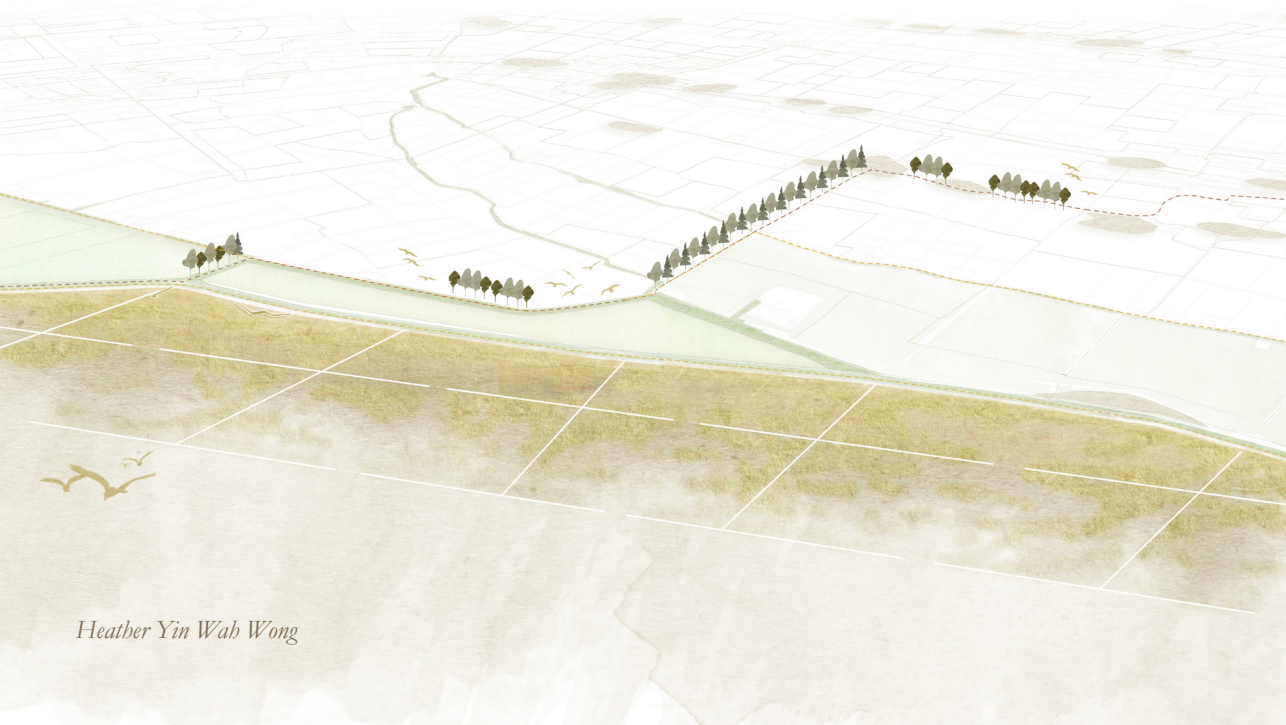
Regression & Progression

Towards a Regenerative Water Landscape in Wadden Coast



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Regression & Progression

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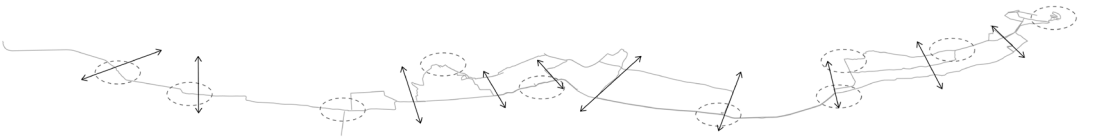

Mudflat along the Wadden Coast.
Photo: Author, 2022.

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I would like to thank my mentors Laura Cipriani and Mark Voorendt for their wonderful support and guidance in the past nine months. Their professional knowledge, indescribable commitment and continuous encouragement have been guiding me and resolving my problems throughout the journey of discovery and knowledge.

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Lastly, I am grateful to my family and friends for the unconditional love and support.

Walking along the sea dike.
Photo: Author, 2022.

Abstract

As the world's largest intertidal area, the Wadden Sea Region has been recognized as a UNESCO World Heritage site in 2009 .In addition to the scenic and ecological values, the Dutch Wadden Sea also serves as an infrastructure to safeguard the coastline of the mainland as a climate buffer, where it is good to live, work and recreate.

The Dutch Wadden sea is a dynamic landscape which is highly vulnerable to the future climate change, demographic changes, as well as the increase in recreation and tourism. The rising sea level and changing climate will lead to prolonged droughts and flooding, posing a water safety crisis to the area. As an indispensable infrastructure protecting the hinterlands, the Wadden Sea dikes define and fragment the features of the landscape. The Wadden Sea coast is also confronting declining populations and a mono-sector economy.

The graduation project seeks for the possible outcomes of the Wadden Sea Coast through in-depth research to analyze, synthesize and develop a strategic design proposal for a resilient and sustainable landscape infrastructure contributing to the whole system. This project sets up an agenda for exploring the prospective capabilities of design-oriented research and cartography. An in-depth research and analysis on the spatial and cultural landscape characteristics identifies the spatial dynamics and transformations undertaken in the Wadden Coast. The future scenarios and narratives are formed based on different climatic conditions. The design assignment is an adaptive landscape approach at multiple times and scales together with scenarios-making for an integral approach on climate crisis, as well as small-scale design interventions along the Dutch Wadden Coast.

Table of contents

Introduction 13

CHAPTER I 19
Methodology - Research by Design Approach

- Problem Statement
- Research Questions & Objectives
- Research Framework
- Methodological Framework
- Theoertical Framework
- Analytical Framework

CHAPTER II 37
The Past - A Cultural Water Landscape

- Geomorphological Evolution
- Fighting Against Water
- Geomorphology & Cultural Pattern
- Major Floods

CHAPTER III 53
The Present - A Dynamic Landscape

- Adminstrations & Borders
- Territorial Site Model
- Dutch Wadden Sea Region
- Landscape Types
- Friesland Boezem
- Flood Defence Systems
- Dike Reinforcement
- Salinization
- Recreations
- Socio-economic Conditions

CHAPTER IV 87
The Future - A Vulnerable Landscape

Sea Level Rise
Future Uncertainties
Flood Scenarios in 2100

CHAPTER V 97
Design - An Adaptive Landscape

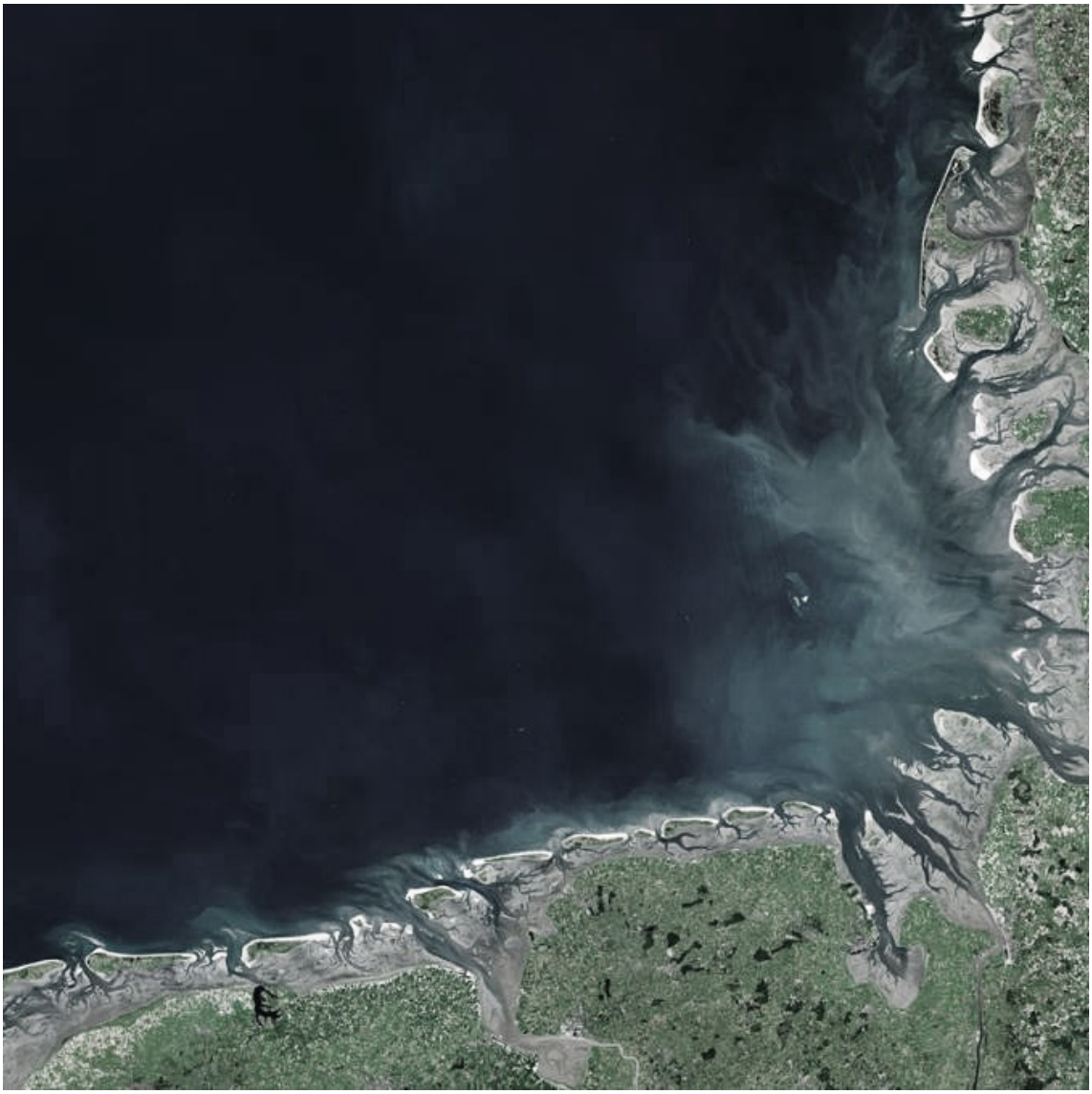
Strategies
Water as Opportunities
Climate-adaptive Waterscape
Water Heritage
Valuable Waterscape
Regional Strategic Plan in 2030, 2050 & 2070
Routing Design in 2030
Design Location
Design Interventions
Two Coastal Defense Systems
Salt Marsh Defense Systems
Double Dike Systems
Time Phases
Bird's Eye View

CHAPTER VI 171
Reflection

Bibliography 180

Introduction

A dynamic and vulnerable landscape



Wadden Sea World Heritage.
Photo: Google Earth, 2022.

Introduction

The Wadden Sea Region is the world's largest intertidal area spanning the countries of the Netherlands, Germany and Denmark, and has been recognized as a UNESCO World Heritage site due to its globally unique geological and ecological features. (Wadden Sea World Heritage, 2021) In addition to the scenic and ecological values, the Dutch Wadden Sea also serves as an infrastructure to safeguard the coastline of the mainland as a climate buffer, where it is good to live, work and recreate. It is not only a dynamic landscape that is highly appreciated by residents and tourists, but also a vulnerable landscape that deserves protection and a resilient approach for future development and climate adaptation.

The changing climate, in particular the rise of sea level and changing precipitation patterns, leads to an increasing pressure on the Dutch Wadden sea coast and even the nation, considering sixty percent of the surface area of the Netherlands is at risk of flooding. (Vergouwe, 2015) The sea level has risen by about 20 centimeters worldwide on average from 1901 to 2018 and the acceleration rate depends on the amount of greenhouse gasses the world continues to emit and the mass loss of the Antarctic Ice Sheet. (Driftwood and Bars, 2021) According to the sixth IPCC report and the Climate Signal' 21, the maximum sea level rise would exceed 1 meter, so it is likely that all the dikes will have to be reinforced again. (IPCC,2021) The sea level will inevitably continue to rise in all emission scenarios, despite the global agreements made in Paris in 2015 and the limited maximum global temperature increase in 2°C. (Driftwood and Bars, 2021) It is expected severe flooding and drought will happen frequently and as a result, a sustainable flood defense and water system are crucial to build a resilient and robust Wadden Coast.

Apart from the climate crisis threatening the region in the long-run, the demographic changes and mono-sector economy is impacting the socio-economic condition in the Wadden Sea coast. The population has declined moderately to strongly in part of Friesland and Groningen, the small villages along the coast are at stake. (Rijk-regio Projectgroep Agenda voor het Waddengebied 2050, 2020) Some of the villages are the old terps which were built to provide safe ground from high tide since 500 B.C., before dikes were made. (Vergouwe, 2015) With the pressure of the aging population and a decline in the working population, the villages are falling to decay and hence we seek for new meanings to restore the role of the villages without losing the cultural values.

Recreation and tourism are still the most important economic sectors on the Wadden Islands, without affecting the islands' own unique values, culture and quality of life. The increase in tourism results in seasonal labor and less basis for facilities such as health care and education, as well as the housing for local people. The issues in the coast are different with the Wadden Islands. The economy of the mainland is dominated by only a few sectors: fishing, agriculture and ports. (Rijk-regio Projectgroep Agenda voor het Waddengebied 2050, 2020) The Wadden Coast is being neglected by the visitors due to the lack of identity and the segregation of the gigantic sea dikes disconnecting the land from the water. Tourism and housing construction are limited carriers for the economy. The presence of nature and the rich cultural history is an opportunity that has not yet been sufficiently exploited for the economy, such as cultural tourism. (Rijk-regio Projectgroep Agenda voor het Waddengebied 2050, 2020)

I am fascinated in this coastal landscape, in particular the coexistence of tranquility and dynamicness in the Wadden Sea.The calm and mirror-like water on the mudflat reflected the colors of the sky from dawn till sunset and the movement of the birds. A soft rustling sound from the reeds in the golden marsh along the coast on a breezy day brought me to find my inner peace. The infinite sea dike is like a gigantic sleeping guardian lying along the coast and safeguarding the people in Friesland. The views of the wadden sea are ever-changing throughout the day and year due to the dynamic tidal systems. The natural processes in which the sand and water brought from the North Sea through the tidal inlets between the islands form this spectacular coastal landscape with unique ecological and cultural values. This quiet marshland together with the magnificent sea dike has become the greatest infrastructure protecting the nation for a long period of time. The landscape palimpsest regarding the geo-morphological development and the flood protection is also fascinating and inspired me to rethink and imagine the future of this land.

A friend of mine who grew up in the village in Friesland brought me to the coast of Friesland. As a frisian, the Wadden Coast means more than merely a flood defense but a place where he grew and belonged to.He has a strong attachment to this landscape and he always believes the Wadden Coast and the water heritages deserve preservation and people's awareness. His father, who was a farmer in Friesland, is optimistic about the future transformation of the landscape and cares a lot for our next generation. Their stories provoked my reflection on the relationship between human and landscape, and became my motivation for the project.

The Wadden Coast is confronting the vulnerability from climate change, declining population and the increase in recreation and tourism. To ensure a more sustainable future for this sensitive landscape, a research question arises as 'how to create a resilient landscape that facilitates sustainable flood protection and socio-economic development for climate adaptation in the Dutch Wadden Sea? 'Other than heightening the sea dike and continuously fragmenting the landscape, what are the alternative landscape-integrated flood defense approaches which could adapt to the future climatic issues? How to strengthen the connection between the Wadden Sea and the hinterlands through design? A group of research sub-questions are set up for the understanding of the major natural and cultural processes involved in the landscape transformation at multiple scales, as well as exploring the possibility of the alternative landscape-integrated approach through scenario-making.

The research project starts with the context analysis in territorial scale, which is the entire Wadden Sea Region across three countries, then scaling down to the regional and local scale mainly in the north of Friesland along the Wadden Coast. Landscape-based approach is regarded as essential for developing the capacity to face natural and human-made threats in multiple conditions, offering a guide to shape spatial transformations in different time frames. Design transition is another important element in the project. The design proposal not only strives for coherent development of the region in the long run, but also sets up conditions for short term local intervention. Take the existing qualities as a starting point for developments, the flood defense systems and the water heritage are the main drivers of the design to strengthen the local identities, develop resiliency and adaptive capacity, and facilitate socio-economic development in the region.

The scopes of landscape architecture have been widened increasingly: the spatial qualities, communities, ecology and urban planning. Landscape architects not only design the aesthetic form and function but also manipulate the complex system and flow behind in multiple layers and scales, working multi-disciplinary to prepare blue-green infrastructure plans and implementation strategies. Interpreting the Wadden Coast as an infrastructure, the graduation project focuses on the water and flood defense system, working with the cultural and socio-economic flows from regional scale to local scale. The project is also an integration with landscape, urban and engineering disciplines. The participation of a hydraulic engineering professor as the second mentor provided invaluable input and additional perspective for the design.

Methodology

Research by design approach

Site Visit.
Photo: Author, 2022.

This graduation thesis is part of the Wadden Sea Lab, which focuses on taking design as a method of research, working in the form of regional scenarios-making and local design projects to envision the present and future of the Wadden Sea.The Wadden Sea Lab has set up an agenda to address global challenges through regional, local and small-scale interventions. The research began with the site visit in Friesland and the road trip along the Wadden Coast. Stephan Smeijers from the Fryslân Municipality and Joca Jansen from Wetterskip Fryslân gave an introduction on the landscape characteristics, as well as the regional and local crisis regarding the climate, culture, ecology and society. A discussion on the water management was particularly drawn to address the unsustainability and the future climatic threats in Friesland. 'Water' served as a backbone in the research and has driven the project to as a design concept and an opportunity for the future. This chapter discusses the problem fields of the territory brought by the landscape complexity forming the research question, as well as the application of the "research by/through design" method and the research framework structuring the entire research.

Despite the globally unique heritage, climate change and economic development simultaneously pose a threat to the preservation of the territory. Hereby, I have defined the problem statement addressing the vulnerabilities of the sea level rise and landscape fragmentation, as well as the opportunity of the dynamic systems. A research question is formed to set up the objectives of the research.

To approach this question, a research framework is set up in the structure of three systems, i.e. water, cultural and socio-economic systems, to address the natural and cultural processes transforming the landscape in the past, present future.Cartography is the main tool for the analysis and synthesis of data in a visual way by superimposing various layers of information. In the light of the future climatic uncertainty, scenarios of different sea level rise in 2100 are made to explore and speculate the implication of different approaches by collecting the national flood data.

The research forms a solid base and notion for the design projection. Design strategies are developed following the concepts of climate-adaptive waterscape, water heritage and valuable waterscape. Design diagnosis on the spatial and temporal relationship in multiple scales leads me to the strategic plans and designs over regional, local and small scales. The design proposal considers the variable of time, thereby developing the adaptation plans for different periods of time (in 2030 ,2050 and 2070).


Rising
Sea level
Unsustainble
water system
Flooding &
droughts
Flood
defense
system
Low
ecological
quality
Salinization
Declining
population
Uninteresting
experience
Dynamic tidal
landscape
Attractive
islands
Mono-
sector
economy
Fragmentation
UNESCO
World Heritage
Lack of
identity
Poor
accessibility

Problem Statement

Wadden Sea Region is an extensively complex landscape with numerous built and natural systems under increasing pressure from climate change and local challenges. The complexities not only bring threats to the future, but also offer opportunities for adaptation. This project addressed three of the most significant problems affecting the future development of the Wadden Sea Region as follows:

1. Climate change

Climate change, in particular the rising sea level, has already impacted the Wadden Sea ecosystem and posed a risk to the safety of the region's residents. The current flood defense systems could protect the hinterland till 2050 and hence require reinforcement in the near future. Drowning of mudflats will reduce the surface and height of the tidal flats, threatening the flora and fauna in the region. Increased salinity affects the agricultural industry which is one of the most important economic sectors in Friesland.

2. Fragmentation

The sea dikes are the primary flood defenses with a height of eight-meter protecting but also segregating the Wadden Sea from the land. These gigantic sea walls bounding the coast form an infinite horizon and block the view of the Wadden Sea from the land. The Wadden Coast is dominated by the large-scale agricultural farms, making the spatial experience along the coast very insufficient. Despite the tourism flourishing on the Wadden Islands, the Wadden Coast is always being neglected by the visitors due to the low accessibility and the lack of landscape identity. The declining population has further put this landscape at stake.

3. Dynamic water heritage

The Wadden Sea is a unique world heritage with an uninterrupted stretch of tidal flats influenced by various processes. The tidal mechanisms form a dynamic and biodiverse coastal landscape, benefiting the ecosystem and society. With highly rich flora and fauna, it is an important breeding ground for hundreds of thousands of migrating birds and other animals.

View of sea dike from the farmland.
Photo: Author, 2022.

Research Questions

How to create a resilient landscape
that facilitates sustainable flood protection and
socio-economic development for climate adaptation
in the Friesland Wadden Coast?

Research Objectives

The aim of the project is to bring up discussion and spatial reflection on climate adaptation in the region of the Friesland Wadden Coast. The design proposal has opted for an integrated and site-specific strategic plan to bring this vulnerable landscape towards an ecologically interesting, integrated and climate-adaptive future.

Sub-questions:

_What does 'resiliency' mean in the context of wadden sea?	Chapter I
_How did the landscape transform over time and what major natural and cultural processes were involved in this transformation?	Chapter II
_What are the opportunities and threats regarding the water, cultural and socio-economic aspects?	Chapter III
_What are the future climatic issues and how will the issues influence the landscape?	Chapter IV
_What are the alternative landscape-integrated flood defense approaches which could adapt to the future climatic issues?	Chapter V
_How to strengthen the connection between the wadden sea and the hinterlands through design?	Chapter V

Keywords
#Landscape Resilience
#Climate adaptation
#Flood management
#Infrastructure
#Identity

Research Framework

01- INTRODUCTION

02- PROBLEM STATEMENT

Problem Statements

- *Rise of sea level*
- *Fragmentation*
- *Dynamic tidal landscape*

03- OBJECTIVES

Research by design

Research Questions

How to create a resilient landscape that facilitates sustainable flood protection and socio-economic development for climate adaptation in the Dutch Wadden Sea?

04- RESEARCH & ANALYSIS

- *Data collection*
- *Site visit*
- *Typology analysis*
- *Historiography*
- *Mapping*
- *Report review*
- *Scenarios-making*

Analytical framework

Past

3 systems

Water

Cultural

Socio-economic

- *Geomorphological development*
- *Major flood events*
- *Defense system development*

05- DESIGN

Design Concepts

Design Strategies

3 pillars

Climate-adaptive waterscape

Water heritage

Valuable waterscape

1. Develop a landscape-integrated

2. Strengthen landscape identity a

3. Enhance the regional economy

Design Diagnosis

06- REFLECTION

This project adopts the 'research by design' method in which the design is taken as a research strategy for approaching the challenges in the Wadden Coast. The research focused on the three landscape systems (i.e. water, cultural and socio-economic systems) throughout the past, present and future, taking into account the variable of time. Design proposals addressing the problem fields and scenarios on multiple scales are done to project the possibilities of the future adaptation in the long run.

Present

- Friesland bosezem systems
-Salinization
-Flood defense systems

- Socio-economic issues
- Tourism & recreations

Future

- Flood data
- Sea level rise data

- Climatic scenarios
1. High sea level rise
2. Moderate sea level rise
3. Low sea level rise

l approach along the coastline for climate adaptation

nd the value of the cultural water heritage

and livability

Regional Strategic Plan
2030, 2050, 2070

- Master plans

Local-scale Design
2030, 2050, 2070

- Routing design
- Double dike systems
- Salt marsh defense systems
- Saline agriculture

Small-scale Design
2030

- Landscape interventions

Reflection

Methodological Framework: Research Strategies

The research approach is inspired by a reflexive approach in which the researcher shifts focus back and forth between theoretical propositions and empirical evidence. (Castells 1983) The following research strategies contribute to my topic and build a comprehensive analysis and speculation of the site.

1. Description
To assemble a collection of information and data, in particular the geodata from PDOK and historical maps from Topotijdreis at multiple scales, for spatial and temporal analysis in the Wadden coast. Thematic maps and sections are made to represent the spatial characteristics of the area. Statistics and the information of the socio-economic conditions in the neighborhoods are collected from AlleCijifers. Observation and photo-taking are made to document the current condition and sensorial experience of the area during the site visit. This research strategy derives knowledge from data, hence I could comprehend the landscape features and the socio-economic development of the Wadden Coast exclusively in which this could contribute to the design strategies.

2. Classification
To better understand the flood defense systems in the Wadden Coast, systematic dike typologies are constructed to classify the primary and regional flood defense system. Looking from the satellite images on google map, different landscape patterns and defense systems can be depicted and drawn in three-dimension axonometric diagrams. The classification allows me to learn and compare the typologies, hence it acts like a basis for the future dike interventions.

3. Interpretation
Mapping is the main tool for the analysis and synthesis of data and information in a visual way. The geodata collected in PDOK will be superimposed or merged with other layers of information in QGIS, such as soil map, hydrology map, land use type map and geomorphology map etc. By cross reference mapping, the relations between different patterns will be explored. For instance, the croplands are usually located at the fertile clay area along the coast and land subsidence occurs at the peatland and gas extraction place. Overlaying and interpreting maps could help understand and determine critical natural and cultural processes transforming the landscape from the past to future, as well as the spatial and temporal relationship in different scales through critical mapping and historiography.

4. Modelling

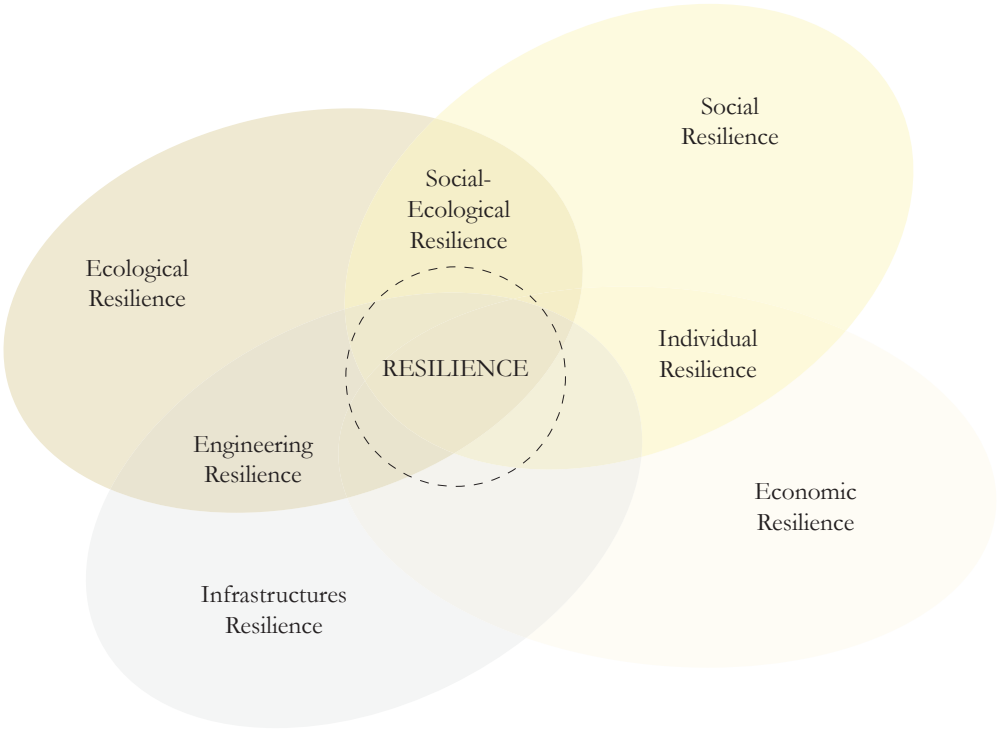
To explore and speculate the implications of different approaches by simulating scenarios of different sea level rises in 2100 based on the latest report of the IPCC and the Climate Signal'21 by KNMI. With the elevation map from AHN3, the area of possible flooding could be speculated in QGIS. The predictive modeling will support and guide the opportunities visualized for the research. The model can contribute to creating, developing and testing spatial possibilities for climate adaptation in the project.

5. Evaluation and Diagnosis

To evaluate and diagnose the feasibility of the existing national Wadden sea development report and explore the collaboration between different stakeholders. The spatial agenda summarizes the existing ambitions, goals and strategies of the government and the region, identifies the most important tasks and associated dilemmas that new developments will face in the Wadden area. (Rijk-regio Projectgroep Agenda voor het Waddengebied 2050, 2020) The evaluation allows me to learn from the current plan and the dilemmas they are confronting, hence it serves like a basis and contributes to the design principles for the resilient landscape framework.

6. Design Projection

To establish a design strategy contributing to the design in multiple scales and develop a local design proposal following various scenarios and transitions in time. Starting from regional concept sketching, the projection of design possibilities would be explored through 3D modeling and map interpretation under different climatic scenarios, allowing flexibility and variety in the resilient framework. Detailed local design intervention will demonstrate how the design strategies works on the ground and its influence on various scales.

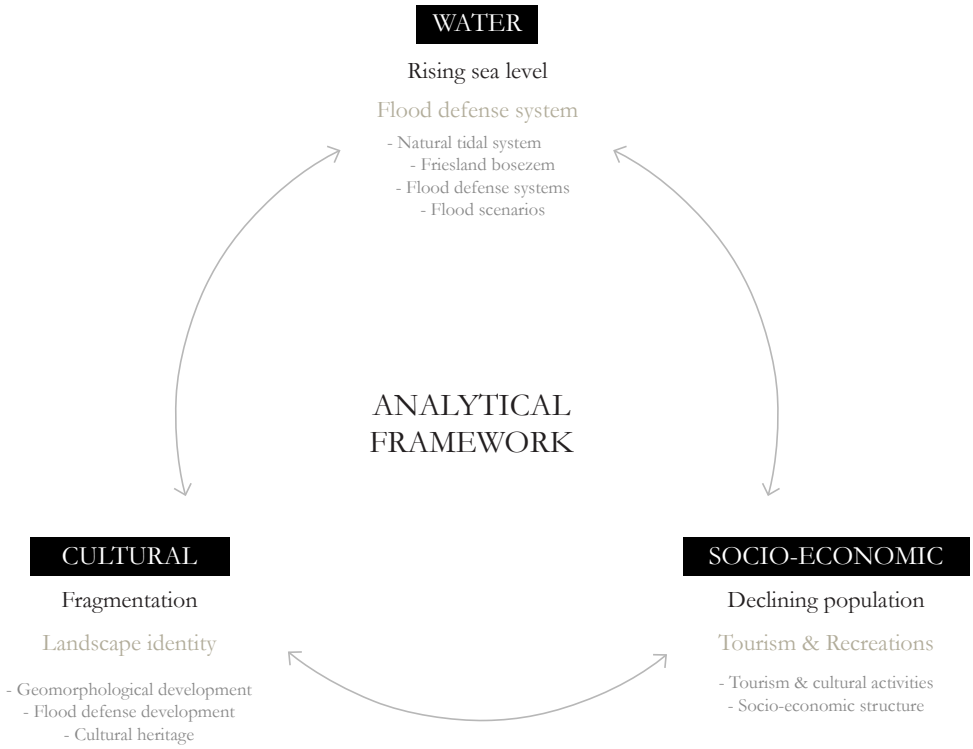


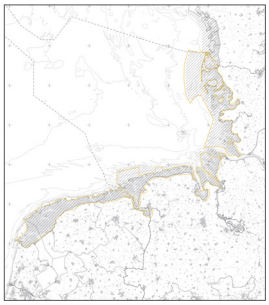
(Beller, Robinson, Grossinger, Grenier, Letitia, 2015).

Theoretical Framework: Landscape Resilience

Landscape resilience is the key concept in my research question. It is the ability of a landscape to sustain desired functions and critical landscape processes over time, under changing conditions. (Beller, Robinson, Grossinger, Grenier, Letitia, 2015) Resilience as applied to ecosystems was first defined as a measure of a system's ability to absorb change and persist after a perturbation (Holling 1973).In addition to ecological systems, the concept of resilience encompasses social, economic, and infrastructure systems. (Curtin and Parker 2014) In this project, the idea of resilience brings me to three design concepts, i.e. climate daptive waterscape, water heritage and valuable waterscape.

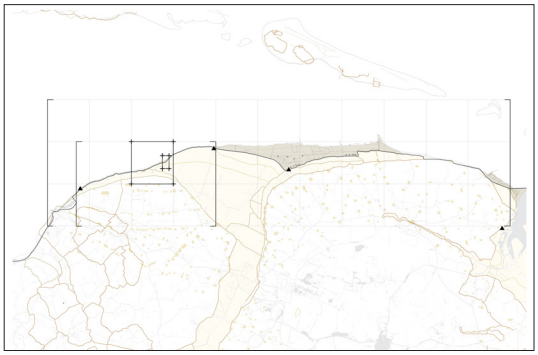
Analytical Framework





Territorial scale

The territory considers the entire Wadden Sea Region and in particular the northern part of the Netherlands including the province of Noord Holland, Friesland and Groningen. Wadden Sea Region refers to the area within the management of the Trilateral Cooperation, as well as the land adjacent to it. IJsselmeer is also included as part of the water systems in the territory. Research on the territorial level addressed the national challenges and the entire landscape systems.



Regional scale

The regional scale targets at the Friesland Wadden Coast and in particular the Koehool-Lauwersmeer dike for in-depth analysis and design projection. Friesland Wadden Coast refers to the coastline of Friesland within the Wadden Sea Region. Strategic plan is designed at this scale to envision the future of the region coherently and set up design conditions for local projects.

Local scale

Zooming in the Friesland Wadden Coast, the local scale is drawn in the dike section of Koehool. Small-scale interventions are proposed to show the spatial and experiential designs in detail.

The Past

A cultural water landscape

Hegebeintum.
Photo: Google Earth, 2021.

The Dutch Wadden Sea can be interpreted as a palimpsest with a succession of layers over time. This chapter discusses the landscape transformations that reveal the geomorphological development, human activities at different periods of time. Natural processes undertaken in the Wadden Sea are not only dynamic but also require a very long period of time. In the modern age, the cultural processes are more dominant than the natural processes.

The inundation of the Pleistocene valleys and the Holocene sea-level rise has formed the tidal basin in the Wadden Sea since 8000 BC.(Oost, Winter, Vos, Bungenstock, Schrijvershof, Röbke, Bartholdy ,Hofstede, Wurpts, Wehrmann, 2017) The rates of sea-level rise and sedimentation influenced the size of the salt marsh and coastal peat marshes, resulting in continuous dynamics in the coastal morphology of the Wadden Sea. The dynamic of the mechanism has been highly reduced with the arrival of the sea dikes and human activities since the middle age, forming the Wadden Sea as today.

