Fluid Soils

(Co)Designing for the Wadden Sea Landscapes

edited by Laura Cipriani

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Laura Cipriani | editor

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TU Delft OPEN Publishing

Laura Cipriani is an assistant professor of landscape architecture at Delft University of Technology. Her current research addresses climate change issues, starting from the materiality of 'water and soil' and adopting (co)design approaches. Over the last decade, she has taught at Venice University IUAV, Politecnico di Milano, National University Singapore, Venice International University, and the University of Padua. She holds bachelor's and master's degrees in Architecture (Hons) from IUAV, a Master's in Design Studies (Hons) from Harvard Design School (2004), and a Ph.D. in Landscape Urbanism from IUAV. In 2008, Laura founded Superlandscape, a landscape and urban design firm.

The relationship between soil and water is at the center of interest now more than ever. Despite being a UNESCO World Heritage Site of extraordinary environmental value and beauty, the Wadden Sea, its territories, and its people now face an uncertain future while wrestling with latent climatic, economic-productive, and social crises. Subsidence increased by gas extraction and peat oxidation, soil erosion, saltwater intrusion, eutrophication, and agricultural water pollution testify to a territory in the throes of long-term repossession by the sea.
Can we (co)design the Wadden Sea landscapes? How can we transform these emergencies into opportunities? Based upon applied research work in regional scenario-making and local design projects, the book attempts to imagine the present and future of the Wadden Sea and its hinterland adopting (co)designing approaches. Peatlands, agriculture, energy, and heritage all intersect to encourage economies and social inclusion projects where the landscapes of soil and water become the driving force to overcome the crises.

This publication is the fruit of the Graduation Studio *Water Landscapes of Crisis and Hope* guided by Laura Cipriani and held during the 2021-22 and 2022-23 academic years at TU Delft, Section of Landscape Architecture.

ISBN: 978-94-6366-823-1
DOI https://doi.org/10.59490/mg.106
BOOKS.OPEN.TUDELFT.NL

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Colophon

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Keywords
Wadden Sea Landscapes, Water and soil, Landscape co-design, Rural landscapes, Climate change landscapes

Published by
TU Delft OPEN Publishing | Delft University of Technology | The Netherlands

DOI https://doi.org/10.59490/mg.106
ISBN: 978-94-6366-823-1 (ebk)

June 2024

Peer-review statement
This book has been peer-reviewed. TU Delft OPEN Publishing selected the reviewers.
The editor gratefully acknowledges and appreciates their contributions.

The electronic version of this book is available at
https://books.open.tudelft.nl

Cover design made by Laura Cipriani. Photo: Bas van Breukelen, 2020.

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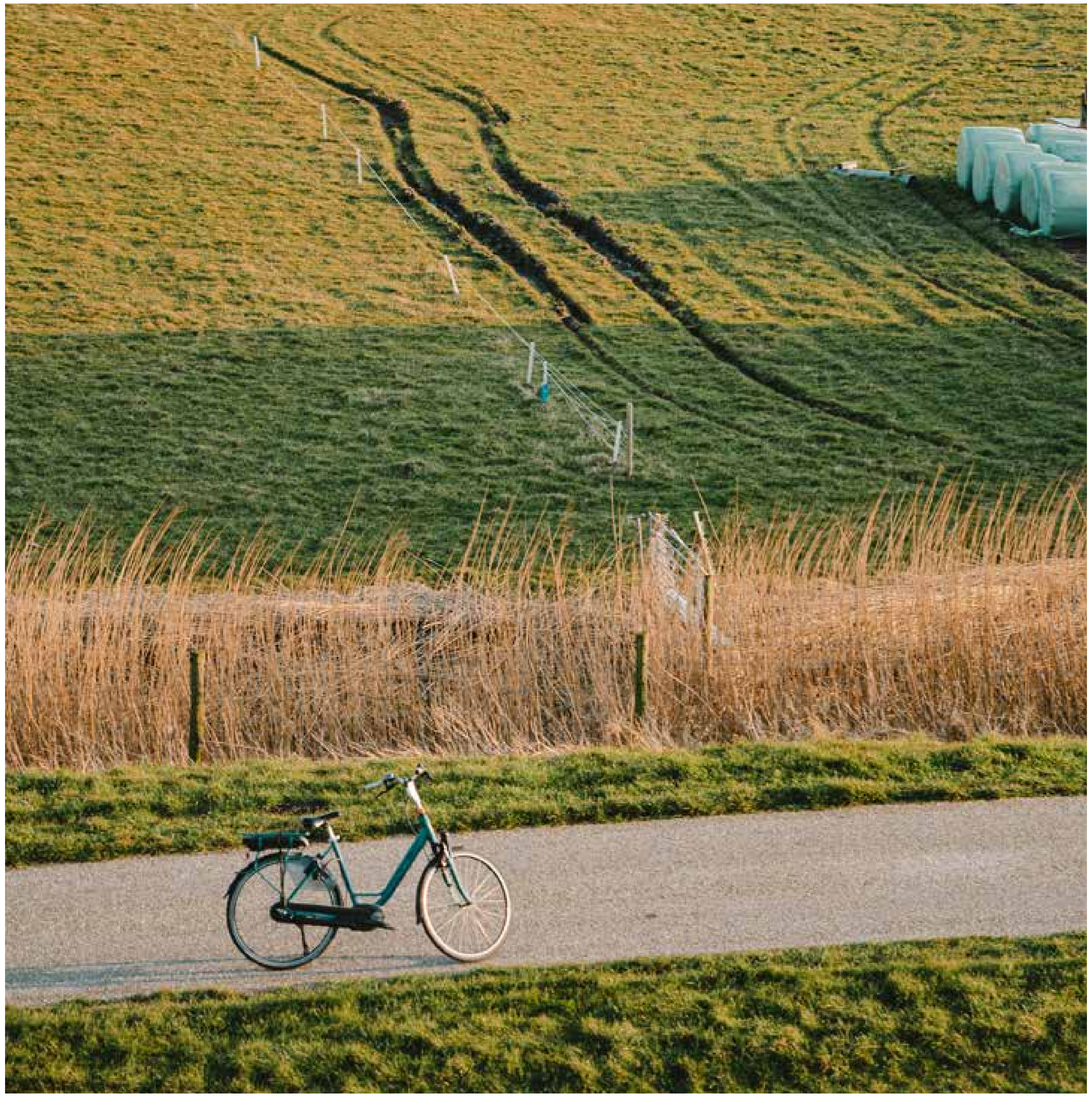
Contents

Forward



Site Visit.
Photo: Heather Wong, 2022.

The Need for Strange(rs) Eyes on Fryslân

New Perspectives

Stephan Smeijers | Province of Fryslân

The province of Fryslân is a beautiful place. Struggling with the threat of the sea and coping with the challenges of water and soil, the people of Fryslân have built their magnificent landscape throughout the ages—a landscape with unique values but also one that faces many challenges in the (near) future. In this dynamic environment, developing future perspectives for Fryslân is necessary to cope with these changes and do justice to the existing values of the landscape. The design results of the TU Delft students show these fresh and exciting perspectives, as well as the value of looking with *strange(rs) eyes*.

In the Wadden region, the balance between nature and man has been a constant factor over time. At the beginning of settlement, nature—in terms of the sea—was dominant, and people slightly adapted their living to unpredictable circumstances. They first did this by building terps (higher hills to live on), but later on, they adapted by developing an ingenious network of dikes to keep the sea out. Gradually, man took over nature and became dominant over the landscape. New land was reclaimed, and ingenious water systems were developed to control the forces of nature, sea, and water.

With this power to develop our environment, we gradually lost our connection with nature and the landscape. Our agricultural sector is the most productive in the world. Our cows are top milk producers, and our seed potatoes are well-known worldwide. We can control and manage the ideal circumstances for this kind of land use; however, we have in fact lost control. Peat is vanishing in the lower parts of Fryslân due to low water levels. Salt groundwater from the Wadden Sea slowly moves toward our freshwater reservoirs in the deeper soil layers. On the other side of Fryslân, the higher sandy soils are becoming increasingly dry, and nature is deteriorating.

With climate change—which will bring higher sea levels, as well as more arid and wet periods—in mind, we must rethink our strategy. We must reconsider our technical-based solutions and move toward more landscape- and system-based ones. If we do so, we have a perspective to restore the balance between nature and man. To create such a perspective, the design power of the younger generation is essential. But what can we do to make our landscape acceptable and future-proof?

First, we must understand the system of landscape formation. Restoring the balance does not mean that we have to go back in time. The landscape is continuously changing and will always do so. If we understand the forces of landscape—i.e. the natural elements (water, soil) and the human elements (networks, occupation)—we can build on these fundamentals. Not to dominate the landscape but to act more in balance with the natural elements. Or, as some people say, we must move from an Anthropocene to a Bioscene society.

The second element we must manage is a thoroughly integrated approach. Due to the complexity of our future challenges, experts from all disciplines are needed and must work together. This will lead the way to new and surprising solutions, as well as multi-functional and space-saving compromises.

The last—but likely the most crucial—element is creating images and designing solutions. In our visually oriented world, we must make the changes visible. For the Wadden region of Fryslân, it is clear that the landscape will change. But what will these changes look like? What will the future perspectives of the inhabitants be? If we can create attractive perspectives and communicate them with the local people, it is more likely that these changes will be accepted.

Sometimes, a stranger must show you your blessings; sometimes, *strange(rs) eyes* can offer new perspectives. In this context, the variety of foreign students at TU Delft has been a blessing. It is pleasant and valuable for the Wadden region to take note of the students' results, step back, and observe a fresh approach to our fascinating landscape.

The Wadden Sea coast.
Photo: Heather Wong, 2022.

Introduction

Sea dike.
Photo: Heather Wong, 2022.

1 | Fluid Soils

(Co)Designing the Future of the Wadden Sea Landscapes

Laura Cipriani | TU Delft

The relationship between soil and water is at the center of interest now more than ever. Like many other littoral areas around the globe, such as lagoons, wetlands, islands, and their inland areas, the Wadden Sea territories struggle between two opposing forces: permanence and transformation. The war between man and nature is waged on various fronts (i.e. geo-morphological, climatic, ecological-environmental, architectural, and landscape) and in urban settlements.
Despite being a UNESCO World Heritage Site of extraordinary environmental value and beauty, the Wadden Sea, its territories, and its people now face an uncertain future while wrestling with latent climatic, economic-productive, and social crises. Subsidence increased by gas extraction and peat oxidation, soil erosion, saltwater intrusion, eutrophication, and agricultural water pollution testify to a territory in the throes of long-term repossession by the sea. Unlike large coastal conurbations, these areas are marginal territories with low levels of urbanization that are characterized by crises and territorial fragility. Notably, these are predominantly rural regions where the countryside becomes the frame within which cities are located. Lands reclaimed from the sea over the centuries now require the radical transformation of agricultural practices and an urgent response to climate change.

Discussing the Wadden Sea landscapes means talking about *soil* and *water*. Better yet, we could even try to mint the binomial *fluid soils* to describe this land. The word *wad* is a Frisian and Dutch term that means 'mud flat.' From its etymological root, this intertidal land, which embraces the countries of the Netherlands, Germany, and Denmark, is described as tidal flats, gullies, and salt marshes that have always characterized these places. Which are halfway between land and water.
The coastal lagoon is a dynamic natural ecosystem shaped over the centuries by natural phenomena and ongoing anthropic interventions. Studying geological structure shows us how the Wadden Sea as we know it today most likely took shape 8,000 years ago. The last three glacial periods and their interglacial phases led to a landscape that evolved from large tidal flats into islands of dunes, sand banks, and salt marshes (Vos and Knol, 2015). Around 2,000 BC,

the deceleration of sea level rise allowed salt marshes to expand seaward and coastal peat bogs to increase in size (Vos and Knol, 2015). Between 500 BC and 1500 AD, inland wetlands subsided, reducing the peat landscape, and clay soils were deposited on the coast, leading to further subsidence inland (Vos and Knol, 2015). Starting from the Middle Ages and in the centuries that followed, human actions modified the original geological configuration. For example, the reclamation of the territory with the construction of dams and the closure of the Zuiderzee and the Lauwersezee changed the coastal structure and formed the coastline as we know it today.
Therefore, the soil of the Wadden lands is a complex system of *sand*, *peat*, and *clay* that have been deposited over time. The soil structure of Friesland and Groningen corresponds to that of the sea due to them sharing the same geomorphological characteristics. The belt of marine clay soil extends along the Wadden coastline and lies much higher than the yielded Wadden hinterland. Sand is encountered on the barrier islands and inland areas. Despite their decline over the last century, the peats are located after the coastal clay soil, which provides solid evidence of their geological evolution.

This soil-water fluidity is a geomorphological characteristic that has extended to urban settlements for centuries. To protect from the recurrent floods, starting from 300 BC until around the 10th century AD, the local populations created the first terps—artificial dwelling mounds upon which raised villages were built (Schroor et al, 2017). Instead of interrupting the sea flow with dam construction, the first settlements adapted to the water action by transforming into raised islands during the tidal period. However, with the arrival of the first dams around the 13th century and the subsequent reclamation of salt marshes for agricultural purposes, the villages and their surrounding landscapes suddenly lost their relationships with the sea. Thus, the adaptive dynamism at the basis of the continuous exchange between soil and water was interrupted forever.

Today, the evidence and data collected indicate that the Wadden Sea, like many other coastal areas of the planet, will be one of the places affected by climate change. Referring to studies by the Intergovernmental Panel on Climate Change (IPCC 2014, IPCC 2022) and assuming, for example, an increase in temperature of 1.5 °C, maps indicate that the coastline will consistently retreat. Sea level rise scenarios related to elevations and topographies (see figure page 59) make us question the existence of these landscapes in 2070 and 2100. Eustatism, salinization, and soil subsidence are all phenomena that make us reconsider how much longer these territories will be protected by water. Even more worrying is understanding what measures to implement when water is scarce and how the 'great thirst' can also bring landscapes and economies to their knees.
If the landscape transformations occurring by 2030, 2050, or 2100 are known, the medium-term project scenarios and the decisions underlying these choices are less known. What plans and interventions exist for retreat, adaptation, and resistance? What will happen if we plan interventions for the future now and then implement them? What will happen instead if we start implementing interventions only after some catastrophic events? Will we still have sufficient time to fix the issues? Will we rely on emergency proposals or reasoned choices? Which lands will we preserve? How will we accept or reject the water that will come?

Discussing soils and water also means opening possibilities for tackling climate change. Soils, particularly moist soils, constitute a promising solution to the climate crisis, playing a crucial role in the carbon cycle by absorbing and releasing carbon dioxide. After the ocean, the soil is the most critical carbon deposit. If this is combined with water, the fluid soil of wetland areas or peatlands can absorb carbon in quantities that are much higher than a forest can absorb.
Therefore, the challenge is to intervene along coastlines and within the internal soil areas of the territories. Here, soil and water also serve central roles not only in climate change mitigation but also in the rethinking of entire economies and supply chains linked to the agricultural world. Monoculture practices, water pollution due to pesticides, and the lack of biodiversity in agricultural spaces have exacerbated the climate crisis and made a paradigm shift necessary. In the summer of 2022, the Dutch government provided measures for reducing nitrogen emissions in the provinces of Friesland and Groningen, including restoring peatlands to the detriment of spaces dedicated to agriculture. This top-down approach, which was adopted without the necessary participation processes with the local population, has sparked protests among farmers and fomented political uncertainty.
Can we (co)design the Wadden Sea landscapes instead? How can we transform this crisis into an opportunity? As designers and educators, can we sow hope through the project in its various scales of intervention, from the regional to the most minute? Based upon applied research work in regional scenario-making and local design projects, we attempted to imagine the present and future of the Wadden Sea and its hinterland. The projects developed during the laboratory originated from the belief that the landscape is not only an environmental resource but that it can also become an economic resource—an essential driving force for alternative development and the transition of the territory, its cities,

Mudflat along the Wadden Coast.
Photo: Heather Wong, 2022.

and its people.
Through accurate and concrete plans, we attempt to give life to renewed economies aimed at proposing ideas to close environmental and economic cycles. Starting from the project, the intention is to promote tiny seeds of hope to trigger change. Peatlands, agriculture, energy, and heritage all intersect to encourage economies and social inclusion projects where the landscapes of soil and water become the driving force to overcome the crises.

Book Structure
This publication is the fruit of the Graduation Studio *Water Landscapes of Crisis and Hope* I guided and held during the 2021-22 and 2022-23 academic years at TU Delft, Section of Landscape Architecture with the precious help of colleagues coming from hydraulic engineering, marine ecology, spatial planning, and urban design and in collaboration with multiple local stakeholders such as the Province of Fryslân and Wetterskip Fryslân, the Friesland water authority.

The first part of the work—'Atlas of Knowledge'—intends to investigate the territories of the Wadden Sea through the development of territorial maps that range from their historical development to current issues: from the geological system of the soil to the water systems, from agriculture to ecological networks, from terrestrial and marine environmental systems to energy networks, from the historical remains of raised villages (terps) to the urban fabric and infrastructure systems of cities. The presented maps constitute a critical operation of data and cartography collections and interpretations from different sources.
What emerges is that the Wadden Sea territory is partly the product of a lengthy geological process of interchange between sediments and water and a relatively recent anthropic process of defense and reclamation when the land is reclaimed from the sea. It is a territory that has long been dominated by a dynamic interchange between land, sea, and sediments, which, starting from the 13th century with the construction of the first dams, transformed into a static landscape due to man's hydraulic defense works. Historical maps have represented a fundamental step in imagining the future territory since many of these lands, today below hygrometric zero, could be reconquered by water in the future.
Beyond the rich remains of the villages built on the mounds, the present territory presents significant challenges: rising sea levels, soil salinization, subsidence due to gas extraction and drainage practices lowering the water table, sediment dredging, and dumping. These factors have modified the natural dynamic processes of coastal morphology and ecosystems, the urbanization of marine-based energy infrastructure, and the coming and going of ships, which threatens one of the most delicate ecological ecosystems—the agricultural industry—with its internal water pollution and indifference to ecological networks.

The second part of the work—'Atlas of Ideas'—is the product of a work initially shared by the entire design studio class aimed at producing—thanks to a series of participatory techniques—shared scenarios and projects over the short, medium, and long terms.
The adopted approach is focused on design as a research method by addressing global-scale challenges through regional-, local-, and small-scale interventions. Territories and cities affected by several climatic, environmental, and economic crises require a holistic approach: from ecological design to resilient planning, from the water management of extreme events to water quality issues and sea intrusion phenomena, and rural-urban landscapes to cultural landscapes and related economic-productive systems.
The design studio included several participatory phases involving the students and some institutional and non-institutional stakeholders to exchange knowledge and ideas. The workshop, entitled *Wet Sand. Wet Mud. Wet Land*, included a co-design session with the Province of Friesland, Wetteskip Frysland, and experts from multiple interdisciplinary fields. The working group highlighted effective short- and medium-term solutions whose effects could be extended to a long-term time horizon. Looking to the future is necessary to guarantee possibilities that make the territory productive, even in the short term.
All of the proposed plans are based on simple elements and aim to redevelop the landscape by strengthening existing micro-economies or establishing latent economies that can become seeds of potential development. Each project starts mainly from the site specificities of the territory to embrace possible futures and design possibilities.

Following the research and project phases, the work was presented at a symposium and exhibition in Leeuwarden to propose small steps of collective action to narrate and promote the territory, its specificities, its crises, and the possibilities for change. The event, *Embracing the Future of the Wadden Sea Landscapes: Voices and Imageries from Students and Educators*, aimed to propose a moment of reflection and exchange between landscape architecture schools, institutions, and associations. How do young generations and educators envision the future of the Wadden Sea territories? How will these landscapes be modified in the years to come? How do we embrace the past and present and imagine the future? The event focused on landscape design as a catalyst for change. Students and educators

Saltmarsh, Friesland.
Photo: Xinjian Jiang, 2022.

presented design results and ideas on the future of the Wadden Sea coasts and landscapes, from the sea to the beach to the rural and urban inland areas.
The hope is to focus on the future of these places, on *fluid soils* and their ecological and climatic transitions, without forgetting how the hope for change starts constructing a *landscape thinking* in the minds of younger generations. Collective work is a way to encourage the construction of transdisciplinary education to tackle today's unprecedented uncertainties and challenges. As in a geological process, I hope that changes to existing practices will take root in the minds and actions of these future professionals. As American soil scientist Charles Kellog once said: '*Nature has endowed the earth with glorious wonders and vast resources that man may use for his own ends. Regardless of our tastes or our way of living, there are none that present more variations to tax our imagination than the soil, and certainly none so important to our ancestors, to ourselves, and to our children*' (Kellog, 1941).

Rescue house in Terschelling.
Photo: Bas van Breukelen, 2020.

2 | A Vision for the Fryslân Future

Managing Water and Soil

Joca Jansen | Wetterskip Fryslân

Fryslân is a water-rich province containing many lakes and canals. It has a system of interconnected lakes and canals known as the Frisian Boezem. The Frisian Boezem serves essential functions for water drainage, supply, and temporary storage. Nearly all of the higher-lying stream valleys in the southeast and the lower-lying polders in Fryslân depend on the Frisian Boezem for the supply and drainage of water.

Water management has improved over the years. Before the construction of the Hoogland pumping station in Stavoren, large parts of the province remained underwater every year due to insufficient drainage capacity. Due to the introduction of technical measures to drain water (e.g., pumping stations and weirs), the potential for inundation has become increasingly small. The system has been designed to drain excess water as quickly as possible, and the natural dynamics have disappeared. This has resulted in the area being laid out in great detail, with more than 8,000 areas with their own water levels, approximately 1,000 pumping stations, and approximately 5,800 weirs to regulate water management. Due to the rapid drainage of the precipitation surplus in winter, Fryslân depends on the supply of fresh water from the Ijsselmeer in the summer to maintain water levels and limit drought damage to agriculture and nature.

Fryslân can roughly be divided into three areas based on the soil type: sand, peat, and clay (see image on page 74). Nearly all of the sandy soils are located in areas higher than the Frisian Boezem. Since water drainage has increasingly improved—and due to the lowering of the water level—agriculture is possible in almost every location. The groundwater levels have dropped considerably here, resulting in the large-scale desiccation of natural areas. During the summer period, both nature and agriculture suffer from drought.

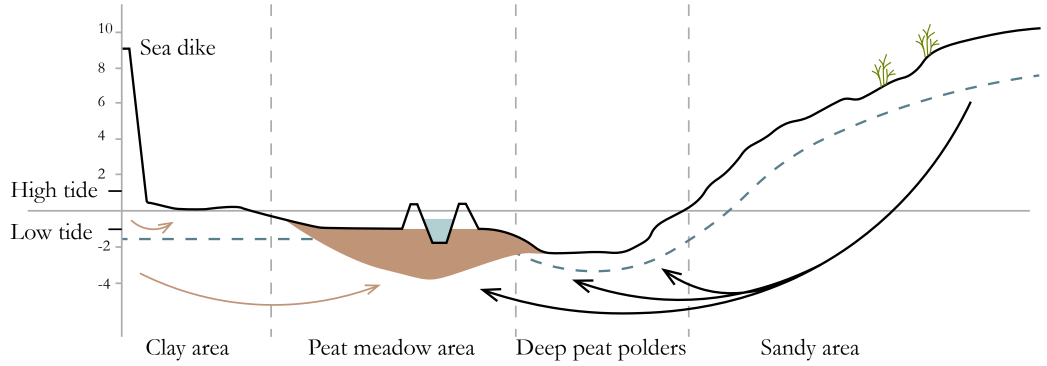
The marine clay soils are located in a broad zone along the Wadden coast. These areas are lower than the Frisian basin and depend on pumping stations for water drainage. Due to the rapid drainage of excess rainwater, these areas also depend on the supply of fresh water via the Frisian Boezem during dry periods. The clay areas along the coast are also affected by salinization. This is because a lot of salty groundwater remains present here from the time when the clay area was still a Wadden area, but also because the average sea level is higher than the polder water levels, which means that salt water can flow upwards.

The peat area covers approximately 25% of the surface of Fryslân. Water management has also been significantly intensified in these areas to enable intensive agriculture (dairy farming). These areas have very detailed water management with many weirs and pumping stations. Due to the low water levels, peat oxidation occurs, causing the ground level to lie increasingly lower. As a result, greater efforts are required to protect the area against flooding.

Until recently, the problems were viewed per area, and solutions were sought per sub-area. This ignores the fact that interactions exist between different areas. Notably, a groundwater study (Vermulst and van der Linde, 2019) was conducted in 2019, which included the entire Frisian water system. This study showed that the sandy area loses a lot of groundwater to the peat areas and that Fryslân also receives saline groundwater from the Wadden Sea. The figure below presents the relationship between the various areas in a simple cross-section (note that the y-axis is to scale). This section shows that Fryslân is a kind of 'soup plate' with a low center and a higher edge. The sandy soils are higher and lose water to the low center. This flow is currently limited by the presence of poorly permeable peat in a large part of the peat area. Only in the so-called deep peat polders along the border with the sandy area has most of the peat disappeared due to peat extraction. In these areas, a great deal of fresh groundwater flows to the surface water and is then pumped away using pumping stations.
Water also flows from the Wadden Sea to the low center, causing the saline groundwater to slowly move further inland. Since the low center receives much water, a large volume of water must be pumped out of this area. This water is then discharged to the sea via the Frisian Boezem.

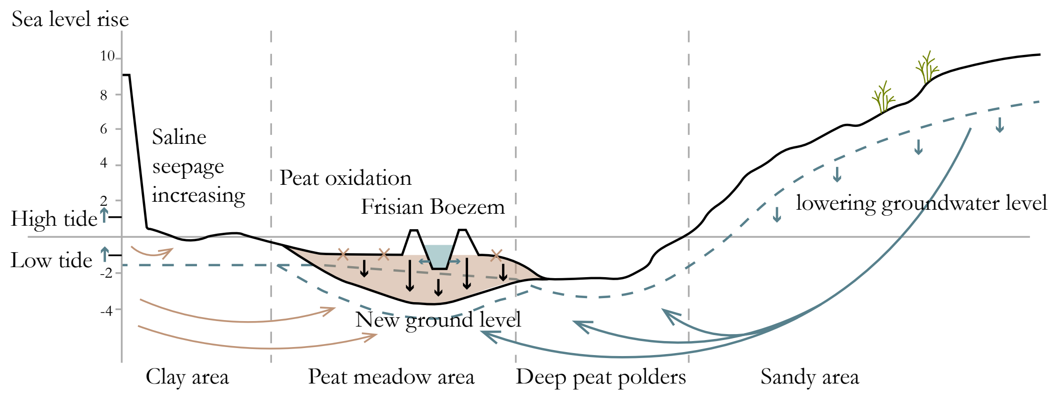
The top right image on the next page shows that the peat meadow area (orange) significantly influences the functioning of the entire Frisian water system. This influence will increase if the current management of the area is continued (see bottom-right image, next page). Peat oxidation causes the ground level to drop, which means that the water levels must be lowered to maintain the current use. This process continues until the peat has completely disappeared and a low-lying sandy area remains. The influx of fresh groundwater from the sandy area

Current Situation



Simple cross-section of the current situation in Fryslân with the main groundwater flows (red arrows are saltwater and blue arrows are freshwater).
Source: Wetterskip Fryslân, Provincie Fryslân, 2023. Image: Zhaolei Li, 2023.

Future Situation



A simple cross-section of the future situation if current water management is continued in Fryslân. Eventually, all the peat will disappear, increasing the salt and fresh groundwater influx to the peat area.
Source: Wetterskip Fryslân en Provincie Fryslân, 2023. Image: Zhaolei Li, 2023.

and the Wadden Sea is increasing due to the lower water levels in the low center. This process is further exacerbated by the fact that peat oxidation causes the poorly permeable peat layer to disappear. This allows the fresh and salt water to easily flow down to the low center. These developments make it increasingly expensive and challenging to maintain the water system.

To achieve a future-proof system in Fryslân, it is very important that peat oxidation is stopped so that the ground level does not sink further. This can only be done by raising the water levels in the area until the peat is nearly underwater. This has significant consequences for current functions, such as agriculture and housing. Fryslân has many areas where only a thin layer of peat remains. Thus, action must be taken for these areas over the short term to prevent the peat from disappearing altogether.

To make Fryslân less dependent on Ijsselmeer water in the future, efforts must be made for the entire area to retain and less quickly discharge the area's own water. This is especially important for sandy soils because only limited Ijsselmeer water can be supplied here. This means that large-scale efforts must be made to retain rainwater on sandy soils so that more rainwater can reach the groundwater. One groundwater study (Wetterskip Friesland, Province of Friesland, 2023) showed that only 15% of the precipitation reaches the deep groundwater. Although raising the groundwater levels in sandy areas will decrease drought damage to agricultural and natural areas, the wet damage to agriculture will increase in the lowest parts. As groundwater levels rise, the peak discharges from streams decrease in the winter, yet the flow to streams remains greater in the summer. Many streams now depend on Ijsselmeer water in the summer to artificially maintain the flow and prevent parts of the stream from drying up. To limit stream discharges, the flow profile of the stream must be reduced and weirs replaced by meanders. In times of high discharge, the stream must be allowed to overflow its banks again. This means that in the stream valleys, areas are becoming less suitable for existing intensive agriculture.

To cultivate arable farming in the clay area, it is important to prevent salinization in the plots as much—and for as long as—possible. This can mainly be done by providing counter pressure against the seepage flow due to higher water levels, but also by deliberately retaining rainwater in the plots so that a freshwater lens is created. Due to the higher water levels, more space is required for water storage to prevent flooding.

The soil subsidence in the peat area, climate change, and sea level rise mean that the current technical water management, which is fully geared to water drainage, is not sustainable in the future. Therefore, we must focus on retaining fresh water and preventing further ground-level subsidence due to peat oxidation. While this will have a significant impact on current land use, continuing in the current manner has a much more significant impact on current land use.

Atlas of Knowledge

3 | Atlas of Knowledge

Exploring the Landscape

Laura Cipriani | TU Delft

The first part of the work—'Atlas of Knowledge'—intends to investigate the territories of the Wadden Sea through the development of territorial maps that range from their historical development to current issues: from the geological system of the soil to the water systems, from agriculture to ecological networks, from terrestrial and marine environmental systems to energy networks, from the historical remains of raised villages (terps) to the urban fabric and infrastructure systems of cities. The presented maps constitute a critical operation of data and cartography collections and interpretations from different sources.

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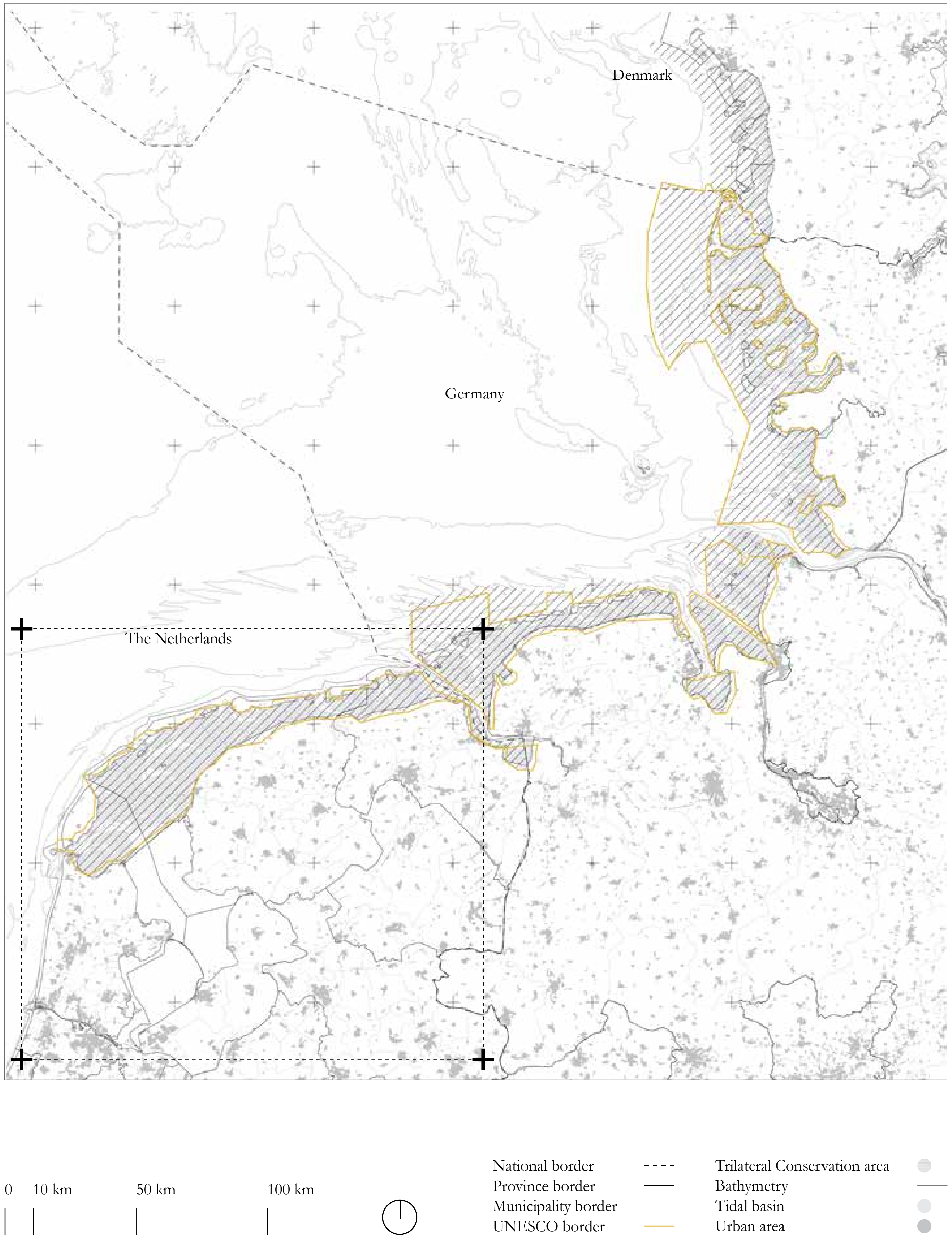
The authors of the images and texts from page 36 to page 110 are the following students: Anna Gorokhova, Xinjian Jiang, Zhaolei Li, Hanneke Wander, and Heather Wong. Texts and images were revised and edited by Laura Cipriani.

Administration and Protection Borders

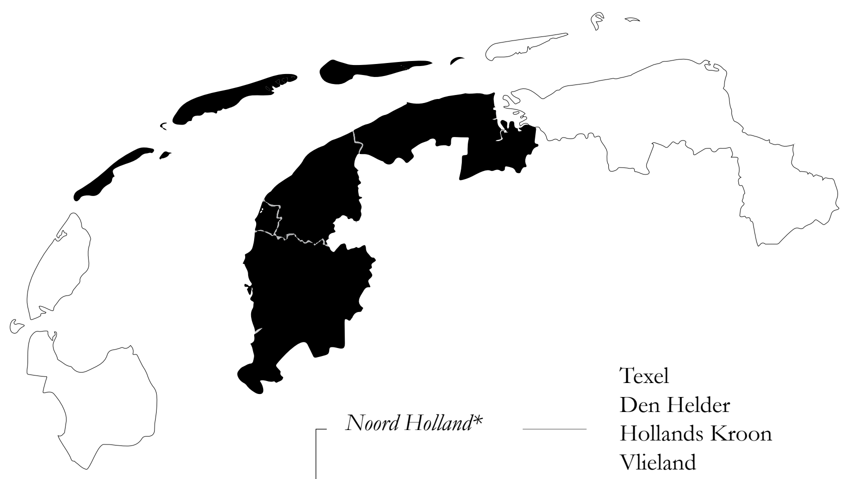
Data: General Bathymetric Chart of the Oceans, 2021.
Image: Heather Wong, 2022.

The Wadden Sea is over 500 km long, has a width of 20 km, and stretches over three countries: the Netherlands, Germany, and Denmark. The continuous tidal system of the Wadden Sea has 39 tidal basins, whose intricate interactions facilitate a multitude of habitats.



Provinces and Dutch Stakeholders

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 water boards to manage the entire 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 the mainland of the Wadden Sea Region. They ensure that the sea-retaining dikes and the retaining sandy coastline 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.
More recently, in 2019, the Wadden Sea Management Authority (Beheerautoriteit Waddenzee) was established to enhance cooperation and mutual consultation among the various authorities involved in managing the Wadden Sea (Lamboy, Venis and Stokkermans, 2019).



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)

Old sea dikes.
Photo: Heather Wong, 2022.

Territorial Site Model and Sea Bathymetry

Data: General Bathymetric Chart of the Oceans, 2021.
Photo: Keyan Tang, 2021.

This model of the Dutch, German, and Danish Wadden Sea is entitled *Altitudes of Flatness*. It conveys the Wadden Sea's unbroken natural system in relation to elevations and juristic boundaries. The vertical scale is intentionally exaggerated to emphasize bathymetries, topographies, and micro-topographies.

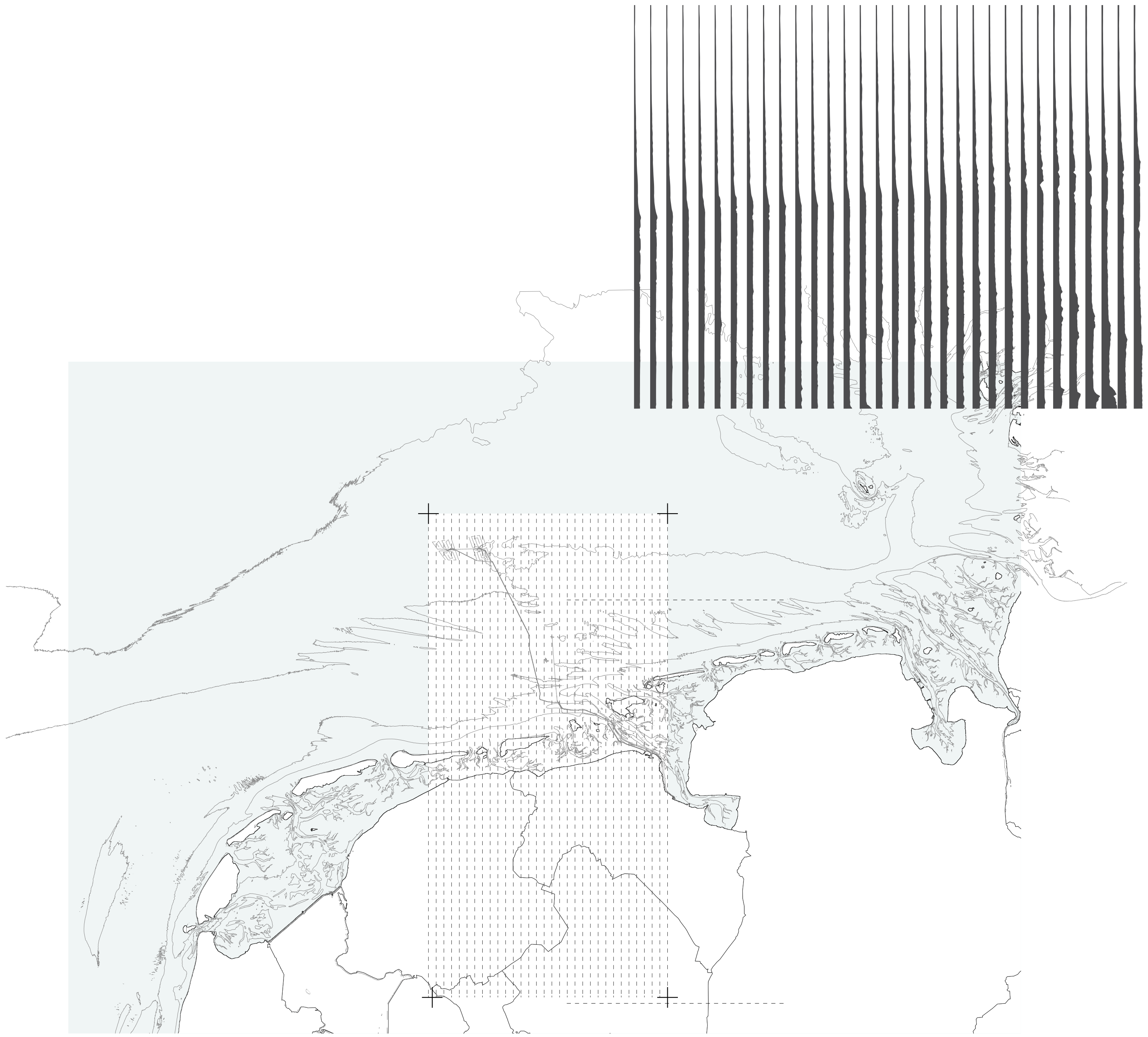
Students: Keyan Tang, Hanneke Wander, Madelief Dekker, Wong Yin Wah, Suihui Kuo.
Docent: Laura Cipriani

The Altitudes of Flatness, Thinking with Sections and Models Course, Year 2020-21.
Horizontal scale (x) 1:750.000. Vertical scale (y) 1:7500. Model size 500 x 500 mm.

Territorial Sea Bathymetry and Sections

Data: General Bathymetric Chart of the Oceans, 2021.
Image: Xinjian Jiang, 2023.

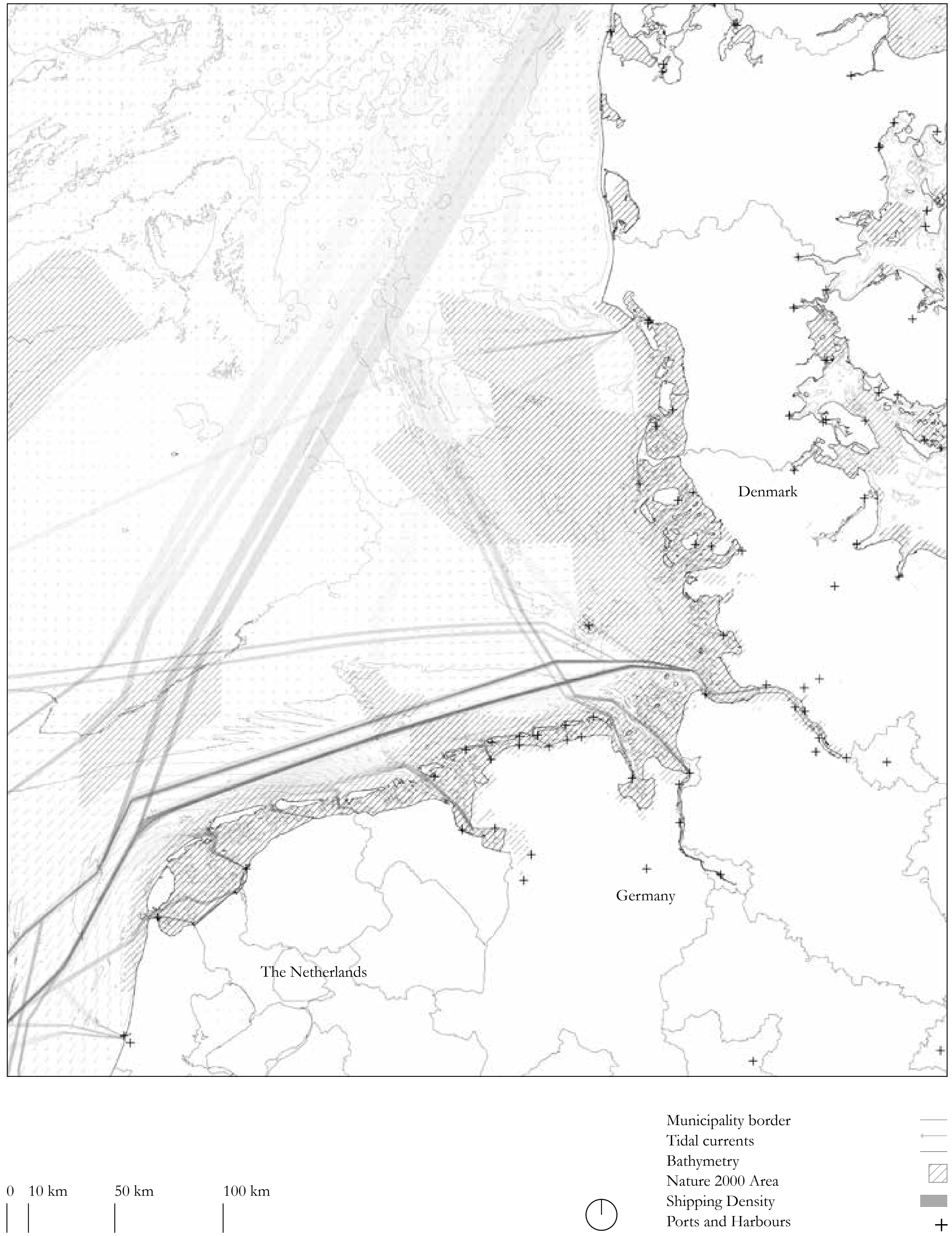
Territorial sea bathymetries and sections of the Wadden Sea show the topographical relationships between the sea, land, and islands.



Shipping, Infrastructures and Nature Area

Data: The European Marine Observation and Data Network, 2022.
Image: Xinjian Jiang, 2023.

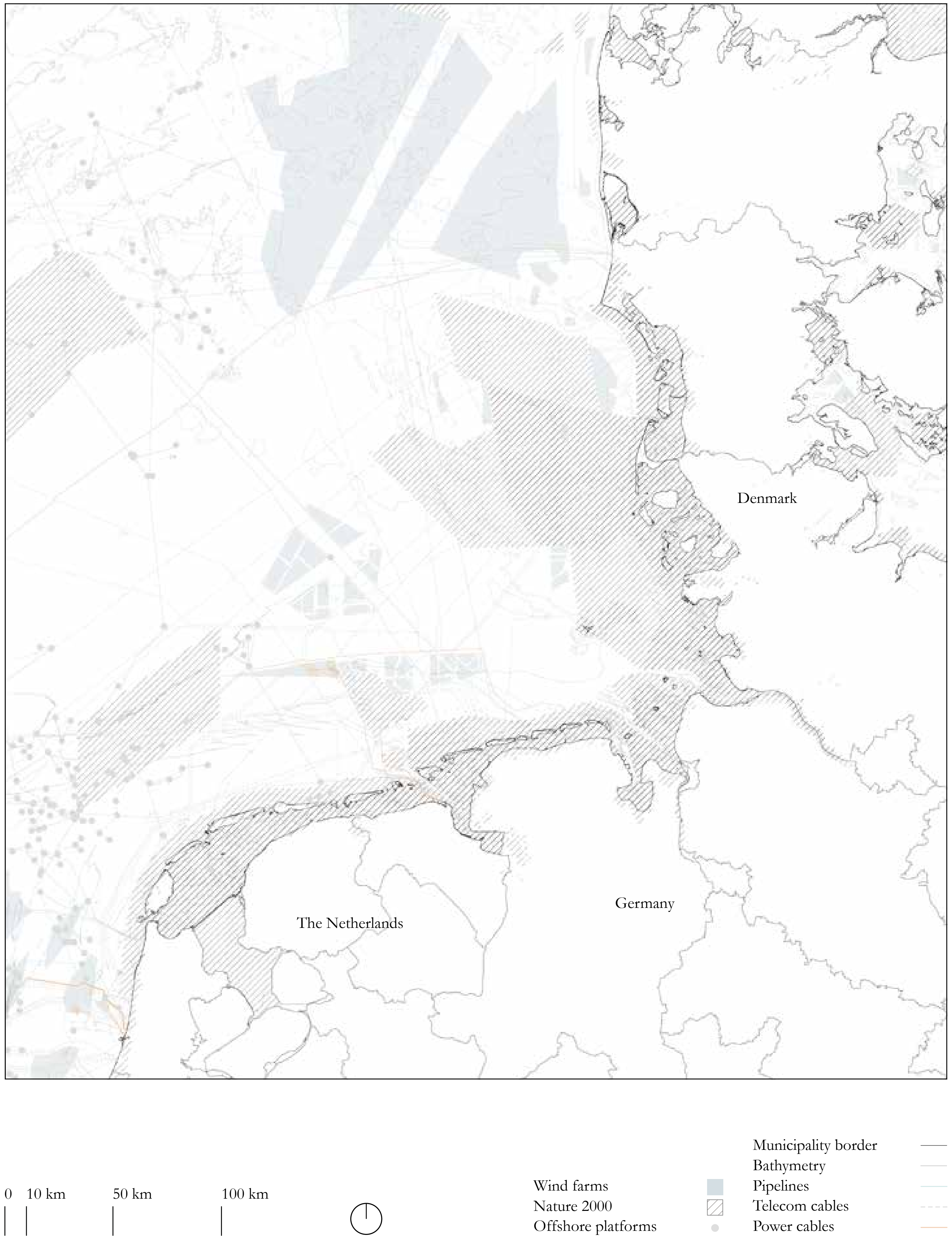
This map represents shipping routes and infrastructure in relation to—and in contrast to—the Nature 2000 areas. The Wadden Sea is near some of the busiest shipping routes of the North Sea. The area is home to some of Northern Europe's most important ports, including Hamburg, Bremen-Bremerhaven, Wilhelmshaven, Esbjerg, and Delfzijl, which hold significant economic importance both regionally and internationally. Additionally, the ports provide a connection to the Baltic Sea via the Kiel channel, which connects to ports worldwide. Offshore wind parks are now being installed in the area seaward of the Wadden Sea, leading to increased ship traffic for maintenance purposes.
Due to the region's vulnerability and ecological significance, it was declared a Particularly Sensitive Sea Area (PSSA) in 1994. This designation allows the states adjacent to it to implement measures to provide improved protection against marine pollution. The area also benefits from stronger shipping laws and initiatives such as BE-AWARE, which aim to reduce the risk of marine pollution in the broader region.



Turbines.
Photo: Irfan Alijagic, 2018.

Energy Infrastructure and Nature
Data: The European Marine Observation and Data Network, 2022.
Image: Xinjian Jiang, 2023.

This map represents energy infrastructure in relation to—and in contrast to—the Nature 2000 areas. Wind farms, offshore platforms, pipelines, telecom, and power cables traverse the Wadden Sea and its protected areas.



Wind Energy

Images: Xinjian Jiang, 2023.

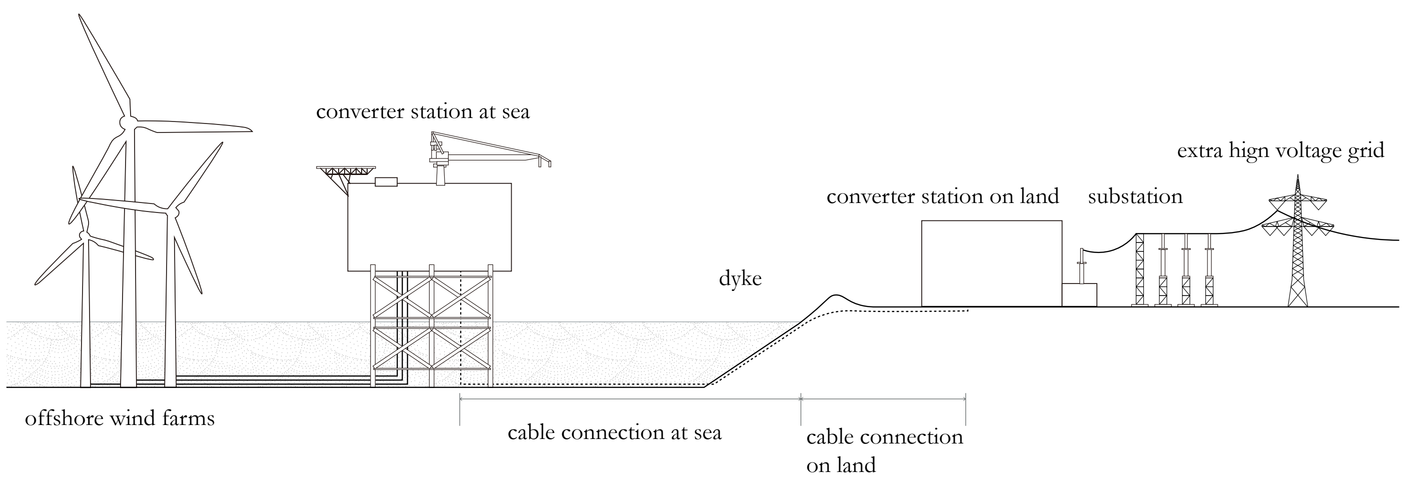
Onshore and offshore wind farms positively and negatively impact nature and the seabed.

Positive Impacts
Offshore wind farms contribute to reducing greenhouse gas emissions by generating clean, renewable electricity, thus mitigating climate change impacts.
Artificial reefs formed by wind turbine foundations can create habitats for marine life. These structures can attract fish and other marine species, effectively acting as artificial reefs.
Offshore wind farms can stimulate local economies through job creation, investment, and revenue generation for coastal communities.

Negative Impacts
Construction activities, such as pile driving and cable laying, can disrupt marine habitats and ecosystems. Noise pollution from construction and operation can also impact marine life, including marine mammals and fish. There is also a risk of collision between marine animals (e.g., birds, marine mammals, fish) and wind turbine structures, especially during migration or feeding.
Furthermore, installing turbine foundations and cables can cause physical disturbance to the seabed, potentially affecting benthic communities and habitats and the electromagnetic fields generated by underwater cables can disrupt the behavior and migration patterns of certain marine species, such as sharks and rays.
Finally, the presence of large wind farms can potentially alter local ocean currents and sediment transport patterns, which may have downstream effects on coastal erosion and sedimentation.

Wind Farms in the Wadden Sea
Currently, the Wadden Sea Plan states that '*the increasing energy production in the Wadden Sea Region, both onshore and offshore, will have several side-effects, such as increasing ship traffic in the coastal sea and cable crossing through the conservation area. Air pollution may increase, as well as interference with bird flyways. The increasing ship traffic in general results in increased dredging and harbor extension*' (Common Wadden Sea Secretariat, 2010).

Offshore Wind Farm

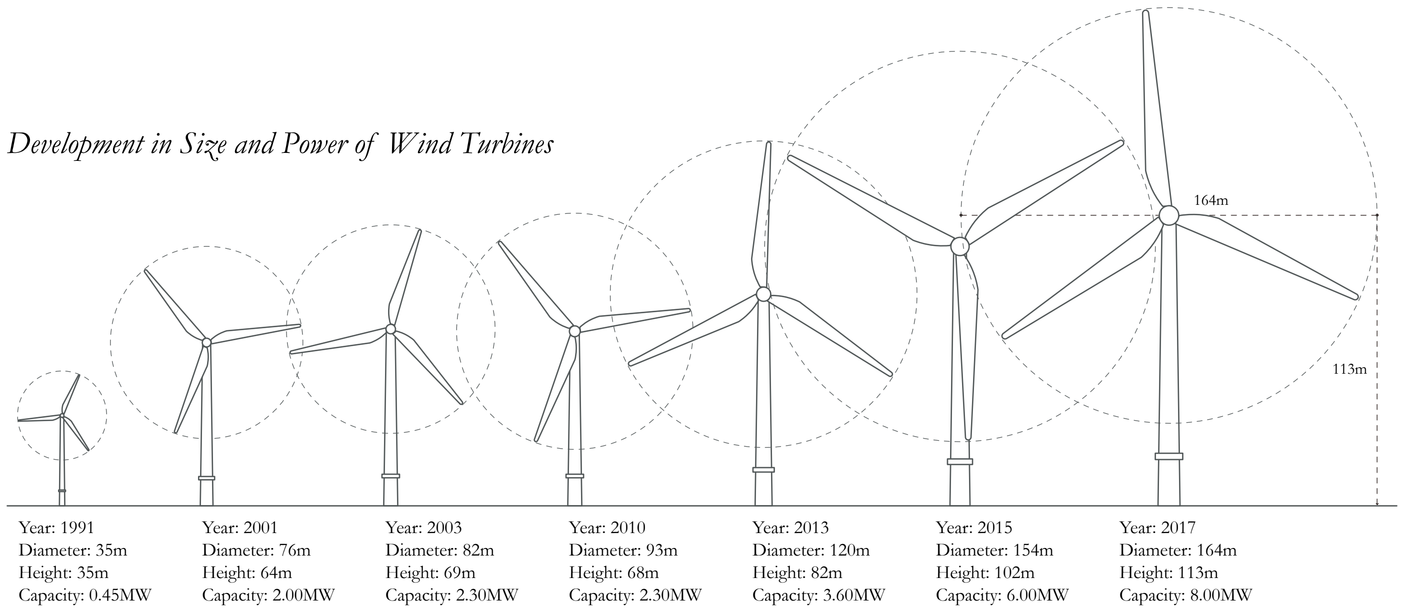


Impacts of Energy Infrastructure

Impact	*Activities causing the impact*	*Construction-related*	*Operation*	*Plant-related*
Underwater noise	wind energy	X	X	
Reef effect	wind energy, gas and oil			X
Physical disturbance of the seafloor	cables and pipelines	X		
Turbidity and Sedimentation	cables and pipelines	X		
Sealing/ habitat loss	wind energy, gas and oil	X	X	X
Heat dissipation	cables and pipelines		X	
Electromagnetic fields	cables		X	
Spills	oil, ships, pipelines		X	
Ground surface subsidence	gas		X	
Collision	wind energy, gas and oil	X	X	X
Scaring	wind energy, gas and oil, ships	X	X	X
Pollution	wind energy, gas and oil, ships	X	X	

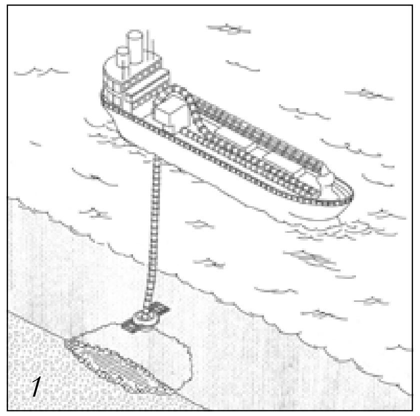
Table 1. Overview about possible impacts of renewable and fossil energy infrastructure, which might affect the Wadden Sea area during the construction and operation phase and plant-related (indicated with X).

Development in Size and Power of Wind Turbines

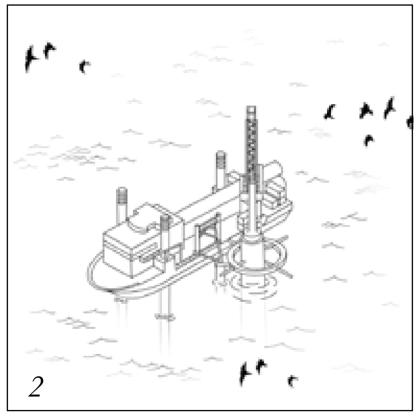


Wind Turbine Installation Steps

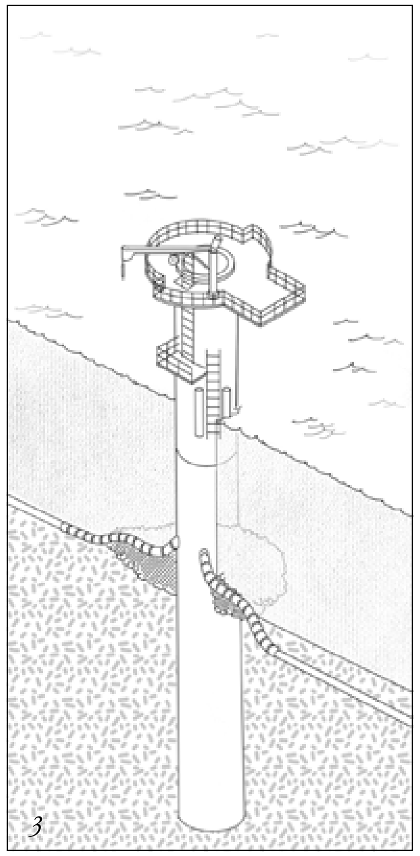
Data: The Gemini Offshore Wind Park, 2017.
Images: Xinjian Jiang, 2023.



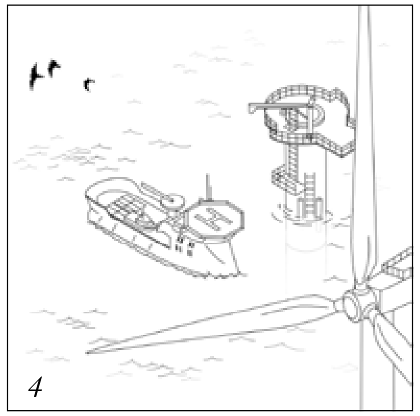
Protection material is deposited by a flexible fallpipe vessel onto the seabed before each monopile is installed.



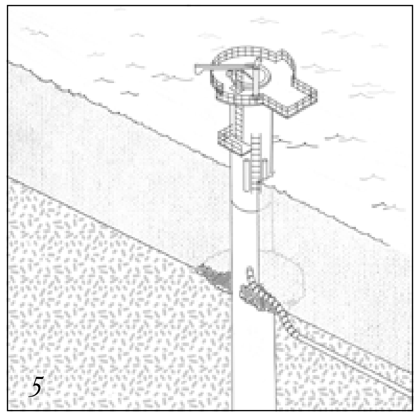
An offshore installation vessel is used to transport and install the monopile.



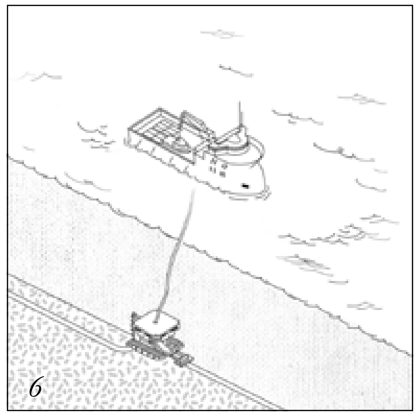
Monopile installation
The monopile is installed.



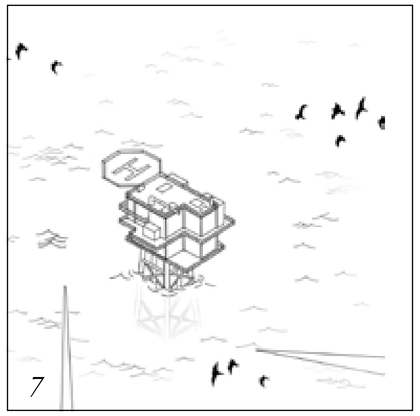
Transition piece installation
The transition piece is installed.



