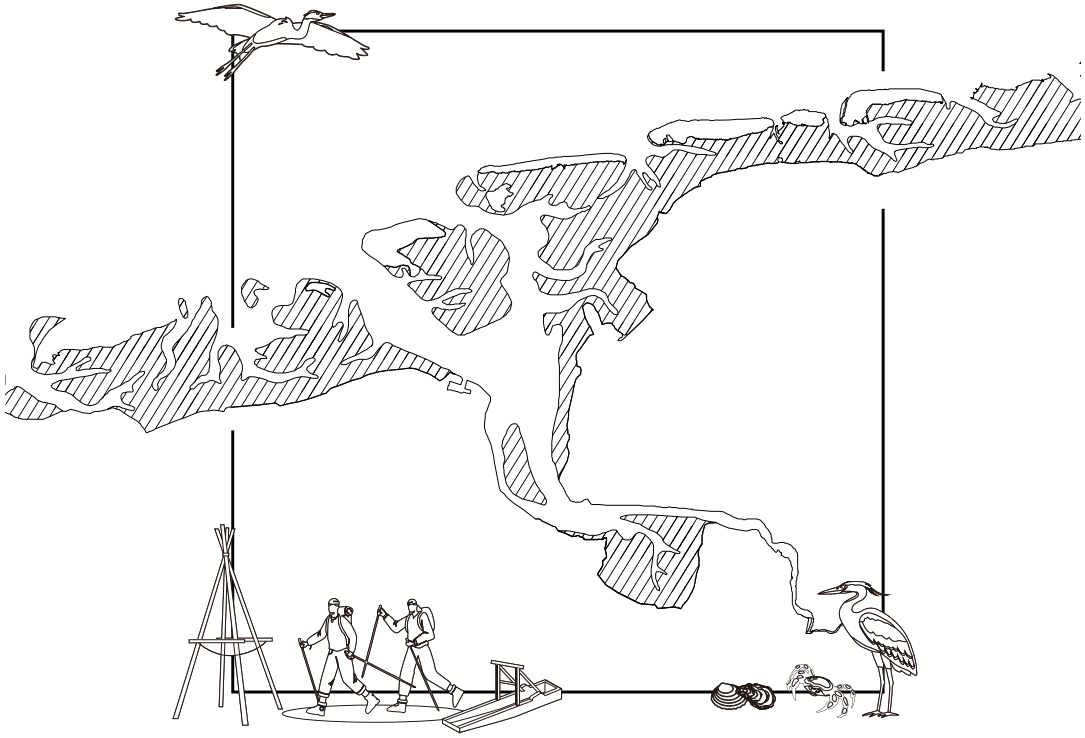
Mudscapes

Embracing Nature, Feeling Culture in the Ems Estuary



Zhaolei Li

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Site visit at Wadden Sea region
Photo: Xinjian Jiang, 2022

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Satellite image of the Wadden Sea.
Photo: U.S. Geological Survey.

Abstract

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 establishing 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 like waterway deepening and riverbank embankment, has resulted in substantial alterations to the morphology, hydrology, and ecological composition of the area. The major challenges are 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 compared to the southern Netherlands and the 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 plays a vital role in the overall estuarine system, significantly influencing the economy, ecology, and cultural memory formation. The 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.

Keywords

Ems Estuary, Mudscape, Economic Boosters, Ecological Crisis, Cultural heritage.

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Introduction

The Wadden Sea is a UNESCO World Heritage Site and one of the largest tidal systems in the world, which also contains many estuaries, they are transitional areas where rivers meet the sea. There are five estuaries in the Wadden Sea region: the Varde Å estuary in Denmark, the Eider, Elbe, and Weser estuaries in Germany, and the Ems estuary in Germany and The Netherlands (B. Schuchardt & J. Scholle, 2017).

The River Ems rises in the central German state of North Rhine-Westphalia and flows through the Netherlands before emptying into the North Sea. The Ems estuary, part of the larger Wadden Sea, plays a crucial role in the dynamics of the Wadden Sea ecosystem, serving as a transition zone between the fresh waters of the Ems and the saline waters of the North Sea and hosting a variety of habitats such as mudflats, salt marshes, tidal channels, and sandbanks. These habitats provide breeding, feeding, and resting places for numerous bird species, fish, marine mammals, and invertebrates.

However, compared to the other two main estuaries of the Wadden Sea, where the tidal flats mainly consist of fine sand, the Ems-Dollard estuary's mud content is relatively high (typical mud content is >70%). So, it is currently referred to unfavorably as the "yellow river" of Europe. The Ems estuary is now regarded as having a degraded ecosystem due to its high turbidity levels, significantly artificial morphology, oxygen deprivation in some sections, falling estuarine habitat quality and quantity, etc. (Bos et al., 2012)

The Wadden Sea's estuaries have enormous cultural and economic worth and are ecologically significant. They are a vital link between the interior and the expansive Wadden Sea, the site for numerous commercial activities, such as fishing grounds and shellfish harvesting. Amongst these activities, its most notable economic function is as a trade route so that products from the coast and inland, such as bricks, porcelains, boats, and fabrics, could be sold far abroad.

The Wadden Sea region has seen extensive dredging and sediment extraction throughout the years. Nowadays, the primary goal of these actions is to maintain and deepen shipping channels, unlike in the past, when these materials were mainly used to construct dykes, residential mounds, and roads (M. Schultze & G. Nehls, 2017). The sediments in the Ems estuary are mainly of marine origin and are therefore not very polluted and are worth reusing. Still, the environment around chemical plants and industrial estates is very monotonous, with pollution problems by four heavy metals. At the same time, the coast is at risk of saltwater intrusion because the interior of the Netherlands is sinking, and the sea level is rising. This mud, constantly transferred between sea and land, becomes so valuable.

In order to maintain the waterway, people have paid a tremendous and costly price. However, Dollard's economy has yet to develop as expected. There is insufficient infrastructure, declining attractiveness, and a continuous population loss. Even the once-in-five-year event, Delfsail, is unable to reverse the trend. People are more willing to seek employment in southern cities and travel to northern islands. The primary entities remaining in the local area are factories, workers, and farmers, resulting in a relatively homogeneous economic structure.

Amidst the wave of globalization, differentiated development and the preservation of local characteristics have become particularly crucial. Throughout history, the Ems estuary has undergone significant transformations influenced by natural and human factors. The estuary's formation dates back to the distant past when rising sea levels shaped its contours. Subsequent storm surges in the 14th and 15th centuries further altered the landscape, creating the Dollard area. Since the 16th century, extensive land reclamation efforts have profoundly impacted the shape of the Ems estuary (A. Talke & E. De Swart, 2006). These natural and anthropogenic forces have shaped the present-day estuary, but the change continues. Ongoing activities, such as harbor expansion, channel dredging, and the construction of gas pipelines, continue to influence the estuary's hydrology and ecology. These activities contribute to increased tidal differences and turbidity in the Ems estuary.

When exploring the mud biographies of this region, everything is so new to someone from the highlands like me. In researching the history, I was fascinated by the distinctly local landscape of the terp, where people used to live, a very intelligent way of surviving by accumulating mud to build

uplands and allowing for seasonal partial flooding – which is precisely the ‘resilient landscape’ that is being promoted today. However, they were not safe enough, and more than 30 dwelling villages in Dollard were later permanently buried under mudflats during significant floods. To reduce the damage caused by the floods, people chose to survive in a way that was temporarily more favorable to them: the forging of dykes, which gradually lost their resilience, with a series of consequences such as the lack of replenishment, inland soil subsidence, saltwater intrusion, salinization of the land, etc.

While dykes are now widely used in various areas at risk of flooding, for example, in the Yangtze River Delta region of China, where similar dykes and agricultural landscapes can be found, the history of the terp is a unique historical and cultural heritage of the Wadden region. Unfortunately, mudflat hikers frequently pass these mudflats without understanding the land beneath their feet because the history of the lost 30 terps in the Dollard area must be acknowledged.

Mud plays an essential role in the whole estuarine system and significantly influences the economy, ecology, and the shaping of cultural memory. When we talk about mud, we always have a bad image of it, such as dirt and ugly, but it is one of the most essential landscape elements of the area. Whether it is the muddy river, the waterways closely linked to the economy, or the mud flats where people go hiking and play.

After learning about the area and doing some field research, I was moved to stand in the vast polders of the small village of Peazens, where humans are small and isolated compared to the vast, awe-inspiring nature that has shaped the landscape for so many generations. I can imagine how the people who lived here thousands of years ago battled with the sea to create these fields inch by inch while enjoying the gifts of the sea on the mud flats, and the people who settled here deserve to be called pioneers. At the same time, cycling past the industrial area of Delfzijl, I felt a little disappointed that the factories here were as same as any in the world, with similar pipes and layouts and largely empty, boring plots of land, which robbed the landscape of this area of its original character.

Therefore, this graduation project aims to explore the possibilities of shaping landscapes using mud, examining its ecological, economic, and cultural aspects. It will investigate how natural forces can help us compensate for land subsidence and accumulate mud for alternative uses. Additionally, it will explore the integration of mud purification with new energy sources as a novel economic opportunity. Furthermore, it will explore how mud can reshape local characteristics, aiding people in understanding the history of the land.

In this regard, the role of landscape architecture is akin to that of a needle and thread, stitching together different oppositions.

It is believed that the dual categorization between natural and cultural heritage in the perception, research, and management of the Wadden Sea region hinders the development of future sustainable development strategies in the area. (Egberts & Schroor, 2018) Landscape architecture is the best glue to break down the dichotomy and integrate nature and culture. The purification and reuse of dredged mud around the plant, the reopening of parts of the river and the renovation of the dykes, the recreational activities of the inhabitants, and the development of tourism are landscape projects that can be perfectly integrated with the rich cultural heritage and natural landscape of the Dollard area.

Simultaneously, landscapes are essential to alleviate the conflicts between the economy and nature. The negative spaces in industrial areas can be addressed through landscape design, where vegetation can play a part in purifying some industrial pollutants. Moreover, landscapes can function as an economic component, much like factories, for instance, through biomass energy, circular agriculture, and fisheries.

In this process, the practical projects and experiences of landscape architecture have contributed significantly to the exploration of the potential of mud, enabling the identification of the enhancement possibilities for numerous ongoing projects in the region. This aligns with the theme of this Lab: transforming crisis into potential. It is sincerely hoped that through the collective efforts of the government, residents, designers, and other experts, the Dollard region can rejuvenate and flourish.

Magnificent Wadden land.
Photo: www.visitwadden.nl, 2022.

Mudflat walking
Photo: Marketing Groningen

Mud in the Wadden region.
Photo: Albert Oost et al., 2021

Methodology

Problem Statement
Research Questions
Methods & Techniques

Methodology and Framework

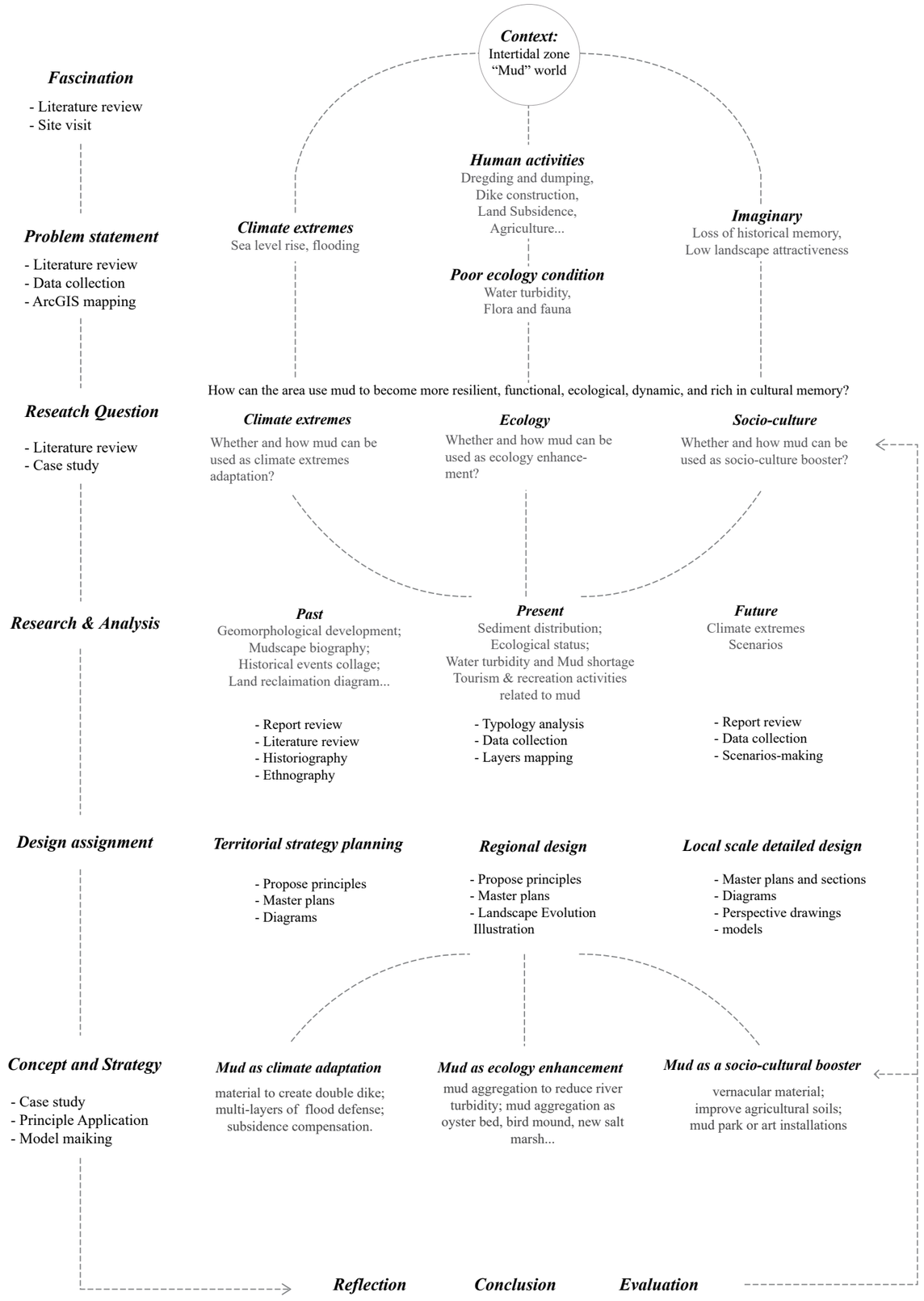
There are three main methodologies utilized in this thesis, which are: Design by research, research by design, and sustainable landscape.

1. Design by research

This is the primary method used in this thesis to gain theoretical and empirical knowledge that will help understand site issues and improve design time by conducting systematic research within the design field. Examples include historical landform change studies, fieldwork, and recording. The research commenced with a thorough site investigation of the Wadden Sea coast in Friesland and Groningen, aiming to gain insights into the natural and human aspects of the Wadden Sea landscape. Subsequently, a comprehensive presentation by Stephan Smeijers provided an initial grasp of the local crisis. This was followed by an extensive review of relevant literature and in-depth project analyses conducted along the Wadden Sea, further refining the three specific problem statements encompassing ecology, economy, and culture. Initially, the significance of mud for the Ems-Dollard region was established, and an exploration of historical sources supplemented this to unveil the interconnection between mud and local culture. Furthermore, the landscape potential of mud was investigated through detailed case studies.

2. Design as research (research by design)

Design as research focuses on design activities as a way to produce fresh information and insights. It entails approaching the design process as a research inquiry in which designers conduct investigations, experiments, and contemplation in order to examine research topics, confront presumptions, and develop fresh insights. Critical thinking, investigation, and the creation of new information are all encouraged by design as research. In Chapter 3, the scenario is presented as an expression of this approach, helping me to test the feasibility and consequences of the scenario by extrapolating backward from the future scenario to the means and costs of design needed now.



Problem Statement

The Wadden Sea, particularly the Ems-Dollard region, confronts numerous challenges that encompass ecological preservation, economic development, and cultural heritage per se and the inherent conflicts between these aspects.

1. Natural disasters and climatic extremes
Sea level rise, storms and floods, land subsidence behind dykes, and salinization continue to threaten the region. Consequently, there is a demand for higher embankments and a shift in agricultural practices, all of which entail significant economic and labor costs.

2. Ecology
The Ems estuaries represent the section of the Wadden Sea exhibiting the most degraded ecological condition. In contrast to the other two estuaries within the Wadden Sea, where the tidal flats are primarily composed of fine sand, the Ems-Dollard estuary features a relatively high concentration of mud (with typical mud content exceeding 70%), more sediment flows into the system than it can naturally handle. Industrial advancements along the estuaries, including the dredging of waterways and embanking of river shores, have brought about significant alterations in the area's morphology, hydrology, as well as its flora and fauna, leading to the disappearance of brackish and freshwater marshes, among other changes. Additionally, a conflict arises between the pursuit of a healthy ecological environment and the necessity for further deepening of the waterway.

3. Culture & Economy
The economic situation in the region is relatively unfavorable, and recreational and tourism activities exhibit lesser appeal compared to other islands, Even the once-in-five-year event, Delfsail, is unable to reverse the trend, People are more willing to seek employment in southern cities and travel to northern islands. The area experiences population decline, and tourism remains sluggish. At the same time, neighboring cities such as Delfzijl and Emden rely heavily on industrial sectors for sustenance, resulting in a relatively homogeneous economic structure. Moreover, the cultural value of the Wadden Sea, despite its natural heritage status, has been overlooked for many years.

4. Landscape imagination
Various factors, including spatial quality, infrastructure, and cultural atmosphere influence the perception and attitude towards a place. However, in the current Ems-Dollard region, the visual connection between the sea and the land is firmly obstructed by towering embankments. At the same time, factories and wind turbines have become the dominant landscape elements, saturating people's field of view. This makes it challenging to appreciate the vast mudflats and sky characteristic of other Wadden Sea areas. This visual obstruction limits people's perception and appreciation of the region, diminishing the unique charm of its natural landscapes and hindering the enhancement of cultural experiences and identity.

Research Questions

"How can mudscapes contribute to integrating and promoting economic, ecological, and cultural development in the Ems-Dollard region?"

1. Understanding questions :
What are the main crises facing the Wadden Sea region?
What are the mud landscapes and practices in the context of the Wadden sea?

2. Application questions

Ecology:
What role does mud play in the ecology of the estuary?What function does it serve?
What is the ecological potential of mud and according to what principles can it be used to promote ecology?

Climate extremes
What can be the coping potential of mud in extreme climatic conditions? Is it possible that the mud suspended in the river could be compensation for land subsidence? Is it possible to collect mud as a material for strengthening dykes?

Identity & Culture
How have people lived with and used mud in the history of the region?
What is the cultural potential of the mud? Is it possible to use this material to enhance the sense of place?
How to translate ancient cultures, legends, and literature into a tangible, material landscape that can fit well into a new reality of global tourism as well as the need in modern humans for a vague, mythical past?

3. Reflection questions:
What are the limitations of the mud and what further research and practice are required for the Wadden sea?
What other landscape elements need to be drawn upon to help shape the mudscape of the Wadden Sea?
How does the mud landscape system work, how much manual maintenance is required and how long can it be effective for?

Methods and Techniques

Literature study and mapping are the main research methods.
The Wadden Sea represents a vast and intricate ecosystem. As a student specializing in landscape studies, my current knowledge is insufficient to comprehend this system's complexities and develop suitable approaches fully. To address this gap, the literature research explores the crisis and challenges confronting the Wadden Sea. Subsequently, relevant theories within the landscape discipline are examined to extract the necessary knowledge from this perspective. The literature study also serves as a valuable resource in the design phase, offering a theoretical foundation and practical feasibility for the proposed design interventions and integrating other disciplines, such as civil engineering and ecology.

Mapping activities are conducted simultaneously with the literature study to enhance the understanding of the landscape. By mapping various thematic elements and overlapping layers, the spatial distribution of specific landscape components can be expeditiously comprehended regarding their distinctive features and challenges. The derived features and conclusions from the mapping process align with the findings from the literature study, facilitating novel discoveries. For instance, mapping recreational activities can unveil disparities in landscape elements between the islands and the northern Dutch coast, while mapping dredging and dumping sites can reveal their correlation with ecological corridors.

Design for Human Ecosystem is the principle. A human ecosystem is very different from the natural ecosystem that would have been created without human intervention. It can function well under appropriate management. Ideally, with deliberate design and continuous management, the city and natural processes can co-exist and eventually merge into an organic whole, a human ecosystem in the true sense of the word, including human systems. (Lyle, 1985) This concept emphasizes that Ongoing human maintenance and management are also part of ecology because humans are part of ecology.

For the graduation project, it is essential to understand the mechanisms of nature's workings and man's means of management, taking the sediments of the Wadden Sea as an example, to understand the direction of currents and sites of deposition, to explore where the polluting elements in the sediments come from, how they will be transformed and so on, which are part of the material flow. It is also important to realize that humans, having chosen to continue developing the consequences of the shipping industry, must maintain and manage it. It is no less important to consider subsequent management and maintenance in the design process than making decisions following suitability analysis using GIS.

Furthermore, scale continuity, landscape process, and palimpsest principles are consistently applied throughout the research and design process. The history of the whole area and the unique historical events and relics of the particular area are highlighted as part of the landscape imagery and identity. Regional-scale, local-scale, and small-scale studies were carried out and resulted in local-scale plans and small-scale designs. The landscape's temporal dimension was considered, and potential scenarios and designs for 2023, 2030, and 2050 were delineated, accounting for future possibilities and contextual variations.

Magnificent coastal weather.
Photo: Xinjian Jiang, 2022.

All about Mud(scape)

Mud Biography
Mud Imagery & Memory
Mud Recreation & Perception
Mud Status
Dredging & Dumping
Industry & Economy
Sea Level Rise
Land Subsidence & Soil Type
Ecology & Species Status

2.1 Biography of Wadden Mudscapes

Mud has played an essential role in the evolution of the Wadden Sea landscape from ancient times to the present day, a process that can be divided into five stages.

The first stage is the extensive mudflats, mud fills the river valleys and is deposited in the river bays. Before humans began to impact the development of the mainland and the coastal zone, the Wadden Sea region was characterized by an untouched mud landscape, encompassing approximately half of its total area. This pristine environment, existing before 500 BC, consisted of vast expanses of sand, mud, and tides, which, in conjunction with the surrounding peatlands, gave rise to extensive tidal marshes. These tidal marshes, alongside the expansive tidal mudflats, stretched for tens of kilometers, showcasing the region's natural beauty.

During the last millennium BC, significant changes shaped the Ems River estuary. Elevated shores and river banks narrowed the tidal river mouth, separating the main river bed from the submerged valley system of the Fivel tributary to the west. Drowned reed swamps and bogs, covered by substantial sediment deposits, further divided the two. As a result, the Fivel tidal basin in North-East Groningen gradually filled with sediment, creating new salt marshes and partially obstructing the mouth of the Fivel River. Consequently, the drainage of inland fens and bogs was impeded. This period of transformation also saw the rapid infilling of embayments, such as the Dollard, highlighting the abundant presence of mud in the region. (Vos & Knol, 2015)

Subsequently, the coastline becomes smoother and has less room for mud, but mud still plays an important role in coastal dynamics. As the mainland coast experienced energy fluctuations, areas with excessive energy witnessed erosion and retreat. In contrast, the overall trend was towards smoothing out of the coastline, with protrusions being eroded and indentations filled in. ("Mud in the Past, Present, and Future," 2020) However, periodically, new valleys and low-lying areas opened up to flooding, shaping the coastal history. During these processes, mud was a key player in shaping the coastal landscape.

The second stage is when humans began settling in the area, gradually affecting and transforming the landscape. During this period, primitive settlement mounds promoted deposition and created diverse habitats. According to archaeological findings, as early as the first century BC, farmers built low "dykes" on the lower tidal marshes, which may be only a few decimeters in height ("Mud in the Past, Present, and Future," 2020), similar in form to the shrub fences on the tidal marshes today. These low dikes are thought to have enhanced sedimentation.

By the 2nd century BC, these "dykes" became taller and wider, up to 1m in height and 5m in width ("Mud in the Past, Present, and Future," 2020), to protect the area behind them from summer storm surges, which made fresh water available for general use, agriculture Start developing. But this area will still be submerged in winter, but this is also beneficial. When submerged, the sediment and nutrients carried by the storm surge will be blocked behind the dam, replenishing nutrients for the farmland and gradually increasing the height of the land behind the dam. People built houses on such high ground, which we call Terps now. The upslope spaces at the edge of the Terp are flooded for different lengths of the year, creating different habitats with varying levels from seawater to salt marshes to grasslands.

In the 10th and 11th centuries, people began to build dikes systematically, but the number of dikes was not significant, and their strength was not strong. Levee breaks and floods still occurred frequently, and these submerged lands could not be reclaimed immediately, the sea permanently takes away geographic factors such as subsidence and surface soil erosion.

Dollard is such a typical area. From the middle of the twelfth century to the end of the fourteenth century, a series of storm surges hit the estuary of the Ems River. Before that time, it was called Reiderland. There were many villages distributed, with large wheat fields and grasslands. However, conflicts between different villages led to the destruction of the sluices, and the inaction of the Minister of Water Affairs made this place very dangerous. According to archaeological research, the dyke breach at Eemsdijk near Jansum (opposite Emden and Larrert) occurred on January 13, 1277 (Witkamp, 1882). This was followed by several floods over the next two hundred years, which took countless lives of both people, sheep, and cattle, then ended the most inhabitants' settlement history of the area. As a result, a large part of the Reiderland formed a large shallow bay, which was given to Dollard. This bay extends as far as Winschoten (Stratingh and Venema, 1855, Dollardzijlvest 1992).

Survivors of these floods moved to higher areas with no choice. But this series of blows has strengthened their determination to build higher dikes in the future systematically.

