A new dynamic landscape for the Haringvliet

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Landscape architecture explorations for Delta 21

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Abstract

This graduation project presents a landscape architectural design exploration for a new estuarine landscape at the Haringvliet that incorporates the initiative Delta 21. Delta 21 is a hydraulic engineering structure located at the Haringvliet mouth, creating an energy lake and a tidal lake sea inwards. The system of Delta 21 ensures flood protection, increases the use of renewable energy, produces food and creates precious natural habitats and corridors.

The Haringvliet region has a long history of living with water. People build dikes, dams and sluices. As a result, the land is safe from floods, creating opportunities for agriculture and industry to expand. The downside is that the damming caused strict land/water separations. The soft gradients of wet and dry, which once dominated the landscape, disappeared. Over the past decades, the landscape has become more monotone. The disappearance of the dynamic interface and the corresponding natural processes resulted in a landscape that lost the identity of the delta.

This design exploration aims to create a sustainable estuarine landscape in harmony with ongoing natural processes that restores the gradual land-water transitions and brings back the dynamics of this delta landscape for ecology and experience. The proposed design layout is based on morphological processes along the coastline, the expansion and preservation of valuable habitats like the Hinderplaat and the re-opening of the sea -Haringvliet connection.

The design exploration shows that incorporating Delta 21 into the new estuarine landscape can restore the estuarine dynamics and experience. The new estuarine landscape creates the opportunity to add a lot of nature, such as intertidal areas, marshland, creeks and dunes and restores the brackish corridors. The circumstances in the energy lake are suitable for the production of aquaculture. Furthermore, many recreational routes through the new landscape are introduced, connecting the new cultural zones, including holiday housing, shops, restaurants, and a visitor centre.

Acknowledgement

I want to thank my mentors Steffen Nijhuis and Mark Voorendt for their guidance, great advice and pleasant meetings. Steffen, you helped me a lot in understanding the practice of regional design. You have the talent to explain the why and how of the following design steps very clearly. This helped me a lot in continuously moving forward in the design process. Mark, thank you for showing me that hydraulic engineering and landscape design can perfectly co-operate. Your expertise was of great help in designing a landscape that is realistic as a flood protection measure.

Thanks to Huub Lavooij and Leen Berke, the initiators of Delta 21, for including me in their project. It is a great privilege to create a design that is part of something bigger. Your enthusiasm and open attitude made the project extra enjoyable and stimulating.

Thanks to Steffen for introducing me to OKRA and to Wim Voogt, Martin Knuijt and Rani Izhar for giving me the opportunity to work at OKRA. You and my colleagues gave me the freedom and flexibility to balance work with graduation. I am looking forward to becoming a full-time team member.

Thanks to Daan, my family and friends, who have supported me throughout the year and helped me relax in my free hours.

Thanks to my classmates and teachers from who I've learned so much the last two years.

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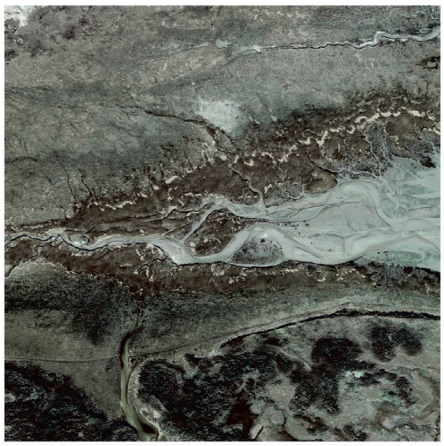
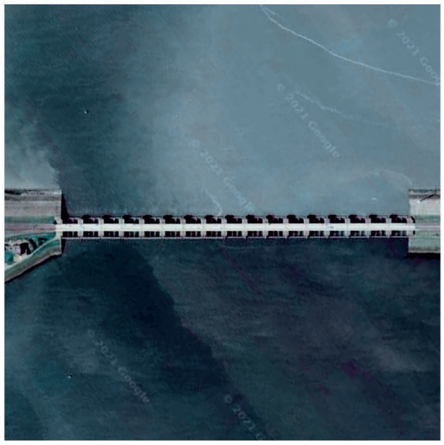






Images from: Google Earth

1. Introduction

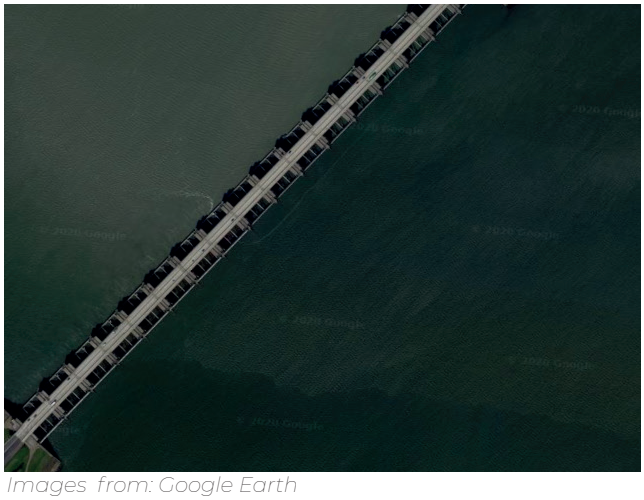
1.1 Fascination

The word ‘delta’ comes with an image of a place where land and water and river and sea merge into a rich and diverse interface. Here, the energy of the dynamics is high, which shape the land. Here nature is thriving, and people use the fertile land and water to produce food. However, this is not the image I see when looking at the Dutch Southwest delta. In this region, we can witness the result of decades of reclaiming, dredging, draining and framing the land and water. There is no rich delta interface but only one single line separating land, river, and sea.

Image of a delta

imgaes from: Google Earth

The Dutch Delta



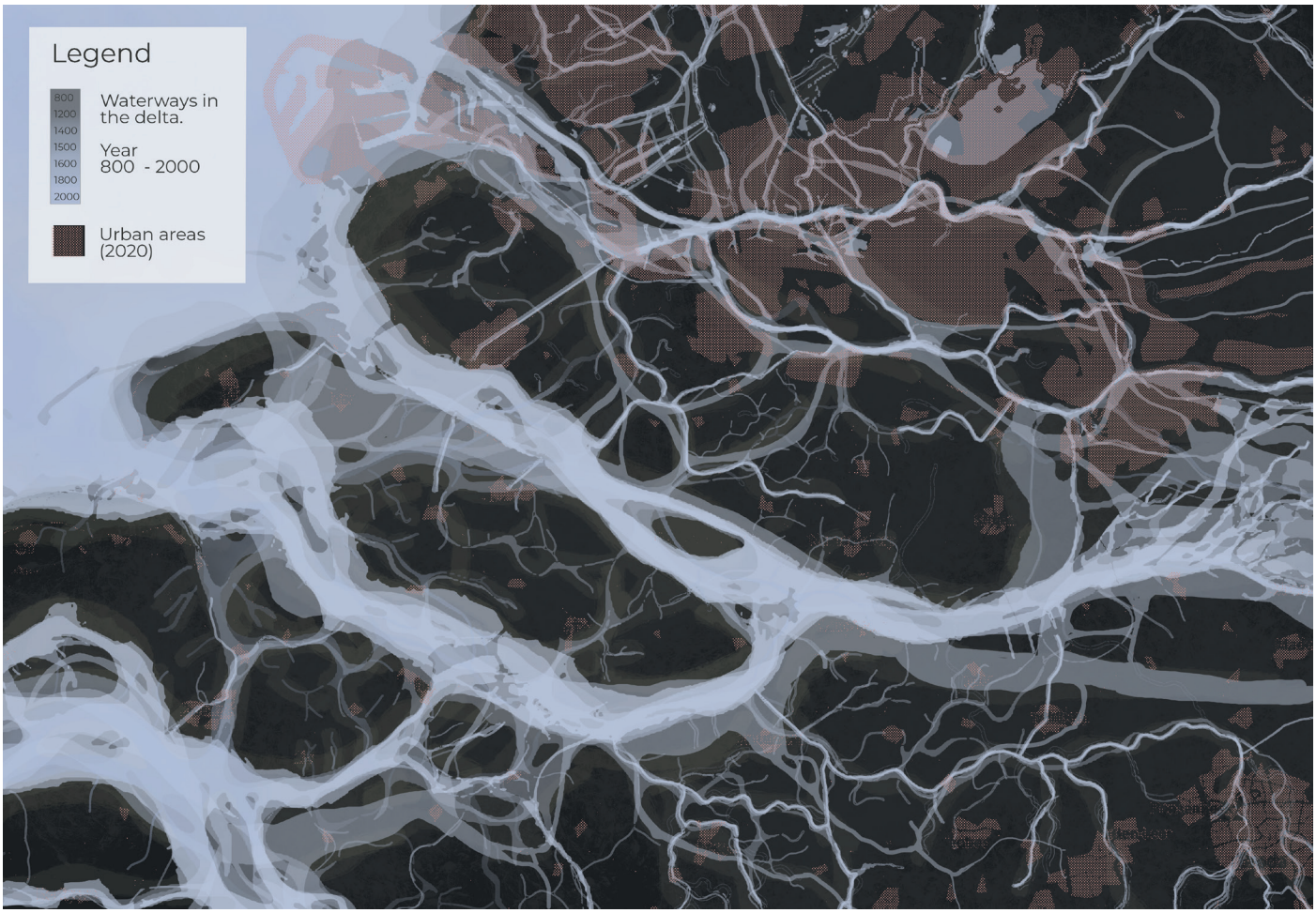
Images from: Google Earth

1.2 The Southwest Delta

The study location for this graduation project is the Haringvliet at the Dutch Southwest Delta, where the two rivers Meuse and Rhine, flow into the sea. The Dutch Delta is famous for it's significant delta works, recreation and the port of Rotterdam. The delta and the delta works is part of the Dutch identity and a Dutch pride. Here, floods are contained and flows are regulated.

The area has a long history of floodings and reclamation of land. Tidal creeks used to meander through the landscape and riverbeds overflow from time to time. For the sake of the Dutch economy and peoples safety, pieces of land were reclaimed for agriculture and riverbeds were framed by dikes, sluices and storm surge barriers. The deltaworks, a collection of fourteen dams and sluices, were established after the last big flood in 1953. This project was the finishing touch in making the delta flood resilient. The increased safety, the new freshwater buffer and the capability of regulating the water levels drew more intense industry and farming to the area. Now the Southwest Delta is shaped for safe living and high production for agriculture and industry. The downside of the waterworks concern the ecology, fishery and water quality.

The Southwest Delta is a region that needs hard work to maintain the current state and to improve the state of ecology. Waterways must be dredged and dikes and sluices need maintenance. Climate change will add challenges and need for adaptation, especially in farming, flood protection and ecology.



In history, the Southwest delta consisted of many small islands, intertidal areas, marshland and sludge plates. The shoreline consisted of an ensemble of sand ridges parallel to the coastline. People settled down because of the abundance of fishes, the fertile reclaimed soil and the opportunity to trade overseas.

Currently, the Southwest is an important centre point. Three rivers flow out into the sea, the Scheldt, Rhine and Meuse. Second, the delta is an essential node for birds migration and fish migration. And third, the area has the worlds largest transit port, Rotterdam. This means that the position and local situation of the Southwest delta is of great importance for worldwide flows.

Zelandia comitatus

Beschrijving Digitale scans van historische kaarten uit de collectie van de Cultuurbibliotheek (Sint-Lodewijkscollege, Brugge), uitgevoerd door het VLIZ in het kader van het project 'Historische kaarten van de kustzone'.
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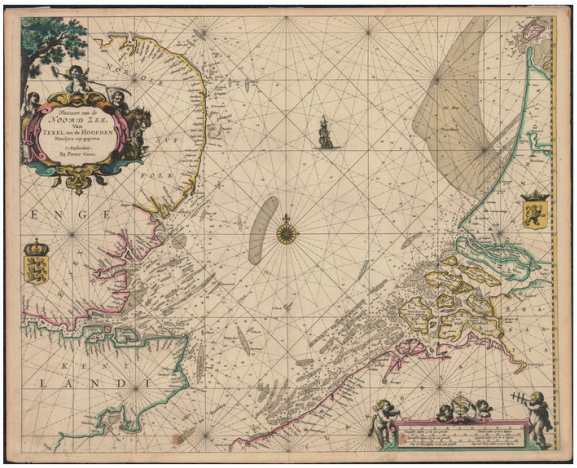

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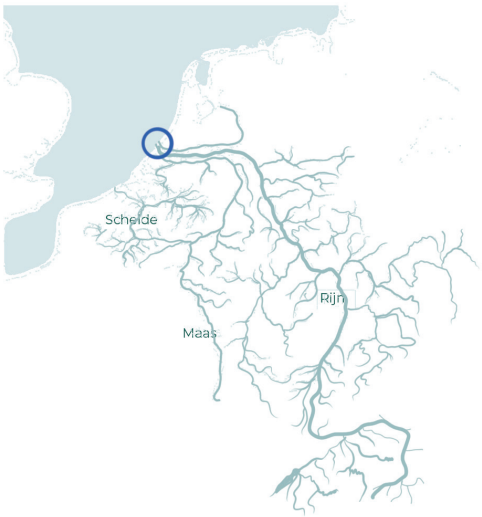
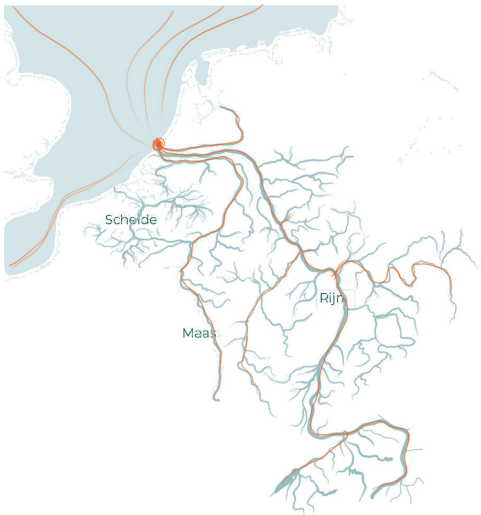
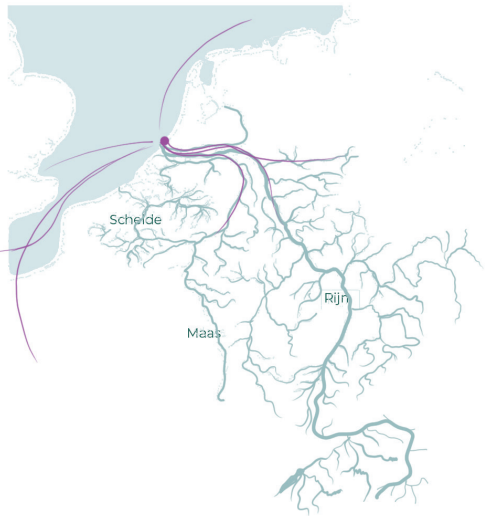






1.3 Problem statement

Problem field

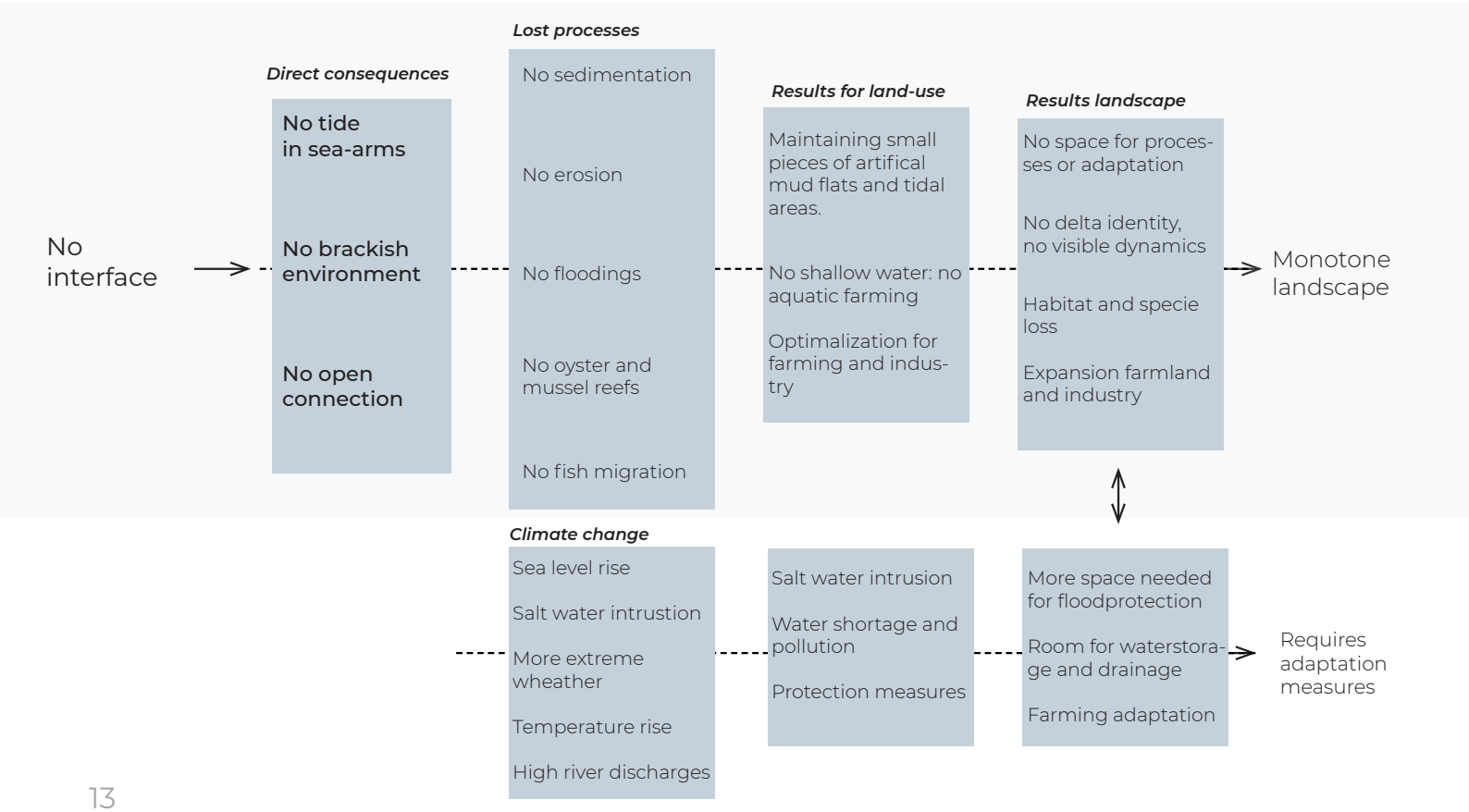
The Dutch South West delta has a long and dynamic history where natural processes and human activities shaped the landscape. Challenges like storms, floods, droughts and water salinisation resulted in societal changes in land- and water management (Klenke, Karrasch, & Woltjer, 2017). People built dikes and dams and regulated the water flows to decrease their vulnerability to environmental challenges. After the delta works, the area had the perfect conditions for a good welfare state. The land was safe from floods and the extra freshwater gave great opportunities to expand the industry and agriculture (Meyer, 2016). Although the crop yield and industrial productivity are high, the duration and sacrifices of this profit are questionable. With the loss of the natural processes, we also lost the capability of the system to adapt and restore after changes and disturbances (Meyer, 2016). Already we suffer from land subsidence, monocultural crop fields, lack of fresh water and losses in habitats and ecology (Karrasch, Maier, Kleyer, & Klenke, 2017).

The interface between water and land and salt- and freshwater used to be a gradual and dynamic transition in which many different biotopes settle, which are necessary for a healthy ecological balance (Meyer, 2016). Instead, the gradual transitions are replaced by dikes, sluices and canals. The loss of the interface and the corresponding natural processes resulted in a more monotone landscape with its own system.

Problem statement

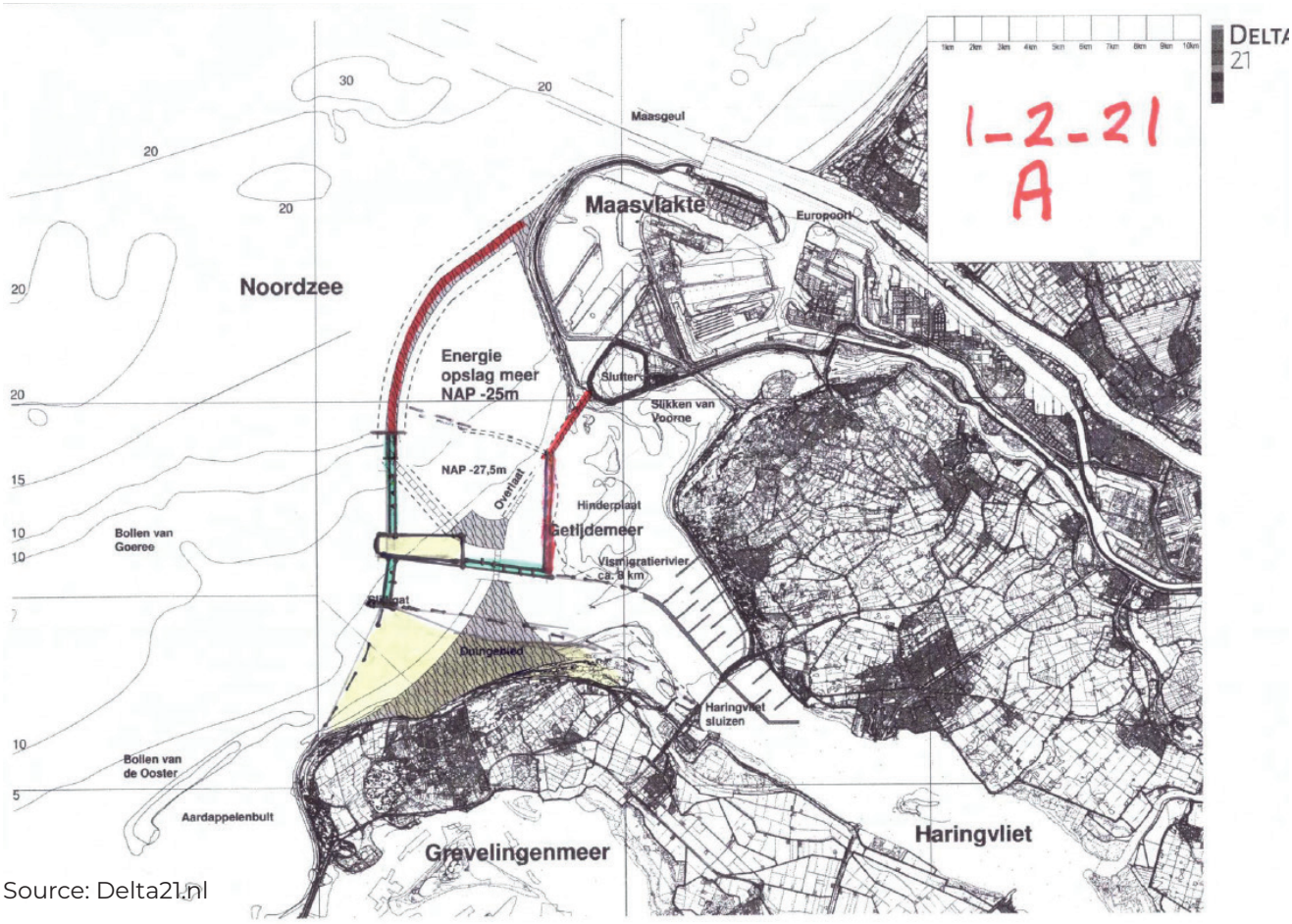
The disappearance of the **dynamic interface** and the corresponding natural processes resulted in a more **monotone landscape** with habitat losses, no space for dynamics or adaptation and a loss in the **identity of the delta.**

The damming resulted in no interface between sea and river, the consequences are:



Design brief - Delta 21

This graduation project started with a design brief for Delta 21 (Berke & Lavooij, 2019). This project is located at the Haringvliet mouth and plans to implement an energy lake and a tidal lake sea inwards. With this coastal engineering structure, the Haringvliet sluice can re-open and flood protection is created by new storm surge barriers and enormous pumps that can also generate energy. So far, this project is presented as a technical design intervention. Within this graduation project, I will approach this project as a landscape-based design intervention to develop a new estuarine landscape for the Haringvliet in which Delta 21 is incorporated. The new interventions must harmonise with the ongoing natural dynamics and strengthen each other (Aarninkhof, van Dalfsen, Mulder, & Rijks, 2010). In that way, the implemented structures and the region around will be flexible enough to cope with environmental challenges. New implementations must help to restore the gradual transitions in which natural processes can thrive and create a less monotone landscape that supports human well-being. When the Haringvliet sluice is open again, dynamics such as tide, sediment deposition and erosion returns. The saline and freshwater will merge again and vegetation will adjust towards more salt-loving species. In the natural situation, these morphological and biological processes would shape the landscape. In this anthropogenic landscape, human determine the extent of occurrence of these processes. The inclusion of natural processes in a landscape design requires an understanding of the behaviour of these processes and ways to use these processes as a landscape shaping tool. The Southwest Delta is a complex system with many different flows. Engineering structures like dikes, sluices, pumping stations, roads or other infrastructure regulates these flows. The challenges that the delta faces, affect the existing flow scheme and will change the spatial outcome of the delta. In search of solutions, everything must be taken into account. Therefore, an inclusive strategic design is essential in this delta landscape.



Source: Delta21.nl

1.4 Research objective

My research goal is to investigate how the interface at the Haringvliet can be restored and what role natural processes and dynamics can play in the design and planning of the Delta 21 initiative. I also want to investigate the possibilities that the new interface creates for recreation, sustainable economies, ecology and flood protection.
To structure this, I will use the following research questions to structure the research. With the design assignment, I will specify the steps to end up with the desired result.

Research objective

How can socio-ecological inclusive design be used to create new dynamic estuarine landscape interfaces that integrate flood protection, ecology, sustainable economies and recreation?

Sub-questions

1. How did the delta landscape evolved to its current state and what landscape sha ping processes where involved in this?

2. In what way can natural processes be introduced in the design of land/water inter faces?

3. How can I develop a landscape interface in which the occurrence of natural processes create a dynamic delta landscape and which facilitates flood protection, ecology, recreation and sustainable economies.

design assignment

The goal is to design new land/water interfaces for the Haringvliet and the Delta 21 project. The new interface has several requirements. First, I want to (re-)introduce the dynamics of natural processes in the interfaces. Second, I want to trace the interfaces in such a way that they strengthen the infrastructural flows in the area. Third, the spatial implementation of the interfaces must diversify the experience of the delta. Last, the interfaces must cope with challenges from ecology, recreation, energy demand and flood protection.

1.5 Structure of the report

This report is built up as followed:

First, theoretical research is done to gain a basic set of knowledge about designing with natural processes, regional design and socio-ecological inclusive design. With this knowledge, a theoretical framework is created to establish the research approach. The third chapter is all about the analysis. The analysis is split up into the six different landscape types and a regional analysis where the focus is more on the transitions and dynamics between the landscape types. From the analysis, the challenges and opportunities are generated.

The next step is the indication of design principles derived from books, web pages and existing landscapes. The next chapter is the design exploration. The first section of this chapter focuses on specific knowledge on natural dynamics that need to be derived to design with natural processes. In the second section, the layout of the Delta 21 plan is proposed from a design exploration. The following section is about exploring the zones of the new landscape. The fourth section is a design exploration of transitions within the new proposed landscape of Delta 21. Here the focus lies on experiencing the soft transitions with spaces for natural dynamics, ecological flows, aquaculture and recreation.

In the last chapter, the conclusion and reflection of the project are presented. Enjoy reading!

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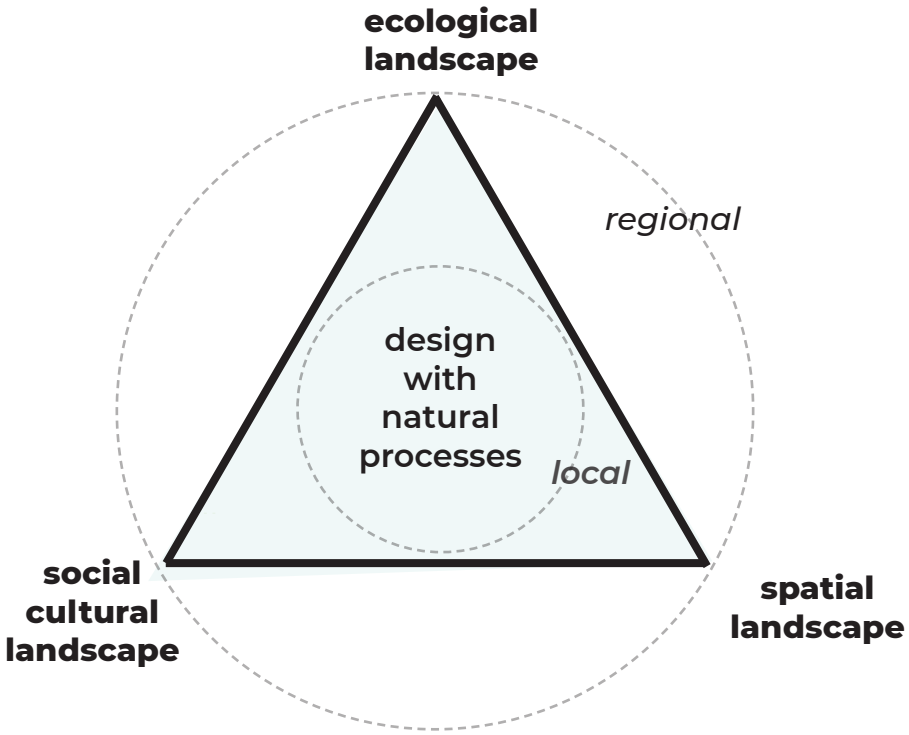
2. Methodological framework

2.1 Theoretical framework

Introduction

At first sight, Delta 21 project appears as a harsh engineered structure, artificial and man-made. These structures are designed to sustain for a certain period of time including a maintenance programme. This means that a lot of input in terms of money and energy for maintenance and management is needed (Keesstra, et al., 2018). However, if this project can be implemented in such a way that it is based on the natural processes that are in line with the temporal changes of the ecosystem the new implementation will become more sustainable (Keesstra, et al., 2018). For this project I want to create a socio-ecological inclusive regional design by taking the local natural processes as a basis. Natural processes will be used to define the original natural shape and form of the project site and will let this natural landscape define the local/regional activities and habitats. Second, the natural processes will be used as a tool to shape the new to implement landscape Delta 21. The expected and desired outcome is a new landscape that is in harmony with the ongoing natural processes and will be strengthened by these processes (Aarninkhof, van Dalfsen, Mulder, & Rijks, 2010). This makes the new landscape a good fit in the region for both humans and non-humans and will be sustainable with low maintenance requirements.



Designing with natural processes as strategy

Designing with natural processes is a broad concept for many different purposes. In the nature-based solution approach, the forces of nature are used in a design to end up with a certain solution for a problem. This solution can be ecosystem restoration, erosion prevention, water accumulation etc. The concept of ecosystem services focuses more on the implementation of a certain strategy whereby the natural processes can deliver a certain good or quality for humans or nature (Keesstra, et al., 2018). Within this project the purpose of designing with natural processes is to develop a design for an entire new landscape that is in harmony with the natural processes. It is important to thoughtfully define the role natural processes will play in the design approach. When starting a large design, it is conceivable to approach the design assignments through different contexts or themes, focusing on infrastructure, ecology, experience, and natural processes as an additional loose element. However, with this approach the natural processes do not shape and organize the landscape but the concept thinking of the landscape architect is (Nijhuis & Jauslin, 2015). The biophysical landscape will become a result of the program and concept that the landscape architect is focussing on (Nijhuis & Jauslin, 2015) and not on the relation that the design has with the natural processes. Therefore in this project, the basis of designing with natural processes starts with all local naturally occurring processes of matter and energy and follows the seasonal changes of the ecosystem (Keesstra, et al., 2018). By understanding the natural processes and their functioning deeply, the processes can be used as a basis and as a tool (Keesstra, et al., 2018). The natural biophysical landscape is a direct product of these natural processes (Nijhuis & Jauslin, 2015). Consequently, in this project, the biophysical landscape as a result of natural processes will be put as the basis. Then, the structure of the shape and form become the carrier for the programmes, habitats, processes, cultures etc (Bobbink & de Wit, 2020). This will follow naturally because a landscape on itself is never solely focussing on society or ecology (Nijhuis & Jauslin, 2015). In each landscape al themes are interconnected.

Socio-ecological inclusive design

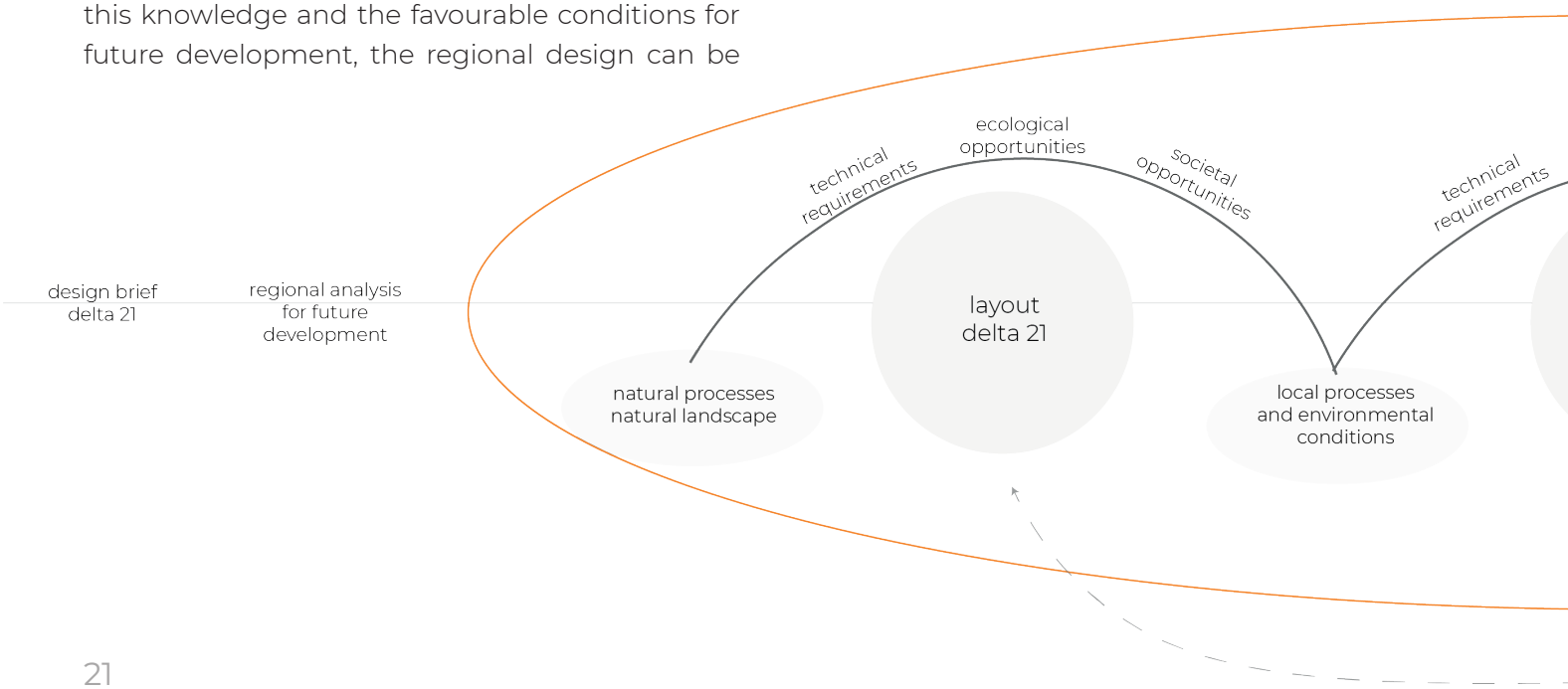
This is when the socio-ecological inclusivity comes forward. Inclusive means that the design assignment is approached from different perspectives and that there is room for future changes in this design (Bobbink & de Wit, 2020). Aiming for inclusivity is often a reaction to earlier exclusivity (Bobbink & de Wit, 2020). In reference to the Haringvliet; the Deltaworks focussed more on societal demands rather than ecological demands. In reaction, we seek for more ecological solutions in this area. However, it is easy to exclude the less visible that drew less attention over the past (Bobbink & de Wit, 2020). When aiming for inclusivity, the starting point should not be the problem statement but the specific character of the place and its situation (Bobbink & de Wit, 2020). This confirms the earlier statement about programme that follows from the shape, form and conditions of the natural landscape. A landscape design should therefore always be inclusive (Bobbink & de Wit, 2020). The different perspectives for ecology and society become structured design assignments that are derived from the landscape in relation to its processes.

Spatial role in inclusive design

The spatial landscape in combination with the ongoing natural processes is the foundation for the design approach. Thereby, the societal and ecological design interventions in relation to the natural processes can also turnout explicit spatially (Simenstad, Reed, & Ford, 2006). Reading and understanding the landscape can indicate the performance and spatial outcome of a design intervention over time (Simenstad, Reed, & Ford, 2006). The perception of the spatial outcome is the core of the relationship between people and landscape (Bobbink & de Wit, 2020). The aesthetic dimension is about creating experiences and places for social routines and activities ((Braae, 2015, p. 122) in (Bobbink & de Wit, 2020)). To conclude, within the design we must focus on the interaction between the natural processes and the spatial form that communicates with natural and human systems (Nijhuis & Jauslin, 2015) and aim for a desired spatial landscape that is satisfying for experience and social activities.

Spatial role in inclusive design

The approach of inclusivity is wider than the spatial, ecological and societal factors. It establishes a relation between shape and form and goes trough scales of time and space (Nijhuis, Xiong, & Cannatella, 2020). A regional design means that a transdisciplinary approach is required in which changes the socio-economic and environmental situation is guided and shaped to ensure coherent development (Nijhuis, Xiong, & Cannatella, 2020). By applying a regional view to the design assignment, its is easier to indicate the identity of the place and the suitable measures that improve the region. Within the region the complex web of relations and systems can be understood and the original biophysical landscape can be identified. Based on this knowledge and the favourable conditions for future development, the regional design can be determined (Nijhuis, Xiong, & Cannatella, 2020). The regional design can be seen as an open-ended strategy that guides future developments (Nijhuis, Xiong, & Cannatella, 2020). Within this graduation project design interventions will continually be examined within the different scales of space and time. By this means the design intervention is tested whether it fits the requirements of the region over time. Regional design creates space for strong interaction between research and design (Nijhuis, Xiong, & Cannatella, 2020).



2.2 Research approach

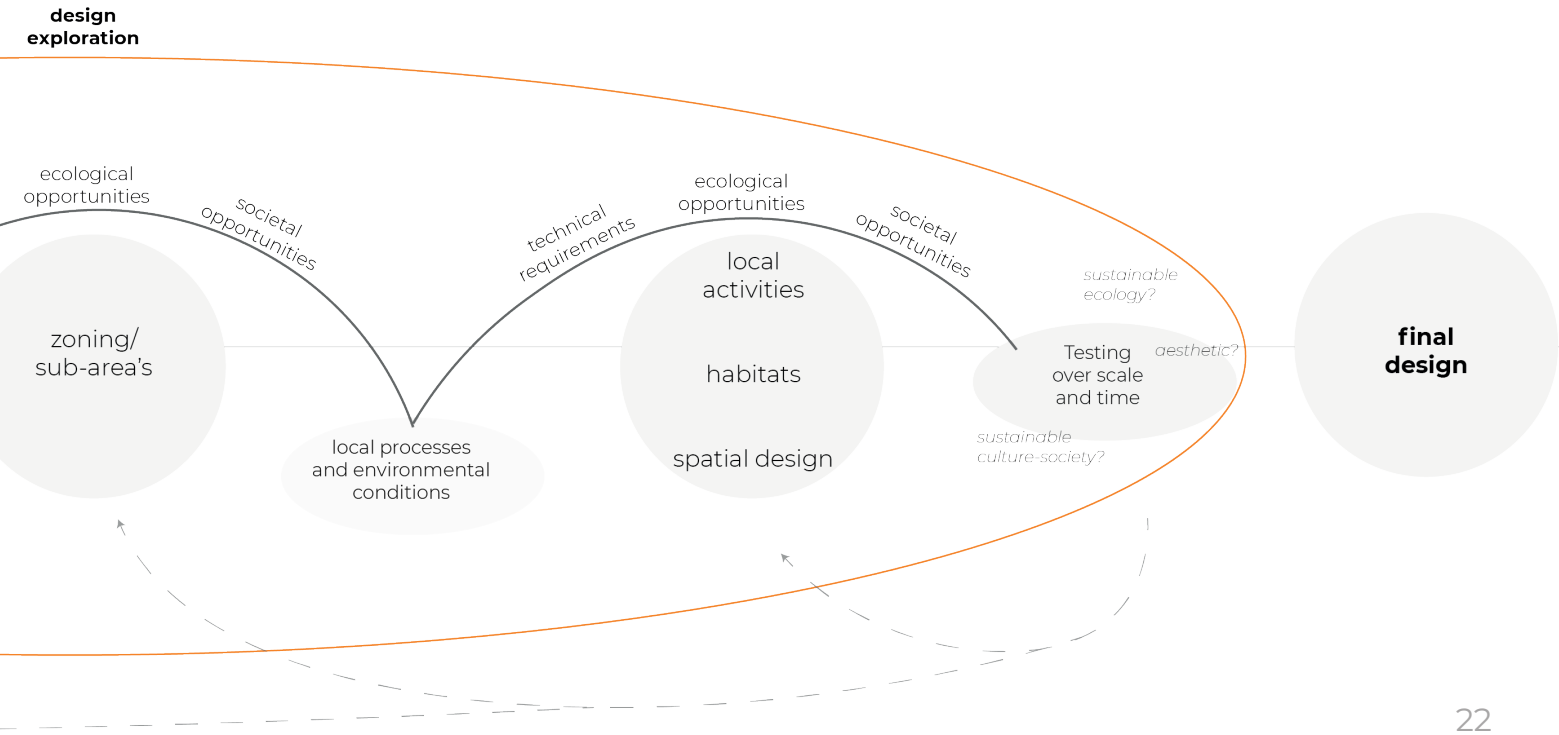
Data collection

The framework of this project overlaps with principles like nature based solutions, designing with nature, ecosystem services and ecological landscape design. The challenge is to derive the required information from these principles and use it for my own project. A basic set of knowledge is necessary to start the research and design. I will generate this knowledge by reading scientific papers derived from Google Scholar. Used search terms are: Coastal OR delta OR estuary, and, nature based solutions OR ecosystem services OR designing with nature OR design with natural processes, and a more specific search term such as dikes OR marshland OR aquaculture etc. The outcome gave me great insight in the possibilities of designing with natural processes. Site specific information is derived from public webpages. For objective information I used webpages such as: Google Earth, AHN viewer, DINO Loket, the Rijksoverheid database with among other things culture historical maps and palaeographical maps. For more subjective information I look at blogs, forums, websites by local institutions or municipalities and place bound reviews by tourists and visitors.

Research and design approach

This project starts with the design brief Delta 21. First, its important to obtain insight in the historical and desired future developments of the region in all aspects. The designing phase is a constant dialogue between researching and sketching. The design exploration starts with investigating what role the natural processes play in defining the local natural landscape. Hereafter, some requirements and perspectives can be added to sketch the layout of the delta 21 plan. This structure continues as we zoom in to the more detailed design. Eventually, each part of the design is tested for its sustainability in the region and over time and whether it fits the spatial aesthetic, ecological and societal demands. If not, the exploration and sketching continues. Finally, the final design will be achieved.

Research and design approach scheme



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3. Analysis

3.1 The Southwest Delta

Before the large waterworks, the Southwest delta consisted of several islands disconnected by estuarine river-arms or, in this booklet, sea-arms. The project area is the first sea arm, the Haringvliet, and the first island, Goeree-Overflakkee, part of the province of South Holland. Goeree Overflakkee was disconnected from the mainland until 1964. In comparison to the mainland of South Holland, the island is a more remote area. As a consequence, there are no large cities on Goeree Overflakkee, no highways and no train tracks. The smaller villages have strong communities with local culture.

The Southwest delta is an important node for migratory fish. However, due to pollution and damming, a lot of the species are in danger of extinction. To let these species return and recover, target species can be indicated. These target species require strict environmental conditions to return to this area naturally. Seven target species are appointed, which have high ecological demands that need to be considered during the design phase. If these species can return, many other species that are native to the Southwest delta will return as well.

At the Southwest delta, six landscape types can be distinguished. The six landscape types are analysed separately to understand the natural landscape, the processes, the cultural landscape and the spatial landscape. By doing so, a deep understanding of the natural processes, historical evolvement and identity of the area can be obtained. This information is necessary for the design phase.

Consulted literature for ecology & target species:

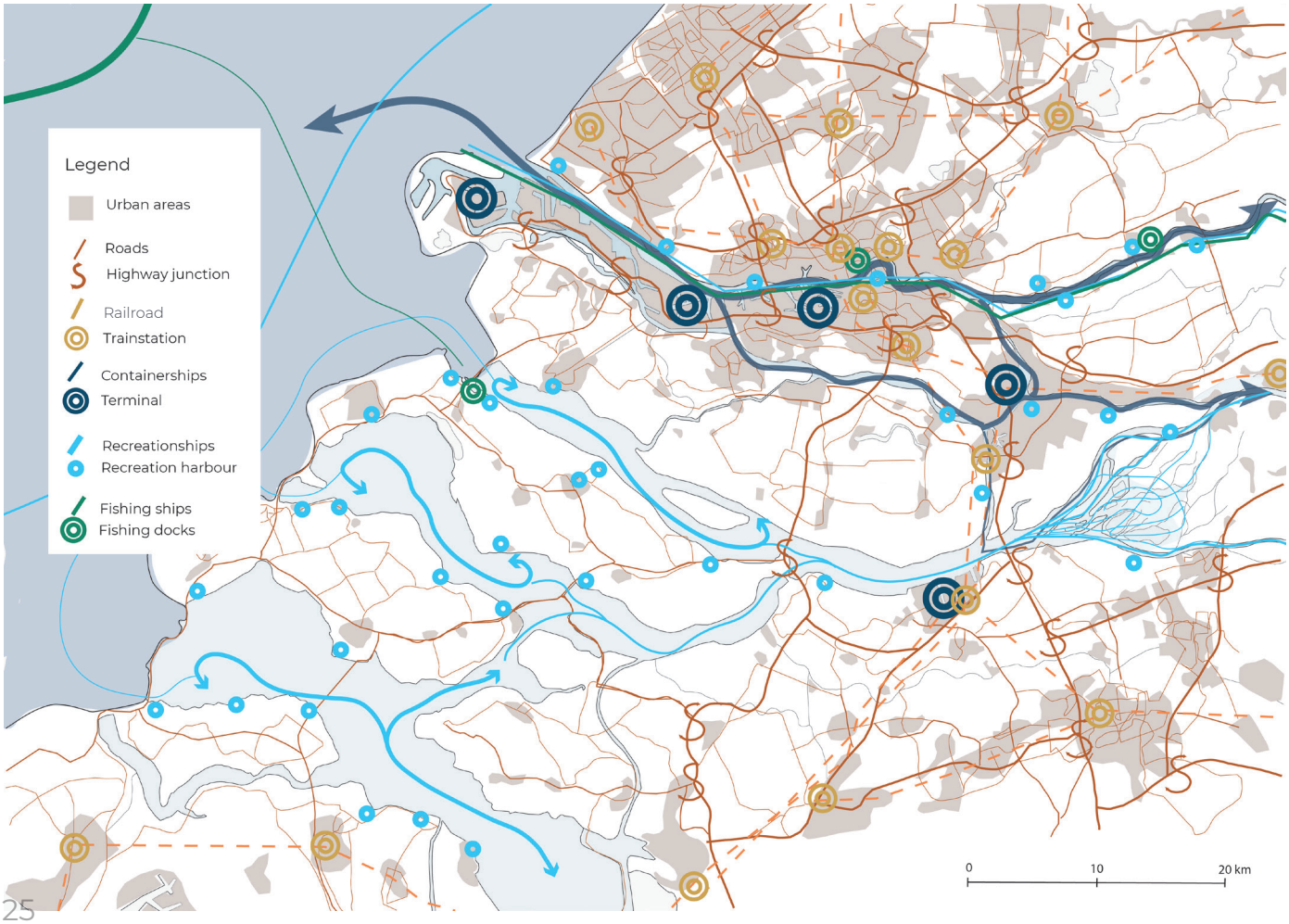
Noordhuis, R. (2017). Het Haringvliet na de kier. Deltares.