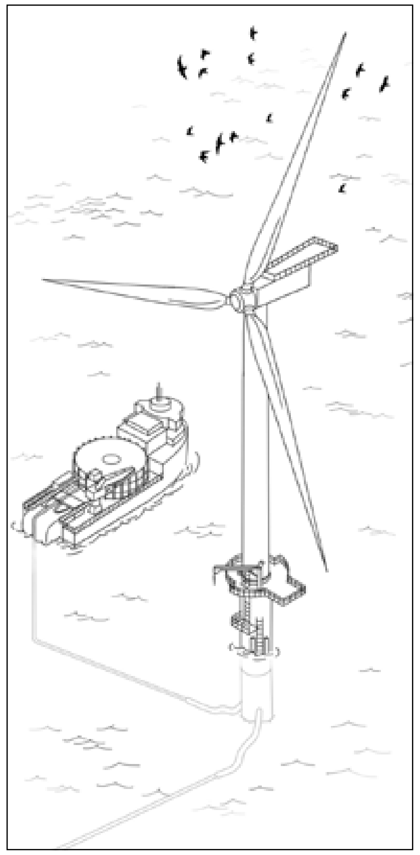
The electrical interconnection cable is laid.



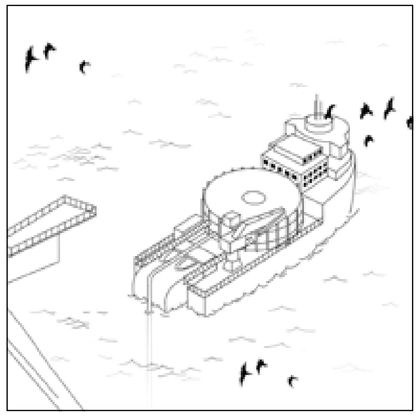
The cables are placed and buried on the seabed.



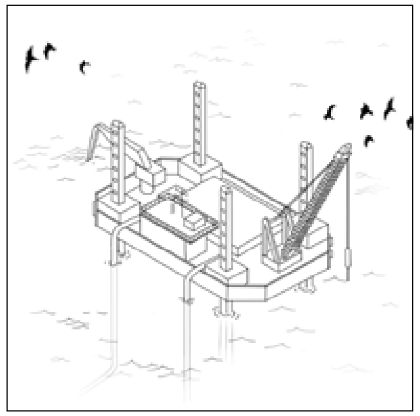
Offshore high-voltage substations are positioned in the wind park.



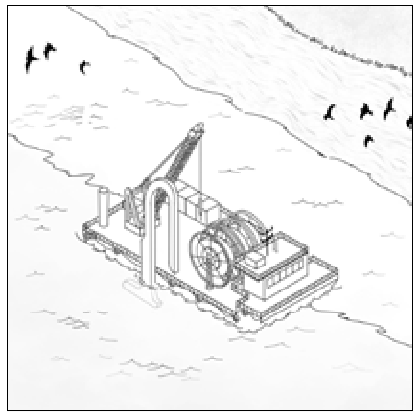
Wind turbine generator
The tower is lifted on and bolted to the Transition piece. The electrical cables are connected.



The electrical cable is laid onto the seabed.

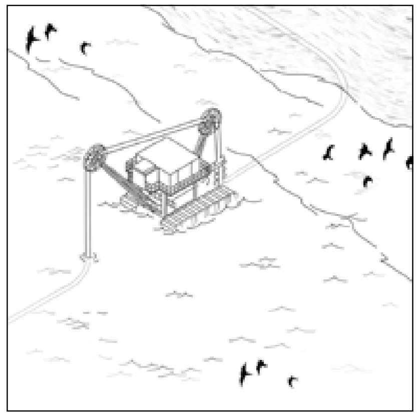


The cable sections are connected.

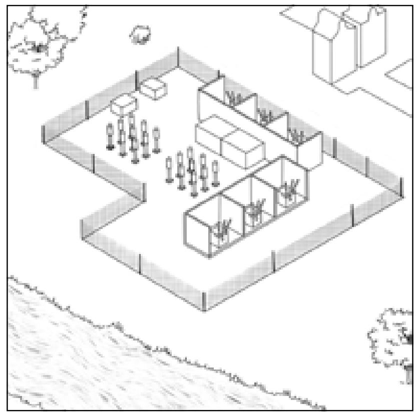


The cable is laid in tidal flats.

The cable is laid in tidal flats.



This is a trencher typically used in intertidal areas to minimize impact on coastal areas.



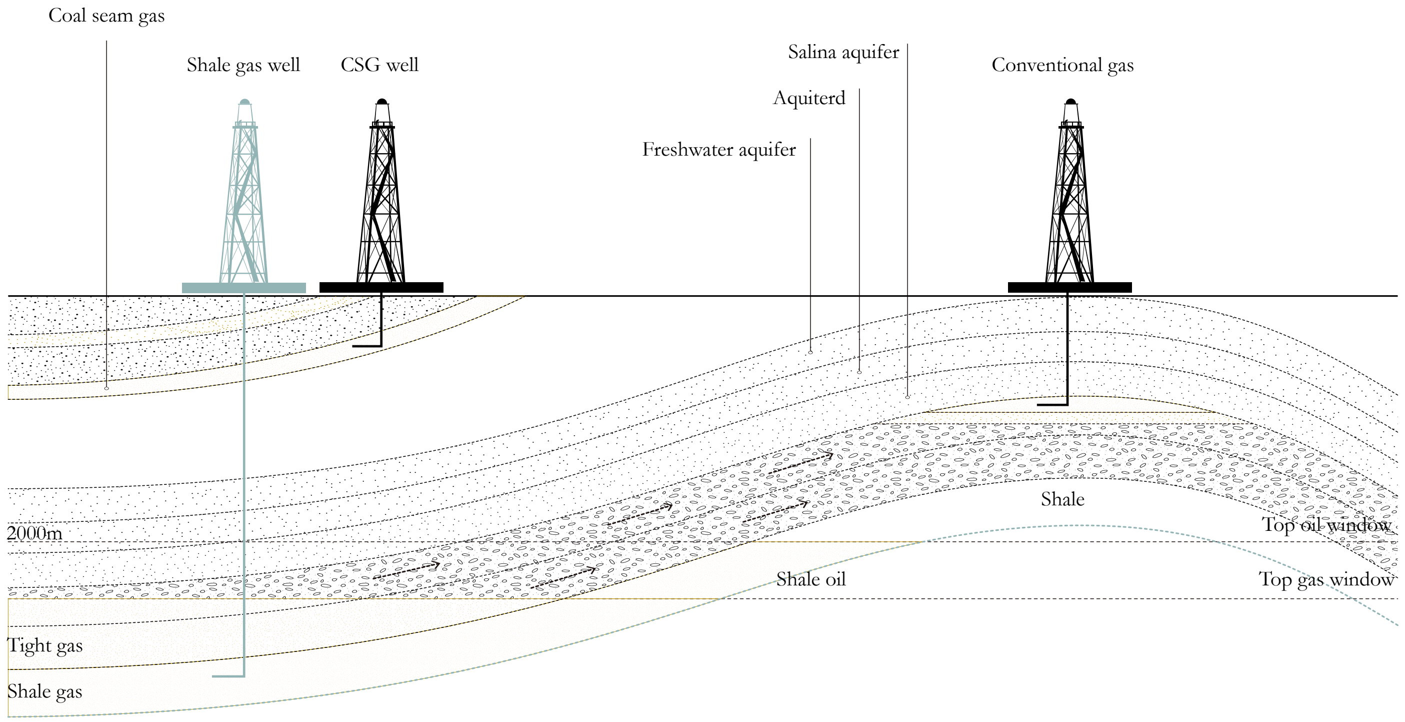
The wind park is connected to the high-voltage grid. The land station transforms the electricity from the export cables to a higher voltage.

Onshore and Offshore Gas Infrastructure

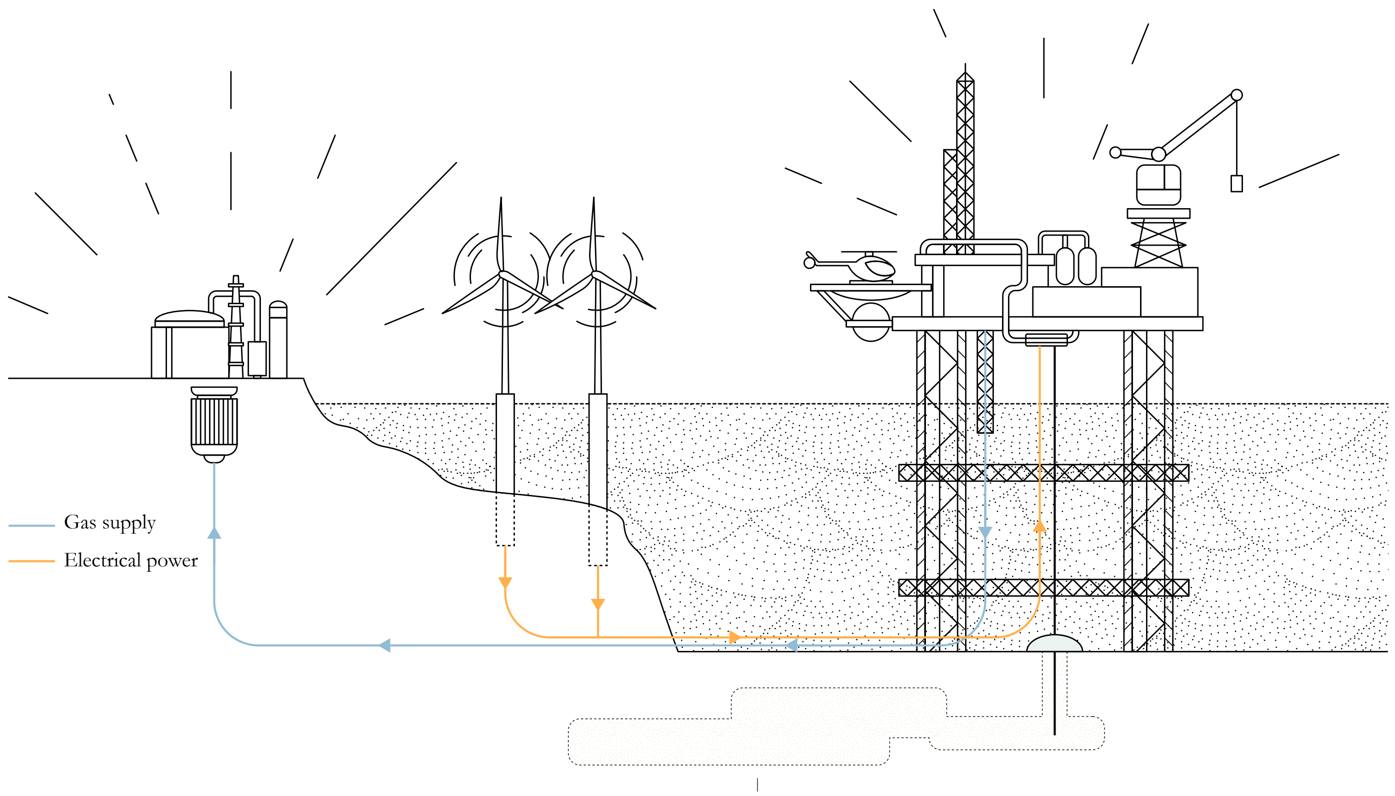
Images: Xinjian Jiang, 2023.

The diagrams below show onshore and offshore gas infrastructure. There are currently more than 100 active mining projects in the Netherlands, and the Wadden Sea is one of the most sensitive areas. Both onshore and offshore gas infrastructure have contributed to subsidence. For example, the Ameland gas field on the island of Ameland has been producing gas since 1986 and caused up to 35 cm of subsidence in 2018.

Conventional/ Unconventional Gas



Offshore Gas and Oil Sector



Elevations and Sea Level Rise

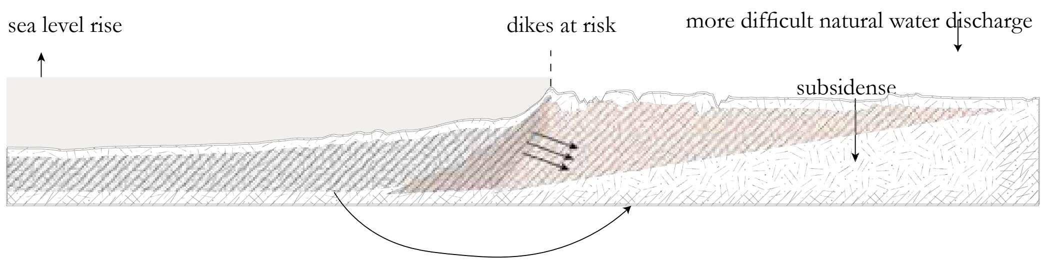
Data: National Aeronautics and Space Administration, 2015.
Image: Zhaolei Li, 2023.

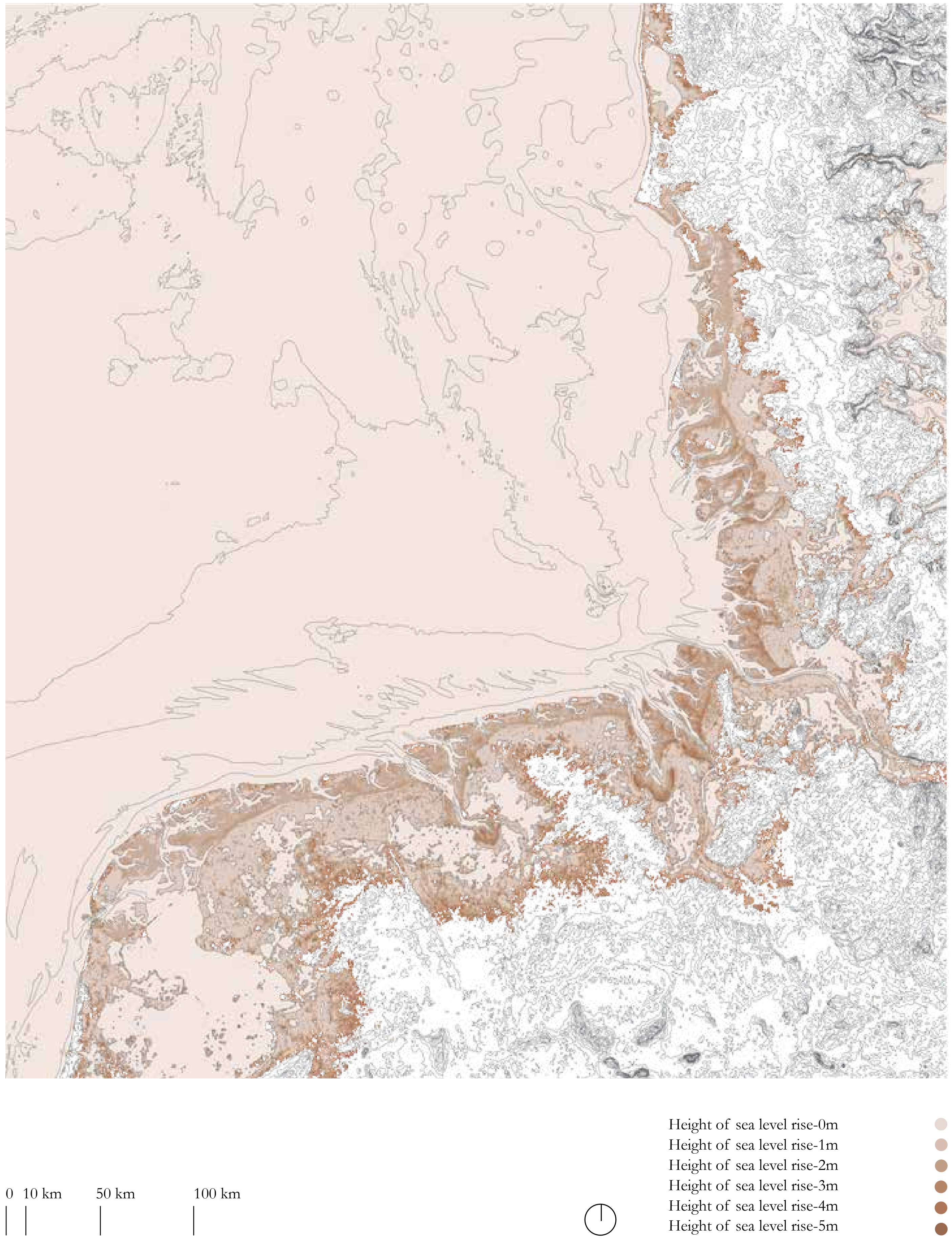
The greenhouse effect has led to a variety of climate problems, including rising sea levels. This map shows sea level rise in relation to elevations of 1, 2, 3, 4, and 5 meters. Temperature extremes, storms, and flooding are still listed as the greatest threats to the Wadden Sea region. The IPCC (2014) concluded that '*Global mean sea level rise will continue during the 21st century, very likely faster than observed from 1971 to 2010. For the 2081–2100 period relative to 1986–2005, the rise will likely be in the ranges of 0.26 to 0.55 m for RCP2.6, and 0.45 to 0.82 m for RCP8.5 (medium confidence). Sea level rise will not be uniform across regions*' (IPCC, 2014).

Sea Level Rise and Salinization

Salinization is a global issue threatening agricultural activities accelerated by rising sea water levels. Apart from rising sea levels, land subsidence and increasing temperatures also result in groundwater salinization. Groningen, Friesland, and Northern Holland are all at risk of salinization. In Friesland, since the elevation is below mean sea level, salinization of the polders occurs by the lateral intrusion of seawater (Tzemi et al, 2021). The salinization risk is constantly increasing due to rising sea levels—a process that will likely intensify after 2050. Seawater intrusion processes are expected to influence croplands along the Wadden coast.

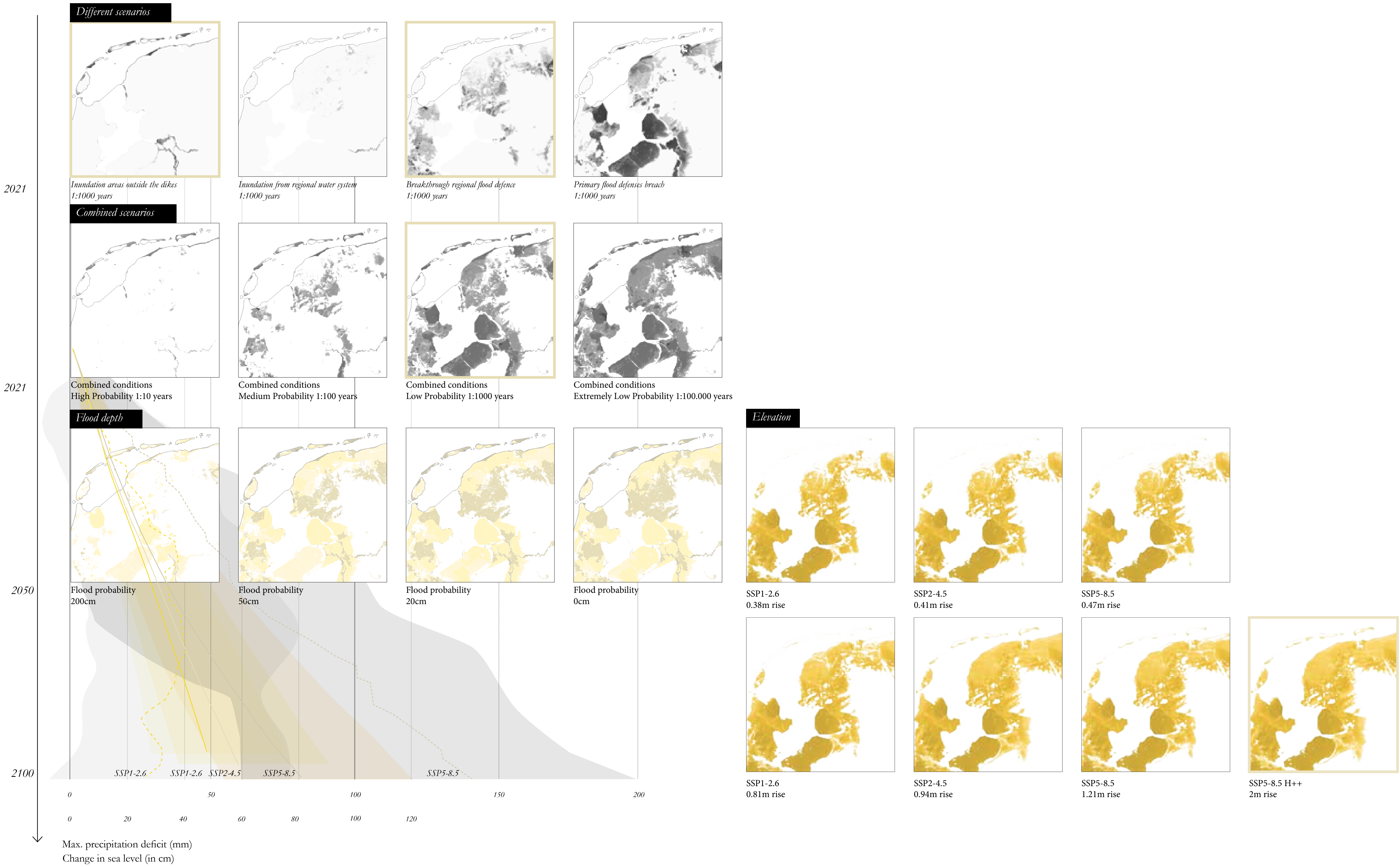
Sea Level Rise Risk





Future Uncertainties

Data: Climate Impact Atlas, 2021.
Photo: Heather Wong, 2022.



This image merges all the national maps of flooding caused by the sea and rivers from the Water and Floods Information System (LIWO) and was 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 approximately once every 1000 years. The dark color represents the high flood depth. The second row is the maximum flood depth of 2021, with a combined condition showing the flood area with different probabilities. The maps combine the four aforementioned flood conditions along the primary and regional water systems. These maps depict possible flooding that, in reality, will not all co-occur. 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 in the flood defense along the main or regional water system, or by the flooding of unprotected areas. Therefore, this map shows the probability of all possible flooding regardless of the resulting flood depth. All primary flood defenses precisely comply with the flood probability standard in the Water Act. The provincial exceedance probability standard has been used for regional flood defenses 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 based on the current failure definition and without emergency measures (Deltares, 2015). The darker yellow area represents a higher probability of flooding.
There is no spatial flood data on the Netherlands for 2100. Therefore, the elevation maps shown indicate the possible flood level regardless of the flood defense systems. The graph at the back suggests the future sea level rise projection and the maximum precipitation deficit under various emission scenarios.

Wooden lifeguard house on Terschelling beach.
Photo: Bas van Breukelen, 2020.

Timeline and Major Flood Events

Data: Zijlstra et al, 2017.
Timeline: Heather Wong, 2022.

Infrastructure and policy development are closely related to historical flood events. Protection and conservation work specific to the Wadden Sea began in 1978.

Natural processes

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 Flood

Cultural processes

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 Act

1969
Lauwersmeer

2009-15
Dike reinforcement

Policies

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

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

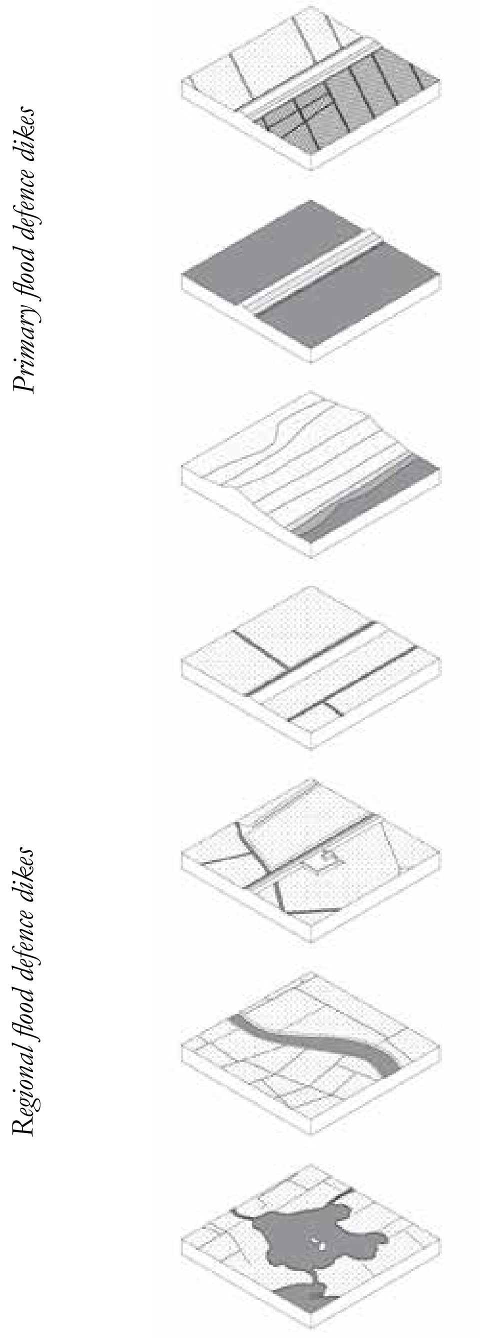
Flood Defense Systems

Data: National Georegister, 2021.
Images: Heather Wong, 2022.

Primary flood defenses are the first barriers protecting the country from high sea levels. 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 and Veeken, 2014). Dunes are mainly present on the Wadden Islands to prevent water intrusion from the North Sea.

Regional flood defenses refer to all flood defenses with a set standard constructed to protect areas inside or outside of a dike ring (Pleijster and Veeken, 2014). The regional flood defense system includes the former sea dikes, polder dikes, canal dikes, lake dikes, forelands, and summer dikes. Since the water level in the Boezem is higher than the land in the polder, regional dams are crucial to protecting 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 approximately 3,200 km of dikes.



Sea dikes

Dams

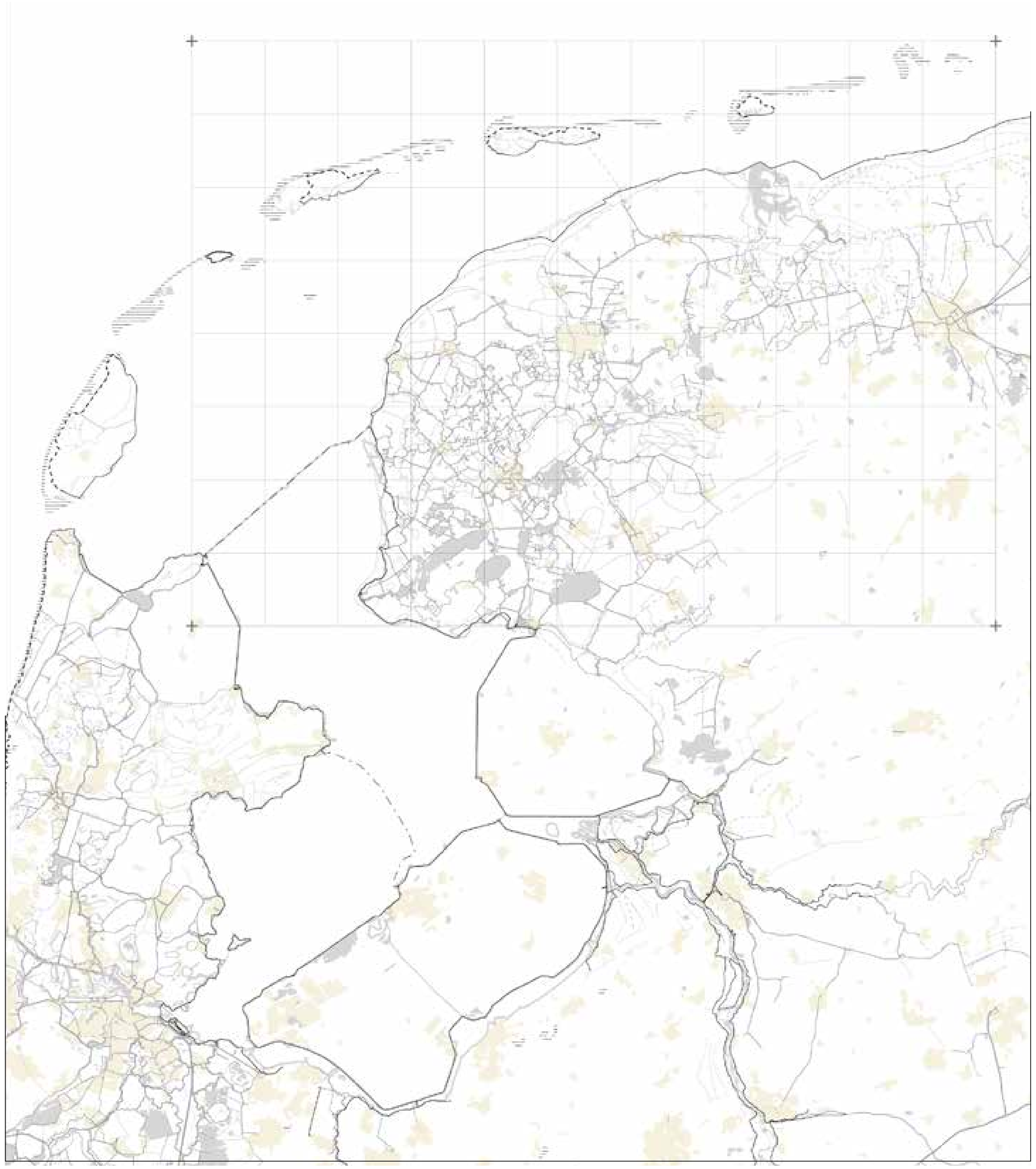
Dunes

Old sea dikes

Polder dikes

Canel dikes

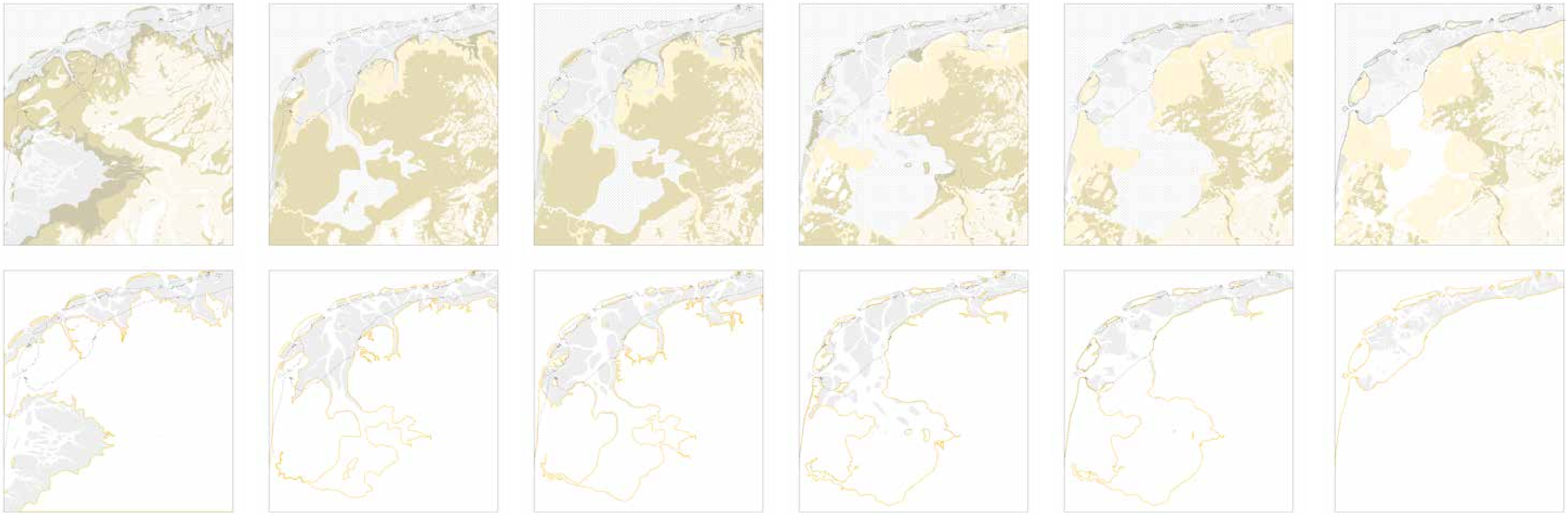
Lake dikes



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

Geomorphological Evolution

Data: Vos et al, 2020.
Images: Heather Wong, 2022.



Land

Water

3850BC — Bronze Age
100AD — Iron Age
800AD — Middle Age
1500 — Middle Age
1850 — Modern Age
2000 — Anthropocene

0 10 km 50 km 100 km

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

Cultural Heritage

Images: Anna Gorokhova, 2023.

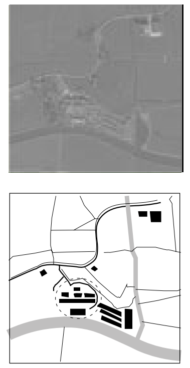
The eternal battle against the sea required significant landscape amendments, in which terps-pioneer settlements, dikes, ditches, canals, mills, etc. all served a role in the process. Historical traces of the past can still be clearly seen in the landscape, forming a unique cultural heritage (Vollmer et al, 2001).

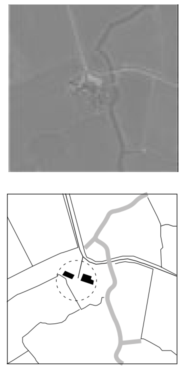
Infrascape

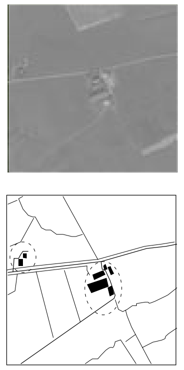

Wind Mill


Old Sea Dike

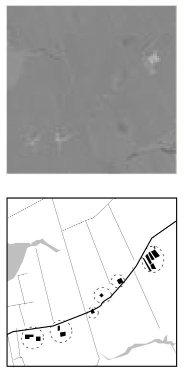
Waterscape

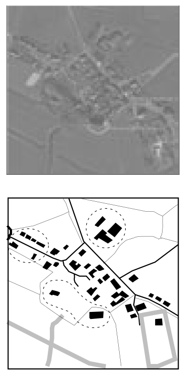

Major Canal

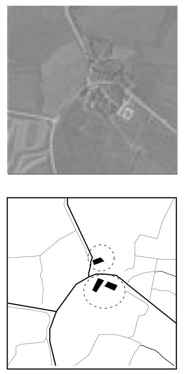

Secondary Canal

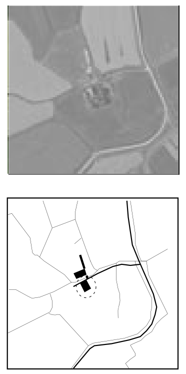

Minor Waterway

Terpscape


Terpichelago


Multi Isle


Double Isle

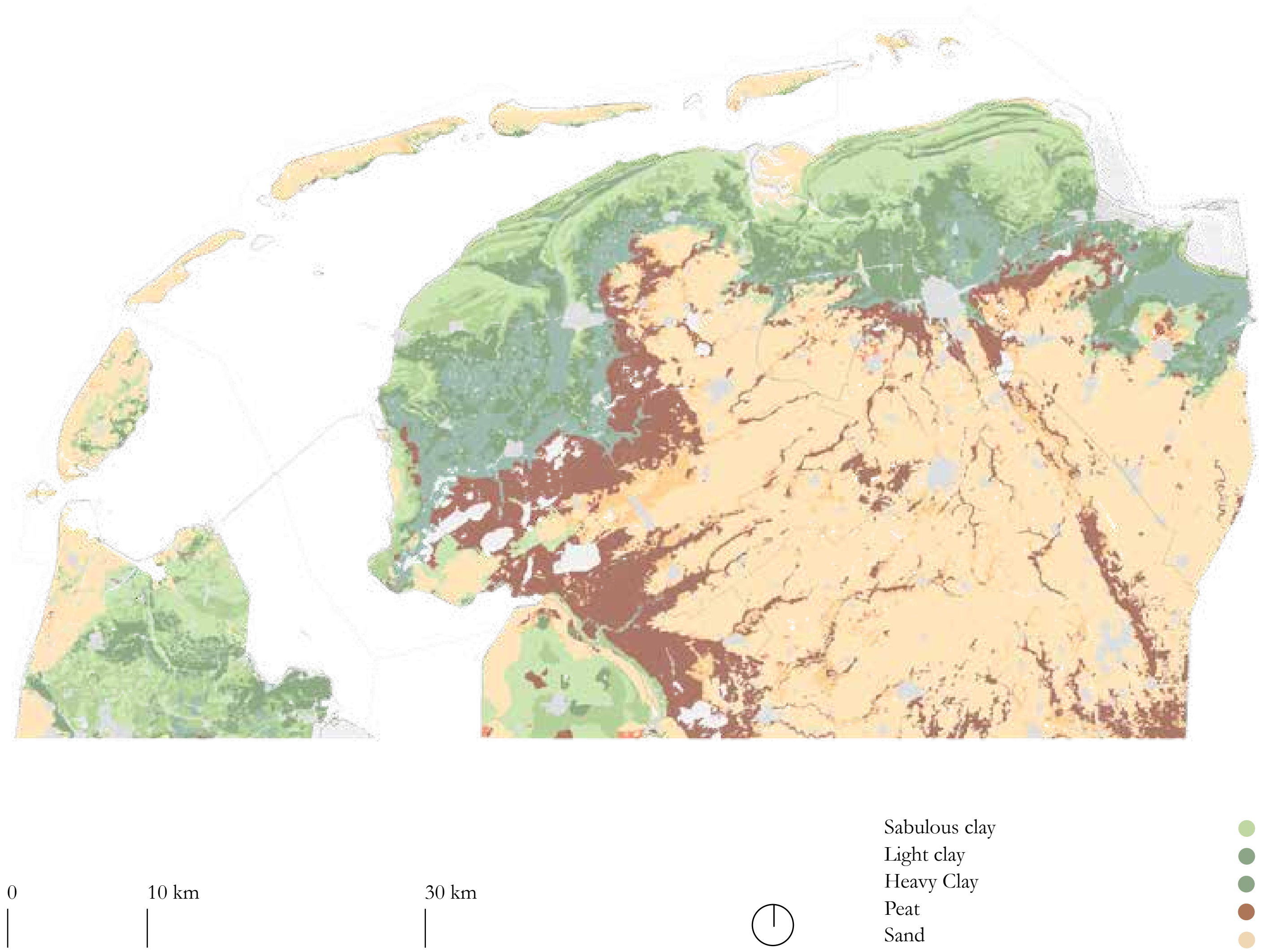

Isle


Terp Jannum.
Photo: Hanneke Wander, 2022.

Friesland Peatscapes.
Photo: Anna Gorokhova, 2023.

Soil Structure

Data: Wageningen University, 2006.
Image: Hanneke Wander, 2022.



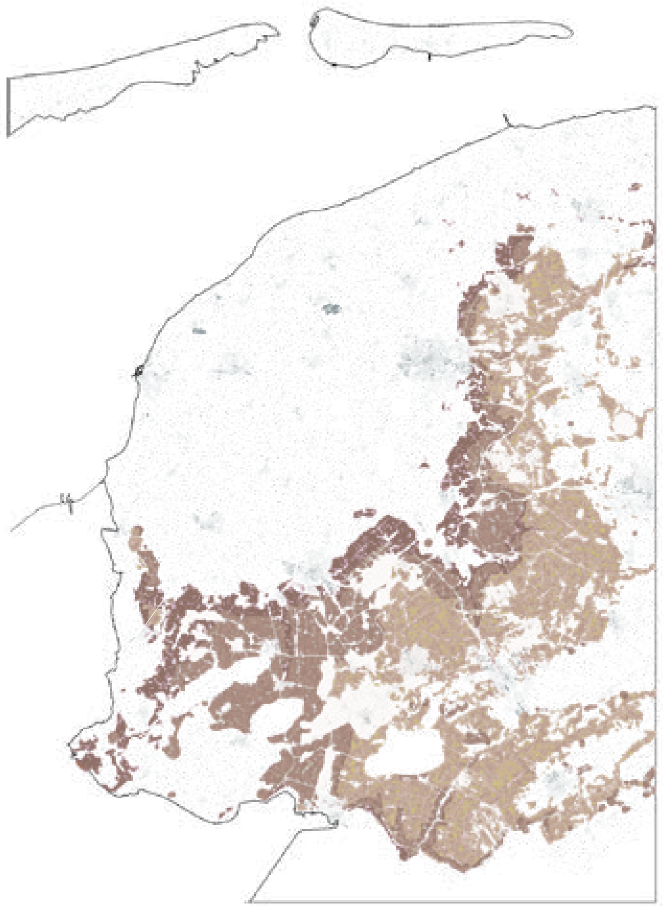
The marine clay soil belt spans the Wadden coast and is much higher than the subsided Wadden hinterlands.

As a result of geomorphological development and natural anthropogenic causes, the soil structure of Friesland and Groningen corresponds to that of the Wadden Sea due to the '*penetration of tidal creeks, which drained and lowered the peat, leading to further subsidence, while the marine clay soils deposited at the coast created a naturally elevated coastal clay belt*' (Oost al, 2017).

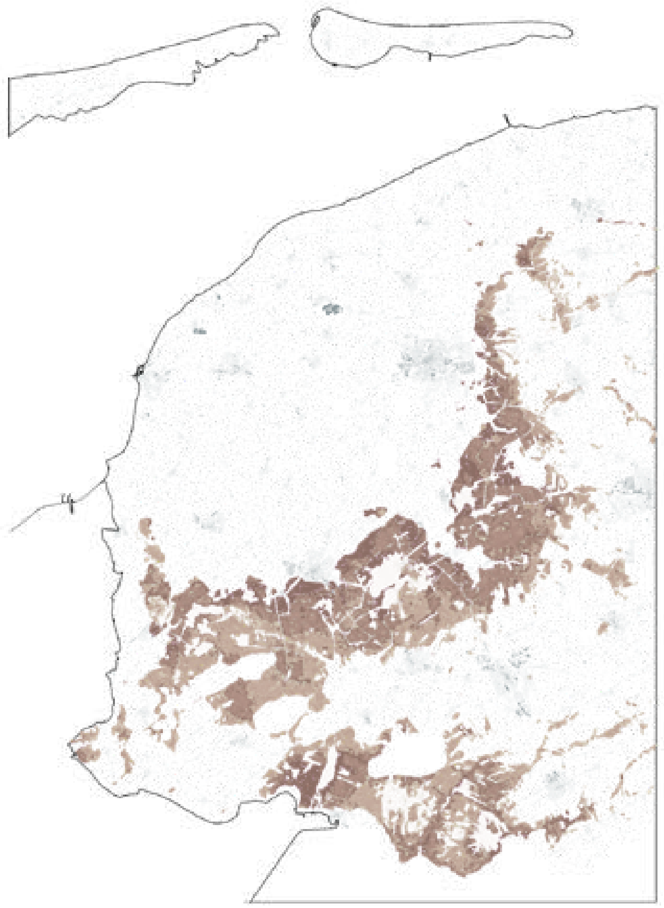
The Dutch geomorphological development and soil structure reveal the Frisian cultural history. As people settled in the salt marshes of Friesland and Groningen in 600 BC, they would inhabit the area temporarily, only during summers. They would retreat to their old villages in the elevated sandy soils during winter to avoid storm surges (Vollmer et al, 2001). Arable farming was complicated as salty storm surges would be disastrous for arable crops. The settlers relied on livestock that they would bring with them and temporarily grew crops until the next storm surge would destroy the harvest (Vollmer et al, 2001). With the embankment of salt marshes, arable agriculture was no longer in danger, and people started to settle permanently. To fight the increasing sea level rise and the threats of storm surges and flooding, the settlers raised their settlements, which are now surrounded by vast agricultural landscapes (Vollmer et al, 2001).

Peat Oxidation

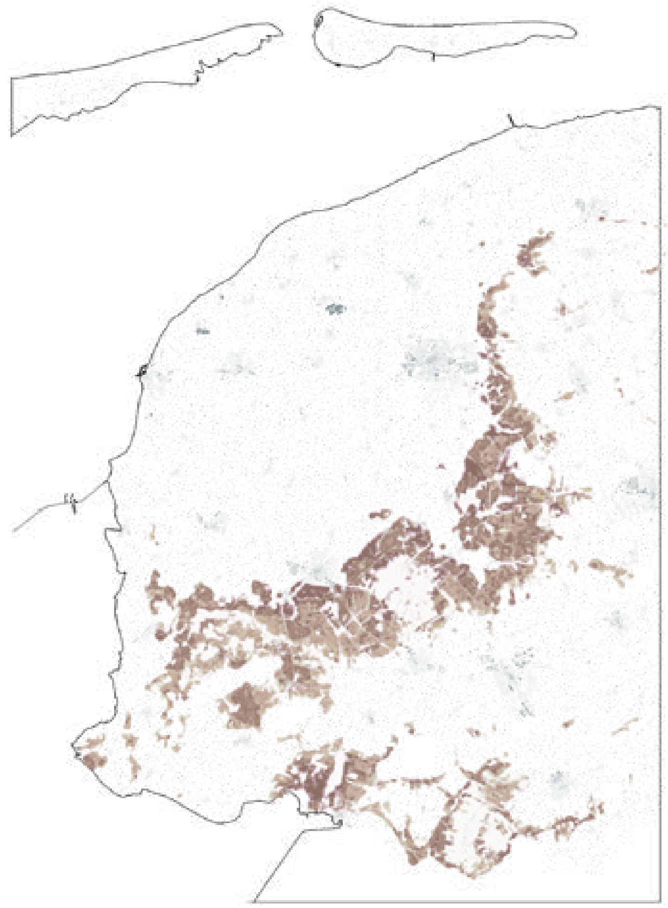
Data: Wetterskip Friesland, Province of Friesland, 2021.
Images: Anna Gorokhova, 2023.



2015



2050



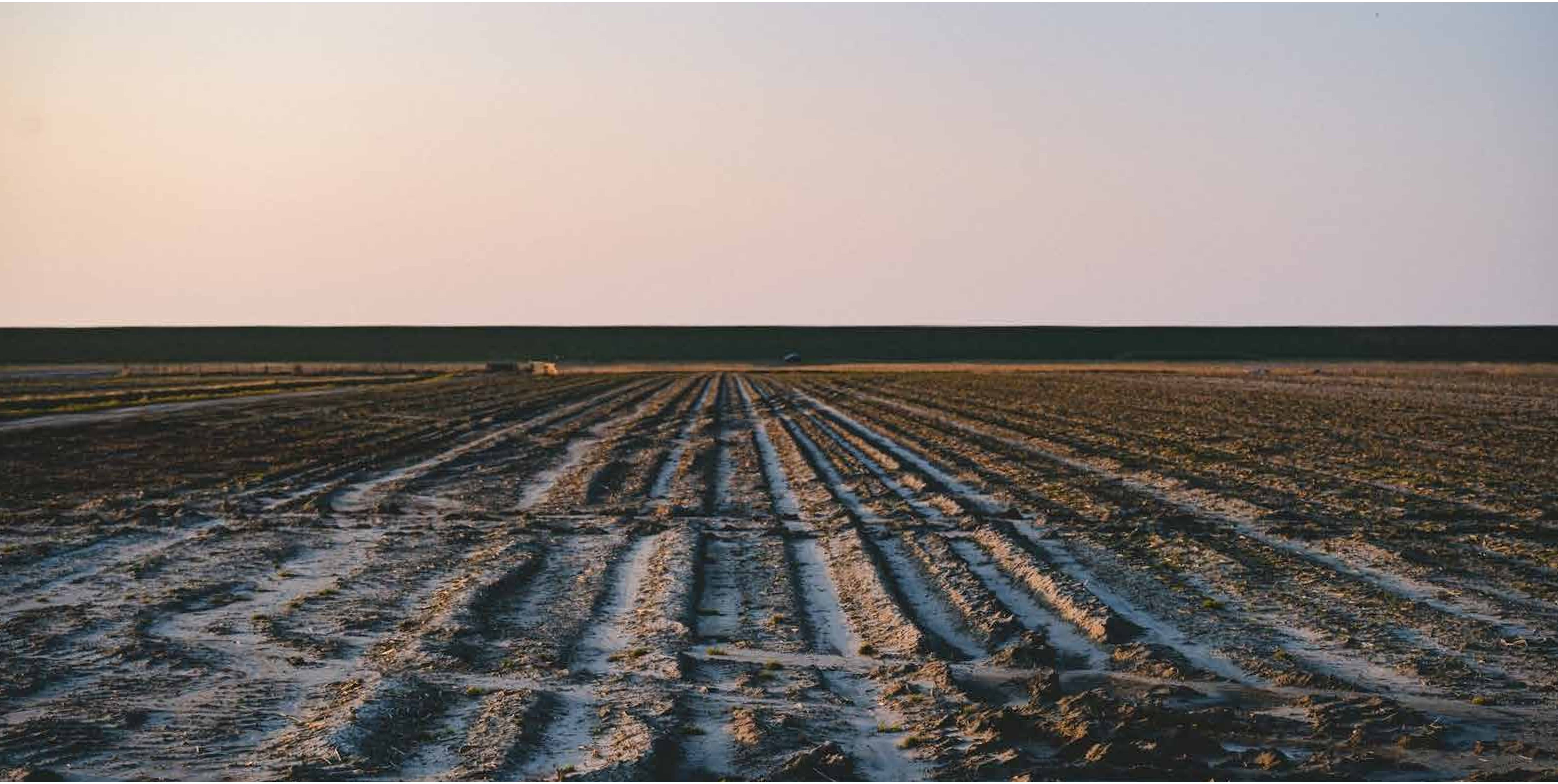
2100

One of the most significant climatic impacts of agriculture due to the draining of excess water is peat oxidation. '*Peat soils cover only 3% of the world's land surface but store one-third of the world's soil carbon*' (de Jong et al, 2021). As '*the water table is lowered for making peat more suitable for cultivation, drainage exposes peat to oxygen, which causes it to decompose and reduce in volume rapidly*' (de Jong et al, 2021). The loss of the peatscape is expected to impact climate change through peat oxidation, during which CO2 emissions are released into the atmosphere. The Dutch government predicts that the unsustainable process of draining excess water in peat landscapes will most likely result in the massive loss of the peatscape (Wetterskip Friesland, Province of Friesland, 2021). '*Drained peat soils emit, on average, 19 tons of CO2/ha/year*' (Brouns et al, 2015). The government has attempted to tackle peat oxidation by raising groundwater levels and other strategic activities (Wetterskip Friesland, Province of Friesland, 2021).

'*Peat subsidence and change in peat properties have been widely observed after drainage, which further accelerates microbial decomposition and carbon loss*' (Zhong, Jiang and Middleton, 2020). '*It has been predicted that the peat areas will subside between 40 and 60 cm between 1999 and 2050*' and is very likely to significantly reduce in size and disappear in the coming 100 to 200 years (Brouns et al, 2015).

0 10 km 30 km

Water
Urban
Peat
Peat with Clay Layer <40cm
Peat with Clay Layer 40-50cm



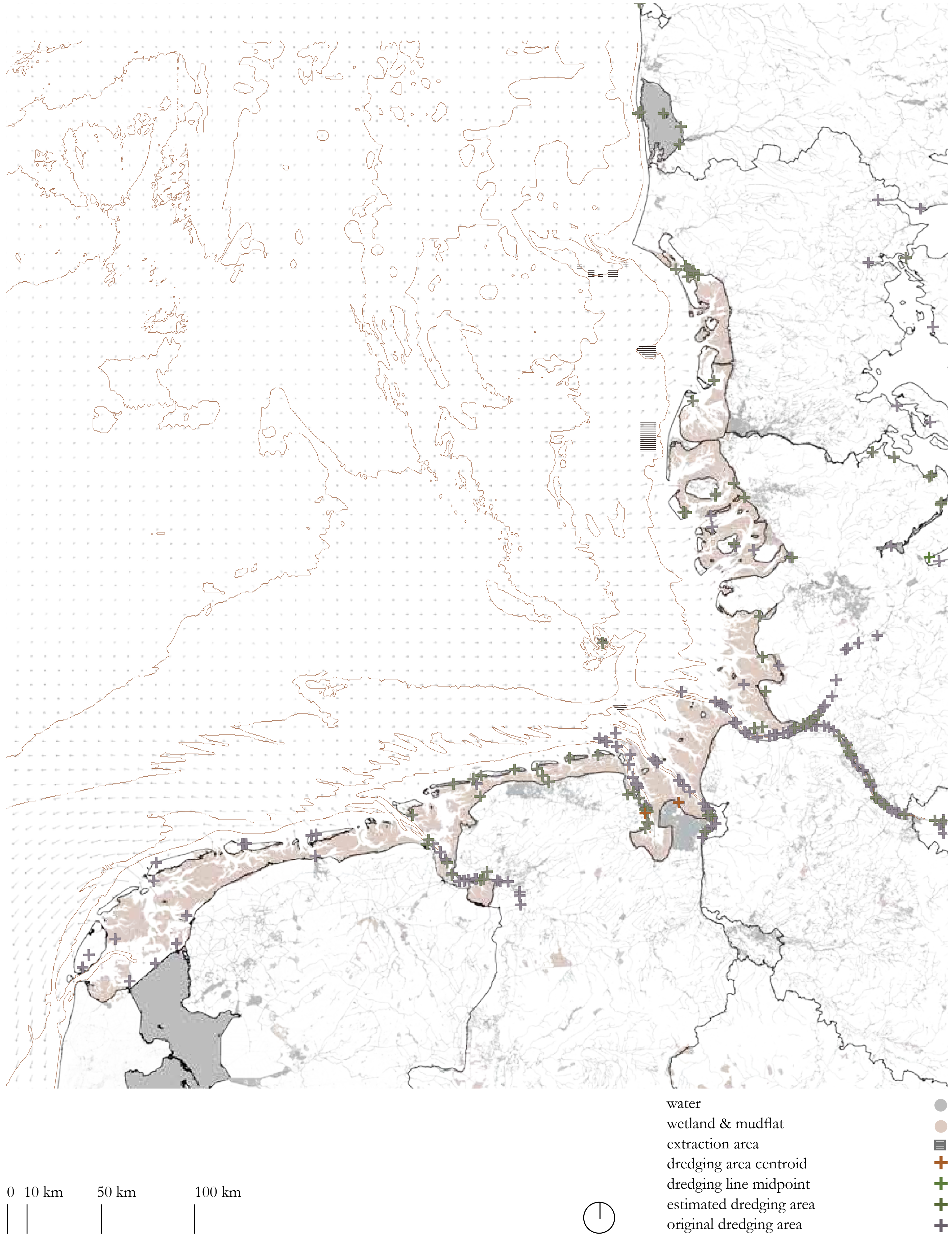
View of sea dike from the farmland.
Photo: Heather Wong, 2022.

Dredging and Dumping

Data: pdok.nl, 2022.
Image: Zhaolei Li, 2023.

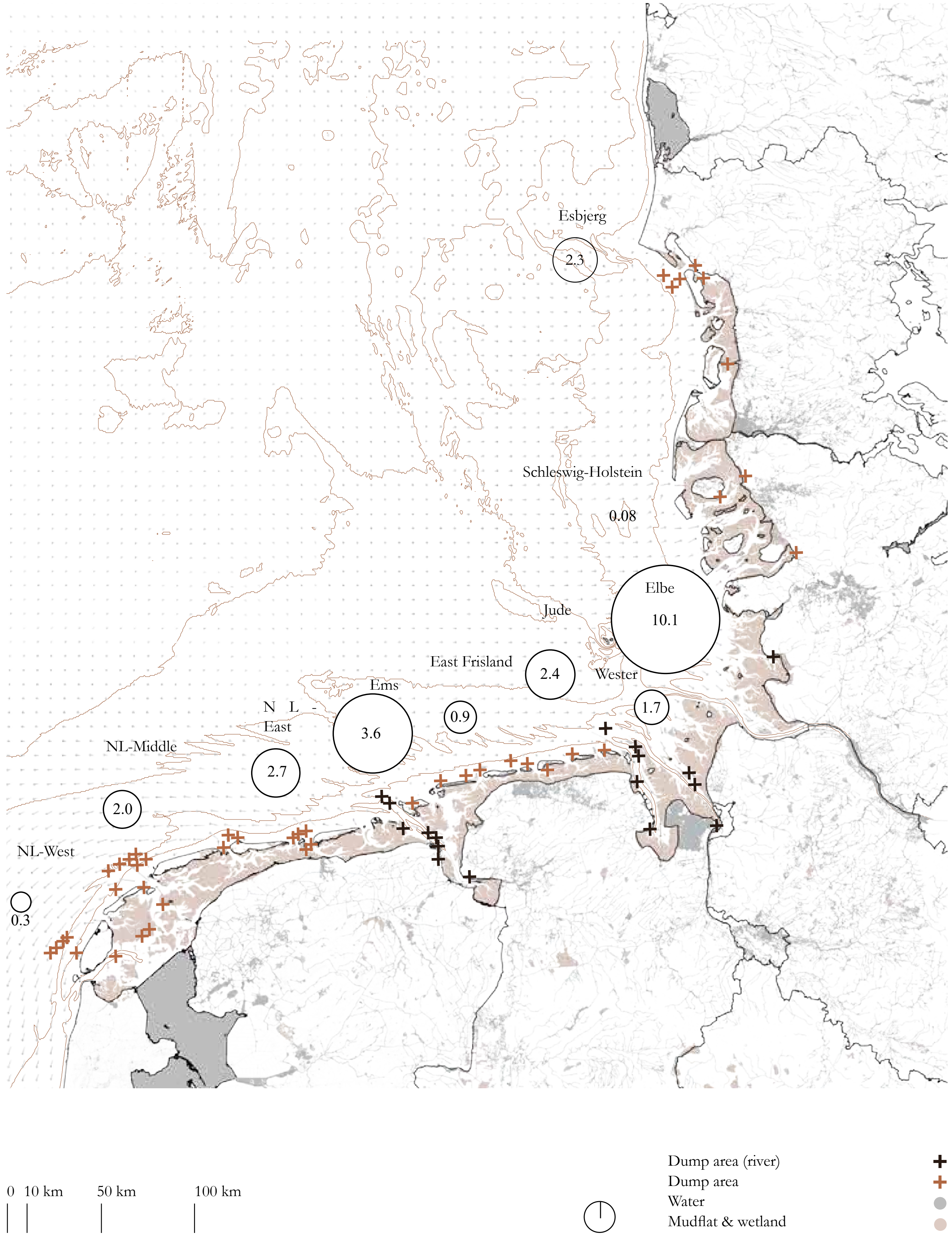
In 2009, the dredged material dumped into the Wadden Sea was 23. 900,000 t/yr, of which 18.5000,000 t/yr was dumped into the German part, 3.4000,000 t/yr into the Dutch part, and 2.9000,000 t/yr into the Danish part (Marencic and Vlas, 2009).

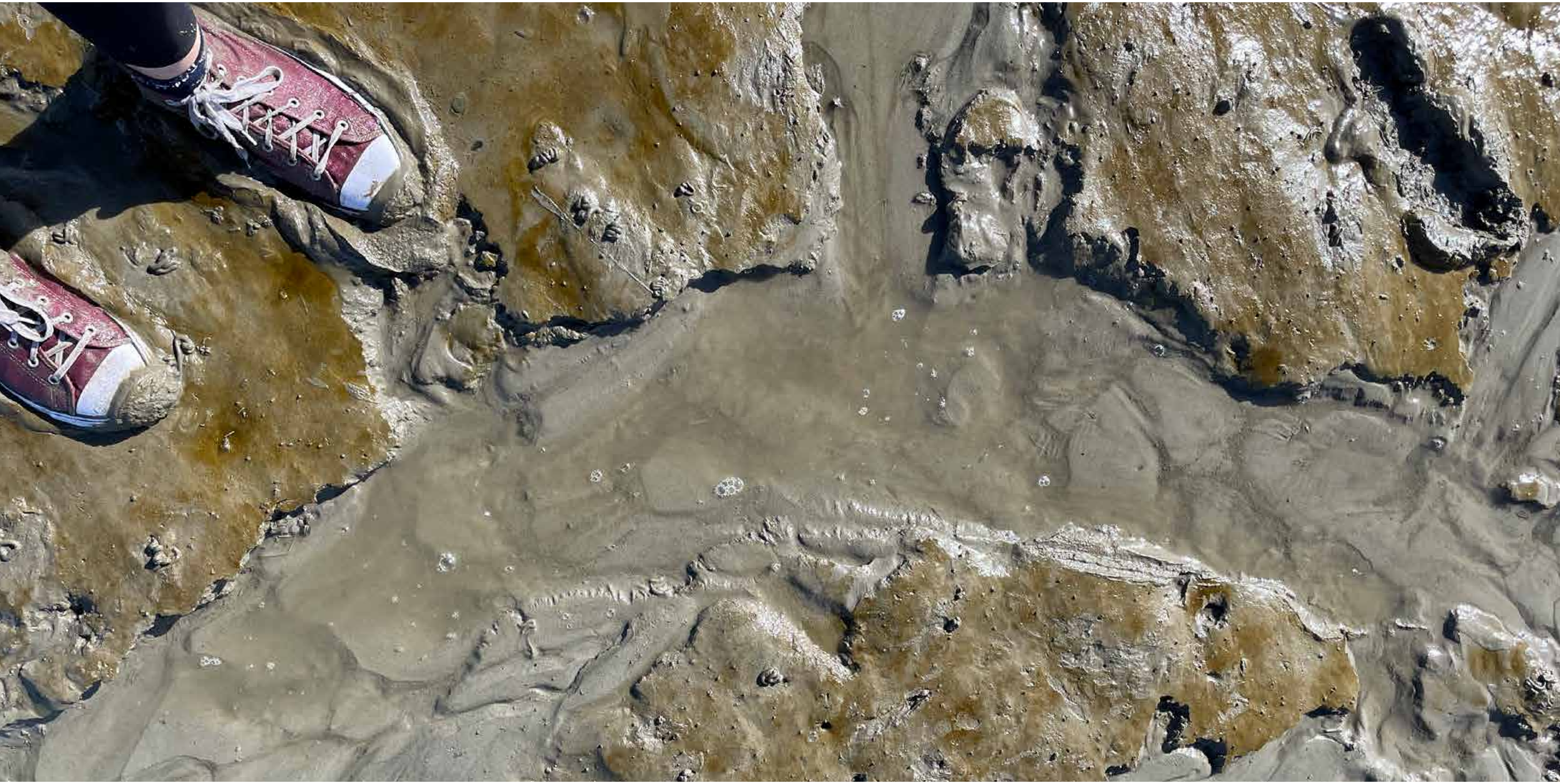
The traditional method of dredging involved using a bucket dredger equipped with a large bucket or scoop that excavates the underwater sediment and deposits it elsewhere. Since the 1970s, dredging operations have been performed by a suction dredger that employs powerful pumps and suction pipes to remove sediment from the bottom. Both dredging methods have impacts on ecological quality: they disrupt habitat, harm benthic organisms, and stir up sediment, which can affect water clarity and quality. Today, dredging and dumping are decreasing, new technologies are being used, and people stir mud in the water without digging it out. However, this also leads to too much soil being suspended in the water, resulting in the water body becoming increasingly turbid and ecological conditions being affected.