By the sixteenth century, a new technique was used to collect mud and reclaim the land. The traditional method of land reclamation involved the construction of low-earth dikes on salt marshes to accelerate sedimentation. These dikes were later replaced by rijsdams or Lahnungs, which consisted

Aerial view of the Brede Groene Dijk, 2022
Photo: Ecoshape.org

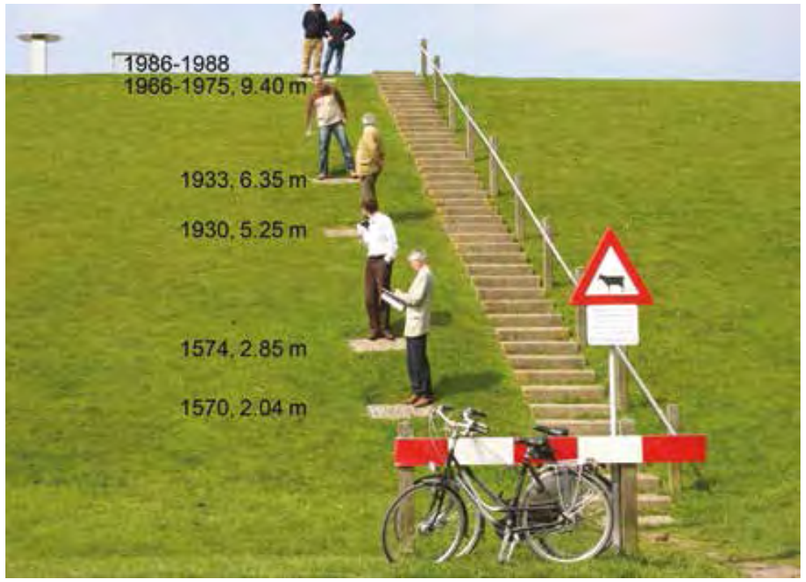
of two rows of wooden stakes filled with brushwood. In the Netherlands, rijsdams were built on mud flats and the sea floor, while in Germany, they were limited to tidal marshlands (Faber, 2022). With the help of such a technique, mud deposition in the tidal marshes was greatly facilitated and gradually, large areas of land were reclaimed. In the Dollard region, from the sixteenth century to the end of the twentieth century, about three-twentieths of the land was thus recovered from the sea again. (Schumacher, 2003)

As land was reclaimed and dikes cast, however, the coastline began to flatten out again, depressions and bays were greatly reduced, and where salt marshes and collecting devices were not available, the possibility of permanent mud deposition was greatly reduced.

Towards the conclusion of the 20th century, the protracted process of reclamation in the Netherlands finally came to a halt. During this period, the presence of salt marshes had significantly diminished, leading to a negative impact on intertidal habitats and a subsequent decline in their ecological significance. Notably, the highest points of certain dikes rose to nearly ten meters above the average sea level, forming a formidable barrier that effectively sealed off the land. Consequently, one side of the barrier became entirely isolated from the sea. Compounding the issue, the land located behind the dike continued to experience subsidence, sinking even below the mean sea level. This exacerbates the disparity in ground elevation on either side of the dike, intensifying the force exerted by the saline water.

There were different dominant players at different times in the land reclamation history. The Middle Ages began with the church, driven by religious beliefs and carried out by dedicated Cistercian monks. After the Protestant Reformation, farmers known as dike wardens took up the task. They gradually reclaimed lost land through the efforts of mud workers. In the Netherlands, the central government assumed responsibility for land reclamation in the early 20th century. The focus shifted from creating new land to recognizing the importance of tidal marshlands as a natural defense against the sea, protecting the surrounding dikes.

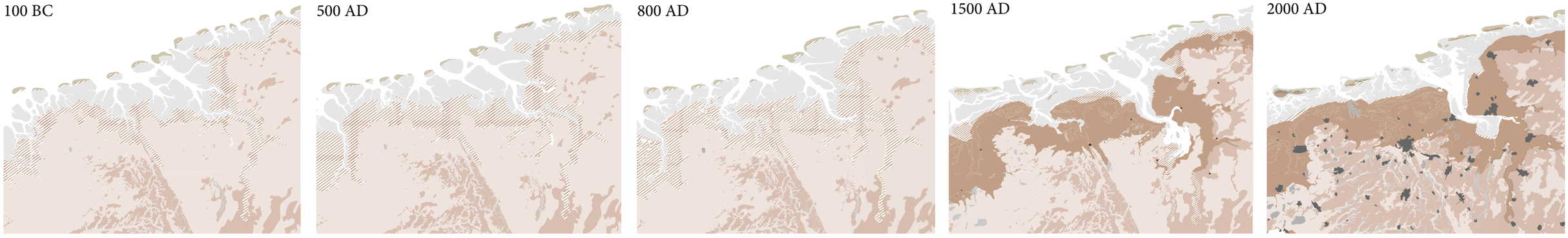
These are the biographies of people who have lived with the muddy landscape and the tides and storms in the Wadden Sea for a long time.
In addition to reclamation and embankment, people use peat to make bricks and slide “sleds” on the mudflats. As one of the most essential landscape elements in the Wadden Sea and Ems-Dollard area, people have accumulated mud, used mud, and got along with mud with rich experience, which provided the basis for this graduation project.

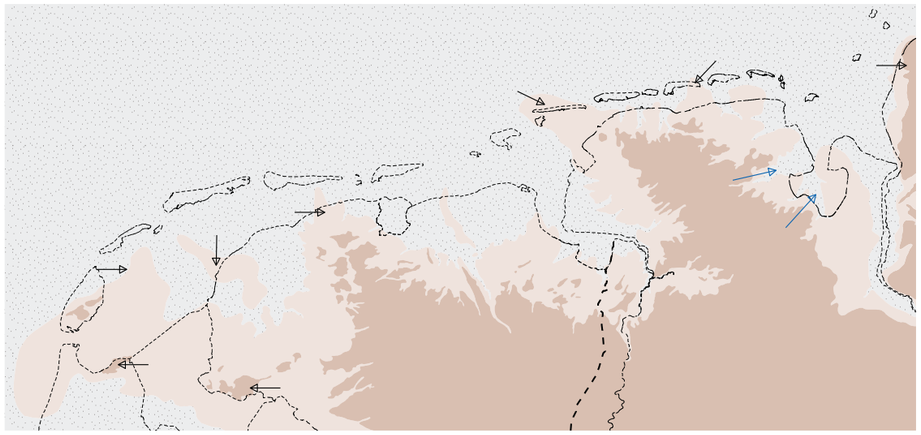


The Slachtedijk/Zeedijk at Oosterbierum. A number of stones mark
Source: Sytse Keizer, 2018

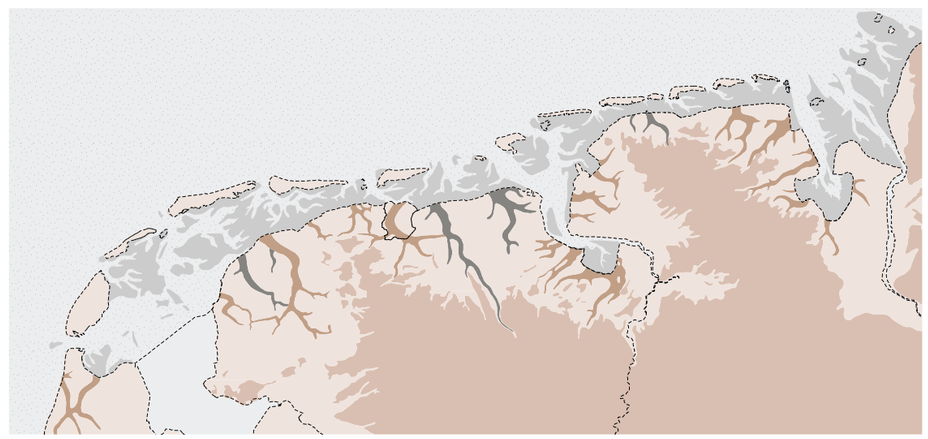
Biography of Wadden Mudscapes

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





Location of the Early Holocene tidal basins in the northern Dutch and northwestern German coastal areas.
Data: Vos & Knol, 2015.

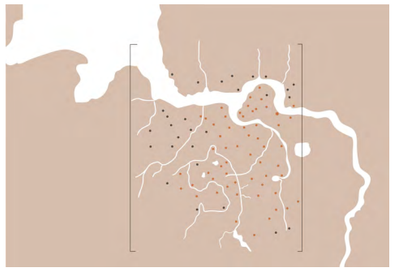


Locations of active tidal systems during the past 2400 years.
Green: tidal channels of older tidal basins which were still active; red: channels new ingressions
Data: Vos & Knol, 2015).

Biography of Wadden Mudscapes

Geomorphological Evolution of Ems-Dollard region
Data: https://sanderusmaps.com/our-catalogue/antique-maps/europe/low-countries-netherlands

1270 AD

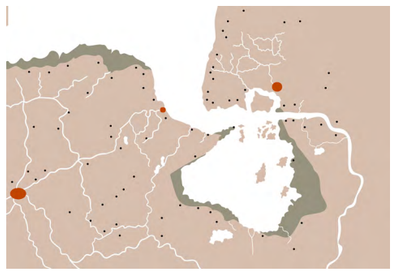


1550 AD

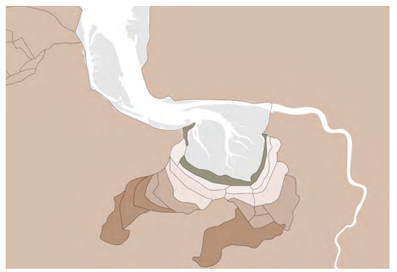
1617 AD

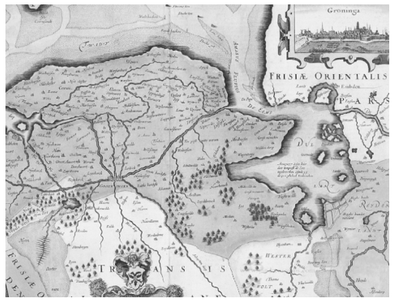
1650 AD

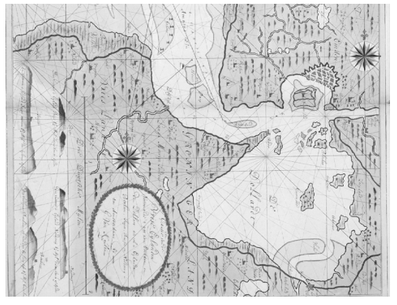
1720 AD

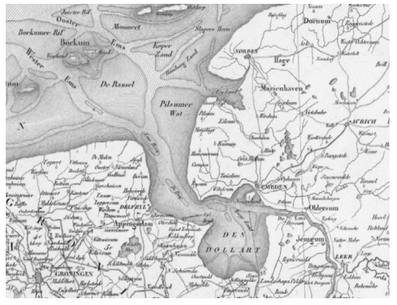


1850 AD









Mainland
Saltmarsh
Intertidal areas
Rivers & lakes
Cities
Terps

Comparison of the Ems River at 600BC and 2000BC
Photo: Zhaolei Li, 2022

Comparison of the Ems River at 600BC and 2000BC
Photo: Zhaolei Li, 2022

Biography of Wadden Mudscapes

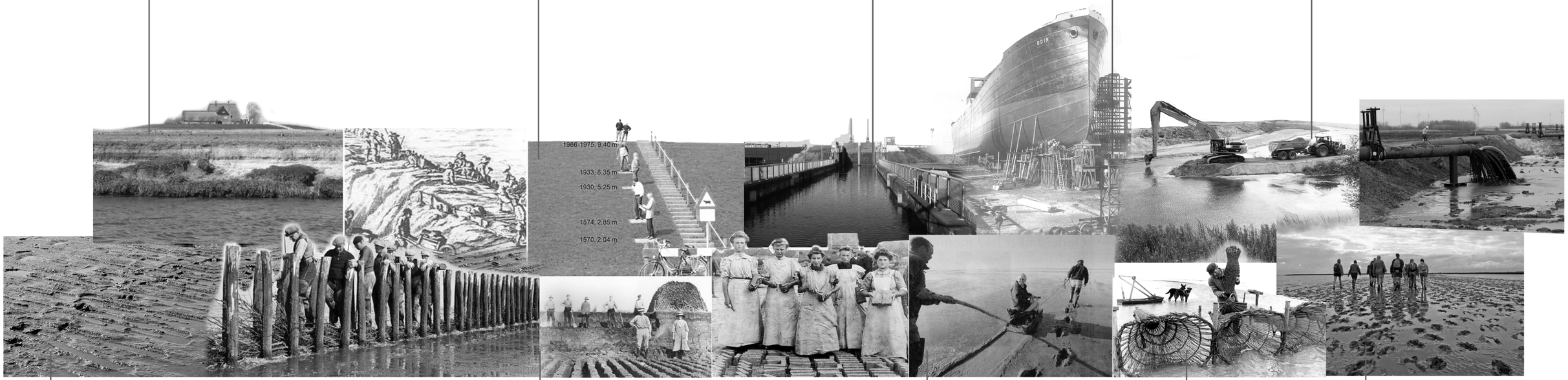
As early as 2nd Century BC
Low dikes and terps, enhancing sedimentation.

Around the 10th – 11th Century
Systematic building of lines of dikes became the norm

Large-scale construction of gates and artificial control of the river

The end of the 19th Century
Modern shipbuilding in the German town of Emden.

In the 20th century, settlement of larger industrial companies such as the Nordseewerke shipyard and the Volkswagen factory.



Before humans started to influence the development of the mainland coastal zone, the mud landscape formed about the half of the Wadden Sea area.

With the hard labour of mud workers,they slowly took back land from the sea.

People lived on the mud flats and even invented unique means of transport in order to catch fish.

Fishermen used to catch fish, prawns and crabs by weaving fish traps and taking advantage of the tides.

Mudflats walking has become a very popular tourist activity.

Stienen man on the Westerzeedijk near Harlingen, remembering the people who cast the dike.
Photo: www.friesland.nl, 2022

Sculpture “De Wadloper ”, a mudflat runner standing waist-deep in water, looking out over the mudflats.
Photo: Lammert Kwant

Imagery & Memory

In addition to an objective understanding of the evolution of the Wadden Sea mudscape, the cultural heritage that has emerged during this long process should not be overlooked, as it not only reflects the distinctive local identity that has emerged from the historical development of the Wadden Sea and the Ems-Dollard region but is also relevant to the sense of place, the identity of the inhabitants, the experience and perception of visitors, and the future development strategy. In addition to tangible heritage such as dykes, historical buildings and monuments, intangible folklore, songs, novels, and poetry, festivals and events can also reflect the interaction between landscape and people.

A large part of the folklore of the Wadden Sea coast comes from the awe and fear of nature in the early days, when people were unable to cope with natural disasters and therefore saw the sea and storms as symbols of evil and punishment, reflecting the power and unpredictability of the Wadden mudflats. However, the story's protagonist manages to overcome the danger in a different way, which demonstrates the resourcefulness and ingenuity of humans in adapting to the challenging conditions of the Wadden Sea. These folk legends intertwines the themes of survival, resilience, and the mysterious allure of the Wadden Sea, emphasizing the deep historical and emotional The folklore intertwines the themes of survival, resilience, and the mysterious allure of the Wadden Sea, emphasizing the deep historical and emotional connection between the people and the dynamic coastal environment.

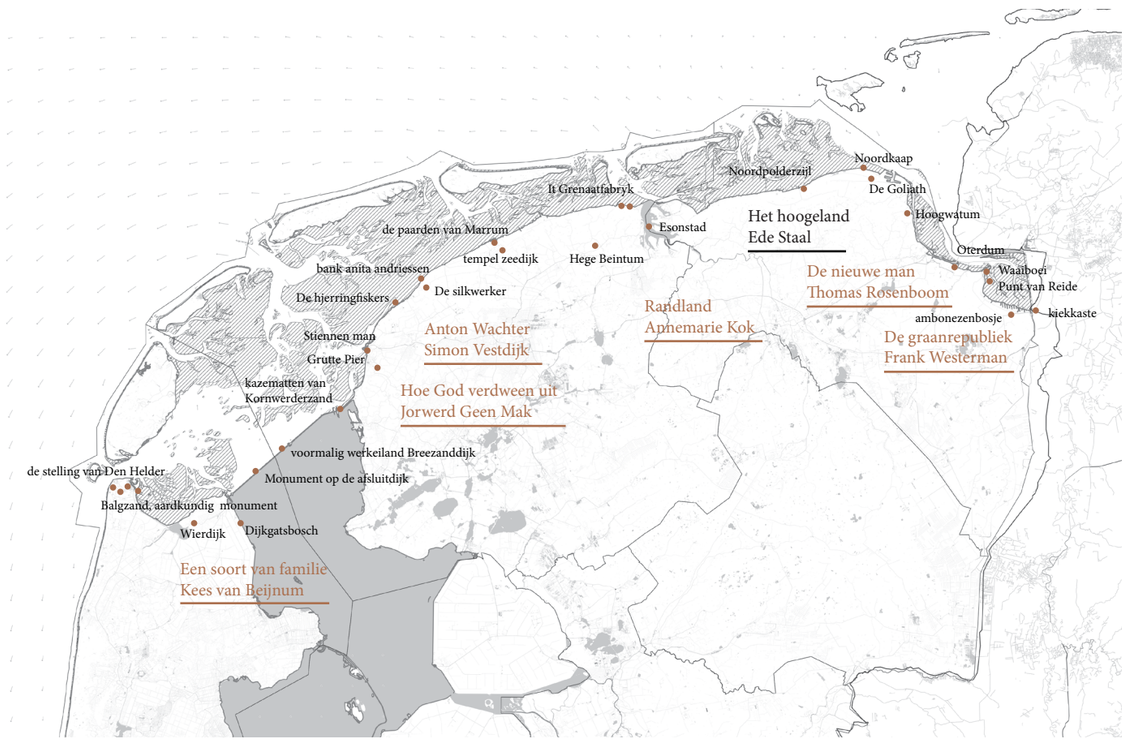
In recent modern literature, writers have focused on capturing and representing the characteristics of this sparsely populated, remote and unknown place in the landscape, and through personal narratives of the people who live there, showing the unique relationship between the local landscape and the people who call it home. between the physical environment, human experiences, and the formation of individual and collective identities.

In the quest to salvage a depleted economy, stimulating tourism through the use of cultural heritage and landscape experiences has the potential to not only reduce the squeeze on ecological habitats and interventions but also to embody regional identity and complement the spiritual needs of contemporary people. However, the Friesland region of the Netherlands currently has a range of artworks along its coast, such as sculptural installations, but is not sufficiently attractive for visitors to stay, participate, and experience. There is potential for landscape design to try to fill this gap.

Stories & Interlude

Poems, books and spaces
Data: Atelier Fryslân, 2012.

In the far North, the Wadden region is celebrated through numerous stories, poems, and songs. Artworks and plaques along the coast pay tribute to this rich cultural heritage. The Stiennen man monument on the Westerzeedijk near Harlingen symbolizes the resilience of the people and their historical dike repairs. Books like 'Randland' by Annemarie Kok and 'De Ent' by Annie Regnerus artfully capture life's essence in these coastal regions, intertwining the sense of confinement within the vast landscape and reflecting the personal and cultural identities shaped by places like Oudebildtzijl. They offer readers an immersive experience and deepen their understanding of the profound connection between the land and its inhabitants. (Berger et al., 2012, pp.31-32)



Imagery & Memory

Legend, Literary works and old Festivals
Data: Dutch sagas, Cor Bruijn, 1946. Atelier Fryslân, 2020. Schaapman, J., Jukema, N. Rixt, & Wagenaar, T. ,2022.

The light of Zeerijp (Legend)

This legend has it that a lawyer and linguist from Friesland were punished by Charlemagne and left adrift at sea in a boat without sails, oars, or anchor. A violent storm ensued, but their prayers were answered when they received a wooden rudder, enabling their survival. The rudder, now placed in the harbor and burned every night, is believed to emit the devil's light, luring ships astray into the treacherous mud. The brave Wimoedes, choosing to face the sea rather than succumb to their fate, embarked on a fateful journey. Zeerijp, where these events unfolded, is situated in Groningen. (Schaapman et al., 2022)

White Women (Legend)

People on the Wadden islands and along the shore commonly spotted White Wieven in addition to witches. Unlike witches, they are frequently far less malevolent. Witte Wieven were easy to spot thanks to their long white robes, pale faces, and long white hair. They could be seen in the blue moonlight, dancing on the seashore at night, or enjoying a cup of 'joosjes' tea in the meadow. Joost was the name of the devil. They would treat you the same way if you didn't intervene. However, they frequently served as a warning sign that something negative was about to occur.
(Schaapman et al., 2022)

'Randland' (Book)

By Annemarie Kok, provides a platform to explore the relationship between the local landscape, identity, and the people inhabiting the coastal strip along the Wadden Sea. Through the stories of the thirteen individuals featured in the book, readers gain insights into their personal experiences, perspectives, and connections with the land.

The midsummer festival

The festivities often included lighting a bonfire in the evening, symbolizing the triumph of light over darkness.partygoers would engage in a unique ritual known as "rolling in the wet grass" or "morning dew bathing."

Dark parties

The dark parties on the Wadden Sea Islands are vibrant celebrations where people light torches and make a lot of noise. This has its origins in local folklore and cultural traditions, and may be used to ward off evil spirits, or to celebrate the return of warriors who have returned from months of whaling at sea and to show off their status.
This connection to whaling reflects the historical significance of maritime activities and their impact on the local identity.

The lur (Musical Instruments)

The lur was traditionally used during the solar service held on 21 March, which marked the vernal equinox or the beginning of spring. This service was performed as a way to celebrate the changing seasons and to invoke blessings for a fruitful year ahead. The haunting and deep tones produced by the lur added a mystical and solemn ambiance to the ceremony.

Delf Sail

Delf Sail occurs every five years and serves as a grand gathering of ships from various parts of the world.The event attracts nearly a million visitors who flock to Delfzijl to witness the impressive fleet of ships on display. It offers a unique opportunity for maritime enthusiasts, locals, and tourists alike to admire the majestic vessels, ranging from historic tall ships to modern sailing yachts.

"Many a skipper who sails the Dollard in calm weather has clearly seen houses and towers at the bottom of the sea, and others have heard on a quiet evening that in the depth still ringing bells." (F. Groefsema, 2022)

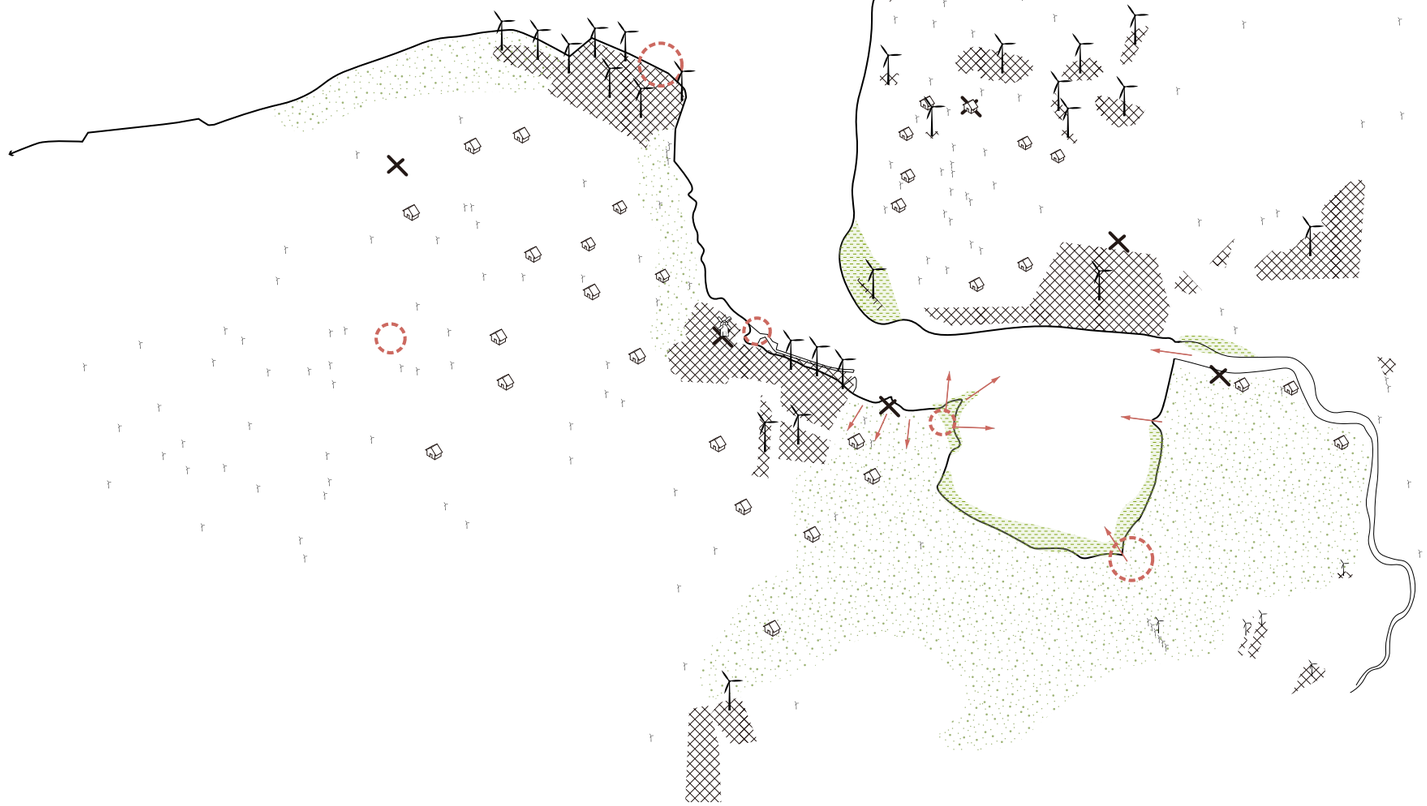
Shipwrecks in the Wadden Sea
Source: lotussailing.calltheone.com

" God created the sea, the Frisians the coast."
(Frisland folk proverb)

Danger on the mudflats
Author: Thorvald Niss (1842-1905)