Paalvast, P., Iedema, W., Ohm, M., & Posthoorn, R. (1998). MER Beheer Haringvlietsluizen Over de grens van zoet en zout. Deelrapport ecologie en landshap, Minesterie van Verkeer en Waterstaat, Rijksinstituut voor Integraal Zoetwaterbeheer en Afvalwaterbehandeling RIZA.

Stam, J., Groen, M., & Walburg, L. (2002). Haringvlietmonding: reconstructie van een aflsuiting. Rijksinstituut voor kust en zee (RIKZ).

Storm, K., Kuijpers, J., & Harmsen, C. (2016). Eb...en weer vloed in het Haringvliet. Landschap, 199-207.

Wagteveld„ M., & Neijsen„ M. (2016). Droomfondsproject Haringvliet. Zeist: WNF.



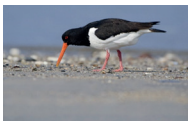
Specie	Cause
Salmon 	*Fishery* *Pollution* *Damming*
Shad 	*Fishery* *Pollution* *Damming*
phocoena (porpoise) 	*Fishery* *Pollution (PCB)* *Noise*
shellfish beds 	*Fishery* *Diseases* *Cold winters*
Sea eagle 	*Shooting* *Pollution* *Poision*

Target species

Name (scientific): Alopecurus bulbosus (foxtail grass)
Origin: Indigenous
Endangered: Red list
Representative for: Salt water presence in groundwater
Habitat: Dry salt marsh, absence soil disturbance like mowing, intense grazing, fertilizing. (reason for decreasing)

Name (scientific): Anarhynchus alexandrinus (kentish plover)
Origin: Europe
Endangered: On red list
Representative for: Insects, shrimps, crabs, snales
Habitat: Dynamic coastal areas with little vegetation, young sandbanks/beaches

Name (scientific): Haematopodidae (oystercatcher)
Origin: Europe Afrika (winter)
Endangered: Decreases (decrease in habitat and food)
Representative for: Insects, shrimps, oysters, snales, worms
Habitat: Sandbanks and mud plates, diverse and wet grasland.



Name (scientific): Phoca vitulina (harbour seal)
Origin: Coast Northern Hemisphere
Endangered: No
Representative for: Disturbance (noise, light), fish stock
Habitat: Tidal areas, rocky coast, sand banks, cliffs, deeper water (for hunting).

Name (scientific): Alosa fallax (twaite shad)
Origin: East atlantic ocean
Endangered: No, but extinct in the Netherlands
Representative for: Gradual fresh/salt water transition
Habitat: Fresh water for breeding, estuaria to grow up (important), sea as adult fish

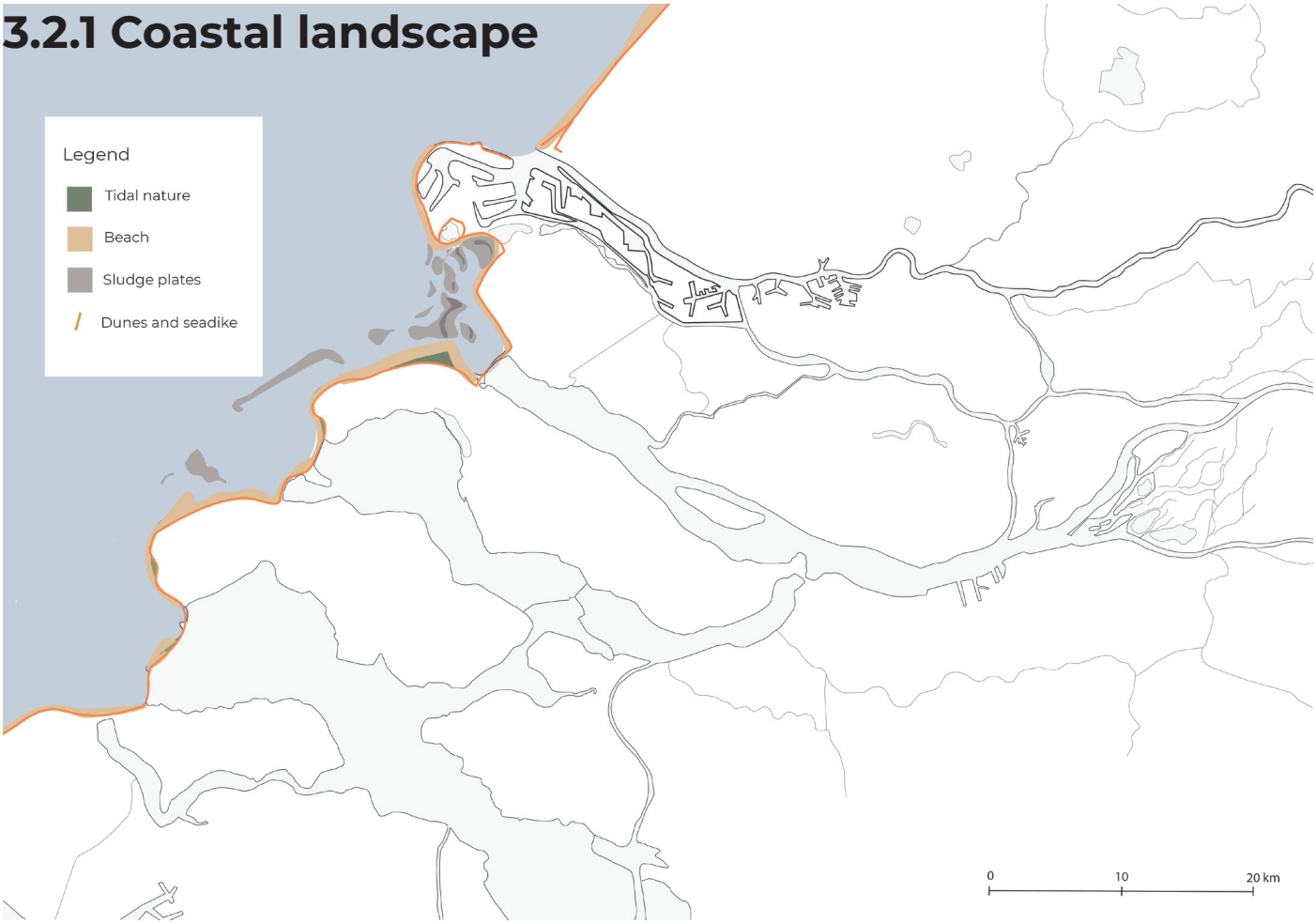
Name (scientific): Zostera (seagrass)
Origin: Shorelines Northern Hemisphere
Endangered: Red list, rare in the Netherlands
Representative for: Biodiversity of fish and birds
Habitat: Lives in saline and brackish water and settles in the soil.

Name (scientific): Lacerta agilis (sand lizard)
Origin: Northern Hemisphere, Europe and Asia
Endangered: Red list
Representative for: Dynamic dunes, in first states of succession
Habitat: Sun orientated sand dunes with a combination between open land and shrubs.

3.2 Landscape types

In the Southwest delta, six different landscape types can be indicated. In this sub-chapter each landscape type is analysed. This is done by looking at the historical development of each landscape type and at the influencing factors that shaped the landscape. Second, for each landscape type, the spatiality is explained with a focus on the spatial structure, character and experience. By doing so, I hope to investigate how this Southwest delta came to being and what processes were dominant in shaping this landscape. Also, this analysis will help to identify the challenges and opportunities of the region.

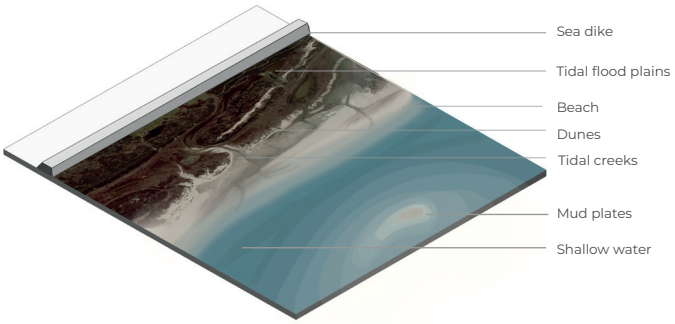
3.2.1 Coastal landscape



Retrieved from: https://beeldbank.rws.nl, Rijkswatervstaat Photo by: Joop van Houdt

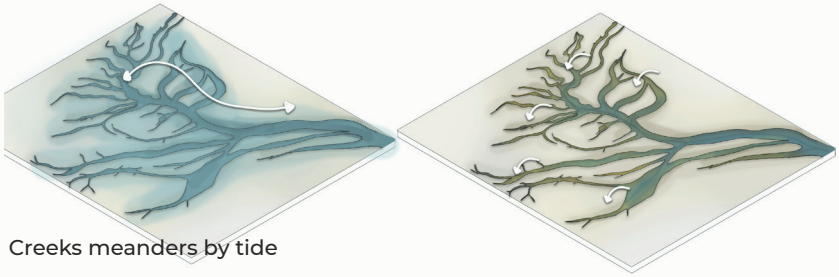
Development of the coast

The coastal landscape exists of dikes and dunes that protect the hinterland from the sea. This is an ongoing structure along the entire shoreline. Besides this human intervention, the coast is also shaped by natural processes. A broad coastline creates space for these processes to shape the coast. Wind and waves move sand particles on beaches, sandbanks and dunes, and tidal movements create creeks and marshlands. The deposit of sediments in the creeks elevates the land and changes the composition of the soil. The abiotic processes like wind, wave and tide continuously erode some parts of the landscape. This creates a mosaic with different stages of succession in one relatively small area.
The natural development of this landscape results in a very diverse landscape.



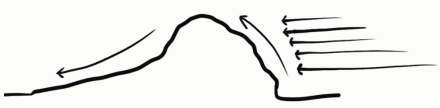
Shaping processes

Sediment deposition and erosion by tidal currents and river currents



Creeks meanders by tide

Variety of vegetation by differences in soil conditions and succession stage



Sand movement by wind and water

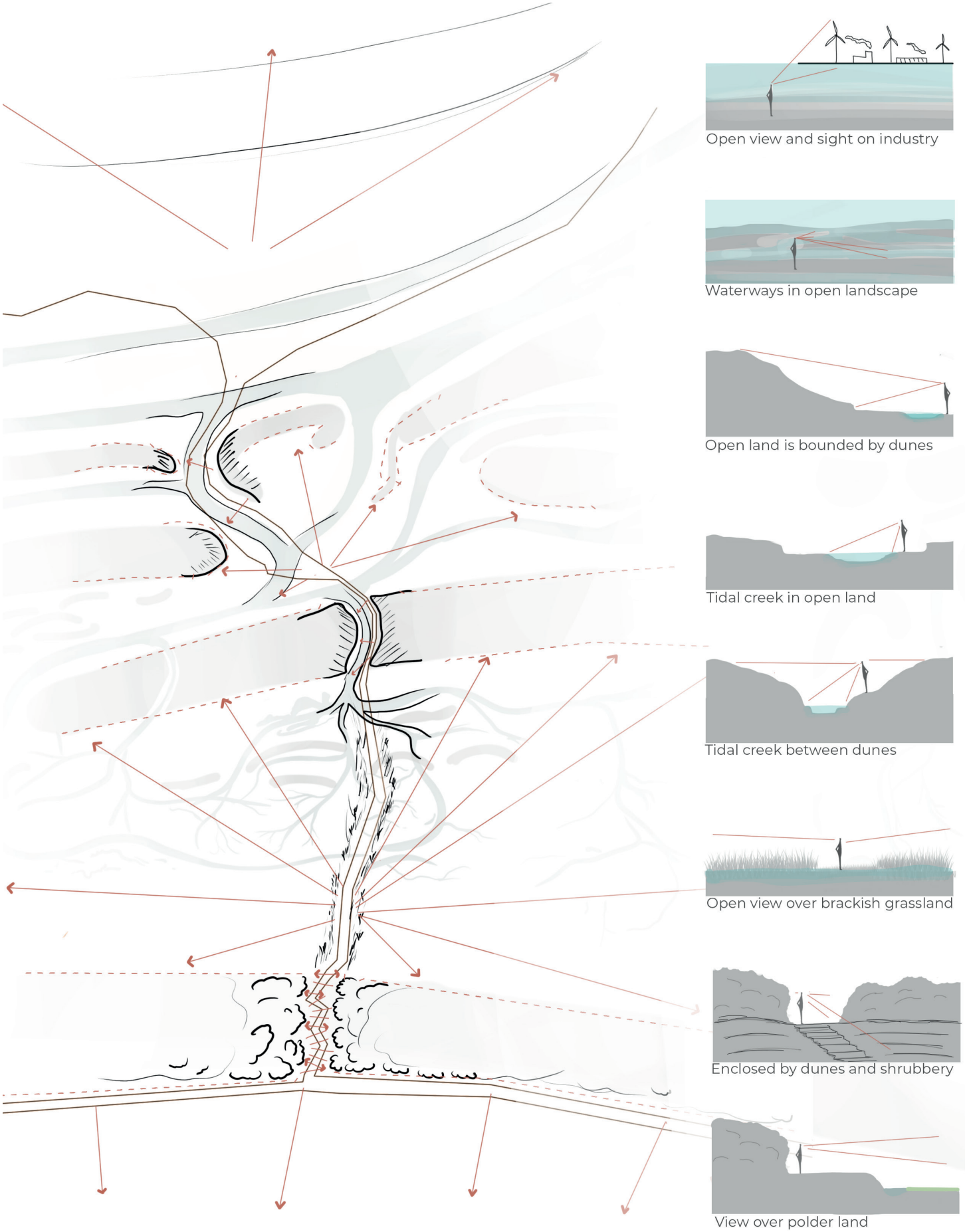
Spatial structure

Spatial character

The coastal landscape is full of dynamics. The wind erodes the dunes and forms them into a parabolic shape. The tidal creeks meander through the land and erode into the soil.

The coastal landscape type is very diverse in elevation. The lowest areas consist of the sea, beach, creeks and tidal floodplains. The higher areas consist of hilly sand dunes and artificial dunes for protection. Due to the difference in elevation, the area reveals itself while walking through it. The alternation of narrow passings and open fields creates a sense of mystery and curiosity. The large beach and open view to the sea emphasise this experience even more.

Spatial experience



Open view and sight on industry

Waterways in open landscape

Open land is bounded by dunes

Tidal creek in open land

Tidal creek between dunes

Open view over brackish grassland

Enclosed by dunes and shrubbery

View over polder land

3.2.2 Polder landscape

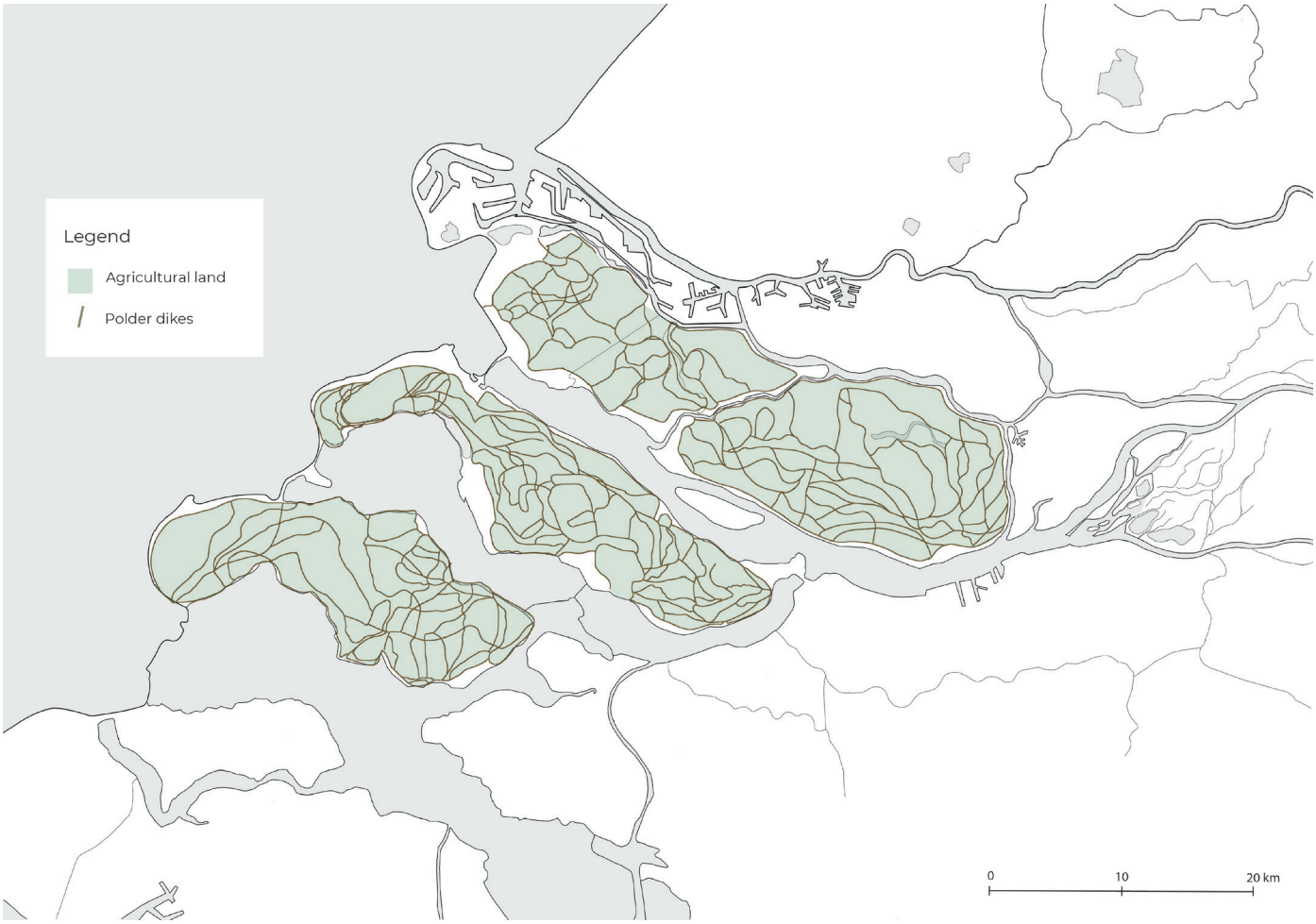


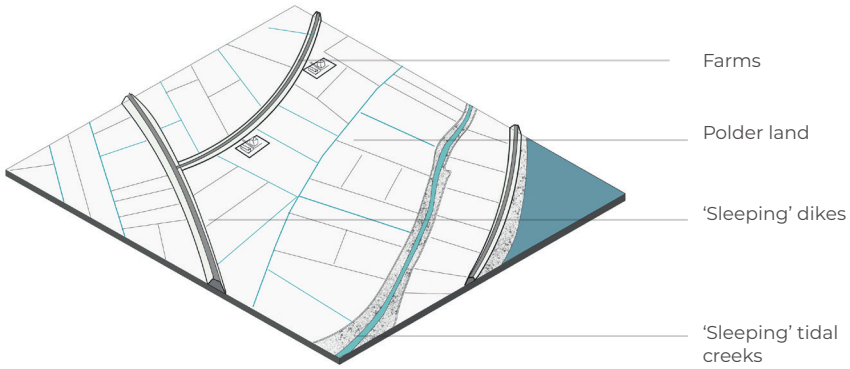
Image of the polder landscape

Retrieved from: https://beeldbank.rws.nl, Rijkswaterstaat, Photo by: Joop van Houdt

Development of the polder

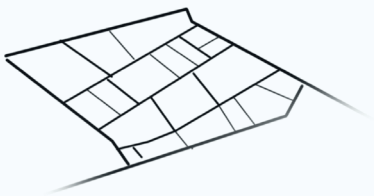
The polder landscape came to being by continuous land reclamations that followed each other up. After reclaiming a piece of land, the land outside the dikes started to fill up again with small clay sedimentation and was again reclaimed after a few years. This continuous growth of land characterises the layout of the dikes and polders in the delta landscape in rings that grow to the water edge. This method of reclaiming results in a dike grid with many dikes that are not primary necessary for protecti-on against seawater. These dikes are called 'sleeping' dikes. Although these dikes do not have a direct water pro-tective function, they are still useful to keep and maintain. In case a dike breaks through, these sleeping dikes will work as secondary protection and compartmentation. In this way, most of the land will still be protected against seawater whenever there is a dike breakthrough.

Spatial elements

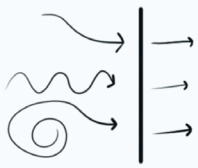


Shaping elements

Production and efficiency

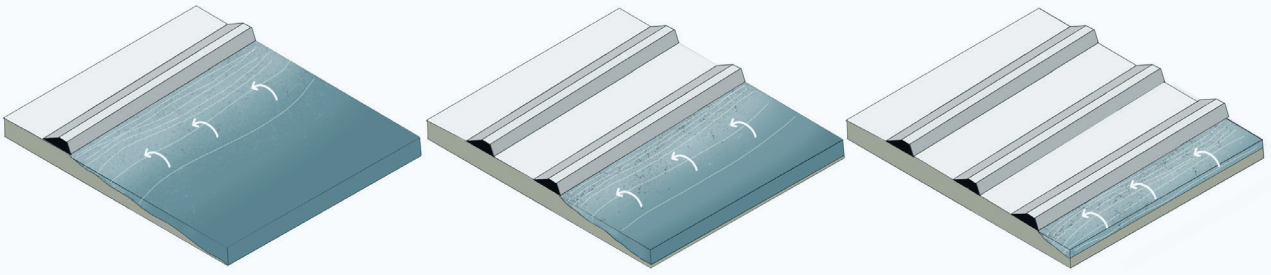


Parcelation



Control of flows

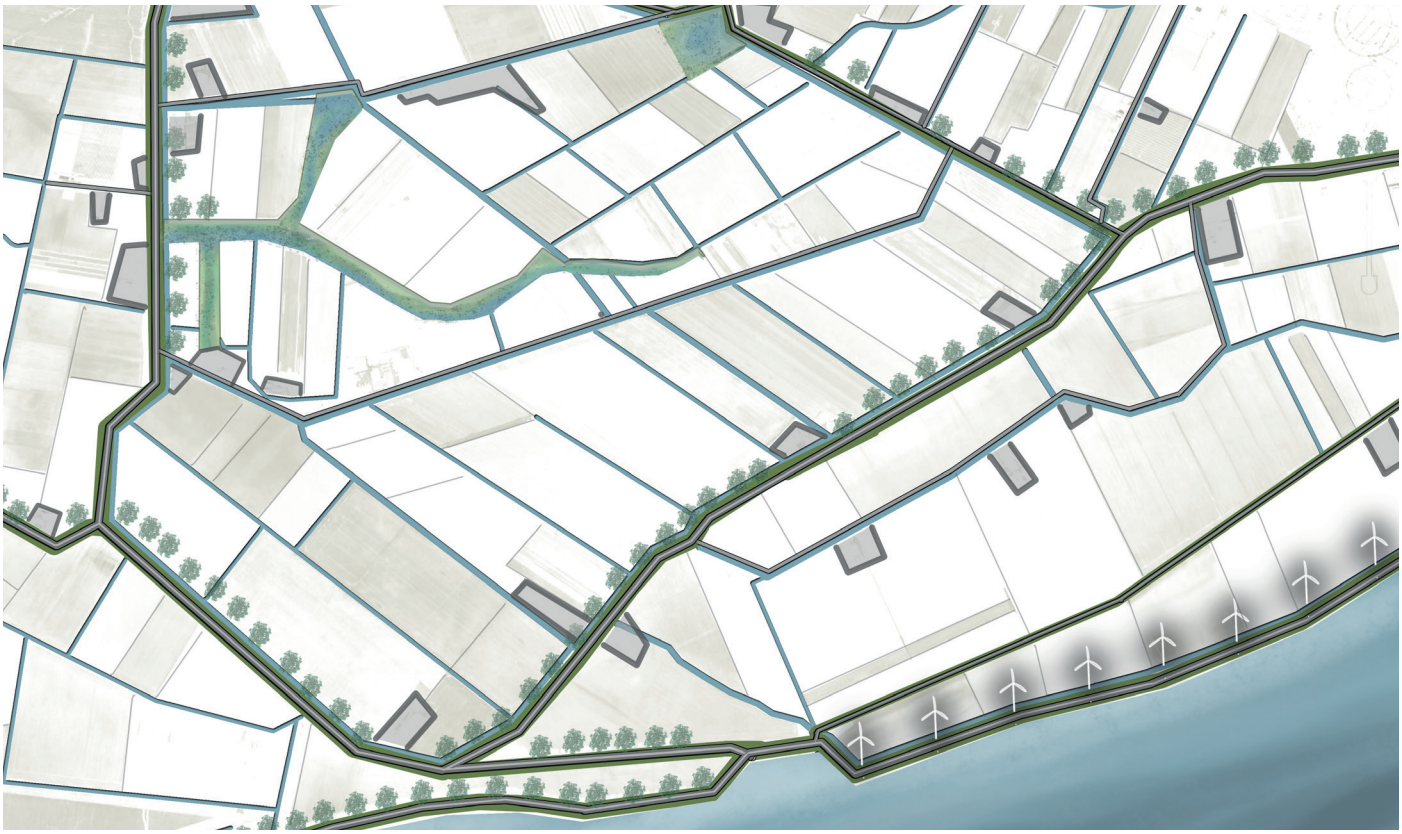
Land reclamation by sediment accumulation and dikes



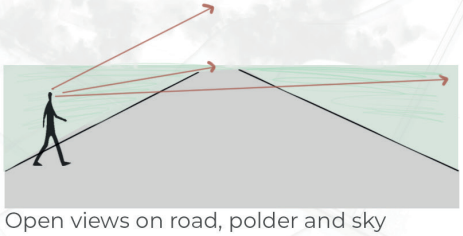
Spatial character

The polder landscape characterises itself by the productive agricultural purpose. The land is divided into clear parcellation patterns within the dikerings. The waterways and ditches lay within the same parcellation grid and have a role as a land divider. The land is flat, therefore a far and open view is always possible. The dikes and tree rows frame this open view because of the higher elevation. Therefore, the view is always bounded by dikes. The dikes are multifunctional, besides the flood protection function they also serve as roads. Within this clear grid of parcels the old tidal creeks are still visible. However, they are strictly separated from the agricultural fields and lost their former dynamics. The first river dike separates the polderland and from the water at the sea-arm. This means that the water is not visual accessible from the polder.

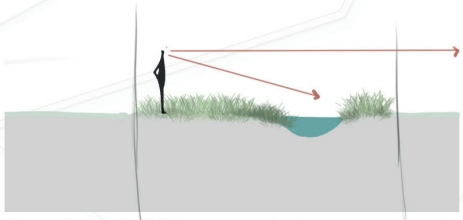
Spatial structure



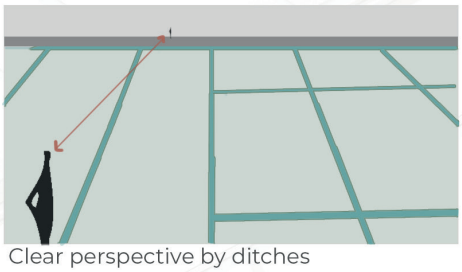
Spatial experience



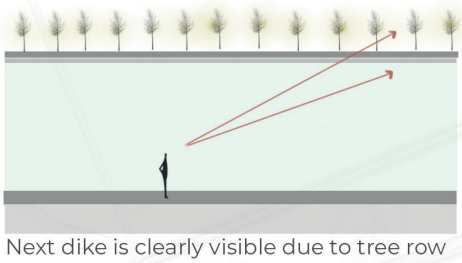
Open views on road, polder and sky



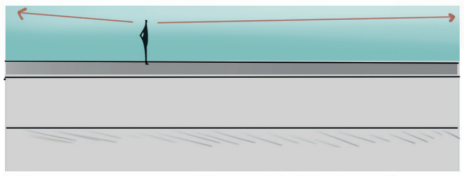
Remains of old tidal creeks in polder land parted with a strict border



Clear perspective by ditches

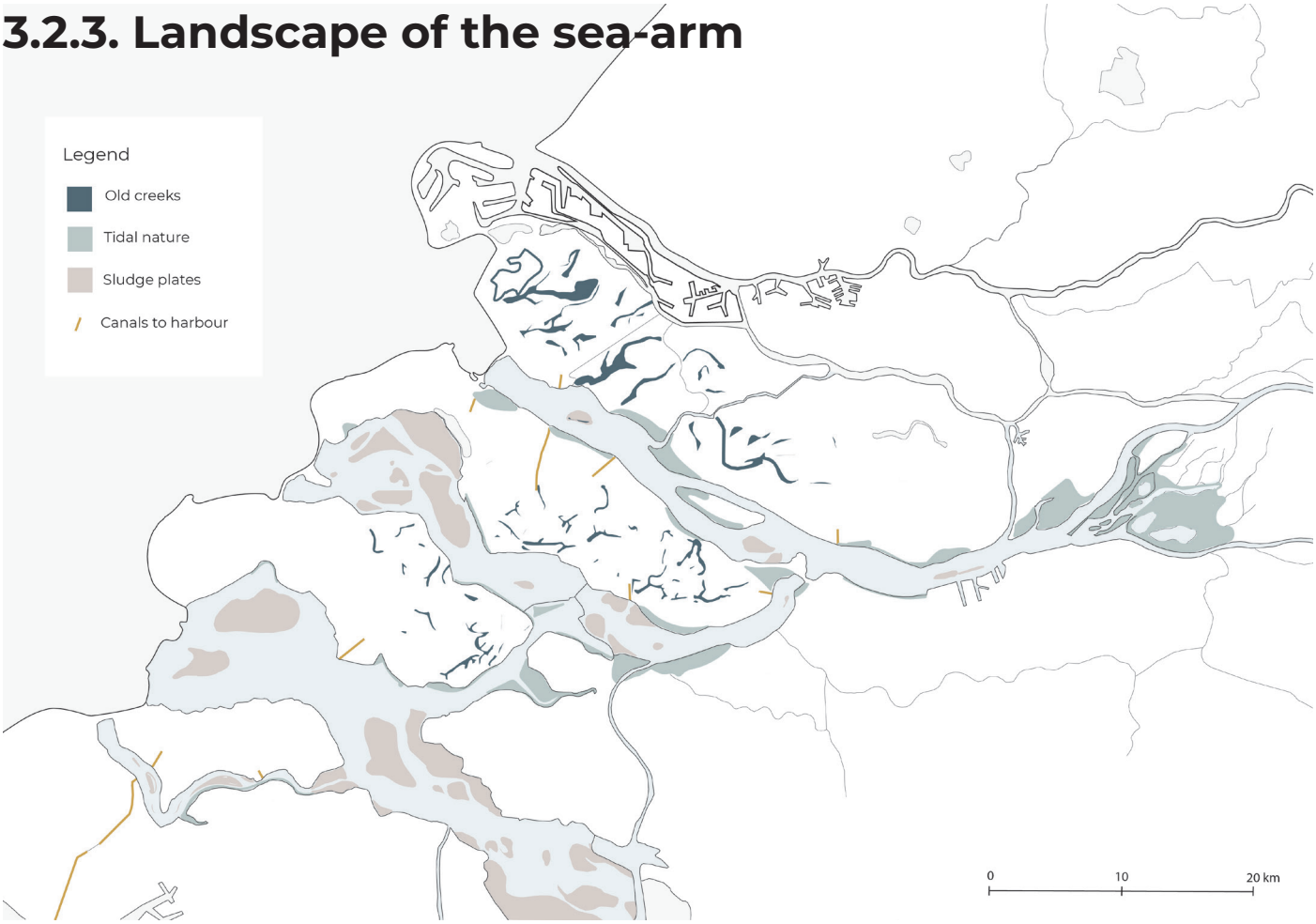


Next dike is clearly visible due to tree row



Dike seperates polder with Haringvliet and provides a wide view

3.2.3. Landscape of the sea-arm



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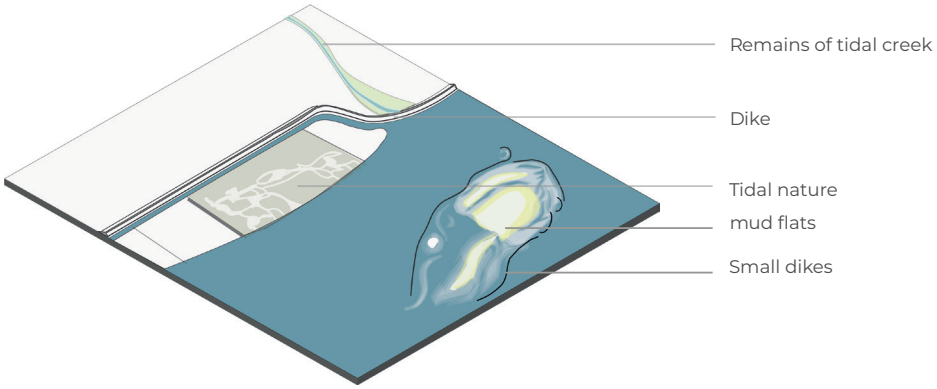
Elements

Development of the sea-arm

The landscape of the sea-arm has a rich and dynamic history. During the beginning of this era, the Southwest delta was more a delta shaped water system of small streams meandering towards sea. Later, when the sea level started to rise, the tidal movement of the sea became more important. The sea eroded the river mouth and created wide sea-arms with small meandering tidal creeks land inwards. Nowadays, dikes close of the sea-arms, which stop the occurrence of tidal creeks. In the landscape, the remains of the tidal creeks are still visible.
The tidal movement has almost disappeared in the sea-arm. Shoals and marshland do not occur naturally in the area anymore. Small dikes and narrow openings hold the sand together.

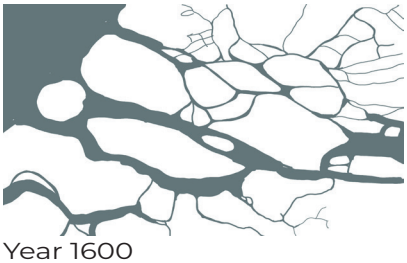


Landscape shapers


Year 800


Year 1250


Year 1500


Year 1600


Year 1850


Year 2000


Dikes

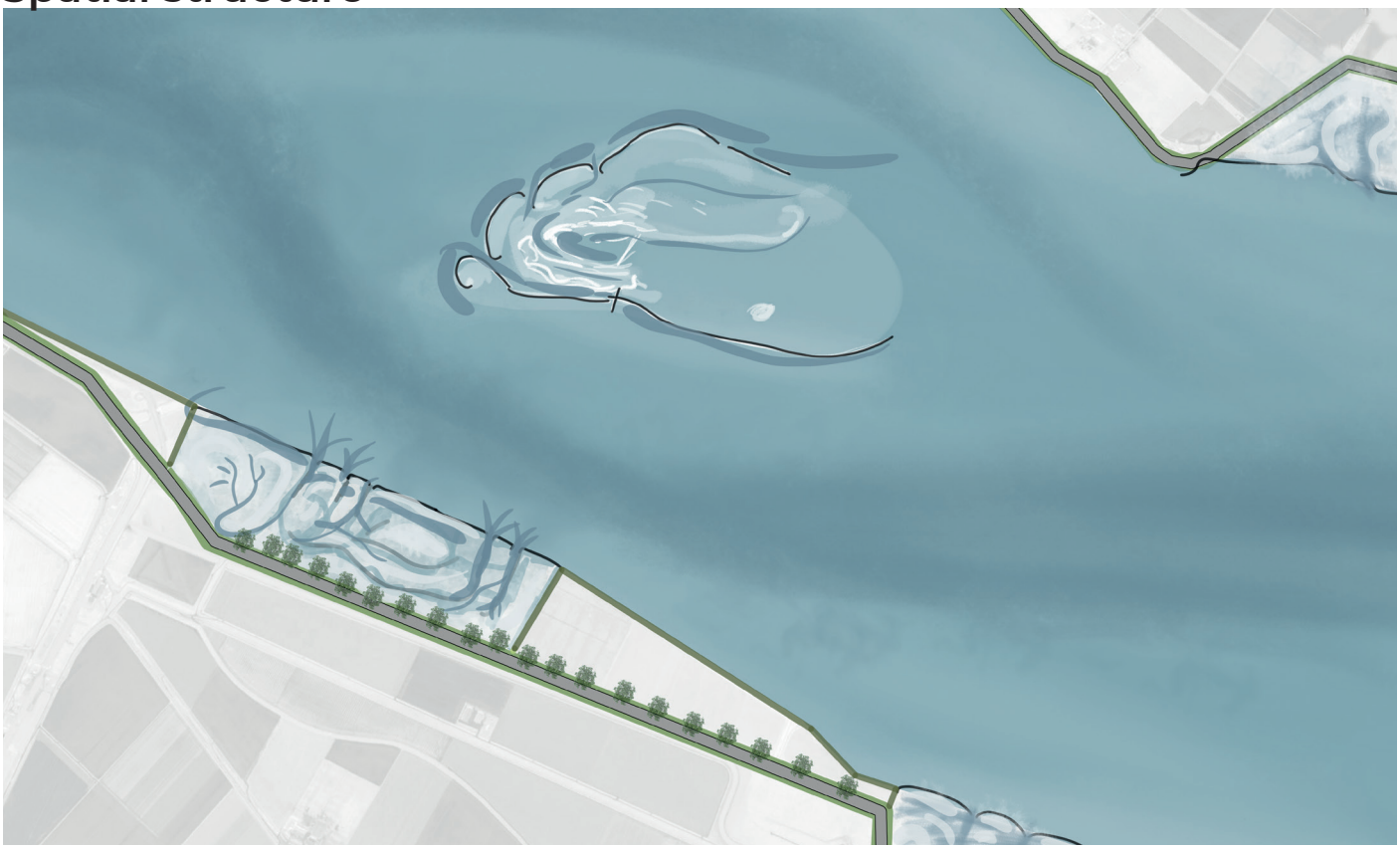

Small dikes


Sediment


Tidal currents


Vegetation

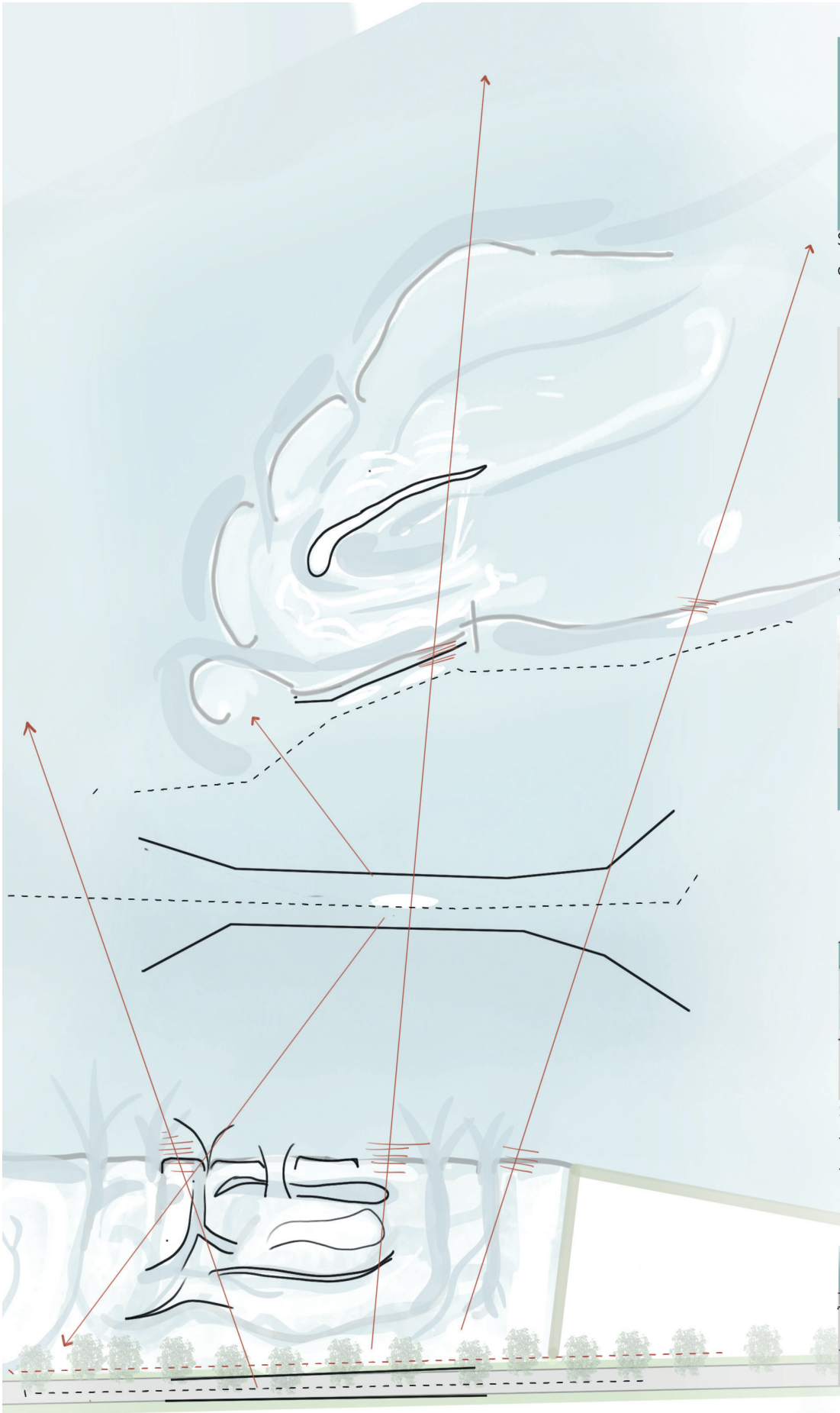
Spatial structure

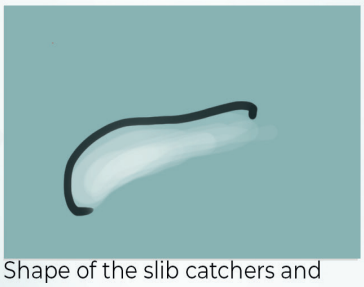


Spatial character

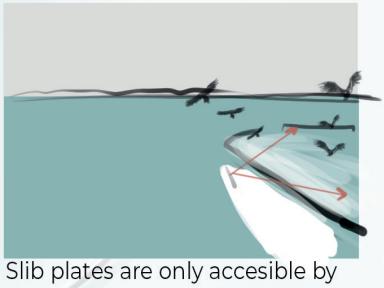
The sea-arm landscape is dominated by the waterbody that connects the sea to the river. The river current and tidal currents form mudflats and tidal floodplains. However, human involvement is necessary to stimulate sediments to settle. Therefore, small dikes are made on the edges of the mudflats to slow down the water velocity. In other areas, the border between the polder and the water is very abrupt and consists only of one main dike.
The view over the water is very open and expansive. The water surface and the sky are both very visible. The perspective from the water has the same openness. The mudflats are only accessible by boat and therefore create a unique nature experience.

Spatial experience

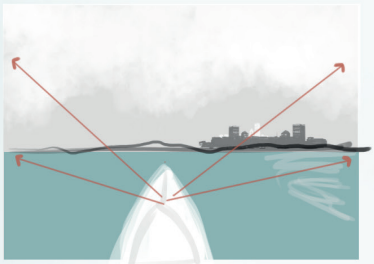




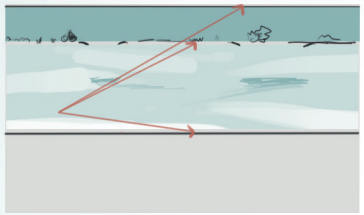
Shape of the slib catchers and corresponding slib plates



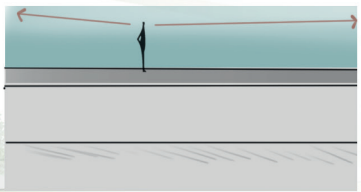
Slib plates are only accesible by water, clear view on human work and nature



A panoramic view from water but always bounded by land

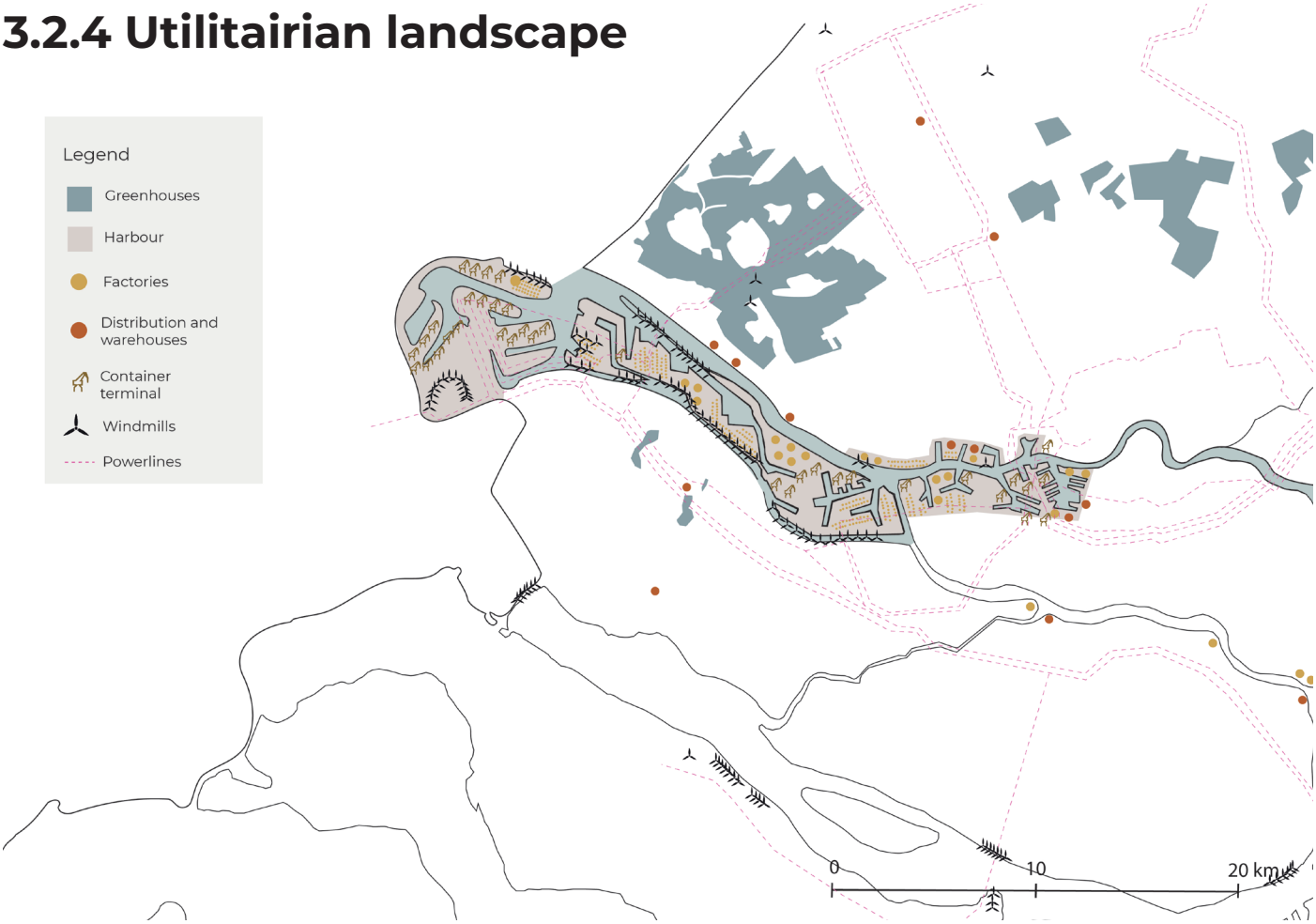


Small slib catchers create a tidal area with strict seperation from lake



Dike seperates polder land and Haringvliet and provides for a panoramic view

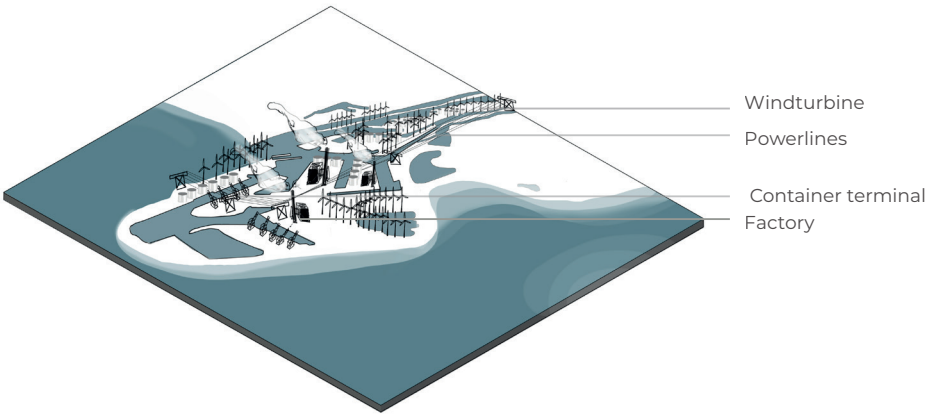
3.2.4 Utilitairian landscape



 Retrieved from: https://beeldbank.rws.nl, Rijkswaterstaat, photo by: Joop van Houdt

Development of the utilitarian

The development of the port of Rotterdam is directly relatable to the population growth and changes in society. There is a higher demand for goods and electricity, and due to globalisation, we trade more with other parts of the world than ever before. The harbour and the industry became more and more important. Over the years, the port of Rotterdam extended to the west and sea inwards.



