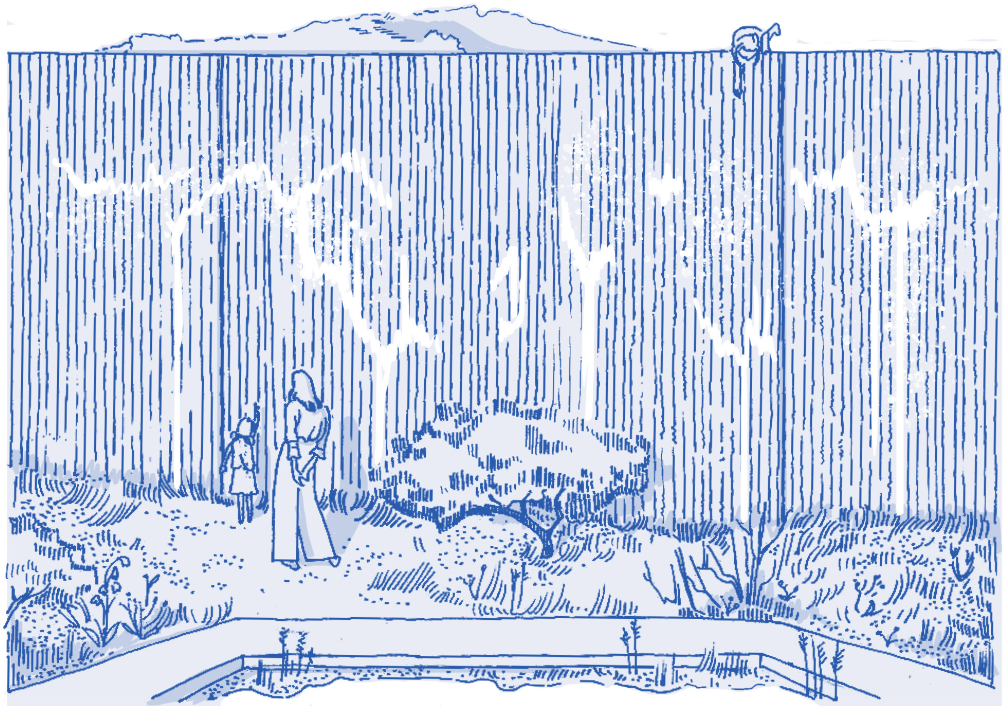
the rediscovery of *duinwater.*

TU Delft
Floor Klapwijk
MSc Thesis



A transformation and spatial experience of the dune drinking water system.

Delft University of Technology
Architecture, Urbanism and the Built Environment
Track: Landscape Architecture

MSc Thesis

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Circular Water Stories #8

Unless stated otherwise, all photographs, images and drawings are made by the author.

DUNEA Duin & Water is ***not*** *responsible for this project. It is an independant thesis for the TU Delft, about the drinking water landscape Dunea maintains, and has been conducted using public sources. My gratitude, however, to Loeki Vos for answering my questions.*

Additionally, Claude AI has been used to check (not change) the academic formality and spelling of the writing. It has ***not*** *been used for changing the content of text in any way. All texts, analyses and conclusions presented in this thesis remain the author's own.*

Abstract.

Freshwater scarcity is becoming more imminent in the face of changing climate conditions, which put a lot of pressure on Dutch water systems. The river-dune drinking water system in South Holland is facing transformation to properly keep up with drinking water demands. And yet, coastal residents remain largely unaware of the dunes as the production landscape of their drinking water.

The aim of this thesis is to design a proposal for an adaptive water system, where coastal dwellers are included as participants of the system and stewards of the drinking water landscapes. The main research question is: *How can landscape architectural strategies mediate a renewed relationship between contemporary coastal inhabitants and sources of freshwater within the drinking water extraction landscape of the Dutch dune system?* The question is answered through systemic analysis, site visits with observations and design experimentation.

The research offers insight into the growing detachment between humans, landscape and infrastructure and how that detachment is now facilitating the effects of water scarcity to remain invisible. In order to include people in tackling the issue of water scarcity, a regional water strategy is developed where pressure on the dune landscape is relieved by separating water flows for potable and non-potable water. The result is a circular and adaptive drinking water system from Meijendel to the Vlietlanden. Furthermore, very explicit design interventions translate the water filtration processes spatially in order to facilitate renewed water relationality. Two design interventions translate valuable water filtration processes at the source and in the dunes, which offer interactions with their drinking water to coastal dwellers.

Key words: drinking water landscapes, Meijendel, Dutch coastal dune landscape, river-dune system, water scarcity, human-water interaction, public awareness

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water obscurity.

'We spend very little time thinking about where our water comes from [...]'

— Bélanger, 2017, p. 46 in Landscapes as Infrastructure.

0.1 Duinwater

The word 'duinwater' used to carry significant meaning. Whoever was lucky enough to live near the coast could boast of their source for clean drinking water: the dunes (Croin Michielsen, 1974). The canals of The Hague flowed colourless and public pumps delivered clean dune water to drink. In places like Amsterdam, a bit further from the coast, 'duinwater' was prized for its cleanliness and pure taste, as opposed to the dirty brown 'slootwater', 'grachtwater', or the salty 'grondwater' (Croin Michielsen, 1974). The word 'duin-water' itself implies an awareness of the source of the water, and the inherent quality and taste. It was an understanding of the landscape that provides life-sustaining drinking water.

Nowadays, the word has fallen out of use. When we speak of drinking water, we use terms like 'water' or 'kraanwater' (tapwater). The use of 'kraanwater' is an example of the fact that we have distanced ourselves from the source of our drinking water, getting no closer than the faucet. Centralizing the drinking water distribution has resulted in a multi-source, single-use network, with pipelines transporting the water underground and delivering it straight to people's homes (Loen, 2020). This development is a successful infrastructural advancement. Clean drinking water in the Netherlands is accessible quickly, straight from the faucet, and has been in most Dutch cities since the 19th century (Loen, 2020). However, this development also an example of the gradual displacement of industrial and extractive landscapes away from urban life (Hill et al., 2020). It signals a growing disconnection between people and the landscapes that provide for them.

The emergency of water scarcity is imminent. '6: Clean water and sanitation' has been a goal on the agenda of the UN (n.d.) for some time now. That clean water access could become an issue in a country rich in water like the Netherlands, seems far-fetched. However, the Netherlands is suffering from extremer conditions of both excess waterfall and periods of heavy drought, which put extreme pressure on our water systems (UvW and VEWIN, 2026). And yet, because the extensive drinking water system protects us from feeling this scarcity in our homes, very few people are making effort to reduce their water consumption. Water scarcity can, however, be felt by the productive landscapes which provide drinking water.

As people, we are heavily dependent on the conditions of our environment to live. We breathe the air, drink the water and eat the crops. The Dutch coastal dunes have been a source for fresh water for over a century and a half (Van der Meulen, 1982). Yet most coastal inhabitants, if asked, would be hard-pressed to name the source of their drinking water. This thesis is an exploration of the way people relate to nature, specifically the Dutch coastal dunes as a hybrid landscape of drinking water production, coastal defence and nature conservation. It questions the obscurity of productive landscapes, and whether the growing detachment between people and their productive landscapes can be reversed to return to sustainable and symbiotic relationship.

Figure 1:
One of the Dunea public drinking water taps. One of the only clear signs of drinking water production.

0.2 Fresh water in the Dutch dunes

Close to the cultivated polder landscape of the Randstad, a rough patch of sandy hills protects the hinterland from seawater. As you get closer to the sea, the hills rise up to thirty meters above sealevel, an effective border between man and sea. Behind these tall dunes, the hills are softer. More vegetation covers the sand, and some depressions are filled with water. Despite this natural look, the dune coastal landscape is described as one of the only half-wildernesses left in the Netherlands (Croin Michielsen, 1974). It is valued for being a unique landscape near the Randstad where someone can feel completely surrounded by 'nature' (Croin Michielsen, 1974). However, the description half-wilderness, or semi-wilderness, indicates some form of contradiction, of interference with the natural state of the landscape.

The dunes of Meijendel are not a full wilderness; they are an industrial landscape of drinking water extraction, where the natural processes of water filtration are used to provide 1.3 million people in South Holland with clean drinking water (DUNEA Duin & Water, n.d.b). Above ground 66 percent of Dutch plant species grow due to a large diversity in habitat types (DUNEA Duin & Water, n.d.f), whilst an underground network of pipelines, lakes and dune filtration processes provide drinking water daily. Visual markers of drinking water production in Meijendel are the Scheveningen water tower and the lakes, both perfectly visible from a viewpoint on the Prinsenberg. The lakes between the dune hills are the infiltration lakes (see figure 2.). These lakes are specifically filled with fresh water from the Afgedamde Maas, which infiltrates the sandy soil to merge into the clean freshwater lens underneath the dune surface (Van der Meulen, 1982). After two months, the water is clean enough to be pumped up (DUNEA Duin & Water. n.d.d.).

The present-day coastal dunes are called the Younger Dunes, which have stored fresh water, infiltrated form rainfall, since their formation in the 12th century (Van der Meulen, 1982). The water that emerged to the surface from this freshwater lens has been used as drinking water for centuries (Leeflang 1974). The first users were coastal residents who drank the clear water of natural duinrellen (Roos, 2009). These were valued places, often

Figure 2:
An infiltration lake, including a pipeline transporting freshwater to the dune lakes.

considered sacred, inextricably tied with the dune landscape (Roos, 2009). Today the dunes look different. A constant flow of water transportation, infiltration and extraction have diminished the dynamic dune landscape to a static one, leading to the disappearance of seasonally occurring dune slacks and dune creeks (Van der Meulen, 1982). The cause is the gradual industrialisation of drinking water extraction in the Dutch dune landscape.

The described area, Meijendel, will be the focus area within the Dutch coastal dune strip for this thesis. Meijendel is a nature reserve near The Hague under the care of drinking water company Dunea. This specific area has been used as an area for drinking water catchment since at least the end of the 18th century (Van der Meulen, 1982). Draak (2012) describes the gradual industrialisation of the system from the first interventions, when water was still extracted from resurfacing freshwater in dug canals. However, since Meijendel is located near urbanised areas dependent on the dune drinking water, natural resurfacing of water proved insufficient, leading to the introduction of pumps to reach the lower levels of freshwater. This, in turn, led to the overextraction of drinking water and thus to the introduction of the artificial infiltration of river water (Roos, 2009). What we are left with is the river-dune system, which has remained unchanged since its implementation in 1955 (Draak, 2012).

0.3 The threat of obscurity

The coastal dunes of North and South Holland are a place of critical human infrastructure, as part of the river-dune system, which provides us with clean drinking water. Although it is vital, the system mostly operates out of sight. The modern technique of drinking water extraction is a multi-source, single-use network where drinking water companies infiltrate fresh water through the dune sand, and extract it as drinking water (Loen, 2020). The fact that the dune landscape is very efficient in filtering and storing a large amount of fresh drinking water (Croin Michielsen, 1974) is known, albeit not common knowledge. However, that the modern source of fresh water comes from surface river water 60 kilometres inland, remains largely unnoticed. The system has evolved into a network of drinking water infrastructure that is invisible, buried, and stretches for miles. As is the case with most centralized infrastructural systems, this infrastructural distance has caused a physical and perceptual detachment (Bélanger, 2017). The current system facilitates use of fresh drinking water without awareness of its spatial, ecological and infrastructural origins.