Human's intervention has had an increasing influence on the landscape since the middle age. Historical Frisian settlements had been found on the artificial dwelling mounds, known as terps, since 500BC.(Schroor, Enemark,Fischer, Guldberg, 2017) The construction of the sea dike from 1200 AD reclaimed the salt marsh for agriculture.The closures of the Zuiderzee and Lauwersezee shortened the coastline and a primary sea dike was built to protect the hinterland up until now. By studying the patterns and layers through mapping, the landscape appears as a palimpsest which can be read and speculated about the past development. The geomorphological layer reveals the occurrence of the marine ingressions and the land reclamation over time. The flood defense systems have been evolving throughout history and have been part of the cultural heritages in Friesland.

This landscape is a layered entity where traces of different times are still visible and remained as water heritages. The remnants of terps are the oldest remaining artifacts of human intervention in the Wadden Coast which have a significant influence on the field patterns and cultural landscape. The historical sea dikes are still recognizable in the form of roads. A landscape-integrated design should take the cultural values into account, strengthening the cultural-historical identity of the Wadden Coast and enriching the tourist experience with the water heritage.

Geomorphological Evolution

Data: Vos, Meulen, Weerts, Bazelmans, 2020.
Pleijster, Veeken, 2014.

3850BC
Bronze Age

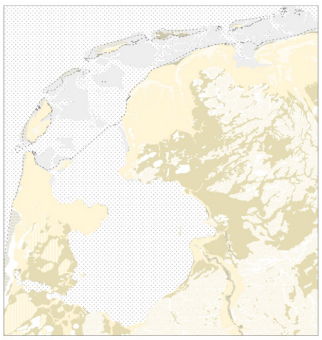
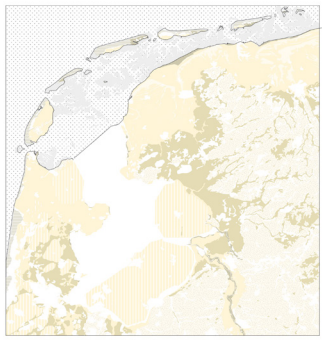
100AD
Iron Age

800AD
Middle Age

1500
Middle Ag

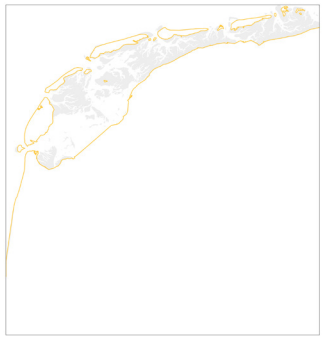
0 10 km 50 km 100 km

N

Land





Water

1850

2000

ge

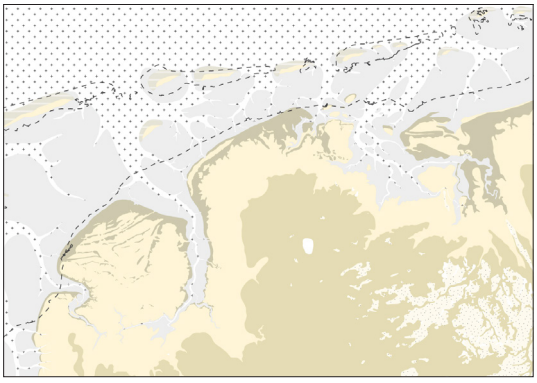
Modern Age

Anthropocene

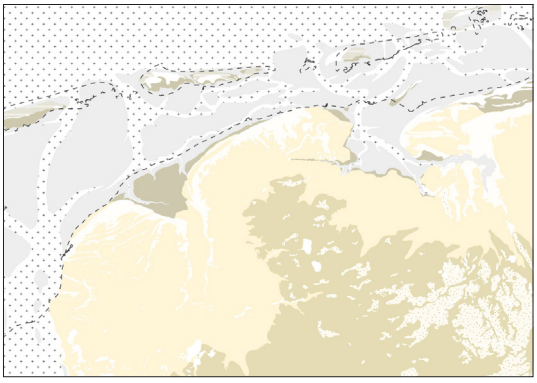
Open water
Intertidal zone
Salt marshes
Dryed salt marshes & river plains
Peatland
Reclaimed land
Coastline
Current coastline

Geomorphological Evolution

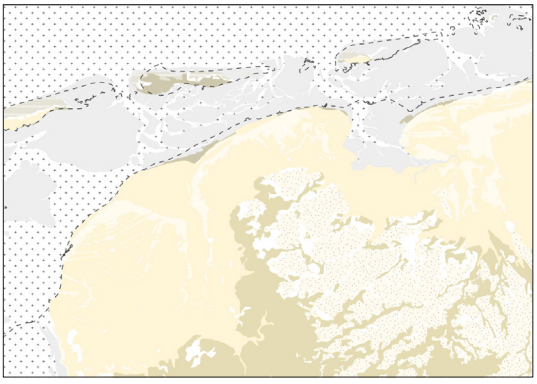
Data: Vos, Meulen, Weerts, Bazelmans, 2020.



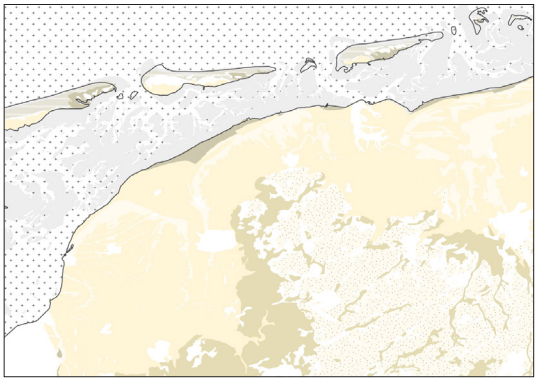
800AD
Middle Age



1500
Middle Age



1850
Modern Age



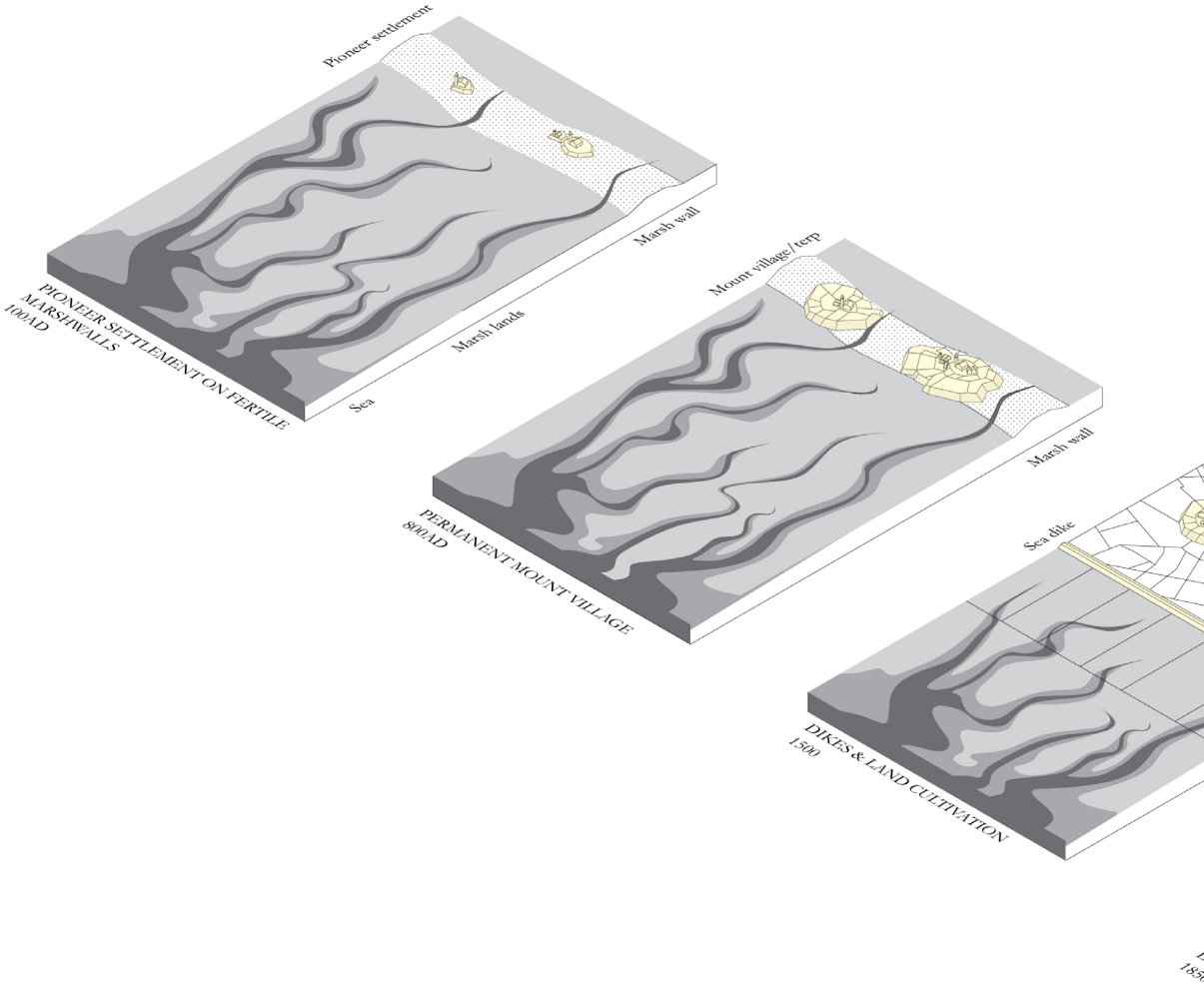
2000
Anthropocene

Open water
Intertidal zone
Salt marshes
Dryed salt marshes & river plains
Peatland
Reclaimed land
Coastline
Current coastline

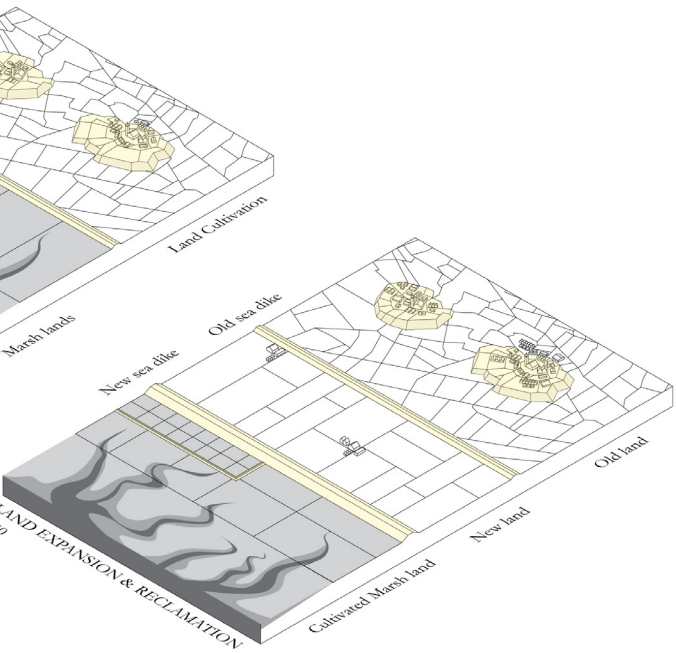
The geomorphological development of the Wadden Sea has been closely related to sea-level rise and sediment supply.(Wang, Elia Spek, Lodder, 2018)The inundation of the Pleistocene valleys and the Holocene sea-level rise has formed the tidal basin in the Wadden Sea since 8000 BC.(Oost A. P., Winter C., Vos P., Bungenstock F., Schrijvershof R., Röbke B., Bartholdy J.,Hofstede J., Wurpts A. & Wehrmann A., 2017) The Wadden Sea reached its greatest extent during the Middle Ages due to the marine ingressions. Since then, the Wadden Sea has gradually diminished in size through successive reclamation of the newly accreted salt marshes for agricultural purposes.(J.P. Bakker, P. Esselink,K.S.Dijkema,W.E.vanDuin& D.J. de Jong, 2002)

In the last century, the morphological development of the Wadden Sea has also been strongly influenced by human activities. From the Middle Ages onward, the land reclamation brought by dike construction and the closures of the Zuiderzee and Lauwersezee shortened the coastline and formed the land as we know it today.

Fighting Against Water

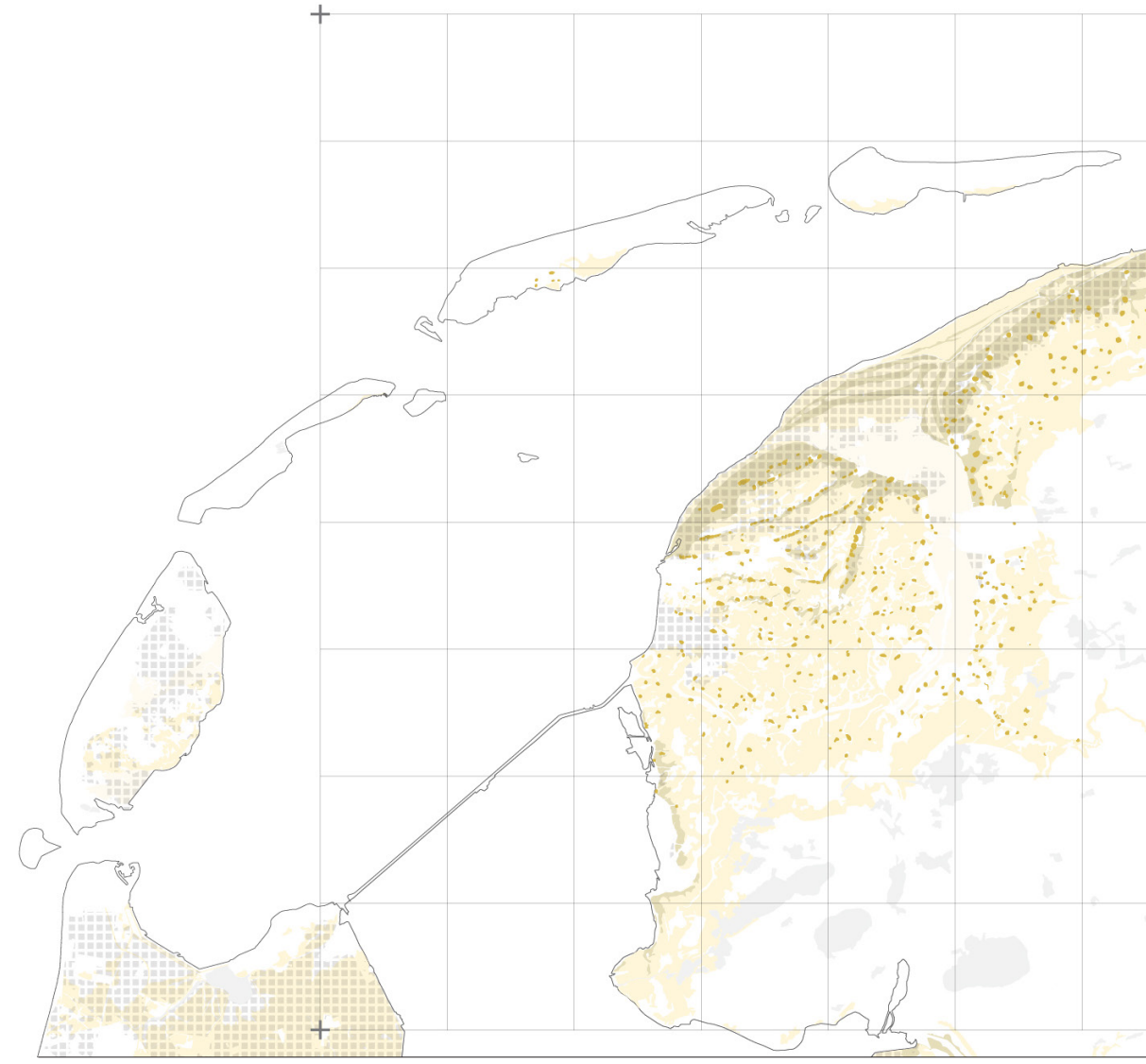


The Frisians have had a long battle against the water and manipulated the coastline by dike construction and land reclamation.Historically, the coastal regions were often subjected to large floods. The pioneer settlements were found on salt marsh walls. To safeguard the ground from flooding, artificial dwelling mounds up to 15 meters, known as terps, were built from 500 BC. The construction of terps ended with the arrival of the first dikes in the area in around 1200. During the 18th and 19th centuries, many terps were destroyed to use the fertile soil to fertilize farm fields. Saltmarsh was reclaimed for farming and a primary sea dike was built to protect the land up until now. Summer quays were built for summer grazing on the foreland along the coast. The time series showed how the primary sea dike has moved further seawards due to land reclamation.The villages gradually lost their connections with the sea.

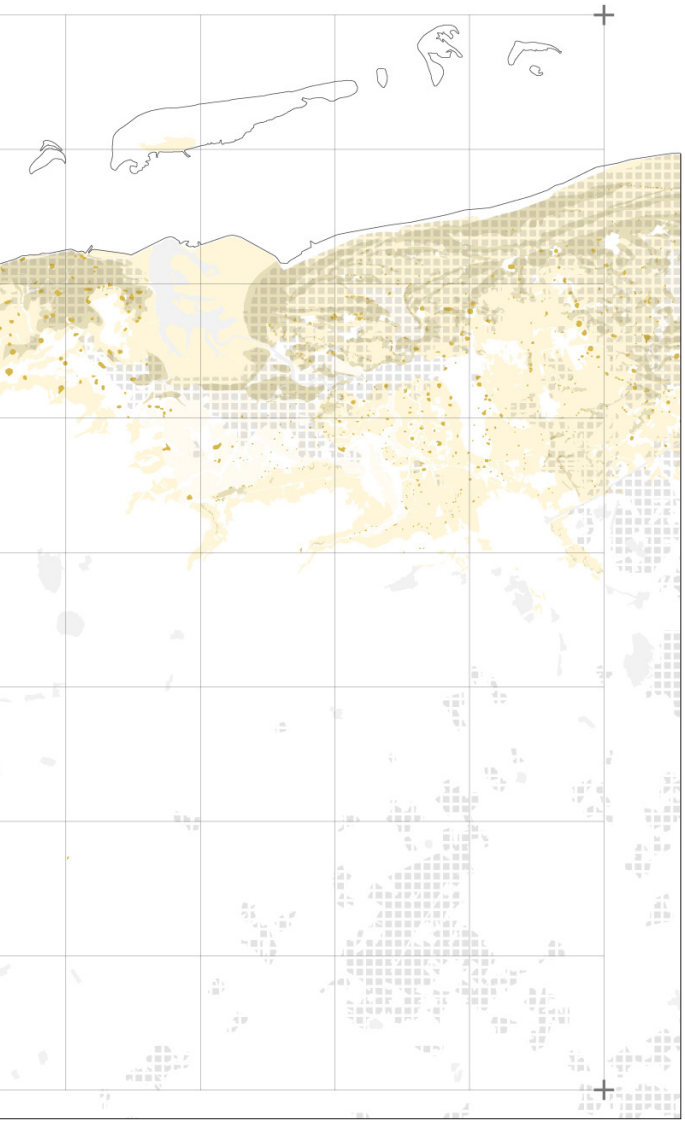


Geomorphology & Cultural Pattern

Data: BRO Geomorphology, 2018.



0 | 10 km | 30 km | N



Salt marsh walls and terps on the mainland are the morphological characteristics of the Wadden area. The terps were constructed on the salt marsh wall from 500 BC.The salt marsh walls which were sand heighted from the Pleistocene were later covered with peat and clay from 1000 AD. Despite the destruction of the terps in the 18th century, the remaining patterns are still visible. This old salt marsh landscape can be found in the Westergo and Oostergo in Fryslân and around Hunsingo, Fivelingo and Oldambt in Groningen. (Agenda voor het Waddengebied 2050, 2020) The agricultural lands are mainly located on the newly accreted salt marshes reclaimed in the 16th century.

Timeline & Major Flood Events

Data: Wikipedia, 2021, Wadden Sea World Heritage, 2021

Natural process

Natural disaster

1219
The Saint Marcellus' Flood

1703
Great Storm

1717
Christmas Flood

1730
Dike damage by shipworm

1825
February Flood

1916
Storm Flood

1953
North Sea F

Cultural process

Infrastructures

1200-1500
1st large-scale building of dikes

1505
Reclamation of Bildtdijken & polder

1500-1650
large-scale land reclamation ,polders and large-scale peat extraction

1700s
Villages linked to marine network of canels

1800-1950
Modernization of the dikes and dike management

1933
Afsluitdijk

1958
Delta

Policies

The infrastructure and policy development are closely related to the historical flood events. Since the modern age, the cultural processes have become more dominant than the natural processes. The protection and conservation work of the Wadden Sea has been done since 1978.

lood

Act

1969
Lauwersmeer

1975
1st International Scientific Wadden Sea Symposium (ISWSS)

1978
1st Trilateral Governmental Conference between Denmark, Germany and the Netherlands

1982
"Joint Declaration on the Protection of the Wadden Sea"

1987
Common Wadden Sea Secretariat (CWSS)

1996-2001
Lancewad

1997
1st Trilateral Wadden Sea plan

1998
Nature Conservation Act

2009-15
Dike reinforcement

2002
Designated as PSSA under IMO
Establishment of Wadden Sea Forum

2003
International Wadden Sea School (IWSS)

2005
Overleg Orgaan Waddeneilanden (OOW)

2007
LancewadPlan (LWP)
Framework Vision on the Wadden Sea

2008
1st National Water Plan

2009
UNESCO World Heritage
The Dutch and German parts of the Wadden Sea were inscribed on UNESCO's World Heritage List

2010
Revised Wadden Sea plan & Joint Declaration

2015
Second National Water Plan
Delta Programme "Nieuwbouw en herstructurering"

2018
Leeuwarden Declaration

2019
Wadden Sea Management Authority

2020
Agenda for the Wadden Region 2050

2022
14th Trilateral Governmental Council Meeting in 2022

Single integrated management plan (SIMP) Meeting in 2022

Old sea dikes.
Photo: Author, 2022.

The Present

A dynamic landscape

Sea dike.
Photo: Author, 2022.

This chapter discusses the dynamic systems together with the present opportunities and challenges in the Dutch Wadden Sea and Friesland, focusing on the relationship between the land and Wadden Sea.

Wadden Sea is characterized by the intertidal systems with an extensive tidal basin connecting to the islands. The tidal systems bring the sediments from the North Sea through the tidal inlets, forming the tidal mudflat and salt marsh. Currently, the sedimentation process outpaces the rate of sea level rise and protects the land from flooding. The foreland and salt marsh in Noord-Friesland Buitendijks provide adequate dike protection and could be considered as part of the flood protection.

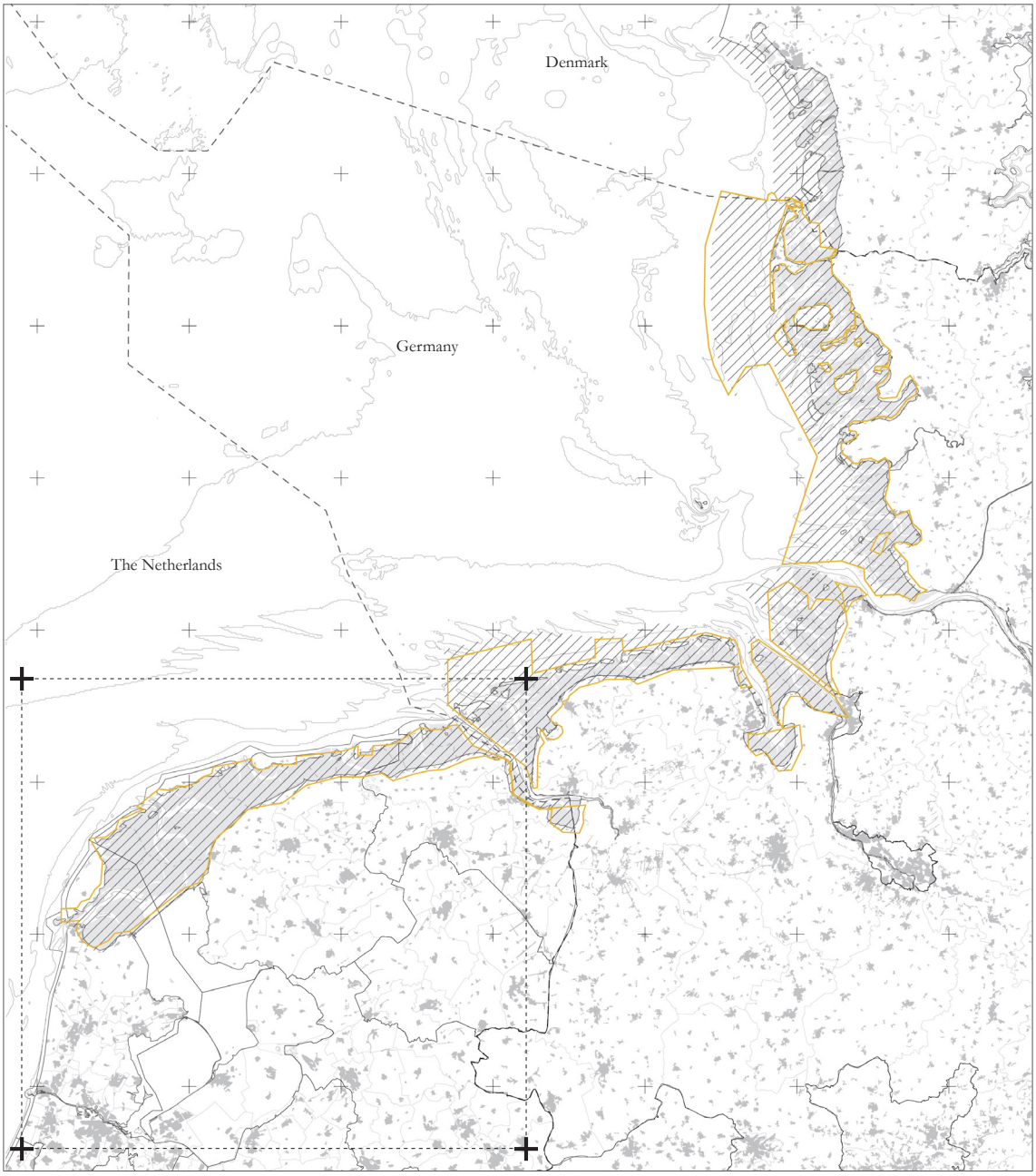
A primary flood defense bounding along the coast clearly defines the land and water in the region. The flood defense systems consist of the sea dikes and regional flood defenses ensure the safety of flood protection in the nation. Together with the water boezem systems in Friesland, excessive water is discharged back to the sea and Ijsselmeer by pumping stations and sluices to maintain the water level. The above systems (tidal systems, flood defense systems and boezem systems) explain the flood management in the region, revealing the opportunities and threats of this coastal landscape.

Along the Wadden Coast, the major type of landscape is agricultural polder, with extensive potato croplands and grasslands for grazing. The marshlands formed in the Holocene provide fertile soil for farming. Nevertheless, salinization has become increasingly significant due to climate change, threatening the agricultural industry in the long run. The northern Friesland is also confronting a declining and aging population affecting the economic development. Tourism and recreation along the coast and on the islands offer opportunities to enhance the regional economy.

Wadden Sea World Heritage Site.
Photo: Wadden Sea World Heritage Site, 2021.

Administration & Protection Borders

Data: General Bathymetric Chart of the Oceans (GEBCO), 2021.



National border
Province border
Municipality border
UNESCO border
Trilateral Conservation area
Bathymetry
Tidal basin
Urban area

0 10 km 50 km 100 km

N

"One Wadden Sea.
One World Heritage."

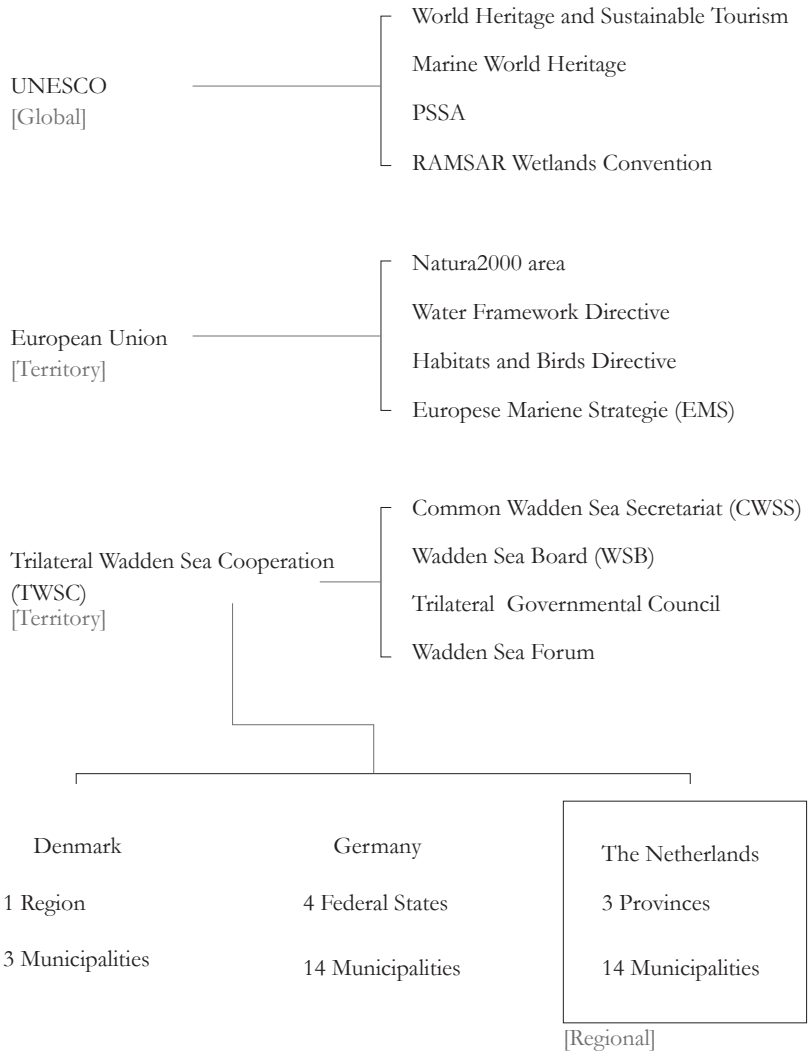
The World Heritage Committee 2014, requested the States parties "to develop a single integrated management plan for the entire transboundary property".

The Wadden Sea Region is an intertidal area spanning the countries of the Netherlands, Germany and Denmark. In 2009, the Dutch and German part were listed in the UNESCO World Heritage and the Danish part was added in 2014.

The Wadden Sea region is almost equally divided between water (51.5 %) and land (48.5 %), the water coinciding with the Wadden Sea World Heritage property, consisting of tidal flats, gullies and salt marshes.(Schroor, Enemark, Fischer, Guldberg, 2017) The land area breaks down to about fifty Frisian or Wadden Islands, sandy and marshy islands separating the Wadden Sea from the North Sea, and the adjacent and diked marshlands on the mainland. The inland area along the water, in the following referred to as "Wadden Coast", is not included in any international conservation or protection entities but within the national territories.

The administrative boundaries of the Wadden Sea including International and European protection and conservation boundaries differ from each other. We can observe that what is considered part of the Wadden Sea region by UNESCO does not correspond to the area by the Trilateral Cooperation. These administration and protection borders somehow fragment and bring challenges on the integral management for the entire region. As a result , a single integrated management plan is necessary to draw the plan into an entity.

Administration & Protection Borders



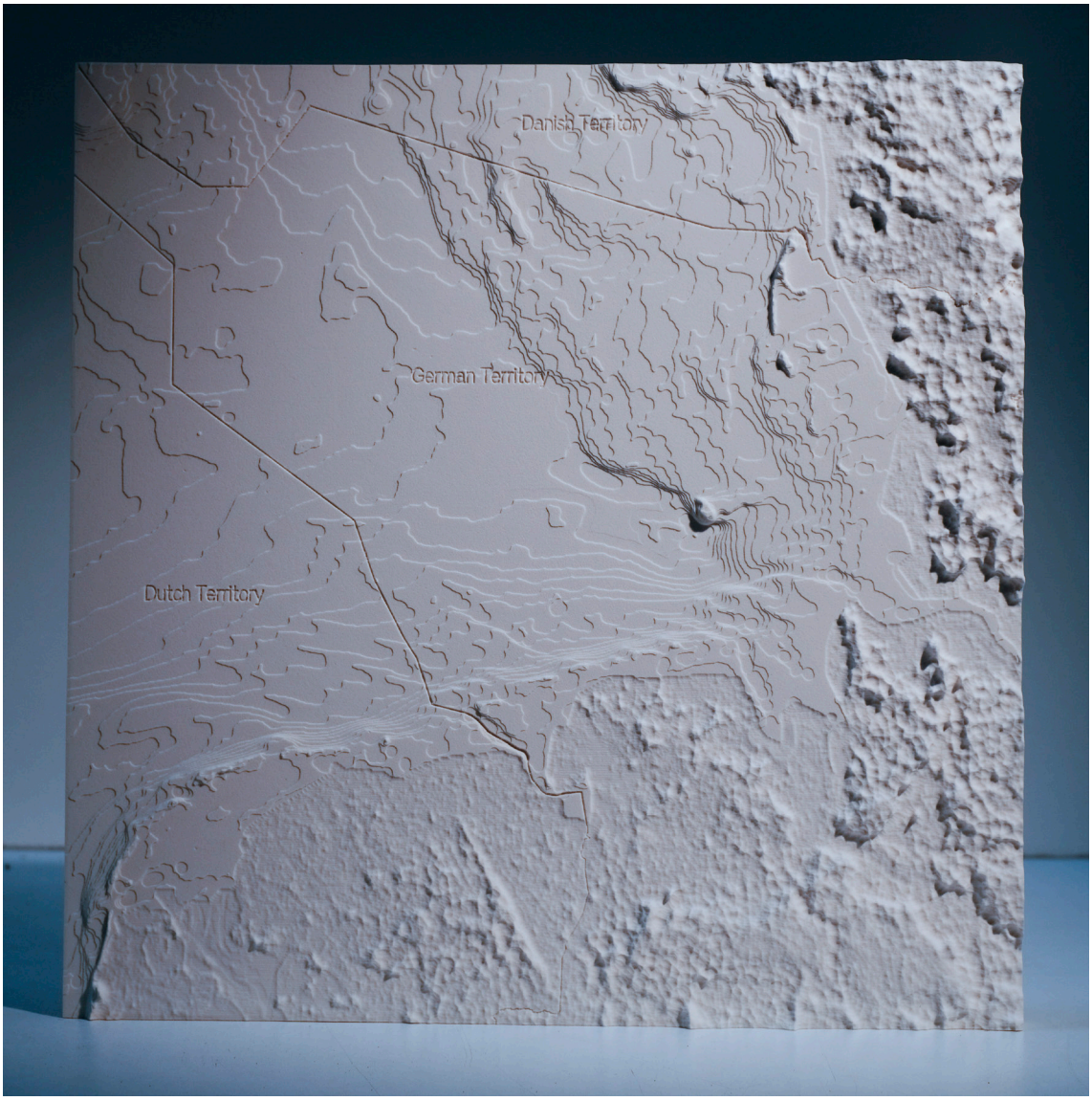
Although the Wadden Sea encloses the coastal waters of three nations, the Wadden Sea is considered as a region because of the extension of intertidal dynamics and the similar socio-cultural development. The governments of the Netherlands, Denmark and Germany have been working together since 1978 on the protection and conservation of the Wadden Sea. In 1982, the "Joint Declaration on the Protection of the Wadden Sea" was signed to protect and preserve the Wadden Sea as an ecological entity through common policies, management and research. The Trilateral Wadden Sea Cooperation is a transboundary ecosystem-based collaboration for the designation of the Wadden Sea as a World Heritage site.(Wadden Sea World Heritage, 2022)

"the long-term protection and development of the Wadden Sea as a nature reserve and conservation of the unique, panoramic landscape".