Landscape shapers

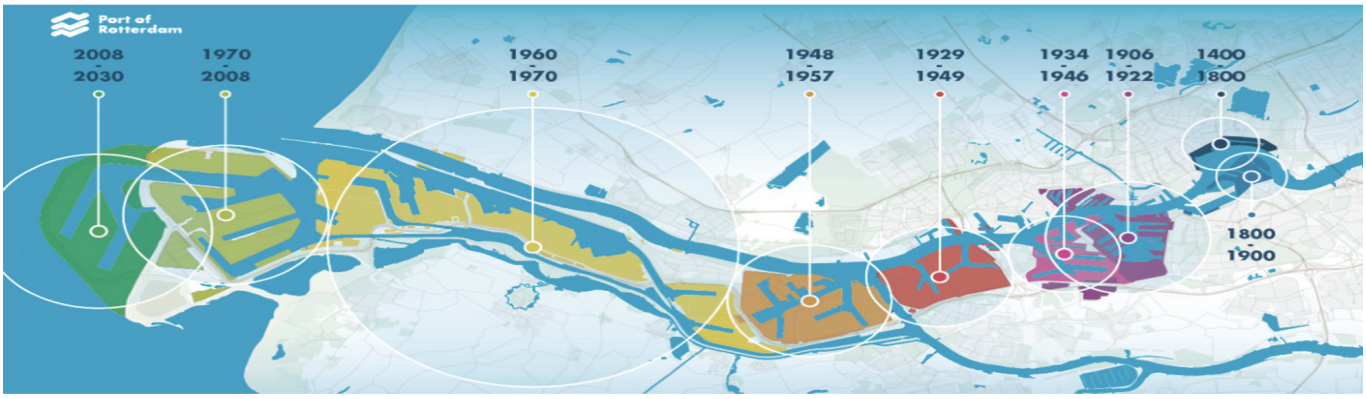
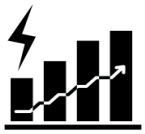


Image retrieved from: PortofRotterdam.com



Electricity demand

Production of goods

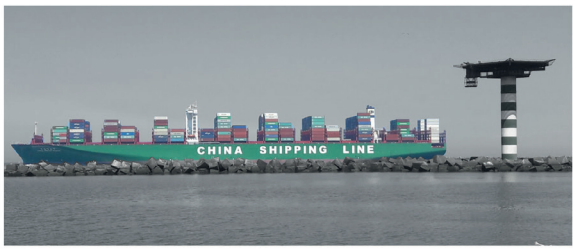
Dredging and dikes

Marine traffic and trade

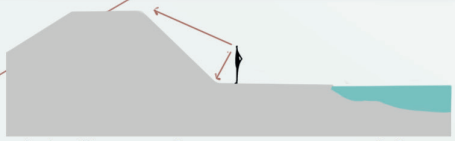
Spatial structure

Spatial character

The harbour needed to expand. Humans created the land by dredging and filled the land with electricity generators, factories, distribution centres and other utilitarian buildings. To protect the newly generated land, dikes were built.
The spatial structure is derived from a providing perspective for humans whereby order and efficiency were important aspects. The high rise of the wind turbines, powerlines and chimneys are visible from a far distance. However, standing at Maasvlakte, the sea is only visible occasionally because of the high dikes surrounding the land. Contradictory, the Maasvlakte is clearly visible from its surroundings but from standing within, the surroundings are not.



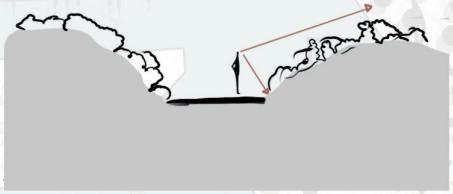
Spatial experience



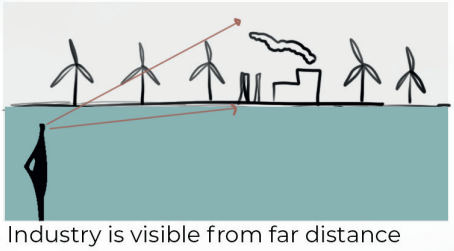
High dikes enclose most parts of the Maasvlakte

The sky is occupied, the view is always interrupted

The industry creates a landscape that is always partially obscured, this creates a sense of mystery



Very high dikes enclose the Maasvlakte



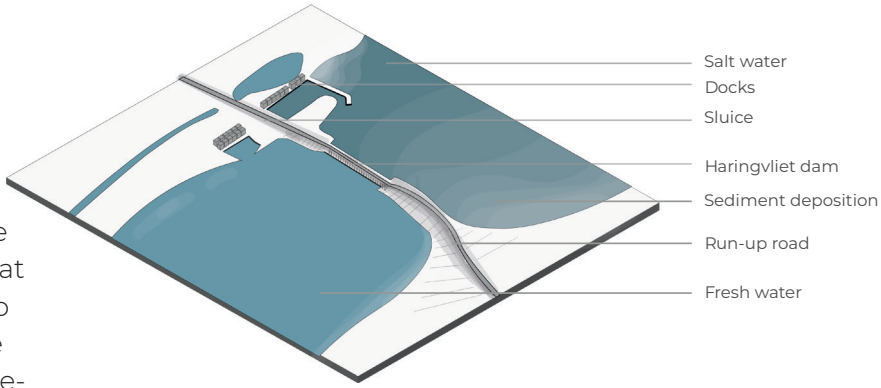
Industry is visible from far distance

3.2.5 Landscape of the engineering works

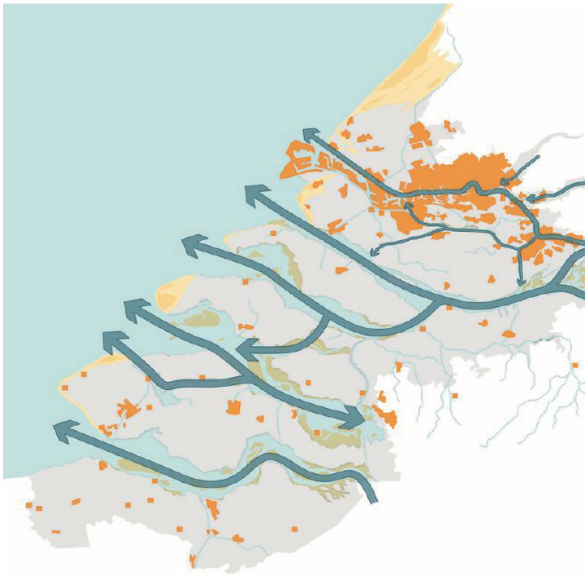
 Retrieved from: Rijkswaterstaat, photo: Siebe Swart

Development of the engineering works

The entire system of sluices at the Southwest delta was part of the Deltaworks project to increase flood protection. The structures cut of the sea-arms near the sea and the rivers at the inlet of the sea-arms. In his way, the outflow and water level of river water can be regulated.
The focus of the Deltaworks was on protecting the land from high water and storms on sea. The situation where there is high water at sea and high water in the rivers, was not considered. The flood threat by high river water levels has increased to due climate change. This means that the river dikes and dams need regular maintenance and strengthening. Nowadays, the focus is shifting towards a situation where we adapt to climate change and create sustainable and multifunctional measures.

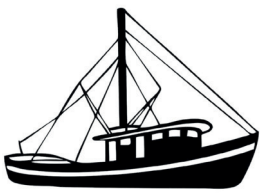


Landscape shapers



Flood defence structures

Cultural movements



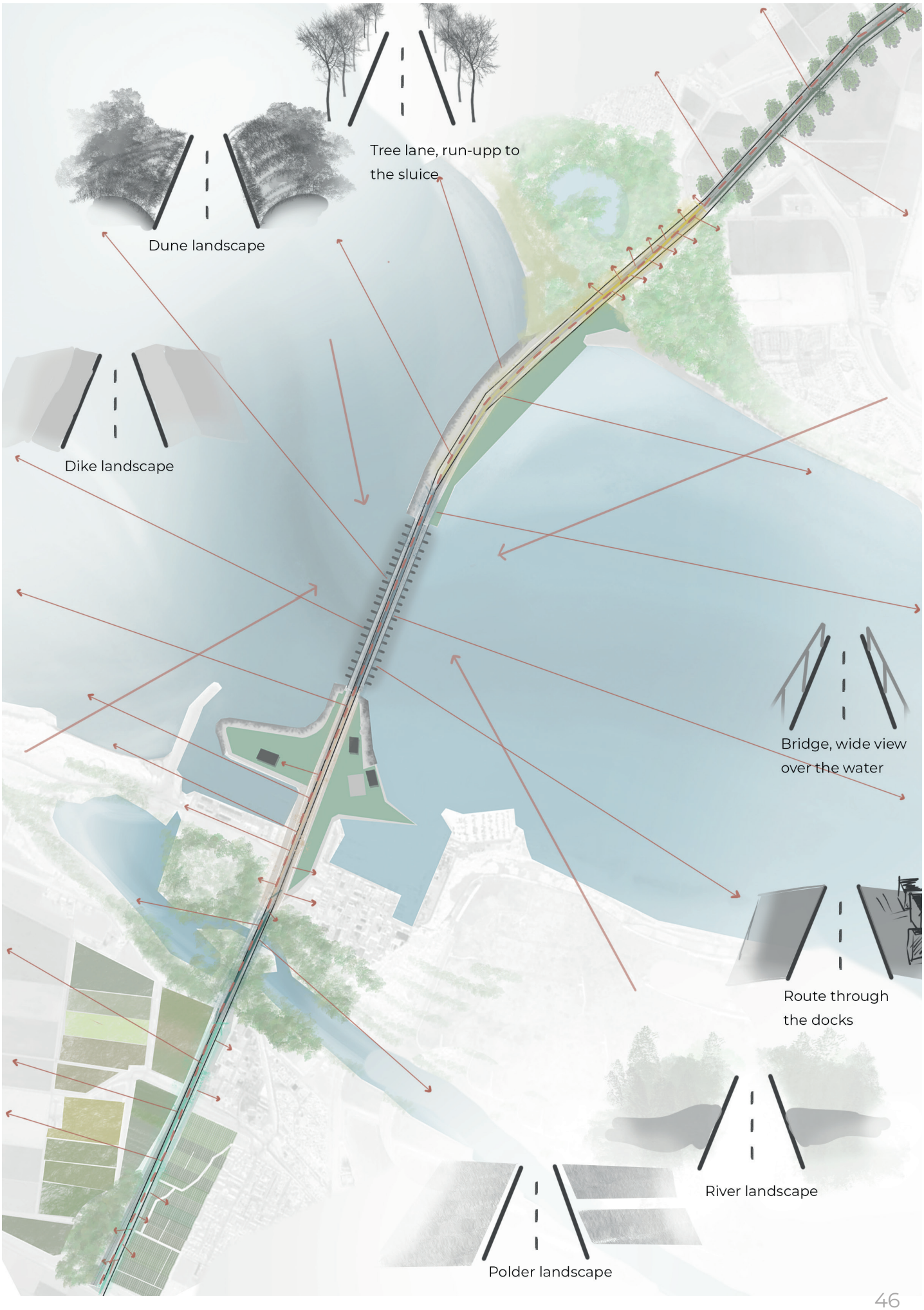
Fishery and trade

Spatial structure

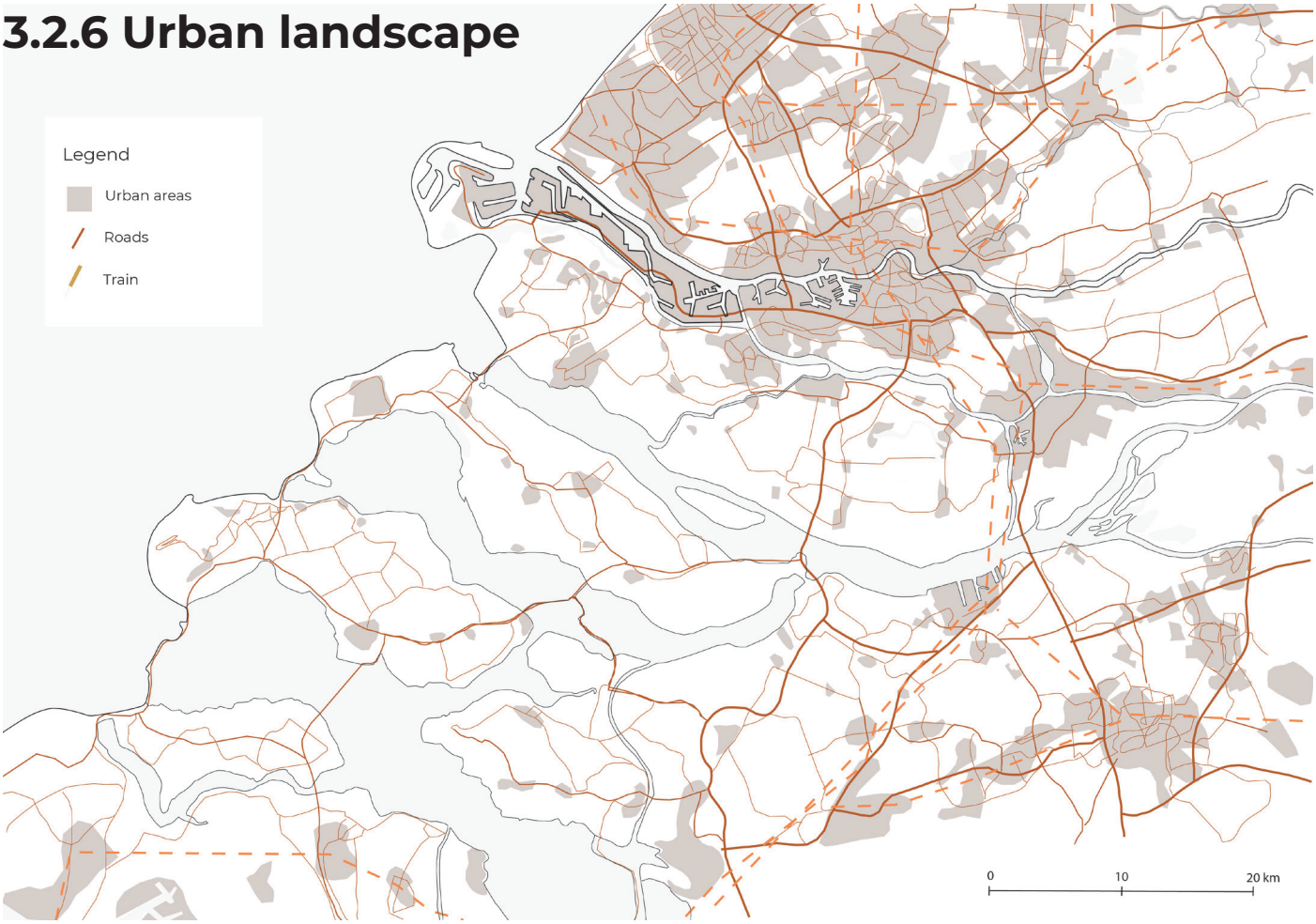
Spatial character

The dam, dikes and sluices separate the river and sea. From that perspective, the dam is a divider in the landscape with a clear seaside and sea-arm side. The Haringvliet dam is visible from a far distance because of the flat water surface in front and the large size of the dam.
From another perspective, the dam, and more specifically, the road upon the dam, is a connector. It connects the mainland with the island Goeree-overflakkee. The road itself is a journey through different landscapes. The rows of trees make lane from the road in the polder and create some sort of run-up for the sluice. The route continues through a dune area, a dike area, a bridge between the Haringvliet and sea, and runs down via the docks, over a river and ends up in the polder. The entire sequence is a journey an sich. The surrounding landscape reveals itself as a film.

Spatial experience

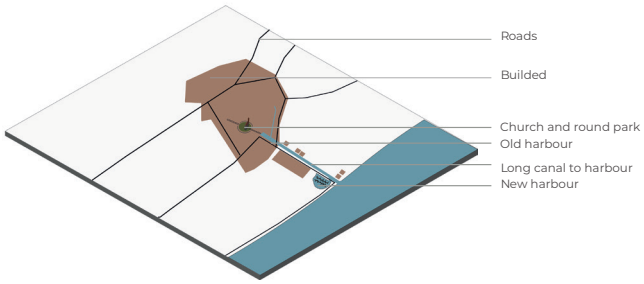


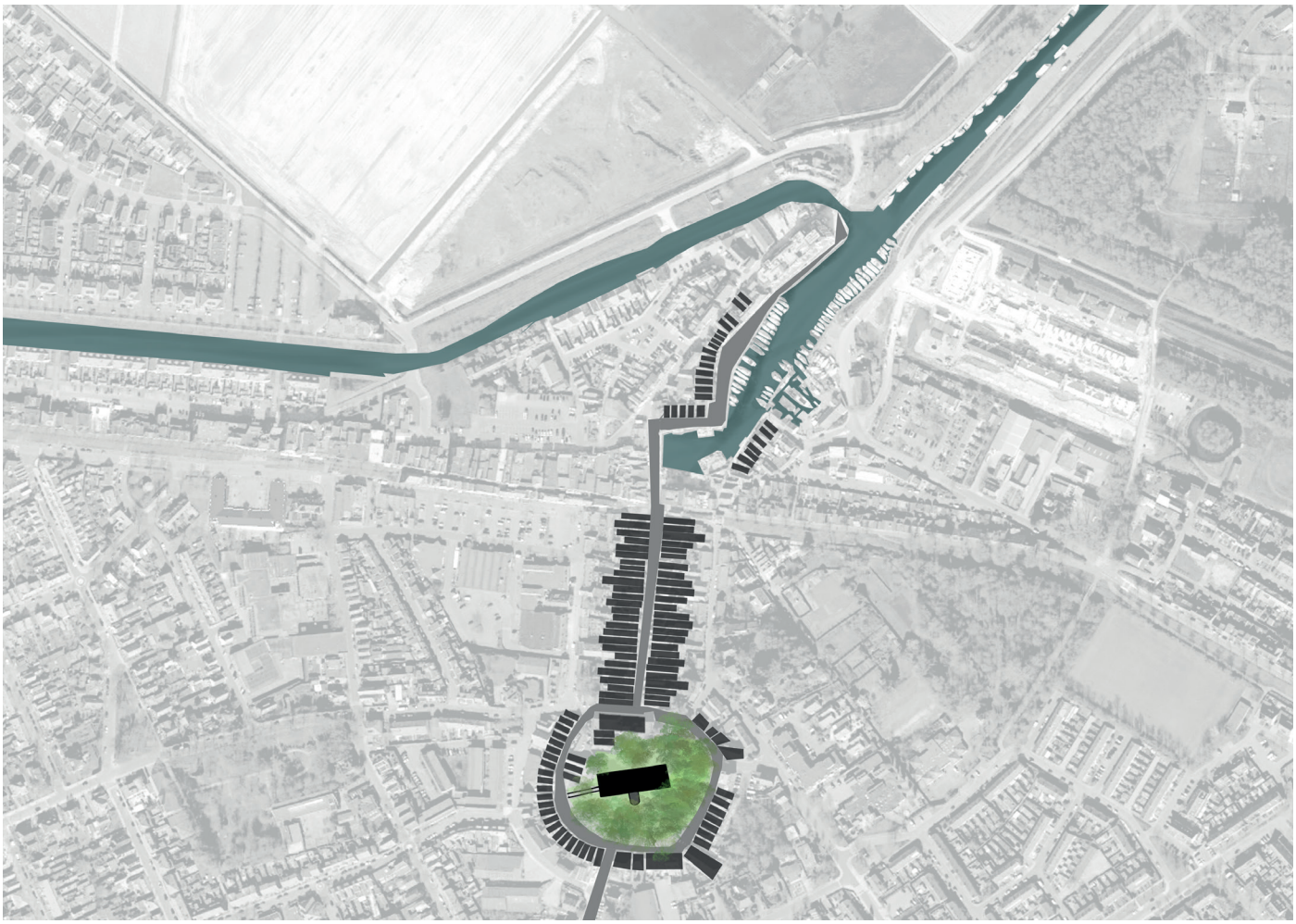
3.2.6 Urban landscape



Retrieved from: https://beeldbank.rws.nl, Rijkswaterstaat

The sea isolated the islands of Zeeland and South-Holland for a long time. Because of this, the inhabitants of the island were self-sufficient and had their own robust culture. The fishery, farming, the community and religion is very important for them. In the city plan the church is the centre point, the harbour with access to the sea is the market square.
Floodings occurred often; the battle against water is as old as people inhabit the area. Flood protection is therefore an important issue.



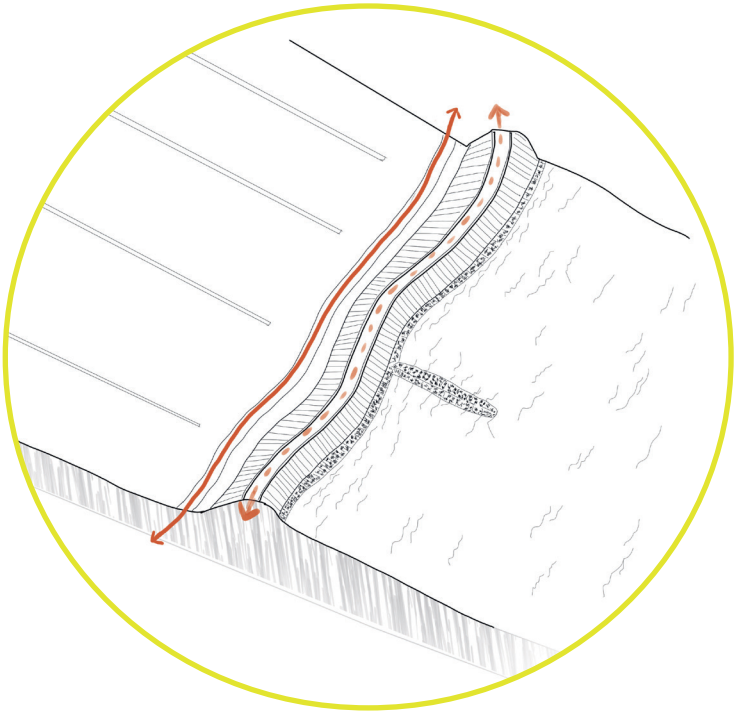


3.2.7 Overall landscape structure

The Haringvliet Delta is a very **rich landscape in structures and experiences**. Each landscape type **adds value** to this delta landscape in different ways. However, each landscape type **stands on its own**, with there own systems and experiences. **The delta is a fragmented landscape.**

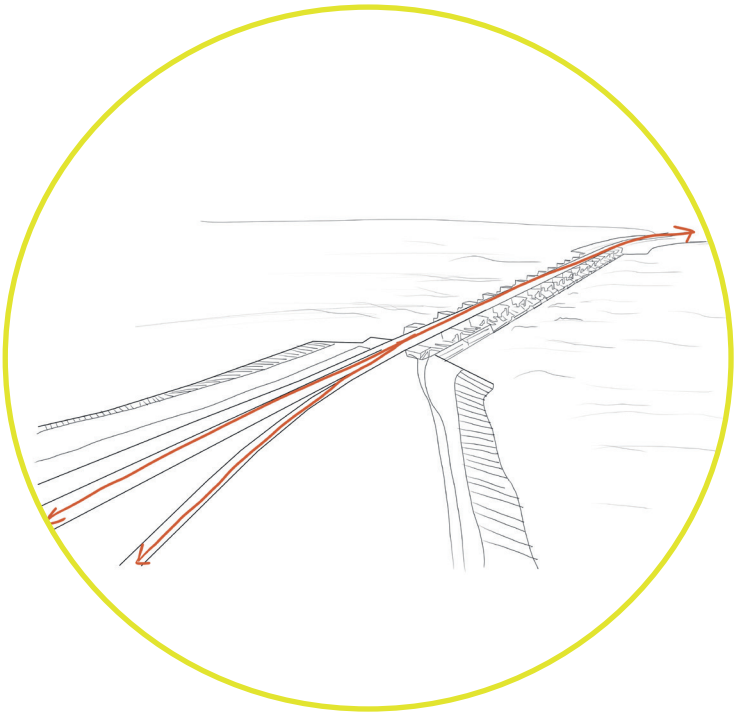
3.3 Transition between types

The characteristic of the edge between two landscape tyes can vary a lot. The first characteristic of the edge that separates the polder and the sea arm is a small single-line interface. The line also works as infrastructure for cyclist and pedestrians. The slopes are steep and there is no crossing or sight possible from the polder to the water.
The Haringvliet dam has a similar characteristic, although with more emphasis on infrastructure. The third edge is softer. Tide and wind shape the dune landscape and beach. Here, people recreate to be in nature. This edge is more about the landscape experience and ecology itself than infrastructure or function.



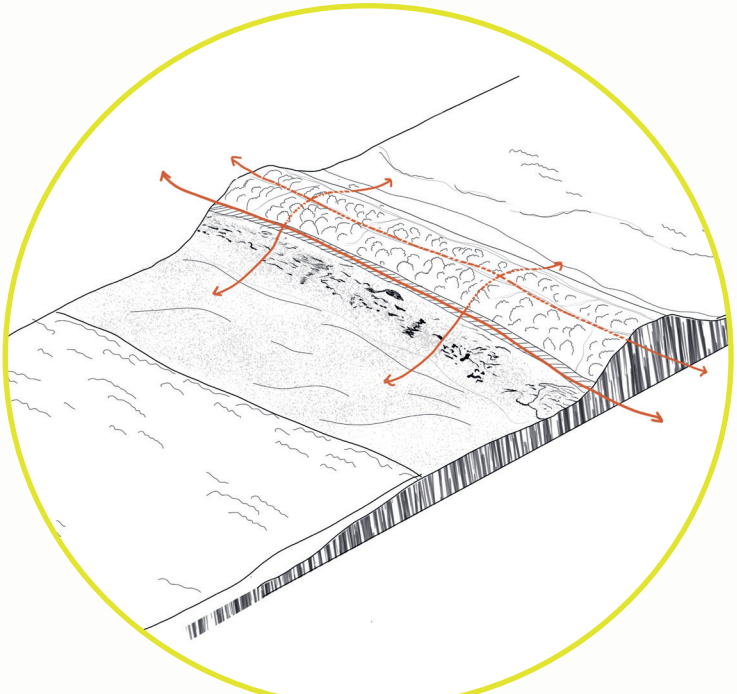
1. Polder - Haringvliet

Narrow single line edge that also guides the infrastructure. Only for linear connection, no connection from polder to the water edge.



2. Sea - Haringvliet

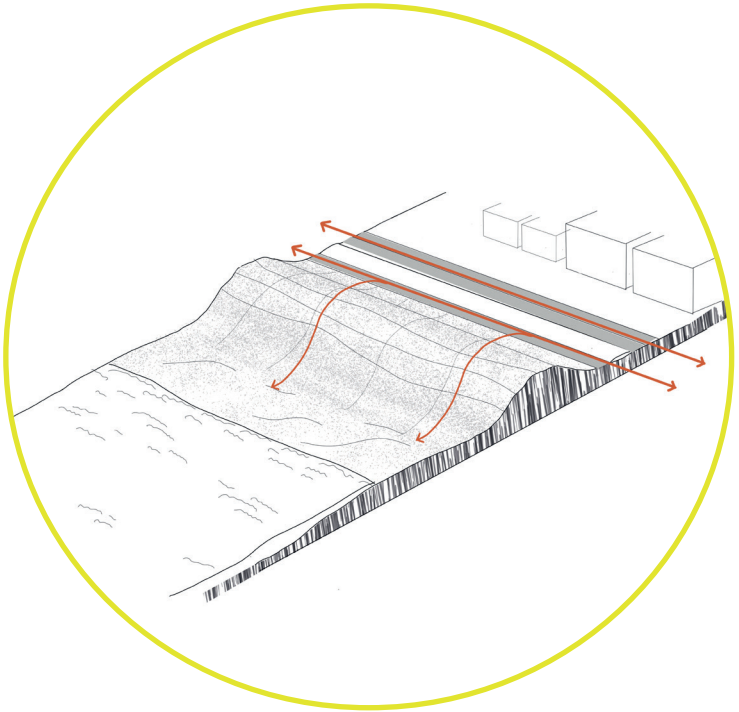
Rich scenery when moving over the dam. Standing next to the dam, the dam is a visual barrier.



3. Sea - Lake

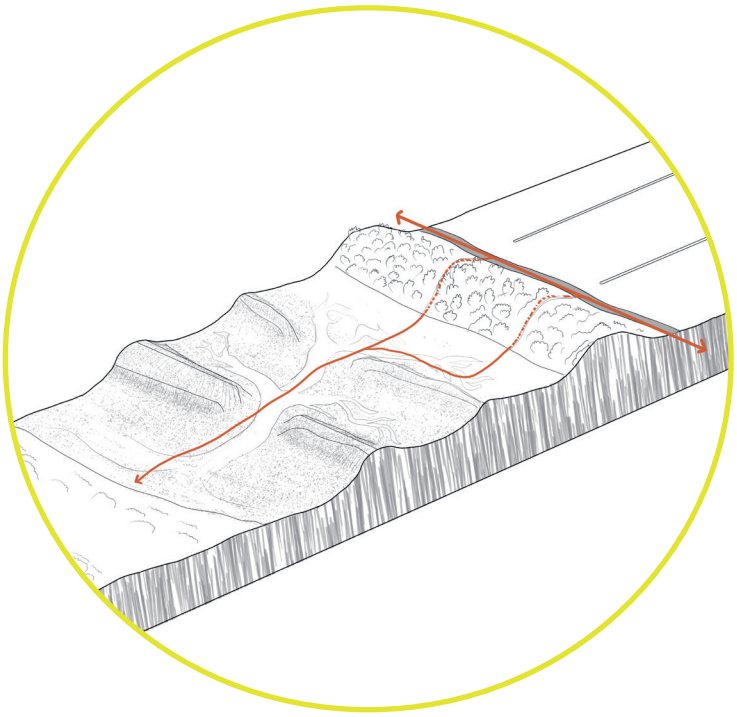
More a soft edge where natural dynamics influence the shape. Open for hikers, mainly longitudinal connection.

The fourth transition is the edge between industry and the sea. This is a dike in dune situation. The transition is a single line interface without infrastructure. The crosswise connection is important for people to get to the beach. Here, recreation is an important characteristic. The sea-polder transition stretches out over a long distance. Natural processes between land and water shape this landscape in a very dynamic and diverse way.
This space is crucial for ecology and recreation. The last edge is a hard line between the Haringvliet and the polder. This edge does not serve recreation, infrastructure or ecological function but only acts as a barrier.
The characteristics of the edge between different landscapes can be designed for multiple purposes and with many different outcomes. For example, a soft wider transition allows more space for natural processes to occur, resulting in more different biotopes and habitats.



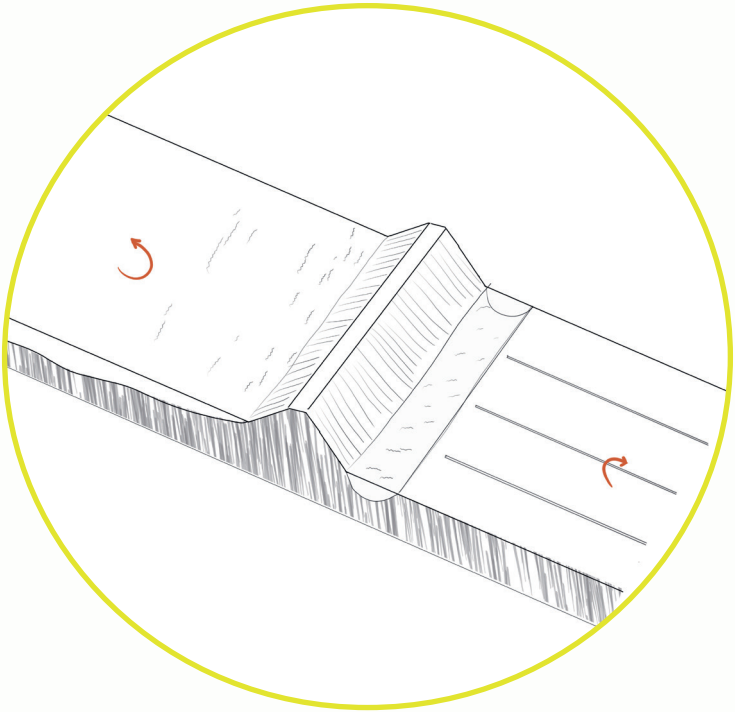
4. Sea - Industry

A dike in dune, crosswise connection for beach visitors. A narrow row of dunes with little ecological value or dynamics..



5. Sea - Polder

Large crosswise connection between sea and polder with a lot of dynamics. Interesting for visitors and ecology.



6. Haringvliet - Polder

Single line interface. Not accesible for people, visual barrier and no ecology value due to concrete coating.

3.3.1 Transitions as key feature

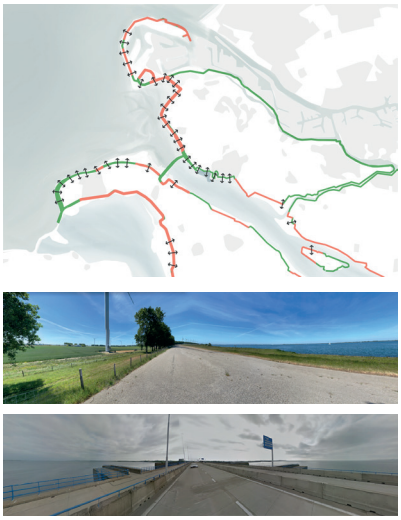
The dikes and dunes in this area form a connected structure but cannot be experienced as such. The dikes/dunes are always the horizon from a ground-level perspective, whether you stand in the polder landscape, sea-arm or utilitarian landscape. The dikes and dunes form the precious biotope of land/water. The transition to land and water is something to consider more consciously because it creates space for experience, recreation and ecology. At least the dike and dune are the biggest connecting infrastructure in the delta. However, they cannot be used as infrastructure. Often the dikes are not accessible or don't provide a sequence route.

State of existing dikes and dunes

Enclosure and connection by dikes

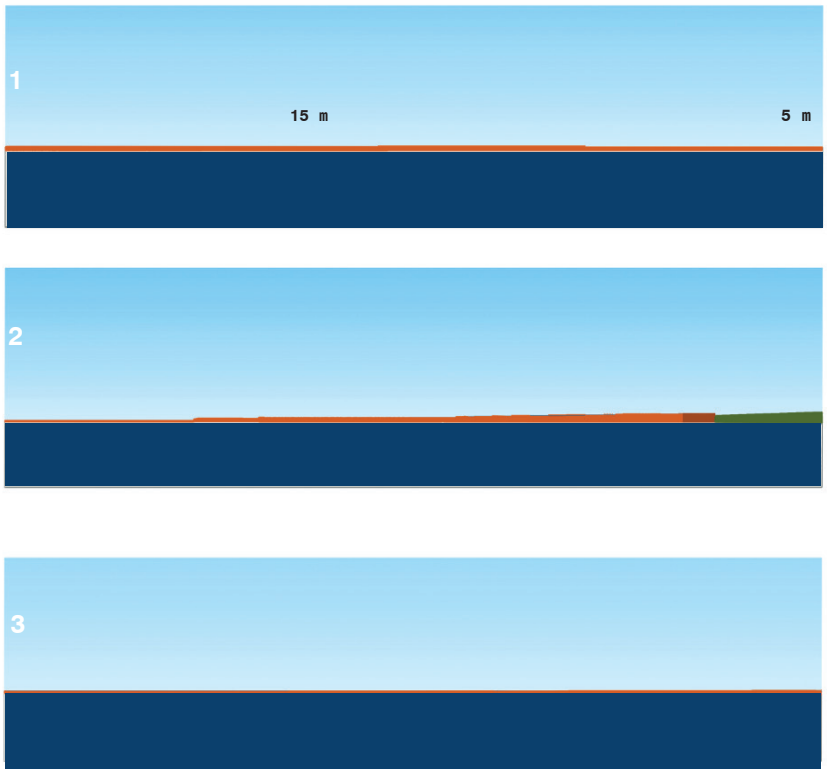
Interface by dikes

Infrastructure



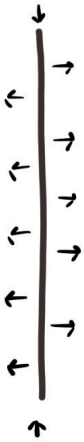
View on new dikes and dunes of Delta 21

view direction

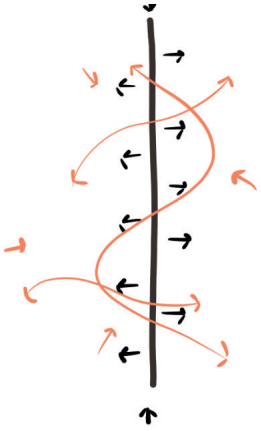


Connection

The character of the interface defines the area as being experiencea-ble as a whole or in enclosure. It can work as an edge or be part of the regional infrastructure.



Boundary element



Binding element

Gradient

The character of the interface in the delta is too often the monoton-ous shape of the hard edge. There is no space for natural formation of biotopes, ecology gets little chance.

Seperation of systems

Transition of systems

3.4 Conclusion

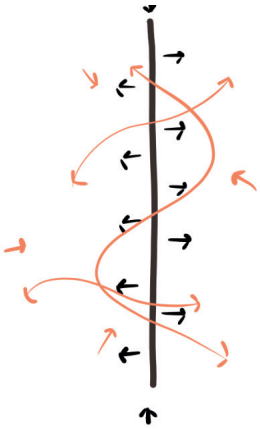
The Southwest delta is fragmented into different landscape types which are strictly separated from each other spatially and systematically. Natural processes do not shape the landscape but human regulation is. This means that natural dynamics do not create the dynamic estuarine experience that belongs to the Southwest delta. The region is now better protected against floods but also more monotone.

The natural processes are still present and can be stimulated by opening the Haringvliet sluice and by replacing the hard edges into more gradual transitions with space for natural adaptation. This is where the opportunity lies in connecting the diverse landscape types to each other with interesting and valuable transitions that are inviting to explore the diversity of landscapes in the region.

By following the structure of the natural processes and the natural biophysical landscape, the starting point for the design can be achieved. This natural landscape can be read and used to introduce Delta 21 in this landscape.

3.4.1 Challenge and opportunity

The analysis brought me insights in what challenges and opportunities the region has. These challenges and opportunities will guide the design exploration for the new Delta21 landscape.



Challenge:

Get rid off the hard edges and to return the estuarine environment and experience without comprising the protection against floods.

Opportunity:

Create one dynamic estuary by implementing more gradual dynamic interfaces for the Haringvliet and Delta21 to reintroduce the estuarine landscape in the Haringvliet region that can be experienced as a whole.

4. Design principles and guidelines

4.1 introduction

In this chapter, the derived knowledge is transformed into a set of design principles that can be used as building blocks for the design. The analysis showed that the dikes are too often a single barrier that only fulfils the purpose of flood protection. To create softer transitions, the dike must be put into different perspectives to see how to serve other values besides flood protection and create more space for dynamics in the land/water transition. In this chapter first conceptual statements of multifunctional flood protection measures are presented. Second, the conceptual design principles are translated to more applicable design choices.
Third, some case studies present the transition between land and water as a soft or multifunctional gradient. From the existing case studies, lessons can be learned in how to apply the design principles.

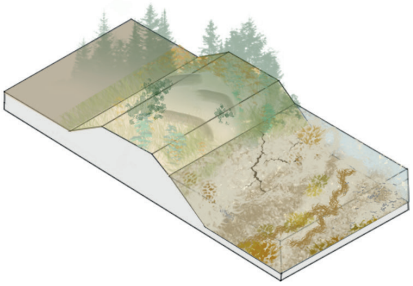
Design principles are a result from readings from:

Book: Dutch dikes (2014) by LOLA

Book: Scherpe grens (1988) by Staatsbosbeheer Utrecht

Project: Rijkere Dijken (2013) by Delva.

Website: Ecoshape.org, 2021



Dynamic dike

Sediment accretion by tide

Sediment accretion by river slib

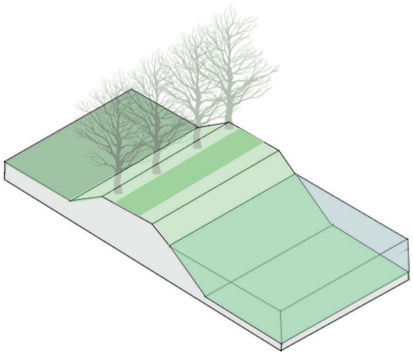
Toplayer movement by wind

Erosion by tide

Erosion by river discharge

Ecological succession

Sensible to water forces



Spatial dike

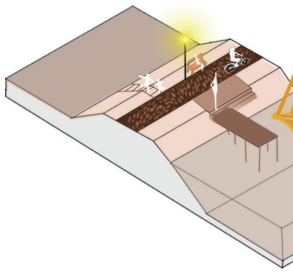
Profile (view towards and view top)

Material and arrangement (view towards and view top)

Movement and trace

Width dike

Height dike



Social dik

Dike as infra

Dike for recr

Dike as land

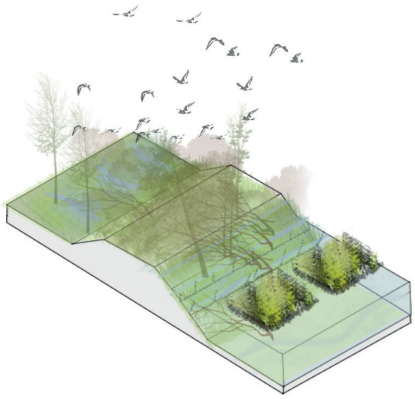
Dike as herit

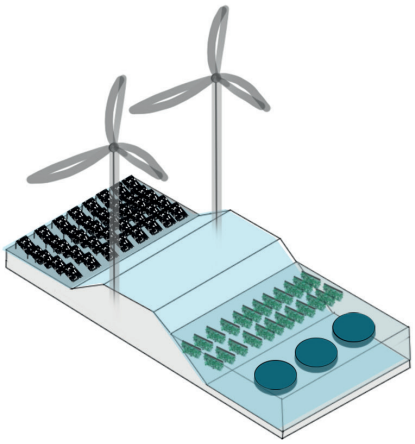
Orientation

Playing

4.2 Conceptual design principles

The dike is more than a flood protection measure.
The first principle shows that the dike is in constant dialogue with natural processes like tidal movements, sedimentation and succession. As a result, the dike requires maintenance. However, these dynamics can also be advantageous if the sediment is captured to strengthen the dike naturally.
Spatial dike, the dike has an enormous spatial influence on the Dutch landscape. Being aware of that will influence the way a dike can be designed. Third the social dike, dikes create infrastructural networks, can be a recreational hub and can give identity to a place. The fourth dike is the ecological dike. The material, vegetation, gradient of wetness determine the ecological life that is possible on the dike. The fifth dike is the economic dike. Changes of waterlevels can generate energy and the elevation of a dike can make the place more suitable for wind turbines.
Being aware of these different perspectives, although conceptual, helps to become creative in the way a flood protection measure can turn out.





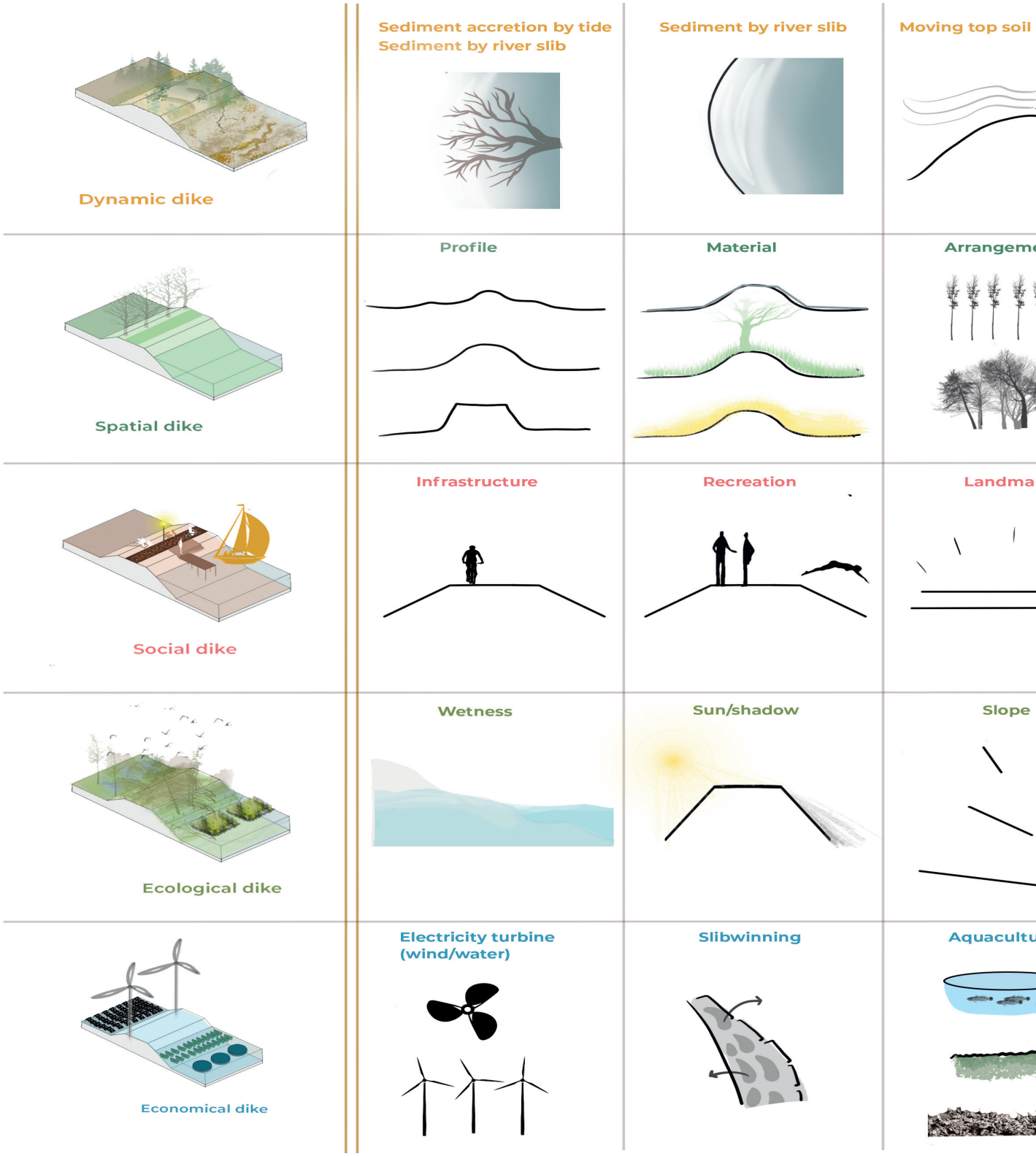
e
structure
eation
mark
tage and storyteller

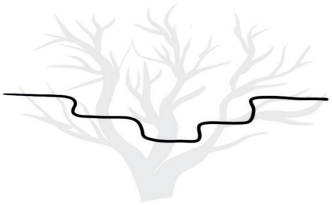
Ecological dike
Wetness
Sun/shadow
Slope
Material
Maintenance
Wind/water/gravity force

Economical dike
Electricity generator: windturbine, waterturbine
Slib winning
Aquaculture
Saline agriculture
Waterpurification
Housing or holiday cabins

4.3 Applicable design principles

The conceptual design principles are enriched by applicable tools which can be used when designing the new land/water interfaces.