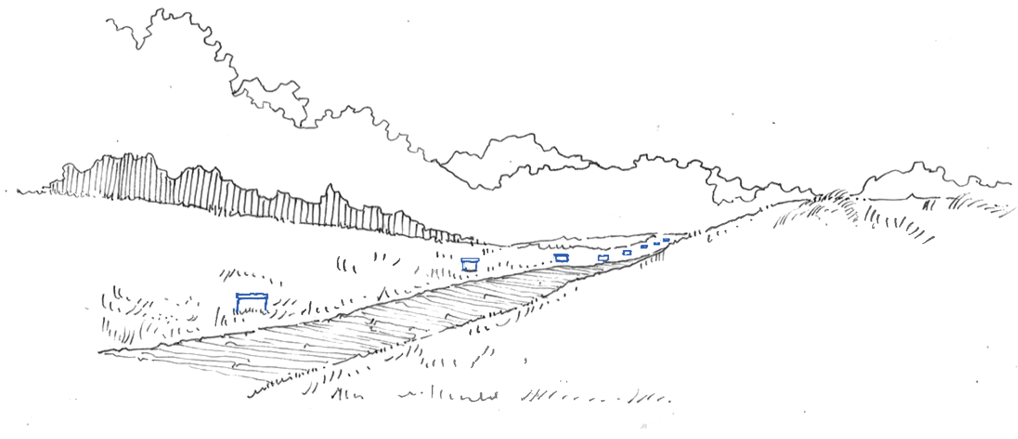


Figure 3:
Subtle signs of drinking water production.

Hooijmeijer et al. (2021) formulate the problem quite accurately, where they state that people have created a human-nature dichotomy, where landscapes and ecosystems become services to exploit. It is as if people perceive themselves as being separate from nature, instead of an active participant in its processes and systems (Hooijmeijer et al., 2021). Characteristic to most industrial areas, the extraction and production of essential goods are operating out of sight from everyday urban life, whilst supporting it (Bélanger, 2017). However, the Dutch dunes are more than just a landscape of extraction. In addition of being utilized industrially, they are valued for their natural processes, flora, fauna, recreational beauty and for their key role in the Dutch coastal defence.

Drinking water infrastructure is already in transition. Increasing drinking water demands combined with increasing drought due to climate change, are the cause of a growing water scarcity (DUNEA Duin & Water, n.d.a). Within the momentum of transformation, the question is how the system is going to change. The how is essential, because the first time the dune drinking water system transformed to meet growing demands, it paved the way for the distance and detachment that mark the system today (Roos, 2009). Fresh water scarcity is a technical issue, in essence a question of water management. The apparent obscurity of the infrastructure that facilitates the system might not immediately seem like a problem, but the created disconnection from a critical resource like fresh water is. The problem cannot be seen or felt, which means it lacks an element of urgency. Further transformation risks amplifying existing issues. Instead, the question becomes *how,* within this transformation, the water infrastructure can include people as participants of the landscape processes and systems and reconnect humans with the landscapes that sustain their life.

0.4 Rediscovery

The aim of this thesis is gain a deeper understanding of the river-dune system, in order to reconnect coastal inhabitants with their dune drinking water landscape as stewards. Within Landscape Architecture as a design discipline, a renewed relationship between humans and nature can be explored through research and analysis into the Dutch dunes as a landscape system and the drinking water extraction as a man-made system. The main research question directly addresses the connections between system, landscape and human-water interactions.

How can landscape architectural strategies mediate a renewed relationship between contemporary coastal inhabitants and sources of freshwater within the drinking water extraction landscape of the Dutch dune system?

To properly analyse all parts of this interdependent relationship, the research is divided in segments formulated as sub questions. These questions roughly coincide with the three chapters of the thesis, Water Plurality (1 + 2), Water Circularity (3), Water Relationality (4 + 5).

The first chapter is a deeper historical analysis of the drinking water system, and how the relationship between people infrastructure, water and landscape has evolved over time. This not only enables a better understanding of how modern drinking water infrastructure operates and what its influence is on the dune landscape, but also offers insights from historical and indigenous drinking water practices that have fallen out of use. Through an elaboration on human-landscape interaction, this chapter explains the interdependencies between the people, their drinking water and the hidden industrial landscapes their society has formed.

(1) How did the South Holland drinking water system develop over time?

(2) What is the relationship and interdependence between the contemporary coastal inhabitant and their drinking water?

Chapter two follows with the current infrastructural system, how it operates, and why it will have to change in the future. Insights from chapter one will shape a vision on how the system can change in response to water crises, whilst closing the gap between people, water and landscape.

(3) Why and how will the current river-dune system need to change to respond to the threat of water scarcity?

The third chapter will provide insight in how lifting the obscurity of the system can result in awareness and thus a renewed relationship. Within this chapter, design explorations will bridge the gap between research and design. The research synthesizes in a spatial solution for lifting the obscurity of drinking water landscapes, and use visibility and care to shape the future transition of water systems.

(4) What Landscape Architectural strategies on different scales can relate people to water — or the process of their drinking water?

(5) What types of design interventions unearth the drinking water system and inspire care for the dune landscape and its drinking water?

These last two questions provide direct input for the design assignment, which is formulated as follows:

To design interventions in the industrial freshwater extraction landscapes of the Dutch dunes and at the intake area of water that foster a meaningful reconnection between the contemporary coastal dwellers and their freshwater source.

This research brings the topic further than instrumental water management, by looking at the topic from a landscape architectonic point of view. It questions the interspecies relationship between people and landscape, and how a closer connection can shape future transformations. The link between research and design is the ability to identify key elements of the infrastructure and translate hidden processes into spatial design, which inspire awareness and care for our landscapes through sensorial interaction with water.

0.5 The road to rediscovery

This thesis is about the visibility, tangibility and legibility of the landscape and natural processes that have been utilized for industrial purposes, but are hidden in obscurity. Thus, the approach is a combination of the technical and systemic analysis of industrial infrastructure with a theoretical and spatial exploration of the relationship between people and their living environment. To answer the research question, the research will span from the regional, systemic scale which will result into a regional vision, to the identification of key points, to the design of specific, human scale interventions on these key points. The combination of these approaches and attached methods will result in the rediscovery of water in a specific, recognizable place.

The main focus within the methodology is drawing, which is not only a tool for visualisation, but an action that stimulates understanding and processes information (Van der Wal et al., 2024). The basis for every part of the research is theory or data, but drawing is the process of analysis. Whether consciously or intuitively, drawing is an effective selection of the information that is the most relevant. Because the research reaches from a larger scale systemic analysis of drinking water extraction to a human scale exploration of the interdependence between people and freshwater, a range of drawing methods are applied.

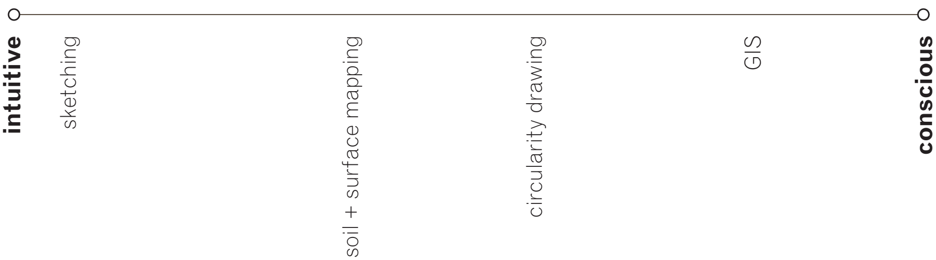


Diagram 1.
Spectrum of drawing methods.

This range spans from the intuitive to the conscious, all with a basis of knowledge from Geodata and theory. However, the process is circular. An intuitive start of human-landscape interaction through time is followed by a conscious deep dive into the system, which leads back to an intuitive manipulation of the relationship between people and the landscape system. The loop from intuitive, to conscious, to intuitive is unfolded to show a chronology (see diagram 2). When the intuitive drawing methods are applied, they will be evaluated afterwards.

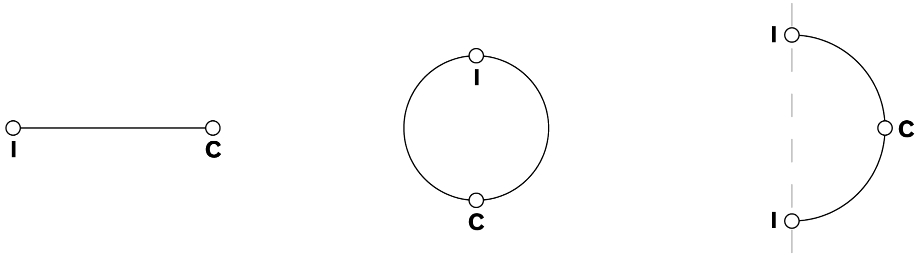


Diagram 2. Explaining the range (I: intuitive - C: concious) of the roadmap diagram.

The methods applied in this research can be classified into three groups: (1) literature study, (2) site visits, (3) drawing as analysis, (4) design experimentation. Diagram 3 shows which methods are applied in which part, and how they are interrelated. But first, the range of methods must be explained.

Building the frame

Before starting on drawing, mapping and modelling, a certain frame of knowledge is critical; especially because the aim is to understand a technical system enough to intervene on both a systemic and on a spatial-relational level. This frame consists of the following elements: literature study to build a theoretical framework of human-nature relationships in the context of industrial sites, literature study to research existing facts and findings on the drinking water system and the dune landscape, and precedents studies that visualise and redesign abandoned or operating industrial landscapes. This frame provides the guidelines for the project. The theory is the foundation that guides the theme of the project, whilst the instrumental knowledge and precedent study form the boundaries possible outcomes.

Site visits

A project on a complex, hybrid landscape like the Dutch dunes necessitates several site visits to make observations and speak to professionals in the field. Individual excursions to the Meijendel area serve to find physical signs of productive infrastructure. Guided tours offer the opportunity to talk with specialists about topics which are harder to fathom from online sources.

Drawing

The drawing analyses are based on the knowledge gained using the first methods. However, the knowledge gained does not result in a single direction, but instead consists of information on different scales and themes. The applied drawing methods can be found on different places on the intuitive-conscious scale and thus will be applied in different phases of the project. On the far intuitive side, sketching and hand drawing are a way of simplifying information. They are a way of visualising only that which is necessary or that which is perceived, emphasizing the most important parts. The soil cartography, is a self-devised method combining section and surface in an axonometric drawing, is placed little closer to conscious. This method will be elaborated further, but the combination of human perception above ground and industrial processes below ground will require both intuitive and conscious decisions. The circularity diagrams are placed closer to conscious, in which the data and information of the system will be applied in a drawing method that visualises the movement of water. These drawings require intuition to design and adjust the system. On the far side of conscious, GIS data driven maps provide insight into the technical elements of the system, like the location of infrastructure and the area of distribution.

Soil + Surface mapping

To effectively analyse the industrial infrastructure of drinking water extraction, which is partly buried, both maps and sections reveal critical information. Whilst both these drawing types will be applied separately, another type of drawing will be applied to achieve new, combined insights. This 'other' type of drawing, with a method I will address as 'soil + surface mapping'. This method is inspired by the theories and ideas of 'Terra Forma: a book of speculative maps' (Aït-Touati et al., 2019) and a figure (see figure 4.) in 'Urban Ecosystem Participation in Extraction Landscapes: 'Extraction Ecologies''(Hooijmeijer et al., 2021). Aït-Youati et al. argue for an exploration of a new, speculative map, *'a map of the earths underside rather than it's surface'* (2019, p. 29). Their result is a visualisation of living systems and interactions, which warp the spatiality in the drawing.

The ideas and theories presented resonated with the aim of this topic, but the result is less legible and thus less usable for the presentation of research. Thus, I will attempt to draw a deeper map; a combination of map and section to visualise and analyse the perception of the landscape above ground, and the extraction and exploitation within the soil. This type of mapping can be used to explore the visible and the obscure in a single drawing.