-the Framework Vision on the Wadden Sea,2007

Territorial Site Model

(Group Work, 2021)
Data: General Bathymetric Chart of the Oceans, 2021.



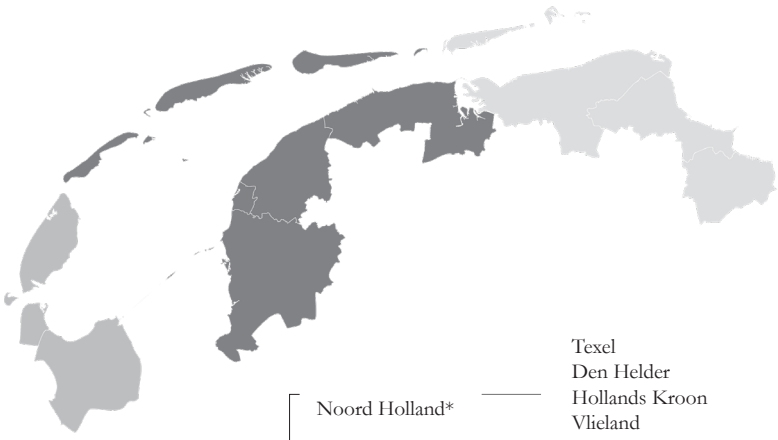
Model of the Dutch, German and Danish Waddensea, horizontal scale 1:750.000, vertical scale 1:7500 (model size 500 x 500mm).
Photo: Keyan Tang, 2021.

A 500 x 500mm 3D model is made during the workshop of 'Thinking with Maps' with Laura Cipriani in a group of five students. (Keyan Tang , Hanneke Wander, Madelief Dekker, Suihui Kuo & Author) This 1:500.000 scale level model conveys the Waddensea's unbroken system in relation to the contemporary cultural layer added by humans. We added four layers in the model: the bathymetry, the topography, the country borders and the names of the territory. These layers combined tell the story of the Wadden Sea on this scale with the theme of "Altitude Of Flatness".

Dutch Wadden Sea Region

The Dutch Wadden Sea Region encloses three provinces (Noord-Holland, Friesland and Groningen) and 14 Wadden municipalities. Represented in the Wadden Region Regional Council, they coordinate policy and management with different ministries and waterboards to manage the whole region. To protect this nature reserve, they have made agreements on nature conservation, recreation, tourism and mudflat hiking. Four water boards are responsible for flood protection and water management on the islands and on the mainland of the Wadden Sea Region. They ensure that the sea-retaining dikes and the retaining sandy coast remain in good condition. Dike reinforcement along the Wadden Coast is a task for the Wetterskip.The Ministry of Infrastructure and Water Management is the initiator and formal client for the process of the Agenda for the Wadden Region 2050. Research groups like Wadden Academy publish scientific research from time to time.

More recently, in 2019, Wadden Sea Management Authority (Beheerautoriteit Waddenzee) was established to enhance cooperation and mutual consultation between various authorities involved with the Wadden Sea. (Lambooya, Venisd, Stokkermans, 2019) One of the most important products for the joint management of the Wadden Sea is the Integrated Management Plan.

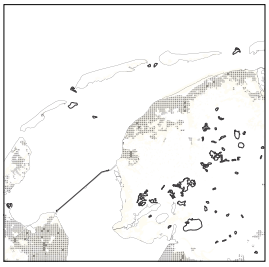


Wadden Sea Region
The Netherlands

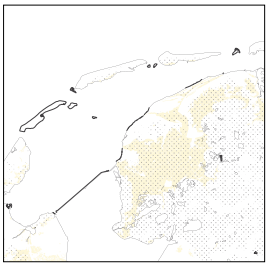
- 3 Provinces
  14 Wadden Municipalities
  - Noord Holland*
    - Texel
      Den Helder
      Hollands Kroon
      Vlieland
  - Friesland*
    - Terschelling
      Ameland
      Schiermonnikoog
      Súdwest-Fryslân
      Harlingen
      Waadhoeke
      Noardeast-Fryslân
  - Groningen*
    - Het Hogeland
      Eemsdelta
      Oldambt
- 4 Water boards
  - Wetterskip Fryslân
    Noorderzijlvest
    Hunze en Aa's
    Hollands Noorderkwartier
- 3 National Parks
  - Texel Dunelands National Park
    Lauwersmeer National Park
    Schiermonnikoog National Park
- Ministries
  - The Ministry of Economic Affairs
    The Ministry of Infrastructure and Water Management*
    The Ministry of Agriculture, Nature and Food Quality*
    The Ministries of Education
    The Ministries of Culture and Science
    The Ministry of Defense
    Rijkswaterstaat
- Wadden Sea Management Authority
  - Wadden Sea Administrators Collective
    Wadden Region Regional Council
    **Clients of the Managing Authority*
- Organizations
  - Wadden Academy
    Young Wadden Academy
    Rich Wadden Sea (PRW)

Landscape Types

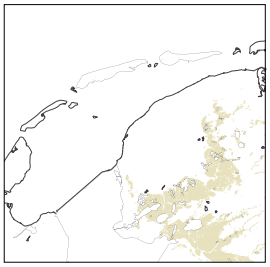
Data: Soil types, GeoDesk, Wageningen University & Research, 2006.



Fertile Clay Landscape

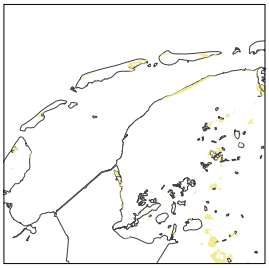


Grazing Grassland



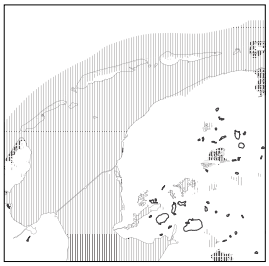
Peatland

Terp Villages

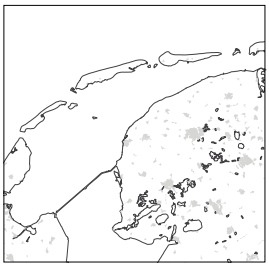


Marshland

Dune



Nature Park



Cityscape

Along the Wadden Coast, the major type of landscape is agricultural polder, with extensive potato croplands and grasslands for grazing. The arable land is mainly located on the former salt marsh walls because of the fertile clay soil. Large amounts of the clay grasslands are used for farm grazing. The peatland is located in the south eastern lowland area. The remaining terps are the old villages and house mounds distributed on the historical salt marsh wall. The dunes and marshlands are located on the islands and the coast outside dike rings. The largest foreland is located at the Noord-Friesland Buitendijks with summer polders and low marsh lands. Little nature park can be found in the land of Friesland. The major cities near the Friesland Wadden Coast are Leeuwarden, Harlingen and Dokkum.

Coastal salt marshes as flood fighters.
Photo: NIOZ/Edwin Paree, 2021.

Friesland Boezem

Data: Wetterskip Fryslan, 2021.

The Frisian Boezem is a continuous system of waterways, lakes and canals which is responsible for maintaining the water level for both water drainage and storage. During the dry season, water is supplied from the Ijsselmeer to maintain the water level in the polders. Water is discharged to the Wadden sea and Ijsselmeer by pumping stations and sluices in the wet season.In the southwestern part of the area, there are two huge pumping stations for the discharge of water to the IJsselmeer. The most famous one, Woudagemaal, was built hundred years ago. It is the largest operational steam-powered pumping station in the world.

The yellow areas indicate the places which are below the water level of the Frisian Boezem system. The surface in the other areas is above the water level of the Frisian Boezem. Only the white areas are high enough to discharge water without pumping stations. Almost all the other areas have pumping stations that drain water to the Frisian Boezem. There are almost 1000 pumping stations in the total catchment of the Frisian boezem. The boezem also serves as important functions for water recreation,commercial shipping , nature, ecology and agriculture.

R.J. Cleveringsluizen

1969
28 million cubic feet of water in 5hr

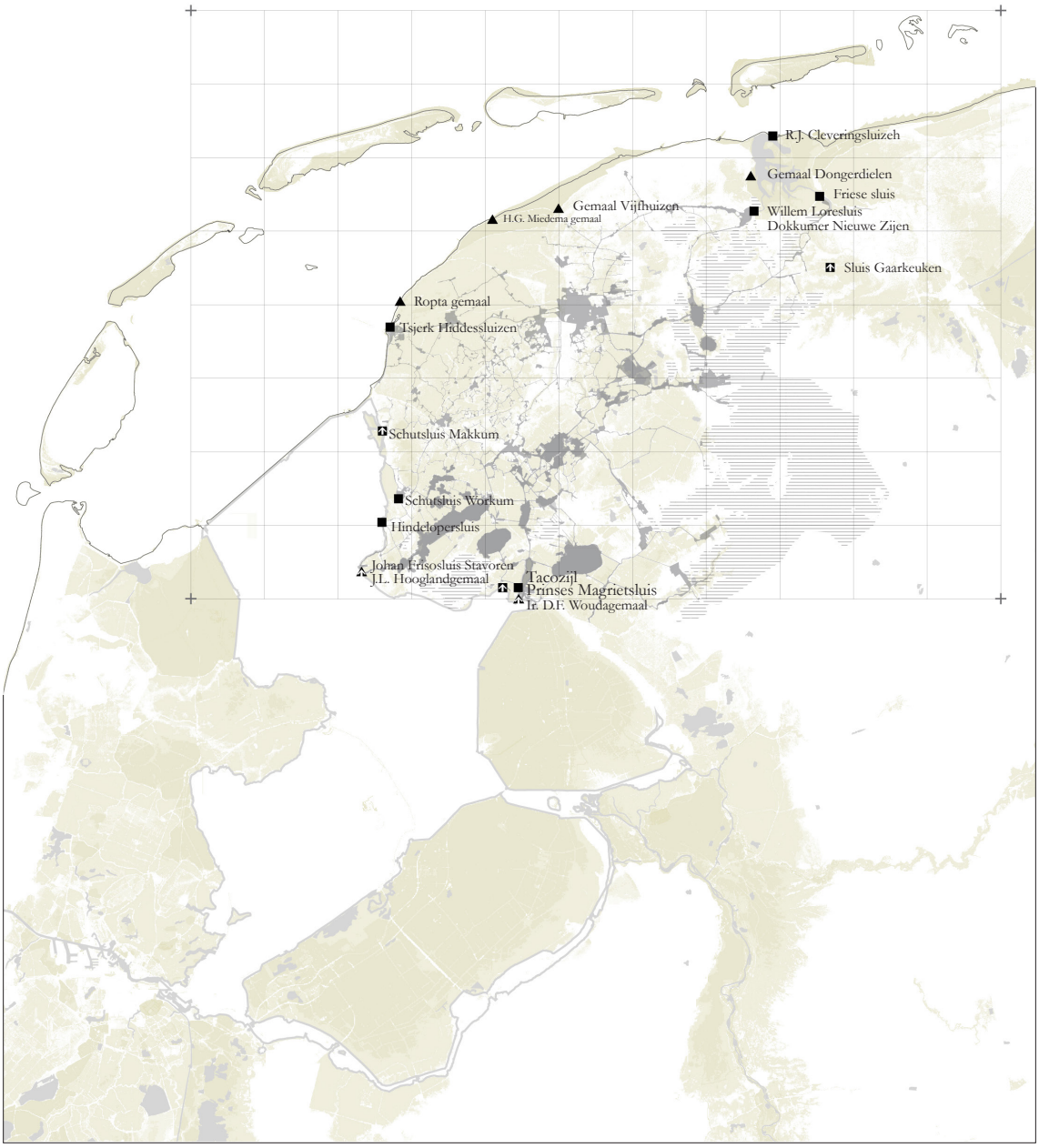
Dokkummer nieuwe zijlen

1729

Woudagemaal
1920
4000 m³ per minute
UNESCO World Heritage List

Hooglandgemaal
1967
7,300 m³ per minute.
National monument

0 10 km 50 km N



Boezem
Frisian river basin
Land below sea level
Water
Inlet
Sluice gate
Pumping station

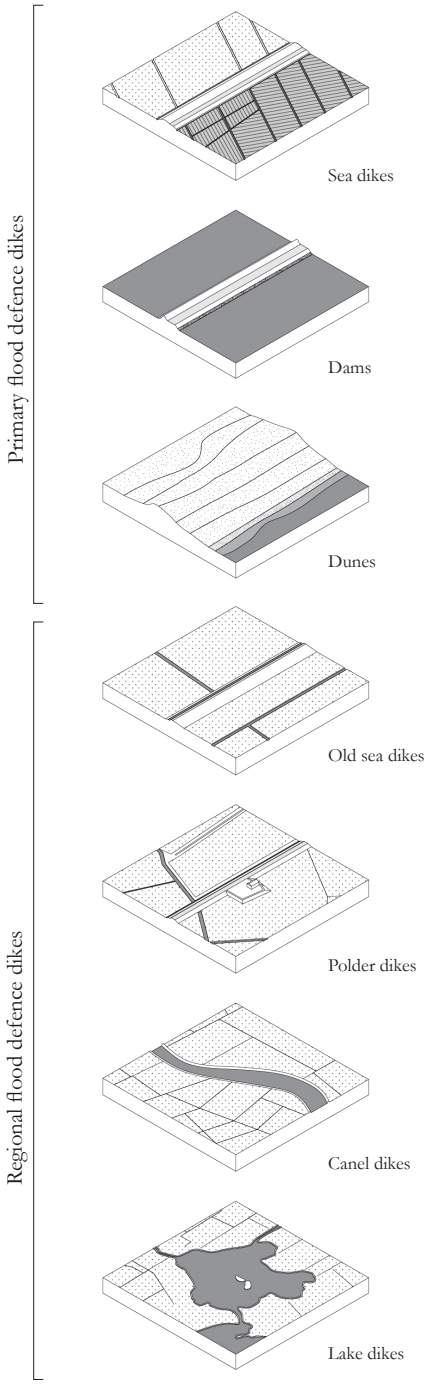
Flood Defense Systems

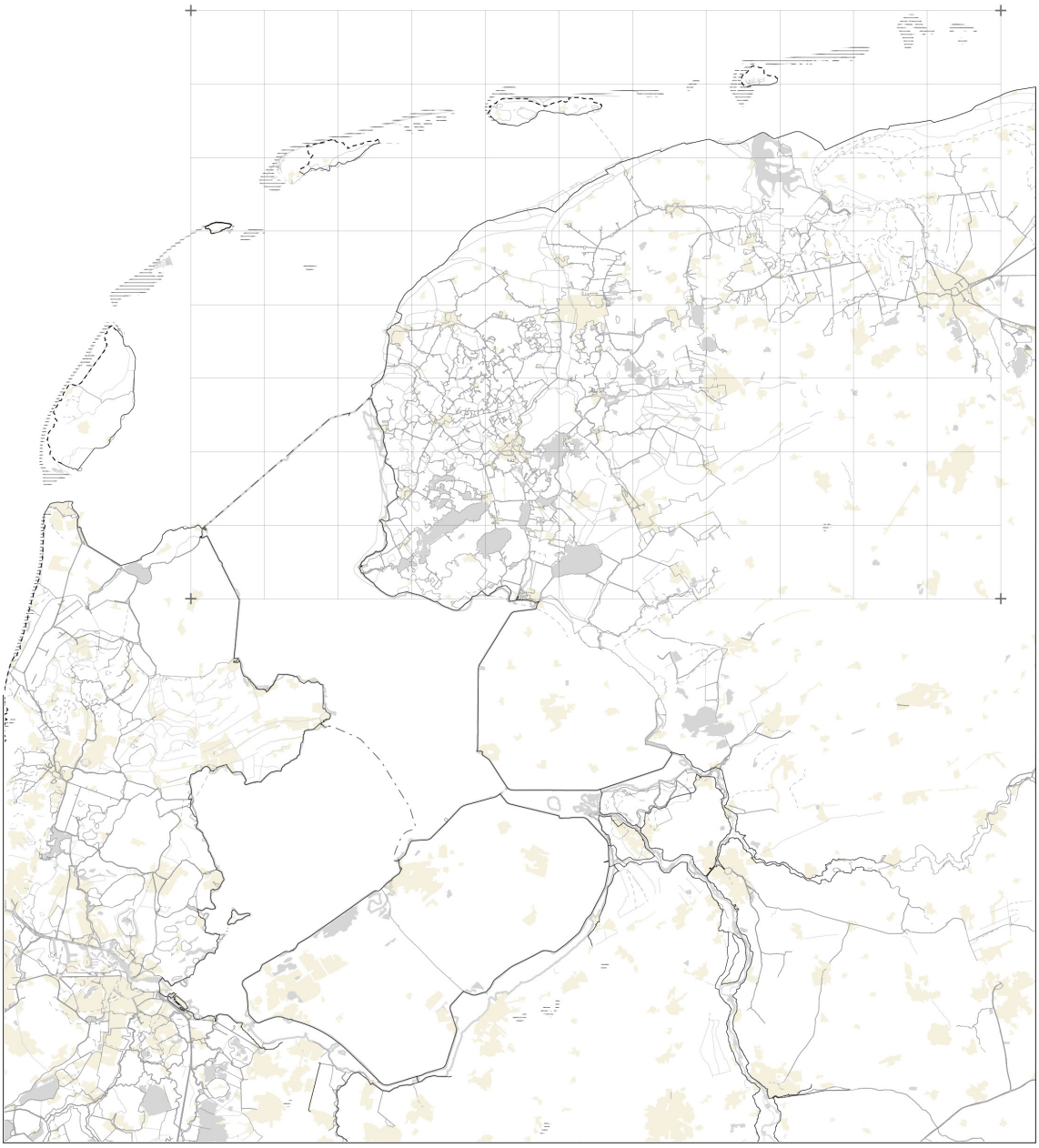
Data: RCE-Dijkenkaart, 2021.

Primary flood defenses are the first barriers protecting the country from high sea water. The primary defense system in the Wadden Sea Region consists of sea dikes, dams, and dunes. Sea dikes are relatively high (about 8 meters above ground level) with an asphalt revetment at the lower part of the outer slope. The 32-kilometer Afsluitdijk was built in 1932 to close off the former Zuider Zee from the North Sea to protect the north and central regions of the Netherlands from storm surges from the sea. (Pleijster, Veeken, 2014) Dunes are mainly present on the Wadden Islands to prevent water from the North Sea.

Regional flood defenses refer to all flood defenses with a set standard constructed to protect areas inside or outside a dike ring. (Pleijster, Veeken, 2014) The regional flood defense system includes the former sea dikes, polder dikes , canel dikes, lake dikes, forelands and summer dikes. Since the water level in the boezem is much higher than the land in the polder, regional dikes are crucial to protect the land in the polders from flooding. In the northern part of Friesland, forelands are present along the coast to accelerate the silting up of the land.

In Friesland, there are about 3200 km of dikes.



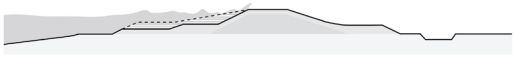


Primary flood defence dikes
Primary dams and storm barriers
Primary dune dikes
Regional flood defence dikes
Disappeared dikes
Other dikes
Sand dunes
Urban area

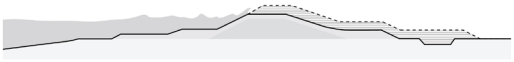
Dike Reinforcement

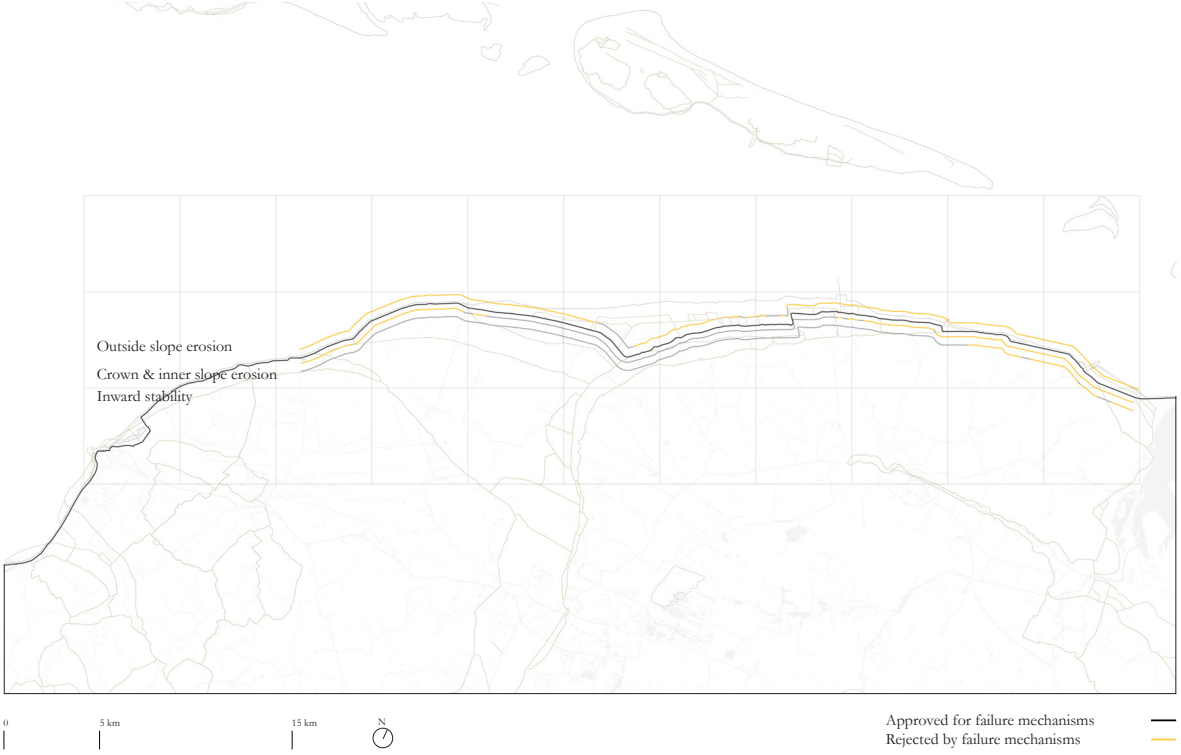
Data: Witteveen+Bos, 2021.

1. Increasing the outer slope

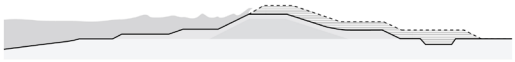


2. Increasing the height/making the inner berm wider





3. Reinforcing revetment (roughness or resistance to wave overtopping)



FAILURE MECHANISMS

Outside slope erosion

Crown & inner slope erosion

Inward stability

The management of flood defenses is a government task, which is mainly carried out by the water boards and Rijkswaterstaat. The Transport and Water Management Inspectorate (IVW) has conducted periodic inspections since 1996 to check whether the primary flood defenses meet the statutory requirements. (Pleijster, Veeken, 2014) The Water Act provides safety standards for the primary flood defenses. The safety standards for regional flood defenses are set by the provincial authorities.

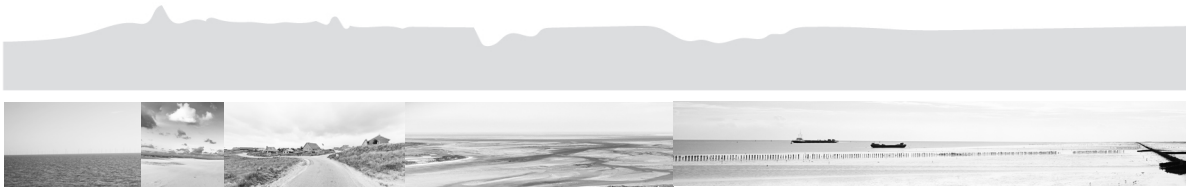
The Wadden Sea dikes protect Friesland and the Northern Netherlands against high water. The safety inspection of the sea dikes was carried out in 2009. Around 100 kilometers of the in total about 200 kilometers of dike (excluding islands and Afsluitdijk) along the Wadden Sea and Ems estuary did not meet the current national safety standard for various reasons and hence need further improvement. (Zijlstra, Hofstede, Piontkowitz, Thorenz, 2019) The manager of the flood defense, Wetterskip Fryslân, has therefore been commissioned by the National Flood Protection Program (HWBP) to strengthen the dike. (Witteveen+Bos, 2021) Dike reinforcement has been done on several dike stretches between the years 2009-2015 and the work will continue.

The Wetterskip Fryslân is improving 47 kilometers of sea dikes between the Koehool area and Lake Lauwersmeer. The yellow lines are the sections of dike which do not meet the safety standards and have to be strengthened. Apart from merely heightening the dike, new concepts are investigated for multifunctional dikes, overtopping resistant dikes and wide green dikes.

Sections

Data: General Bathymetric Chart of the Oceans, 2021.

North Sea | Dune (Island) | Wadden Sea | Marsh



North Sea | Dune (Island) | Wadden Sea | Marsh

North Sea | Dune (Island) | Wadden Sea

D

Wadden Sea | Dam | IJsselmeer

A

land Dike Cropland

B

land Dike Terp

C

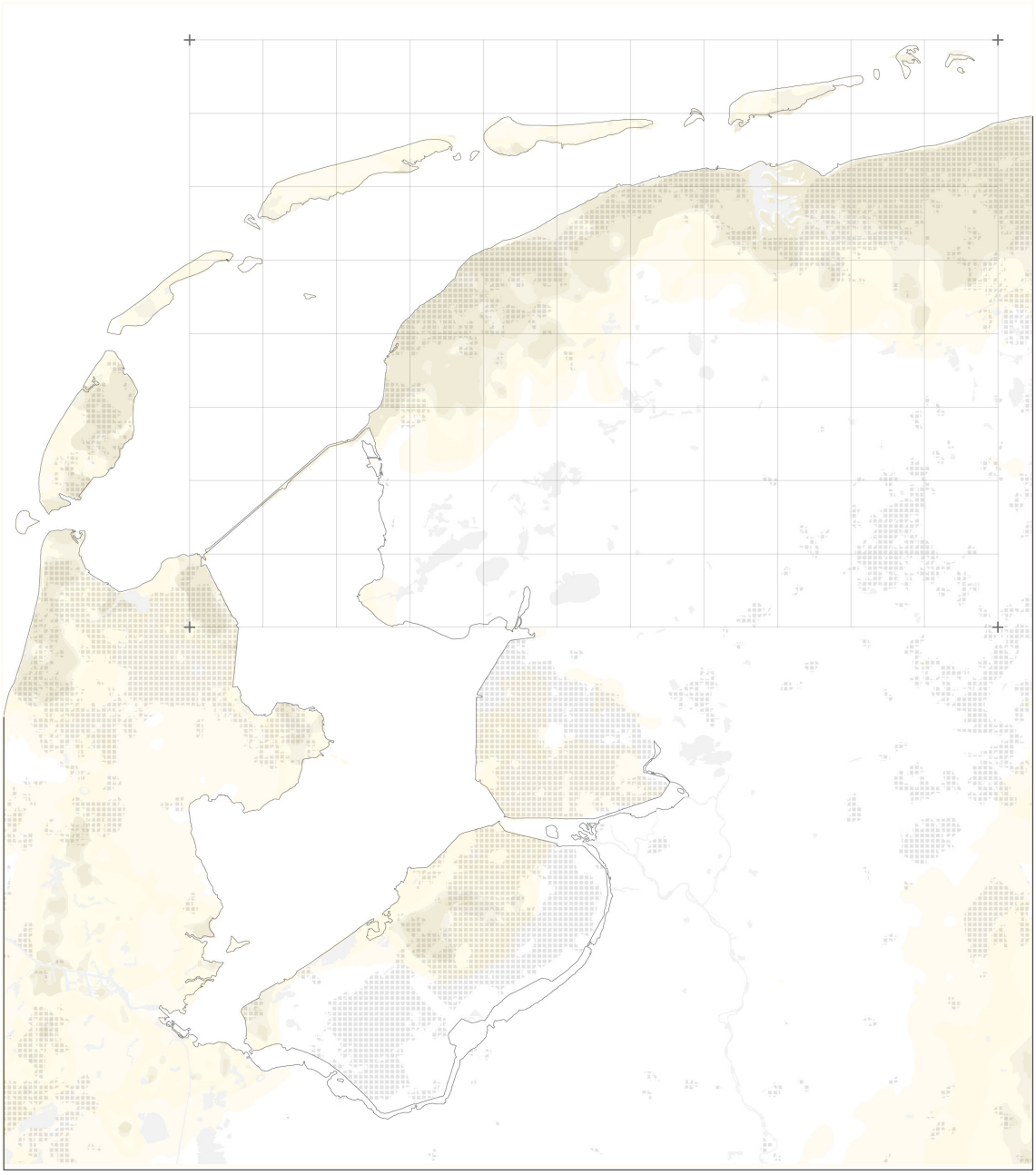
Marshland Dike Cropland

Salinization

Data: Deltares, 2021.

Salinization is a global issue threatening the agricultural activities and accelerated by the rising sea water level. Apart from sea level rise, land subsidence and the increase in temperature also result in groundwater salinization. Groningen, Friesland, Northern Holland are at risk of salinity. In Friesland, since the elevation is below mean sea level, salinization of the polders occurs by lateral intrusion of seawater. (Tzemi, Bosworth, Ruto, Gould, 2020) The seawater intrusion processes are expected to continuously influence the croplands along the Wadden Coast.

Saline agriculture is the major solution to adapt to the increasing salinity in the soil. On Texel, there is an experimental saline farm to cultivate salt tolerant crops. It is also an open-air laboratory evaluating the salt tolerance of conventional crops and halophytes, and performing large-scale screening of possible salt tolerant cultivars. (Salt Farm Texel, 2019)



Salinization of groundwater

0-5m below ground level

5-10m

10-25m

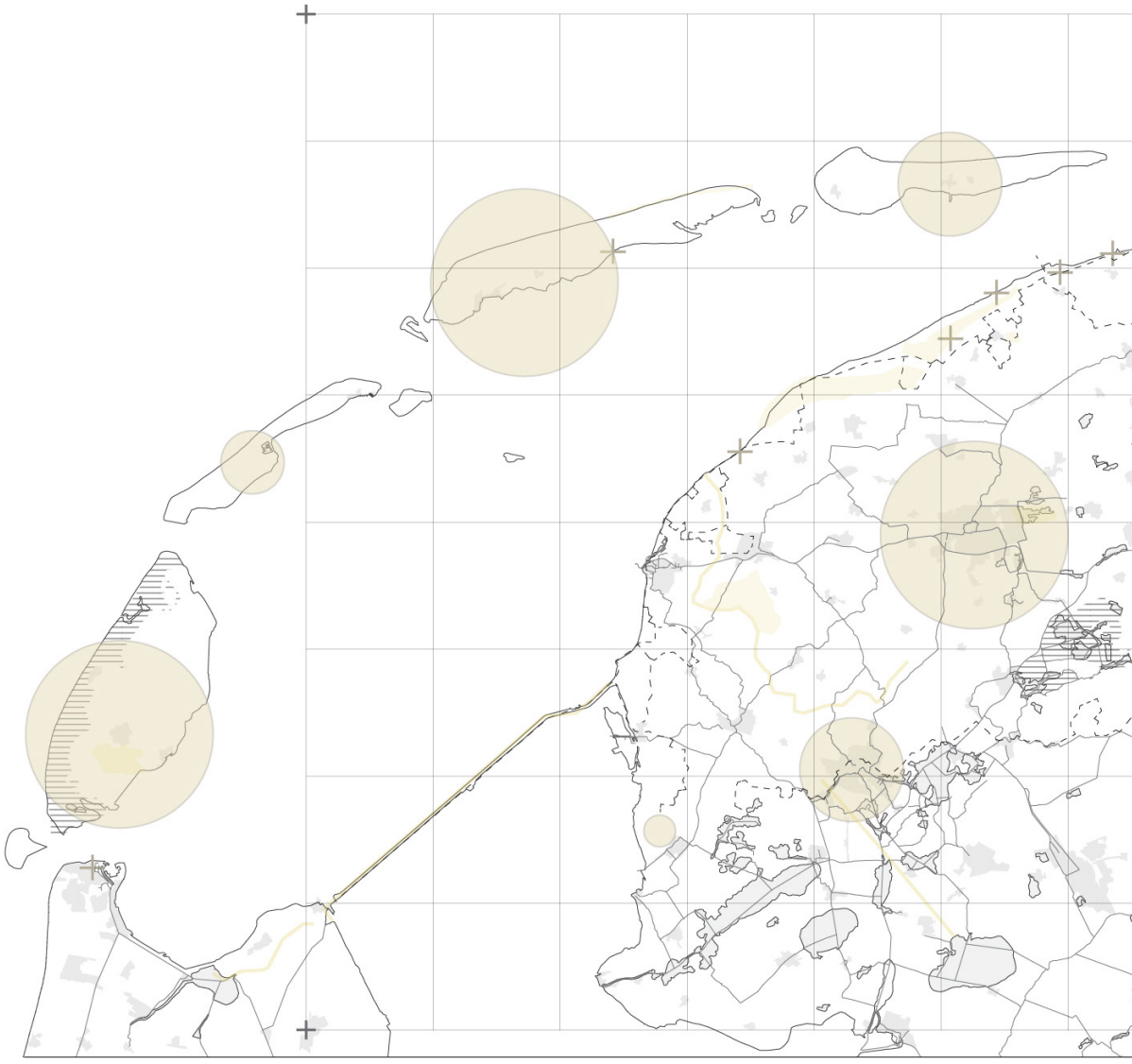
25-50m

50-100m

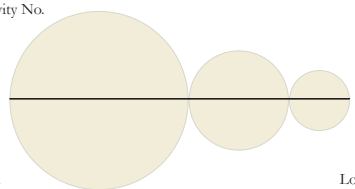
Cropland

Recreations

Data: Hydrografie waterschappen INSPIRE, 2021.

