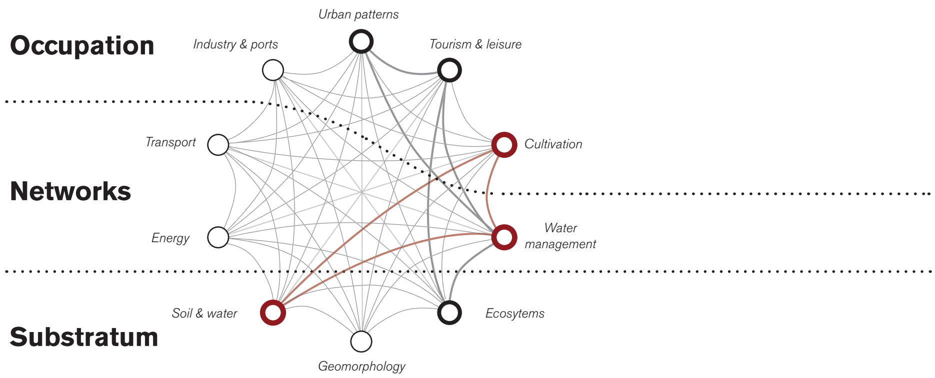
Collection
The collection stage focuses on infiltration of fresh surface water in the subsurface. This stage mainly focusses on collection in the higher and middle high grounds. The dunes are an already present natural fresh water collection system.

According to STOWA creek water infiltration can be optional method for parts of the island. In order for this to work they set out the following conditions (Stowa, 2014, p.26):
- Presence of high sandy creek ridges or old gulleys;
- Brakish to salt interface less then 25m depth;
- Surface needs to infiltrate;
- Soil needs to be suitable for infiltration via drainage tubes;
- Sufficiently deep groundwater level;
- No presence of clay and peat layers in the top 15m that might limit growth of the water lenses.

An indication of the possibility for creek water infiltration according to STOWA has been projected on the map. Combined with the10% of the highest parts of the drainage areas, this lead to the selection of some key areas to start creek ridge infiltration.

NOTE: Data from STOWA had been obtained on a national scale, therefore there might be some slight differences with more local data.

Storage
This stage focusses on maintaining the surface water in the system as long as possible for instance in ditches or lakes. It incorporates storage areas in the lowest areas.



Collection areas
made by author

- Build environment
- Lock
- Drainage areas
- Infiltration
- 10% highest surface drainage areas
- Dunes
- Re-naturalization waterways
- 10% lowest parcels
- Link storage to villages

Posibility Creek ridge infiltration
(STOWA, 2014)

- Very promising
- Promising

Storage areas (seasonal)
made by author, based on
(Provincie Zeeland, 2015)

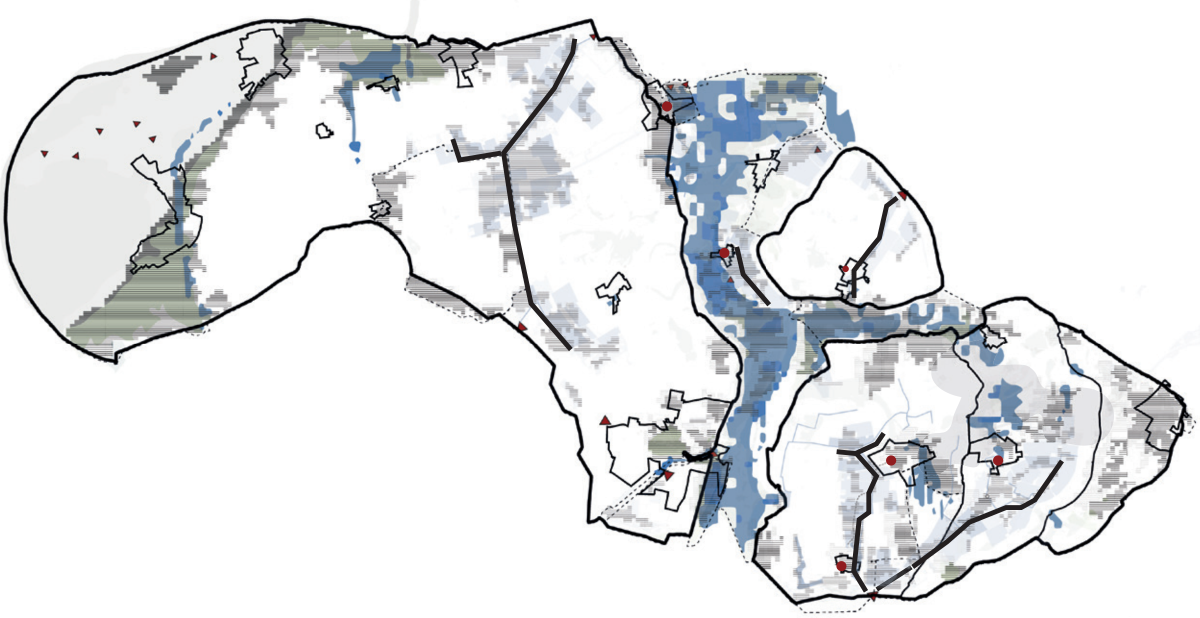
- Build environment
- Lock
- Drainage areas
- Salt seapage (heavy > low)
- 10% lowest surface drainage areas

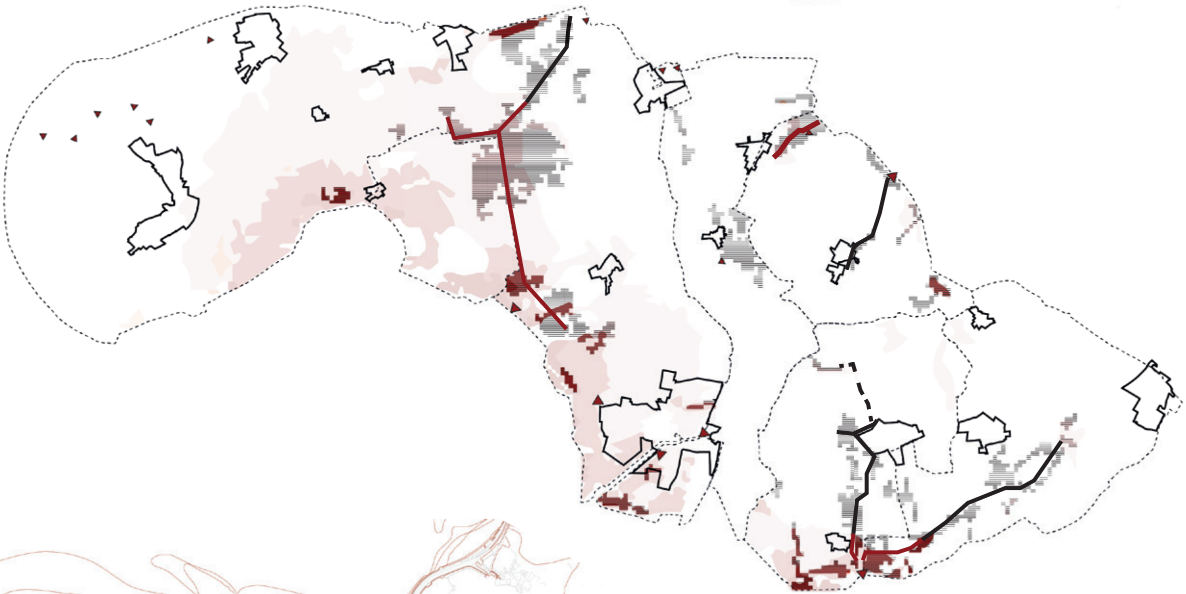
Re-naturalization of water
Made by author

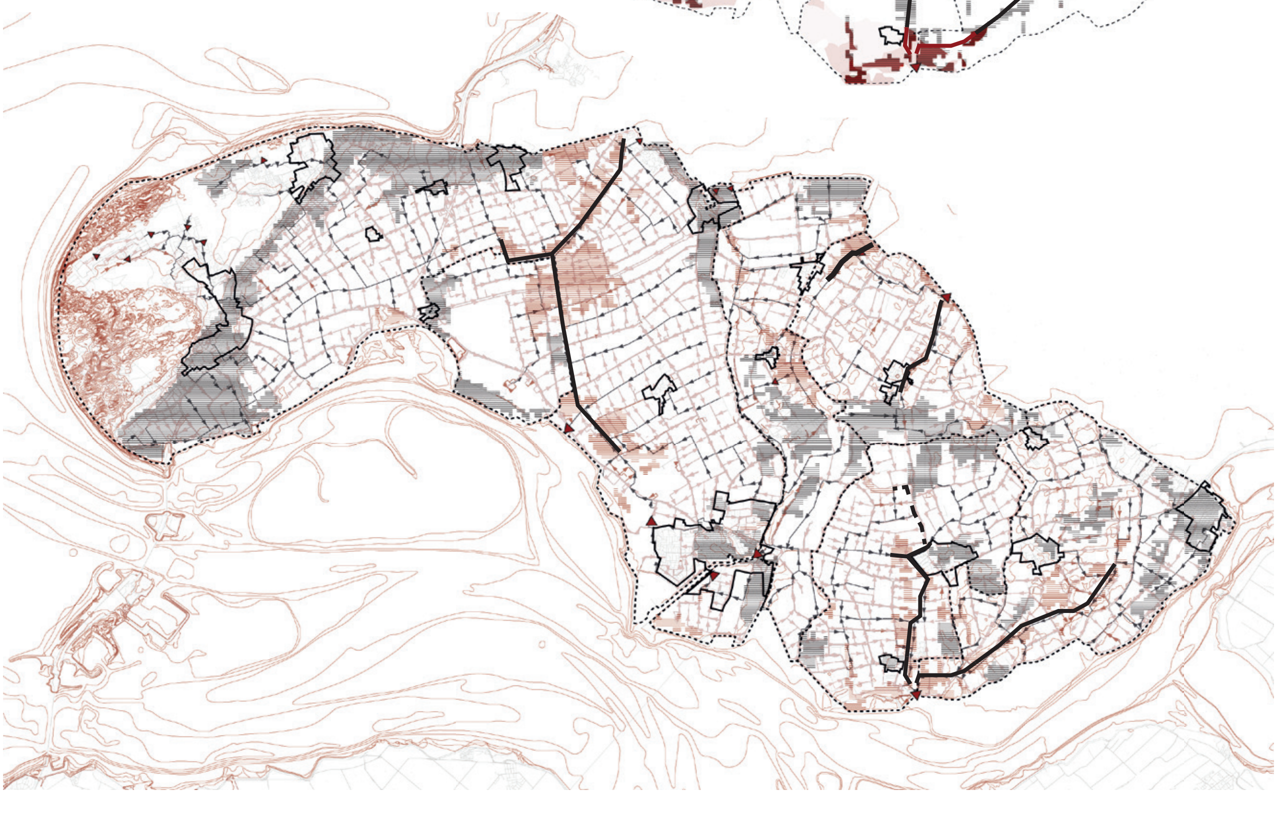
- Fresh water system
- Affected by seepage

Current watersystem
Made by author based on:
(Waterschap Scheldestromen, 2020)

- Build environment
- Lock
- Primairy watersystem
- Secundairy watersystem
- Drainage areas
- Of drainage areas: 10% lowest surface
- Of drainage areas: 10% highest surface
- Height







8.7 Development adaptive framework

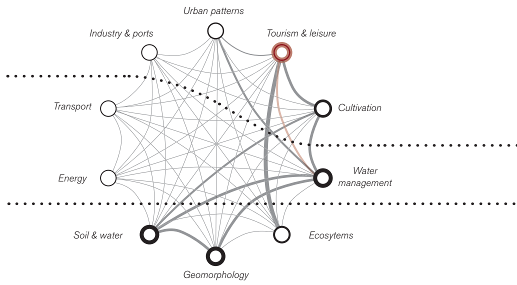
The development of an adaptive framework for the island is based on the three main issues. Some keypoint will be shortly explained. The schemes address which layers will be actively addressed for future development of the area.

Fresh water supply and peak water storage:
- Optimize the possibility of freshwater infiltration in creek ridges and the dunes. When possible link to urban water retention.
- Use of old creeks for peak water storage, and link the new developments to expand cycling & walking routes.
- Set limitations on the use of fresh water for recreational purposes.
- No additional urban developments in th area of the Gouwe creek.

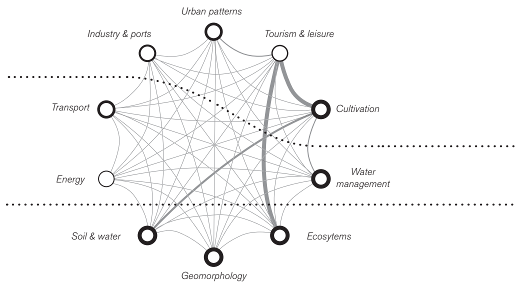
Living with floods:
- Indicate meadows, areas for maritime cultivation and nature as initial search areas for development of bufferzones.
- Initiate an open water connection with the Grevelingenmeer on the long term, following existing patterns of land use change
- Maintain the open character of the Gouwe creek as means to emphasize the edge of the island. This can support the narrative of floods in the area.

Urban development:
- Support a productive land-water zone for Duiveland. Initiate a transition from traditional agriculture to maritime based production. Combine with recreation as a supporting sector. No large scale parks but foccused on exclusive ecotourism.
- Support accessibility to main road and harbours.
- New developments can support some of the general characteristics of the island. Whereas the north side of the island supports more watersport related activities, the south is characterized by a more natural character of the island Schouwen. The land water zone of Duiveland can be activated as a productive edge to experiment with maritime cultivation. The area adjacent to Ouwerkerk can serve as initial area for hydrological research.

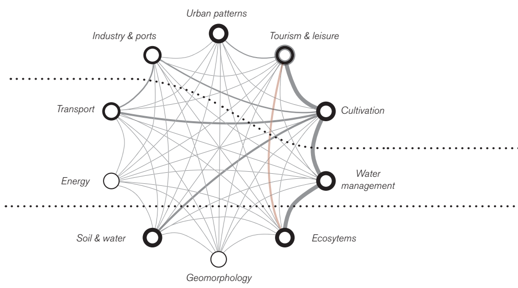
Freshwater supply & peak water storage

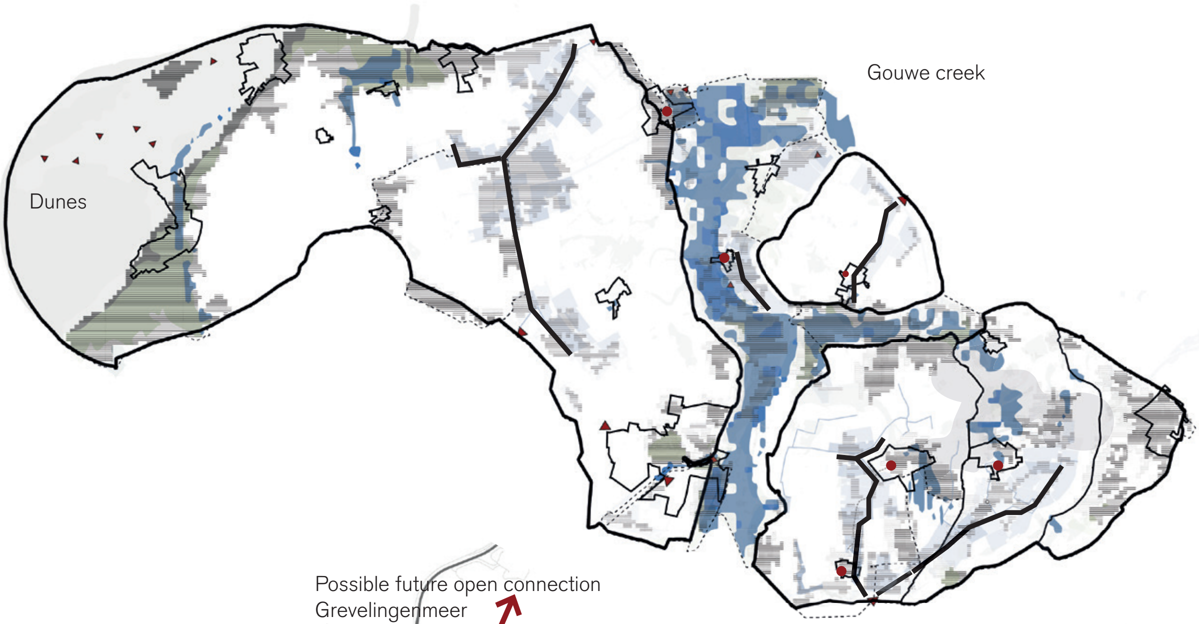


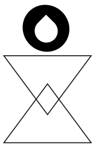
Living with (Safety to) floods

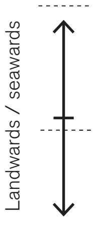


Spatial adaptation & place making

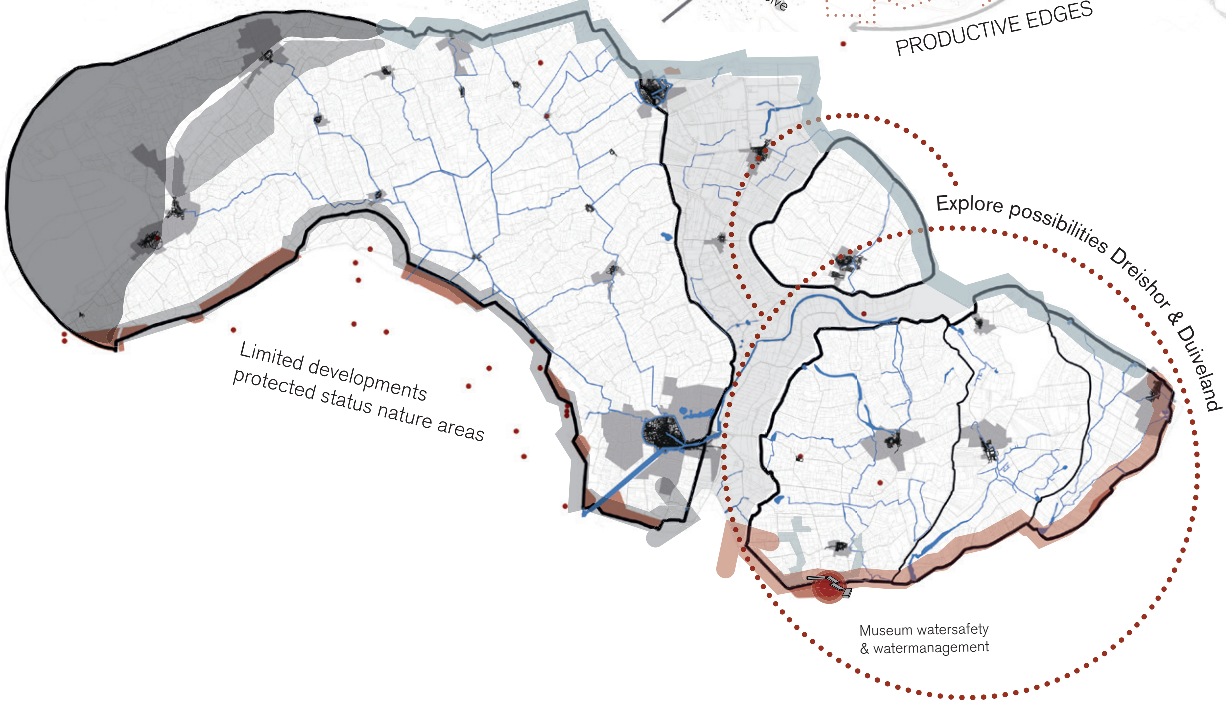



Gouwe creek
Dunes




Landwards / seawards


Possible future open connection
Grevelingenmeer
(Kop van Schouwen)
Productive edges
NATURE
Connection N59
Intensive
Link to bruinisse harbour
Extensive
PRODUCTIVE EDGES

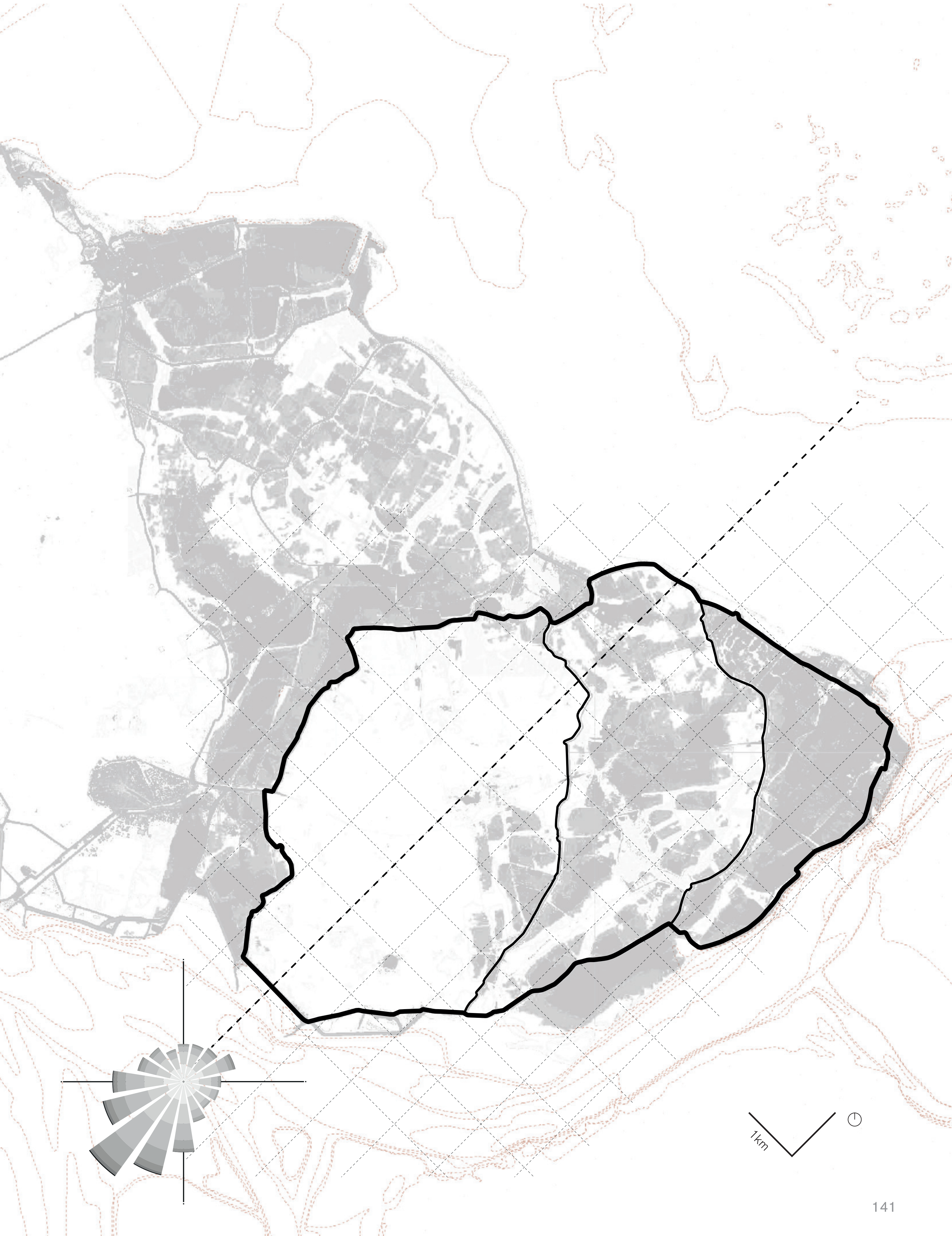

Explore possibilities Dreishor & Duiveland
Limited developments
protected status nature areas
Museum watersafety
& watermanagement

9. Composition

This chapter is concerned with the development of the spatial composition of trajectories alongside the island of Duiveland.

Map made by author

Areas above 0m NAP


1km

9.1 Composition of Duiveland

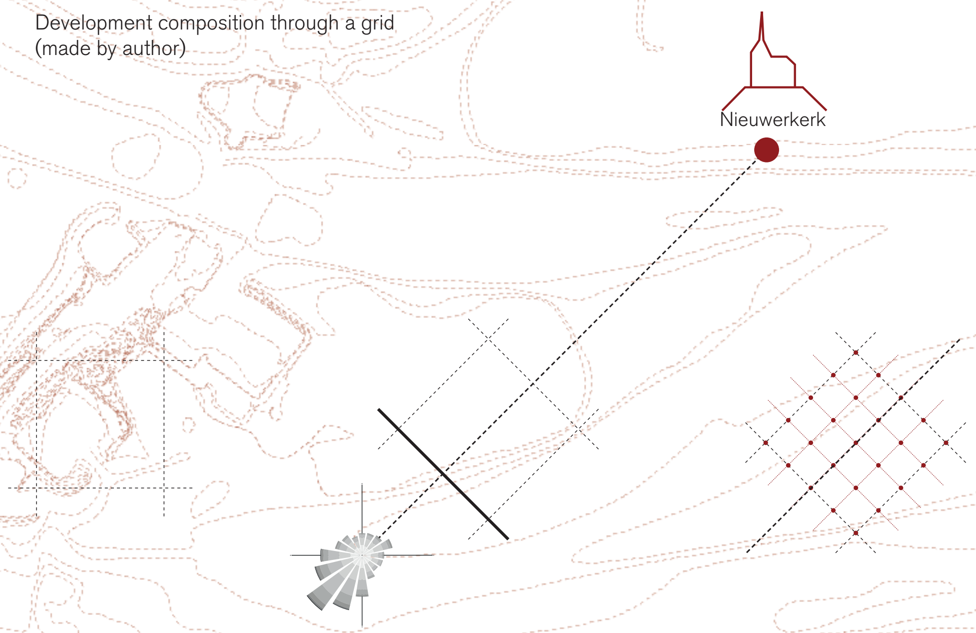
Imposing a grid on the surface
As a means to organize the new infrastructure and programming, a main grid of 1x1km has been projected on the surface with a ZW direction representing the main wind direction affecting the dike trajectory. This grid does not translate al shapes but is used as guideline and reminder of a main direction of impact.

A main axis is located centrally on the dike. The axis functions as a main view line towards the center/church of Nieuwerkerk. It is a reminder of the land ahead.

A smaller grid of 250mx250m with measure points is added as a means to initiate research on hydrological effects of the measures both landwards and seawards. The effect of water management on land (salt intrusion, effect of raising water-levels, effect on fresh water infiltration in adjacent creek ridge) as well as the effects of measures seawards (wave attenutation, velocity water, nutrients for primairy production) can be monitored.

In the following paragraphs the trajectory de Val- Ouwerkerk will be elaborated

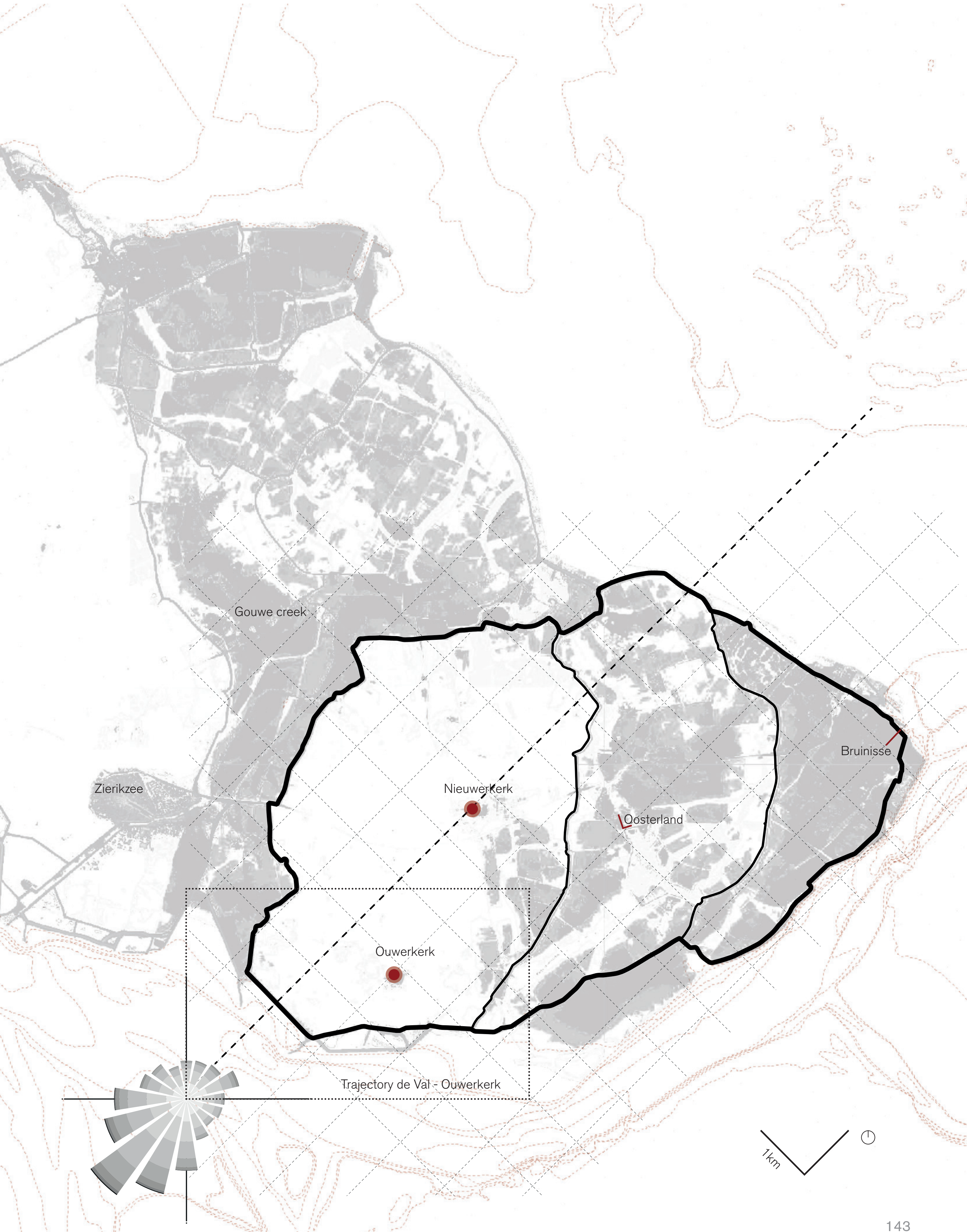
Development composition through a grid
(made by author)



Grid 1 x1 km → Rotate 45 degrees (main wind direction)
Main axis central on dike trajectory → Smaller grid of 250mx250m (measure points) for research on changing hydrological factors.

Map made by author
Heightmap based on
AHN viewer

Areas above 0m NAP

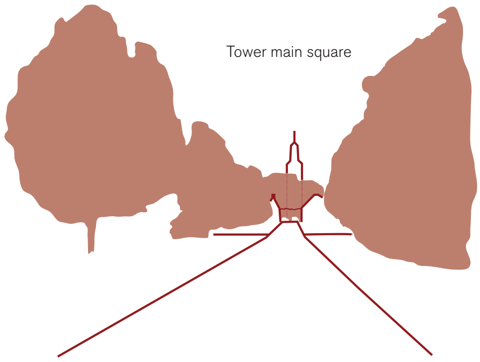

Gouwe creek
Zierikzee
Nieuwerkerk
Oosterland
Bruinisse
Ouwerkerk
Trajectory de Val - Ouwerkerk
1km

9.2 Trajectory de val - Ouwerkerk

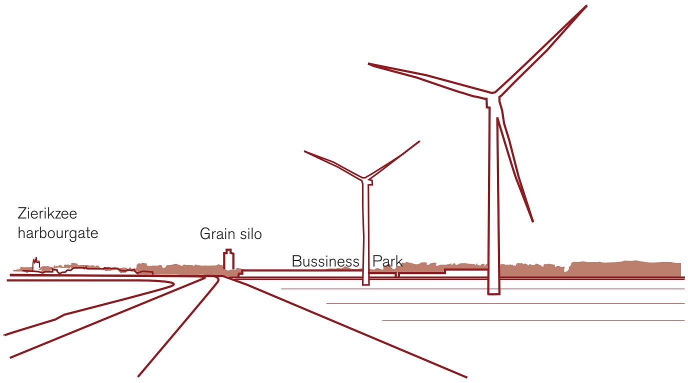
Aerial picture 2019, Ortho 25cm RGB
Retrieved from PDOKserver, qGIS


Nieuwerkerk
Ouwerkerk
Keeten
250m

Entrance Ouwerkerk
Picture made by author



View towards Zierikzee and open Gouweveerpolder
Picture made by RPW de Jong, 2020



Images traced by author
to substract key qualities

Trajectory de Val -Ouwerkerk
Made by author

Aerial picture 2019, Ortho 25cm RGB
Retrieved from PDOKserver, qGIS

- Endiked areas alongside Eastern Scheldt
- Old dikes
- Villages
- Village boundary
- Location photos
- Indication locations dike breach 1953

based on (Streekarchief Goeree-Overflakkee, 2021)

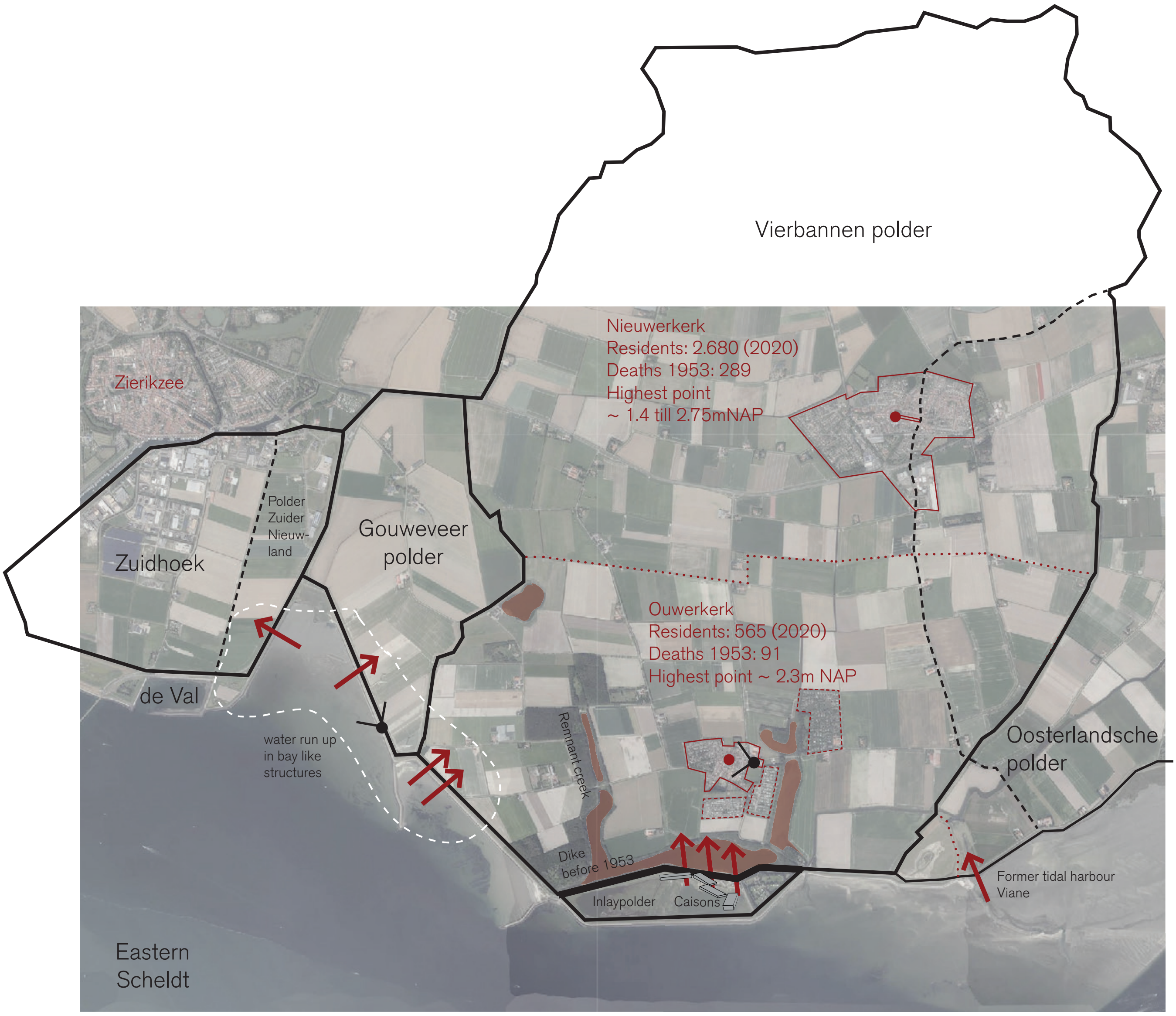
9.21 Introduction De val - Ouwerkerk

Deathly casualties
Ouwerkerk 1/6

Narrative of floods

Ouwerkerk is the oldest village of the former island Duiveland and was named after the initiation of the church in Nieuwerkerk. Both Ouwerkerk and Nieuwerkerk are mound villages in the Vierbannen polder. Heights in the polder range from, about1.74m -NAP in the lowest part till 0,5m NAP (based on AHN viewer), meaning that the entire polder would be flooded even during Mean high water. During the flood of 1953 about 1 in 6 people in Ouwerkerk did not survive. A breach in the dike resulted in the still present creek remnant. As a means to fill the dike breach four concrete caissons were positioned. These currently function as the national museum for the flood in 1953. The narrative of floods and impact of the disaster in 1953 is a main touristic driver for the area.