Dredging and Dumping

Data: Nehls and Witte, 2009; pdok.nl, 2022.
Image: Zhaolei Li, 2023.

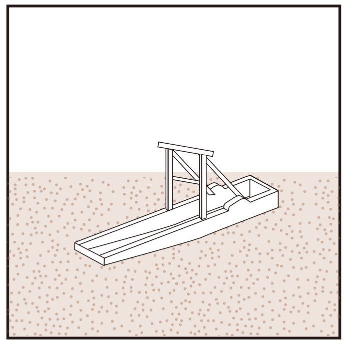




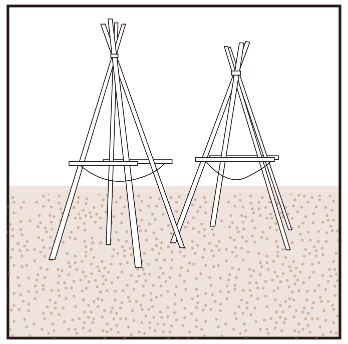
The Wadden Sea at Ebb.
Photo: Hanneke Wander, 2022.

Mud Recreation and Perception

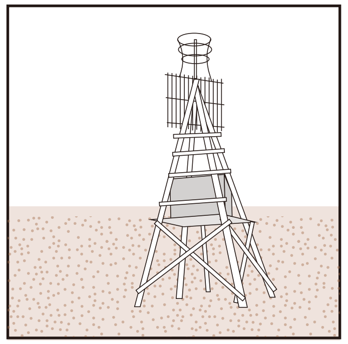
Data:Wadgidsenweb, 2020.
Image: Zhaolei Li, 2023.



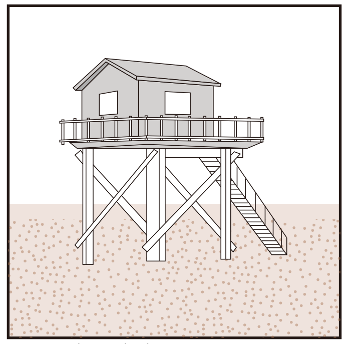
Mud Sled



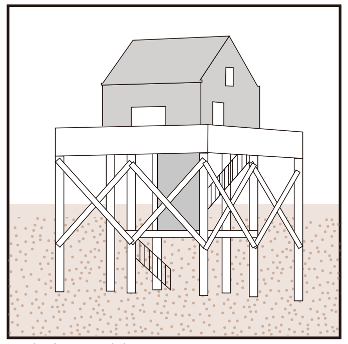
Wad stool (Wadstoel)



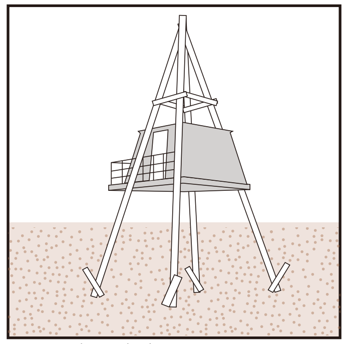
Cape with Shelter



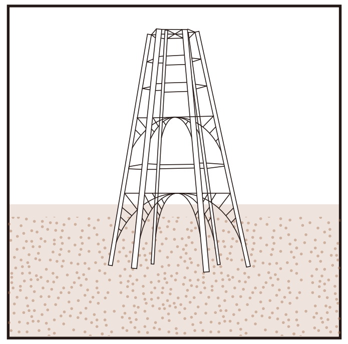
Drowning Shelter



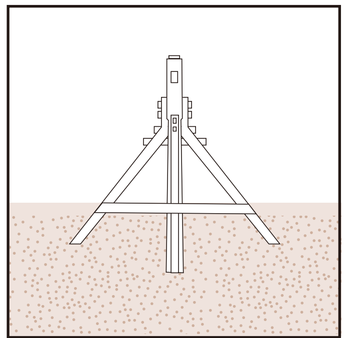
Bird Watching House



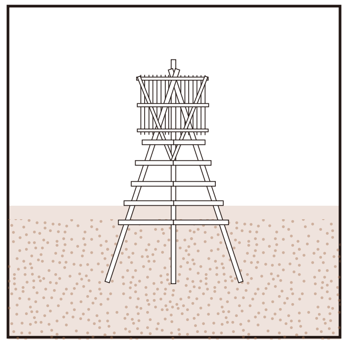
Drowning Shelter



Emder Kaap van Rottumeroog



Boundary Post



Cape

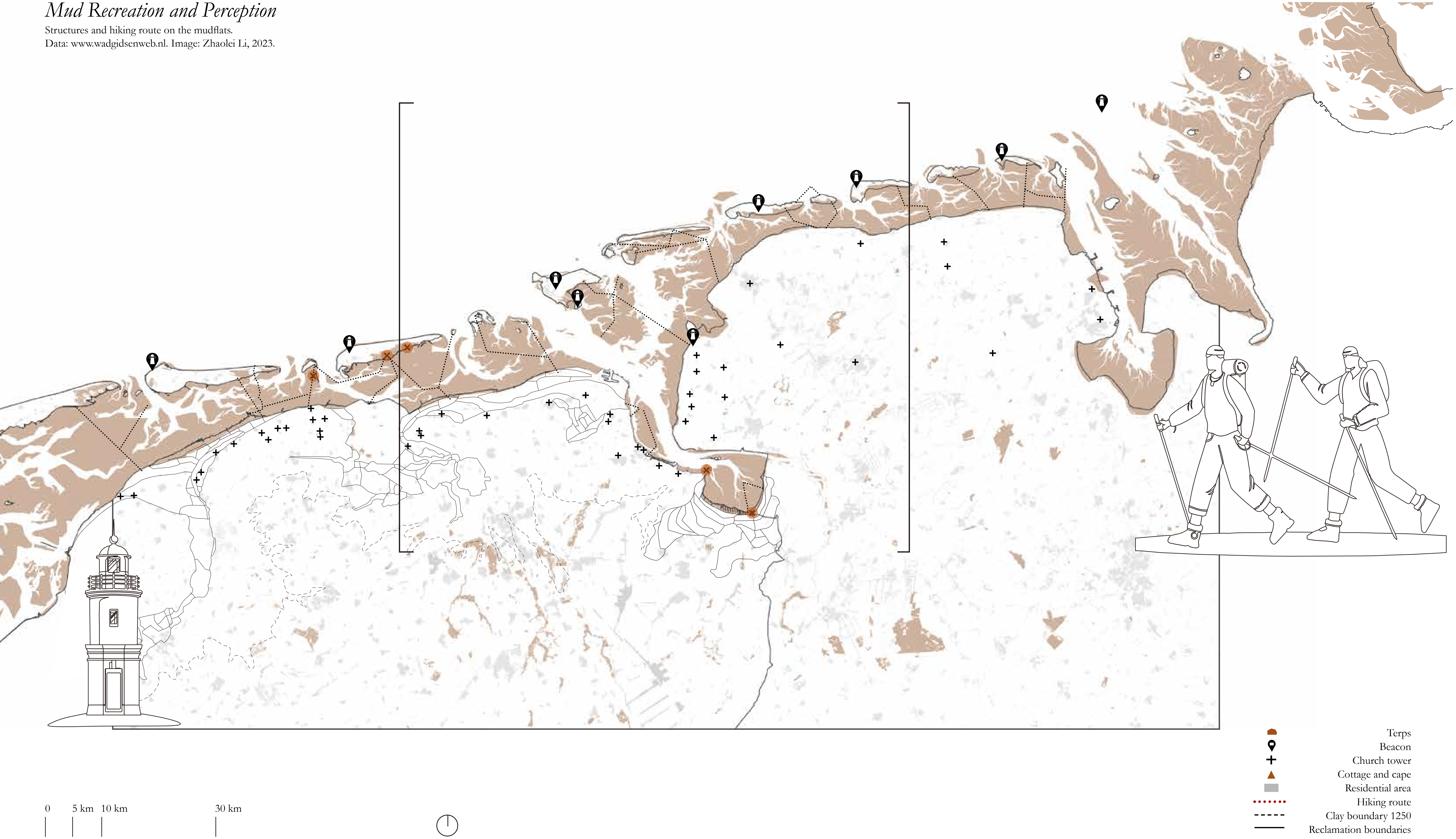
Many multiple mud routes and related facilities are present in the Wadden Sea for recreational purposes.

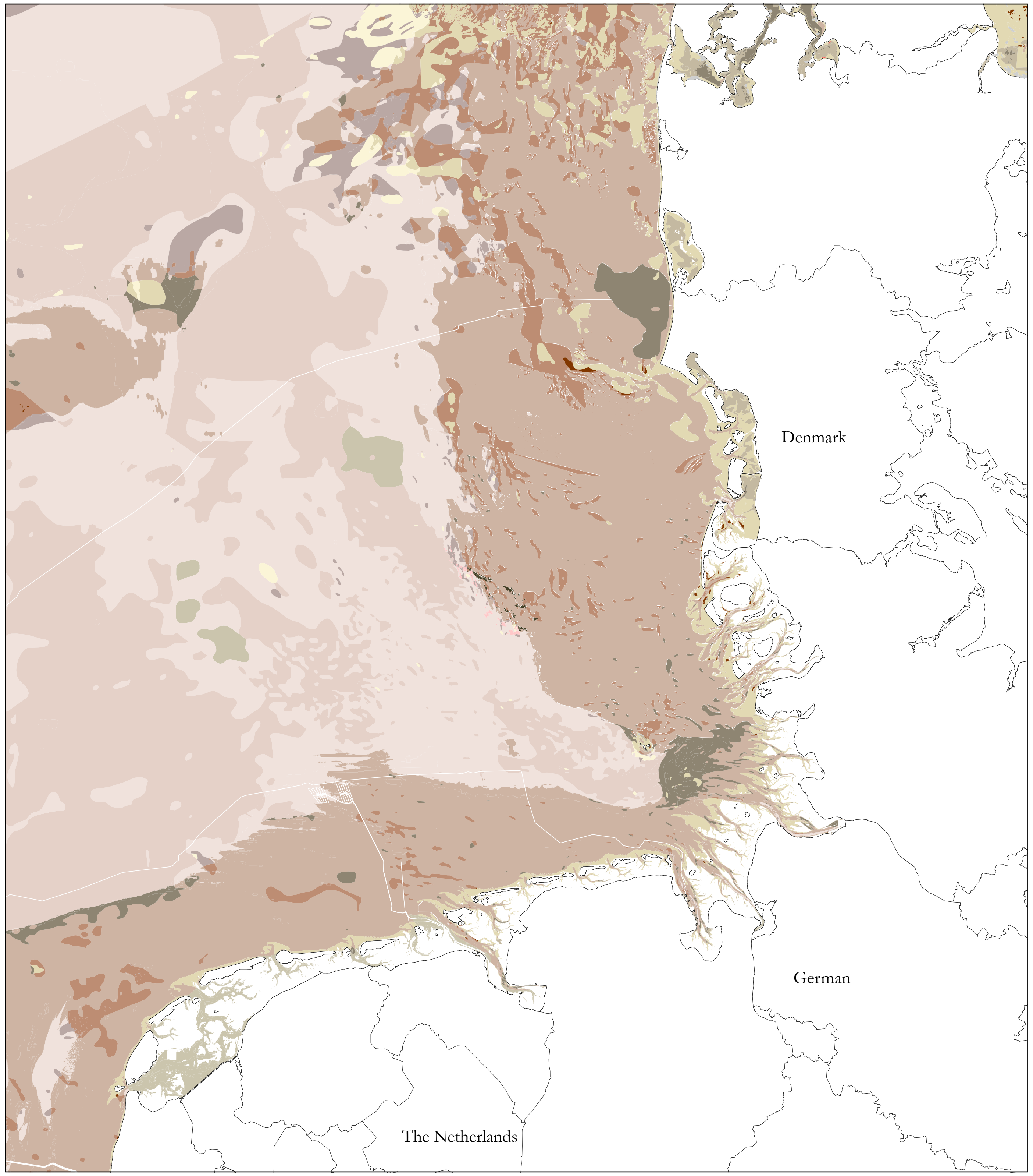
0 10 km 25 km 50 km

Hiking route

Mud Recreation and Perception

Structures and hiking route on the mudflats.
Data: www.wadgidsenweb.nl. Image: Zhaolei Li, 2023.





0 10 km 50 km 100 km

Municipality border

Infralittoral fine sand or Infralittoral muddy sand
Moderate energy deep circalittoral seabed
Circalittoral coarse sediment
Circalittoral fine sand or Circalittoral muddy sand
Deep circalittoral mud
Deep circalittoral sand

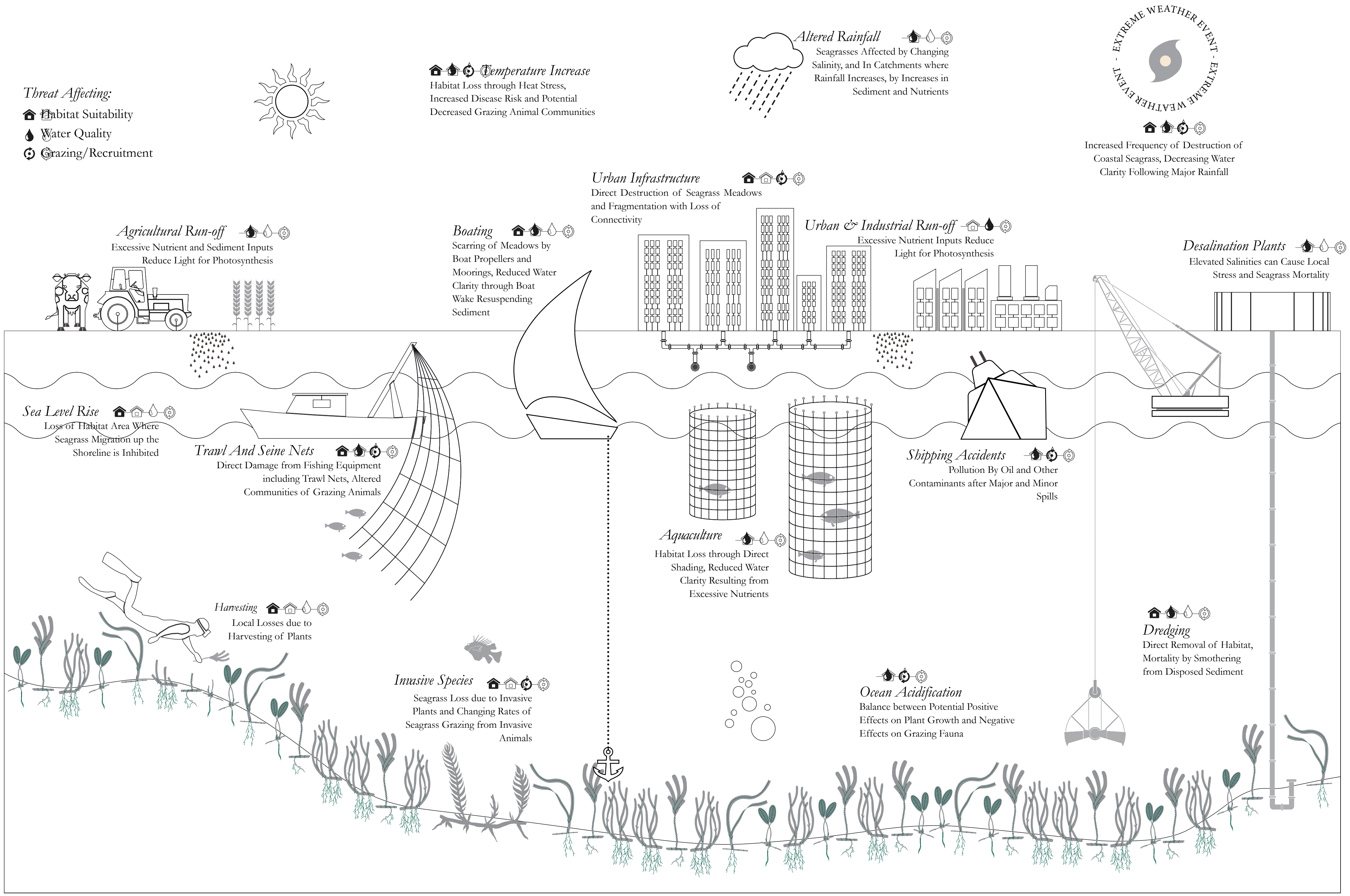
Seabed Habitat

Data: The European Marine Observation and Data Network, 2022.
Image: Xinjian Jiang, 2023.

The Wadden Sea provides habitats for up to 10,000 species (de Jong, 2015) and is crucial for fishes and migratory waterbird species that use the East Atlantic Flyway for staging, molting, and wintering.
This image displays the seabed habitat, the seafloor, whose knowledge is crucial to protect the marine environment. In this case, data are related to energy infrastructure (in white).

Seagrass Ecosystem Survices

Data: United Nations Environment Programme, 2020.
Images: Xinjian Jiang, 2023.



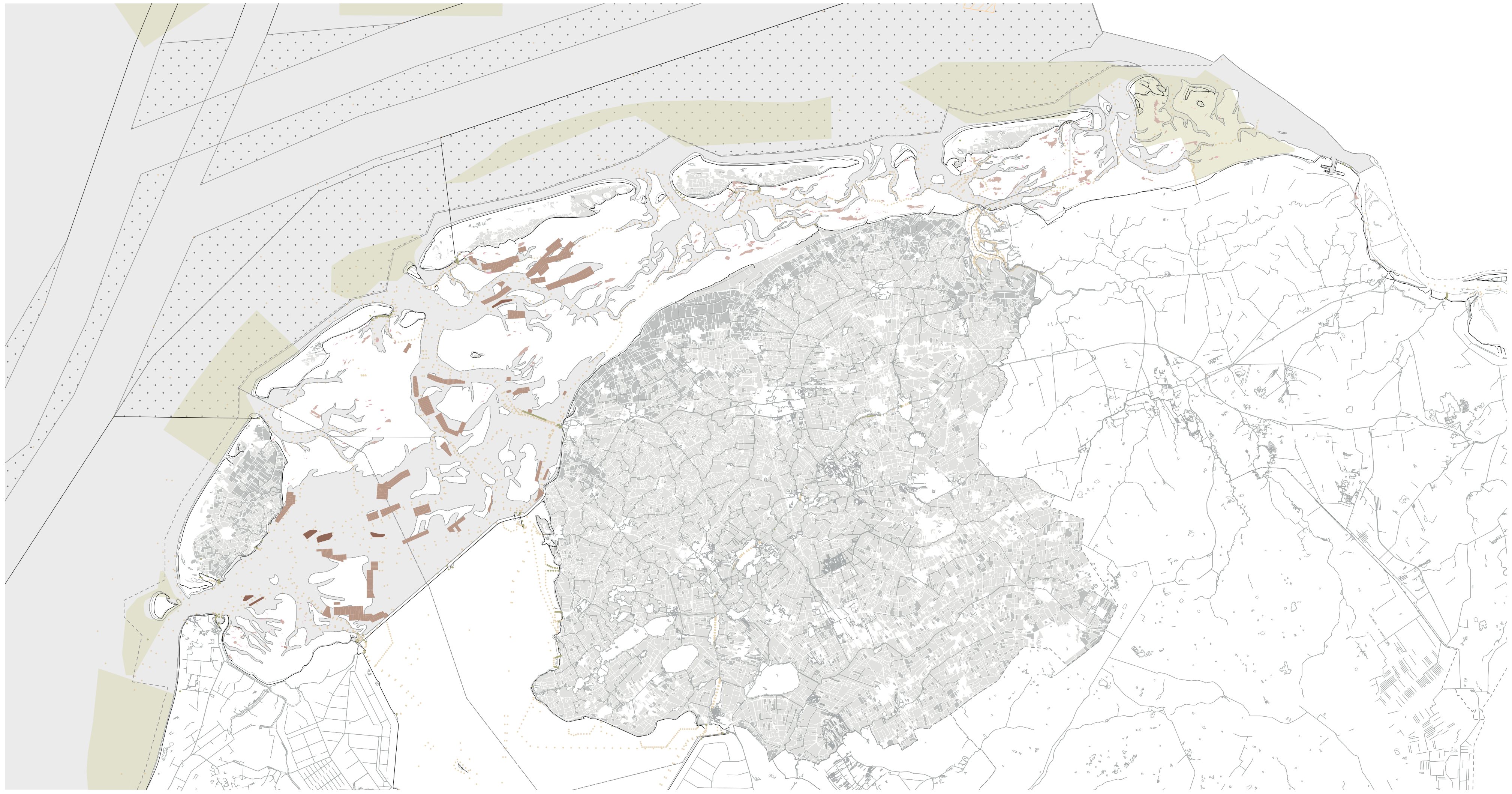
In the Wadden Sea, seagrass grows mainly in sheltered areas near islands and high sands. Seagrass ecosystems are incredibly important coastal habitats that provide a wide range of functions and benefits to both marine life and human communities, such as:

- habitat and nursery grounds for a diverse array of marine species
- biodiversity support hosting a variety of plant and animal species
- carbon sequestration helping to mitigate climate change
- coastal protection by stabilizing sediment and reducing
- oxygen production, contributing to the oxygenation of coastal waters and supporting aerobic respiration in marine organisms
- economic value since seagrass ecosystems provide significant economic benefits to coastal communities through fisheries, tourism, and recreational activities.

Sea level rise or extreme events (e.g. dry summers) could threaten seagrass in the future.

Agricultural Land Use

Data: BRP Gewaspercelen, pdok.nl, 2022.
Image: Hanneke Wander, 2022.



0 10 km 30 km

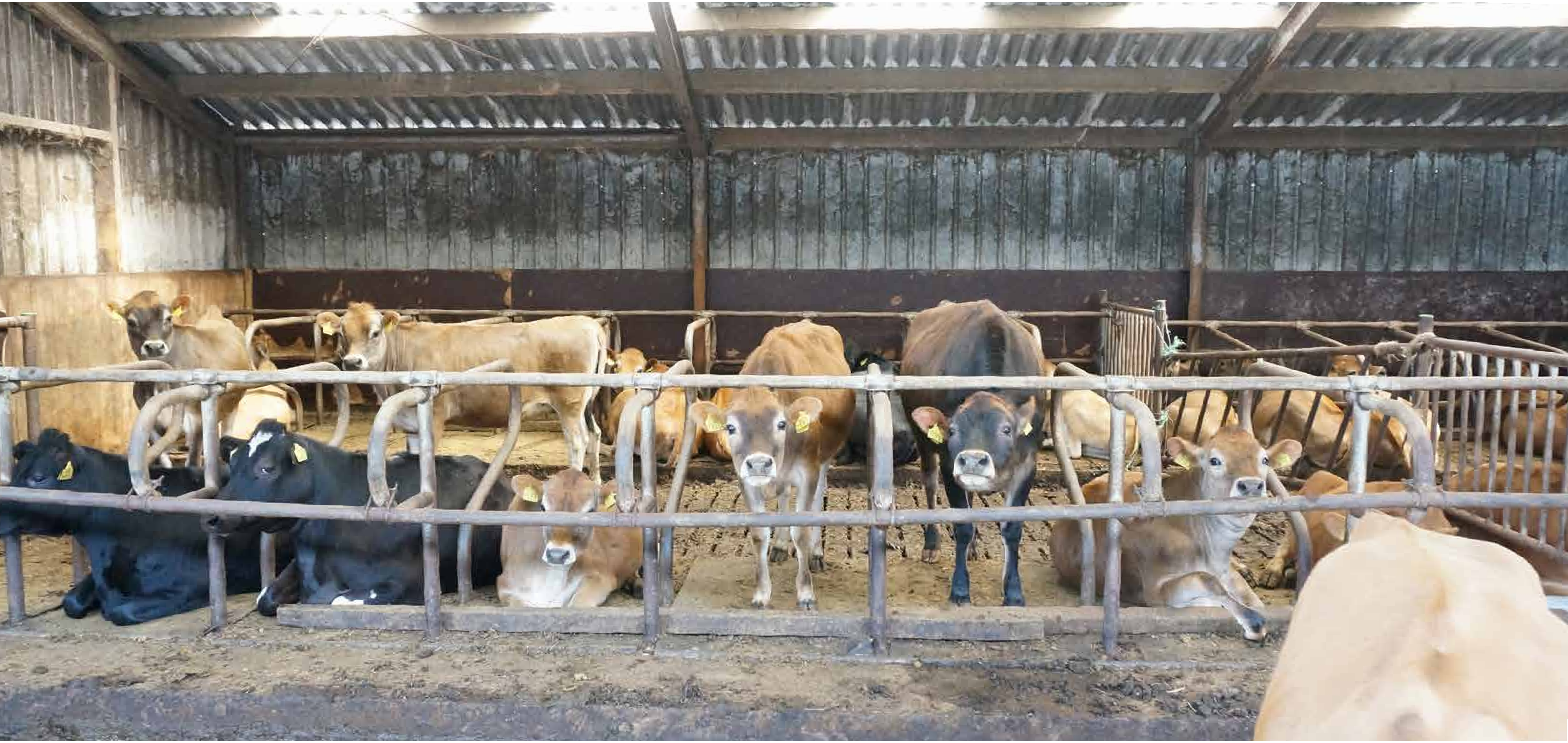
Fixed waterway marks
Floating waterway marks
Traffic separation scheme
Crop production
Grasslands

Anchor areas
Closed areas for fishing
Mussel and oyster habitats
Shellfish plots
Mussel seed capture installations

Subsidies implemented by the EU and Dutch governments significantly impacted the recent expansion of Frisian agricultural land (Plantinga and Molema, 2020). The abolishment of the 'milk quota' in 2008, which aimed to control the development of the dairy market, further contributed to the upscaling of agriculture (Plantinga and Molema, 2020). Abolishing all quotas resulted in the growth of average farm sizes and megafarms, significantly dropping the number of farms in Friesland. In 2021, 77% of the Frisian landscape was dedicated to agriculture. Nearly 1 million m2 of land is attributed to seed potato production, while dairy cattle use up to 500,000 m2 (Centraal Bureau voor de Statistiek, 2022).

The soil structure of the region influences the land use of the area. The clay soils are highly fertile when compared to the peat and sandy soils of the hinterland, turning the coast into a 'potato valley' as it is the main crop produced on the fertile shore. The inland area of Friesland is used mainly for dairy farming, with occasional corn and fodder grass production (Municipality of Groningen, 2023).

The abolishment of all the implemented restrictions created an economic environment in which the upscaling of agriculture became significantly more accessible. Currently, Friesland and Groningen are among the largest exporting provinces for markets outside of the EU. Overall, 23% of all seed potatoes in the world come from Groningen (Municipality of Groningen, 2023). In 2021, Friesland had the highest population of dairy cows in the country (Centraal Bureau voor de Statistiek, 2022). This upscaling led to larger farms, turning the small family-led businesses into mega agrarian corporations.



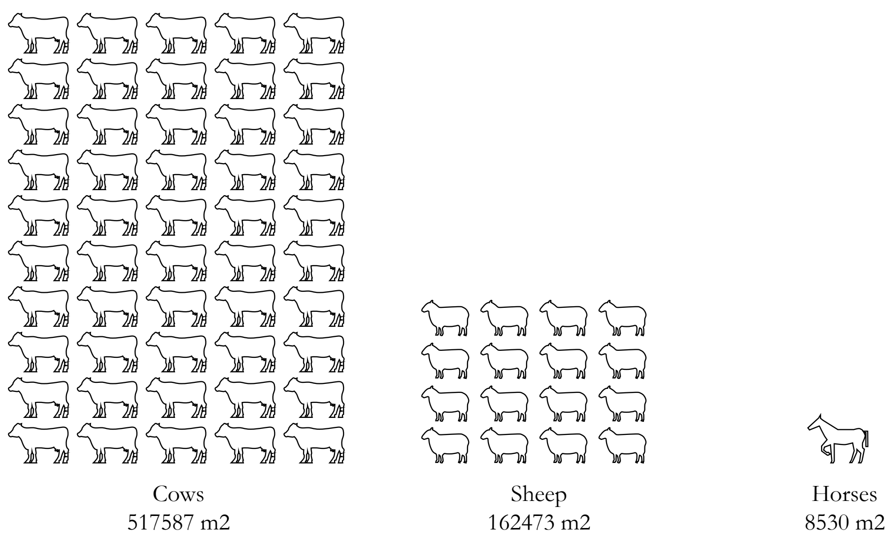
Cows in the barn at Hans Kroodsma's farm.
Photo: Hanneke Wander, 2022.

Agricultural Land-Use in Friesland

Crop production is highly concentrated on the higher clay formations along the coast of Friesland. Here, agricultural production consists of a large proportion of potatoes, grains, and sugar beets. The other part of Friesland consists mainly of grasslands—a highly typical characteristic of the province—primarily consisting of open landscapes with long sight lines.

Upon analyzing statistics for the whole of the Netherlands, it can be seen that the total area of the Netherlands is 4,152,800 hectares. In 2000, a total of around 48% was in use for agriculture. The total percentage of agriculture is slightly declining; for example, in 2016, approximately 43% was still used for agriculture (Nederlandse Akkerbouw, 2017).

In the province of Friesland, the agricultural sector makes up most of its land use. Overall, 77% of land in Friesland was being used for agriculture in 2017, which is well above the Dutch average of 43% in 2016. Also, the province has experienced a slight decline in agricultural land use. Over the last 15 years, this use has decreased by nearly 3%. In most cases, agricultural land was transformed into urbanized, recreational, and natural areas (Nederlandse Akkerbouw, 2017).



Number of farm animals in Friesland.
Data: CBS, 2022.

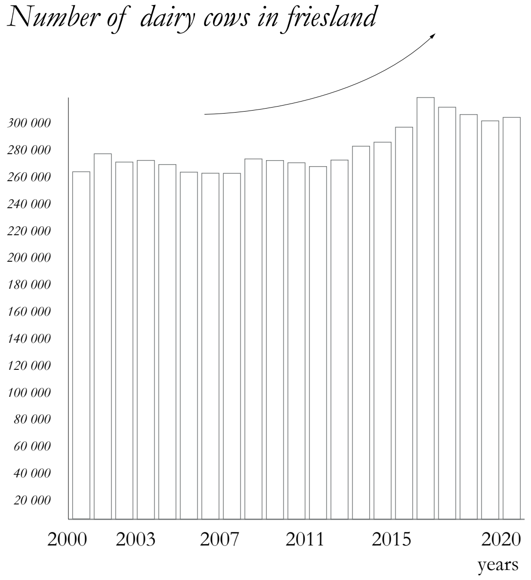
Farm along the Wadden Coast.
Photo: Heather Wong, 2022.

Upscaling and Higher Profits

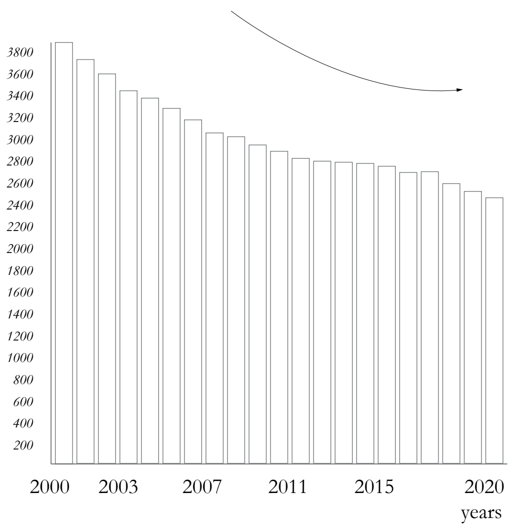
Data: CBS, 2020.

The number of farmers in the Netherlands has decreased rapidly over the last 16 years. Simultaneously, the average farm size and its production are increasing. In 2000, there were 97,390 farmers in the Netherlands, while in 2016, 55,680 farmers were remaining (Nederlandse Akkerbouw, 2017). The same trend can be seen in Friesland. The number of dairy farms fell sharply in this province: from just under 4,000 farms in 2000 to 2,772 in 2017. During the same period, the average number of cows per dairy farm grew enormously, from an average of 65 to 114 cows per farm. In 2016, there was a trend break, and the number of cows per farm fell again. This is related to measures taken against the phosphate surplus (Plantinga and Molema, 2020).

Number of dairy cows in friesland



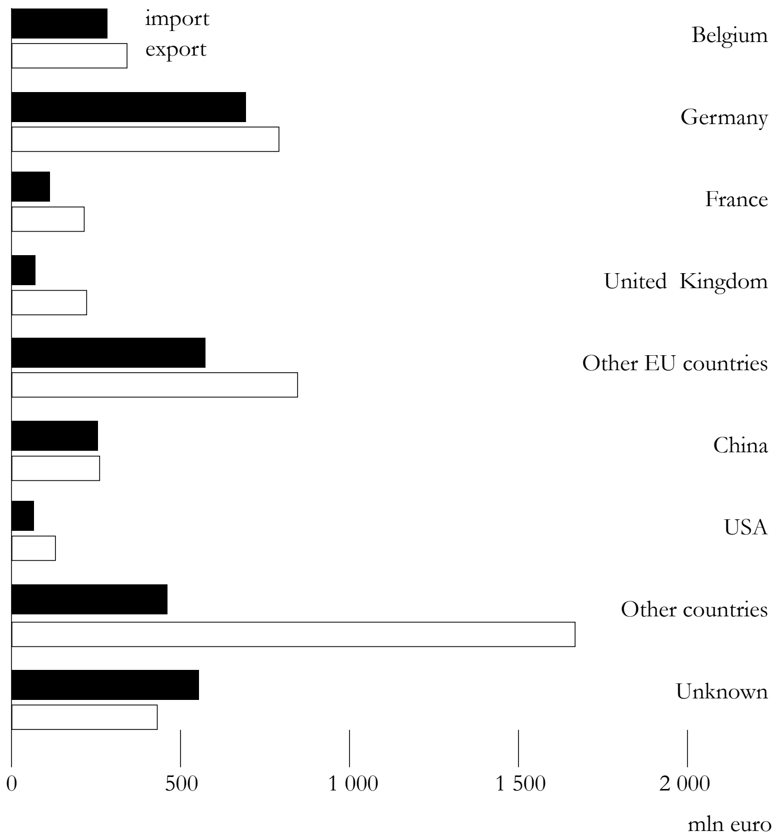
Number of dairy farms in friesland



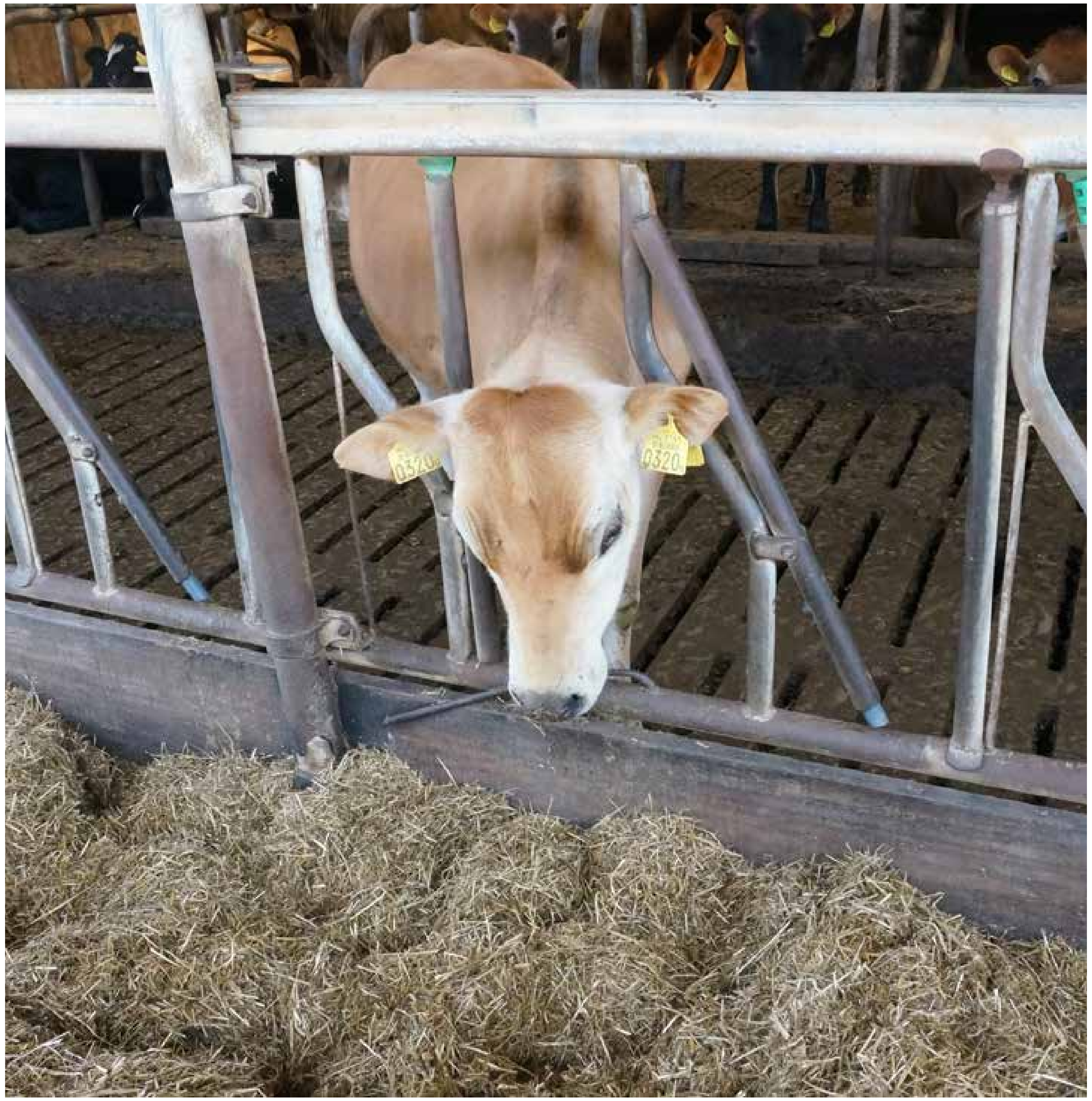
Friesland Farm.
Photo: Anna Gorokhova, 2023.

International Goods Trade from Friesland by Country

Of all the Dutch provinces, Fryslân exports the most to countries outside the EU. This encompasses nearly half of everything that is exported—mainly dairy products. Nationally, this involves nearly 28% of all exports (Centraal Bureau voor de Statistiek, 2016a). For Fryslân itself, the export of agricultural products is of great importance. In 2017, the total export value amounted to more than 2 billion euro, corresponding to 39% of the province's total export value (Centraal Bureau voor de Statistiek, 2016b).



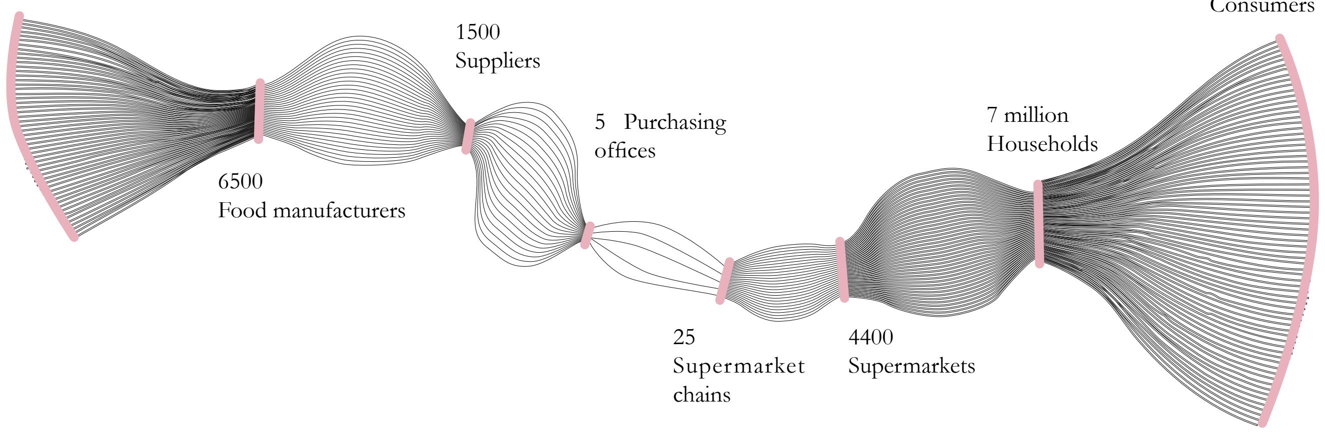
International goods trade from Friesland to country expressed in million euro
Data: Factsheet Friesland, CBS, April 2016.



Young milkcow at Hans Kroodsma's farm.
Image: Hanneke Wander, 2022.

Distance Between Consumers and Farmers

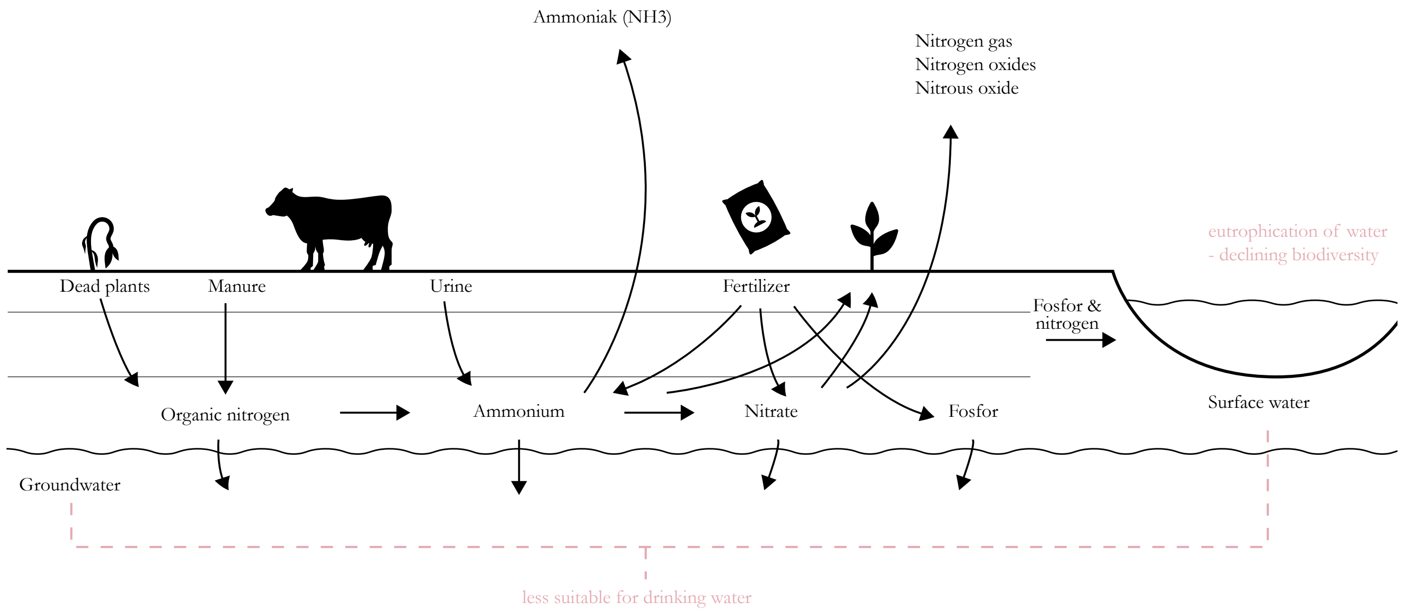
The human connection within the food system has been increasingly lost in recent decades. Due to the many middlemen and traders, consumers often have no idea who made their food or where it comes from. As a result, they also fail to see the social and ecological implications of the production process. Consumers may pick up the cheapest carton of milk from the supermarket shelf. Still, they do not realize that this creates a monotonous, low-diversity landscape to produce this milk as cheaply as possible. On the other hand, farmers often do not know where their products end up or what a consumer is willing to pay for a certain quality. Margins are tiny, and the only thing the farmer can often compete on is price (Fairfood, 2020).



The middle parties between farmers and consumers. Source: Planbureau Leefomgeving, 2012. Image: Hanneke Wander, 2022.

Nitrate and Phosphorus Surplus

Nitrate and phosphorus surplus refers to the excessive accumulation of these nutrients in the environment, particularly in water bodies, which can lead to various ecological and environmental problems.
The diagram shows how nitrate and phosphorus surplus, primarily originating from agricultural runoff, wastewater discharge, and industrial activities, can lead to eutrophication, a process in which an overabundance of nutrients stimulates the rapid growth of algae and other aquatic plants.



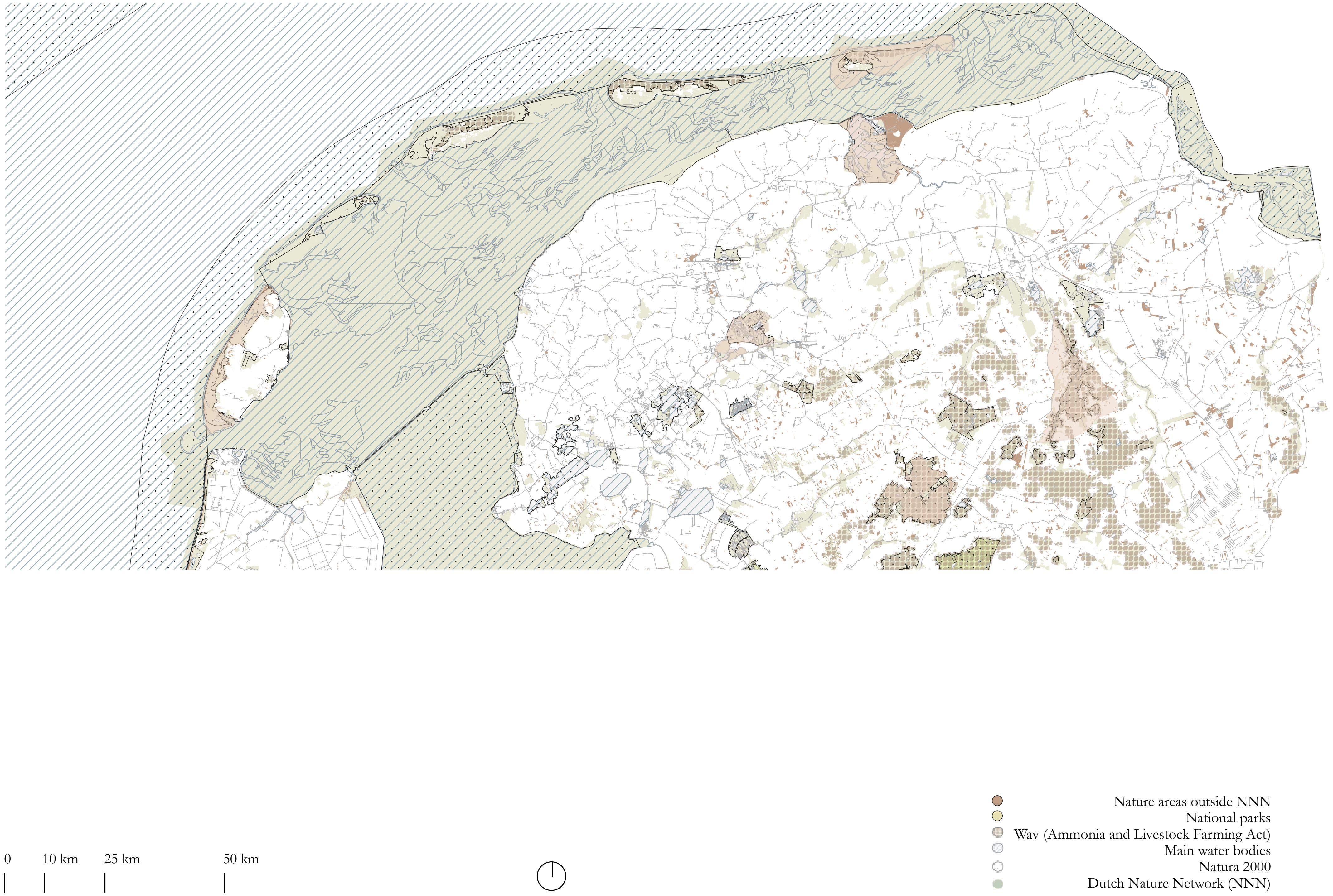
Processes in the ground resulting from manure and fertilizers. Source: RIVM, 2020. Image: Hanneke Wander, 2022.

Nature Network

Data: Nationaal Georegister, 2020.
Image: Hanneke Wander, 2022.

Despite nature networks being present in Friesland, these areas are scarce. A harsh line divides the protected nature area of the Wadden Sea, which became a UNESCO World Heritage in 2009, with Friesland behind the sea dike. Biodiversity loss, water pollution, and a lack of ecological corridors are consequences of the current monocultural agricultural practices.

Natura 2000 is a European network of protected nature areas to preserve biodiversity. Biodiversity in Europe has been under pressure for years. Therefore, the EU decided that the sustainable protection of flora and fauna is desperately needed. In this way, nature preservation is managed at the European level. All EU Member States designate protected areas for specific habitats of animal species. These form the Natura 2000 network (Ministry of Agriculture, Nature and Food Quality, 2020).
All Natura 2000 areas are part of the Nature Network of the Netherlands (NNN). The NNN includes further existing and planned nature areas and safeguards the quality of the natural values present. The protection of the Natura 2000 areas is stricter than that of the NNN since the latter does not have European targets set for preserving species and habitats (Provincie Zuid-Holland, 2020).

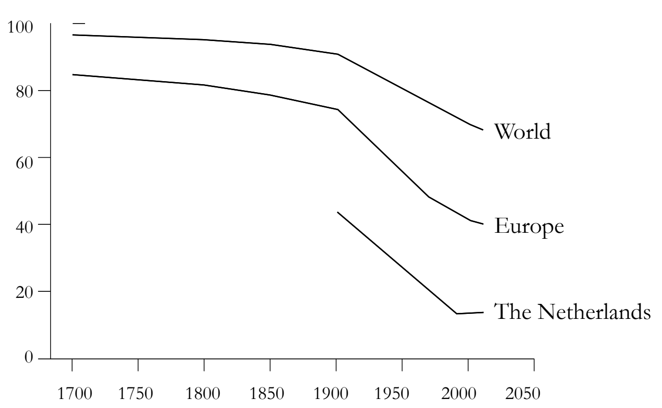


Biodiversity on a Rapid Decline

Data: Environmental Data Compendium 2020.

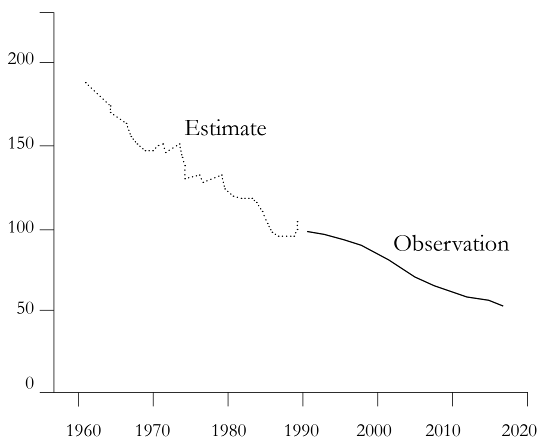
Biodiversity is the total variety of life on Earth and not only relates to individual species but also the diversity of ecosystems and their connections. Diversity increases the chance of survival when the environment changes. Biodiverse ecosystems are generally more resilient and thus able to cope with unpredictable conditions. Since biodiversity loss leads to increased vulnerability, the system can no longer perform its functions properly once disturbances occur. The World Food Organization has warned of the adverse effects on our food supply when sharp declines in biodiversity continuously occur (Erisman and Slobbe, 2019).
As seen in the graph below, biodiversity is at a record low in the Netherlands and well below the European average. Only 15% of the indigenous plant and animal species occurring in the Netherlands in 1900 have remained. Meanwhile, the European average is 40%. Few living habitats for species and intensive agriculture are the leading causes of this dramatic loss.
Moreover, this trend has translated to the populations of many native animal species, such as meadow birds, declining for years in the Netherlands. Numerous campaigns have been organized to raise awareness of this trend (Birger, 2020).

Biodiversity



Mean species abundance % of reference

Meadow birds in the Netherlands



Meadow bird indicator

Loss in Landscape Diversity

Over the years, the agricultural landscape has been heavily transformed to be able to produce the highest possible agricultural yields. Diverse landscape elements have disappeared, including house animal species and essential habitats. Biodiversity loss and ongoing changes in agricultural practices have led to a more monotonous and monocultural landscape, replacing small-scale and diversified allotments. Consequently, these changes have also influenced the aesthetic qualities of the landscape.

Lapwing (Kievit) | Black-tailed godwit (Grutto) | Oystercatcher (Scholekster) | Redshank (Tureluur)

Friesland Peatscapes.
Photo: Anna Gorokhova, 2023.

Atlas of Ideas

The exhibition.
Photo: Xinjian Jiang, 2023.

4 | Atlas of Ideas

Diving into Possible Futures

Laura Cipriani | TU Delft

This second part of the work—'Atlas of Ideas'—is the product of a work initially shared by the entire design studio class aimed at producing—thanks to a series of participatory techniques—shared scenarios and projects over the short, medium, and long terms. The adopted approach is focused on design as a research method by addressing global-scale challenges through regional-, local-, and small-scale interventions. Territories and cities affected by several climatic, environmental, and economic crises require a holistic approach: from ecological design to resilient planning, from the water management of extreme events to water quality issues and sea intrusion phenomena, and rural-urban landscapes to cultural landscapes and related economic-productive systems.

The design studio included several participatory phases involving the students and some institutional and non-institutional stakeholders to exchange knowledge and ideas. The workshop, entitled *Wet Sand. Wet Mud. Wet Land*, included a co-design session with the Province of Friesland, Wetteskip Frysland, and experts from multiple interdisciplinary fields. The working group highlighted effective short- and medium-term solutions whose effects could be extended to a long-term time horizon. Looking to the future is necessary to guarantee possibilities that make the territory productive, even in the short term. All of the proposed plans are based on simple elements and aim to redevelop the landscape by strengthening existing micro-economies or establishing latent economies that can become seeds of potential development. Each project starts mainly from the site specificities of the territory to embrace possible futures and design possibilities.

Following the research and project phases, the work was presented at a symposium and exhibition in Leeuwarden to propose small steps of collective action to narrate and promote the territory, its specificities, its crises, and the possibilities for change. The event, *Embracing the Future of the Wadden Sea Landscapes: Voices and Imageries from Students and Educators*, aimed

The exhibition.
Photo: Xinjian Jiang, 2023.

The workshop *Wet Sand. Wet Mud. Wet Land* at TU Delft to envision a common future starting from sand, clay and peat. TU Delft students (Anna Gorokhova, Xinjian Jiang, Zhaolei Li) worked together with an interdisciplinary group of professors (Diego Sepulveda, Laura Cipriani, and Peter Herman) in conjunction with the Province of Fryslân (Stephan Smeijers) and the Friesland water authority called Wetterskip Fryslân (Joca Jansen).

Photos featuring the workshop *Wet Sand. Wet Mud. Wet Land*. Photos: Laura Cipriani, 2023.

The symposium and exhibition *Embracing the Future of the Wadden Sea Landscapes: Voices and Imageries from Students and Educators* aimed to propose a moment of reflection and exchange between landscape architecture schools, institutions, and associations. The event was organized within the Landscape Triennale by Laura Cipriani with Saskia de Wit and was hosted by the Province of Friesland in Leeuwarden. Representatives came from TU Delft, Wageningen University, Amsterdam Academy of Architecture, Hanze Academy of Architecture, Lund University, NVTL, Wadden Academy, Province of Fryslân, Wetterskip Fryslân, and the Landscape Triennale.

Photos featuring the symposium and exhibition *Embracing the Future of the Wadden Sea Landscape*. Photos: Laura Cipriani, 2023.

to propose a moment of reflection and exchange between landscape architecture schools, institutions, and associations. How do young generations and educators envision the future of the Wadden Sea territories? How will these landscapes be modified in the years to come? How do we embrace the past and present and imagine the future? The event focused on landscape design as a catalyst for change. Students and educators presented design results and ideas on the future of the Wadden Sea coasts and landscapes, from the sea to the beach to the rural and urban inland areas.

The hope is to focus on the future of these places, on *fluid soils* and their ecological and climatic transitions, without forgetting how the hope for change starts constructing a *landscape thinking* in the minds of younger generations. Collective work is a way to encourage the construction of transdisciplinary education to tackle today's unprecedented uncertainties and challenges. As in a geological process, I hope that changes to existing practices will take root in the minds and actions of these future professionals. As American soil scientist Charles Kellog once said: '*Nature has endowed the earth with glorious wonders and vast resources that man may use for his own ends. Regardless of our tastes or our way of living, there are none that present more variations to tax our imagination than the soil, and certainly none so important to our ancestors, to ourselves, and to our children*' (Kellog, 1941).

Walking along the sea dike.
Photo: Heather Wong, 2022.

5 | Regression and Progression

Toward a Regenerative Coastal Landscape

Student | Heather Wong

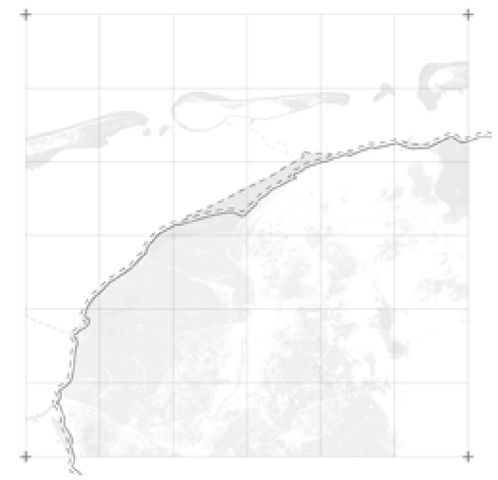
First Mentor | Laura Cipriani
Second Mentor | Mark Voorendt

The Wadden Coast is confronting the vulnerability of climate change, a declining population, and an increase in recreation and tourism. To ensure a more sustainable future for this sensitive landscape, the following research questions arise: 'How can we create a resilient landscape that facilitates sustainable flood protection and socio-economic development for climate adaptation in the Dutch Wadden Sea?' Other than raising the level of the sea dike and continuously fragmenting the landscape, what are the alternative landscape-integrated flood defense approaches that could be used to adapt to future climatic issues? How can we strengthen the connection between the Wadden Sea and the hinterlands through design?

The research project starts with a context analysis at the territorial scale, which is the entire Wadden Sea region across three countries, then scaling down to the regional and local scales—mainly in the north of Friesland along the Wadden Coast. The landscape-based approach is considered essential for developing the capacity to face natural and human-made threats in multiple conditions since it offers a guide to shaping spatial transformations in different time frames. Design transition is another critical 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. Taking the existing qualities as a starting point for development, the flood defense systems and the water heritage are the primary drivers of the design to strengthen local identities, develop resiliency and adaptive capacity, and facilitate socio-economic development in the region.

The scopes of landscape architecture have been increasingly widened in the following ways: 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 them in multiple layers and scales, working in a multi-disciplinary manner to prepare blue-green infrastructure plans and implementation strategies. By interpreting the Wadden coast as infrastructure, the graduation project focuses on the water and flood defense system by working with the cultural and socio-economic flows from the regional to the local scale.