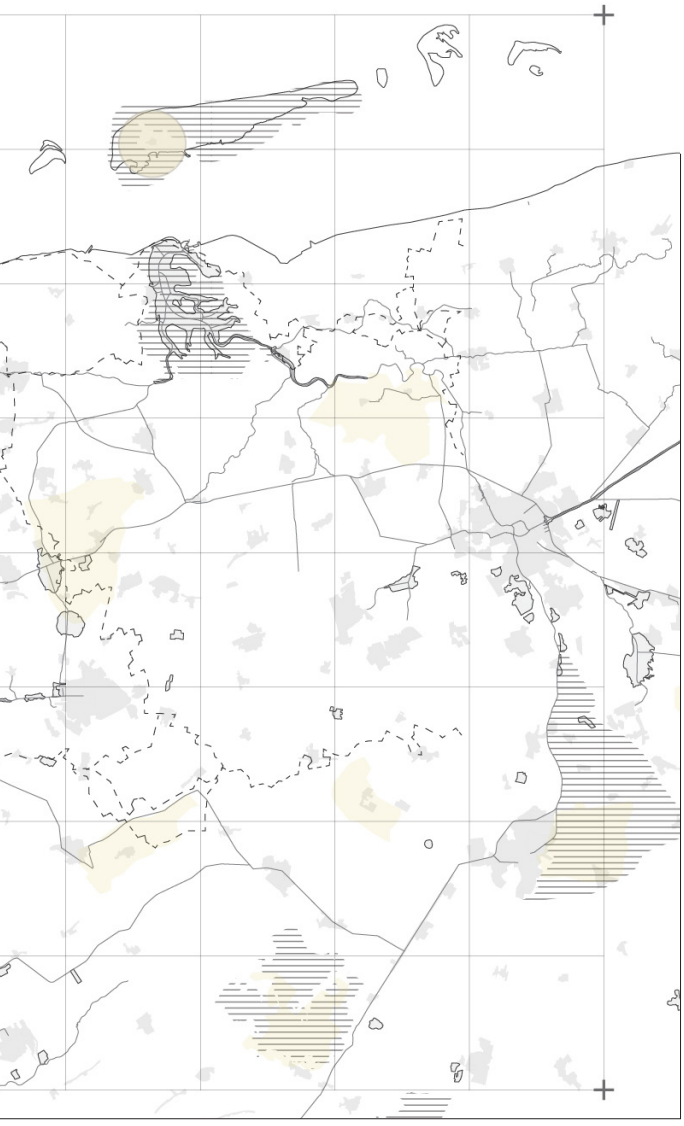


Activity No.



0 | 10 km | 30 km | N | High | Low

Most of the recreations and tourism are located on the islands and in Leeuwarden. Mudflat walking is the major recreation along the Wadden coast which is happening during low tide from May to October. Every year, an art festival known as Oerol is held in Terschelling, facilitating the art development in Wadden Sea. Art installations like 'waiting for high water' integrate art and culture into the Wadden Coast. The tourism on the Wadden Islands, like Texel and Terschelling, is overwhelming every summer. From June to August, numerous music festivals and events are held on the Wadden Islands. The recreational activities are very seasonal and not enough to support the place all year round.



Urban
Lake & open water
Beach & dune
Park
Hiking trail
Main sailing path
Art installation

TEMPORARY

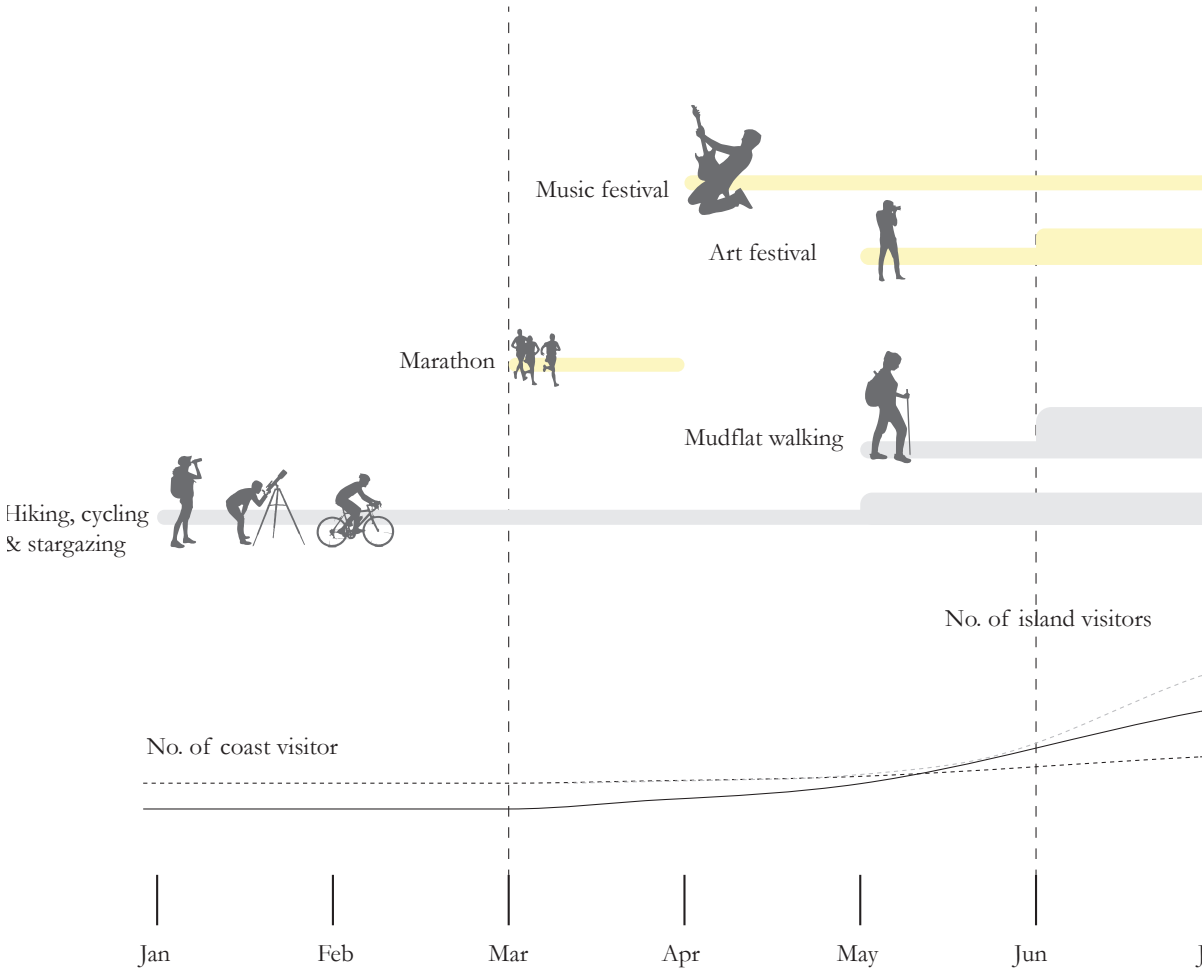
Art festival
Music festival
Marathon
Food festival
Maritime event

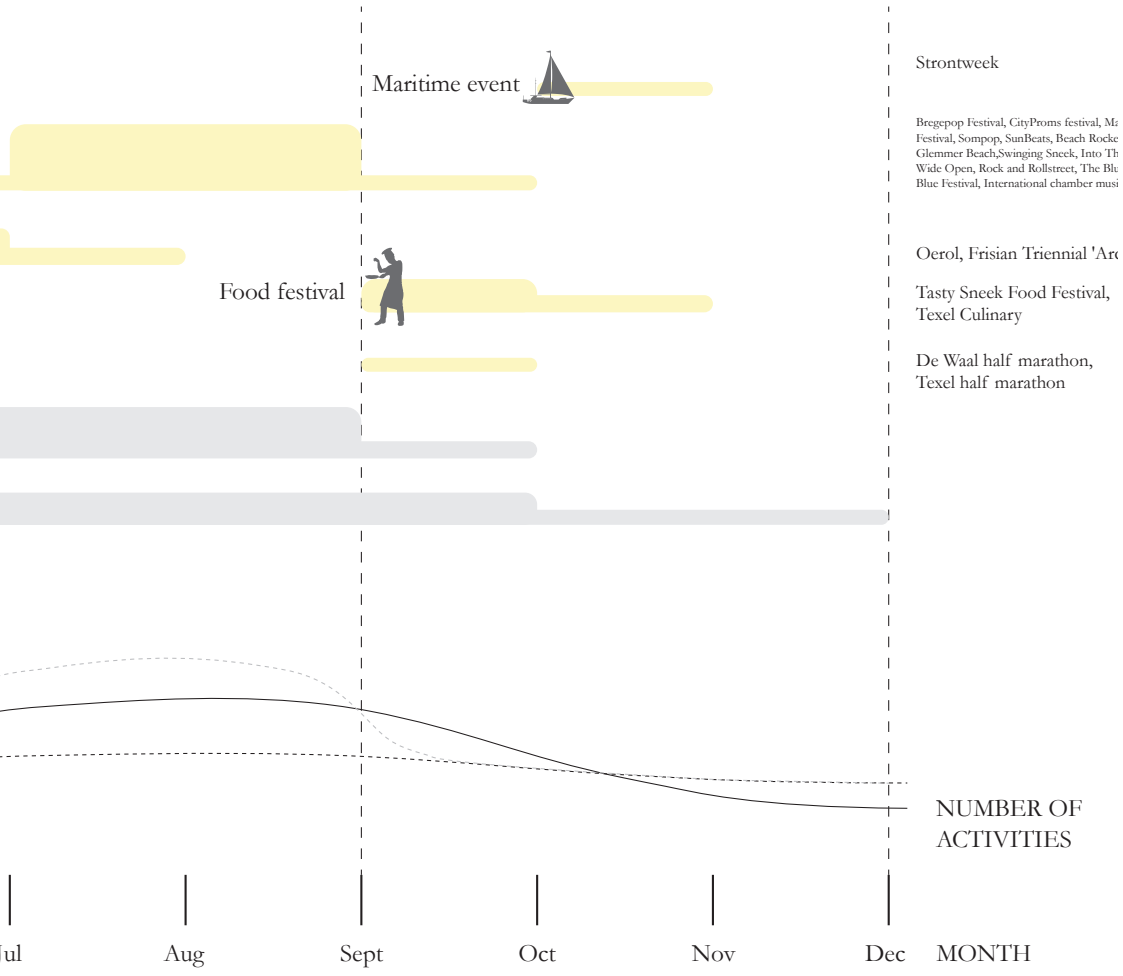
PERMANENT

Mudflat walking
Hiking
Cycling
Stargazing
Sailing
Art installation
Beach & dune
Lake
Nature reserve
Fishing

Recreation Calendar

Data: AllCijfers.nl, 2021.




Maritime event
Food festival
Strontweek
Bregepop Festival, CityProms festival, Ma
Festival, Sompop, SunBeats, Beach Rocke
Glemmer Beach,Swinging Sneek, Into Th
Wide Open, Rock and Rollstreet, The Blu
Blue Festival, International chamber musi
Oerol, Frisian Triennial 'Ar
Tasty Sneek Food Festival,
Texel Culinary
De Waal half marathon,
Texel half marathon
NUMBER OF
ACTIVITIES
Jul
Aug
Sept
Oct
Nov
Dec
MONTH
Temporary
Permanent

Socio-Economic Conditions

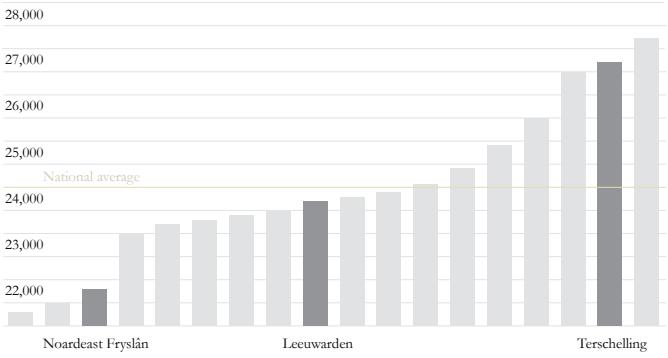
Data: Allecijfers.nl, 2021.
Wadden Academy, 2020.

	Leeuwarden	Noardeast Fryslân	Terschelling
			
Total area(km2)	255.62	516.45	673.99
Population	124,481	45,481	4,870
Population density	516	120	57
Population growth(2016-2021)	15.5%	0.3%	0%
Population Age			
Economic activities			
Average income per inhabitant	23,700	21,800	26,700

Residents by age
- 0-15
- 15-25
- 25-45
- 45-65
- 65+

Economic sector
- Agriculture, Forestry & Fisheries
- Industry & Energy
- Trade & Catering
- Transport Information & Communication
- Financial Services & real estate
- Business services

Share of tourism employment in total employment in 2019



Income comparison municipalities in Friesland municipality of Noardeast-Fryslân

In recent years, the Wadden islands have high economic value due to tourism. The major socio-economic problems of the municipalities along the Wadden Coast are the declining and aging population, as well as the economic income. Most of the young people prefer to live in the cities for better opportunities and social facilities. The farms are replaced by large-scale production running by machinery. The major populations in the villages along the coast are elderly and old farmers. Villages are decaying and hence looking for new development plans, for instance Holwerd aan zee.

The Future

A vulnerable landscape

Wadden Coast.
Photo: Author, 2022.

The future of the Wadden Sea Region is highly uncertain. This chapter contains the collection of the future climatic insights and the flood data in the Netherlands, forming the climate scenarios in 2100 on the basis of hypothetical reasoning.

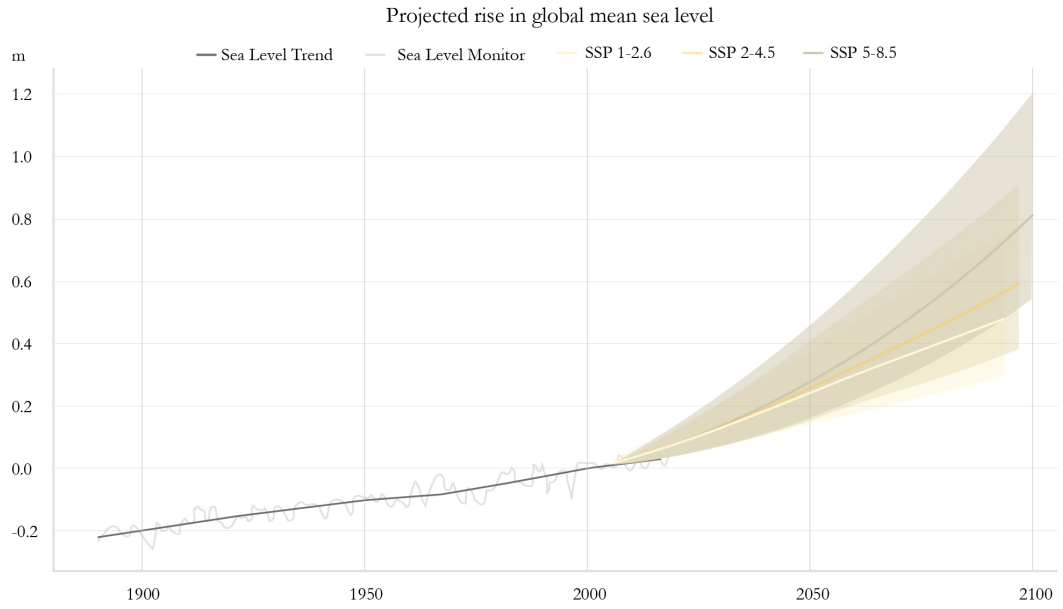
The rise of sea level in the Wadden Sea Region depends on the global trends and the region-specific effect. (Kabat, Bazelmans,van Dijk, Herman, Speelman, Deen, Hutjes, 2009) The Royal Netherlands Meteorological Institute (KNMI) has translated the climatic information on global climate change from the IPCC's report into Dutch climate conditions in Klimaatsignaal'21. The maximum sea level rise in 2100 would possibly exceed 1 and 2 m, depending on the emission of greenhouse gases and a possible accelerated mass loss of the Antarctic Ice Sheet.The height of the tidal flats is related to the rate of silting and resuspension by waves. The impact of the sea level rise is barely noticeable until 2050. Large parts of the tidal flat area will reduce and be inundated by 2100. (Wang, Elia Spek, Lodder, 2018)

To speculate the Dutch climatic scenario with regional projections in 2100, I collected the national flood data. To conclude the result, I depicted three flood maps based on different failures of flood defense and the level of flood extents, forming my scenarios and narratives for the project.

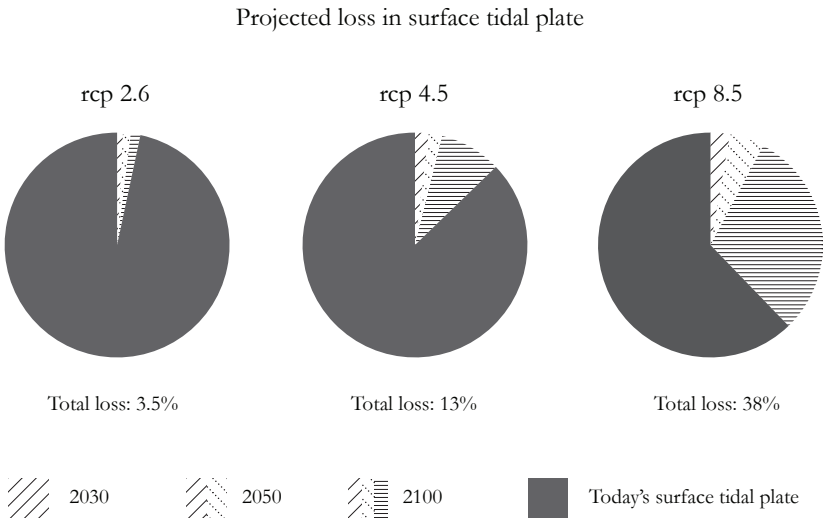
Scenario is a tool for exploring the future uncertainty and inducing reflection on spatial consequences. By asking the question "what if", a design proposal is made based on the scenarios to demonstrate a range of possibilities which is the level of protection of land and the acceptance for the water in the future. The future of the Wadden Sea is full of uncertainties. Rather than a clearly defined plan, the adaptation strategy aims to inspire and anticipate future development towards 2070.

Sea Level Rise

Data: Climate Signal' 21, 2021 & Van der Spek, 2018.



Over the past century, the sea level has risen in total by 20cm with approximately 2 mm each year in the North Sea. The sea level will inevitably continue to rise and the rate will depend on the greenhouse gas emission level in the world. The mass loss of glaciers and ice sheets in Greenland and Antarctica would fasten the sea level rise in the Dutch coast. The Royal Netherlands Meteorological Institute (KNMI) has translated the climatic information on global climate change from the IPCC's report into Dutch climate conditions in Klimaatsignaal'21. The report defined the greenhouse gas emission levels into three scenarios. (SSP1-2.6, SSP2-4.5 and SSP5-8.5) The higher the number indicates a higher emission level. The graph shows the future projection of the sea level in different scenarios. The solid lines in brown, yellow and light yellow indicate the median of those projections, the colored area is the 90% bandwidth. The sea level rises of all scenarios in 2050 are generally small. However, in 2100 ,the sea level rises are significant with the maximum sea level rise of 1.2 meters in the highest emission scenario. (KNMI, 2021) In all emission scenarios, the sea level is rising continuously in the future. The sixth IPCC report acknowledged the possibility of 2 meters sea level rise in 2100 in the extreme scenario.

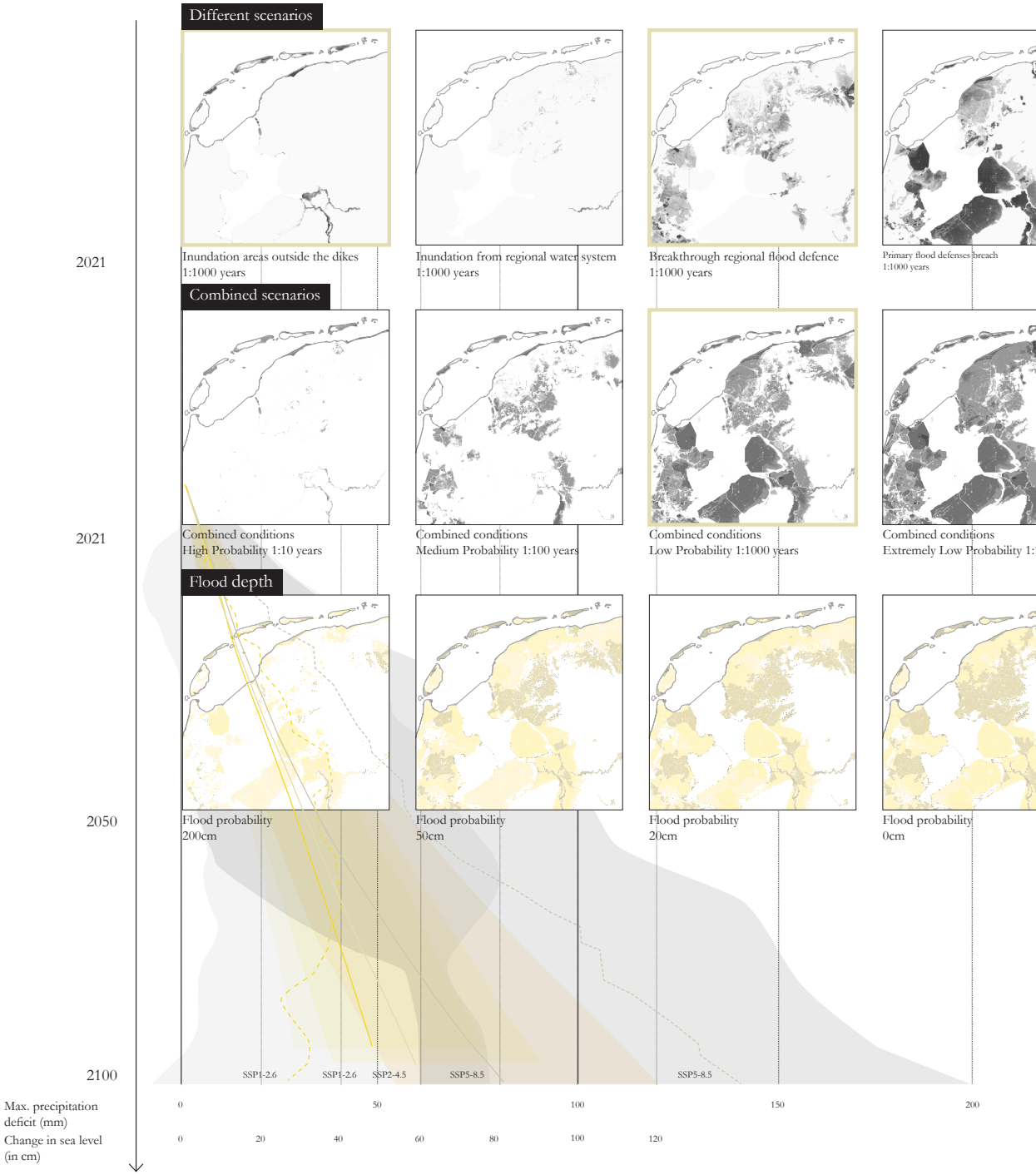


The sea level rise impacts the size of the tidal flat in the Wadden Sea. The height of the tidal flats is the result of the balance between sand supply by the tide and resuspension by waves. (Wang, Elia Spek, Lodder, 2018) The construction of the Afsluitdijk has increased the sedimentation rate and hence it is expected to outpace the rate of the sea level until 2050.

The chart shows the projection of the tidal flat loss in the future.The projection method is based on the critical rate of sea level rise for drowning and a way to evaluate loss of intertidal flat area based on the rise of low water level.(Wang, Elia Spek, Lodder, 2018) The effect of the sea level rise on the tidal flat is hardly noticeable in the near future. In the low-end scenario, there will be hardly any effect until 2100. However, in the high-end scenario, the loss of tidal flats is already noticeable in 2050.

Future Uncertainties

Data: Climate Impact Atlas, 2021.



100.000 years

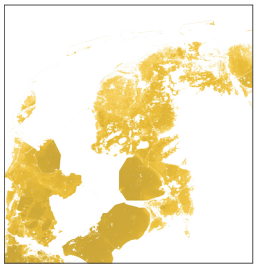
To imagine the future scenarios of the area, I have collected all the national flood maps regarding the flood caused by the sea and rivers from the Water and Floods Information System (LIWO) prepared by Deltares on behalf of Rijkswaterstaat (RWS). The first row of maps is the water depth map of 2021 showing different flood conditions up to about once every thousand years.The dark color represents the high flood depth. The second row is the maximum flood depth of 2021 with a combined conditions showing the flood area in different probability. The maps are the combination of the four aforementioned flood conditions along the primary and regional water system. These maps depict possible flooding that in reality will not all occur at the same time. The map showing the highest flood depth and the lowest probability reflects the most extreme flooding scenario.

Prepared by RWS, the third row is the flood probabilities with various water depths in 2050, caused by a breach of a flood defense along the main or regional water system or by flooding of unprotected areas.This map therefore shows the total probability of all possible flooding regardless of the resulting flood depth. All primary flood defenses comply exactly with the flood probability standard in the Water Act. For regional flood defenses, the provincial exceedance probability standard has been used as the probability of flooding. The failure probability of primary flood defenses has been assumed independently. The failure probability of primary flood defenses has been estimated on the basis of the current failure definition and without emergency measures. (LIWO, 2021) The darker yellow represents the higher probability of flooding.

There is no spatial flood data in the Netherlands for 2100 and thereby I have included the elevation maps indicating the possible flood level regardless of the flood defense systems. The graph at the back indicates the sea level rise projection and the maximum precipitation deficit in the future in the light of different emission scenarios.

Elevation

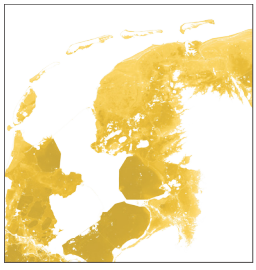
SSP1-2.6
0.38m rise



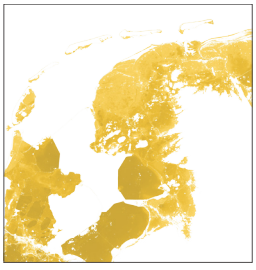
SSP2-4.5
0.41m rise

SSP5-8.5
0.47m rise

SSP1-2.6
0.81m rise



SSP2-4.5
0.94m rise

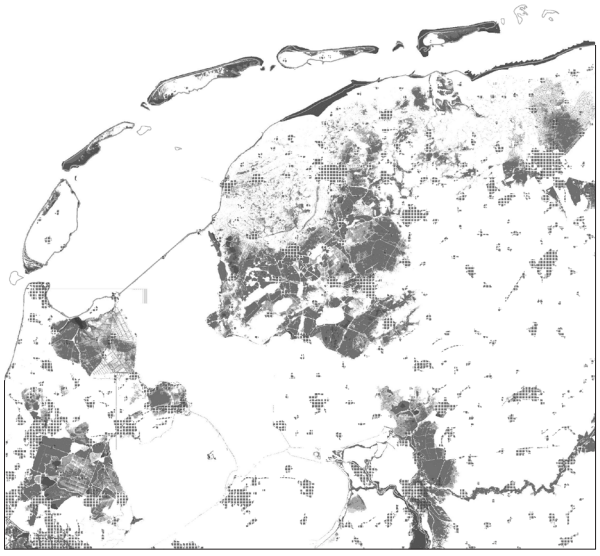


SSP5-8.5
1.21m rise

SSP5-8.5 H++
2m rise

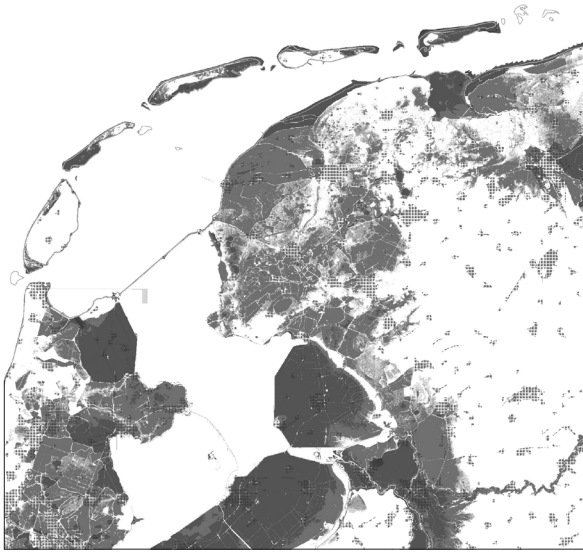
Scenarios In 2100

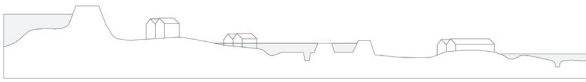
Data: KNMI Klimaatsignaal'21, 2021.



SCENARIO 1
+0.8m sea level rise

High precipitation deficit
Regional dike breach

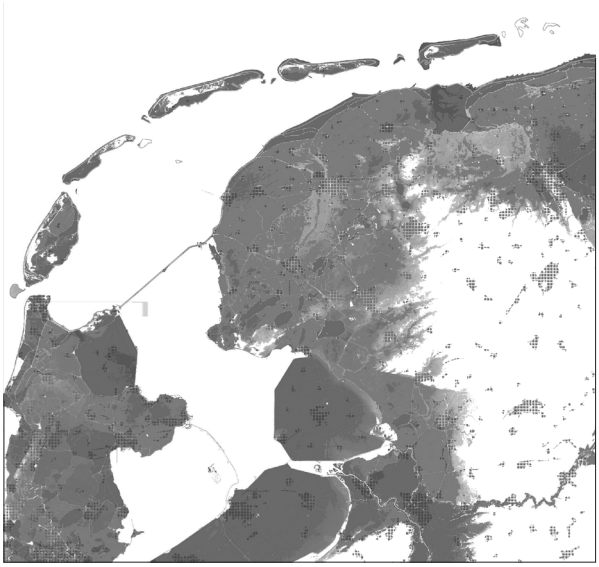




SCENARIO 2
+1.2m sea level rise

Very high precipitation deficit
Regional dike breach & failure of part of primary dike

Moderate sea level rise



SCENARIO3
+2.0m sea level rise

Extremely high precipitation deficit
Primary & regional dike breach

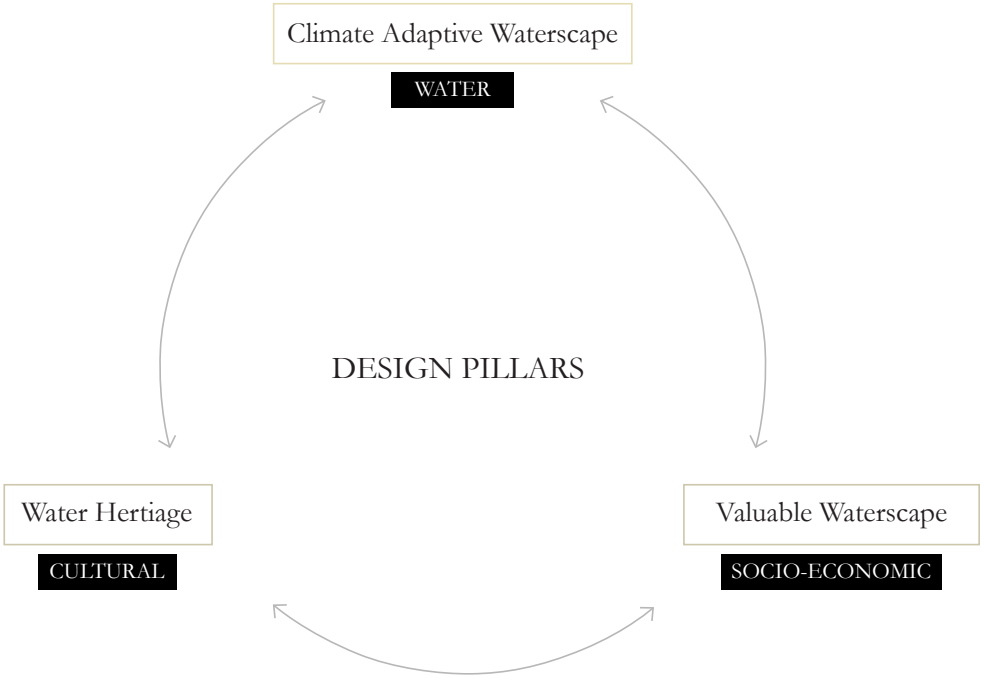
Extreme sea level rise

By studying the flood maps, I extracted and combined the results to form my design scenarios and narratives in 2100 with three levels of floods and conditions. I have combined the water depth maps with the conditions of inundation areas outside the dikes and breakthrough regional flood defense up to about once every thousand years for the first scenario. I assumed that 0.8 meter sea level rise will occur and result in regional dike breach in the basin. In the second scenario, I have depicted the water depth map with combined conditions up to about once every thousand years. The assumption is that 1.2 meter sea level rise will bring regional dike breach & failure of part of primary dike. The last scenario which is the most extreme case is with the 2 meters sea level rise and leading both the primary and regional dike breaches. I chose the map interpreted by elevation to show the extreme condition that is unlikely to happen.

The climatic future is very uncertain and therefore scenario-making is a tool for exploring the future uncertainty and inducing reflection on spatial consequences. The second scenario which I think is the most reasonable guided me to the strategic design on a regional scale.

Design

Future adaptive landscape


Climate Adaptive Waterscape
WATER
DESIGN PILLARS
Water Hertiage
CULTURAL
Valuable Waterscape
SOCIO-ECONOMIC

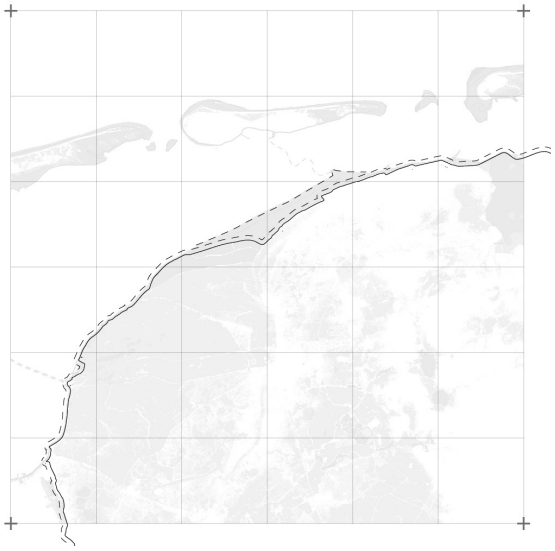
The Dutch Wadden Sea landscape faces vulnerability and multiple threats. To develop resilience and adaptive capacity, spatial strategies and design solutions are necessary for integration and adaptation. This chapter is the transformation of the knowledge acquired from the previous chapters into the design concepts and spatial strategies, projecting the future development in multiple time phases and scales.

With the design pillars (climate-adaptive waterscape, water heritage and valuable waterscape), design strategies are formed with the objectives of the integration of flood risk management into the landscape and strengthening the cultural identity and regional economy. Regional plans in 2030, 2050 and 2070 are drawn for coherent development of the region, while designs in local and small scales are developed for short-term enhancement.

Two flood defense systems, namely regression and progression, play a significant role in the design, integrating flood management into the landscape. The double dike systems which allow overtopping of water with a secondary dike act as a regression approach. The double dike aligned with the objectives of the Delta Programme, in which flood risk management is integrated with the functions of nature, recreation, cultural history and economic activities.The salt marsh flood defense is a nature-inclusive and progressive approach to lower the flood risk and provide added value to the ecosystem and society. The vegetated foreland could reduce the wave energy and hence reduce the load on dikes.