A combination of bad conditions of the dikes, springtide and a northwestern storm affected the area in 1953. Water runup might have caused breaches alongside the baylike structures of de Val. Limited foreshores protected the dike at the location of the current museum.



9.22 Space availability

<u>*Factors stressing flood probability*</u>
Factors that might stress flood probability are increased wave heights as result of long stikelenghts (wind) as well as the erosive character of an abrasive dynamic trench (high water velocites). The trench has a depth of about 40m. The area is affected by both flood and ebb currents. Flood currents appear to have a more erosive character on the foreland due to higher water velocities.

Based on the progression of the low water line it can be expected that a South to Southwest wind might also be an erosive factor in combinations with the longshore currents. This might also lead to a certain degree of water run up in the bay like structure of de Val. Additional is the effect of piping on the stability of the dike of the inlay polder.

<u>*Space availability*</u>
Areas with more than 80m foreland (areas above the low water level) have been mapped as well as the still relatively shallow areas underwater. The inner bend appears to be suitable for parallel underwater reefs or dams or perpendicular structures for erosion and sedimentation regulation. The benthics still offer possibilities for oyster reefs or mussel beds. Limited availability of foreland stresses for measures landwards.

Landward prohibitation of space is the village of Ouwerkerk and present campsites. The campsites offer a combination camping spots and chalets and have a relatively permanent character. It might therefore be preferred to exclude them from a possible buffer zone developments. The campsites mainly offer traditional types of accommodations and have an efficient character in their spatial setup.

Existing campsites & facilities

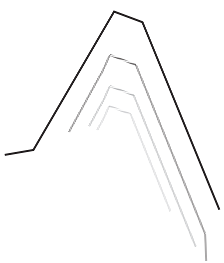
(Salvatorhoeve, n.k.)
(dekreekoever, n.k.)
(Sluitgat, n.k.)

Space availability
(made by author)

Seawards
Foreland > 80m
Relatively shallow areas
Space availability

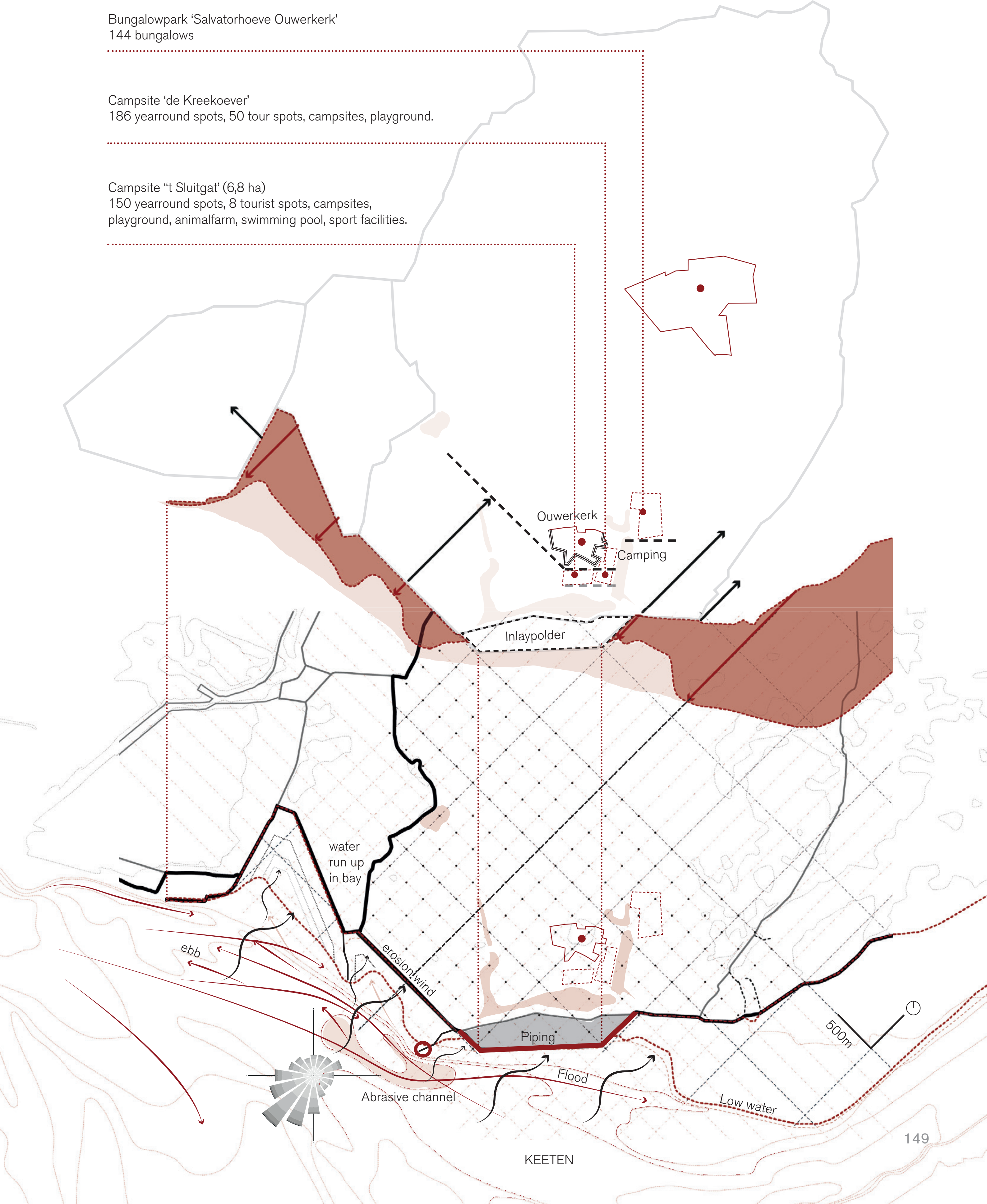
Landwards
Inlay polder
Non urban space

Water run up in bay



Factors stressing floodprobability
(made by author)

Water run up bay
Piping
Wind
Currents based on bathymetry
Vulnerable trench wall


Bungalowpark 'Salvatorhoeve Ouwerkerk'
144 bungalows
Campsite 'de Kreekoever'
186 yearround spots, 50 tour spots, campsites, playground.
Campsite "t Sluitgat' (6,8 ha)
150 yearround spots, 8 tourist spots, campsites, playground, animalfarm, swimming pool, sport facilities.
Ouwerkerk
Camping
Inlaypolder
water run up in bay
erosion wind
ebb
Piping
Flood
Abrasive channel
Low water
500m
KEETEN

9.23 Adaptive pathway

Trajectory de val - Ouwerkerk

Possible measures have been weighed against the indicative effectiveness. Assuming that the effect of reefs and cribs/dams will be limited with increased sea level rise, these are considered short term measures for wave attenuation. The difference between the LAT (-1.80m NAP) and height alongside the most affected trajectory of the current dike (-1.45m NAP) means a difference of about 35cm after which the impact of waves on the trajectory might increase. Measures seawards can be used as a means to limit the erosion alongside the trajectory assuming that it might be possible to stretch the limit until a maximum of 50cm sea level rise.

Long term development of a bufferzone can be opted on the long term as a means to surpass the range of the seawards measures and limit the effect of coastal squeeze. This selected pathway assumes an open Eastern Scheldt system. Options for an exchange polder or slib motor are initially excluded due to the sand deficit in the Eastern Scheldt. After opening the barrier it might be possible to transform the bufferzone between the waker and sleeper dike into a slib motor.

Critical points Eastern Scheldt

Predictions

Sea level rise (cm, 1995 onwards)

Years (2020 onwards)

Sea level rise

Indicative based on maximum projections sea level rise (Haasnoot et al., 2018, p.15)

RCP 8.5

RCP 4.5

Delta scenario

Possible measures

Measures and indicative effectiveness

Scheme made by author

- Robust
  Measure long term safety
- Flexible
  Allows to shift to other measure but might be effective short term
- Only applicable with open Eastern Scheldt (further research)
- Less preferred option

- Selected pathway
- Additional pathway
- Additional research negative impacts

wa: wave attenuation

s: sedimentation regulation

Seawards

Underwater reef (wa)

Cribs/dams/pile heads (s)

Sand nourishment / suppletion

Mussel floats (wa)

Oyster reefs (wa)

Consolidate

Rich dike/ Rich revetments

Wide / Deltadike

Dune dike

Landwards

Safety

Waker + Sleeper: Bufferzone

Slib motor

Mounds development

Fresh water

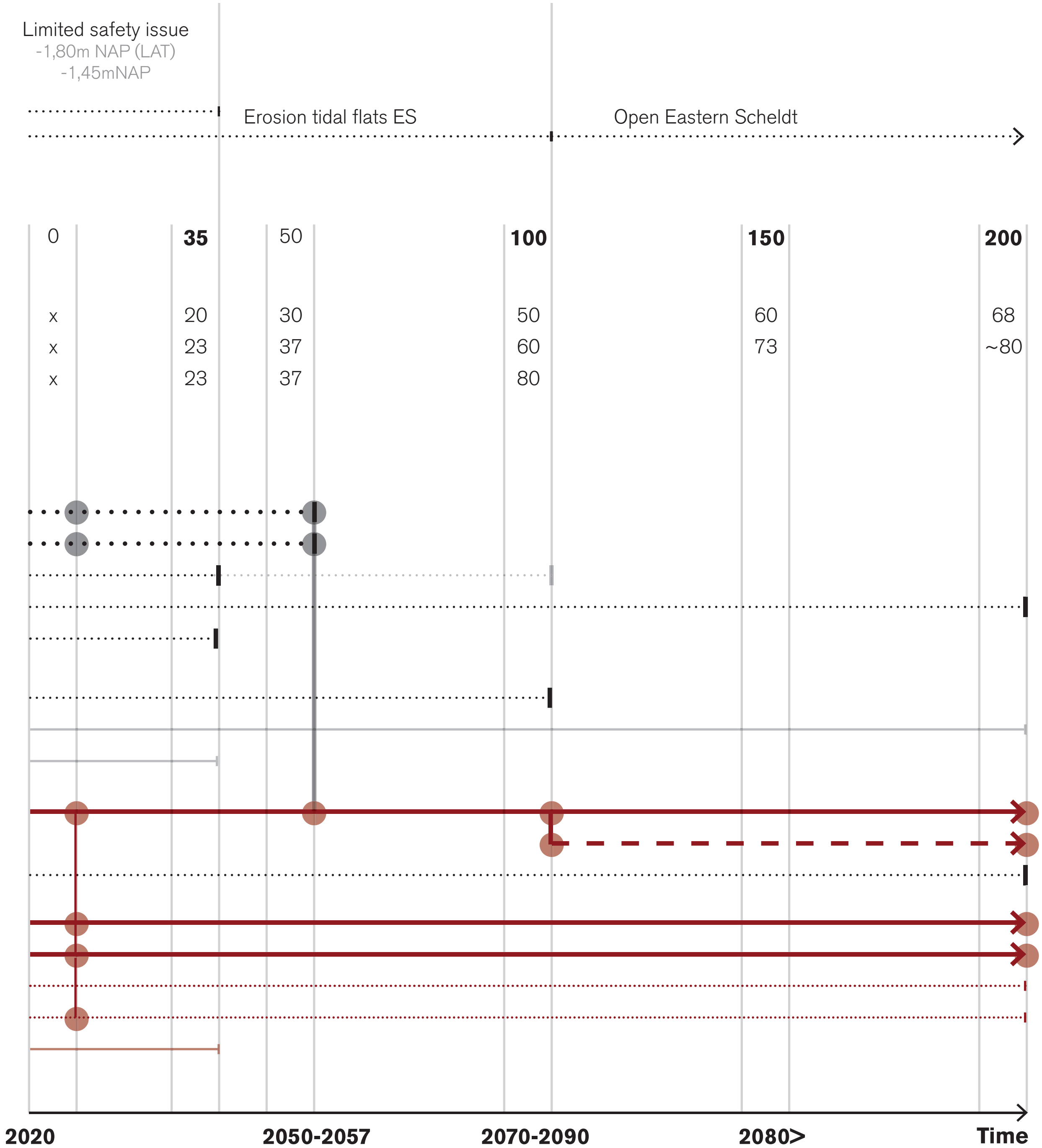
Peak water storage Ouwerkerk - Nieuwerkerk

Creek ridge infiltration (regional)

Urban infiltration (local)

Elevate water level (surface water)

Level controlled drainage (parcel)


Limited safety issue
-1,80m NAP (LAT)
-1,45mNAP
Erosion tidal flats ES
Open Eastern Scheldt
0
35
50
100
150
200
x
x
x
20
23
23
30
37
37
50
60
80
60
73
68
~80
2020
2050-2057
2070-2090
2080>
Time

9.24 Seawards

Proposed short term measures seawards are a combination of an artificial under-waterreef, to break the waves off shore, as well as wooden cribs to reduce water velocity and maintain patterns for limited sand deposit. The initial projection of these measures in shown in the map.

Underwater measures: Artificial under water reef
The artificial reef is a structure parralel to the coast, about 400m from the inner line of the dike. The structure is located below the low water level.

Wooden groynes
Whereas hard groynes can cause reverse currents and swirls, half open pole structures are more likely to reduce currents without these side effects. The wooden poles heads are structured perpendicular to the dike within the grid.

Currently the effect of oyster reefs is tested in the area. This project can possibly be upscaled based on the outcome.

Some elements will be further explained in the pilots.

Projection measures foreland (above LW)

- Artificial underwater reef
- Trench wall reinforcement

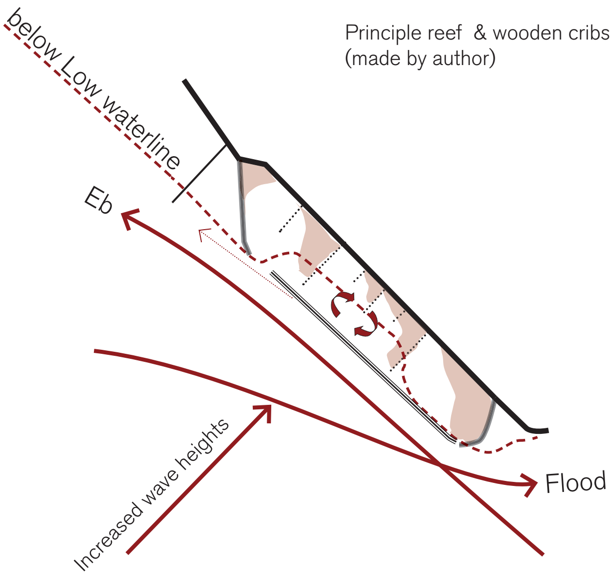
Projection under water measures

- Artificial underwater reef
- Trench wall reinforcement

Perpendicular and parallel structures

- Foreshore until low water line
- Mussel parcels
- Projection parallel structures
- Projection perpendicular structures

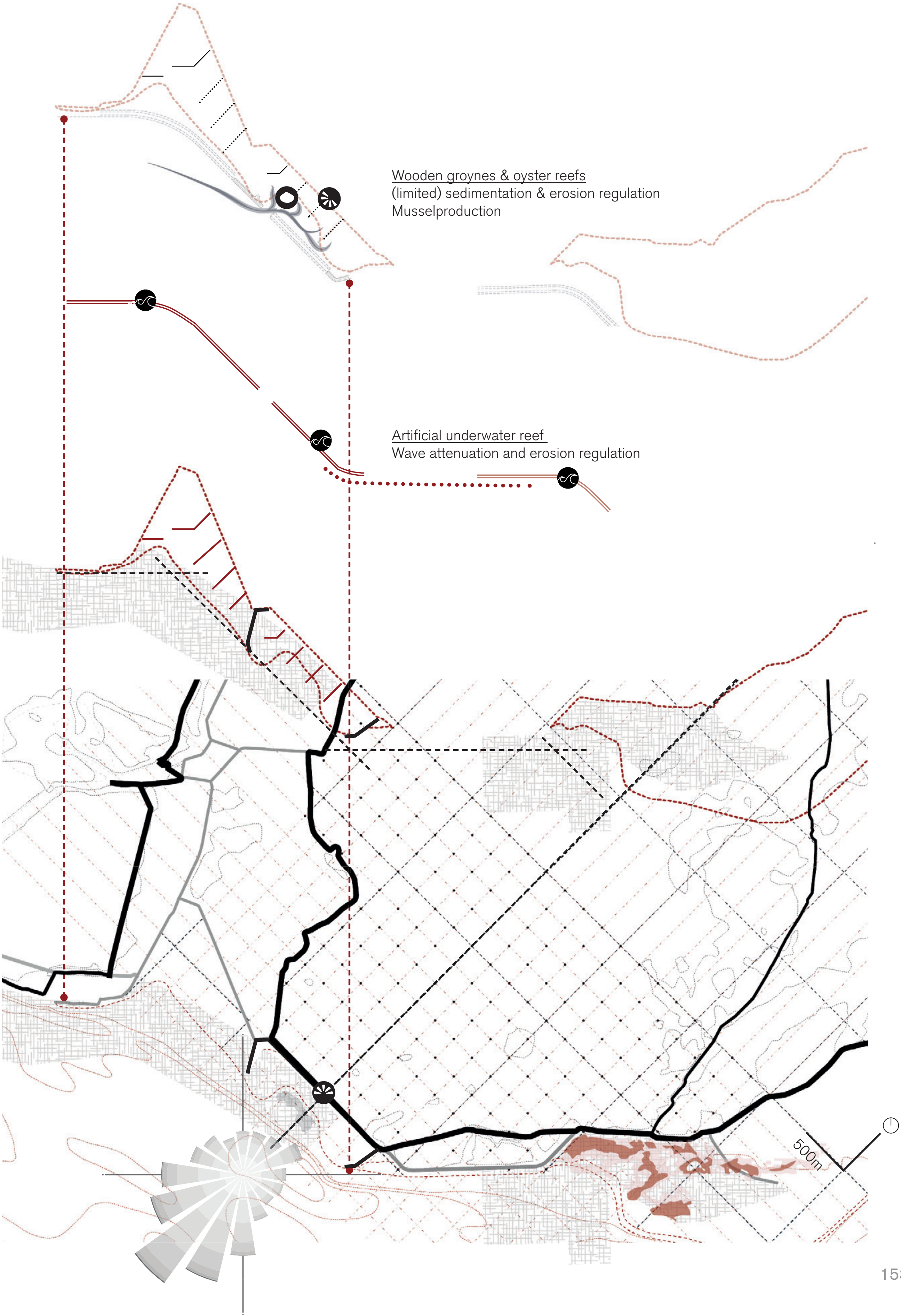
Principle reef & wooden cribs
(made by author)



Functions
Maps made by author

- Lookout
- Food production mussel/oyster hangcultures
- Wave attenuation

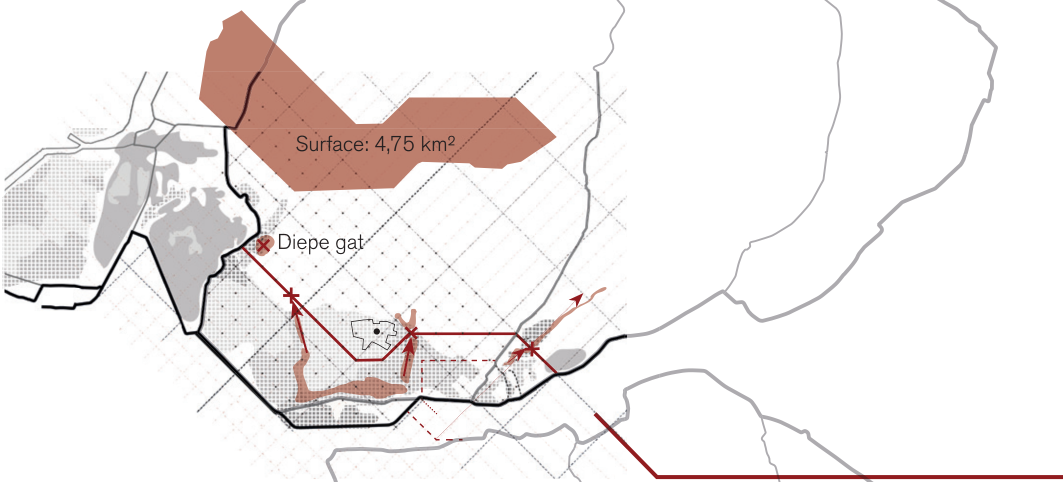
- Musselbeds existing
- Oysters existing


Wooden groynes & oyster reefs
(limited) sedimentation & erosion regulation
Musselproduction
Artificial underwater reef
Wave attenuation and erosion regulation
500m

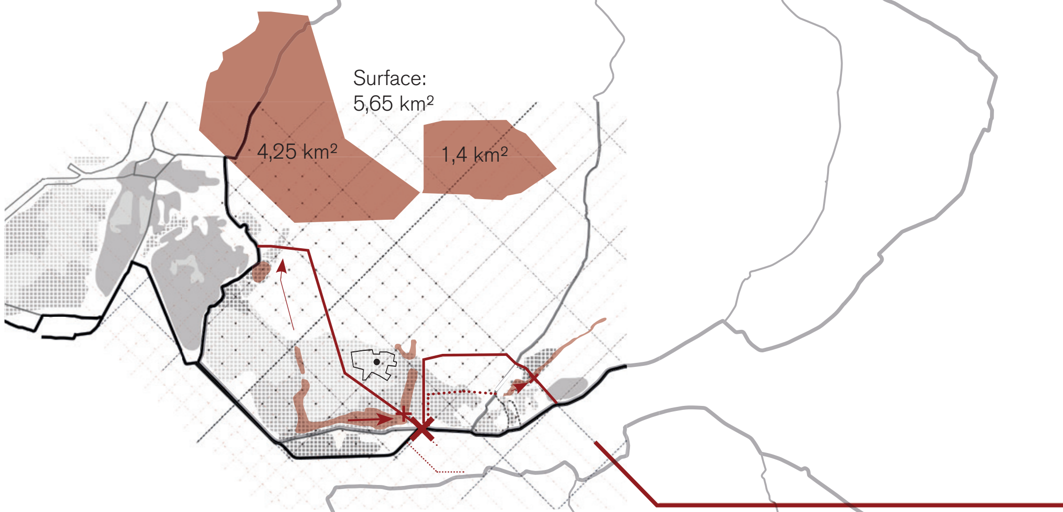
9.25 Landwards - Waker sleeper trajectory

Several secondary dike trajectories can be opted for in the case of 'de Val - Ouwerkerk'. As a means to select a trajectory three options have been quickly reviewed based on soil conditions, length of the dike (costs), and surface of impact. The trajectories can be debated on, but also indicate fragile points such as hydraulic constructions (water inlet), as well as extended intersections with the existing creek since it is expected that water velocity in the creeks might increase when water runs into the area.

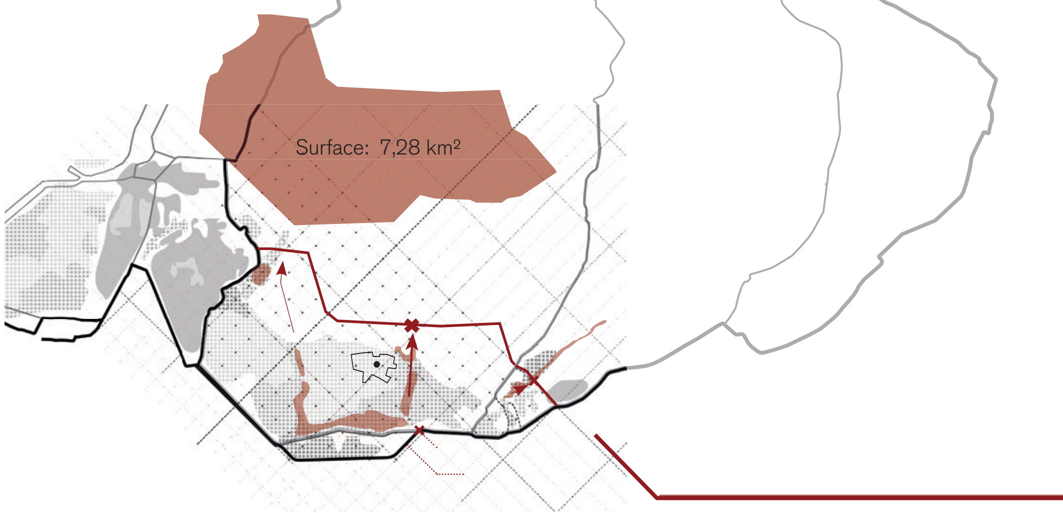
<u>Option 1</u>
The option conforms to the grid meaning that the initial part of the new dike will be parallel to the trajectory of the current dike. This on its turn means that the same forces might impact the new dike. The dike emphasizes the vulnerable position of Ouwerkerk.



<u>Option 2</u>
Following existing infrastructure and parcellation patterns the trajectory might be easier to develop over time. The trajectory can split into two separate buffer zones. The inlet and creek are points of attention since they can be subjected to factors of instability.



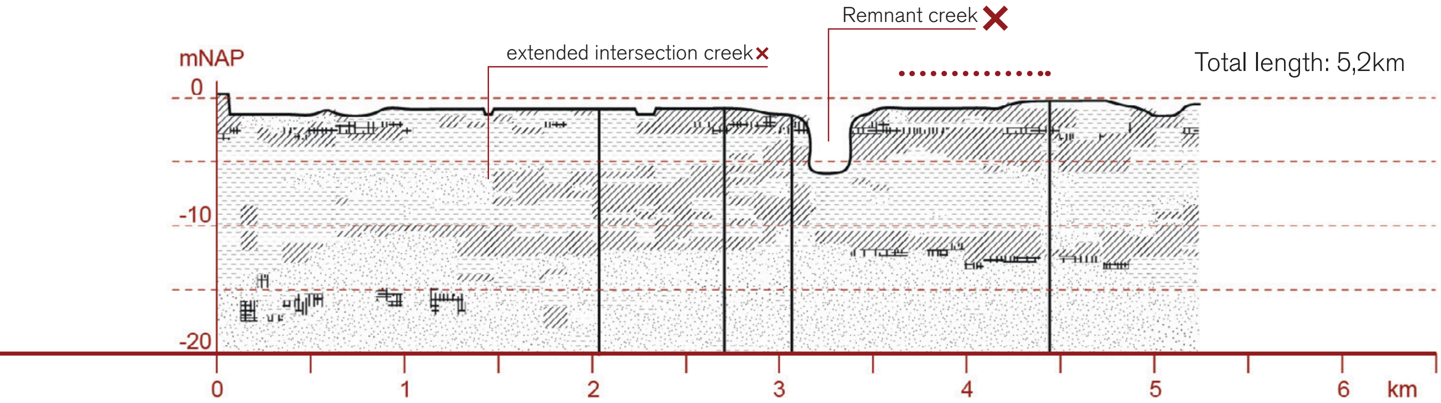
<u>Option 3</u>
Due to the position of Ouwerkerk between the main creek remnants it can be argued to choose a location in which Ouwerkerk is not covered by a second dike. An increased surface of impact might not be preferable but might avoid points with big impact.

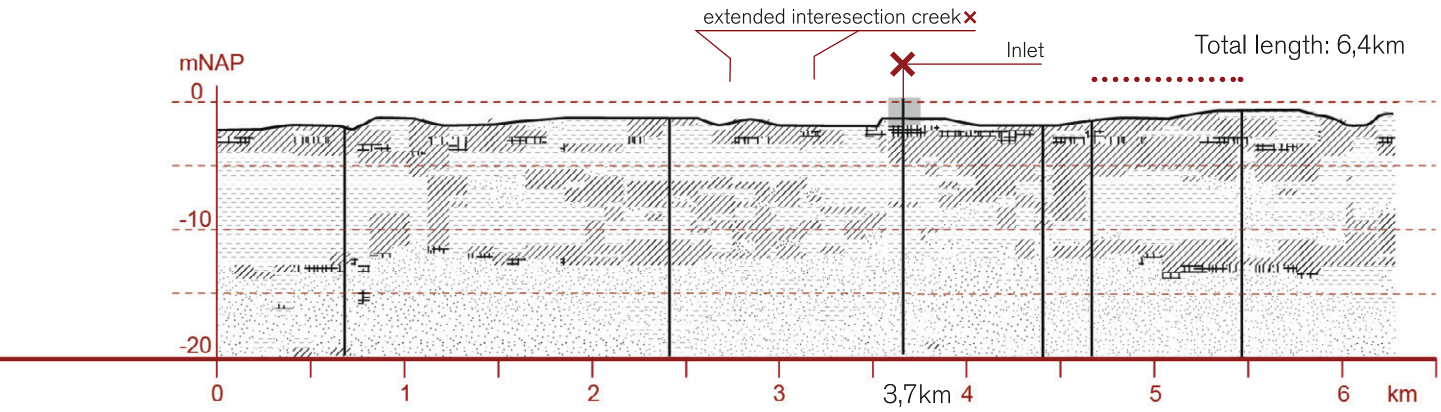


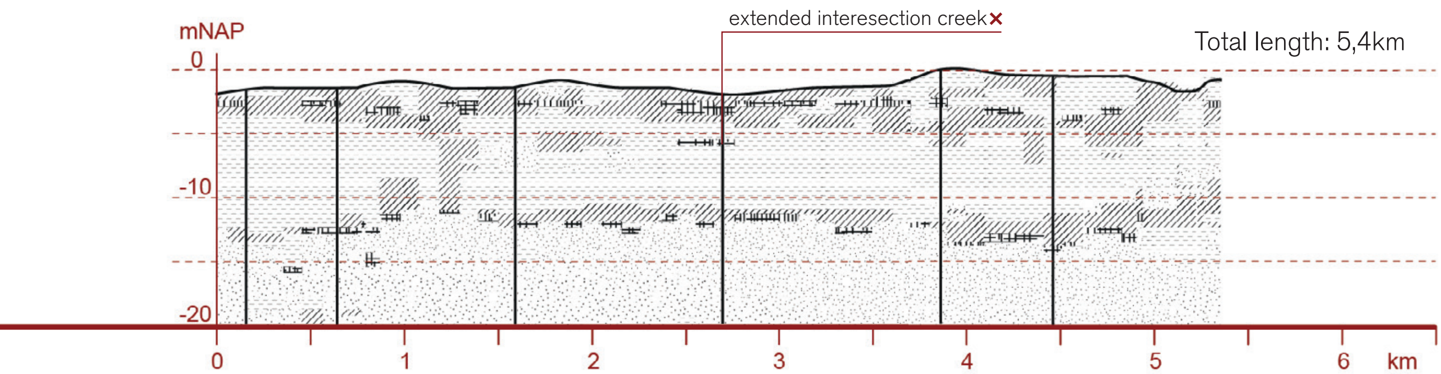
Most probable litho class
BRO GeoTOP v1.3 (Dinoloket, 2021)
- Clay
- Clay, sand and sandy clay
- Fine sand
- Medium sand
- Coarse sand
- Peat
- Anthropogenic
- Water

- Dike trajectory
- Vulnerable location
- Direction of impact

Due to the limited dike length and affected surface option 1 has initially been chosen as dike trajectory for the project. It emphasizes a continuous character alongside the coast. However it is recognized that in practice there might be a preference for an option following existing infrastructures, or an option that can be split in different sections. In this case option 2 would be preferred.







9.26 Landwards - Projection of the sleeperdike

Option 1 of the proposed sleeperdike trajectories has been projected on the territory. The projected line covers the majority of areas with stronger effects of salt seapage. It shifts between main water remnants that might cause instability of the dike. The line shifts towards an East West orientation responding to the orientation of the old creek and location of the center of Ouwerkerk.

New developments within Ouwerkerk will be limited. The focus will shift to improving the edges of the village and use of space for peak water storage.

Indicative map new bufferzone

Space for maritime production & wetland development supporting an atractive territory for ecotourism

Made by author

Occupation
Drowned cities retrieved from (Provincie Zeeland, 2018)

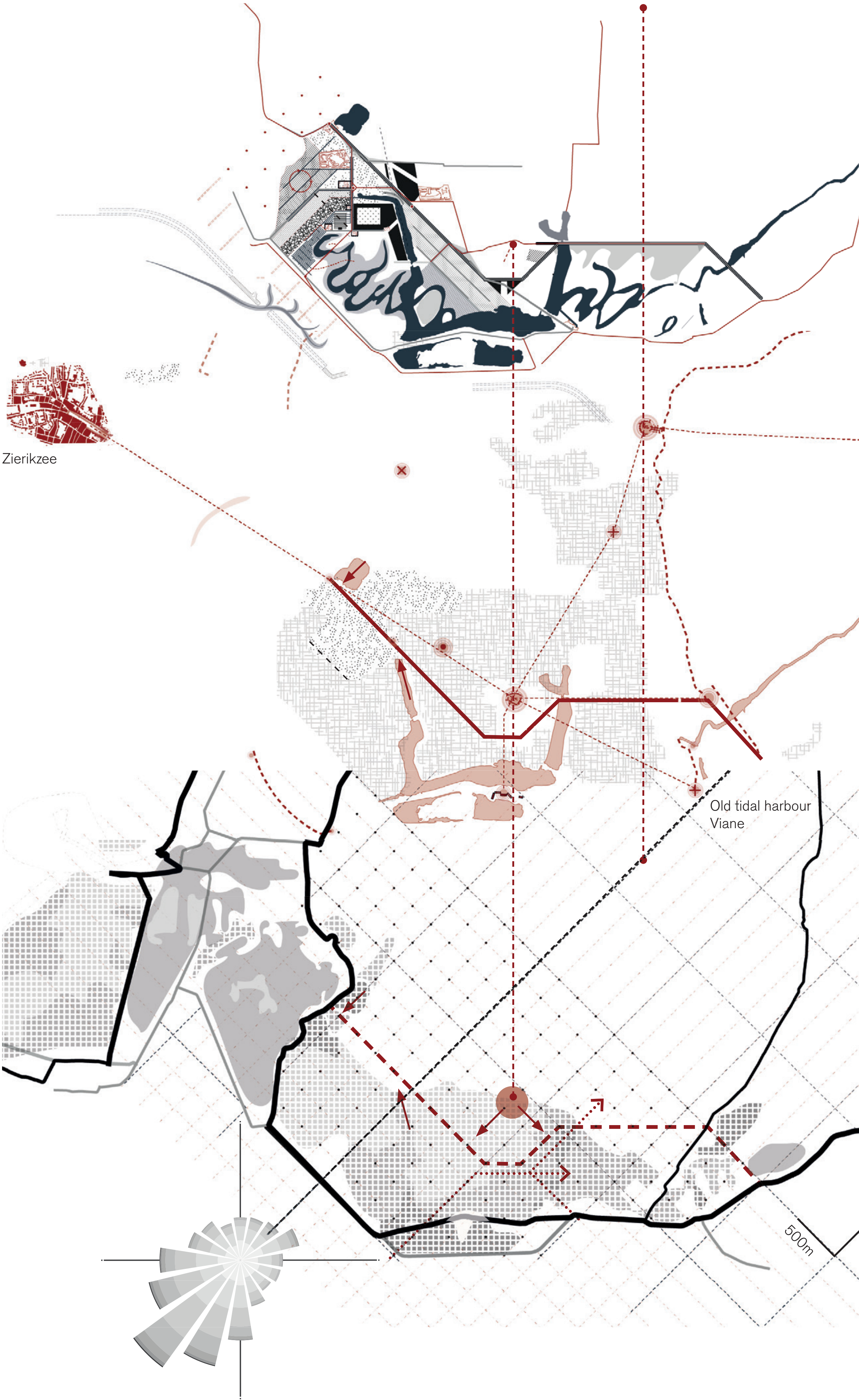
- Old city centres
- Drowned city
- Shrinked city
- Flood museum
- Estate
- Water remnants floods
- Hotspot
- Connection

- Sand
- Clay on peat

Grid & substratum
Base Seapage retrieved from (Provincie Zeeland, 2015)

- Moderate to good infiltration
- Moderate to strong Salt seapage

- Grid 1x1km
- Grid 250m
- Points on grid
- Dike island Duiveland
- Other dikes



Zierikzee
Old tidal harbour
Viane
500m

9.27 Landwards - Fresh versus salt

It is questioned how peak water storage of the fresh water system can contirbute to the narrative of the area. Proposed is the re-naturalisation of a existing waterways within the 10% lowest surface areas, as an extension of the existing creek remnant. A new cycling route can contribute to the densification of the existing network through the story of water movement.