(wind/rain)	Erosion by tide	Erosion by river discharge	Eccological succession
			
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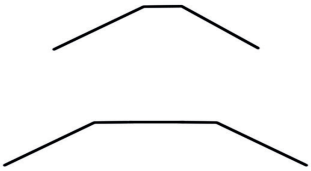
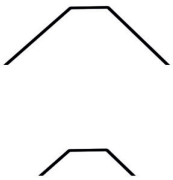
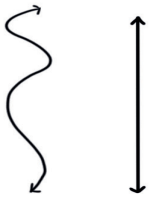
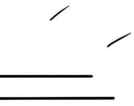
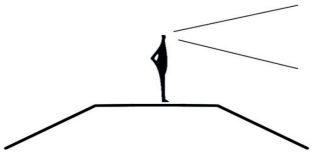
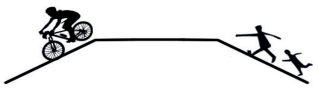
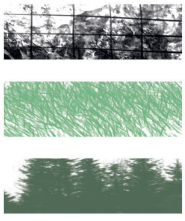
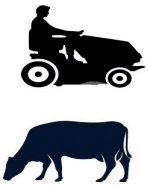
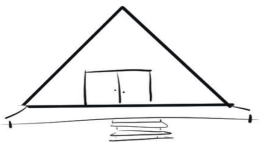
			
rk	Heritage & storyteller	Orientation	Playing
			
	Material	Maintenance	Natural forces
			
ure	Saline agriculture	Water purification	Housing
			

4.4 Case studies

A few existing case studies were explored in depth during the design exploration process. During this process, I continuously looked back to these case studies as a reference. I will briefly summarise each and explain what elements were particularly useful for the design exploration.

4.4.1 Land van Saefethinge

Land van Saefethinge is a tidal marshland in open connection to the sea and the river. Here, a brackish environment has developed which is comparable to the situation at the new proposed estuarine landscape. The size of this landscape is also equal to the size of the new designed landscape with similar conditions. From this landscape I took the dimensions of the creeks, the opening to sea and the ground level elevations as indications for the design.

Retrieved from: Google Earth

4.4.2 Slufter Texel

The Slufter in Texel is a dune breakthrough directly connected to the sea. The water is salt and the dynamics, in terms of wind and tide, are clearly present. Due to these dynamics, the area is thinly vegetated. This case study was used as an example for the area that is more connected to the sea. I also took the dimensions, ground level as indications for the design.

Retrieved from: Google Earth

4.4.3 Coastal zone Katwijk (by OKRA)

The coastal zone in Katwijk is a multifunctional flood protection measure. The landscape appears as a dune landscape, but there is a hidden dike and a parking garage within the dune. The designers also played with the dune's height so that the sea will always be visible from the boulevard. The principle of the hidden dike and measurement of the dune are taken into account for the design exploration.

Retrieved from: Google Earth

4.4.4. Noorwijke duinen, dynamic dunes

The dunes in Noordwijk are a great example of the realisation that dunes are more than flood protection measures. The fixed vegetated first dune row is alternated with bare sand notches where the wind can take the sand. This makes the dune area more dynamic and creates differences in stages of succession resulting in more different habitats.

Retrieved from: Google Earth

5. Design exploration

5. Introduction Design Exploration

The design exploration is done in different stages. 5.1 is about indicating the natural landscape of the project site and to find out how the landscape is shaped by the natural processes. Furthermore, the technical requirements of Delta 21 are also explored, including the relationship that the technical structure has with the morphological processes. In 5.2, the design exploration for a new estuarine landscape that incorporates Delta 21 is presented, which is in harmony with the natural processes. In 5.3, the design exploration continues with the zoning of the new landscape. 5.4 Elaborates on the transitions between land and water and shows how the space is used by ecology, humans, natural processes, food and energy production and flood protection.

5.1 Natural processes and natural landscape

Delta or estuary

The Netherlands started as a delta landscape. Many rivers branches flowed into the sea and created land by sediments. Later, the sea level began to rise and tidal energy became more dominant. The narrow river branches eroded into wide river arms with the characteristic funnel shape and with large brackish environments with many shoals and tidal creeks.

Rivers branch out near sea

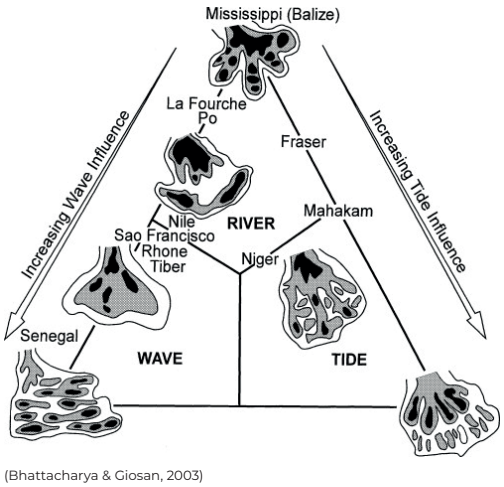
Tidal forces created a funnel shape

Dominating process

Coastal environments can generally be classified on the basis of dominant formative processes, distinguishing: river, tide and wave dominated categories (Yang, Dalrymple, Gingras, Chun, & Lee, 2007). Most coastal systems have a mixed energy system, the morphology of these estuaries will therefore also be a mix. Tide dominated estuaries are often characterized by a funnel-shaped mouth. The tidal channels and their surroundings can be very diverse in intertidal areas and habitats, such as shoals, salt marshes and salt flats. The tidal energy brings a lot of sediments into the estuary. Here, the sediments settle on the shoals or in the tidal creeks or flats. The location of the shoals are not permanent; they often change location due to changes in water levels and discharges (Scanes, Ferguson, & Potts, 2017).
Originally the southwest delta is a tide-dominated / mixed energy estuary (Scanes, Ferguson, & Potts, 2017). The two strong forces are wave and tide. After the deltaworks the tide disappeared, which resulted in a wave-dominated delta.

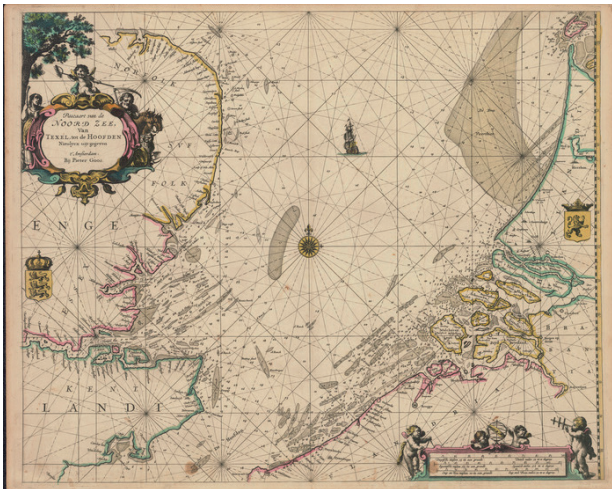
The natural shape of a wave-dominated delta has a smooth longshore coastline. If we look at the ongoing natural processes at the Haringvliet mouth, we see that the morphological changes behave as such.
The old maps show that the dutch delta used to be a tide-dominated delta. Due to damming, the delta transformed to a wave-dominated delta.
The coastline is now naturally transforming into a single line coast without the sand plates and natural island.

By opening the sluices, the tidal energy in the Haringvliet and coast can be restored. This will result into a coastline that is more a mix between wave and tide-dominated delta.



(Bhattacharya & Giosan, 2003)

Kaart van Zuid Holland, Delfland en omgeving Rotterdam, in 1681 uitgegeven door Visscher.
Claes Jansz. Visscher, 1587-1652 Amsterdam.
Retrieved from: oudelandkaarten.eu



Kaart van zuidwest delta,
Naam: pascaart van de Noordzee van Texel tot de hoofden.
Retrieved from: commons.wikimedia.org

Conclusion:
The Dutch delta is an estuary shaped under the influence of tidal forces, by waves and later by humans. The sand ridges are now below sea level and the sand bars near the main islands are reclaimed.

Source: NASA
Retrievied via: https://www.vizualism.nl/satellite-imagery-cloudless-europe/

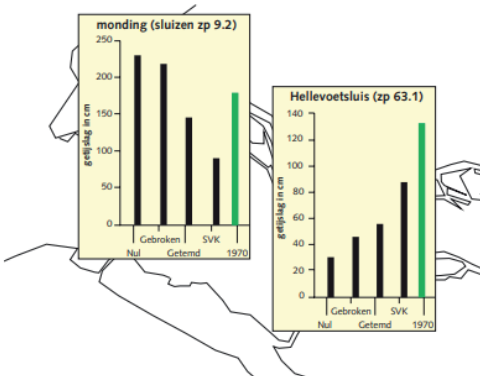
Natural processes - tide and wind

Tidal movements

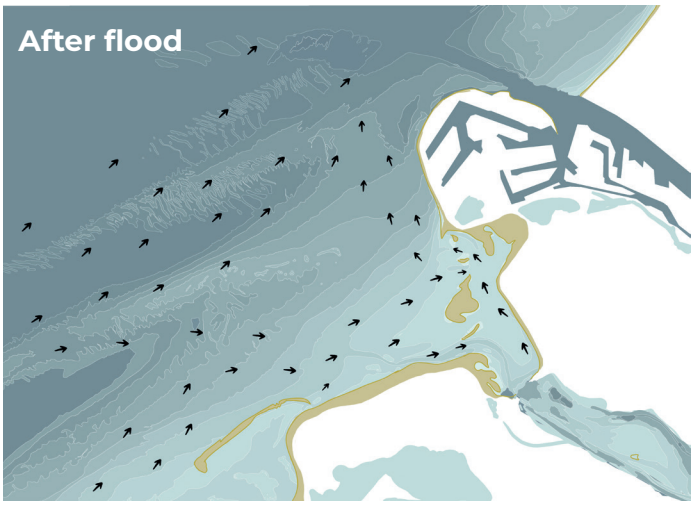
In the situation before the small opening in the Haringvlietsluice, the tidal movement in the Haringvliet was about 30 cm. After the small opening, the tidal differences was increased by 5 cm to 35 cm. The ebb period has a duration of 8 hours and the flood 4 hours.
If the Haringvlietsluice is open in the form of a storm surge barrier, the tidal differences in the Haringvliet would be around 90 cm. In this scenario, the tidal difference at the tidal lake is also approximately 90 cm.
The tidal currents follow a certain rhythm every 12 hours, moving from ebb to flood and back. The directions of the current changes during this cycle. The tidal energy and direction are the main forces for the formation of the intertidal areas and shoals.

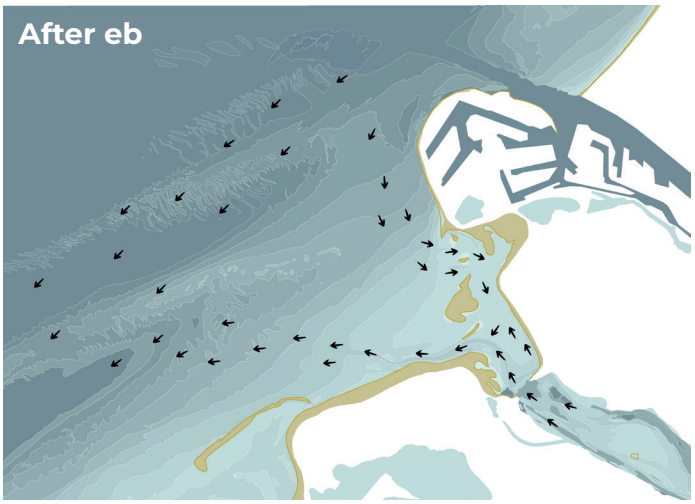
Tidal fluctuations sea (NAP)	High water	Low
Average spring tide:	145 cm	-92 cm
Average tide:	124 cm	-86 cm
Average dead tide:	93 cm	-77 cm

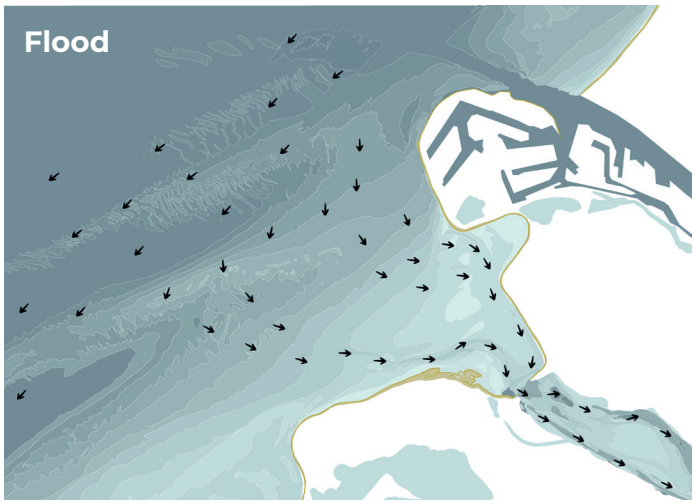
Source: (Storm, Kuijpers, & Harmsen, 2016)



Source: (Paalvast, Iedema, Ohm, & Posthoorn, 1998)



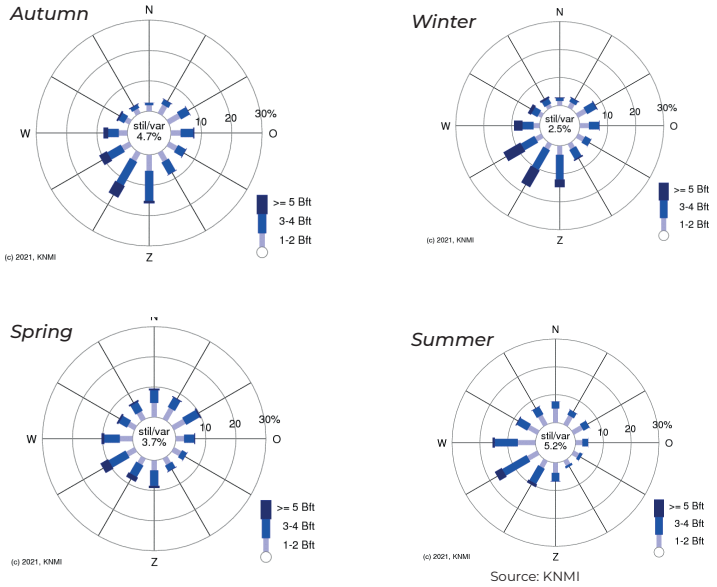




Wind & Waves

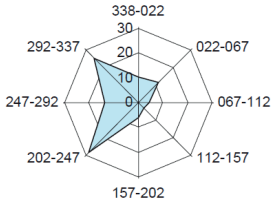
The dominant wind direction is from the southwest. The dominant wave direction and wave height corresponds with this and is also from the southwest. With high water levels, the waves and gusts of wind hit the shoreline perpendicular and by that eroding the coastline. Waves from the other direction also change the morphology of the coastline. Northwestern wind pushes the shoals more land inwards.

Average wind direction

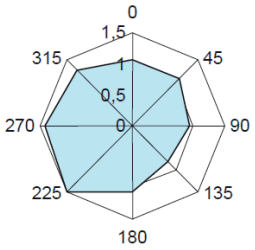


Source: KNMI

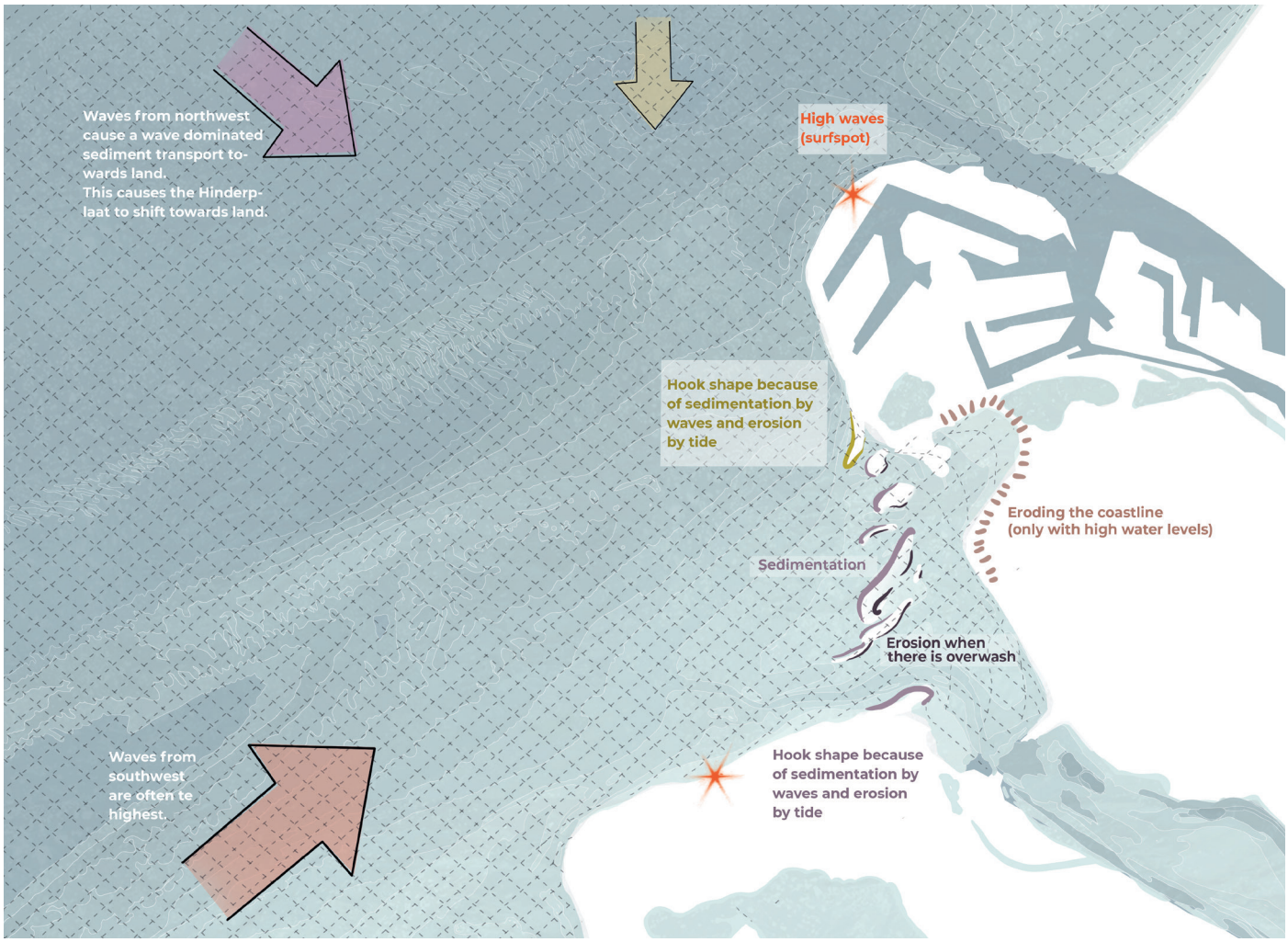
Dominant wave direction



Average wave height (m)



(Stam, Groen, & Walburg, 2002)
Measures between 1979 - 1998



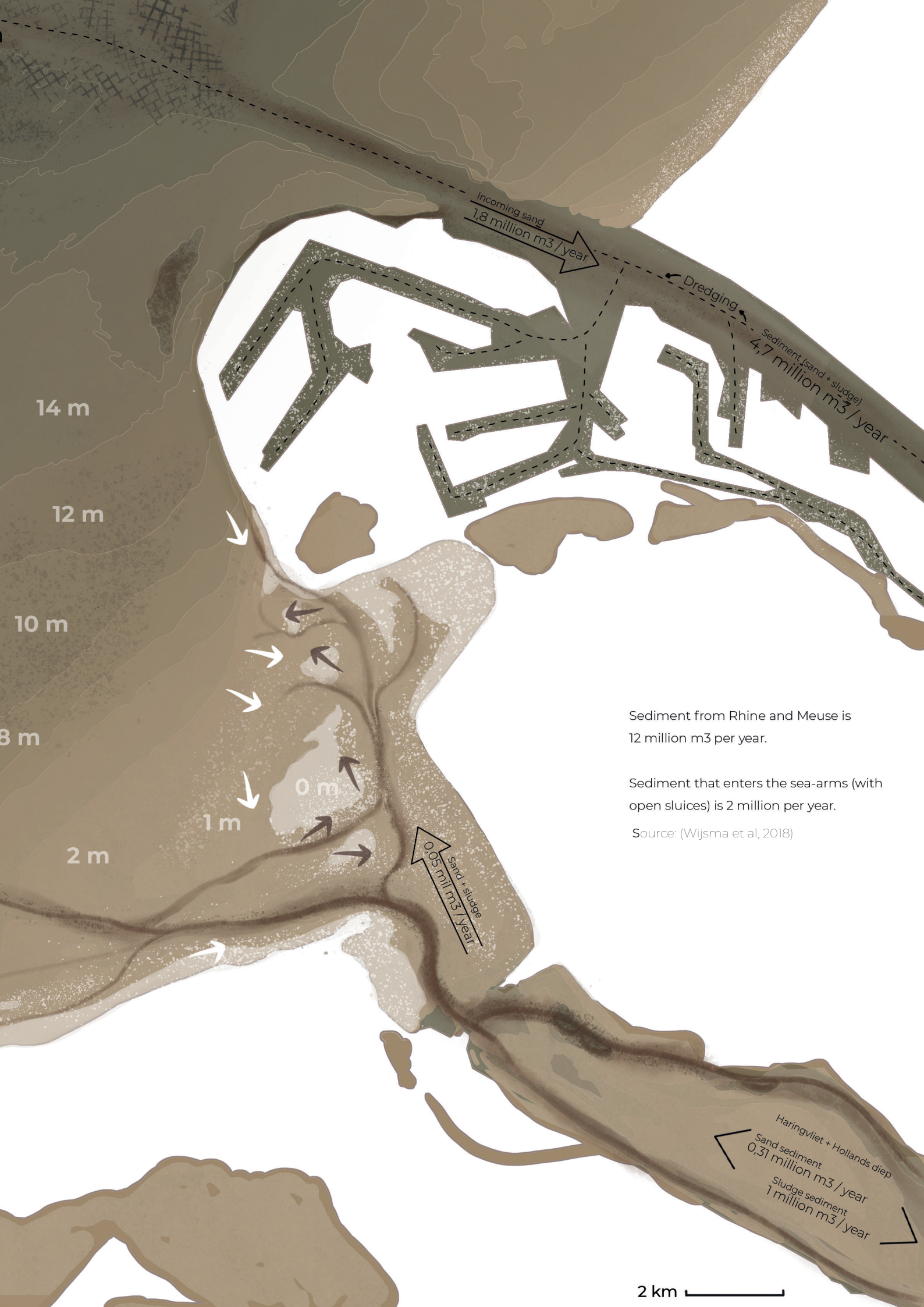
Source: (Stam, Groen, & Walburg, 2002)

Morfology

Sand is always transporting from one place to another. It settles in calm waters such as the harbour and is eroding in moving waters. Dikes and dams upstream the rivers hold a lot of sand. The Southwest delta cannot depend on silt and sand from the rivers to grow with sea level. Parts of the sand and silt that does end up at the Haringvlietmouth is sedimenting at the wrong locations and needs to be dredged.
With the sea level rise, the demand for more sediments in the systems increases as well. Sea level rise without increasing sediments would devastate the intertidal areas and shorelines. The input and distribution of sediments is therefore really important to maintain a healthy and safe estuary.

Conclusion
The dominant direction of the main sea current and the sand ridges on the seabed is from southwest to northeast. This dominant force and natural direction is something to take into account for the new landscape layout. Second, the area just outside the Haringvlietdam is very dynamic in terms of tidal currents and sediment movement. This is an opportunity for dynamic nature.

Source: (Stam, Groen, & Walburg, 2002), (Mulder, Cleveringa, Taal, van Wesenbeeck, & Klijn, 2010), (Noordhuis, 2017), (Rijkswaterstaat, 2013), (Mulder, et al., 2012), (Van Winden, et al., 2010)



Sediment from Rhine and Meuse is 12 million m3 per year.

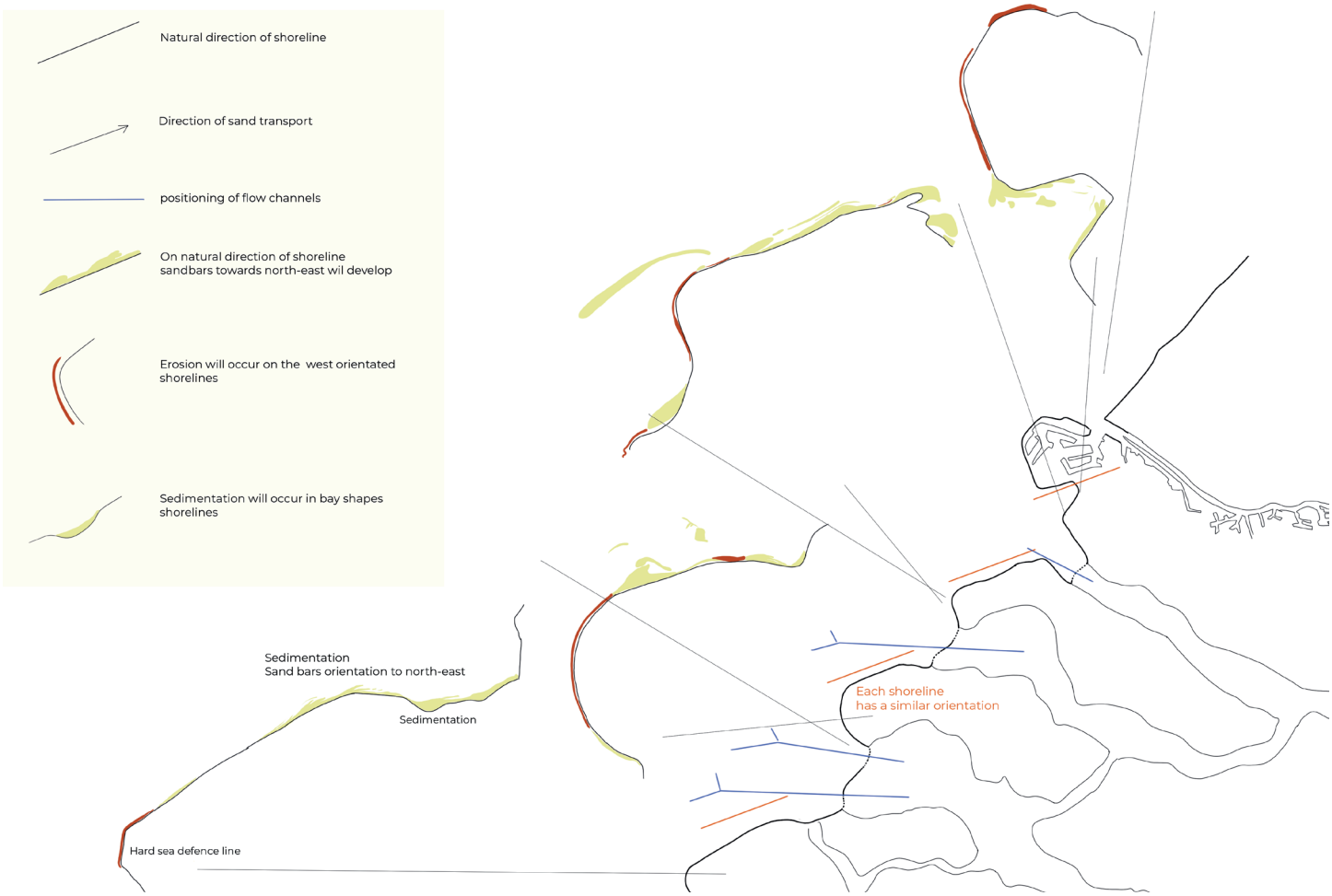
Sediment that enters the sea-arms (with open sluices) is 2 million per year.

Source: (Wijsma et al, 2018)

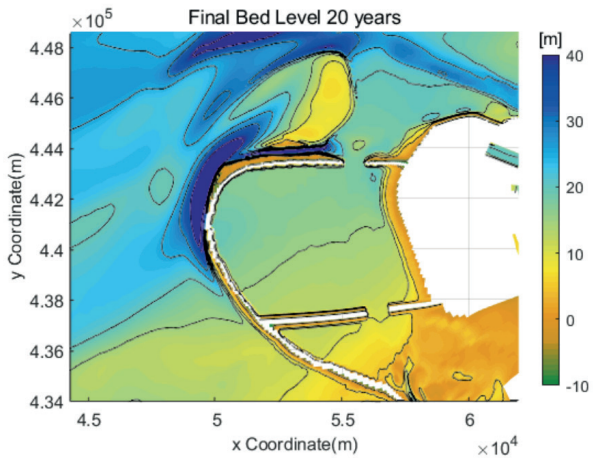
Dynamics of the shoreline

By taking a close view at the situation of the existing shorelines, information can be derived. Erosion preventive measures on the beach indicate erosion, wide beaches with sandbars indicates sedimentation, the orientation of the coastline and channels indicates the dominant natural forces.

Conclusion: The outer edges of the island heads are erosive. The dominant coastline direction is southwest to northeast, shaped by the dominant flow current of the sea. Designing the new landscape layout with this direction in mind will create less resistance from natural forces.



Earlier graduation projects



(d) Bed level after 20 years

Master thesis:

Zhaoyi Li (2020), Large-scale and local morphological impact along the northern side of DELTA 21, TU Delft.

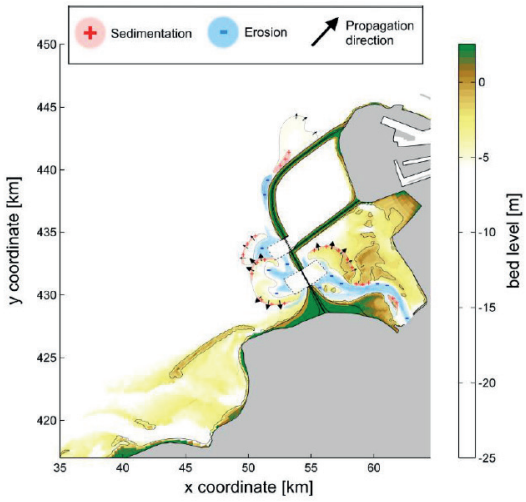


FIGURE 51: CONCEPTUALIZED MORPHODYNAMICS AFTER 5 YEARS

Master thesis:

J.R. Ijntema (2021), Initial morpholdynamic changes in the Voordelta in response to the Delta21 interventions, TU Delft.

5.2 Technical requirements Delta 21

The plan of delta 21 has some technical requirements that need to be taken into account when designing the new estuarine layout. The most important requirement is the pumping station and spillway that need to stay clear from sediments, and second, that the entire area can be closed off by a storm surge barrier, and third, that the slopes of the energy lake and the beaches will not be too steep. The new layout must be in harmony with the natural processes. In earlier graduation projects, students research the morphological behaviour of the delta when implementation the existing layout of Delta 21. This gives great insight into the location of erosive forces and sedimentation. The erosive forces take place on the outer edge of the shape, the northwest side. This can be confirmed when looking at the shorelines at the Southwest delta. Erosive preventive measures were taken at the outer edges of each island head. Sedimentation is taking places in lee bays facing towards the east. Another point of interest is the natural direction of the coastline. All island heads are lying parallel to each other. This is the result of natural morphological forces and is the natural shape.

Technical requirements

Dunes at least 400 meters (width)

Energylake surface minimum of 24 km²

Pumps sea-energylake 2 km long

Pumps tidal-sea 1 km long

Stormsurge barrier sea-tidal lake

Depth energylake -25 meters

Slope energylake minimum 1:10

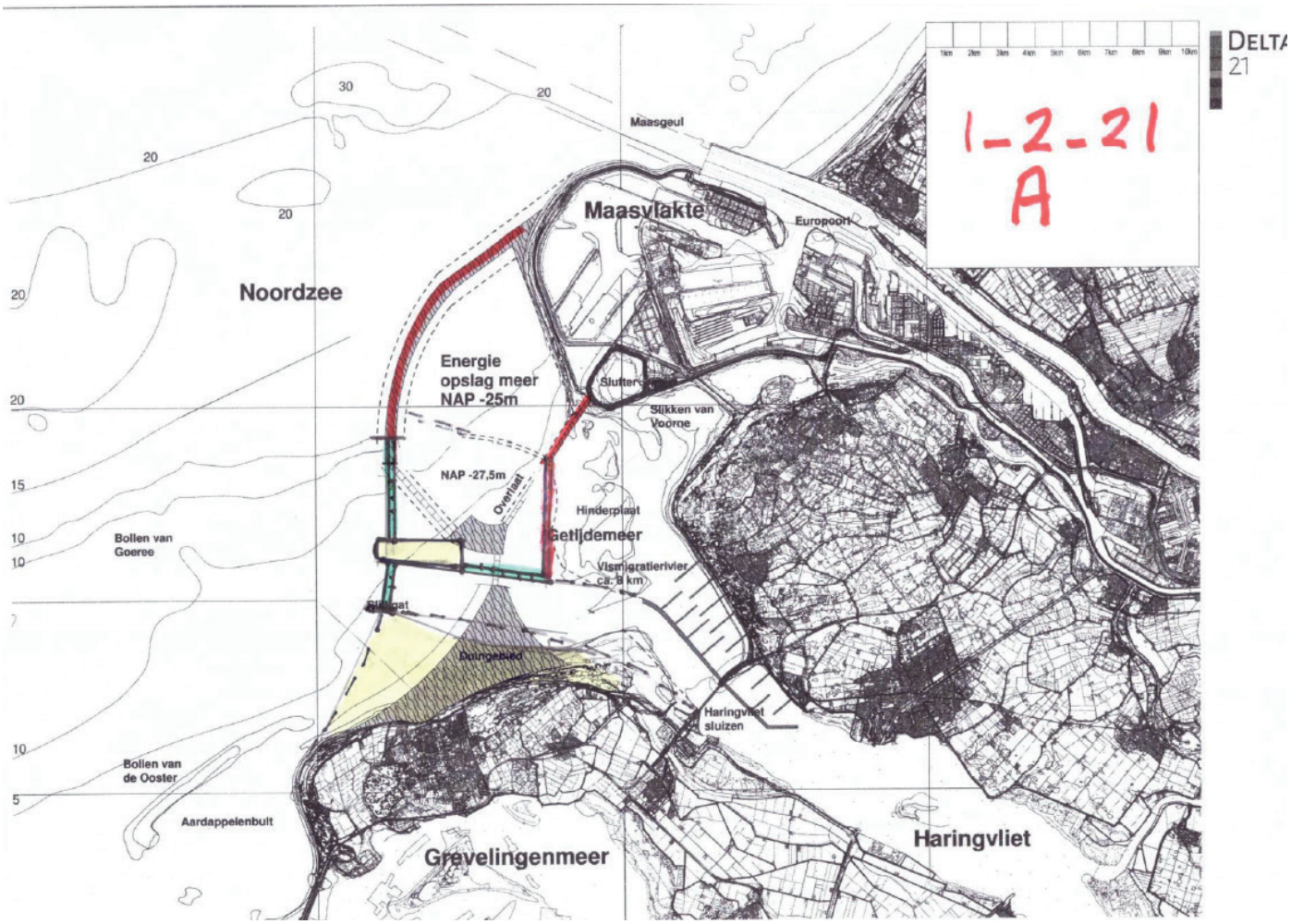
Slope beach minumum 1:50

Water fluctuations energylake 20 meters

Tidal lake is a natural area

Potential implementation of fish migration river vv

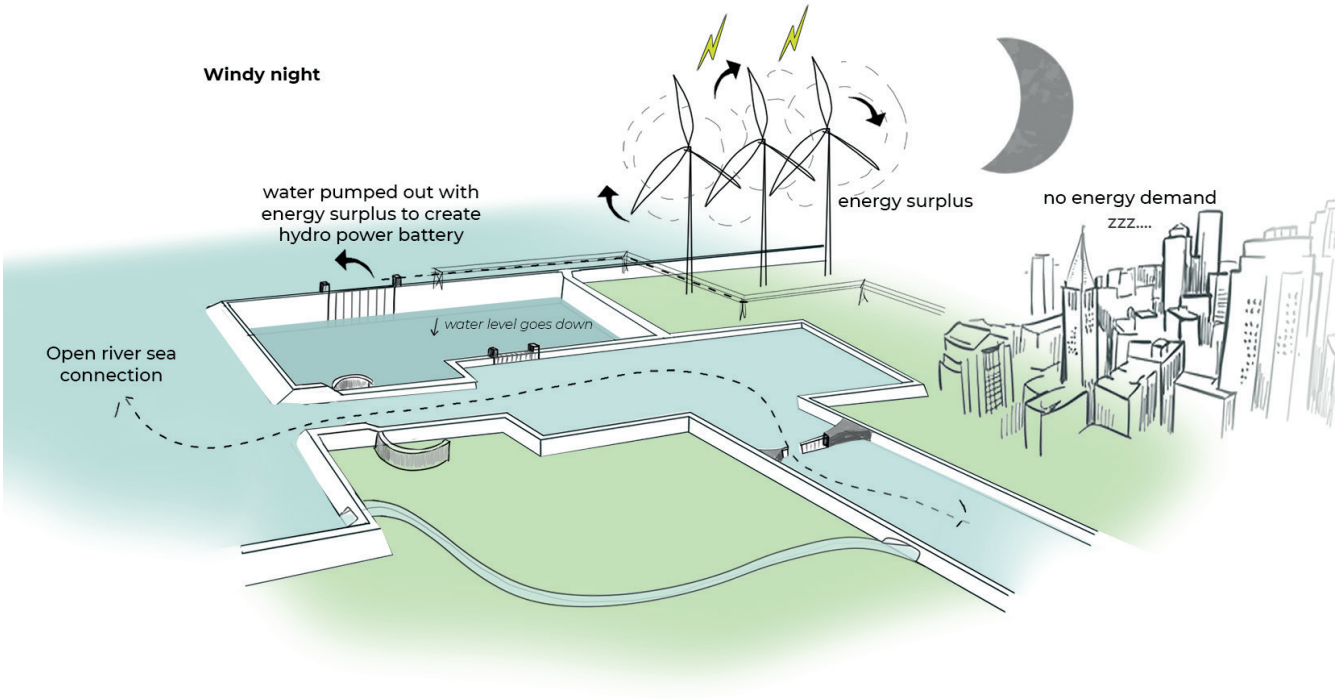
Improved technical layout (1-2-21)



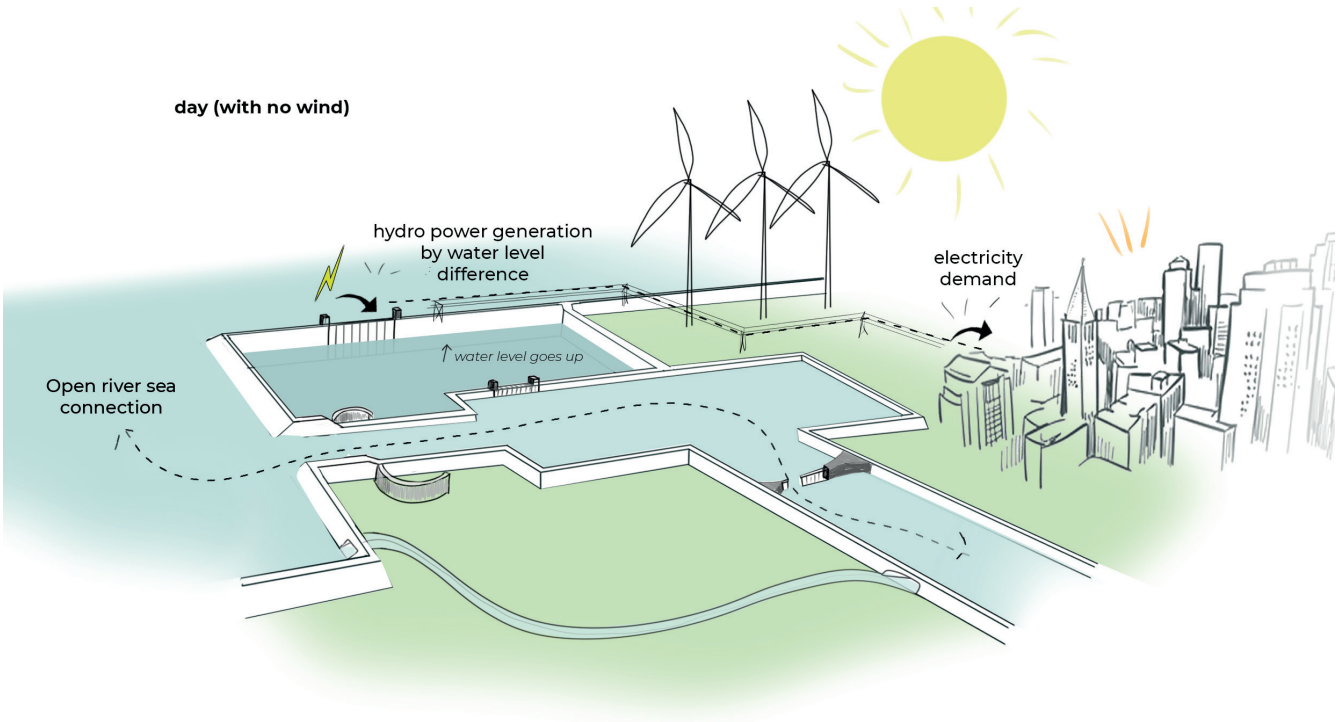
Leen Berke, Huub Lavooi (2021), Nieuwsbrief Delta 21

Functioning of the watersystem

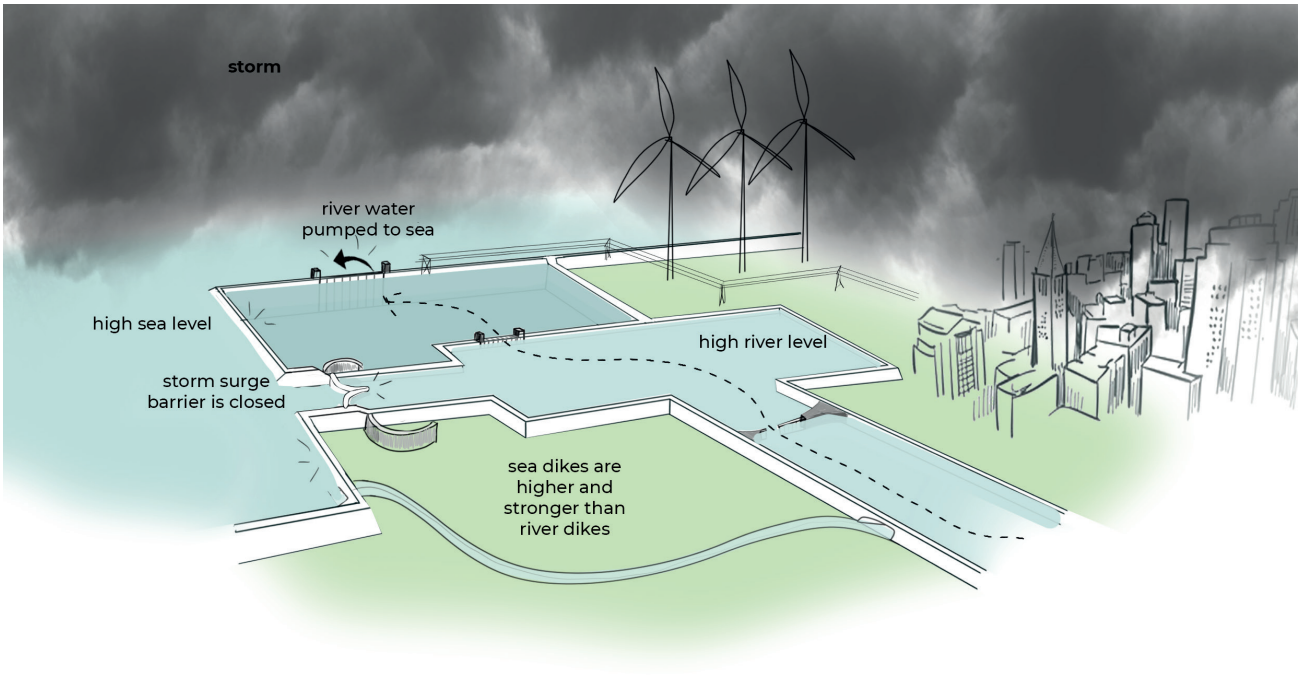
During the night with wind, the wind turbines generate energy but there is almost no energy demand because it is night. The energy surplus (which is normally lost) is used to pump out the energy lake and to create potential energy that can be generated again with turbines.



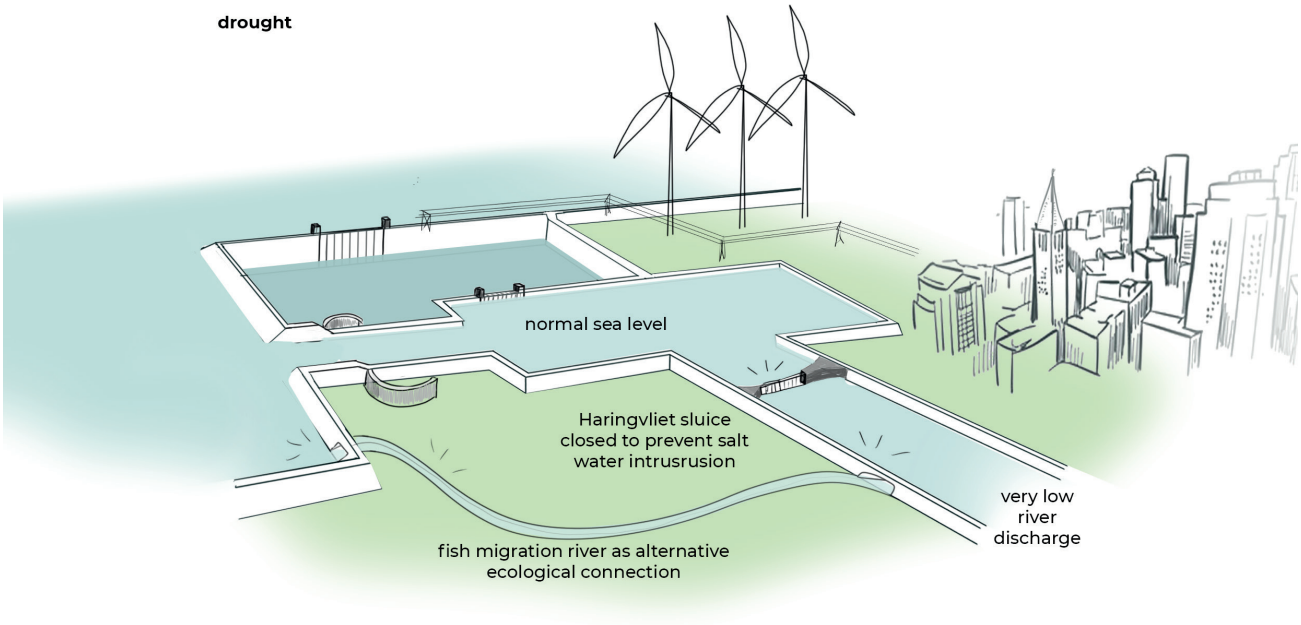
During the day, without wind, there is a demand for energy. Sea water can enter through the turbines back into the energy lake and generates power that is directly transported to the industry and houses.