In the near future, the landscape identity could be enhanced with the routing design addressing the genius loci of the landscape. A series of design interventions are added along the routing to strengthen the connections to the Wadden Sea and create new nodes in the region. Tree avenues could direct people to the Wadden Coast. Meanwhile, the establishment of the brushwood dams and experimental saline farms could prepare the region for future adaptation. In 2050, the design focused on climate adaptation with the expansion of the forelands and the implementation of the double dike systems.The old sea dikes could be restored and become the secondary dikes for the systems. Two flood defense systems integrated with the dike reinforcement are expected to reduce the flood risks and offer ecological and socio-economic possibilities, bringing this vulnerable landscape towards an attractive, integrated, climate-adaptive future.

Design Strategies

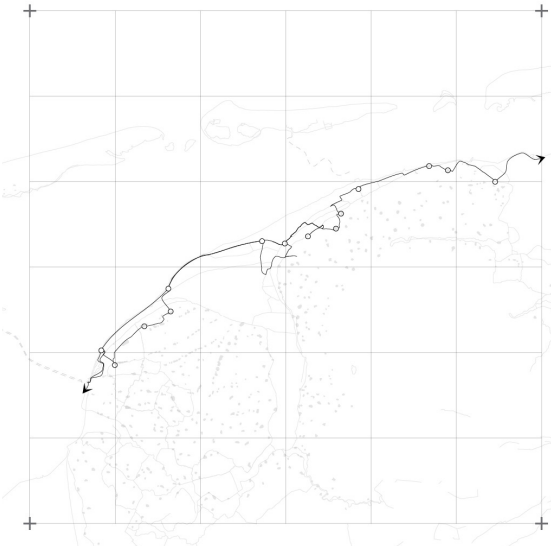


Climate Adaptive Waterscape

WATER

STRATEGY 1.
Develop a landscape-integrated approach along the coastline
for climate adaptation

- Expansion of salt marshes for coastal defence
- Double dike system
-Multifunctional flood protection zone
- Saline agriculture to adapt salinization



Water Hertiage

CULTURAL

STRATEGY 2.
Strengthen landscape identity and
the value of cultural water heritage

- Routing design connecting to the water heritage
- Restoring the role of the old sea dike

Valuable Waterscape

SOCIO-ECONOMIC

STRATEGY 3.
Enhance the regional economy and livability
to make the coast an attractive living and working place

- Bring new socio-economic & ecological opportunities
- Enhance connections to the Wadden Islands
- Introduce saline agriculture as a new type of productive landscape

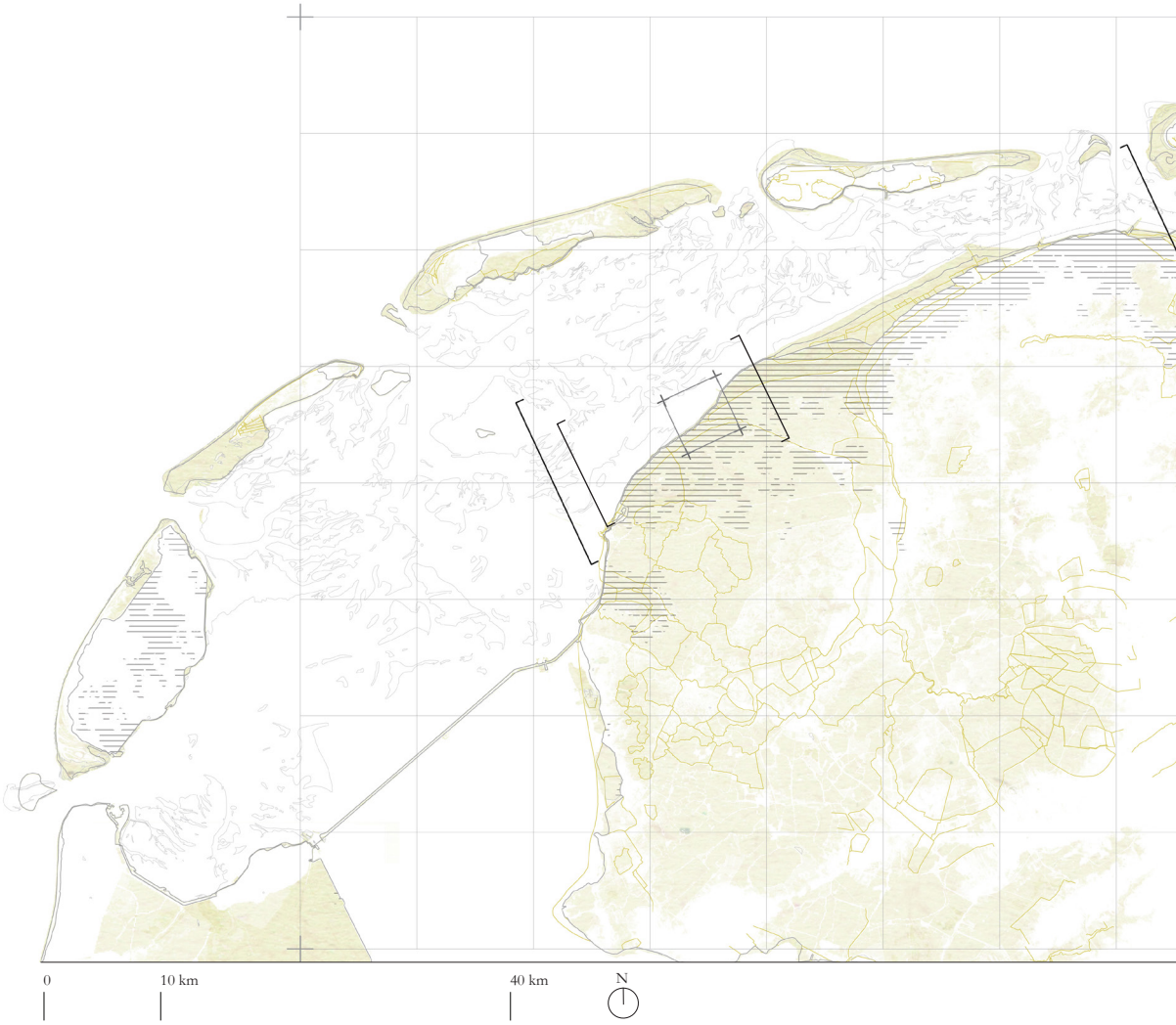
Three design pillars act as a fundamental basis in the project. The water, cultural and socio-economic layer analysis induce the design in three concepts (climate-robust waterscape, water heritage and valuable waterscape). Based on the pillars, three design strategies are made to respond to the problem statement and research question, striving for a resilient and climate-adaptive future in the region.

The first strategy is to develop a landscape-integrated approach along the coastline for climate adaptation."Landscape-integrated approach" refers to a set of methods integrated landscape in multiple interests from different stakeholders through processes, emphasizing on a nature-based approach. The value of the landscape and nature should be considered as part of the flood management.Hereby, two multifunctional flood defense systems and saline agriculture are introduced for a sustainable climate-proof future.

Another strategy is to strengthen landscape identity and the value of cultural heritage. Design intervention along the route could enrich the experience and raise people's awareness of this cultural water landscape. Restoring and accentuating historical water heritages, like the old sea dikes, preserve the unique cultural identity in the Wadden Coast.

The last strategy is to enhance the regional economy and livability by bringing new opportunities like saline agriculture and agri-tourism in the region. Routing connecting to the Wadden Islands could boost tourism and other social values.

Water As Opportunities

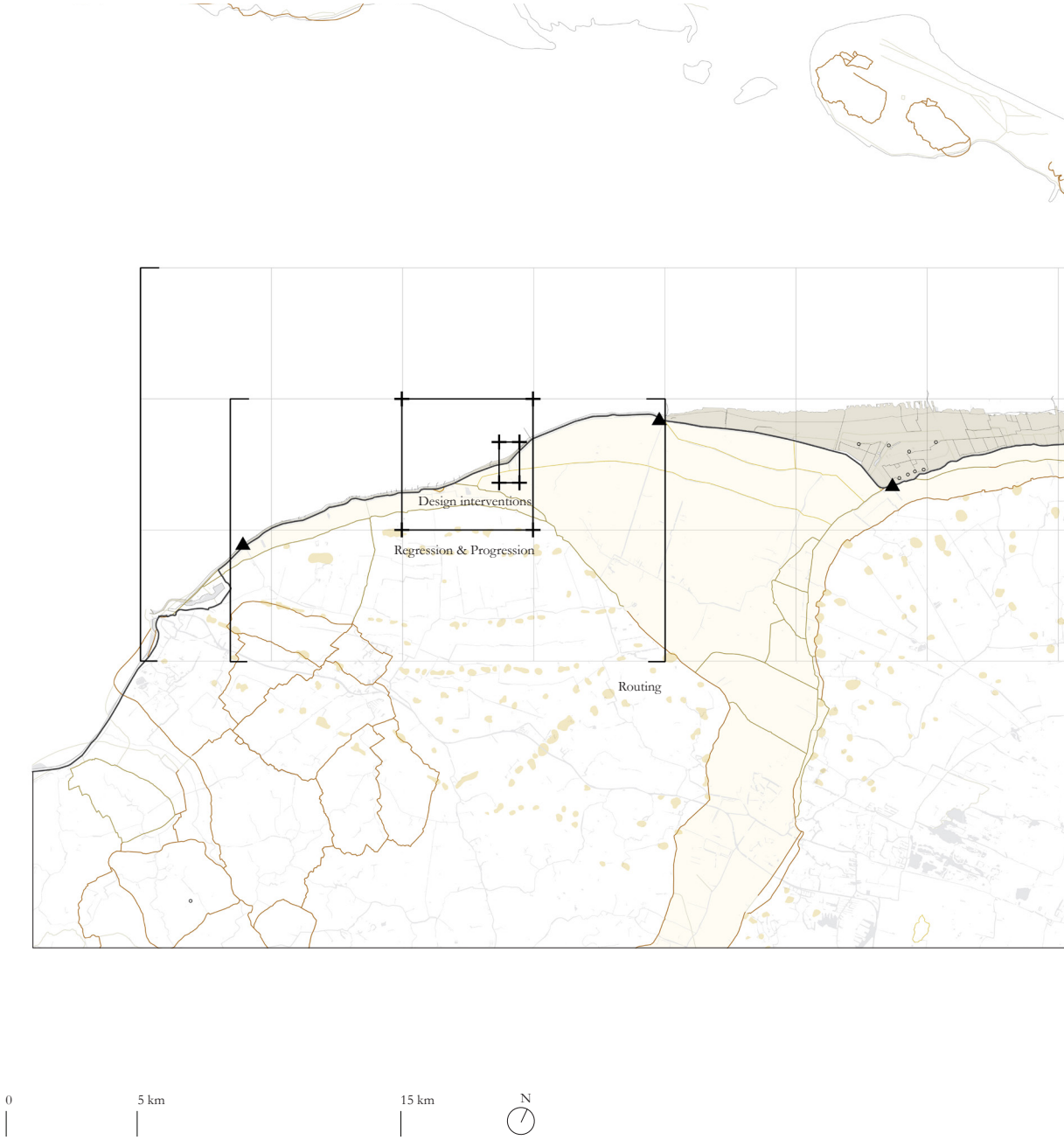


Dikes built before 1500
Dikes built from 1500-1850
Intertidal mudflat
Croplands
Potential flood area in 2100

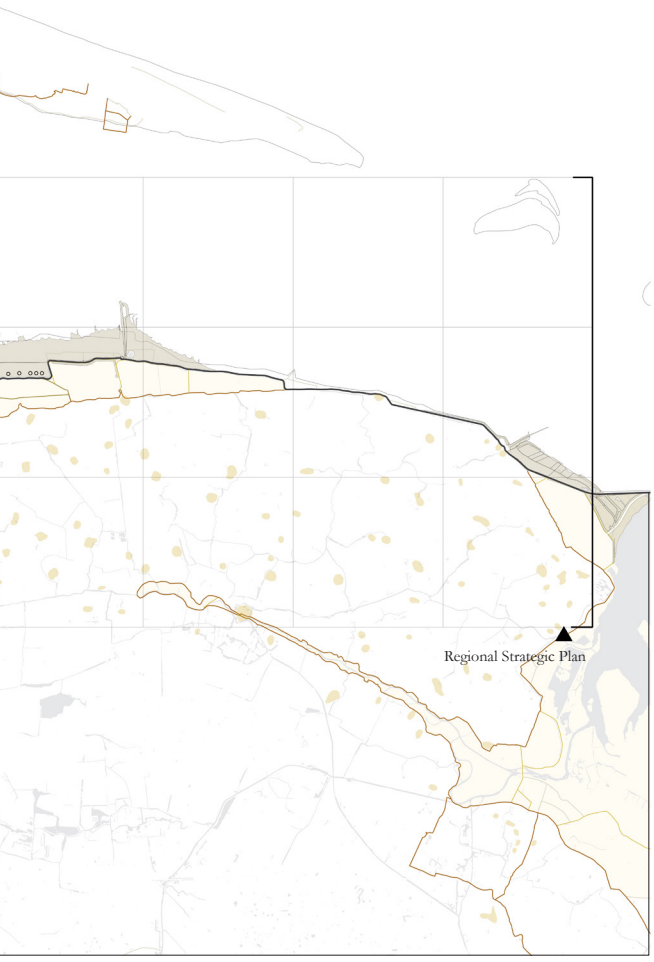
By superimposing the layers in the research, in particular the cultural heritage and the future flood scenario, I selected the site where it is culturally rich but also vulnerable to the future climate to develop my design proposal in detail. According to the flood scenarios, the north-western part of Friesland is more prone to flooding. This area comprises various layers of reclaimed polders and old sea dikes from the 16th century. The coastline also contains biodiverse salt marsh and port facilities to the Wadden Islands.

Water is not only considered as a threat but also an opportunity for future development.

Wadden Coast Design

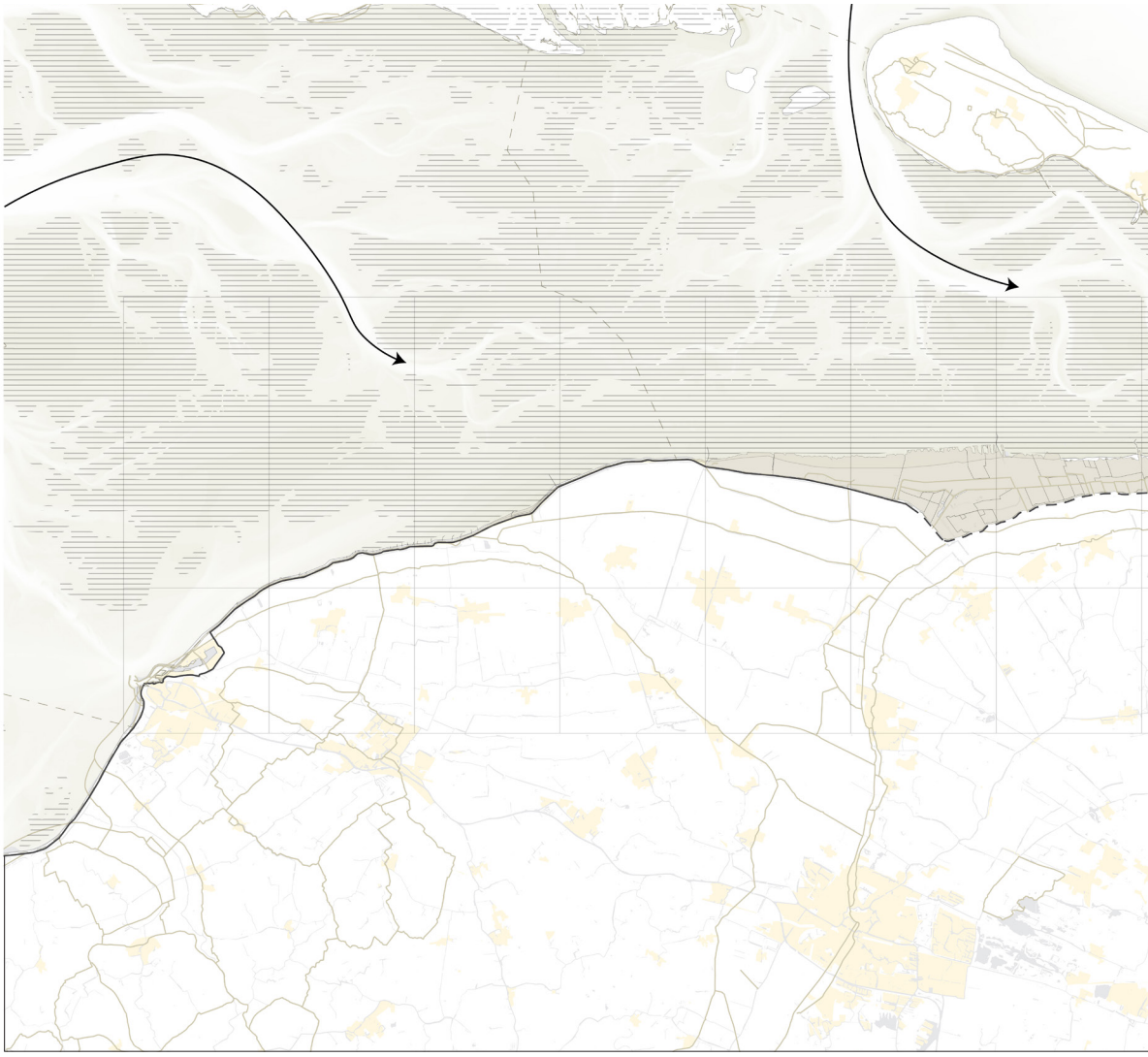


The design will cover the dike section between the Koehool area and Lake Lauwersmeer and focus on the coast along the Koehool area. Detail analysis regarding the three pillars is hereby addressed to show the spatial quality and landscape characteristics in the area.



Dikes built before 1500
Dikes built from 1500-1850
Pumping stations
Salt marsh
Terps
Young polders

Climate Adaptive Waterscape



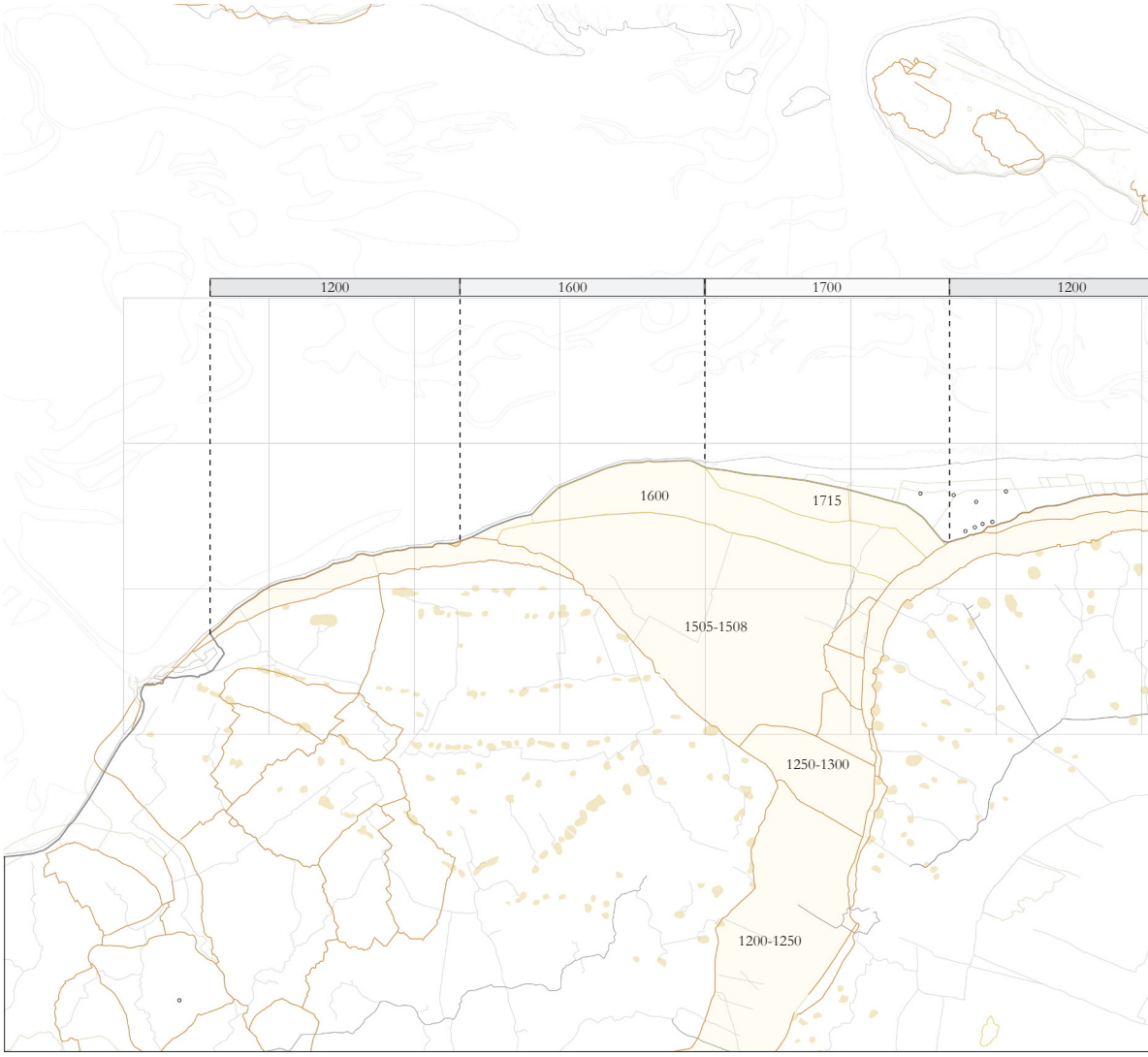
0 | 5 km | 15 km | N

Sea dike with asphalt
Wide green dike
Regional dike
Salt marsh
Intertidal mudflat
Tidal basin
Built area

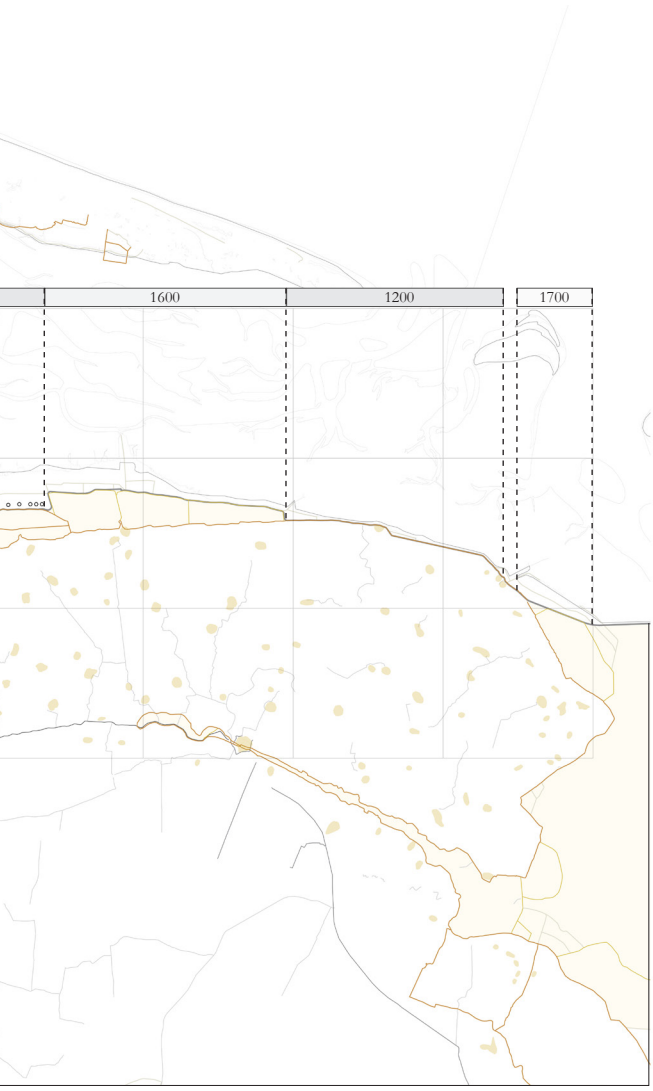
The Dutch Wadden Sea has been accreting by importing sediment from the tidal inlets in the North Sea. This process results in an extensive tidal mudflat and marshland along the coast. A large foreland ranging from summer polders to low-lying salt marsh is situated along Noord-Friesland Buitendijks, with a mix of summer quays and brushwood dams. Excluding the coast near Harlingen, salt marsh are developed naturally all along the coast due to accretion.

The primary flood defenses consist of two types: sea dike with asphalt revetment and wide green dike. Due to the presence of the extensive foreland as a buffer zone, part of the dike section can become wide green dike. During the storm season, the foreland is sometimes flooded and drained by the drainage systems. Two pumping stations are present to discharge the excessive water to the Wadden Sea. The former sea dikes are still present as regional flood defenses for the polders. The flood defense systems protect the city of Leeuwarden and Harlingen from flooding in the region.

Water Heritage



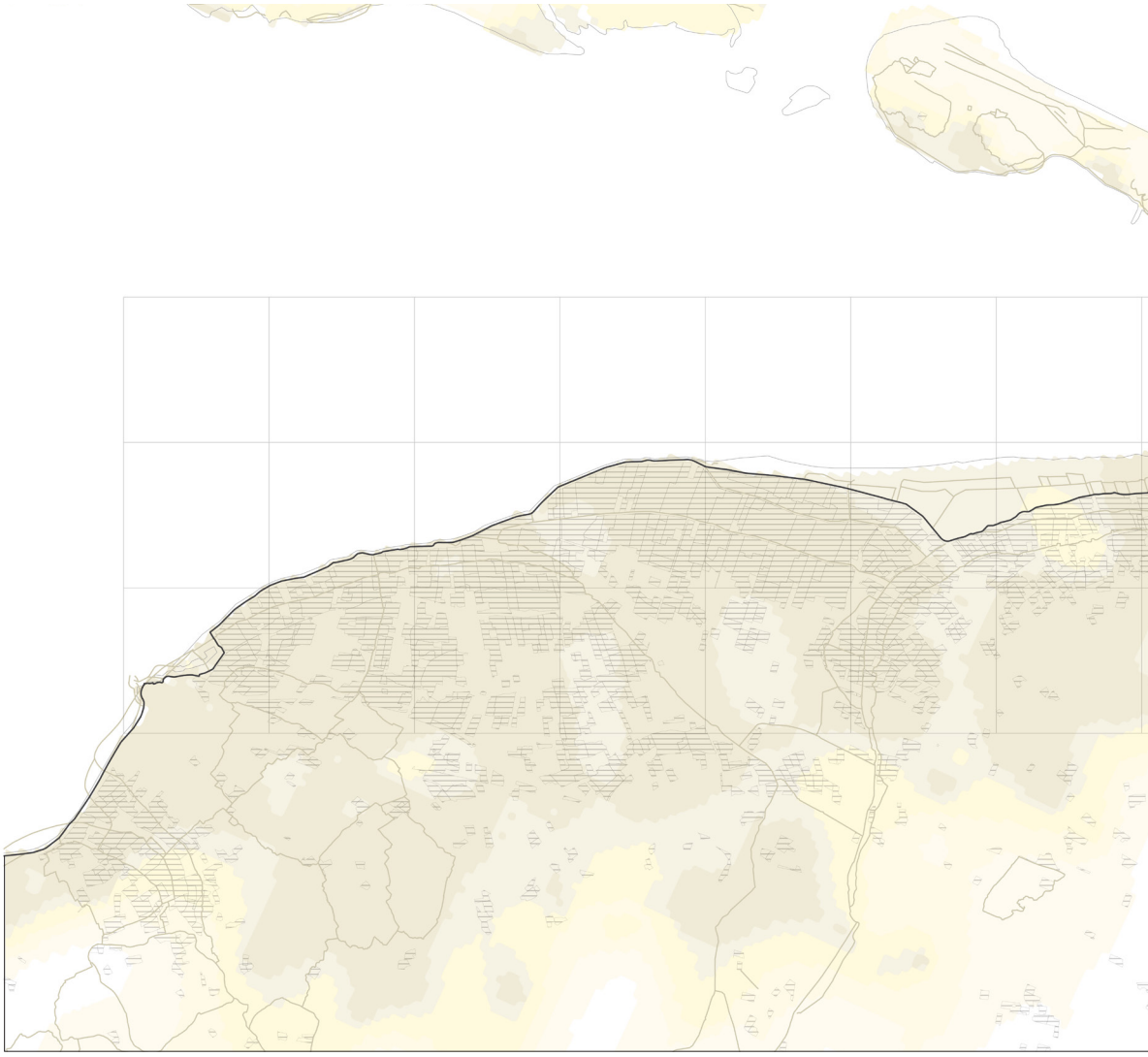
0 | 5 km | 15 km | N



Dikes built before 1500
Dikes built from 1500-1850
Terps
Young polders

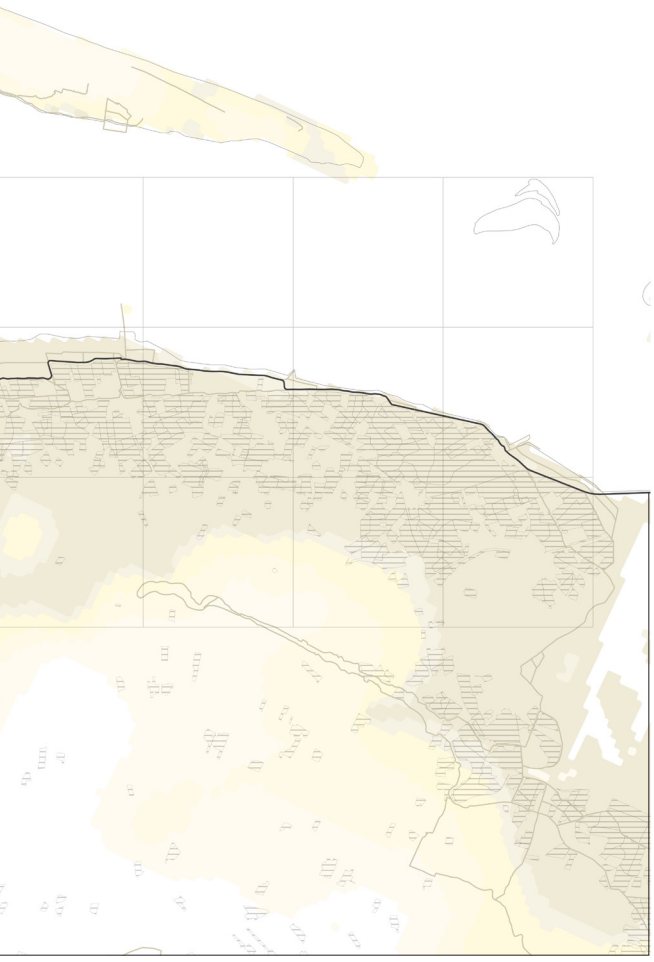
Land reclamation and the construction of sea dikes took place at different times over the entire dike section. As a result, the primary sea dikes consist of dike sections of different ages .Dike improvement in the 1970s made the dike profile uniform over the entire stretch. The palimpsest of the land is still recognizable in the form of roads and terp villages.This map shows the construction year of the sea dikes and the yellow part is the young polders.

Valuable Waterscape



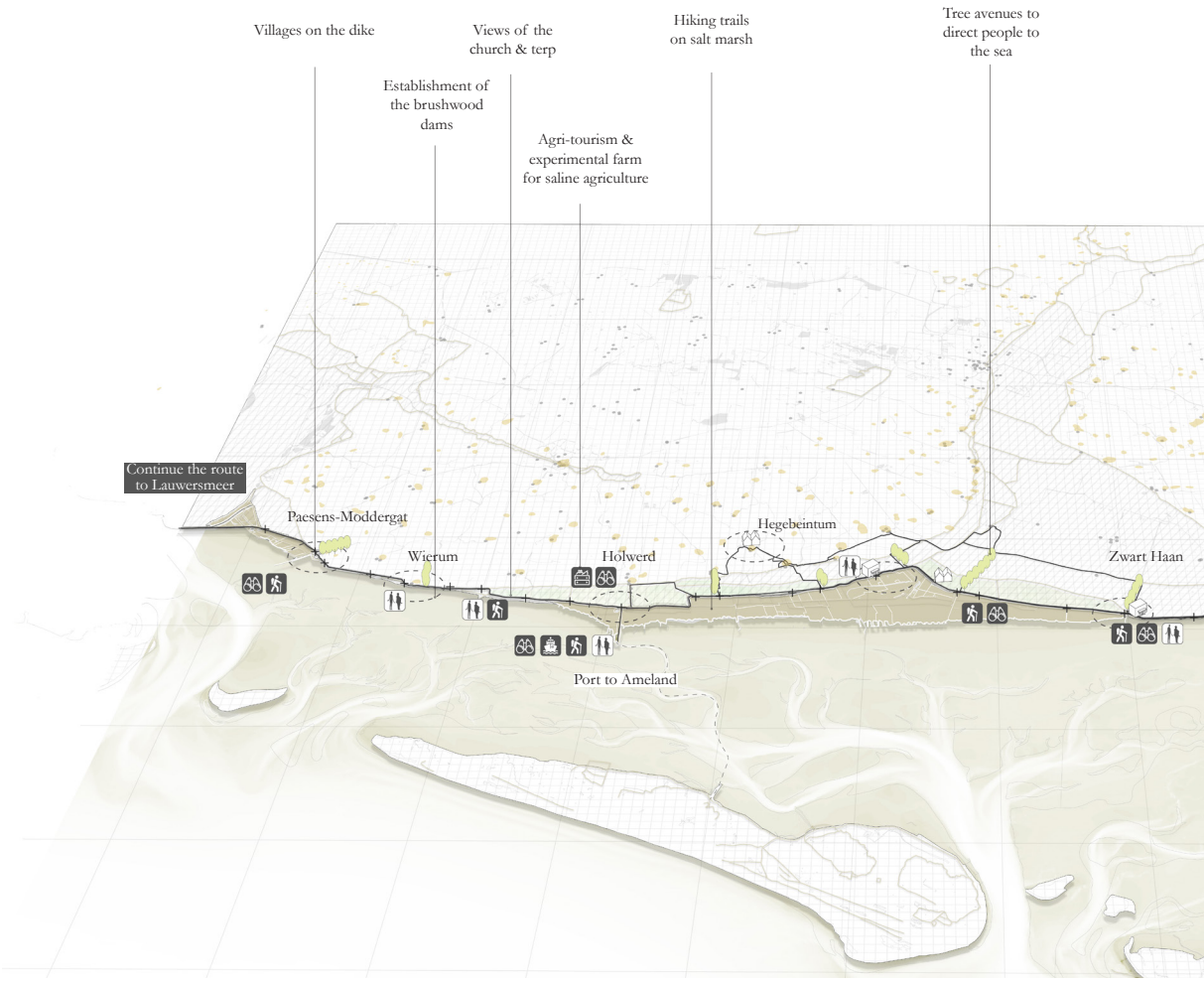
0 5 km 15 km N

Salinization posed a risk on the agricultural activities along the Wadden Coast. The soil in the young polder is fertile due to the former salt marsh walls. Large-scale farmlands are present for the mass production of potatoes and grains. The farms are relatively mono-cultural and dominated by a few types of crops. The declining and aging population also leads to the causes of some abandoned fields.