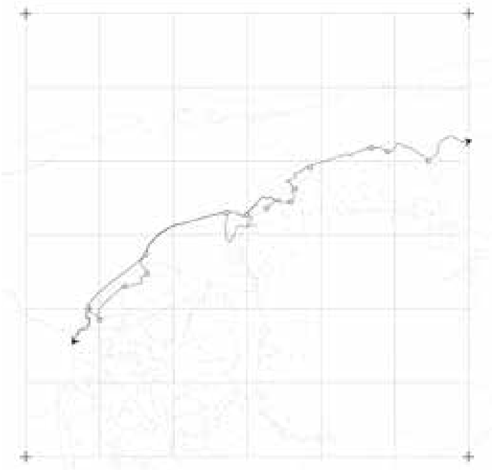
Strategies



Climate Adaptive Waterscape

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

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

Socio-Economic

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

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

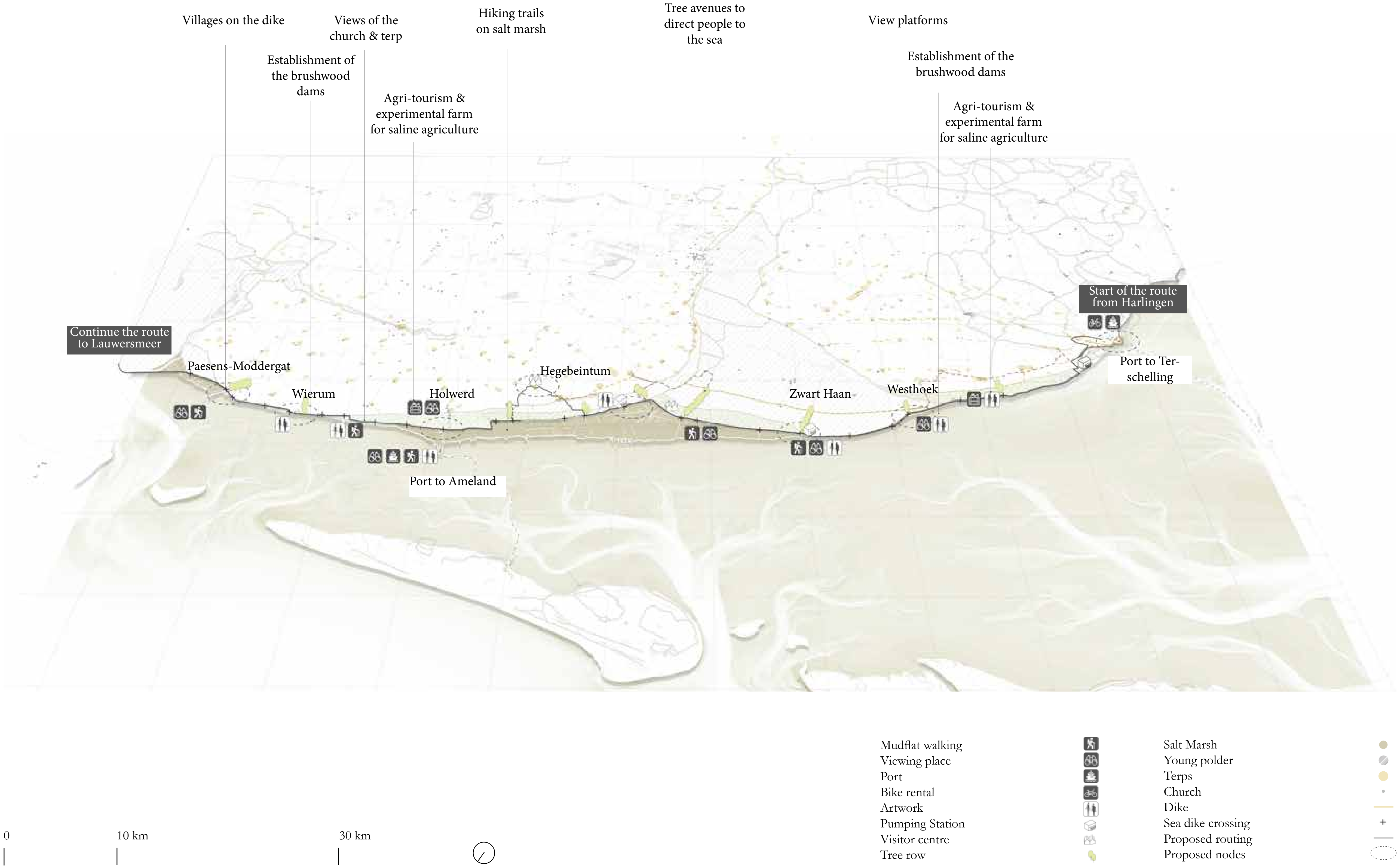
Three design pillars act as a fundamental basis in the project. The water, cultural and socio-economic layer analysis induce the design in three concepts (climate-robust waterscape, water heritage and valuable waterscape). Based on the pillars, three design strategies are made to respond to the problem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

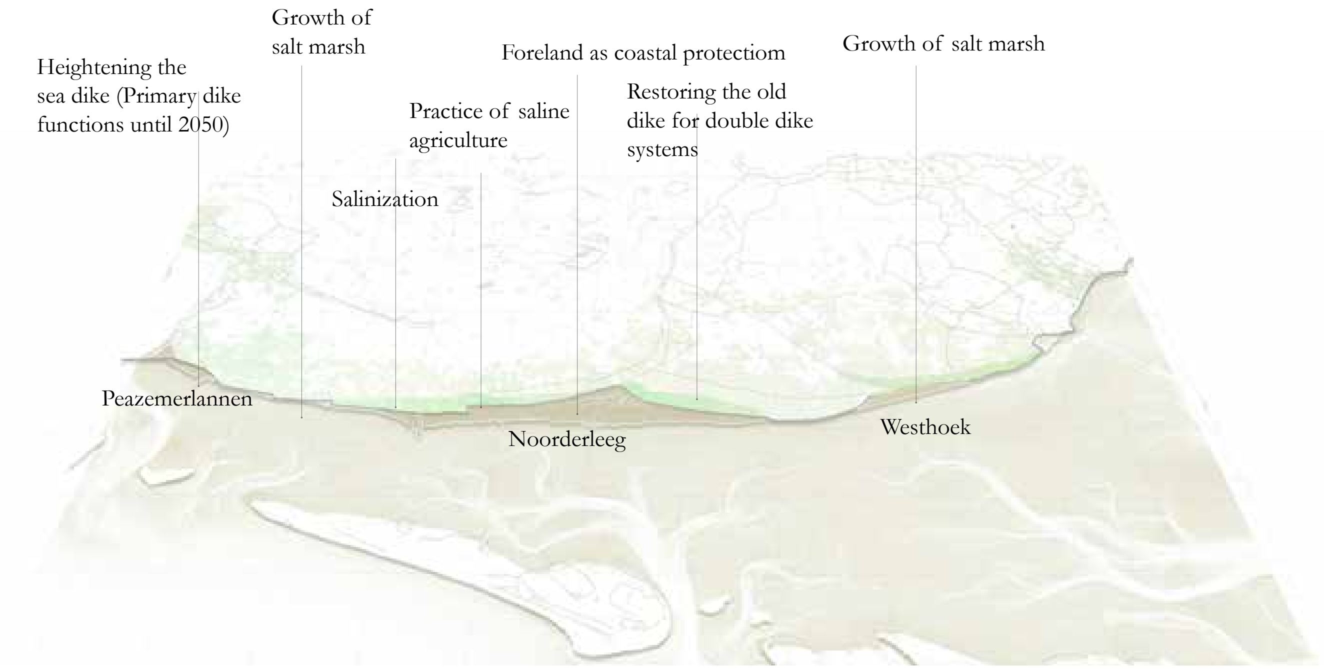
The last strategy is to enhance the regional economy and livability by bringing new opportunities like saline agriculture and agri-tourism in the region. Routing connecting to the Wadden Islands could boost tourism and other social values.

2030

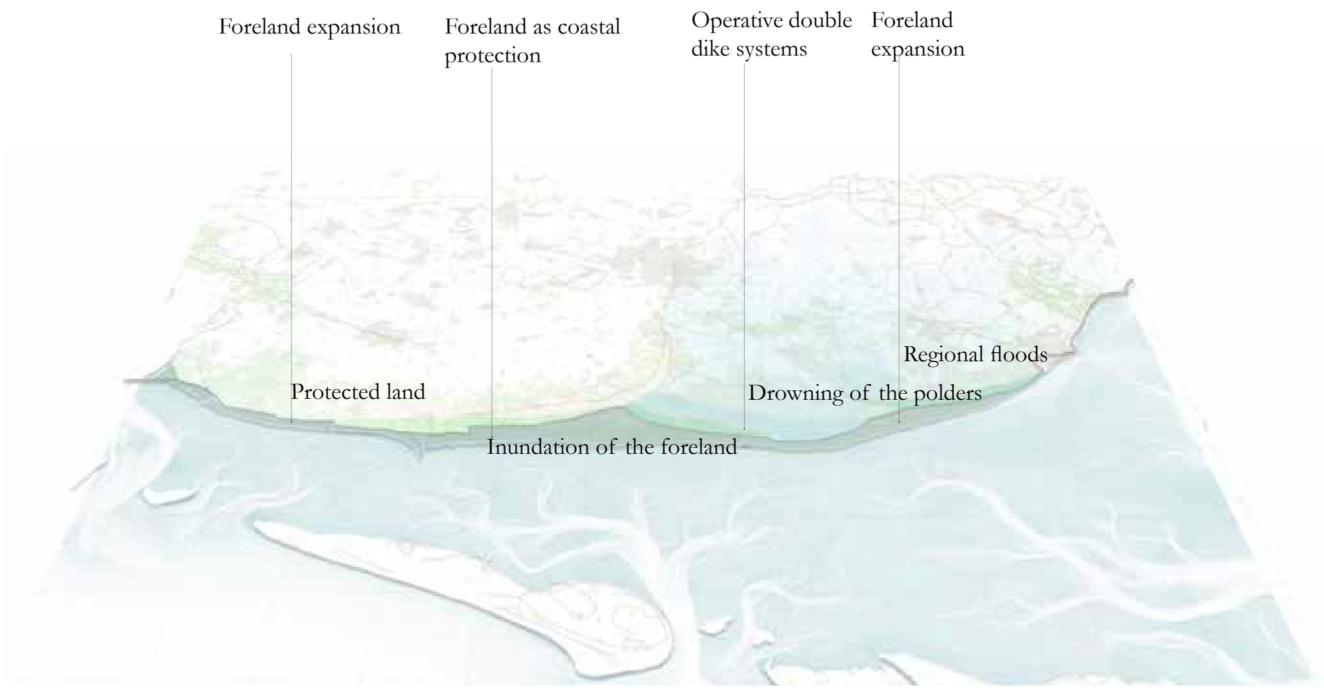


In 2030, the plan focuses on strengthening the landscape identity and enriching the experience along the coast. A routing from Harlingen to Lauwersmeer is designed, connecting to the ports and other interesting nodes. The route, which emphasizes the water heritage, will guide people to visit the terps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

2050



2070

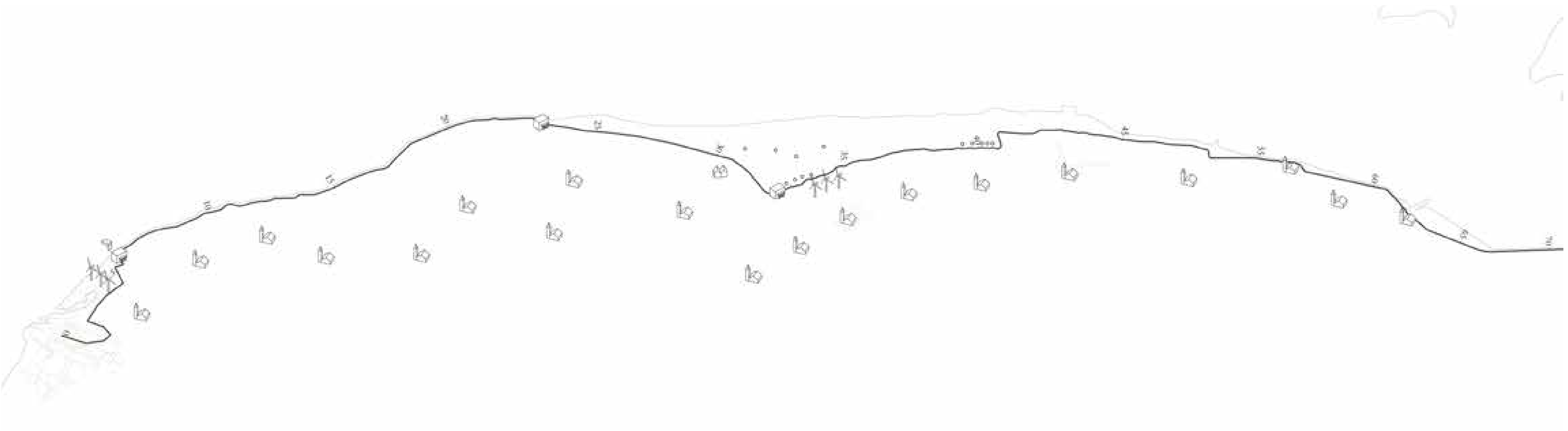


The plan for 2050 is critical to preparing for climate adaptation. Two landscape-integrated flood defense systems will protect the area from flooding. A salt marsh with a valuable ecosystem will be expanded to form a buffer zone for reducing wave energy. Restoring the old dikes could form a secondary defense for the double dike systems. Dike reinforcement that is integrated with the landscape is necessary to meet national safety standards. Saline agriculture is a measure that can be used to adapt the increased salinity in the polder as a new type of production.

The climate in 2070 is highly uncertain. The ideal condition is that the flood defense systems are fully functional and can safeguard the land from high water levels. The foreland will further expand to 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 and ecological and economic functions to enhance resilience in the future.

Routing.
Photo: Heather Wong, 2022.

Routing Experience

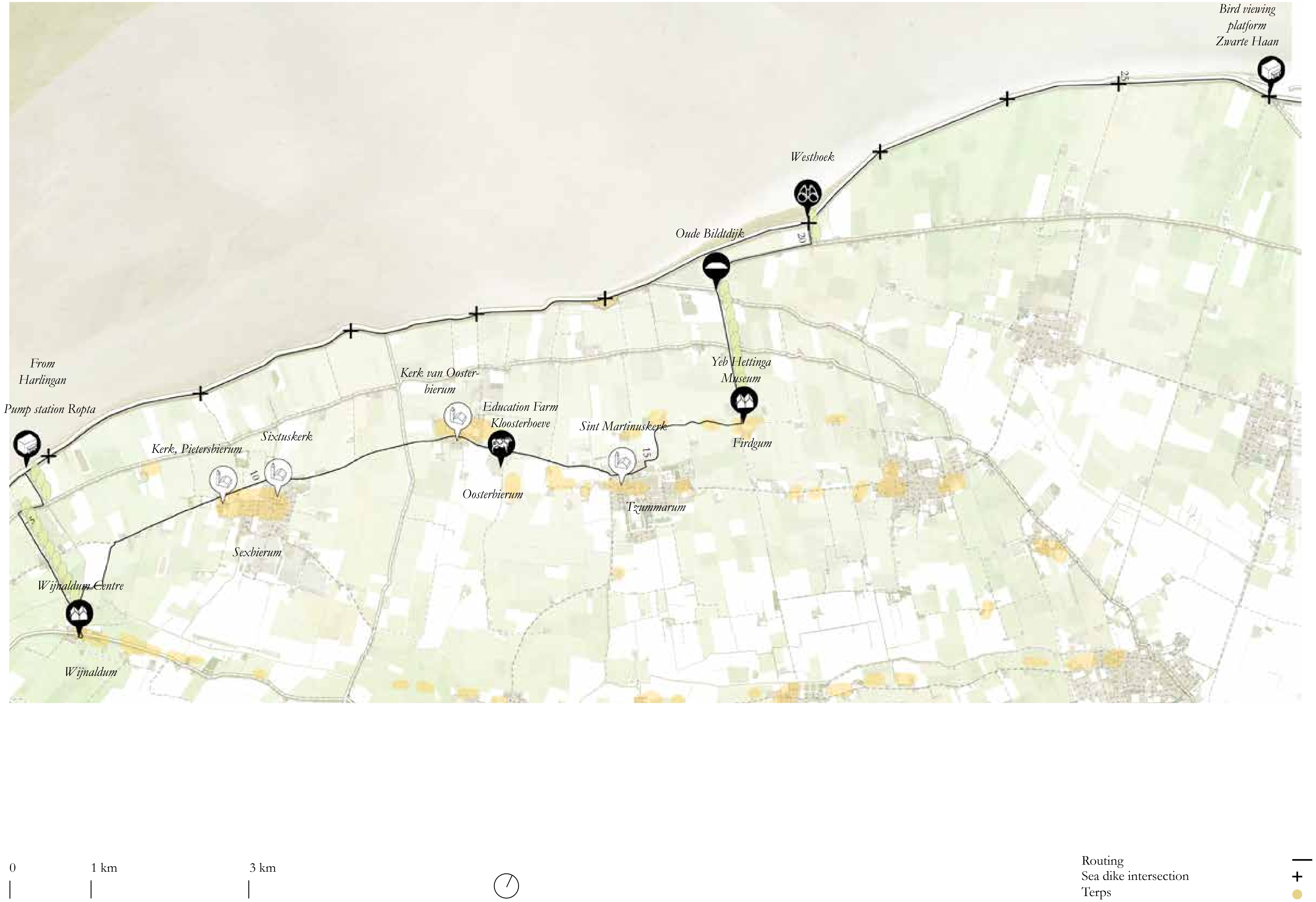


Along the Wadden coast landscape, the church towers and wind turbines are the primary visual points on the horizon. As a visitor, the journey within the dike is not as fascinating as outside the dike due to the lack of visual reference points. The route has the potential for forming a recreational, cultural tour together with the terps. Therefore, three design principles were adopted for routing, strengthening the connectivity and sensory experience, as well as creating new nodes.

Church
Pumping Station
Wind turbine
Lookout
Visitor center
Dobben

Wadden Water

Routing Design



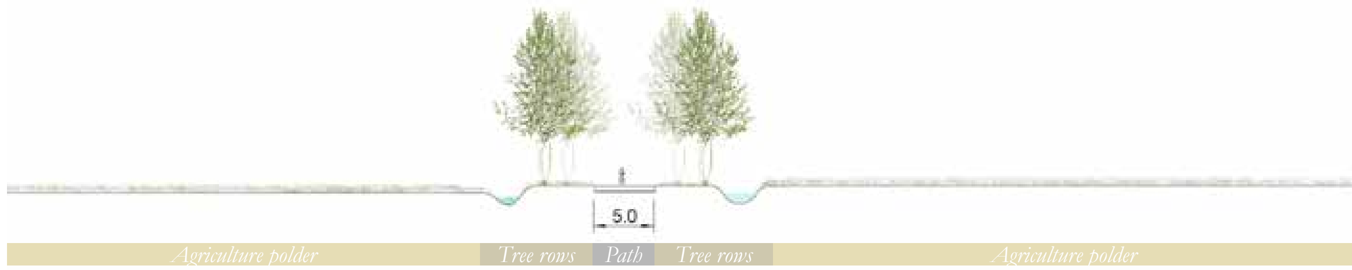
This map demonstrates the routing in Kohoek starting from the city of Harlingen, a lovely port city in Friesland where you could rent a car or a bike for the trip. Harlingen is also connected to Vlieland and Terschelling by ferry. The first stop on the route is the Ropta pumping station, where the excess water from the polder is discharged to the Wadden Sea. A viewing platform brings you to see the deep water of the Wadden Sea. Thereafter, you could travel along the coast or make a detour to the terp villages. Along the coast, some points allow you to bike on the top of the sea dike, which gives 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 Frisian villages such as Sexbierum and Tzummarum, where you can visit their museums and water heritage sites (e.g., churches on the terps). The route also brings you through the OudeBildtdijk—an old sea dike—and the polders that used to be the salt marsh in the sea. The detour ends up at Westhoek, which is an excellent birdwatching area with a high salt marsh along the coast. A design intervention will be placed as a viewing platform.

Routing —
Sea dike intersection +
Terps ●

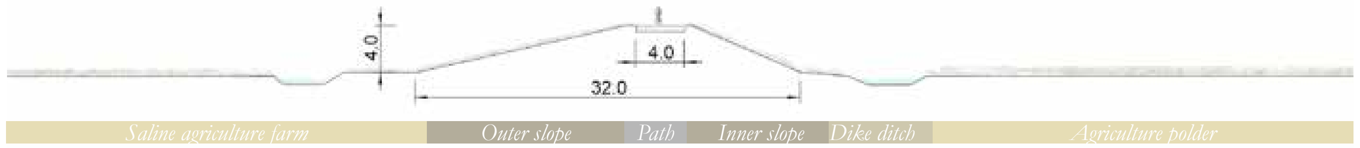
Routing Design

Section 1 Bike path along the canel to the terp village

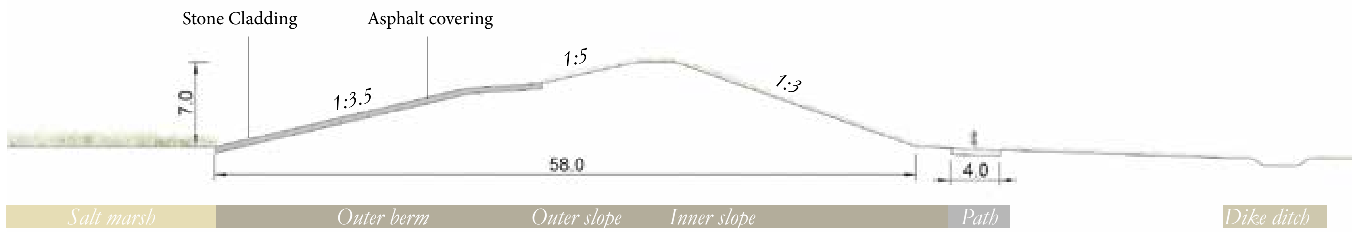
Section 2 Tree avenue leading towards the Wadden coast



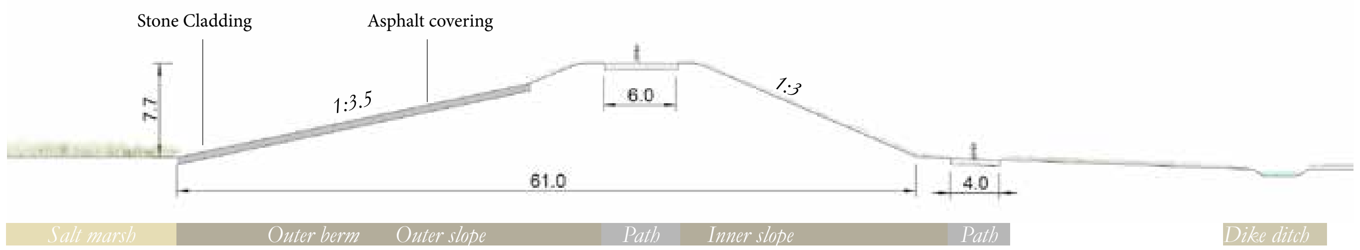
Section 3 Route on the old dike



Section 4 Route along the sea dike



Section 5 Route on top of the sea dike



Design Time Phase

2030

Routing design

2050

Establishment of the brushwood dam

Old dike restoration

Saline agriculture

2070

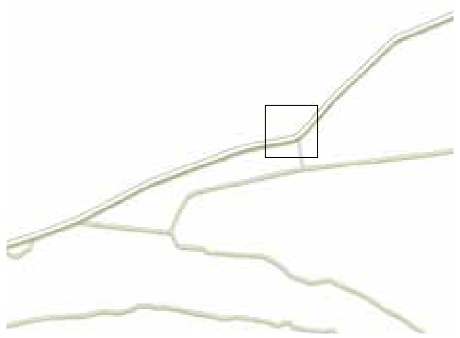
Salt marsh expansion

Functional double dike systems

Tree avenues and design interventions could already be in place by 2030. The route passing through the water heritage sites invites visitors to explore this cultural coastal landscape after a mudflat walk 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 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.

Salt marsh in design location.
Photo: Google Earth, 2024. Map data:
Google ©2024 Aerodata International
Surveys, GeoContent, Maxar Technologies,
Dati Cartografici.

Design Interventions



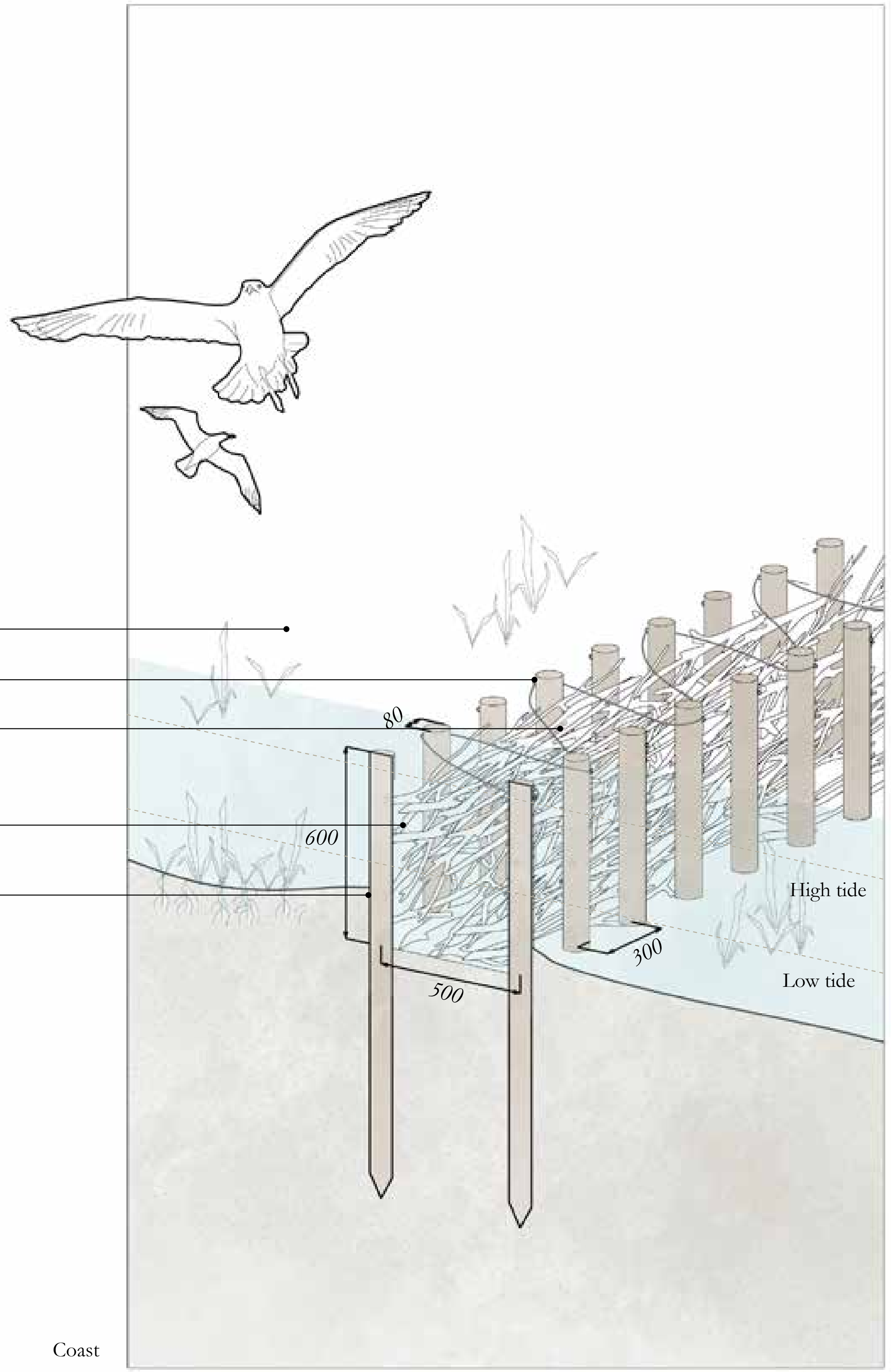
One of the proposed design interventions is the viewing platform in conjunction with Westhoek. This wooden platform is an extension of the path from the dike to the mudflat. The 3-m-tall platform allows you to pass through the salt marsh and have a panoramic view over the Wadden Coast all day, regardless of the tidal change. A treed avenue will direct people to the viewing platform to observe this attractive landscape.

0 10 m 50 m

Brushwood Dams

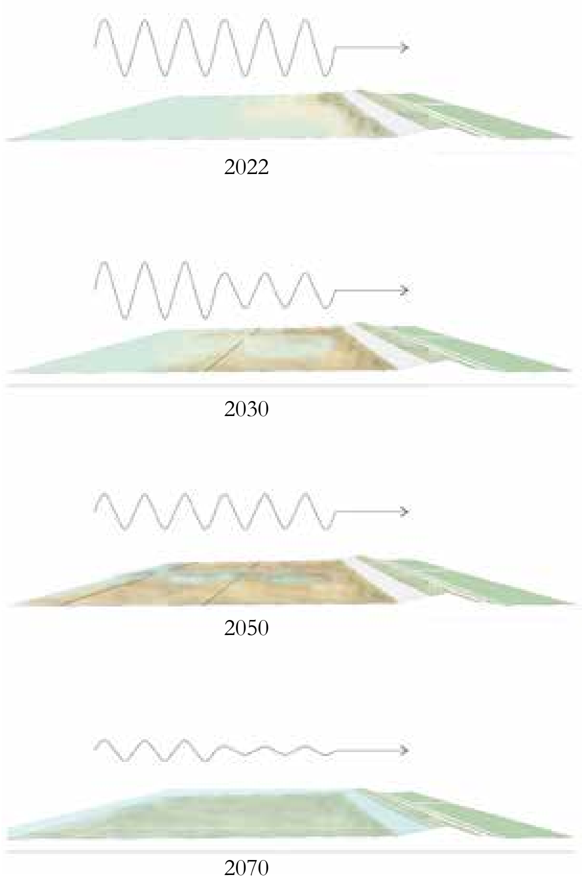
Brushwood dams have been a traditional device used to facilitate accretion in the Wadden Sea since the 18th century (Winterwerp et al, 2020). This type of permeable dam is a nature-based solution that functions like a mangrove forest to reduce wave impact at high tide and enhance the deposition of fine sediment. It comprises two rows of wooden poles with brushwood placed in between. When siltation reaches a certain level, new basins are formed in front. Vegetation begins to grow and expand on the new basins. The T-shaped dams are the most effective form since they allow sediment to enter the basin through the openings within the dam in intertidal areas. This method naturally results in a drainage channel and prevents lateral losses (Winterwerp et al, 2020).

Brushwood dam in Frisland.
Photo: Philipp , 2021.

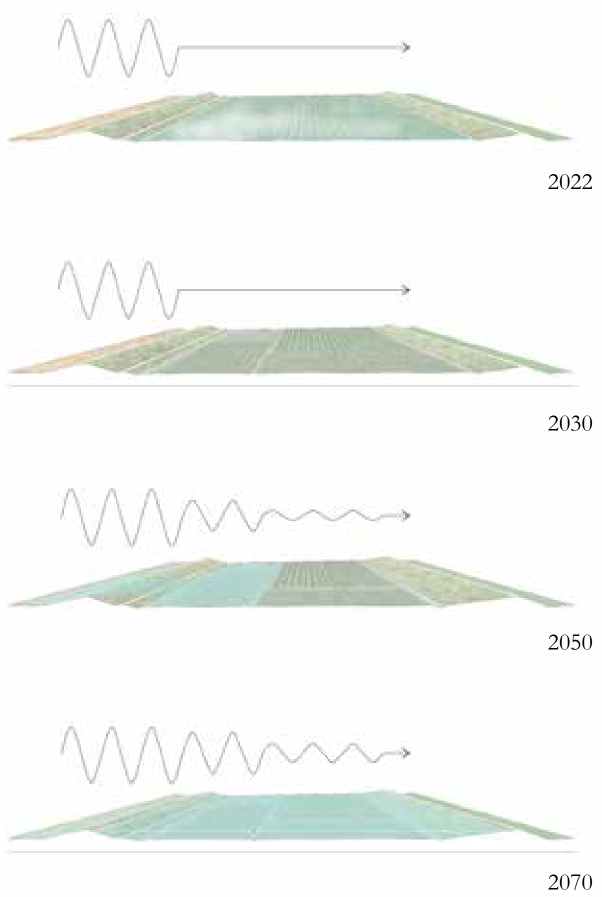


Two Coastal Defense Systems

Progression
Salt marsh defense system

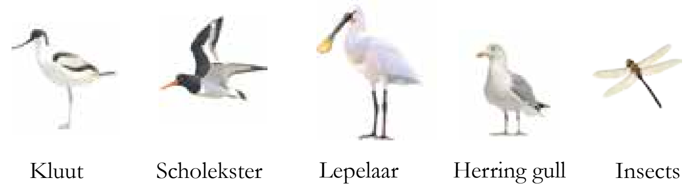


Regression
Double dike system



Grazing in summer

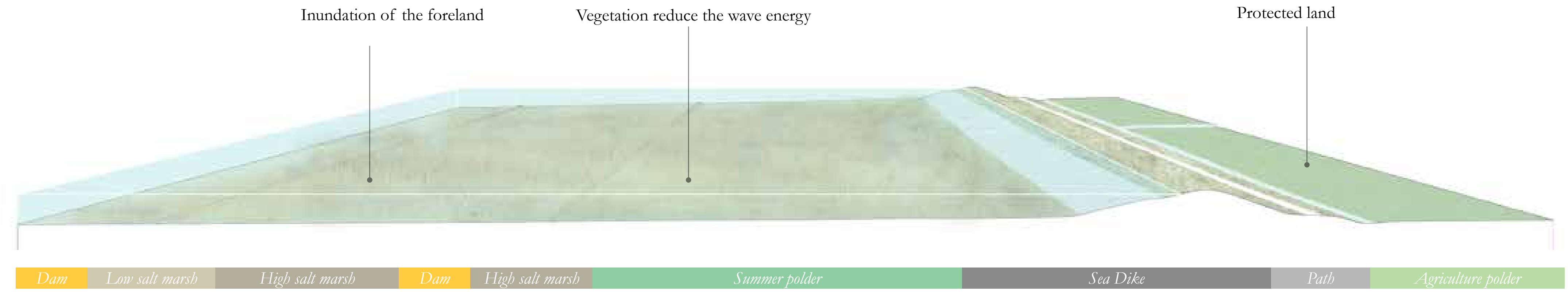
Nesting grounds for birds



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

Double dike systems, which allow the overtopping of water with a secondary dike, act as a regression approach. The double dike aligns 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 economic and social benefits for the wider coastal community and environment.

Salt Marsh Defense Systems 2070



Salt Marsh

Low tide

High tide

Salt marsh.
Photo: Xinjian Jiang, 2022.

White electic windmill.
Photo: Nicholas Doherty, 2019.

6 | Unpaving Nature

Restoring Balance Between Nature and Infrastructure

Student | Xinjian Jiang

First Mentor | Laura Cipriani
Second Mentor | Peter Herman

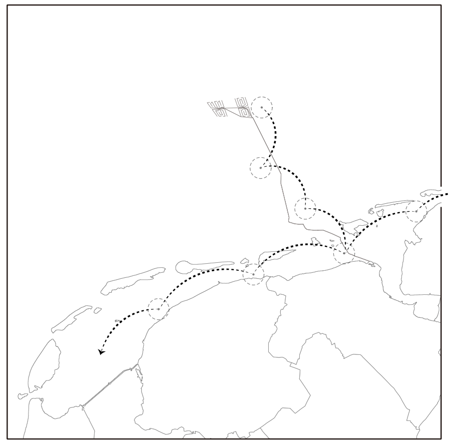
The Wadden Sea is a unique and ecologically important coastal region in the southeastern North Sea, stretching along the coasts of Denmark, Germany, and the Netherlands. It is known for its vast tidal flats, salt marshes, and barrier islands, forming a dynamic and constantly changing landscape rich in biodiversity.

In the Netherlands, the Wadden Sea is composed of the mainland coastal areas and the Wadden Islands (such as Texel, Vlieland, Terschelling, Ameland, and Schiermonnikoog). This area serves a crucial role in protecting the land and supporting the people living there. It serves as a natural defense against storm surges and flooding, supports local businesses through fishing and tourism, and provides a vital ecosystem for numerous plant and animal species.

However, infrastructure development in the Wadden Sea area—including offshore wind farms, shipping routes, and coastal engineering—has impacted some ecosystems. The development is necessary for economic growth, such as shipping infrastructure for tourism on the Wadden Islands and offshore wind energy due to the energy crisis. These developments will shape the landscape in the coming years.

For this thesis, data on infrastructure and ecology were collected and analyzed to identify conflicts between them and how they affect the landscape. This research formed the basis for the design phase. Then, for the territorial scale, three strategies were proposed. Moreover, two sites were chosen to demonstrate how these strategies can be applied to site-specific design. Both sites share the notion of preserving and adapting positive landscape features and restoring the natural process, thereby achieving minimal intervention.

Strategies

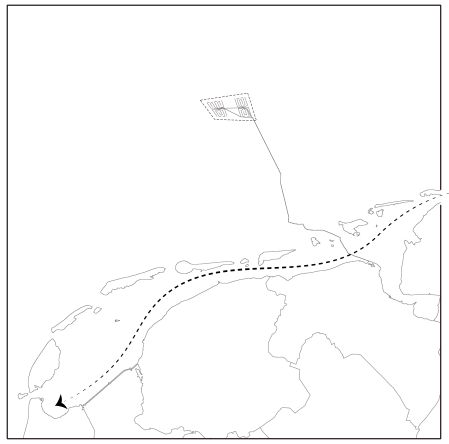


Seabed Ecology

STRATEGY 1

Protect and restore different habitats on seabed and enhance connection of each ecosystem

- Restore the seagrass bad in the Wadden Sea area
- Recover the shellfish reefs with wind farm sturcture
- Enhance connection between ecosystems

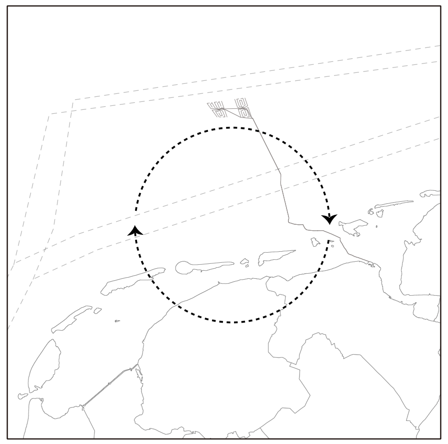


Climate Resilience

STRATEGY 2

Develop a landscape-integrated approach to enhance the ability of carbon sequestration

- Expansion of salt marshes for coastal defence and more carbon sequestration
- Restore various ecosystems to sequester more carbon

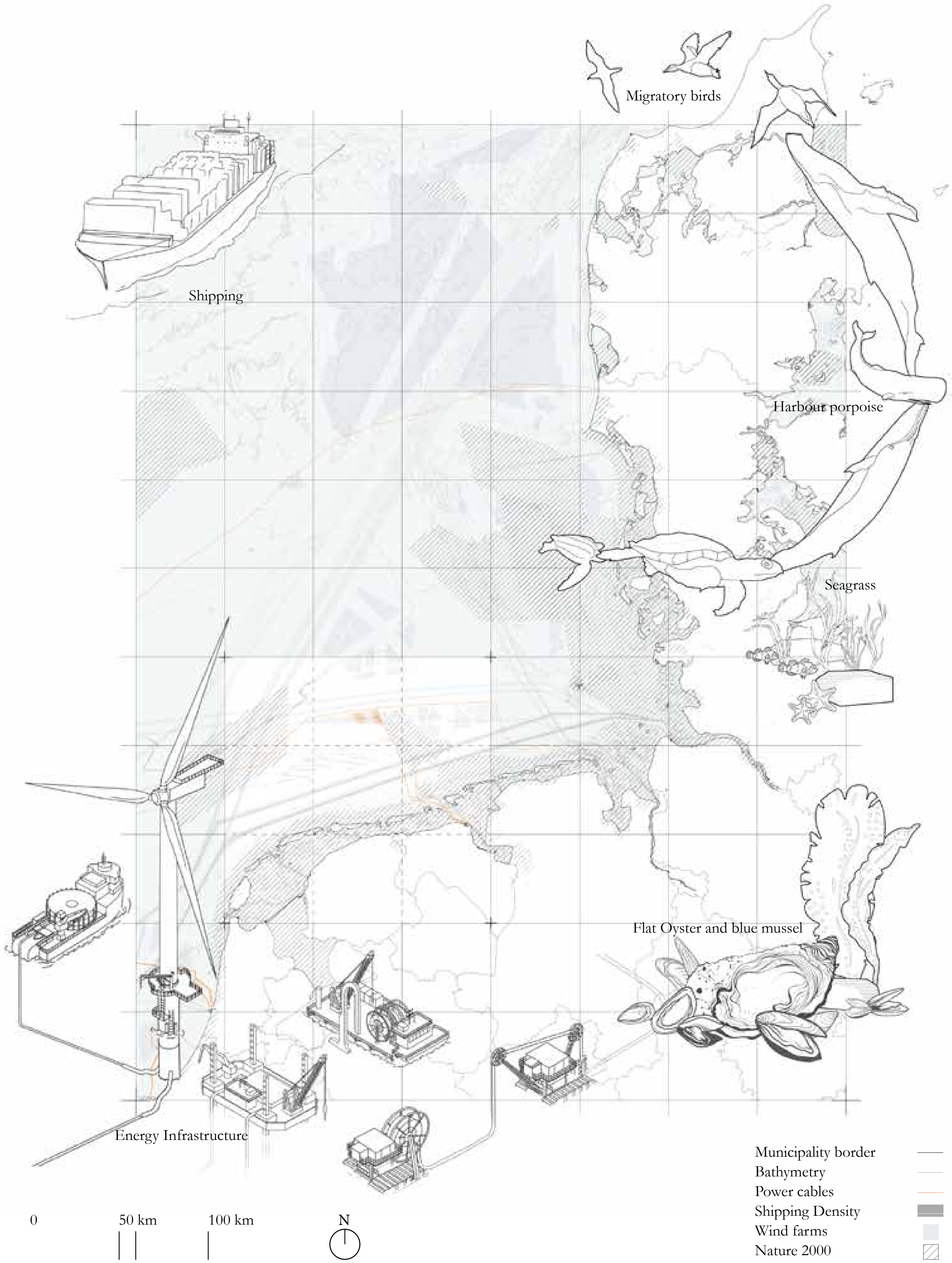


Blue Economy

STRATEGY 3

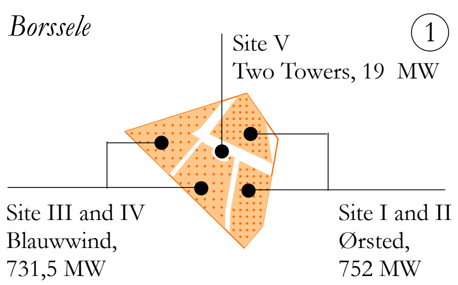
Develop integrated offshore infrastructures to enhance the blue economy.

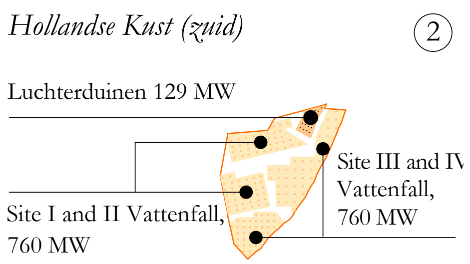
- Develop integrated offshore renewable energy
- Renew the standards for the decommissioning of offshore platforms
- Develop green infrastructure in coastal area combined with tourism and education

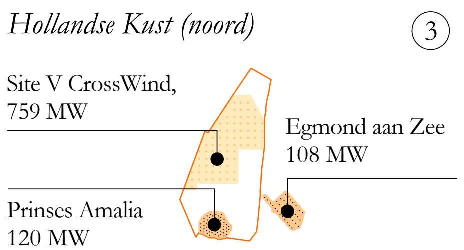


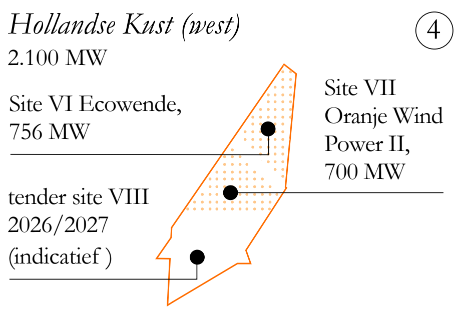
The Offshore Wind Park.
Photo: Jesse De Meulenaere, 2022.

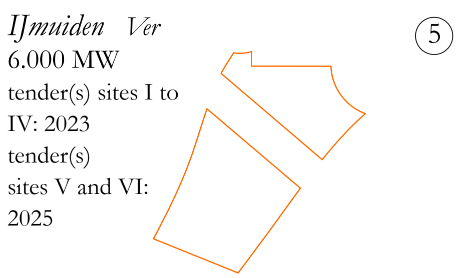
Dutch Wind Energy Target

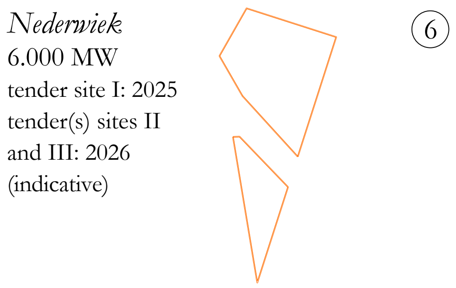


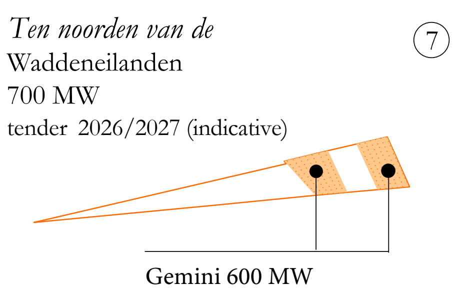


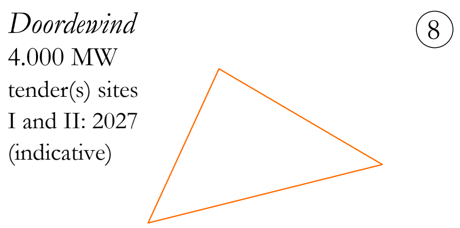


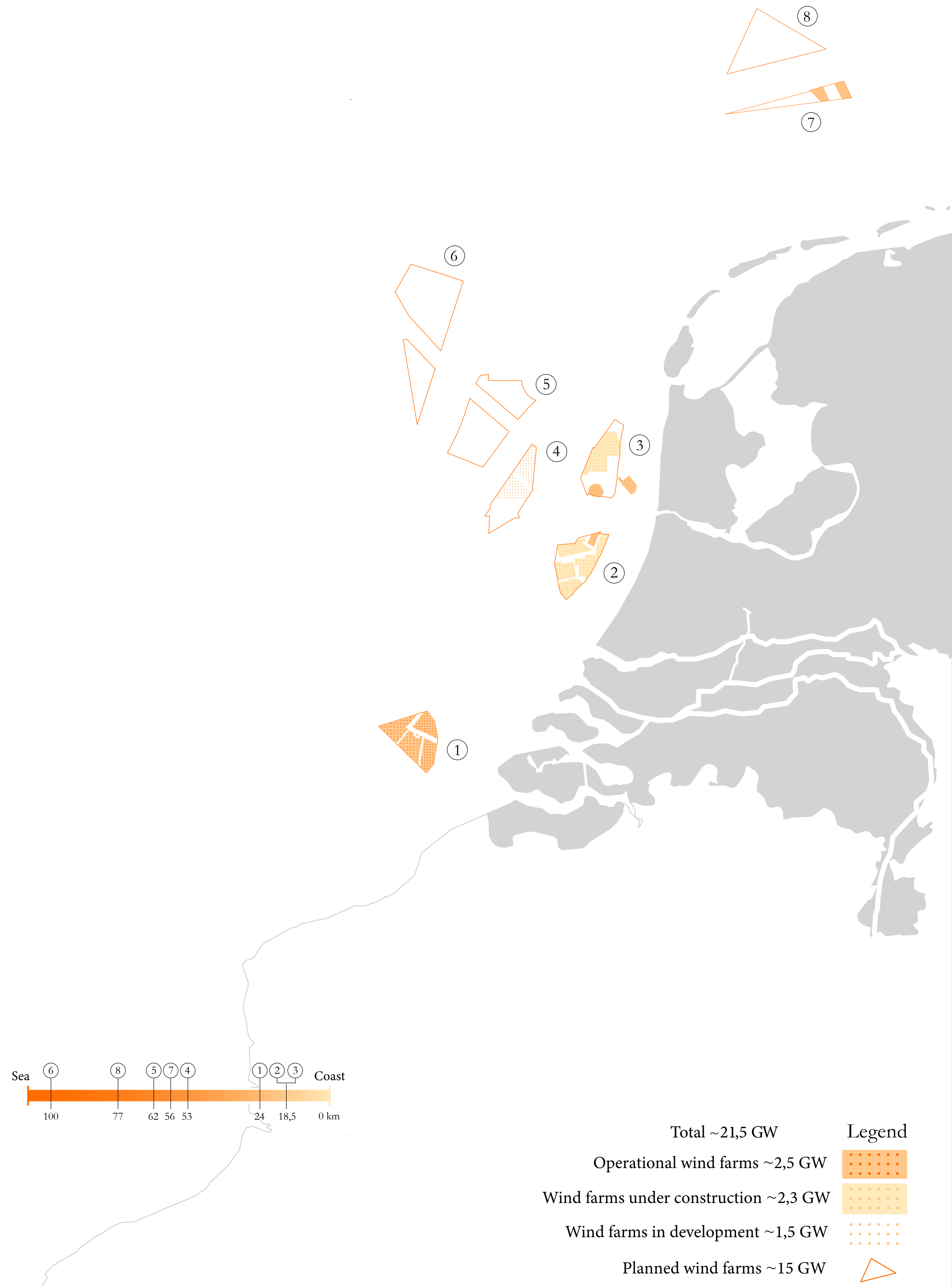






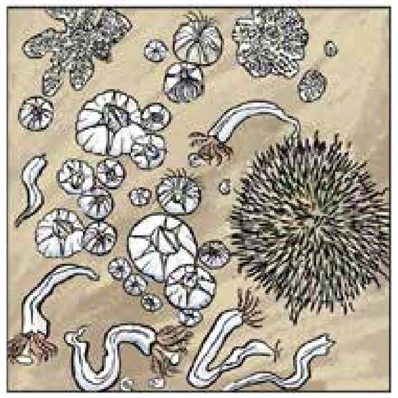






Eco Effect of Artificial Structure

European flat oyster | Alcyonium digitatum | Corynactis viridis | Blue mussel | Cancer pagurus | Homarus gammarus



Pioneer Stage
0-2 Years

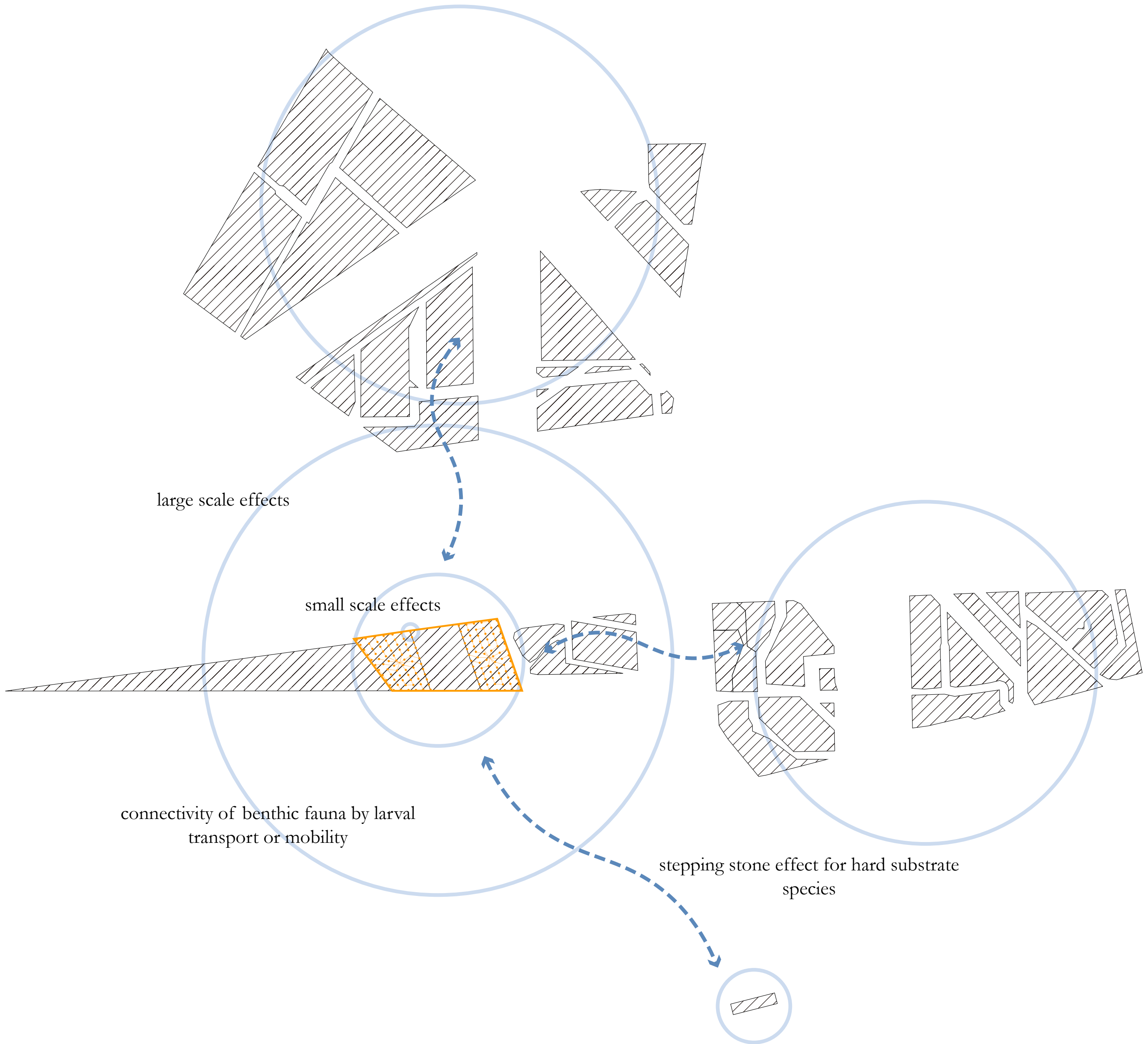
Intermediate Stage
3-5 Years

Climax Stage
6+ Years

The submerged parts of offshore wind farms act as artificial reefs since flora and fauna gradually colonize the structure.

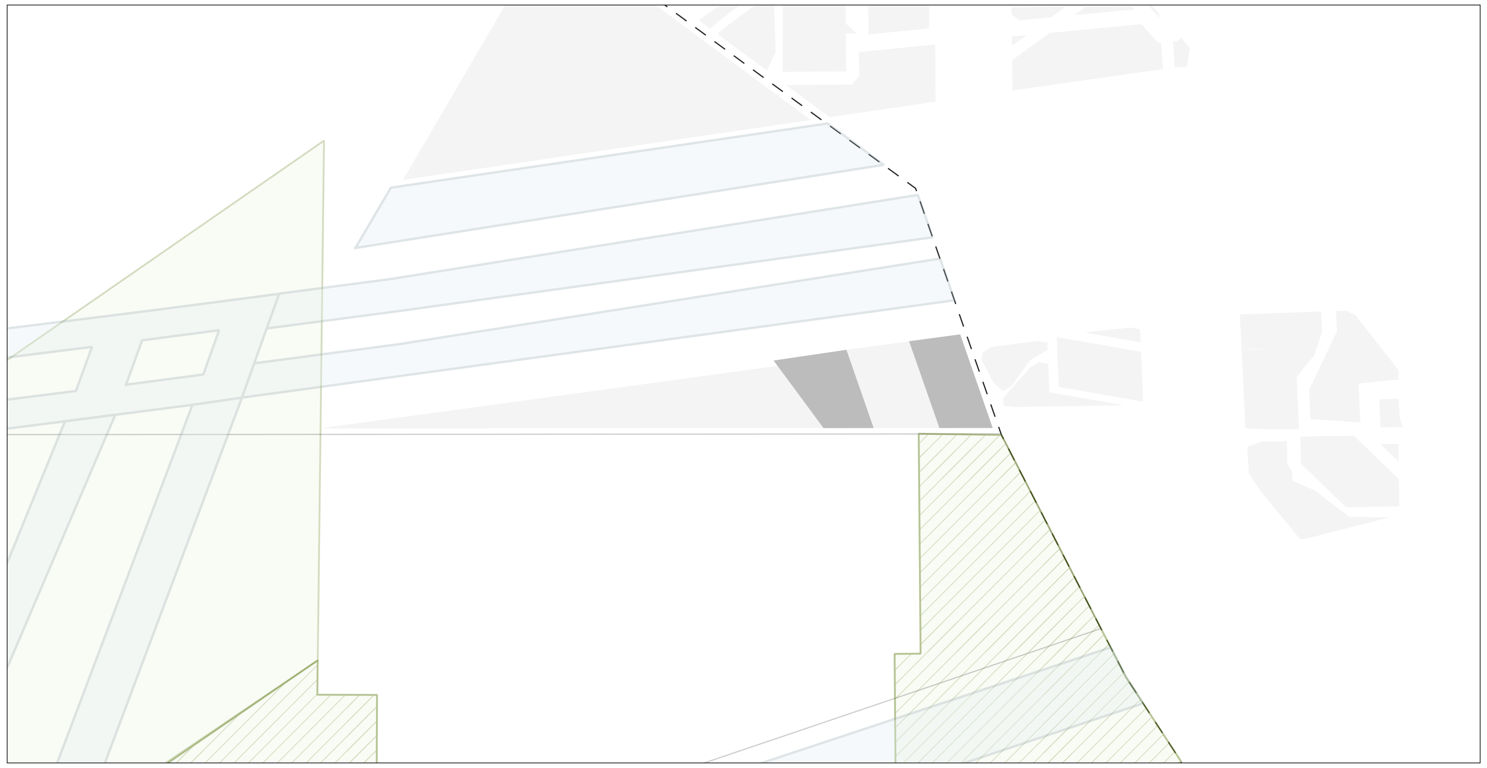
Sphere of Influence

Source: Offshore Wind Farm Artificial Reefs Affect Ecosystem Structure and Functioning: A Synthesis, 2020.



Wadden Sea World Heritage Site.
Photo: Zhaolei Li, 2023.

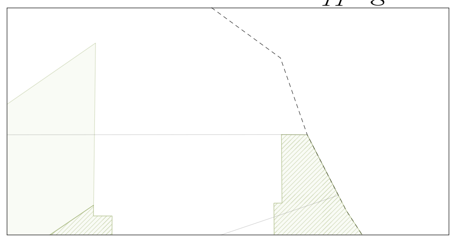
The Gemini Offshore Wind Park | Process



Maritime Spatial Planning

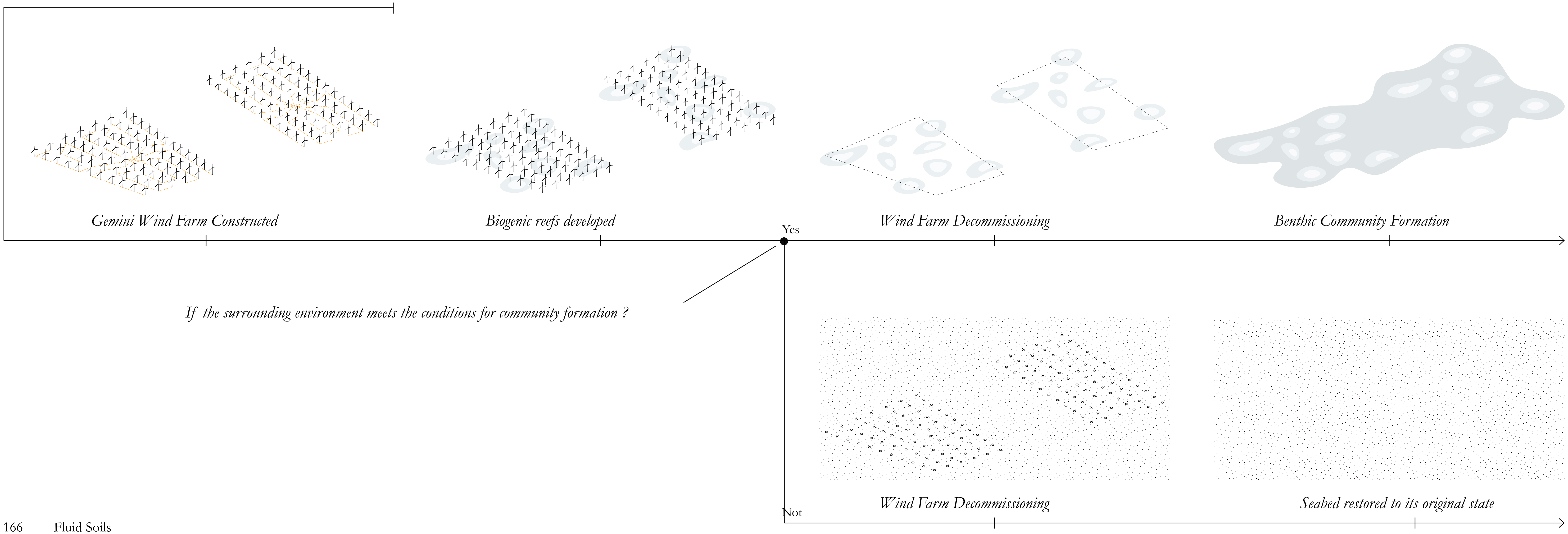
Wind farms

Shipping Area

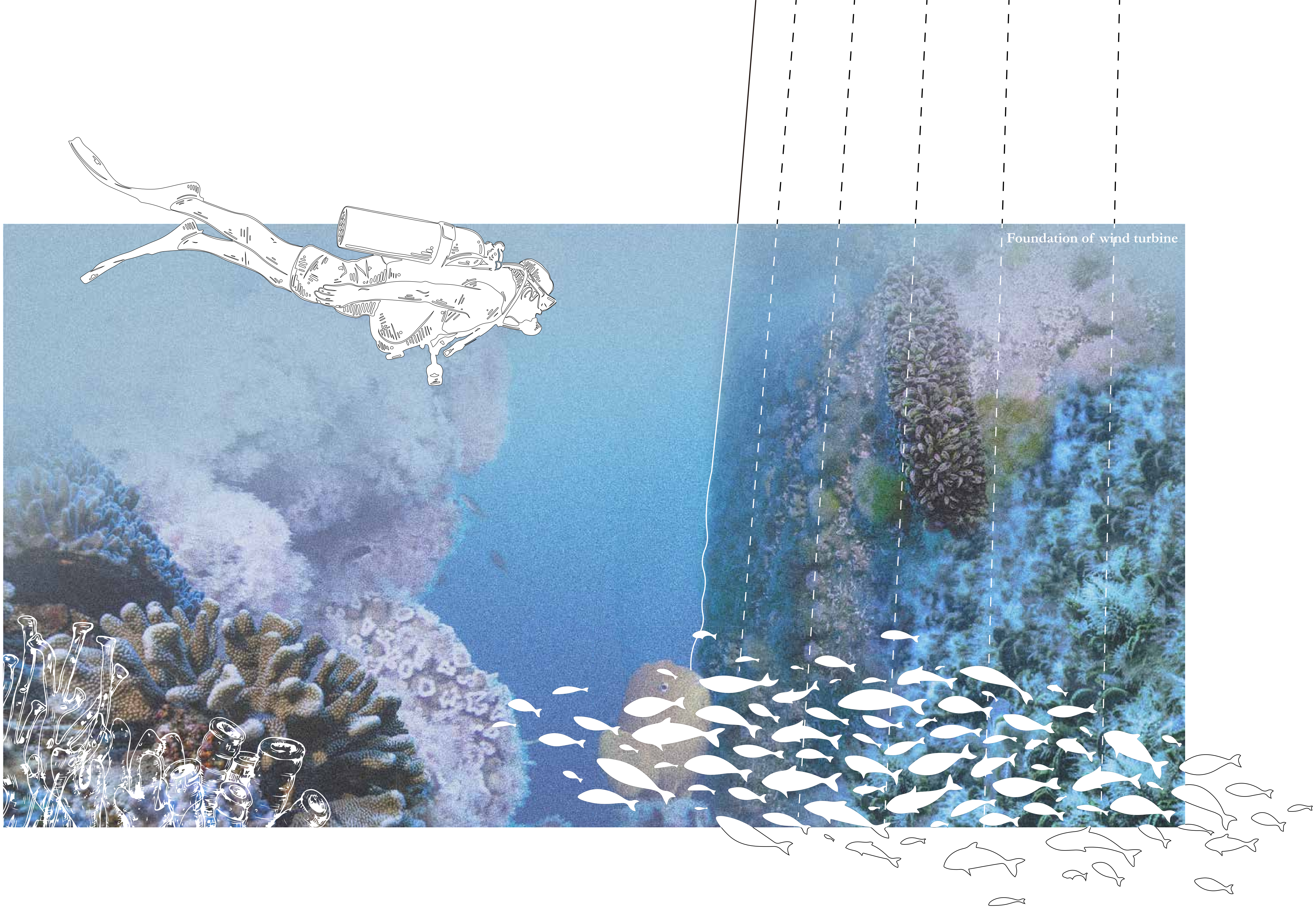


Other Areas

- Wind farm
- Gemini Wind Farm
- Nature 2000
- MSFD Area
- Shipping Area
- Exclusive Economic Zone (EEZ)
- Military Area



Impression



Why Holwert?