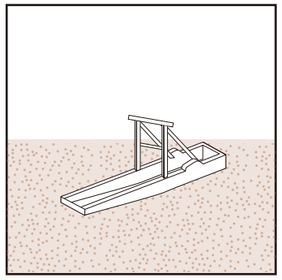
Mud Recreation and Perception

Landscape elements and perception during site visit
Data: openinfrustructure.org

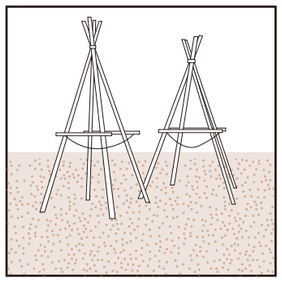


Mud Recreation and Perception

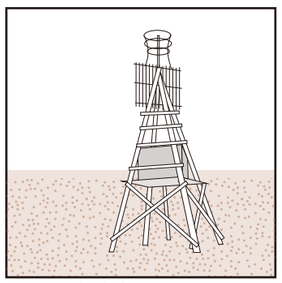
Data: www.wadgidsenweb.nl



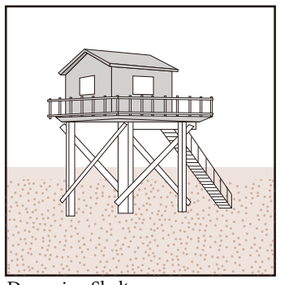
Mud Sled



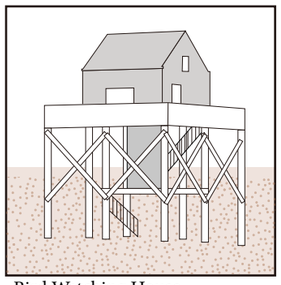
Wad stool (Wadstoel)



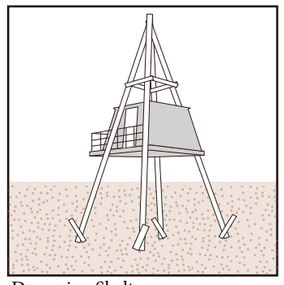
Cape with Shelter



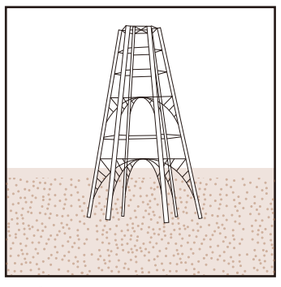
Drowning Shelter



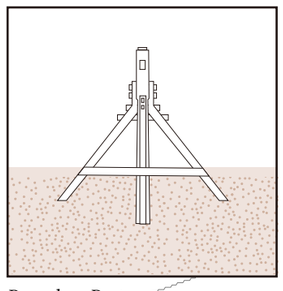
Bird Watching House



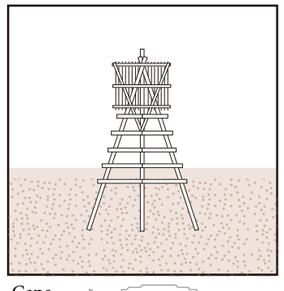
Drowning Shelter



Emder Kaap van Rottumeroog



Boundary Post



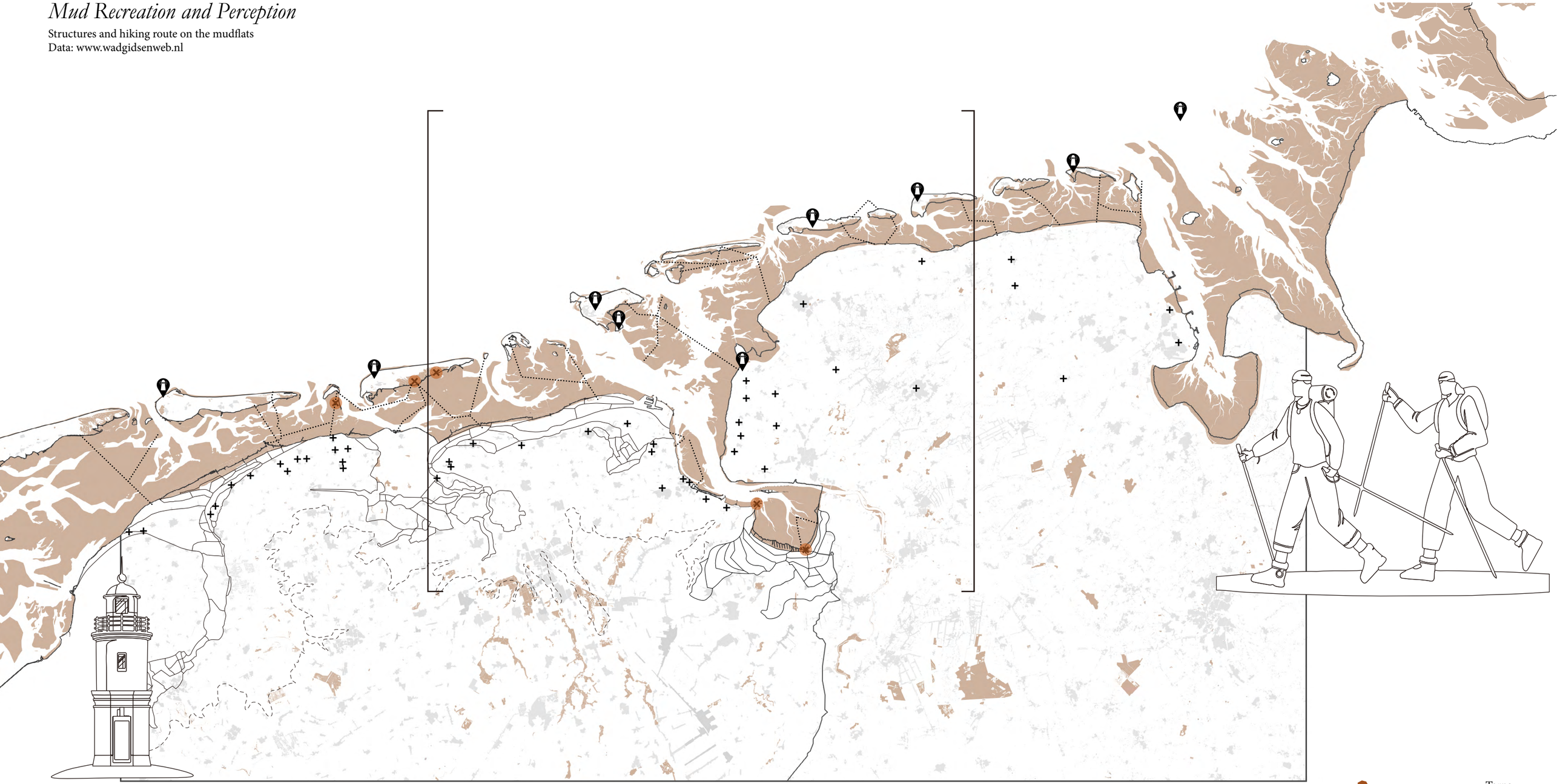
Cape

0 10km 20km 50km N

Hiking route

Mud Recreation and Perception

Structures and hiking route on the mudflats
Data: www.wadgidsenweb.nl



Terps
Beacon
Church tower
Cottage and cape
Residential area
Hiking route
Clay boundary 1250
Reclamation boundaries

0 5 km 10 km 30 km

N

Slicksled races (Sliksleewedstrijden) during Whitsun celebrations Delfzijl
Photo: Jan hendrk van der veen, 2015

Hiking on the mud flats.
Photo: hotspotholland.nl, 2020

Mud status in the Ems-Dollard

The Ems Estuary, including the Dollard area, has experienced significant sedimentation over time, there are four major sources of mud: tidal basins, salt marshes, Dredging, and older deposits from the early Holocene. The gradual decrease of mud sediment in the region has been observed from the 16th century until the early 20th century. The Ems Estuary continues to receive mud deposits, estimated to be significant since the 1960s. Dredging activities have played a role in managing sediment volumes, including the extraction of mud and sand from the port of Emden and fairway, as well as regular dredging of the lower Ems River. The reworking of older deposits, such as Pleistocene and early Holocene formations, may contribute locally to the mud content, although their overall impact is limited compared to the volume of deposited mud. Maintaining a balance between sediment management and ecological preservation is crucial in the region.

Compared to the other two estuaries, the mud content is relatively high in the Ems-Dollard region. The tidal flats of the Dollard are characterized by a typical mud content exceeding 70% (Vroom, et al., 2014). Additionally, the main channel of the Dollard, known as the Groote Gat, shows a pronounced difference in mud content when compared to the Heringsplaat located southwest of the Groote Gat. Furthermore, the lower Ems River and the Emden navigation channel also exhibit a significant presence of mud. Overall, the Ems-Dollard region stands out for its substantial mud content in various areas, highlighting the importance of mud in shaping the estuarine environment.

This has resulted in several adverse consequences. Firstly, the Ems estuary necessitates increased dredging and disposal efforts to maintain proper boat traffic, leading to significant economic costs. Secondly, the suspended sediment in the water remains unsettled and fails to settle in a specific area. This results in high concentrations of suspended matter, obstructing sunlight penetration and significantly impeding primary production in the water, Consequently, fish migration is hindered due to limited food availability, leading to an ecosystem-wide crisis. (de Jonge, 2000; Winterwerp et al., 2013; van Maren et al., 2015).

It is important to highlight that despite the significant dredging activities in the estuaries of the Wadden Sea, the mud sourced from the Elbe and Weser rivers is extensively contaminated, consequently, it necessitates decontamination procedures subsequent to dumping. Conversely, the sediment derived from the Ems River primarily originates from marine sources, resulting in lower pollution levels and rendering it highly valuable in terms of both economic and ecological aspects.

Silt from the Ems-Dollard
Photo: Province of Groningen, 2020

Mud status in the Ems-Dollard

The mud in the Ems-Dollard region originates from tidal basins, salt marshes, dredging activities, and the reworking of older deposits. Over centuries, the region has served as a sediment sink, with mud deposition gradually decreasing. Dredging, especially from the port of Emden and estuarine channels, has been a significant contributor to the mud content. While the reworking of older deposits and salt marshes do add to the mud, their contributions are relatively minor. The overall distribution of mud in the region is influenced by these natural and anthropogenic processes, resulting in substantial amounts of mud being deposited over time. It is important to understand these sources and processes to effectively manage and monitor the sediment dynamics of the Ems-Dollard region, as they play a crucial role in shaping the local ecosystem and coastal morphology.

Data

TOTAL MUD SUPPLY TO THE TRILATERAL WADDEN SEA

12.1-16.5 million ton/yr

THE TOTAL AMOUNT OF MUD DEPOSITION AND EXTRACTION

10.8-11.3 million ton/yr

MUD SOURCES > MUD SINKS

Data

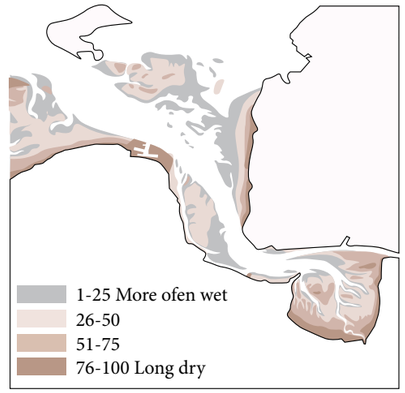
MAINTENANCE DEPTHS OF THE APPROACH CHANNELS TO THE PORTS:

To Eemshaven 12 m

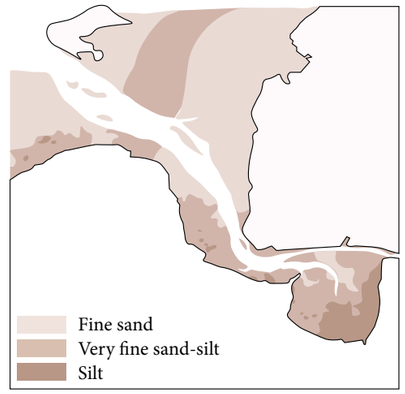
To Emden 11 m

To Delfzijl 10 m

Dry time of tidal flats



Sediment size



Salinity

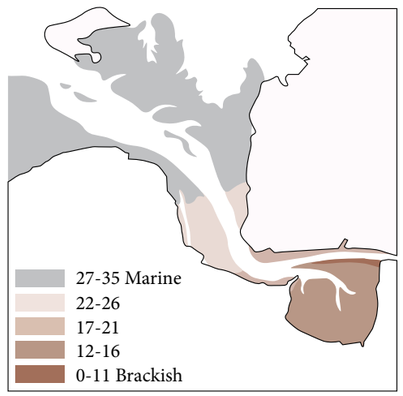


Fig.3.18: Liquid mud in Ems estuary.
Photo: Henk Schuttelaars, 2021

Fig.3.19: Liquid mud in Ems estuary
Photo: Henk Schuttelaars, 2021

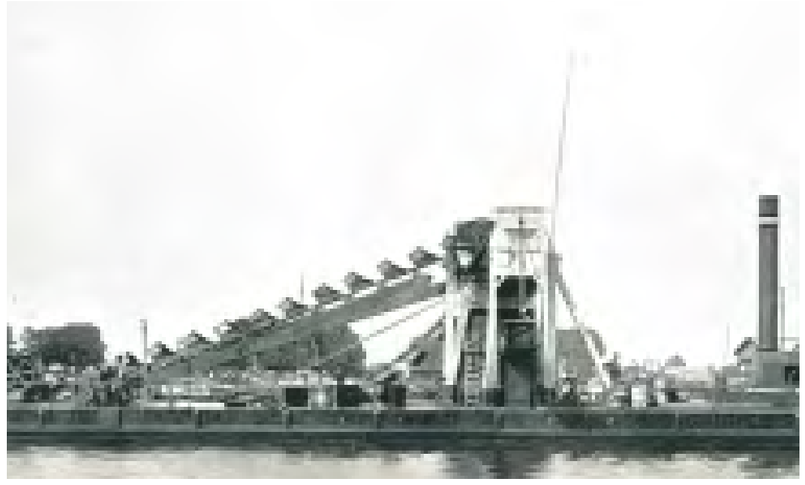
Dredging & Dumping

Dredging and dumping of the river Ems has a long history. As an important waterway between Germany and the Netherlands to the North Sea, the ship-building industry in the cities around the Ems River has a long history. The shipyard in Emden, an estuary city in Germany, has been operating since the eighteenth century, and the shipbuilding industry in Papenburg, a city in the lower reaches of the Ems River The history can also be traced back to 1795, which carried a great deal of the transport needs of the Ems, opening up the waterways, dredging, and dumping, became more sophisticated until today.

Since the nineteenth century, industrial development has accelerated and continued to grow. The chemical industry in the Dutch estuary city Delfzijl and the automobile industry in Emden have flourished.

As early as the late nineteenth century, weirs were built and channels were dredged to promote shipping, causing mudflats to be affected (A Talke & E De Swart, 2006). This was intensified in the twentieth century by dredging the channel to a depth of seven meters or more, allowing for increased tidal differences in the Ems. Today the channel is more than ten meters deep.

In the 1970s, the volume of dredging in Ems reached its climax, with a maximum volume of 1,800,000 m3. (A Talke & E De Swart, 2006). The chief sediments are sands, shell beds, mud, and clay. Later, due to the development of technology, People changed the way of dredging. The traditional way of dredging is to use a bucket dredger, equipped with a large bucket or scoop, it excavates the underwater sediment and deposits it elsewhere. After the 1970s, the dredging operation was done by a suction dredger, It employs powerful pumps and suction pipes to remove sediment from the bottom. Both dredging methods have ecological quality impacts: they disturb 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 having to dig it out. But this will also lead to too much mud suspended in the water, the water body will become more and more turbid, and the ecological conditions will become worse and worse. Therefore, it is important to improve the process.

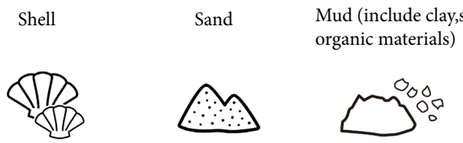


Dredging ship: friesland *II*, 1953
Source: www.dredgepoint.org

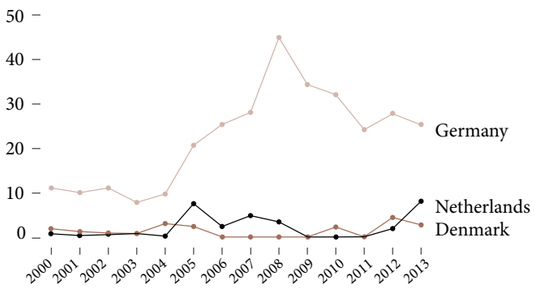
Raising sludge by pipeline in plots with ring dyke. Image of clay mill.
Source: Christiaan van Velzen, 2018

Dredging & Dumping

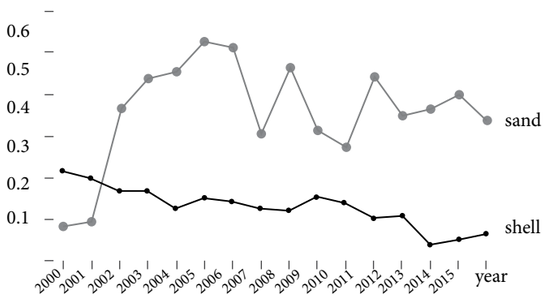
Chief sediments in the Wadden Sea
Data: L.M.J.U. van Straaten, 1954

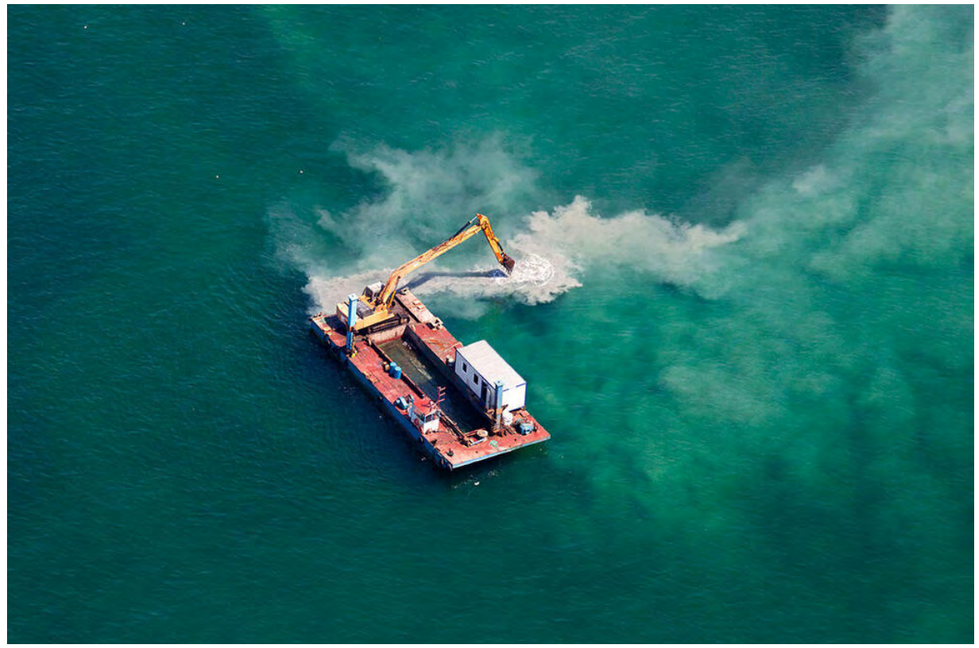


Amounts of dredged sediments within the Wadden Sea areas
Data: OSPAR Reports.

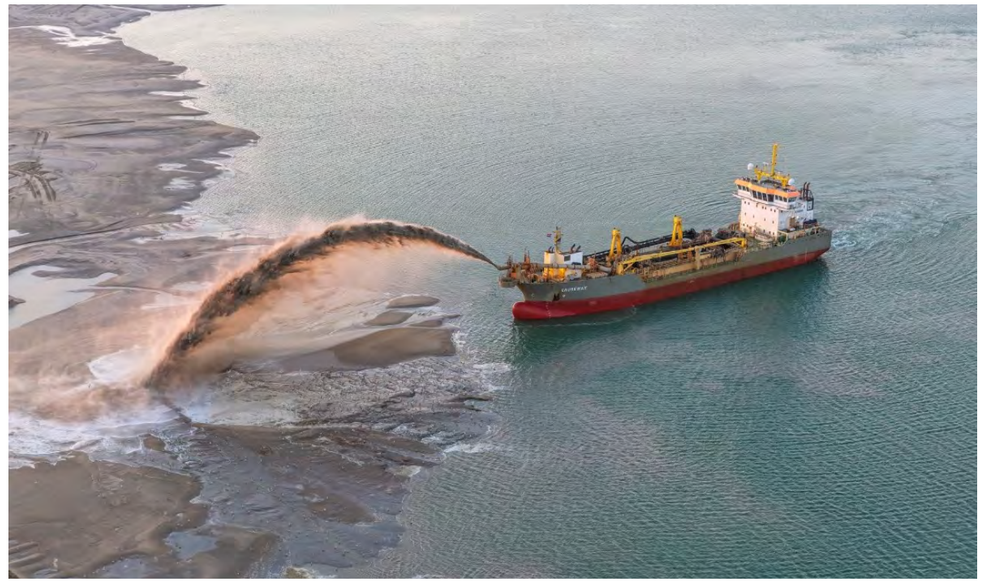


Amount of extracted sediments within the Dutch Wadden Sea
Data: ICES, 2016, and Rijkswaterstaat, personal communication





Dredging
Photo: Hayden Burke, 2022

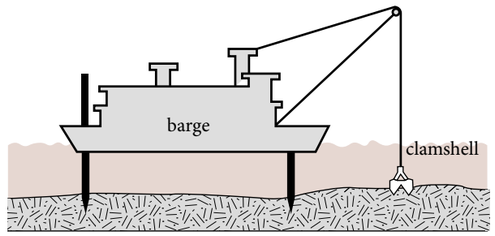


Replenishments, dredging and pumping sand onto beaches.
Photo: Zlatan Hrvacevic, 2022.

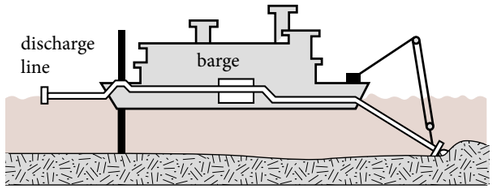
Dredging & Dumping

Data: pdok.nl, 2022

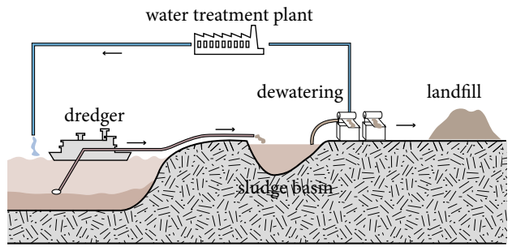
Mechanical Dredging



Hydraulic Dredging



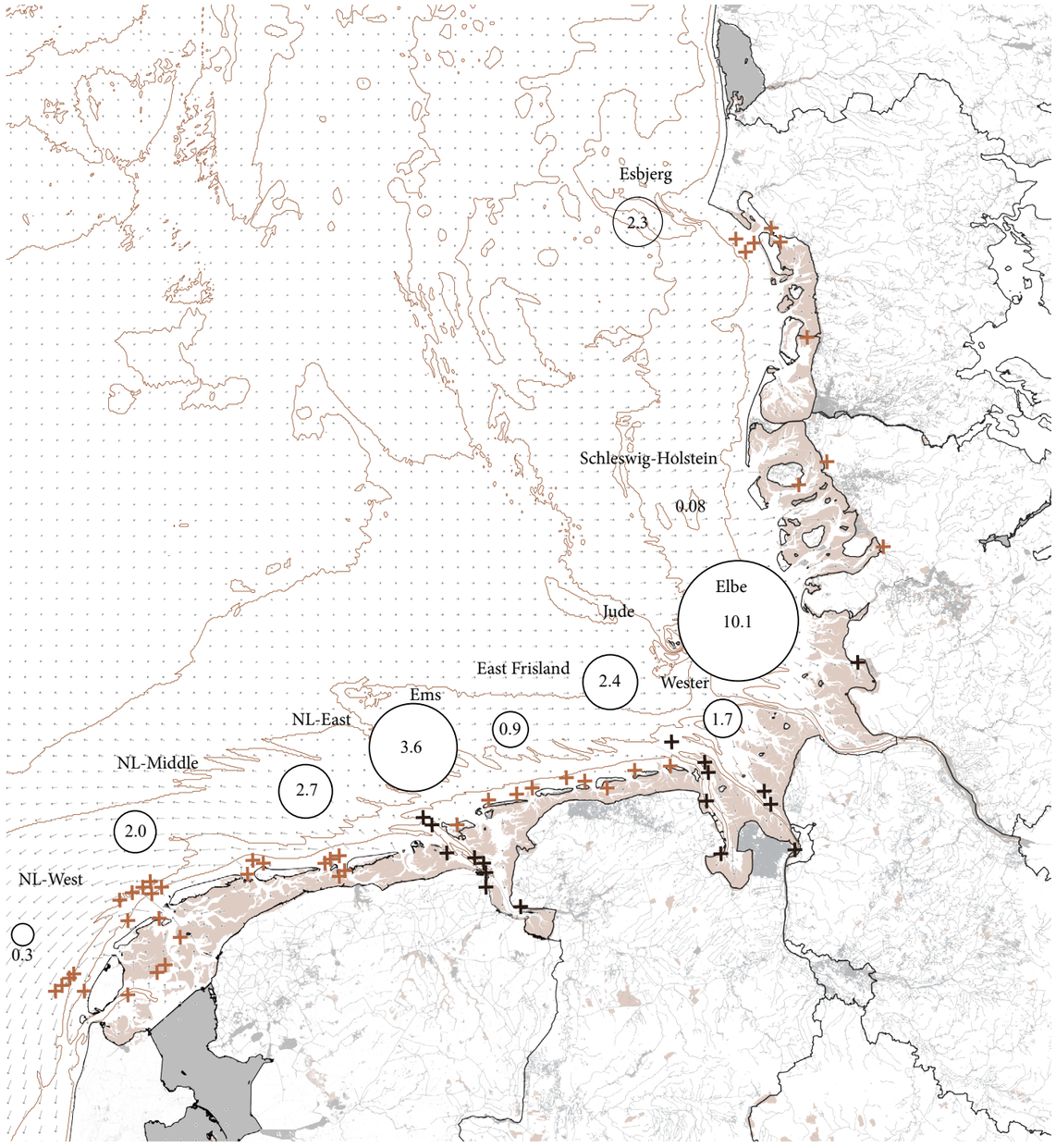
Dredging Process



Schematic of dredging techniques and processes
Data: Federal Remediation Technologies Roundtable, 2020.