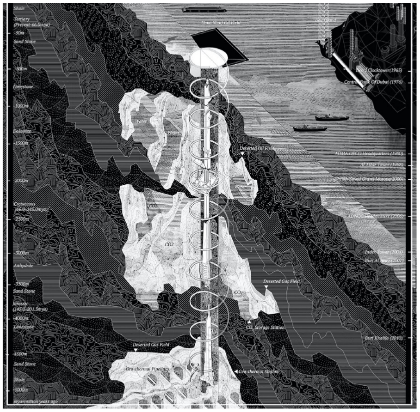


Figure 4. From Hooijmeijer et al, 2021. Caption: *'Drawing what is beneath the surface reveals the unseen despoliation of the Earth in the pursuit of extraction and settlement, write Rania Ghosn and El Hadi Jazairy of Design Earth.'*

This image used by Hooijmeijer et al. (2021), presents some of the theories by Aït-Touati et al. in a simple, understandable way. The surface and soil are connected, resulting in a drawing that visualises the perceived space above, with the buried infrastructure underneath. Within this format movement, organisms, systems, and natural processes can be included, within the spatial framework. The form of the drawing is a familiar axonometric. However, in this project the soil cartography method is really intended to visualise themes of human nature relations, in an axonometric form.

Design experimentation

The human scale interventions will be a spatial translation of the landscape, with the aim to facilitate understanding of the drinking water extraction and inspire care for the source of fresh water. The spatial translation should not need a plaque of information, where visitors can read what they need to know. Instead, the form tells the story, and emphasizes those elements of the environment that need to be seen. This phase of the project is the most challenging, because there is no right

answer. The only way to find potential, fitting options, is through the trial and error of experimentation (Van Dooren, 2020).

In order to find the spatial translation, a combination of sketching and modelling is applied. In this phase of the project, the key points have been identified based on the analysis, where a translation of the system and landscape will reach the most eyes. Especially sketch/study modelling will allow for experimentation and evaluation on a three dimensional level. The two most important elements to experiment with and assess are: the form and space created, and the materiality in combination with the environment.

The roadmap:

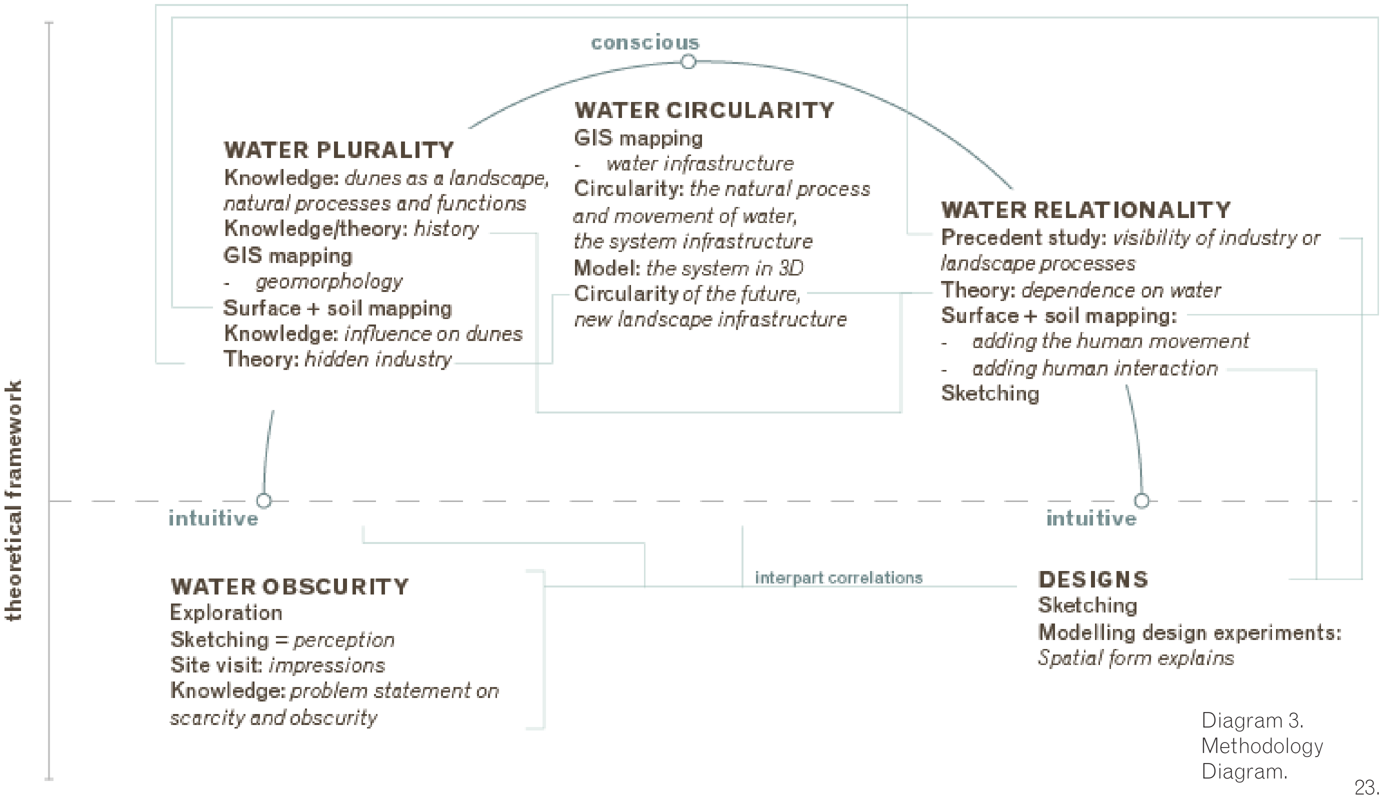


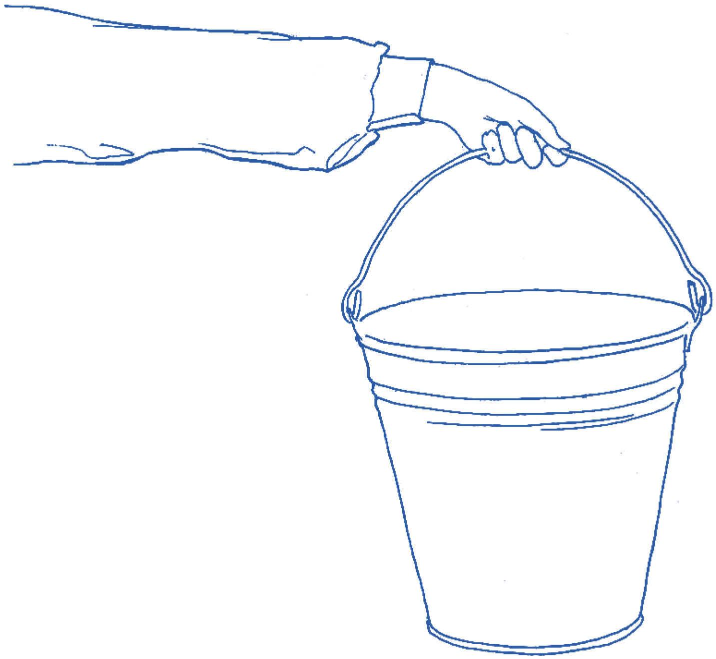
Diagram 3.
Methodology
Diagram.

Chapter 1.

water plurality.

'Dutch systems for accessing drinking water developed from decentralized off-the-grid systems, which included rainwater harvesting, into large-scale centralized urban utility networks with a civil engineering orientation.'

— Loen, 2020, p.80 in Thirsty Cities: Learning from Dutch Water Supply Heritage.



1.1 Freshwater and seawater

Visitors to the Dutch western coastal landscape can smell the salt of the sea in the air. Whether they walk the streets of coastal settlements or the paths of national dune parks, the roughness of the sea is ever present in the feel of the wind and sand on skin. These sensory conditions reflect the ongoing coastal natural processes: water, wind, and sand continuously shape the landscape through sand drift, sedimentation, peat growth, and coastal erosion (Neefjes, 2018).

The same is evident in the dune vegetation: the sight of *Ammophila arenaria* is familiar as one of the only pioneer species which can stand the conditions of the driest dune ridges. The dune grasses shape the landscape by acting as an anchor. Dune ridge formation is an interplay of several forces: wind direction, wind force and vegetation coverage (Spek, 2025). It is a mix of biotic and abiotic elements which together determine where sand drifts and where it settles. The result is asymmetrically formed dune ridges, high on the sea side, low on the land side (Spek, 2025). On the seaward face, the presence of wind and salt create harsh conditions in which few plant species can grow (Neefjes, 2018). Further inland, where depressions in the landscape offer shelter from wind and sea, sand gives way to shrubs and trees. Even so, the wind's influence remains visible in the bent, wind-sculpted shape of the trees.

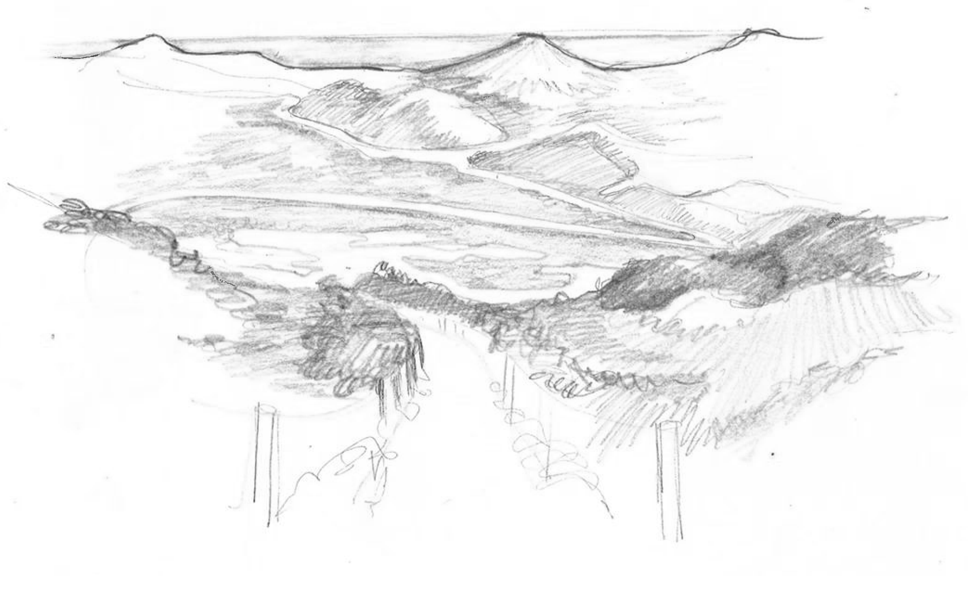


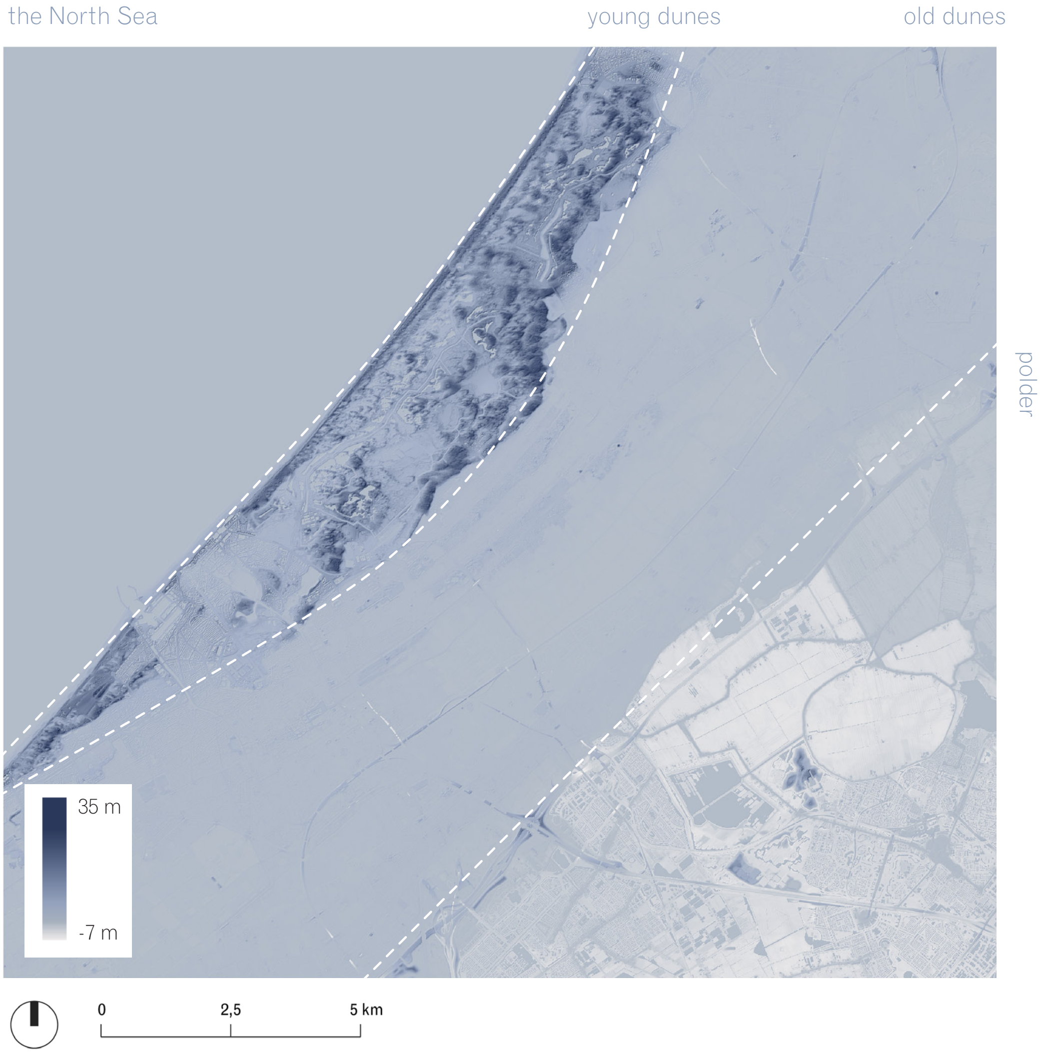
Figure 5.
The dune
landscape.