Importance

The mudflats south of Ameland are becoming higher and drier. The Wadden Sea carries more sand and silt at high tide than the sea discharges at low tide. The seabed south of the island has been rising by several millimeters per year over the past few decades.

At Holwerd, the current east of the ferry dam is restricted. As a result, silt sinks to the bottom. We call this the tidal flats. The salt marshes also grow toward the sea, giving the Wadden Sea less and less space. These are uncontrollable, natural processes that are causing the channels to become longer and narrower. Therefore, dredging the channel between Ameland and Holwerd is required over an increasing length.

- Due to natural processes, the shipping channel between Ameland and Holwerd is silting up.
- For every passenger traveling to Ameland, we dredge three trailers full of sand and silt.
- This intensive dredging disturbs nature and is very expensive.
- The ferry is also regularly delayed.
- We expect the silting of the channel to continue.

82000 cars make the crossing per year

670000 residents/tourists make the crossing per year

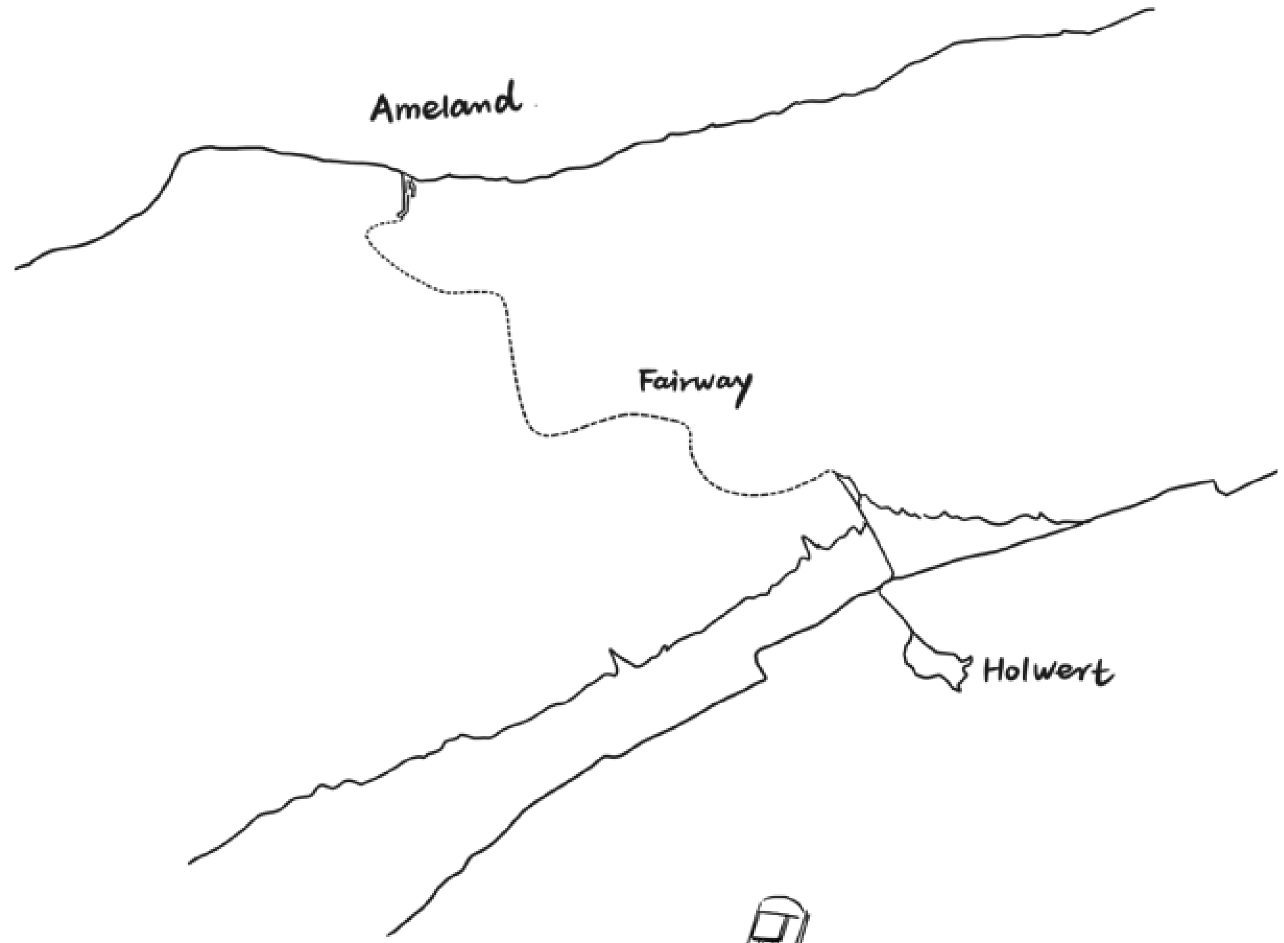
100000 metres of freight crossings per year

6600 sailings ferry services per year

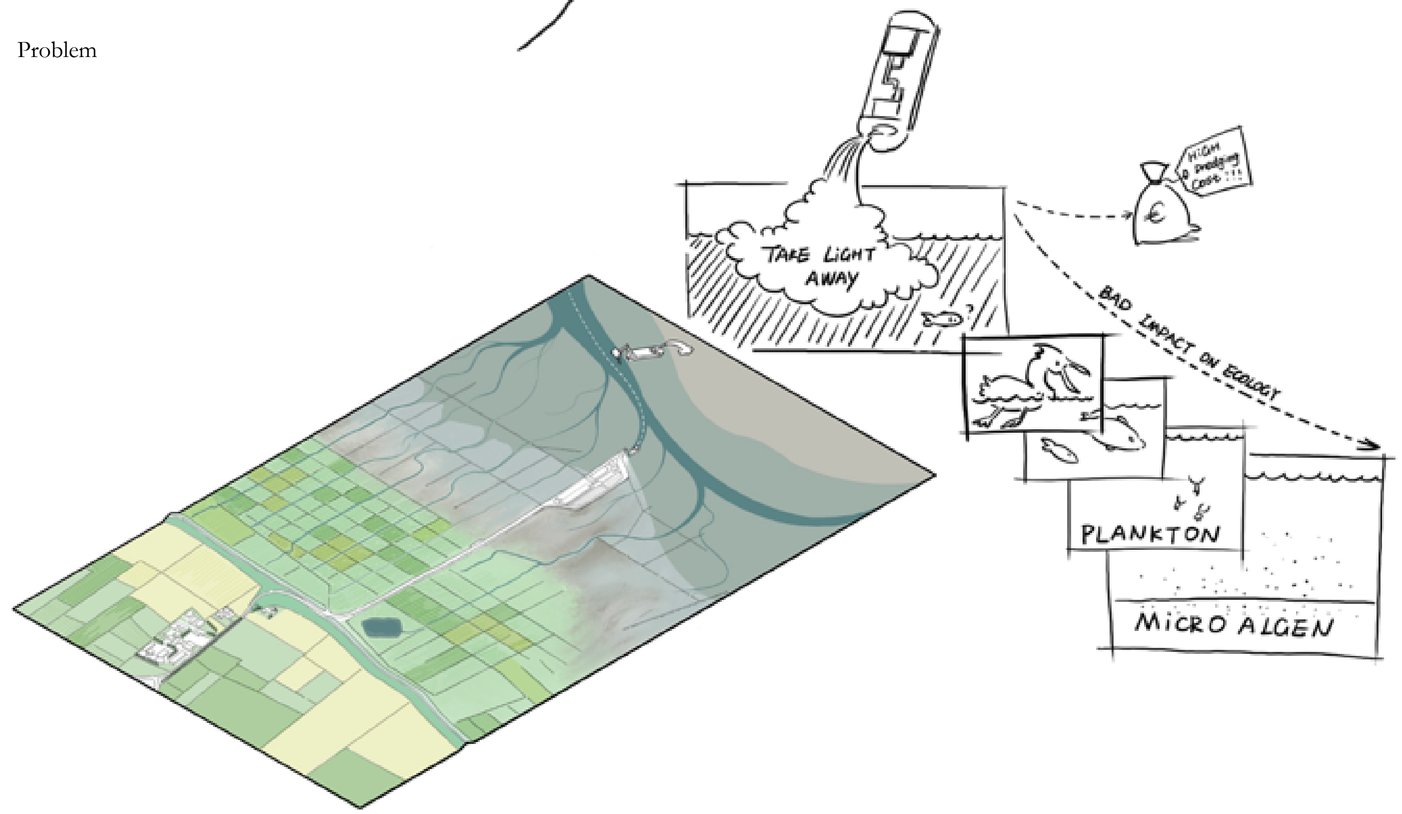
3200 sailings fast services per

The total length of the channel is 11.36 kilometres

1.7 million m^3 is dredged annually. That is about 3 cubic metres per person per crossing.

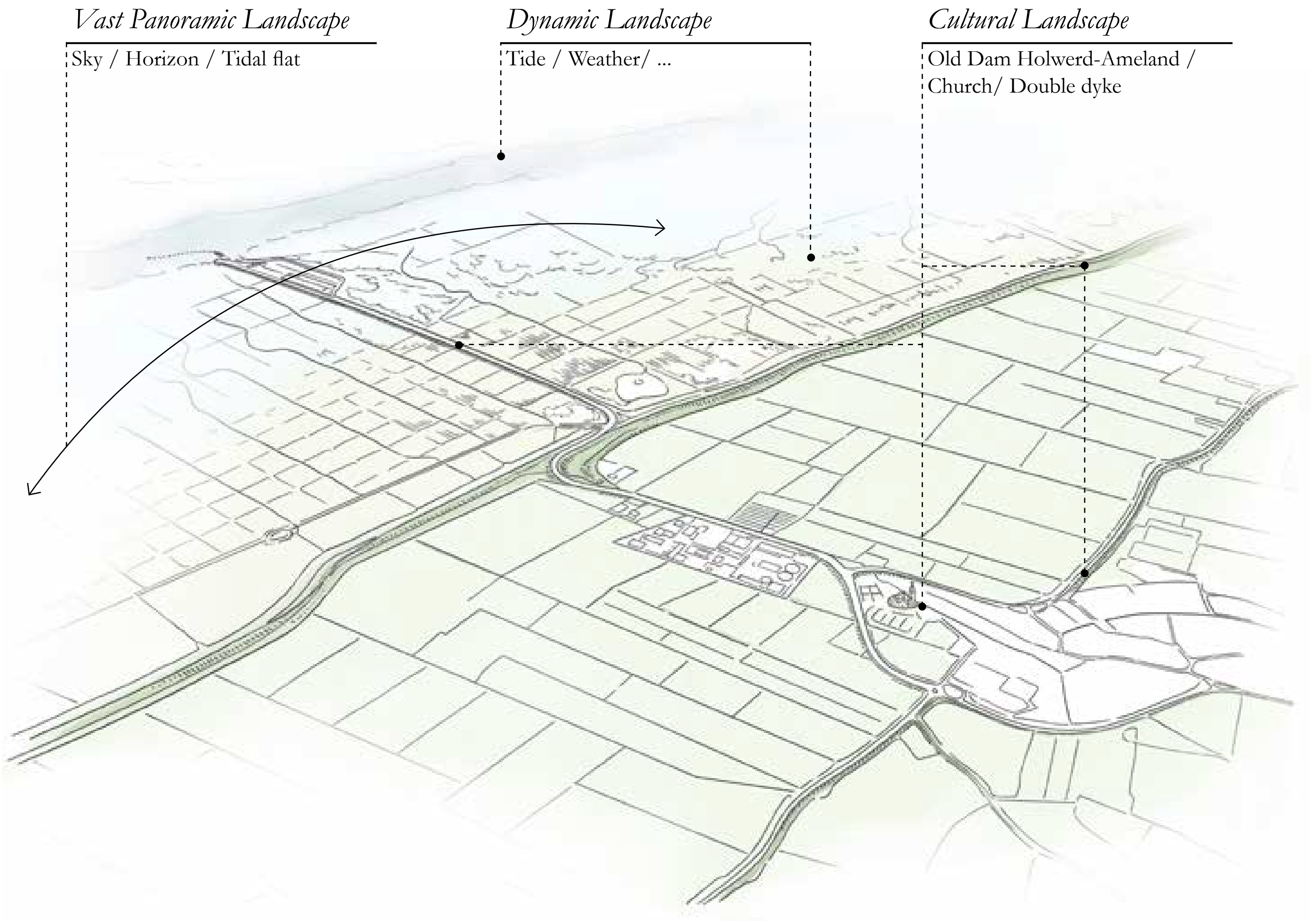


Problem

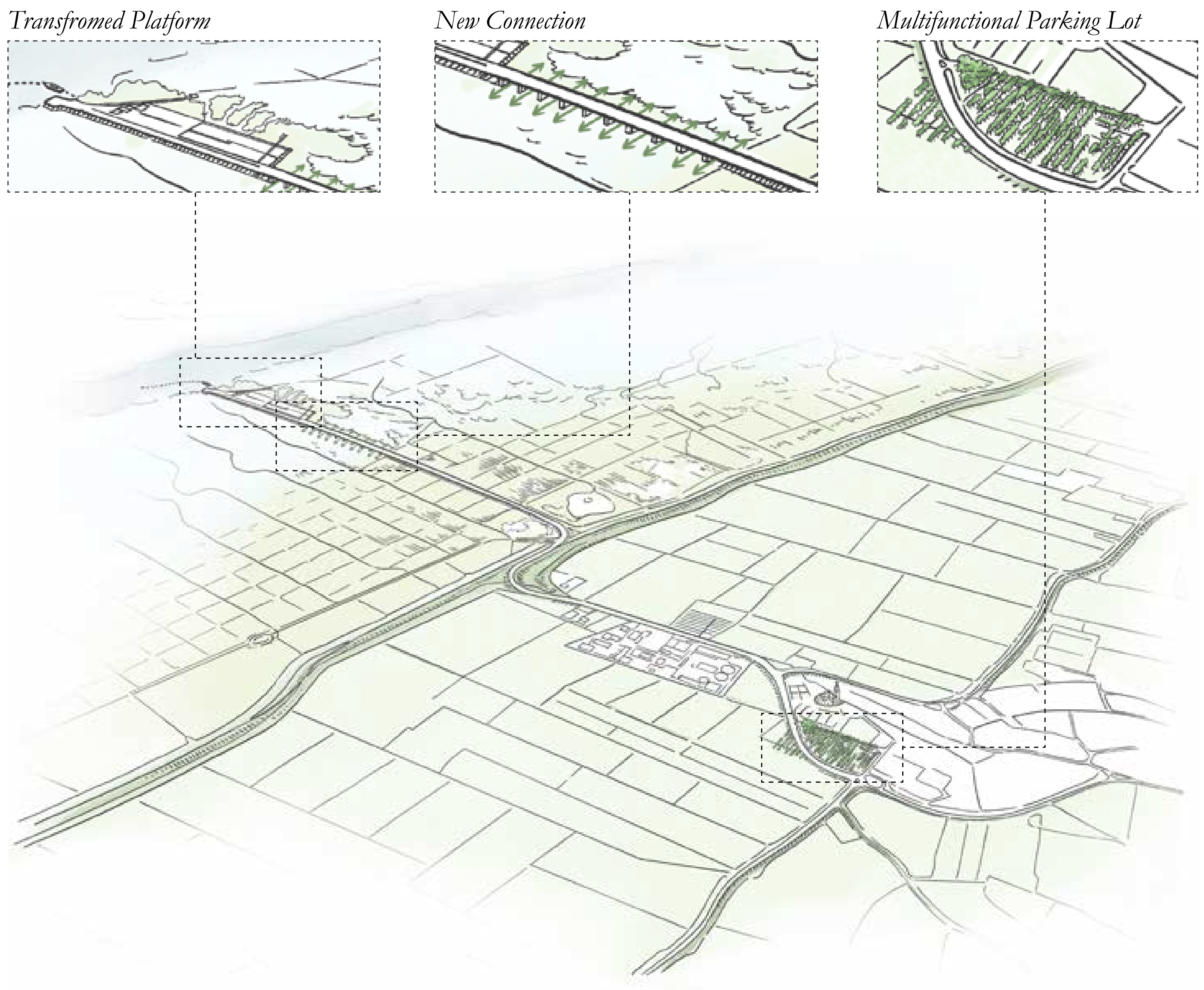



Ferry at low tide heading to Ameland.
Photo: Ries Bosch, 2023.

Design Principles

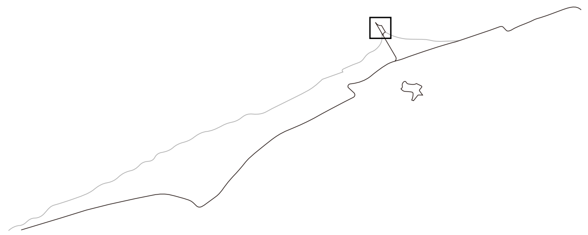


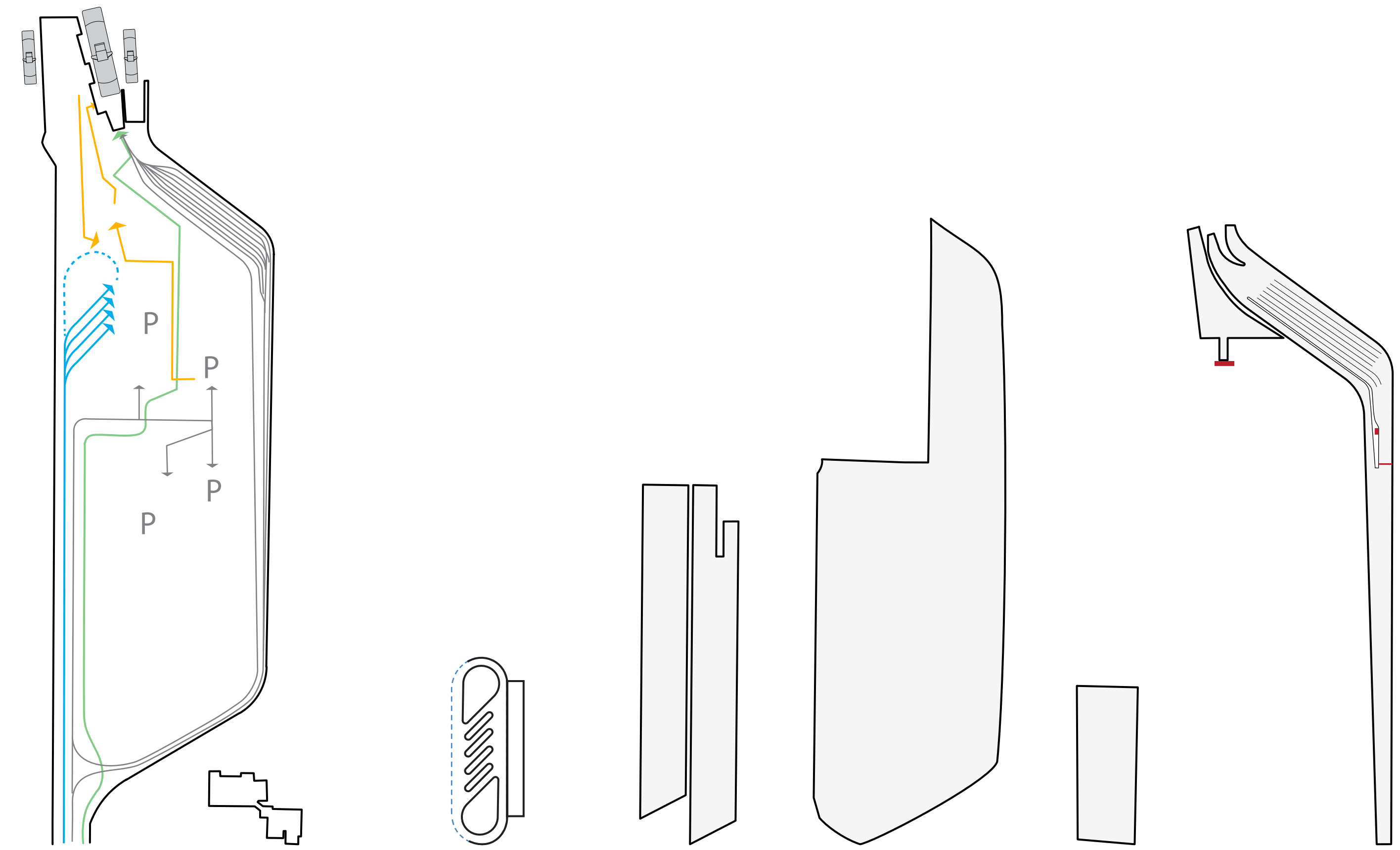
Before



After

Pier Holwert | Before





Cycle
cars
walking/biking
bus

Building
1125 m²
-Terminal
-Restaurant

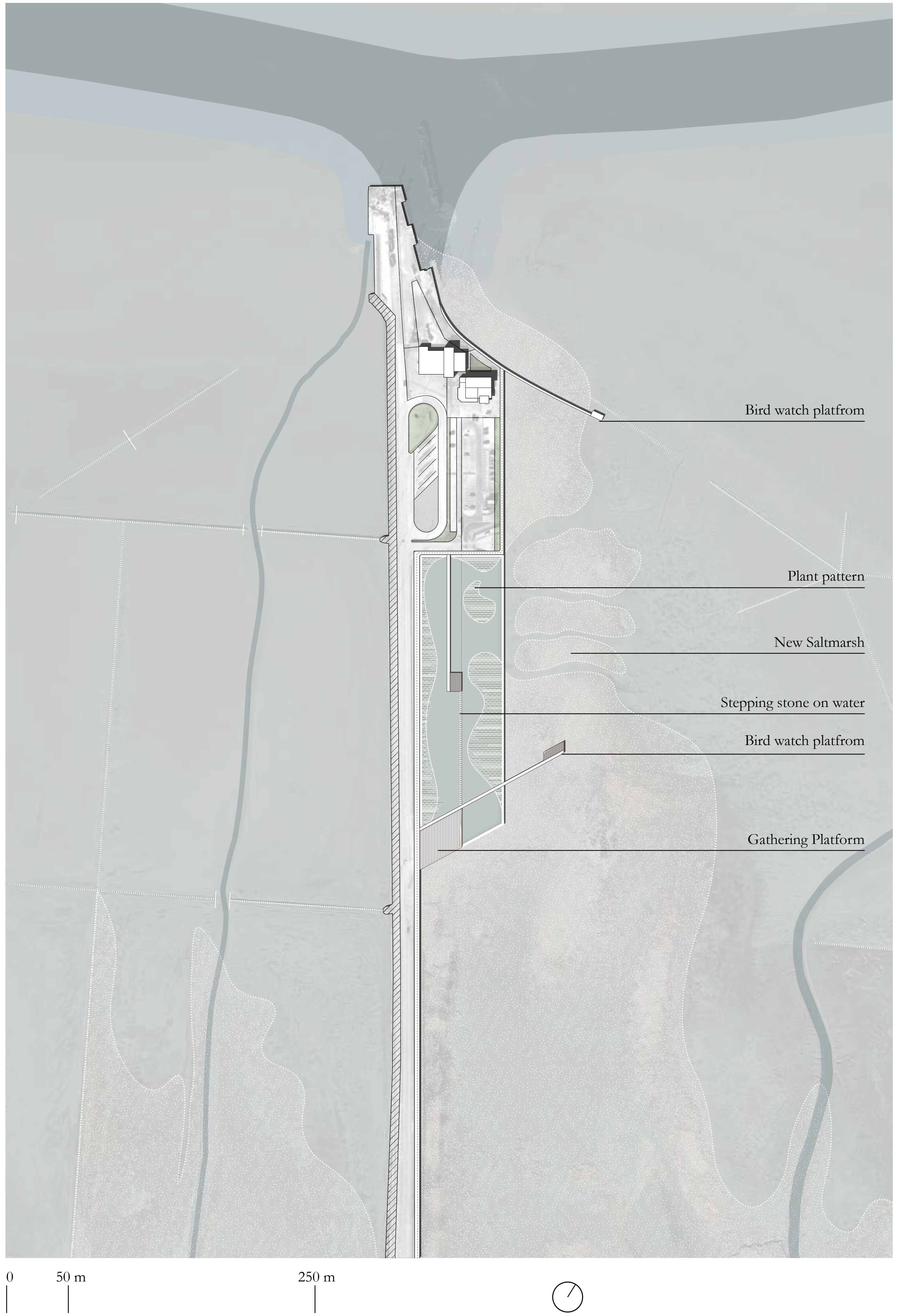
Bus Station
3000 m²

Parking Garage
11000 m²

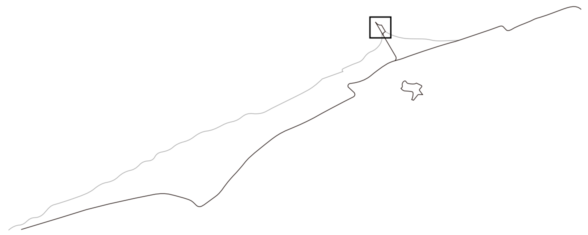
Parking Lot - P1
30000 m²

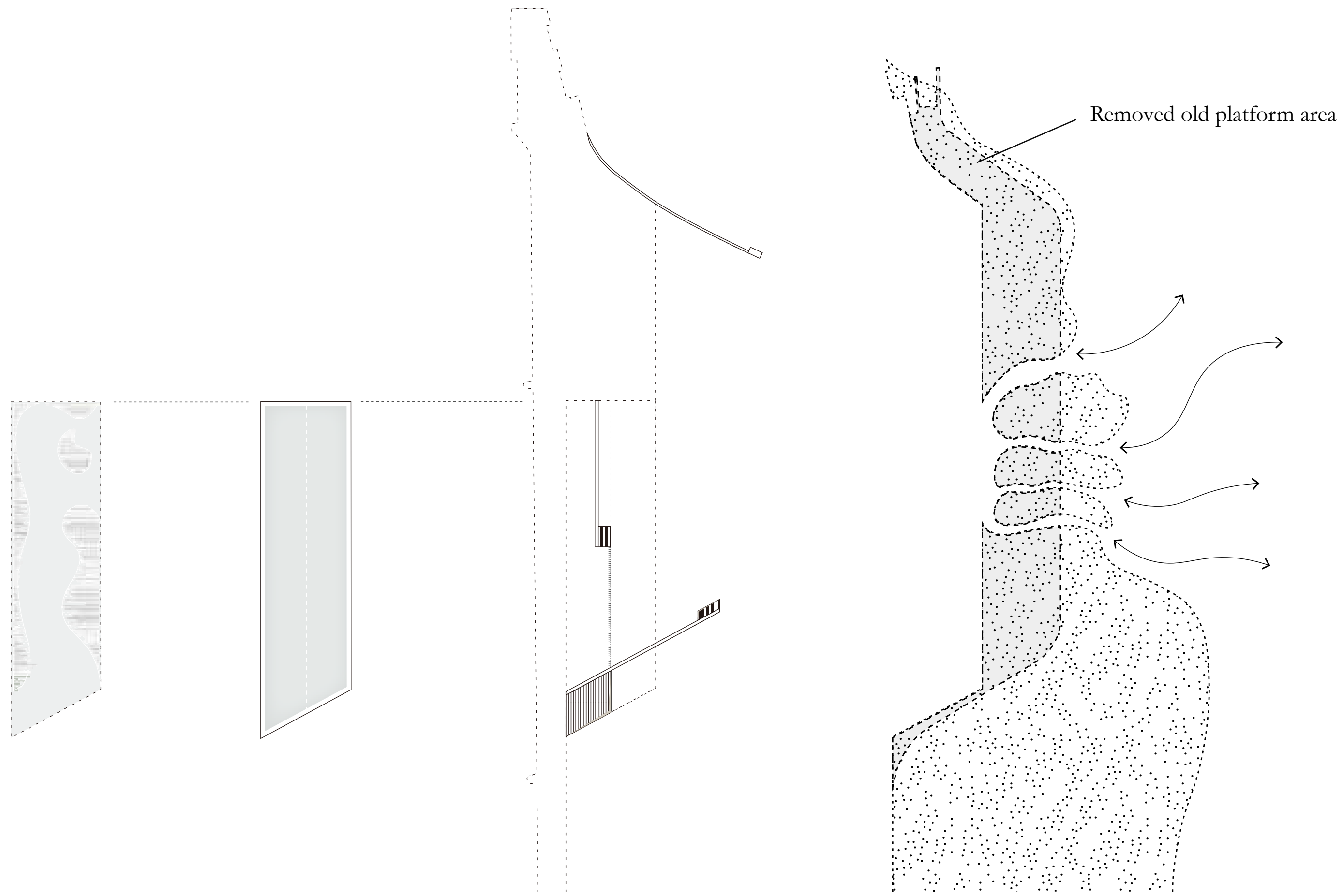
Restaurant Parking
3300 m²

Departure Space
5300 m² for cars
1000 m² for passengers



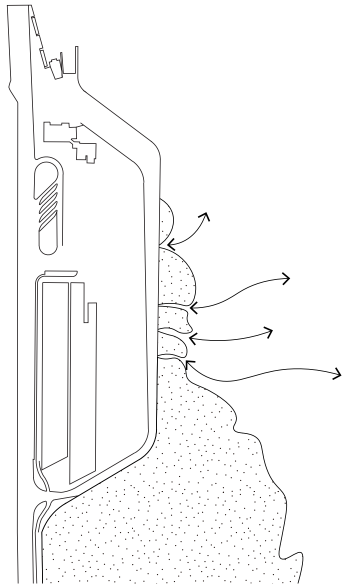
Pier Holwert | After



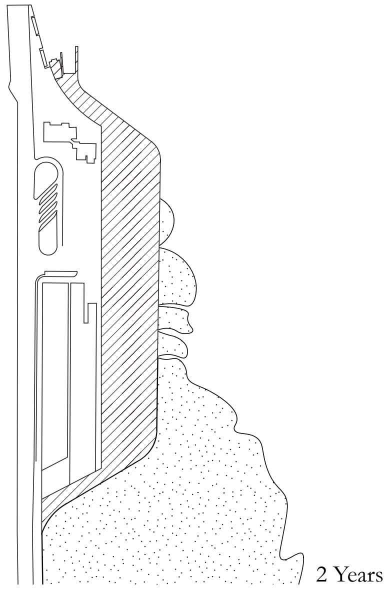


Plant Pattern   *Constructed wetland*   *Walkways & Platforms*   *Saltmarsh*

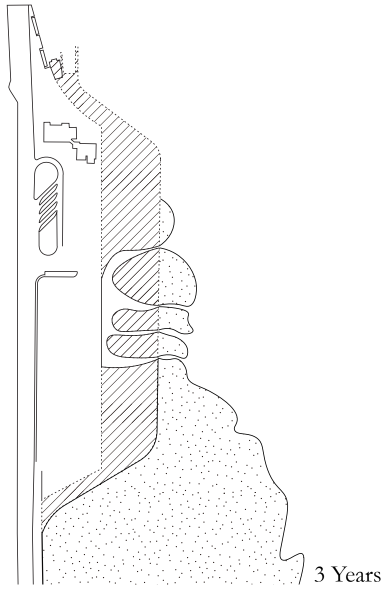
Salt Marsh Design Process



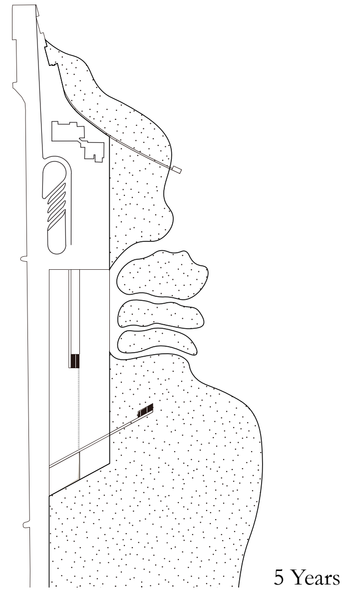
Follow the natural-grow salt marsh pattern around the platform.



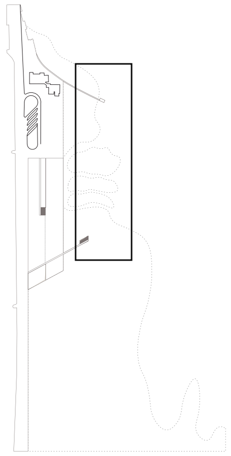
Remove parking area and make room for the salt marsh growth.



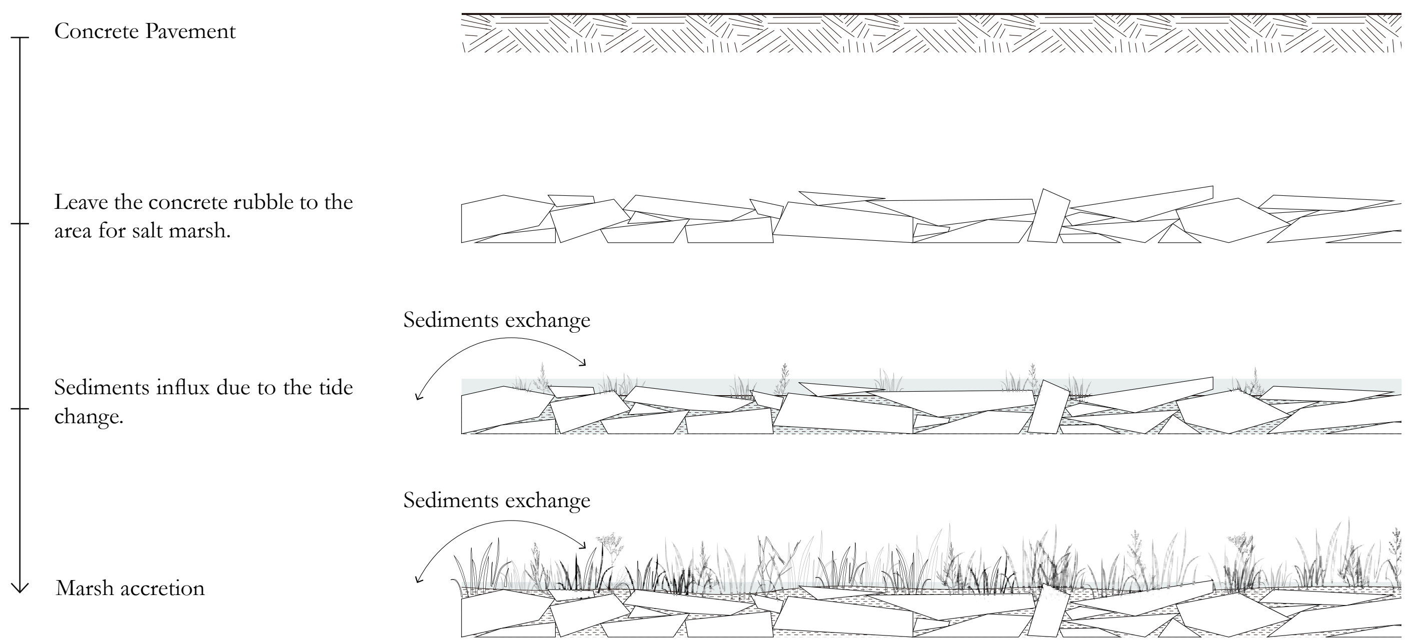
Dig diches to make natural boundaries.

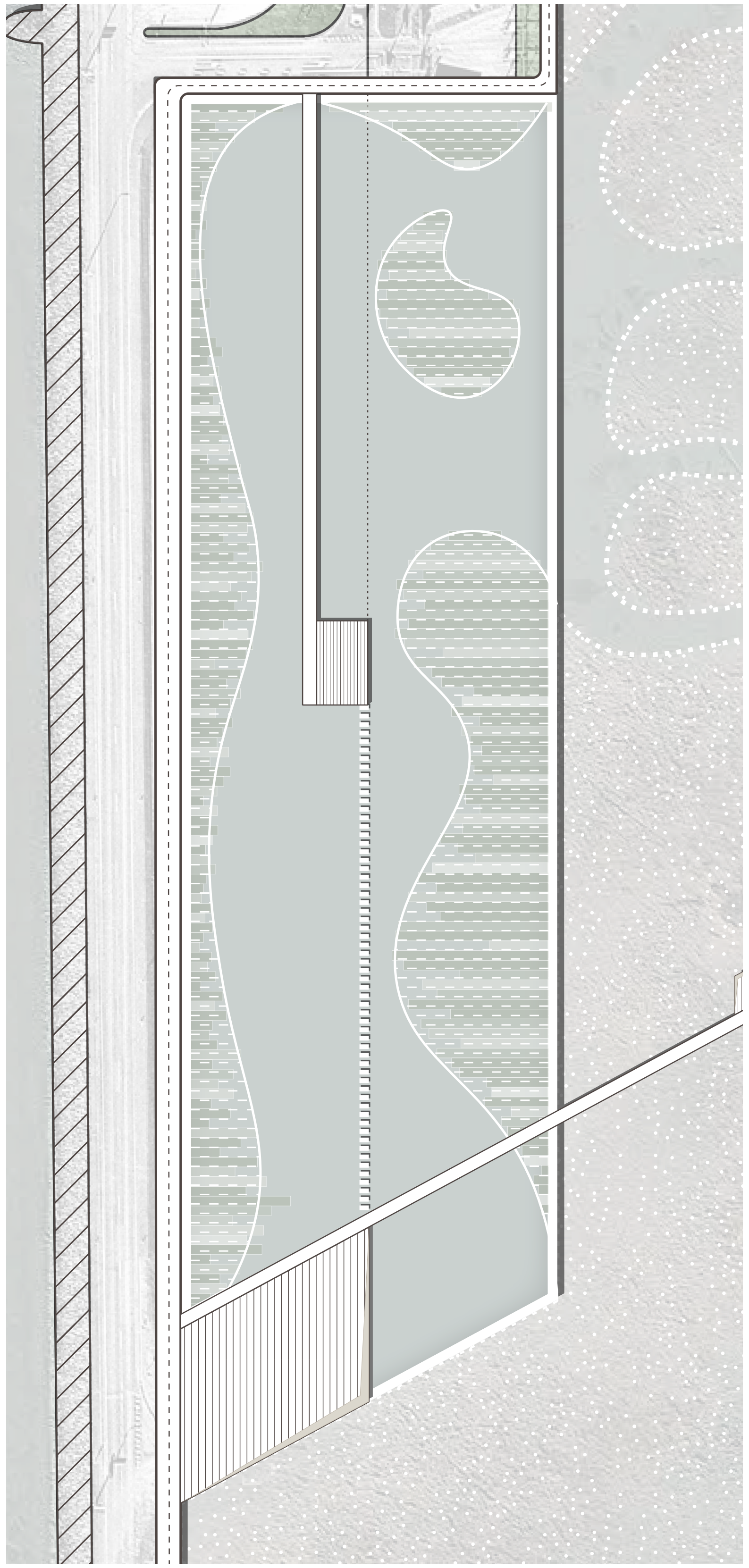


Let natural process work.

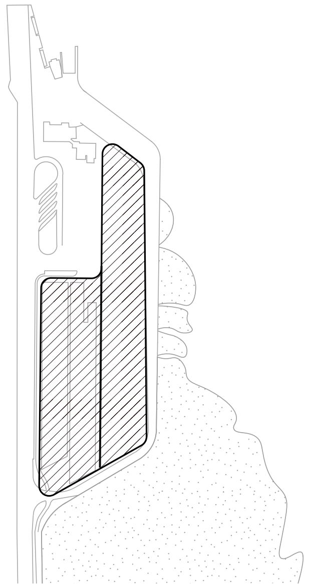


Sediment Process

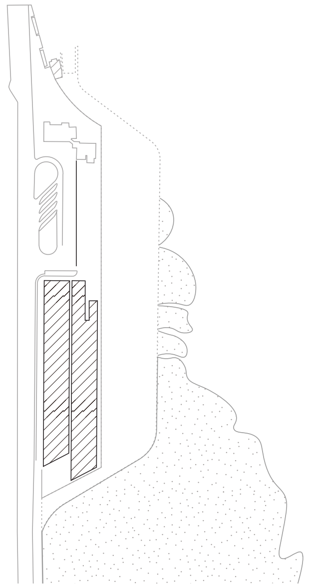




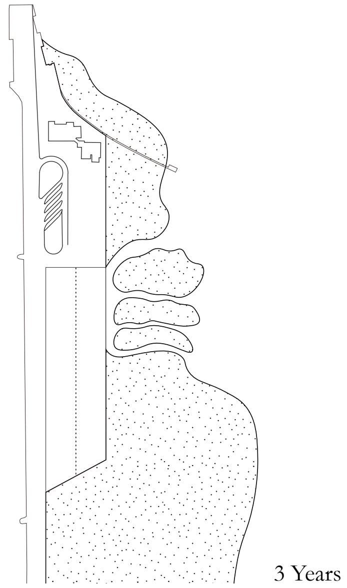
Wetland Design Process



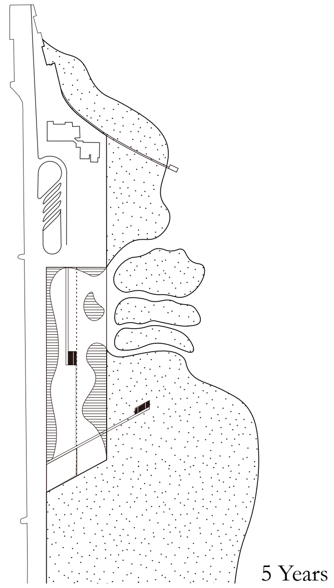
Parking area is relocated and the right parking lot area is designed to be new area for saltmarsh.



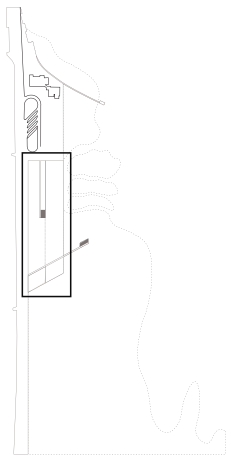
Follow the palimpsest of old parking garage to transform this area to a constructed wetland.



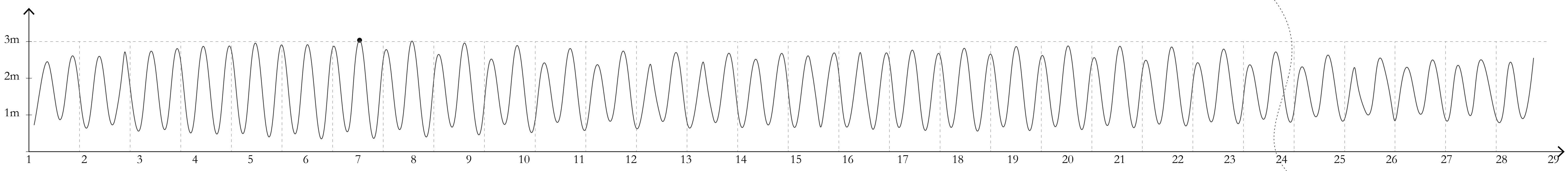
Use the dike to divide the wetland into two sections with different water levels.



Add the walk path, stepping stone and plant to the wetland.

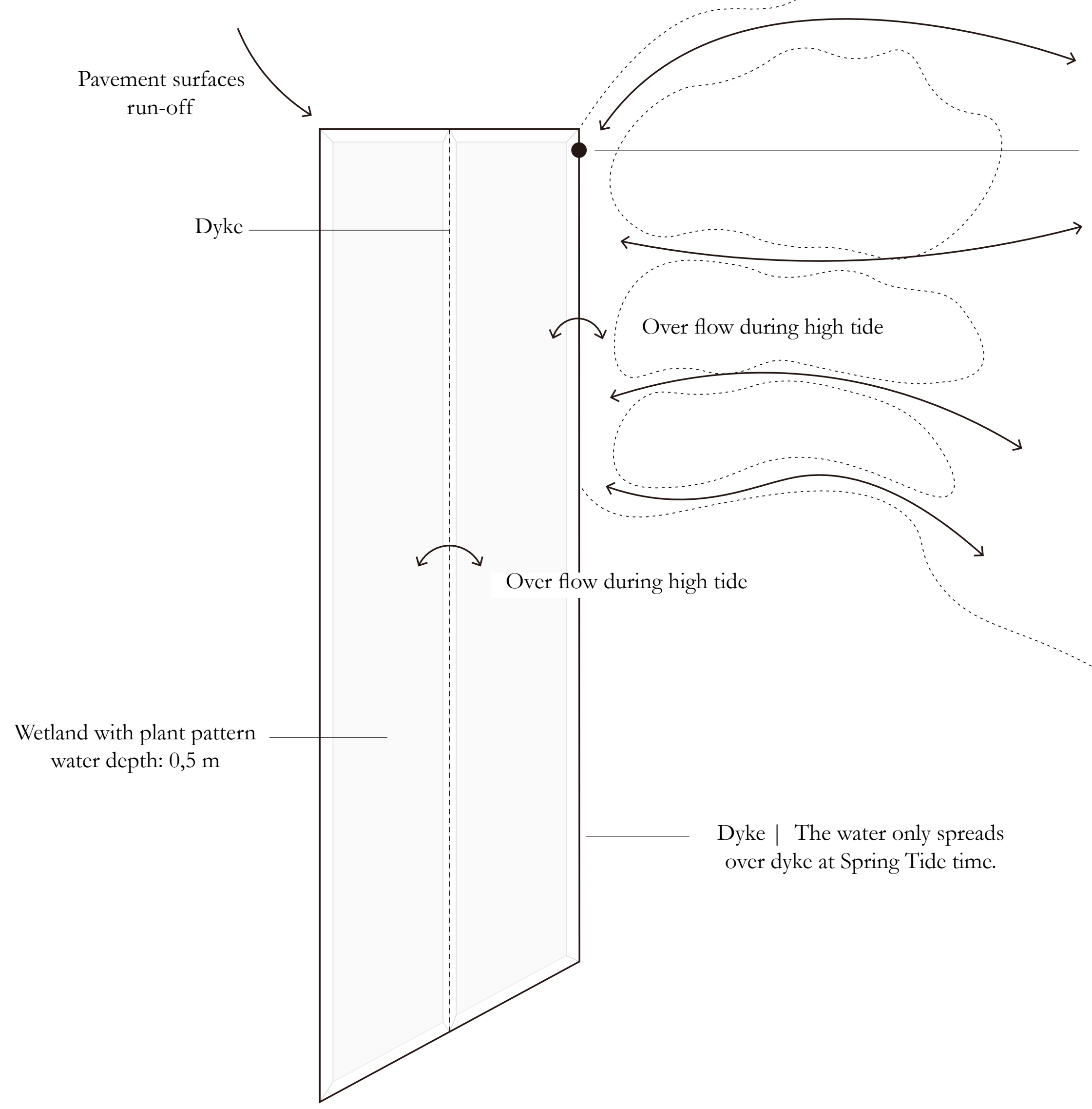


Wetland Water System



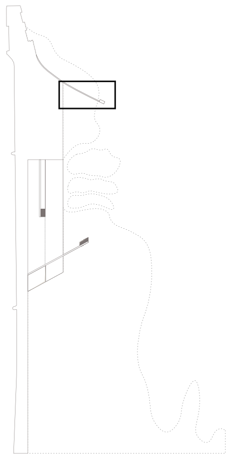
Spring Tide

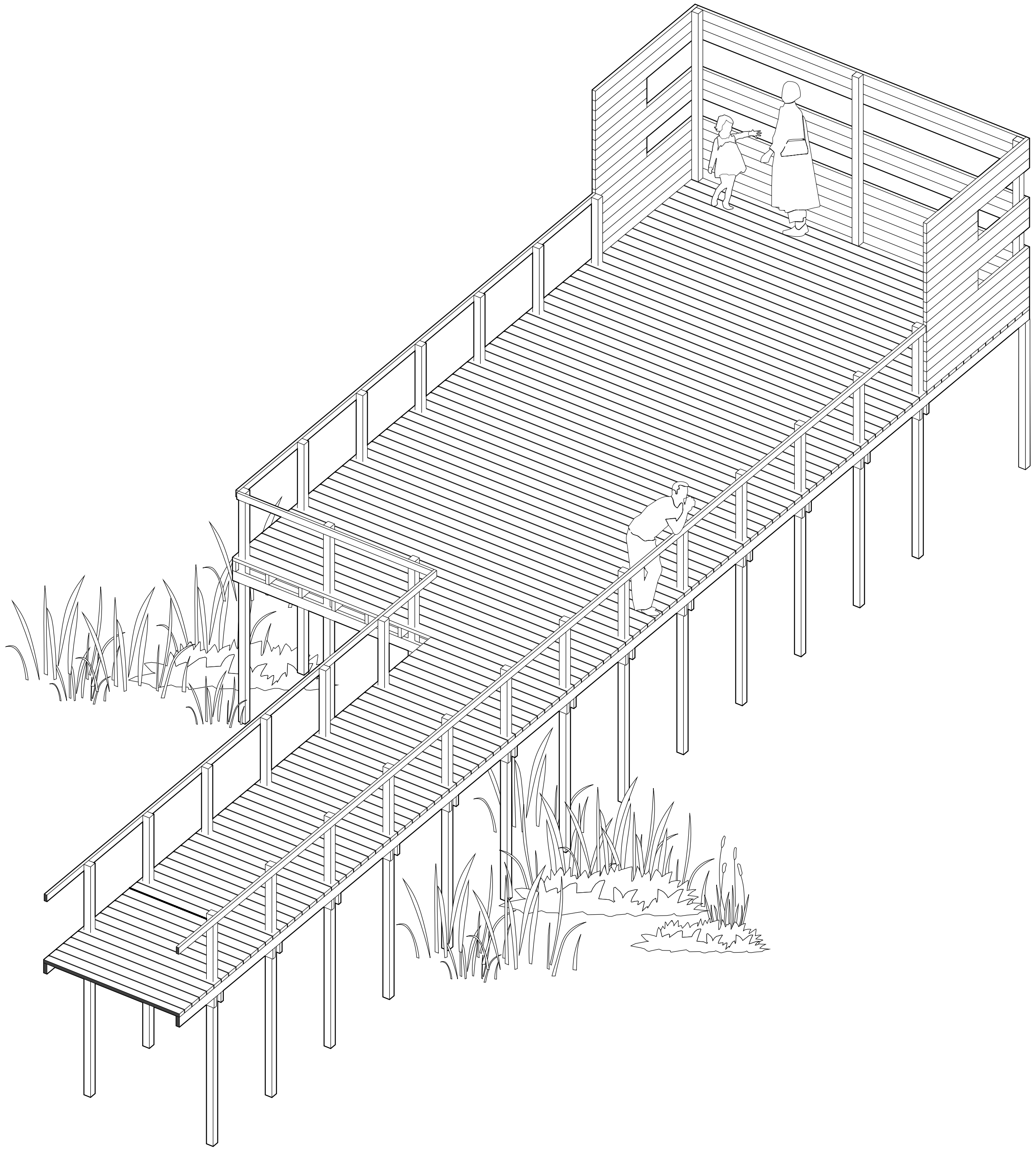
When the sun and moon are in alignment, the force of attraction they exert on the Earth increases. This occurs during the full moon and new moon approximately 12 times per year. At these points, there is a large difference between high and low tides. The tide then rises higher than average, and ebb is lower than average. This is known as a spring tide, and it always occurs two days after the full moon and two days after the new moon.



Wooden Walkway and Platform

The wooden walkway and platform allow visitors to pass through the salt marsh and have a panoramic view over the Wadden Sea. Moreover, the birdwatching frame can guide visitors' views and reduce the disturbance to surrounding birds.





Mudflat walking.
Photo: Lukas S, 2022.

7 | Mudscapes

Embracing Nature and Feeling Culture in the Ems Estuary

Student | Zhaolei Li

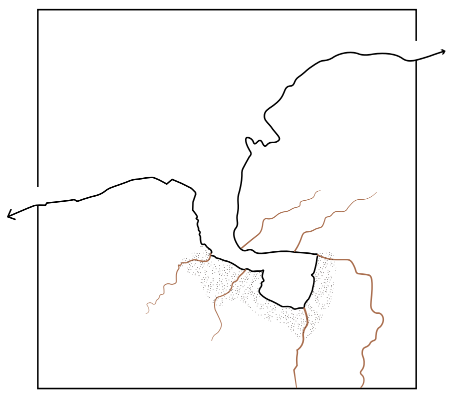
First Mentor | Laura Cipriani
Second Mentor | Bram van Prooijen

The Wadden Sea region is characterized as a diverse and contradictory area. On the one hand, it stands as the largest intertidal area globally, supporting a rich and diverse flora and fauna habitat showcasing nature's power and allure. On the other hand, it is a landscape shaped by human habitation and extensive transformations, including the establishment of numerous polders, reclaimed land, and imposing dikes. The region's history reveals the enduring struggle of its inhabitants against the sea over the past millennium, leaving behind a valuable cultural heritage.

One particular area exemplifying this dichotomy is the Ems Estuary, which represents the Wadden Sea's most ecologically compromised section—often referred to as the 'Yellow River' of Europe. The industrial development occurring along the estuary, including activities such as waterway deepening and riverbank embankment, has resulted in substantial alterations to the morphology, hydrology, and ecological composition of the area. The most significant challenges include the loss of brackish and freshwater marshes and the conflicting objectives of ecological preservation and further waterway deepening. Additionally, the area's cultural significance often remains overlooked due to its designation as a natural heritage site. Consequently, the region lacks sufficient allure, resulting in a declining population and an inferior economic state when compared to the southern Netherlands and surrounding islands.

This master's thesis addresses the crisis in the Ems Estuary by focusing on the transformative potential of mud as a catalyst. Through a comprehensive study analyzing the status and role of mud and integrating various strategic options, the project explores opportunities for revitalizing the estuary. As the muddiest estuary within the Wadden Sea and the last naturally connected river in the Netherlands, mud in this area plays a vital role in the overall estuarine system, significantly influencing the economy, ecology, and cultural memory formation. This thesis proposes a spatially dynamic transformation of the Ems Estuary through small-scale design interventions and pilot projects by conducting research and analysis in these three domains.

Strategies



Climate Adaptation

STRATEGY 1

Mud as subsidence compensation

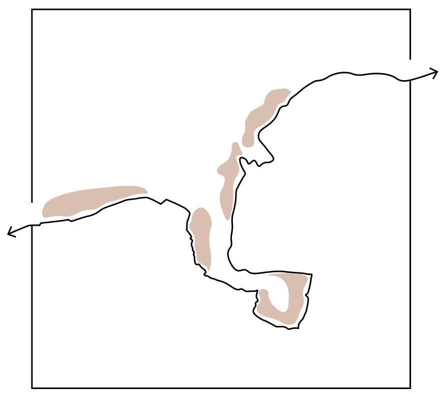
- Double dike and aquaculture

Socio-Economy Booster

STRATEGY 2

Mud as socio-economy booster

- Recreation activities
- City-terp-mud hiking
- Biomass.

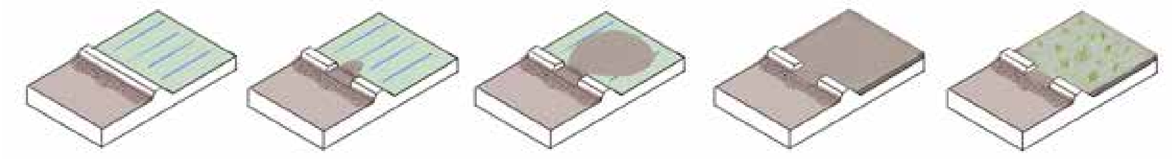


Ecology Enhancement

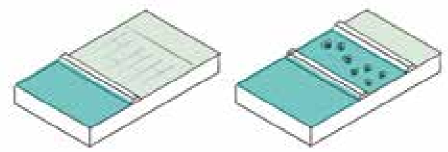
STRATEGY 3

Mud as an ecological ooster

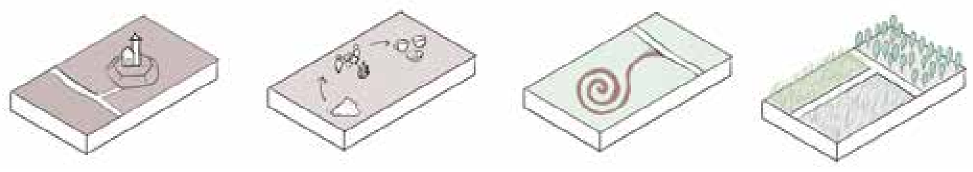
- Mud accumulation as mussel bed and bird mound
- Mud accumulation as salt marsh
- Phytorediation



Subsidence mitigation

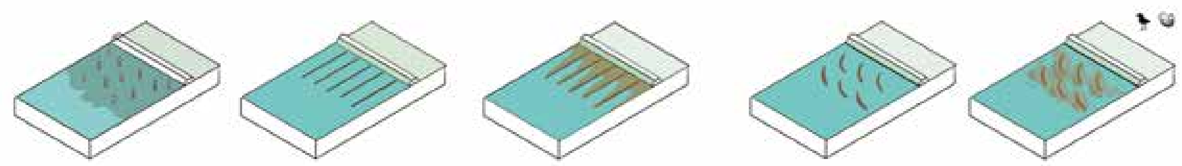


Double dike and aquaculture



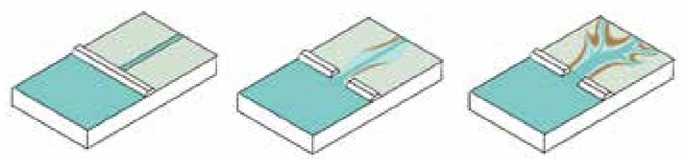
Recreation & Handicrafts

Biomass

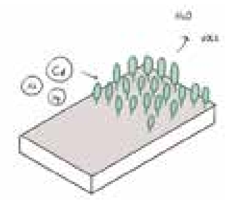


Sediment capture

Mussel bed or bird mound



Fish passage



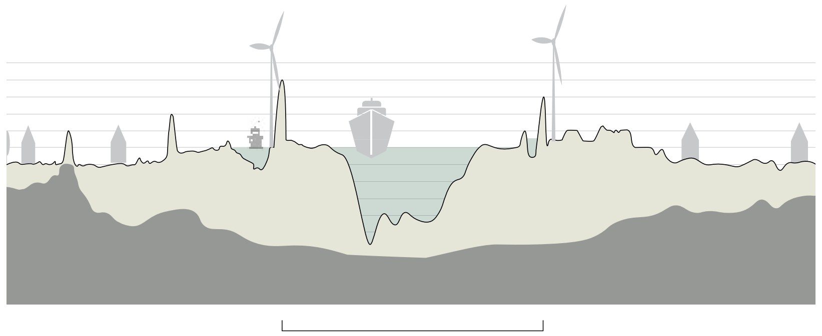
Phytoremediation

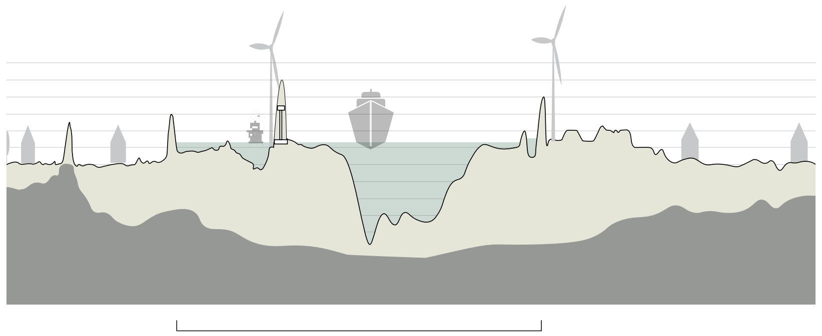
Time Process

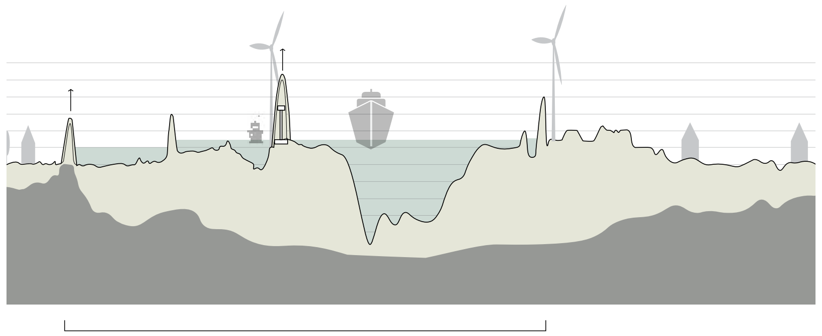
2025

2035

2050





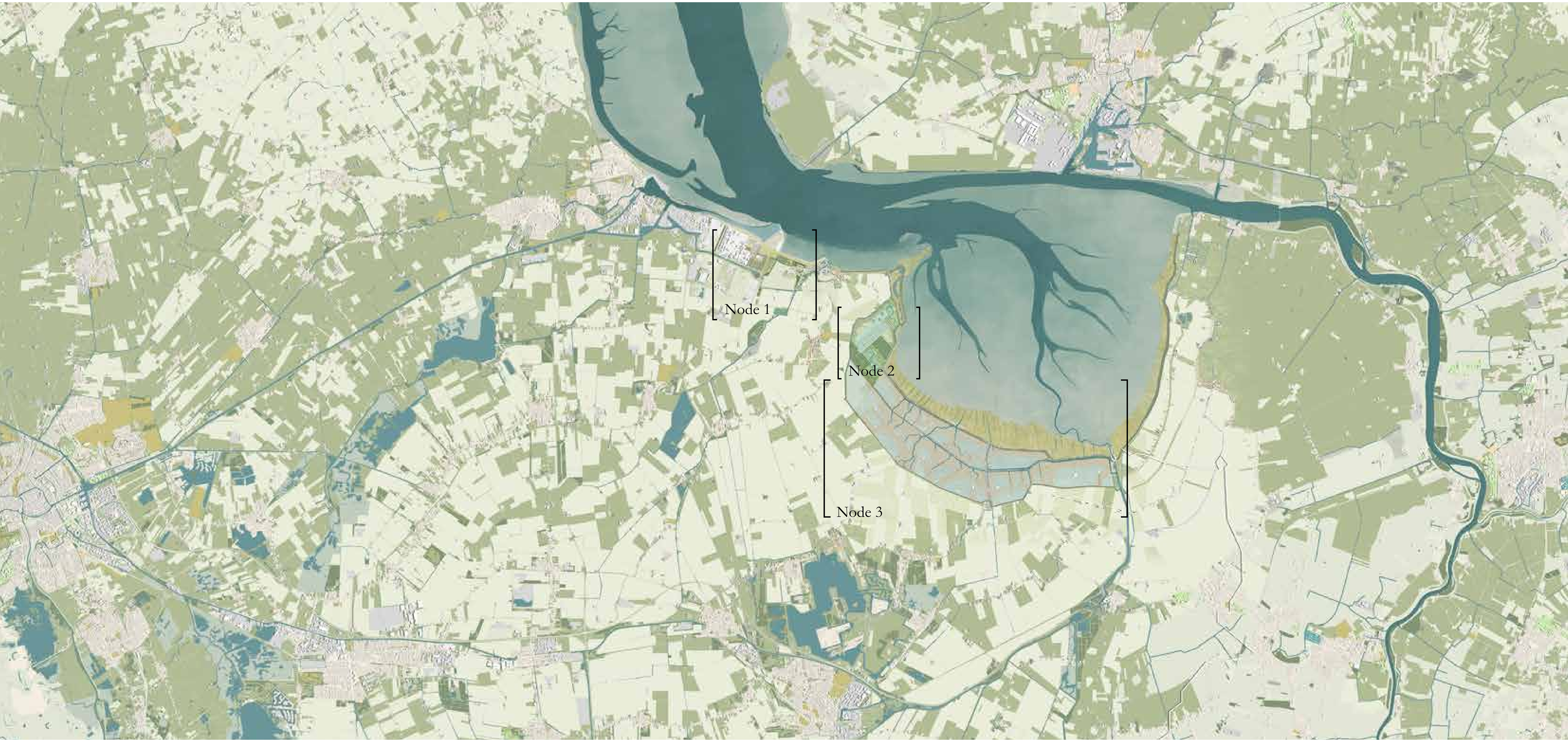


The design is divided into three phases:
Within the short term (i.e., the last 2 years), the main focus has been on tour route planning and small node design, using existing mud disposal sites and materials to increase recreational opportunities and improve the quality of tourism. During this period, the mud will be used to reinforce the dikes and protect inland areas from the threat of flooding.
Within 20 years, preparations will made on a larger scale for the installation of gates, partial reinforcement of the dikes, reuse of the old dikes, some relocation of farm buildings, and industrial transformation from crop cultivation to aquaculture to simultaneously improve economic efficiency, which will allow some areas to be inundated and lay the foundation for ecological restoration.
In 2050, the reinforcement and renovation of more of the old dikes will be completed, further opening up some areas to inundation, with the hope that natural processes will take over and that the tides will enter and bring silt, with some artificial structures guiding the deposition of the mud. This will create a new mound, attracting birds and resulting in the establishment of appropriate vegetation so that the area will gradually become a wetland.