Dredging & Dumping

Data: Nehls & Witte, 2009, pdok.nl,2022

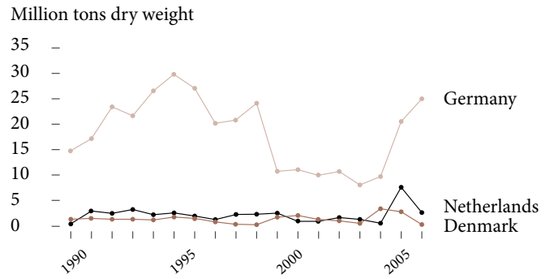


Data

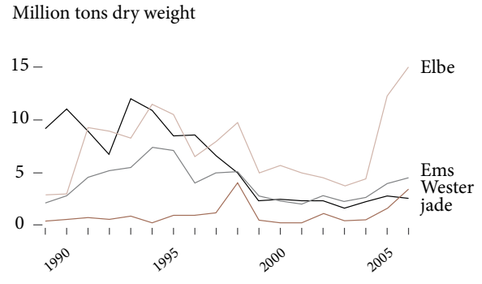
AMOUNTS OF DUMPED DREDGED MATERIAL
23. 900,000 t/yr

DUMPED INTO THE GERMAN PART:
18.5000,000 t/yr
DUMPED INTO THE DUTCH PART:
3.4000,000 t/yr
DUMPED INTO THE DANISH PART:
2.9000,000 t/yr

Amounts of dumped dredged material
Date: Wadden Sea Ecosystem Quality Status Report 2009



Amounts of dumped dredged material
Date: Wadden Sea Ecosystem Quality Status Report 2009



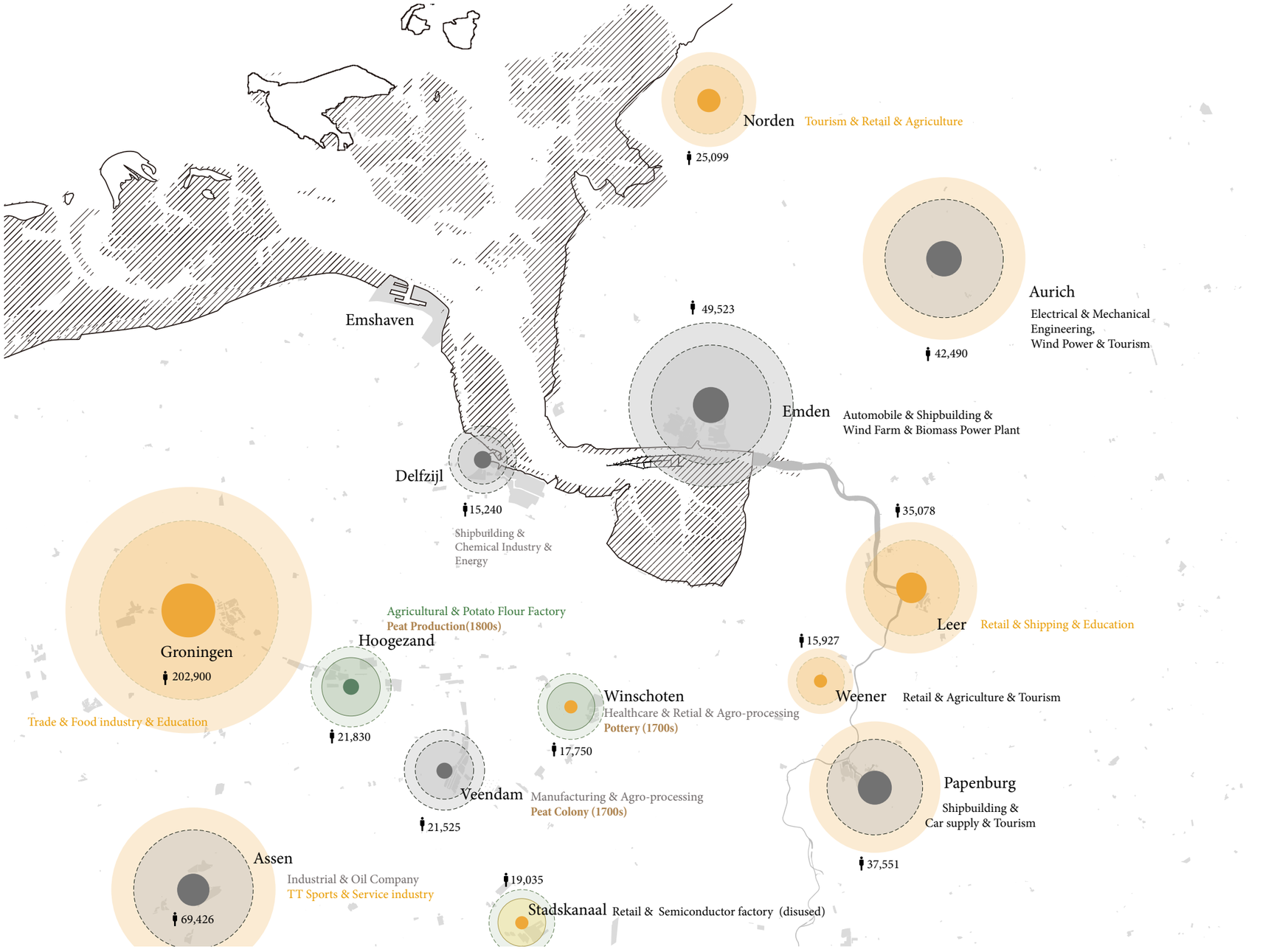
Odyssey of the Seas transits the Ems River
Photo: Royal Caribbean, 2021

The Ems backwater near Hembergen is reconnected with the river Ems
Photo: Bezirksregierung Münster, 2018

Economy & Industry

The main industries and populations
Data: Wikipedia; the official websites of each cities.

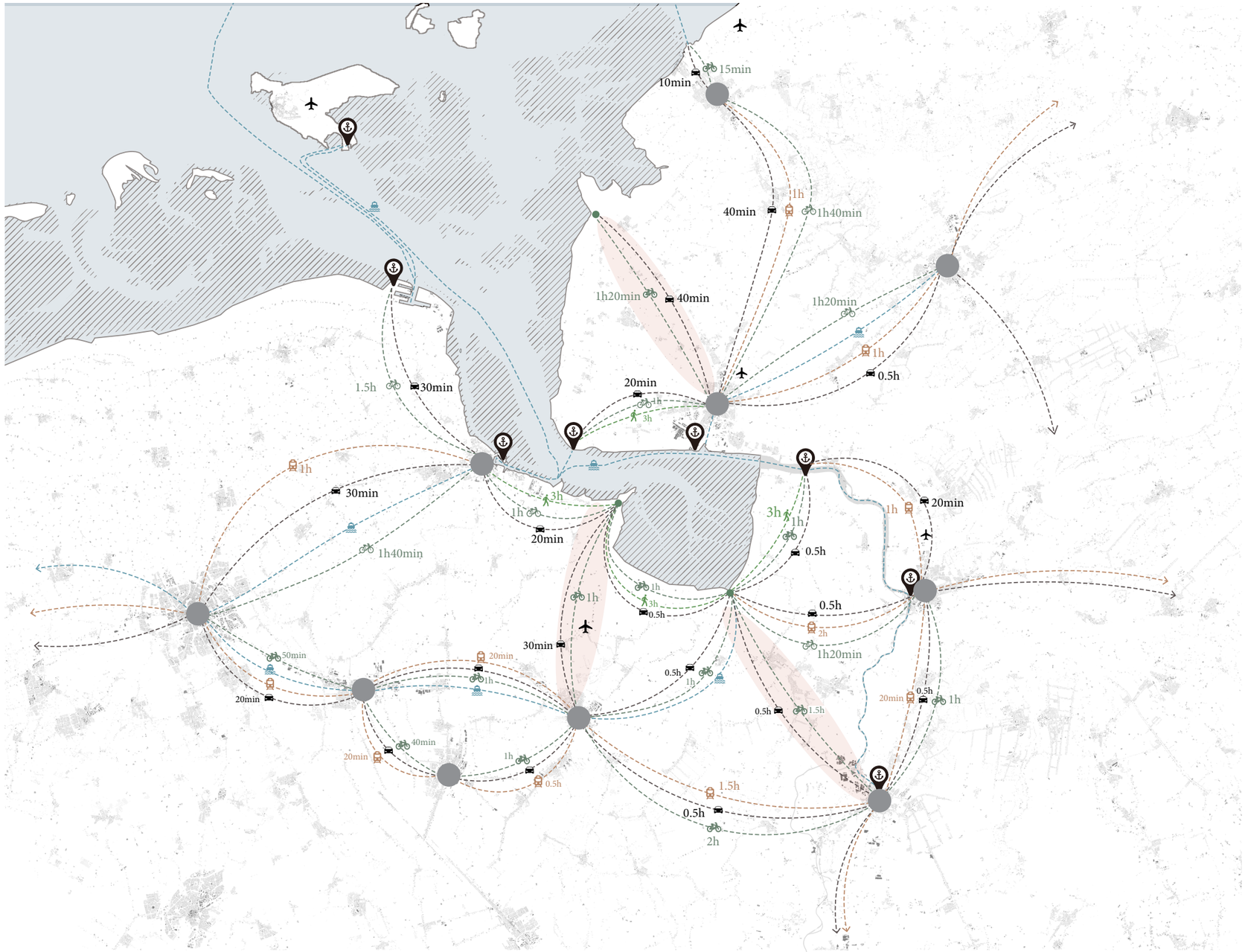
The most typical cities around the ems-dollard region are Emden and Delfzijl, both of which are predominantly industrial, with Emden being dominated by the automotive and shipbuilding industries and Delfzijl by the chemical and energy industries, but Delfzijl is facing problems such as a declining population and an economic downturn. The most important city in the region is Groningen, which has a certain influence on the surrounding area, both in terms of population and economy. A stronger connection and cooperation with groningen would benefit the development of the Dutch towns near the Ems estuary.



Accessibility

The main modes of transport in the ems-dollard region
Data: Open street map, Google map

The region's transport system is well developed and accessible, and the International Dollard Route, which is now available to cyclists and visitors alike, provides a great deal of convenience. However, the villages and towns along the Ems are less well served by public transport, relying mainly on cycling, driving and walking. From Delfzijl to the Pogum area, for example, there are only a few buses, which serve very limited hours on weekdays.

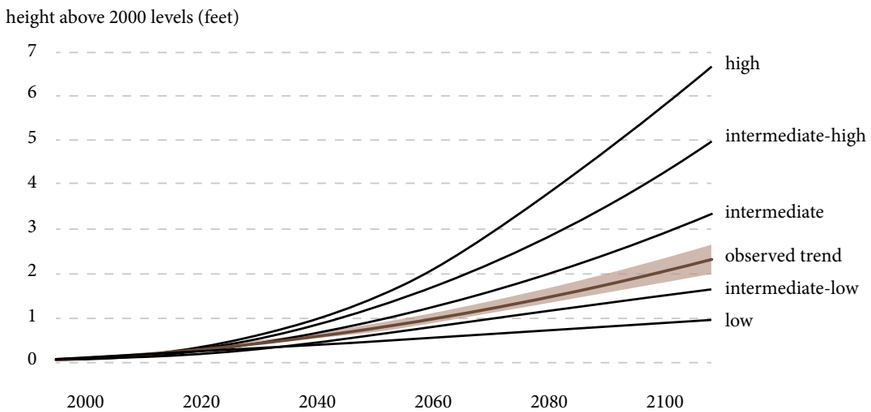


0 5 km 10km 20 km N

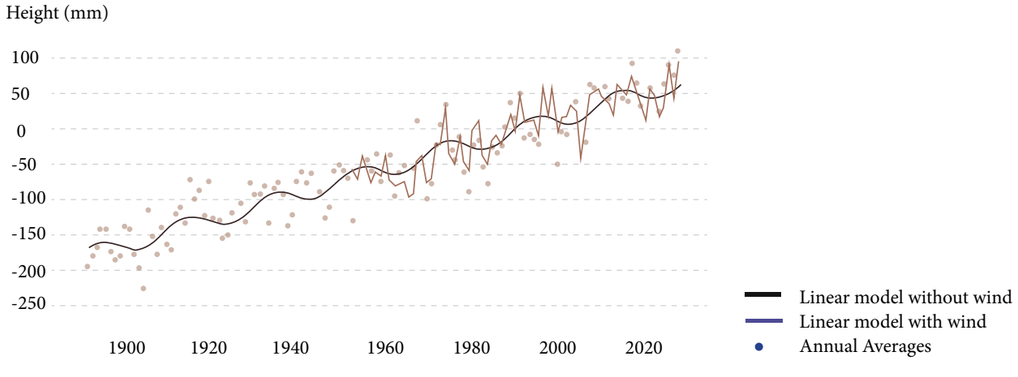
Driving
Train
Cycling
Water transport

Sea level rise

Global sea level rise
Data: NOAA climate.gov, 2022.

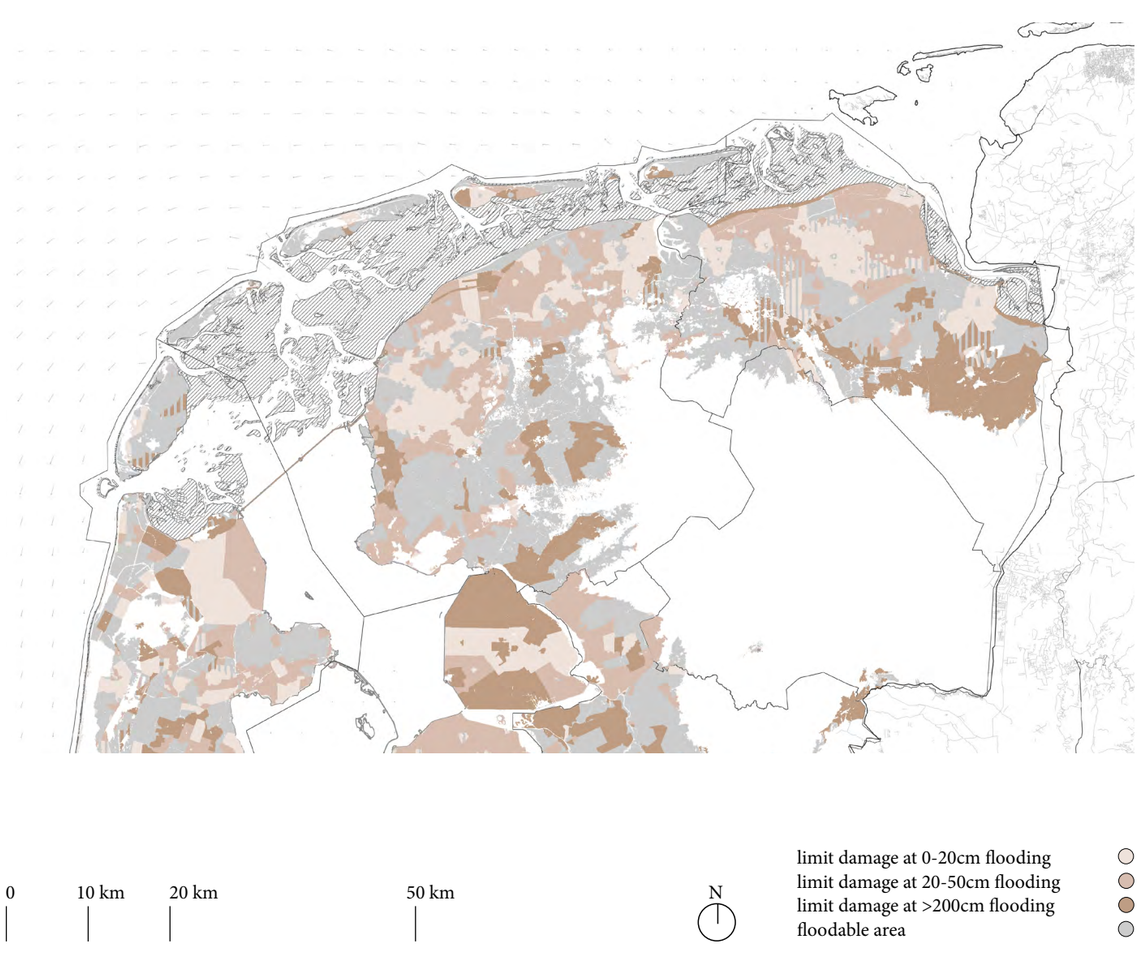


Sea level rise in the Wadden sea
Data: Sea level monitor 2018. E Baart et al., Deltares, 2019

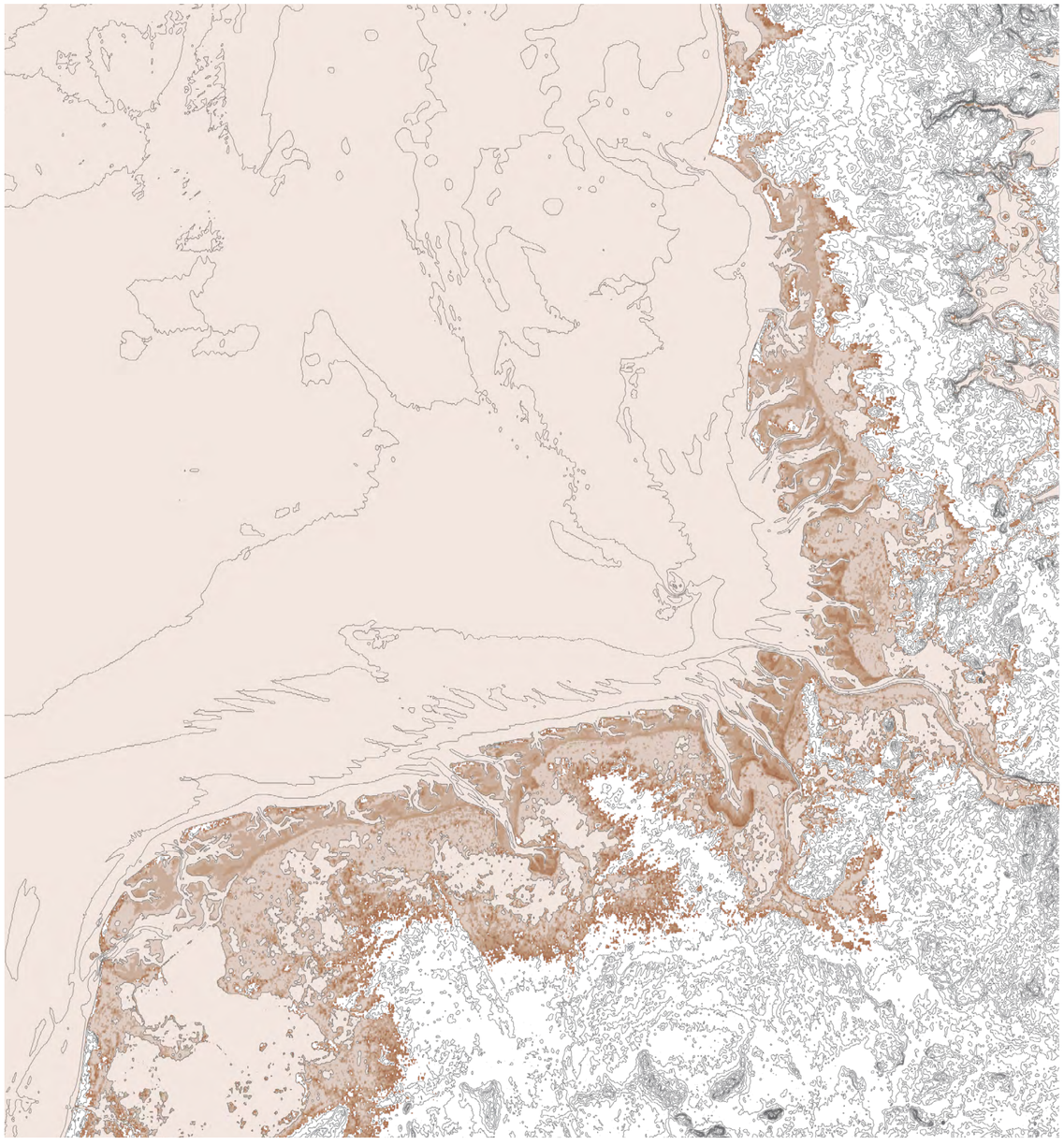


Flood Damage Oppotunity Map
Data:https:pdok.nl, 2022

The greenhouse effect has led to a variety of climate problems, such as rising sea levels, which means once the flood comes, it will be worse than ever. Actually temperature extremes, Storms/ Flooding are still listed as the biggest threats to the Wadden Sea region. IPCC (2014) concludes : "Global mean sea-level rise will continue during the 21st century, very likely at a faster rate than observed from 1971 to 2010. For the period 2081–2100 relative to 1986–2005, the rise will likely be in the ranges of 0.26 to 0.55 m for RCP2.6, and of 0.45 to 0.82 m for RCP8.5 (medium confidence). Sea-level rise will not be uniform across regions". (Oost et al., 2017)



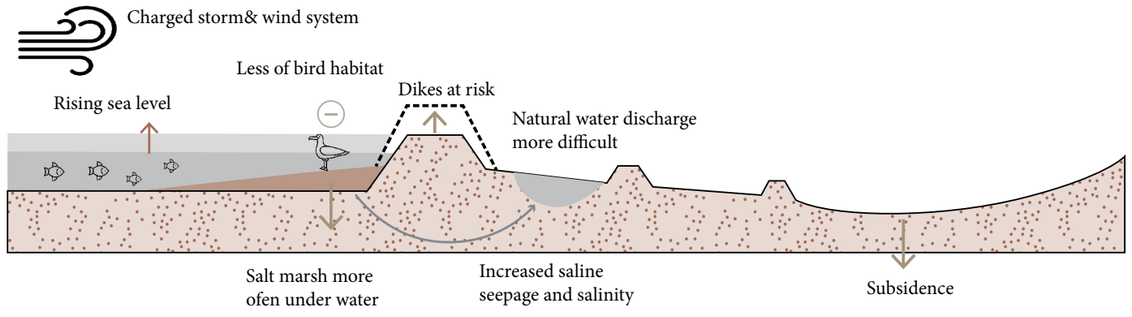
Sea level rise



Inundated areas of flooding
Data: Earthdata.nasa.gov/sensors/Srtm

In addition to the sea level rise itself, it brings with it a series of crises, increasing pressure on the defense of the coast. It is manageable at the moment, but in the long term, this pressure and thus the scale of the measures required / will increase exponentially. In the longer term sandbanks and salt marshes may be flooded more often and for longer periods, entailing a considerable reduction in the size of these special habitats. The risk of salinity is increasing as a result of the rising sea level and that process will probably intensify after 2050. Finally, it will become more difficult to discharge water naturally into the current border strip between sea and inland, whereas open connections with the sea offer the most options, as well as a concomitant increase in coastal security. There is as yet not enough support for this line of thought.

Fig.3.7: Impact of sea level rise
Data:Verstild getij. Een atlas van de Nederlandse Waddenkust, 2020.



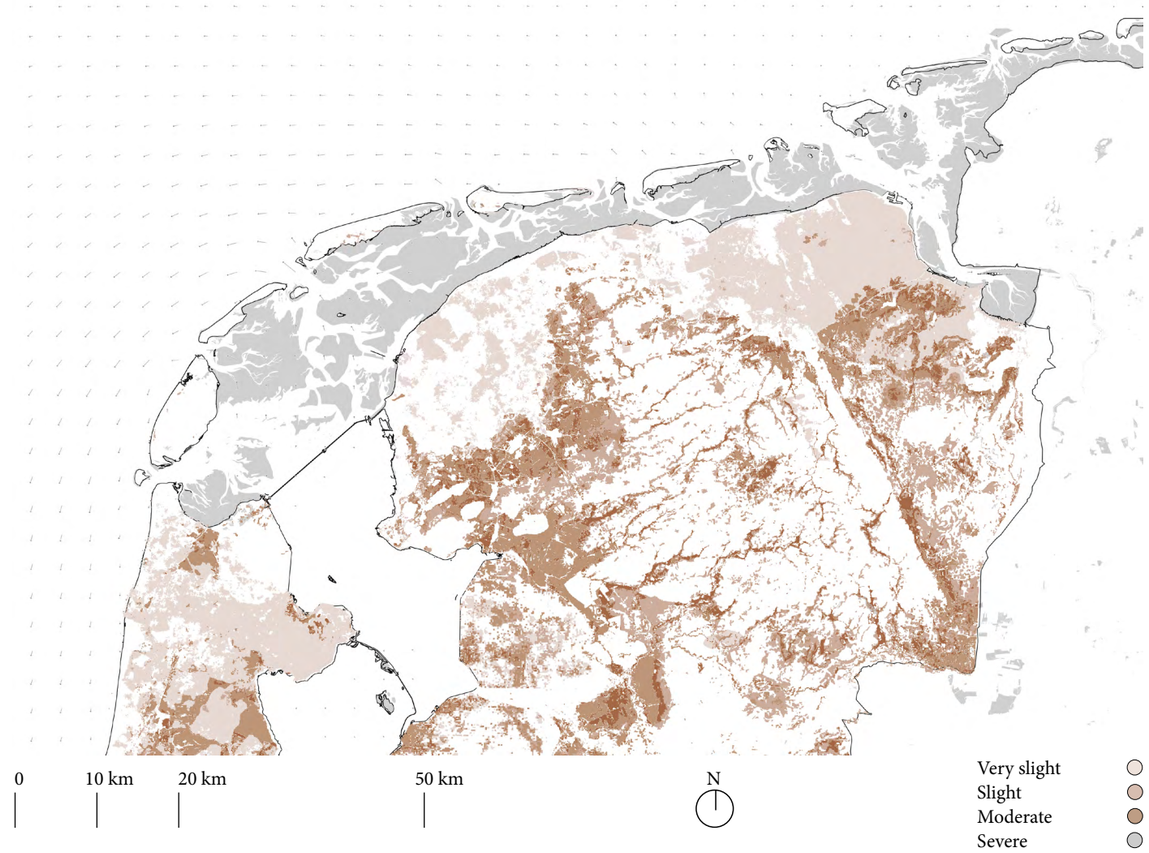
Land Subsidence

As can be seen from the expected soil subsidence in the map, the most severe subsidence in the ems-dollard area is concentrated between Delfzij and Groningen. Although gas extraction in Groningen has ceased, the whole province is in an area relatively susceptible to subsidence and at higher risk of flooding.