Translation peak water storage
To narrative of waterflow

Made by author

Main watersystem polder
based on
(Waterschap Scheldestromen, 2021)

- Main water and direction
- Existing lock
- New lock

- 10% lowest parcels
- Affected parcels 10% lowest area
- Affected parcels 10% lowest area + affected by salt intrusion

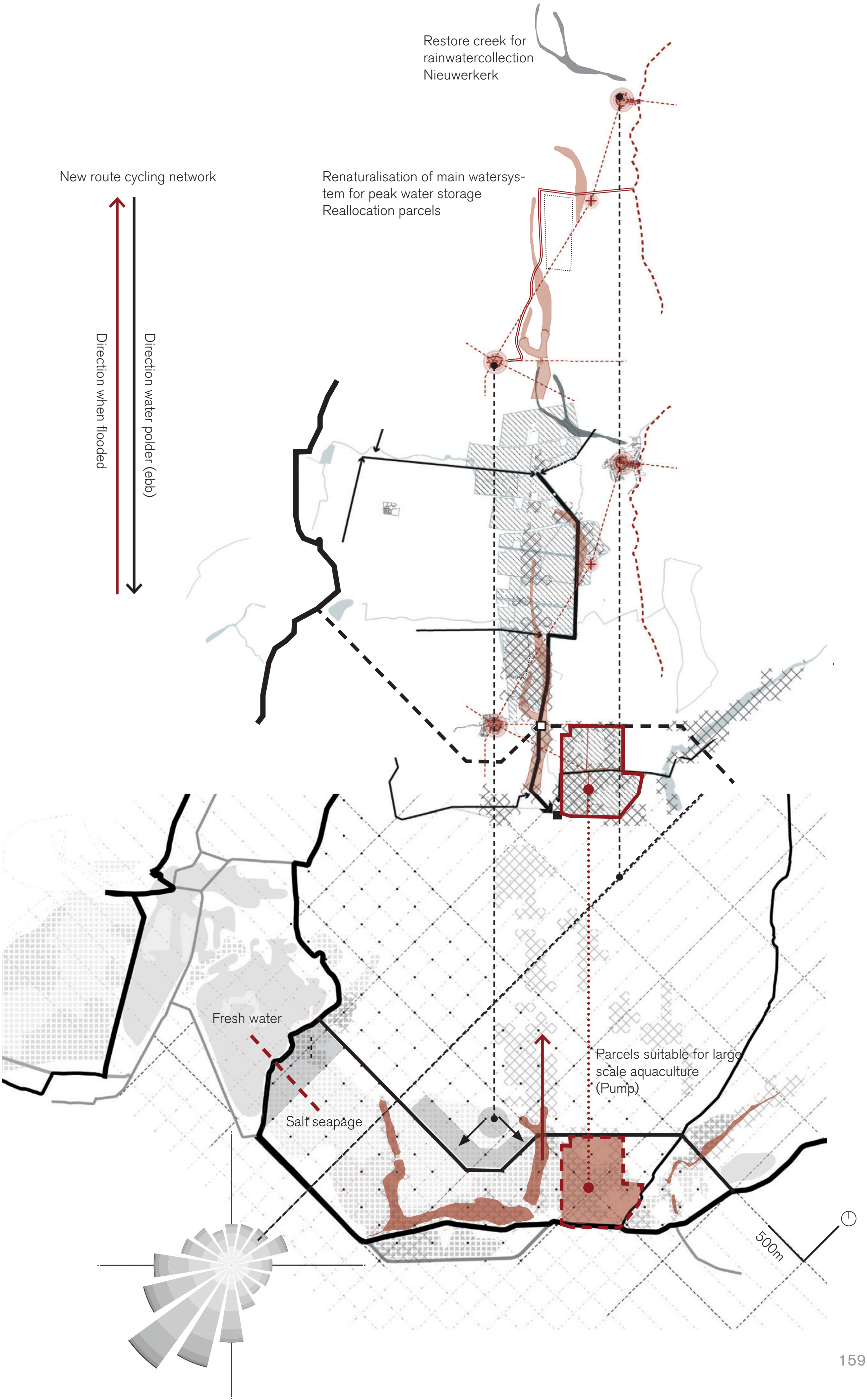
Occupation
Minuutplan 1832
(Provincie Zeeland, 2018)

- Former waterstructures
- Old city centres
- Drowned city
- Shrinked city
- Flood museum
- Estate
- Water remnants floods
- Hotspot
- Connection

Grid & substratum
Base Seapage retrieved from
(Provincie Zeeland, 2015)

- Moderate to good infiltration
- Moderate to strong Salt seapage

- Grid 1x1km
- Grid 250m
- Points on grid
- Dike island Duiveland
- Other dikes


Restore creek for
rainwatercollection
Nieuwerkerk
New route cycling network
Renaturalisation of main watersys-
tem for peak water storage
Reallocation parcels
Direction when flooded
Direction water polder (ebb)
Fresh water
Salt seapage
Parcels suitable for large
scale aquaculture
(Pump)
500m

9.28 Programmatic organization

As a means to define the programmatic organisation key zones have been determined with different levels of accessibility and recreational activities. The areas also represent different elevation gradients and water levels. The remnant of the creek crosses the different zones and has a protected Nature status, this requires limitations alongside its edges.

Intensive zoning:
- Concentration of recreational clusters and/or productive activities
- Good access to N59 for transportation
- Focus on saline agriculture
- Elevation of water level due to adjacent fresh water areas

Mixed zoning
- Combination of extensive saline production and exclusive overnight accommodations
- Accessible for cyclist and pedestrians

Extensive: bird resting areas
- Limited accessibility alongside the edges
- Bird islands as breeding areas
- Extensive aquaculture

Subsidies:
The province of Zeeland offers (Agricultural) nature subsidies for stated parcels. These have been categorized as follows (Provincie Zeeland, 2006):
- Dry zone : Grassland management and landscape management
- Wet zone : Management of banks, wells and pools
- Open arable land: Management of arable birds

The zoning responds to the given categories.

Subsidies
(Provincie Zeeland, 2006)

- Wetlands/ aquaculture
- Parcels subsidies

Accessibility network
Made by author
- N59
- Regional road
- Local road

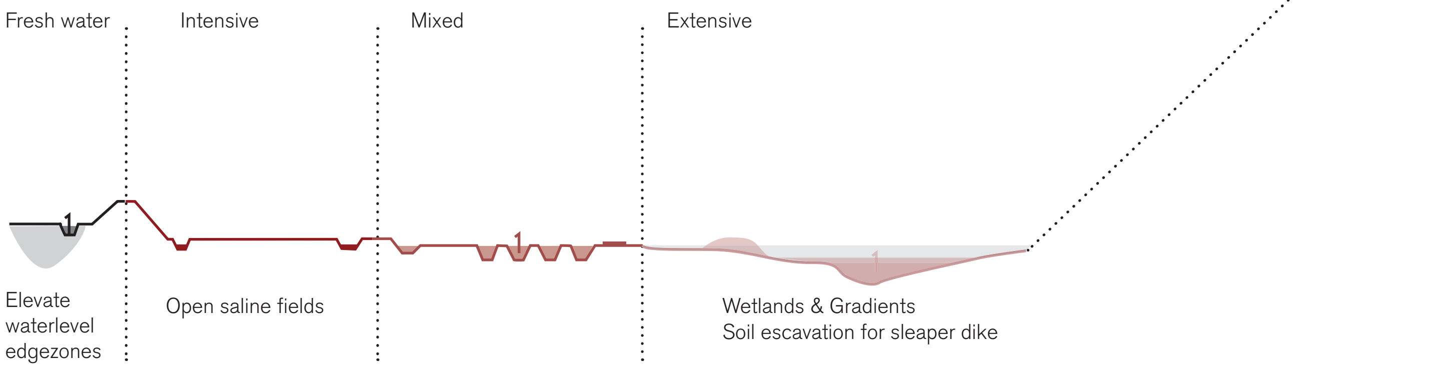
- Nod cycling network
- Cycling path
- Walking path

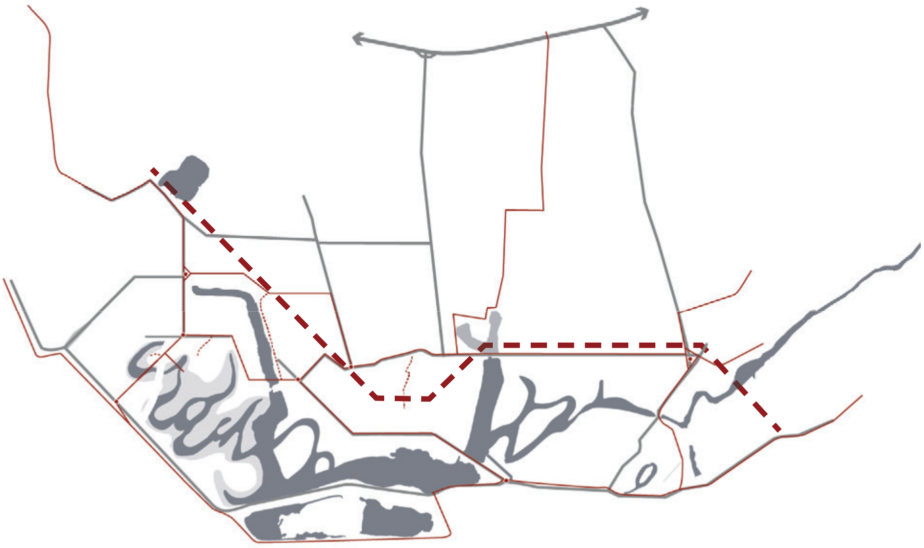
Zoning
(Made by author)
- Intensive zoning
- Mixed zoning
- Bird resting areas
- Remnant creek
- Parcels appointed for subsidie

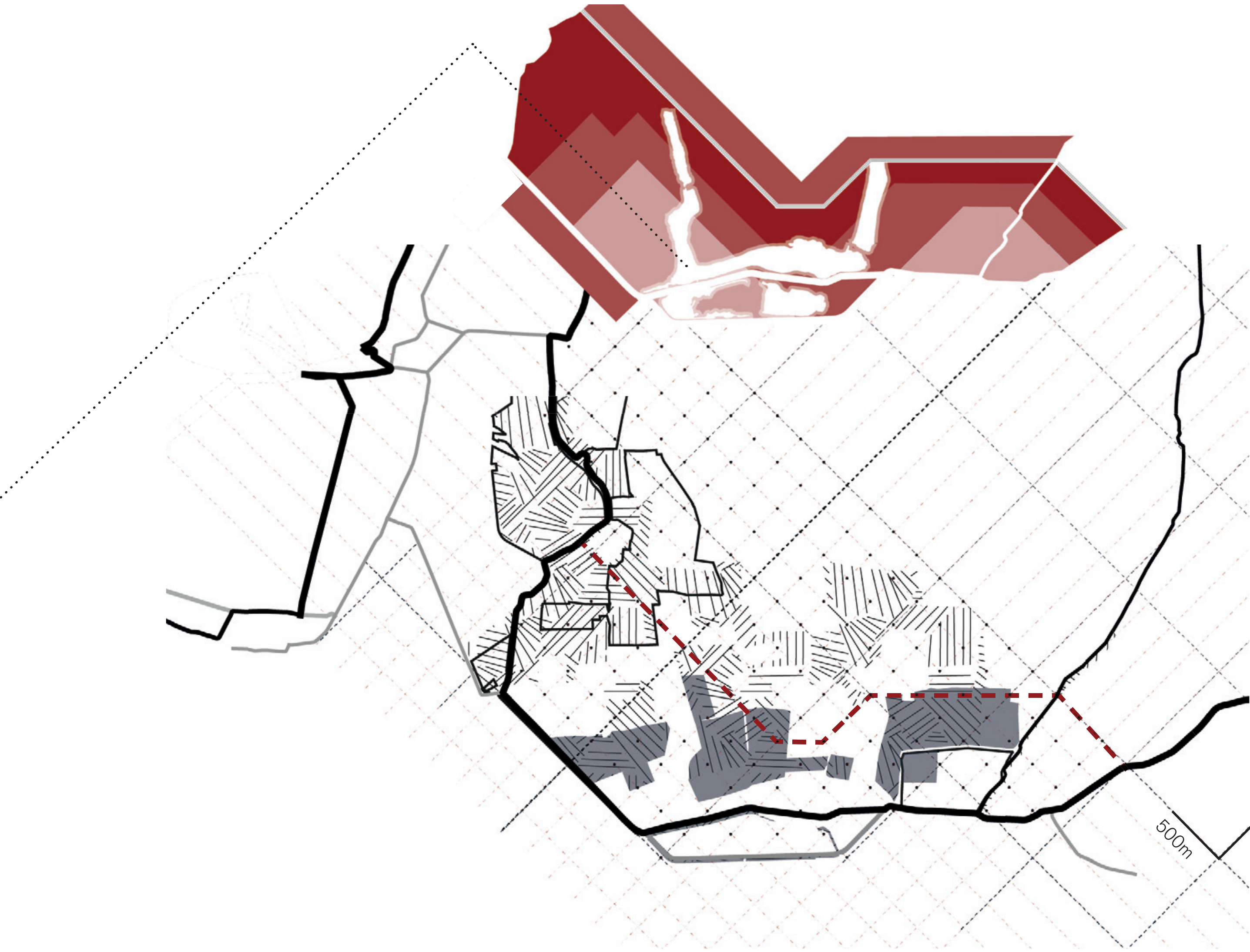
Subsidies
(Provincie Zeeland, 2006)

- Dry zone
- Wet zone
- Open area

Indicative section zoning
(made by author)






500m

9.29 Proposal Trajectory de Val - Ouwerkerk

Indicative map made by author
Aerial picture 2019, Ortho 25cm RGB
Retrieved from PDOKserver, qGIS

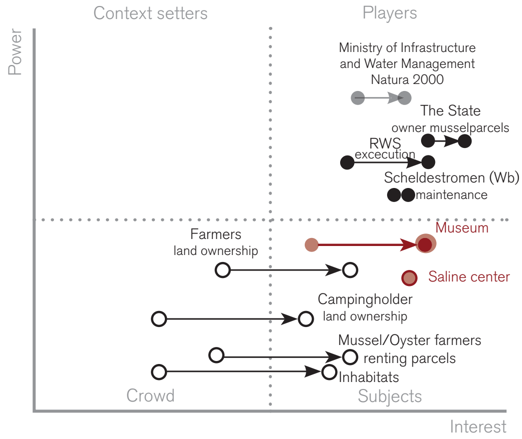

250m

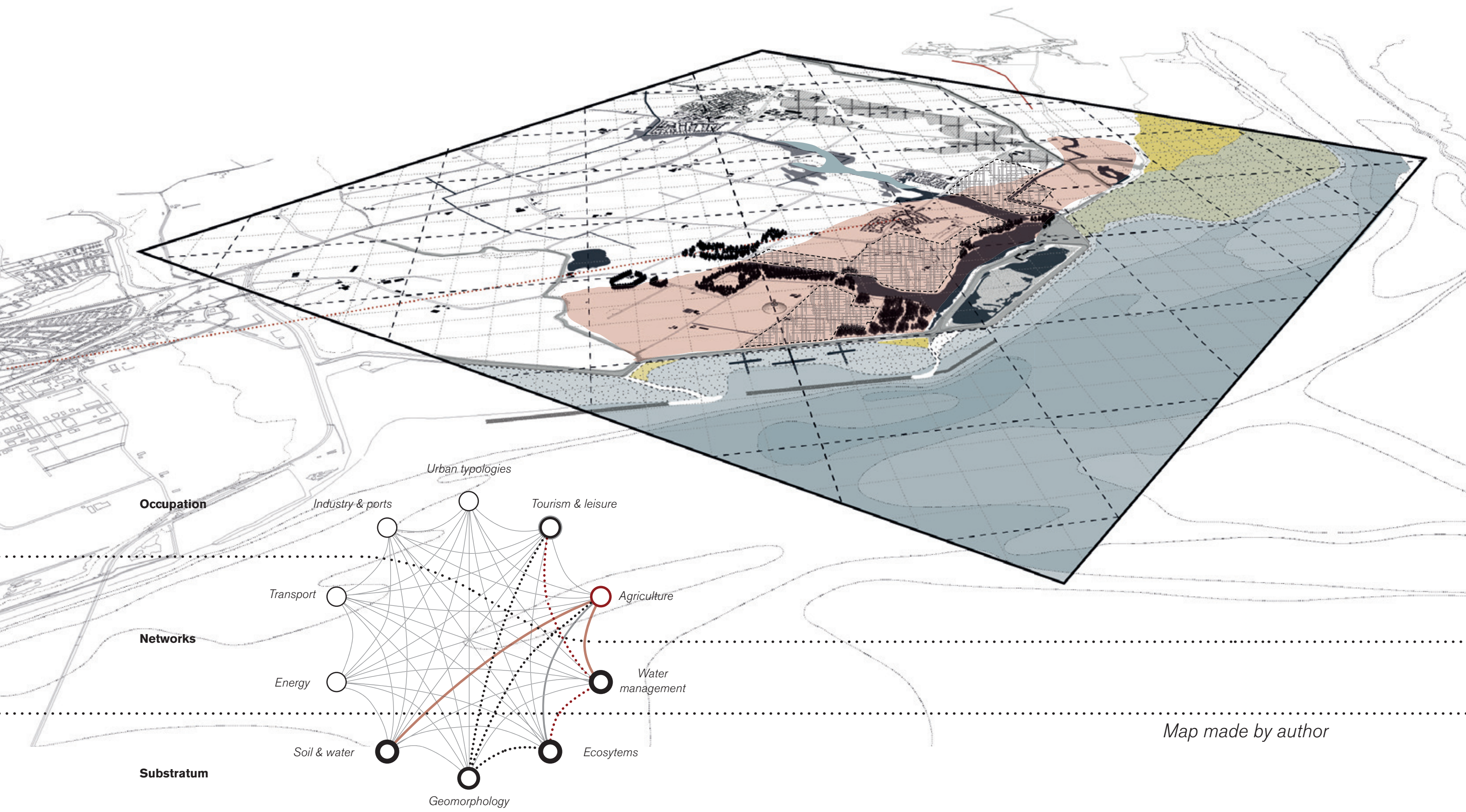
9.3 Development trajectory

<ins>2030: Short term developments seawards</ins>
An artificial reef will be initiated for wave attenuation. Additional cribs can function to sustain limited local sediment deposit on the short term..

Initial landwards developments for peak water storage between Ouwerkerk and Nieuwerkerk are located adjacent to the main water in the 10% lowest surface areas. The museum for water safety can function as a means to create a public debate on landwards developments and water management, initiating meetings with stakeholders affected in the area.

Most likely farmers will still show resistance, since stressors might still be limited perceived. In this stage main concerns can be opted, and a first initial proposal for managed retreat can be shown. RWS can actively address the area as search area for spatial adaptation.



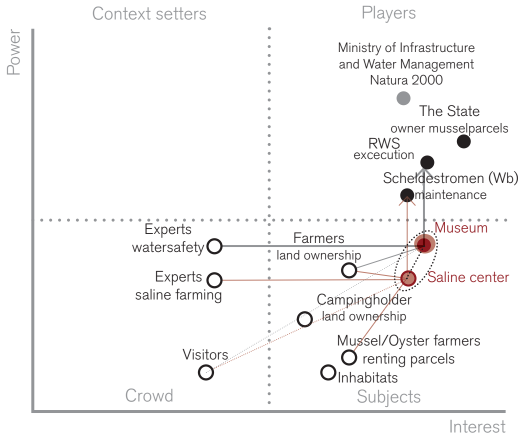


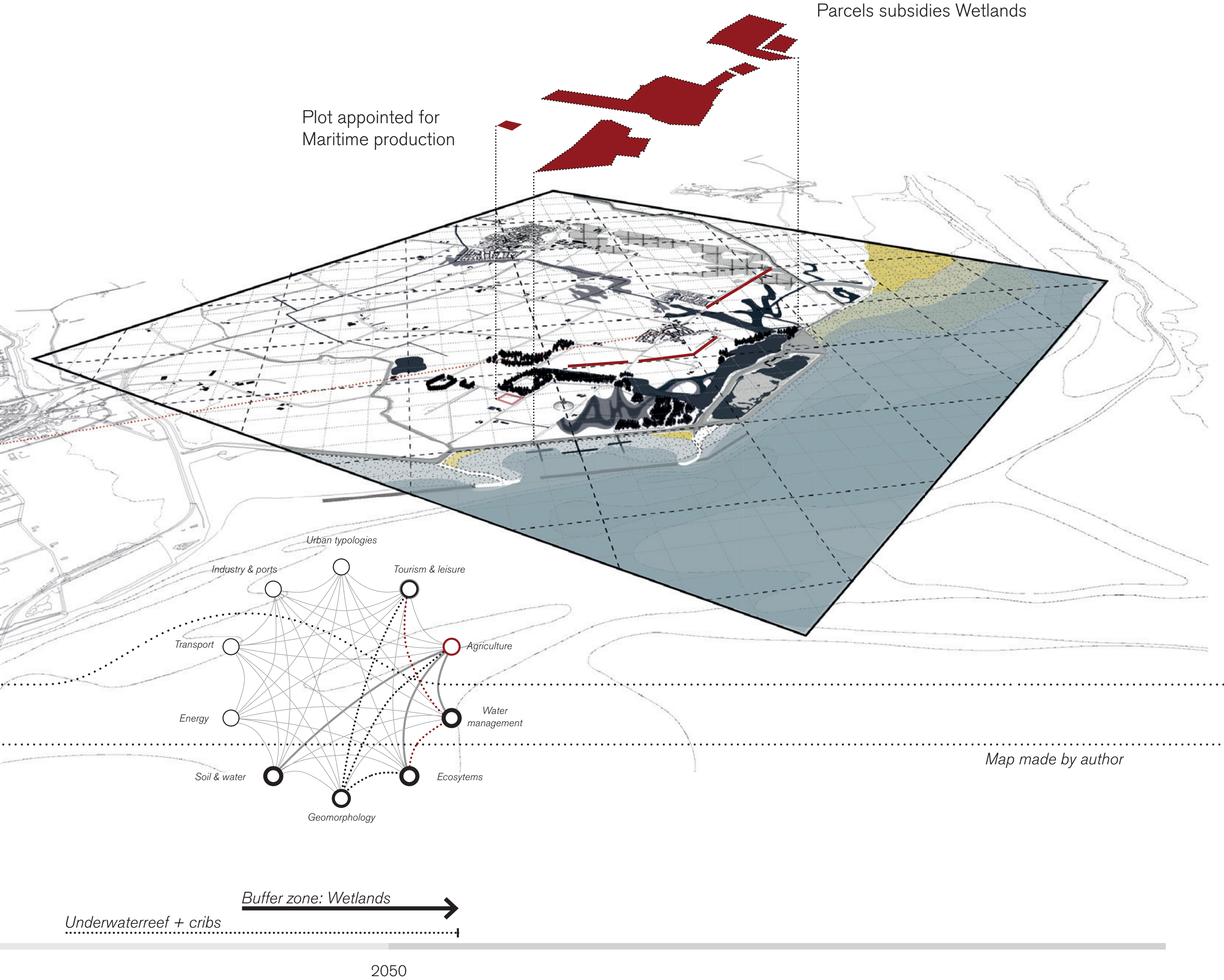
Map made by author

2050: Dike trajectory & wetland development

Developments seawards will be monitored as to determine the rate of erosion and additional measures, such as local sand nourishments.

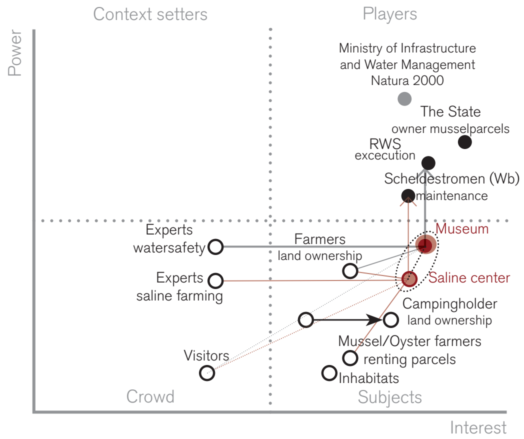
Landwards farmers will most probably undergo the affects of increased salt intrusion and reduced crop production. As a means for initial nature compensation parcels with salt seepage will be addressed for wetland development, using the substrated soil for initial development of the sleeeper dike trajectory. This can be partially funded by subsidies for nature compensation by the State as well as subsidies for wetlands as appointed by the province. A central mound is developed with remaining soil, and can be used as small recreational cluster.



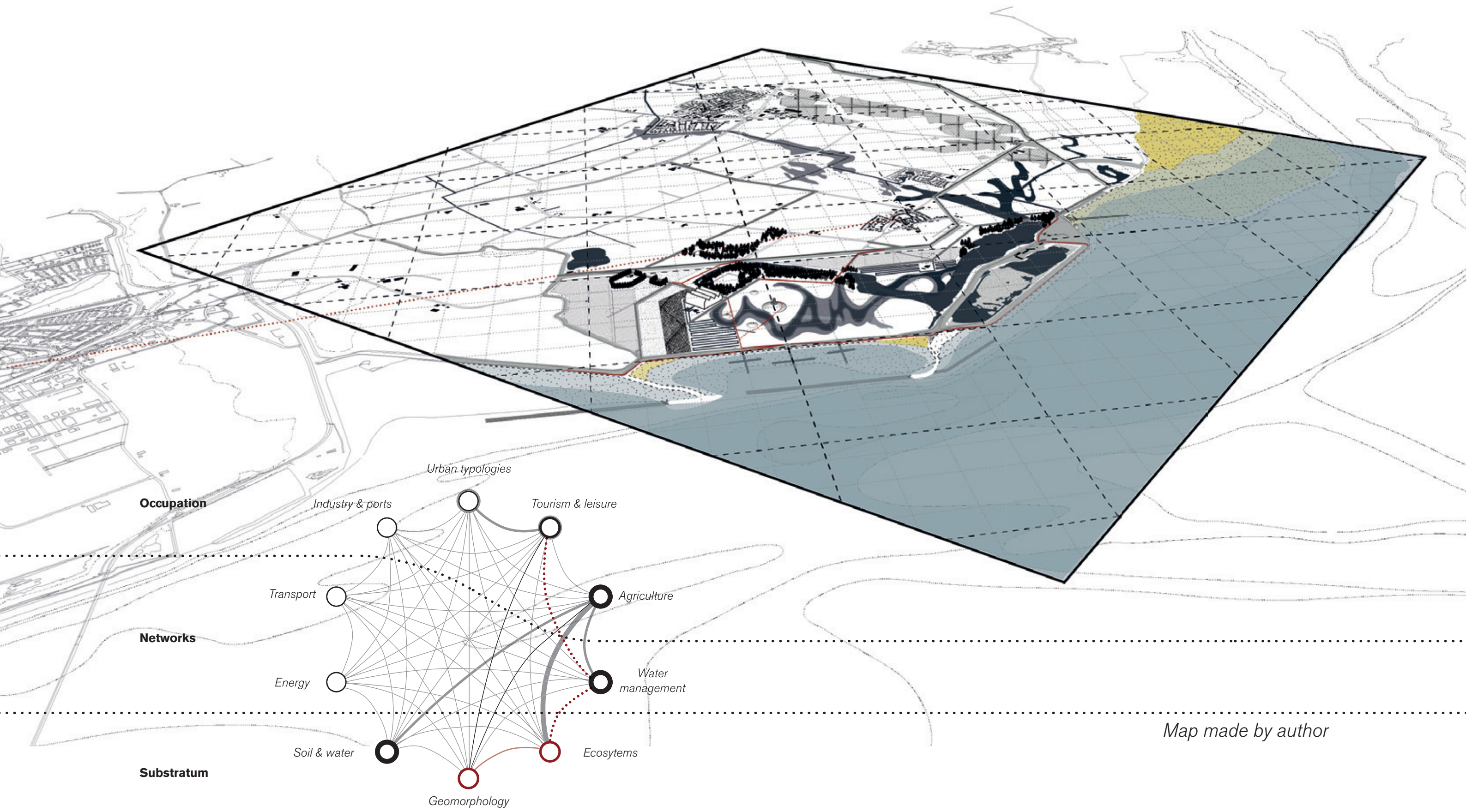


Map made by author

9.3 Development trajectory



<u>2070:</u>
The dike trajectory is finished, therefore the area between de waker and sleeper dike is actively functioning as bufferzone. Additional clusters of transportable accommodations (maximum of 80 accommodations) are located around the developed wetland areas. Small campsites are integrated in allotments of existing farms as a means to compensate for loss in agricultural functions. These campsites cannot facilitate permanent buildings. Landbased as well as seabased production techniques are tested, marking the area as territory for water related research and saline agriculture. Saline products are sold at the central farm for saline innovation.

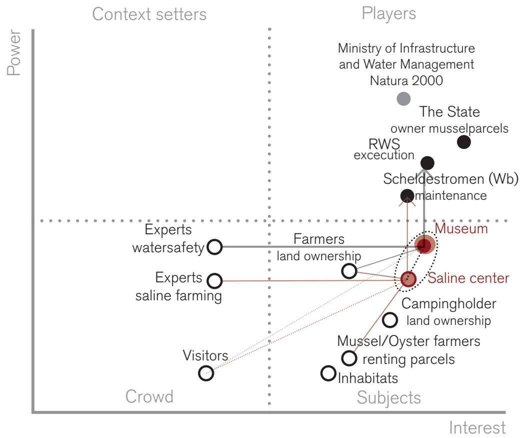


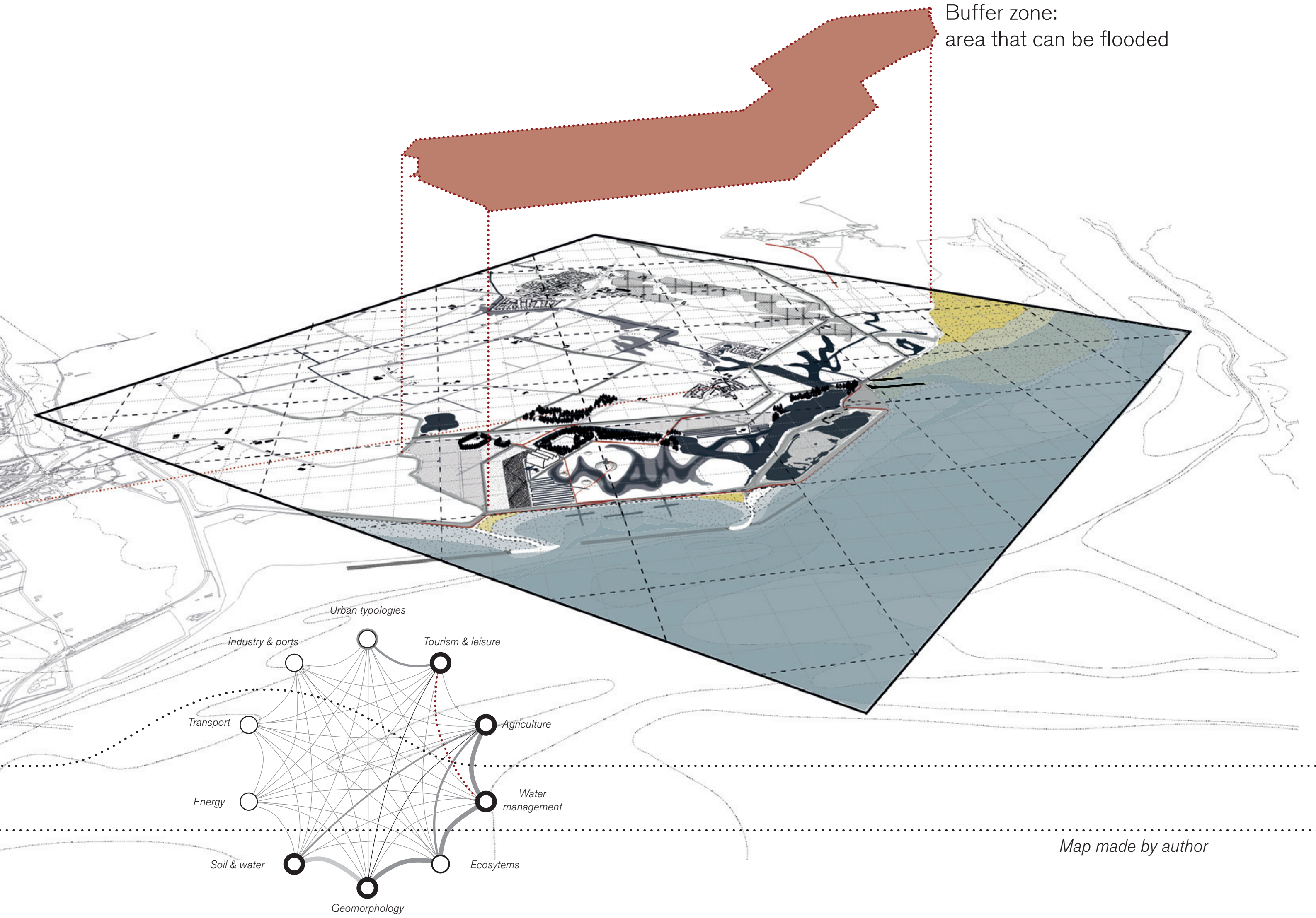
Map made by author

Buffer zone: Completion sleeper dike & Saline production

2070

2100: Landscape for innovation
Depending on the state of the Eastern Scheldt and the developments related to the sand deficit, research is done into the possibility for an inlet and the bufferzone to function as a slib motor.