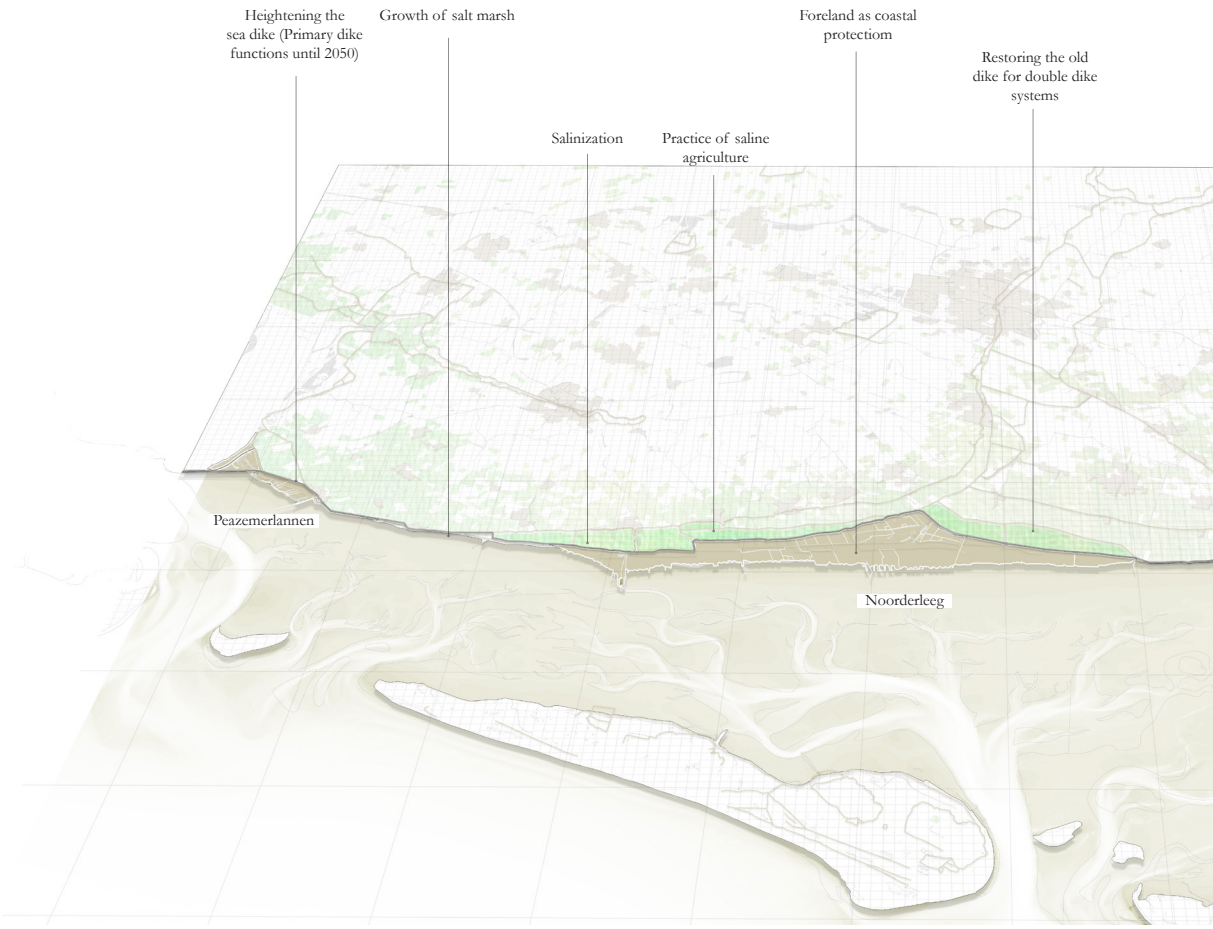
Salinization of groundwater
0-5m below ground level
5-10m
10-25m
25-50m
50-100m
Cropland

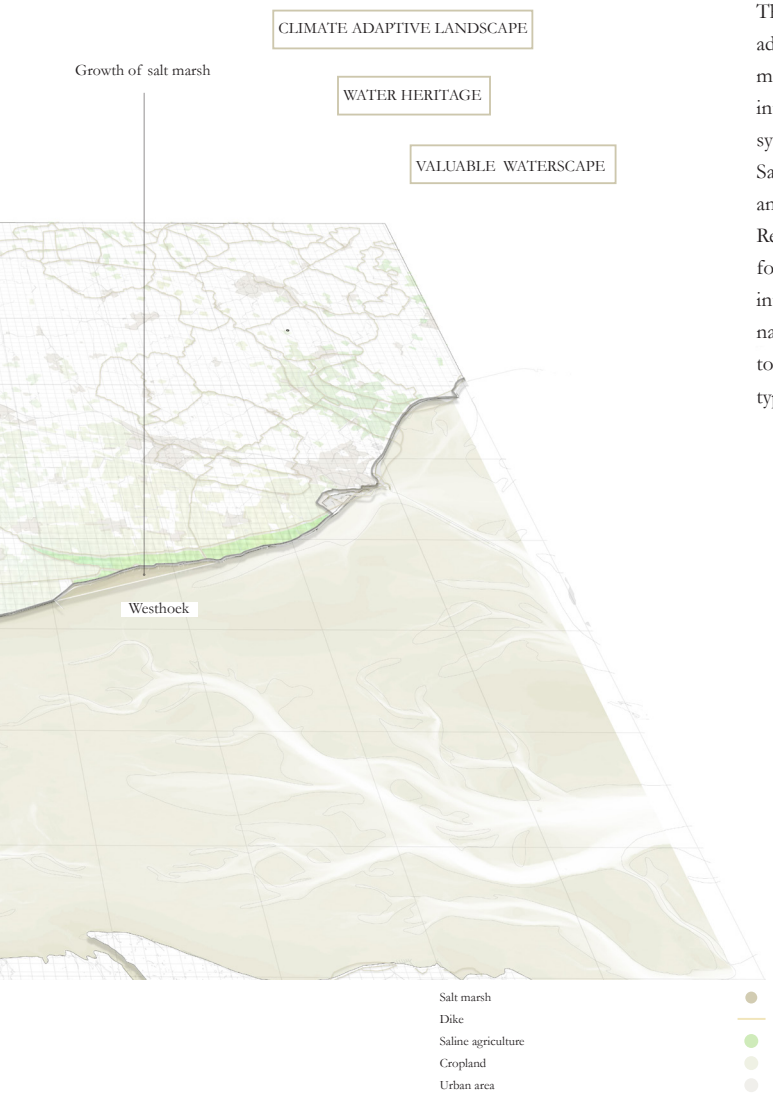
2030


Villages on the dike
Views of the church & terp
Hiking trails on salt marsh
Tree avenues to direct people to the sea
Establishment of the brushwood dams
Agri-tourism & experimental farm for saline agriculture
Continue the route to Lauwersmeer
Paesens-Moddergat
Wierum
Holwerd
Hegebeintum
Zwart Haan
Port to Ameland
0
10 km
40 km
N

In 2030, the plan focuses on strengthening the landscape identity and enriching the experience along the Coast. A routing from Harlingen to Lauwersmeer is designed, connecting to the ports and other interesting nodes. The routing which emphasizes on the water heritage will guide people visiting the terps and the Wadden Coast as a recreational cultural tour. Experimental farms for saline agriculture will be launched and the brushwood dam will be established to prepare for the climate adaptation.

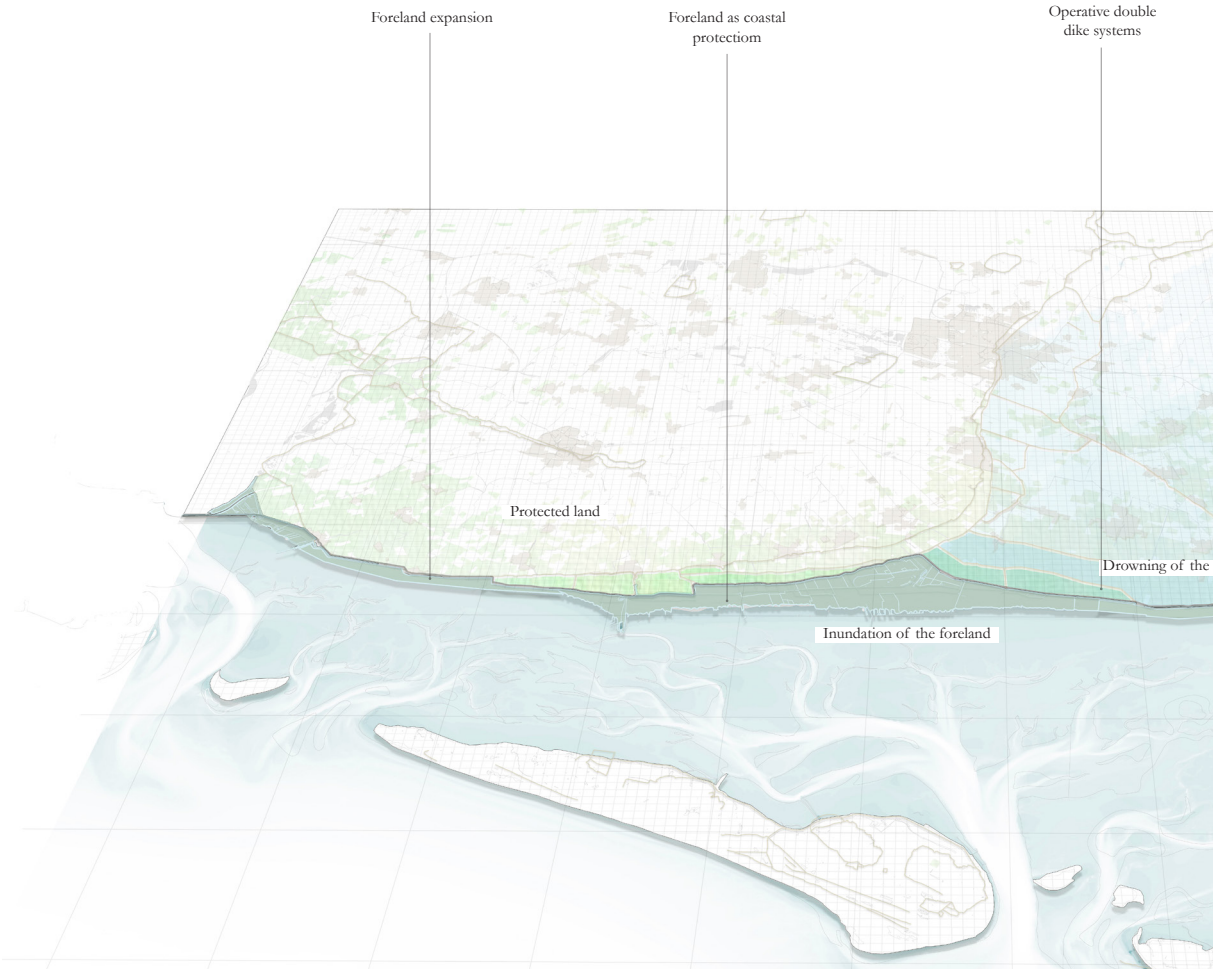
2050

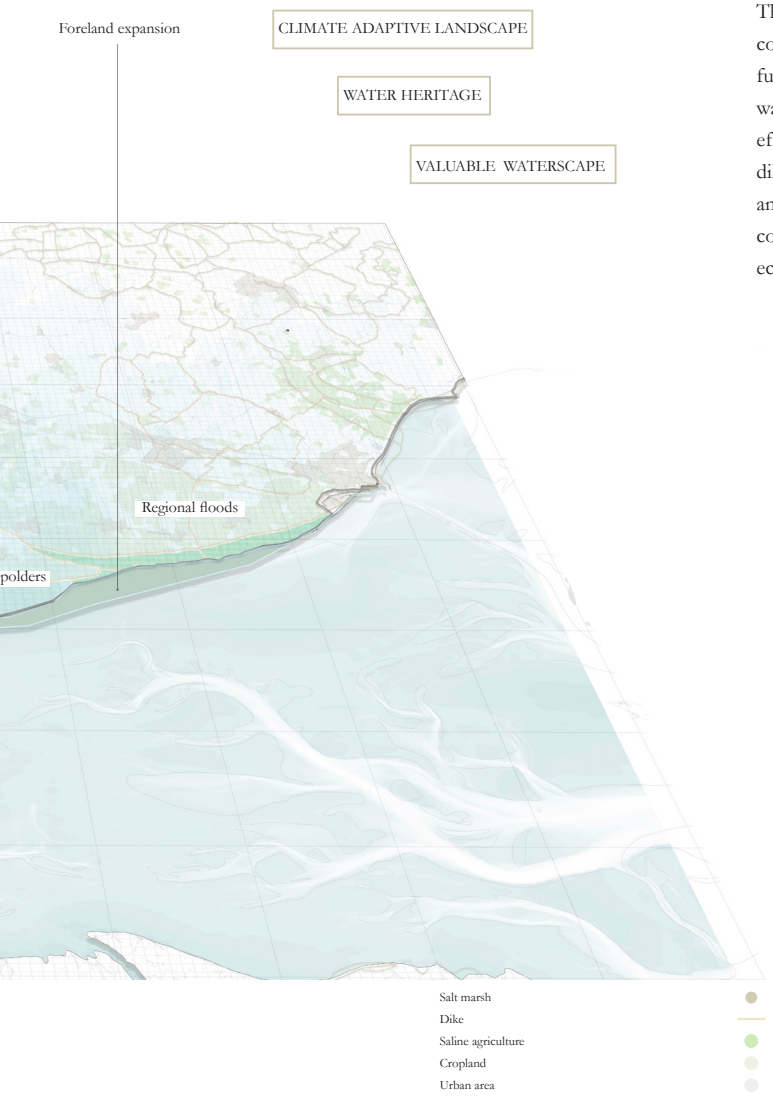

Heightening the sea dike (Primary dike functions until 2050)
Growth of salt marsh
Salinization
Practice of saline agriculture
Foreland as coastal protectiom
Restoring the old dike for double dike systems
Peazemerlannen
Noorderleeg
0
10 km
40 km
N



The plan in 2050 is critical in preparing for climate adaptation. Efforts are made to integrate coastal flood management with nature conservation and other interests. Two landscape-integrated flood defense systems will take place to protect the area from flooding. Salt marsh with a valuable ecosystem will be expanded and form a buffer zone to reduce the wave energy. Restoring the old dikes could form a secondary defense for the double dike systems. Dike reinforcement integrating with the landscape is necessary to meet the national safety standards. Saline agriculture is a measure to adapt the increased salinity in the polder as a new type of production.

2070

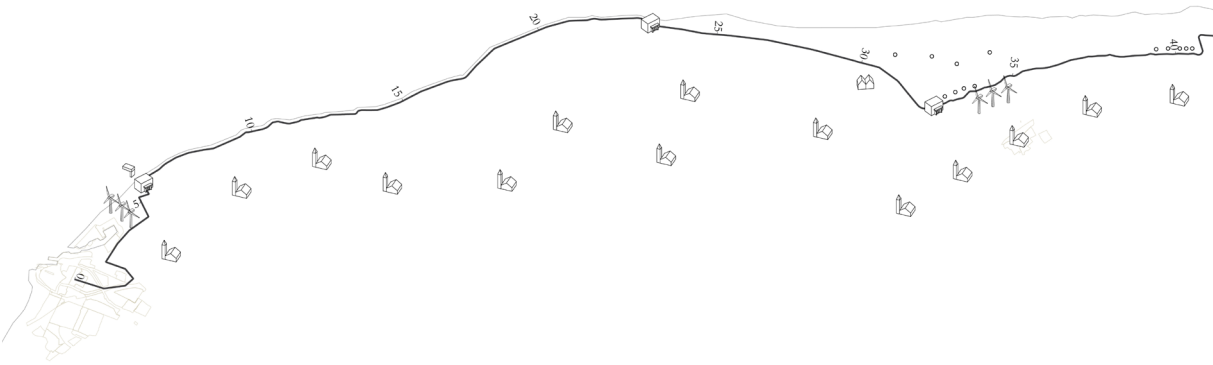

Foreland expansion
Foreland as coastal protectiom
Operative double dike systems
Protected land
Drowning of the
Inundation of the foreland
0
10 km
40 km
N

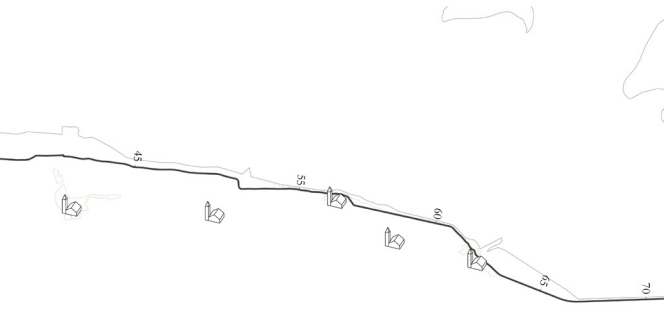


The climate in 2070 is highly uncertain. The ideal condition is that the flood defense systems are fully functional and be able to safeguard the land from high water. The foreland will further expand and form an effective flood defense to reduce the load on the sea dikes. The double dike systems allow seawater to intrude and flood the polders within the dikes. This approach combines safety with natural dynamics, ecological and economic functions, enhancing resilience in the future.

Routing.
Photo: Author, 2022.

Routing Experience



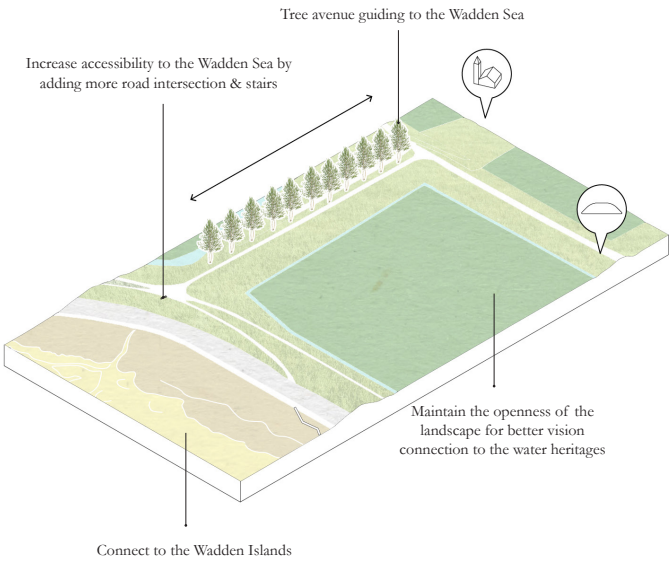


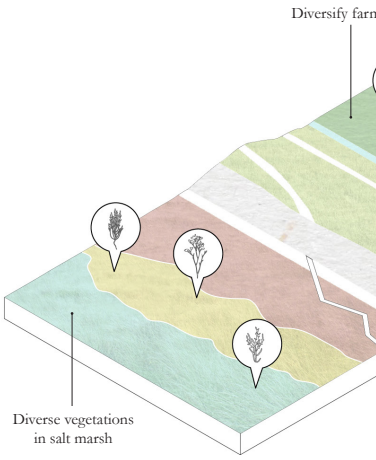
Church
Pumping Station
Wind turbine
Lookout
Visitor center
Dobben

I went on a bike trip and documented the experience along the Wadden Coast. The landscape is so open, and the church towers and wind turbines are the major visual points in the horizon.As a visitor I think the journey within the dike is not as interesting as it is outside the dike. The edge of the water is attractive but I never know where to stop when I am inside the dike. The route has the potential of forming a recreational cultural tour together with the terps. Therefore, I came up with three design principles for the routing, strengthening the connectivity and sensory experience, as well as creating new nodes.

Wadden Water

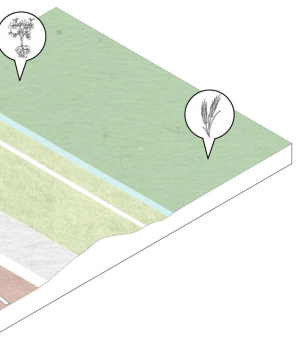
Routing Design Principles

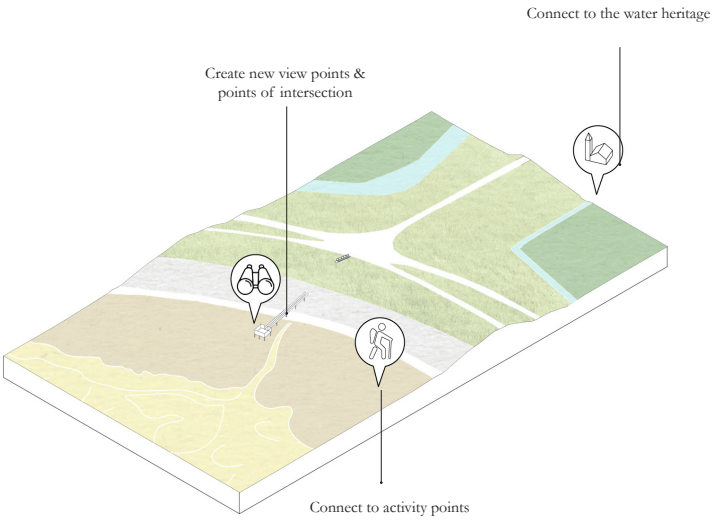


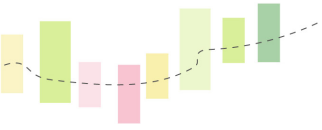


1. CONNECTIVITY

2. SENSORY EXPE







ERIENCE

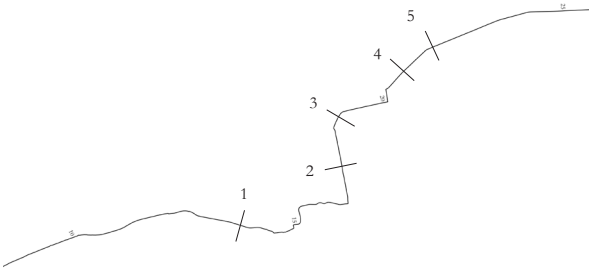
3. NODES

Routing Design

Routing
Sea dike intersection
Terps

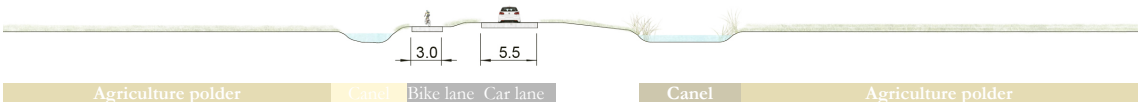
This map demonstrates the routing in Kohoek starting from the city of Harlingen, a lovely port city in Friesland where you could rent a car or a bike for the trip. Harlingen is also connected to Vlieland and Terschelling by ferry. The first stop of the route is the pumping station Ropta where the excessive water from the polder is discharged to the Wadden Sea. A view platform brings you to see the deep water of the Wadden sea. After that, you could either travel along the coast or make a D-tour to the terp villages. Along the coast, there are some points that allow people biking on the top of the sea dike which give you a good view of the Wadden Sea. The water along the coast gets shallower with mudflats all along the way. The tree avenues guide you to the Frisian villages like Sexbierum and Tzummarum, visiting the museums and water heritages like the churches on the terps. The route also brings you passing through the OudeBildtdijk, an old sea dike, and the polders that used to be the salt marsh in the sea. The D-tour ends up at Westhoek where it is a good bird-watching place with high salt marsh along the coast. A design intervention will be placed as a view platform.

Routing Design

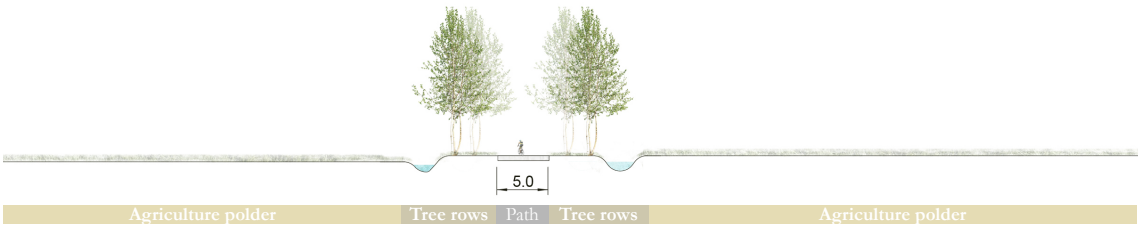


0 20 m 50 m

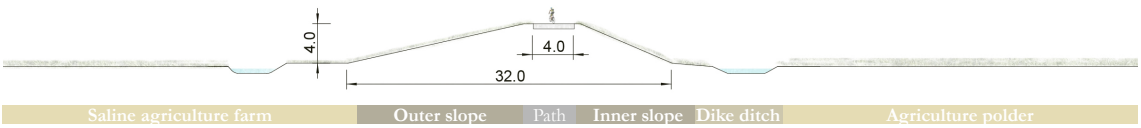
Section 1 Bike path along the canel to the terp village



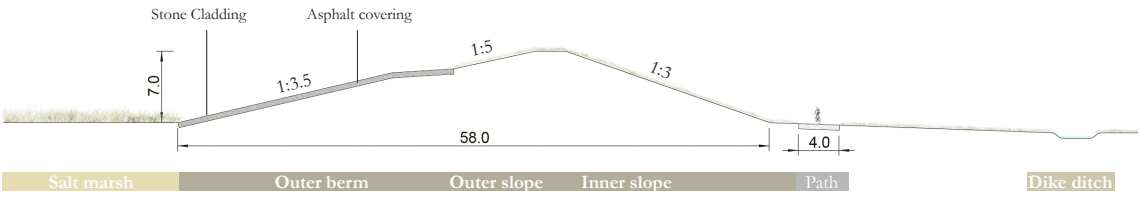
Section 2 Tree avenue leading towards the Wadden coast



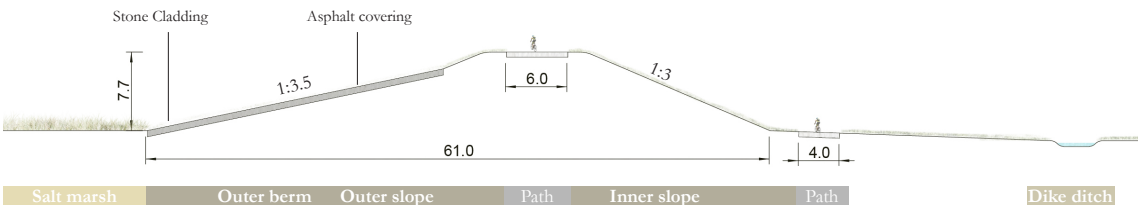
Section 3 Route on the old dike



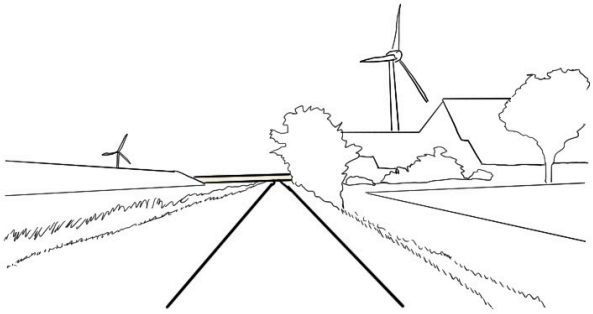
Section 4 Route along the sea dike

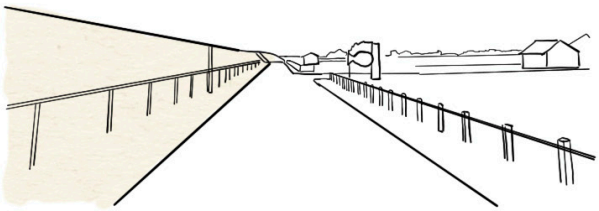


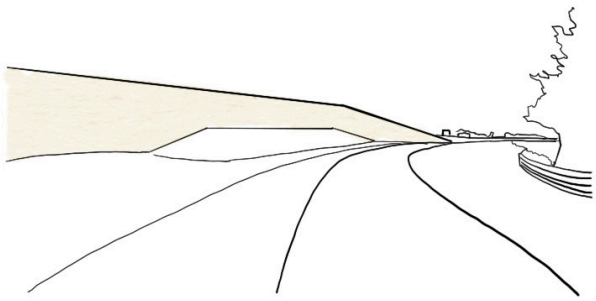
Section 5 Route on top of the sea dike

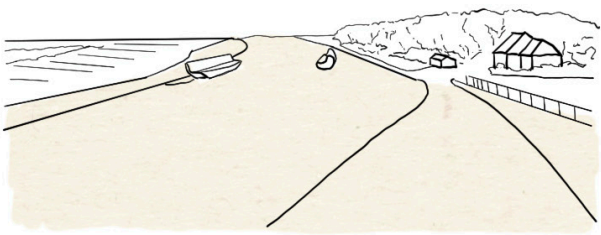


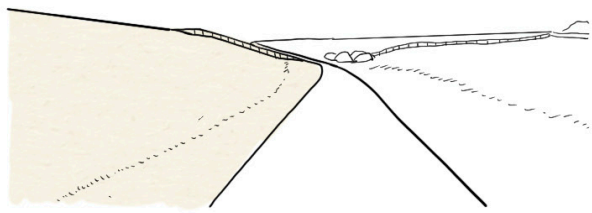
Routing Design

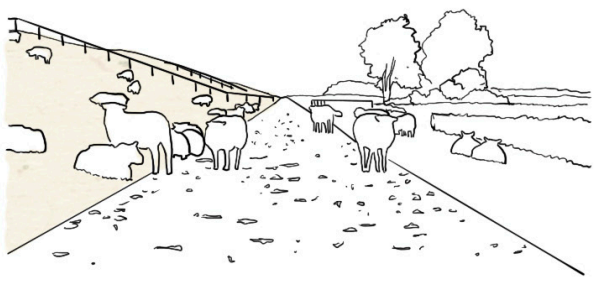




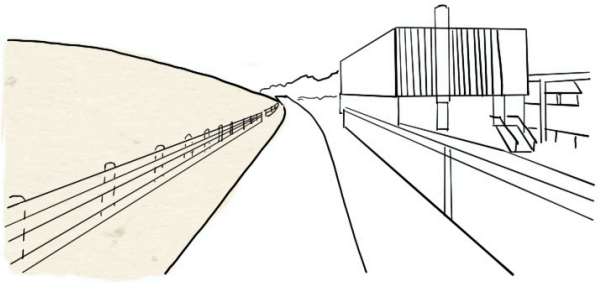


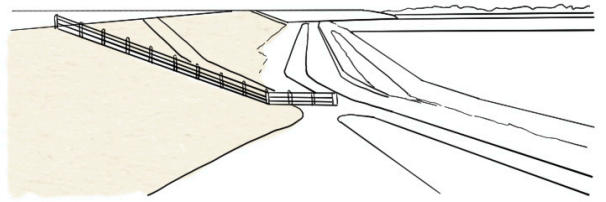


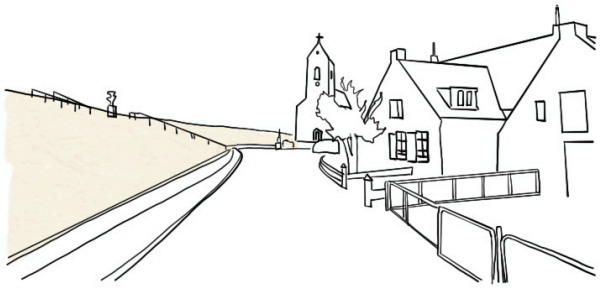




These are the views of the route along the coast. The sea dikes(yellow part) play an important role guiding the visitors along the route.

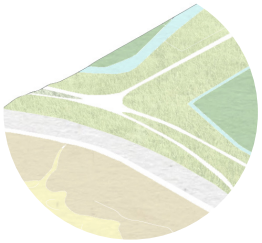




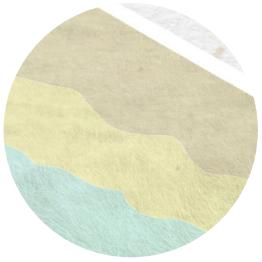


Design Location

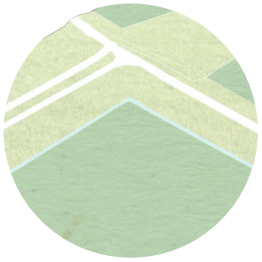
Point of intersection



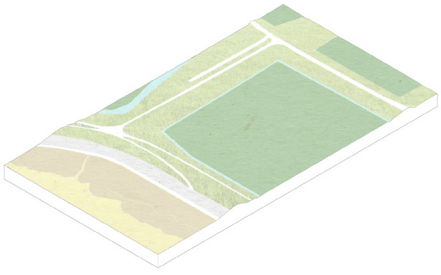
Salt Marsh



Old sea dike

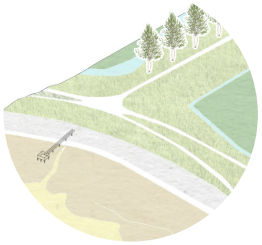


Westhoek is a design location between the old and the young polders in which the former coastlines are recognizable by the old sea dikes. Some former sea dikes remained as a road along the polders. A narrow strip of the salt marsh is found along the edge with a tidal difference of two meters twice a day.

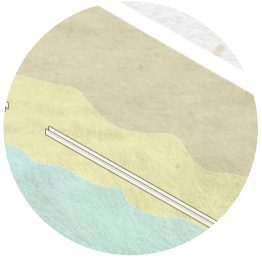


Design Location

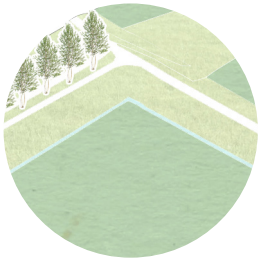
Node

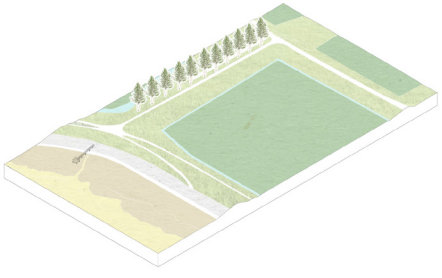


Salt Marsh Flood Defense



Double Dike Systems &
Saline agriculture

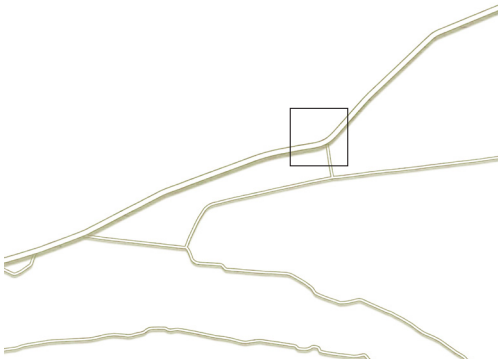




Salt marsh in design location.
Photo: Google Earth, 2022.