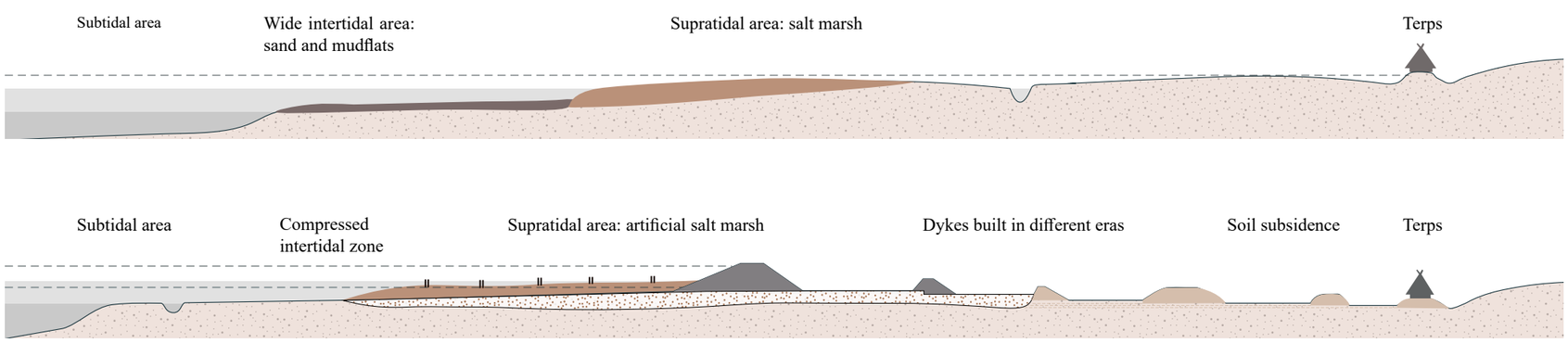
The rate of subsidence is often higher than the rise in sea levels, with an average of 0.5 centimeters to 2 centimeters per year. This ongoing process has been occurring for centuries, resulting in significant meters of land sinking. However, the urgency surrounding subsidence has increased due to various factors, including greenhouse gas emissions in rural areas and the escalating damage to buildings and infrastructure in urban centers.

The subsidence faced in rural areas is largely due to drainage practices that promote agriculture. The need for efficient drainage has led to a lowering of the water table, which compacts and sinks the soil over time. In contrast, subsidence in built-up areas is due to the accumulation of fill material, as well as the effects of increasing droughts and the extraction of underground energy.

Forecasting land subsidence until 2100.
Data: www.arcgis.com/apps/mapviewer/, Klimaateffecatlas

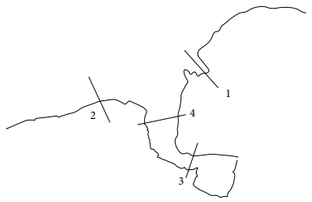


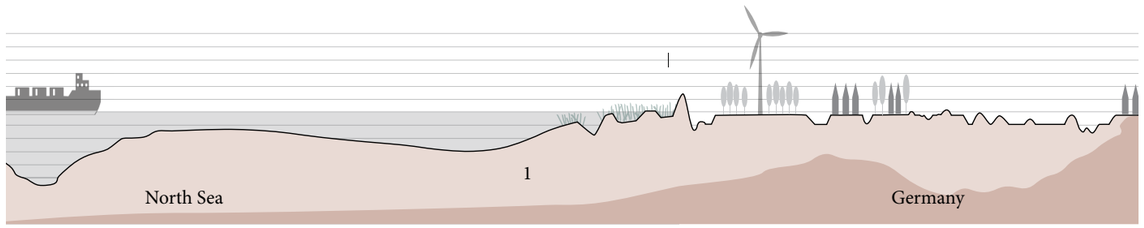
Evolution of the sections.
Data: Google Earth , 2023

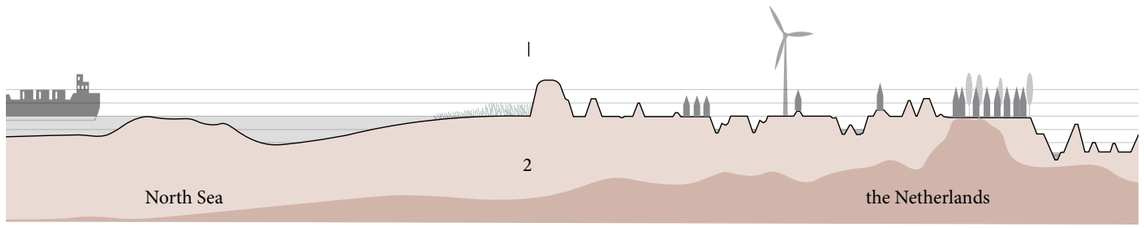


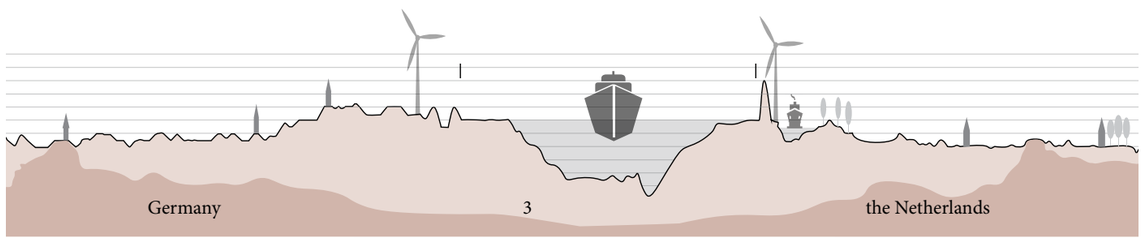
Sea level rise

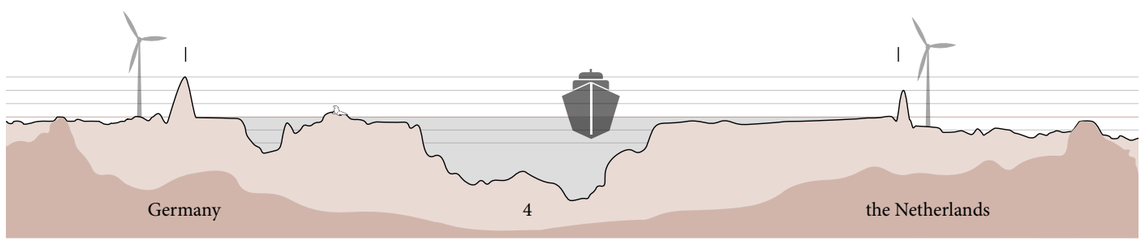
Sections of Costal Area
Data: openinfrustructure.org



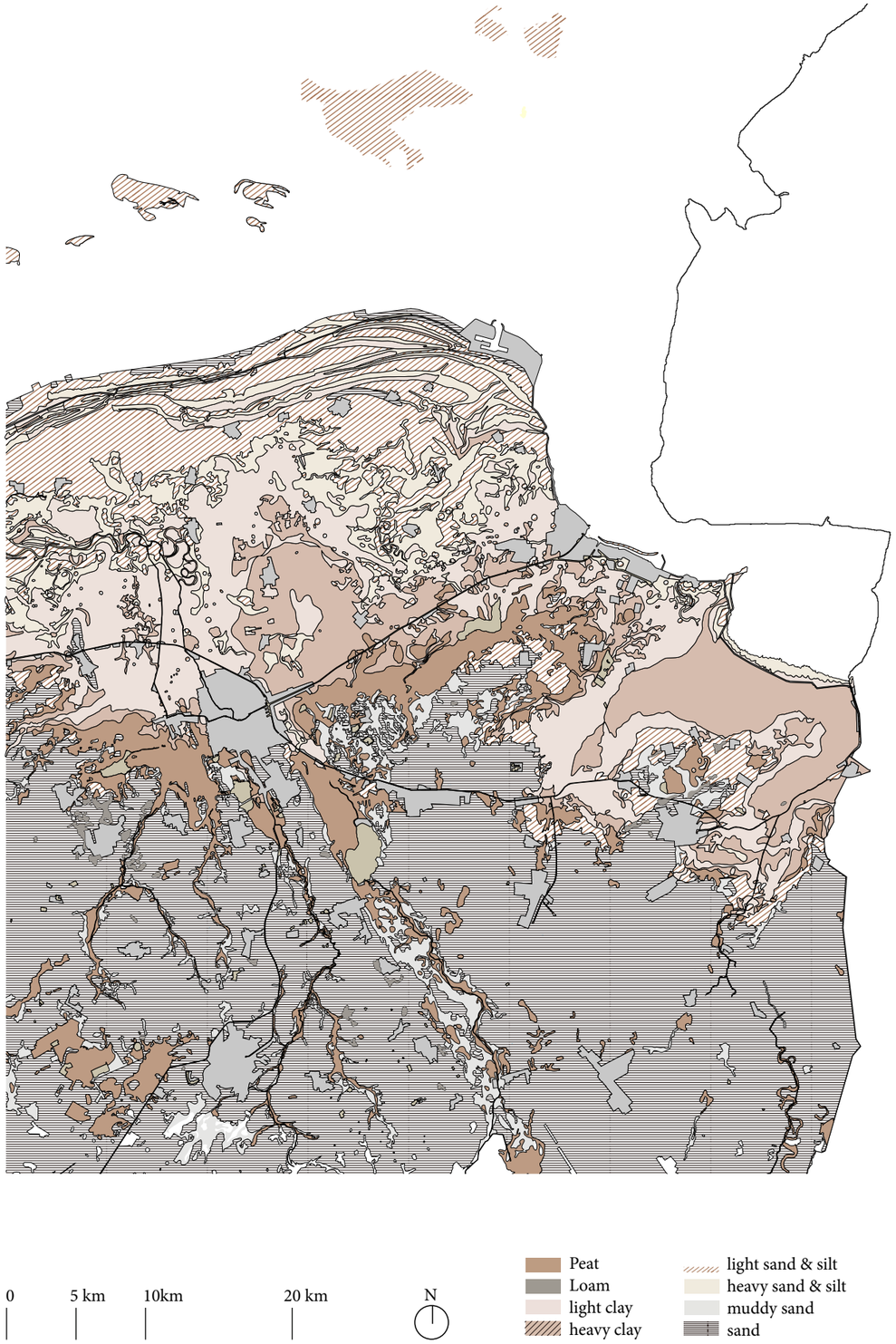








A sheep on the dike in Emssperrwerk
Sauce: Ems-Dollard 2050 Vlog



Soil Type

Data: PDOK.nl, 2022

The Ems-Dollard region exhibits various soil types that significantly influence agricultural practices and land use.

Light clay are prevalent in the Ems-Dollard region. These soils consist of a mixture of clay, silt, sand, and organic matter. It offer good drainage and moderate water-holding capacity. They are suitable for various agricultural crops, including cereals, vegetables, and root crops.

Heavy clay have high water-holding capacity but can be prone to waterlogging and compaction when poorly drained. They are challenging for agriculture, only with proper soil management practices, they can support the cultivation of crops like sugar beets, potatoes, and grasses.

Along the coast and riverbanks, marine and fluvial deposits can be found. These deposits consist of sandy and silty sediments. These soils are often utilized for coastal protection and may not be extensively used for agriculture.

And peat are mainly found in low-lying areas with poor drainage, including marshes, peatlands. Peat have a high organic matter content and are typically fertile, making them suitable for agricultural use, especially for grassland and dairy farming.

Ecology and Species Status

In the nineteenth and twentieth centuries, agricultural and industrial organic waste was dumped in the Ems-Dollard Region, leading to eutrophication and pollution of heavy metal elements, and the ecological situation here was worse than it is today. But this practice was banned at the end of the last century, and coupled with the continuous replacement of water by the currents of the Wadden Sea, its water pollution has been greatly improved. However, the chemical factory in Delfzijl has always had heavy metal pollution discharged, which has an impact on the surrounding land. Such as Akzo Nobel Chemicals BV (Chemie Park Delfzijl), E.ON Energy from Waste Delfzijl BV, Zeolyst CV, RWZI Delfzijl, all emit heavy metal elements such as As, Cd, Hg, Pb, which pollute habitats and human settlements.

The main research on threatened organisms are fish, shellfish, birds, and mammals.

The estuarine ecosystem of the Ems River supports a variety of fish species, including the Smelt (Osmerus eperlanus) and Twaite Shad (Alosa fallax). However, the fish population faces several challenges. In the upper reaches of the estuary, ecological conditions are poor, adversely affecting spawning habitats and larval survival. Water quality issues, such as periods of anoxia, high concentrations of suspended matter, and fluid mud, contribute to these unfavorable conditions. Additionally, the connectivity between the estuary and its tributaries and inland waters is hindered by physical barriers, limiting the migration of fish. Furthermore, power plants along the estuary, requiring significant water for cooling purposes, elevated water temperatures, further impacting the fish population. (Bos et al., 2012)

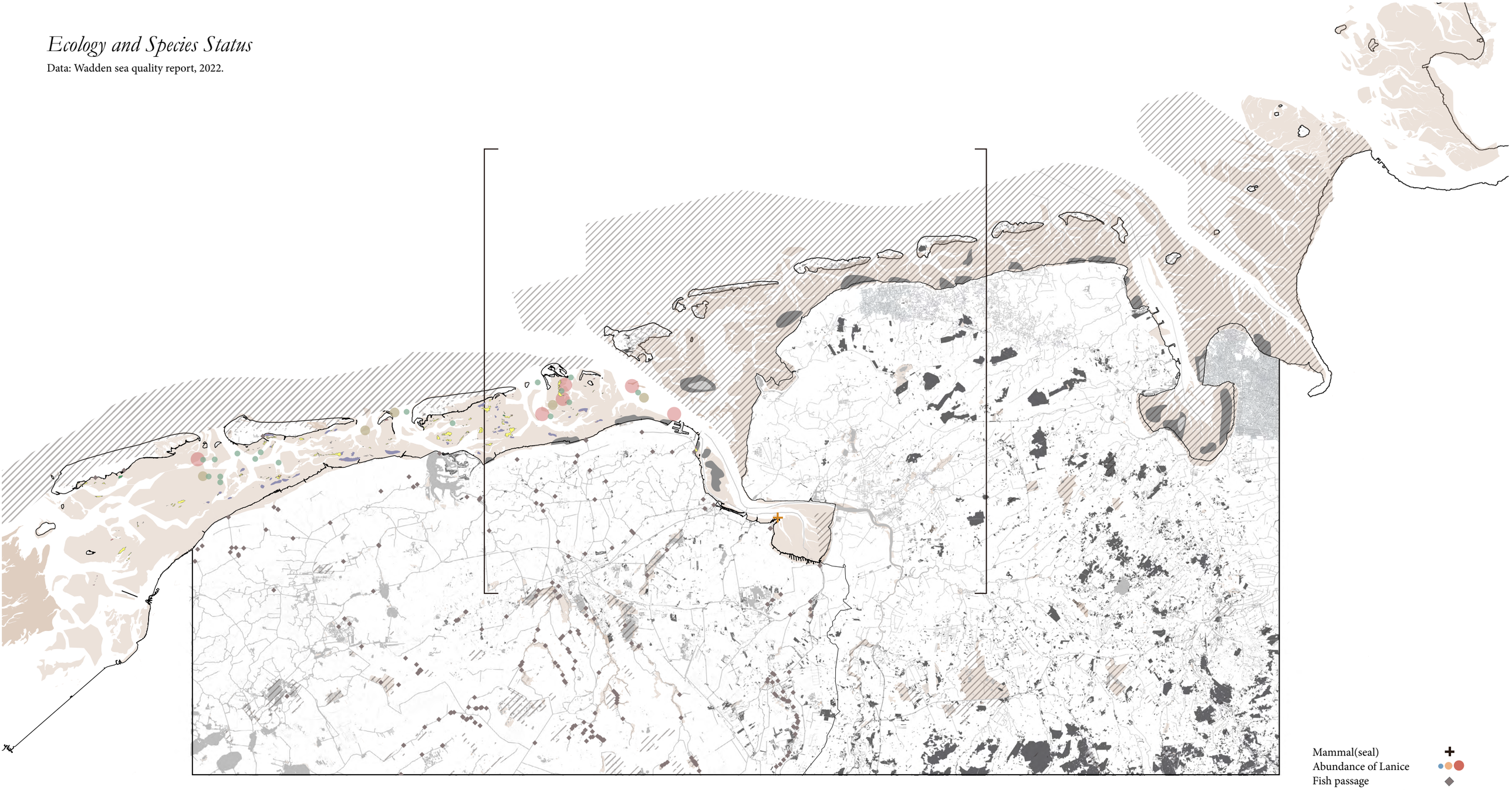
There are three mammal species found in the estuary: the common seal (Phoca vitulina), the grey seal (Halichoerus grypus), and the porpoise (Phoecoena phocoena). The Dollard area is extremely important to them as they spend their breeding period on the mudflats here. There is an observation point at Punt van Reide near the dyke, which is a good place for science education, but human activity, as well as incoming and outgoing boats, can interfere with their lives.

The abundance and diversity of birds in the Ems-Dollard area are high (ca. 40 species)(Prop, Ubels, et al., 2012). Several groups of species can be identified: Ducks and geese, waders, and gulls. In numbers, waders are the biggest group. The species most typical to the Dollard are the Barnacle Goose (Branta leucopsis), Graylag Goose (Anser anser), Common Teal (Anas crecca), Avocet (Recurvirostra avosetta), Spotted Redshank (Tringa erythropus) and Twite (Carduelis flaviostris). (J.Dijkstra, 2010). Their main habitats are shallow water, intertidal areas, and bordering salt marshes provide plenty of food, as well as nesting opportunities. Within a year, the largest numbers of birds are present in March-May and September-November. Every group of species has its own peak: ducks are most abundant in fall, geese at the end of winter, gulls occur year-round in small numbers and waders peak in spring and fall.

Much of the crisis for birds stems from the quality of the habitat, the abundance of food, and how it is found. Apart from some exceptions, most ducks and geese are herbivores, whereas most waders and gulls eat fish or invertebrates. Reduction of the intertidal feeding area by sea level rise, erosion, or gas mining will increase this predation pressure. Strong winters also lead to reduced numbers of birds; an effect that can last several years. The current problems in the tidal river estuary relate to the breeding of birds in the foreland, such as harriers, passerines, and meadow birds. Part of the breeding habitat declined in quality because of intensive use by agriculture. (Bos et al., 2012)

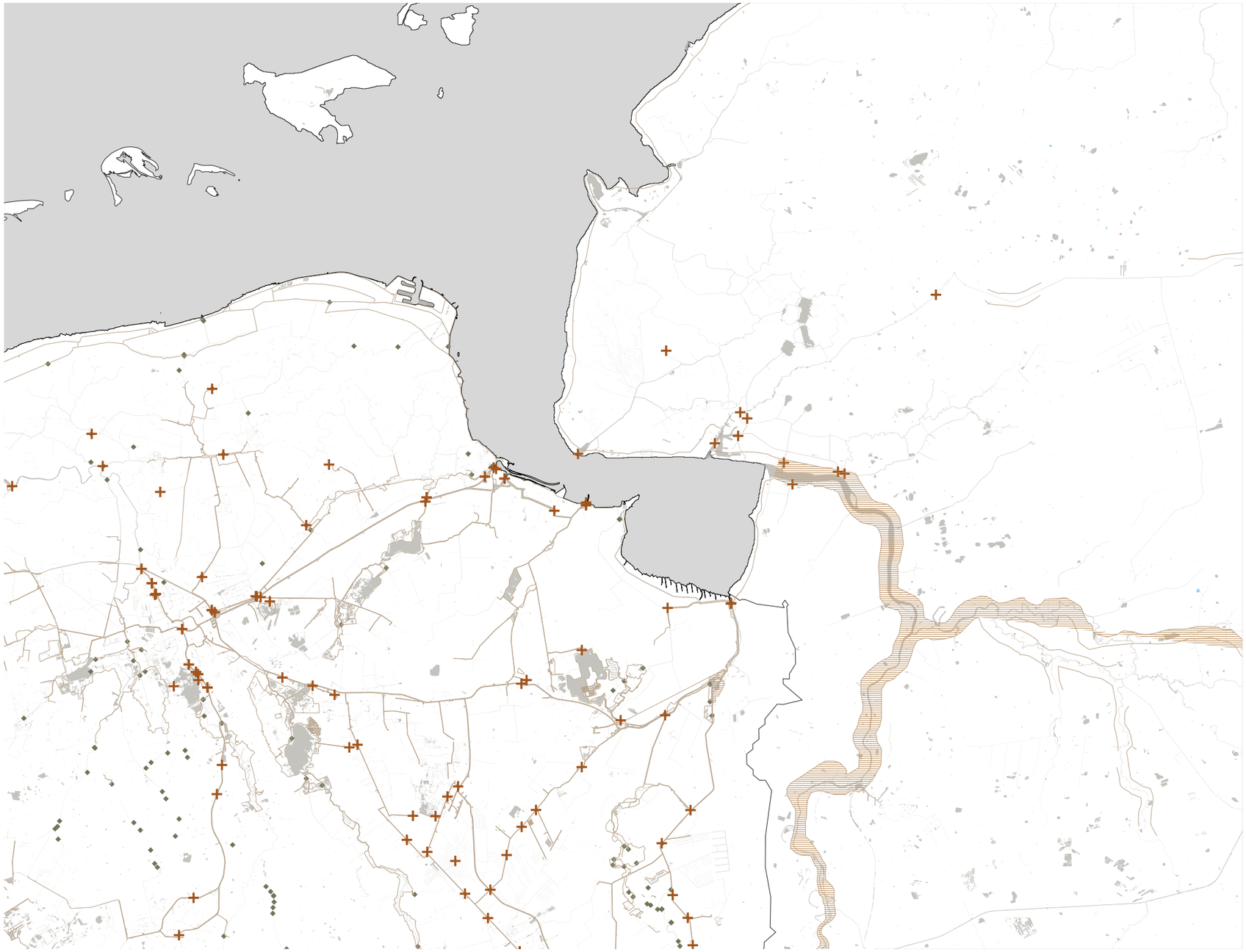
Ecology and Species Status

Data: Wadden sea quality report, 2022.



Water Barrier

Data: geoportaal.provinciegroningen.nl, pdok.nl, 2022



The major rivers in the Dutch Wadden sea, such as the Eems, and the smaller rivers like the Lauwers, Reitdiep, and Drentsche Aa, are managed and regulated by Dutch authorities

The Ems is very important for fish as the last natural river in the Netherlands. It provides a unique habitat for a diverse range of fish species, and it supports various ecologically valuable fish populations, including migratory species, such as salmon and sea trout, which rely on the river for spawning and completing their life cycles.

Under strict water level management, many gates and management facilities are needed to ensure the migration of fish.

The Punt van Reide is important for birds and seals to breed
Photo: sealsanctuary.sealifetrust.org, 2019

Birds on the Mudflat
Photo: Floris Boogaard, 2021

Design by Mud

According to the research, the Wadden Sea landscape is facing multiple challenges, and a large amount of sludge is dug up from various ports and channels and distributed in the Wadden Sea every year. Neither economically nor environmentally sustainable, the Wadden Sea system has no shortage of silt. This chapter is dedicated to using the research content of the previous chapter to answer research questions through practical design strategies and spatial layouts. Through the drawing of scenarios, the future scenarios of 2025, 2050, and 2070 are conceived as the basis for design.

For this study, the design purpose is to explore how to form a systematic and sustainable industrial chain of sludge utilization, reduce the spread of dredged sludge in the Wadden Sea, and address the challenges of water security and quality of life ((population, social items) while being A starting point for ecological improvement.By balancing flood protection, economic expenditure, agricultural production, and landscape recreation, etc., and then creating a strong pre-dynamic landscape framework against climate change.

Three design strategies are thus proposed: mud as an adaptation measure to climate change, mud as a land subsidence compensator, and mud as a socioeconomic booster. And formulate a space strategy for the three stages of 2025, 2050, and 2070.

In terms of climate change, the existing dikes are partially strengthened by dredging mud, forming strong protection for the inland areas. At the same time, the setting of gates and the submergence of some areas bring more flexibility and dynamic changes, which in turn allow more mud to be deposited on the shore.

In terms of socio-economy, tap the potential of the existing historical dykes and form a cost-effective double dyke system through the setting of gates, thereby allowing industrial transformation, making the Dollard area have the conditions and possibilities to introduce new energy and aquaculture. Pollution from industrial areas on the site will also be decontaminated by phyto-decontamination and biomass energy, which is based on existing projects such as the further development and design of the landfill project at Wybelsumer Polder.

In terms of culture, it emphasizes the status of historical heritage. Through the proposal of cultural routes, it guides tourists and residents to commemorate the terps that disappeared under the mud during the mudflat walk in the dollar area. For residents, it stimulates the sense of place, and for tourists, to deepen the impression of local characteristics.

The design process is continuous. In the short term, through route design, the role of mud will be introduced into the public's field of vision, and more attention will be paid to the changes in plants throughout the year, the fluctuation of tides, and the experience of tourists. In the long run, it is more hoped to play the role of nature and use the power of nature to deposit mud to form wetlands and improve the ecological environment.

Scenarios

Flood risk, soil subsidence
Data: Esri Netherlands Content

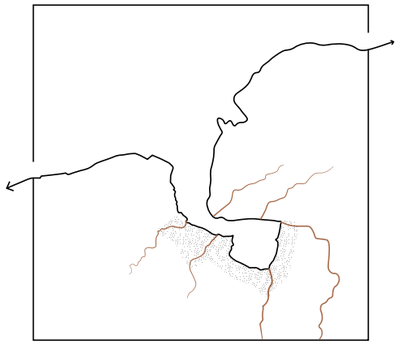
Three future landscape scenarios were envisioned: 2023, 2050, and 2070, assuming no intervention. Soil subsidence, extracted from the climate impact atlas by Esri Netherlands Content, showed a range between more serious maximum predictions and more optimistic minimum predictions. Inevitably, subsidence poses a challenge to agricultural production, necessitating transformation.

The research indicates that dikes hinder mud deposition on the land. Removing them might alleviate the subsidence crisis, but the Digital Elevation Model reveals a significant proportion of the area below sea level. With few exceptions, most areas, apart from some highlands in Germany, face the fate of being submerged.