The Younger Dunes have never lent themselves easily to human interference. Because of the dynamic nature of the coast, traces of human settlements and interventions historically have never survived for long (Neefjes, 2018). Abandoned roads, buildings and agricultural fields are covered quickly by drifting sand and shrubbery. The dune relief, the dune vegetation and the complete lack of roads and buildings form a stark contrast with the densely inhabited and planned hinterland. However, on the Old Dune landscape, between the Younger Dunes and the polder, are the oldest inhabitable areas of the Netherlands (Neefjes, 2018). In the Middle Ages, noblemen had castles built on the lower lying sand ridges, and even now the land between Meijendel and the Vliet is marked by estates, villas, castles and parks (Neefjes, 2018). The current landscape of the Old Dunes is on sealevel, with the polders behind the Vliet reaching depths of minus 7 NAP (Algemeen Hoogtebestand, n.d.).

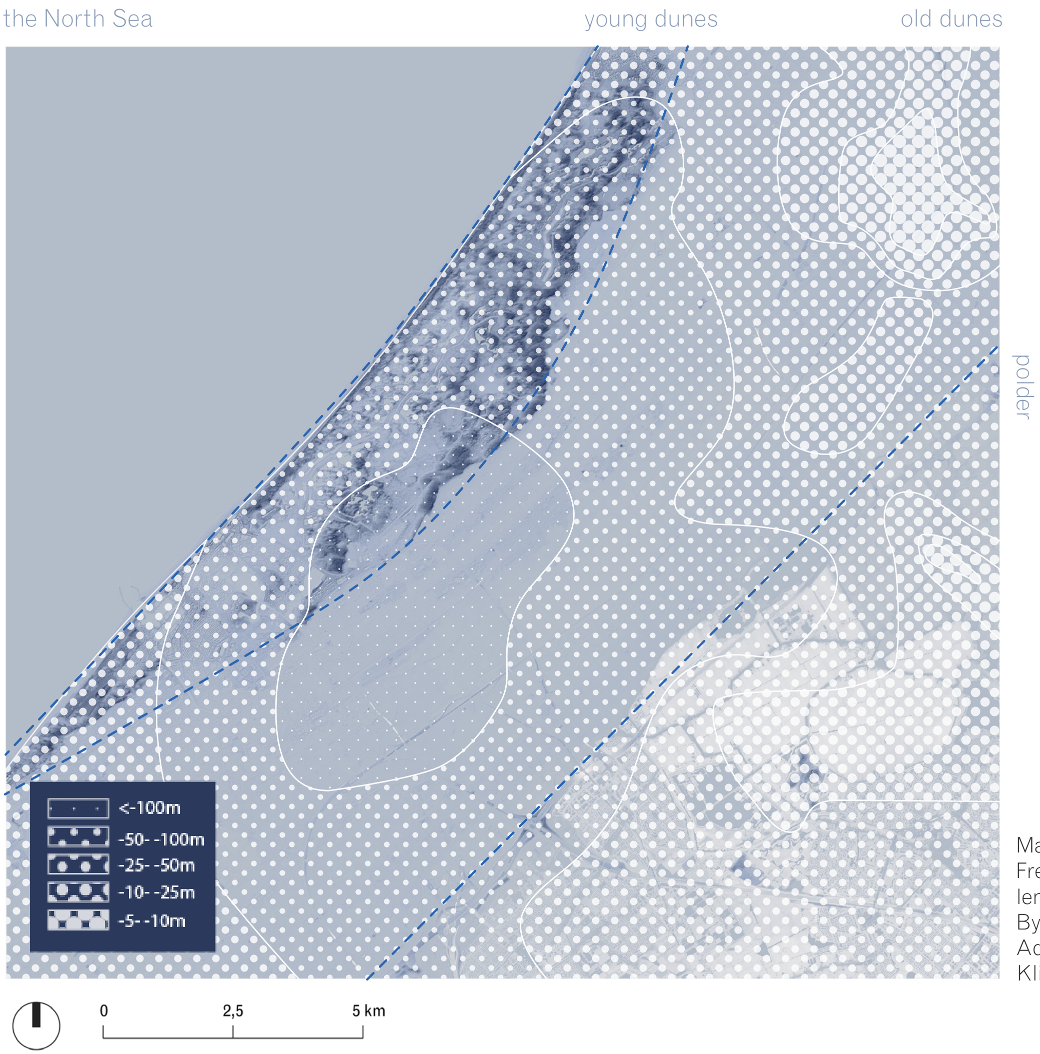
The dunes are a threshold between land and sea, and thus also between freshwater and seawater. They form a boundary both above ground and below ground. The sandy hills of the ‘zeereep’ prevent the surface seawater from flooding in (see map 1. Heightmap), and the collected freshwater in the sandy soil press down the salty groundwater to hinder salinisation (Draak, 2012) (see map 2. Freshwater lens ‘depthmap’). In a landscape thoroughly formed by the harsh conditions and natural processes of the sea, a collection of freshwater in such close proximity to the seashore makes for a striking contrast.

Figure 6:
The coastline:
seawater.

Figure 7:
Infiltration Lake:
freshwater.



Map 1.
Heightmap.
By the author.
Adapted from
AHN data.



Map 2.
Freshwater
lens ‘depthmap’.
By the author.
Adapted from
Klimaateffectatlas.nl

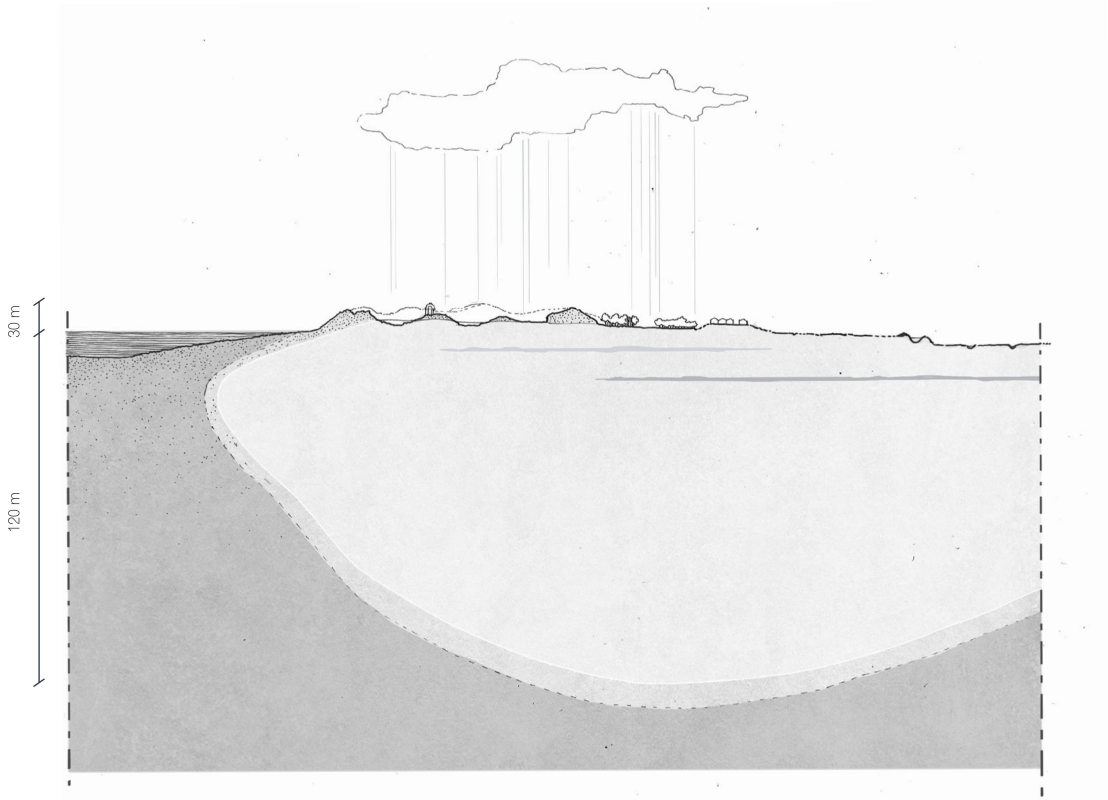
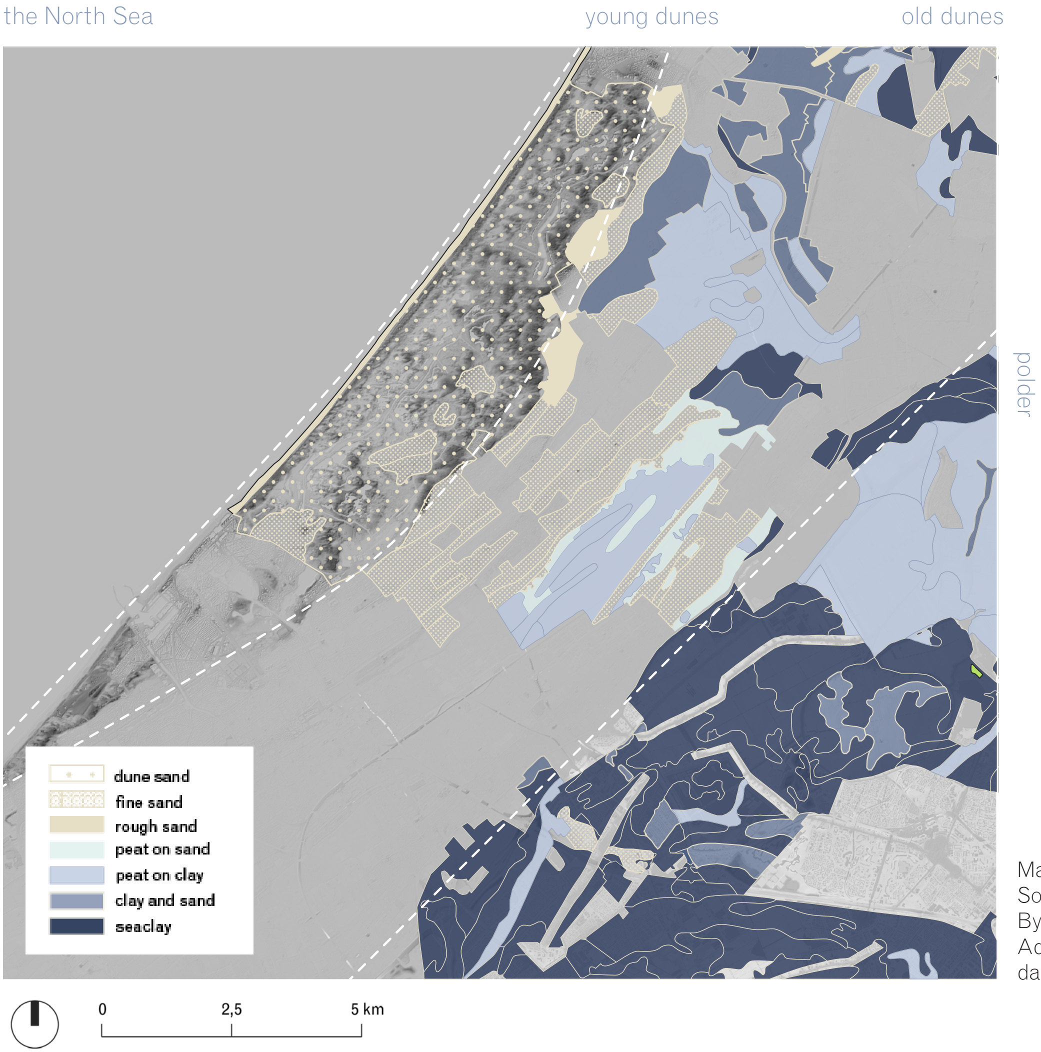


Figure 8:
Water interface section of the dune landscape.