Floodable areas
Saltmarsh
Nature reserve

Masterplan 2025

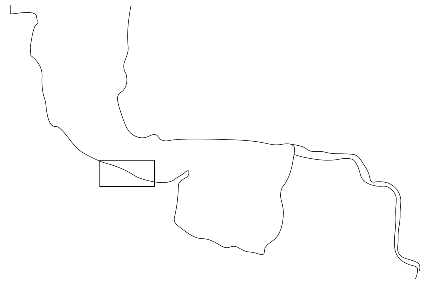
Masterplan 2050



0 1 km 5 km 10 km

Mudflat
Saltmarsh
Grassland
Farmland

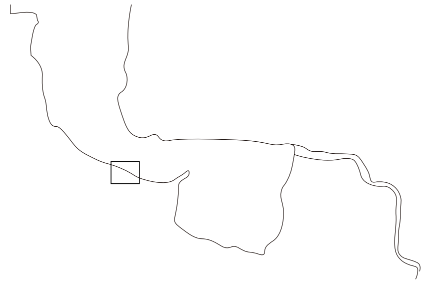
Energy and Ecology Routing



Existing terps
Solar panels
Biomass park
Recreation node
Transport

The energy journey
Waterways
Ems river
Mudflat
Grassland
Farmland

0 100 m 500 m 1 km



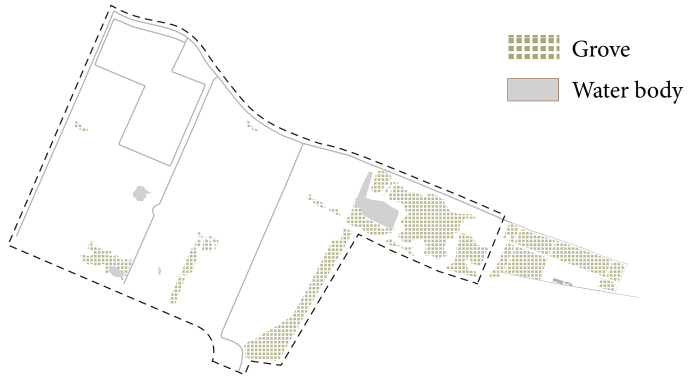
Energy Routing

The first design node is part of the Energy Journey. The site is located on the southeastern side of Delftzell and is bordered to the west by EEW Energy from Waste Delfzijl BV and Reym Delfzijl, which are mainly waste management services. To the east of the site is a small park and some fragmented green areas. The area at Oterdum is divided into 15 compartments. In each basin, the sludge is dried differently. Compartments, sun, and wind have to provide dewatering, while in others, drainage or the plant samphire ensure that the water disappears from the sludge (Been, 2018).

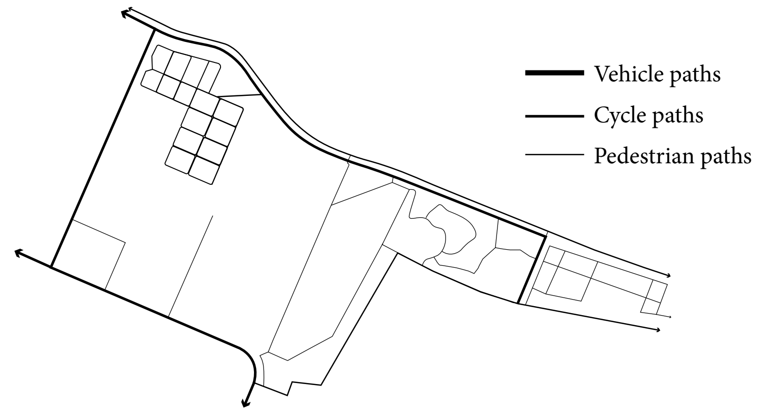
As an over-area between the industrial park and the extensive polder area, the design aims to combine the existing mud maturation test site and waste treatment function with the introduction of biomass planting and plant purification through biopile and landfarming, both of which can help to treat the contaminated soil and connect the fragmented woods to create as much of a green corridor as possible while also increasing recreation opportunities.

Satellite image of the area.
Photo: Google Earth, 2024. Map data: Google, GeoBasis-DE/BKG ©2024 AeroWest, Aerodata International Surveys, Airbus, CNES/Airbus, GeoBasis-DE/BKG, GeoContent, Landsat/Copernicus, Maxar Technologies, Planet.com, Dati Cartografici.

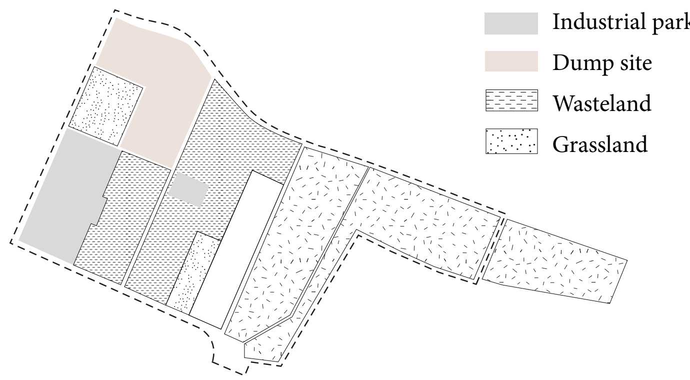
Green Corridor



Connection



Land Use



Phytoremediation and Biomass

Phytoremediation Species


Alpine Pennycress
(Thlaspi caerulescens)


Common Sunflower
(Helianthus annuus)


White Lupin
(Lupinus albus)


Indian Mustard
(Brassica juncea)


Fescue Grass
(Festuca arundinacea)

Phytoremediation and Biomass Species


Hemp
(Cannabis sativa)


Reed
(Phragmites australis)


Switchgrass
(Panicum virgatum)


Willow
(Salix spp.)


Poplar
(Populus spp.)

Biomass Species


Bulrush
(Typha orientalis)


Purple willow
(Salix purpurea)


Maize
(Zea mays)


Sugar beet
(Beta vulgaris)


Rapeseed
(Brassica napus)

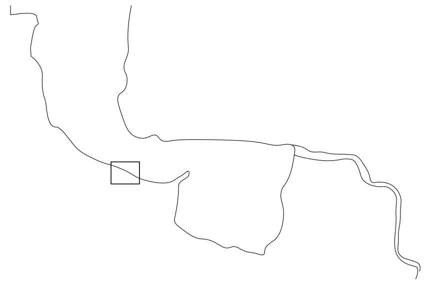

Elephant Grass
(Pennisetum purpureum)


Miscanthus
(Miscanthus spp.)

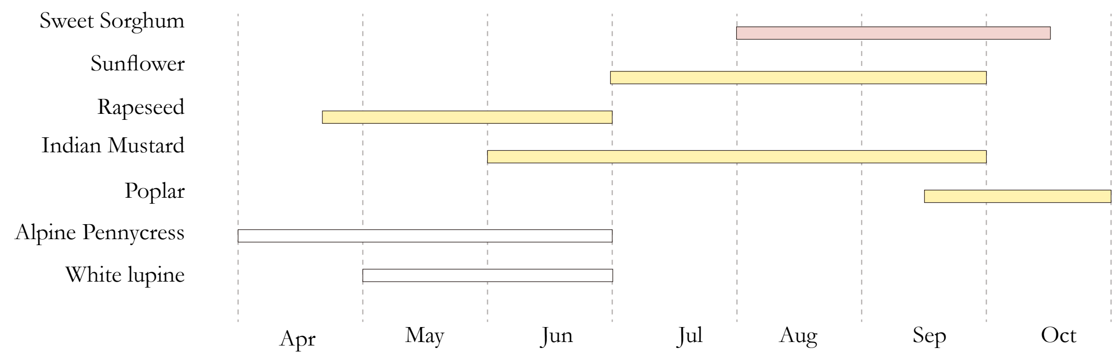

Silvergrass
(Miscanthus sinensis)


Giant Reed
(Arundo donax)

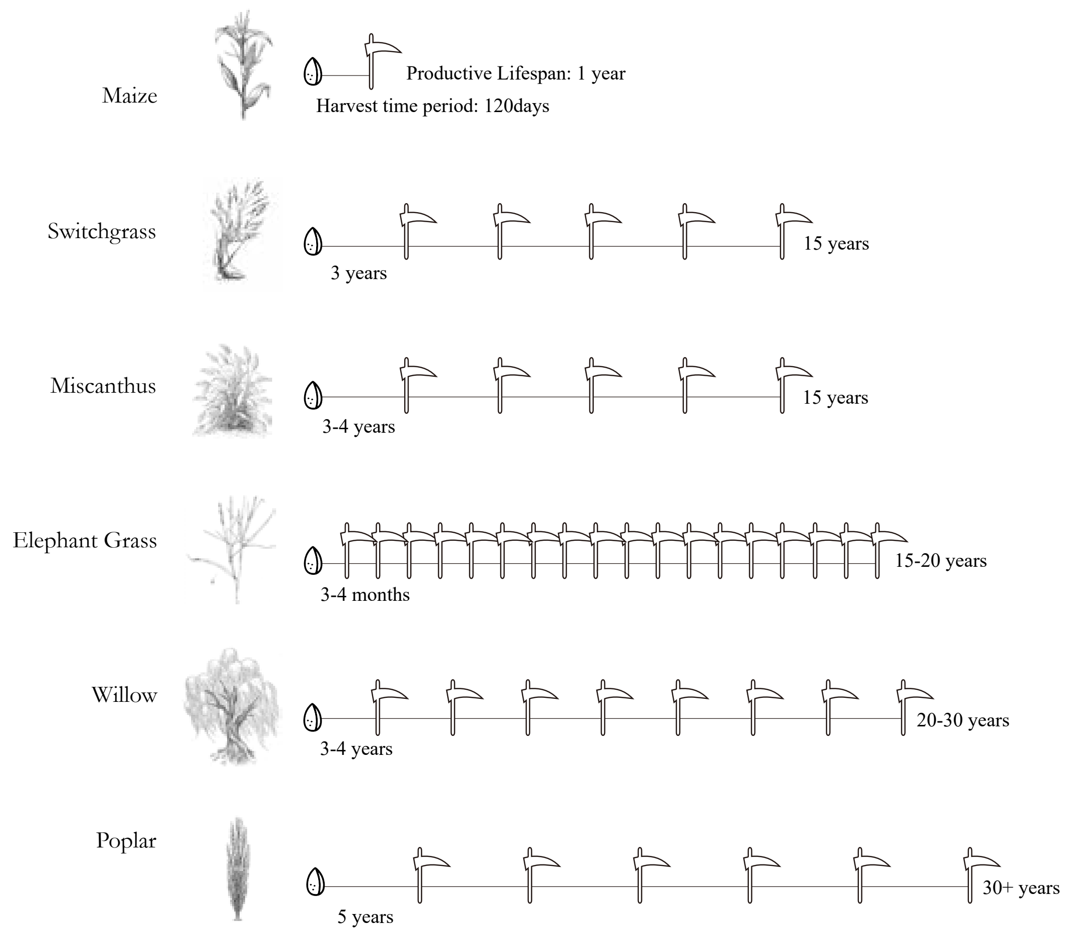

Sweet Sorghum
(Sorghum bicolor)



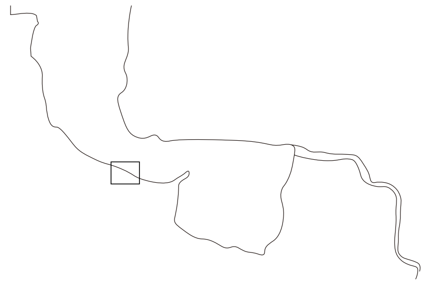
Flowering period and flower colour

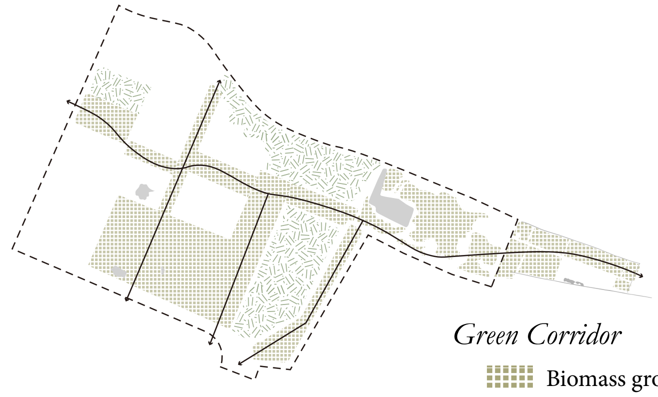


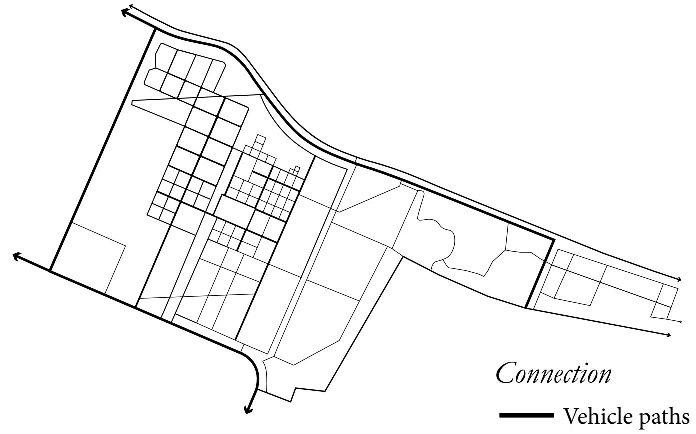
Productive Lifespan and Harvest period

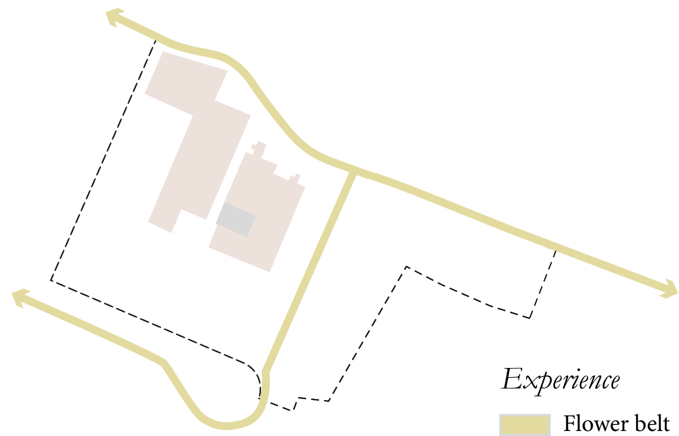


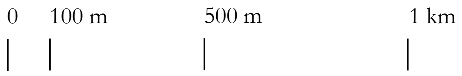
Design Node 1

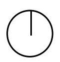


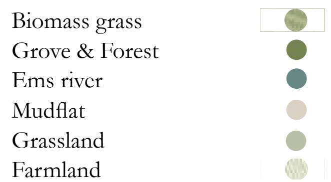


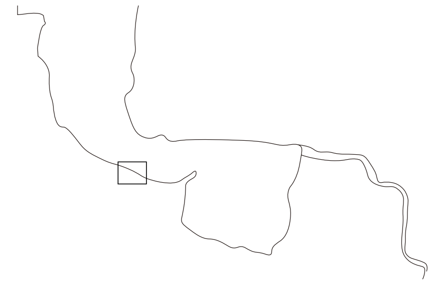




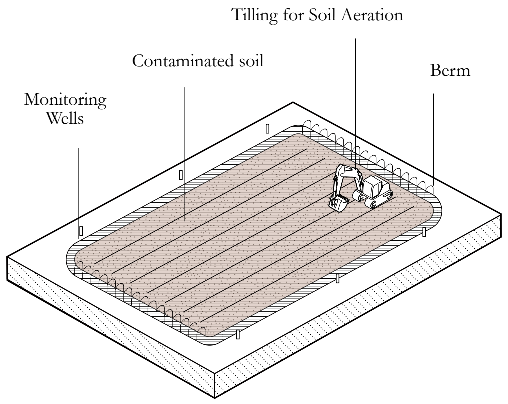




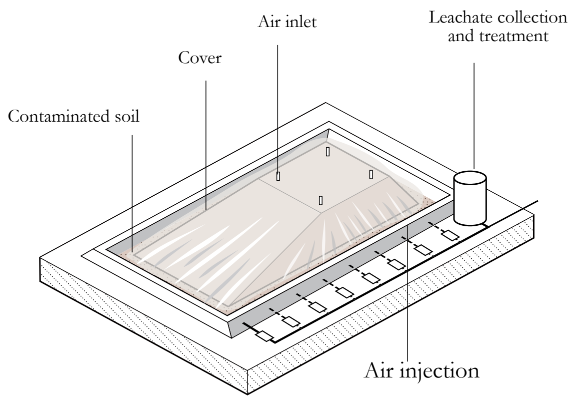




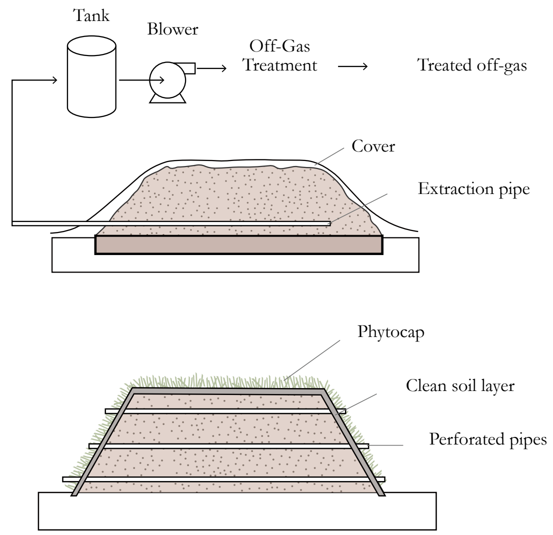
Soil Purification



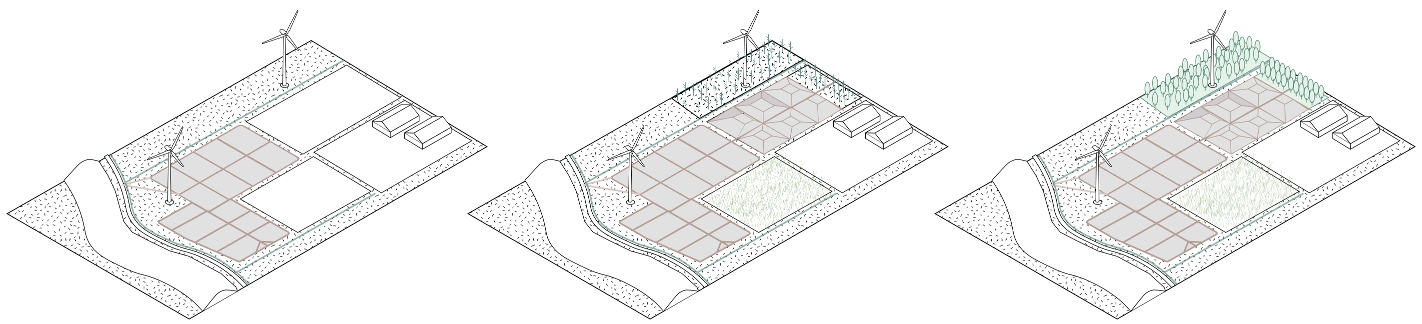
Land Farming



Biopile



Biopile

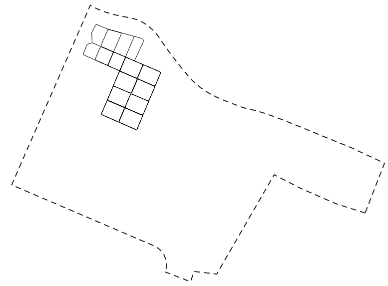


Process

The soil purification methods for treating the land around the Delfzijl chemical plant include biopile, landfarming, and phytoremediation. Biopiles involve excavating contaminated soil, mixing it with suitable soil amendments, and forming a heap on a prepared surface. Forced aeration is used to provide oxygen to the pile, thereby promoting microbial processes that break down the contaminants. Biopiles are effective for treating efficiently degradable pollutants such as petroleum hydrocarbons, making them suitable for the dredged mud from the Ems River. The objective is to convert the contaminants into harmless substances, thereby making the soil safe for on-site disposal or other beneficial uses.

Combining these techniques with landscape design allows for the creation of unique spaces. The diamond-shaped mound of the biopile itself can shape different spatial experiences, and the surface mulch can be artistically manipulated. Additionally, these methods will be integrated with the existing silt-drying pond and the introduction of biomass to create a mud-themed visitor experience.

By employing these approaches, the project aims to reduce the costs associated with soil purification and transport. Furthermore, the use of biomass can provide additional economic benefits. Overall, the combination of biopile, landfarming, and phytoremediation techniques offers an efficient and environmentally friendly solution for treating the contaminated soil around the Delfzijl chemical plant.



Mud Maturation

The experimental field for mud maturation on the Groningen coast is a large container of waste from the dredged material of the shipping channel and silt excavated from the Breebaart polder. The channels to Delfzijl and Emshaven must be maintained at a certain depth for large ships. In the basin along the dike between Delfzijl and Eemshaven, water sinks from the spoil, leaving behind materials such as clay, which account for approximately 30% of the total quantity. The dredged material is suitable for use as construction material for the dikes, thereby saving money since it is no longer necessary to import expensive clay from abroad to reinforce the Groningen dikes. This also makes the Eems-Dollard cleaner since the sediment is permanently removed from the system. The sludge from the Breebaart polder is used to improve the agricultural land around Eemshaven and in the Vinkelnirn area (RTV Noord, 2015).

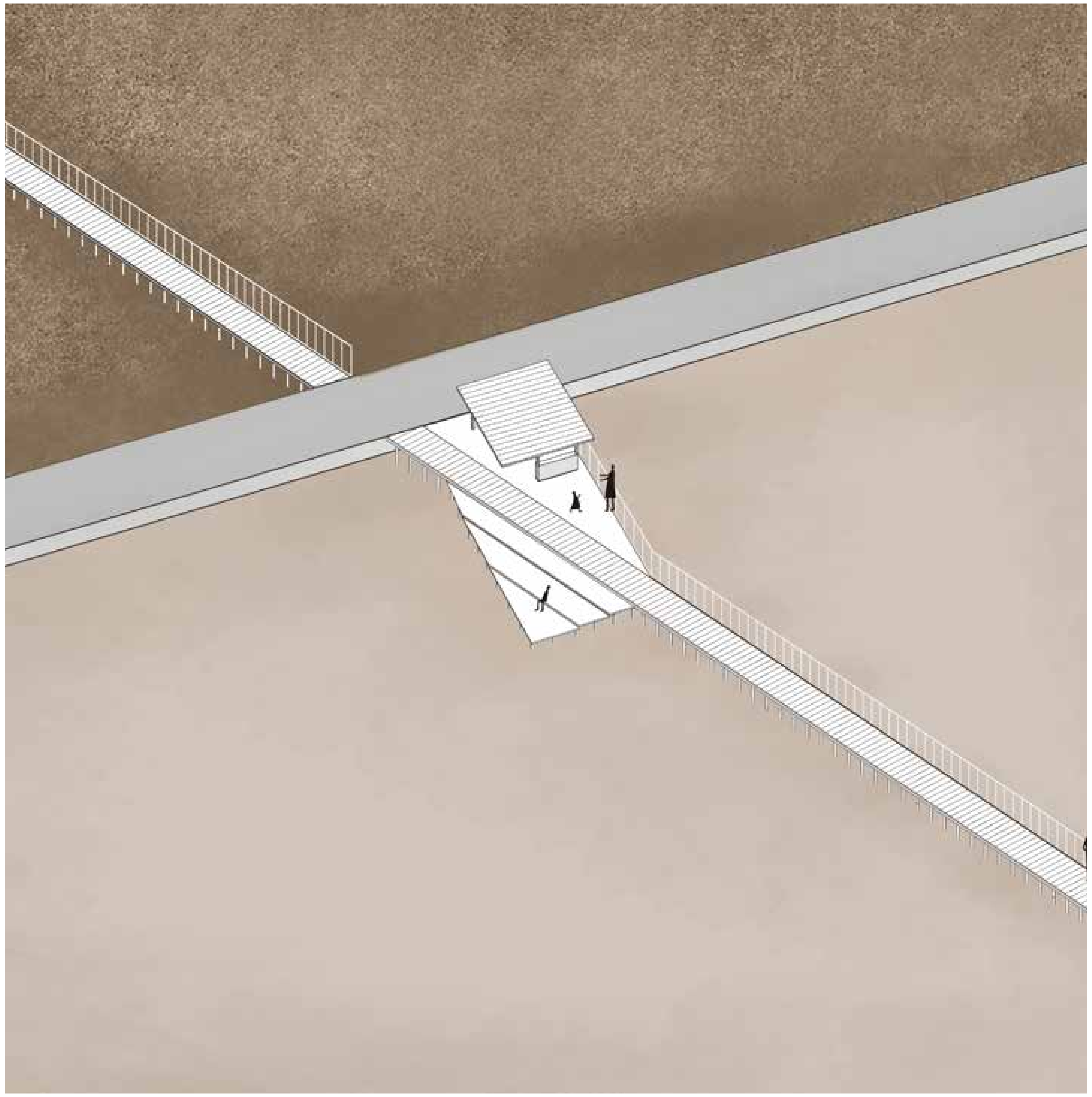
In this large mud-drying field, the mud dries differently in each pool. In one section, sunlight and wind are responsible for dewatering, while in another section, the drainage or sea poncho plants ensure that water disappears from the sludge. Based on these conditions, I have added a recreational route (a wooden walkway) and recreational nodes (a small pavilion and resting platform) so that the area is no longer industrial in the eyes of visitors and residents. Instead, it appears as a place that can be entered and experienced in person, where the mud dries differently in the different pools, thus providing other tactile sensations that can enhance one's understanding of the local process of mud change.

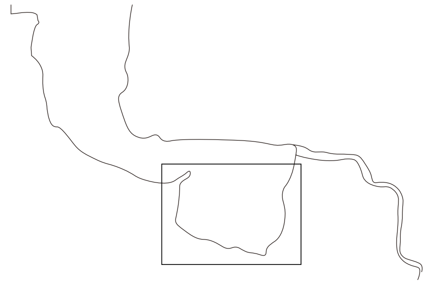
In terms of management, it usually takes a year or two for the mud in each pool to fully mature and dry. Therefore, construction is infrequent and the area is not closed for long periods each year, leaving the remainder of the year for residents and visitors to experience.

Photo: Fabrizio Conti, 2019.

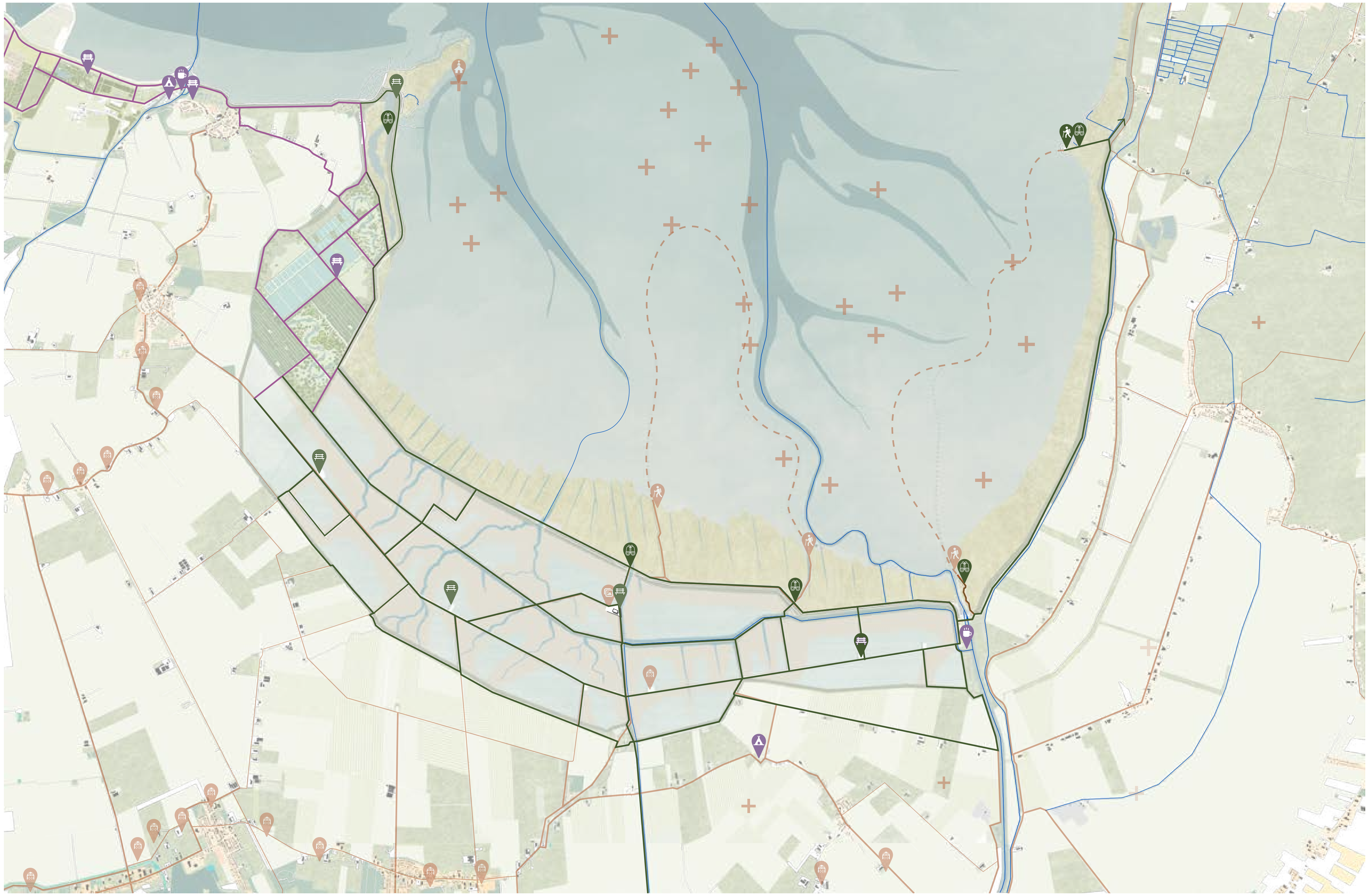
The Kleirijperij site of Delfzijl just after deposition.
Photo: Luca Sittoni, 2019.

Photo: José Ignacio Pompé, 2020.





Ecology and Cultural Routing



The history of mankind battling floods and the game between land, sea, and rivers in this area makes for a vibrant cultural resource. Not only are there many layers of dikes, but also a wealth of historical buildings.

In the area of the ecological route, the historical resources that can be seen and perceived are not as rich since parts of the area were once submerged. However, these were reclaimed by man after the first three centuries and turned back into the land. During the long process of reclamation, layer after layer of dikes were simultaneously built, some of which are no longer visible today. However, the closer you get to the sea, the newer, better preserved, and stronger they become. In the face of overly turbid water, the ecological challenges include severe salinization, and land subsidence, as well as the degradation of salt marshes and rising sea levels. Therefore, this area will be used as a test area for ecological landscapes, creating a tidal polder by activating the old dikes in an attempt to bring in the forces of nature to shape new resilient landscapes that provide habitats for the various species in the estuary and the Wadden Sea.

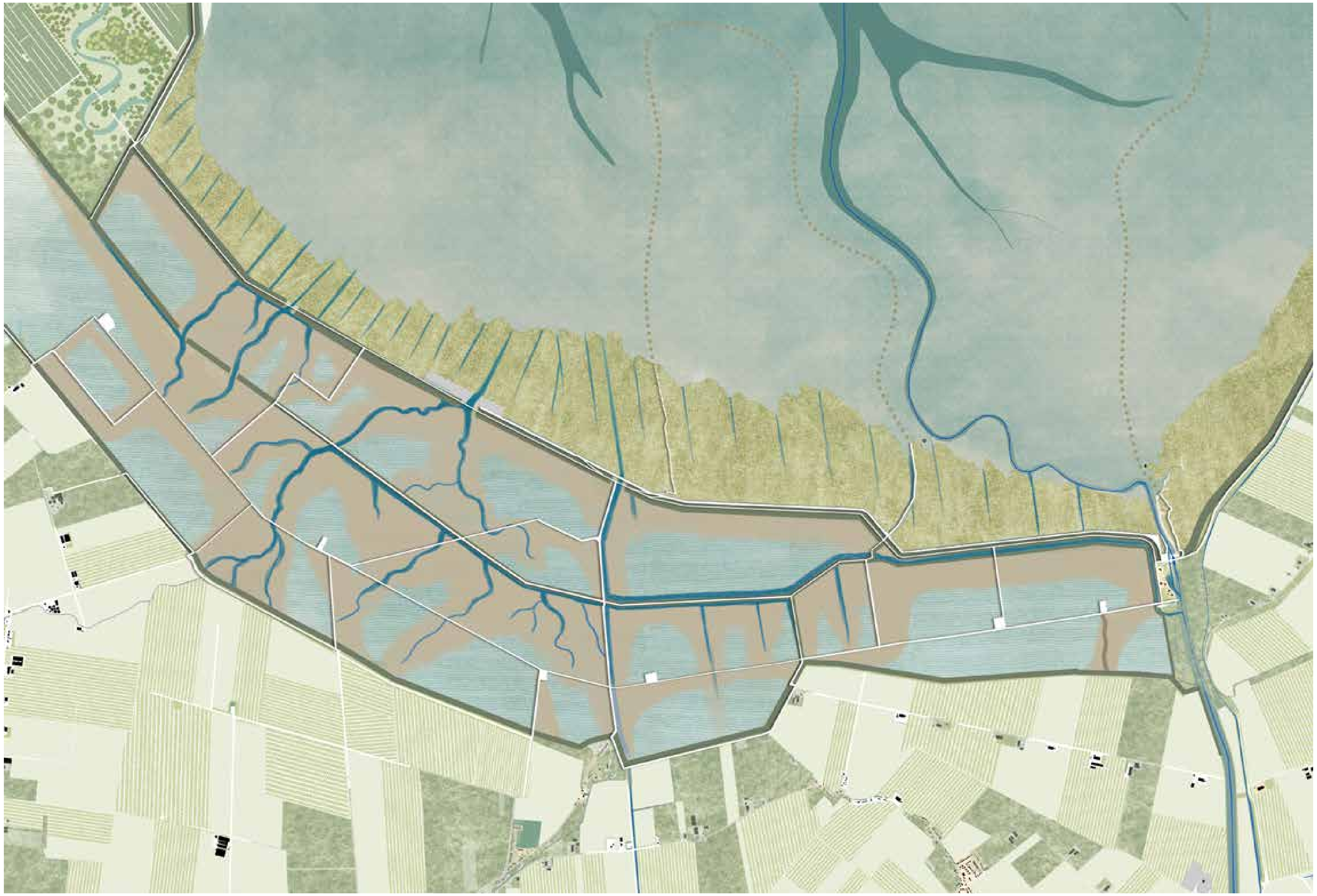
The cultural route lies between the historic land and the newly reclaimed land—a path rich in historical buildings along which one can walk and imagine that the land on either side has an entirely different history. Eventually, people can follow the cultural trail over the dike, past the wooden walkway, past the birdwatching houses, and onto the mudflats of Dorade for a mudflat walk. Here, they will be surprised to find landmarks appearing on the empty mudflats, symbolizing the 12th-century terps and villages (and even a monastery) that existed here and are now buried under the mud.

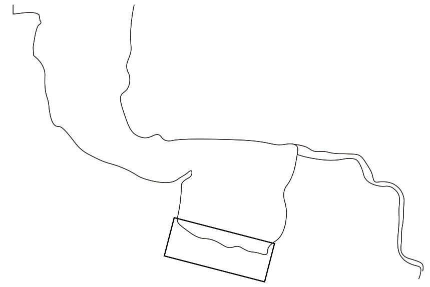
0 1 km 3 km

Culture monuments
Recreation nodes
Buried villages

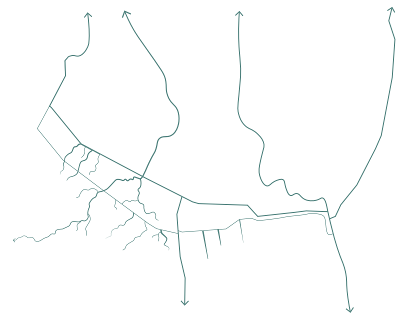
Old terps
Culture routes
Mud hiking
Ecology routes

Design Node 3

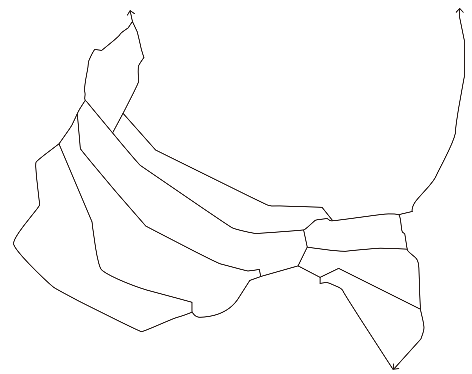




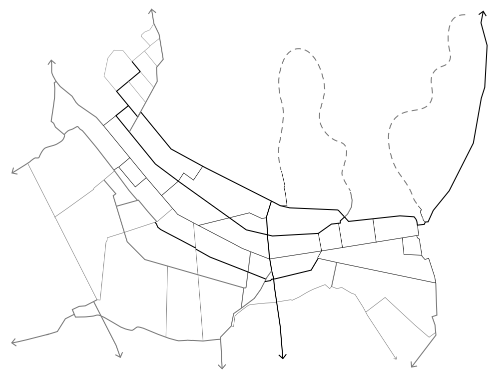
Water



Old Dike System



Connection



0 500 m 1 km

Dikes
Mudflats hiking
Sedimentary area

Saltmarsh
Farmland
Grassland

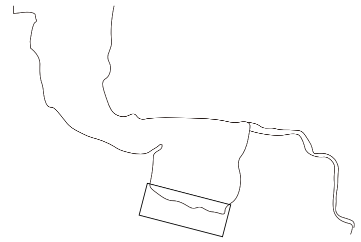
Scenarios

Prior to the design, a status quo analysis was carried out, as well as scenario assumptions.

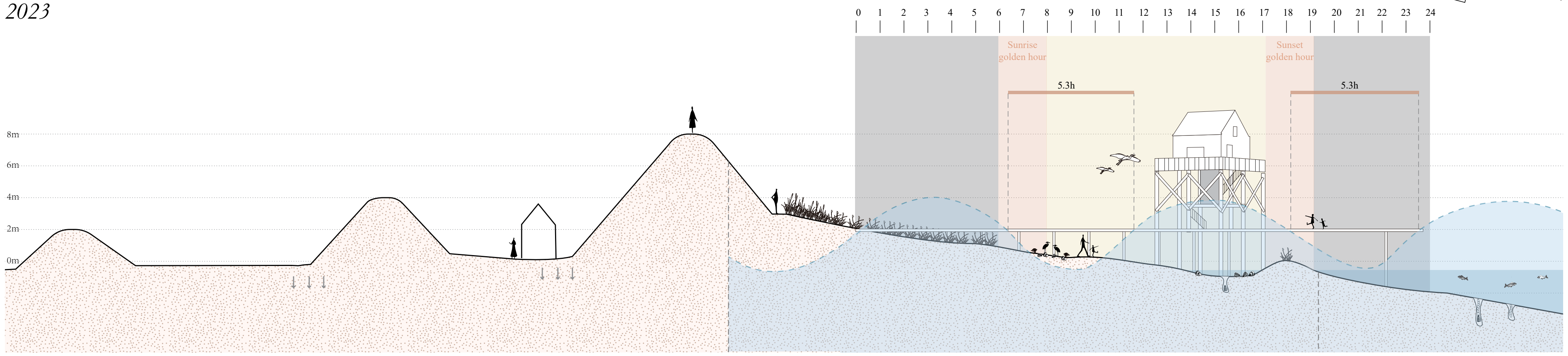
In 2023, with two high and low tides in one day, during which the intertidal mudflats are exposed, birds are provided with suitable habitat and feeding conditions. People can also walk on the mudflats using a wooden walkway 2 m above mean sea level, which can be traversed for a total of approximately 10.6 hours.

Without intervention, by 2050—and assuming extreme conditions of sea level rise—daily tidal differences will increase, mean water levels will rise, and the mudflats will become less exposed, with a corresponding reduction in the length of time birds can remain in optimal habitats and people can rest. Taking the aforementioned wooden walkway as an example, the total time during which people can use the walkway is approximately 7.5 hours, which is 3 hours shorter than before.

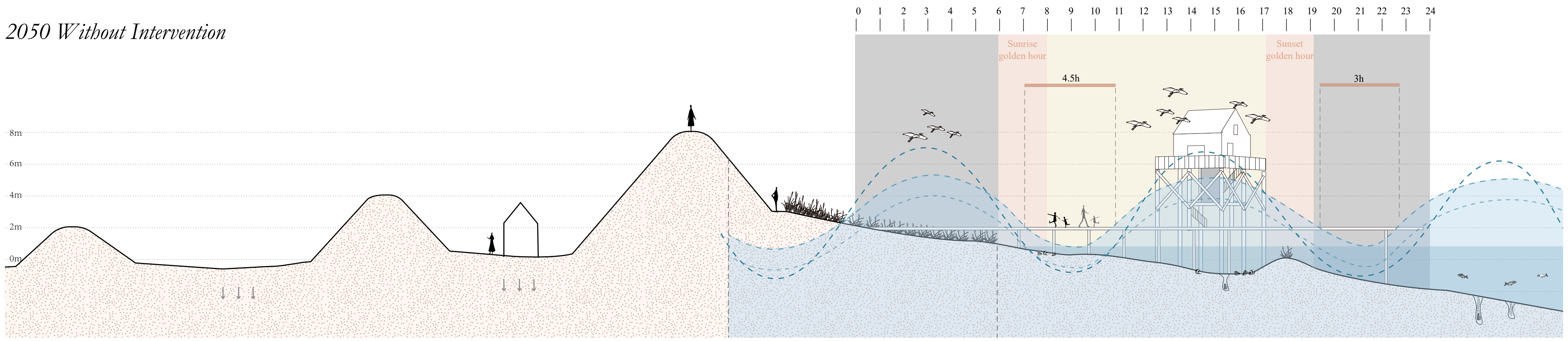
The intertidal zone is an important ecological area. One measure that can be taken to stop the continuous compression of the intertidal zone is to raise the old dike inland, abandon the new one, and return part of the polder to nature, leaving it as an intertidal zone. However, the disadvantage of this is that the old dikes would need to be raised and reinforced significantly to become the new mainstay of flood protection, which would be very costly, and the new dikes currently in use would lose their function and not be fully utilized.



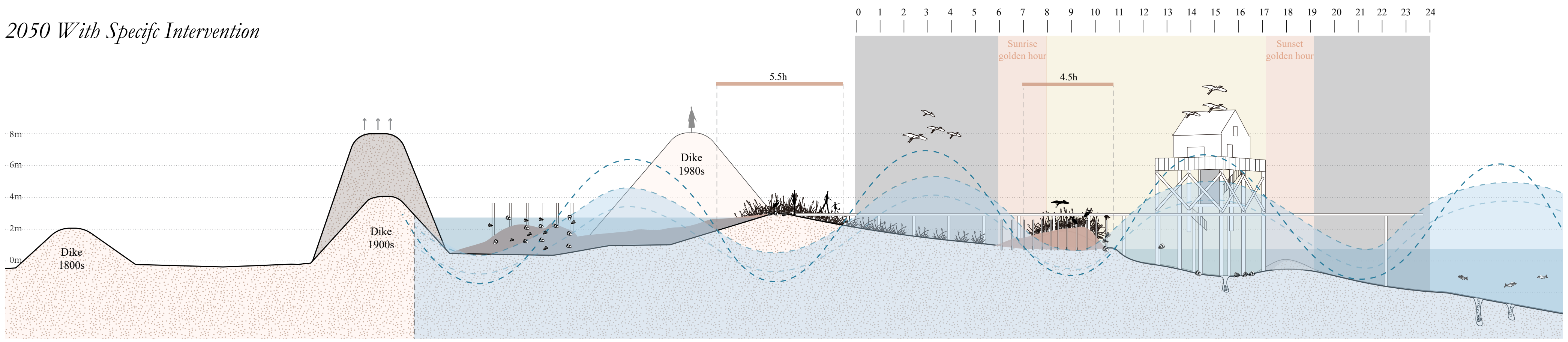
2023

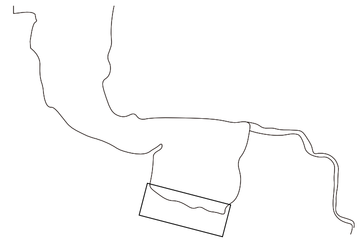


2050 Without Intervention



2050 With Specifc Intervention





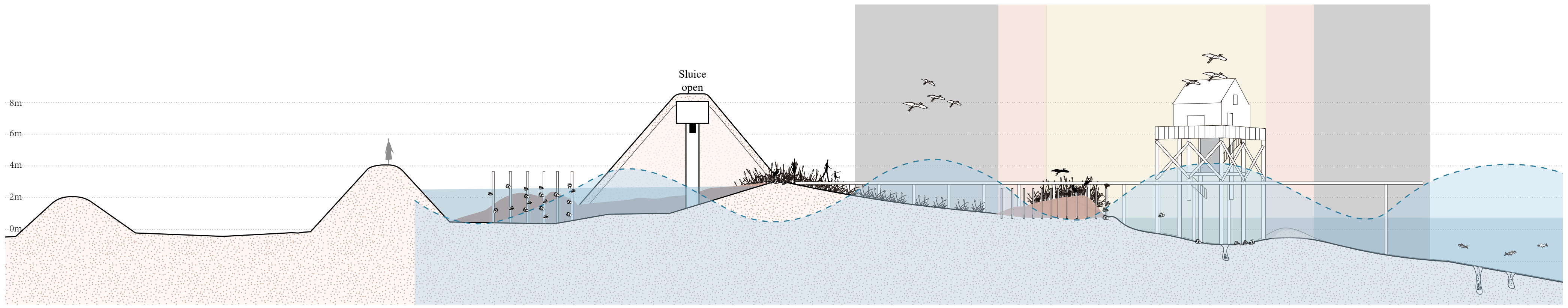
Design Node 3

Based on the scenarios envisaged in the previous section, it was decided to keep the new dikes and the old dikes as they are and to make the area between the two dikes a tidal polder by means of gates and culverts on the new dike.

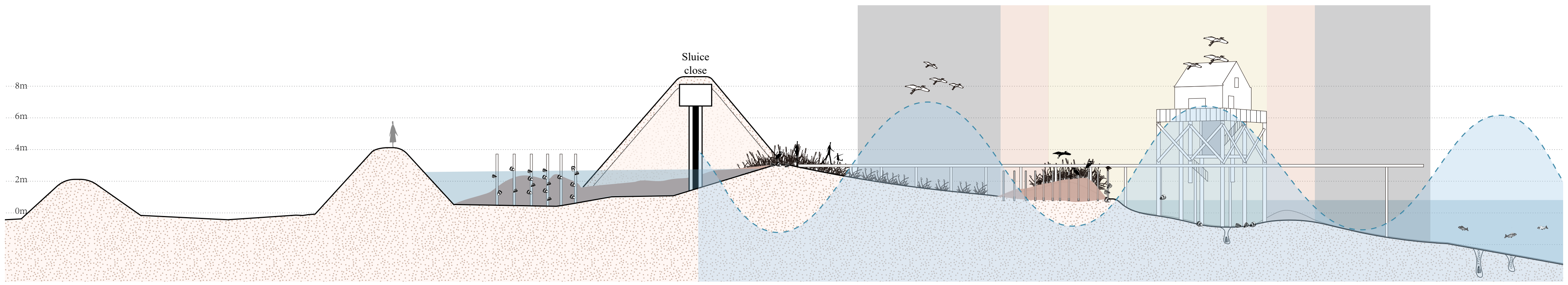
During the period without storm surge (i.e. most of the year), the gates are kept open, and the twice-daily tides can freely enter the area. In combination with some stacks and the arrangement of silt collection structures, this area will collect the mud brought in by the tide. Suspended material is left here at low tide, forming some mounds similar to intertidal habitats.

In 30 years, with the natural action of the mounds, the soft soil animals will attract birds, which will bring seeds. Moreover, combined with the artificial planting of reed wetland plants, this area will gradually become a wetland.

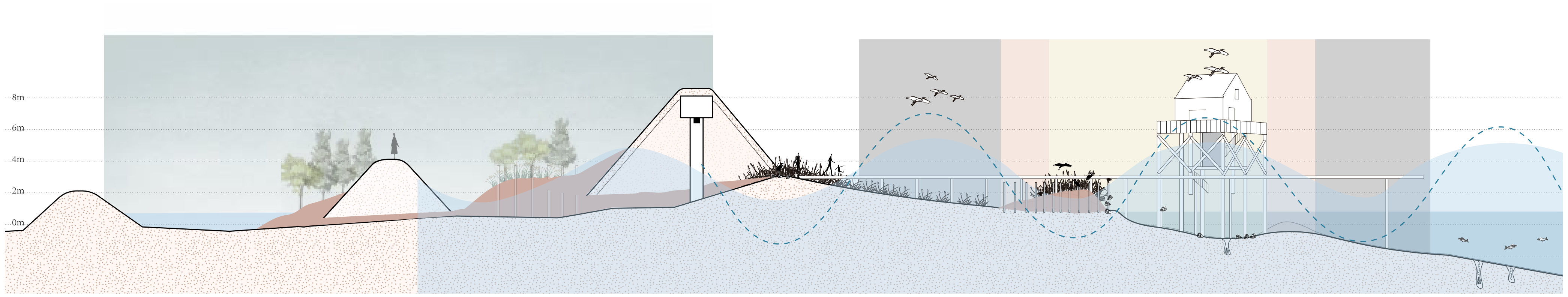
2035 Normal Water Level

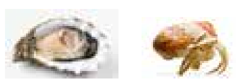


2035 Spring Tide Period



2050

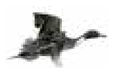




Small invertebrates

Black Rider
Tringa erythropus

Redshank
Tringa totanus



Pintail

Oystercatcher
Haematopus ostralegus

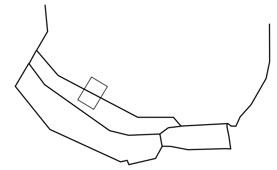
Greenleg Rider
Tringa nebularia

Curlew Numenius arquata

Knot Calidris canutus

Shelduck
Tadorna tadorna

Teal
Anas crecca

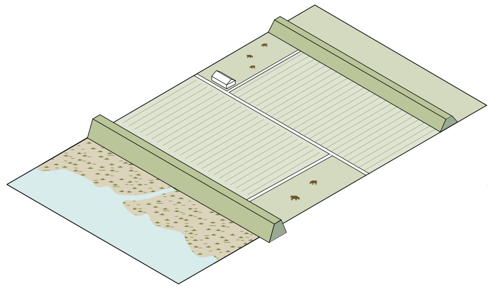


Design Node 3

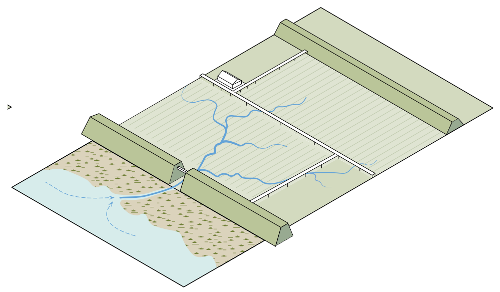
The elevated topographic map of the area shows the meandering and winding track of the river that once ran from the mouth of the Ems. Today, these channels are hardly recognizable and mixed in with the farmland, replaced by straight water channels. Since the soil structure under these disappeared channels is different from the rest of the area, the river will reassert its former position as soon as the water can flow freely here again, which is the basis of the river form in the design.

While restoring the river, the wisdom of traditional brushwood dams can be borrowed to promote the deposition of suspended matter in the water. Notably, the existing paths in this area will be flooded. In designing the new paths, in addition to the wooden trestle, paths shaped like brushwood dams will appear as a link between the new dike and the old one, while chamomile or daisies will be planted alongside the path to create a distinctive appearance that encourages people to look into the area's history. Although the path will eventually be submerged in the years to come, it will still serve to collect sediment.

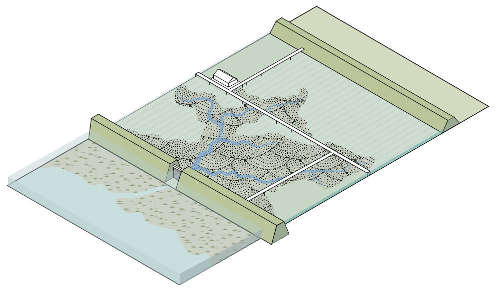
2023



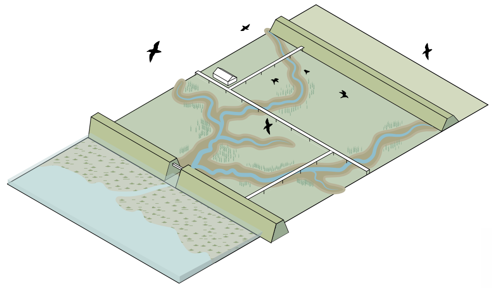
2025



2035

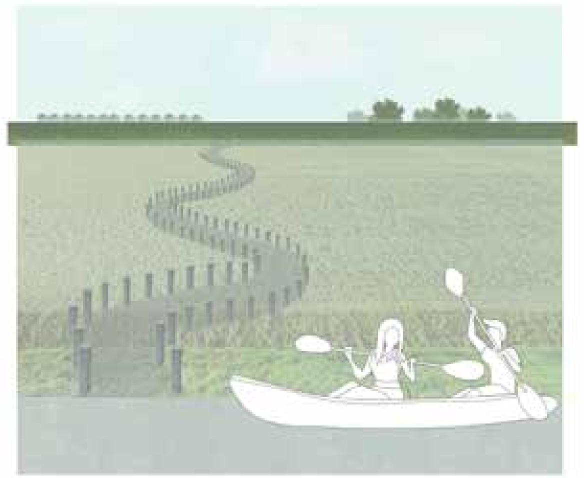


2050



"I remember the days when you would find chamomile or daisies on the side of the road. You can hardly see it anymore."

Enhancing Sedimentation
Photo: Philipp, 2020



Friesland Pastures.
Photo: Xinjian Jiang, 2022.

8 | Re-Peating Nature

Ruralities in Transition

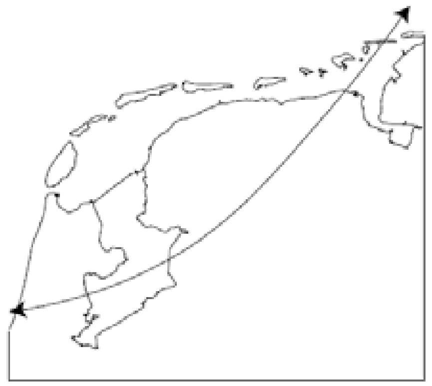
Student | Anna Gorokhova

First Mentor | Laura Cipriani
Second Mentor | Diego Andres Sepulveda Carmona

Due to its unique history, the Frisian landscape has developed into the largest dairy production area in the Netherlands. Years of scaling up and production growth have created a situation in which the productive landscape conflicts with Friesland's cultural and natural heritage and contributes to climate change. Frisian agricultural practices place immense pressure on the peat soils in the province, resulting in significant carbon emissions and a high likelihood of water shortages in the future. 'Peatlands are the largest terrestrial carbon store on earth, storing about 25% of global soil carbon, which is twice as much as forests' (UN Environment Programme, 2019). Peatlands have immense value for the region's natural and cultural development.

This graduation project looks into the past, present, and future of the agricultural landscape of Friesland. It aims to envision an alternative resilient future for its peatscapes, in which the productive properties of the landscape are not lost but strengthen the cultural and natural Frisian narrative of the future. The future scenarios are formed based on different outcomes related to agricultural practices, through which the most desired one is explored further. The thesis seeks to provide an in-depth analysis of the productive landscape, resulting in a strategic design proposal for peat restoration and preservation. These strategies are implemented in close collaboration with the local stakeholders using regional- and small-scale designs. The alternative scenario involves strategies that strengthen ecological connectivity and cultural heritage while proposing climate mitigation and adaptation activities. Further explorations on forming carbon banks, paludiculture corridors, and nature for people are part of the project for peat restoration and preservation for future generations.

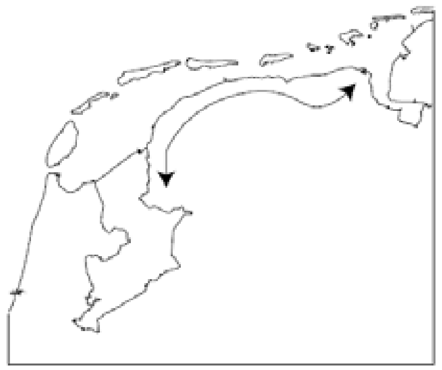
Strategies



Stronger Eco Corridors

STRATEGY 1

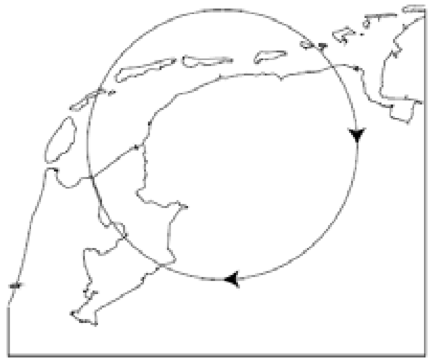
Nature Inclusive Agriculture



Valuable Heritage

STRATEGY 2

Stronger Cultural Heritage



Mitigation and Climate Adaptation

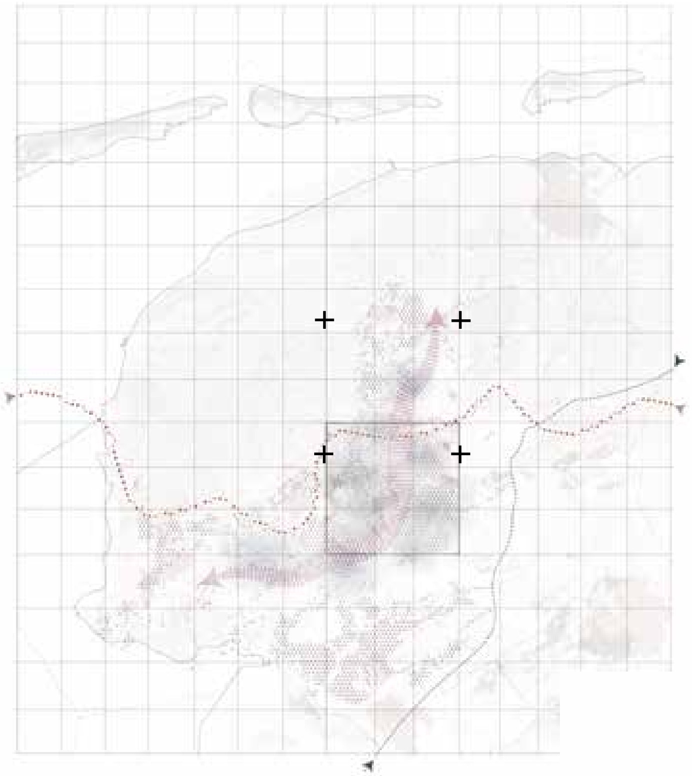
STRATEGY 3

Climate Responsive Agriculture

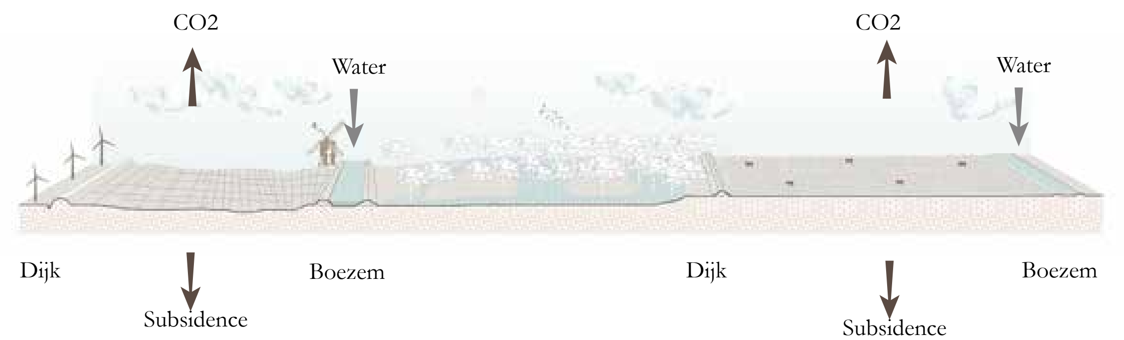
Landscape management often lacks a holistic approach and, as a result, overlooks '*the broader context within the physical landscape*' (Schepers et al., 2021). This leads to a major '*gap between physical, geographical, biological, and cultural (historical) approaches*,' contributing to fragmentation and division in policies and often strategies (Schepers et al., 2021).
Landscape management in practice often brings higher biodiversity, disregarding possible cultural values, leading to '*serious problems regarding the management of heritage and the readability of our landscape*' (Schepers et al., 2021). '*This is exemplified by UNESCO, which often separates natural from cultural and awards sites based on either of the categories*' (Schepers et al., 2021).