Continuing dike maintenance exposes the dikes to bursting due to rising sea levels and flood pressure. The Atlas Living Environment in Groningen Province indicates that, in case of a dike breach, water levels could reach a depth of five meters, concentrated between Groningen and Delfzijl, with minimal areas below 0.5 meters.

In summary, regardless of the scenario, a crisis looms that we desperately wish to avoid. This underscores the crucial role of dikes in ensuring water security. The Ems-Dollard area takes the lead in inland flood control. The design strategy should prioritize mud deposition promotion, ecological restoration, and maintaining the embankment's flood control function.

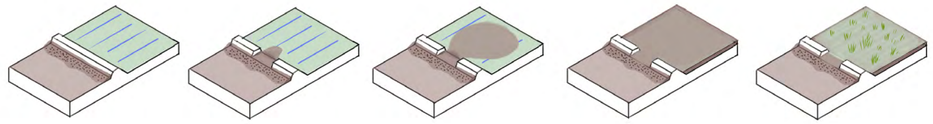
Strategies



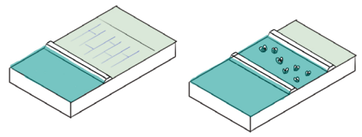
Mud as climate adaptation
Subsidence compensation

Mud as Socio-economy booster
Recreation, city-terp-mud hiking, biomass.

Mud as Ecology enhancement
Mud accumulation as mussel bed, bird mound, salt marsh



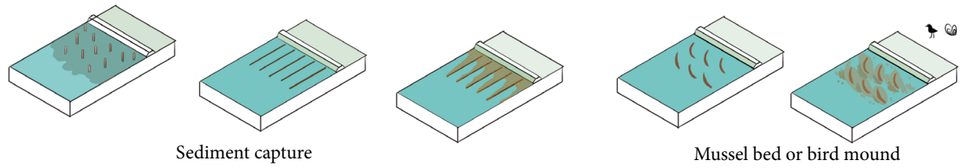
Subsidence mitigation



Double dike and aquaculture

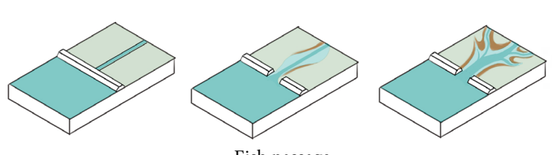
Recreation & Handicrafts

Biomass

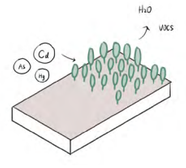


Sediment capture

Mussel bed or bird mound



Fish passage



Phytoremediation

Strategies

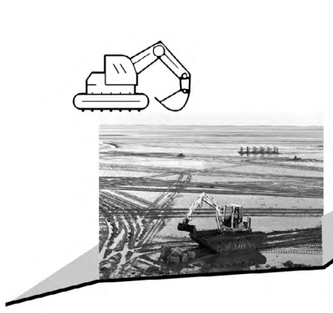
The first strategy is mud as an adaptation measure to climate change, mainly to deal with flood crisis and soil subsidence. In this strategy, mud plays the role of embankment stabilizer and material to compensate for land subsidence. The Kleirijperij project is a trial near Delfzijl, the clay ripening plant was officially commissioned. In the 14-hectare facility, dredging sludge from the Eems-Dollard and the port of Delfzijl is collected and dried. In the design, the area of this test site is expanded, and mud will also be deposited in the Dollard Bay area, but it will not be transported through artificial pipelines, but will be deposited naturally through the force of tides. In addition, the old dams will be used to form a double dam system as a multiple guarantee measure for water safety.

The second strategy is mud as an ecological enhancement. On the basis of ensuring safety in strategy one, capture as much sediment as possible, purify the soil, provide habitat for local birds, provide migration channels for fish, and enhance the resilience and dynamics of coastal areas. After four centuries of casting dikes and land reclamation, the compression of the intertidal zone, the loss of local resilience due to strict water management measures, and the contamination of the soil by the industrial development of factories and docks, It is urgent to re-emphasize ecology. Therefore, in industrial areas, plants are used to purify the soil to prevent further pollution; in polder areas, through the activation of the double dike system and the setting of gates on the main dikes, the dikes are opened in non-storm surge seasons to allow tides to enter, bringing various microorganisms and Sediments, which can naturally create more bird habitat, allow fish to connect with the outside world. Given enough time, the area between the double dikes will form a wetland, which will be a dynamic system, capable of carrying greater dynamics of environmental change.

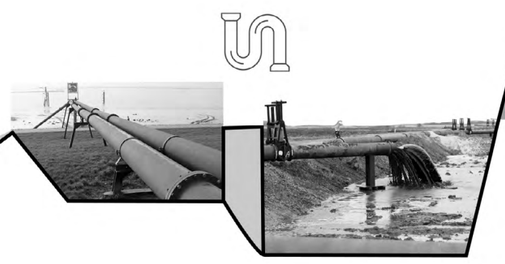
The third strategy is Mud as Socio-economy booster. On the basis of the first two strategies, further enhance the local economic and cultural development, mainly explore the role of mud in energy and landscape experience, and form a mud industry. At present, the clay maturation project in Delfzijl is only drying the soil, and has other potentials, which can be combined with nearby plant purification, biomass energy and other projects. By introducing projects such as biomass energy, biopile, land farming, and phytomediation in industrial areas, connect the nearby fragmented green land and form a mud-based multi-functional zone for sustainable development. At the same time, aquaculture and algae cultivation are introduced in the area between the double dikes, taking into account economic benefits, energy output and sewage purification. In terms of experience, guide tourists and residents to perceive the different states and textures of the mud through route guidance and art installations, appreciate the historical buildings and monuments along the road, remember the terps buried under the mud during the mudflat walk, and deepen the local characteristics and identity.

Mud Industry

There is the potential for a complete mud industry on the Ems-Dollart coast. The location makes it easy for dredgers to dump in close proximity, and there are also already established mud pipelines and mud drying test sites, as well as disused brickyard buildings that have been preserved. It is also a place where mud is in high demand, where clay is preferred to the more environmentally friendly and cost-effective asphalt for reinforcing levees, where mud is needed to offset subsidence and salinization in extensive polder areas, and where artificial reef blocks are needed to protect and enhance marine life habitat.



Decades ago, engineers had begun dredging parts of the Ems River so that new boats could be navigated upstream from the shipyard.



The Kleirijperij is a trial near Delfzijl, the clay ripening plant was officially commissioned. In the 14-hectare facility, dredging sludge from the Eems-Dollard and the port of Delfzijl is collected and dried.

Brickworks at risk of dismantling.
The ruins of the former brickworks Rusthoven is the only remaining brickworks with ring furnace in the province of Groningen, forming a beautiful piece of cultural-historical heritage in Groningen.

In-situ stacking for park construction

3 years waiting for maturity

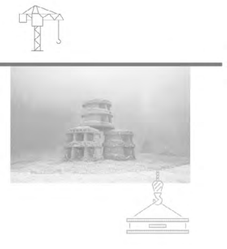
Crop cultivation

Dikes need extra reinforcement

Pottery

Brick Industry

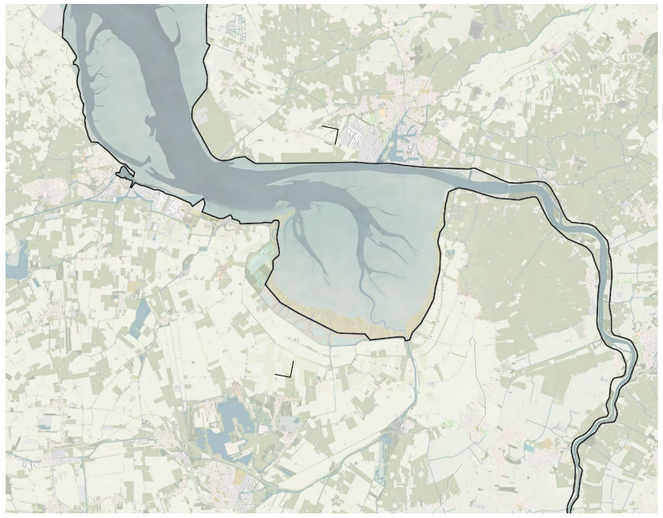
The large hall, brick oven and drying rooms are still there and intact.



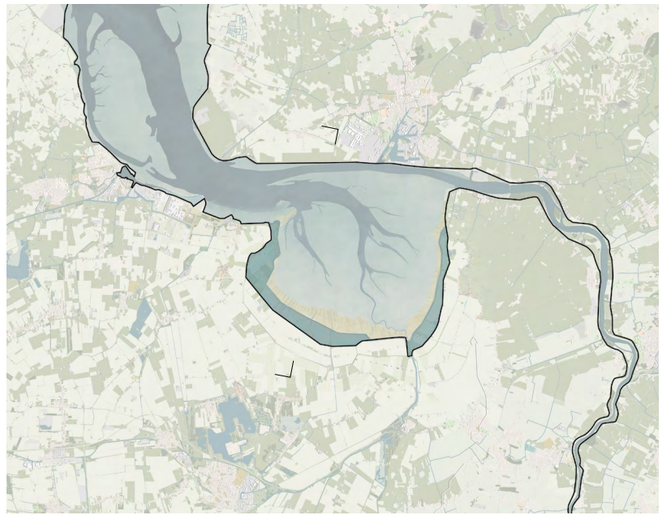
Reef Block

Time Process

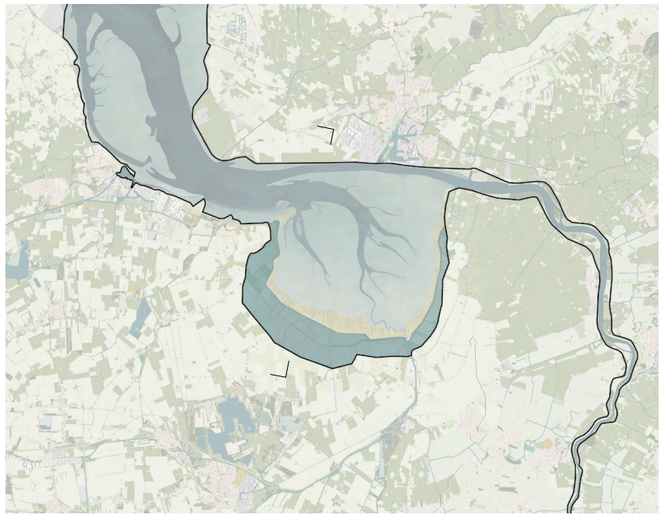
2025

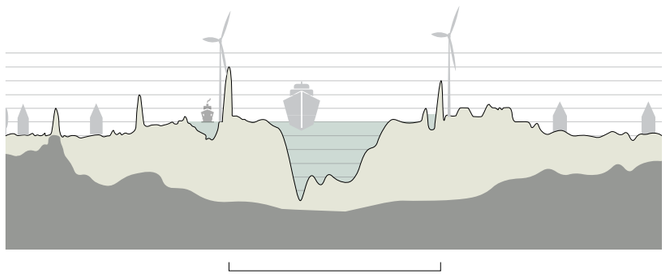


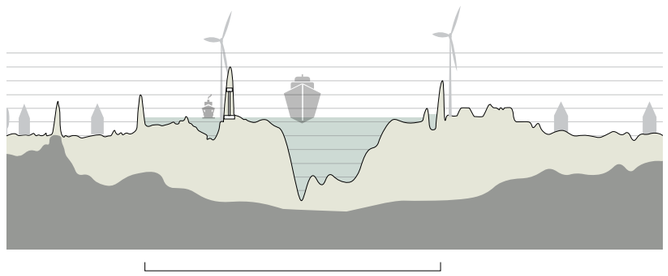
2035

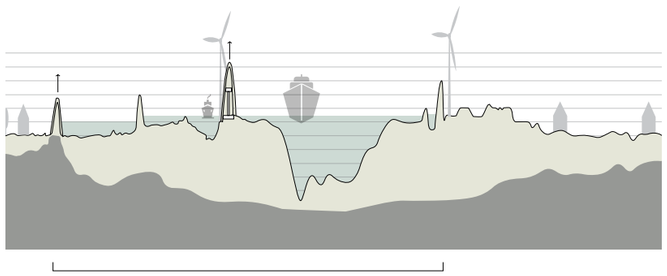


2050









0 2km 4km 10km

N

Floodable areas
Saltmarsh
Nature reserve

The design is divided into three phases:

Within the short term, i.e. the last two years, the main focus is on tour routes planning and small nodes 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 the inland areas from the threat of flooding during this period.

Within twenty years, preparations are made on a larger scale for the installation of gates, partial reinforcement of the dykes, reuse of the old dikes, some relocation of farm buildings and industrial transformation from crop cultivation to aquaculture to improve economic efficiency at the same time, 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, thus creating a new mound, attracting birds and planting the appropriate vegetation, so that the area will gradually become a wetland.


0
2km
4km
10km
N
Existing terps
Historical buildings
Disappeared terps
Monastery sites
Monuments
Transport
The energy journey
The ecological journey
The cultural journey
Mudflat
Saltmarsh
Grassland
Farmland

Masterplan 2035

Masterplan 2050

Node 1

Node 2

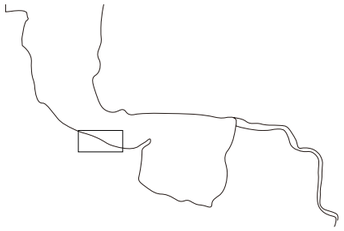
Node 3

0 2km 4km 10km

N

Mudflat
Saltmarsh
Grassland
Farmland

Energy & Ecology Routing



0 200m 500m 1km

N

Existing terps
Solar panels
Biomass park
Recreation node
Transport

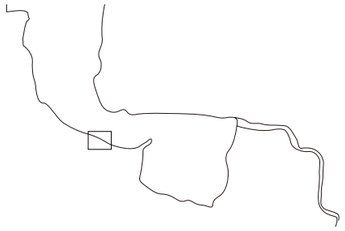
The energy journey
Waterways
Ems river
Mudflat
Grassland
Farmland

Design Node 1

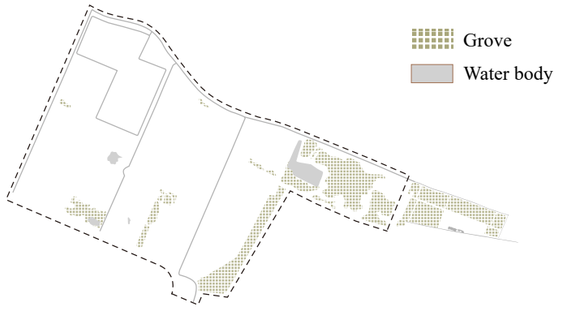
The first design node is part of the Energy Journey. The site is located on the south-eastern side of Delftzell and is bordered to the west by EEW Energy from Waste Delfzijl BV and Reym Delfzijl, both of which are mainly waste management services. To the east of the site is a small park and some fragmented green areas. The area at Oterdum is divided into 15 compartments. In each basin, the sludge is dried in a different way. compartments, sun and wind have to provide dewatering, while in others drainage or the plant samphire ensure that the water disappears from the sludge" (Jan 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, the waste treatment function, with the introduction of biomass planting and plant purification through biopile and landfarming, which can both help to treat the contaminated soil and connect the fragmented woods to create as much of a green corridor as possible, while also increasing opportunities for recreation.

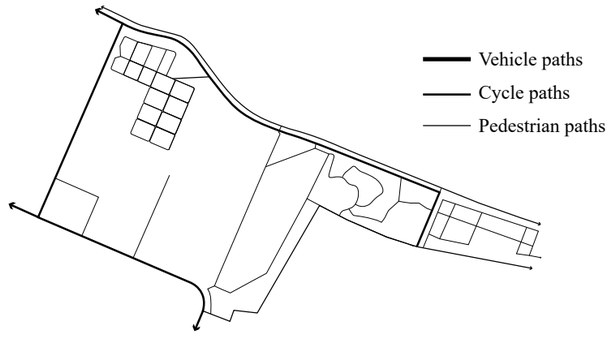
Satellite image of design node 1
Data: Google earth pro, 2023



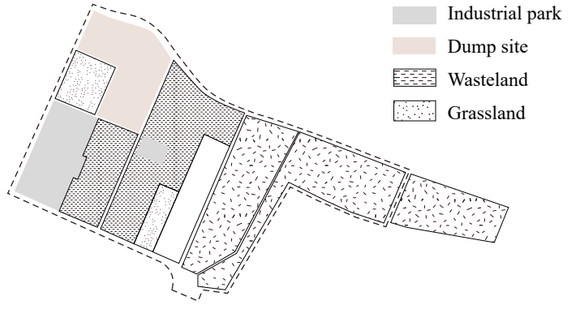
Green Corridor



Connection



Land Use



Phytoremediation & 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)

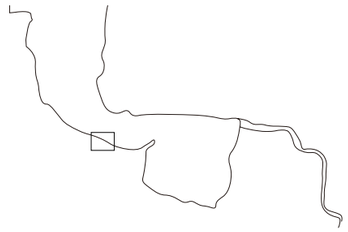

Elephant Grass
(Pennisetum purpureum)


Miscanthus
(Miscanthus spp.)

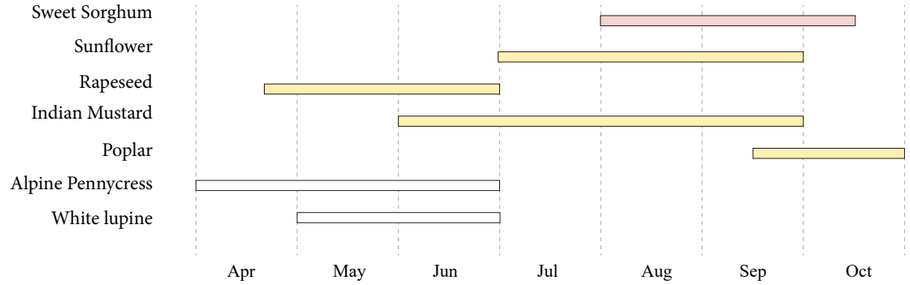

Silvergrass
(Miscanthus sinensis)


Giant Reed
(Arundo donax)

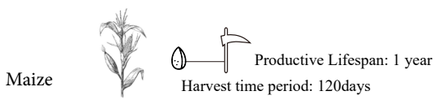

Sweet Sorghum
(Sorghum bicolor)

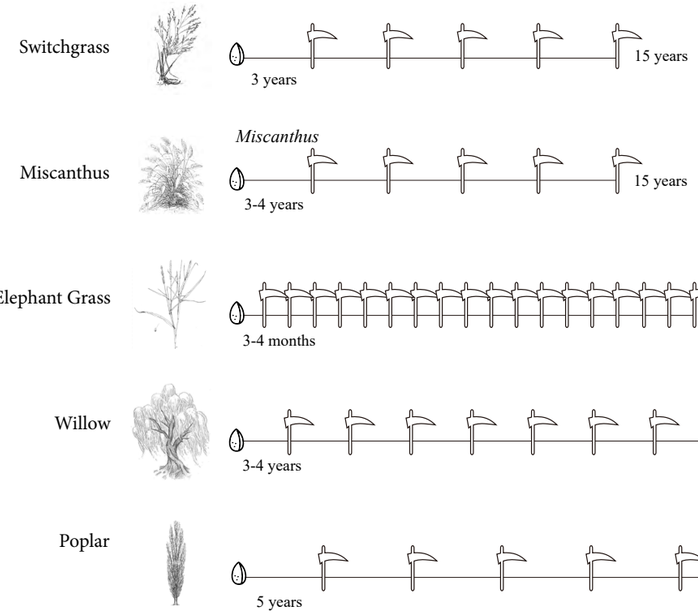


Flowering period & flower colour

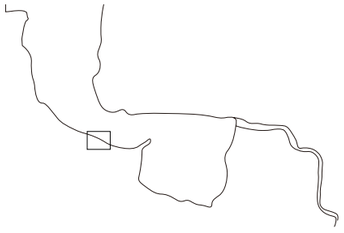


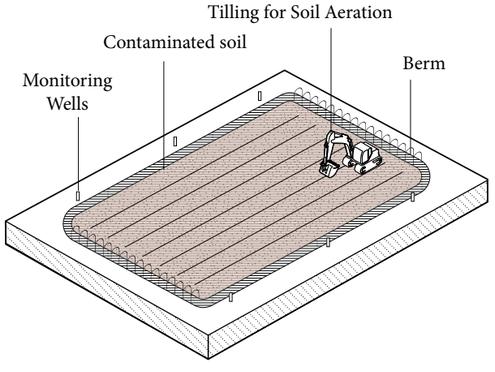
Productive Lifespan & Harvest period



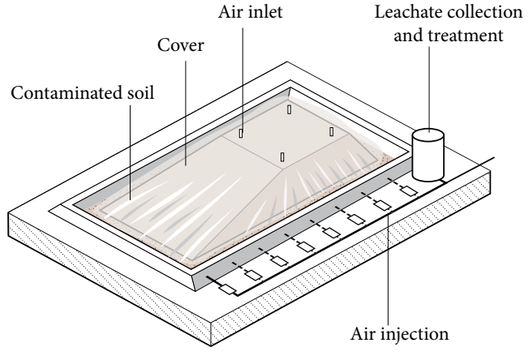


Design Node 1

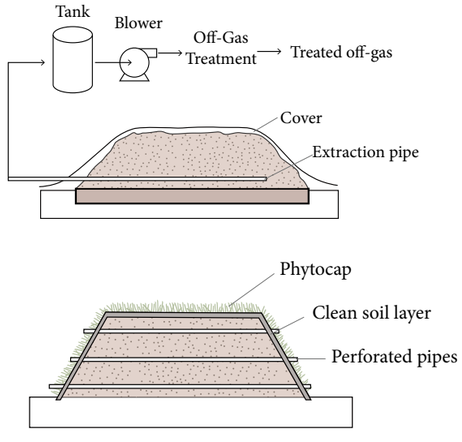




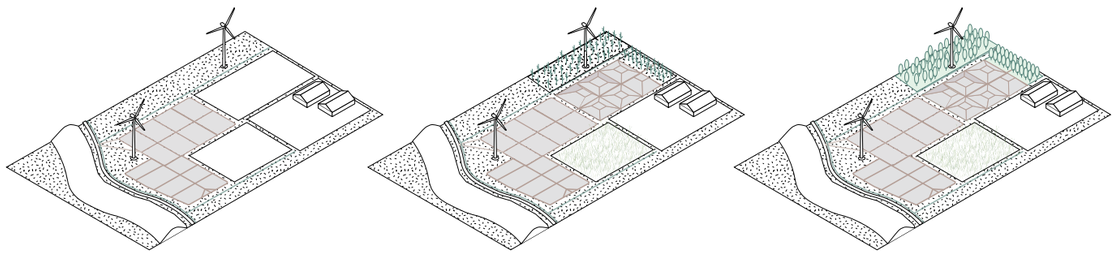
Land Farming



Biopile



Biopile



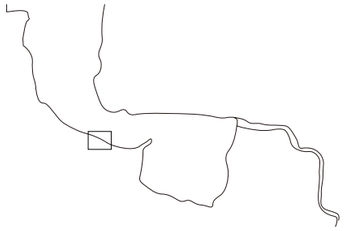
Process

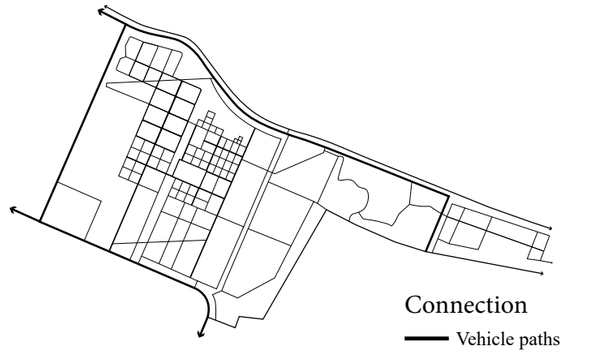
The soil purification methods chosen for treating the land around the Delfzijl chemical plant include biopile, landfarming, and phytoremediation. Biopiles involve excavating contaminated soil, mixing it with suitable soil amendments, and forming a heap on a prepared surface. Forced aeration is used to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

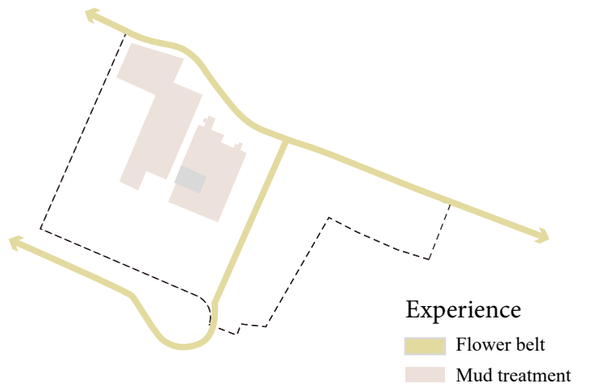
Combining these techniques with the landscape design allows for the creation of unique spaces. The diamond-shaped mound of the biopile itself can shape different spatial experiences, and the surface mulch can be artistically manipulated. Additionally, these methods will be integrated with the existing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

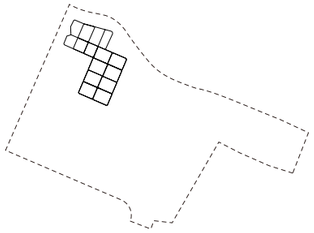
By employing these approaches, the project aims to reduce the costs associated with soil purification and transport. Furthermore, the use of biomass can provide additional economic benefits. Overall, the combination of biopile, landfarming, and phytoremediation techniques offers an efficient and environmentally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