When there is a storm which creates a high sea level and a high river level the water accumulates in the rivers. The river dikes are less high and not so strong as the sea dikes. To prevent dike failure, the storm surge barrier is closed, the spillway (between tidal lake and energy lake) is opened and the river water is pumped out to the sea. In this scenario, it is really important that the pumps are working. However, since the pumps are working almost everyday to store energy this will not be a problem.



In the scenario with a drought, the risk is that seawater intrudes too far in the rivers and causes salinization. In this case, the Haringvlietdam will be closed. This can happen more often in the future and when it takes too long this will negatively influence the fish migration. Therefore, if this scenario occurs, the fish migration route is an alternative route for migratory fishes.



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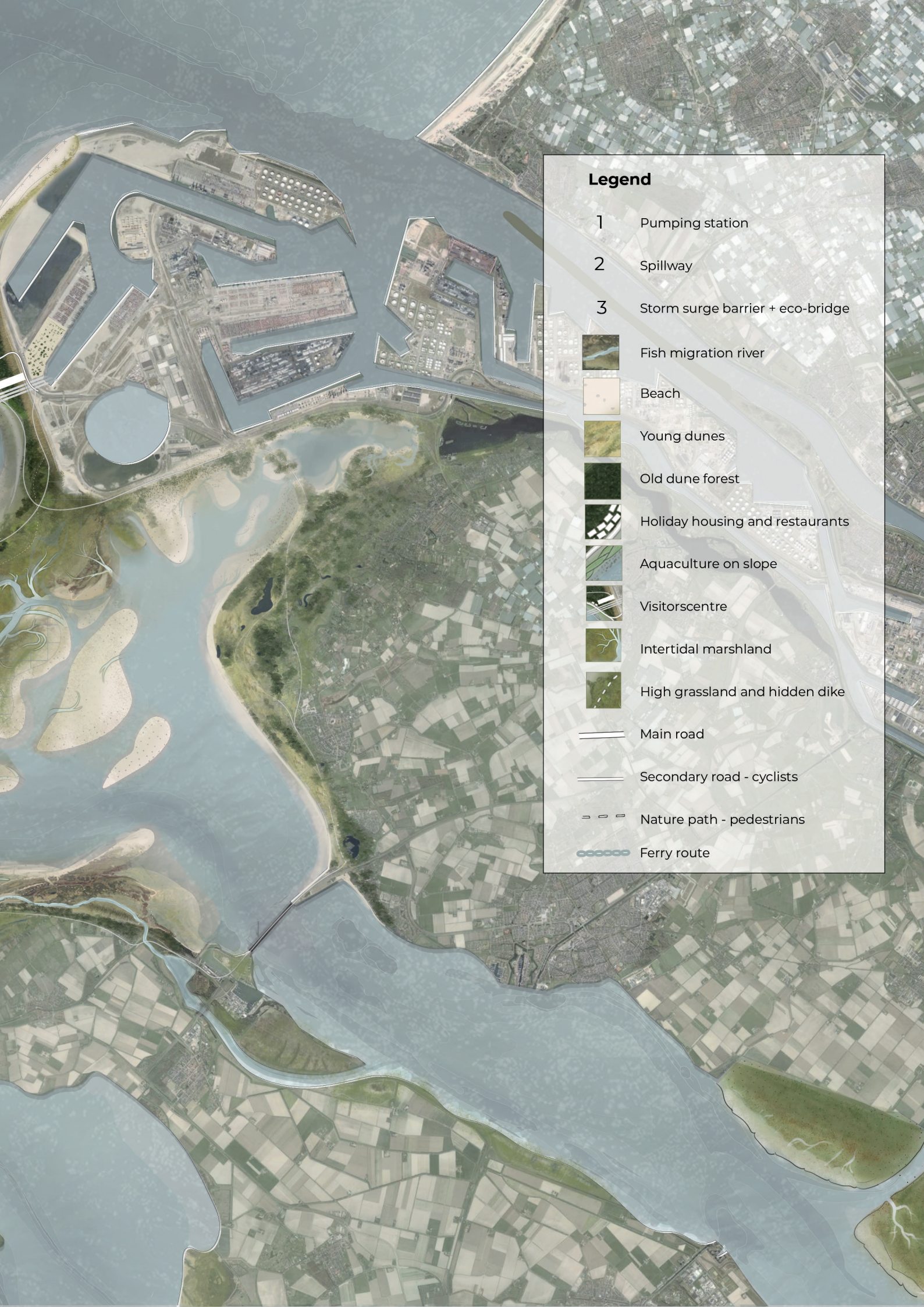
5.3 Exploring the layout

5.4. Transition zones

5.5 Layers of masterplan and implementation

5.3 A new estuarine landscape

This masterplan shows the new estuarine landscape that incorporates Delta 21. The layout of the plan is the result of designing with natural processes. The sub-zones and vegetation result from the technical requirements and the local conditions and are based on case study research. The key purpose of the design is to create soft transitions between land and water to build space for natural dynamics to occur and for recreation and ecology. Some small scale interventions like green bridges, dunes notches, paths, holiday housing, and the visitors centre result from more detailed design explorations. Here, the focus lies on the experience of the dynamic estuarine nature and ecology. To make the new landscape more interesting, the dominant soft transitions are alternated with one harder gradient northeast of the energy lake. Due to this harder gradient, changes in water level can be experienced. This can greatly be sensated at the steep shoreline with aquaculture and at the visitors centre where a water cascade exposes the water level differences between the sea and energy lake.


Legend
1 Pumping station
2 Spillway
3 Storm surge barrier + eco-bridge
Fish migration river
Beach
Young dunes
Old dune forest
Holiday housing and restaurants
Aquaculture on slope
Visitorscentre
Intertidal marshland
High grassland and hidden dike
Main road
Secondary road - cyclists
Nature path - pedestrians
Ferry route

Exploring the layout

The following chapters explain the reasoning behind the masterplan and dive further into the detail.

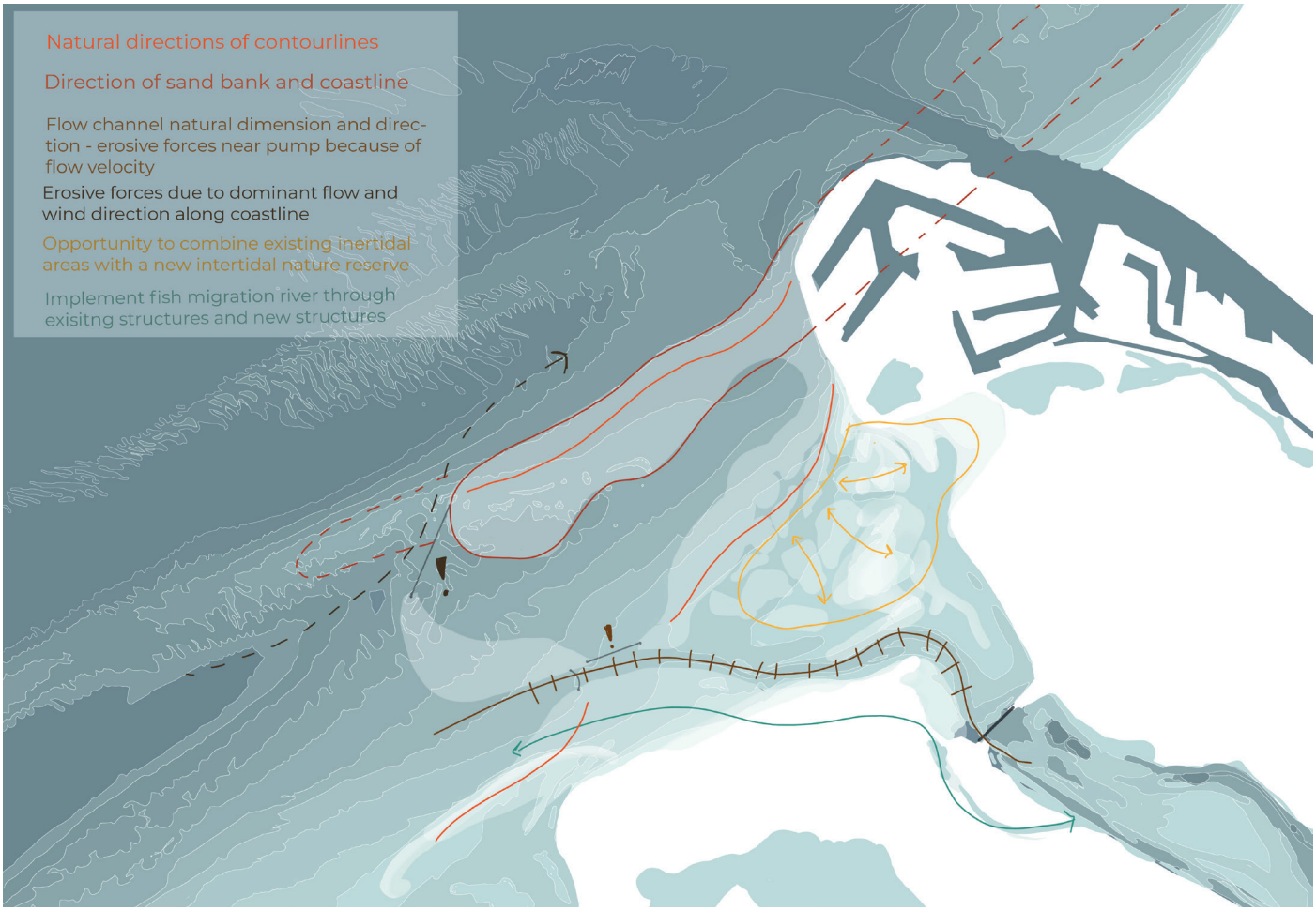
introduction

In the process of exploring the layout, a few elements were taken as base points. First, the sedimentation and erosive patterns along the shoreline. This is the result of the main sea current, wind direction and strength and river discharge. Second, the new landscape introduces a dynamic island landscape that connects to the existing intertidal mudflats, like the Hinderplaat. This is done to protect the ecological value of this area and to expand it as a nature reserve. Least, the open flow connection from the sea to the Haringvliet with the correct orientation and dimensions is recovered. The channel is narrow enough to stimulate erosion near the spillway but wide enough to secure tidal dynamics in the tidal lake.

Outline layout

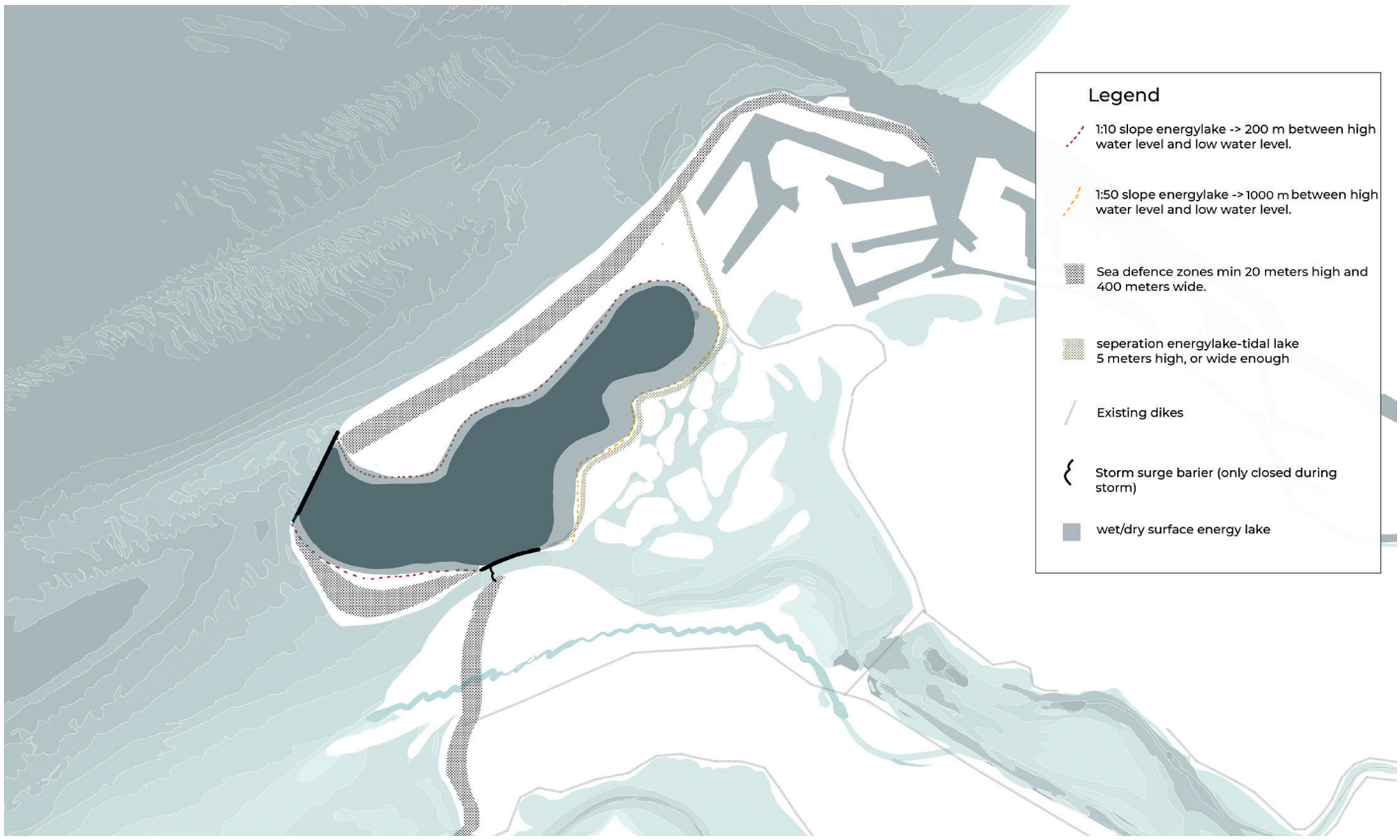
The layout follows the contour lines of the seabed. The orientation is parallel to the existing coastline (a consequence of the dominant sea current). The new proposed peninsula southwest of the Maasvlakte is positioned on top of the sand ridge. The outer edge of the new layout is expected to be erosive. Therefore at this location, I propose to position the pumping turbines. In this way, the erosive forces are desired for the pump station to stay free from sediments. The same is for the spillway at the tidal lake to the energy lake, which is positioned at the in- and outflow channel. Due to the narrow width, the water velocity is higher and erosive forces will dominate here as well. The separation between the energy lake and the tidal lake is lying just beside the Hinderplaat and the other intertidal sandbanks. The new proposed land can contribute to the ecological value of the intertidal areas by expanding the intertidal surface. At least with the new layout, a fish migration river is implemented. This river follows the existing structure of the former tidal creeks and coastline partly and ends up in the tidal lake through the newly introduced creeks.

Design - Outline plan explained



Technical requirements to fulfil

The layout must fulfil the flood protection measures and the option to store energy in the energy lake. The first flood defence line is the outer edge dune, including the storm surge barrier at the in/outflow channel. The slope of the energy lake must be 1:10 or more gentle. The separation between the energy lake and the tidal lake must be at least 5 m + NAP.



Design - Plan in aerial photograph

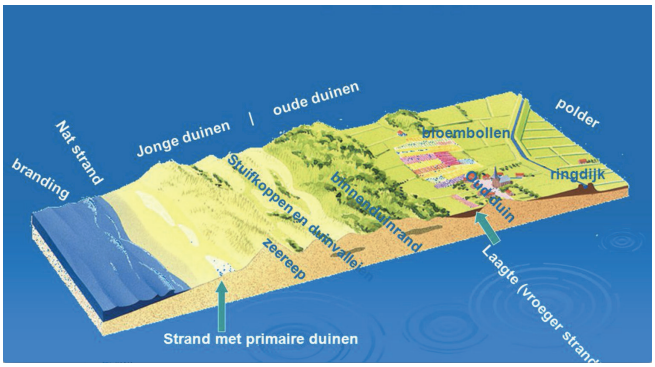
The layout was tested by photoshopping the plan in an aerial photograph. Delta 21 appears as a naturally developed island head with a similar size and orientation. The new peninsula is in line with the sand ridges on the seabed.

Retrieved from: Google Earth

Zoning

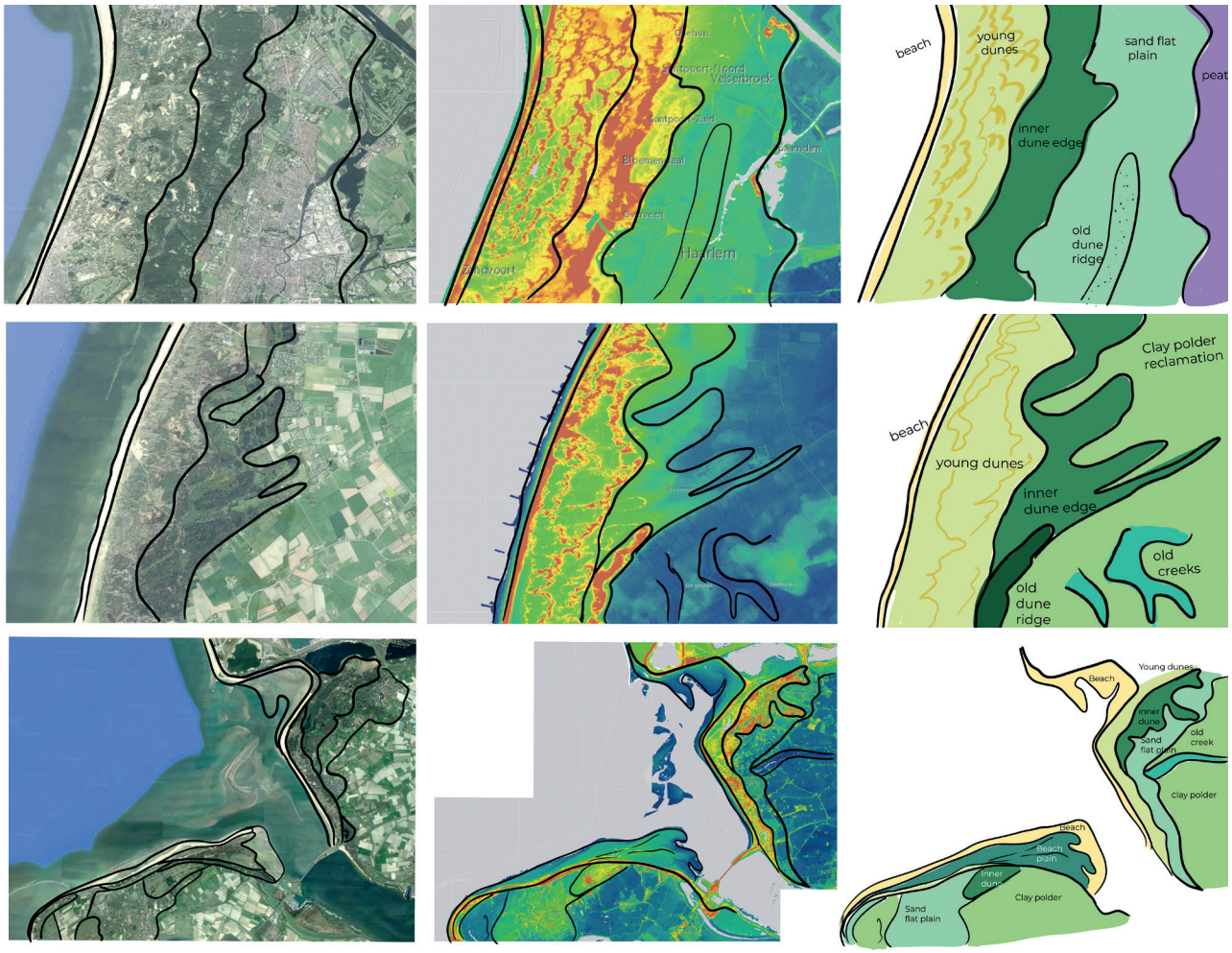
For the new estuarine landscape layout, the following zoning is porposed. This is partly based on the technical requirements to serve the water protection system. The dunes must be high and wide enough to protect the hinterland.

For the zoning, I took the natural coastal landscape as a basis. The coast structure has the same built-up; sea, beach, embryo dunes, young dunes, dune valleys, old dunes, inner dune edge, lowlands, marsh. This structure is used as a basis for the new landscape. The edge from the old dunes connect to the energy lake will be shaped like the inner dune edge. After the energy lake, the landscape character is based on the lowlands and marshland. In the new landscape, the marshland connects to the sea, the tidal movement and the river.

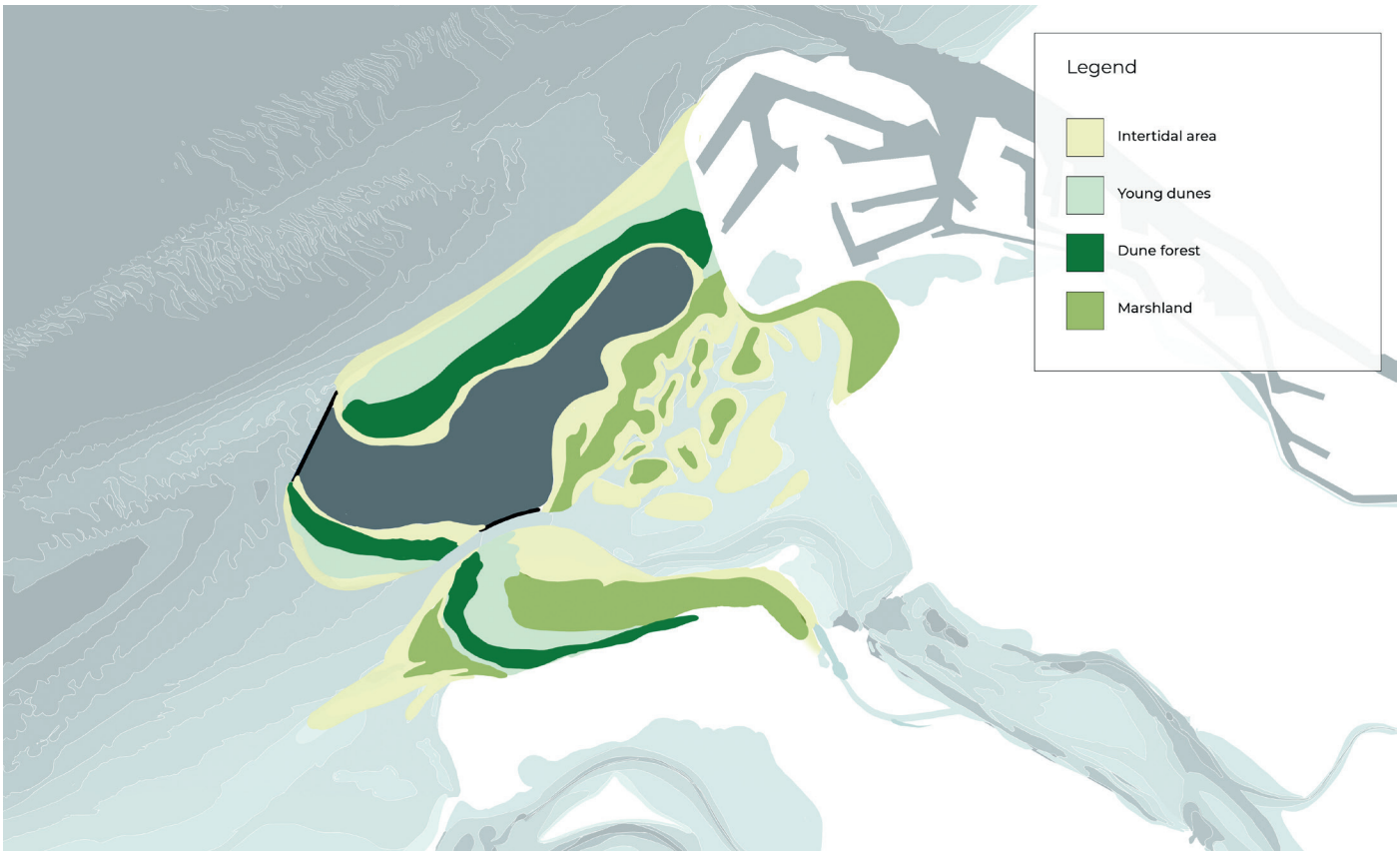


Source: Hans van Lamoen, https://www.laedgeimages.com/3968882-vogelenzang-aw-duinen

Natural landscape

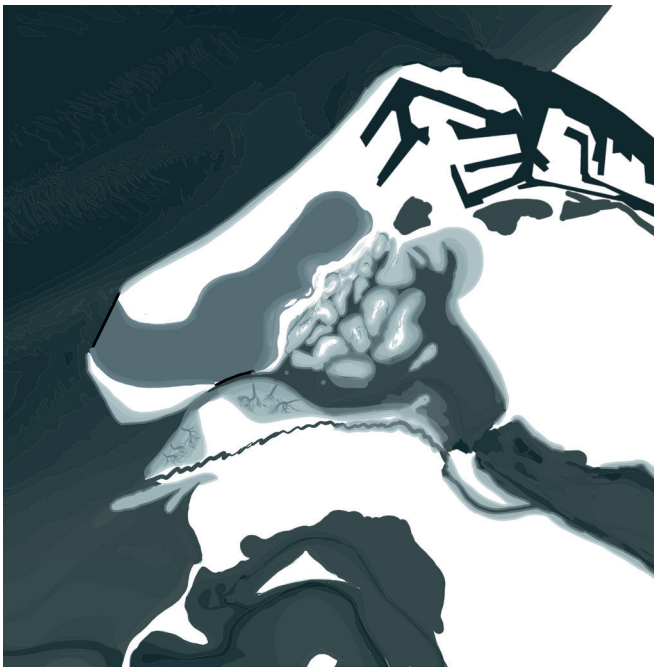


Zoning



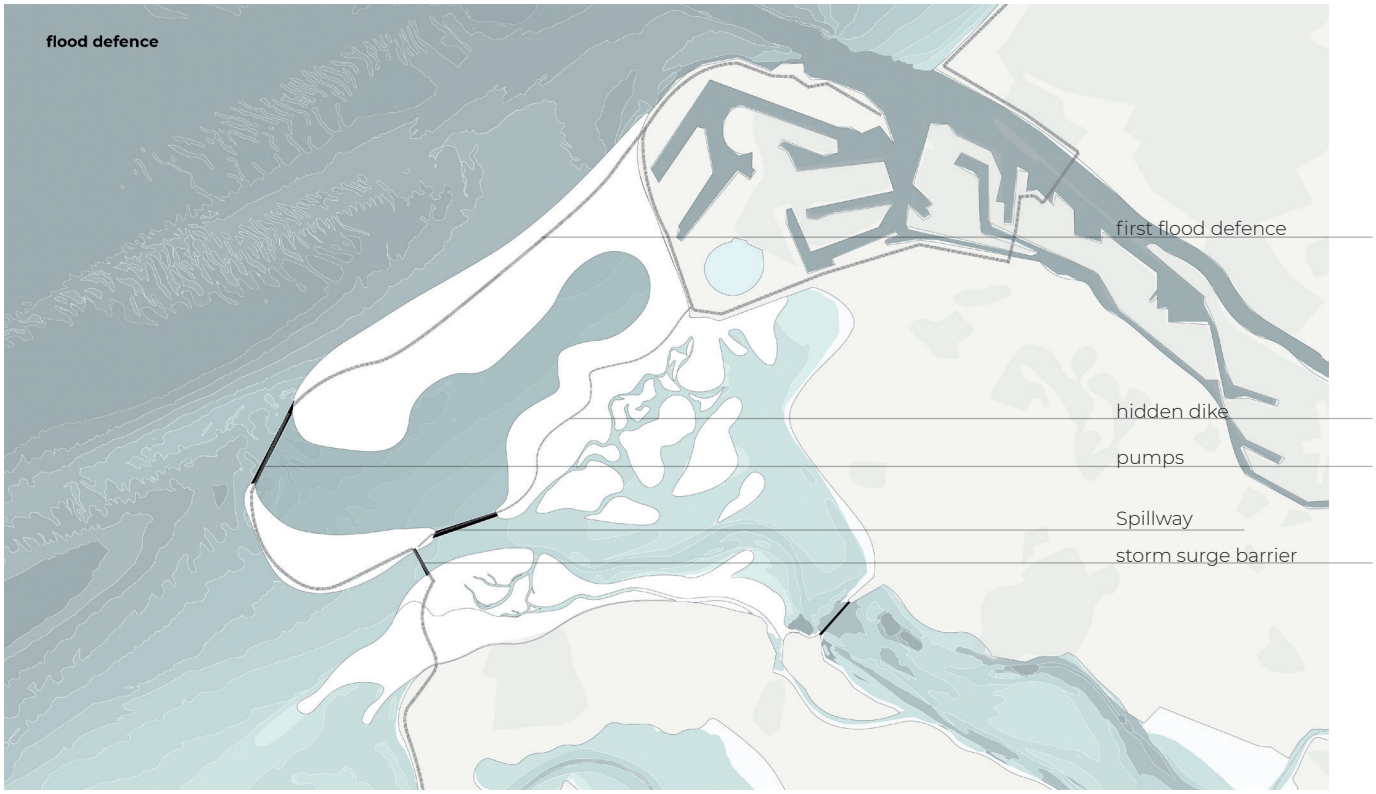
Gradients

The gradient of the ground level is an important design choice. The more gentle the gradient, the greater the intertidal surface can be. Here lie the opportunities for tidal marshland and creeks to develop. The energy lake can have a daily water level difference of up to 20 m difference. The steepness of this gradient defines for a large part how the water level changes can be experienced. Therefore on the north side of the energy lake the slope is 1:10, which is the steepest option. This will create a better opportunity in experiencing the water level. The slope on the south side of the energy lake is very gentle. Here, the transition between the energy lake and the tidal lake is almost unnoticeable because of the very gentle gradients on both sides.

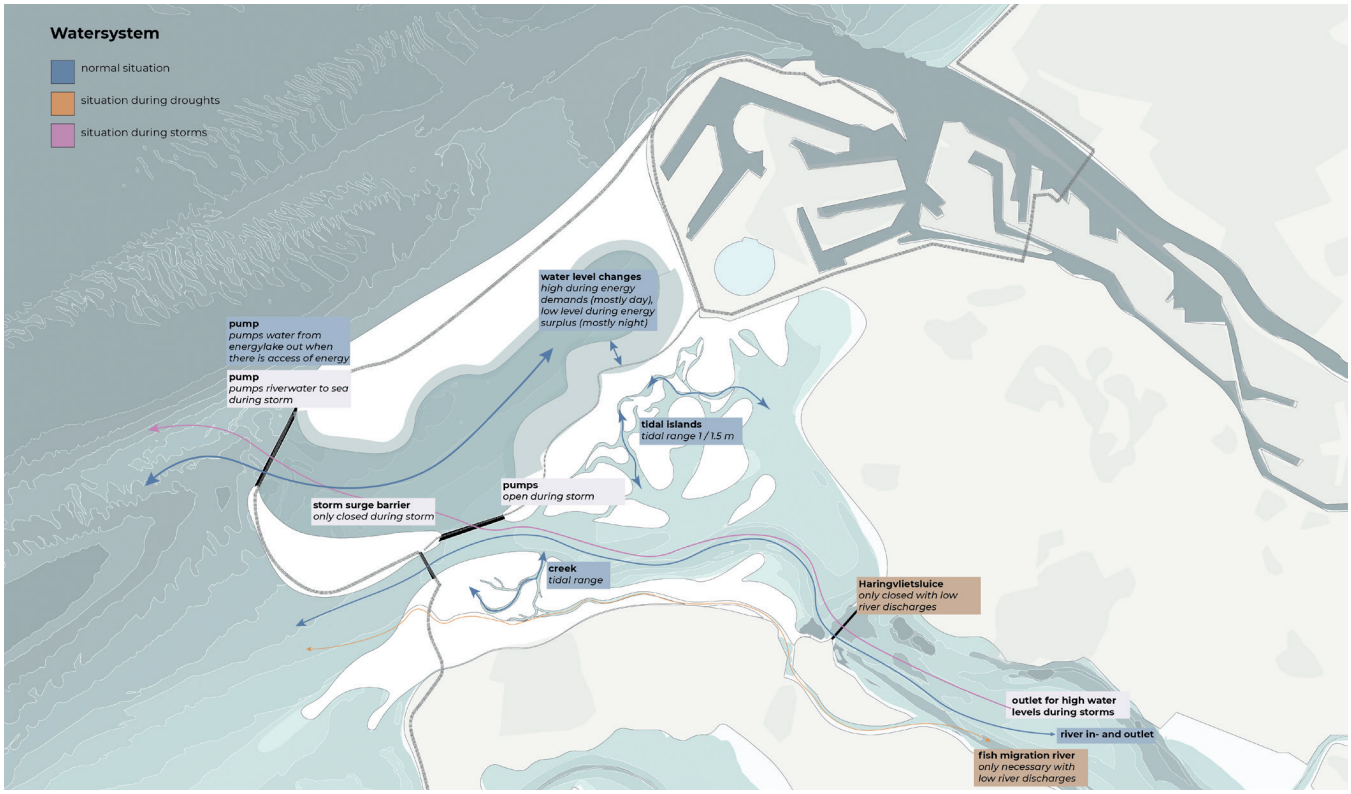


Masterplan layers

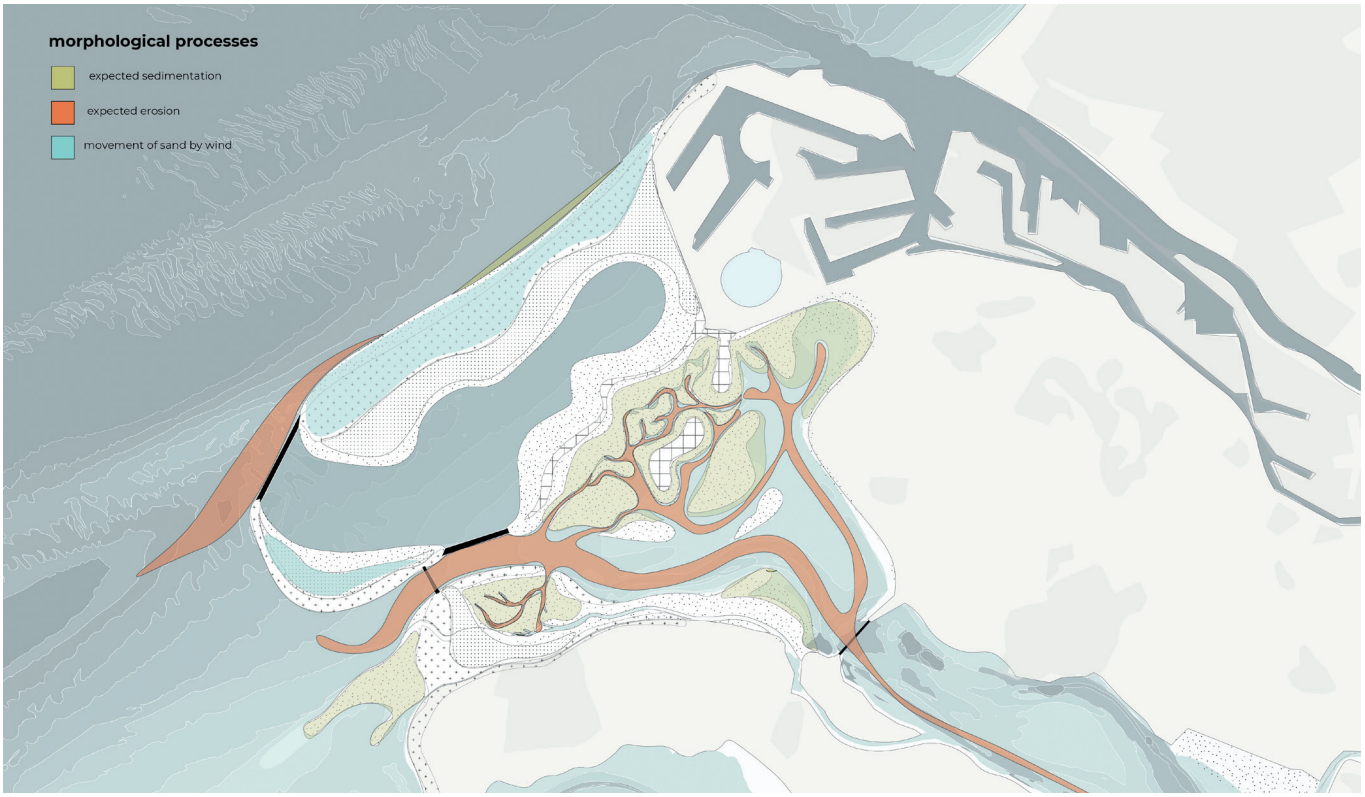
The proposed flood defence structure fulfils the technical requirements. The width of the dune area is even bigger than needed, this is to create space for recreation and nature. The dike separating the energy lake from the tidal lake is hidden to create the feeling of a gradual continuous landscape.



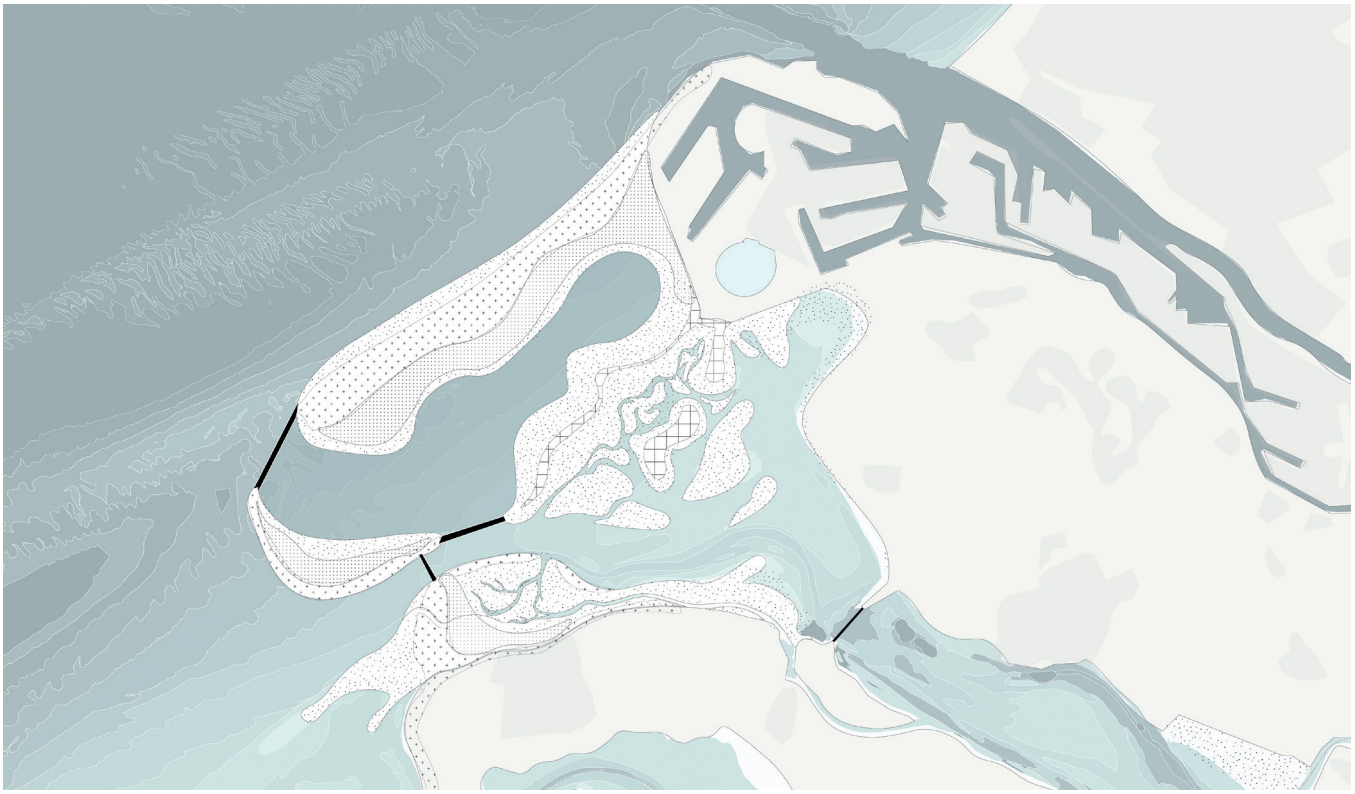
The water system is quite complex. Expected is that in the normal situation, the tidal differences in the tidal lake 1.5 m is. This is enough for creek and marshland to develop. The 12 km long fishmigration river is always open for fish, the lenght is expected to be long enough for a gentle salt to freshwater transition.



The morphological processes shape this landscape. The expected erosive forces are desired to make sure the pumping station and spillway stay free from sediments. Erosion in the tidal lake is the consequence of tidal movements and will create the creek landscape. Wind can create a dynamic dune area at the young dunes with opportunities to create different habitats in different stages of succession. At least, sedimentation in the creeks is the result of the deposition by tidal overflows. The sedimentation northeast of the head of Goeree is the result of lying at the lee side of the flow currents. These morphological processes are expected with this design exploration, however, it is necessary to run a hydraulic model in further research..

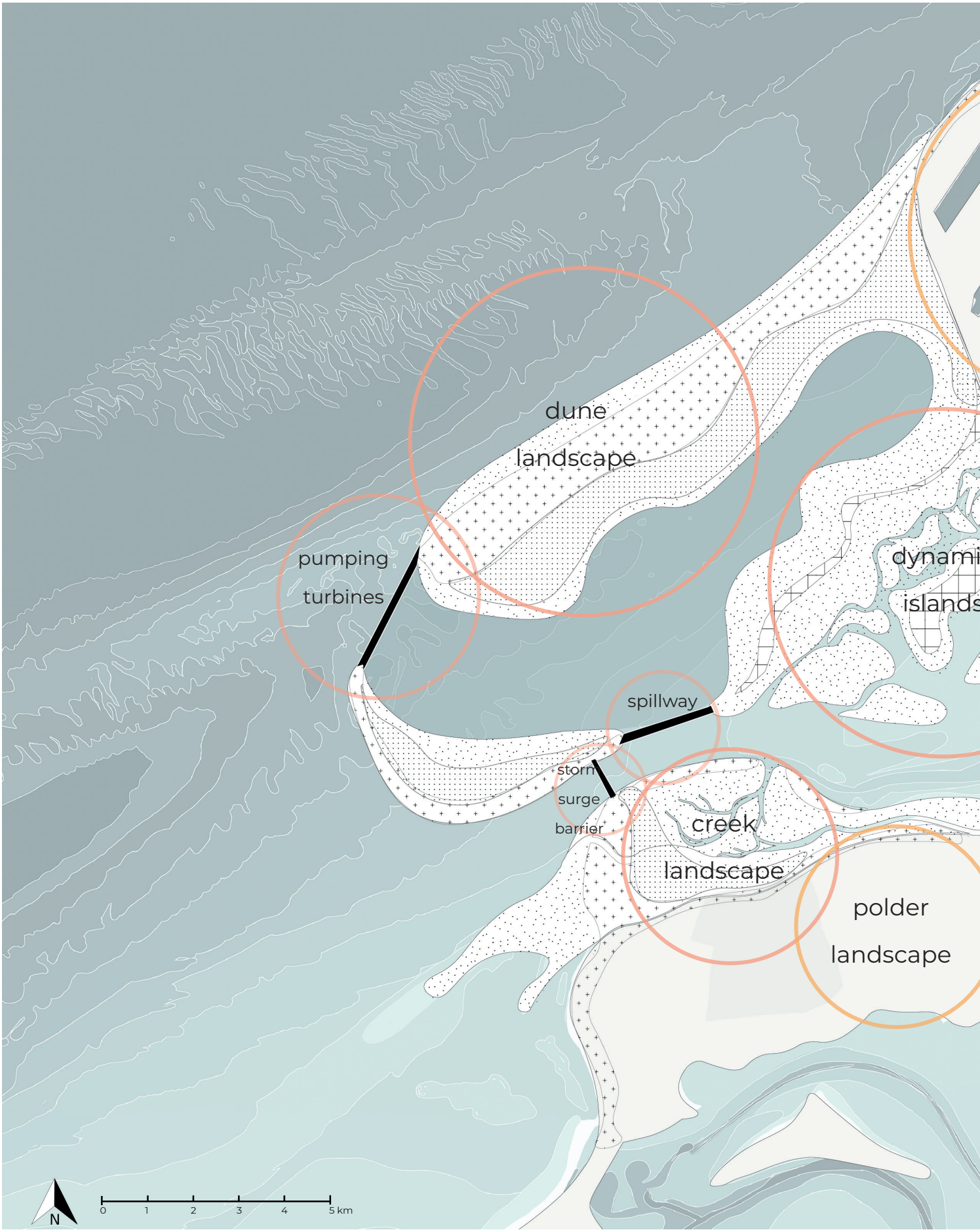


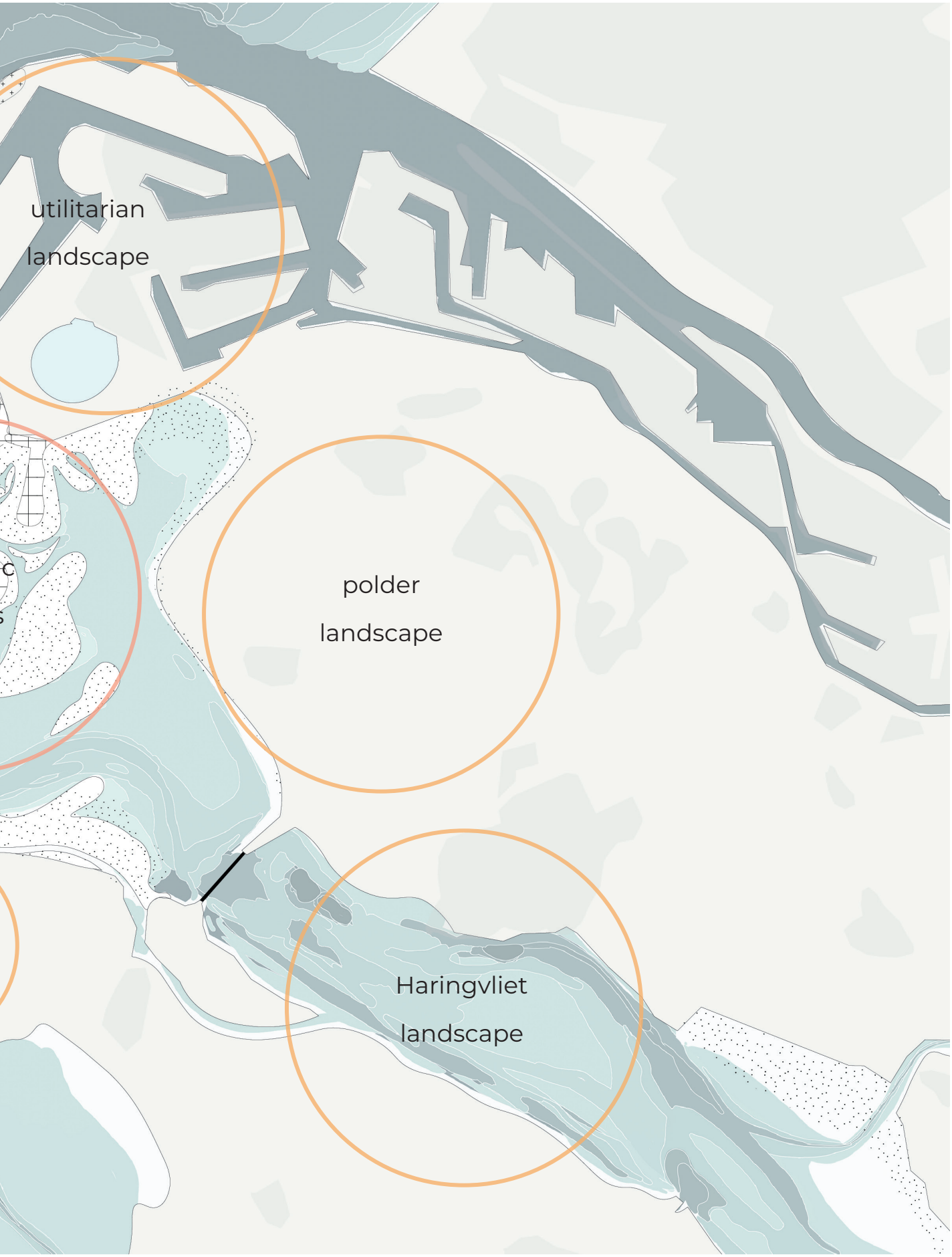
The landscape structure is a continuation of the zoning. The island and the creek landscape have the correct dimensions derived from the case study review. The hidden dike is a higher grassland zone in the middle of intertidal areas to create a soft, almost unnoticeable, transition between the tidal lake and the energy lake.