As mentioned, the coastal dunes are a unique landscape where seawater and freshwater exist in interaction. The freshwater infiltration principle works as follows: rainwater falls on sandy soil of the dune landscape. The rainwater infiltrates quickly into the sandy soil, but at some point, it reaches the salty groundwater from the sea. The fresh rainwater cannot sink through the salty groundwater and thus lays on top, slowly collecting more freshwater over time. As shown in figure 8, the freshwater lens underneath the Younger Dunes has grown since its formation in the Middle Ages to a maximum depth of 120 meters (Draak, 2012). This freshwater is the subsurface boundary between sea and hinterland, and prevents or hinders salinisation, dependent on the depth of the lens.



Map 3.
Soil map.
By the author.
Adapted from BRO data.

The freshwater lens steadily grew until the mid-nineteenth century, slowly softening the landscape behind the ‘zeereep’ (Van der Meulen, 1982). These areas were not suitable for agriculture or settlement, but people quickly discovered the quality of the freshwater resurfacing form the dune landscape. Excess water flowed inland in the form of dune creeks, or ‘duinrellen’ in Dutch. The water quality of dune creeks was prized, which is why most estates built on the Old Dunes were located near a dune creek (Neefjes, 2018). Since these dune creeks flowed with the excess water from the freshwater lens, the limited extraction of freshwater using buckets was in essence nothing more than a trickle (Roos, 2009).

Around 1850, however, the first step was taken towards the centralization of the drinking water network. This step effectively reduced the dunes from a dynamic landscape rich in water, to one node in the South Holland river-dune drinking water system, increasing the levels of extraction to problematic heights. The following paragraph explains in detail the gradual growth of extractive infrastructure in the dune landscape.

the river-dune system

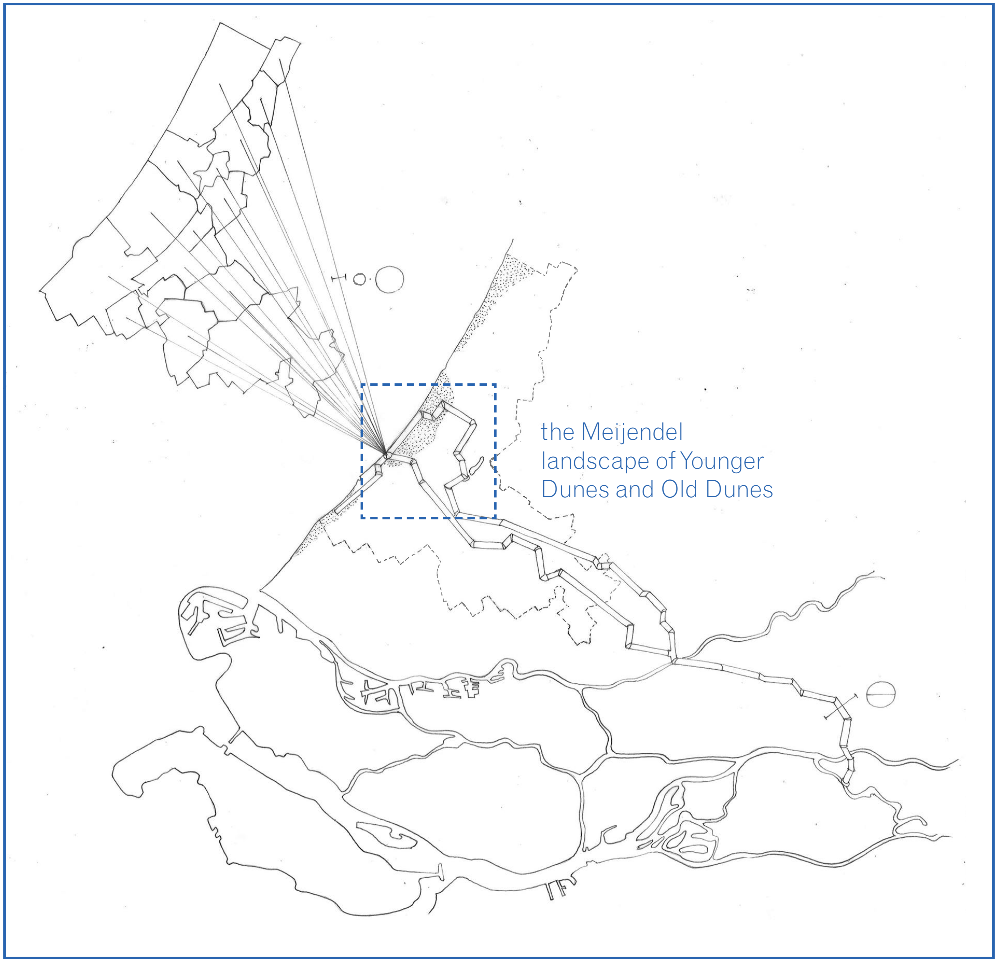


Figure 9:
The upscaling of drinking water access.

1.2 The evolution from water plurality to water singularity

Historically, there are three main sources of water: surface water, rainwater, and groundwater. For centuries, rivers and brooks, wells, or harvested rainwater were sufficient to meet the drinking water demand (Loen, 2020). Before the age of faucets, people fetched water from these groundwater wells, rainwater cisterns and fountains. Fetching water was not only an activity of interaction with water but also with other people, transforming these urban places into social meeting places (Loen, 2020). Natural surface waters could gain cultural significance as well. Some dune creeks in the coastal region were revered as sacred and locals believed that the water possessed healing properties (Roos, 2009). It is assumed that the worship of these surface waters also prevented any human contamination (Roos, 2009).

The same cannot be said for other surface waters. The fifteenth century marks the start of a growth in economic activity in Dutch cities, which was accompanied by highly polluting industries (Loen, 2020). This wave of industrialisation polluted the waterways in cities like Rotterdam and Amsterdam so severely that it damaged the self-cleaning capacity of surface waters (Loen, 2020). Continued use of surface water as the dominant source of drinking water increased the risk of the waterborne disease cholera, leading to many deaths (Loen, 2020). Thus, surface water was quickly dismissed as a source, replaced by a search for ‘good waters’ (Pierik, 2024).

However, the densely populated west of the Netherlands is located in the coastal regions, deltas and low-lying polders, where salinisation from the sea makes the groundwater salty (Loen, 2020). This meant that in addition to the industrial and domestic pollution of waterways in cities, groundwater also proved undrinkable (Loen, 2020). Two main solutions were found to compensate for the unavailability of both clean local surface water and potable groundwater: rainwater harvesting and the import of other surface waters of sufficient quality (Pierik, 2024). The import of surface waters was done by transporting containers of water on a boat over now polluted waterways to Amsterdam; an early version of upscaled transportation of water as a resource.

The freshwater underneath the dune surface remained just one element in the diverse network of local water access for a long time. Estates were built near the dune creeks which transported excess dune water inland, functioning as a personal source of high-quality freshwater (Neefjes, 2018). For coastal settlements like Scheveningen, from the sixteenth to the eighteenth century, freshwater was extracted locally using very shallow wells in the dune landscape (Loen, 2020). However, the quality of this water was coveted by residents of inland settlements and cities, who extracted freshwater from the dune creeks in buckets and transported those to the city to sell in small quantities (Loen, 2020).

Figure 10.
Person fetching water from a dune creek.

In Amsterdam the demand for such clean freshwater rose drastically when it became clear that grachtwater as the dominant source of drinking water was spreading cholera (Loen, 2020). In 1853, the first steps were taken to centralize drinking water distribution of the high-quality freshwater from Haarlem. On December 12th of that year, buckets of dune water were sold at the Willemspoort fountain in Amsterdam for one cent apiece (Loen, 2020). It was not long until pipelines replaced manual transport, and faucets were installed in the houses of the upper class, and later the lower class. (Loen, 2020).

The following analysis visualises the gradual development from the dune system as one place for drinking water access to an upscaled industry of centralized drinking water distribution. Note that the physical detachment between people and freshwater sources quickly grows.

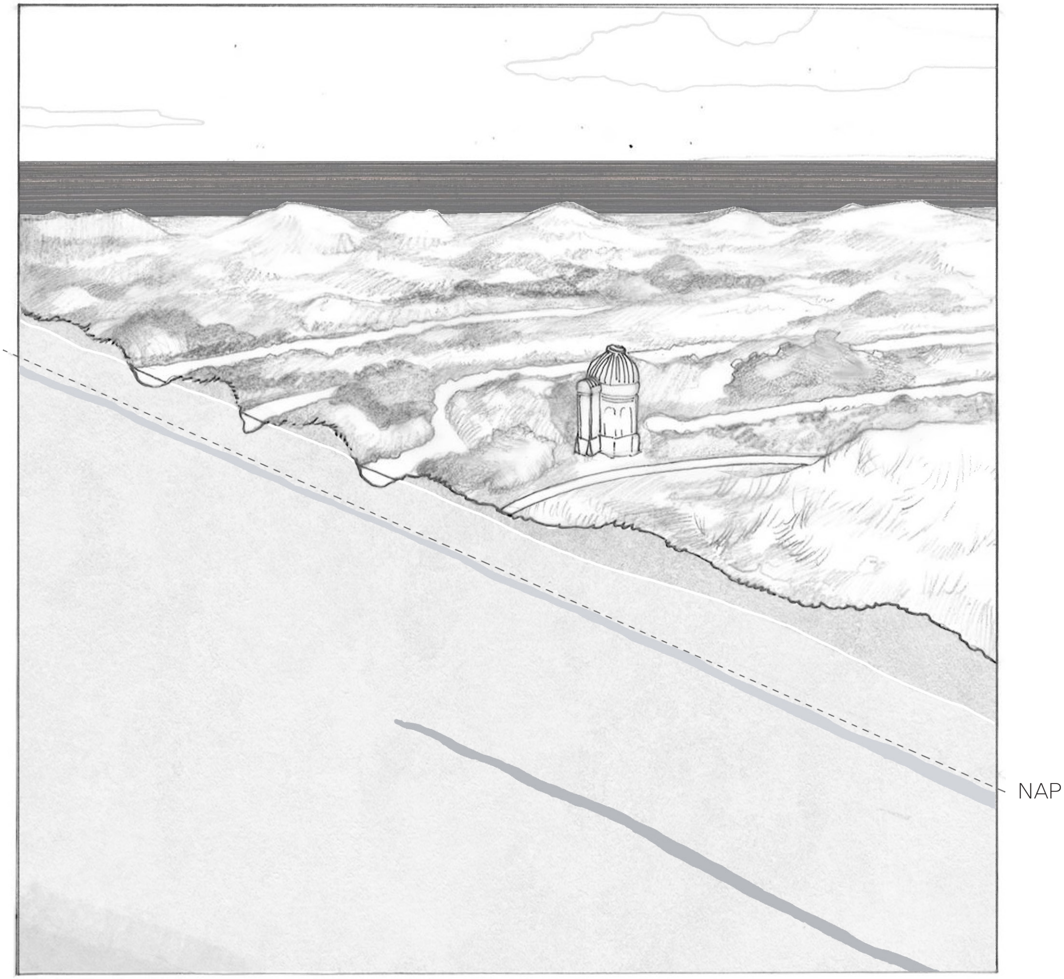


Figure 11.
1874-1930.
Canals were
dug from which
groundwater
welled up.
Dunes are still
unaffected.