Design Node 1







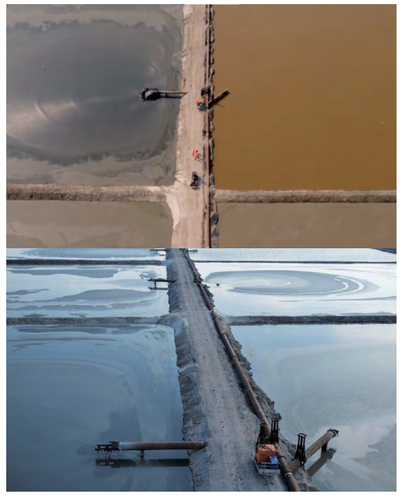


Design Node 1

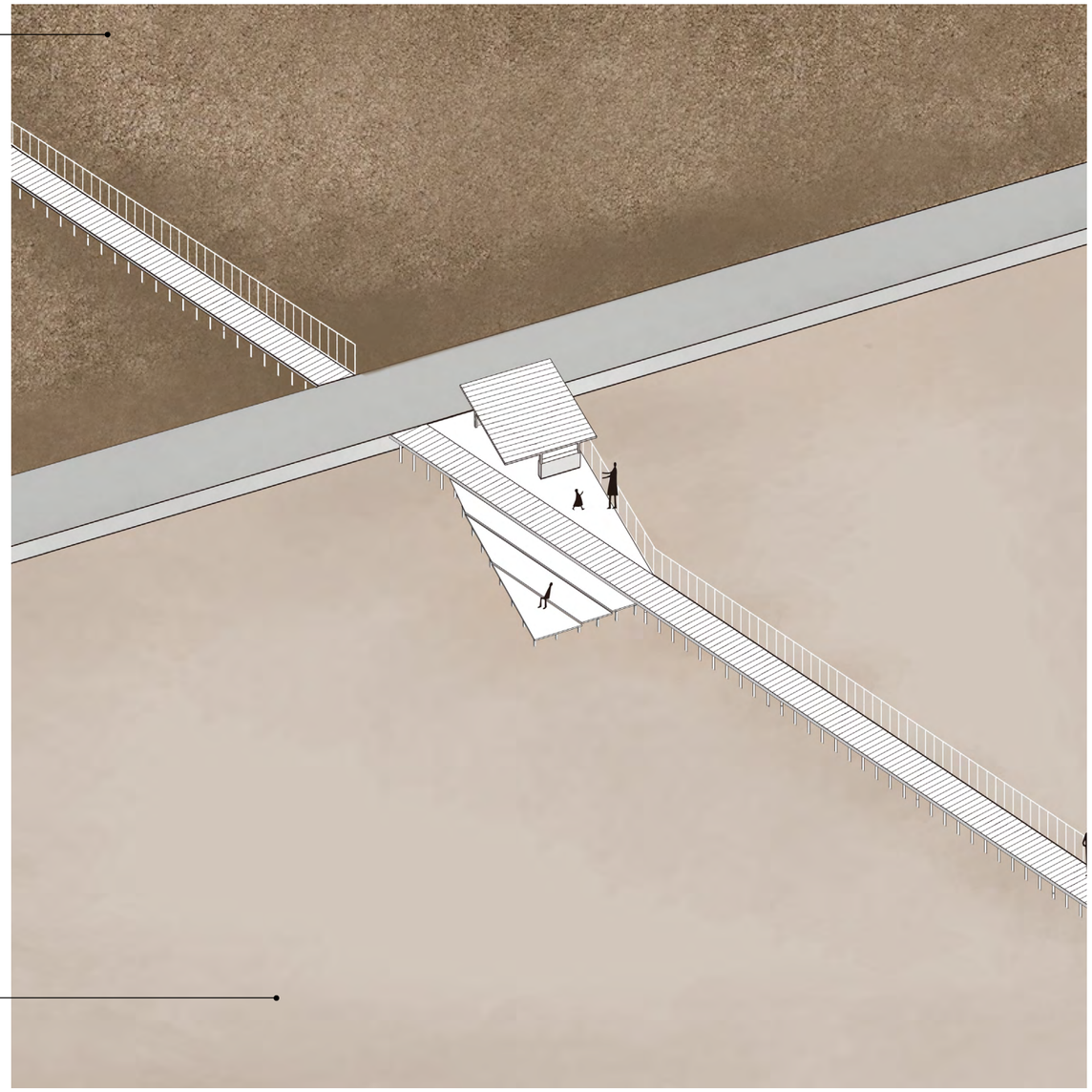
The experimental field for mud maturation on the Groningen coast is a large container of waste from the dredged material of the shipping channel and also excavates silt from the Breebaart polder. The channels to Delfzijl and Emshaven have to be kept at a certain depth for large ships. In the basin along the dike between Delfzijl and Eemshaven, water sinks from the spoil, leaving behind materials such as clay, which would account for around 30% of the total quantity. The dredged material is suitable for use as construction material for the dykes, saving money as it is no longer necessary to import expensive clay from abroad to reinforce the Groningen dykes, and making the Eems-Dollard cleaner as 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.("Kleirijperij Toverwoord Voor Sterke Groningse Dijken," 2015)

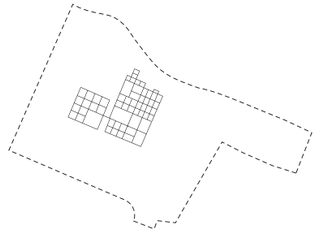
In this large mud drying field, the mud dries in each pool in a different way. In one section, sunlight and wind are responsible for dewatering, while in another section the drainage or sea poncho plants ensure that water disappears from the sludge. Based on these conditions, I have added a recreational route (a wooden walkway) and recreational nodes (a small pavilion and resting platform) so that the area is no longer an industrial area in the eyes of visitors and residents, but a place that can be entered and experienced in person, where the mud dries differently in the different pools, thus providing different 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, so construction is infrequent and the area is not closed for long periods of time each year, leaving the rest of the year for residents and visitors to experience.

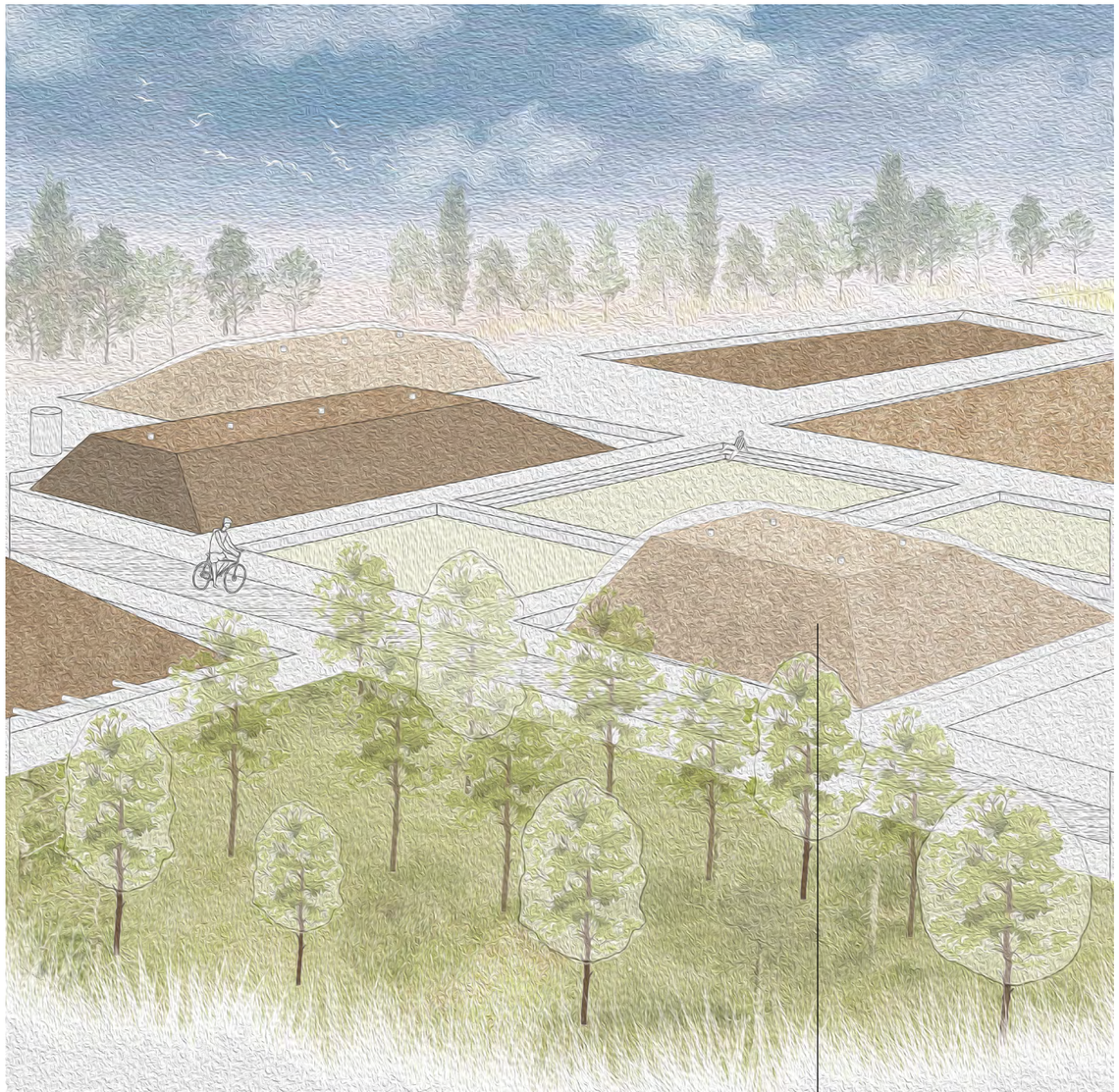


The Kleirijperij site of Delfzijl just after deposition
Photo: Luca Sittoni, 2019





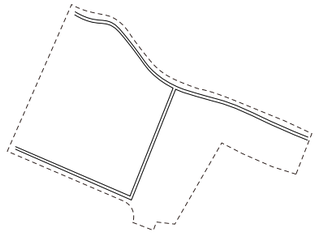
Design Node 1



Willow
(Salix spp.)

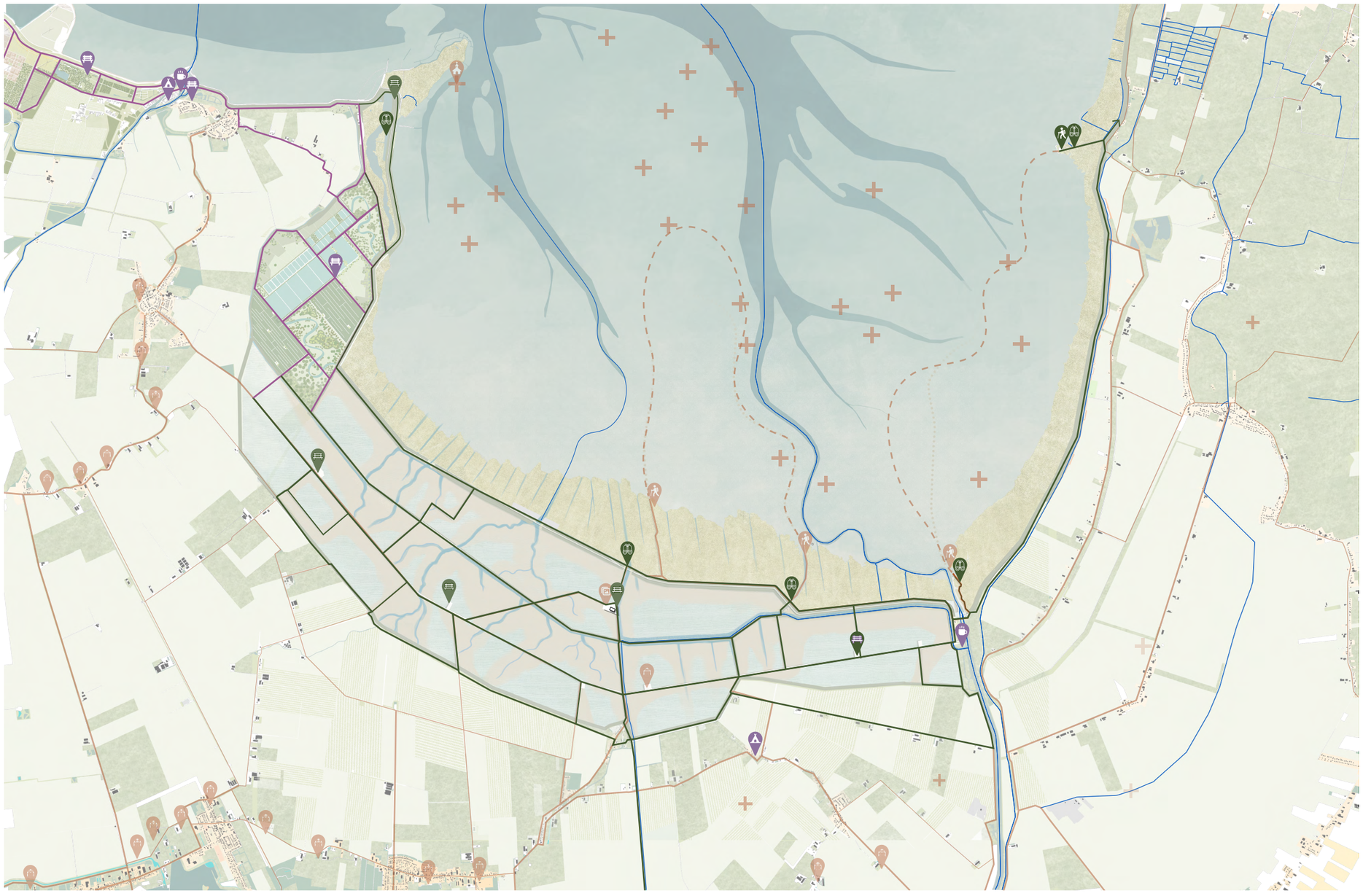
Poplar
(Populus spp.)

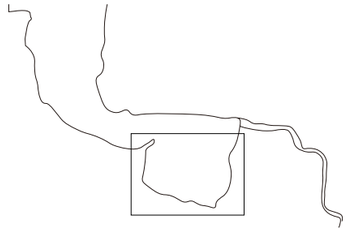
Bulrush
(Typha orientalis)



Design Node 1

Ecology & Cultural Routing





The history of mankind battling floods and the game between land and sea & river in this area makes for a very rich cultural resource. Not only are there many layers of dykes, 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, as parts of the area were once submerged, although reclaimed by man after the first three centuries and turned back into the land. At the same time, during the long process of reclamation, layer after layer of dykes were built, some of which are no longer visible today, but the closer you get to the sea, the newer, better preserved and stronger they become. The ecological challenge is severe in the face of overly turbid water, salinisation and land subsidence, as well as the degradation of salt marshes and rising sea levels. This area will therefore be used as a test area for ecological landscapes, creating a tidal polder by activating the old dykes in an attempt to bring in the forces of nature to shape new resilient landscapes that provide habitats for the various species of life 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 of one has a completely different history. Eventually, people can follow the Cultural Trail over the dyke, 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, symbolising the twelfth century terp and village (and even a monastery) that existed here and are now buried under the mud

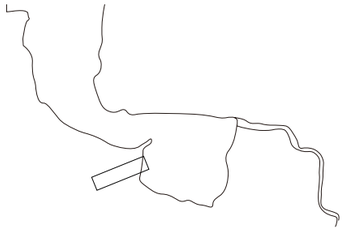
0 500m 1km

3km

N

Culture monuments
Recreation nodes
Buried villages

Old terps
Culture routes
Mud hiking
Ecology routes



Culture Routing

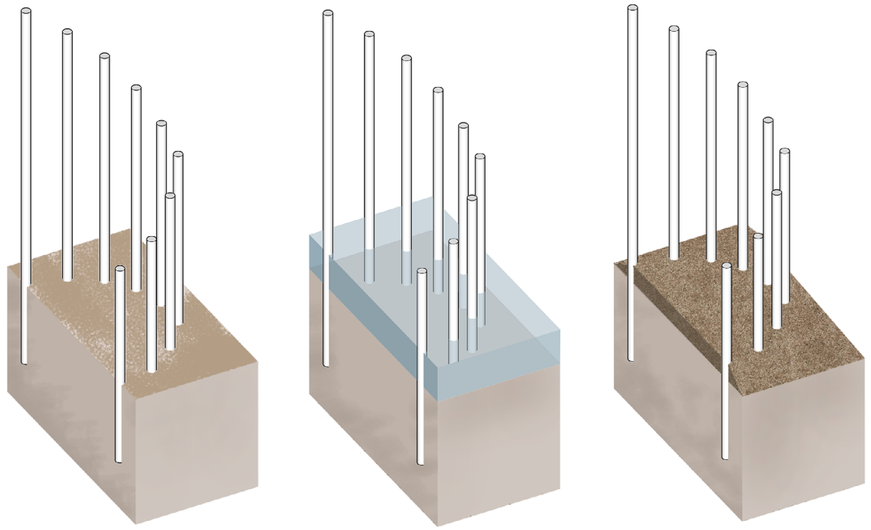
Historic buildings and historical monuments
Data: Google Earth Pro; nazatendevries.nl

0 500m 1km 2km N

Old Terp
Church
Monumental Farmhouse
Monumental Mansion
Culture Routing
Grassland
Farmland

Culture Routing

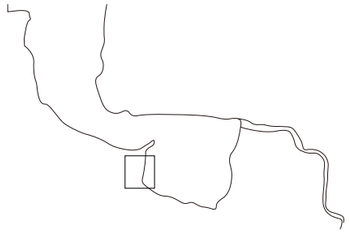
There are already many art installations and landmarks along the Wadden Sea and on the islands, such as lighthouses, bird-watching houses, sculptures, etc. In the mudflats, though, there are also structures that are either shelter huts or navigation signs. At the end of the cultural tour, in the same place as the terp, which was buried under the mudflats, several very simple art installations were added to remind people of what had happened here and also to serve as a collection of mud.



When it was first built

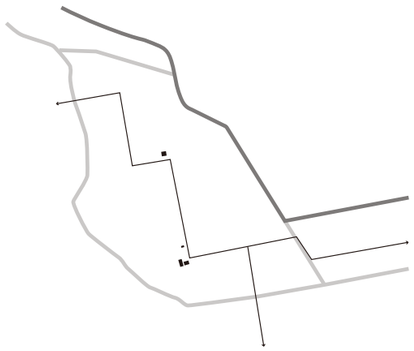
At high tide, the tide brings sediment

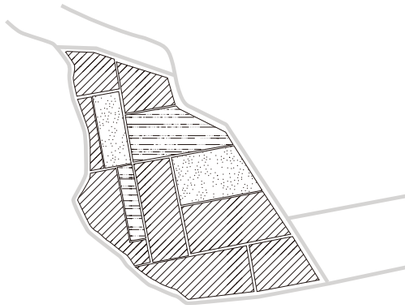
A year later, more sediment around the pillar

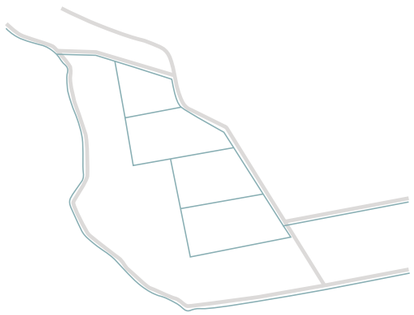


Design Node 2 : Aquaculture

Satellite image of design node 2
Data: Google earth pro, 2023







Connection
- Building
- Road
- Old dike- 4m
- Main dike- 8m

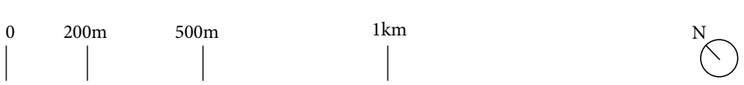
Farmland Pattern
- Potato
- Sugarbeet
- Wheat

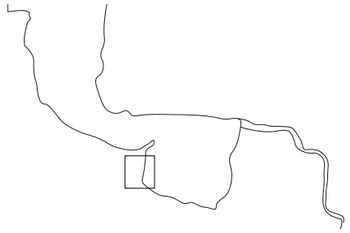
Water
- Ditches

Design node 2 is located between a new 8m embankment and an old 4m high embankment and contains two farmhouses where the main industry is now the cultivation of potatoes and sugar beets. The design aims to explore the feasibility of industrial transformation and aquaculture.
In the north of Delftzell, a pilot project for a double dike is already underway: in 2019, an additional dike is being built behind the existing seawall in Hoogwatum, with a second dike preventing further inland flow of seawater during floods. (Ontwikkeling Dubbele Dijk, n.d.)

This is an innovative experiment, but the cost of the new dykes is very high. In contrast to the twin dykes at Hoogwatum, the historical dykes in this area deserve to be reused.

Under the protection of the double dike, culverts and gates will be added to the new dike and the area in the middle of the dike will be divided into two wetlands and an aquaculture industry in between. The river water will flow from the culverts into the area, be purified in the wetlands and then supplied for fish and shellfish farming; the effluent from the farming will flow into the algae ponds to generate energy and finally flow again into the wetlands, where it will be purified and discharged back into the Ems River.





Design Node 2 : Aquaculture

Algae farming or algal biofuel is an alternative to fossil fuel that uses algae as its source. Harvested algae, like fossil fuel, release CO2 when burnt but unlike fossil fuel the CO2 is taken out of the atmosphere by the next generation of growing algae. (Sustainable Footprint, 2013)

The introduction of algae farming is well suited to the area. Algae need nutrients, sunlight and water to thrive in salt, brackish and waste water, which means that both brackish and fresh water are very suitable in the Ems-Dollard area. Wastewater, human, animal and plant manure, as well as carbon dioxide emissions from industrial processes, can all be used as nutrients for seaweed farming, making dirty water from fish, shrimp and shellfish farming a very suitable water for algae. After the oil has been extracted from the seaweed, the residue can be used as animal feed or as a soil fertiliser, which can be useful for the development of the surrounding polder and agriculture.

Besides algae farming, the cultivation and harvesting of shellfish provide a sustainable source of income for farmers and fishermen. It can also stimulate tourism and create jobs related to shellfish processing, distribution, and culinary experiences. Local residents and visitors can participate in activities such as guided tours, educational programs, marketing, and hands-on experiences related to shellfish farming. What's more, shellfish, particularly oysters, have the capacity to sequester carbon dioxide (CO2) and mitigate the effects of climate change.

And by cultivating fish, such as salmon, trout, or tilapia, the project can ensure a steady supply of fresh and nutritious seafood to meet the demands of the local population.

Oyster
(Oysters)

Mussel
(Pteriomorphia)

Clams
(Schelpdieren)

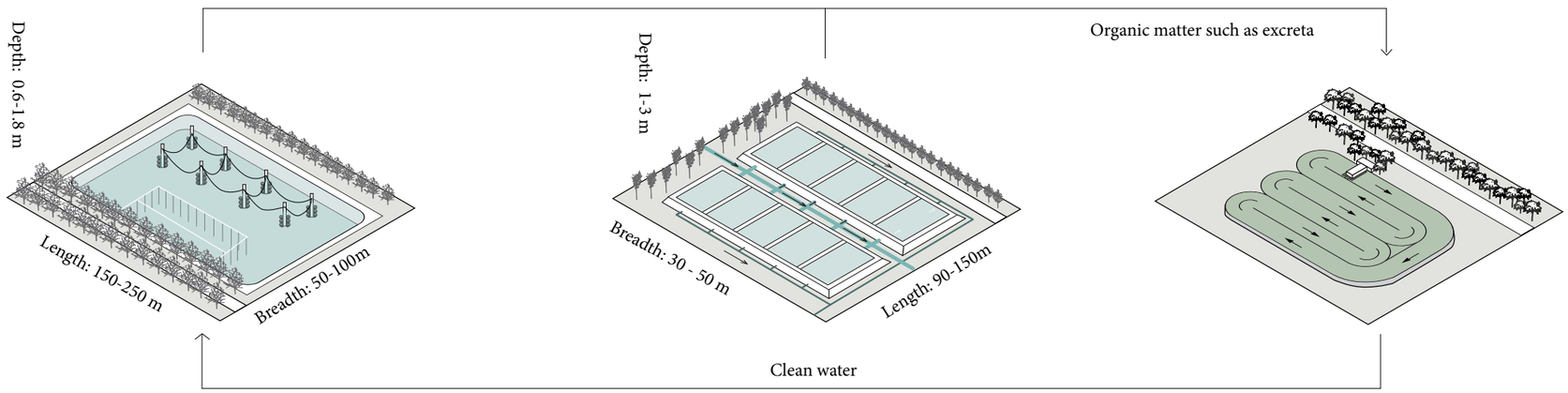
European Sea Bass
(Dicentrarchus labrax)

Gilthead Sea Bream
(Sparus aurata)

Rainbow Trout
(Oncorhynchus mykiss)

Chlorella
(Chlorella sp.)

Spirulina (Arthrospira sp.)