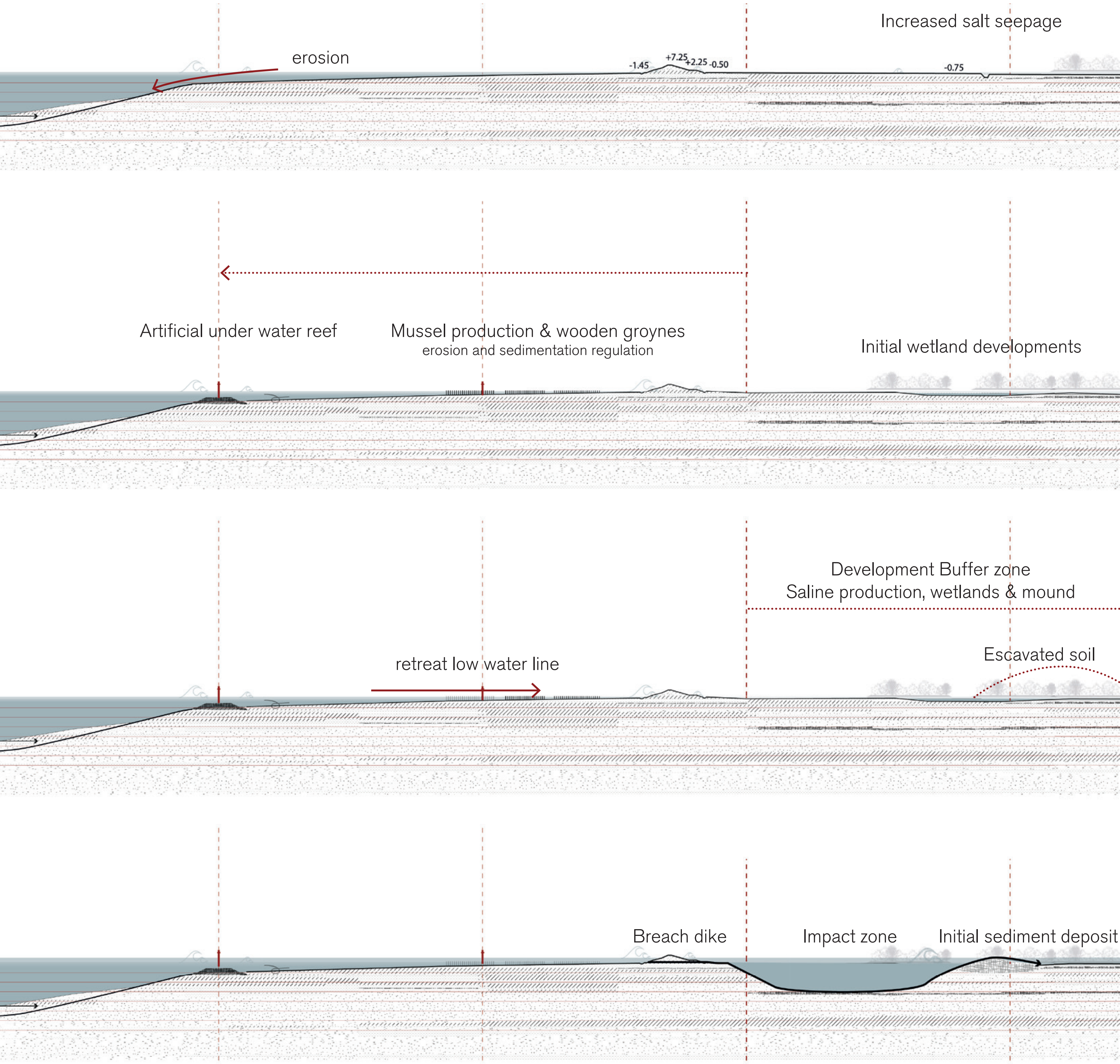


Map made by author

Buffer zone
Possibility slibmotor : inlet development

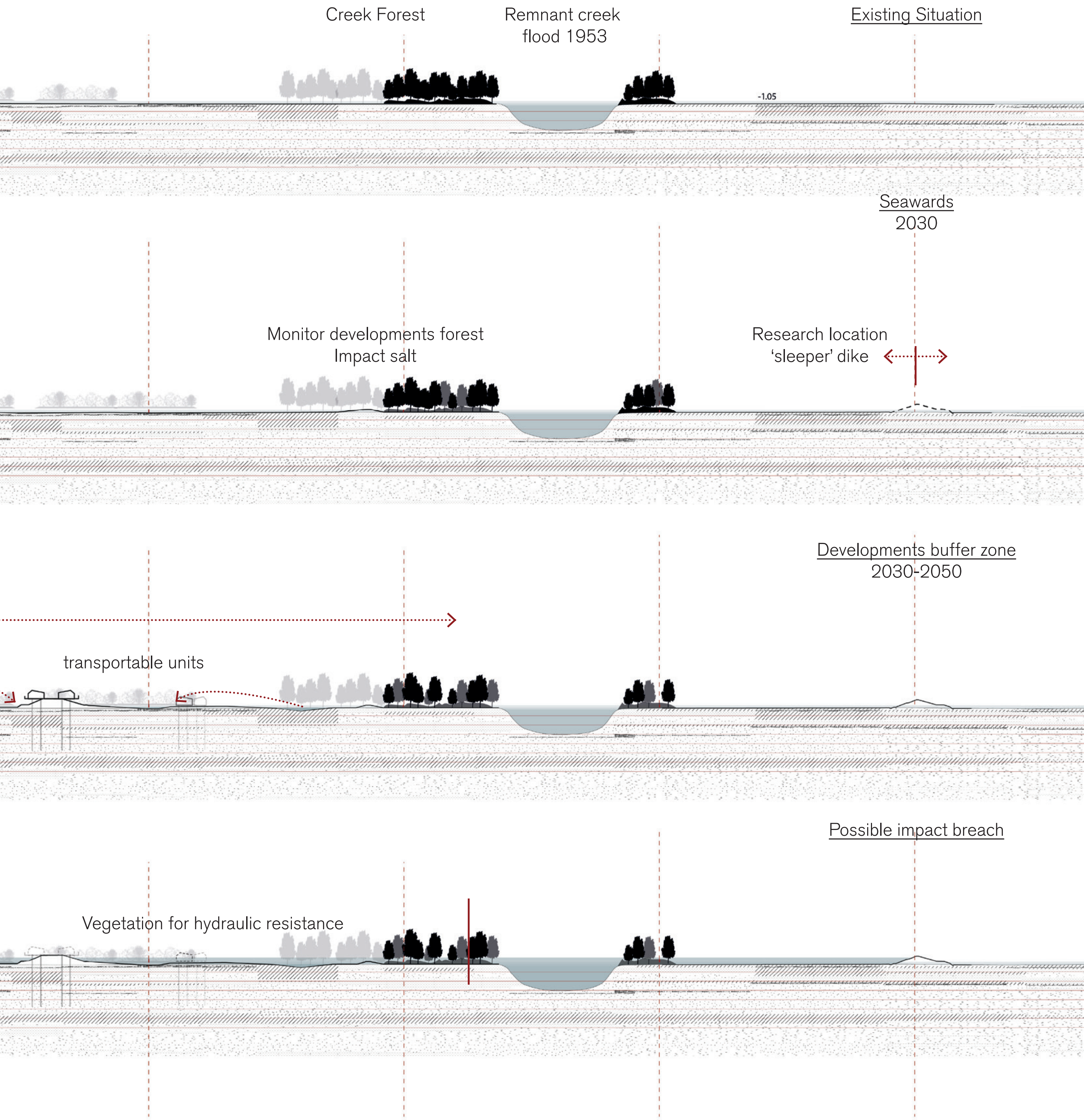
2100

9.4 Transformation land-water zone



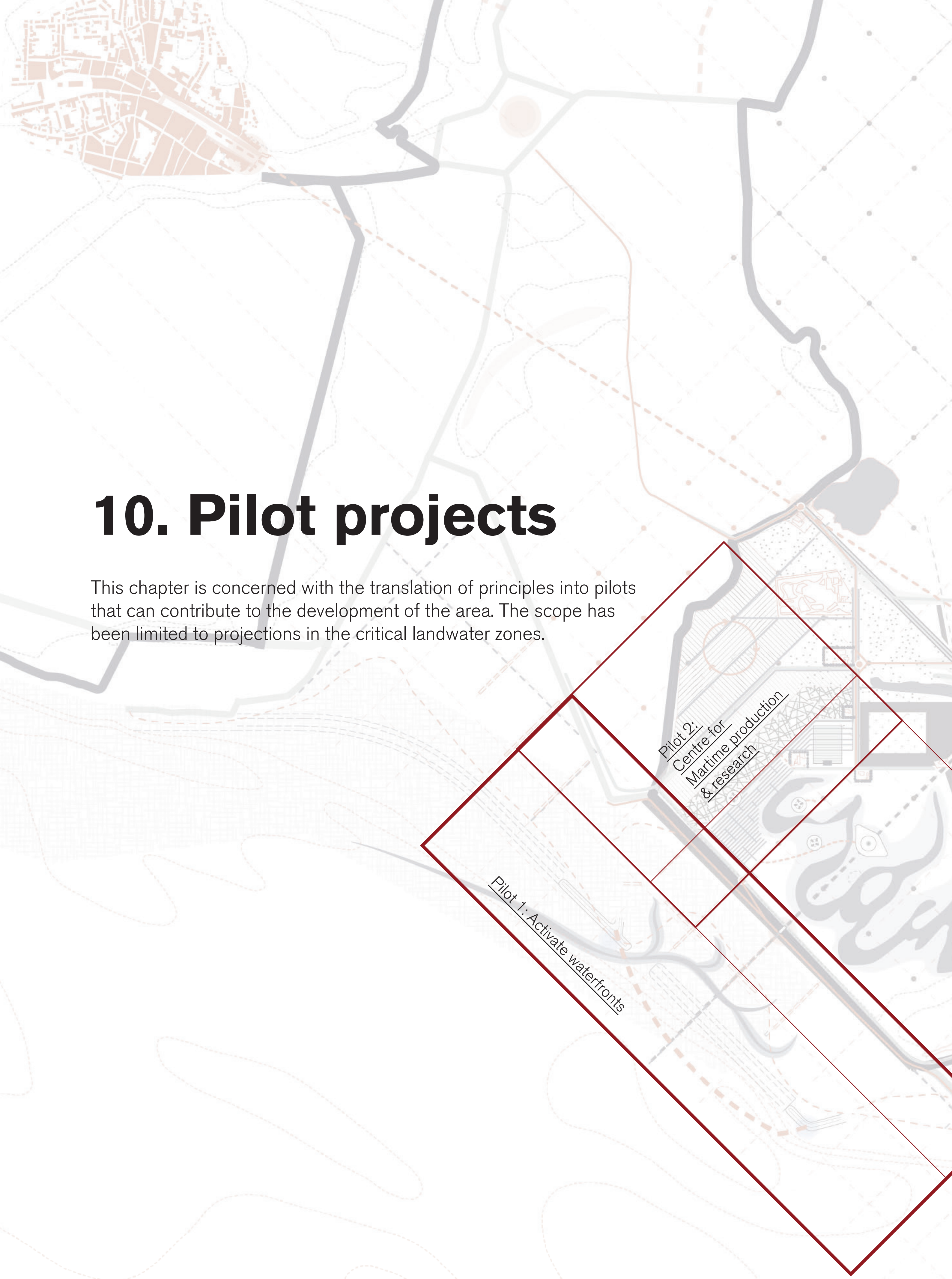
Most probable litho class
BRO GeoTOP v1.3 (Dinoloket, 2019)
Sections made by author

- Clay
- Clay, sand and sandy clay
- Fine sand
- Medium sand
- Coarse sand
- Peat
- Anthropogenic
- Water


Creek Forest
Remnant creek flood 1953
Existing Situation
-1.05
Seawards 2030
Monitor developments forest Impact salt
Research location 'sleeper' dike
Developments buffer zone 2030-2050
transportable units
Possible impact breach
Vegetation for hydraulic resistance

10. Pilot projects

This chapter is concerned with the translation of principles into pilots that can contribute to the development of the area. The scope has been limited to projections in the critical landwater zones.

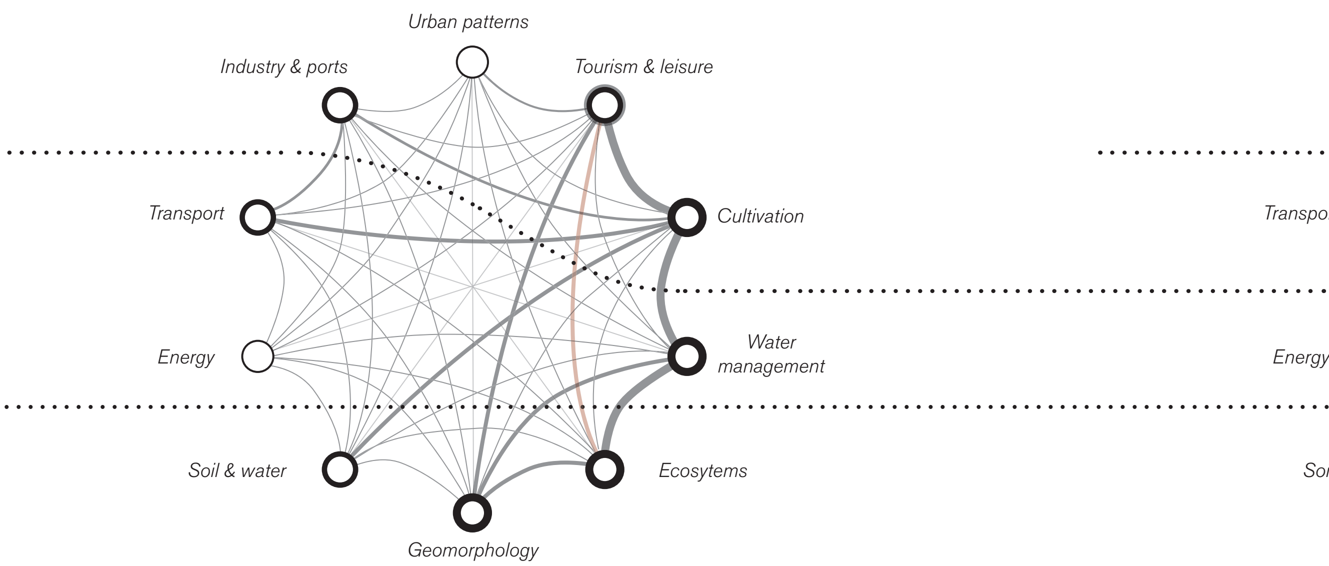


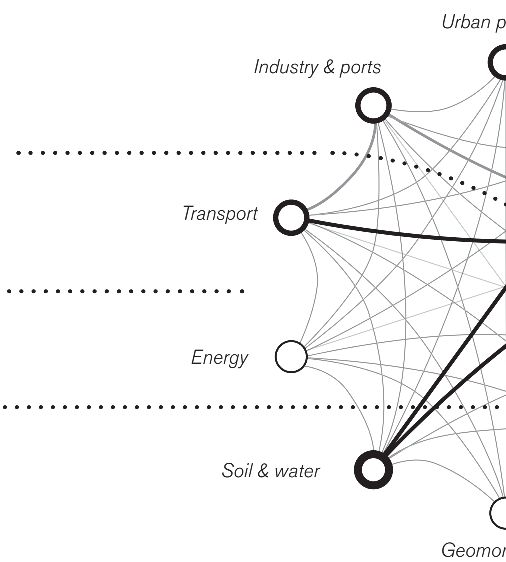

Pilot 3: The new floodplain

10.1 Overview Pilot projects

Activate waterfronts
Activate waterfronts and create visual attraction points while enhancing the productive character of the coast.

Centre for saline production & research
Research centre for land based martime

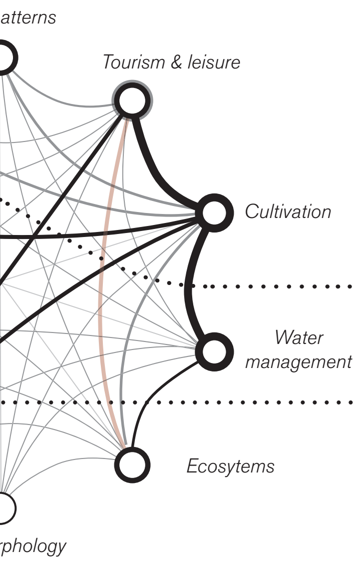


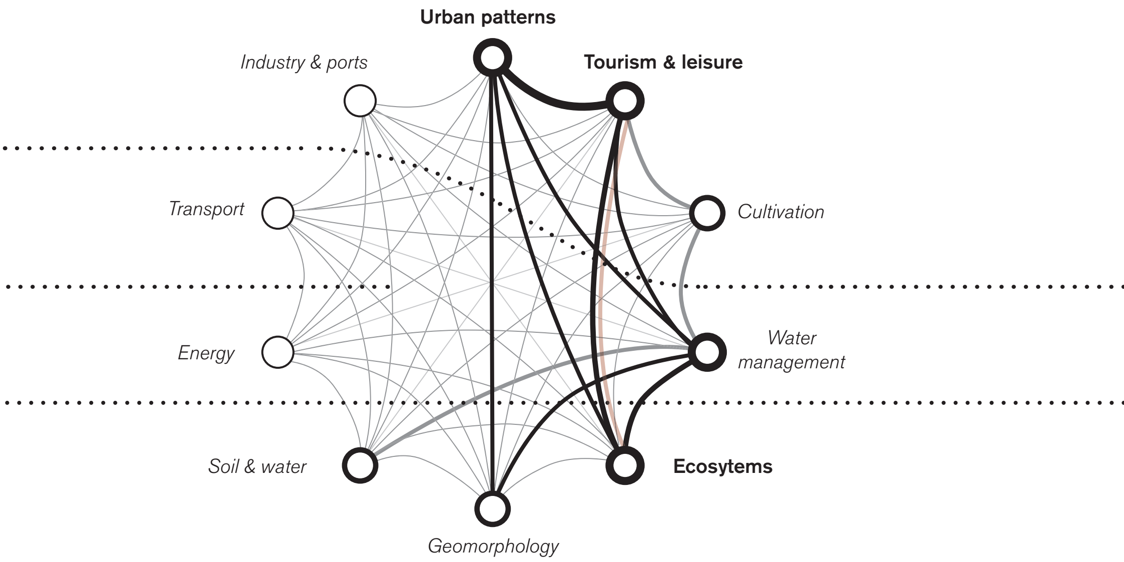


(Images & pictures made by author)

production & water management.

The new floodplain
Transformation of the wetland and mound typology in the new floodplain



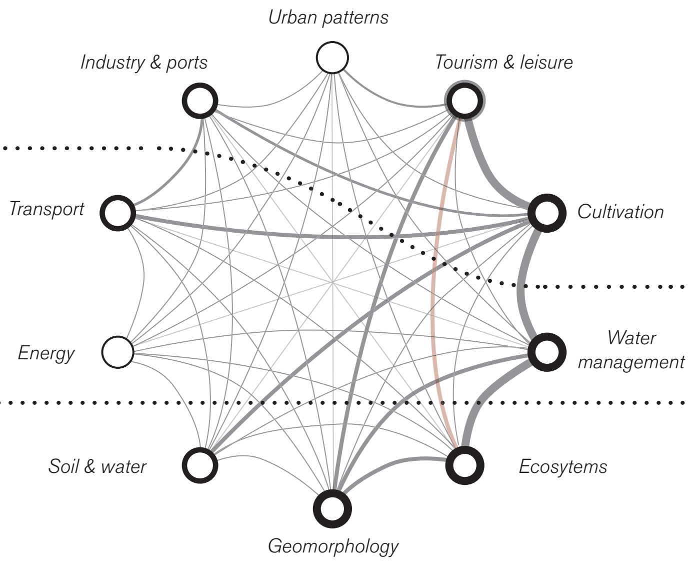


Pilot 1: Activate waterfronts

Whereas the dike is often perceived as a straight defense line the project proposes to emphasize the waterfronts as a zone of interacting elements. This pilot explores the possibilities to activate waterfronts linking the narrative of water safety and presence of exogene processes to productive activities such as mussel cultivation. Measures aim to sustain the still present foreland and related habitats for an extended period of time.

The perpendicular structures break the length of the dike, emphasizing the width of the zone. The esthetics of the wooden elements attracts attention.

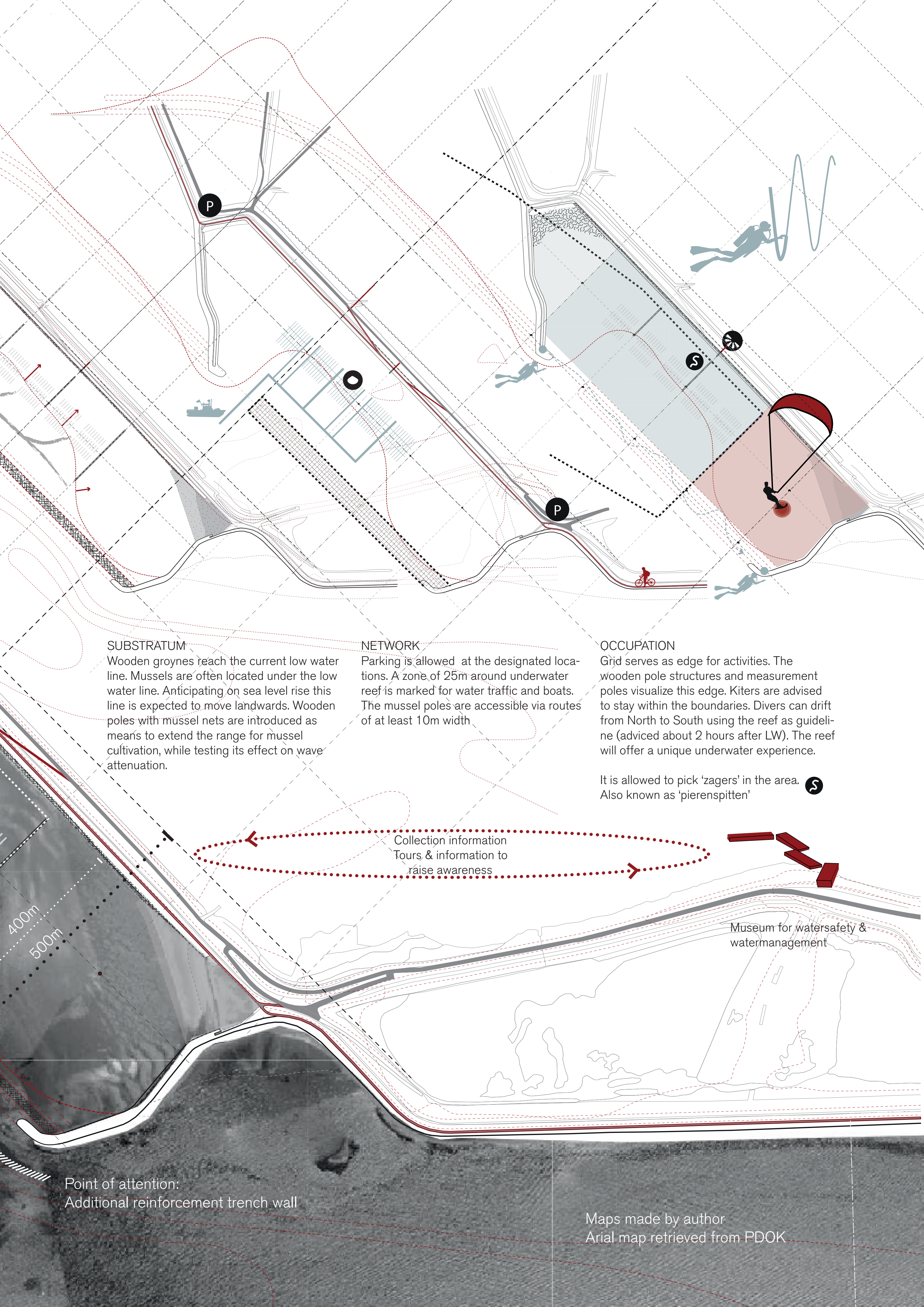
Keywords: erosion and sedimentation regulation, awareness of floods in critical land water zones, productive waterfronts

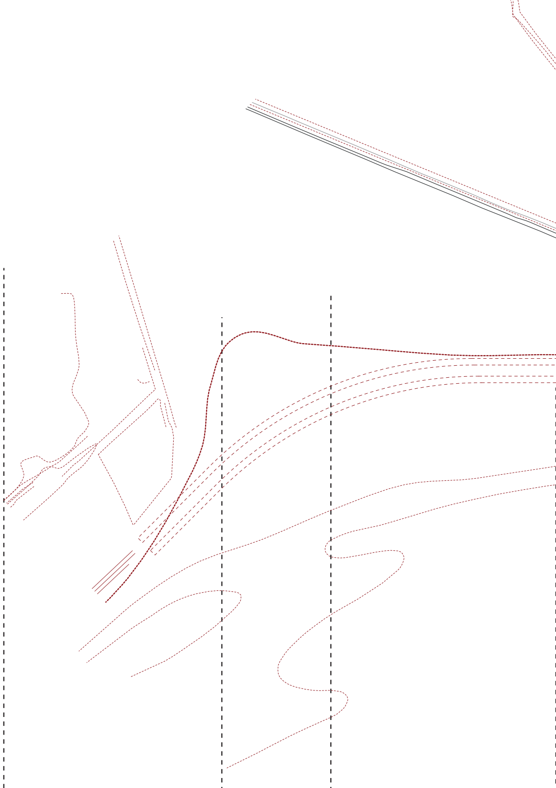


Pilot 1:
Activate waterfronts

Underwater reef
It is assumed that a hard offshore breakwater (parallel) or typical groynes (perpendicular) above high water can possibly negatively affect the already limited transportation and sedimentation patterns, or might cause downdrift erosion. Therefore other options have been evaluated. An underwater reef is proposed parallel to the coast as means to reduce wave energy. It is assumed that an underwater structure will have less impact on longshore processes. The underwater reef is positioned about 400m from the outer line of the dike. Its length can be subdivided in areas of 250m.

Productive waterfront
Wooden groynes are used to support the process of sedimentation. Within the same esthetics smaller wooden poles might be able to support mussel cultivation.


P
P
S
SUBSTRATUM
Wooden groynes reach the current low water line. Mussels are often located under the low water line. Anticipating on sea level rise this line is expected to move landwards. Wooden poles with mussel nets are introduced as means to extend the range for mussel cultivation, while testing its effect on wave attenuation.
NETWORK
Parking is allowed at the designated locations. A zone of 25m around underwater reef is marked for water traffic and boats. The mussel poles are accessible via routes of at least 10m width
OCCUPATION
Grid serves as edge for activities. The wooden pole structures and measurement poles visualize this edge. Kiters are advised to stay within the boundaries. Divers can drift from North to South using the reef as guideline (adviced about 2 hours after LW). The reef will offer a unique underwater experience.
It is allowed to pick 'zagers' in the area. Also known as 'pierenspitten'
S
Collection information
Tours & information to raise awareness
Museum for watersafety & watermanagement
400m
500m
Point of attention:
Additional reinforcement trench wall
Maps made by author
Arial map retrieved from PDOK



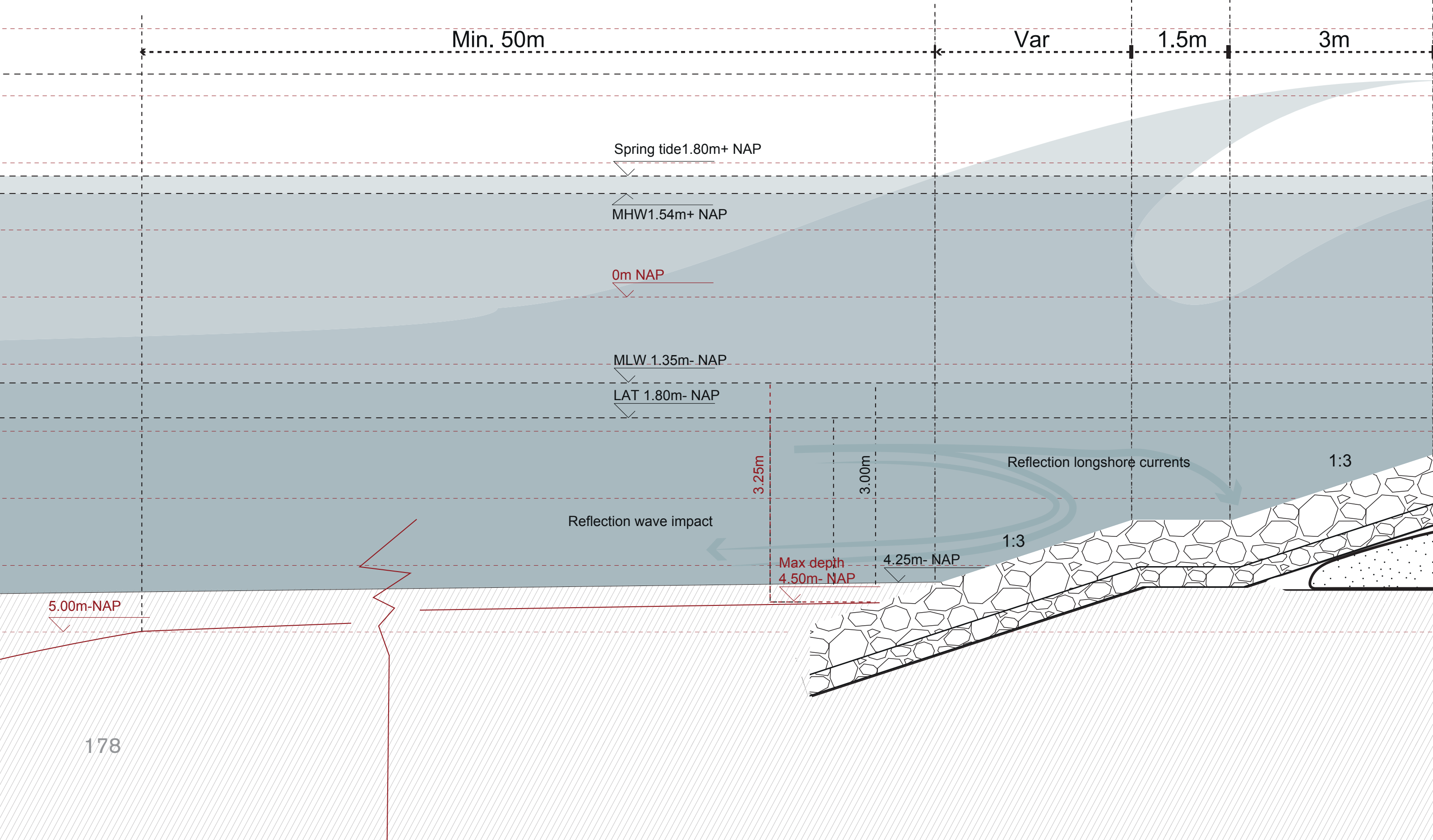
Pilot 1: Activate waterfronts

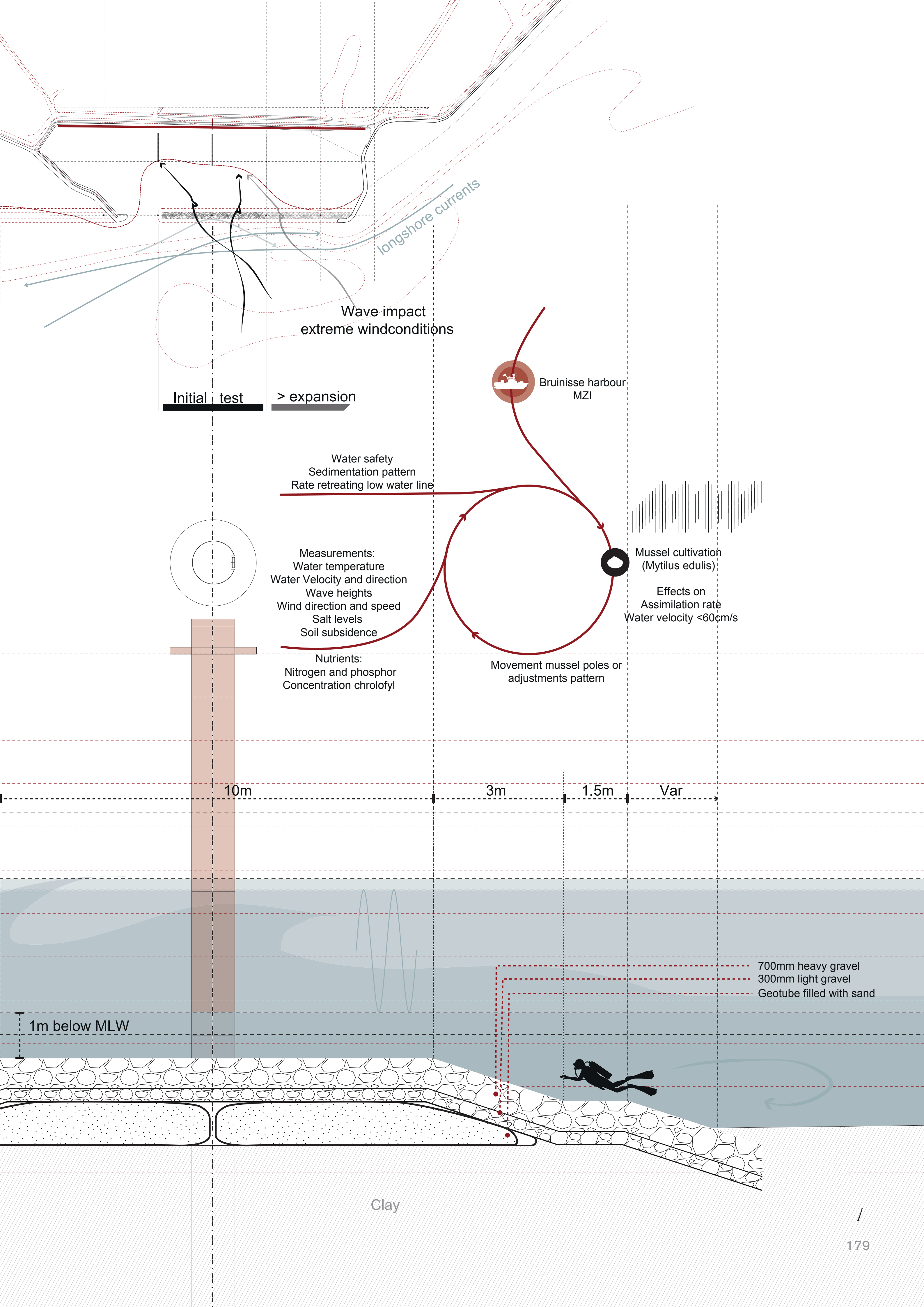
<u>Artificial under water reef</u>
The effectiveness of a reef is depending on the following parameters (Meijerink, M. van Bemmel, E. Arnold, E., Jacobse, S., de Ronde, J., 2008, p. 25):

- The depth of the reef (about 3,35m below MLW).
- The distance from the shore to the reef, which is about 400m. The reef therefore maintains in below the MLW and has a minimum distance of 50m from the steep trench wall that starts around 5.00m-NAP.
- The length and orientation of the reef (parallel). The full length is about 900m. The ideal length of the structure is still questioned. It is expected that the erosive wave impact is dominantly caused by wind. To cover the main wind directions would mean addressing a full parallel length. The reef can be made in stages as means to verify its effectiveness as well as the impact of the structure on reflection of longshore currents.
- The water depth of the crest (1m below MLW= 2.35-mNAP) as well as the steepness of the construction and porosity of the material. Often the steeper the construction the more reflection of wave impact there might be expected. In this case a steepness of 1:3 is used to moderate between expected reflection.

It is expected that the lee side of the structure (landside) might host marine organisms that are less affected by high water velocities.
To host marine organisms the reef is therefore constructed with a layer of gravel. The base of the reef is stabilized with geotubes.

Section proposal underwater reef (made by author)





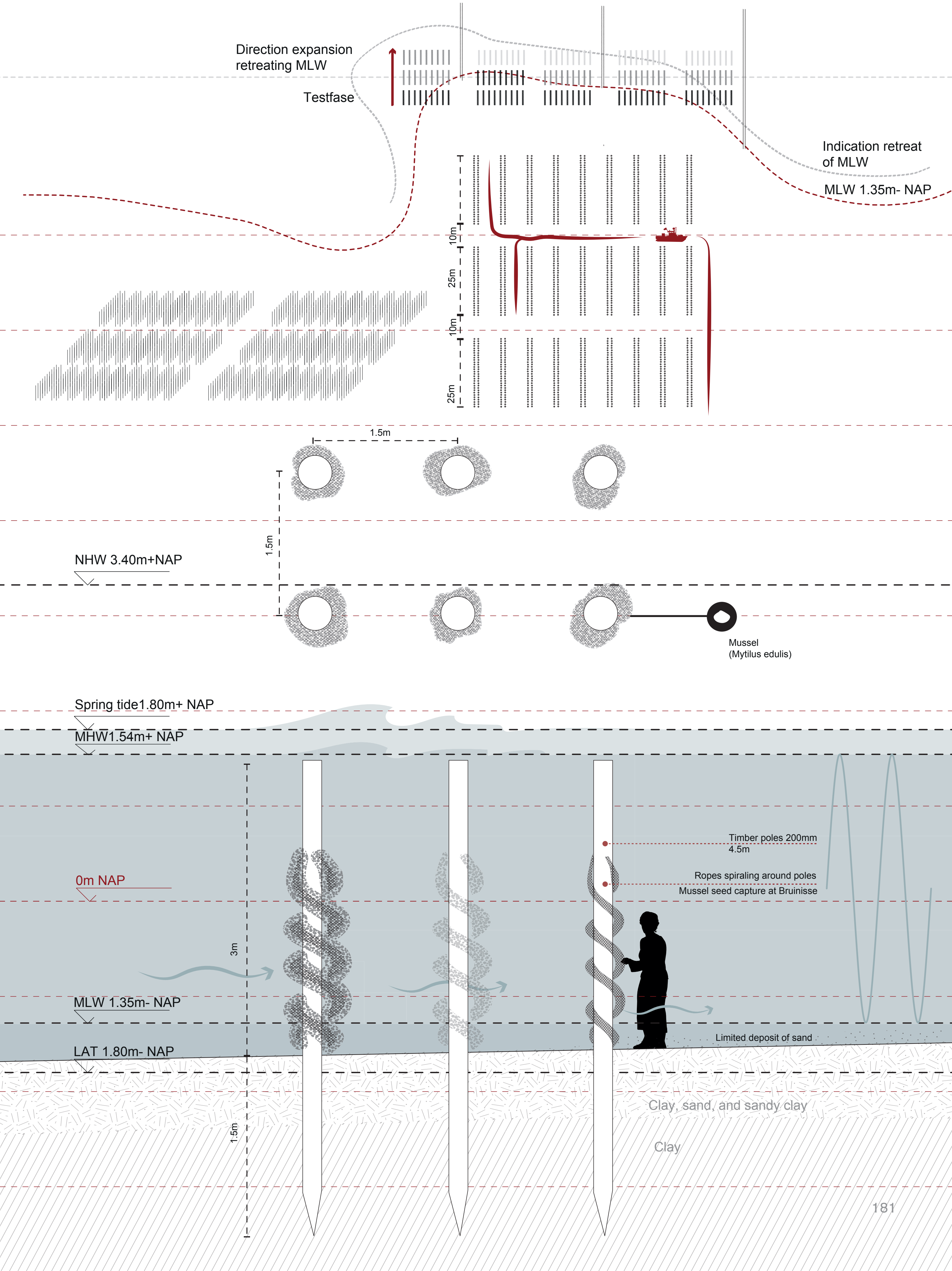
longshore currents
Wave impact
extreme windconditions
Initial test
> expansion
Bruinisse harbour
MZI
Water safety
Sedimentation pattern
Rate retreating low water line
Measurements:
Water temperature
Water Velocity and direction
Wave heights
Wind direction and speed
Salt levels
Soil subsidence
Nutrients:
Nitrogen and phosphor
Concentration chrolofyl
Mussel cultivation
(Mytilus edulis)
Effects on
Assimilation rate
Water velocity <60cm/s
Movement mussel poles or
adjustments pattern
10m
3m
1.5m
Var
700mm heavy gravel
300mm light gravel
Geotube filled with sand
1m below MLW
Clay

Pilot 1: Activate waterfronts

Productive waterfront
Wooden groynes are used to support the process of sedimentation. Within the same esthetics smaller wooden poles might be able to support mussel cultivation. The construction is inspired by the production of the Bouchon mussel in France. Mussels that are above the low water line for a period of time will not grow as fast, but are said to have an intense taste. Initially the constructions can be tested around the MLW line. When effective the plots can be extended anticipating on the retreating MLW line.