Masterplan - landscape types

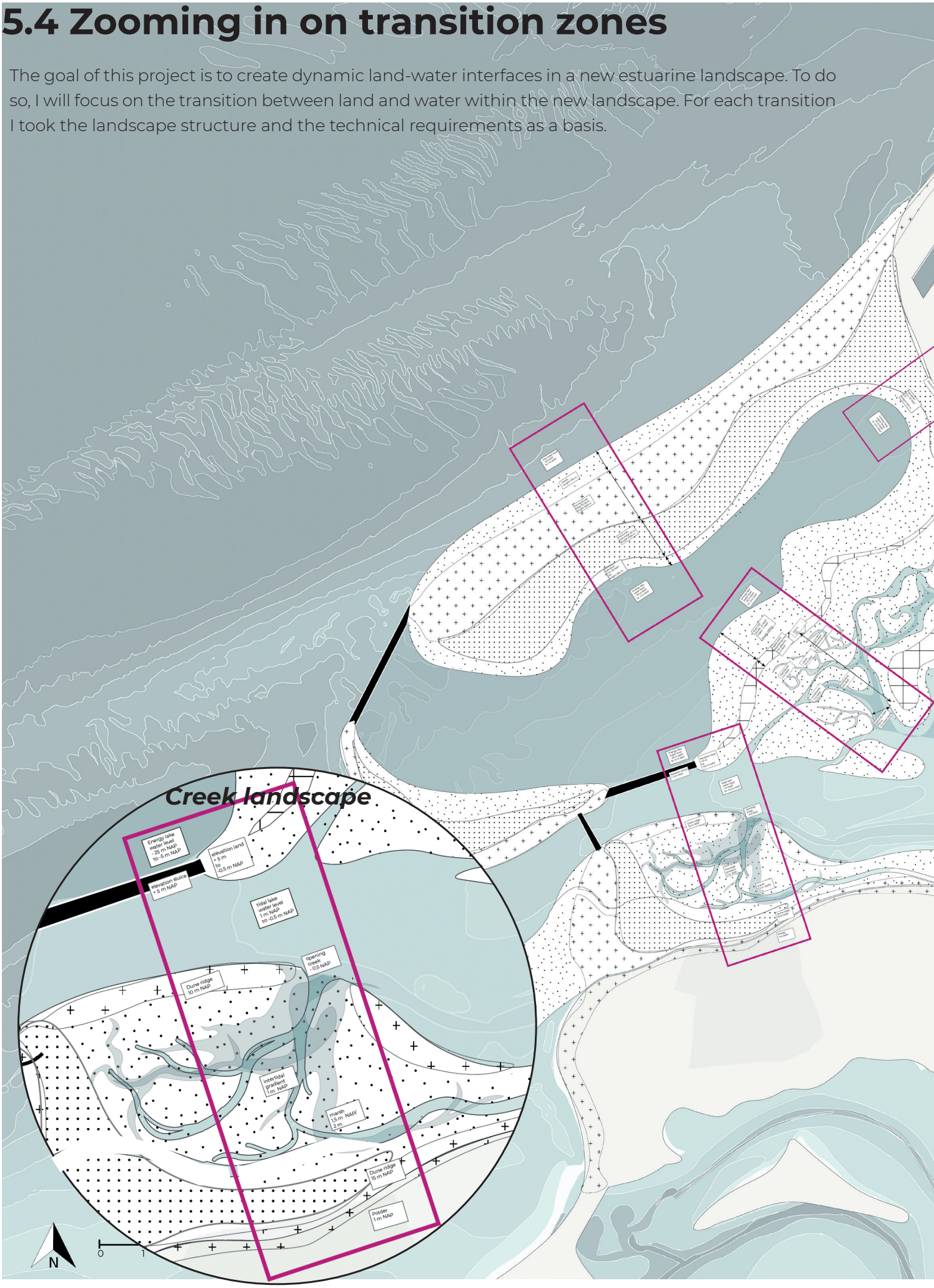
The new estuarine landscape can roughly be divided into different landscape types to contribute to the existing landscape types in the region. The newly added are: dune landscape, the dynamic islands and the creek landscape.

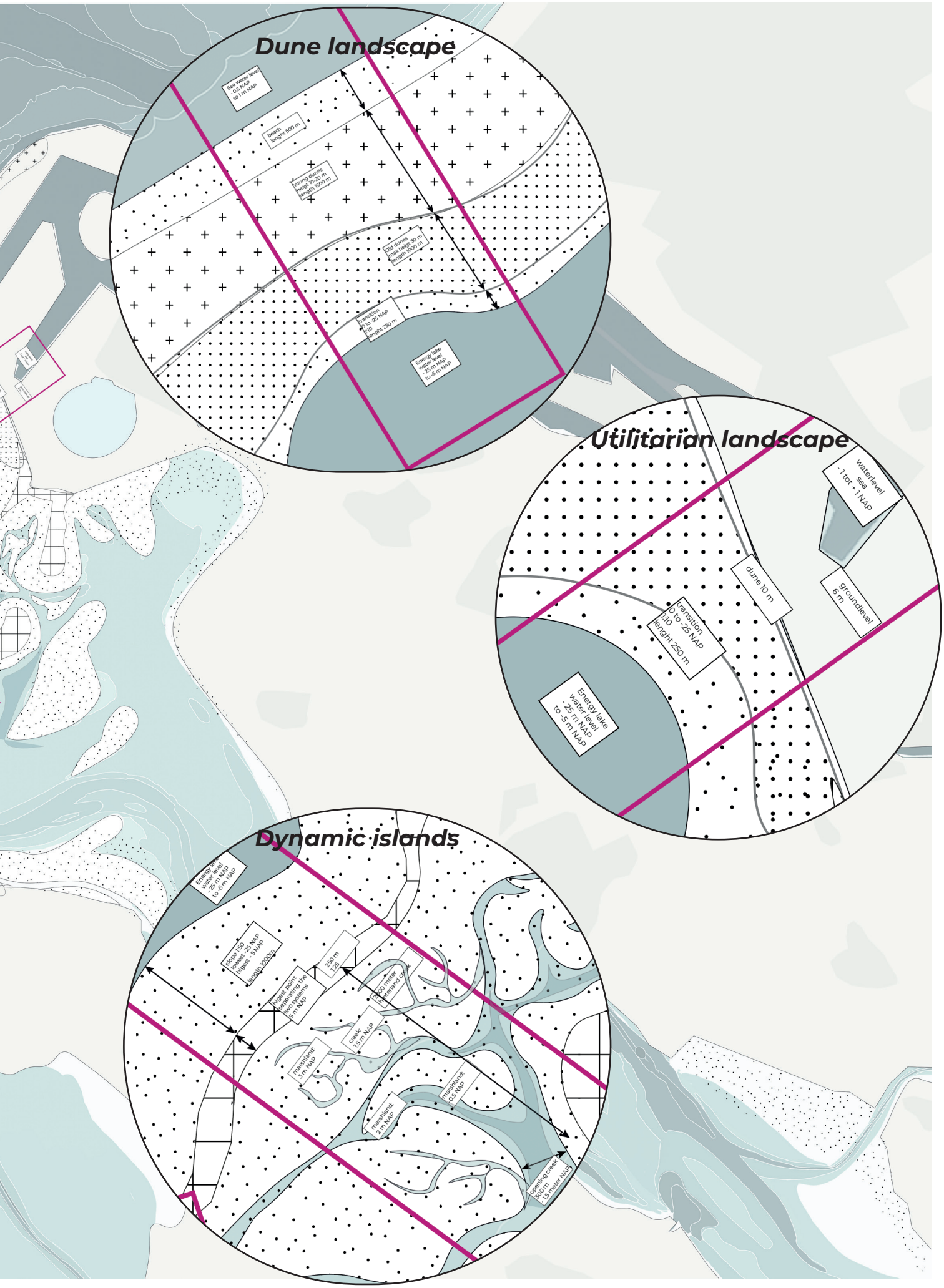



utilitarian
landscape
polder
landscape
Haringvliet
landscape

5.4 Zooming in on transition zones

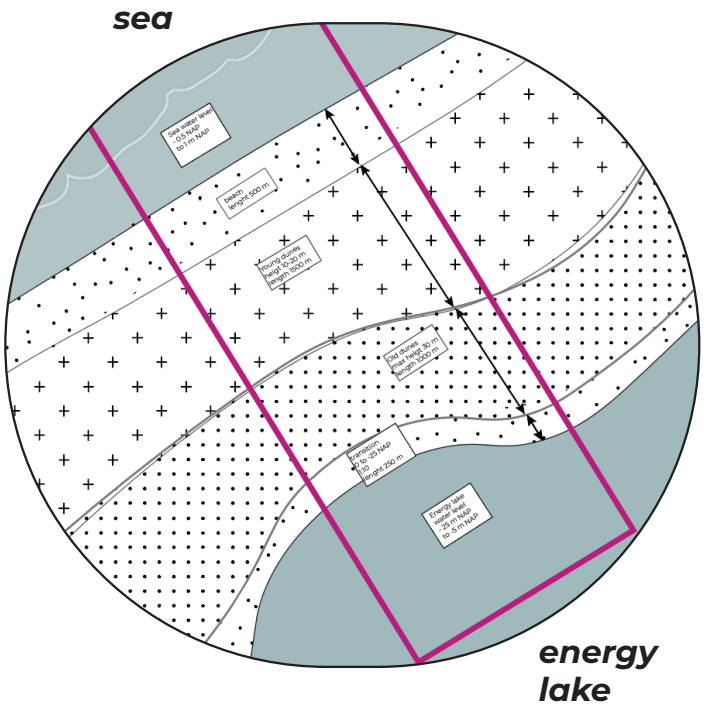
The goal of this project is to create dynamic land-water interfaces in a new estuarine landscape. To do so, I will focus on the transition between land and water within the new landscape. For each transition I took the landscape structure and the technical requirements as a basis.



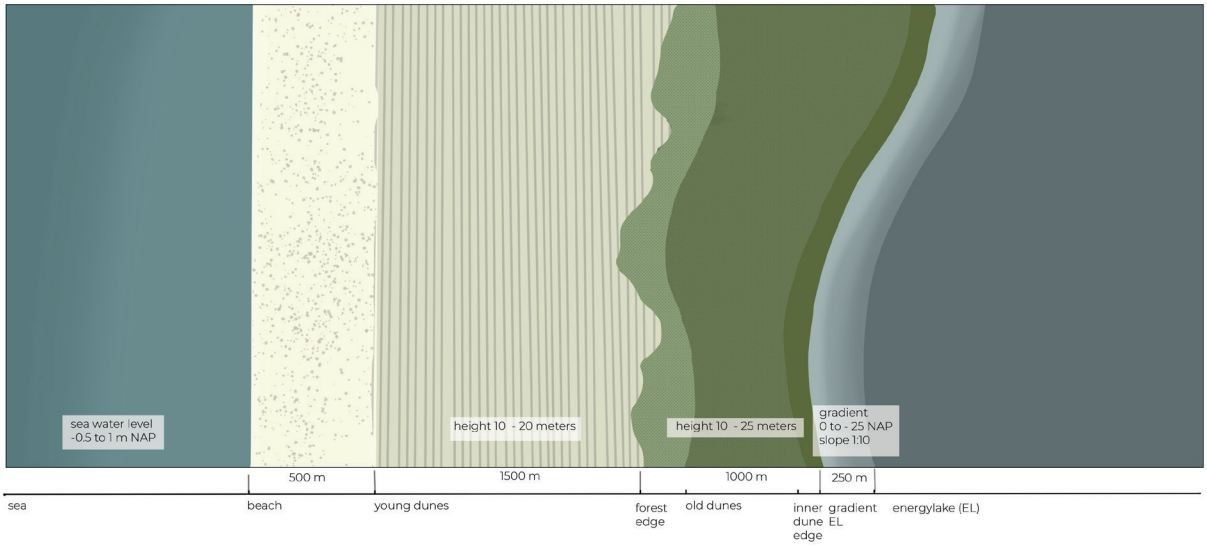

Dune landscape
Sea water level
-0.5 NAP
to 1 m NAP
beach
lenght 500 m
Young dunes
height 10-30 m
lenght 1000 m
Old dunes
max height 50 m
lenght 1000 m
Transition
+10 to -25 NAP
lenght 250 m
Energy lake
water level
-25 m NAP
to -5 m NAP
Utilitarian landscape
waterlevel
sea
- 1 tot + 1 NAP
dune 10 m
groundlevel
6 m
transition
+10 to -25 NAP
lenght 250 m
Energy lake
water level
- 25 m NAP
to -5 m NAP
Dynamic islands
Energy lake
water level
-25 m NAP
to -5 m NAP
slope 1:50
lowest: -25 NAP
highest: -5 NAP
length 1000m
250 m
1:25
1000 meter
hinterland
hinterland
creek
1.5 m NAP
marshland
3 m NAP
marshland
2 m NAP
marshland
0.5 NAP
opening creek
300 m
1.5 meter NAP

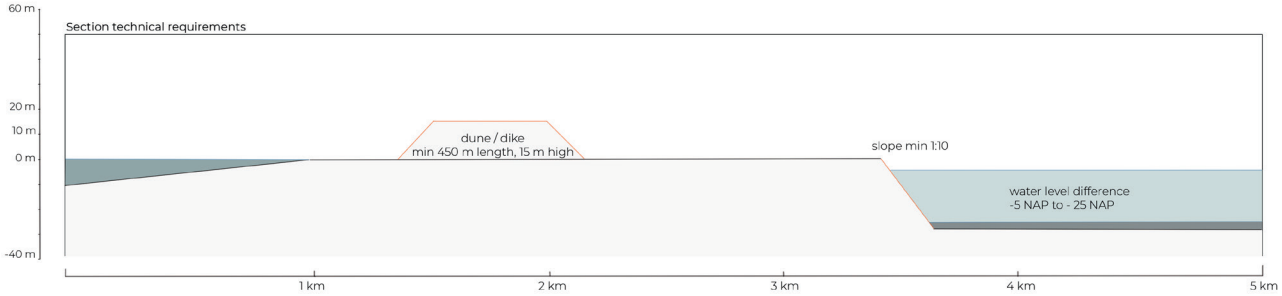
Transition zone: dune landscape

The transition from the sea to the energy lake goes through the dune zone. The sub-areas from the sea to the energy lake are: the beach, the young dunes, forest edge, dune forest, inner dune edge and energy lake slope. To make this transition dynamic, notches, areas that consist of bare sand, are placed in the first dune row. Here, the sand can be blown out by the wind. The second dune row is laid down as parabole dunes. In the natural situation, this would be the result of centuries of exposure to natural forces. In this new landscape, the parabolic dunes are implemented to create an interesting dune landscape and to create the opportunity for fresh dune lakes to develop. The forest edge is the area with a half-open forest, the most biodiverse area of this transition zone. The dune forest is a lovely area for recreation, and on the inner dune edge, smaller villages serving as a tourist hub. Here, the water level difference of the energy lake is interesting to observe, and food that is produced on the aquacultural slope of the energy lake can freshly be consumed.

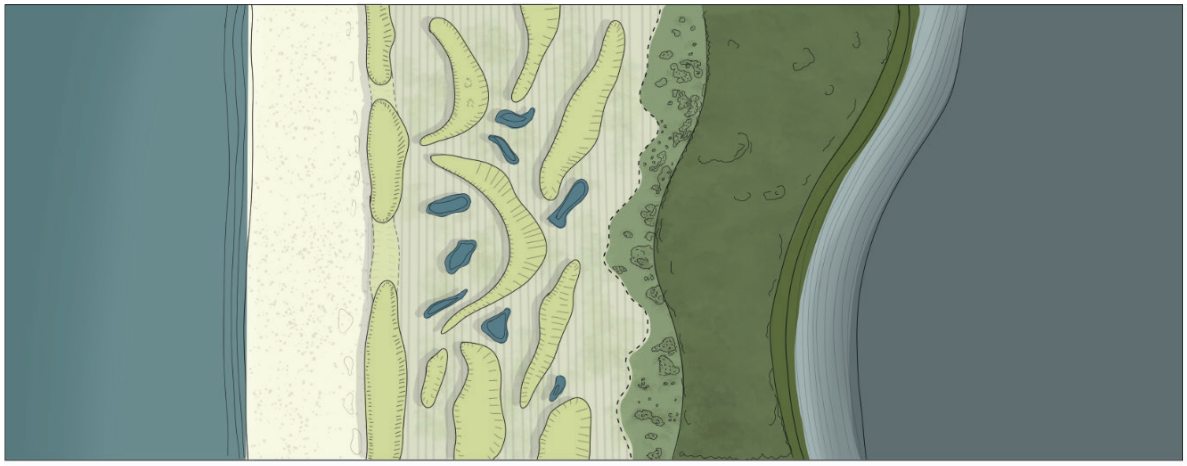


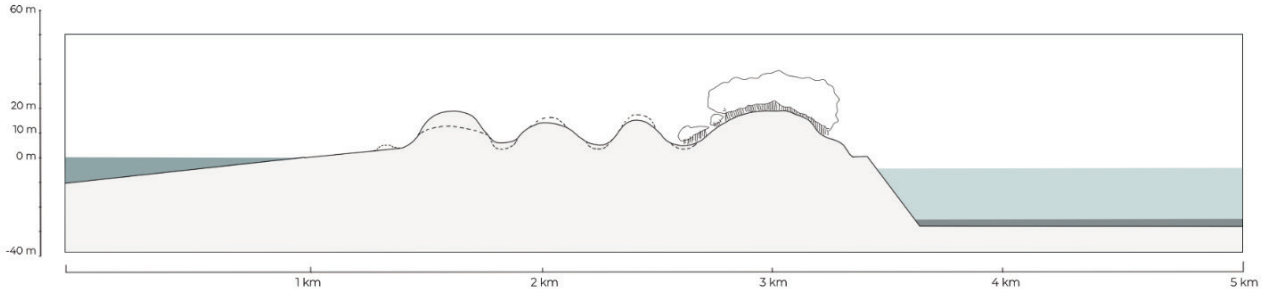
Basic landscape structure, measurements and technical requirements



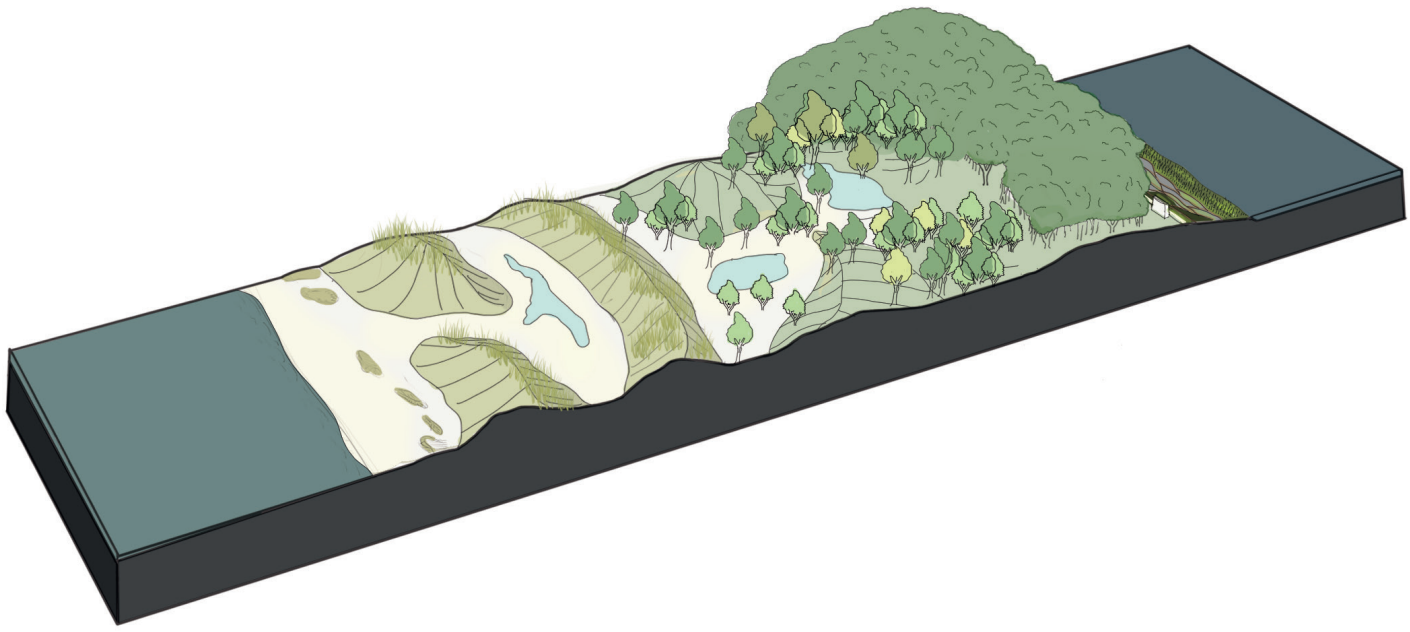


Structural design





Spatial design

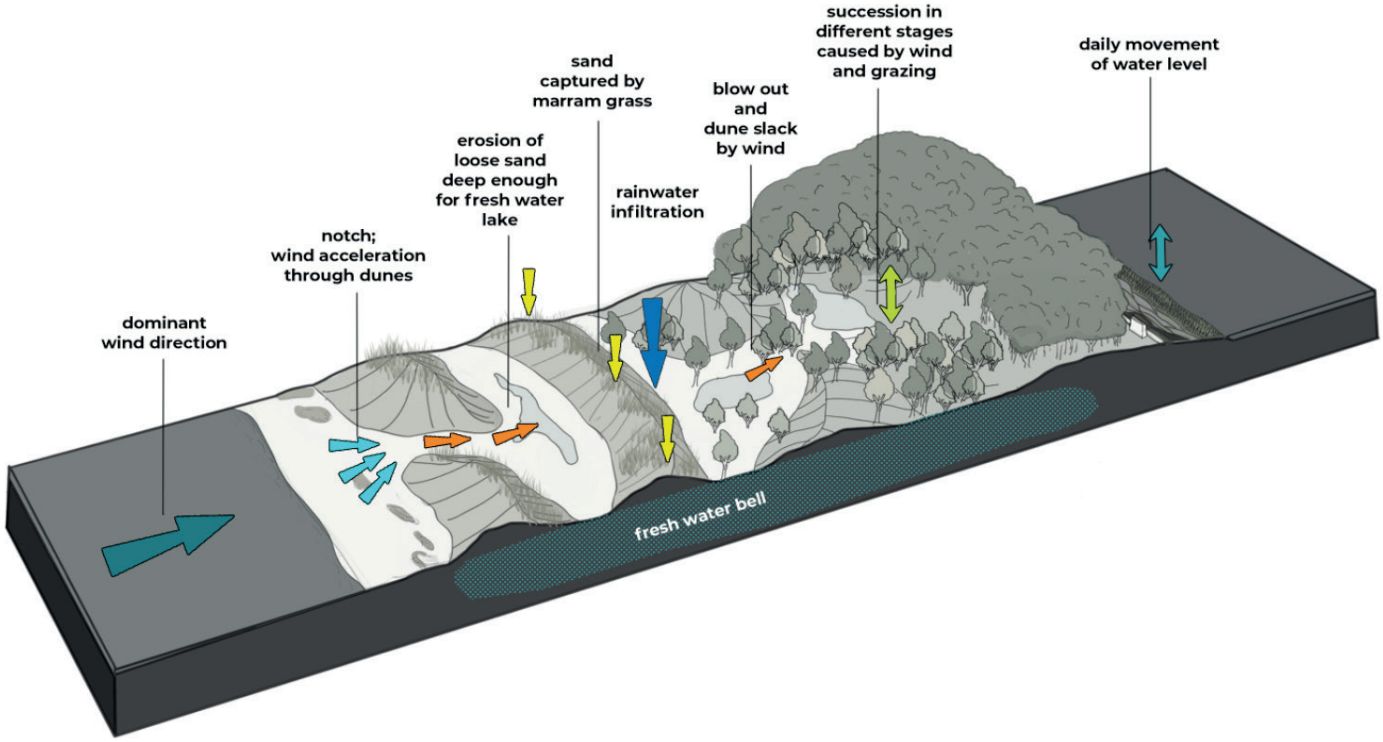


Processes and ecology

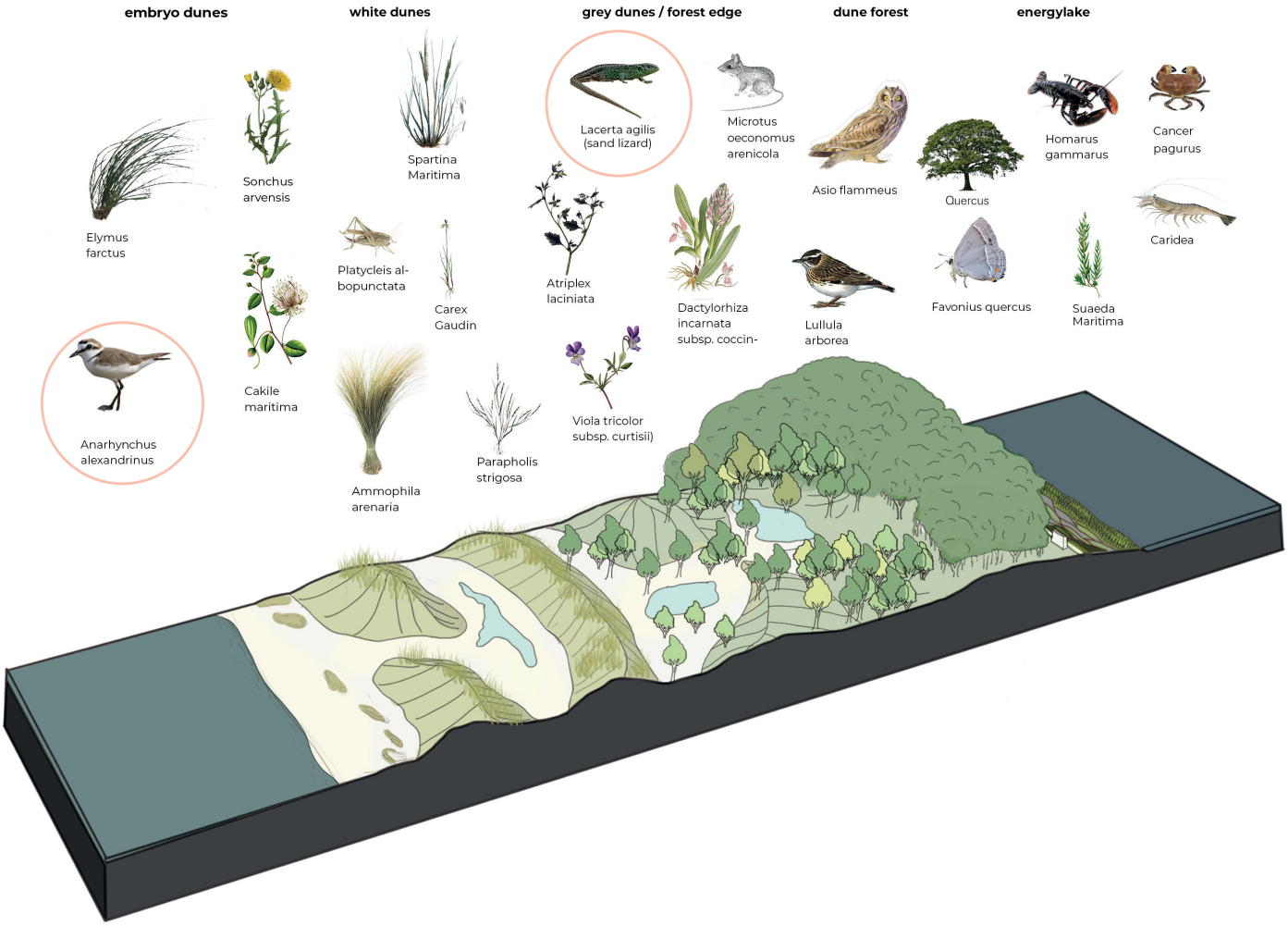
The implementation of the dune area is done in different stages to create a highly dynamic dune system. First, the sand is placed in the first dune row with notches, the second dune row in parabolic dunes and then the third dune row. After that, the continuous dune row for the forest dunes is placed. In the second stage, the areas where the sand must stay in place, vegetation is planted. In the young dune area marram grass, and the old dune area grass, shrubs and trees. The third stage is done by wind, rain and succession. The wind blows out sand and creates a freshwater pond just beyond the notch. The places where the marram grass is planted will capture the blowing sand and will move to next stages of succession. The vegetation and the low lying areas between the dunes capture and infiltrate the rainwater. After a few years, a freshwater bell will form in the subsoil. When this happens, freshwater ponds with rare flora and fauna will occur. The circled species in the flora and fauna scheme, refer back to the target species that were stated during the analysis. With this new landscape, the desired habitat for those target species is created.

Stages of development

Natural processes that shape the landscape



Flora and fauna



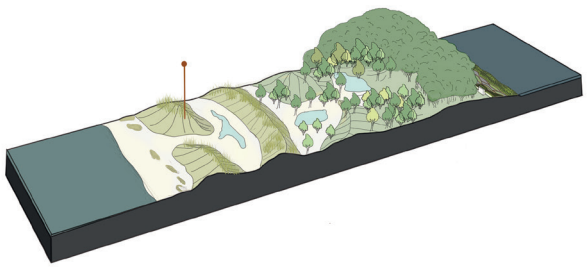
Program and recreation

The recreational program is divided over the entire transition zone and is directly related to the natural landscape at the sub-areas. Biking can only occur at the vegetated dunes, while strolling in the dunes is really fun to do in the bare dunes. The dune edge is the most ecological valuable zone, so it is important not to disturb this area too much. Activities like bird watching are suitable for this location.

Dynamic transitional experience

To increase the experience of the dynamics, a climbing dune can be installed. The climbing elements are made of reed and the whole structure replaces the sand capturing purpose of the marram grass.

Climbing dune that holds sand



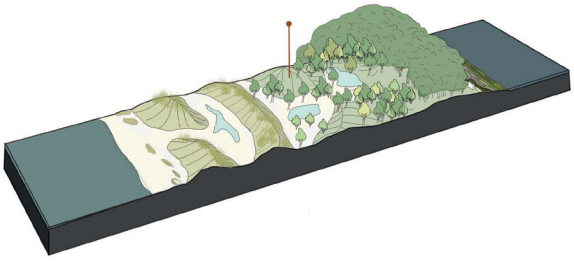
Pathways

Placing pathways invites the visitor to explore the area. By guiding the path to hilltops, a view of the area is created, giving the visitor a sense of orientation. Besides a concrete path, there is also a natural adventurous path. This will lead the visitor to more intimate spots and will enhance the feeling of nature engagement.

Pathways over hilltop and a choice for one adventureus path and a concrete path

Overview of the transitions and how the path leads you trough it.

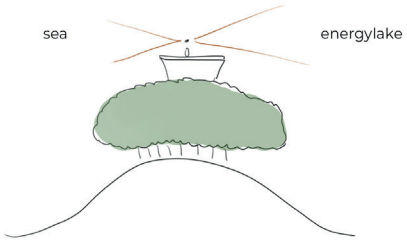
Secret side pathways that leads the visitor to more intimite spots.

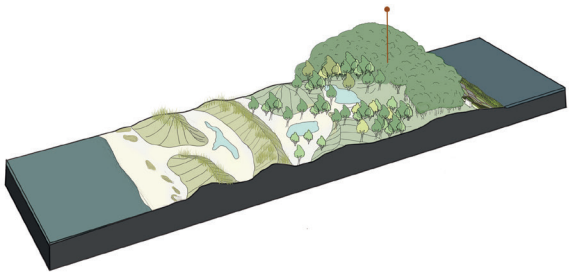


Viewing tower in forest dune area

The dune forest is a visual barrier between the dune landscape and the energy lake landscape. This strengthens the feeling of the dune area as a natural area and the inner dune edge and energy lake slope as a production and tourist hub. At the dune area, the highest point of the transition zone, a viewing tower is installed. Visitors will have a wide-open view to the surroundings, where they will experience the transition zone as a whole.

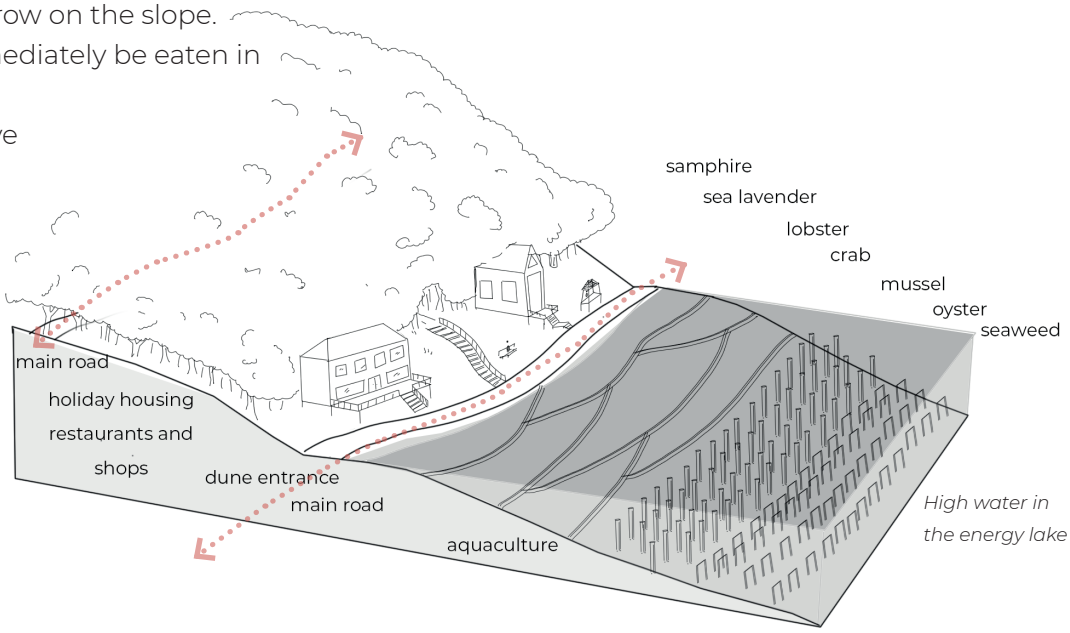
Viewing tower



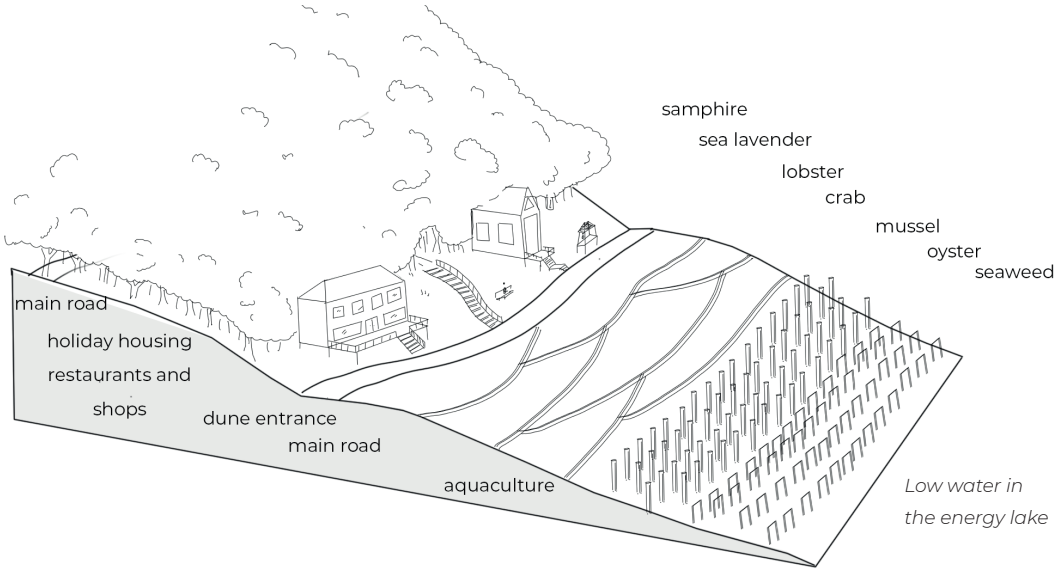


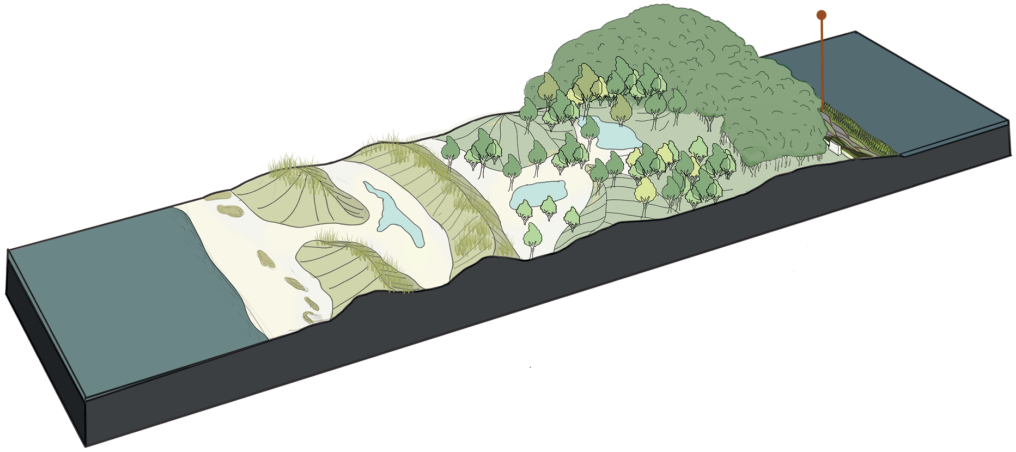
Structure energy lake

After the natural dynamics of the dune area, the inner dune edge and the steep slope of the energy lake provides an interesting contrast. Here, the experience of the transitions is focused on the water level movements of the energy lake. The dune entrance is mysterious, while the view over the energy lake is open and wide. The inner dune edge is the hub of recreational activities and food production. The edge of the dune is used for (holiday) housing, restaurants and shops. On the slope of the energy lake there is a place for aquaculture. The order of the crops and animals on the slope is based on the amount of time the specie prefers to stay above or under water. Therefore, there will always be multiple products that grow on the slope.
The fresh products can immediately be eaten in the restaurants.
This creates a high qualitative culinary experience.



Sometimes main road is located next to the energy lake at other places the rmain road goes through the dune area.





Aquaculture

Samphire

Sea Lavender

Lobster

Slope up

Crab

Mussel

Oyster

Seaweed

Slope down

References holiday housing and restaurants energy lake

Sea side restaurant (Source: Rocksalt Folkstone)

Holiday homes on dune slope with a view

Holiday cabin (design by: Lendager Groupne)

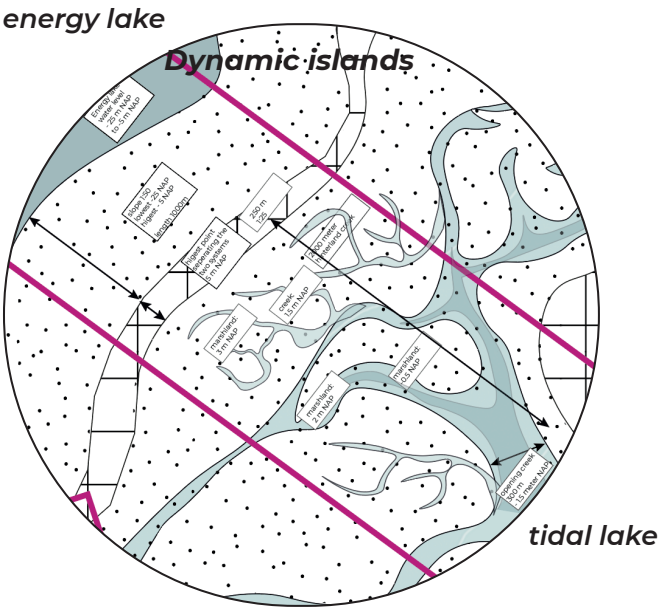
Boulevard on lake side (via: Eco Inn Warners Bay)

Impression transition dune - energy lake

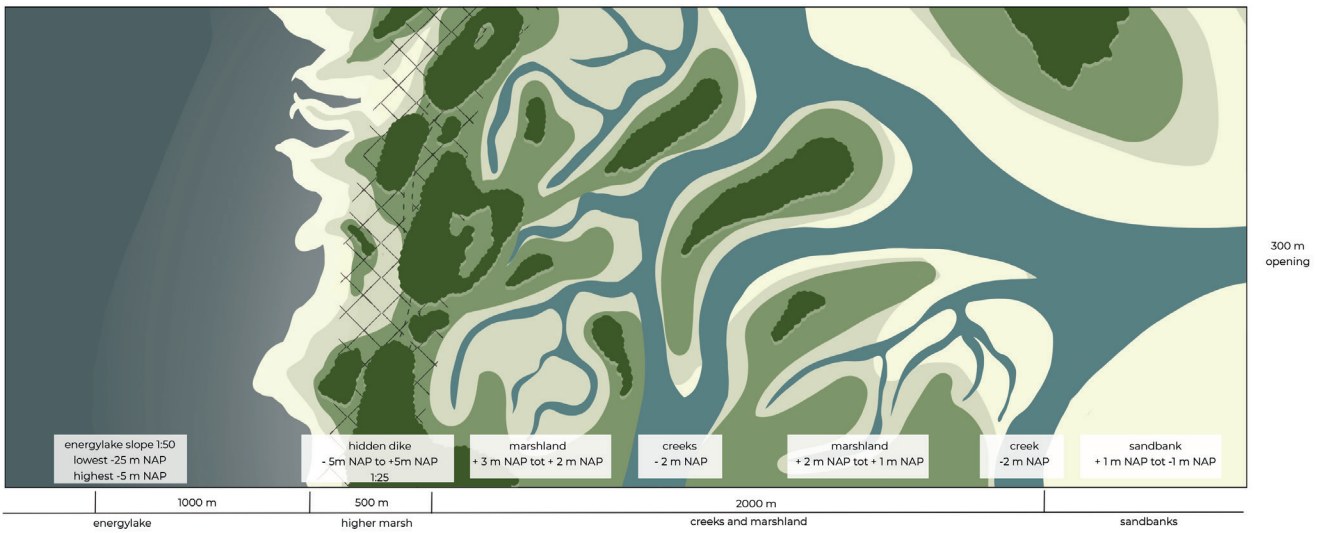
This impression is to provide an image of how this area might turn out at some places of the lake edge. During the day, the energy lake is filled with water. During the night, if there is wind, the water in the energy lake is pumped out. At this moment the farmers need to work and harvest their crops and shellfishes.

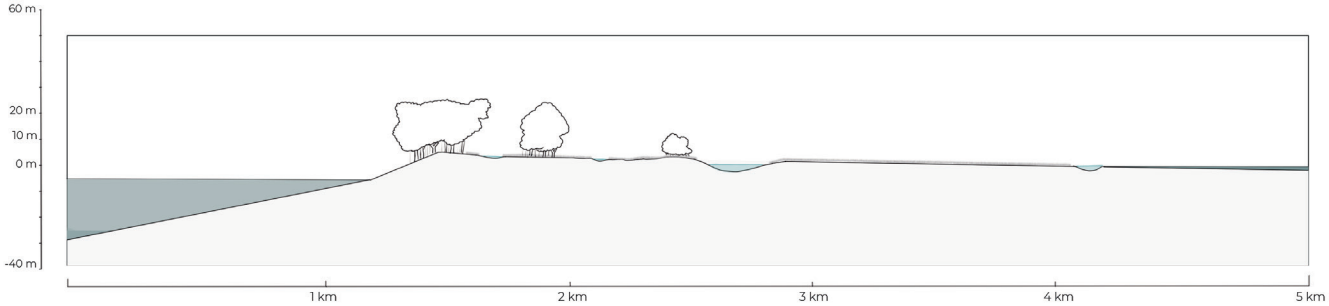
Transition zone: dynamic islands

The transition of the dynamic island zone is a transition from the energy lake to the tidal lake. In this transition, the gradients are very soft. This creates space for nature like shrubbery, (high) grassland, marshland and creeks. The technical requirement is a dike that separates the energy lake and the tidal lake. To keep the transition as gradual, open and wide as possible, the dike is designed as a hidden dike. The area above the hidden dike is higher grassland with a half-open landscape with trees and shrubs. In this way the view is obscured and the elevation differences that is needed for the hidden dike appears as a natural landscape.