Freshwater lens
Brackish water
Salty groundwater
Peat layer
Clay layer

Figure 12.
A digger in the dune landscape.

1874 - 1930

The South Holland extraction of the Scheveningen dunes started in 1874 (DUNEA Duin & Water, 2019). The start of drinking water extraction was simple. Canals were dug parallel to the coastline, from which the fresh groundwater welled up and flowed to the pumping station (DUNEA Duin & Water, 2019; Draak, 2012). Once there, it would be purified further using a slow sandfilter and transported to consumers (Draak, 2012) using the pressure provided by the newly constructed water tower. The digging of canals marks the first phase of upscaling of changing the dune scape to utilize its processes. Extraction of the upwelling water was no longer an individual process of fetching water with a bucket, but rather an upscaled industry of a network of canals, filters and a pumping station. Individuals were relieved from a necessary journey to the dune creeks.

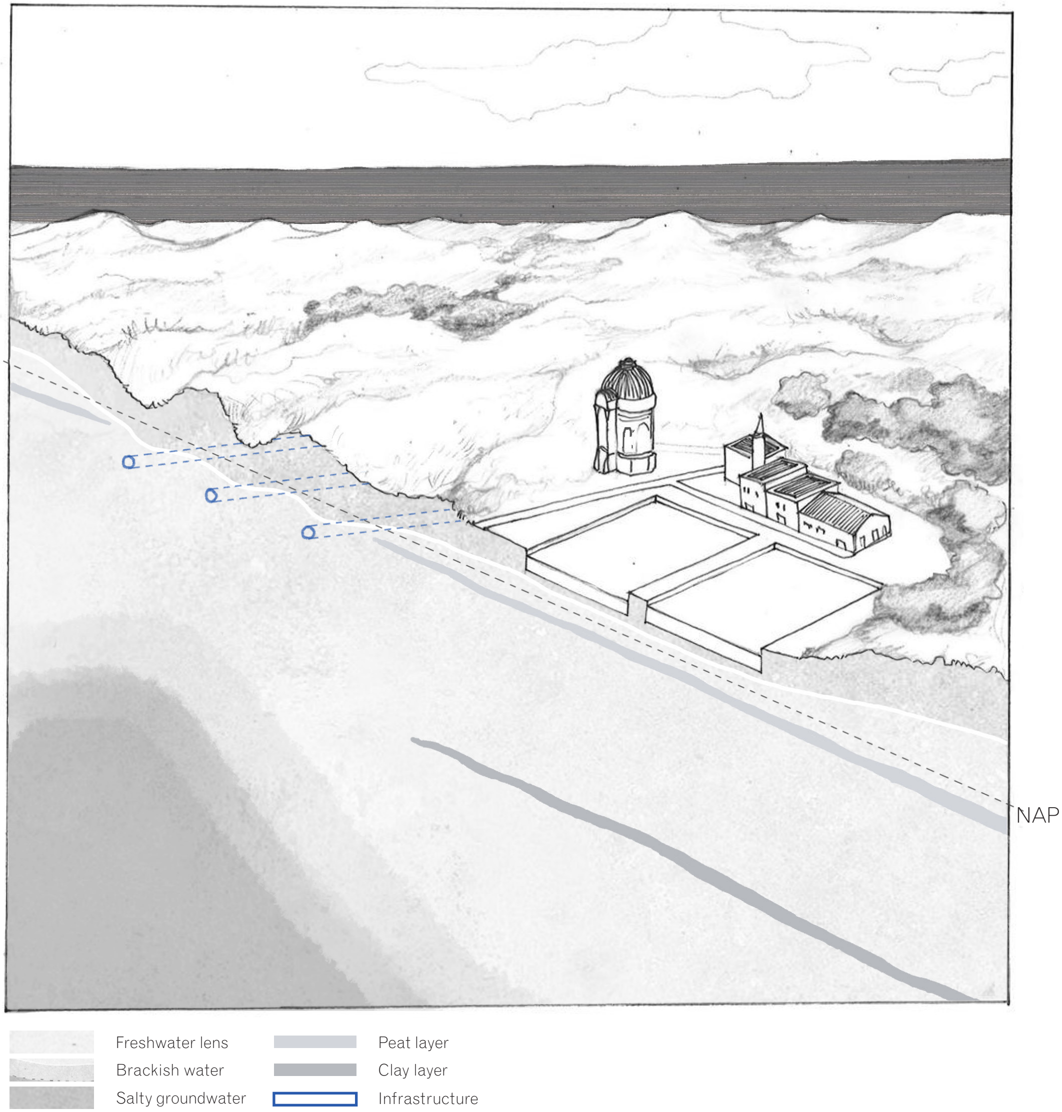


Figure 13.
~1930.
Pipeline placement underneath canals caused for lowering of the water table.

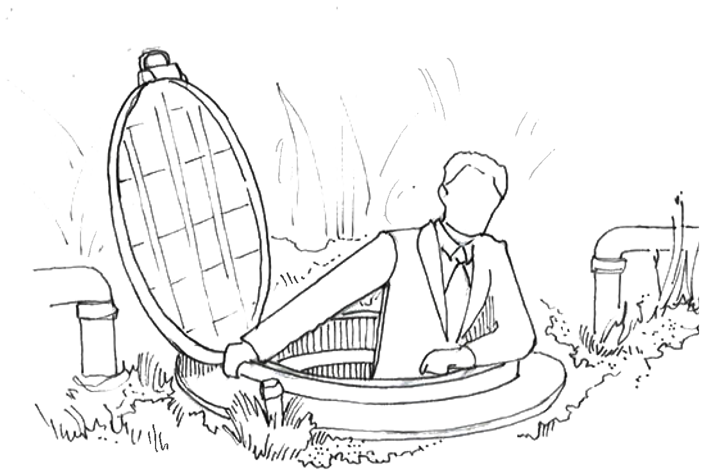


Figure 14.
A PWN employee in a lysimeter monitoring well.
By the author.
Adapted from Roos, 2009.

~1930

As the South Holland population grew in number, the demand for potable water surpassed the extraction capacity of the dune landscape (DUNEA Duin & Water, 2019; Draak, 2012). Since there was not enough rainwater infiltration to compensate for the increase in extraction, the water table gradually lowered. Overextraction started to dry out natural dune slacks and canals. To reach the water which had disappeared beneath the surface, the extraction company decided to dig through the peat layer and place pipelines under the former canals, roughly at minus 3 meters NAP (DUNEA Duin & Water, 2019; Draak, 2012). Continued extraction led to the further lowering of the water table to the inevitable point where the pipelines lay dry. Additionally, the extraction of water from the freshwater lens beneath the peat changes the equilibrium between the freshwater and the saltwater (Van der Meulen, 1982). The interface between freshwater and saltwater rises steadily to the surface when the amount of extraction is not met by the same amount of rainwater infiltration. (DUNEA Duin & Water, 2019; Van der Meulen, 1982).

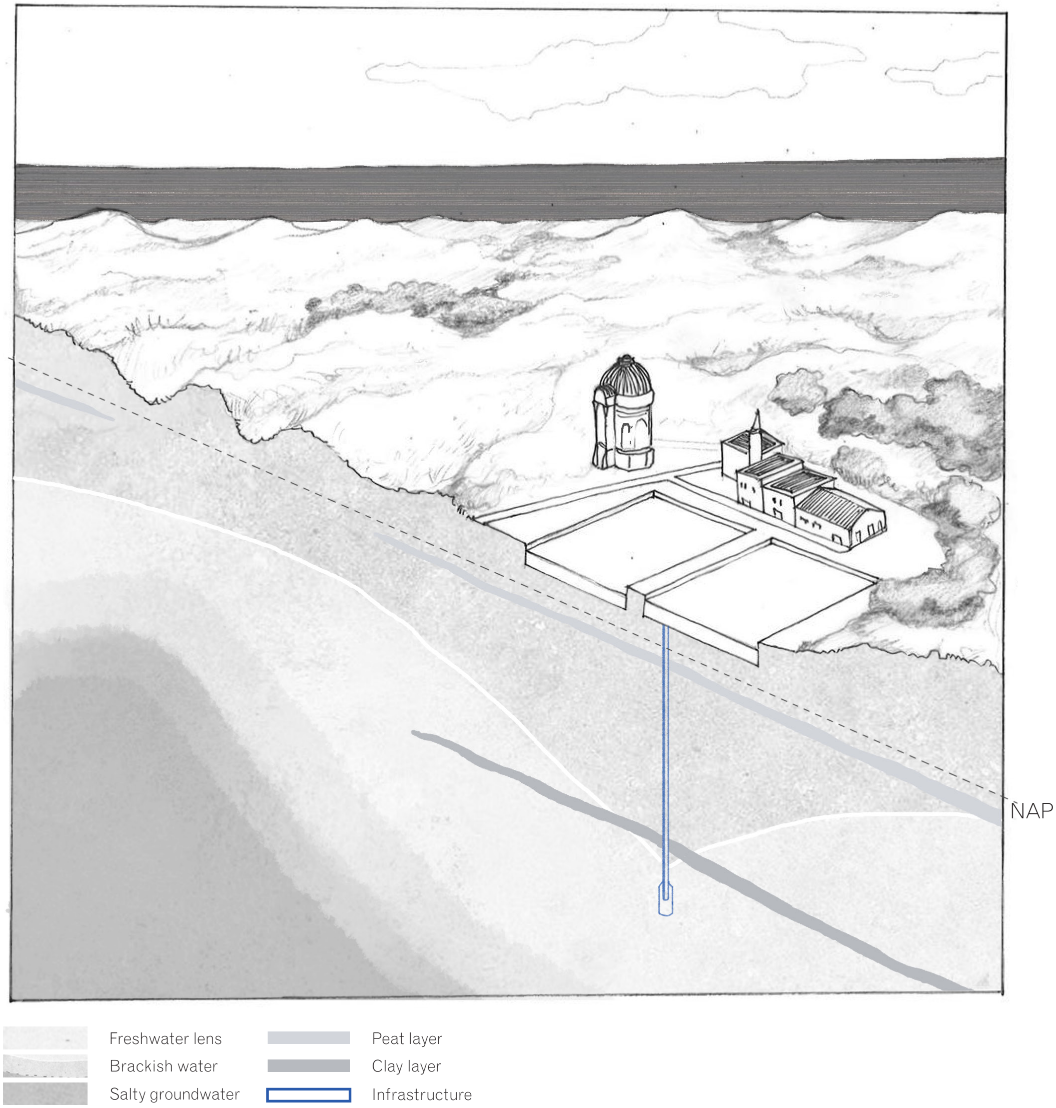


Figure 15.
1930-1955.
The switch to vertical extraction caused to water table so sink lower and salinisation to occur.

Figure 16.
Faucets are the new norm. There seems to be no way back.