Due to the fact that the constructions have a maximum height around the MHW line, they are most likely to be effective for sedimentation regulation during mean conditions.

Section mussel cultivation
(made by author)



Direction expansion retreating MLW
Testfase
Indication retreat of MLW
MLW 1.35m- NAP
10m
25m
10m
25m
1.5m
1.5m
NHW 3.40m+NAP
Mussel (Mytilus edulis)
Spring tide1.80m+ NAP
MHW1.54m+ NAP
0m NAP
3m
MLW 1.35m- NAP
LAT 1.80m- NAP
1.5m
Timber poles 200mm 4.5m
Ropes spiraling around poles
Mussel seed capture at Bruinisse
Limited deposit of sand
Clay, sand, and sandy clay
Clay

Pilot 1: Activate waterfronts

Current
The current highwaterline alongside.

2030
The new perpendicular pole structures f
alongside the main route. Revetments al
coastline and create small puddles. On t
the esthetics of the poles will . Via a sma
picking. Signing on the pavement can be
thereby not hindering the main estetics c
clearly recognizable due to their red col

or mussel cultivation will attract attention
longside the dike are optional to enrich the
he central axis a viewpoint on the dike with
all stair people can go into the area for Piers
e used to limit additional direction signs,
of the dike. Stations for measurements are
our.

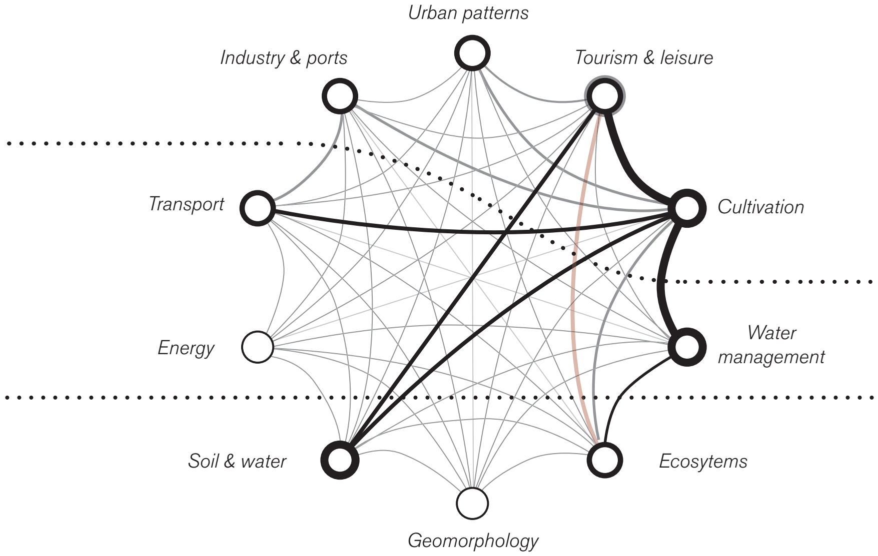
<u>After 2050</u>
The area will be increasingly affected by wind and erosion. With the development of the new polder overflow over the existing dike is accepted. The poles can be used for attachment of floating structures.

Images made by author

Pilot 2: Center for saline production & research

Although salt intrusion is a main topic for the island of Schouwen Duiveland a main issue is the still present knowledge gap about saline agriculture and the profitability of different crops, as well as the effect of brakish to salt buffer zones adjacent to freshwater polders.

This pilot explores the possibility for integration of saline production in zones affected by salt intrusion. Research on water management and production and crop technology are concentrated in a new center for Saline production offering an informative platform. Additionally daycare activities and a restaurant can accommodate a communal space. An interactive grid can facilitate research into hydrological changes in the area. Saline production can be a touristic trademark for the area, offering both land based as well as sea based products.

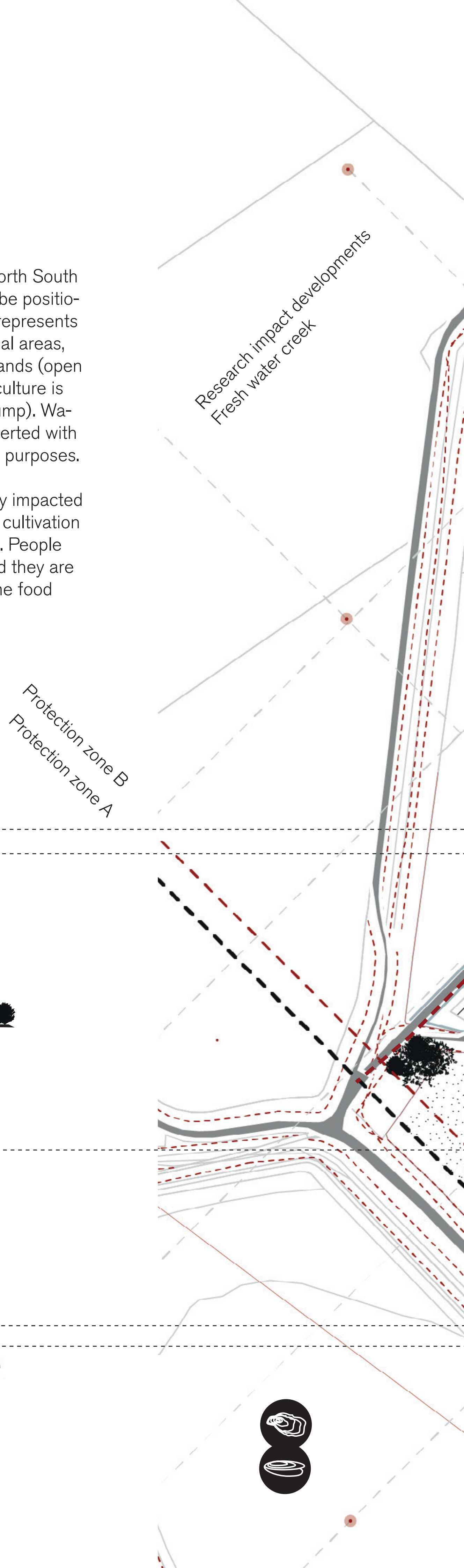


Pilot 2: Center for saline production & research

The grid interacts with the composition of the existing, more or less North South oriented, line of occupation. The new center for Saline production will be positioned at the cross point of these shifting patterns. The central line also represents the edge with sandy soils. The center is a cross point of different spatial areas, namely, the existing creek forest (protected nature site), the new wetlands (open fields for sheep farming), And semi open fields for saline crops. Aquaculture is located alongside the dike due to the necessity of a saltwater inlet (pump). Water systems for saline production are seperated. Main traffic will be diverted with a new road to relieve the road towards the new center for recreational purposes.

The plot is currently in use by a fruit cultivator, a practice that is directly impacted by the effect of salt intrusion. It is therefore expected that a change in cultivation practice is necessary. Existing buildings are maintained when possible. People are informed about the possibility of floods. When storms are expected they are requested to go to Ouwerkerk for shelter. It is advised to maintain some food and warm clothes on the highest floor.

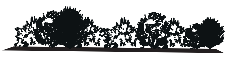
No adjustments within the protection zone A & B of the dike.



Interactive grid:

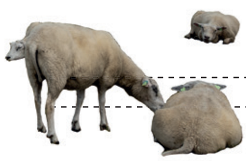
Saline farm: Center for saline production & research
The centre is constructed within the characteristics of the farm allotments Parcels saline crops:12,5 ha.

Adaptation of the 'Zeeuwse Hedge'
Restore vegetation elements of the typical productive landscape.

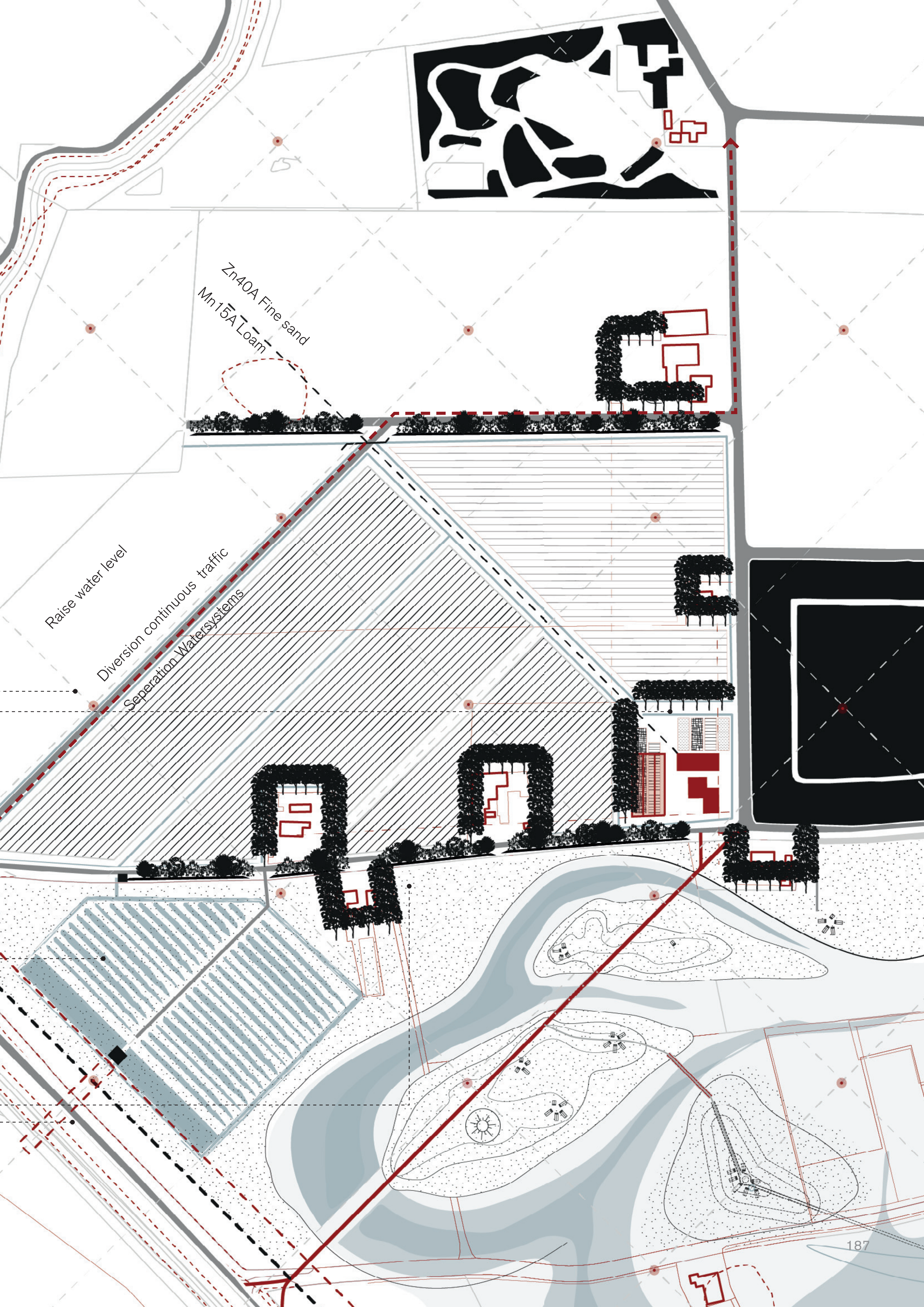


Transformation of the inlay polder typology:
It is questioned whether the ditchlike structures of inlaypolders can have a productive side character for aquaculture (5 ha)

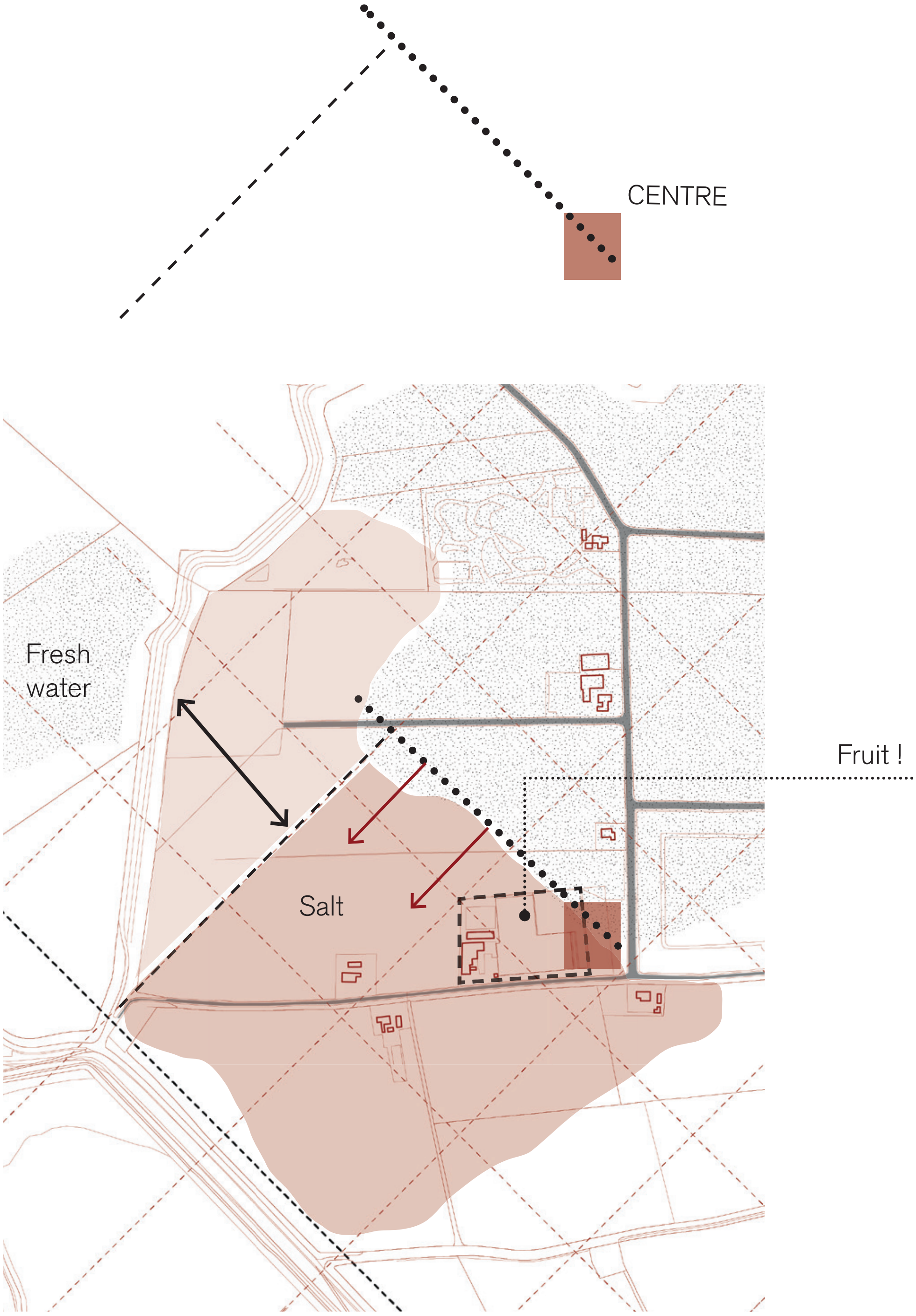
Sheep farming
Typically the dikes are maintained by sheep. Sheep farming can be further explored in the wetlands.



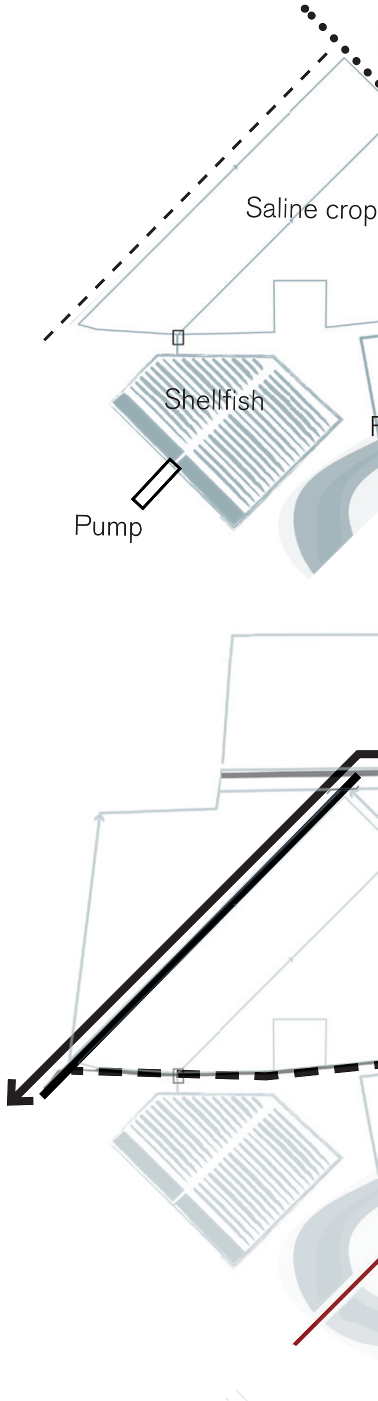
Proposal integration saline center
(made by author)


Zn40A Fine sand
Mn15A Loam
Raise water level
Diversion continuous traffic
Seperation Watersystems

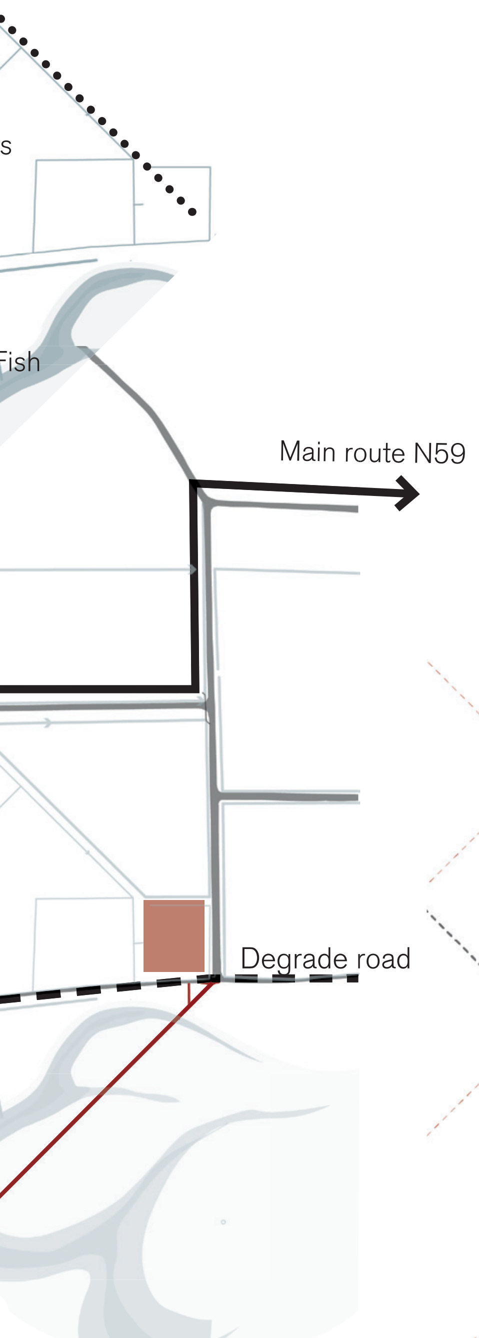
Pilot 2: Center for saline production & research



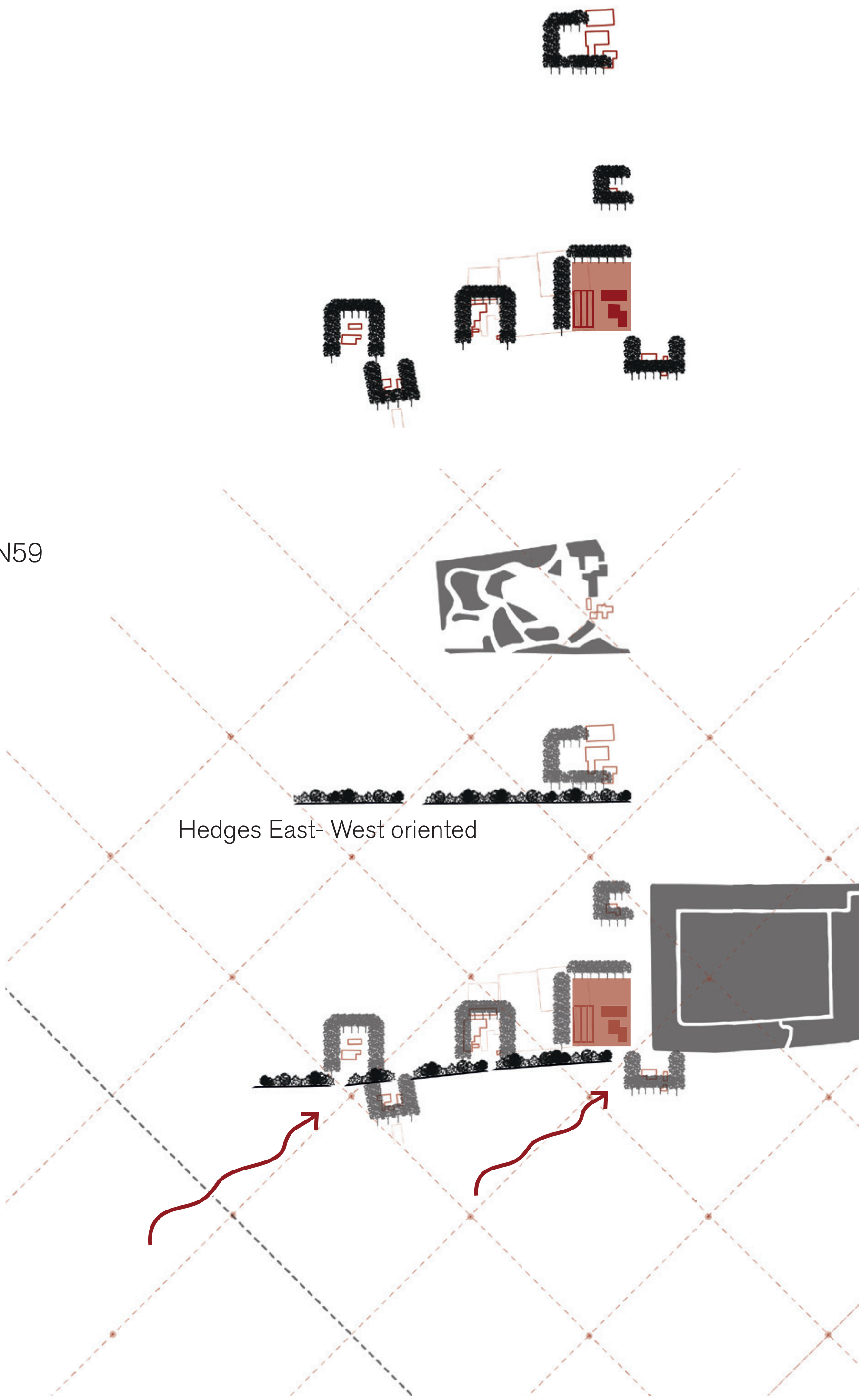
SUBSTRATUM
Maritime cultivation preference
Edge fine sand & loam
Buffer between Gouwe creek



NE
Seperati
New road to acc
Degrad



ETWORK
on watersystem
comodate a quick route
e existing road



OCCUPATION
Clusters alongside the road
use of vegetative edges and 'Zeeuwse hedges'

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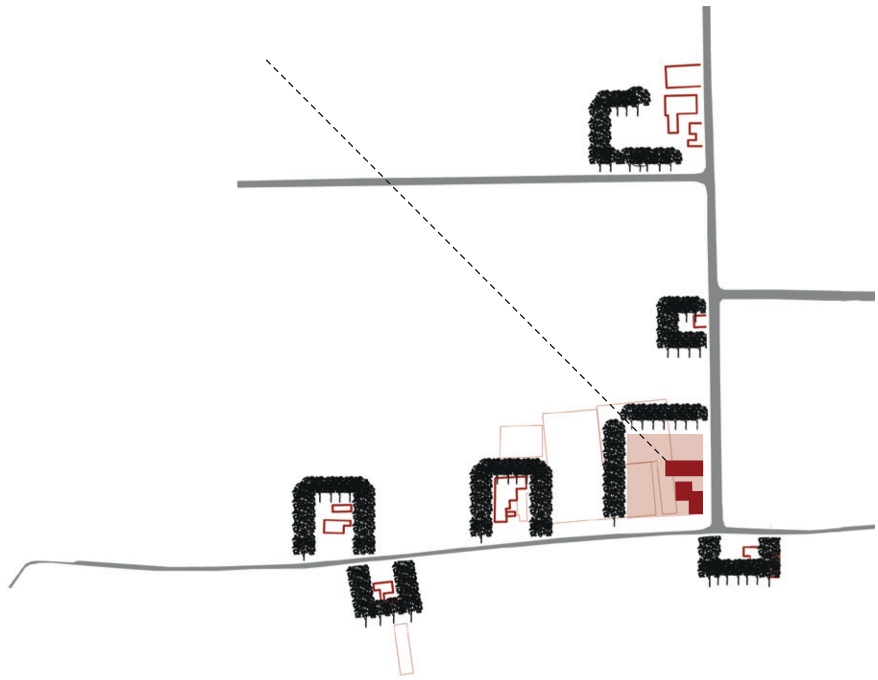
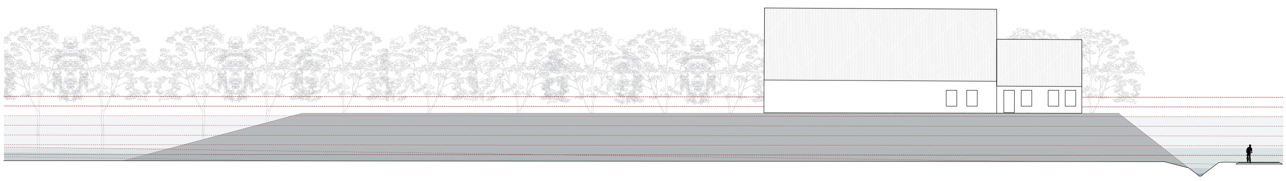
<u>Farm allotment</u>
Farms in the area are recognizable as green clusters in the (half) open landscape. The main house is often positioned perpendicular to the main road. A ditch separates the road from the parcel. A large shed is positioned backwards and is either attaches or detached from the main house. The center is constructed within the confinements of the typical farm allotment.

The farm has at least the following elements:
- Building for equipment 480m2
- Main house and restaurant 600m2
- Testcentre: 1800m2 (re-use of glashouse)
- Total plot about 1,5 ha
- Vegetative edge

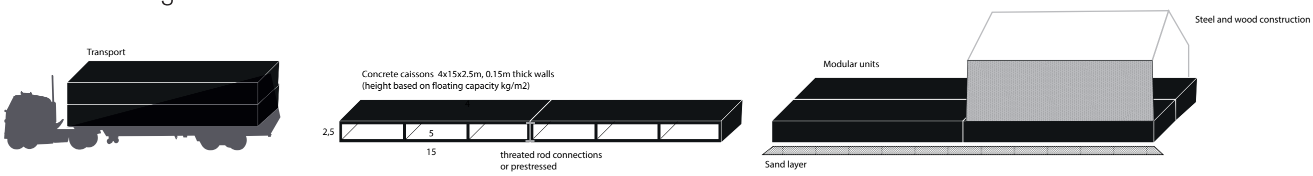

Farm allotment
(Picture made by author)

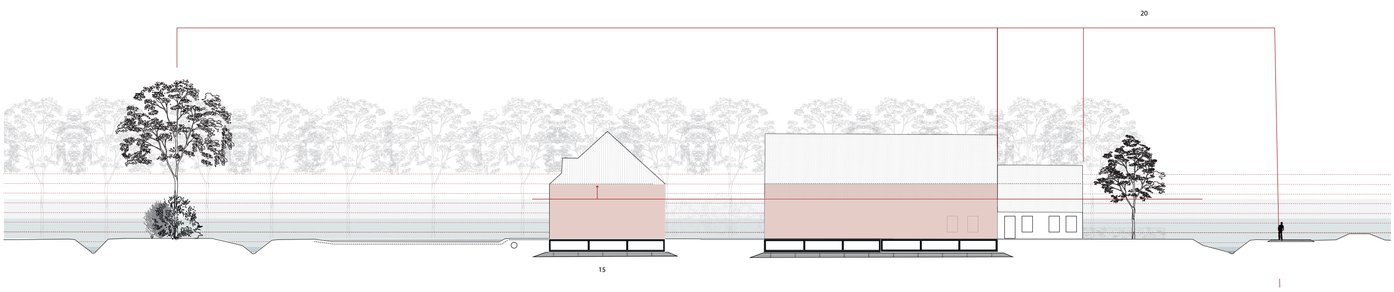


The use of a mound to elevate the new centre would outscale the existing plots



Proposal for floating caissons as a reference to the museum.





(Sections & maps made by author)

Public functions on groundfloor

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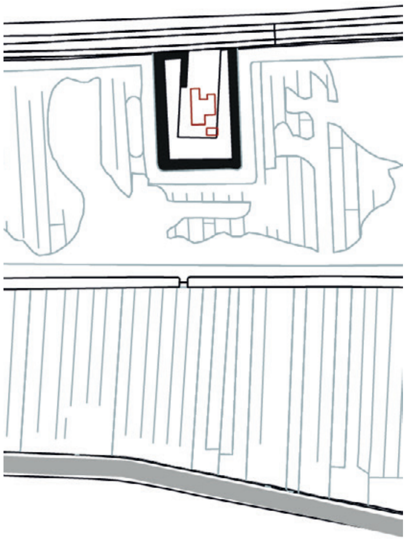
Decomposition of typical elements
To enhance the qualities of the area some typical elements have been decomposed and transformed to accommodate new conditions.

The inlay polder for extensive landbased aquaculture.
It is questioned how the typical industrial character of land based aquaculture can be adjusted to fit in the area. Typical for the island are long ranging stretches of ditches often perpendicular to the dike in the inlay polders. This typology can be linked to spatial structures of aquaculture. Therefore guidelines for the integration of aquaculture are linked to the transformation of the inlay polder typology.

- Use the characteristic structure of the inlay polders with stretching ditches;
- Natural edges instead of industrial edges;
- No basins above ground level, but excavated below the current plain;
- Low hanging nets to maintain the openness of the area.

Inlay polder
(Natuurmonumenten, 2021)



Example inlay polder Zierikzee

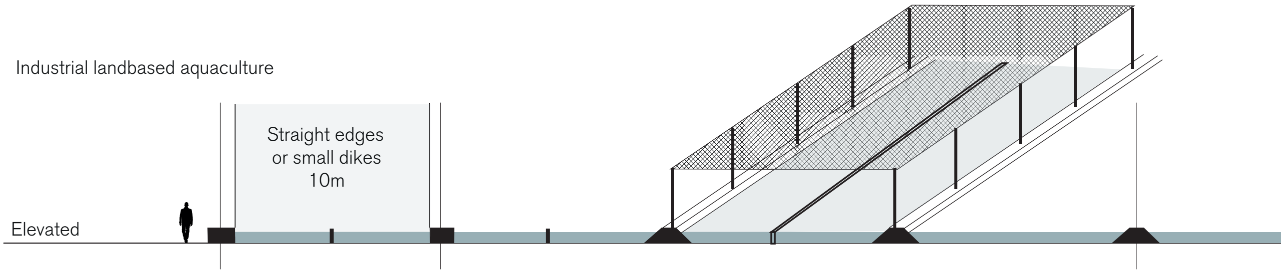
New (floodplain) vegetation:
'Zeeuwse' hedges can be reintroduced or recovered to create hydraulic roughness in case of a breach. These elements emphasize the cultural character and give shelter for the wind. The existing forest will be maintained and monitored.

- The hedges should be positioned alongside main roads;
- Vegetation height should be above normative high-water levels to be effective;
- Vegetation should be planted on elevated ramparts of maximum 0.5m. Vegetation will then have a small freshwater lense and be less affected by salt intrusion;
- The elements can be partially in maintenance by farmers, addressing them as safekeepers (awareness).