Design Interventions

Here are the examples of the design interventions along the route. One of the proposed design interventions is the view platform in the conjunction of Westhoek. This elevated wooden platform is an extension of the path from the dike to the mudflat.



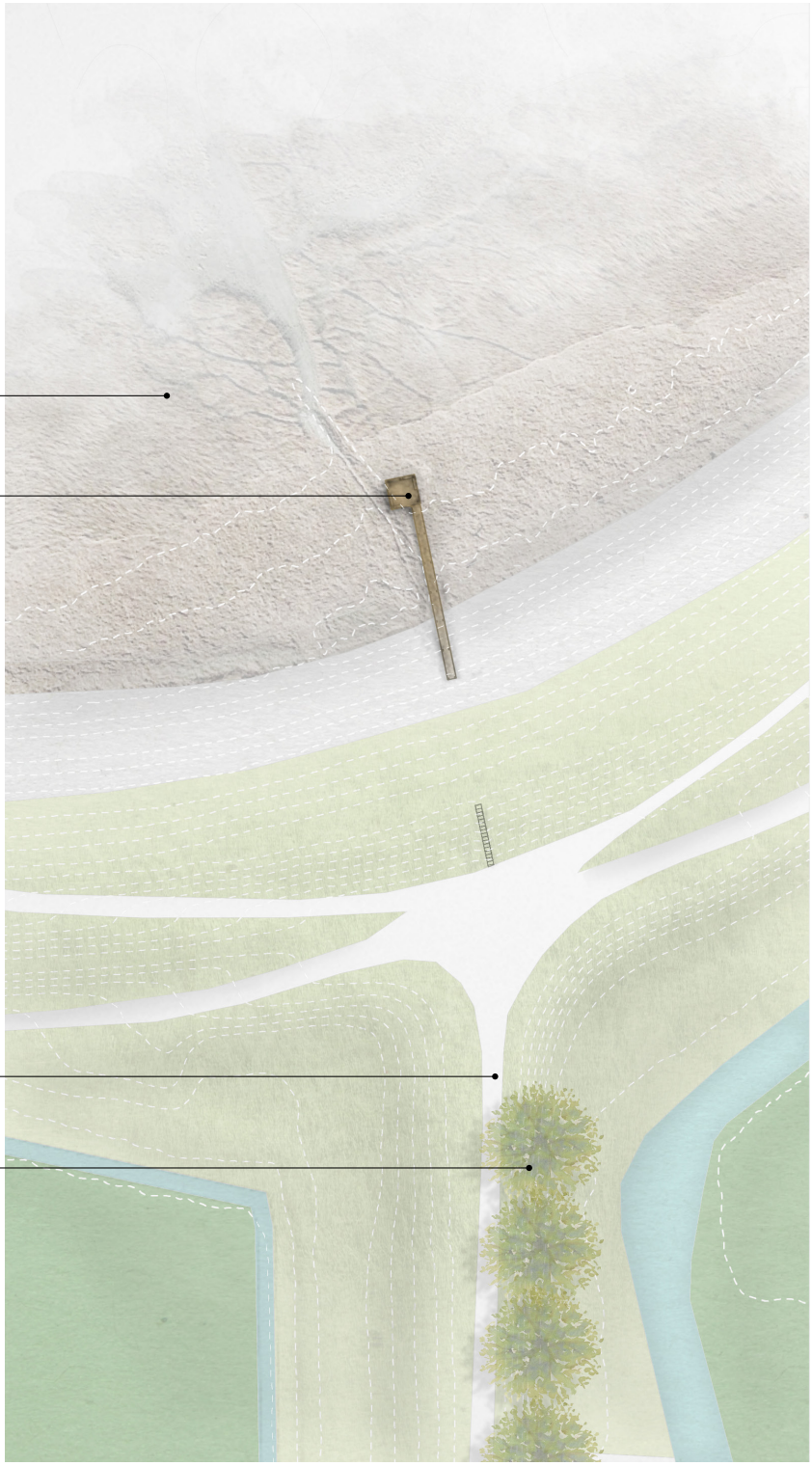
View tower

Seat

Platform

Wind shelter

0 10m 50m N


Salt marsh naturally developed
Bird watching platform
Routing
Tree avenue

Design Interventions

The 3-meter tall platform allows you to pass through the salt marsh and have a panoramic view over the Wadden Coast all day regardless of the tidal change. Tree avenue will direct people to the view platform to look at this attractive landscape.

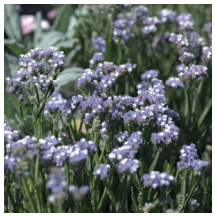
Wooden panel

Wooden beam

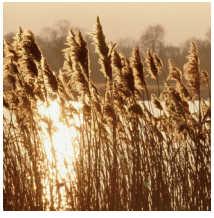
Salt Marsh Cord Grass

Seaside Goldenrod

Glasswort



Sea Lavender



Common Reed

High tide

Low tide

Design Interventions

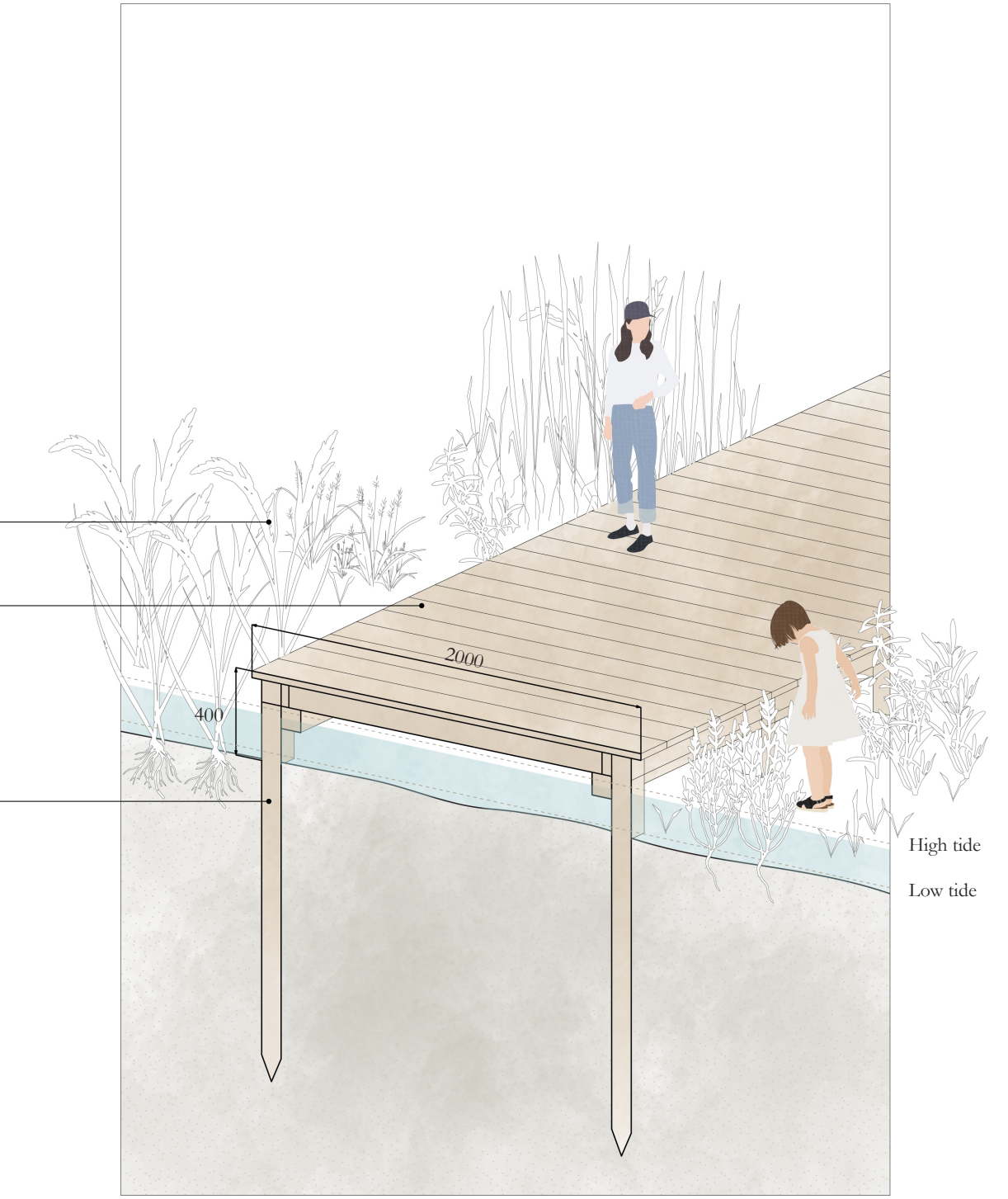
Another intervention is the wooden boardwalk along the coast on the salt marsh. During the low tide, people could sit on the boardwalk and walk on the marshland whenever they like. When the water comes, people can stay on the pathway to experience the tidal difference throughout the day.

Low salt marsh

10m wide wooden panels

Wooden pole

(Marker Wadden, 2022)


2000
400
High tide
Low tide

Brushwood Dams

Brushwood dam is a traditional device to facilitate accretion in the Wadden Sea since the 18th century. (Winterwerp, Albers, Anthony, Friess, Mancheño, Moseley, Muhari, Naipal, Noordermeer, Oost, Saengsupavanich, Tas, Tonneijck, Wilms, Bijsterveldt, Eijk, Lavieren, Wesenbeeck, 2020) These permeable dams are a nature-based solution which function like a mangrove forest to reduce wave impact at high tide and enhance deposition of fine sediment. It comprises two rows of wooden poles and brushwood placed in between. When the silting has reached a certain level, new basins are formed in front. Vegetation starts to grow on the new basins and expands. The T-shaped dams are the most effective form as they allow sediment to enter the basin through the openings within the dam in the intertidal areas. This method results in a drainage channel naturally and prevents lateral losses. (Winterwerp, Albers, Anthony, Friess, Mancheño, Moseley, Muhari, Naipal, Noordermeer, Oost, Saengsupavanich, Tas, Tonneijck, Wilms, Bijsterveldt, Eijk, Lavieren, Wesenbeeck, 2020)

Mudflat intertidal

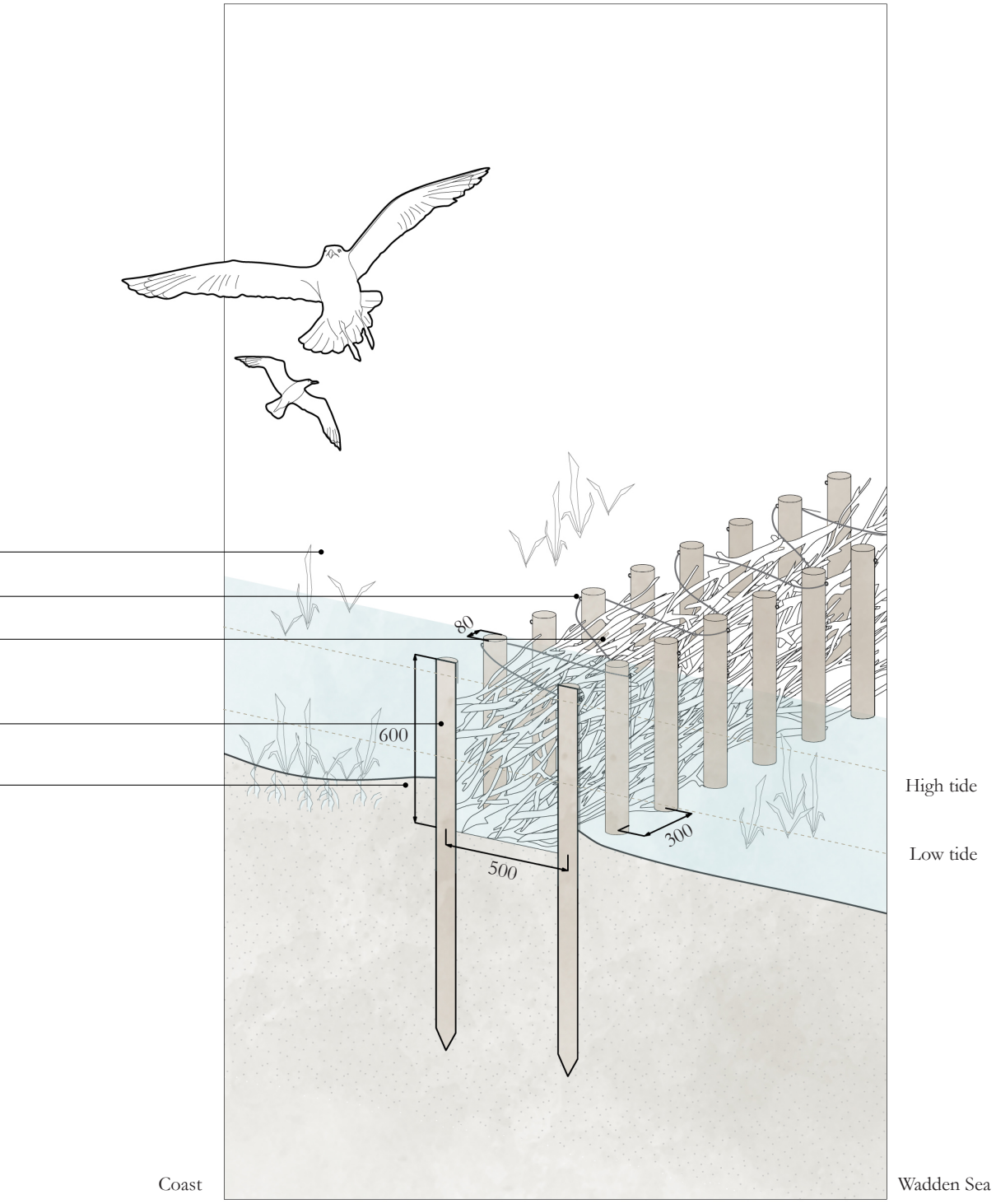
Rope

Brushwood bundles length 2m

Wooden pole

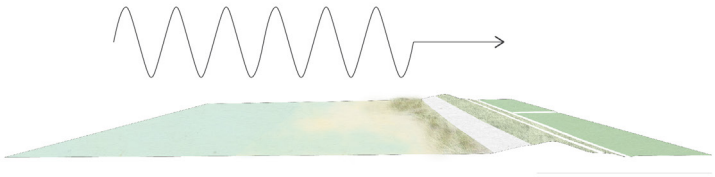
Sediments accumlated

(Author, 2022)

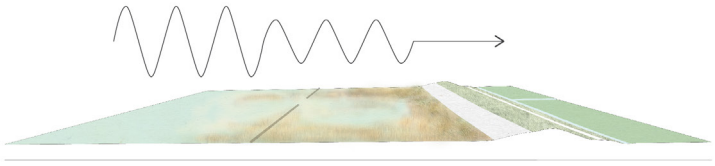

80
600
300
500
High tide
Low tide
Coast
Wadden Sea

Two Coastal Defense Systems

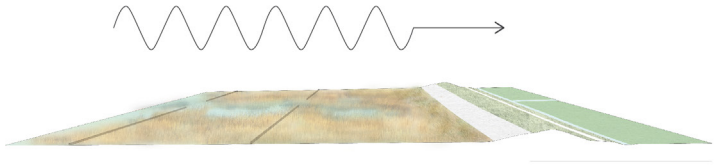
Progression
Salt marsh defense system



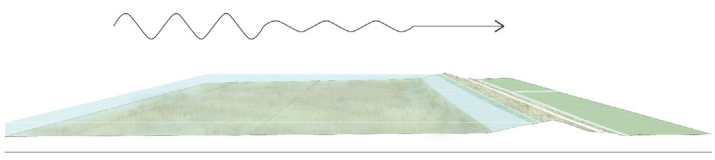
2022



2030

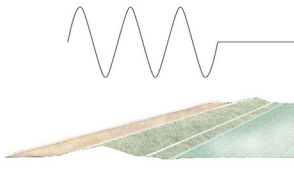


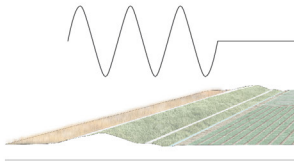
2050

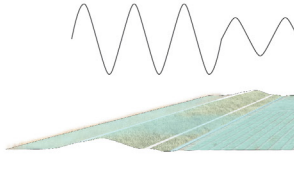


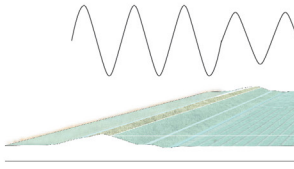
2070

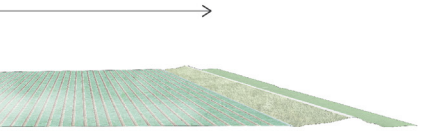
Regression
Double dike system



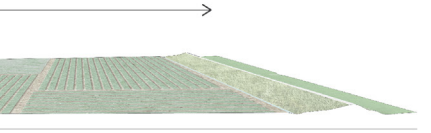








2022



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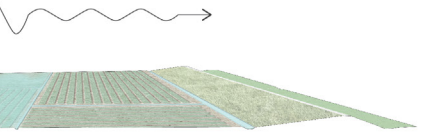
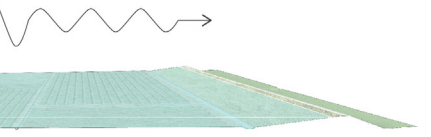


2050

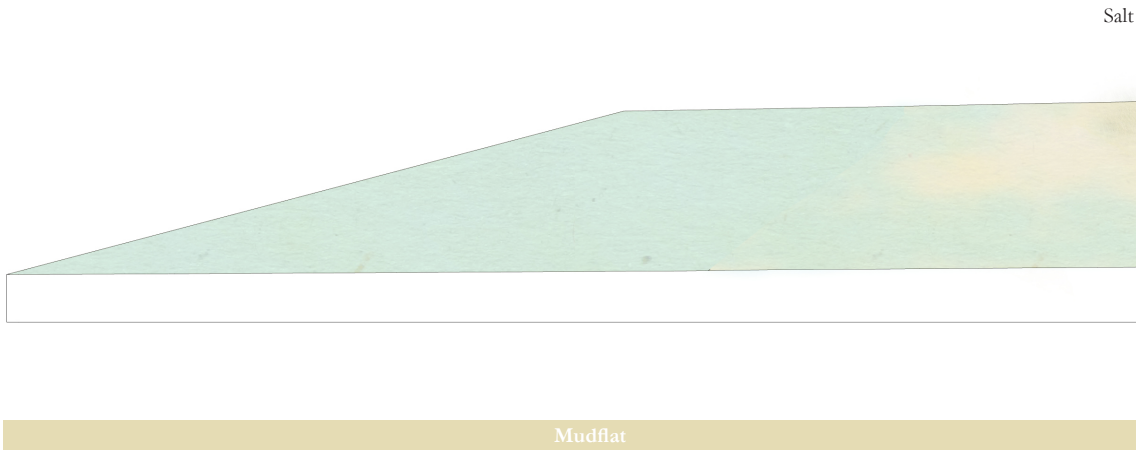


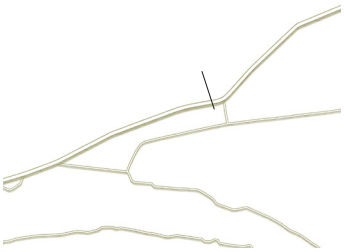
2070

Two flood defense systems, namely progression and regression, are designed for flood protection in the future. Salt marsh defense system is a nature-inclusive and progressive approach to lower the flood risk and provide added value to the ecosystem and society. The vegetated foreland could reduce the wave energy and hence reduce the load on dikes.

Double dike systems which allow overtopping of water with a secondary dike act as a regression approach. The double dike aligned with the objectives of the Delta Programme, in which flood risk management is integrated with the functions of nature, recreation, cultural history and economic activities. The transitional zone between the double dike offers economically and socially benefits for a wider coastal community and environment

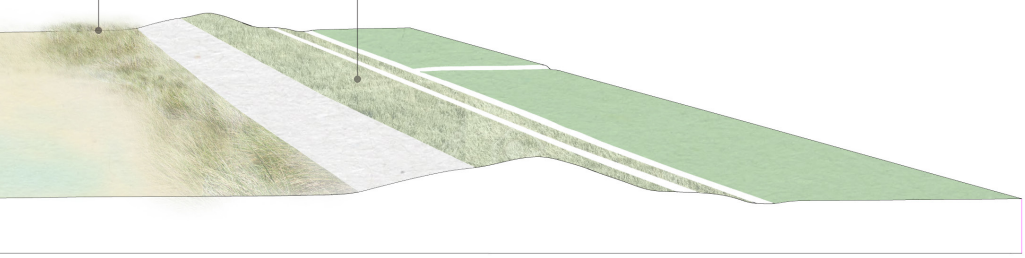
Salt Marsh Defense Systems 2022





Functional primary dikes until 2050

marshes naturally developed



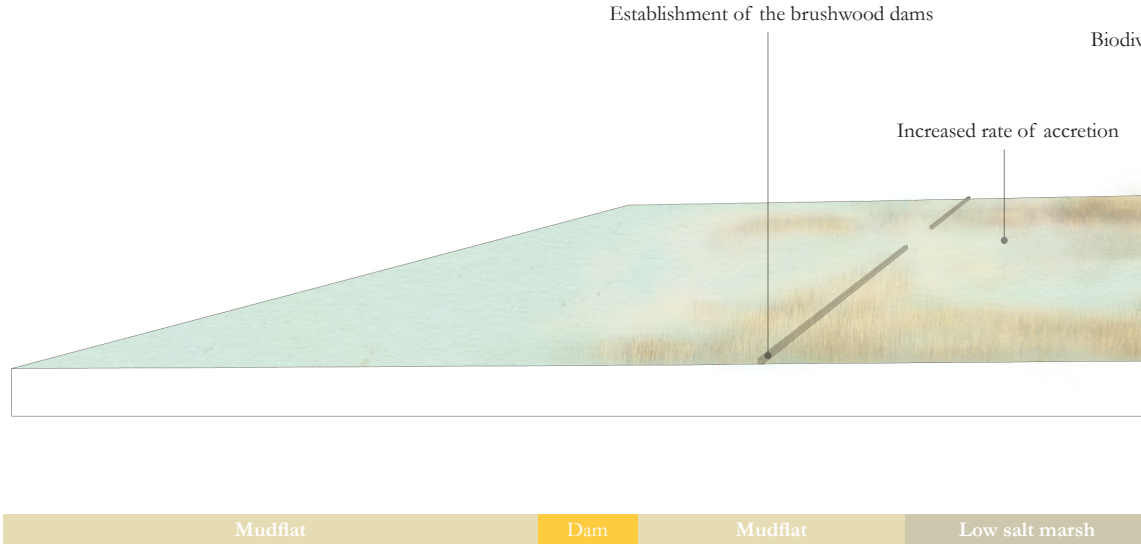
Low salt marsh | Sea Dike | Path | Agriculture polder

narsh sometimes inundated in high tide

Little vegetation

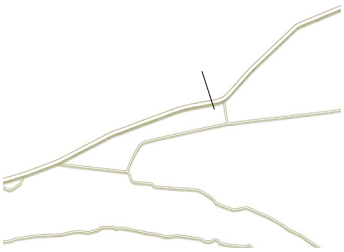
Sea grass

Salt Marsh Defense Systems 2030

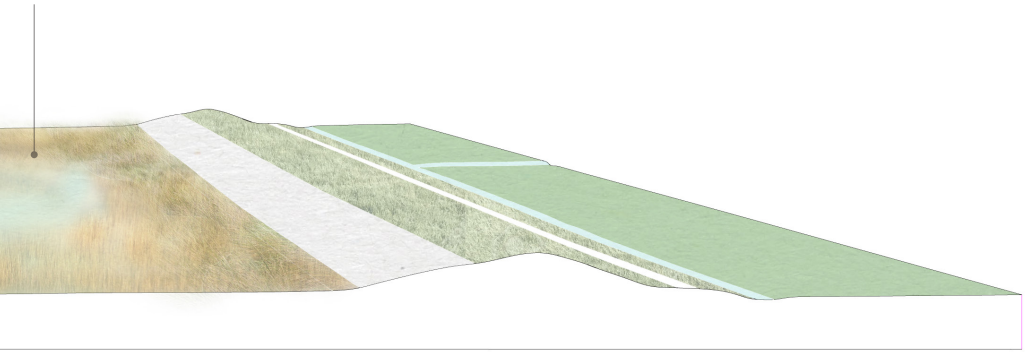


Birds foraging for small shellfish

Kluut | Scholekst | Lepelaar | Herring gull | Small crustaceans & shellfish



verse salt marsh



High salt marsh | Sea Dike | Path | Agriculture polder

high tide

Pioneer plant species

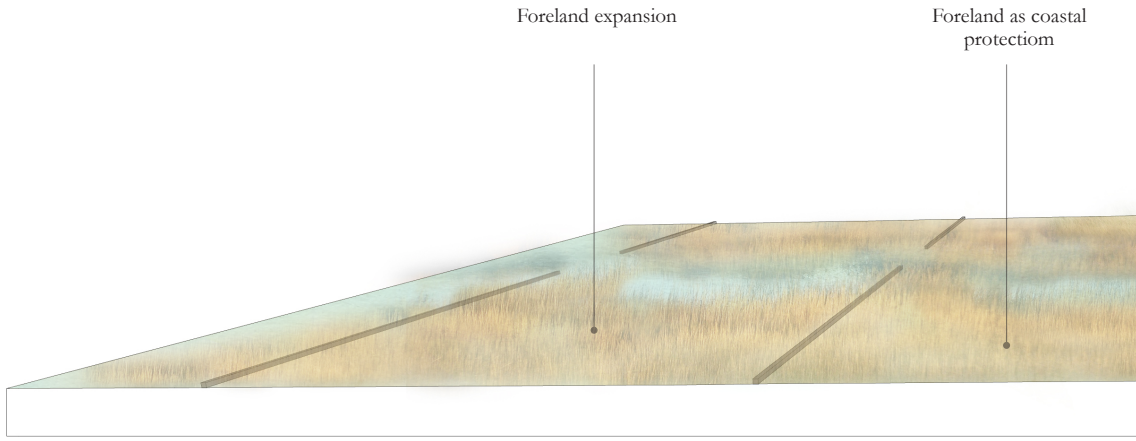
Glasswort

Common cord grass

Sea lavender

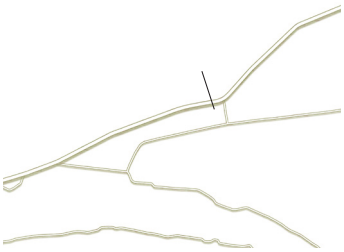
Samphire

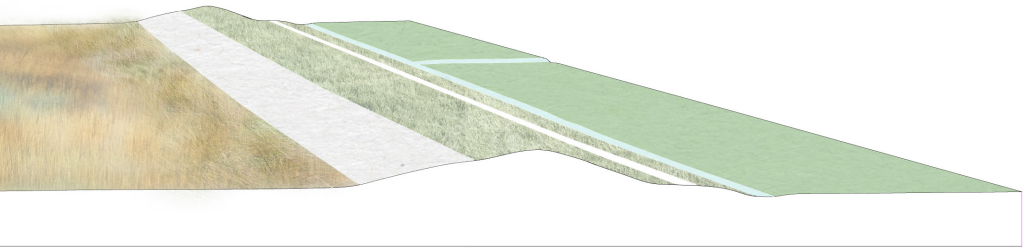
Salt Marsh Defense Systems 2050



High salt marsh inundated a few tin

Birds recuperate & breed in spring





arsh | Sea Dike | Path | Agriculture polder

nes each year at spring tides

More pioneer plant species

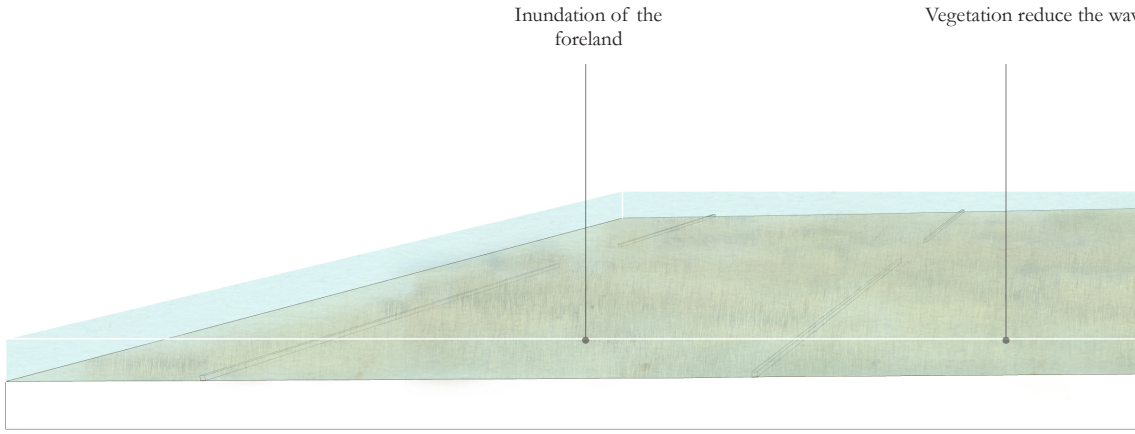
Annual seablite

Sea purslane

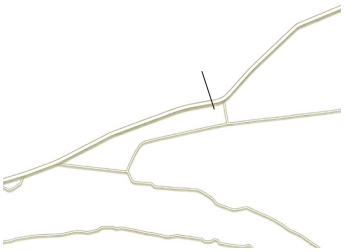
Red fescue

Weed

Salt Marsh Defense Systems 2070

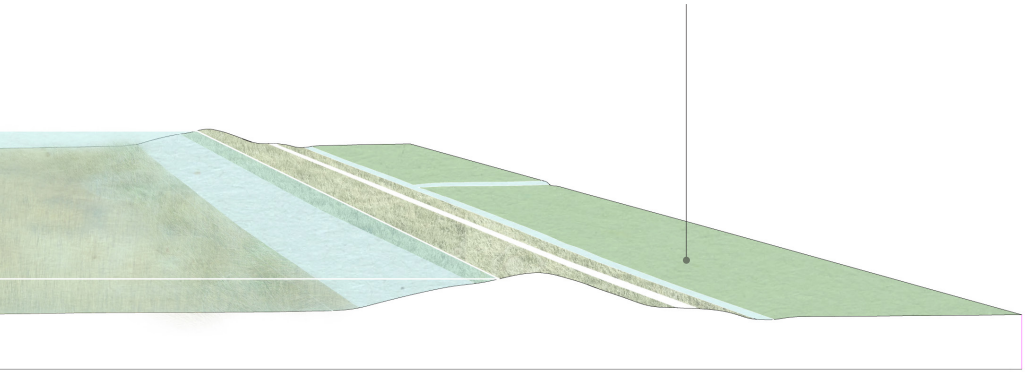


Nesting grounds for birds



ve energy

Protected land



Sea Dike | Path | Agriculture polder

lly high tides

Grazing in summer

Cattle

Sheep

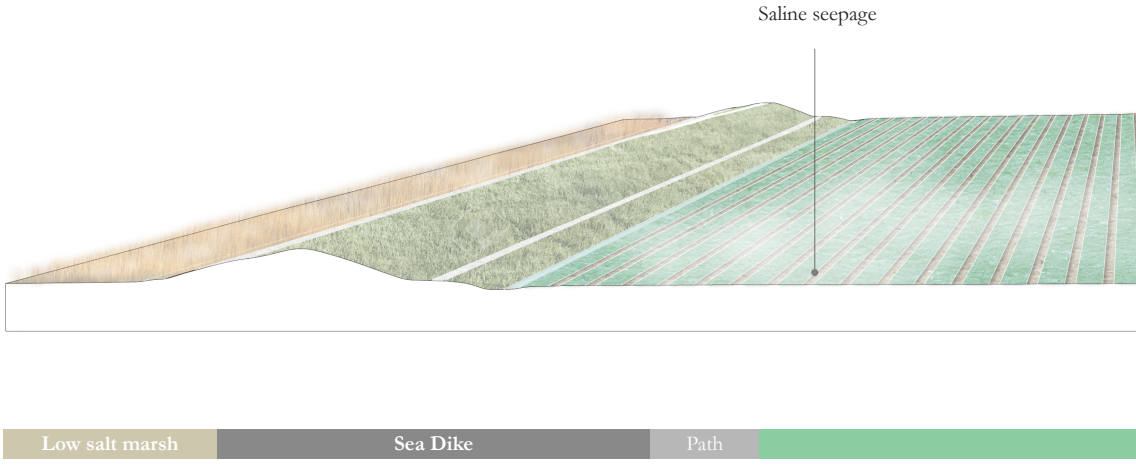
Horse

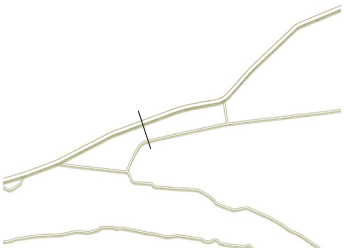
Salt Marsh

Low tide

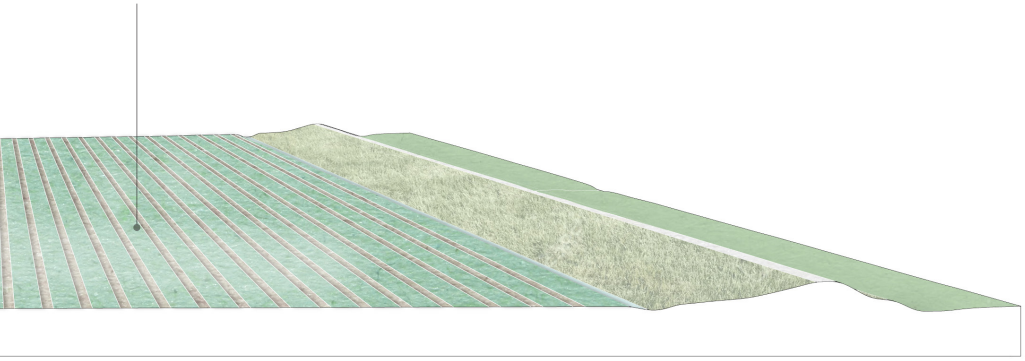
High tide

Double Dike Systems 2022



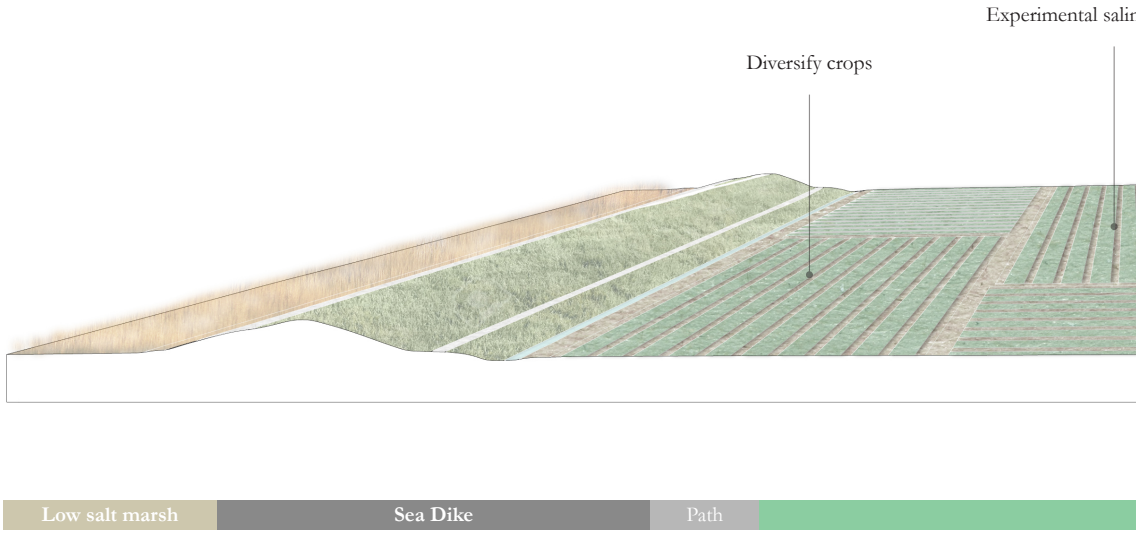


Large-scale farmlands



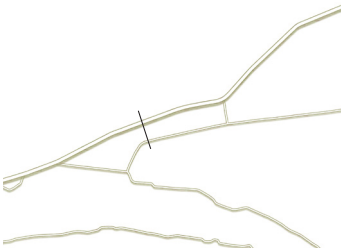
Saline agriculture farm | Old sea dike | **Agriculture polder**