1930 - 1955

Despite a growing amount of warning signs, the increasing demand was such that society proceeded without caution (Draak, 2012). Vertical extracting wells were installed to reach the deepest parts of the freshwater lens, breaking though the clay layer (Van der Meulen, 1982; DUNEA Duin & Water, 2019). Breaking though the second protective layer meant access to the deepest layers of the freshwater lens, but it also heightened the freshwater-saltwater interface further (DUNEA Duin & Water, 2019). Without sufficient rainwater replenishment, only brackish water could be extracted from these depths, which is completely undrinkable without further filtration. Further filtration of brackish water was not yet possible in the mid-20th century, making the intervention close to futile. To make matters worse, the intervention dried out the dune conditions to such an extent that flora and fauna completely disappeared (Van der Meulen, 1982). The effects will be further explored in paragraph 1.3.

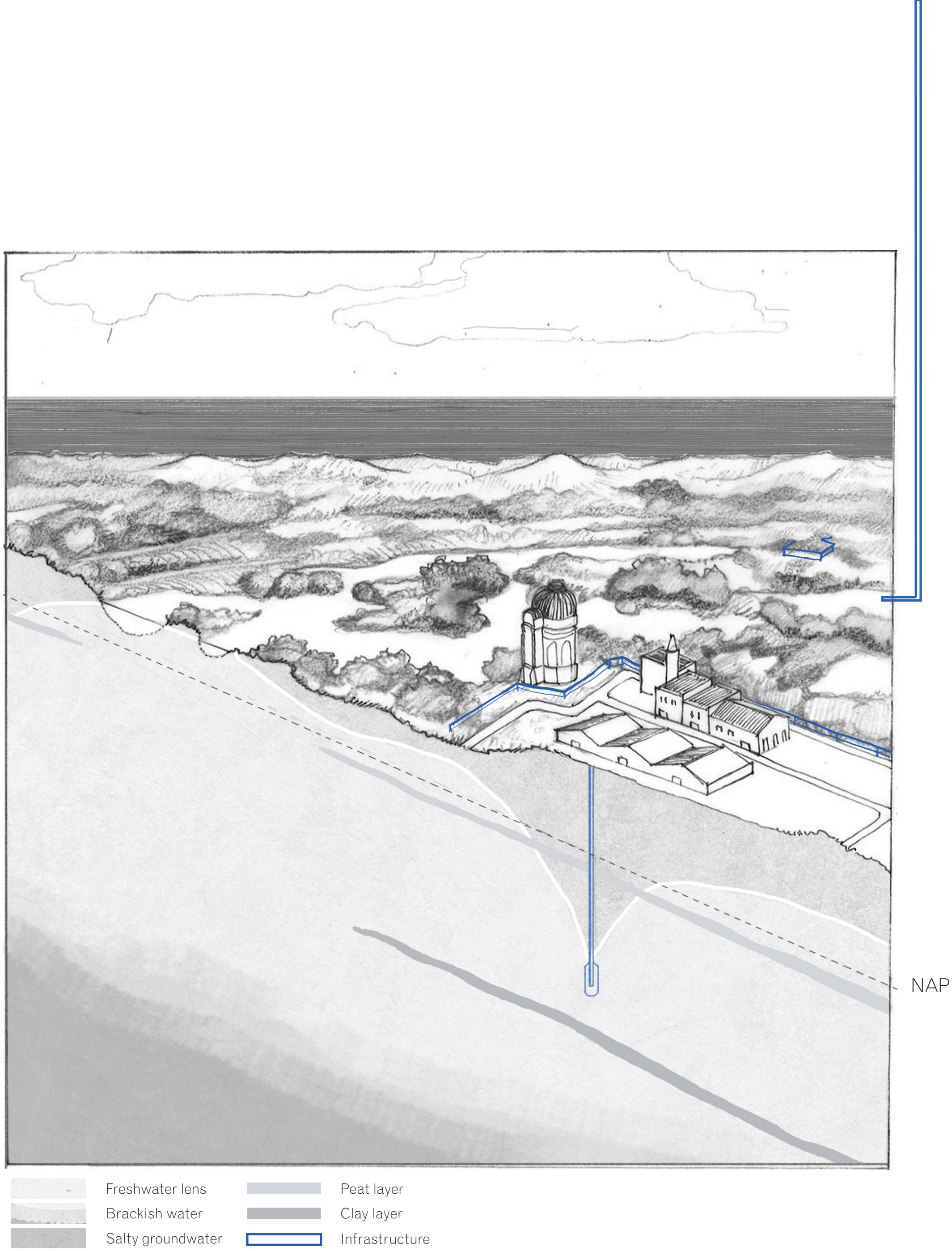


Figure 17.
1955-2025.
River water infiltration as replenishment of the freshwater lens.

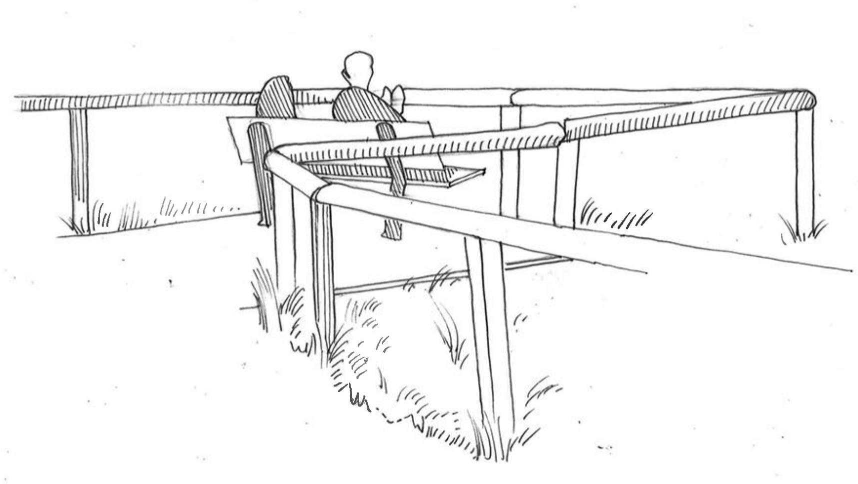


Figure 18.
Looking at the infiltration lakes from way up high.

1955 -2025

More freshwater extraction than infiltration proved unsustainable for both production and landscape, leading to the decision to start infiltrating river water in the dune sands. In 1952, the company started with the construction of a pumping station in Berg Ambacht and burying the transport pipelines all the way to Scheveningen (Draak, 2012). Because the infiltration water was eutrophic river water, the period between infiltration and extraction is a minimum of two months to guarantee a proper water quality (Draak, 2012). This intervention tears a rift people and the source of their freshwater. Visitors still visit the dunes and make photographs of the infiltration lakes from constructed viewpoints. An information plaque on the Prinsenberg mentions the infiltration of river water in a short sentence but omits the location of sourcing completely.

Scenarios

In 2026, water companies are facing a new threat: increasing water scarcity (UvW and VEWIN, 2026). Dunea faces extraction restrictions in the Natura2000 regulated dune areas, which means that to solve the problem of they cannot rely on the river-dune system as is. Scenario 1, more extraction with less replenishment will cause severe drought. Nature 2000 prohibits that, which means that scenario 1 is not realistic. To be able to keep up with drinking water demands, two other options were considered. Scenario 2 is the extraction of brackish water and filtrating it separately from the dune system (DUNEA Duin & Water, n.d.h).

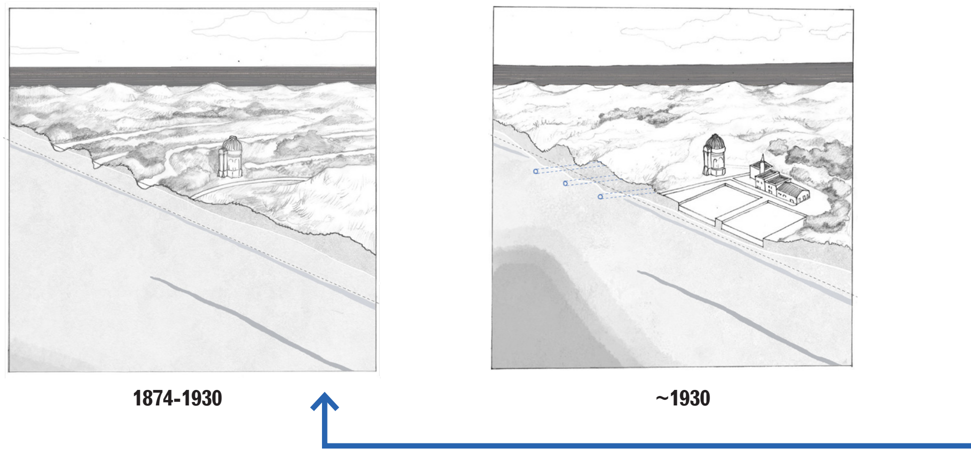
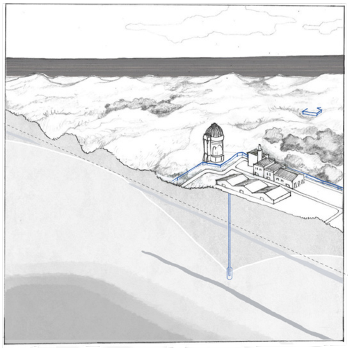


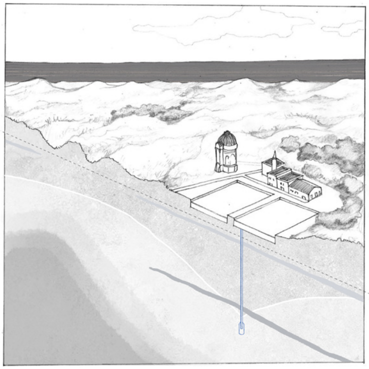
Figure 19. 1874-future. Historical development leading into three possible scenarios. Scenario 3 had the potential to return the dune landscape some of its original dynamics.

The second scenario visualises an increase of infrastructural presence and impact in the dune landscape. These pipelines would be installed to extract brackish water, which is too salty to drink.

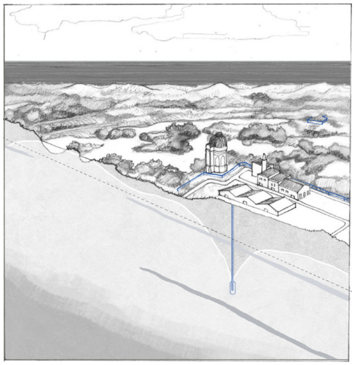
Scenario 3 is a search for a regional source, and filtering it separately from the dune infiltration system (DUNEA Duin & Water, n.d.a). This option offers more opportunities for local circular water systems, and a transition in which the dunes will regain some of their dune slack habitats. This will be further explained in paragraph 2.3 and 2.4.