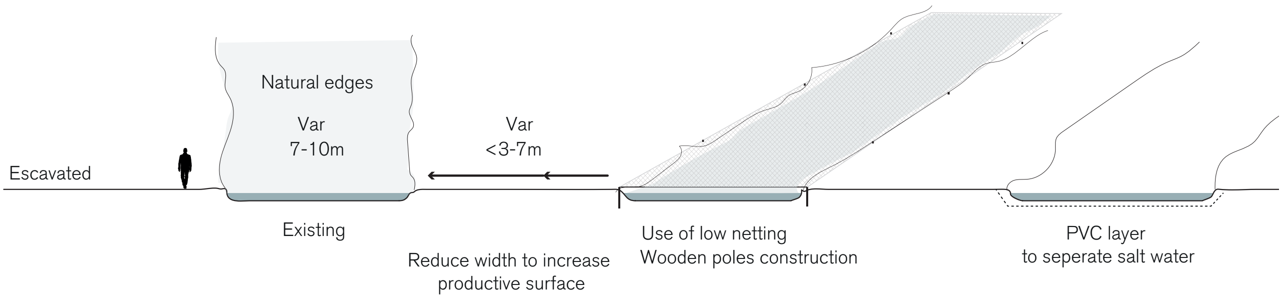
'Zeeuwse' hedges
(Picture made by author)

Typical plantspecies
Hawthorn - Crataegus monogyna
Blackthorn - Prunus spinosa
Dog rose - Rosa canina
Wild privet - Ligustrum vulgare
Guelder rose - Viburnum opulus
Field maple - Acer campestre

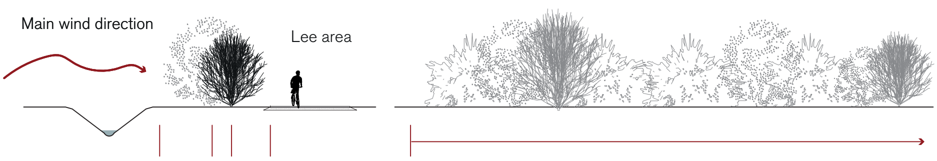
Industrial landbased aquaculture



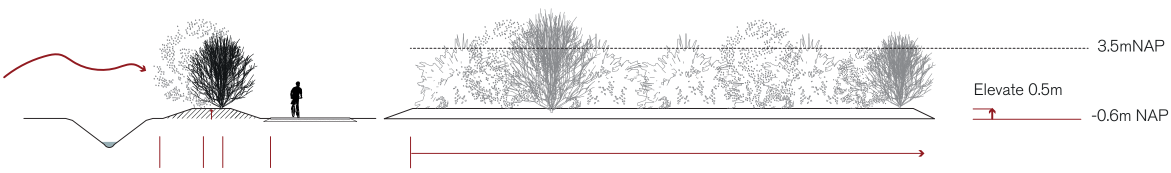
Transformation inlaypolder typology to accomodate landbased aquaculture

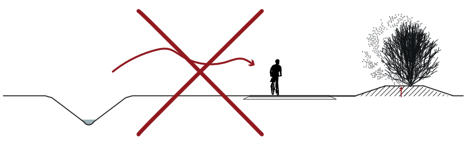


Existing hedges



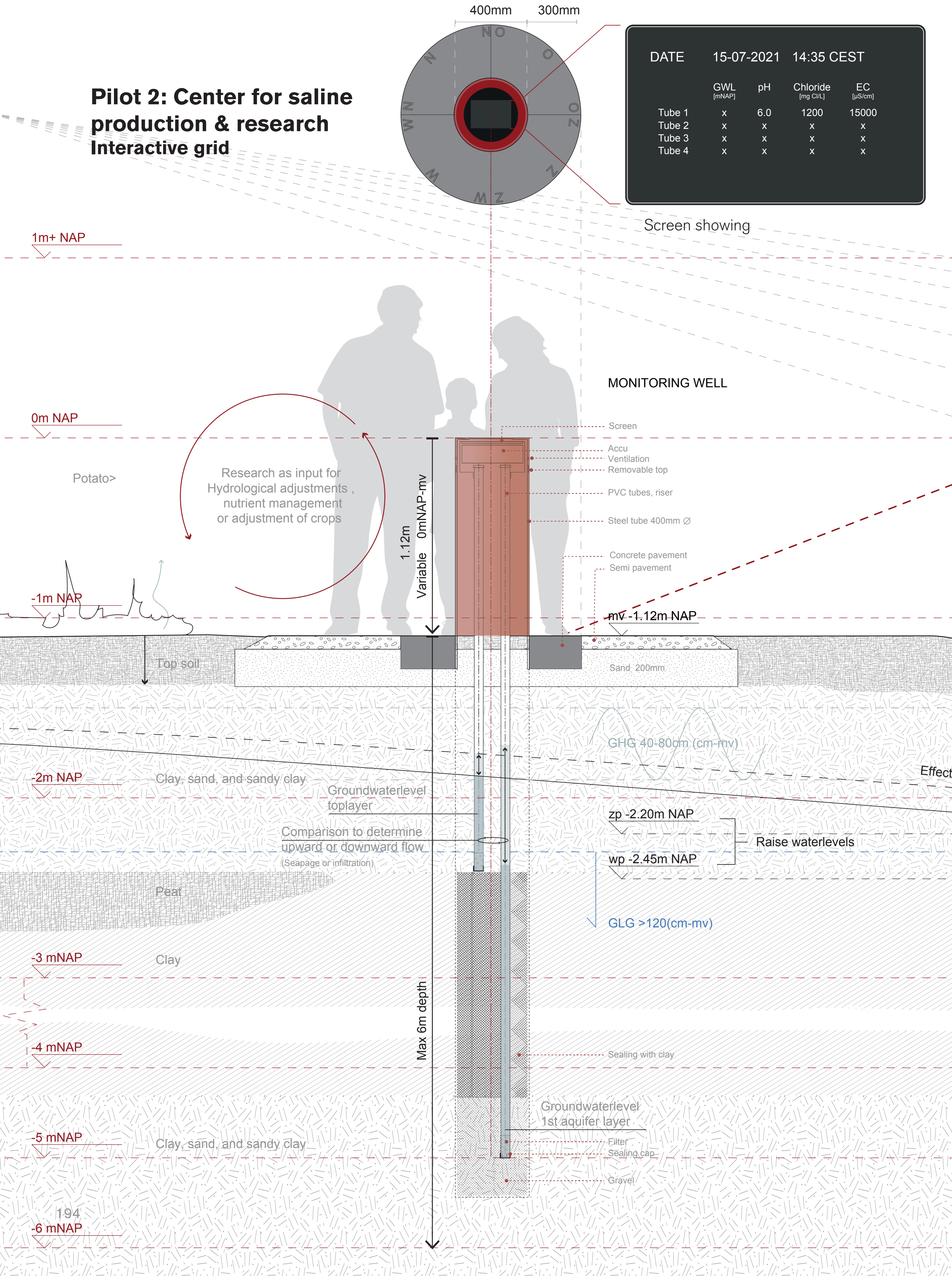
Transformation of the hedge typology

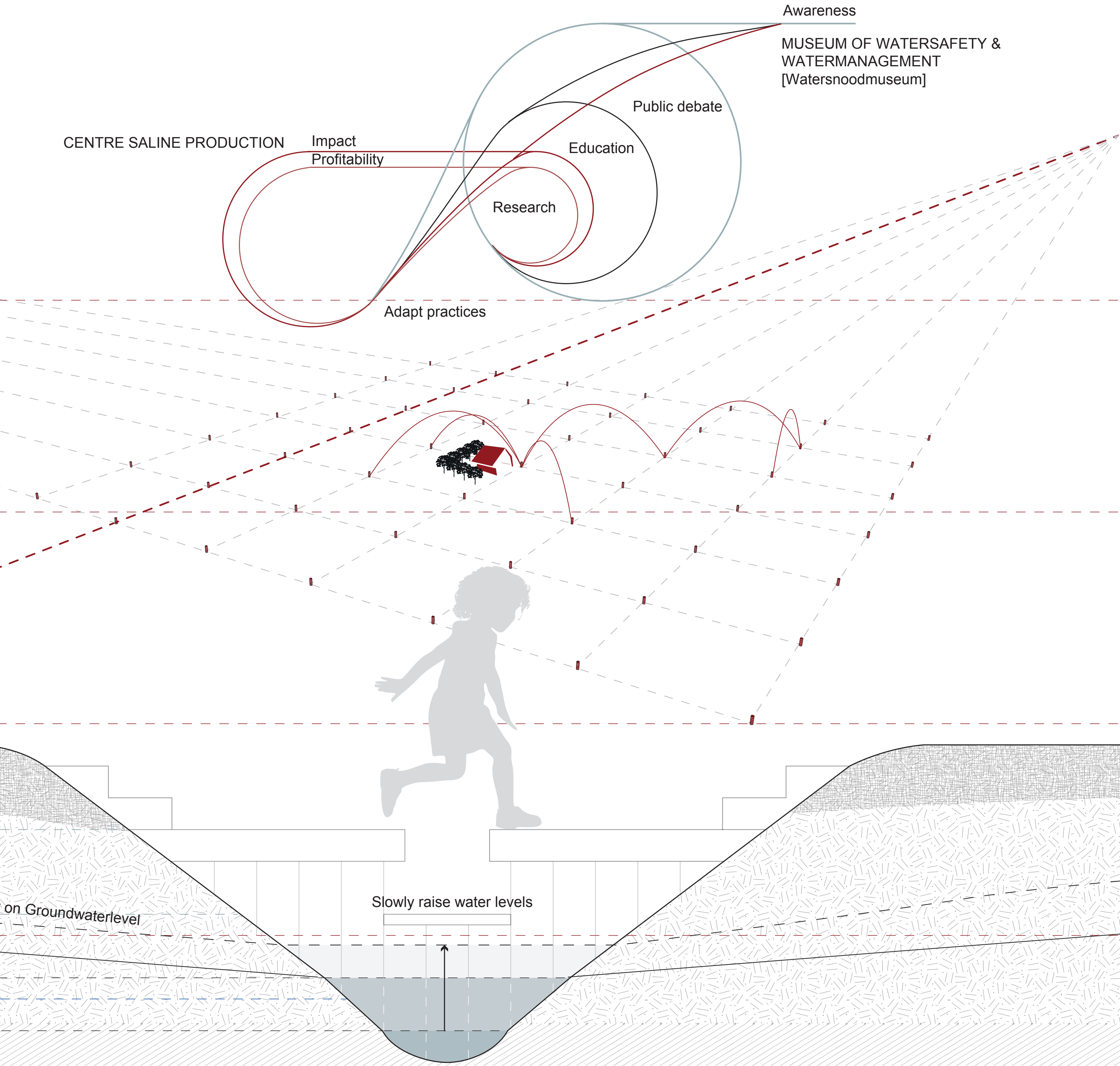




Sections indicating main principles
Made by author

Pilot 2: Center for saline production & research
Interactive grid





Awareness for processes in flood prone areas can be accommodated through (spatial) research, education and initiation of public debates. Two main contributing parties can be the museum of water safety and water management, and a new saline center for agricultural developments in transforming zones.

The points on the grid facilitate a interactive digital monitoring network as a means to analyze hydrofysical parameters of the soil (transport of nitrogen, phosphate or organic matter content) as well as hydrological aspects such as salinity of groundwater in and outside the buffer zone. They are visible as red tubes in the landscape. The red colour of the elements is a representation of the old production of madder, that was used for red colouring. The height of the elements represents the 0mNAP line, as a guideline for people to perceive the territory. The public is most likely to perceive the tubes in different settings, and some can be accessible for the public to read.

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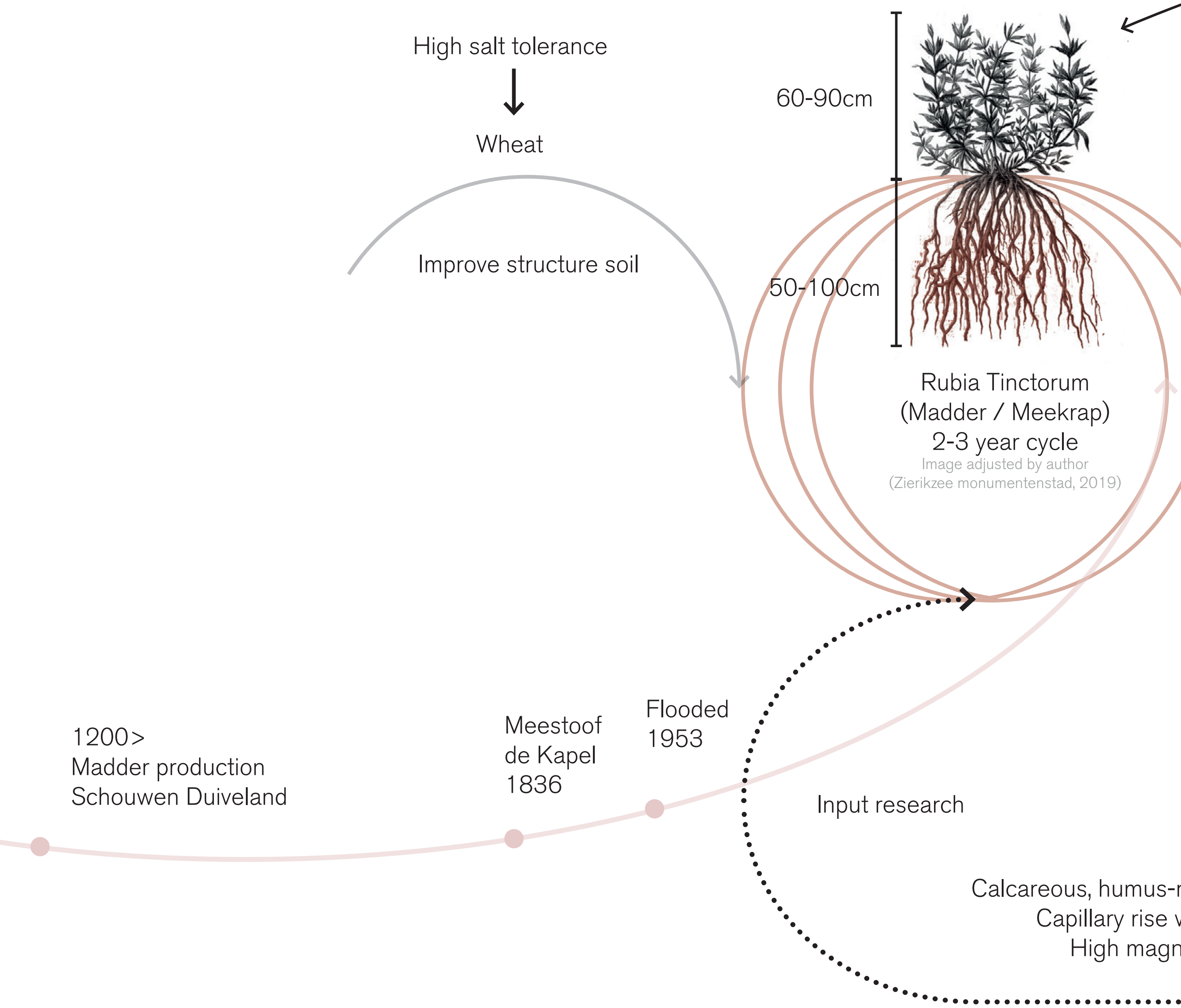
<u>Additional production chain</u>
Possible additional nichemarket that can be explored is the production of Madder. The plant was traditionally cultivated for the use of its roots for red pigment. The production of madder can go alongside with traditional sheep farming practices.



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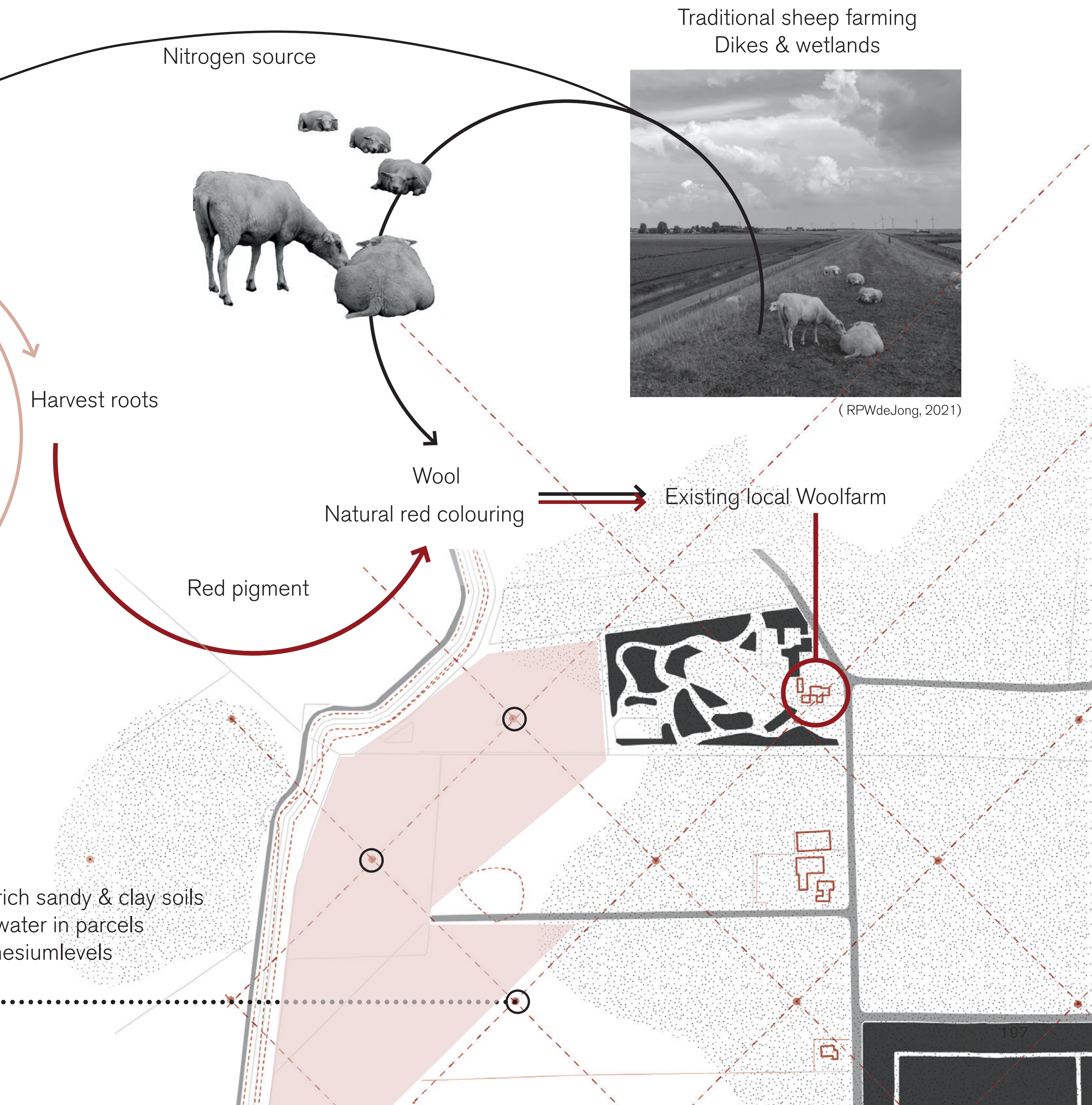

Traditional sheep farming
Dikes & wetlands
Nitrogen source
(RPWdeJong, 2021)
Harvest roots
Wool
Natural red colouring
Existing local Woolfarm
Red pigment
rich sandy & clay soils
water in parcels
nesiumlevels

Pilot 2: Center for saline production & research

Current
The area affected by increased salt intrusion, most probably leading to reduced crop productivity.

2030
A new road will be developed within the gr
as wel as degrade the existing road from r
the waterlevel will be raised as means to n
adjacent polder. Some elevated ramparts v

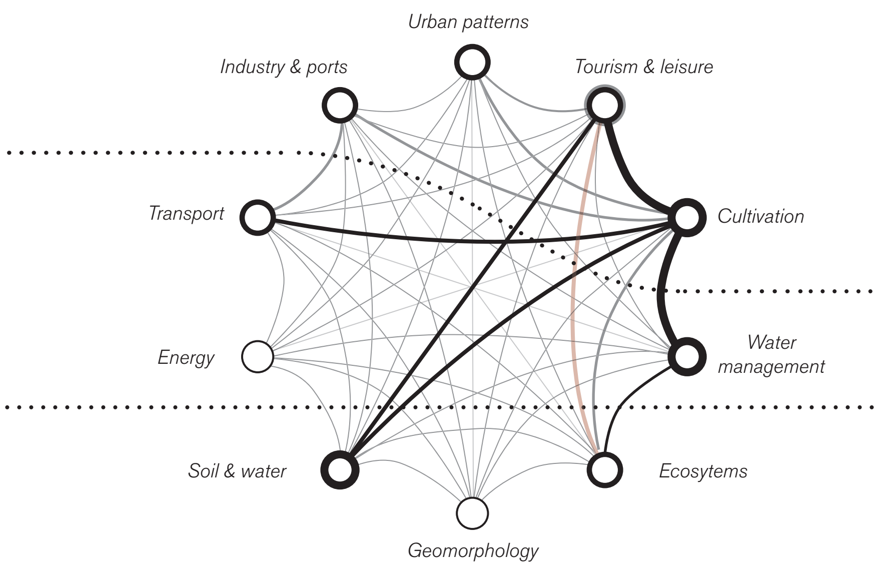
rid as means to seperate watersystems
egional traffic. On the left of the road
ninimize the effect of salt intrusion in the
will be planted.

2050
The saline farm is in function. The salt water from the aquaculture in the inlaystructures is used to irrigate the crops.

Pilot 3: The new floodplain

New developments should contribute to the activation of eco-tourism and leisure, offering exclusive accomodations appropriate for the characteristics of the area. The wetland typology as well as the mound typology typical for Schouwen Duiveland can be transformed in accordance with the main perceived threats. The scale of the interventions as perceived by the audience raises awareness of potential impact. Although the wetlands can initially not function as tidal creeks (the entire area is below the Mean high water level / sand starvation), underwater gradients are added and water levels are slowly raised and hydrological changes are monitored.

The area is perceived as a new floodplain. In this pilot it is questioned what the effect of structural elements can be on water levels and wave energy during a dike breach as means to limit the damaging effect on the sleaper dike as well as the existing infrastructure and farms in the area.

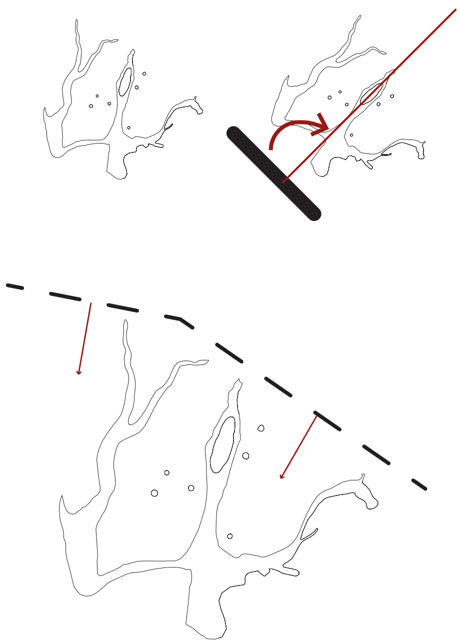


Pilot 3: The new floodplain
Composition

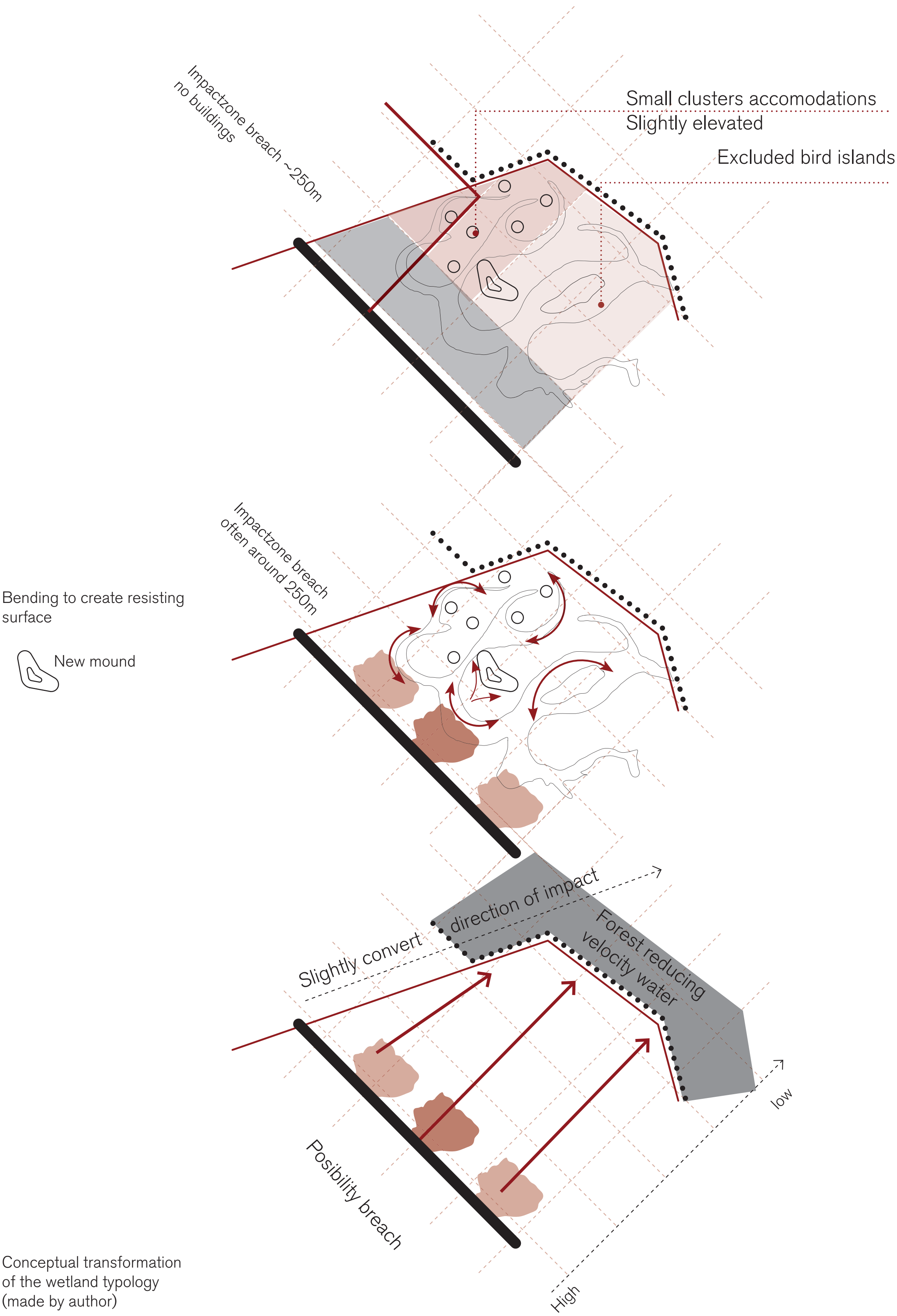
Territory as a new Floodplain
Heights in the new polder range from about -0.20 to -1.5m NAP. When flooded the entire area will therefore filll like a bathtub. The area is therefore perceived as a new floodplain. It is assumed that structural elements, such as vegetation (existing forest, hedges), ramparts (mounds) or wetlands might have a reducing effect on water levels and wave energy during a breach, or steer the initial incomming water, therefore slightly limiting the damaging effects or impact on the sleaper dike during a breach.

Conceptual transformation of the wetland typology
Characteristic for Schouwen Duiveland are wetland developments alongside the Eastern Scheldt. The wetlands often represent creek like structures but are limited accesible, often just observable from the sides.

The existing wetland typology is transformed. Wetlands are rotated to match the main direction of the grid with a slight convertion to the forest following the existing road pattern. Adjacent to the road hedges with ramparts are positioned to slightly convert the initial direction of impact.



Current wetland typology located at Zierikzee
(made by author)

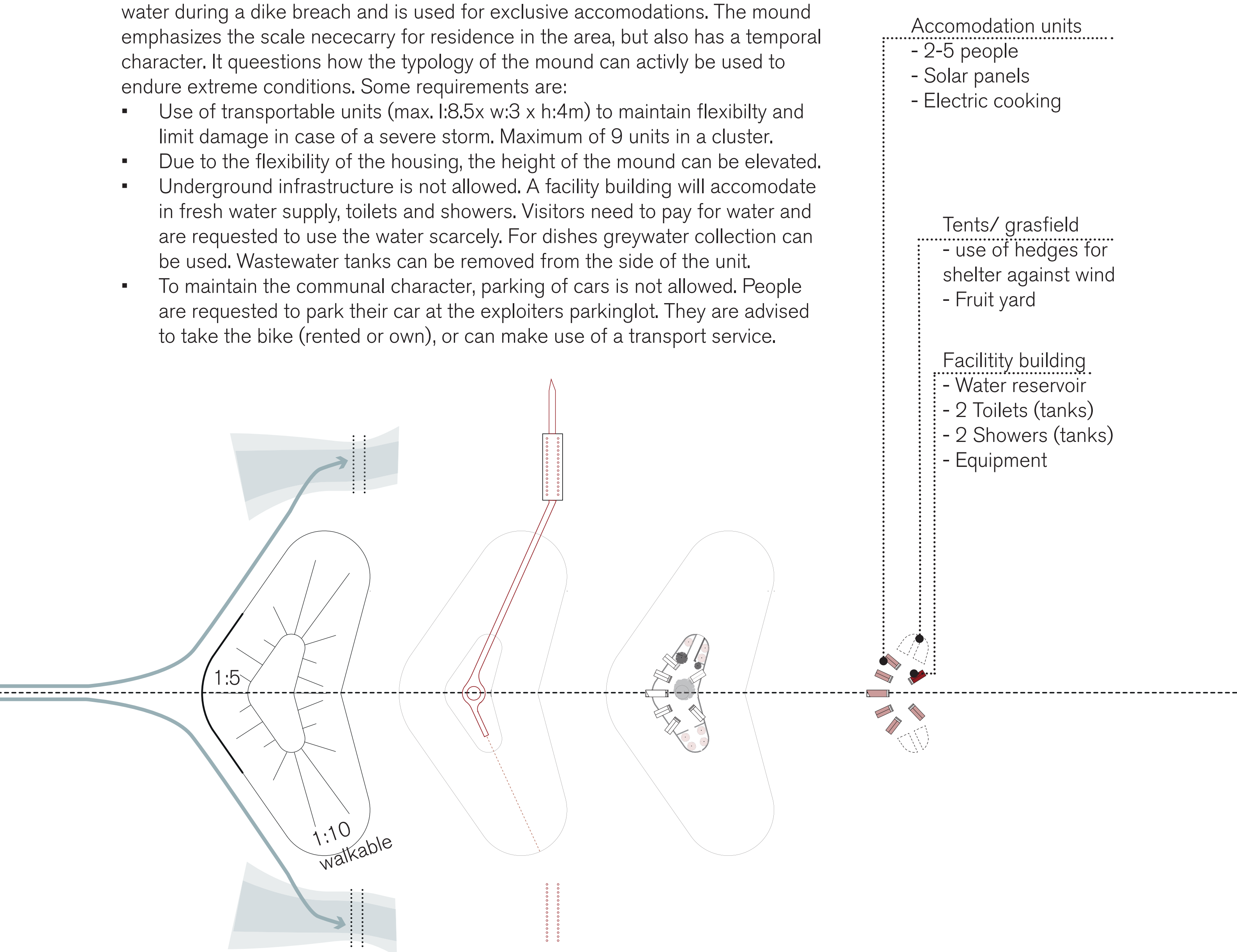


Conceptual transformation
of the wetland typology
(made by author)

Pilot 3: The new floodplain

The existing typology of the mound is transformed as means to actively steer water during a dike breach and is used for exclusive accomodations. The mound emphasizes the scale nececarry for residence in the area, but also has a temporal character. It queestions how the typology of the mound can activly be used to endure extreme conditions. Some requirements are:

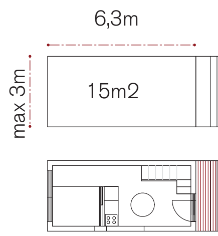
- Use of transportable units (max. l:8.5x w:3 x h:4m) to maintain flexibilty and limit damage in case of a severe storm. Maximum of 9 units in a cluster.
- Due to the flexibility of the housing, the height of the mound can be elevated.
- Underground infrastructure is not allowed. A facility building will accomodate in fresh water supply, toilets and showers. Visitors need to pay for water and are requested to use the water scarcely. For dishes greywater collection can be used. Wastewater tanks can be removed from the side of the unit.
- To maintain the communal character, parking of cars is not allowed. People are requested to park their car at the exploiters parkinglot. They are advised to take the bike (rented or own), or can make use of a transport service.

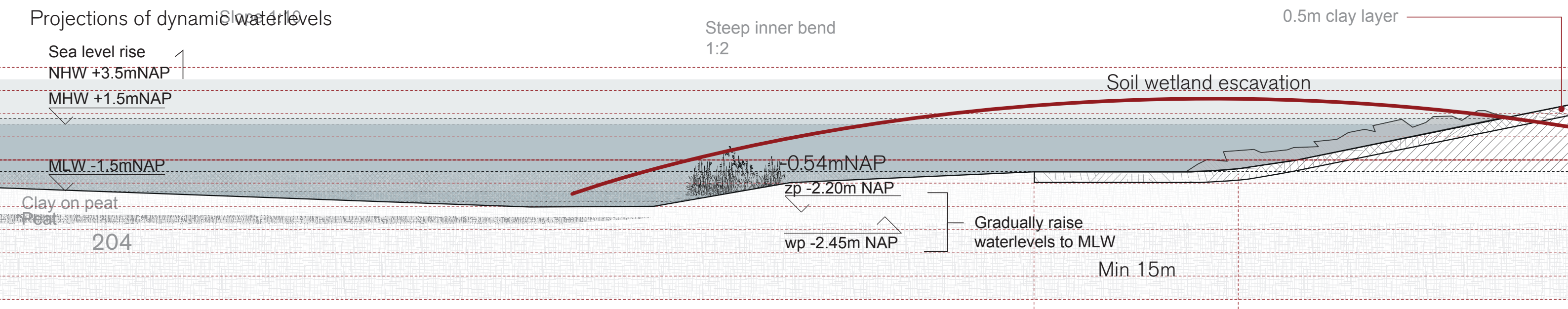


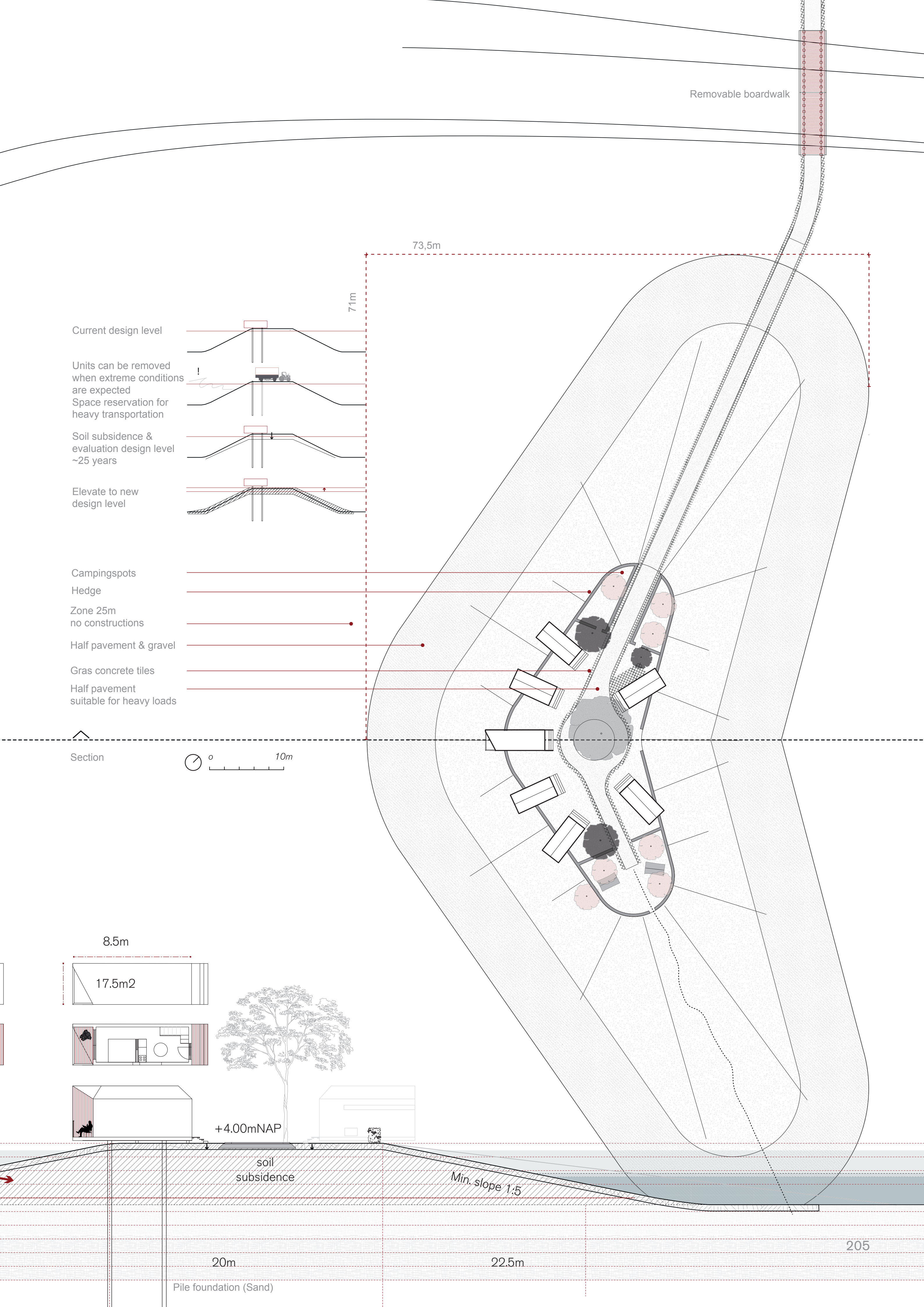
Transformation of mound typology V-Shaped to steer water