Double Dike Systems 2030



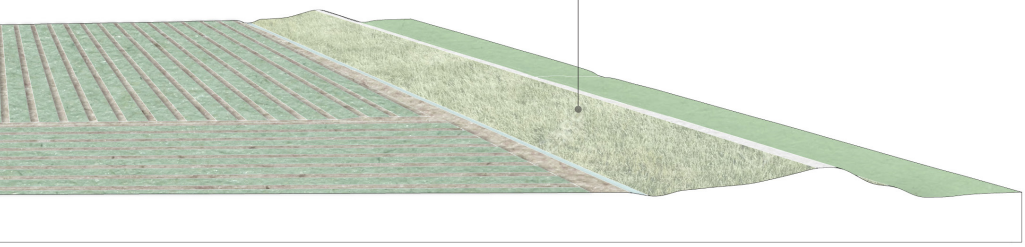
Potato

Wheat



he agriculture

Heighten & restore the
function of the old dikes



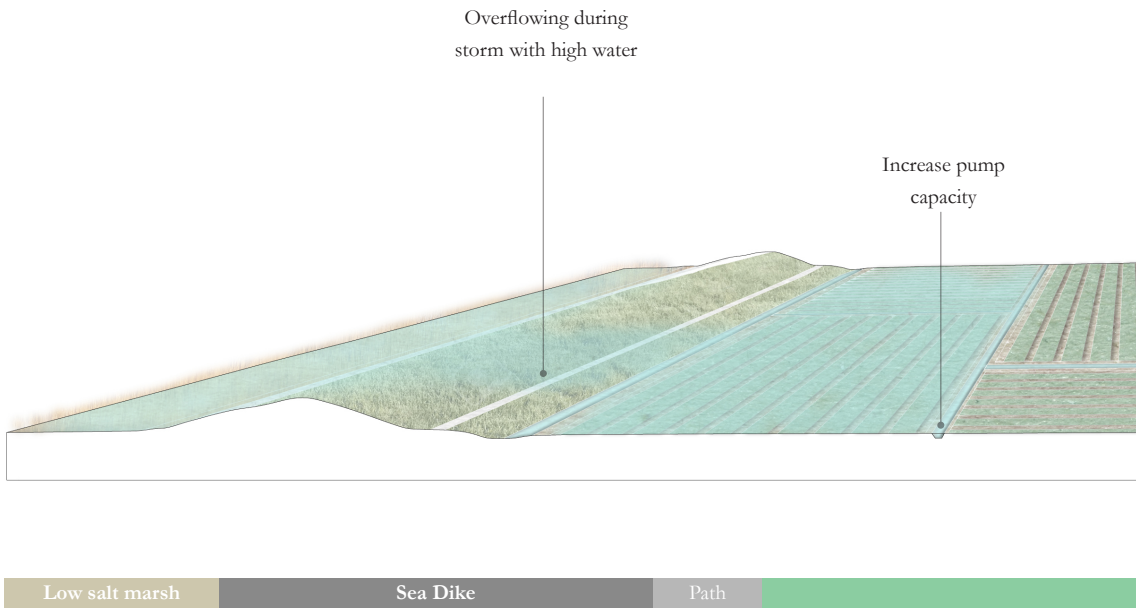
Saline agriculture farm | Old sea dike | **Agriculture polder**

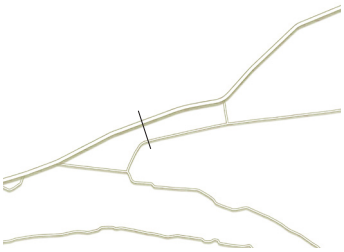
Salt-tolerant crops

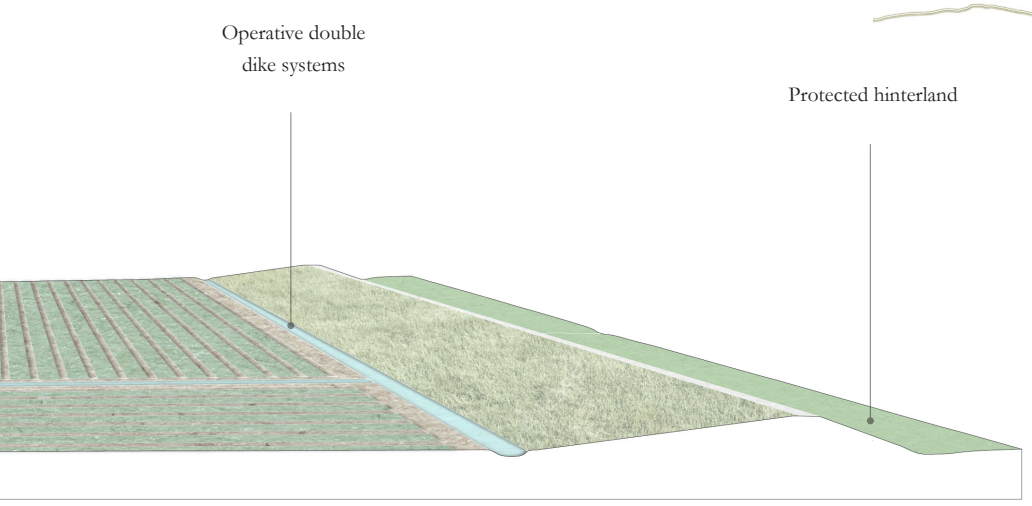
Sugar beet

Carrot

Double Dike Systems 2050

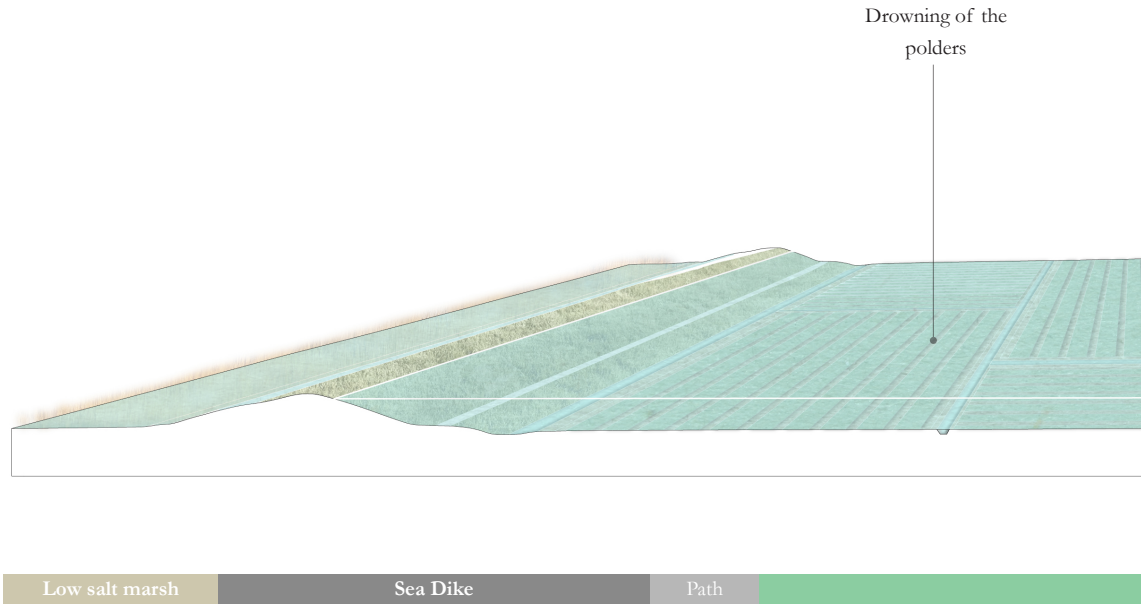


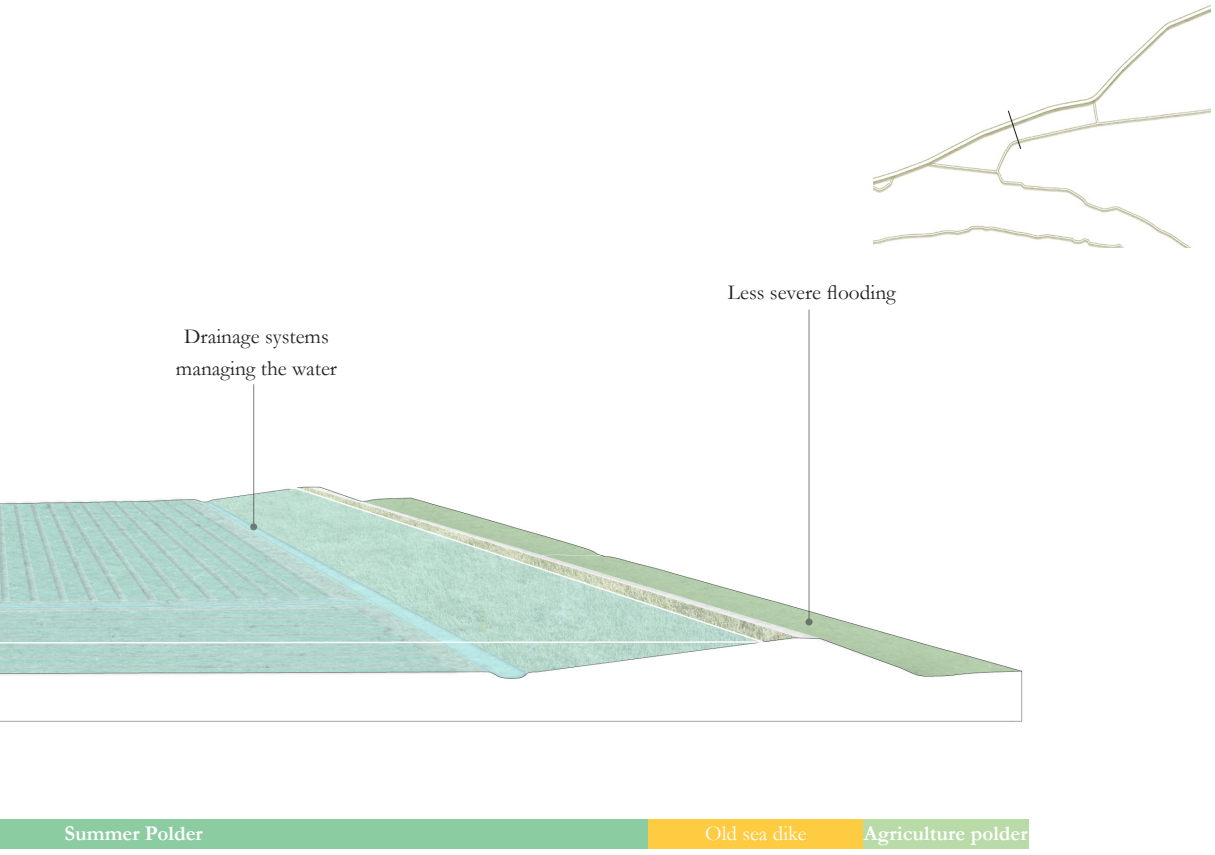




Saline agriculture farm | Old sea dike | Agriculture polder

Double Dike Systems 2070



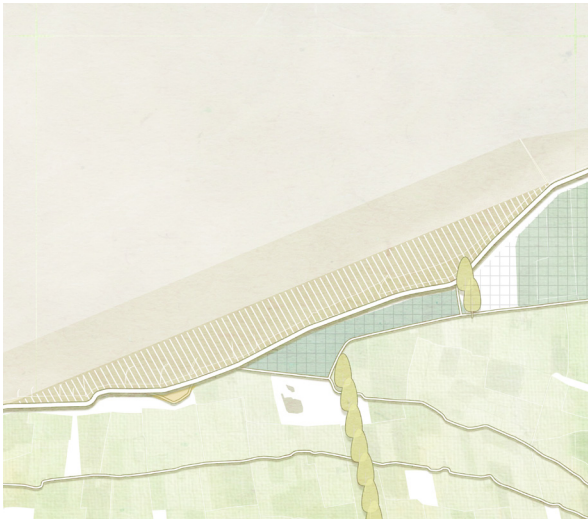

Less severe flooding
Drainage systems
managing the water
Summer Polder
Old sea dike
Agriculture polder

Double Dike Systems

Design Time Phase

2030

Routing design

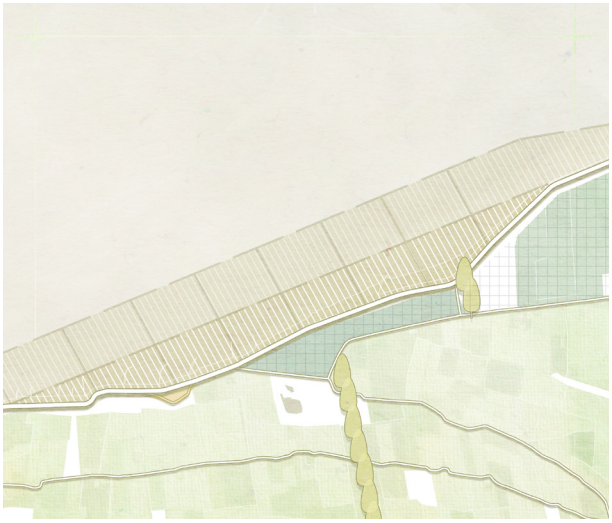


2050

Establishment of the brushwood dam

Old dike restoration

Saline agriculture



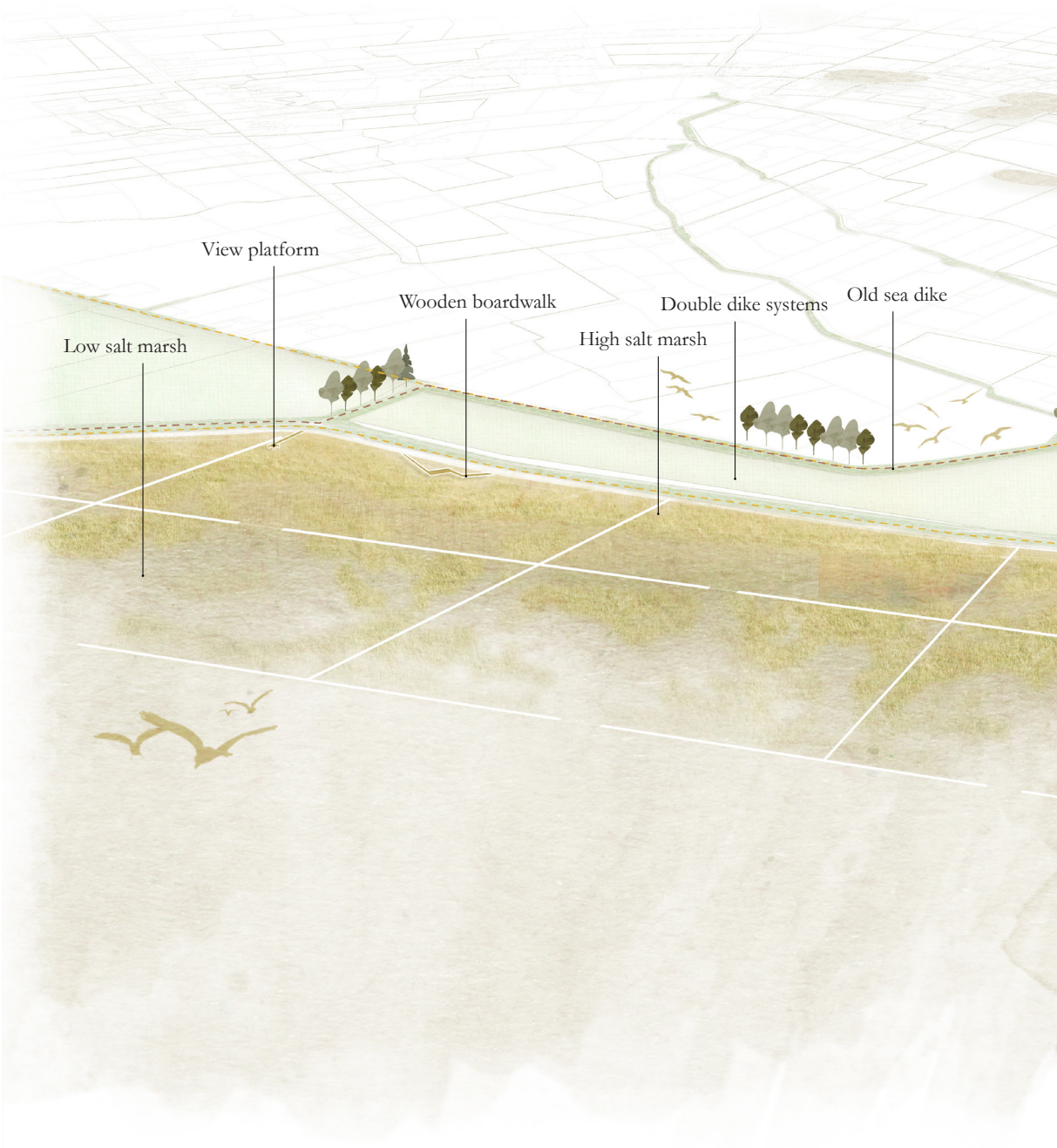
Tree avenues and design interventions could already be placed in 2030. The route passing through the water heritages invites visitors to explore this cultural coastal landscape after a mudflat walking or a stay on the Wadden Islands. Brushwood dams are established along the coast and the salt marsh is expected to grow into a biodiversity rich upper salt marsh by 2050. Dike reinforcement and restoration of the old sea dikes construct the double dike systems to protect the cities from flooding. Saline agriculture is a new productive landscape in the transition zone between the double dikes. Together with the extensive foreland developed by the salt marsh systems, the coast is adaptive to the future climate in 2070.

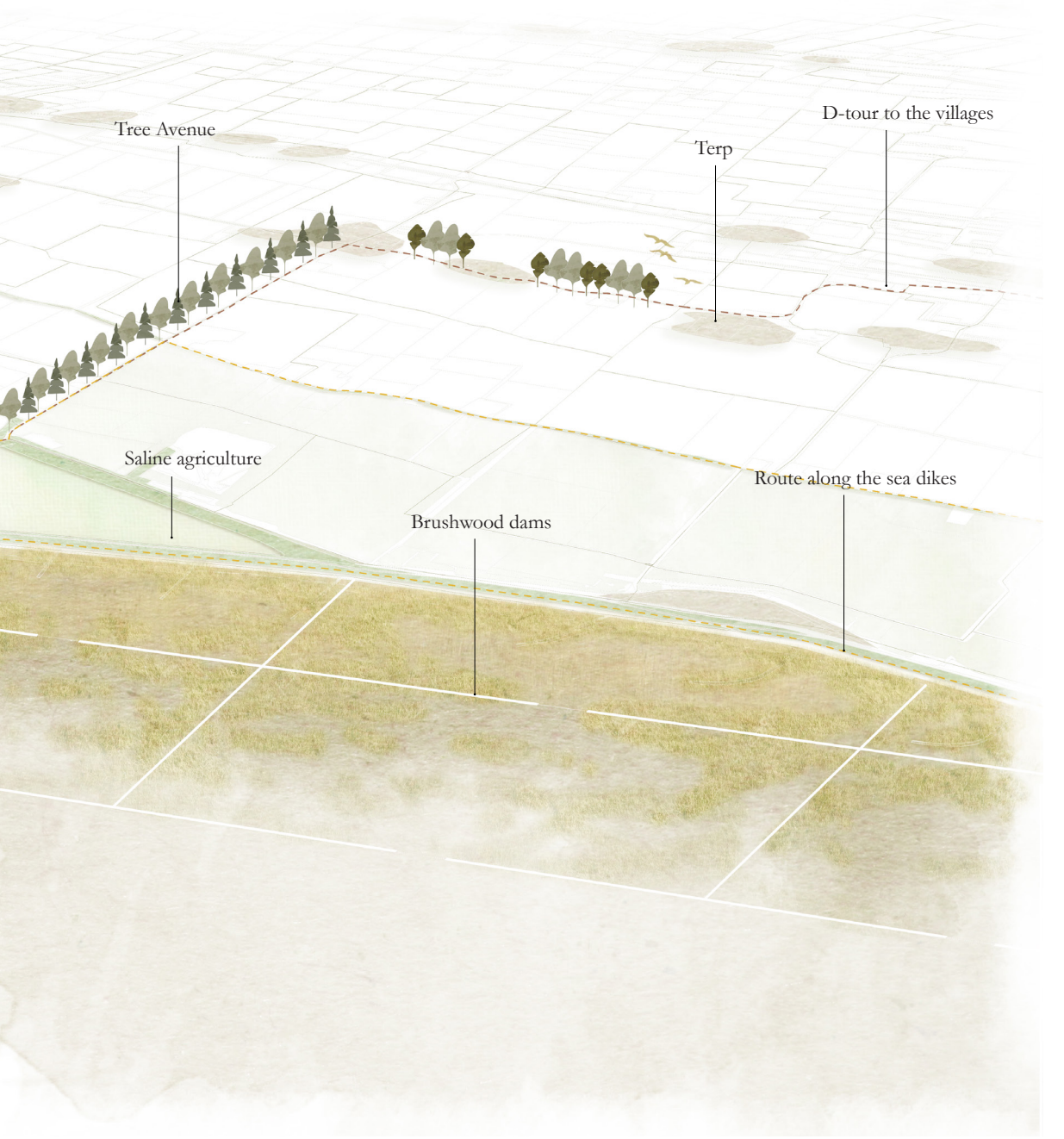
2070

Salt marsh expansion

Functional double dike systems

Bird's Eye View




Tree Avenue
Terp
D-tour to the villages
Saline agriculture
Brushwood dams
Route along the sea dikes

Reflection

The conclusion

Farm along the Wadden Coast.
Photo: Author, 2022.

Reflection

1. Research approach

This project adopts the 'research by design' method in which the design is taken as a research strategy for approaching the challenges in the Wadden Coast . The research part involved the collection of data regarding the three systems (water, cultural and socio-economic systems) to analyze, synthesize and identify the major landscape processes which act as a basis for the design projection. The information is quite overwhelming but this analytical framework helped me organize and structure the research part and gave me ideas on how to approach the project. By overlaying data and interpreting the maps, the mapping process results in knowledge acquisition which built up the research part and contributed to the design proposal. Due to the huge amount of information and data, I collected unnecessary data that was not related to the design proposal. Nonetheless,the selection of information is part of the learning process and it allows me to explore and understand the landscape in a holistic approach

Scenario-making plays an important role in the project which supports the decision-making processes in the issues with a high level of uncertainty. The research developed three scenarios with different sea level rises and flood conditions in 2100 by collecting and studying the flood data in the National Water and Floods Information System (LIWO) . Scenario is a tool for exploring the future uncertainty and inducing reflection on spatial consequences on the basis of hypothetical reasoning. By asking the question "what if", a design proposal is made based on the scenarios to demonstrate a range of possibilities which is the level of protection of land and the acceptance for the water in the future. Nevertheless, I found it difficult to interpret the flood data. The flood probability and flood depth maps are the speculation of flooding under a variety of conditions, such as the primary dike breach and the flood caused by the regional defense systems. The explanation and the reasoning behind those maps are insufficient so that the flood scenarios I have made might not be accurate. The future climate uncertainty and the dike reinforcement also weaken the accuracy of the scenarios.

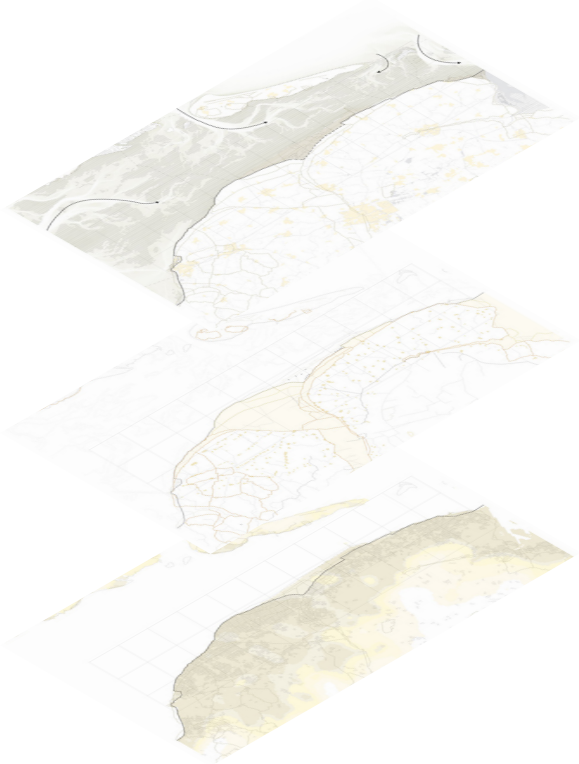
The research worked on multiple scales, ranging from the territorial scale to the local scale. Analysis on territorial scale addressed the global challenges like the rise of sea level and the vulnerability of the Dutch Wadden Sea. Regional scale highlighted the cultural identity of landscape and the social and environmental crisis in the province of Friesland. Lastly, the local scale illustrated the sensorial and spatial landscape qualities along the coast of Friesland.

This research approach synthesizes the particularities and temporality of the Friesland Wadden Sea landscape and forms a solid basis regarding the problem fields and design interpretations for the design proposal.

2. Research & Design

The design proposal is a translation of the research results into an integrated and innovative project.The research part which focuses on the water, cultural and socio-economic layer analysis induces three design pillars (climate-adaptive waterscape, water heritage and valuable waterscape). Based on that, three design strategies were made and built up the vision for sustainable flood protection and resilient landscape in the Friesland Wadden Coast.

Landscape diagnosis is done by compositing the layers of my research, in particular the cultural heritage and the future flood scenario, for site selection to develop the strategies in detail. I think this process is crucial since it determines the site location and helps me shift the design thinking from regional scale to local scale. I picked three design locations regarding three water conditions at first: 1. Brackish water along the coast 2. Freshwater in the polders along the sea dikes 3. Freshwater in the river basin. I am aware that a comprehensive design on water management should take account of the river basin in the inland areas. Nevertheless, my interests on the coastal landscape and the fact that the research on the river basin is not abundant enough to support the design brought me to the decision of focusing on one design location that is the most significant. This decision is difficult but I believe it is the best outcome for a nine-month graduation thesis.



CLIMATE ADAPTIVE WATERSCAPE
Water defense system

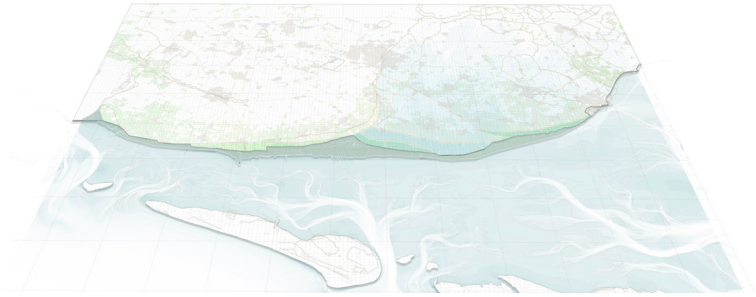
WATER HERITAGE
Cultural system

VALUABLE WATERSCAPE
Socio-economic system

Three master plans are made for the year of 2030, 2050 and 2100 to illustrate the proposal in short-term and long-term development. Climate adaptation is a long-term measure working with the natural processes to resolve the global climatic issue. Meanwhile, the routing together with a set of small-scale interventions could be implemented in the short term as an instant measure to enhance the landscape identity. Schematic design and small-scale interventions showcased how the strategies work on the ground and the spatial design facilitating landscape processes.

2030

2050



2070

3. Relation between graduation topic, studio topic, and master track

This project is part of the Wadden Sea Lab in the Flowscape studio as the graduation studio of the MSc Landscape Architecture. The Flowscape studio focuses on the integration of the spatial design with the landscape processes, the continuation of spatial quality and cultural identity of the landscape. The studio specifically discussed 'infrastructure as landscape' and 'landscape as infrastructure' in which the research project addresses both the regional and small interventions interrelating and being part of the territorial transformation processes. The Dutch Wadden coast, in particular the sea dikes and marshlands, is a significant infrastructure acting as an interconnected network for the dynamic natural ecosystems and protecting the nation from coastal flooding. My graduation topic redefines infrastructure beyond its traditional definition while introducing an integral approach to facilitate the natural and socio-economic processes, and strengthening resilience and local identity.

The Master's Program in the Landscape Architecture track trained students in systematic thinking, ecological design, and cultural literacy with a view to providing a holistic approach to protect and enhance the living environment. The track teaches students to transform and create compositions 'through' scale, time and as a process through critical academic research. My graduation project is design research which designs on multiple scales and involves in a phasing design plan, taking account of cultural, ecological, social and economic conditions. Landscape palimpsest is interpreted with a thorough research on the past and mappings. The track's emphasis on the intersection between architecture, engineering, and landscape allows me to collaborate and get new insights from my second mentor, Mark Voorendt, an engineering professor in the Hydraulic Engineering department.

4. Relationship between the project and the wider social, professional and scientific framework

The research and design proposal will be a new knowledge contributing to the society, landscape architecture and the scientific fields, offering a new perspective dealing with the climatic and social issues in the Wadden Sea. 'Research by design' is a powerful research approach in which complex issues can be resolved by spatial design. The research methodology which emphasized on site specificity and complexity is a possession of knowledge that can be applied to other projects all over the world. The design proposal itself might also be applicable to other places with similar conditions and issues along the Wadden Coast. Also, the Wadden Coast is often being neglected and hence the research targeting the Wadden Coast could gain knowledge on the natural and cultural identities, as well as raising the awareness from the public.

Furthermore, the research responded to the needs of the society and the environmental challenges. The project explored the spatial, societal and environmental issues by design research and made design proposals addressing the above issues. The discussion with the Friesland municipality and the local dwellers allowed me to understand the issues from different perspectives and their needs so that the proposal could respond to them. The local dwellers value the cultural identity and the short-term development while the municipality has the responsibility to ensure the flood protection and the livability of the region in the long run. Therefore, a design proposal with a long phasing plan is part of the consideration.

The profession of landscape architecture has been diversified, from working multi-disciplinary to preparing strategy within legal frameworks, advising on policy-making, and master planning for development and regeneration schemes. My graduation project is an integration with landscape, urbanism and engineering disciplines. The project is a new input for the municipalities and urban planners to carry out in the future. The project also demonstrated a holistic landscape approach on dike reinforcement and flood management in the nation.

5. Ethical issues and dilemmas

In this project, I am looking for a landscape integrated approach as a catalyst for the coexistence of the flood protection and landscape resiliency to deal with the global climatic issues. Rather than taking the sea dikes as a hard infrastructure, the project challenged the traditional mindset of regarding flood management merely as a hydraulic engineering element. Dike reinforcement is also a task for landscape architects to rethink and design the dike integrating with this ecologically and culturally rich landscape, to provide maximum resiliency.

As one of the UNESCO World Heritages, the Wadden Sea is under international protection and hereby with strict regulations. To make a design enhancing the values of the heritage and without harming it is always the top priority. Human interventions within the protection zone should be avoided. Changing the agricultural production model by introducing saline agriculture and double dike systems is a long-term proposal which involves negotiations and public participation.

6. Feedback and Response

I had a discussion with my mentors about the research outcomes and the idea of making a set of strategic design toolbox was declined. Instead of making a generic design toolbox which is not site-specific, it is more meaningful to have a design driven by the site context and address the particularity and the uniqueness of the area.

The materials for the dike reinforcement could be considered in the proposal and further research is needed to see where and how the materials could come from within the region for the sakes of circularity.

Design assessment could also be taken into account in the final part of the project. Therefore, a preliminary design assessment with a list of assessment criteria is discussed with Mark. However, there are limitations on the assessment. For instance, the double dike system is still a relatively new concept and lacks experience in implementation and assessment on the environmental impact to the landscape. The effectiveness of the salt marsh on coastal flood protection is controversial due to the future uncertainty. The assessment is only considered as a preliminary one and would not discuss in detail in the project.

7. Limitations, lessons and recommendations

After the nine-month-research, the major accomplishment is the practice of 'research by design' and making design decisions on multiple scales. The studio has trained me to think with maps and landscape processes in which I could integrate into the design. Narrative is also important for expressing and delivering the focuses of the research and design, engaging people in the project as in a story. The Wadden Sea Lab worked in a very small group of people, therefore the research process is inefficient whereas the scope of the research is insufficient. But working in a small group allows me to focus on individuality and we always have sufficient time to discuss every week.

The research started with the topic of 'water' which involves the brackish water as well as the freshwater in the river basin and bosezem systems in Friesland. My interests in the landscape processes along the coast have driven me to focus on the flood management of the sea water. The design proposal would become more coherent and inclusive if the flood management in the river basin is also part of the scheme. Moreover, the project only took one location for the small-scale interventions. Working on several design locations could demonstrate a variety of interventions and the implementation of the design strategies comprehensively.

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Regression & Progression

Towards a Regenerative Water Landscape in Wadden Coast

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