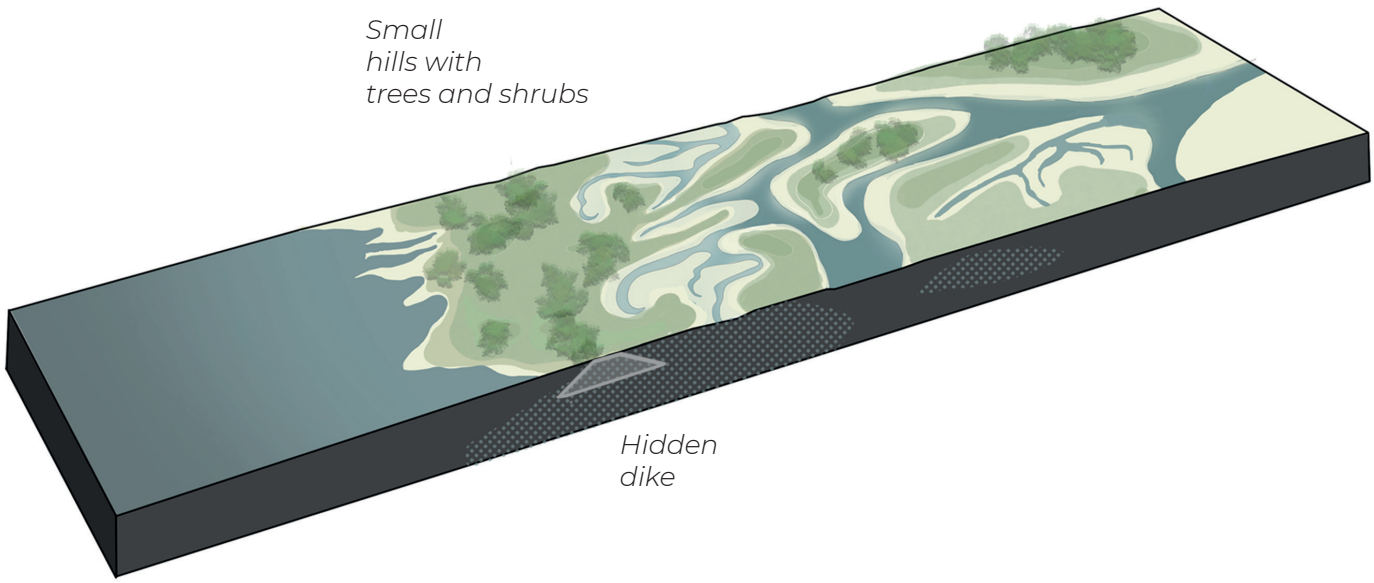


Basic landscape structure, measurements and technical requirements



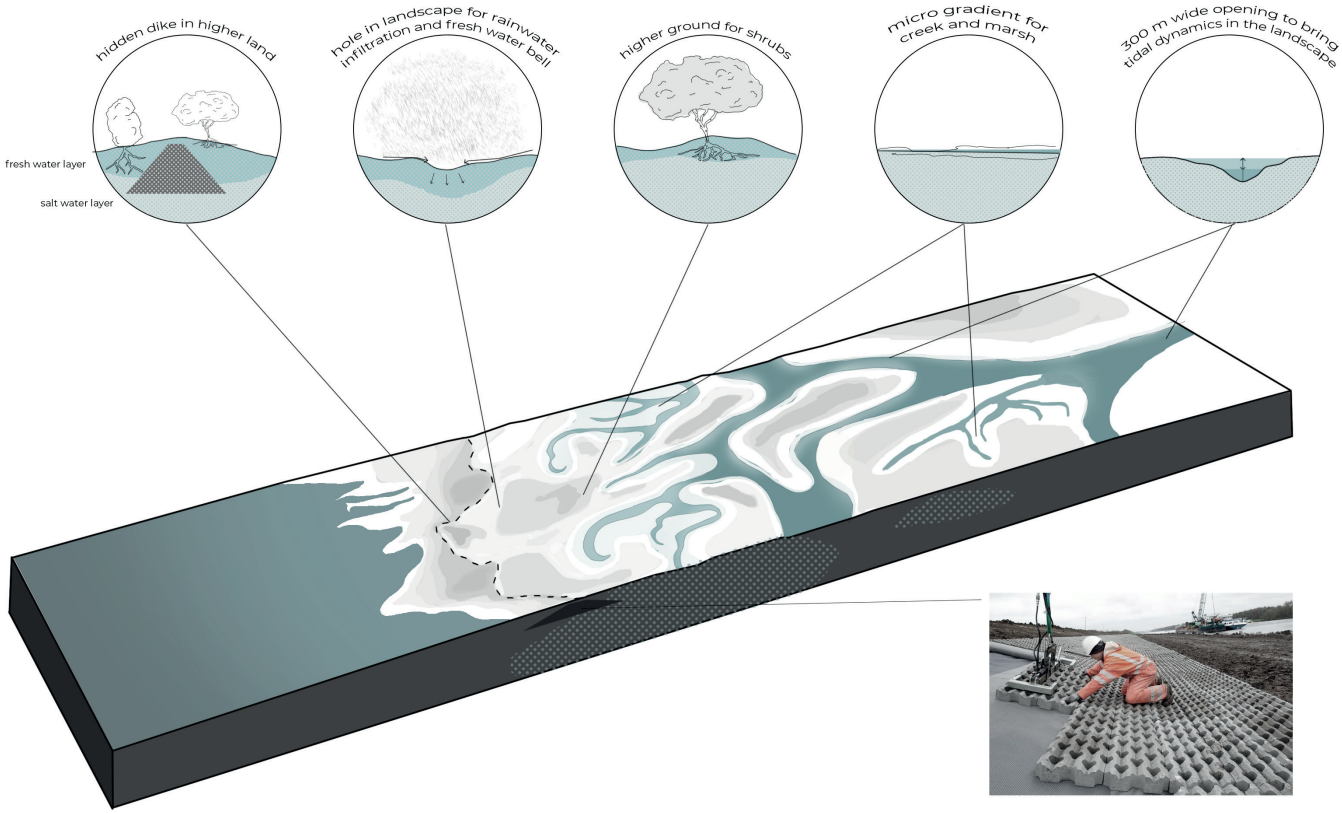


spatial structure



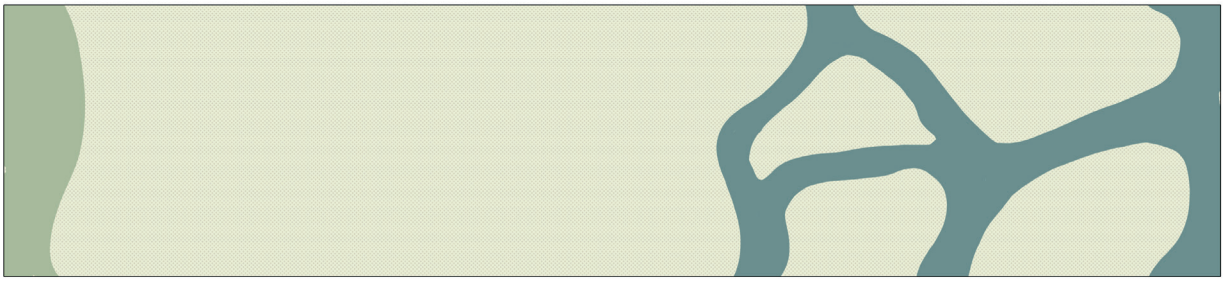
Gradients and watersystem

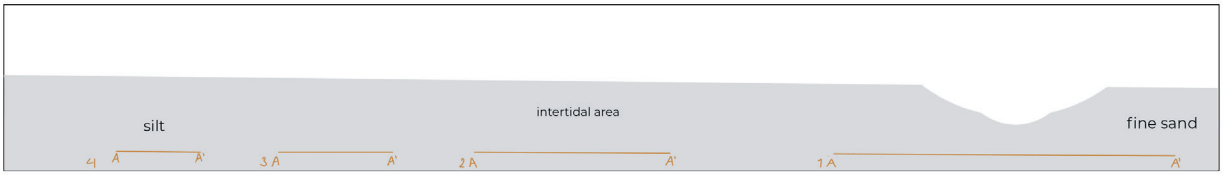
Due to the hidden dike, there are some elevated areas created in the landscape, at these higher areas, trees and shrubs can grow. In between some elevated areas, some low lying areas are situated in the higher grassland. When it rains, the water will flow to these areas and will infiltrate into the soil. Eventually, the water accumulates and a fresh water bell will be created in the subsoil. This makes the area more diverse in flora and fauna. The islands in the tidal lake have a micro gradient of max 3 meters. This makes most of the area an intertidal area, where creeks and marshland can develop.

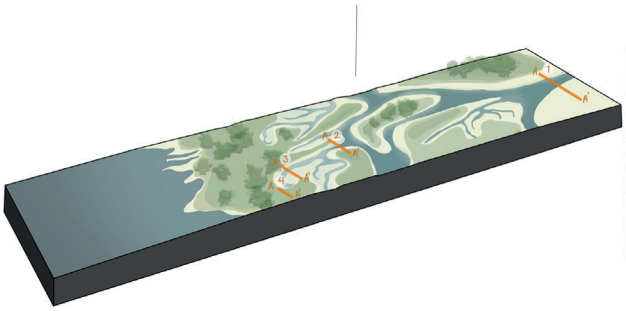


Stages of implementation - creek landscape

During the implementation stage sand and silt is brought into this area with a gentle gradient. The islands are formed and in between the main creek openings are digged.

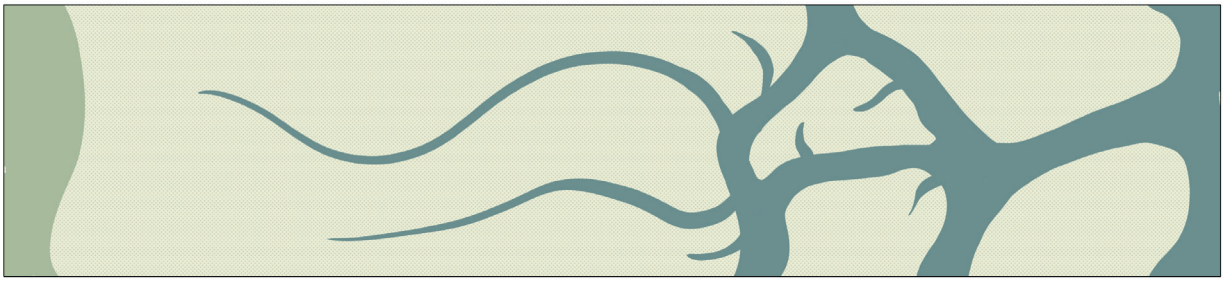


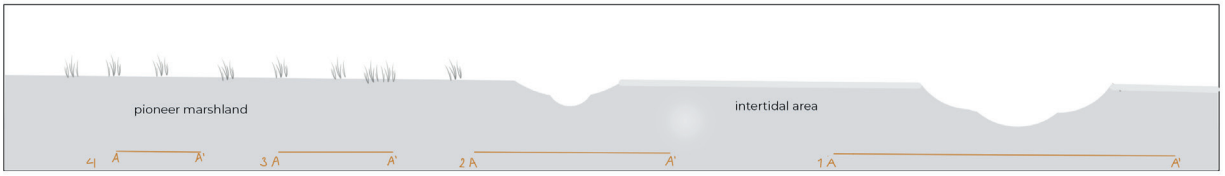


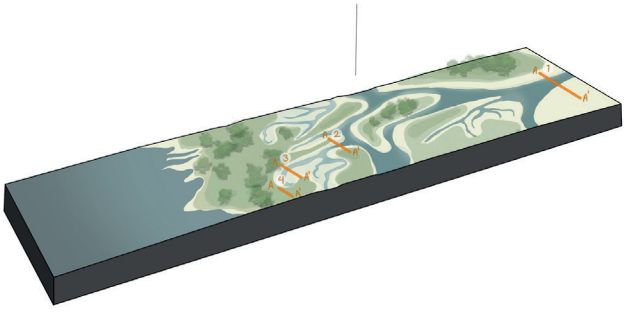


Source: https://qsr.waddensea-worldheritage.org/reports/salt-marshes

The second stage is the result of natural processes. The first creeks will develop with pioneer species.

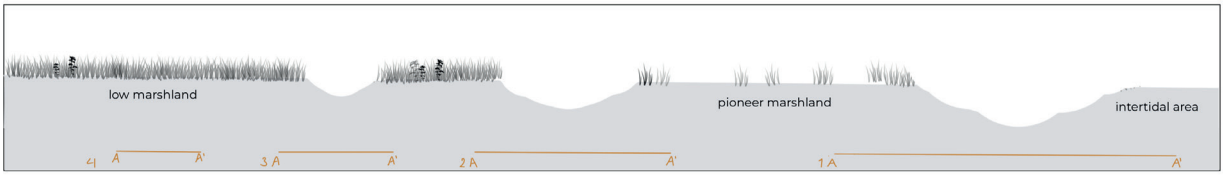


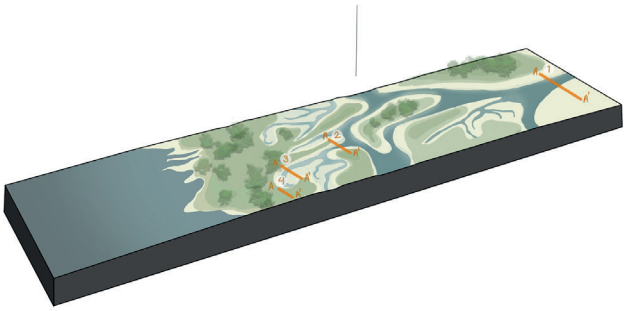




Source: https://qsr.waddensea-worldheritage.org/reports/salt-marshes

The creek network is expanding and low marshland will form.



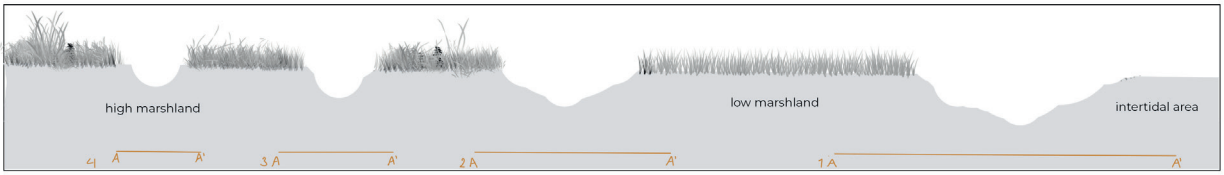


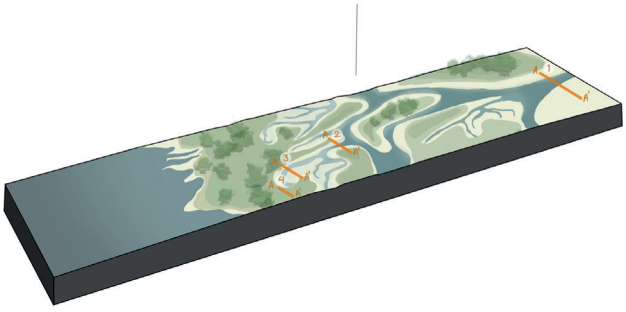
puccinellia maritima

Aster tripolium

Source: https://qsr.waddensea-worldheritage.org/reports/salt-marshes

The creek network has expanded further and the low marshland changed into higher marshland.





Elytrigia atherica

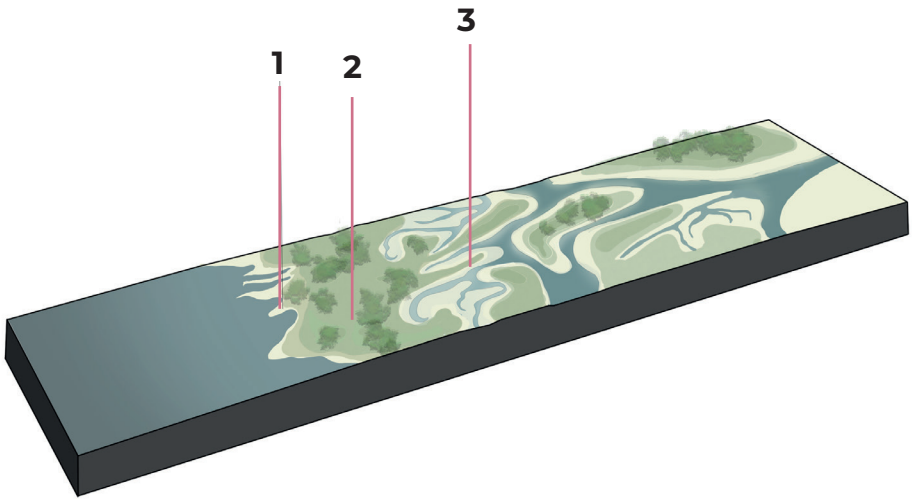
Limonium vulgare

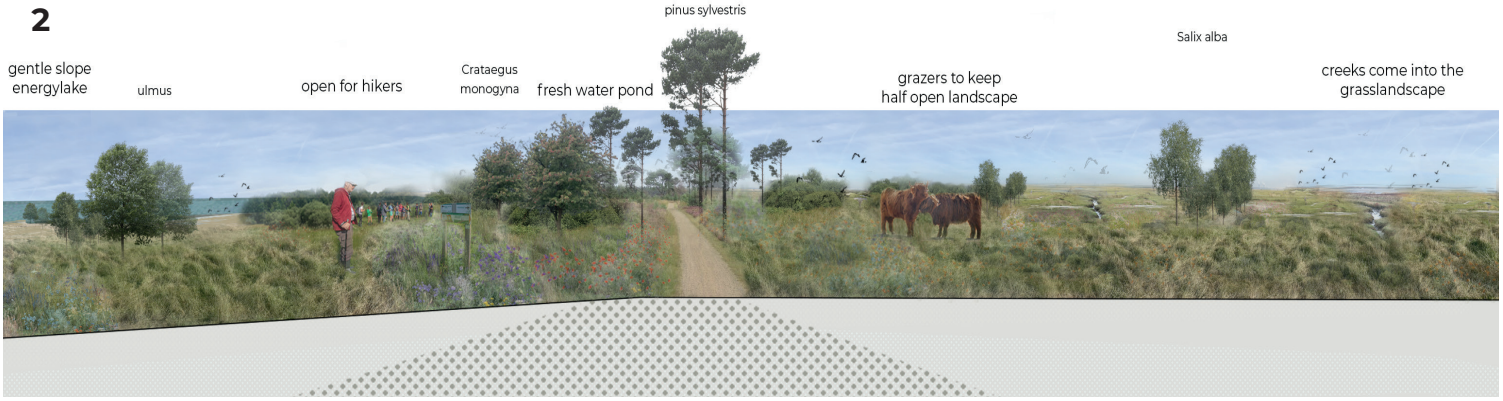
Source: https://qsr.waddensea-worldheritage.org/reports/salt-marshes

Experiencing the transition

The experience of this transition zone is shown in three different impression. The first impression shows the energylake with high and low water. The slope is gentle enough to have a soft gradient. The second impression is the hidden dike. There is higher half open grassland with open view from east to west.

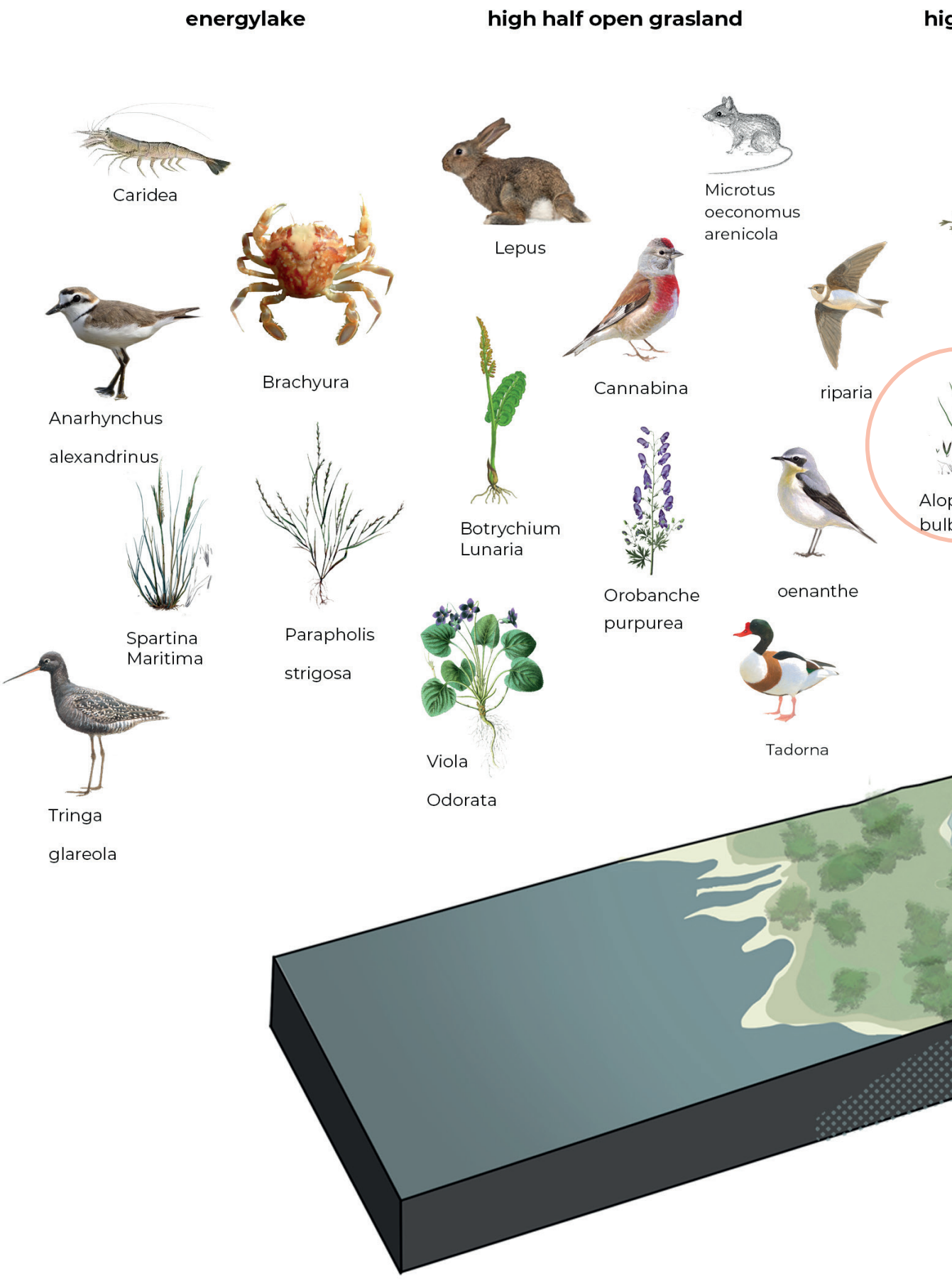
The third impression shows a view over the islands from the elevated hidden dike. The view is open and wide and dynamics are very well experiencable and inviting to explore.

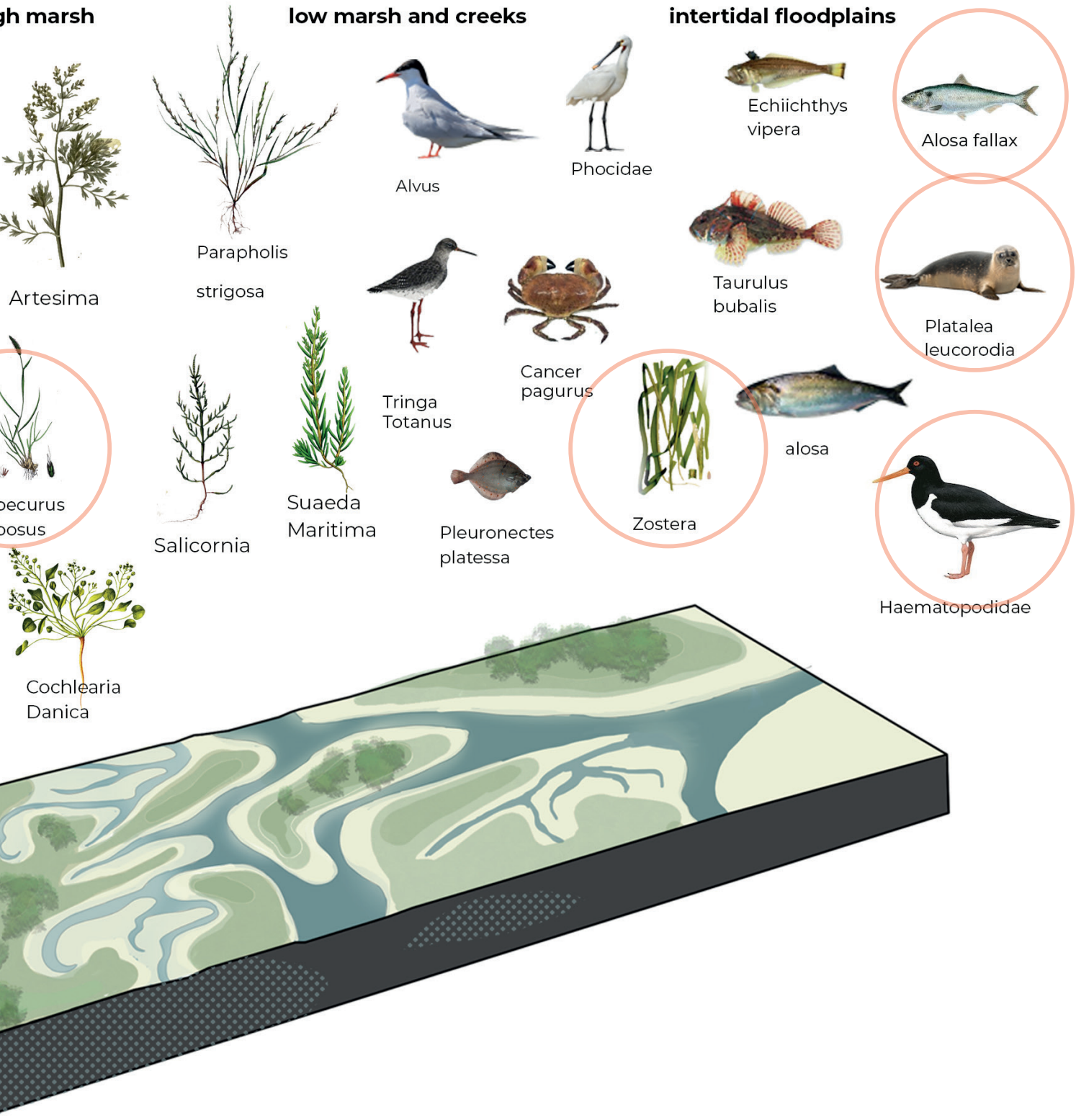

1
2
3


2
gentle slope
energylake
ulmus
open for hikers
Crataegus
monogyna
fresh water pond
pinus sylvestris
Salix alba
grazers to keep
half open landscape
creeks come into the
grasslandscape

Ecology

At the dynamic island zone, a lot of space is created for nature and different desired habitats. The circled species are the species that were indicated as target species in the analysis. This means that the right habitats are created to bring back suitable living environments for endangered species. All the stated target species in the analysis can be brought back in this new landscape.

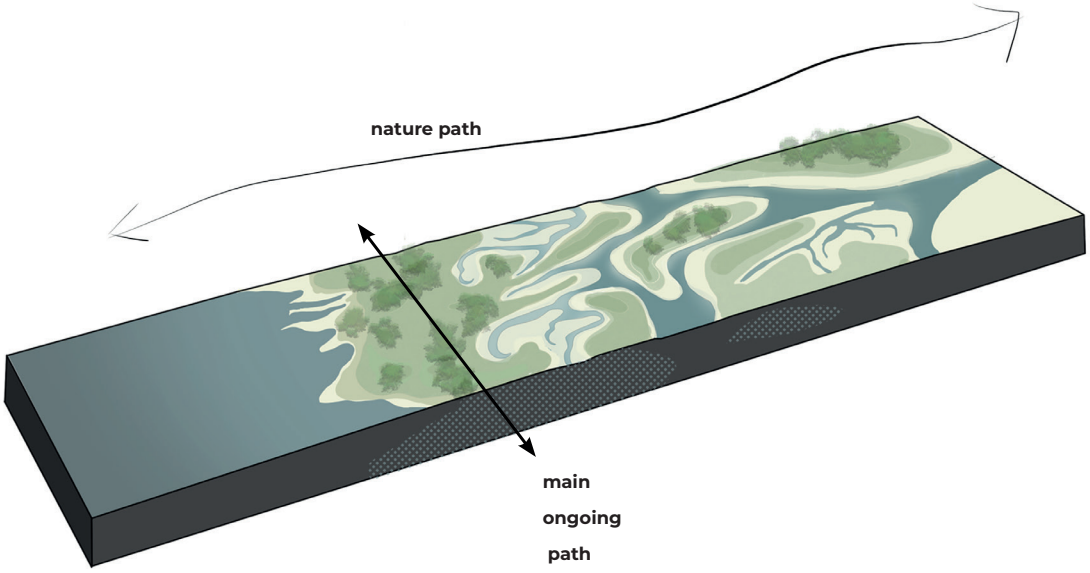


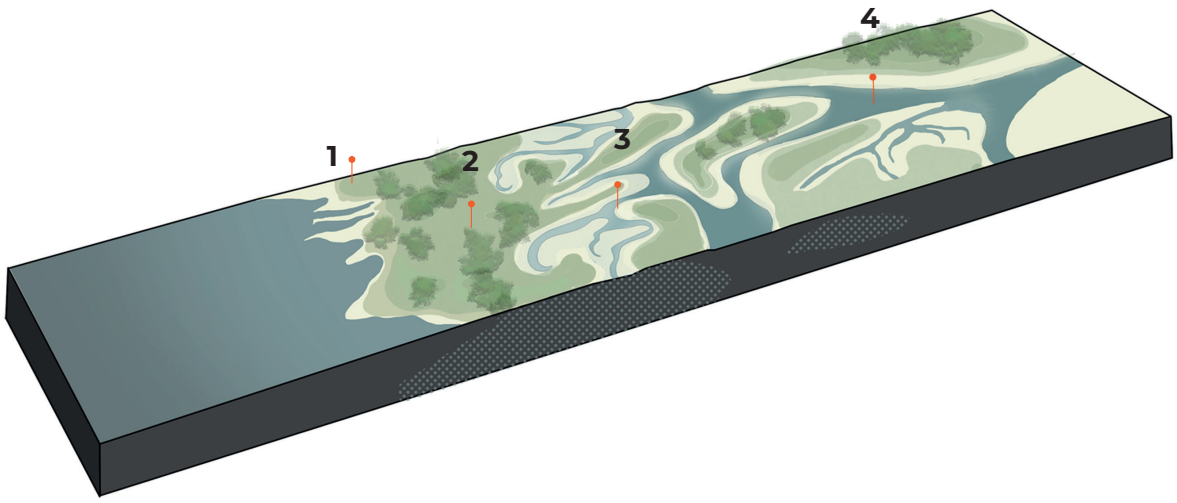

gh marsh
low marsh and creeks
intertidal floodplains
Artesima
Parapholis
strigosa
Alvus
Phocidae
Echiichthys
vipera
Alosa fallax
Taurulus
bubalis
Platalea
leucorodia
becurus
posus
Salicornia
Suaeda
Maritima
Tringa
Totanus
Cancer
pagurus
Zostera
alosa
Pleuronectes
platessa
Haematopodidae
Cochlearia
Danica

Program

This area is a tidal nature reserve because it provides a suitable living environment for many endangered species. For recreation, this means that there has to be as little disturbance as possible for ecology. The area will only be open for cyclists (only one lane), pedestrians and in small amounts for kayaks. In the entire transition zone, the focus for recreation lies on nature experience. The higher grassland above the hidden dike is less vulnerable to human interference in comparison to the marshlands. Therefore in this area, the main route to move through the transition zone is situated. The marshland and island area is too big to visit alone because it is easy to get lost due to high grasses and creeks. Therefore this area is only accesible with a guide.

Some design interventions can be installed to enhance the nature experience. At the water edge of the energy lake a tidal path will be placed. When there is low water, the path can be used by visitors to explore the vegetation of the lake bed. The main road will be a soft pathway. The secondary roads are mowed paths which will direct the visitor to stay on this path, while keeping the experience of walking through nature. Alongside the path, a bird-watching tower will be installed. At the creek landscape a bird watching tower/ viewing tower will provide a beautifull view over the creek landscape.
More towards the islands and tidal lake kayak routes can be guided via signs which will create a kayak safari experience.





1

tidal path - high water

tidal path - low water

searching for sea life

2

natural bike lane

mowed path to guide visitor

bird watching tower

3

bird watching tower
(Lookout Loop by Ulf Mejergren Architects)

guided tours

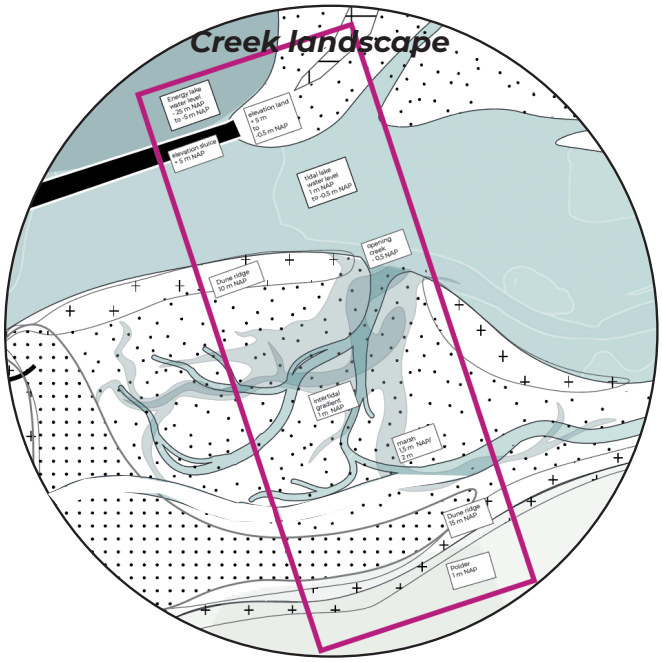
4

kajak safari

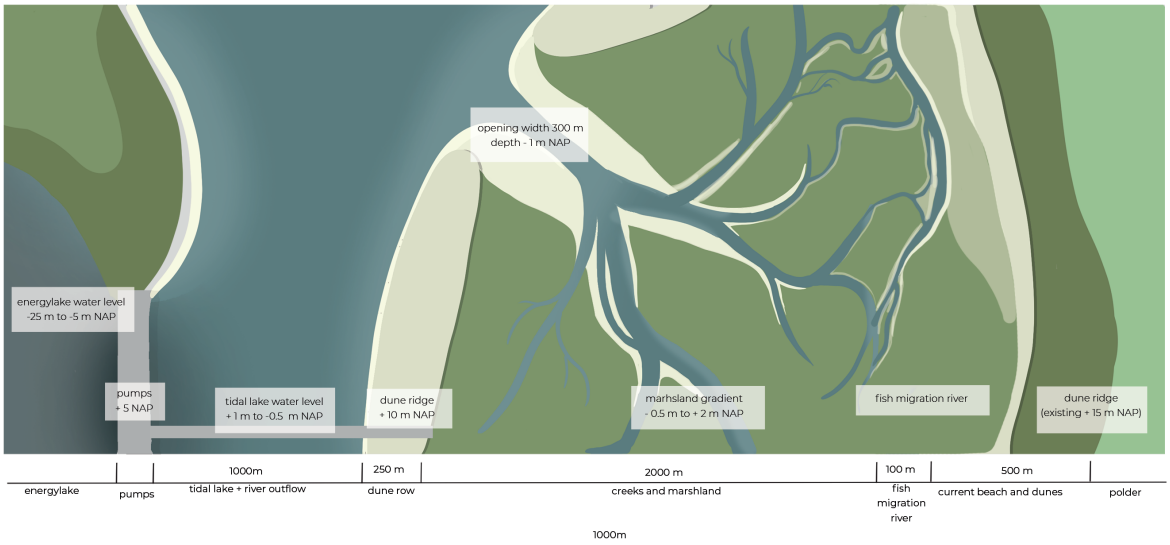
seal watching

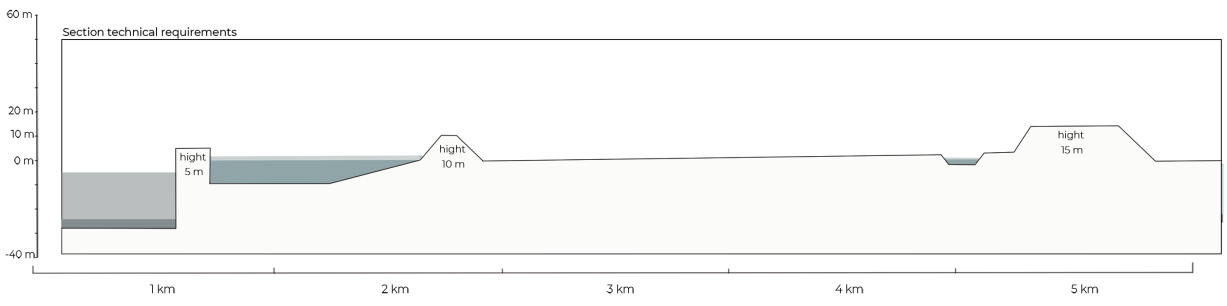
Transition zone: creek landscape

The transition zone of the creek landscape is very diverse. It includes the energy lake, the spillway, the in/outflow channel, the creek landscape, fish migration river, dune row and polder. The creek landscape is the soft transition that glues this transition zone together. The spillway and the storm surge barrier are designed as an eco-bridge. This eco-bridge is accessible for both humans and animals and connects the natural landscape of Voorne to Goeree-Overflakkee. This bridge increases the recreational opportunities for the new estuarine landscape because it is an alternative route for the Haringvliet bridge. The fish migration river follows the contour of the current coastline. In this way the experience of a water edge just beyond the dune will not disappear. The fish migration river joins the creeks at the creek landscape and connects the Haringvliet to the tidal lake. The creek landscape is an important node for the flow of ecology and the flow of people that visit the new estuarine landscape.

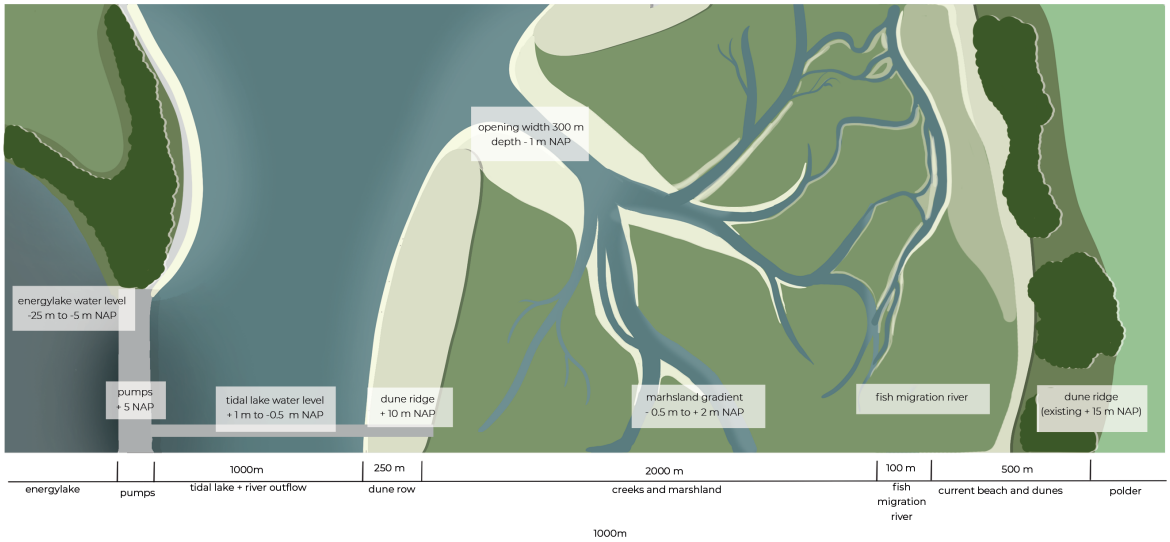


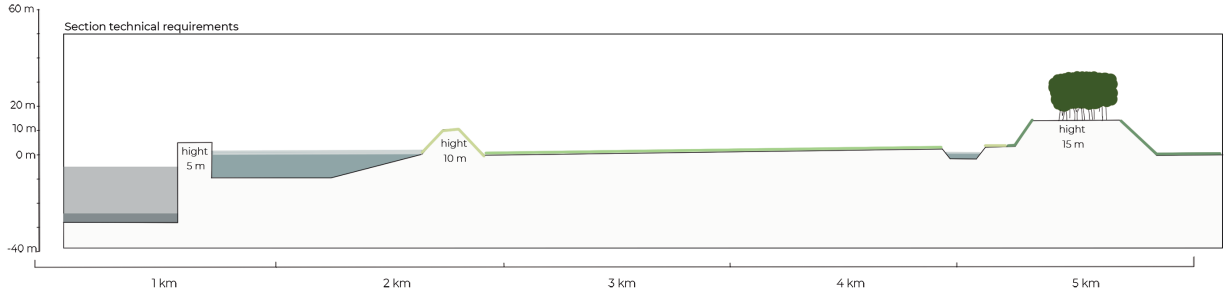
Basic landscape structure, measurements and technical requirements



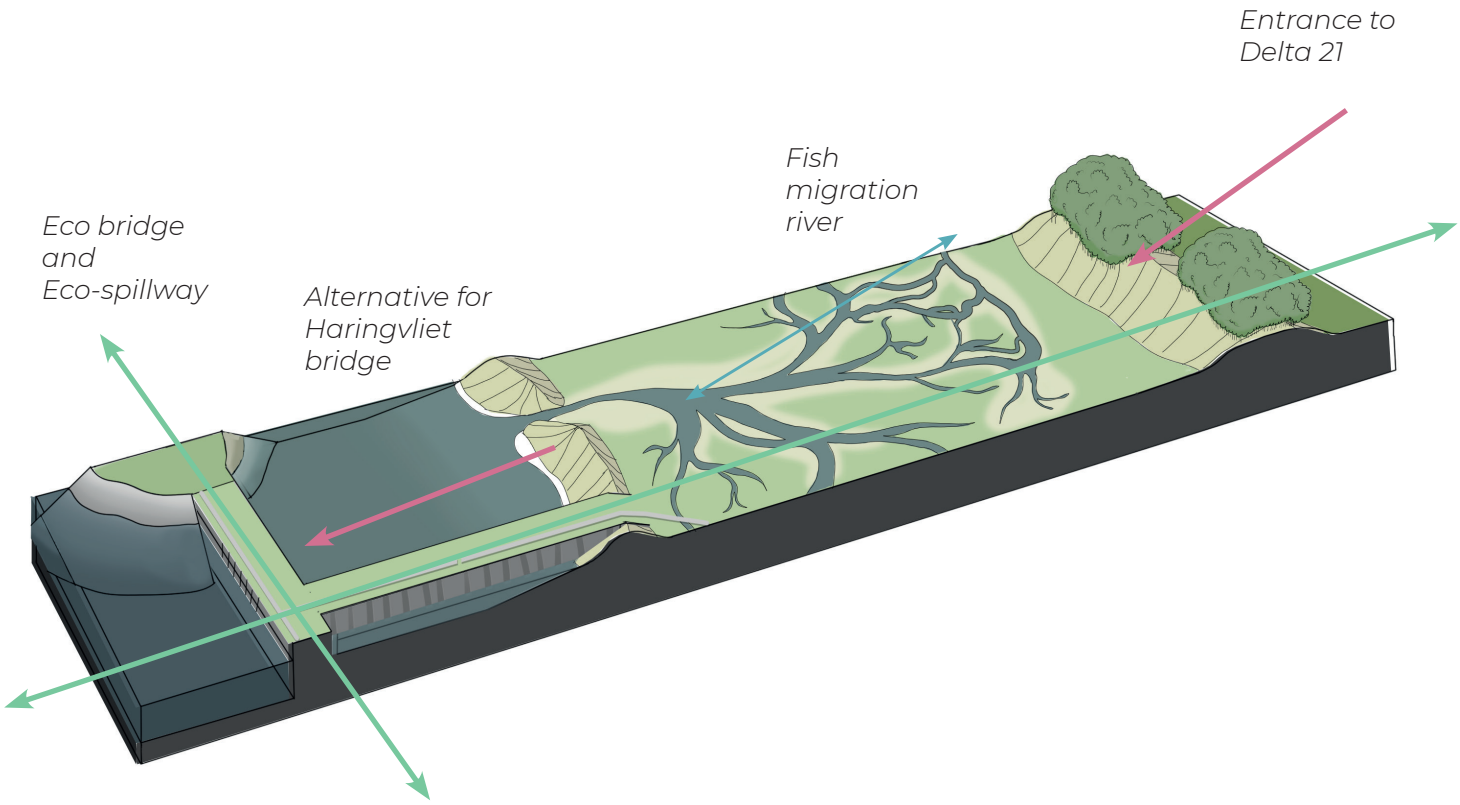


Landscape structure





Spatial structure and flows



Impression spillway and eco-bridge

The spillway and the storm surge barrier need to be accessible all the time for maintenance and as a road for visitors. At the same time, it serves as an important ecological corridor between the mainland and the island. This impression shows how the flow of people and the flow of nature can coexist.

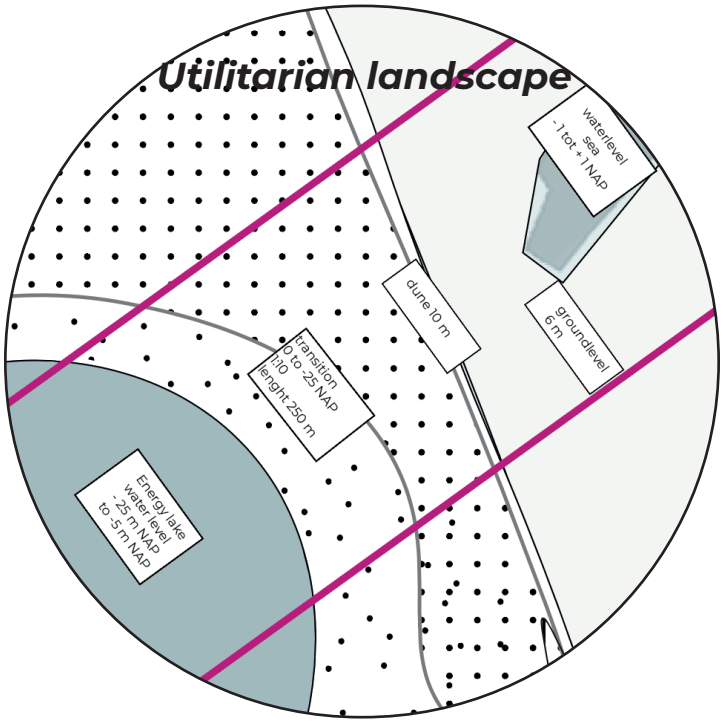
Impression fish migration

The entrance to the new landscape is located at a current beach entrance. The entrance guides the visitor over the dunes and the fish migration river through the creek landscape. This new entrance is the transition between polder and Delta 21.

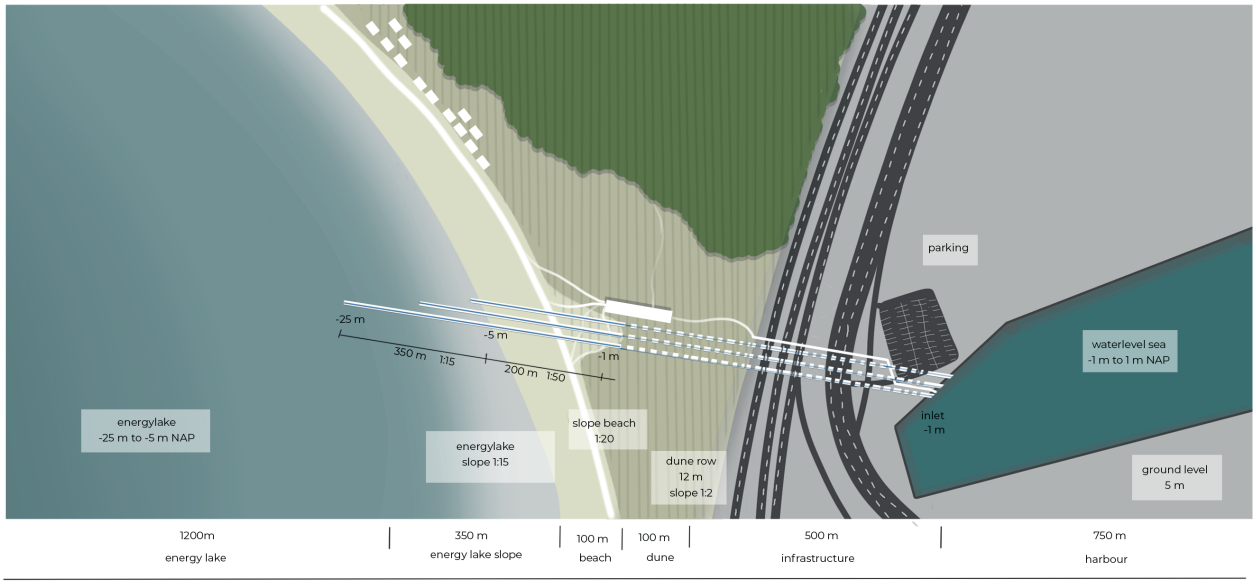
Collage of the
new transition

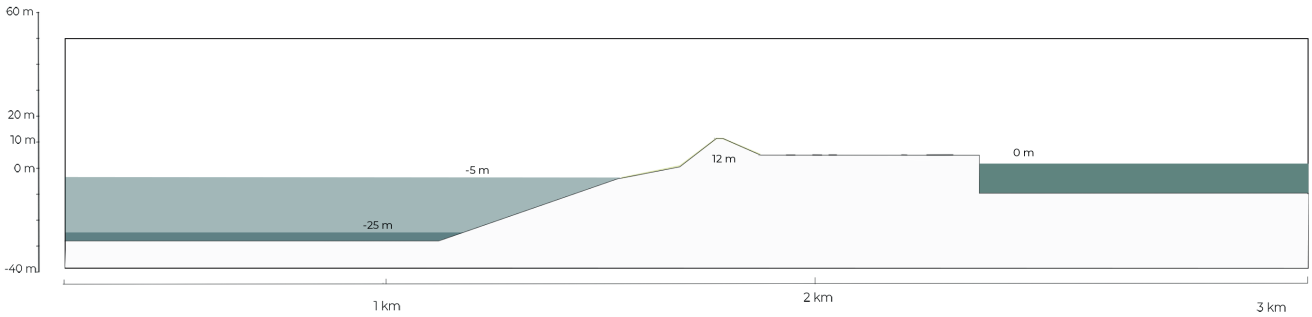
Transition zone: Utilitarian landscape

The transition zone of the utilitarian landscape serves as a destiny in itself. Here, the utilitarian landscape of the Maasvlakte comes together with the utilitarian landscape of the energy lake. Both worlds are separated from each other by a row of dunes but can be experienced as a whole at the visitors centre. The visitors centre will be high enough to look over the dune row to the Maasvlakte, while, when turning around, a great view over the energy lake can be perceived. To stimulate the experience of the interconnection of the two landscapes and explain the working of the energy lake a water cascade is proposed. This water comes from the harbour at the Maasvlakte (0 m NAP), goes through the dunes by pipes, opens up as water cascade at the side of the energy lake, and flows out in the lake (-25 to -5 NAP). This structure emphasizes the water level difference and helps in understanding how the energy lake operates. Besides this, the water cascade will be very interesting and fun to walk over and for children to play. All together, it makes the place more interesting to visit and explore.