Communal square Main route for maintenance & (waste) collection

Units positioned around central square



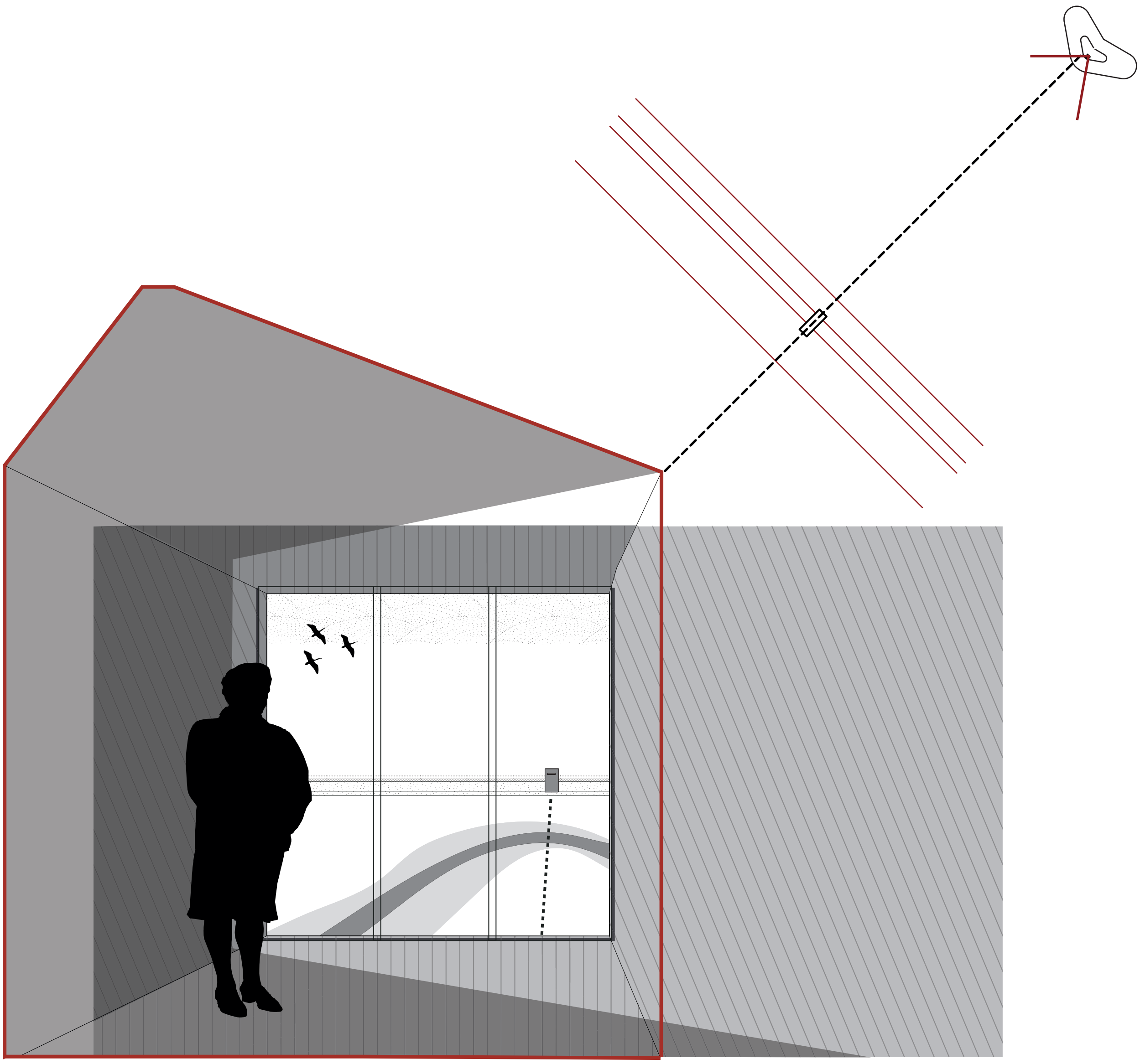



Removable boardwalk
73,5m
71m
Current design level
Units can be removed when extreme conditions are expected
Space reservation for heavy transportation
Soil subsidence & evaluation design level ~25 years
Elevate to new design level
Campingspots
Hedge
Zone 25m no constructions
Half pavement & gravel
Gras concrete tiles
Half pavement suitable for heavy loads
Section
0
10m
8.5m
17.5m2
+4.00mNAP
soil subsidence
Min. slope 1:5
20m
22.5m
Pile foundation (Sand)

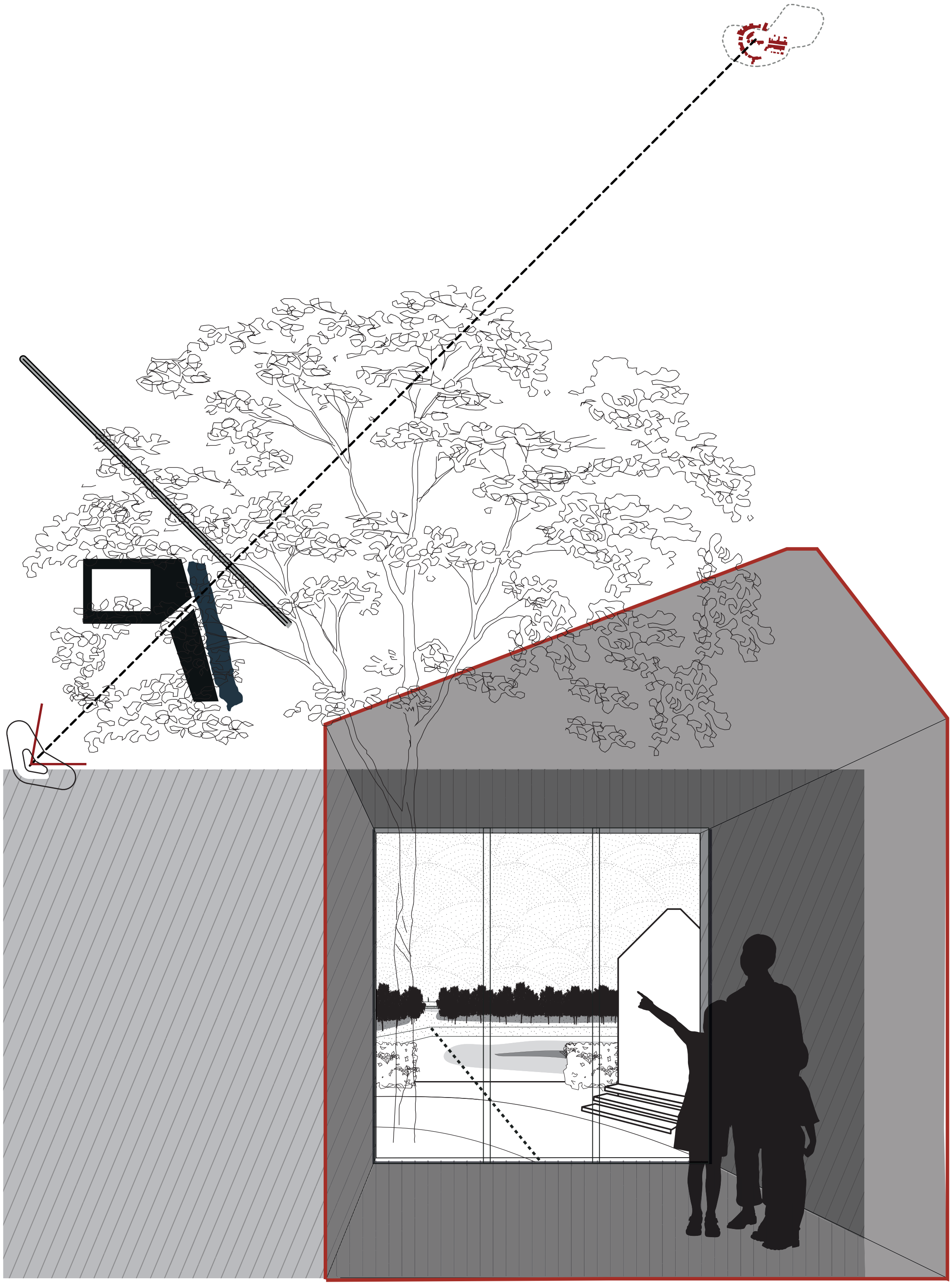
Pilot 3: The new floodplain

Narrative of the waiting land

Accomodations are positioned so people can experience their surrounding. The main accomodation on the mound has an amazing view on two sides. One can caze towards the sea expecting the waiting land to once rejoin, whereas the other side projects to the centre of Nieuwerkerk, offering a backside with the remaining forest within the communal setting of the mound.



Impression view towards the Eastern Scheldt
Image made by author



Impression view towards Nieuwerkerk
Image made by author

Pilot 3: The new floodplain

Current

The area affected by increased salt intrusion, most probably leading to reduced crop productivity.

2030>

Initial parcels are appointed for wetland de
the area will be elevated. The parcels offer
Sheep farming can be used as maintenanc
as on the dikes. The monitoring wells in the
ving the changes of hydrological condition

velopment. Waterlevels in
a lot of water gradients.
e of the wetlands as well
e grid are installed obser-
s.

2050>
Wetlands areas will be expanded using the soil to develop V-shaped mound and smaller elevated areas that can support small clusters of accomodations. These transportable units offer exclusive experience based accomodations within small communal settings. The Adjacent forest will be monitored.

11. Discussion

In this chapter i discuss the outcomes of the project to answer the posed research questions.

11.1 Discussion 1: Analytical analysis

1: What is the possible climatic impact in the Rhine-Meuse-Scheldt delta?
(In other words: which systems are affected?)

2. What are social, economic and environmental drivers for change?

ANALYTICAL

Some of the main affected subsystems of the delta are shown in the scheme below. Different climatic stressors ultimately lead to an increased concern for safety, fresh-water availability and pressured agricultural practices which can be referred to as an economic driver as well as a decline in ecosystem health. It is recognized that adaptive practices are constructed through the layers of substratum, networks and the occupation. On a local scale stressors have been translated in the activation of layers.

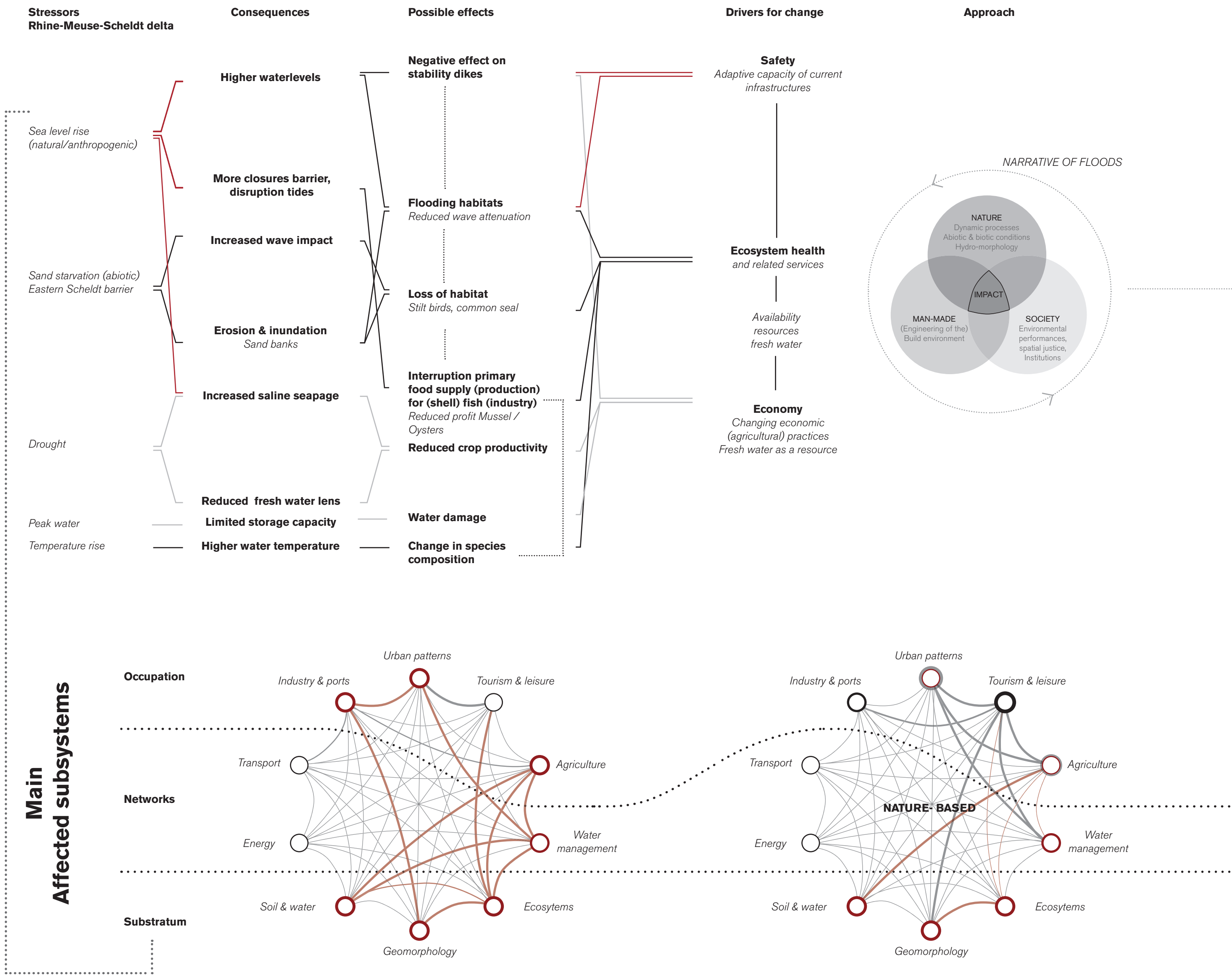


Image11.1 Scheme affected subsystems & translation from stressors to activation of layers
Made by author based on (Meyer et al, 2013, p.122)

THEORETICAL

Discussion 2: Theory

3. What constitutes the adaptive capacity of systems in the delta, and how can this be improved through behavioral, institutional and (bio) physical adjustments?

4. What do theories on climate/flood resilience imply for applied (urban) practices?

Trough theories of Resilience the adaptive capacity can be understood as adjustments through the domains of Society and Engineering. Preparedness, change of economic drivers, and the ability to learn from floods are concerned as key issues through the domain of society. Localized flood response, timely adjustments after floods, and redundancy in sybsystems can be met through the domain of engineering. Although this theory applies to floods, this can also be understood through other climatic stressors, such as salt intrusion and fresh water availablity. Most important therefore is the note for presumed dynamism (acceptance for changes) instead of presumed environmental stability. This reflects on the spatial adaptation of the area. As stated by the Province of Zeeland, spatial adaptation as meantioned in the Deltaprogramm concludes that a dike breach cannot be ruled out complete, therefore parties should note this in order to prevent large scale damage (Provincie zeeland, 2021). Translated to applied adaptive practices this has been linked to nature-based solutions.

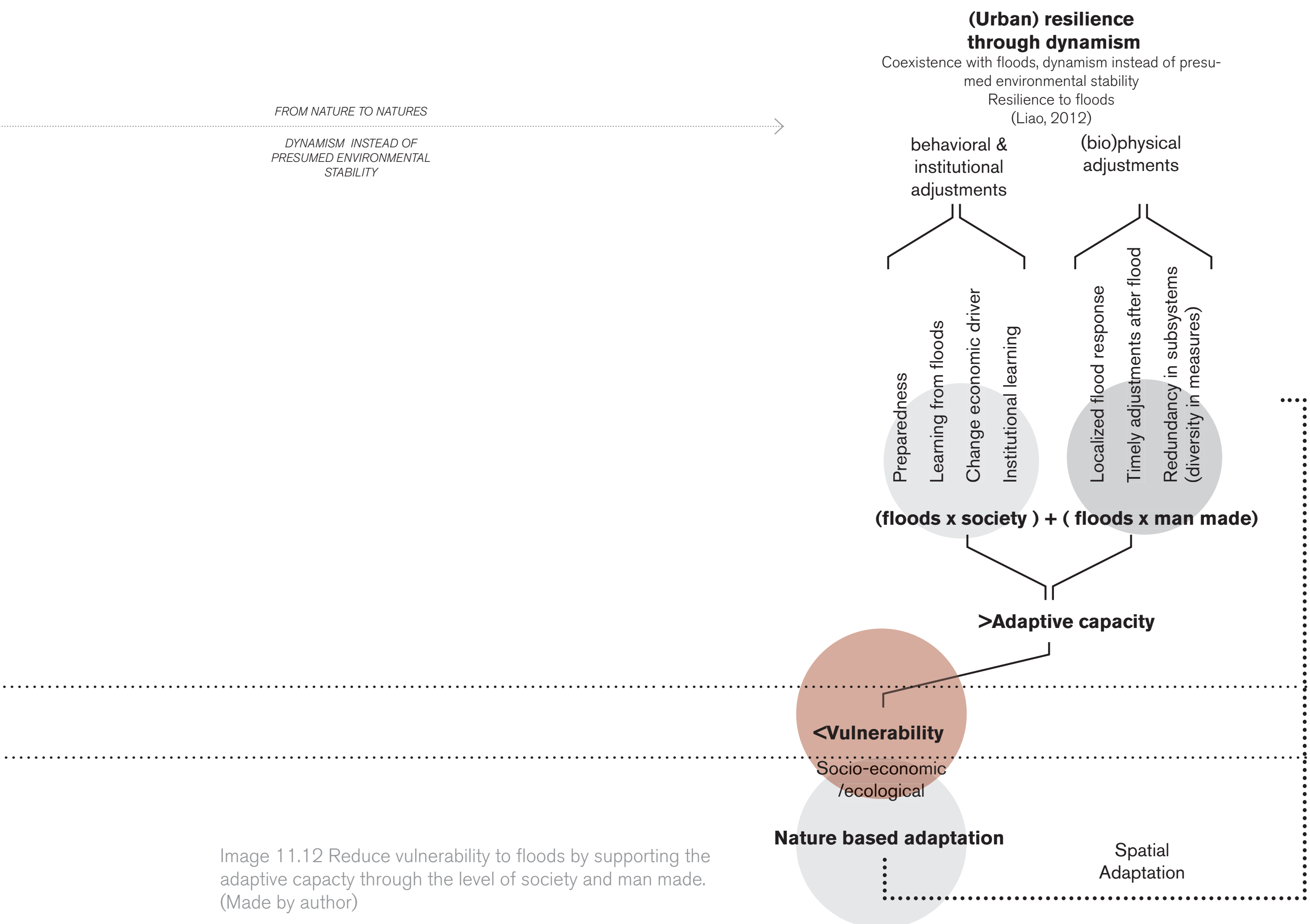


Image 11.12 Reduce vulnerability to floods by supporting the adaptive capacty through the level of society and man made. (Made by author)

Discussion 3: Applied

APPLIED

5. How can nature-based solutions be applied in order to contribute to (urban flood) resilience?

Main concern for application of nature-based solutions is the solution space through which they can be applied, and the frame through which choices can be made and supported. Therefore, a choice model has been developed as tool in which nature based solutions are opted as preferred options.

The initial question of the choice model is, are there one or more combined stressors that might stress flood probability? This question serves three purposes. Firstly, it prioritizes areas that might be more prone to floods, making it easier to support a case based on the issue of water safety. Affected stakeholders might therefore be more willing to engage. Secondly it states some of the conditions under which measures also need to be effective. Thirdly the question assumes that that conditions might change over time, and therefore the output can change.
The second question relates to the space availiability in the area, either landwards or seawards or by consolidation of the line. The choice model does not exclude consolidating approaces, but mainly prioritizes nature based solutions when the solution space allows.

<u>Implementation on a local scale - activation of economic drivers</u>
Additional to the choice model it became apparent that for the area to adapt a trademark was necessarry to activate the layer of tourism and leisure as supportive economic driver. The given trademark for ecotourism stems from an increased need for additional exclusive accommodations on the island of Schouwen Duiveland, linking this to the experience of the narrative of floods (mounds, creeks) as well as new Saline practices to support the productive character of the island.

<u>Perceivance of the territory as a new floodplain</u>
To raise awareness to floods, as well for the impact of climatic stressors on traditional agriculture, developments are directly linked to visualizing adaptive practices in these fields (the vulnerability as driver for change). The perceivance of the new territory as a new floodplain, and creation of visual cues as well as interactive elements help the spectators recognize a possible scale of impact.

It is questioned what will happen during a dike breach, and in what way localized responses can be used to limit initial damage. The spatial composition of existing typologies (mound, inlaypolders, creeks, farm allotments) have therefore been translated into contributing elements through the understanding of their ecosystem services in flood conditions. The diversity in measures aim to contribute to the adaptive capacity while also enhancing the local characteristic elements.

To accommodate in the debate of adaptive practices helpfull institutions such as the museum of water safety, as well as a new research institute can serve as a platform to support institutional learning. Since the museum already supports in the debate this quality is upscaled and the area is used as a life performing research area.

It was concluded that to maintain a certain degree of interaction between the activated layers, programmatic organization of zones was necessarry to exclude negative externalities.

Image11.13
Dike trajectory de Val Ouwerkerk
(Picture made by author)

Image 11.2 Diving location
(Picture made by RPW de Jong)

11.2 Conclusion

How can a nature-based approach be used to support the adaptive capacity of the Rhine Meuse Scheldt delta and mitigation of altered future climate conditions, while meeting multiple environmental, ecological, social, and economic objectives to support its inhabitation?

The inclusion of a nature-based approach operates on different levels.

<u>Assessment of stressing factors & decision-making process:</u>
A nature-based approach can support the adaptive capacity of the Rhine Meuse Scheldt delta through the construction of a frame for decision making in which nature based solutions are prioritized.

<u>Development of an adaptive framework:</u>
As means to structure proposals an adaptive framework has been developed on the scale of Schouwen Duiveland to assist in maintaining the existing qualities of the island, as well as selecting and excluding a solution pathway based on the systemic functioning of the island.

<u>Local adaptation of spatial typologies:</u>
Adaption of local spatial typologies, such as the mound, inlay polders, or creeks, can support ecosystem services related to floods as well as other stressors while maintaining and improving the spatial qualities of the area. Behavioral and institutional adjustments can be linked to cultural services such as cultural heritage (narrative of floods) to activate a sense of place, education (water safety and water-management, as well as ecotourism (esthetics). Biophysical adjustments are linked to regulating and provisioning services (fresh water & saline crops) as well as supporting services. Perceiving the area as a new floodplain helps to support the narrative of the island.

12. Reflection

In this chapter i will reflect on the preliminary results of the research and design, questioning the overall effectiveness of the approach and methods as well as the applicability of the project and its limitations.
It also exposes the personal journey through which i developed the project.

12.1 Research & design

Personal process

The project has been a journey in which I have had to give new priority to my physical and mental health. The impact of my dropout during the process was a wakeup call to find more balance and to monitor my personal conditions more actively. A challenge, especially during an ongoing graduation phase, in which the initial personal stressors were at a constant re-appearance. This period has given me some tools to work on a balance, but it still requires daily adjustments and acceptance.

The physical impact on my ability to concentrate and make choices were intense. I can only describe it as a constant fog in my head. Never before has it been so difficult to monitor, convey, organize and adjust my own ideas, simply losing myself in detail. Day by day i work on regaining confidence in myself, as it initially felt like a loss of strength. However, as is the case with the Eastern Scheldt, i believe that that in order to become more resilient as a person, i have to work on a more adaptive version of me. I might never go back to the person i was, but i believe it was not the best version of me.

Image 12.1 Dike Bruinisse
(Picture made by RPW de Jong)

Research & design

The relationship between research and design

Whereas the initial research focused on nature-based adaptation as a main approach for the project, the design phase required the development of a 'choice model' to frame the extend and type of measures that are deemed necessary to facilitate transition accommodating two main goals, namely water safety and freshwater supply. Preconditions of the Eastern Scheldt system were used as indicators to determine urgent locations for water safety, requiring short-term interventions. Additionally, factors related to space availability, and the presence of foreland determine whether initial developments go landwards, by the establishment of buffer zones and an indication of its potential use, seawards (sand nourishments, ecosystem engineers, or rich revetments), or by consolidating the line through adaptive dike concepts.

Spatial planning, urban design, and landscape architecture

In the context of the Rhine-Meuse-Scheldt delta, fair urban developments require attention to two main issues stressed by climate change, namely: safety to floods and freshwater supply. Whereas developments in highly urbanized metropolitan areas such as Rotterdam are not questioned to be part of urban practices, (limited space requires optimal planning), also predominantly rural contexts require alignments of interests and new infrastructures to accommodate an adaptive framework. The project is therefore shifting through practices of spatial planning, urban design as well as landscape architecture. Pressure is not always the availability of space, but the different interest in space, and avoidance of maladaptive practices that might result in reduced future pathways. Specifically, in the context of an island, such as Schouwen Duiveland, it becomes of relevance to sustaining long-term independence of critical resources (such as freshwater) and accommodation of changing economic drivers. Interests need to be aligned with local strategies to accommodate an optimal frame to transition while maintaining or improving the availability of these resources. Regional (urban/rural) developments in the context of climate change, therefore, require tuning with the specific opportunities of the given biotic, abiotic (hydrogeomorphic), and cultural conditions of the Eastern Scheldt. Hence the initial choice model is focused on assessing the initial preconditions.

12.2 Methods & approach

Managed retreat as a circular form of land use

The project perceives managed retreat as a circular form of land use, acknowledging the fact that changing stressors will adjust the territory. Something that has been further explored through the inquiry of flux, erasure, and terraforming in the Transitional Territories studio. The shift from defensive to more dynamic mode is projected in the hierarchy of the choice model and focus on nature based solutions as opposed to concepts for consolidation (a.o. adaptive dike concepts).

The fascination for a choice model as a method for decision making reflects on the capacity that the outcome of the model is changing over time, given that the input (the stressors as well as the preconditions of the territory) will change. It can also be modified according to a different approach or perspective.

Transferability of the projects results

Choice model:

The choice model has been used as a tool to facilitate a possible strategy for the Eastern Scheldt and zoom-in locations for the island of Schouwen Duiveland. Additional information and perspectives from stakeholders or researchers and governance can on its turn improve the model. Translated the model can also be applicable in other areas, to accommodate a structure for decision-making. In the end, the questions reflect on a certain hierarchy of decision points. If not framed through a nature-based approach the choice model can be changed accordingly.

Introduction of a grid:

The introduction of a grid system for the composition of the area has been specifically tuned into the concept that the programmatic organization should be linked to main stressing factors, as well as providing a systemic approach for saltwater research on a large-scale territory. Its concept can be of interest to the development of other areas but should be tuned to local conditions.

It can be questioned how rigidly the concept of a grid should be used for the organization of a territory. It is recognized that a grid might elude other options, however it also offered a way of perceiving the territory from a different perspective. The grid is the architectural layer that allows to show direct or indirect relations, other than what can be perceived based on the existing composition of the area.

12.3 Significance & innovation

Ethics and dilemma

Territories in transition encounter the struggle with the repurposing of land-sea zones based on stressing climatic factors. Specifically areas with limited demographic growth (Zierikzee, Bruinisse), and shrinking communities that dominate the predominantly rural areas of Schouwen Duiveland, marking it as an 'anticipation region'. New (urban) developments, and financial resources, might therefore be limited. Initially, the carrying capacity to initiate change appears to be forced from the 'water safety assignment' and incentives on governance level. However this somehow also eludes adaptive practices on a lower level. Specifically vulnerable for instance are land based farmers. The static requirements of their current practices simply don't align with the expected changes. However, the profitability of saline agriculture is still highly questionable.

Contradicting to the agricultural use is a possible necessity to compensate natural areas. Ecological decline, as a result of drowning sandbanks, can merely be mitigated through initial maintenance of foreshores by sand nourishments, and the use of ecosystem engineers. However anticipated compensation of these areas on the long term is critical to maintain future biodiversity. It is therefore critical to represent a voice for the benefit of biodiversity. Buffer zones can, over time, transition and become new intertidal areas. The research and design aimed to find alignments with nature, saline production, and recreational shared use.

It can be argued that the island has a limited capacity to facilitate recreation, and peaks throughout the year make it a very seasonal sector. This stressed a search for combined economic drivers that can be supported throughout the year.

Resources: Time and a higher level of awareness

The project aims to win important resources, namely time and a higher level of awareness. The acceptance that floods might simply occur in the future translated the project into the discussion of how to support a frame for managed retreat. Initial spatial concepts might be able to contribute to the awareness of floods as a natural occurrence. The main issue can be the inability of people to perceive new potential qualities, as opposed to the possible loss of land. The possible spatial outcomes of transition might be able to support the carrying capacity of new developments, by showcasing possible trajectories or open a platform to a discussion as of the scale and timeframe of interventions.

What is the future of these areas after 2100?

Although the project is a projection until 2100 the question maintains what the future of these areas will be after 2100. When the sand deficit will not restore in the Eastern Scheldt, the concept of a slibmotor in the bufferzone will not be effective. It can be assumed that the Vierbannen polder will therefore eventually be flooded. This should also be stressed in urban practices. It is not a question if it will flood, but mainly when it will flood.

Image 12.3
Sustainable development goals
Modified by author based on
(United nations, 2021)

Sustainable development goals
The project works through levels of society, economy and environment, addressing several of the stated goals by united nations.

Society:
[Climate action, Sustainable cities and communities, Partnerships for the goals]

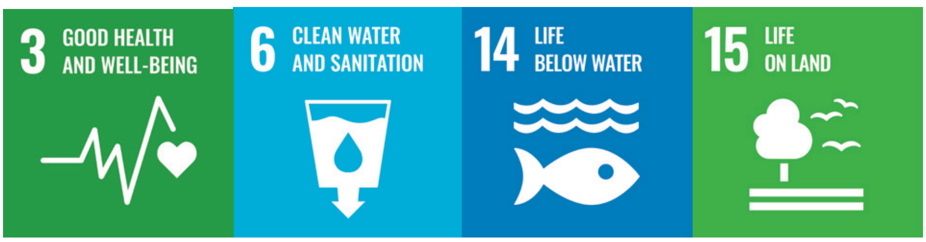
Economy:
[Quality education, Decent work and economic growth , Industry, innovation and infrastructure, Responsible consumption and production]

Environment:
[Good health and well-being , clean water and sanitation, life below water
life on land]

SOCIETY

ECONOMY

ENVIRONMENT



12.4 Evaluation

Feedback & response
A highly analytical and technical approach towards the project initially limited the creative input to establish an architectural intervention. I easily lost myself in details. In part i recognize the perfectionist in me trying to understand and include everything, leading to a difficulty to prioritize parts of the project. I also recognize the difficulty in finding suitable ways of communication. So underrated is the importance of simply talking to peers, looking at their work discussing and drawing together. It gave me much more appreciation for the simple moments at the faculty, put also made me realize i had to search for new ways to structure my own thoughts to not lose myself in them.

An essential question for this project was: Can the project be considered an urban project? To this i answer yes. The choice to continue in urban design from my background in landscape architecture does not lie in the fact that I think I think it is essentially a different profession. I recognize the separation as a way to more easily distinguish bodies of knowledge. However, my personal belief is that we are an intrinsic part of a large system (from nature to natures). All choices regarding the design and planning of the built and unbuilt environment have a direct or indirect effect on the performance of the entire system. Part of my choice for Transitional territories was therefore also a personal development about the meaning of a “territory”. I initially wanted to show this with through my key notions: multi temporalities & performance, Palimpsest and from Nature to Natures. Similarities of the work on a territory are in fact that they underlie the elements of time and change, the mutual dependency for their performance, and the fact that rewritable ideas and concepts determine their appearance (palimpsest). We shape conditions through which a territory can perform.

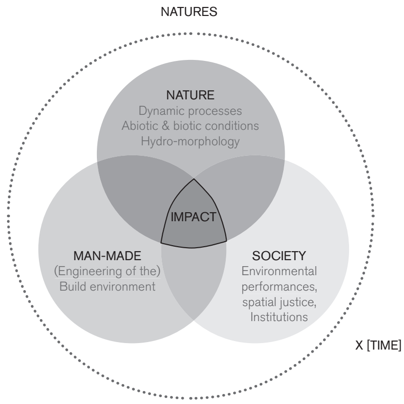


Image 12.41 Diagram showing the domains of the project.
(Made by author)

Limitations & recommendations
Framing the problem field:
Climate change induced hazards are a broad topic. Different types of hazards can therefore pose a threat to the delta. Due to the complexity and specificity of each hazard, the project mainly focusses on floods. This allows for a more indepth analysis on flood phenomena, and its related actors.

Fresh water integration in Choice model:
It can be concluded that the integration of the freshwater issue in the choice model can be improved. The choice model mainly focuses on the outcome based on water safety as the main issue, and improvement of freshwater availability is mainly addressed as an option landwards. It has been questioned to create a separate model to address the freshwater issue, however, this might exclude the negative impact of other interventions on the freshwater conditions. For instance, managed retreat can lead to higher salt loads further inland. Therefore, a recommendation for future research could be to investigate the impact chain between fresh and saltwater systems.

Image 12.42
(Picture made by RPW de Jong)

References

(Abma, R., Brouwer, J., Tangelder, M., Wiersma, A. (2014). *Sustainable scenarios for the Southwest Delta based on Building with Nature strategies.* Retrieved 01-2021, from: https://library.wur.nl/WebQuery/wurpubs/fulltext/317873

Abram, S. (2014). The time it takes: Temporalities of planning. The Journal of the Royal Anthropological Institute, 129-147. Retrieved September 3, 2021, from http://www.jstor.org/stable/43907802

Allen, S.T., Stagg, C. L., Brenner J., Goodin, K. L., Faber-Langendoen, D., Gabler, C.A., Ames, K.W. (n.k.). Chapter 2. *Ecological Resilience Indicators for Salt Marsh Ecosystems.* Retrieved 01-01-2020, from: https://www.natureserve.org/sites/default/files/chapter_2_-_salt_marsh_indicators.pdf

Alexander, D.E. (2013). *Resilience and disaster risk reduction: an etymological journey. Natural Hazards and Earth System Sciences.* 33(11): 2707-2716. Retrieved, 24-11-19, from: https://www.researchgate.net/publication/307810633_Resilience_and_disaster_risk_reduction_an_etymological_journey

Bélanger, P., & Williams, R. (2016). *Landscape as infrastructure : A base primer.* Abingdon, Oxon: Routledge. (2016). Retrieved November 3, 2019, from: https://www-taylorfrancis-com.tudelft.idm.oclc.org/books/9781315629155

Berkes, F., Colding, J., & Folke, C. (2003). *Navigating social-ecological systems: building resilience for complexity and change.* Cambridge: Cambridge UniversityPress.

Berkes F., C. Folke, eds. (1998). *Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience.* Cambridge, UK: Cambridge Univ. Press.

Climate Change Post (n.k.). *Coastal erosion United kingdom.* Retreived from: https://www.climatechangepost.com/united-kingdom/coastal-erosion/

Colten, C., & Sumpter, A. (2009). *Social memory and resilience in new orleans. Natural Hazards : Journal of the International Society for the Prevention and Mitigation of Natural Hazards.* 48(3), 355-364. doi:10.1007/s11069-008-9267-x

Costanza, R., D'Arge, R., De Groot, R., Farber, S., Grasso, M., Hannon, B., Van den Belt, M. (1998). *The value of the world's ecosystem services and natural capital.* Ecological Economics, 25(1), 3-15. doi:10.1016/S0921-8009(98)00020-2. Retrieved, 20-11-2019, from: https://www.researchgate.net/publication/229086194_The_Value_of_the_World's_Ecosystem_Services_and_Natural_Capital

Delta Alliance. (n.k.). *Rhine-Meuse Delta.* Retrieved from: http://www.delta-alliance.org/deltas/rhine-meuse-delta .

Dam, van, P..J.E.M. (2012). *Denken over natuurrampen, overstromingen en de amfibische cultuur.* Tijdschift voor waterstaatsgeschiedenis 21 (2012). Webversie 2014. Retrieved 20-11-19, from: http://www.jvdn.nl/Downloads/WG/2012/TWG2012_01-10.pdf

Davoudi, S. (2012). *The legacy of positivism and the emergence of interpretive tradition in spatial planning.* Regional Studies, 46(4), 429-441. doi:10.1080/00343404.2011.618120

Davoudi, S., Brooks, E., & Mehmood, A. (2013). *Evolutionary resilience and strategies for climate adaptation.* Planning Practice & Research, 28(3), 307-322. doi:10.1080/02697459.2013.787695
De Hoog, M., Sijmons, D. & Verschuuren, S. (1998a). *Laagland. HMD (Het Metropolitane Debat) – Herontwerp: Amsterdam.*

den Biemand, J., Groeneweg, J. (2017). *Hydraulische Belastingen Oosterschelde - Wettelijk Beoordelings-instrumentation 2017.* Retrieved, from: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwiRqcvd6O_yAhVKgf0HHYtHABQQFnoECAUQAQ&url=https%3A%2F%2Fwww.helpdeskwater.nl%2Fpublish%2Fpages%2F157094%2F1230087-006-hye-0001-r-hydraulischebelastingenoosterschelde_def.pdf&usg=AOvVaw1jMLw_4S-7vAG6PVN-5PFy-

de Ronde, J.G. , Mulder, J.P.M., van Duren,L.A., Ysebaert, T. (2013). *Eindadvies ANT Oosterschelde.* Retrieved 07-01-2020, from: https://www.commissiemer.nl/docs/mer/p25/p2595/2595-052eindadvies-ant.pdf

Deltacommissie. (2008). *Samen werken met water-Een land dat leeft, bouwt aan zijn toekomst.* Retrieved from: http://www.deltacommissie.com/doc/2008-09-03%20Advies%20Deltacommissie.pdf

Dolman, M. ,Jukema, G. & Ramaekers, P. (2019). *De Nederlandse landbouwexport in 2018 in breder perspectief.* Retrieved 11-01-2020, from: https://www.rijksoverheid.nl/documenten/rapporten/2019/01/18/de-nederlandse-landbouwexport-2018-in-breder-perspectief

Doyle, A. (2016). *Operationalizing resilience within Urban planning – Bridging Theory and Practice. plaNext – next generation planning.* 3: 101-113.doi:10.24306/plnxt.2016.03.007

Estrella, M. and Saalismaa, N. (2013). *Ecosystem-based disaster risk reduction (Eco-DRR): An overview.* In: Renaud, F.G.; Sudmeier-Rieux, K.; Estrella, M.; Nehren, U. (eds.) 2016: Ecosystem- Based Disaster Risk Reduction and Adaptation in Practice. Springer, pp. 26-54

GIZ. (2018). *Climate Risk Assessment for Ecosystem-based Adaptation - A guidebook for planners and practitioners.* Retrieved, 18-11-2019, from: https://www.adaptationcommunity.net/wp-content/uploads/2018/06/

giz-eurac-unu-2018-en-guidebook-climate-risk-asess-ment-eba.pdf

Geange, S., Townsend, M., Clark, D., Ellis, J., & Lohrer, A. (2019). *Communicating the value of marine conservation using an ecosystem service matrix approach.* Ecosystem Services, 35, 150-163. doi:10.1016/j.ecoser.2018.12.004

Gunderson, L., & Holling, C. (2002). *Panarchy : Understanding transformations in human and natural systems.* Washington, DC: Island Press. (2002). Retrieved 01-10-2019, from: http://web.a.ebscohost.com.tudelft.idm.oclc.org/ehost/ebookviewer/ebook/bmxlYmtfXzk3MjY1OF9fQU41?sid=ef527d9b-235a-4fd8-babc-c79e684bae95@sessionmgr4006&vid=0&format=EB&rid=1

Haasnoot, M., Bouwer, L. Diermanse, F. , Kwadijk, J., van der Spek,A., Oude Essink,G., Delsman,J., Weiler,O., Mens, M., ter Maat, J., Huismans,Y., Sloff, K., Mosselman, E. (2018). *Mogelijke gevolgen van versnelde zeespiegelstijging voor het Deltaprogramma*. Een verkenning. Deltares rapport 11202230-005-0002. Retrieved from: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=6&ved=2ahUKEwiytdzz6fTmAhXGYVAKHZtcCZgQFjAFegQIBxAC&url=https%3A%2F%2Fwww.deltacommissaris.nl%2Fbinaries%2Fdeltacommissaris%2Fdocumenten%2Fpublicaties%2F2018%2F09%2F18%2Fdp2019-b-rapport-deltares%2FDP2019%2BB%2BRapport%2BDeltares.pdf&usg=AOvVaw2q6PqvCCMyBjlC-3fegI3Z

Haasnoot, M., Kwakkel, J., Walker, W., & Ter Maat, J. (2013). *Dynamic adaptive policy pathways: A new method for crafting robust decisions for a deeply uncertain world.* Global Environmental Change, 23(2), 485-498.