The three main design principles dictate a holistic approach to the development of the Frisian landscape: nature-inclusive agriculture, culture-inclusive agriculture, and agriculture that adapts and mitigates climate change.
The design principles respond to the ideal scenario developed with the local stakeholders. Using the design principles and aligning goals of different legislative entities/stakeholders, I propose strategies and sub-strategies that result in a 2035 vision for the area, which is further explored.

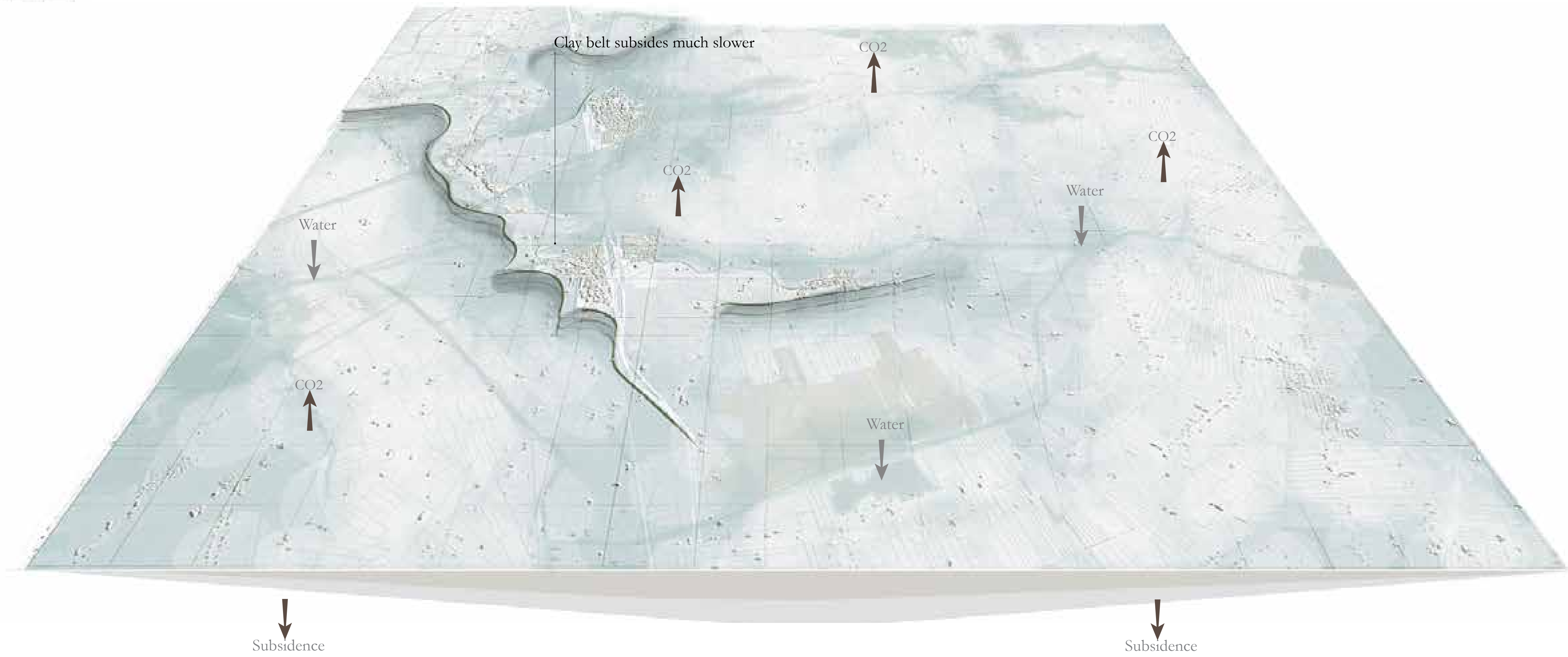
What if we do Nothing? No Peat. The Beyond 2100 Scenario
System Limits



Droughts
Peat Oxidation
Subsidence
Salinisation



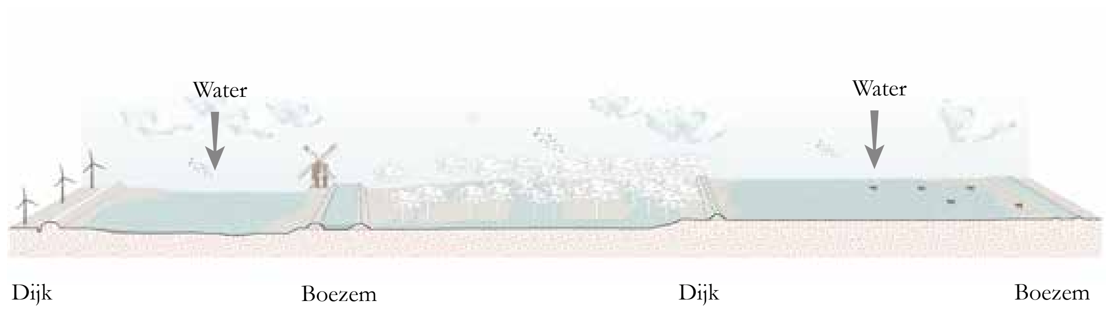
If current unsustainable soil and water management practices prioritize the needs of dairy farming over the preservation and appreciation of the unique Frisian peatlands, the peat is expected to disappear within the next 200 years (Brouns et al, 2015). In this scenario, Friesland is expected to experience '*damage to building foundations, desiccation of nature reserves, emission of greenhouse gasses, increasing costs for water management and infrastructural maintenance, deterioration of surface water quality and, finally, loss of the characteristic landscape*' (Brouns et al, 2015). As a direct result of increased subsidence due to lowered water tables, the cost of water management will rise. This scenario also speculates that increasing pressure to obtain freshwater from Ijsselmeer will result in immense freshwater shortages in the region, threatening the productive landscape and peoples' livelihoods.



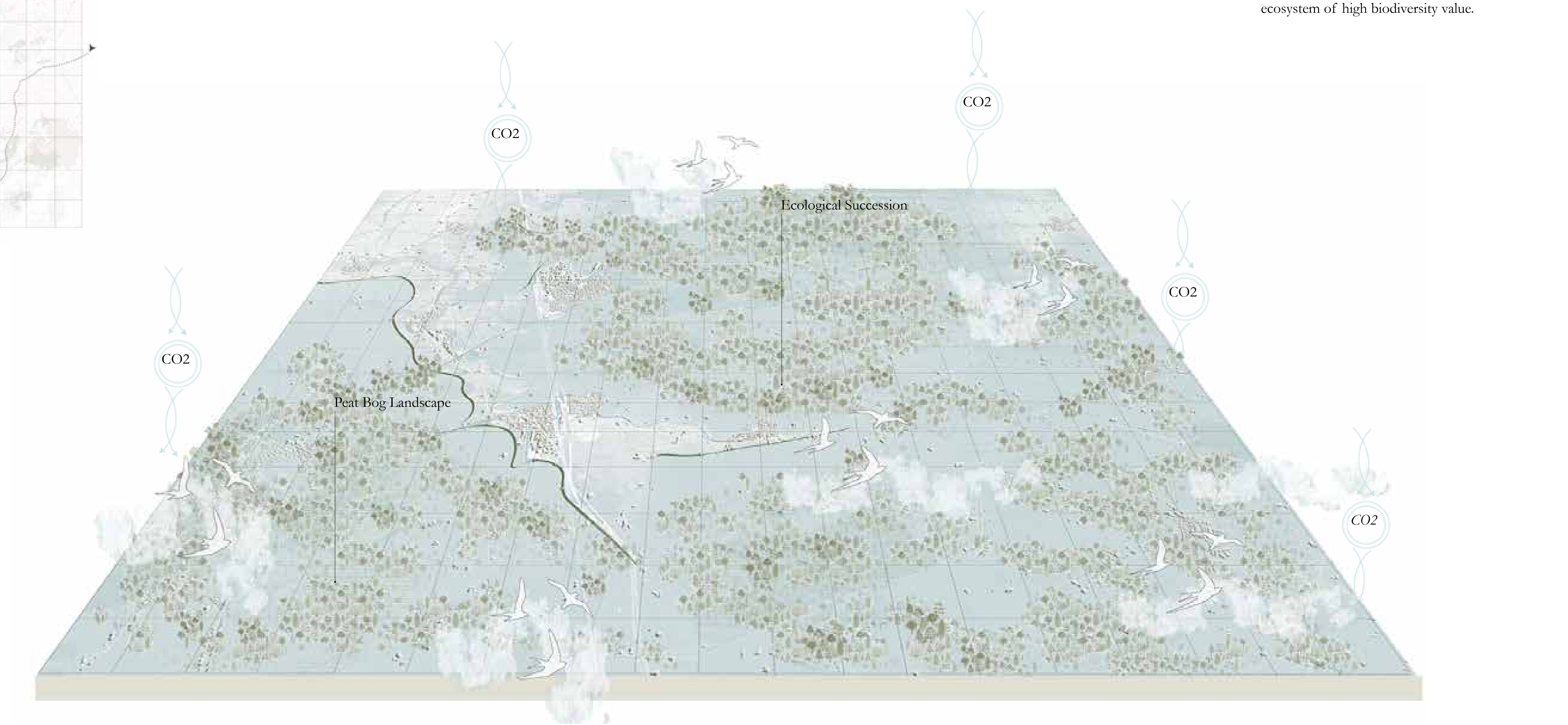
What if we Stop Draining? The Beyond 2100 Scenario

System Limits

Peat Bog Landscape
Peat Oxidation
Subsidence
Salinisation

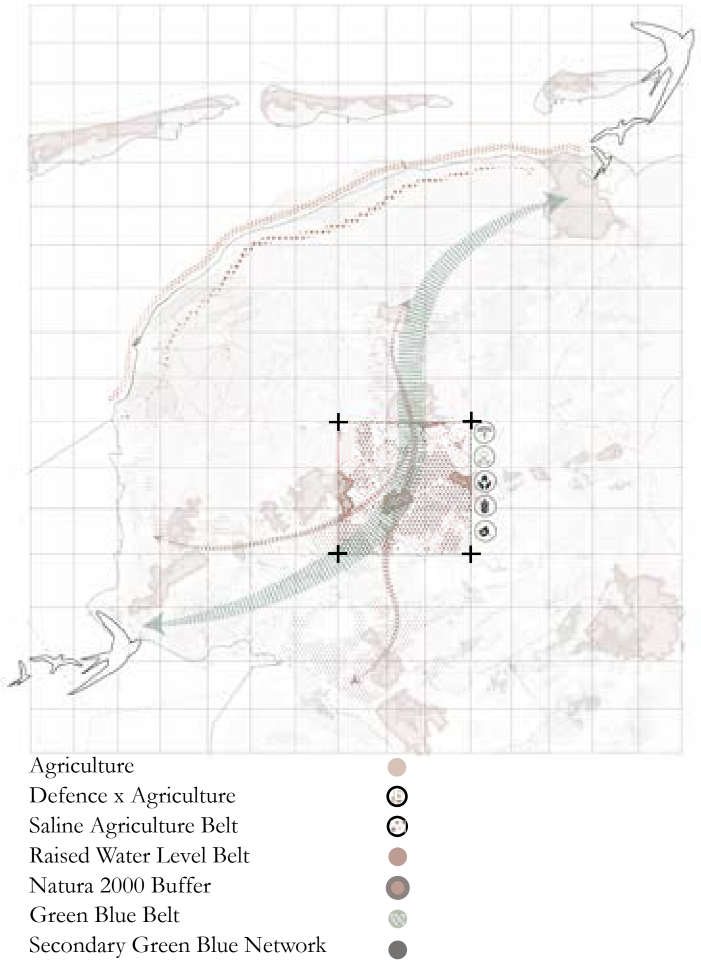


With the complete abandonment of the current water/soil management system, the low-lying peatlands are expected to accept water, balancing the water table across water bodies. Under such circumstances, an increased water table will reduce subsidence and peat oxidation. However, the establishment of the natural peat wetland system will lead to a complete loss of the modern agricultural landscape and practices currently operating in Frisian peatscapes, unless they transform into something else. In 100 years, the fen peatscapes are expected to ecologically succeed into a peat bog landscape, an ecosystem of high biodiversity value.

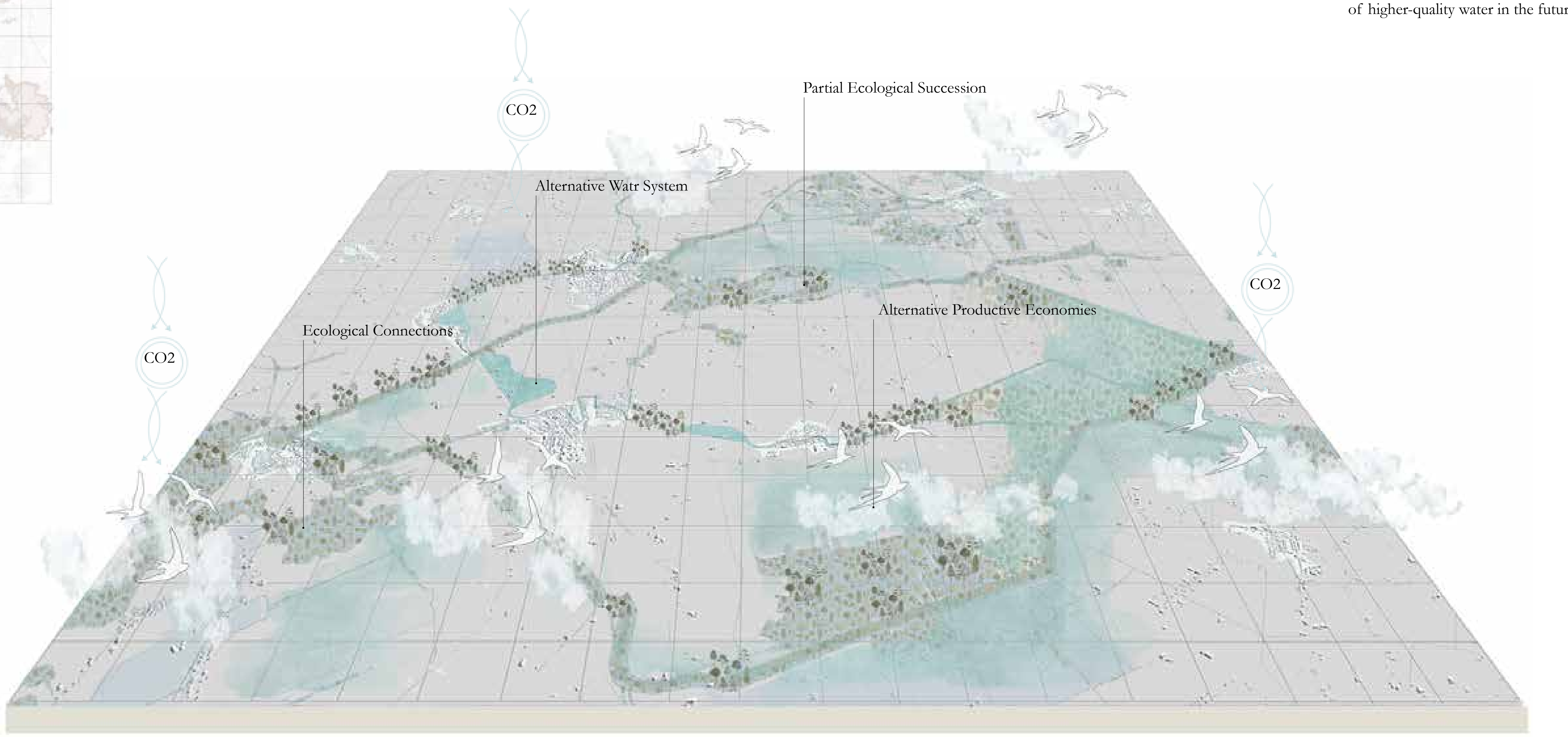


What if we Develop Nature? The Beyond 2100 Scenario

System Limits



The establishment of ecological networks, strengthening of Natura 2000 zones, carbon sequestration through peat preservation and restoration, the establishment of new sustainable nature-inclusive economies, paludiculture, the establishment of a water purification system, and strengthening of the cultural landscape are pictured in the 2100 scenario. The new landscape is expected to act as carbon storage with three distinct nature types of different nature values: carbon banks, where significant carbon sequestration occurs; paludiculture, representing a new form of sustainable, productive landscape; people and nature, including a water purification system to ensure the provision of higher-quality water in the future.



Friesland Peatscapes.
Photo: Anna Gorokhova,2023.

Expanded Strategies

One way to ensure the establishment of nature-based solutions involves understanding the complexity of the interests of different legislative entities and stakeholders (Ruangpan et al, 2021). The diagram aligns multiscalar goals and strategies that could respond to the goals of different stakeholders involved in the area.

Goals and Strategies

Stakeholders	*EU*	*National Gov*	*Regional Gov*	*Scale*	*Regional*	*Local*	*Farm*
Goals			*Sub - Goals*	*Strategies*			

Establish Natura 2000 Buffer Zones

Reduce Nitrogen by 47% in Peat Areas

Improve Water Quality / Quantity
- Incerase Ground Water Quality
- Incerase Surface Water Quality
- Incerase Fresh Water Storage
- Reduce Risk of Inland Salinisation
- Manage Excess Water Flow

Improve Soil Quality
- Minimise Soil Subsidence
- Minimise Peat Oxidation
- Increase and Maintain Soil Quality
- Strengthen Manure Treatment Cycle

Improve Biodiversity/ Habitat
- Increase Habitat Provision and Distribution
- Increase Habitat Quality

Improve Cultural Heritage
- Increase Accessibility of Cultural Heritage
- Increase Value of Cultural Heritage

Improve Socio - Economic
- Encourage New Business Models
- Increase Recreational Opportunities

Green Blue Infrastructure Backbone
- Water Storage
- Wetland Establishment and Enhance ment
- Raising of Water Levels
- Blocking of Drainage Channels
- Nature Bank Stabilisation
- Natura 2000 Buffer Zone
- Primary, Secondary, Tertiary Green Blue Network
- Peat Restoration
- Paludiculture

Cultural Heritage Network
- Reconnected Cultural Heritage Network
- Valuable Cultural Heritage Routing
- Local Agro Heritage Network
- Small Scale Leisure
- Agrotourism

New Economies
- Green Blue Recreation Netwrok
- New Job Opportunities
- Carbon Credit Model
- Biomass Energy
- Valuable by Agro production

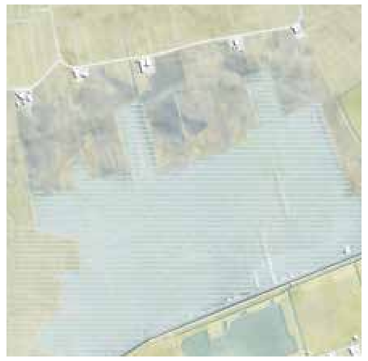
What if we Develop Nature? 2035

Alternative Future

Natura 2000
Grassland
Water
Buildings
Polder Paludiculture
Grassland Paludiculture
Purification Wetlands
(Re) Peat Buffer
Cultural Network

0 1 km 5 km

3 Natures



Carbon Bank

Paludiculture Corridor

People Nature

The graduation thesis responds to the 2100 scenario, developed with the local stakeholders, and introduces a short-term 2035 vision to prepare for the alternative future. The proposal suggests developing nature for short- and long-term carbon sequestration and introduces strategies for ecological, cultural, and climate-responsive development. The three types of nature are listed in the following subsections.

Carbon Bank

In response to the EU's desire to strengthen Natura 2000 areas and develop buffer zones surrounding the protected ecological zones, the proposal suggests converting the agricultural land in direct proximity to the Natura 2000 border into a 1-km buffer zone for peat preservation and restoration. The proposal re-envisions the productive economies in the buffer zone and prepares the farmers for an uncertain future. Waterways on the site act as ecological connectors and ensure the provision and distribution of local habitats.

Paludiculture Corridor

Peatlands are '*wetlands with partially decomposed plant material*' (Zhong, Jiang, and Middleton, 2020). A high water table serves a vital role in peat restoration and preservation. Paludiculture is 'the cultivation of crops on rewetted peatlands' (de Jong et al, 2021). Paludiculture '*is a valuable climate mitigation option that reduces greenhouse emissions and provides novel agricultural solutions*' (de Jong et al, 2021). The project proposes the creation of a paludiculture corridor in the embanked deep-lying polders that have higher water retention capacity and strengthen ecological connectivity between the carbon banks.

People Nature

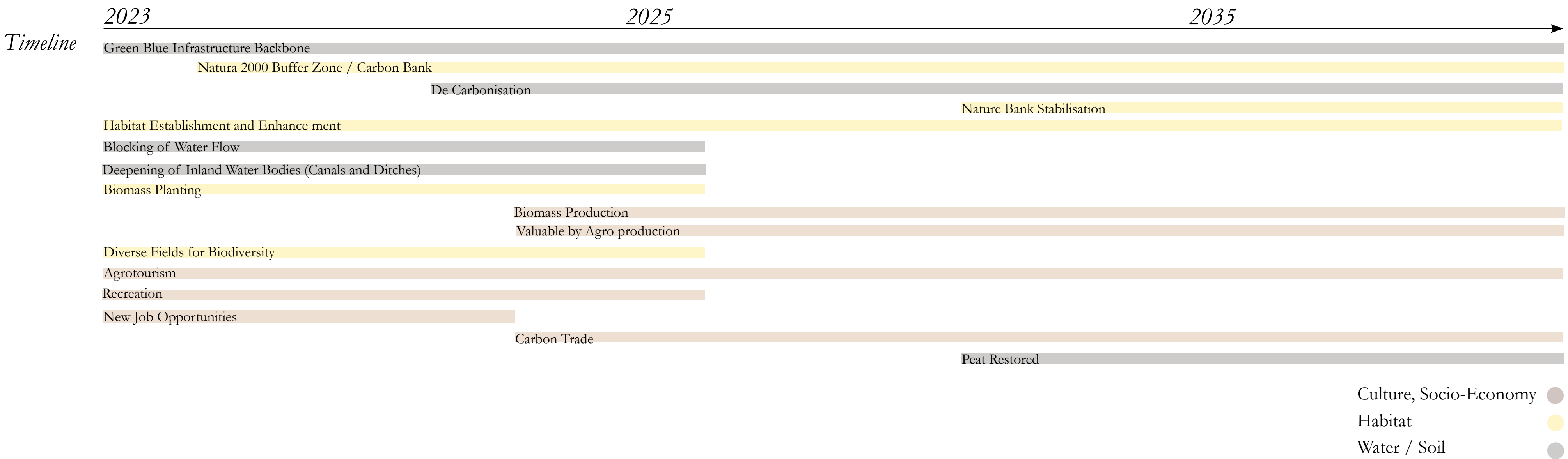
To tackle the urgent issue of low water quality and a homogenized cultural landscape, People Nature aims to create a water purification network that also provides new recreational opportunities and enhanced connectivity between cultural structures at the site. The proposal appreciates the cultural values of the local landscape and enhances the existing experiential qualities.

De Deelen Peat Bog Natura 2000.
Photo: Google Earth, 2024. Map data:
Google ©2024 Aerodata International
Surveys, GeoContent, Landsat/Copernicus
Maxar Technologies, Dati Cartografici.

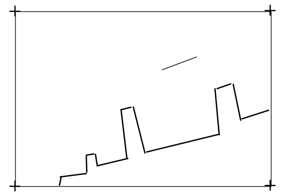
De Deelen Carbon Bank

2023 *2025* *2035*

The green-blue backbone infrastructure, which contributes to peat restoration, is expected to develop as soil and water management strategies are introduced. Within ten years, the area is expected to fully transition into a new economy, where dairy farmers rely on biomass production, agrotourism, and the sequestrated carbon credit trade. As time passes, agrotourism should strengthen, thereby allowing the residents of Aldeboarn and other visitors to appreciate the Frisian peatlands.



De Deelen Carbon Bank

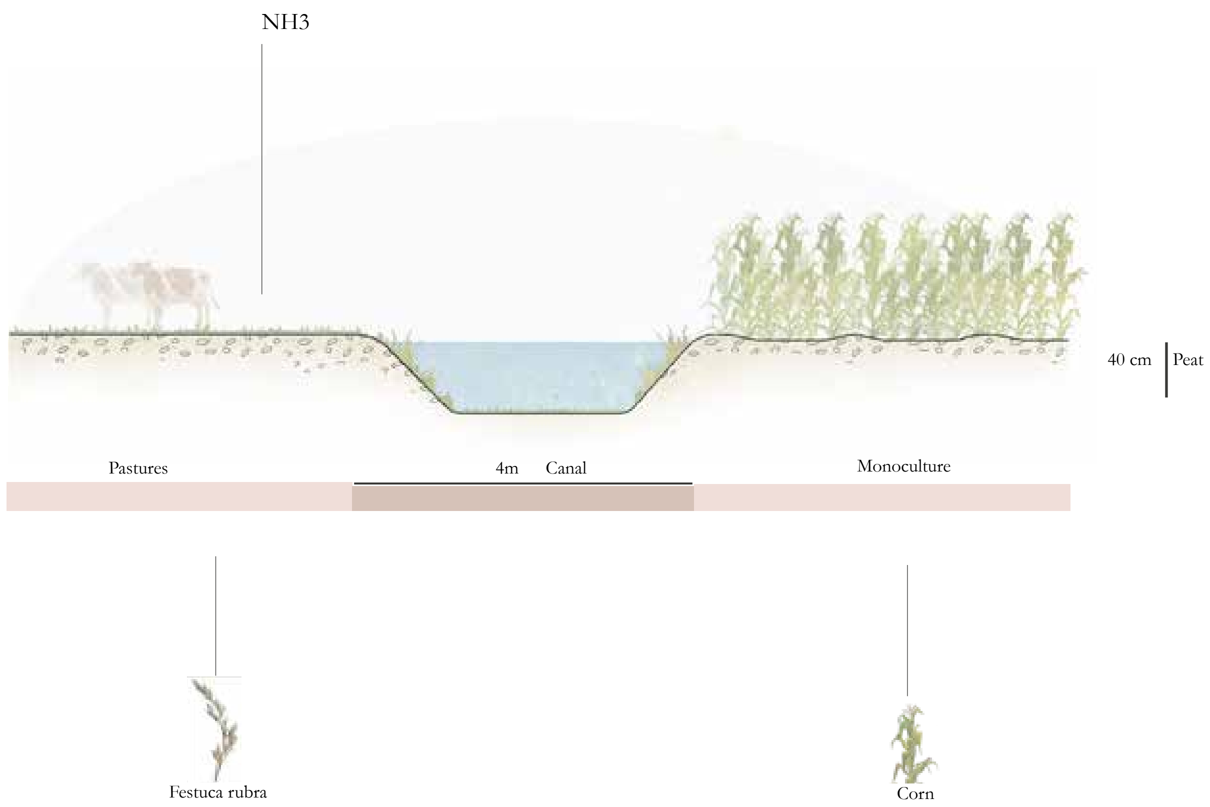


Blocking of Drainage Channels

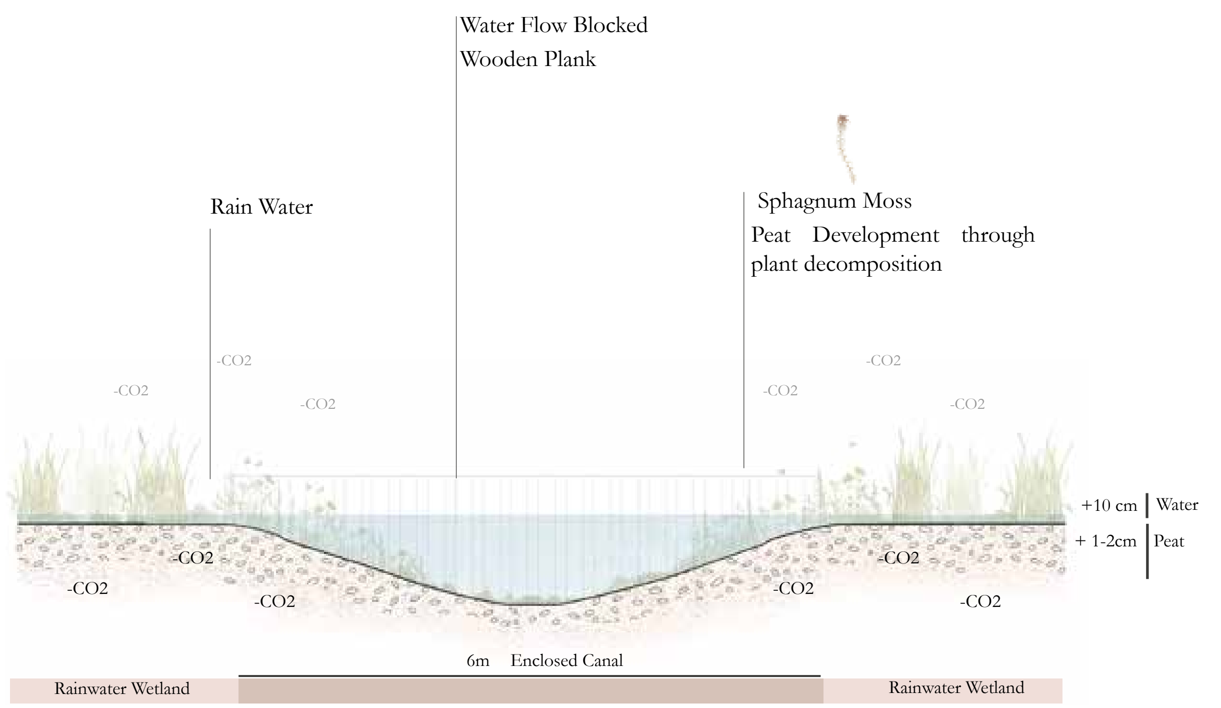
Blocking of Drainage Channels

One of the main ways to restore degraded peat 'is to restore their hydrological functions' (Dinesen and Hahn, 2019). Ditch and canal water drainage blocking is the primary technique used at the site for hydrological function restoration. The introduction of peat-growing species, such as sphagnum moss, is part of the restoration process.

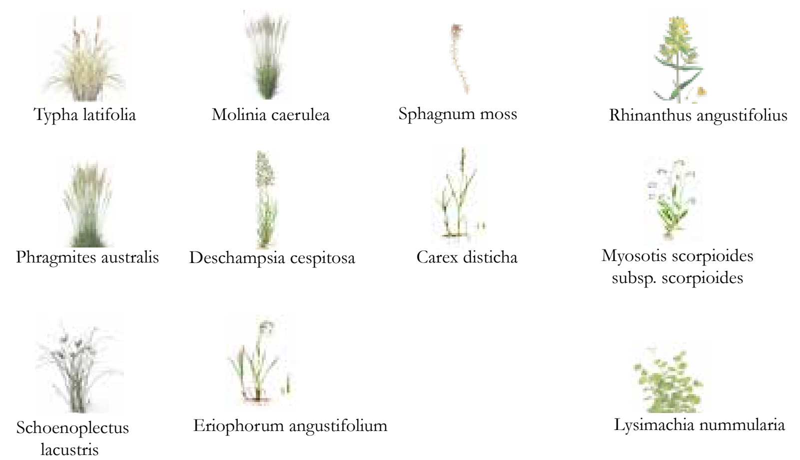
2023

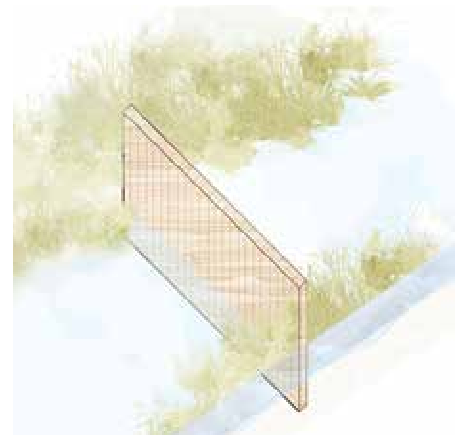


2035



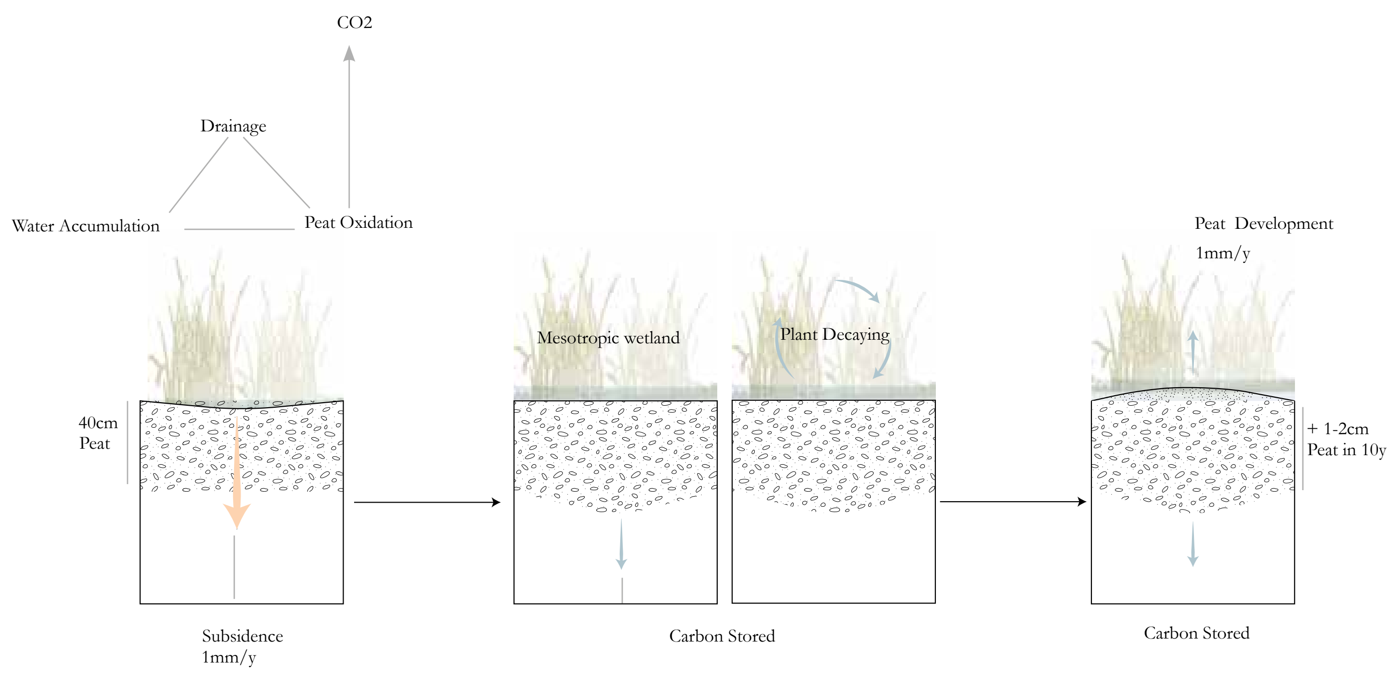
Peat Species





De Deelen Carbon Bank

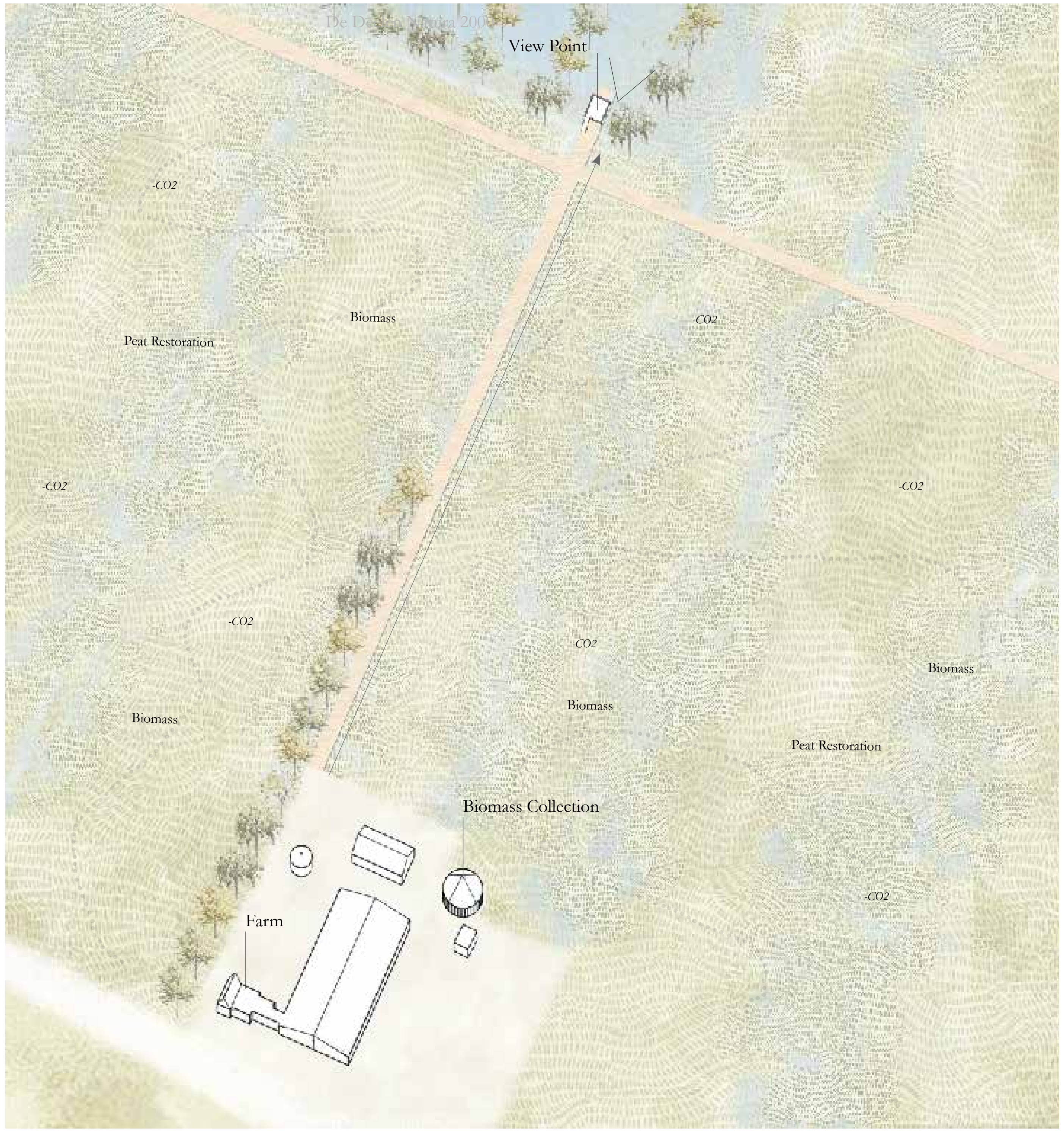
Peat Restoration
As the water table is restored, submerged plants decay under the mesotrophic wetland conditions that the blocked drainage ditches and canals create. In the process, decaying plants contribute to carbon sequestration and peat restoration. The average peat restoration rate under such conditions is 1mm/year or 1–2 cm in ten years (Dinesen and Hahn, 2019).



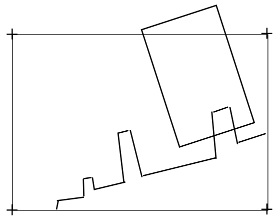
Peatlands in Kõnnu Suursoo vaatetorn, Estonia. Photo: Maksim Shutov, 2020.

Carbon Bank

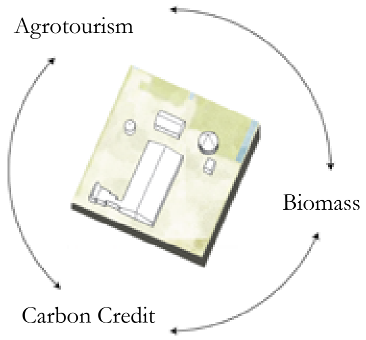
Carbon and Biomass Farming



0 40m 80m

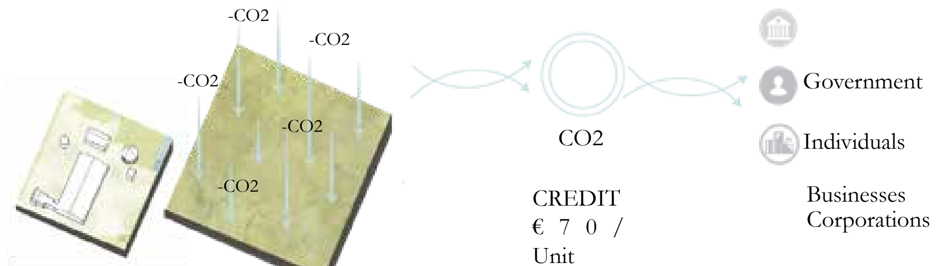


Alternative Economy



Experimental Carbon Farm

Carbon Credit Model



Going down in scale, the proposal suggests the five farms transition into a new economy that relies on sustainable practices and has minimal impact on local biodiversity. The farms, while becoming an agritourism hotspot for Aldeboarn citizens to access the restored peatlands and De Deelen Natura 2000, also rely on biomass production and trade of sequestrated carbon. The alternative economy model suggests that restored peatlands, due to their ability to store carbon, will allow the farmers to sell carbon credits to governments, businesses, and individuals. Currently, to the North of the site, the 'Lytse Deelen' farm has sacrificed part of its land for peat restoration and participates in the scheme, where carbon is sold for 60 euro/carbon. Biomass planting not only contributes to the alternative economy model but also creates an experiential landscape for the visitors, thereby contributing to agrotourism and peat restoration since it relies on active plant decaying processes. To ensure the resilience of independent farms, biomass energy production is also considered. As climate change is further impacting the way we live, there will be an increasing opportunity for biomass production in Frisian peatlands (Kuhlman et al, 2011). Species local to Frisian peatscapes, such as willow and typha, are most suitable for biomass cultivation.

Paludiculture

Rice Fields, Pastures
Peat Restoration
Agrotourism
Recreation

Cranberry Wet Crops
Peat Restoration
Agrotourism
Recreation
Protected Farms

Primary Ecological Corridor

0 500 m 1 km

Rice Paludiculture
Cranberry Paludiculture

Low water table crops such as rice have a minimal impact on the infrastructural landscape. Therefore, they require less work in the transition into paludiculture. In contrast, high water table crops such as cranberry require the land to be embanked with dikes and are more likely to appear in deep-lying polders. As a result, the substantial paludiculture corridor intervention involves low water table crops with minimal impacts on farms.

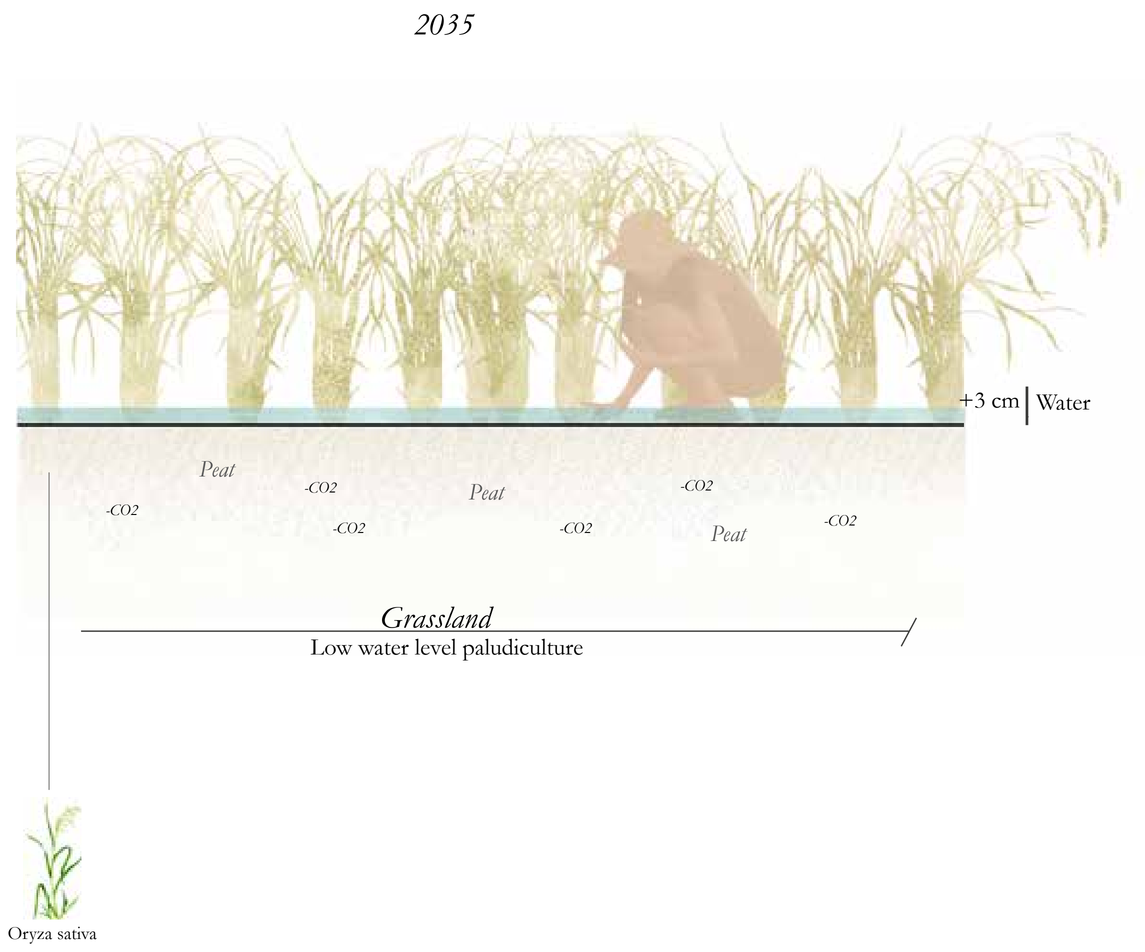
Farms located in the deep-lying polders will be under the threat of moving elsewhere. However, the use of temporary dams to protect structures during the high water level harvest season reduces the risks of flooding and property damage.

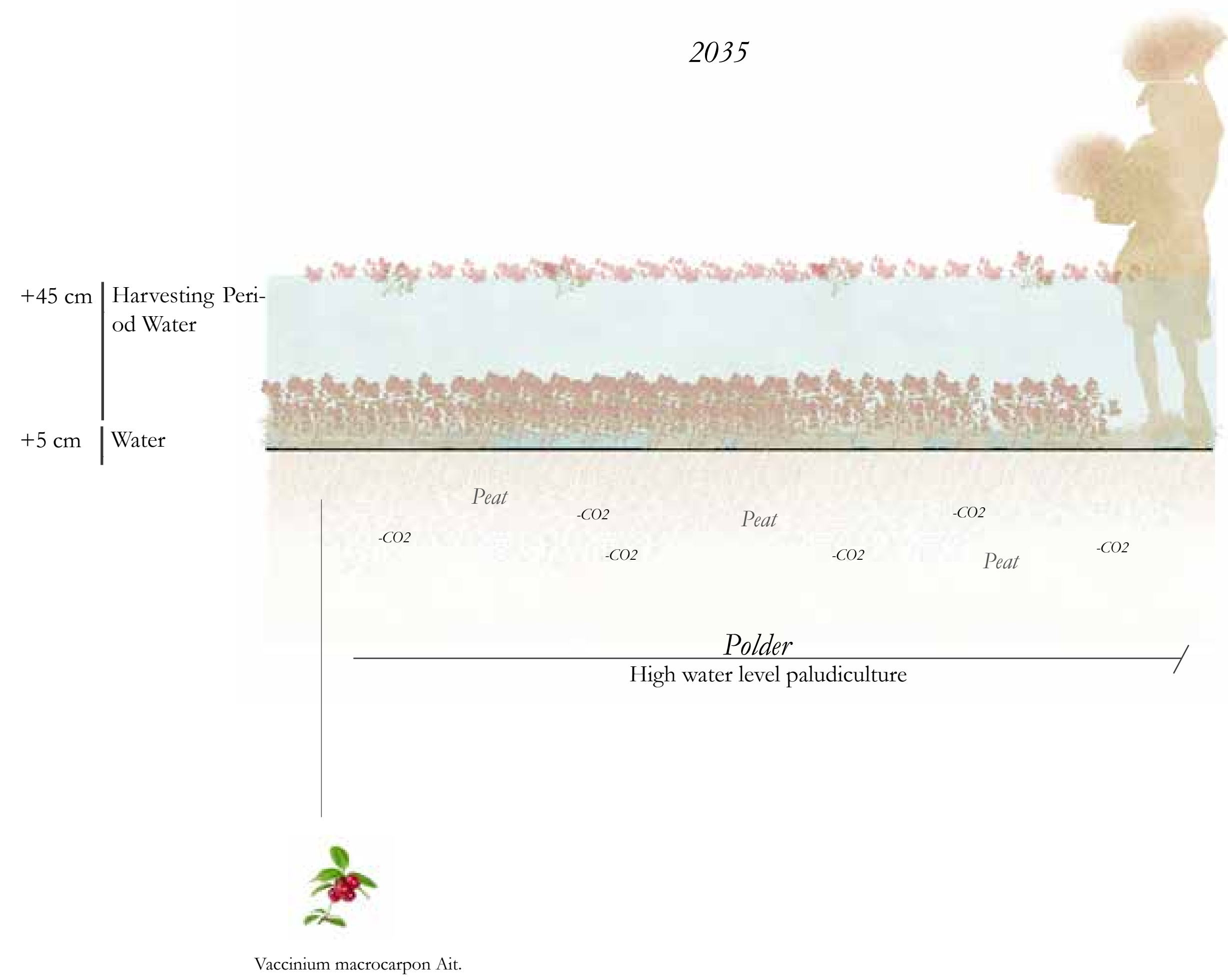
Due to its unique properties, the newly established paludiculture landscape not only becomes a resilient, productive landscape of the future but also provides new opportunities for local farmers. Cranberry harvesting season is appreciated for its beauty and is very likely to establish a new economic flow into the region.

Paludiculture Crops

'Better Wetter' is an experimental farm located to the North of the site that has successfully cultivated rice and cranberry. The paludiculture corridor proposal speculates that growing rice and cranberry will create a new resilient, productive landscape in Friesland. Rice '*is the second most important cereal and staple food in the world*' (Monaco et al, 2016). The crop requires continuous flooding up to 3 cm during growth and up to 10 cm during the harvesting season (Monaco et al, 2016).

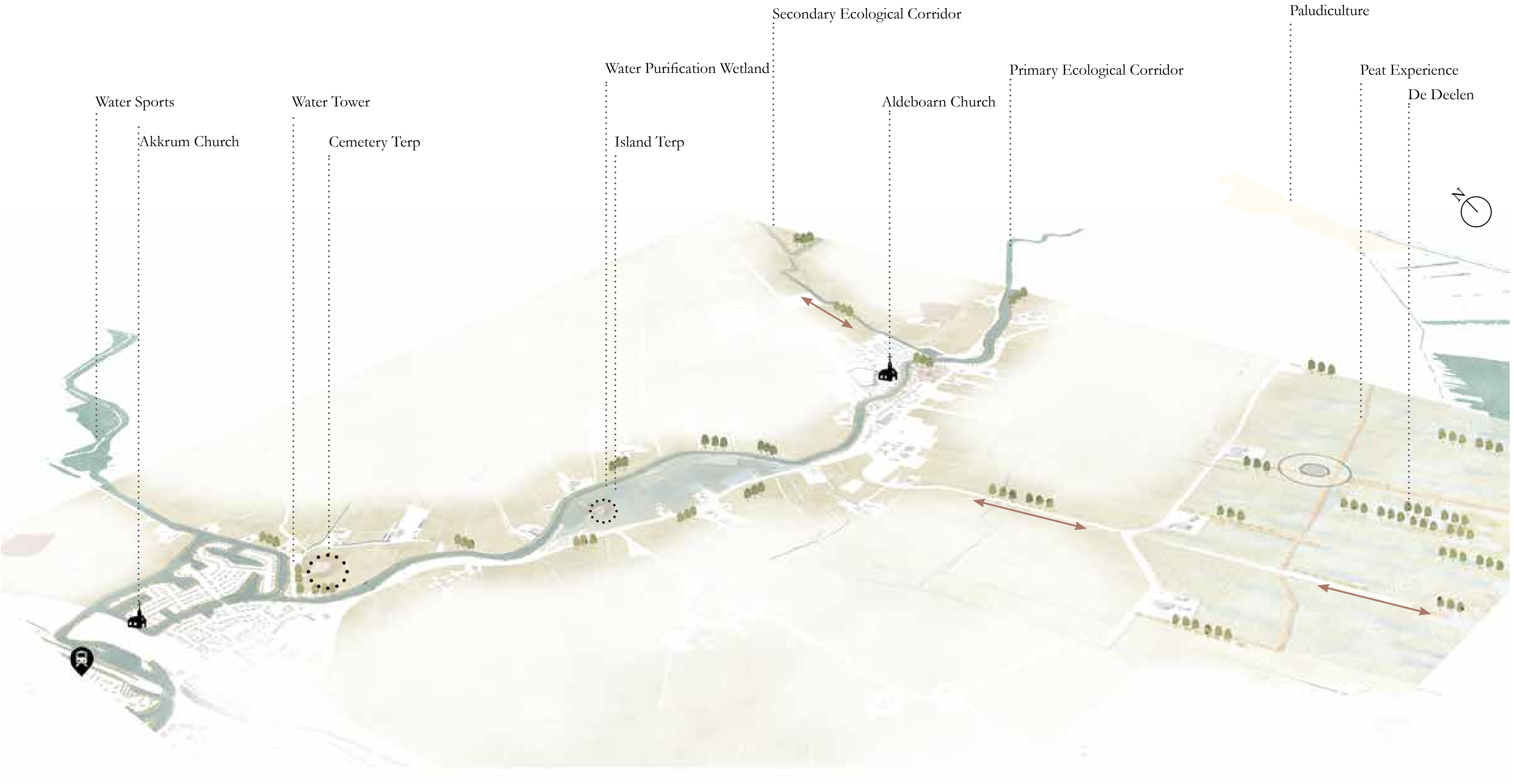
'*The most widely-known use of flooding in cranberry cultivation is for harvest*' (Cape Cod Cranberry Growers Association, Cranberry Watershed Education Initiative, 2001). Up to 90% of cranberry harvesting is performed through field flooding, during which up to half a meter of water is accepted. In the process, the ready-to-harvest berries float, creating a unique aquatic landscape while significantly simplifying the required labor. Water is often recycled and shared between farmers during the harvesting process (Cape Cod Cranberry Growers Association, Cranberry Watershed Education Initiative, 2001).

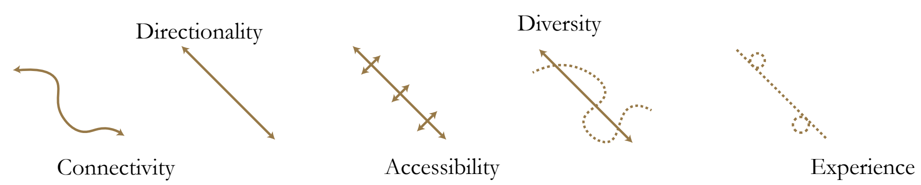




Paludiculture crops.
Image: Anna Gorokhova, 2023.

Cultural Routing 2035





During site visits to Akkum and Aldeboarn, I noticed that these areas are heavily fragmented and lack experiential landscape diversity. Major visual landscape nodes include the water tower in Akkrum (which has been converted into a hotel) and a church in Aldeboarn. Unfortunately, although De Deelenis is located very close to Aldeboarn, it is not accessible to the public from the site unless people travel to the South of De Deelen, which is estimated to involve at least 40 minutes of travel time. Notably, the cultural landscape is under significant threat of homogenization.

There is great potential in the landscape to strengthen the cultural traces and reconnect them with one another. Increasing the connectivity and accessibility of the site will provide a clear sense of direction. Planting is used to create a visual and spatial sense of direction on the site while reconnecting individual design node interventions to bring new experiences to the landscape. Therefore, Aldeboarn and Akkrum, located on the clay belt cultural backbone, become central residential points and benefit greatly from the newly established cultural landscape.

People Nature

Dual Constructed Wetland

The people nature wetland uses the existing landscape structure and creates a double wetland system in which the water is purified in both directions. The goal of the wetland is to purify the low-quality water and provide a new experience for the people residing in Akkrum and Aldeboarn. The farms on the site are expected to transition into an agri-tourism economy and support local tourism development. The farms will become central hubs for lodging and unique wetlands and water experiences outside the two towns.

The constructed wetlands.
Image: Anna Gorokhova, 2023.

View on Frieslands' agricultural fields as seen from the seadike.
Photo: Hanneke Wander, 2022.

9 | Land and Farmers Equilibrium

Restoring the Balance Between Land and Humans

Student | Hanneke Wander

First Mentor | Laura Cipriani
Second Mentor | Luisa Calabrese

Terps in the Frisian landscape are remnants of the province's rich history and relationship with the sea. With farms on the terps, cattle grazed on the plains when the sea temporarily receded. To this day, Friesland remains characterized by its dairy farming, now guarded by the sea dike. Agriculture is ingrained in the Frisian landscape. However, it has seen a significant change over the past 70 years. After World War II, government-driven agricultural policies that aimed to ensure a steady food supply led to the upscaling of farms, resulting in the loss of small-scale structures and increased agricultural waste in surface water. This change has adversely affected biodiversity, impacting the habitats of animals, including the nation's beloved meadow birds.

The balance between landscape, ecology, and agricultural practice has been lost. However, nature-inclusive agriculture could represent an opportunity. Emphasizing cultural-historical structures, enhancing ecological values, and working with local input and values could promote a better balance between agriculture, ecology, and the topographic landscape. These strategies emerged from multiple conversations with a local farmer transforming his farm into an organic practice.

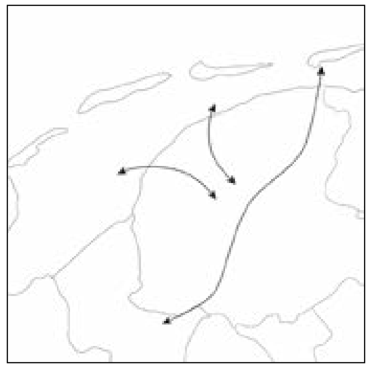
Introducing nature-friendly riverbanks along waterways strengthens ecological corridors in the area. Additionally, flower-rich field edges and farmyards can act as stepping stones for biodiversity, thereby creating a small-scale farm nature network. A water-purifying helophyte field can be constructed on a meadow, which will help filter the agricultural wastewater runoff. An intertwined recreation network is created on the ecological corridors, which were once a vital piece of infrastructure between terps and through the meadows. It lets visitors experience the connection of the present nature-inclusive agricultural practice with the rich cultural history of the Frisian landscape.

From the research, three strategies were formulated. These will form the basis for the research by design. The three strategies respond to the research questions and problem statement and aim to find a new balance between agricultural practices, ecology, and landscape topography in the northern province of Friesland.

Strategies

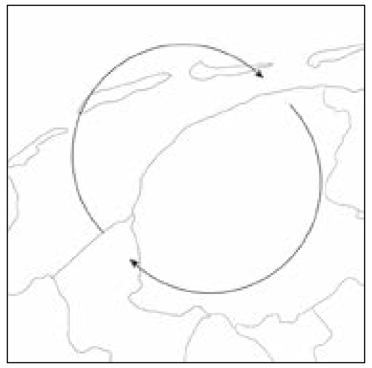
Emphasize Cultural Historic Structures

STRATEGY 1



Enhance Ecological Values

STRATEGY 2



Strengthen the Vernacular

STRATEGY 3

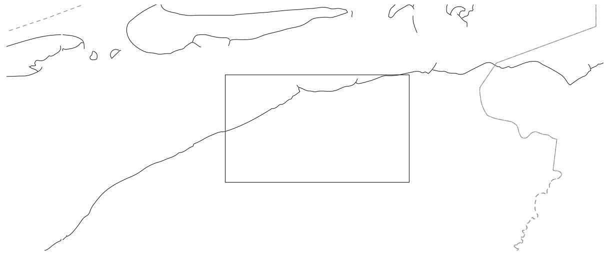
Three main strategies guide the territorial design.

First, cultural and historic structures are emphasized and function as sources of inspiration in the design. Friesland has a rich history that is noticeably present in the landscape, which is to be acknowledged and serve as a driver in the design.