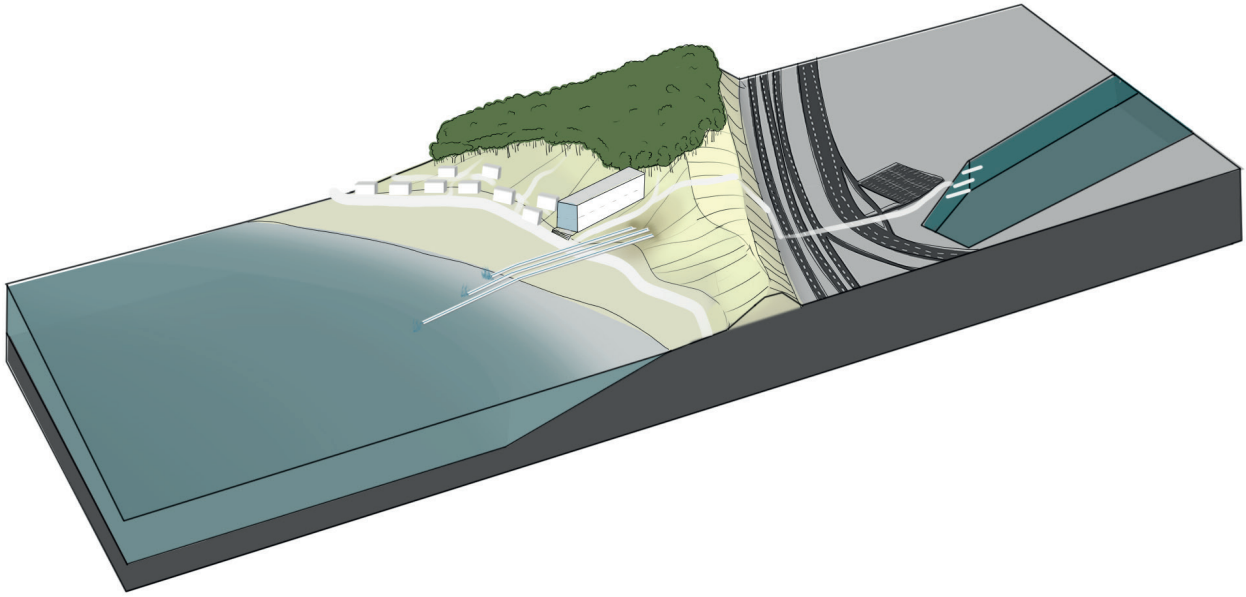


Basic landscape structure, measurements and technical requirements





spatial structure

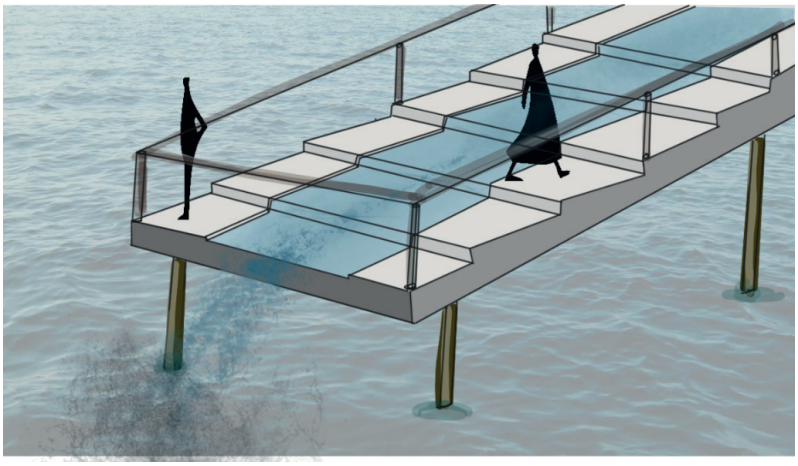


References

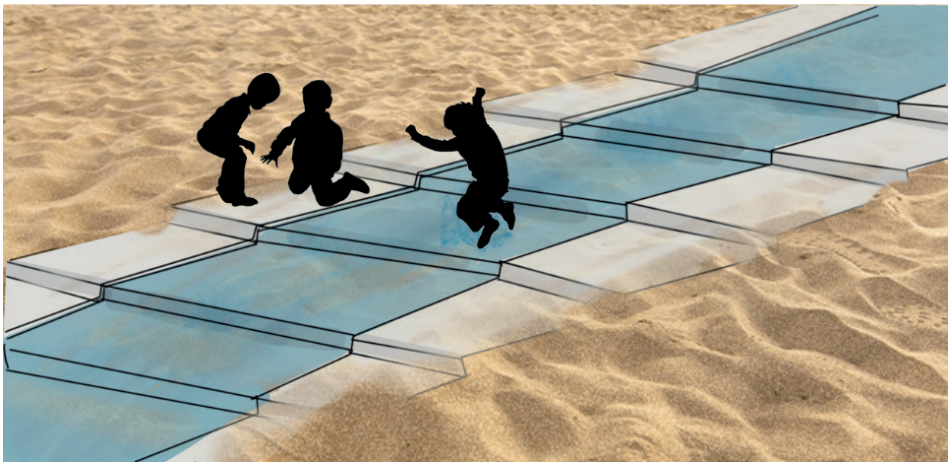
Watercascade Ballyfin

Roofpark Rotterdam by Sant & Co

Impression section visitorscentre and water cascade



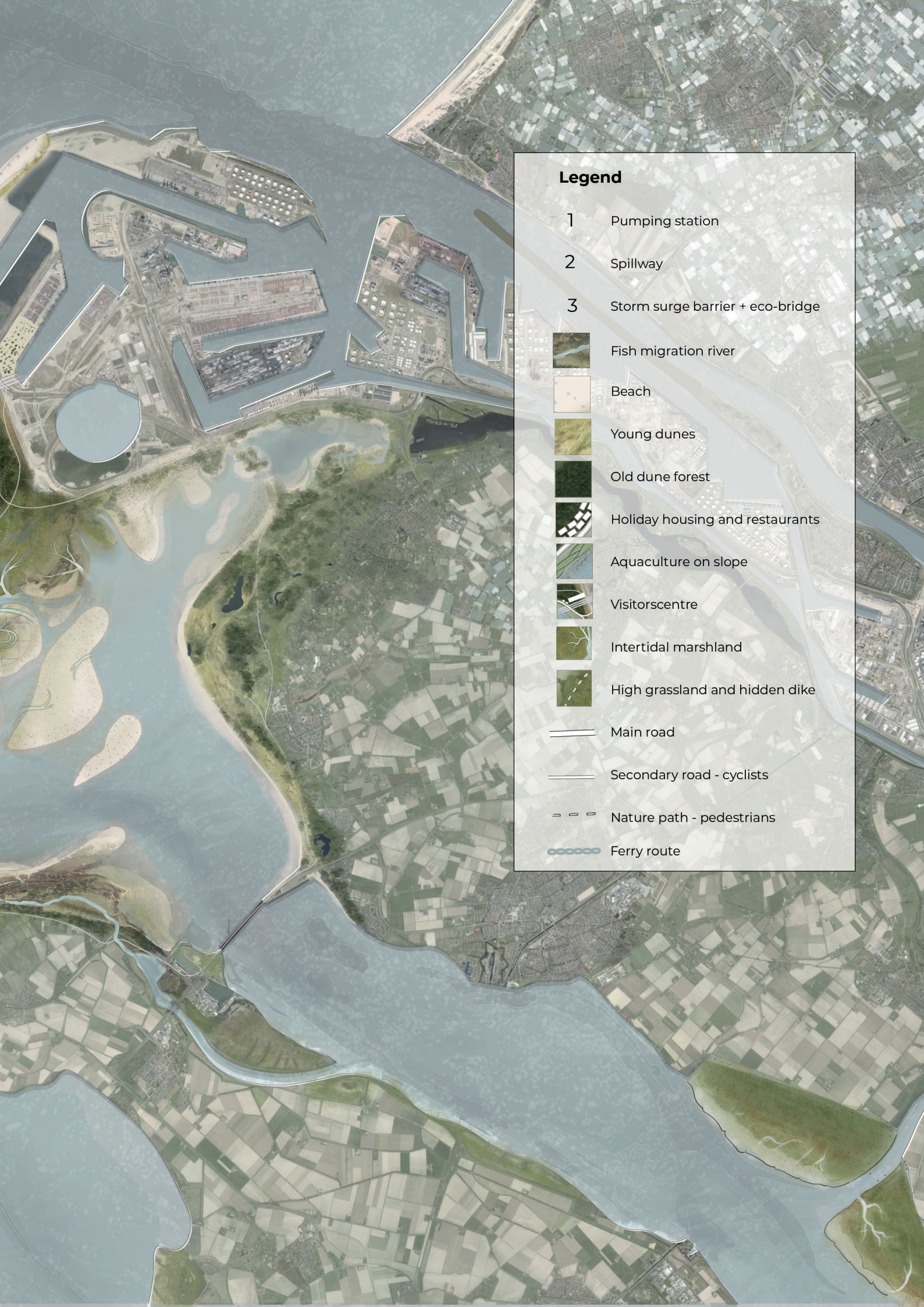
impression cascade above energy lake



impression cascade at dune area

5.5 Layers of the new landscape

The design exploration of each transition zone provides new insights and created a deeper layer to the masterplan. In this sub-chapter the layers of the masterplan are briefly discussed to get an overview and summary for the proposed new estuarine landscape.

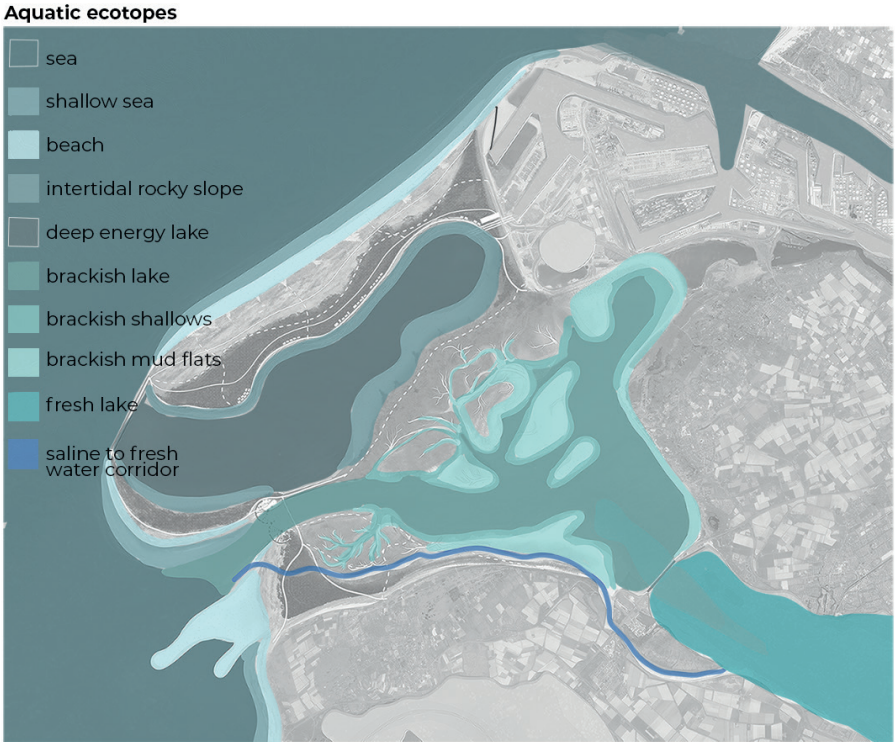

Legend
1 Pumping station
2 Spillway
3 Storm surge barrier + eco-bridge
Fish migration river
Beach
Young dunes
Old dune forest
Holiday housing and restaurants
Aquaculture on slope
Visitorscentre
Intertidal marshland
High grassland and hidden dike
Main road
Secondary road - cyclists
Nature path - pedestrians
Ferry route

Layers of the new landscape - ecology

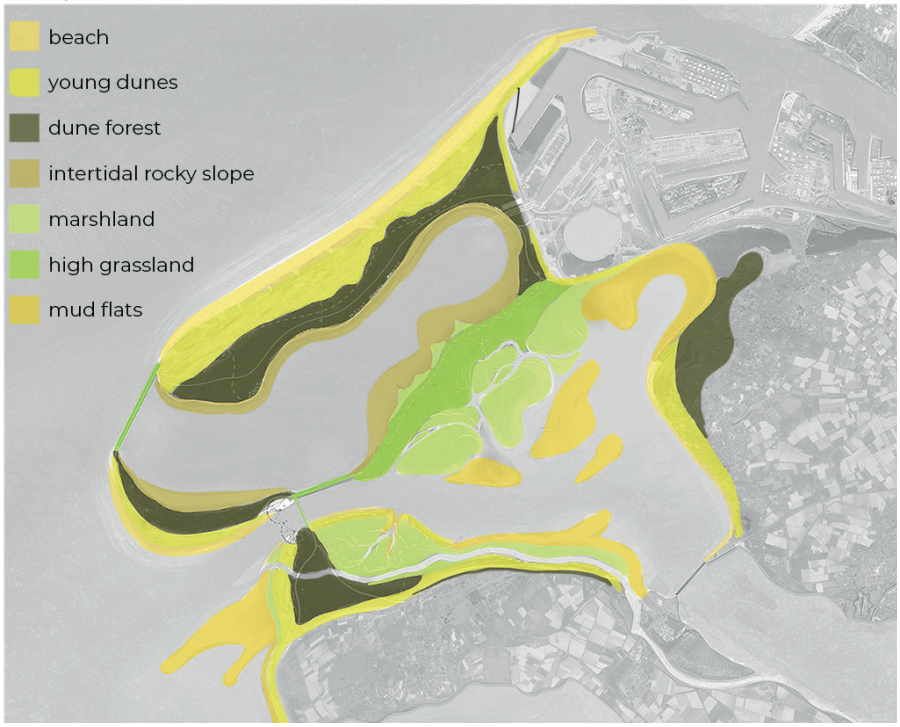
The following diagrams give an impression of the ecological gains created by the new estuarine landscape. The diversity in ecotopes on land and water is very high. This is mainly because of the large variations in gradients of wet/dry, plantation, diversity in stages of succession (by wind, tide and grazers) and the variety of salinity. Specifically, the marshlands, mudflats and dunes, are very suitable for endangered species to settle. The new estuarine landscape is a buffet for migratory birds. Here, they take a break, rest and feed themselves. The eco-bridge creates the opportunity for mammals to increase their territory from Voorne to Goeree-Overflakkee. The river-sea connection is re-opened again. The brackish environment in the tidal lake creates an essential habitat for migratory fishes. Here, the fishes can acclimate to the changing salinity. This will help in restoring the fish colonies. When there is a period of drought and the river discharge is not high enough, the Haringvlietdam needs to close. In this case the fishes can still use the fish migration river as an alternative route.

To conclude: implementing the new estuarine landscape creates much more surface for qualitative nature to the Netherlands and helps to restore ecological corridors for fishes, birds, and mammals.

Aquatic ecotopes



Ecotopes on land



Layers of the new landscape - infrastructure

This new landscape will attract many daily visitors and long-stay visitors. Three very large parking lots (4000 cars) provide the area with enough free parking space. Visitors can park here and walk, bike, or take the bus deeper into the new estuarine landscape. The new landscape will therefore be a low-traffic area. As a result, nature will not be disturbed too much and the experience for people within the landscape provides much more stillness and calmth. The first parking lot is situated at the beach entrance and is very suitable for daily beach visitors. From here, you can walk to the beach or you can hop on the beach bus to drive a bit further to the beach more southwest. The second parking lot is the main entrance of the new landscape and guides the visitor directly towards the visitors centre. From here, the visitor can take the bus or the ferry over the energy lake, to visit another part of the new landscape. The main road through the new landscape is accessible for cars and goes from parking lot three to two. This road is used by maintenance troupes, long stay visitors, public bus or delivery vehicles. Some small secondary roads lead from the main road to the beach, this is open for public transport, delivery or people with disabilities.

To conclude: the low amount of traffic in this area will provide more quietness, less pollution, and slow down the visitors, who will experience the visit as more remote where they spend time in nature.


Legend
1 Main entrance and free parking 3000 spaces
2 Second entrance and free parking 4000 spaces
3 Third entrance and free parking 3000 spaces
Village
Parking
Road (car)
Busstop
Ferry
Ferrystop
Beach bus
1
2

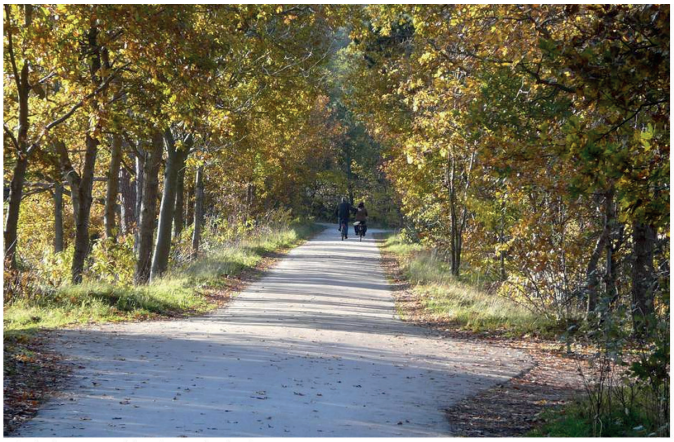
Layers of the new landscape - infrastructure

The images below provide an impression of the infrastructure at the new landscape. Little space is preserved for cars. Public transport is an important way to move through this area; a public bus, a ferry and a beach bus can get visitors anywhere. Bicycle lanes, hiking trails and mountain-bike parcours are recreational infrastructures. The combination of public transport, bicycle lanes and hiking trails create many opportunities for recreation. A visitor can take the bus or ferry to a specific point and hike or bike back to another bus stop or directly to the parking lot. This creates an endless variation in recreational routes.

Main road - cars and bikes

Google maps, Vierhouterweg Gelderland

Secondary road - cars and bikes



Schoorlse duinen, retrieved through: Hetoudeatelier.nl

Ferry to cross the energy lake

Shutterstock

Beach bus along the coastline

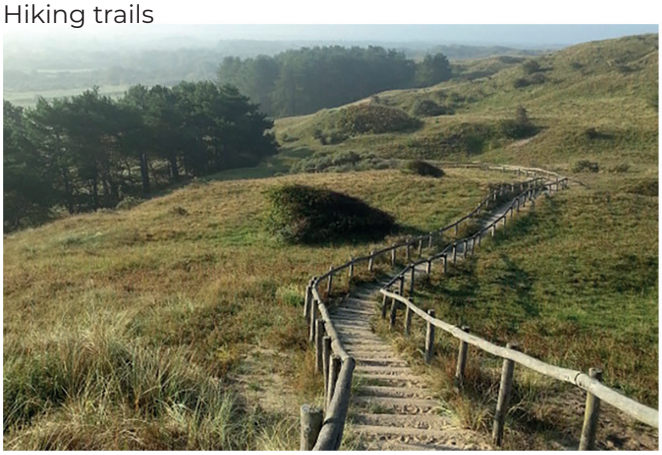
Trein Scheepstra, via Twitter

Bicycle lanes

Schoorlse duinen, retrieved through: residentieCalifornie.nl

Mountainbike parcour

Hiking trails



Schoorlse duinen, retrieved through: Watgaanwedoen.nl

Public bus

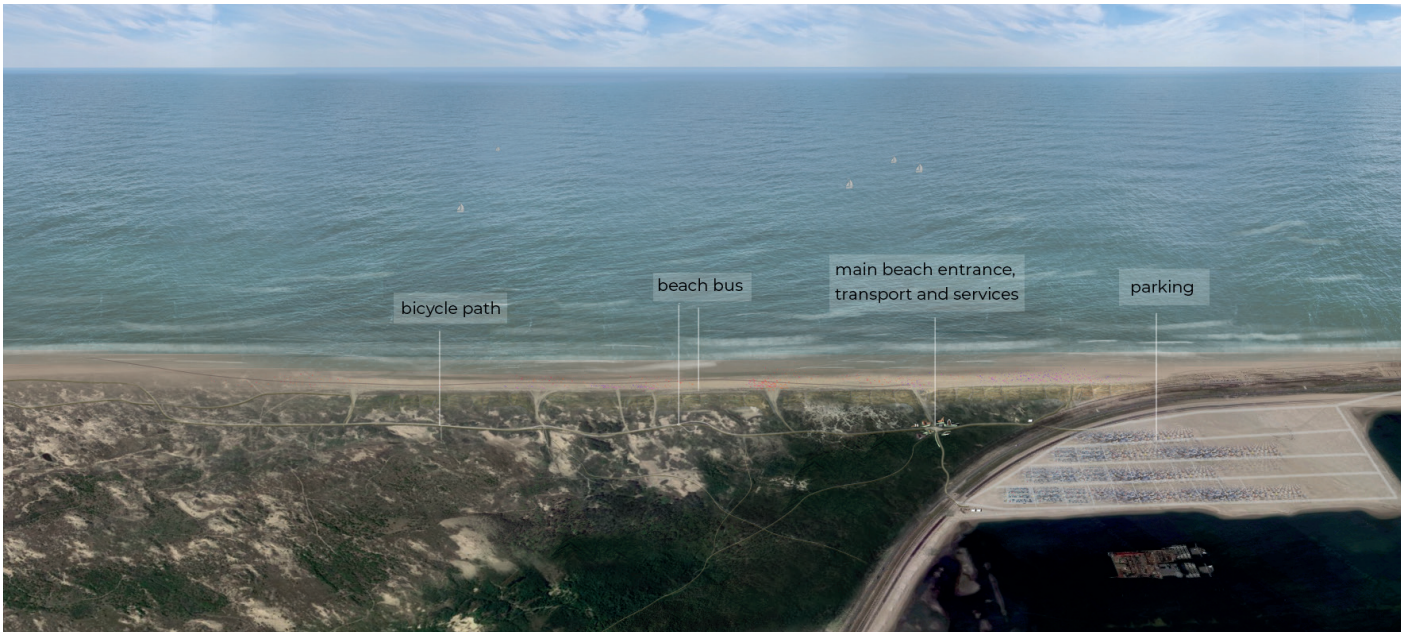
Layers of the new landscape - Recreational nodes - beach entrace

At the new estuarine landscape, the recreational experience is mainly nature-based. Being in nature is a restorative activity and stimulates active leisures such as hiking, cycling, mountain-biking, swimming, surfing, sailing etc. In this new landscape, recreational activities are embedded in all different sub-areas. The type of the activity is based on the type of nature and its vulnerability to disturbance. Within the dune area there is a network of bicycle paths and pathways for pedestrians. The marshland is more vulnerable for human interference. Here the activities are more small scale with only natural paths. On the north side, a large beach is created where people can swim and go surfing. The dune entrance shows how people will arrive to this area, enter the beach entrance with facilities and eventually end up at the beach. Alongside the shoreline of the energy lake small villages are located, with housing, shops, restaurants and the visitors centre. The small villages form recreational nodes and can easily be used as a coffee stop and destiny for a route. This makes the large new landscape more intelligible, breaking up the large area into smaller distances.

To conclude: the implementation of the new estuarine landscape introduces an enormous amount of recreation and experience to the Netherlands. The water level difference and the aquaculture on the slope creates an entirely new landscape experience that will draw many visitors.

Recreational nodes - small villages with own identities break up the area into smaller more tangible pieces.

Beach entrance



Beach entrance & parking

Beach opening, restaurants and services

Pathways to other beaches

Beach entrance

Layers of the new landscape - Flood protection system

Implementing the new estuarine landscape with the incorporation of Delta 21 is of great innovation for the Dutch flood protection system. Climate change will increase the sea level and the chance of heavy rain events followed by a very high river level. In some cases, the sea level might be too high for the river to naturally flow out into the sea. The water will accumulate in the rivers and might cause a dike breakthrough. to prevent this, all the river dikes must be strengthened. This is very costly and requires a lot of space that is often not available. The plan of Delta 21 reveals an alternative. Instead of heightening the river dikes, the river water can also be pumped out into sea. The sea defence structure is the first, most important, water defence line (the orange line on the plan). The river dikes are the second water defence line, and have therefore less strict requirements.

To conclude: the incorporation of Delta 21 into this new landscape is a sustainable solution for the flood protection threat in the Netherlands. It has the capacity to adapt to changes in sea level and river level. Weak spots or lack of space in river dikes will not form an issue anymore. Because the pumping turbines are used daily or weekly for energy storage, the risk of pump failure is reduced significantly. The installation of the pumping turbines, the spillway and the storm surge barrier are technically uncomplicated to install and are, in combination with the energy storage system, cost-effective and reliable.

Flood protection

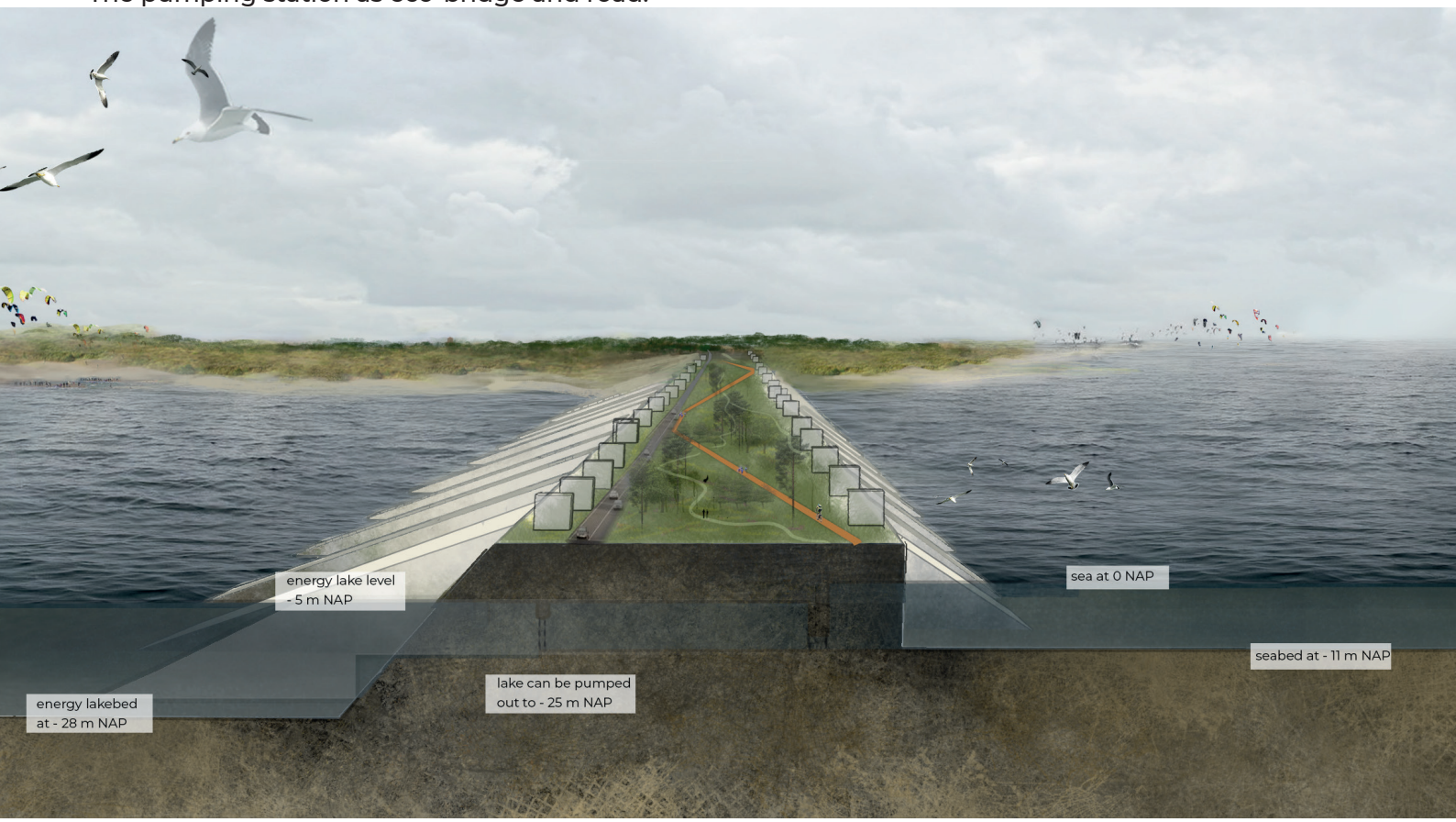
Areas prone to floodings

This map shows what areas in the Netherlands are prone to floodings by sea or river water. With the installation of Delta 21 the vulnerability of these areas will decrease enormously.

retrieved from: BHIC.nl

The spillway (left) and the storm surge barrier (right) as eco-bridge and road.

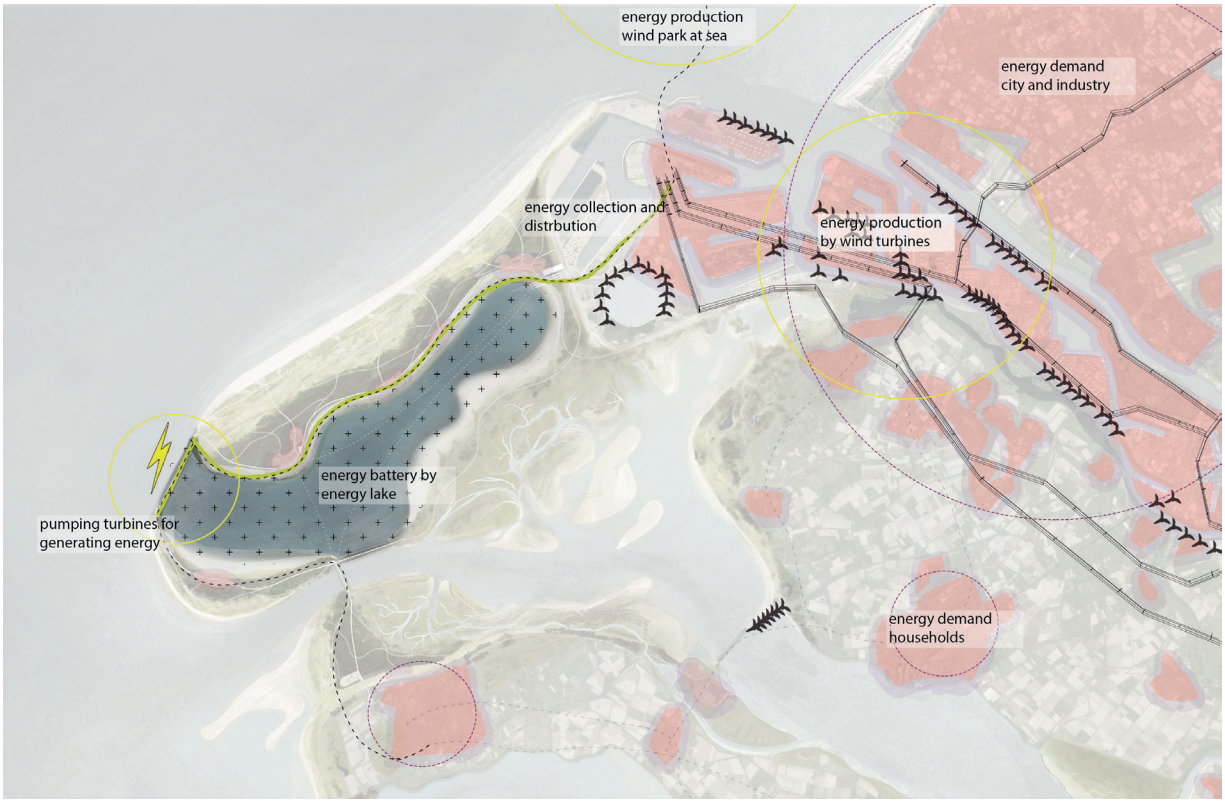
The pumping station as eco-bridge and road.



Layers of the new landscape - utilities

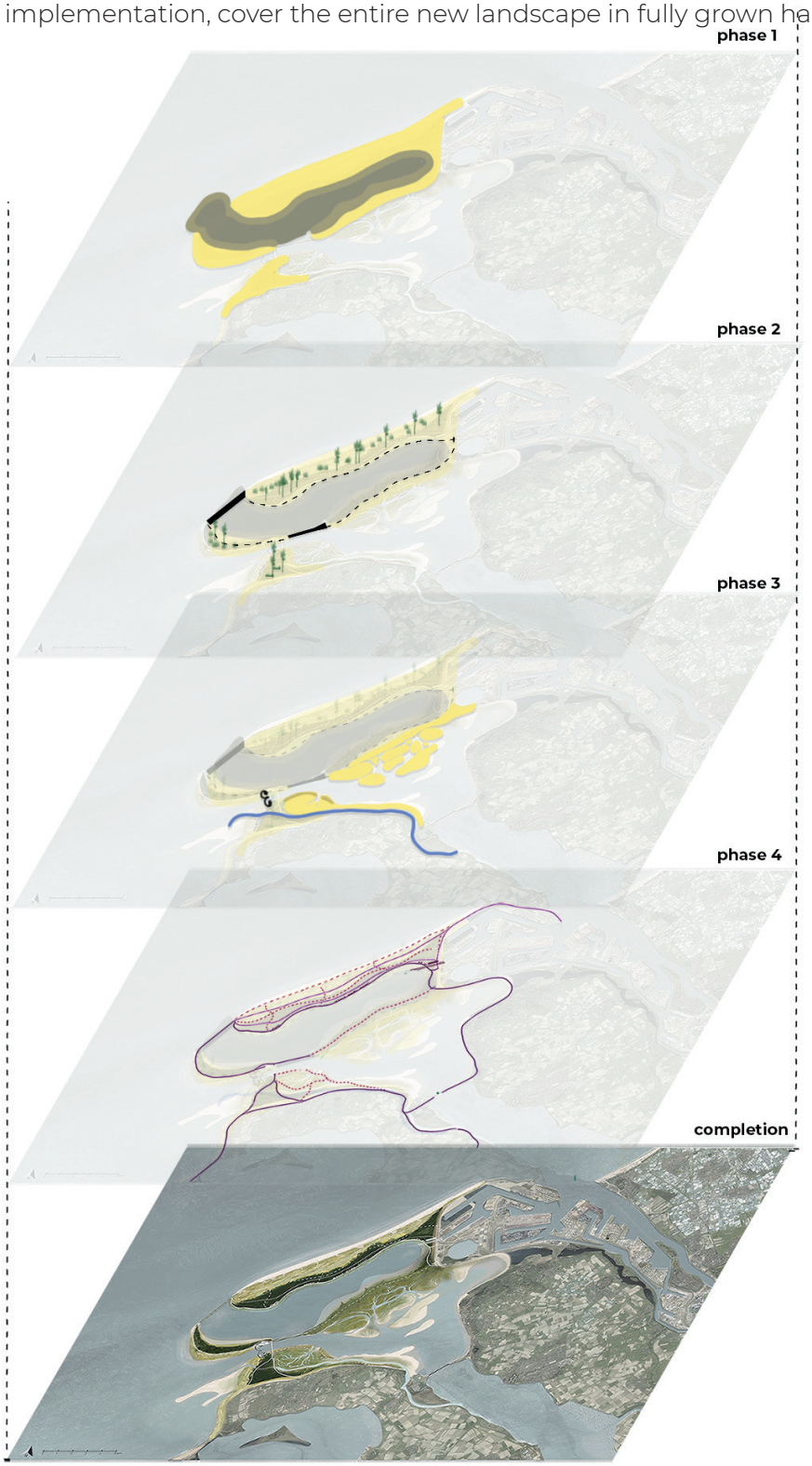
Besides flood protection, the new landscape also introduces aquatic food production and a (renewable) energy storage installation. The energy is produced by wind turbines or other installations. When the energy net is full and the energy demand is low (often at night), the energy is stored in the energy lake. An underground network in the new estuarine landscape transports the energy from the producers to the net, the turbines, the energy lake, and generates it back into the energy network (often during day), eventually, it ends up at the households.

To conclude: the potential of energy storage will help the Netherlands in achieving the climate goals. The possibility of aquaculture might reduce the fishing pressure at sea and helps in creating a more circular food system with shorter production-consumer chains.



5.6 Stages of implementation

The new estuarine landscape is a very large new piece of land that needs to be installed in different phases. During the first stage, sand is removed from the location of the energy lake to make it deeper (-27 m NAP). The sand that comes free is used to build up the frame of the new landscape. During the second stage, the pumping station, spillway and hidden dike are installed and the dunes are planted with marram grass to prevent it from eroding. During the third stage, the aquaculture edge, the storm surge barrier, bridge and fish migration river are installed and the sand is placed at the creek landscape and the island landscape with the correct gradients and dimensions for the tidal inlets. The last stage is about installing the recreational layers with the houses, infrastructure and visitors centre. During all the stages, flora and fauna occupy the landscape and will eventually, in about 20 years after implementation, cover the entire new landscape in fully grown habitats.



6. Conclusion and reflection

Conclusion and reflection

Introduction

This graduation project started with a design brief for the initiative Delta 21, so far only presented as a technical design intervention. This graduation project approaches the Delta 21 initiative as a design exploration from a landscape architectural view. This means that the design starts with the underlying landscape and not with the flood protection measure. The Haringvliet region has a long history of living with water. To reclaim the land and protect it against floods, people build dikes, dams and sluices. As a result, the land is safe from floods, creating opportunities for agriculture and industry to expand. However, this also has a downside. The damming caused strict land/water separations and the soft gradients of wet and dry, which were once dominating the landscape, are mostly gone. Many natural habitats and ecological corridors disappeared. The landscape has become more monotone. The disappearance of the dynamic interface and the corresponding natural processes resulted in a landscape that lost the delta identity. This design exploration aimed to restore the gradual land-water transitions and bring back the dynamics to this delta landscape by implementing the new estuarine landscape with incorporating Delta 21. Hereby, the project was approached as a socio-ecological inclusive design assignment where flood protection, ecology, sustainable economies and recreation is integrated.

Reflection of the design process

Six different landscape types and six different land-water transitions were analysed to gain insight into the development of the deltaic landscape and the role of different dikes and dunes in the experience of estuarine dynamics. I could conclude that even in small gradual transitions, the influence of the dynamics (wind, tide, succession) is greatly noticeable while serving the flood protection system. The conclusion: the dikes and dunes must be approaches as a flood protection measure and as dynamic landscape transition. The design exploration started with in-depth research of the morphological processes. The most sustainable option for the new landscape layout is to be in total harmony with the ongoing natural processes while meeting the technical, ecological, and societal demands. This phase is best described as trial and error. Each layout sketch was tested by the layers of natural processes, estuarine ecological environments and flood protection. Where would erosion and sedimentation take place? Is this layout sustainable? During this process, many insights came from meetings with Leen and Huub, Steffen and Mark, earlier morphological studies of Delta 21 done by civil engineering students and one helpful talk to Zheng Bing Wang (professor Morphodynamics of Estuaries and Tidal Lagoons). Looking back, the importance to talk with experts from other disciplines to exchange thoughts seemed essential in proposing the new estuarine landscape layout. During the second phase, the zoning of the layout, the natural processes were used as a basis together with the technical requirements to meet de flood protection. These two elements combined lay down the basic conditions for each sub-area. From here, the natural landscape for each zone was indicated, including the ecology that belongs to each zone. During the third design step, the transition zones were developed. First, the technical requirements were indicated, such as elevation, slope and water levels. Then, the natural landscape was projected on the transition. Next, a brief design phase to find elements that introduce the natural dynamics in the area creating unique habitats and interesting recreational areas. Some examples are: the notches in the dunes, the opening in the dune for the creek landscape and the digging of the main creeks at the island landscape. Finally, the recreation was introduced in the landscape where the type of recreation depended on the resiliency of the local nature.

Reflection on the objective

In this project, I aimed to recover the deltaic landscape at the Southwest Delta by implementing a new estuarine landscape that incorporates the structure of Delta 21. The goal for this new landscape was to make a socio-ecological integral design by harmonizing the layout with the ongoing natural processes. The location of the pumping turbines, spillway and storm surge barrier are based on the morphological processes and the expected erosive forces near the installations. Knowledge of how these processes behave is based on statements derived from remote sensing studies (looking at erosive and sedimentation patterns by satellite images), morphological models, historical images and climatic, environmental and morphological studies. With this knowledge in mind, I argued the areas of erosion, sedimentation, and the level of tidal range. This way of thinking helps in searching for creative design solutions but will not accurately predict the real-life situation.

The location of the dune landscape is based on the dominant coastline direction and the seabed morphology. When looking at older maps, the estuary appears as a very dynamic landscape with a lot of small islands and sand ridges. This estuary shape is reintroduced, with dynamic islands and a sand ridge (the dune area) that rises above the water.

Another essential requirement was reintroducing soft transition zones between land and water, where the tide, wind and succession have space to shape the landscape while meeting the flood protective requirements. To achieve this, the size of the newly added land is made larger than would be necessary for installing Delta 21. The larger size creates space for soft slopes and longer interfaces within the newly implemented landscape zones; the dune, islands and creek landscape.

Some design choices were taken to bring tidal dynamics into this landscape. First, the implemented gradients at the islands and creek landscape are very gradual to create large intertidal areas. Second, the in/outflow of the tidal lake to the sea needed to be broad enough to let enough tidal energy into the tidal lake. Last, the primary main creeks need to be dug during the landscape implementation to kickstart the development of the creek-, and marshland. All these elements and design choices affected the layout of the new estuarine landscape.

After this main layout was achieved, the focus was more directed to the use of the new landscape by nature and people.

The soft and dynamic transition zones between land and water protect the hinterland from floods, the same as a dike. However, since these new transition zones move along with the natural dynamics, they are much more sustainable and valuable for people and nature. These natural zones, grow in size due to succession and sedimentation, are water buffers, precious habitats and very interesting areas for people to explore. This leads to another objective, a less monotone landscape. The strictly regulated polder and sea-arm arm do not trigger the imagination of a lush estuarine landscape. The new estuarine landscape consists of a dune area, islands, energy lake, creek landscape and engineering structures. All these areas are under the influence of natural dynamic and will thus always evolve and change over time.

Creeks will become more deep, marshland becomes green and wild, and fresh water lakes develop in the dunes. Even the engineering installations are changing because succession changes flora and fauna at the eco-bridges. All the sub-zones in the new estuarine landscape are open for visitors. Therefore, in this new landscape, people will be able to perceive many different habitats and views. The experience is due to the difference in habitats, ecotypes and sub-zones, including the dynamics that continuously change the spatial outcome, very diverse.

A third goal was to restore the estuarine habitats and corridors. I choose to preserve the existing precious habitats such as de Kwade Hoek and the Hinderplaat and expand them by adding more land. More islands and marshland expand the Hinderplaat, and the Kwade Hoek is expanded by introducing a slufter and a creek landscape. The tidal lake is a new brackish zone in the Southwest Delta and serves as an important acclimatizing habitat for migratory fishes. The engineering structures, necessary to fulfil the flood protective requirements and the energy lake as battery, are developed as eco-bridges. All flood protection structures are implemented multifunctional, they serve infrastructure, habitats and recreation.

Reflection on the role of design

The role of design can be separated into two domains; design research and research by design. Design research is a methodical approach to gain knowledge about the site and to understand the evolvement of the landscape. During the analysis, mostly design research was done to investigate how the landscape was developed due to (unconscious) design choices and to indicate the structures and patterns. A deep understanding in the historical developments of the site, the spatial outcome, the cultural meanings and the current trends was obtained. During this process, the problem statement, objective, challenges and potentials were generated. Research by design creates the opportunity for the designer to transform this knowledge into creative thinking and creative design. First innovative design principles were generated to use as building blocks. This helped me to structure the design process and to formulate new original design ideas. The process of research by design is highly experimental. For this graduation project, each design sketch was tested by the layers of natural processes, spatial situation, flood protection measures, ecological flows and societal demands. The loop of sketching and testing brought me more knowledge with each sketch about the interaction and dynamics between all the different layers. The drawing technique used by designing can be a tool in creating new insights from different angles. Change of perspectives, scales and through time, helped in creating new insights. During this process of sketching and designing, more and more knowledge is obtained, which eventually leads to the drawing of the final result.

Reflection on the role of landscape architect

The role of landscape architect for this project is very interesting to discuss. Delta 21 was so far only approached as an engineering design, communicating only the more practical functions and outcomes like flood protection, energy storage, tidal nature reserve and aquaculture. A landscape architect will approach this design assignment from a landscape based perspective through different lenses. The master landscape architecture uses the following four lenses: palimpsest, process, scale continuum and perception. A full landscape based analysis and design can only be obtained when the project site is viewed from these different perspectives.

Some small examples of design choices will help indicate how looking through these lenses defined the design. Old maps, seabed morphology and the land reclamation patterns learned me how this Delta landscape came to being (palimpsest). The dominant flow current is the base of the position of the engineering works and the marshland develops through the presence of tide (process). The installation of the fish migration river and the large parking lots are the result of placing the new estuarine landscape into a larger scale (scale-continuum). Finally, the location of the villages alongside the energy lake and the types of local recreation are based on the way people will experience this landscape (perception).

Lessons learned

Designing is a creative process and it is easy to lose structure of to get stuck in one way of approaching the design assignment. I have learned that it helps to structure the process in order to move forward. This sometimes feels like pushing the creative process. However, after a while of moving on it is easier to look back on the design and indicate what needs to be improved. Second, I have learned the power of talking to experts. Estuarine morphology and engineering waterworks are not my specialities. Going too deep into the research is not necessary because talking to the right person for half an hour can give all the answers you were looking for. Third, I have noticed that inclusive design is done automatically when you take the landscape as a basis. During the process of designing, there were only a few moments I consciously checked whether the design fulfilled the objective.

Most of the time the inclusivity was automatically included in the design sketches because all elements come together in the landscape. Fourth, an important lesson that I am still learning is to indicate what elements in the design are important to elaborate and emphasize to bring across to the audience. Some aspects in the design speak for itself and are easier for the audience to image, while other aspects of the design need more explanation. Learning this will help me to bring across better the essence of the design more clearly.

Recommendations

This design is based on the expected behaviour of morphological processes. This can vary from the way that morphological processes actually behave. Therefore, modelling studies are necessary to indicate whether this design really fulfils the demand for flood protection and sustainability. Second, the tidal range and salinity in the tidal lake are uncertain. This can affect the vegetation and development of the creeks and marshland and therefore needs to be measured. Third, the fish migration river is now presented as an open connection between the Haringvliet and the tidal lake. It needs to be investigated whether the open connection suits the situation. It might be that some hydraulic engineering elements need to be installed for flood protection, droughts or salinity. The length of the fish migration river (now about 10 km) is probably long enough for a correct fresh to saltwater transition. However, the range of salinity needs to be modelled to be sure. Fourth, the implementation of the new landscape affects the inhabitants at Voorne and Goeree.

They will lose their existing beaches and get a marsh landscape in return. Their opinion is important, and their views on this project can lead to new insights that need to be considered. Fifth, the Oostvoornse lake can be reopened with this design. Research needs to be done in order to predict what this means for the local ecology and environment