Haasnoot, M., Diermanse, F., Kwadijk, J., de Winter, R., Winter, G. (2019). *Strategieën voor adaptatie aan hoge en versnelde zeespiegelstijging. Een verkenning.* Deltares rapport 11203724-004 Retrieved, from: https://publications.deltares.nl/11203724_004.pdf

Holling, C.S. (1996). Engineering resilience versus ecological resilience. Pages 31- 44 in P. Schulze, editor. Engineering within ecological constraints. National Academy Press, Washington, D.C., USA.

IPCC. (2007). *Climate Change 2007: Impacts, Adaptation and Vulnerability.* Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 976pp. Retrieved 26-10-2019, from: https://www.ipcc.ch/site/assets/uploads/2018/03/ar4_wg2_full_report.pdf

IPCC. (2014). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)].* IPCC, Geneva, Switzerland, 151 pp. Retrieved, from: https://www.ipcc.ch/site/assets/uploads/2018/02/SYR_AR5_FINAL_full.pdf.

Kenniscentrum Kusttoerisme. (2019). *Toerisme op Schouwen-Duiveland - Omvang en economisch belang 2016 – 2017 - 2018.* Retrieved 26-09-2021, from: https://www.kenniscentrumtoerisme.nl/images/a/a1/Rapportage_Schouwen-Duiveland_2016-2017-2018.pdf

Kenniscentrum Recreatie. (2011). *Behoefteonderzoek recreatiewoningen gemeente Schouwen-Duiveland.* Retrieved, 26-10-2021, from: https://www.schouwen-duiveland.nl/fileadmin/Schouwen-Duiveland/Pdf/Beleidsstukken/Recreatie_en_economie/Behoefte_onderdoek_recreatiewoningen_gemeente_Schouwen-Duiveland.pdf

Klimaateffectatlas. (2019). Downloaded 20-12-2019, from: http://www.klimaateffectatlas.nl/nl/

Le Bars, D. Drijfhout, S., & de Vries, H. (2017). *A high-end sea level rise probabilistic projection including rapid antarctic ice sheet mass loss.* Environmental Research Letters, 12(4). doi:10.1088/1748-9326/aa6512

Liao, K.-H. (2012). *A theory on urban resilience to floods—a basis for alternative planning practices.* Ecology and Society, 17(4), 48. Downloaded 20-11-2019, from: https://www.ecologyandsociety.org/vol17/iss4/art48/

Liao, K., Le, T., & Nguyen, K. (2016). *Urban design principles for flood resilience: Learning from the ecological wisdom of living with floods in the vietnamese mekong delta.* Landscape and Urban Planning, 155, 69-78. doi:10.1016/j.landurbplan.2016.01.014

Meijerink, M. van Bemmel, E., Arnold, E., Jacobse ,S., de Ronde, J. (2008). *Verkenning Kunstrif Scheveningen - Fase rapport bureaustudie Maatschappelijke Meerwaarde.* Retrieved from: http://docplayer.nl/55802774-Verkenning-kunstrif-scheveningen-faserapport-bureaustudie-maatschappelijke-meerwaarde.html

McHarg, I,l., (1971). *Design with Nature.* Published for the American Museum of Natural History. p.7.

Meyer, H., Born, G., & Geodan. (2013). *Nieuwe perspectieven voor een verstedelijkte delta : Naar een methode van planvorming en ontwerp.* (Ipdd cahier, december 2013). Delft: S.n.

Meyer, H., & Nijhuis, S. (Eds.). (2014). *Urbanized deltas in transition.* Amsterdam: Techne Press.

Ministerie van Infrastructuur en Millieu. (2016). *Advies Raad van State inzake het voorstel van wet tot wijziging van de Waterwet en enkele andere wetten (nieuwe* *normering primaire waterkeringen).* Staatscourant 2016, 23043. Rubriek Adviezen Raad van Staate. Retrieved 24-11-19, from: https://zoek.officielebekendmakingen.nl/stcrt-2016-23043.html

Oppenheimer, M., M. Campos, R. Warren, J. Birkmann, G. Luber, B. O'Neill, and K. Takahashi (2014). *Emergent risks and key vulnerabilities. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability.* Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1039-1099. Retrieved 23-10-2019, from: https://ar5-syr.ipcc.ch/ipcc/ipcc/resources/pdf/IPCC_SynthesisReport.pdf

O'Neill, E., & Scott, M. (2011). *Policy & Planning Brief, Planning Theory & Practice.* 12:2, 312-317, DOI: 10.1080/14649357.2011.583146
Retrieved, 22-11-19, from: https://www.tandfonline.com/doi/full/10.1080/14649357.2011.583146?scroll=top&needAccess=true

Resilience Alliance. (n.k.). *Resilience.* Retrieved 01-10-2019, from: https://www.resalliance.org/resilience

Ronde, J.G. Mulder, J.P.M., van Duren, L.A., Ysebaert, T. (2013). *Eindadvies ANT Oosterschelde*. Retrieved, from: https://www.deltaexpertise.nl/images/2/27/Eindadvies_ANT_Oosterschelde.pdf)

RWS. (2017). *Integrale Veiligheid Oosterschelde, MIRT onderzoek – knikpunten, oplossingsrichtingen en effecten, 6 april 2017.* Retrieved from: https://www.deltaexpertise.nl/images/5/51/RW1929-201-17-004991-rapd-IVO_nieuwe_norm.pdf

Schein, R. (1997). The Place of Landscape: A Conceptual Framework for Interpreting an American Scene. Annals of the Association of American Geographers, 87(4), 660-680. Retrieved September 3, 2021, from http://www.jstor.org/stable/2564404

Silver, Cheryl S., Ruth S. DeFries, and National Academy of Sciences Staff. 1900. One Earth, One Future : Our Changing Global Environment. Washington: National Academies Press. Retrieved 04-01-2020 , from https://public.ebookcentral.proquest.com/choice/publicfullrecord.aspx?p=3376340.

Storm, K. (1999). *Slinkend onland.* Retrieved 02-01-2019,from: https://docplayer.nl/69183294-Slinkend-onland-rijkswaterstaat-zeeland-slinkend-onland-over-de-omvang-van-zeeuwse-schorren-ontwikkelingen-oorzaken-en-mogelijke-beheersmaatregelen.html

STOWA. (2014). *Methode voor het selecteren van lokale zoetwateroplossingen en het afwegen van hun effecten 'Fresh Water Options Optimizer'.* Retrieved, 16-10-2020, from: https://www.stowa.nl/sites/default/files/assets/PUBLICATIES/Publicaties%202014/STOWA%202014-43.pdf

Pielke, R.A. (1999). *Nine fallacies of floods.* Climate change. Volume 42: 413-438. Retrieved, 22-11-2019, from: https://link-springer-com.tudelft.idm.oclc.org/content/pdf/10.1023%2FA%3A1005457318876.pdf

Poelman, M., van der Heuvel-Greve, M. Smaal, A.. & Steins, N. (2018). *Factsheet: Tetrodotoxine (TTX) in schelpdieren.* Retrieved 07-01-20, from: https://www.wur.nl/upload_mm/f/e/4/850684c4-bf40-4d52-a767-c71f713ebc68_8412103349_ASG_Factsheet_Ttx_Schelpdieren_v03.pdf

Van Slobbe, E., De Vriend, H., Aarninkhof, S., Lulofs, K., De Vries, M., & Dircke, P. (2013). *Building with Nature: in search of resilient storm surge protection strategies.* Nat Hazards 66, 1461–1480 (2013). Retrieved from: https://doi-org.tudelft.idm.oclc.org/10.1007/s11069-013-0612-3

Walker, B., Holling, C., Carpenter, S., & Kinzig, A. (2004). *Resilience, adaptability and transformability in social-ecological systems*. Ecology and Society, 9(2). doi:10.5751/ES-00650-090205

INFORMATION CAMPSITES

Dekreekoever. (n.k.). Retrieved 04-09-2021, from: https://www.dekreekoever.nl/voorzieningen/

Salvatorhoeve. (n.k). Retrieved 04-09-2021, from: https://salvatorhoeve.nl/index.php

Sluitgat. (n.k.). Retrieved 04-09-2021, from: http://www.sluitgat.nl/camping

IMAGES

Burwell, H. (n.k.). *Coastal squeeze.* Retrieved 10-05-2021,from: https://www.vims.edu/newsandevents/topstories/_images/sea_level_plan_art.jpg

Eurac. (2014). *The components of vulnerability to climate change.* Retrieved, 02-12-2019, from: https://www.researchgate.net/figure/The-components-of-vulnerability-to-climate-change-Adaptation-measures-can-be-implemented_fig1_328940560

Fisk, H. (1944). *The Alluvial Valley of the Lower Mississippi River.* Downloaded, from: https://www.researchgate.net/figure/The-Alluvial-Valley-of-the-Lower-Mississippi-River-Harold-Fisk-1944_fig2_340055057

J.R.T. van der Velde, M.T. Pouderoijen, J. van Bergen. (2018). *Aeolis_Gap the Border: Landscape Architecture On Site, Oerol Festival 2018.* Retrieved 12-20, from: http://resolver.tudelft.nl/uuid:e96ec1dc-cf0d-43cf-8046-5a0d8301df3f

United nations. (2021). *Sustainable development goals.* Retrieved 05-2021, from: https://www.un.org/sustainabledevelopment/news/communications-material/

Meyer, C. (2013). *Animals - Lion.* Retrieved 26-09-2019, from: http://soelaasnet.blogspot.com/search?q=leeuw

Nederland Waterland. (n.k.). *Watersnoodramp 1953.* Retrieved 23-10-2019, from: https://sites.google.com/site/nederwaterlandje/pakketten. Traced map

NOS. (n.k.). *Dijkdoorbraak - Rijkswaterstaat.* Retrieved 23-10-2019, from: https://lab.nos.nl/projects/waternood/index.html. Image

Scott T. Allen, Camille L. Stagg, Jorge Brenner, Kathleen L. Goodin, Don Faber-Langendoen, Christopher A. Gabler, Katherine Wirt Ames. (n.k.). *Chapter 2. Ecological Resilience Indicators for Salt Marsh Ecosystems.* Retrieved 01-01-2020, from:
https://www.natureserve.org/sites/default/files/chapter_2_-_salt_marsh_indicators.pdf

Sorgeloos, H. (2009). Fase. Four movements to the music of Steve Reich. Retrieved from: https://www.flickr.com/photos/desingel/4195428458

Vos, P. & S. de Vries (2013). *2e generatie palaeogeografische kaarten van Nederland (versie 2.0).* Deltares, Utrecht. Downloaded 17-11-19, from: www.cultureelerfgoed.nl.

Witteveen + Bos. (2011). *MIRT Verkenning Zandhonger Oosterschelde - Notitie Reikwijdte en detailniveau.* Retrieved, 10-11-2019, from: https://www.deltaexpertise.nl/images/6/63/MIRTzandhonger-oosterschelde.pdf

Witteveen+Bos. (2013). *BIJLAGE IX EFFECTBESCHRIJVING VISSERIJ EN SCHELPDIERKWEKERIJ (RW1809-28/ HITM/222).*Retrieved, 15-12-2019,from: https://www.commissiemer.nl/docs/mer/p25/p2595/2595-044mer_bijl09.pdf

Ysebaert, T. & Meire, P. (n.k.).
Ecosysteemdiensten – een nieuw begrip voor een nieuwe delta. Werkconferentie Zuidwestelijke Delta 'De nieuwe Delta'. Retrieved, 26-11-19, from: https://edepot.wur.nl/441401

Ysebaert , T. (2017). 30 jaar veranderingen in het oosterschelde ecosysteem. Retrieved, 02-01-2020, from: https://www.deltaexpertise.nl/images/7/70/30_jaar_aan_veranderingen_in_het_Oosterschelde_ecosysteem_Ysebaert.pdf

Zierikzee monumentenstad. (2019). *Handgekleurde gravure uit: J. de Kanter, de meekrapteler en bereider, 1802.* Downloaded 09-21, from: https://www.zierikzee-monumentenstad.nl/meekrap

MAPS

Behrens, H.W.A. (2008). *Uitwerking informatie behoefte waterstanden Rijkswaterstaat.* Retrieved 11-02-2020, from :https://docplayer.nl/42468867-Uitwerking-informatiebehoefte-waterstanden-rijkswaterstaat.html

CBS. (2019). *Banen van werknemers in december; economische activiteit (SBI2008), regio.* Retrieved 11-2-2020, from: https://opendata.cbs.nl/statline/#/CBS/nl/dataset/83582ned/table?dl=2F4D6

CBS. (2019). *Bodemgebruik; uitgebreide gebruiksvorm, per gemeente.* Retrieved 11-2-2020, from: https://opendata.cbs.nl/statline/#/CBS/nl/dataset/70262ned/table?dl=2F058

Dataportaal zeeland. (2006). *Haven.* Downloaded 03-01-2020, from: https://dataportaal.zeeland.nl/dataportaal/srv/dut/catalog.search#/metadata/ca979f4c-0bfe-4eb6-93df-4311531948cf

Dinoloket. (2021). *BRO GeoTOP v1.3 - Verticale doorsnede* . Downloaded, from: https://www.dinoloket.nl/ondergrondmodellen

EEA. (2018). *Natura 2000 End 2018 - Shapefile.* Downloaded 02-01-2019, from: https://www.eea.europa.eu/data-and-maps/data/natura-10/natura-2000-spatial-data/natura-2000-shapefile-1

Freshem. (2015). *Grens 1500mg Cl/l 'midden' m tov maaiveld.* Downloaded 08-01-20, from: https://www.zeeland.nl/sites/zl-zeeland/files/grens_1500_mgcll_maaiveld_midden.jpg

Inspectie Verkeer en Waterstaat (2011). *Derde toets primaire waterkeringen Landelijke toets 2006-2011.* Downloaded 07-01-2020, from: https://www.nationaalgeoregister.nl/geonetwork/srv/dut/catalog.search#/metadata/9bc22d59-427f-45c9-9f55-7dbe3985a73c

Kadaster Apeldoorn. (2017). *TOP10NL CAD June 2017.* Downloaded, 10-02-2020, from https://sites.google.com/a/g-tudelft.nl/top10nl-2017/products-services

Kuipers, S. F. (1960). *Een bijdrage tot de kennis van de bodem van schouwen-duiveland en tholen naar de toestand van vóór 1953: a contribution to the knowledge of the soils of schouwen-duiveland and tholen according to the conditions prior to 1953 (dissertation).* Centrum voor Landbouwpublikaties en Landbouwdocumentatie (PUDOC). Retrieved, 03-03-21, from: https://edepot.wur.nl/346198

Klimaateffectatlas. (2019). Downloaded 20-12-2019, from: http://www.klimaateffectatlas.nl/nl/

Ministerie van Infrastructuur en Millieu, Rijkswaterstaat. (2015). *Deel 27. DEEL II - Definitief rapport NB- wet_tcm117-337886.* Retrieved 05-01-2020, from: https://www.platformparticipatie.nl/binaries/27.%20DEEL%20II%20-%20Definitief%20rapport%20NB-%20wet_tcm117-337886.pdf
National Georegister. (2017). *Nationale Basisbestanden Primaire Waterkeringen.* Downloaded 20-12-2019,from: https://www.nationaalgeoregister.nl/geonetwork/srv/dut/catalog.search#/metadata/9bc22d59-427f-45c9-9f55-7dbe3985a73c

National Georegister. (2017). *Northern soil map.* Downloaded 20-12-2019, from: https://www.nationaalgeoregister.nl/geonetwork/srv/dut/catalog.search#/metadata/9bc22d59-427f-45c9-9f55-7dbe3985a73c

Nationaal georegister. (2019). *Download Service van BRP Gewaspercelen.* Retrieved, 18-12-19, from: https://www.nationaalgeoregister.nl/geonetwork/srv/dut/catalog.search#/metadata/dd8e0fb8-0f09-40ba-a884-7e23c0680ae2

Provincie Zeeland. (2006). *Bestaande en verdwenen dijken in Zeeland.* Retrieved 05-2021, from: https://dataportaal.zeeland.nl/dataportaal/srv/dut/catalog.search#/metadata/e5c91c39-8cff-435f-a45d-3218e4584d5c?tab=general

Provincie Zeeland. (2019). *Buslijnen.* Retrieved 24-08-21, from: https://dataportaal.zeeland.nl/dataportaal/srv/dut/catalog.search#/metadata/adb5ae3c-57d1-4541-86ec-b5888a3e1641?tab=general

Provincie Zeeland. (2010). *Grondwaterhuishouding.* Downloaded 08-01-20, from: https://dataportaal.zeeland.nl/dataportaal/srv/dut/catalog.search#/metada

Provincie Zeeland. (2012). *Geomorfologische kaart.* Downloaded 05-01-2020, from: https://dataportaal.zeeland.nl/dataportaal/srv/dut/catalog.search#/metadata/%7BABB62C30-9169-4774-A521-73C62876D-18C%7D

Provincie Zeeland. (2015). *Grondwater onttrekking.* Downloaded 20-12-2019, from: https://dataportaal.zeeland.nl/dataportaal/srv/dut/catalog.search#/metadata/42ae677d-eb84-4aff-b6a4-217860ef4f11?tab=contact

Provincie Zeeland. (2006). *Polders na 1953.* Downloaded 20-12-2019, from: https://dataportaal.zeeland.nl/dataportaal/srv/dut/catalog.search#/metadata/dab8ef56-9013-4cb8-96ee-32a2cbe2dc48?tab=general

Provincie Zeeland. (2006). *Oppervlaktewater peilgebieden.* Retrieved 05-2021, from: https://dataportaal.zeeland.nl/dataportaal/srv/dut/catalog.search#/metadata/fc0924c1-eefd-4b30-be99-da1101b7a990?tab=general

Provincie Zeeland. (2008). *PMV Natura-2000 gebieden.* Retrieved 05-2021, from: https://dataportaal.zeeland.nl/dataportaal/srv/dut/catalog.search#/metadata/9e938805-9997-4cec-aa28-f4e781ee2dd6?tab=relations

Provincie Zeeland. (2018). V*erdronken dorpen.* Downloaded 01-01-2020, from: https://dataportaal.zeeland.nl/dataportaal/srv/dut/catalog.search#/metadata/6eb9a0b2-b751-40a3-9a7d-5f3ed9d78a8b

Provincie Zeeland. (2015).*Waterkansenkaart Waterhuishouding – Combinatie kwel/infiltratie.* Retrieved 05-2021, from: https://dataportaal.zeeland.nl/dataportaal/srv/dut/catalog.search#/metadata/ebc21ae3-55c8-4c41-aba8-b638a3d629d2

Provincie Zeeland. (2016). *Maximale waterdiepte (beschermd).* Downloaded 03-01-2020, from: https://dataportaal.zeeland.nl/dataportaal/srv/dut/catalog.search#/metadata/4f61b081-cc5b-4804-ad93-d31eb51a829c?tab=general

Provincie Zeeland. (2018). *Verdronken dorpen.* Downloaded 01-01-2020, from: https://dataportaal.zeeland.nl/dataportaal/srv/dut/catalog.search#/metadata/6eb9a0b2-b751-40a3-9a7d-5f3ed9d78a8b

Provincie Zeeland. (2021). *Zoekgebieden agrarisch natuurbeheer ontwerp 2022.* Retrieved 05-2021, from: https://dataportaal.zeeland.nl/dataportaal/srv/dut/catalog.search#/metadata/cf51ee4c-512c-420d-a929-232d7a3a510e

PDOK. (2021). *Luchtfoto 2019, Ortho 25cm RGB* Retrieved 05-21, from PDOKserver qGIS

Risiscokaart. (2019). *Natuurrampen.* Downloaden 02-01-2019, from: https://flamingo.bij12.nl/risicokaart-viewer/action/combineimage?getImage=t&imageId=K4WYFGUY6D&JSESSIONID=8CA1C95BE6D-6F028F45E1611BF2A3D83

STOWA. (2014). *Methode voor het selecteren van lokale zoetwateroplossingen en het afwegen van hun effecten 'Fresh Water Options Optimizer'.* Retrieved, 16-10-2020, from: https://www.stowa.nl/sites/default/files/assets/PUBLICATIES/Publicaties%202014/STOWA%202014-43.pdf

Vos, P. & S. de Vries (2013). 2*e generatie palaeogeografische kaarten van Nederland (versie 2.0).* Deltares, Utrecht. Downloaded 17-11-19, from: www.cultureelerfgoed.nl.

Waterschap Scheldestromen. (2020). *Legger Oppervlaktewatetrlichamen.* Retrieved, from: https://scheldestromen.maps.arcgis.com/apps/webappviewer/index.html?id=645fc46b232441c19c45e8b01a546e83

PICTURES
de Jong, A. (2020).
de Jong, R.P.W. (2020).
de Jong, R.P.W. (2021).

APPENDIX

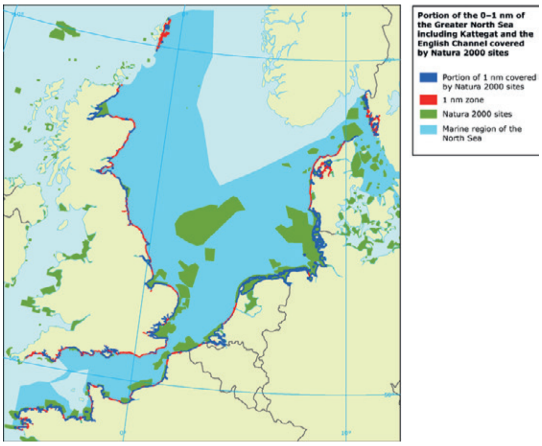
Studio Selection form

Studio Selection form | Graduation orientation

Preliminary Project Definition (max 5 pages) **AR3U040 Graduation Orientation – MSc 3 Urbanism February-June 2019**	
Student Name	Anne de Jong
Student Number	4640845
Preliminary project title	**THE NEW ANTHROPOCENE WATER LEVEL** - The intrinsic relationship between land and water, and a search for robust design strategies alongside the waterfront of the North Sea
Key words (4-7)	New Antropocene Water level , Dynamic land-water interface, Narrative (related to morphology and inhabitation), Building with Nature, Performance of the environment (related to livability and biodiversity)
1st studio choice + argumentation	Transitional Territories Related to territories in risk between land and water, the studio of transitional territories corresponds to both spatio-ecological, as well as socio-economic changes and vulnerabilities that are addressed in the project. The New Antropocene Water level is an uncertainty that can be tackled through scenario planning and systems thinking, which the studio applies. The studio offers an approach of research by design that can test different performances of the environment related to livability as well as biodiversity in areas that are challenged by natural processes (such as erosion, inundation etc.). Within the studio the project can relate to the inquiries of 'flux, erasure, terraforming', concerning inundation and erosion (tidal, Aeolian) of areas, and to a certain extend to the 'pervasive ecology of flows' and 'the dual nature of externalities'. The specific setup of the studio will most probably benefit the personal project due to the fact that: - The studio enables a broader perspective on a larger territory - The territory of the North Sea offers different possible project locations. The planned trip might enable new insights in the area. - The analysis of the North Sea is a collective group effort, and might create a broader perspective on issues in a faster timeframe. - The exhibition allows for experimenting with different techniques (film, beamers, models etc.), which is considered as a personal goal.
2nd studio choice + argumentation	Urban Metabolism Although tackled from a different perspective, the urban metabolism studio might offer insight in the project from a more systematic approach. Within the studio the performances of the environment, livability, and biodiversity can still be investigated and linked to future design strategies. However within the setup of the studio the project is mainly seen as a personal effort, therefore there is less input of information from peers (no collective analysis). This makes it more

	difficult to start from a larger territory such as the North Sea. Within the studio of Urban Metabolism the project would therefore most probably focus on one of the indicated project areas. Although different techniques of inquiry, and representational quality of the products can be point of attention based on the mentor, it is not seen as a focus. The absence of the spatial narrative approach will most probably lead to a more pragmatic project, which suppresses the aim to also relate to more speculative and experience based designs.
1st choice main mentor + argumentation	Louisa Calabrese (Transitional territories) With an interest in the spatial narrative approach Louisa can accommodate in a search into the relationship between the land-water interface and inhabitation of the territory and its drivers (economy and society) over time. With her wide scope and design-based approach Louisa has the capability to think outside prescribed directions, which might help in scenario based planning of uncertain futures. Her active attitude towards different types of representation might help in the exploration of different exhibition methods, and improvement of personal products. Her sharp notions can be helpful in specifying the scope of the project.
2nd choice main mentor + argumentation	Fransje Hooijmeijer (Transitional territories) Fransje might offer more insight in the engineering of waterfronts, and sustainable design. However her quite focused and systematic approach might cloud a broader perspective on the topic, and reduce the input of a more narrative based approach. Therefore a concern is that the outcome might not overcome a more practical state. Or, Kristel Aalbers (Urban Metabolism) With her focus on water management and background in climate adaptive strategies in cities Kristel has the ability to approach the project more systematically. As apposed to the other mentors of Urban Metabolism Kristel might have a more open mind towards the use of different representational techniques.
Main motivation for the project / Problematization	With a continuously changing climate comes the difficulty of predicting the New Anthropocene Water level, and its effects on the spatial and systematic interface between land and water alongside the North Sea. According to the synthesis report of the Intergovernmental Panel on Climate change (IPCC) estimates of global sea level rise range from 0.18 to 0.59m at the end of the 21st century (IPCC, 2007, p. 45). The Delta Committee of the Netherlands even concludes that a regional sea level rise of 0.65 to 1.3m should be taken into account by 2100, and 2 to 4m by 2200 (Deltacommisie, 2008, p.10). Whereas it's not questioned that the interface between land and water around the North Sea will change, one can still speculate about the future shape of the delta and coastal areas and their increased vulnerability for floods.

	Threats alongside the coast of the North Sea, which could be aggravated by sea level rise, vary and relate to both spatio-ecological as socio-economic vulnerabilities. Aeolean and tidal processes are cause for erosion of the cliffs alongside the Eastern Coasts of the UK, causing high damage costs. In England about 28% experience erosion at rates higher than 0.1m/year (Climate Change Post, n.d.), questioning the viability of the coastal settlements. Safety assessment of primary flood defenses in the Netherlands showed that segments do not comply to the current standard (Deltacommisie, 2008, p. 20). Example are the dunes near the Westland, where a lack of natural sand nourishments and space consuming glasshouse developments pressure recovery of the dunes. However there are also threats related to the loss of biodiversity. The Wadden Sea (World heritage) is an important area for migrating birds (East Atlantic bird migration routes). The area of salt marches could shrink as a result of inundation, and is restrained from expanding inland by defense barriers. Delta areas in particular are affected, for instance the Rhine/Meuse delta, since artificialization of waterfronts has constrained the natural processes alongside the waterfronts leading to a loss of wetlands. The issues question the future performances of waterfronts (environments) in terms of livability and biodiversity.
Your possible location(s) for research and/or design	The project aims to relate to different threats of coastal areas and/or deltas, therefore the initial proposal is a comparative analysis. In order to establish a more thorough (design) research it might be necessary to eventually focus on one area. The initial analysis of the transitional territories studio might therefore be beneficial in the selection process of this area. Indication of possible project areas and their challenges (for first three areas see motivation/problematization): - ***Wadden Sea (NL/GE/DE): Accretion versus erosion*** - ***Westland (NL): Dune reinforcement / nourishments*** - ***Eastern coast England (Yorkshire): Erosion of cliffs*** - ***Firths of Scotland: Potential loss of salt marches*** More extreme conditions might lead to the potential loss of salt marshes and mudflats (important for overwintering birds) in the Firths of Scotland. - ***Rhine/Meuse delta (Provinces Sealand/South Holland, Rotterdam, NL) : Artificialization of waterfronts*** While the Rhine and Meuse delta is an important route for migrating fish and birds, artificualisation of the waterfronts (for instance the Port of Rotterdam) have affected the process of delta formation. The result is a loss of wetlands and estuarine habitats. At the same time flood risk management is of great importance for large urban territories that benefited the conditions in the delta (Rotterdam). Saline infiltration threatens the freshwater supply in the future and affects agricultural activities of the polders.

	A more thorough selection process can lead to a selection of other areas.
A (set of) visual(s), e.g. analytical map, illustrating the problem and/or location. **For sources images see Literature**	 **Image 1|** The territory of the North Sea as starting point for the project. The map shows the protective Nature status of the different coastal areas. (EEA, 2012)  **Image 2|** Simplified hypsometric curve of the Netherlands, in which the proportion of land area is related to the different elevations in the country (also read relative area against the relative height). It shows that a mere half of the country is below the 3m level (light grey, of which about 17% below the 0m), and could therefore be affected by future sea level rise.
Aim of study / Main research question	The project aims to: - Speculate about the uncertain future of waterfronts of the North Sea based on a scenario(s) for the New Anthropocene water level. - Create robust design strategies that can cope with different threatened waterfronts (North Sea), and improves the environmental performance (livability and biodiversity). - Reflect on nature- based approaches (such as Building with Nature) as tool to design areas with uncertainties. The preliminary research question is: *In what way can the concept of 'Building with Nature' be used for the development of robust urban design strategies alongside threatened waterfronts of the North Sea coast in order to mitigate the affects of the New Anthropocene Water level, and loss of biodiversity?*
Intended concrete outcomes	- Diachronic mappings North sea (changing land-water interface) - Comparative analysis of different coasts. Selection of different coastal areas, based on the possible impact (spatio-ecological, socio-economical). - Changing projection (with beamer) of diachronic maps on a 3D model, or small movie. - Sections of the different waterfronts and its related activities/systems.
Possible project approach / methods	A spatial Narrative approach might help in understanding the changing land-water interface, and the different forms of inhabitation/urbanization driven by specific economic, cultural and societal drivers over time.

	Secondly through the framework of 'Building with Nature' 3 perspectives (Van Slobbe et all, 2013) can be addressed, namely: 1: Nature: relating to biotic, and abiotic environment and hydro-morphological processes. 2: Man made infrastructures: human interventions aiming to influence the natural system (water, sedimentation, ecology etc.) 3: (Governance of) Society: relating to the institutions, and societal impacts. The layer approach (using mappings or diagrams) can be used in order to understand spatial interrelations, of which narratives can be part. In general, research by design can be a helpful method to explore different outcomes (Mediums: sketching, cartography, narration through film or projections, scenario planning, etc.).
Scientific relevance of your project	Although different scenarios of sea level rise have already been explored, they are mainly based on the timeframe of 2050 till 2100. With the expectation that sea level rise could be significantly higher after 2100 the approach towards a more robust design strategy might have to be rethought. Herein also lies the challenge of the project. Secondly the scientific relevance of the project relates to the reflection on the concept of 'Building with Nature' as a tool to design with uncertainties.
Societal relevance of your project	When considering a New Antropocene Water level, design strategies for Flood risk- or water management can be considered as a sensitive subject. Not only is there a large economic dependency on flood risk management (due to highly urbanized deltas and coasts, and their economic importance), it affects the interests (for instance fresh water supply, health, safety) of people. The loss of ecologically valuable areas might affect certain ecosystem services that are beneficial for society, such as carbon storage of salt marches, or supply of fresh water in the dunes. Therefore a certain voice of/for nature might be necessary to guarantee that future regenerations might still benefit from these services.
Reflection on Urbanism research programme and all five graduation studios PCC, UM, TT, HH, UF.	The introduction of the studios created awareness for the relevant issues within the field of Urbanism, and the wide range of themes and scales to which they relate. From the issue of densification based on typological and structural transformation projected on a neighbourhood scale (UF), towards tackling issues of uncertainty, such as sea level rise, related to the North Sea (TT). However they also clearly distinct themselves through their main approach towards tackling these challenges. Whereas Urban Metabolism offers a very systematical approach, History in the making and Transitional territories might be considered as more explorative studios. And whereas the aspect of 'planning' is emphasized in the studio of Planning Complex cities, Urban Fabrics and Transitional Territories are more 'design' based. This was all considered for the choice of the main studio.
Ethical considerations	Due to the sensitivity of the subject, attitudes towards water related environmental threats might be different. And although natural

	processes might not be affected by political borders, policies and cultural values do and might therefore influence the approach towards design based strategies. As argued by Han Meyer in his book 'The state of the Delta' The battle with water is something that build the 'Nation' in the Netherlands. Second consideration is that, based on the specific conditions of a site different Sustainable Development Goals (SDG's) might be relevant. This all relates to a specific cultural, political and economic climate, and might therefore diver in the countries adjacent to the North Sea.
Literature	IPCC (2007) *Climate Change 2007: Synthesis Report.* Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 104 pp. Meyer, H., & Nijhuis, S. (Eds.). (2014). *Urbanized deltas in transition.* Amsterdam: Techne Press. Meyer, H., & Bouma, T. (2017). *The state of the delta : Engineering, urban development and nation building in the Netherlands.* Nijmegen: Vantilt. Neumann, B., Vafeidis, A., Zimmermann, J., Nicholls, R., & Kumar, L. (2015). *Future coastal population growth and exposure to sea-level rise and coastal flooding - a global assessment. Plos One, 10*(3), 0118571. doi:10.1371/journal.pone.0118571 Pranzini, E., & Williams, A. (2013). *Coastal erosion and protection in europe*. London: Earthscan. Ritzema, H., & Loon-Steensma, V. (2018). Coping with climate change in a densely populated delta : A paradigm shift in flood and water management in the netherlands. *Irrigation and Drainage, 67*(S1), 52-65. Van Slobbe, E., De Vriend, H., Aarninkhof, S., Lulofs, K., De Vries, M., & Dircke, P. (2013). *Building with nature: In search of resilient storm surge protection strategies. Natural Hazards : Journal of the International Society for the Prevention and Mitigation of Natural Hazards,66*(3), 1461-1480. doi:10.1007/s11069-013-0612-3 ***Electronic sources:*** • Climate Change Post (n. d.) *Coastal erosion united Kingdom.* Retrieved 13 September 2019, from: https://www.climatechangepost.com/united-kingdom/coastal-erosion/ • Deltacommissie. (2008). *Working together with water: A Living land builds for its future.* Retrieved 13 September 2019, from: http://www.deltacommissie.com/doc/deltareport_full.pdf ***Images:*** Image 1| European Environment Agency.(2012). *Proportion of coastal waters (0 to 1 nm from the coast) of the Greater North Sea including Kattegat and the English Channel covered by Natura 2000 sites.* Retrieved, 13 September 2019, from: https://www.eea.europa.eu/data-and-maps/figures/proportion-of-coastal-waters- Image 2|Simplified hypsometric curve (Adjusted by author) PawełS. (5 May 2013). *Hypsometric curve of the Netherlands.svg.* Retrieved, 13 September 2019, from: https://commons.wikimedia.org/wiki/File:Hypsometric_curve_of_the_Netherlands.svg