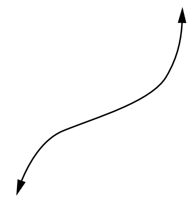
Second, ecological values are enhanced. As seen from the research, biodiversity is declining rapidly. Focusing on ecological corridors, together with nature-inclusive agriculture, can positively influence local ecosystems.

Last, one design strategy is to strengthen the vernacular. By working upward from the site level, local knowledge is gained. The project aims to celebrate the landscape and the people that live and work in it. A routing design aims to show this to visitors as well, which will also strengthen the regional economy.

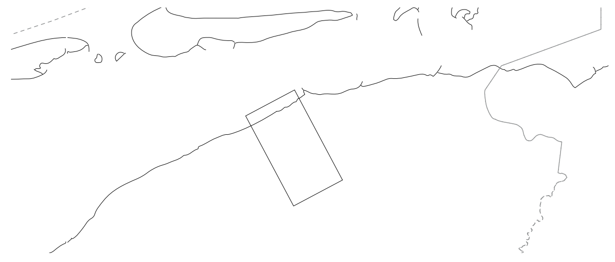
Primary and Secondary Ecological Corridors



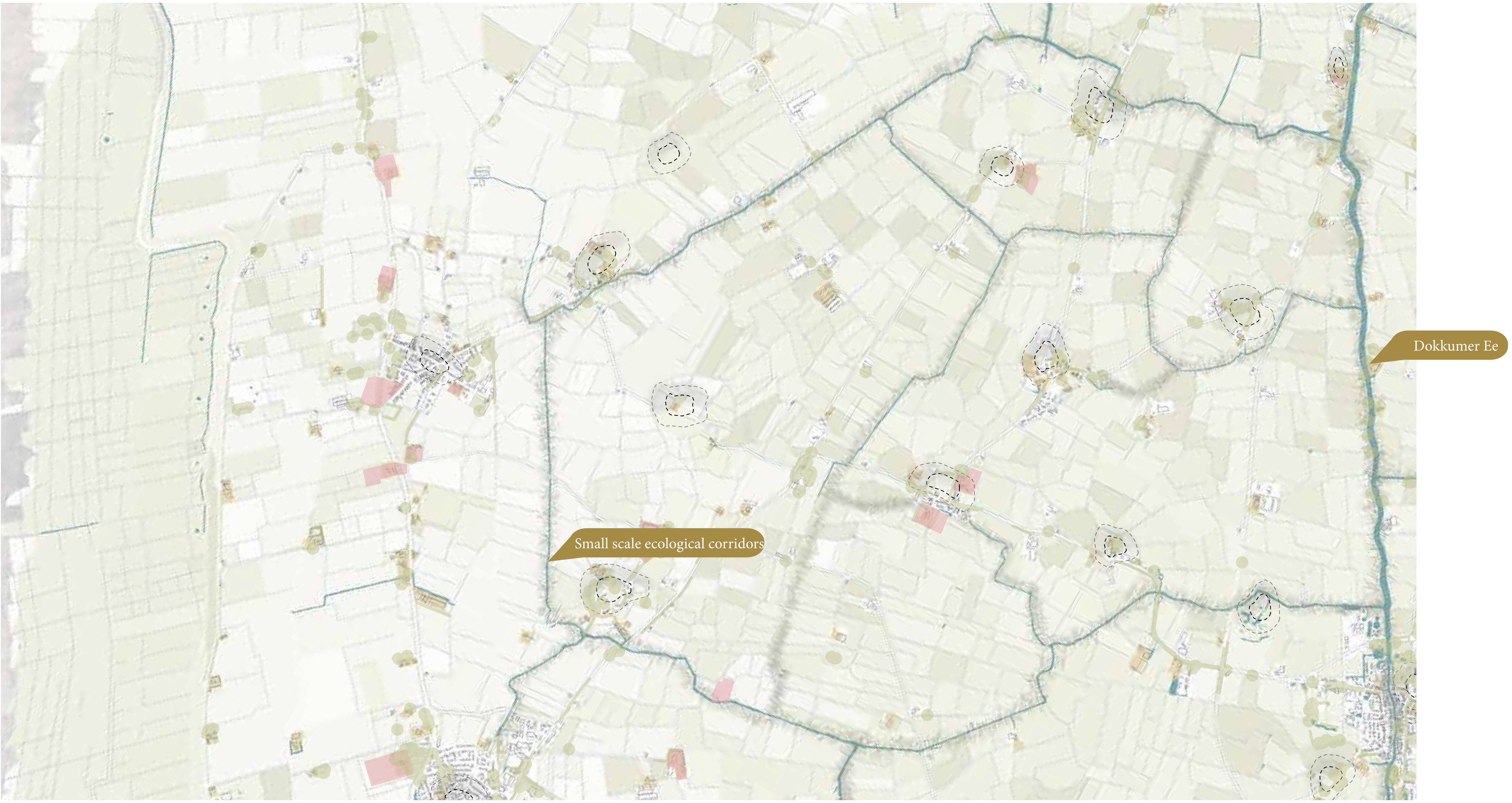
Upon zooming in on the north of Friesland, the main ecological corridor can be seen: the Dokkumer Ee. The smaller ecological corridors form a small-scale network in North Friesland.



Main and secondary ecological water corridors
Trees
Livestock farming
Crop production
Build environment
Terps



Primary and Secondary Ecological Corridors

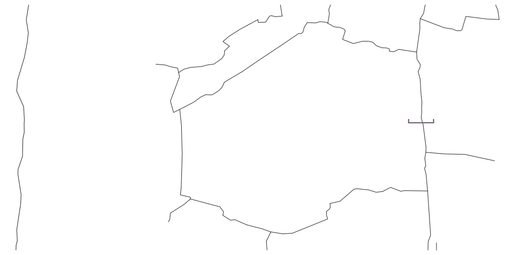


Upon zooming in further, the small ecological corridors can be seen more clearly, which are also historic structures. Most were once dug to connect terp villages with each other, while some made use of existing waterways.

main ecological water corridors

Build environment
Trees
Historical farmyards
Waterways
Enhanced ecological corridors
Livestock farming
Crop production
Terps
Stinzen, stanzen and churches

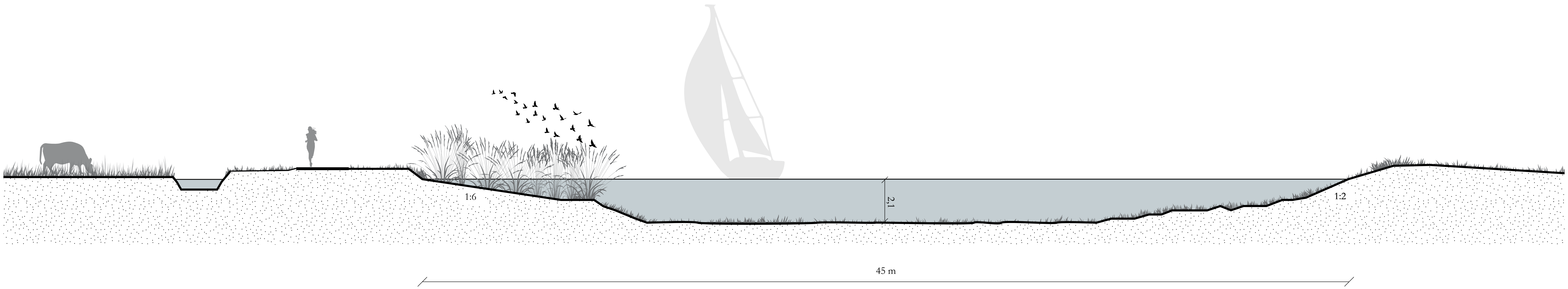
0 1 2.5 km



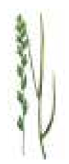
Ecological Corridor: the Dokkumer Ee 2022

2022

The Dokkumer Ee is a much-used waterway and part of a sailboat route through northern Friesland. Currently, the wide waterway has a reed bank on one bank. However, the other side can be ecologically improved. On the adjacent grasslands, a non-biodiverse grass mixture is present, mainly consisting of English ryegrasses.



Fast growing grasses

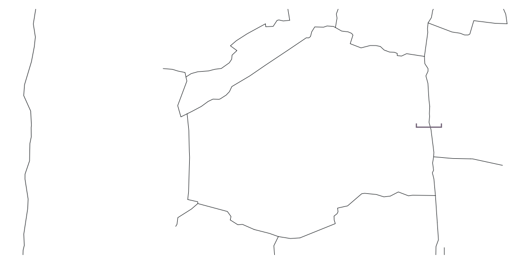


Lolium perenne

Reets

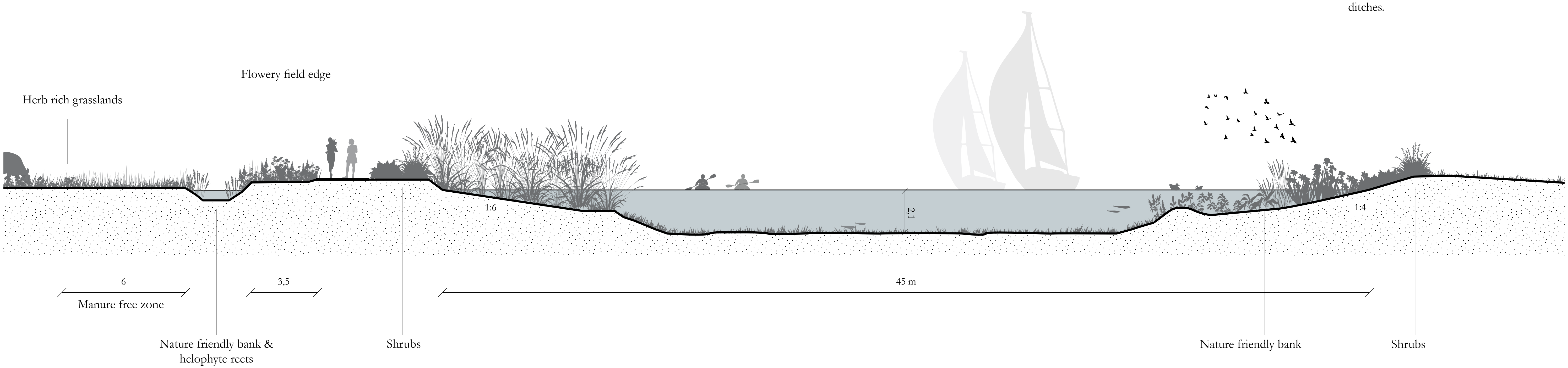
Phragmites australis

0 2 m 10 m

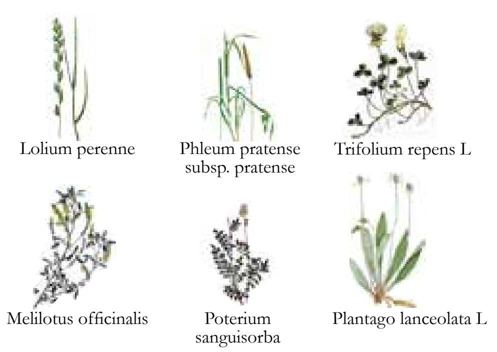


Ecological Corridor: the Dokkumer Ee 2025

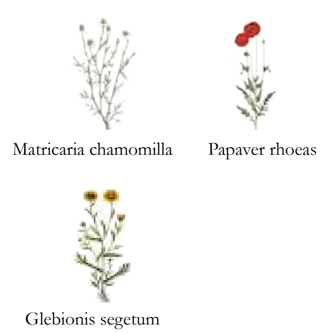
In 3 years, on the right side, a nature-friendly bank is introduced. Flowery field edges—part of the small-scale nature network—are adjacent to the agricultural fields. The grasslands themselves have a more biodiverse mixture of grasses. A manure-free zone next to agricultural ditches results in minimal leaching of eutrophic water into agricultural ditches.



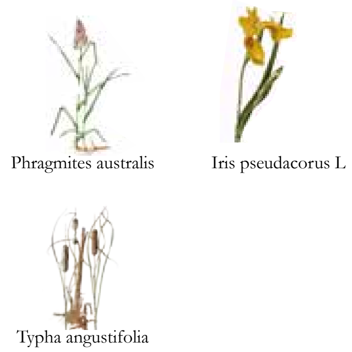
Grasses, herbs and clovers



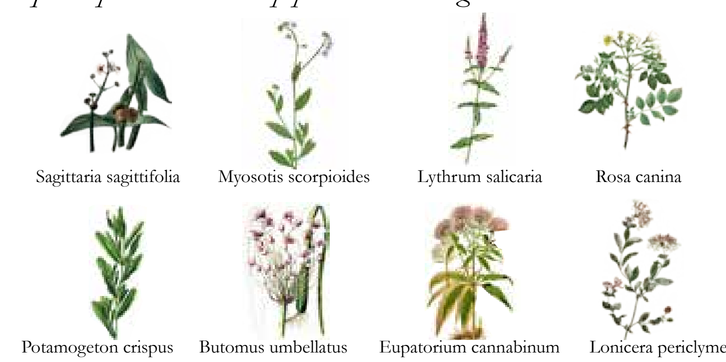
Flower mix



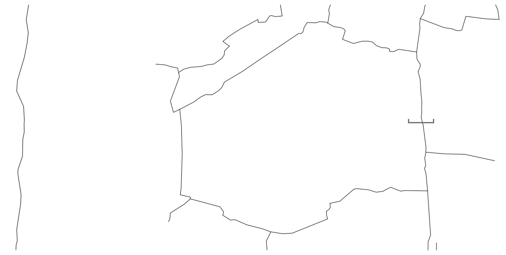
Reets and other helophytes



Aquatic plants *Swamp plants* *Rough herbs* *Shrubs*

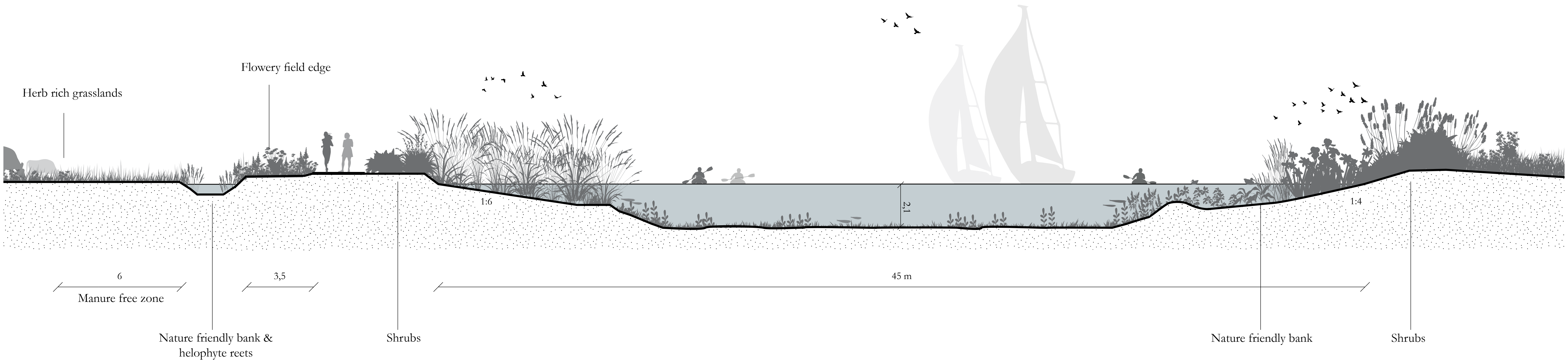


0 2 m 10 m

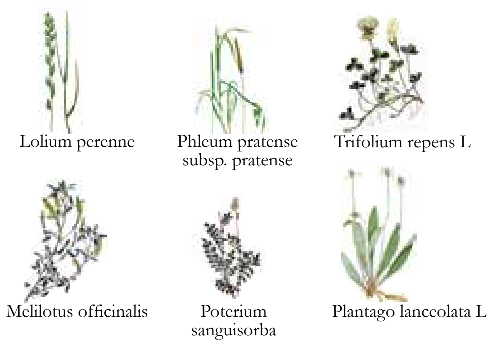


Ecological Corridor: the Dokkumer Ee 2030

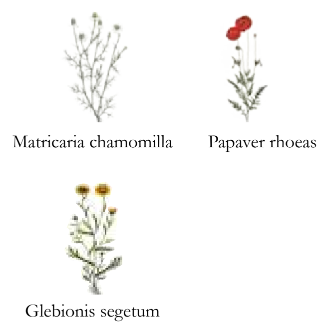
Located next to an ecological improvement, the canal will be an even more attractive environment for visitors. A canoe route (explained later in this thesis) runs through the Dokkumer Ee and into the smaller-scale ecological water corridors.



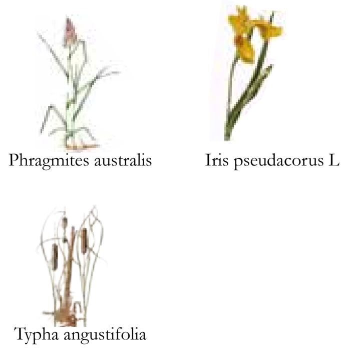
Grasses, herbs and clovers



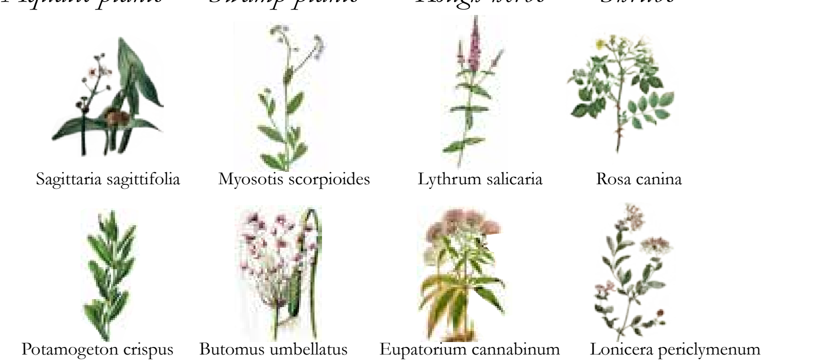
Flower mix



Reets and other helophytes



Aquatic plants *Swamp plants* *Rough herbs* *Shrubs*



0 2 m 10 m

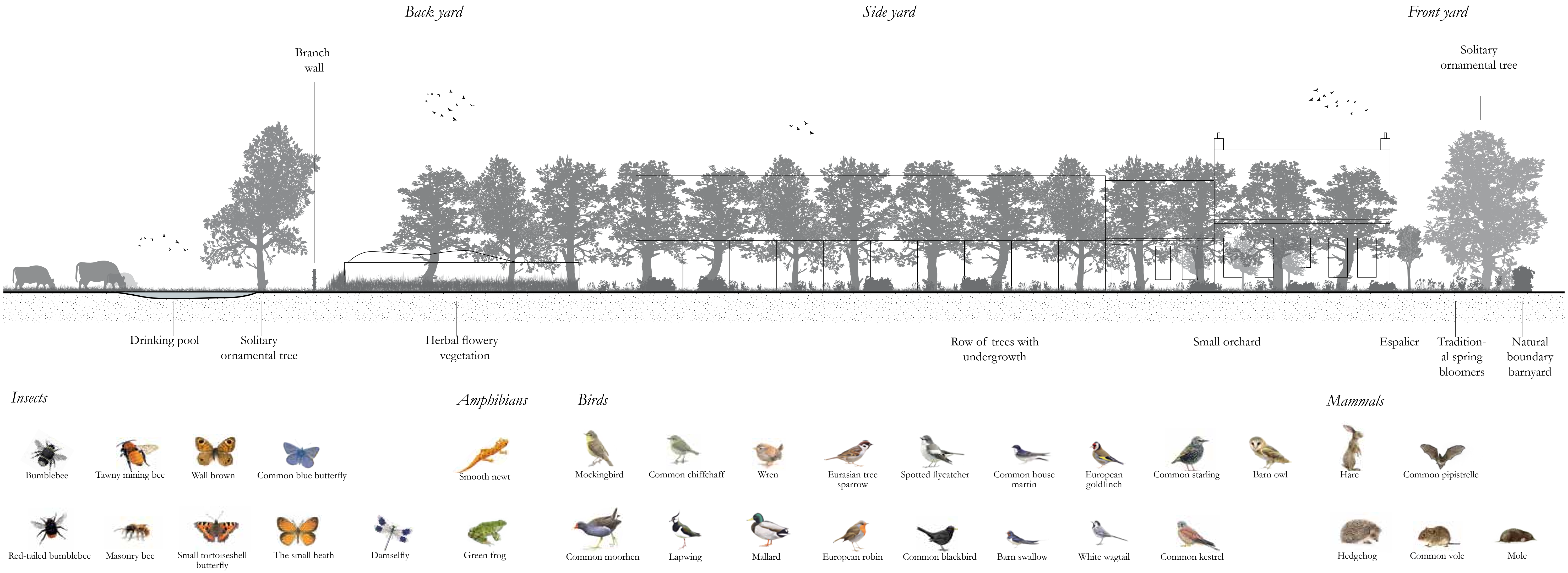
Image: Hanneke Wander, 2022.

Farmers Nature Network

The Farm as a Stepping Stone

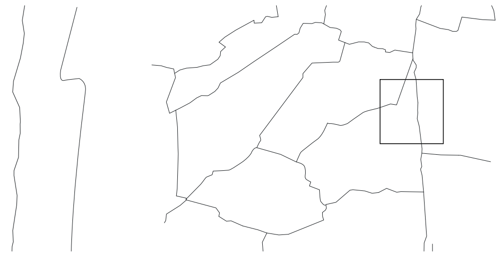
Image by author. Inspiration taken from the project 'Bioferskaat op it Fryske boerehiem: Sa kin dat!'
Data: Living Lab Fryslân, 2021.

Historically, farmyards were exceptionally biodiverse places in the landscape. Characteristically, Frisian farms had a front, side, and a backyard. Each had a different function, such as ornamental plants in the front, a small vegetable garden or orchard at the side, and a connection with the surrounding landscape in the back. Using this as an inspiration for the modern farmyard, the farms will increase their function as a stepping stone in the landscape for numerous birds, insects, and mammals.



Ecological Corridor the Dokkumer Ee

Image: Hanneke Wander, 2022.



Constructed Wetland

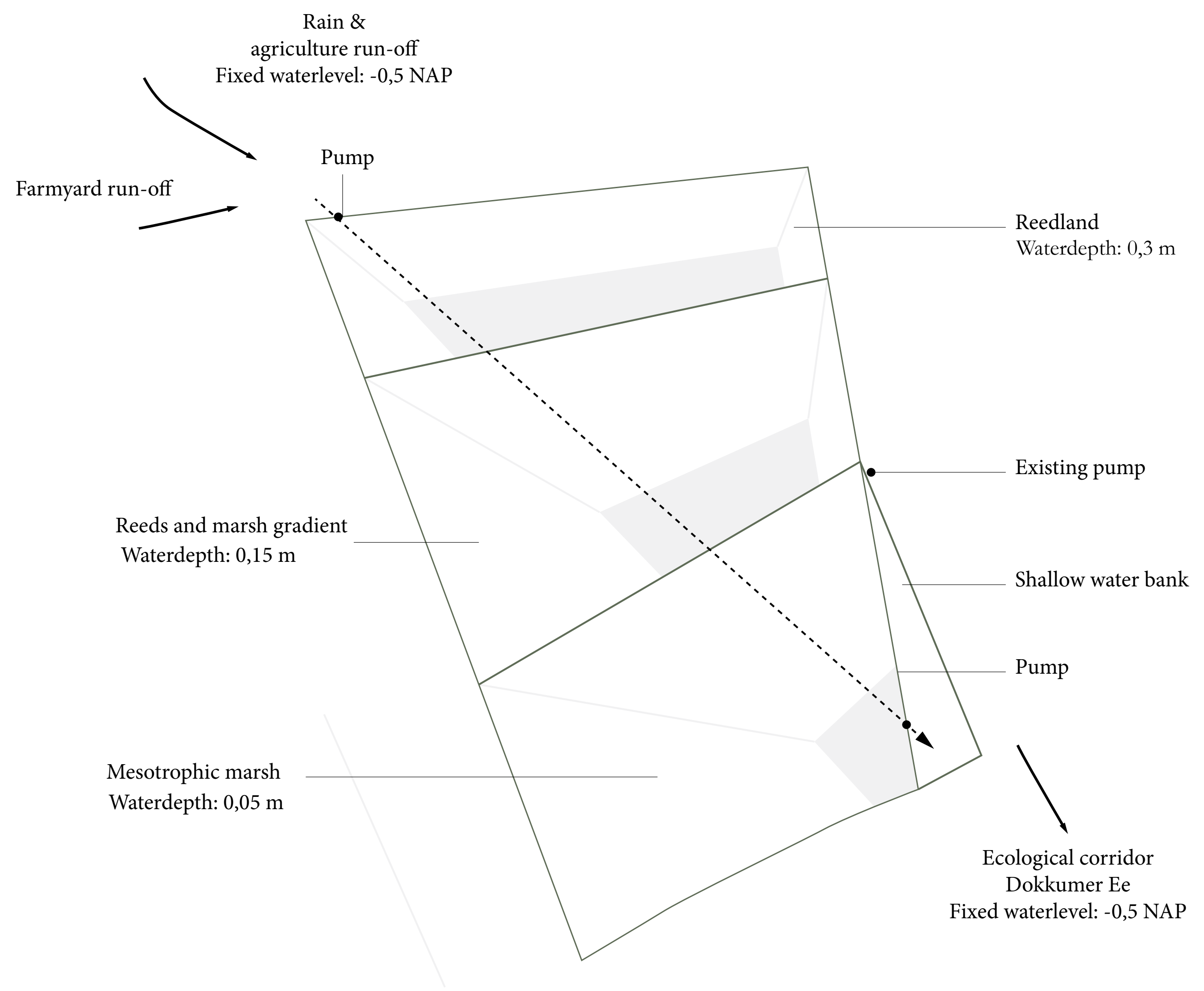
Walking path
Marshland helophytes
Reeds and marshland helophytes
Reeds helophytes
Grasslands
Ecological water corridor
Biodiverse field edges

0 200 500 m

During conversations with a local farmer, he explained that he would like to see one of his meadows become a wet grassland area with the goal of enhancing the meadow birds' habitat. Focusing on this area, this idea is elaborated on by incorporating a water filtration function to it. A constructed wetland, also called a helophyte filter, is projected onto this area, making use of the existing allotment structure.

There are several different types of helophyte filters; however, the simplest type is the flow field, which is applied here. A flow field is a shallow, wide water passage through which the water to be treated flows. The flow field has a depth varying from 30 to 80 cm and is overgrown with helophytes. These are plants such as reeds, which are the most common plants used to achieve this goal. Many biological, physical, and biochemical processes occur in the flow field, which filters the water. The purification effect of the flow field is mainly based on the diffusion and sedimentation of suspended matter to the waterbed. Organic material is broken down, and nutrients are absorbed and converted by bacteria, microorganisms, and plants.

Workings Constructed Wetland

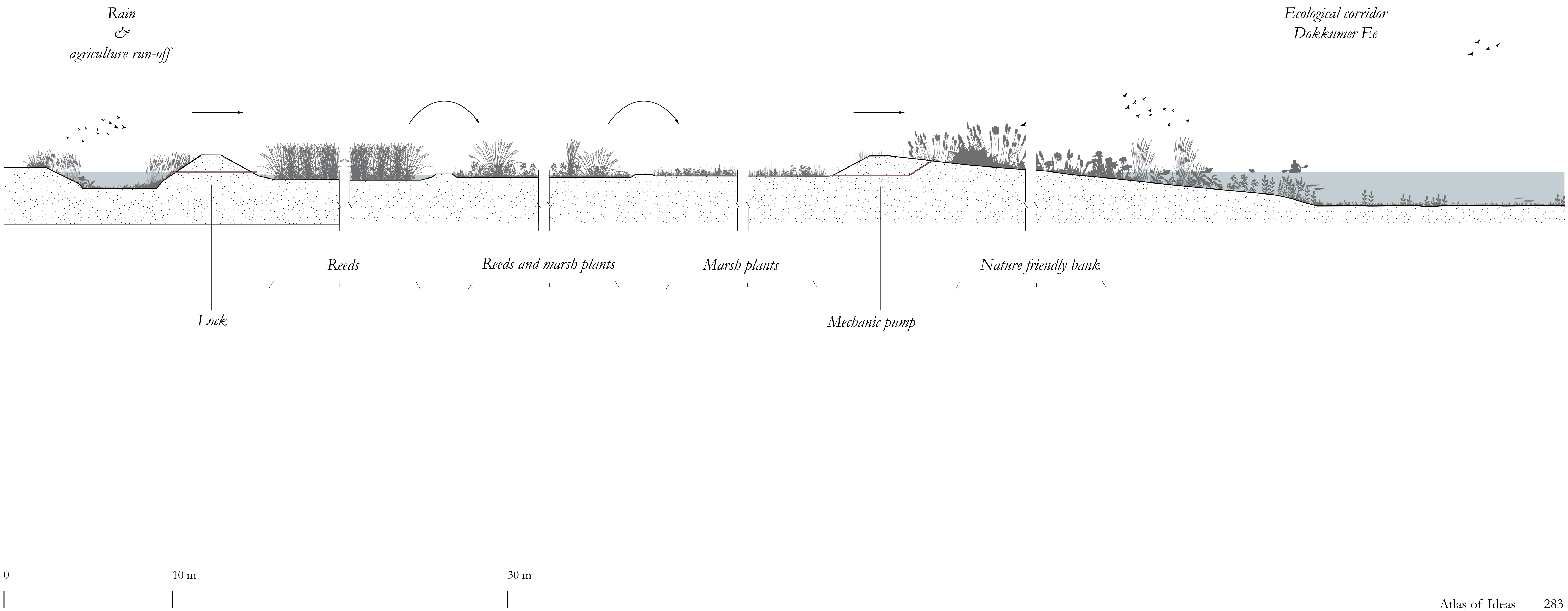


The agricultural water runoff from farmland in the area, as well as water runoff from the farmyard of farmer Hans, runs through the plants across the bottom of the swamp until it is discharged at the end of the flow field into the Dokkumer Ee. Eventually, the water in North Friesland is discharged into the Wadden Sea. This extensive natural treatment can help remove excess nutrients in the water, such as nitrogen, phosphorous, and micropollutants. To work correctly, a large surface area is needed for the flow field, which is present here in the form of agricultural lands. In addition to the result of cleaner water, the constructed wetland adds value to the land since it is a natural filter and an enrichment to the environment and biodiversity. As water flows through the filter, it gets cleaner along the way. This is visually noticeable in the types of plants present. At the start of the filter, a bed of reed plants is present, which does most of the filtering work. At the end of the beds, before entering the Dokkumer Ee, there is a mesotrophic marshland present, which houses different kinds of plants. In between these two beds, a gradient is observed in these types of plants.

Workings Constructed Wetland

Section 2050

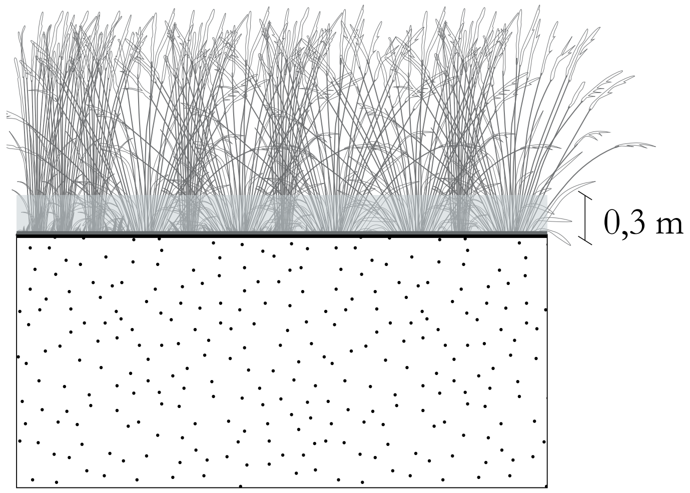
On the left, water is brought in from an agricultural ditch. Instead of immediately discharging into the Dokkumer Ee, the water flows through the constructed wetland from bed to bed by the use of small dikes, which overflow when the water becomes higher. Water is brought into the wetland via a lock, and water is discharged into the Dokkumer Ee by a mechanic pump.

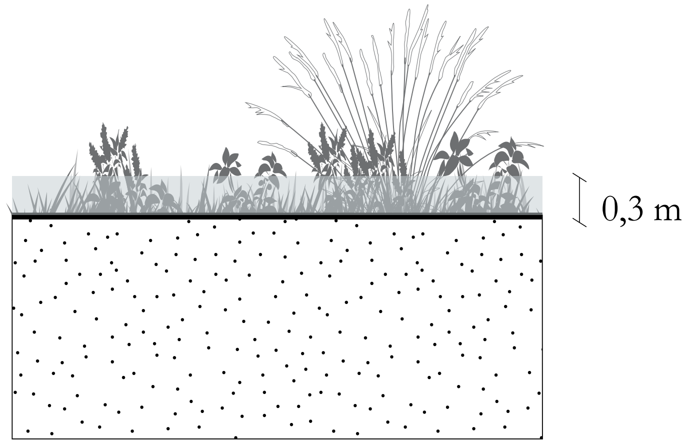


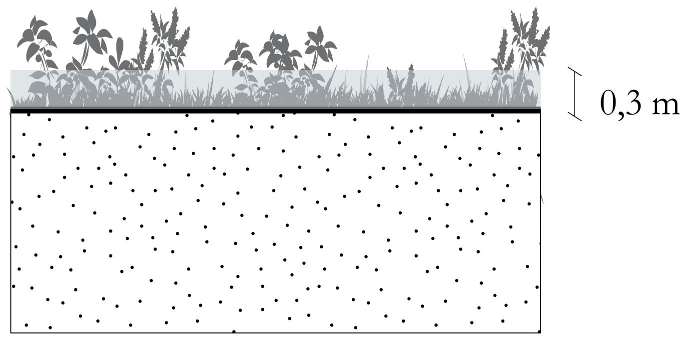
Workings Constructed Wetland

Detail summer situation

In summer, farmers might want to retain water to be able to use it during droughts. In this case, the pump facilitates flexibility, and the water can be retained in the wetland. Due to this flexibility, the farmer can decide when and how to use the wetland. During nesting periods in spring, for example, the wetland can be partly drained to facilitate the meadow birds.



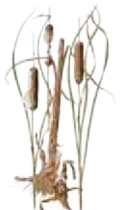




Reeds ~ 3,5 ha

Phragmites australis

Schoenoplectus lacustris



Typha angustifolia

Reeds and marshplants ~ 8,5 ha

Lysimachia nummularia

Myosotis scorpioides subsp. scorpioides

Salix repens

Rhinanthus angustifolius

Mesotrophic marshland ~ 6,5 ha

Parnassia palustris

Dactylorhiza praetermissa

Lythrum salicaria

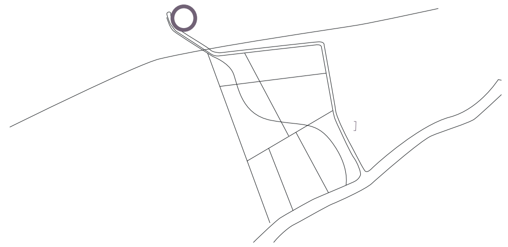
Rhinanthus angustifolius

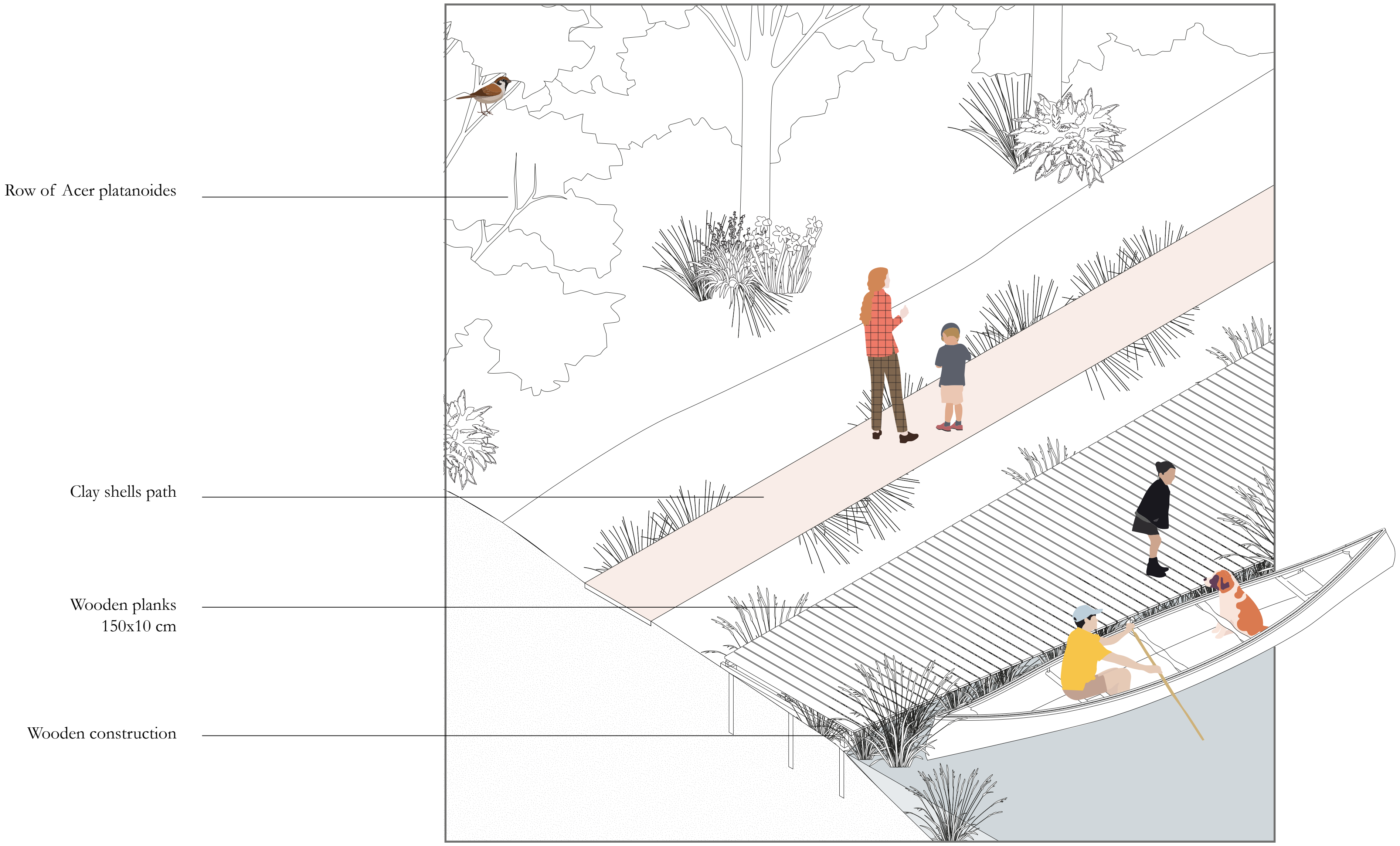
A river running through a lush green field in Friesland.
Photo: Ries Bosch, 2023.

Wooden Boardwalk

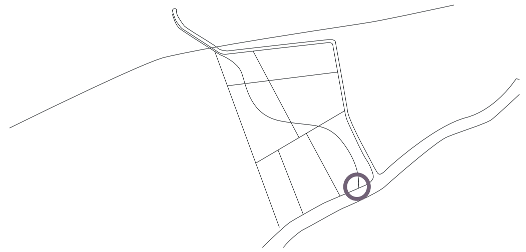
The path through the constructed wetland is slightly elevated to give room for the different water levels in the wetland. The path is made from wood and provides a submersible experience while walking through the woodland.

Wooden board walk, getijdenpark Brienenoord, Rotterdam.
Photo: Hanneke Wander, 2022.

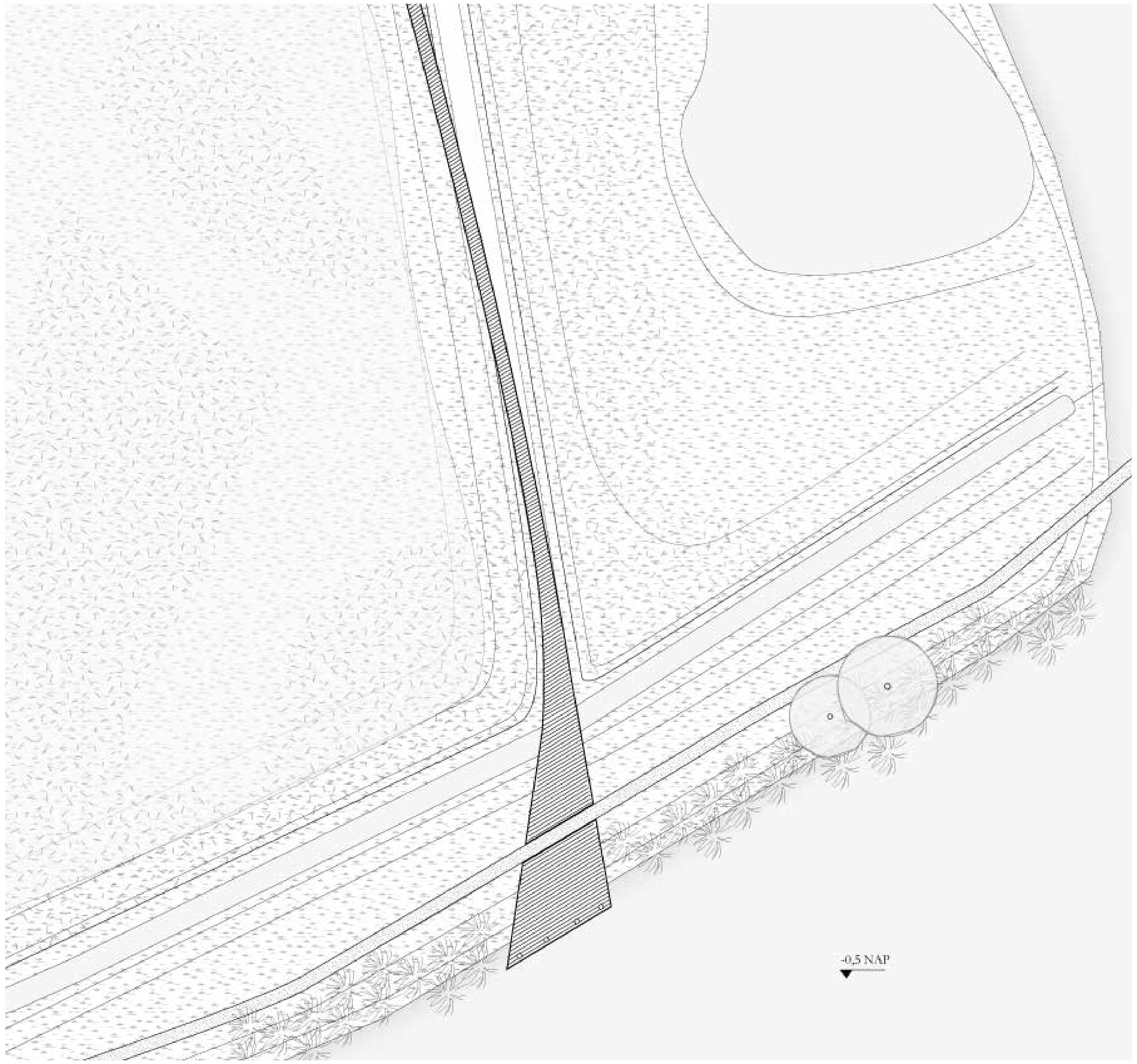




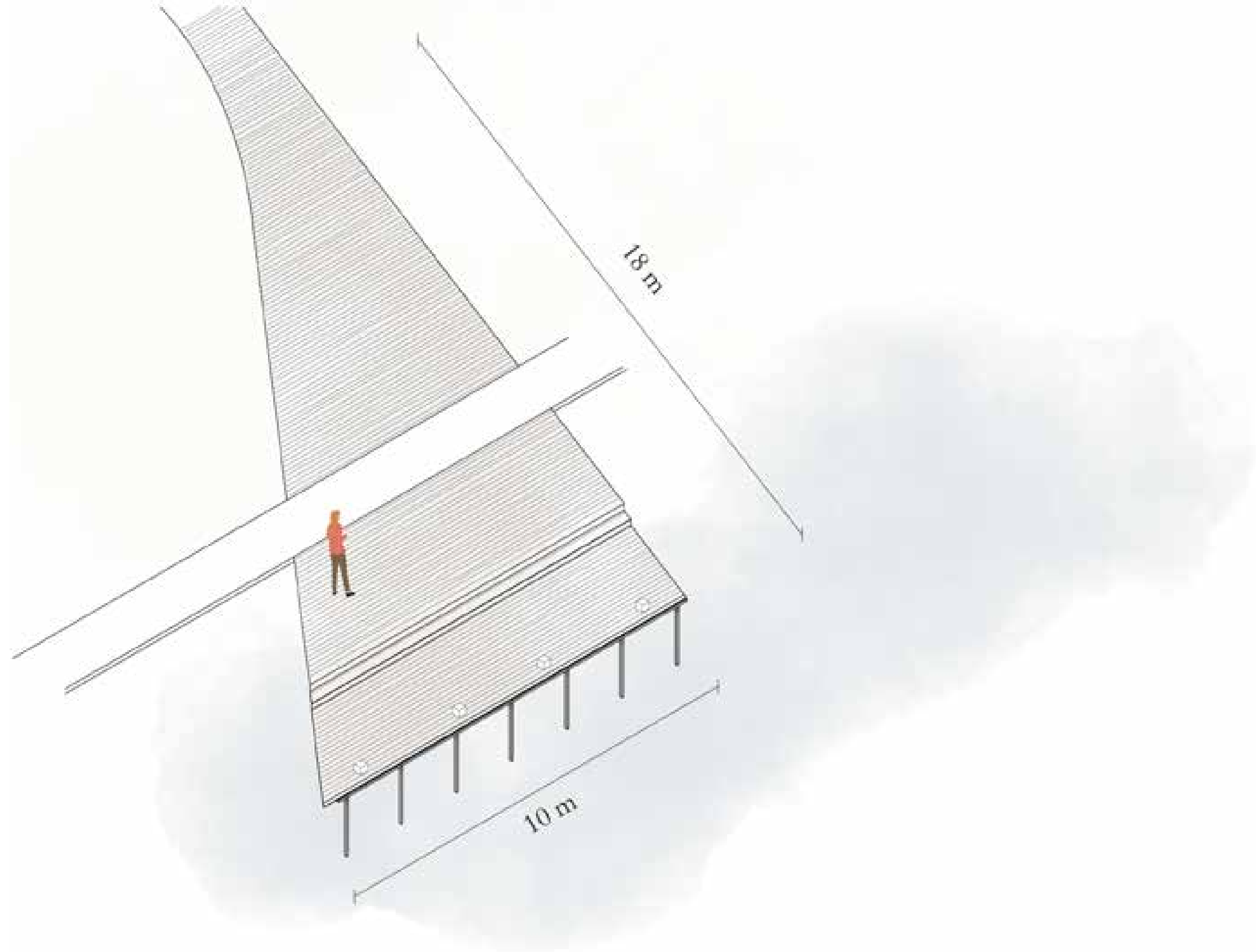
Path through a cornfield.
Photo: Anisur Rahman, 2014.

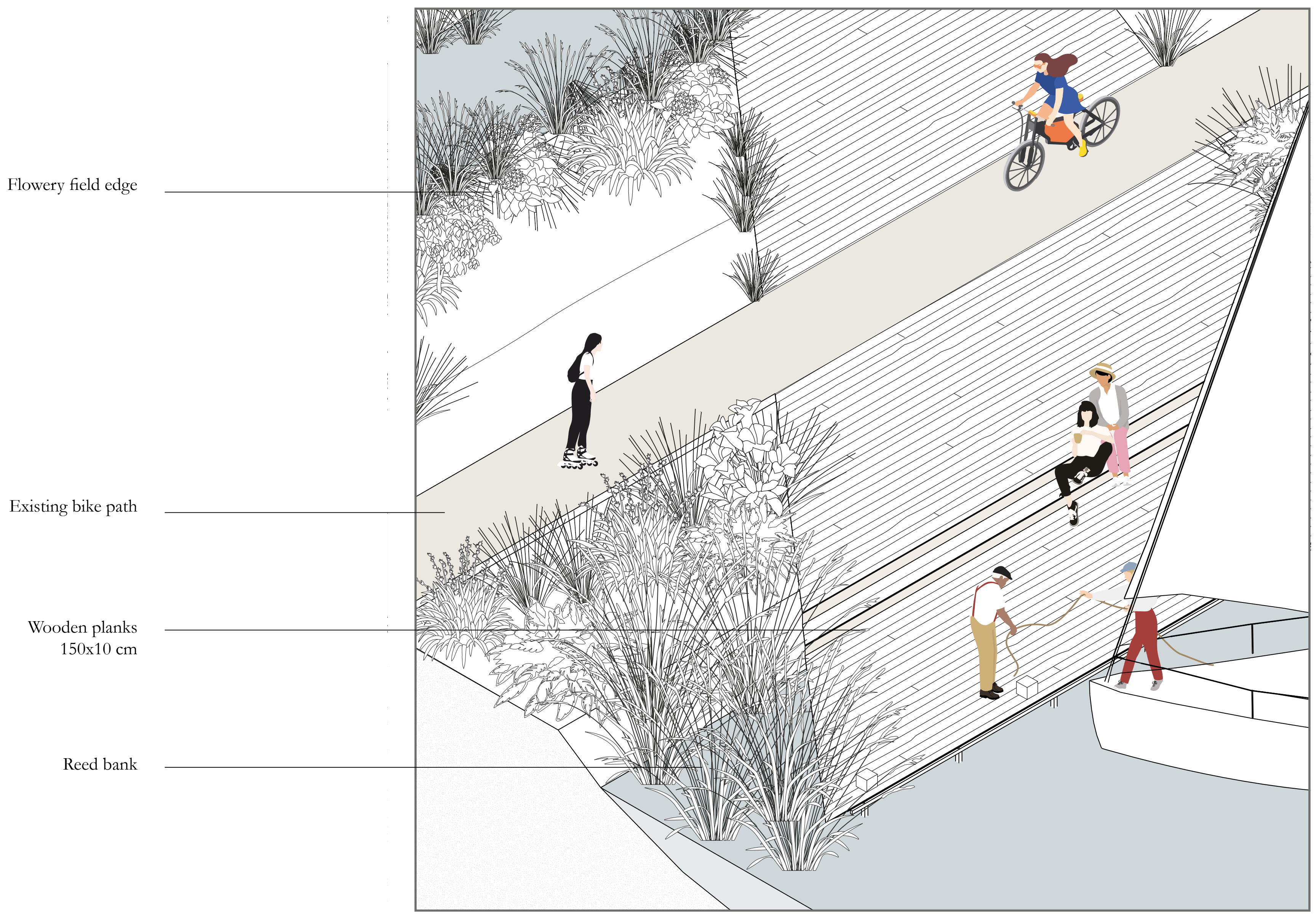


Quay By the Dokkumer Ee



Along the Dokkumer Ee, a small quay will make for a stop along this sailing route. The quay also forms the start of the walking route through the constructed wetland and connects to an existing bike path. This quay can be part of the 'Marrekrite' docking places—a network of such places located throughout Friesland.



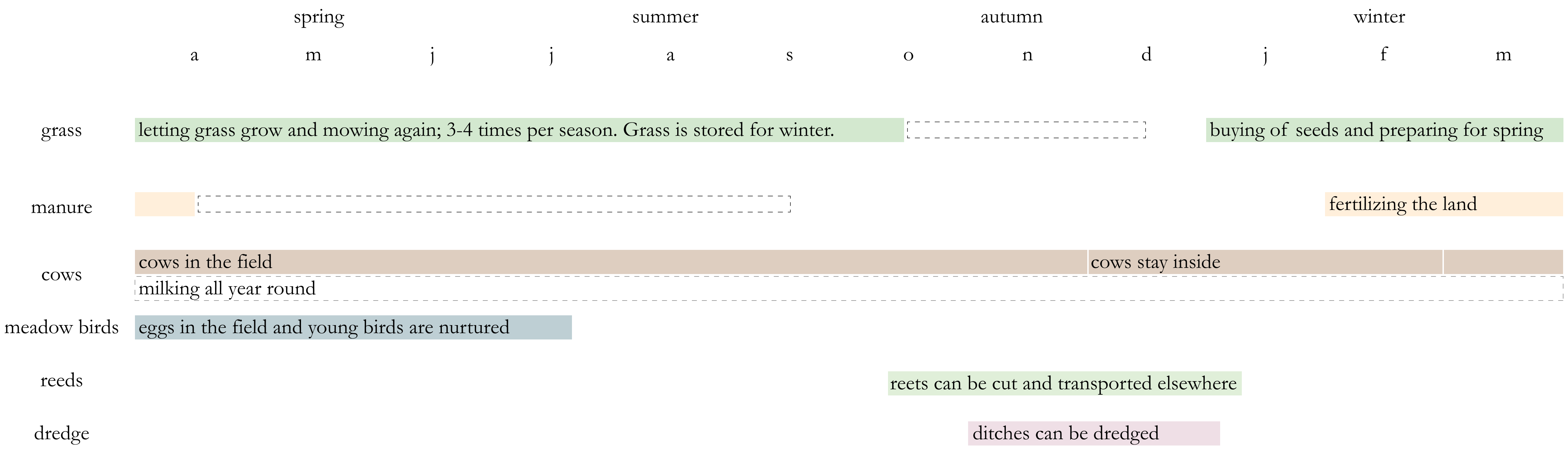


Flowery field edge
Existing bike path
Wooden planks
150x10 cm
Reed bank

Processes

With an enhanced ecological network, more maintenance also comes into play. By mowing reeds and other water bank plants and distributing them elsewhere, vegetation is kept biodiverse and the soil remains nutrient-poor. The mowing is best done in the fall when the least amount of damage can be done to living systems. The same is true for the dredging of ditches. This should be done with care. By not dredging everything at once, animals have the chance to move somewhere else and return later.

These interventions are added to the processes already present on a farm. In a nature-inclusive agricultural practice, meadow birds are protected by mowing grass later or being aware of the bird's nests.

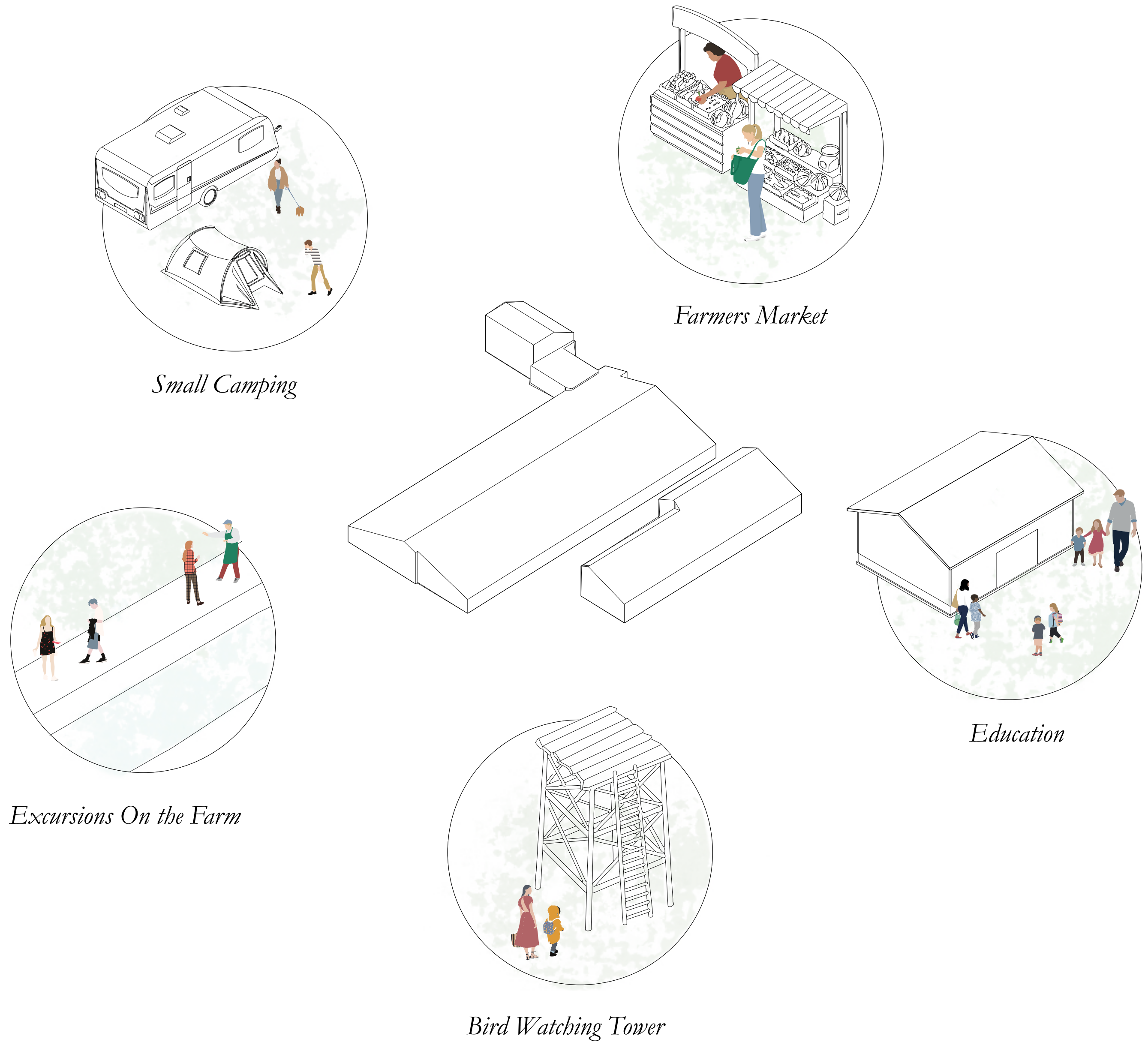


Agrotourism

Agrotourism is a term originating from Italy. It refers to tourism on a farm, which can include people visiting working farms for enjoyment, education, or a holiday. Agrotourism has been a way for farmers to diversify their practices and supplement their income.

There are several ways to introduce agrotourism on a farm, and it entirely depends on the farmer's preference and time. For example, the farmer I spoke with for this project mentioned that he envisions a camping spot on one of the agricultural lands. A bird-watching tower is also one of his wishes, and adjacent to this is an educational building.

Next to agrotourism being an extra income for farmers, it is a tool to make consumers more conscious of the processes on a farm and the protection of the landscape that a farmer performs. Ultimately, a greater awareness among consumers might lead to a shorter food chain, where consumers buy products directly from the farm or a local distributor.



Contributors

Laura Cipriani
Laura Cipriani is an assistant professor of landscape architecture at Delft University of Technology. Her current research addresses climate change issues, starting from the materiality of 'water and soil' and adopting (co)design approaches. Over the last decade, she has taught at Venice University IUAV, Politecnico di Milano, National University Singapore, Venice International University, and the University of Padua. She holds bachelor's and master's degrees in Architecture (Hons) from IUAV, a Master's in Design Studies (Hons) from Harvard Design School (2004), and a Ph.D. in Landscape Urbanism from IUAV. In 2008, Laura founded Superlandscape, a landscape and urban design firm.

Anna Gorokhova
Anna Gorokhova holds a Master's in Landscape Architecture from Delft University of Technology (2023). She previously obtained a Bachelor's Degree in Landscape Architecture from the University of Hong Kong (2021). Originally from the Arctic (Sakha Republic), Anna has a great passion for design that tackles climate vulnerabilities and restores fragile landscapes. She is passionate about social cohesion and climatic resilience.

Joca Jansen
Joca Jansen works as a hydrologist at Wetterskip Fryslân on the climate-robust design of the management area of Wetterskip Fryslân. Based on her knowledge of salinization and subsidence due to salt and natural gas extraction, as well as her involvement in water conservation in sandy soils, her primary motivation is the economical use of fresh water because the water shortage is increasing. Her interest in this field is based on the conviction that not everything can be solved with technology and that people must move along with natural processes. Joca now has more than 25 years of experience in water management.

Xinjian Jiang
Xinjian Jiang completed the MSc in Landscape Architecture program at Delft University of Technology and also holds a Bachelor's Degree in Landscape Architecture from Zhejiang University. During his two years at TU Delft, he developed a keen interest in cross-scale landscape design. Xinjian's design approach emphasizes preserving nature and creating sustainable designs that harmoniously balance nature and the built environment.

Zhaolei Li
Zhaolei Li is a landscape architect who completed a Master's Degree in Landscape Architecture at Delft University of Technology in the summer of 2023 after earning a bachelor's degree from Tongji University in Shanghai, China in 2021. She interned at the China Machinery International Engineering Design & Research Institute (CMIE Shanghai Branch), where she was involved in transforming campus spaces, urban public space design, and the detailed design of national parks. These projects allowed her to gain experience while simultaneously discovering her passion for cultural landscapes and landscape heritage, which connect people to sites while also connecting the past to the present.

Stephan Smeijers
Stephan Smeijers, a landscape architect, was educated in Wageningen. After his studies, he moved to Fryslân and began to work for the governmental Department of Land Development (DLG). He created new perspectives on nature, agriculture, and inhabitants by using design to connect the different parties and demands. In 2015, he started to work for the province of Fryslân, combining policy and the implementation of solutions to various spatial challenges. Since 2019, he has been involved in several design assignments with students at TU Delft, Wageningen University, and Lund University (Sweden).

Hanneke Wander
Hanneke Wander is a landscape architect employed by the Municipality of Rotterdam. She completed a Master's Degree in Landscape Architecture at Delft University of Technology in 2022. She is a passionate designer who views biodiversity and the landscape as her top priorities. She experiments with various visualization techniques in her projects, always seeking a visual language that suits each project. With a thoughtful approach, she aims to strike a balance among the different users in the landscape.

Heather Wong
Heather Wong is a landscape architect at Foster + Partners (F+P), a prestigious global design firm based in London, England. Her passion for creating robust and dynamic landscapes drives her to design projects ranging from large-scale public spaces to innovative commercial developments. Before joining F+P, she gained experience in a landscape design office in Hong Kong and supported the team on various residential and commercial projects in China. She completed a Master's in Landscape Architecture (MLA) Degree from Delft University of Technology in the summer of 2022 after earning a bachelor's degree from the University of Hong Kong in 2018.

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Published in July 2024
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