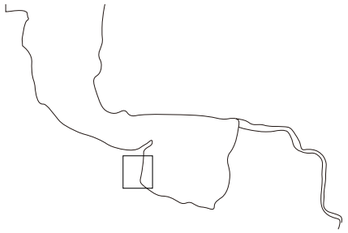


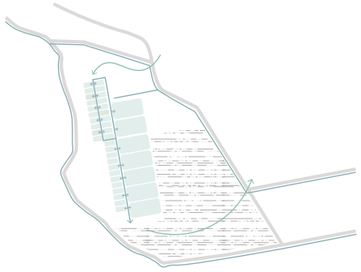
Shellfish farming

Fish farming

Algae farming

Design Node 2 : Aquaculture





Water flow

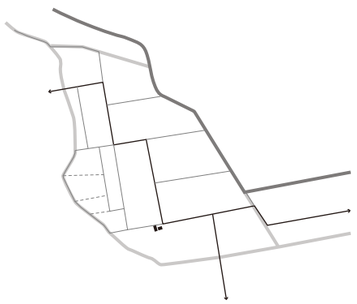
Clean water

Water direction

Water flow

Filthy water

Water direction



Connection

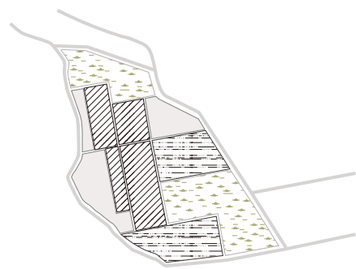
Building

Main Road

Old dike- 4m

Main dike- 8m

Stepping stone



Function

Energy+Purification

Production

Recreation

Purification

0 200m 500m 1km

N

Algea farming

Fish farming

Shellfish farming

Dikes

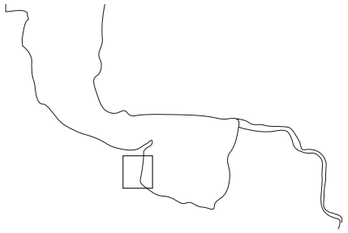
Saltmarsh

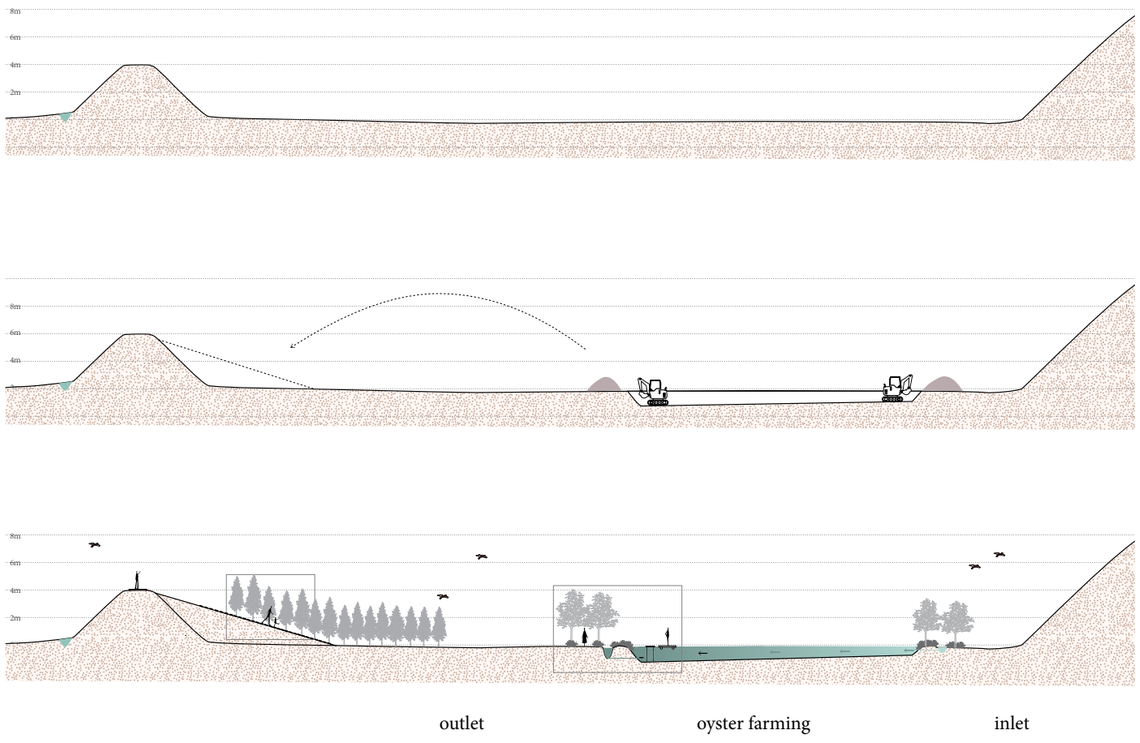
Farmland

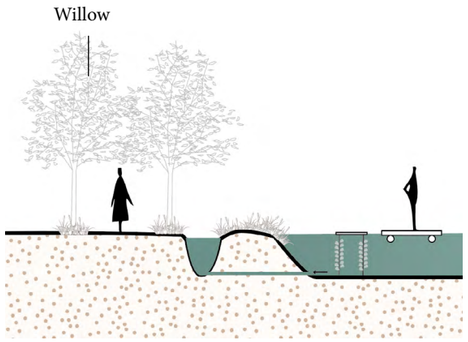
Grassland

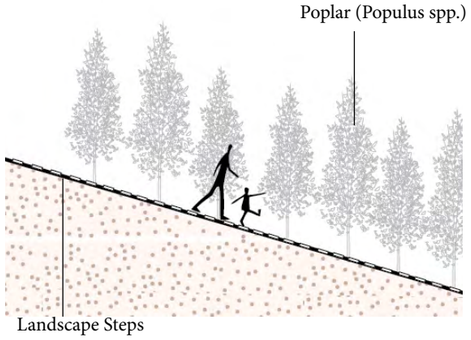
Wetland

Design Node 2 : Aquaculture









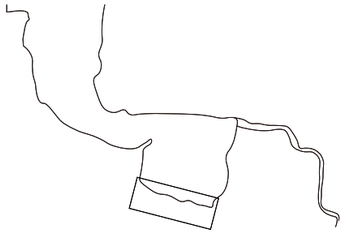
Algae farms, fish farming and shellfish farming all need flat land, preferably with a slight slope, as the water must flow so that it can be moved downwards by gravity. When the water reaches the bottom of the farm, it can be pumped back to the top using energy-saving pumping techniques. Like rice, the fields are flooded.

This site is very flat with very little difference in elevation and therefore requires mud transfer during the construction process. The mud from the excavation of the fish pond can be used on both sides of the dyke, not only to reinforce it, but also to create a gentle slope that makes this area normally available for recreation. A landscaped path over the old dyke attracts and invites people to use the dyke while having a view of the aquaculture landscape between the two dykes.

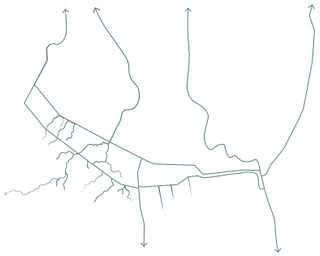
In conjunction with aquaculture and the addition of recreational facilities such as pontoons, aquaculture can be used as part of the economy, as the area outside the Ems-Dollard dyke is now a no-fishing zone, where oysters, fish and prawns are prohibited, a characteristic of the Wadden Sea, which is a reason for the difficulties in tourism. Now, through aquaculture, residents and tourists can be motivated to participate in some fishing and selling activities, which will enrich the recreational content of the area.

0 10m 40m 80m

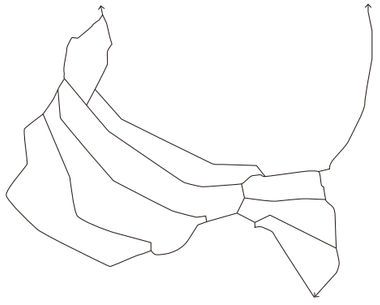
Design Node 3



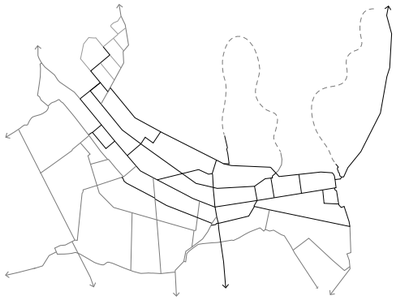
Water



Old Dike System



Connection



0 500m 1km 2km

N

Dikes
Mudflats hiking
Sedimentary area

Saltmarsh
Farmland
Grassland

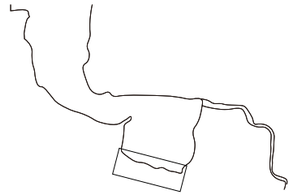
Scenarios of Node 3

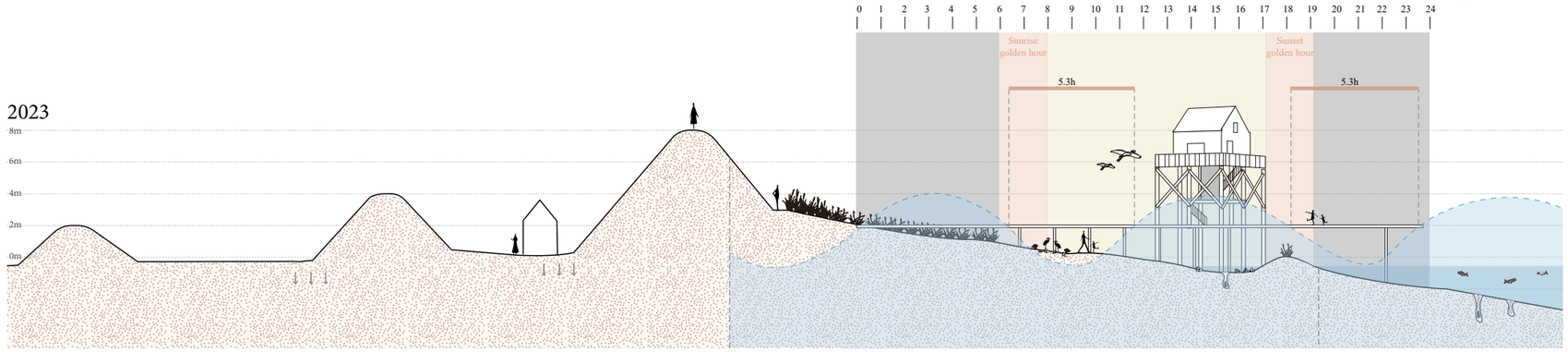
Prior to the design, a status quo analysis was carried out as well as scenario assumptions.

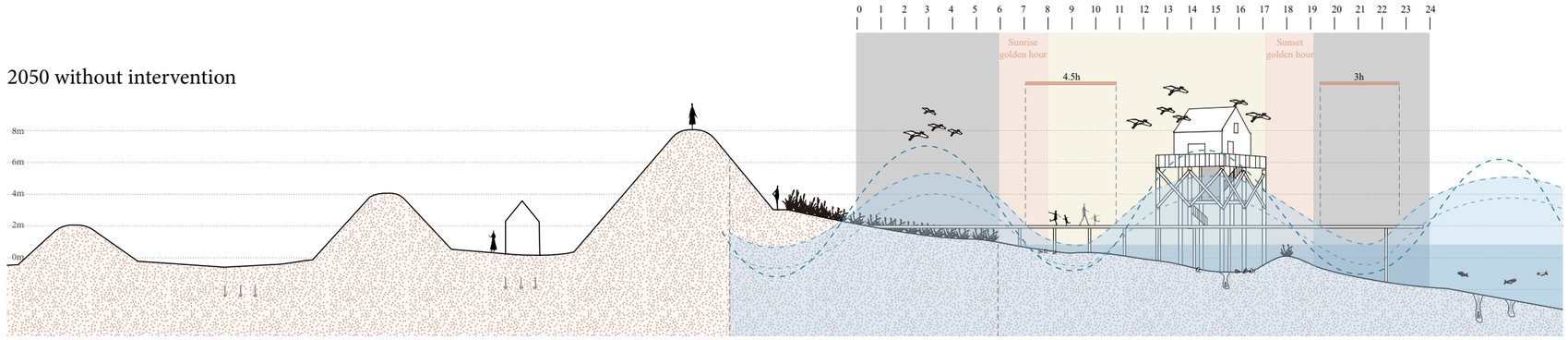
In 2023, with two high and low tides in one day, during which the intertidal mudflats are exposed, birds have habitat and feeding conditions, and people can walk on the mudflats, a wooden walkway two metres above mean sea level is used for a total of approximately 10.6 hours.

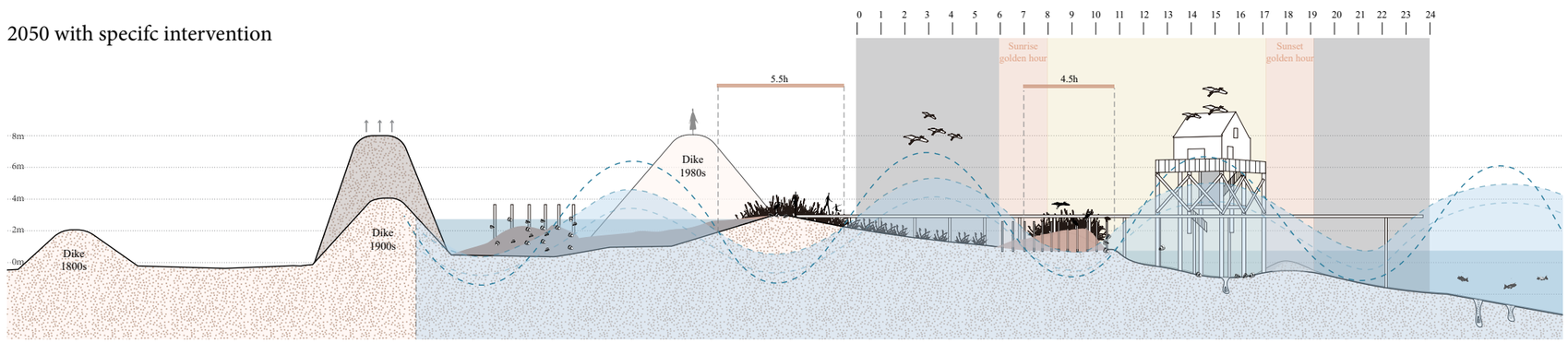
Without intervention, by 2050, assuming extreme conditions of sea level rise, daily tidal differences increase, mean water levels rise and the mudflats become less exposed, with a corresponding reduction in the length of time birds can stay and people can rest. Taking the wooden walkway mentioned above as an example, the total number of hours that people can use the walkway is approximately 7.5 hours, which is three hours shorter than before.

The intertidal zone is an important ecological area, and one of the measures 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. The disadvantage of this, however, is that the old dykes would need to be raised and reinforced significantly to become the new mainstay of flood protection, which would be very costly, and the new dykes now in use lose their function and are not fully utilised.







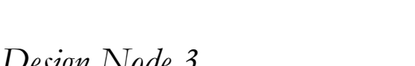


Design Node 3

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

During the non-storm surge period, 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 and suspended material is left here at low tide, forming some mounds, similar to intertidal habitats.

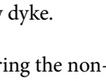
In thirty years' time, with the natural action of the mounds, the soft soil animals will attract birds, which will bring seeds, and combined with the artificial planting of reed wetland plants, this area will gradually become a wetland.



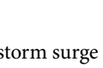
Small invertebrates

Black Rider
Tringa erythropus

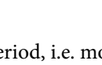
Redshank
Tringa totanus



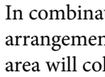
Pintail (Anas acuteostralegus)



Oystercatcher
Haematopus ostralegus



Greenleg Rider
Tringa nebularia

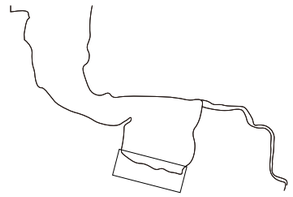


Curlew Numenius arquata

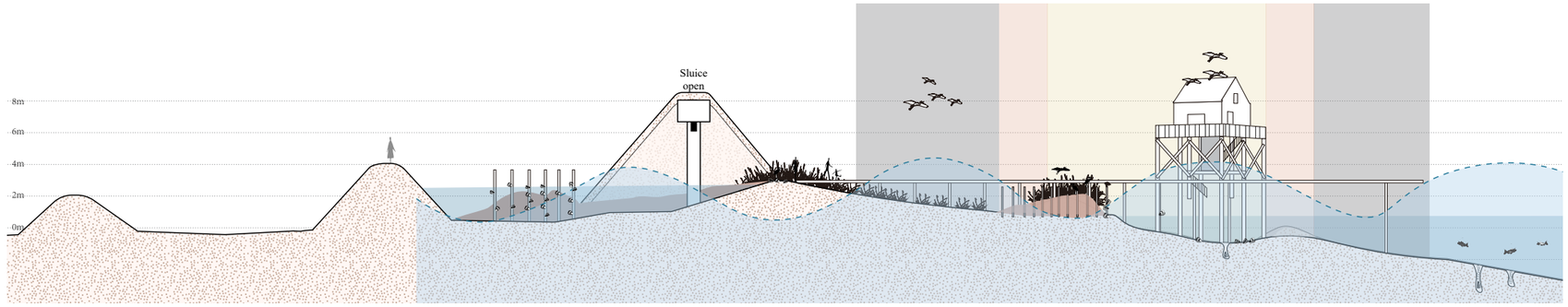
Knot Calidris canutus

Shelduck
Tadorna tadorna

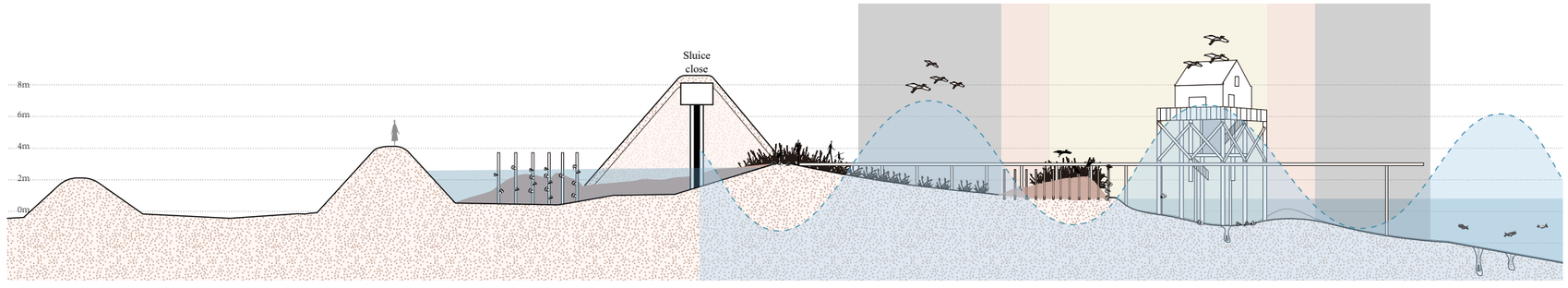
Teal
Anas crecca



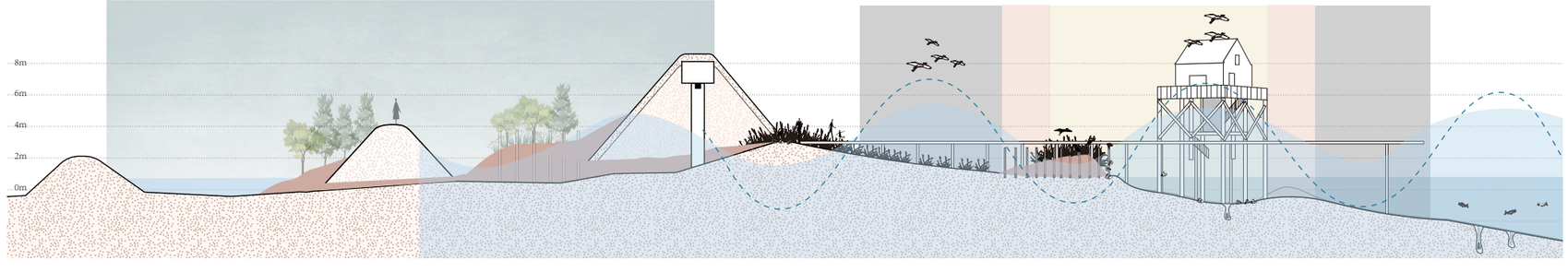
2035 Normal water level

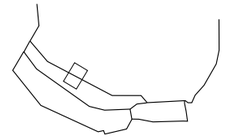


2035 Spring Tide Period



2050



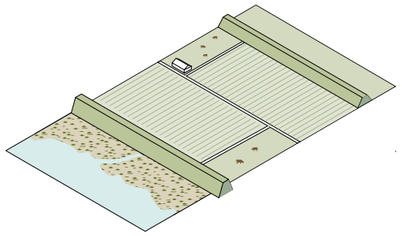


Design Node 3

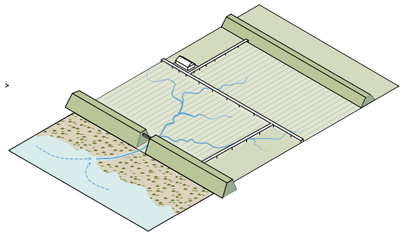
The elevated topographic map of the area shows the meandering and winding track of the river that once ran from the mouth of the Ems. Today these channels are hardly recognisable and are mixed in with the farmland, replaced by straight water channels.
As the soil structure under these disappeared channels 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 the traditional Brushwood dam can be borrowed in order to promote the deposition of suspended matter in the water. The existing paths in this area will be flooded and in designing the new paths, in addition to the wooden trestle, paths shaped like the Brushwood dam will appear as a link between the new dyke and the old one, while chamomile or daisies will be planted alongside the path, making a distinctive path that encourages people to look into history. The path will eventually be submerged in years to come, but no matter, it will still serve to collect sediment.

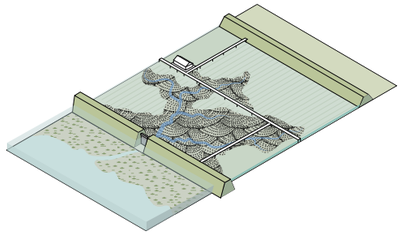
2023



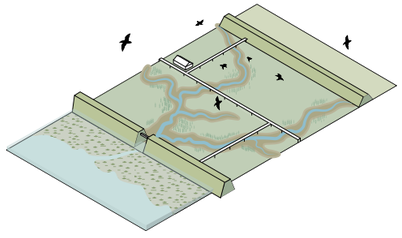
2025



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: wadgidsenweb.nl

Brede Groene Dijk : A dike made of salty dredging sludge
Photo: Elcke Vels, 2022

Ems-Dollard near Pogum
Photo: Programma Naar Een Rijke Waddenzee, 2022

Reflection

Relation between the graduation project's topic, the studio topic and the master program

My graduation project is part of the studio "Water Landscapes of Crisis and Hope" led by Laura Cipriani, which explores the crisis and hope of the Wadden Sea. My graduation project envisions "Mudscape" as a crisis response strategy for Ems-Dollard estuary.
After exploring the general crisis of the Wadden Sea, I found the Ems estuary and the mud as an initial point of entry. Then I studied the great potential of the mud, the ecology of the estuary, and so on. Therefore, I want to use the theme of mud to respond to the various aspects of the crisis, such as the extreme climate crisis, the ecological crisis caused by human activity, and the shaping of a sense of place and historical memory. The climate extremes are a crisis for the entire Wadden Sea region, the estuary ecology is an integral part of the Wadden Sea ecosystem, and the sense of place and historical memory is a cultural commonality of the Wadden land, all three of which are closely related to the theme of the studio.
My graduation project is also a response to my master's program, I applied the four perspectives I learned throughout the master's program.
Landscape-scale continuum: from territory scale to regional scale to location scale, the continuum has helped me better understand the workings and significant crises of landscape systems, switch between scales, and reflect on design.
Landscape Palimpsest and perceiving space: through learning about the history, building a landscape biography, and experiencing the site firsthand, I have become more aware of the cultural landscape of the Wadden Sea region and have been inspired by the local atmosphere, while 'mud as the shaping of the spirit of place and the preservation of historical memory' echoes this theme.
Landscape Process: The resilience and variability of the landscape echoes the landscape process, where ecological processes and maintenance will continue to occur and where people and nature are constantly interacting. Therefore, a resilient landscape in the face of crisis and an open landscape process is essential.

From entry points to design
Entry points can be small landscape elements or large landscape systems. Still, as a complete project, there is a need to explore a complete design strategy through entry points, such as economic, ecological, cultural, and other aspects of contribution.
The mud was my entry point for this project. After an initial analysis of the history and culture and the recreational activities, I concentrated mainly on the shaping and exploration of the landscape imagery, ignoring other issues present in the site, such as the loss of population and the economic downturn. In the joint workshop, Mr. Stephen pointed out that my project lacked sufficient pillars and that thinking about recreation alone was insufficient to turn the crisis into potential. This forced me to think about other possibilities for the mud. With Laura's help, the potential of mud in terms of energy was eventually found as an essential pillar of the project.

The relationship between concept and real site
The deepening of concepts necessitates a foundation based on an actual specific site; anchoring our concepts in such real-world scenarios is imperative. Having selected mud as an entry point, I began a case study that revealed many practical uses of mud and came up with three concepts, one of which was mud as a material to compensate for land subsidence in the hinterland. However, I must admit that I became fixated on applying this concept indiscriminately to any area experiencing subsidence, disregarding that the primary concern at Ems-Dollard Region was not land subsidence. Moreover, I failed to consider this concept's associated costs and feasibility.
Later, I shifted my perspective and approached the issue more practically, considering the actual crisis and existing conditions in the area. The presence of two old embankments within the site, along with the diminishing intertidal zone, sparked a new line of thinking. Consequently, I proposed utilizing these existing embankments to reconnect the river, serving the dual purpose of sediment collection and ecological benefits.
The implementation of concepts can be subtle. Among the three concepts, one involved using mud as a landscape feature, and I had always believed that mud should be used to create prominent landmarks. However, through case studies like Parco Lineare (By Studio Nowa), I realized that concept implementation could be done with large-scale, eye-catching projects. I learned that subtle interventions, such as guiding and suggesting human behavior, and setting pathways, can all contribute to excellent design. This shattered the preconceived notions I formed during my undergraduate studies.

Position in the larger social, professional, and scientific framework
On a larger social level, this graduation project aims to enhance the landscape character of the entire Wadden area, thereby deepening the emotional attachment of residents and visitors to the place and promoting economic

development wherever possible. The mud has not only a historical and cultural value but also a potential economic value, for example, people used to make bricks and handicrafts from it and then trade them; nowadays, people hike on the mud flats ..... It's essential to balance the protection of the natural heritage with the neglect of the cultural heritage and to diversify tourism, preserving the cultural memory and identity of the inhabitants as Frisians.

For the discipline of landscape, this graduation project aims to explore the landscape potential of mud. Mud is an important landscape element, just like trees and water. While it is common enough to use water or plants to shape space and to design systematically, mud has received less attention, and 'Mudscape' is an exciting topic. And since the natural accumulation and formation of mud is a long process, mud dredging in rivers requires human and material resources and continuous maintenance. Designing this landscape system in a way that makes it more efficient is a challenge.
On a scientific level, this graduation project aims to provide a crisis response. Many regions face rising sea levels, flood crises, the development of shipping industries, deepening waterways, and turbid water bodies, where ecological conservation and economic development conflict. This project, on the other hand, is a reconciler of ecology and economy, extracting the critical role of mud and investigating how it can be turned from a pollutant unearthed in the process of economic development into a new ecological enabler, for example, by being reused for agricultural farming or flood control infrastructure, how to collect suspended mud and how to create oyster beds and salt marshes from mud are essential techniques, etc.

Limitations
In the process of research and design, it was difficult to get in touch with local residents and organizations. Although I tried to send emails to the government and organizations in Delfzijl, as well as to contact researchers related to the mud at Wadden Academy, no reply was received, so the wishes and attitudes of the local residents are unknown.

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