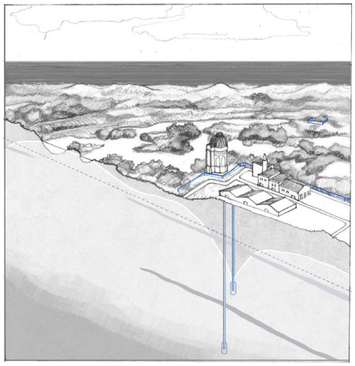
Scenario 1: overextraction



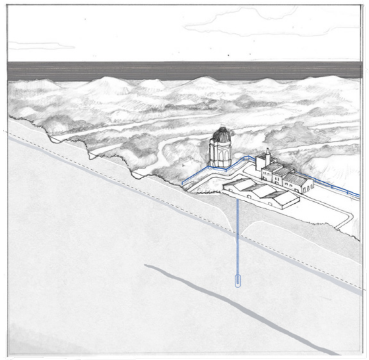
1930-1955



1955-2025



Scenario 2: brackish water

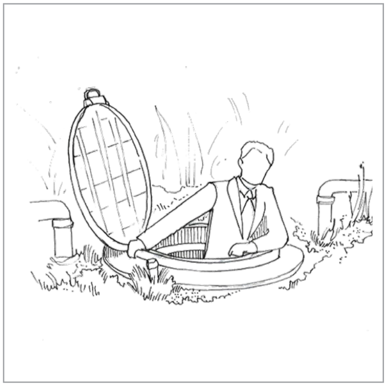


Scenario 3: balance

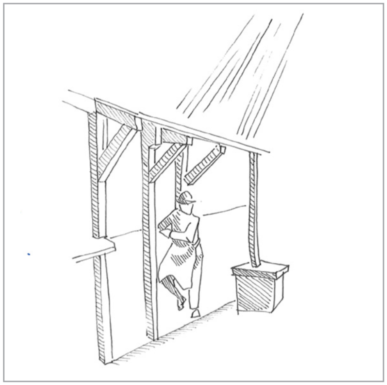
groundwater

surface water

1874-1930



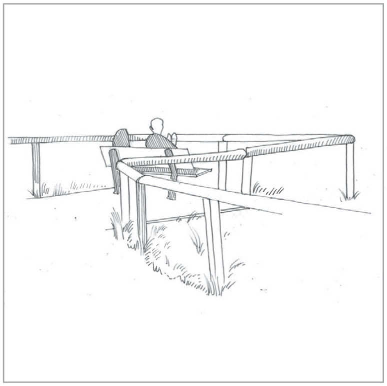
~1930



rain water

As the industrialisation of the dune landscape for freshwater extraction developed from 1855 onwards, centralization of drinking water access became the new norm. Local decentralized infrastructures of water access slowly disappeared (Loen, 2020). The system today is monotonous, singularly focussed, where waters from different sources are melded together and transported and filtered and distributed, miles from the location of sourcing. The disappearance of water diversity, plurality and locality has led to the use of drinking water for all applications, and thus the massive waste of scarce, filtered, potable water for non-potable uses.

1930-1955



1955-2025

Scenario 3

Figure 20. 1874-future. Historical development of human-landscape interaction. Scenario 3 brings people back into closer contact with water.

However, the beauty of historical water supply systems which pre-date centralization is the plurality of it: where water was sourced from different locations and sources, using different infrastructural techniques, was of different qualities and thus also used for different applications (Loen, 2020; Pierik, 2024). The historical development of the system shows the growth of extractive and distribution infrastructure in the dune landscape which has caused disappearance of human-water interactions. Without contact or interaction with water within its natural processes, it is hard to nurture care and appreciation for the unique quality of dune water. Thus within a transition to scenario 3, interaction with water landscapes should be facilitated.

1.3 An extractive relationship

Before the start of drinking water extraction in the Dutch dune landscape, the Younger Dunes consisted of dry dunes and wet dunes (Van der Meulen, 1982). Roughly speaking, the dry dunes were the higher lying areas, and the wet dunes were the lower lying dune slacks which were periodically flooded with fluctuating groundwater. Within these wetter dune slacks, the vegetation was dependent on conditions caused by fluctuating groundwater levels (Van der Meulen, 1982). See figure 21.

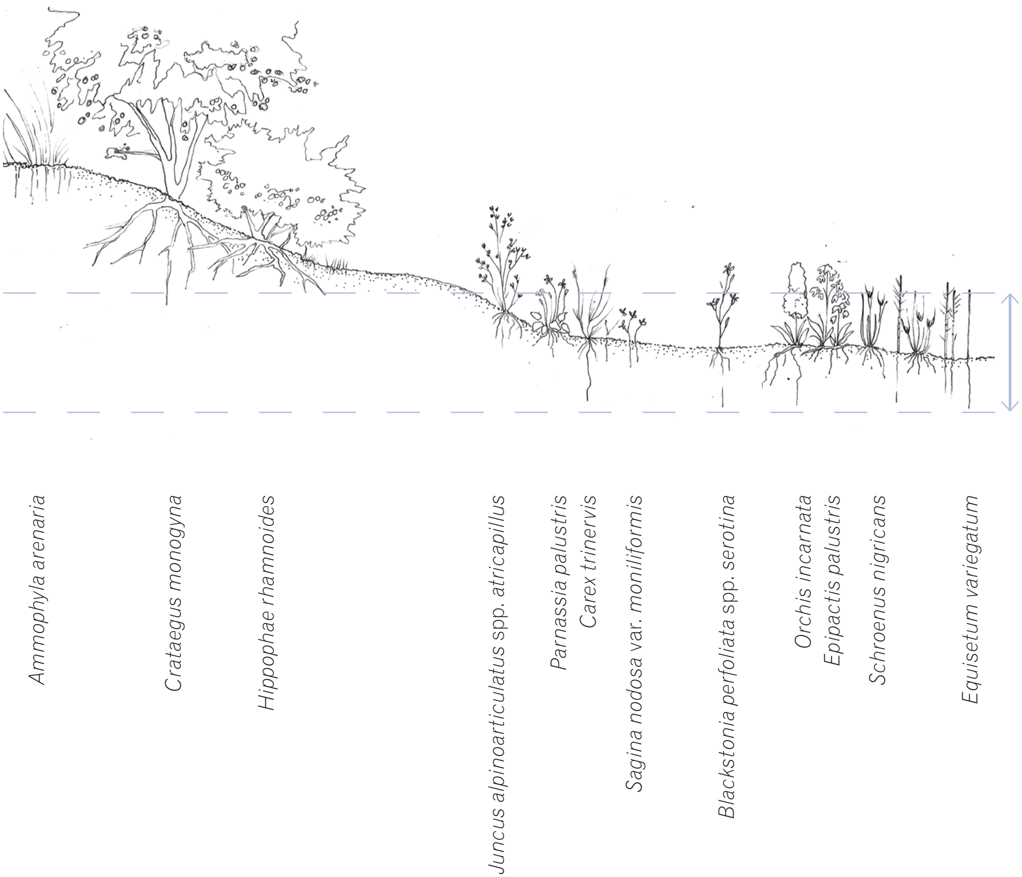


Figure 21. Dune slack vegetation dependent on fluctuating groundwater.

Water extraction within this landscape caused the lowering of the water level in the dune landscape. Dune slacks completely dried out, and the disappearance of periodically wet conditions caused the disappearance or reduction of dune slack associated species (Van der Meulen, 1982).

Some of the disappeared species: ***Parnassia palustris****, Schoenus nigricans,* ***Centaurium* spp.**, *Orchis incarnata,* ***Epipactis palustris****, Equisetum variegatum, Sagina nodosa* var. *moniliformis* and ***Carex trinervis***.

Figure 22.
Dune vegetation disappearance in drought.

Furthermore, dune stabilisation through extensive planting practices hindered the occurrence of sand drifting (Van der Meulen, 1982). Sand drifting is one of the dune-forming natural processes, which can dig dune depressions all the way to the groundwater level: a new dune slack (Van der Meulen, 1982). The anchoring of sand through vegetation complicates the occurrence of sand drifting and dune slack formation.

This period, before river water infiltration, has led to the disappearance of plant and life form species in the Meijendel dune landscape. The period after river water infiltration marks the arrival and return of a range of species. New species appeared along the borders of infiltration lakes, and some dune slack species returned in seepage areas (Van der Meulen, 1982). These species are marked bold.

New species near the infiltration lakes are for example: *Phragmites australis, Lycopus europaeus, Mentha aquatica* and *Typha latifolia*.

Figure 23. Vegetation on the border of infiltration lakes.

These species are characteristically found in permanently wet conditions. The infiltration of river water in set infiltration lakes had created static, permanently wet conditions, which led to the decrease of species and life form diversity (Van der Meulen, 1982). Therefore, we can conclude that the dynamic conditions of the periodically wet dune slacks were beneficial to the biodiversity in the Meijendel area. Specific diversity in species occurs on the flatter slopes of dune valleys, where subtle and gradual changes of wetness under one meter can occur (Van der Meulen, 1982). The occurrence of gradual change in wetness on slopes is further hindered by the irregular water table, caused by vertical water extraction. The disappearance of the normal dome-shaped groundwater table by an irregular table of infiltration and extraction has caused an unfamiliar water regime (Van der Meulen, 1982).

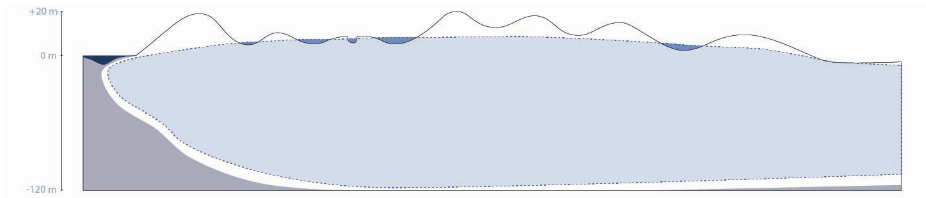


Figure 24.
Dome shaped
groundwater table.

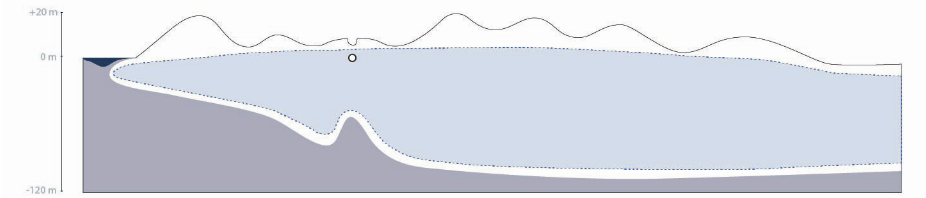


Figure 25. Lowered
groundwater table.

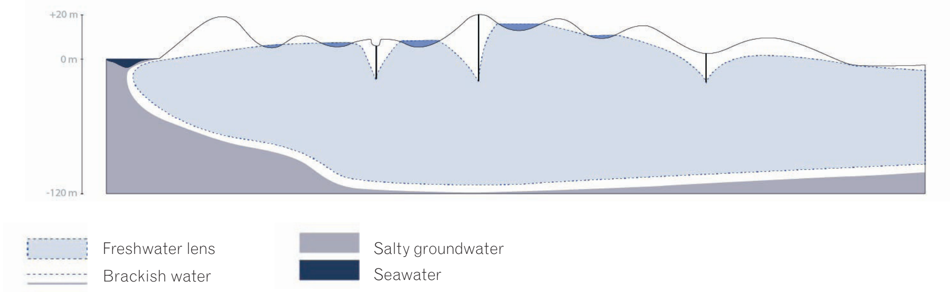


Figure 26.
Highly irregular
groundwater table.

The increase of water in the dune landscape through river water infiltration might have had an influence in the return of species, but the eutrophication of the dune landscape by infiltrating eutrophic river water has had its own ecological consequences. Originally, the soils of Meijendel are rich in lime but poor in plant nutrients (Van der Meulen, 1982), making Meijendel a biodiverse dune landscape. The eutrophication of dune systems, however, increases the nutrient levels. The consequence is an overgrown dune landscape, with very little specie diversity (Van der Meulen, 1982).

The slow ecological changes due to extraction in a landscape such as this are hard to spot by non-professionals. Physical detachment and invisibility negatively affect the cultural and aesthetic recognition of these productive landscapes (Braae, 2015). A lack of social recognition in turn risks overextraction and ecological degradation (Flaquer, n.d.). The dune landscape as a drinking water extraction site is an example. The Dutch dunes are complex landscape of geographical and historical layers of water management, ecological processes, and human intervention accumulated over time. The obscurity of the infrastructure layer conceals the dunes as a landscape of extraction embedded in a complex network. It equally obscures the urgency of water scarcity as a societal and ecological problem.

To counteract the negative ecological consequences of drinking water extraction practices Van der Meulen (1982, p.314) lists some possible measures which have to be undertaken to 'reduce the nutrient load of the ecosystem' and promote the 'regeneration of dune slack vegetation'. The reduction of the nutrient load can be achieved by using less eutrophic river water and reducing the total area of surface water for infiltration (Van der Meulen, 1982). Regeneration of dune slack vegetation can be obtained by raising the water table by reducing extraction and by promoting wind excavation through sand drifting. If sand drifting cannot be immediately promoted, lowering the soil surface through manual digging will have the same effect (Van der Meulen, 1982).

Promote sand drifting | Using less river water | Raising water table

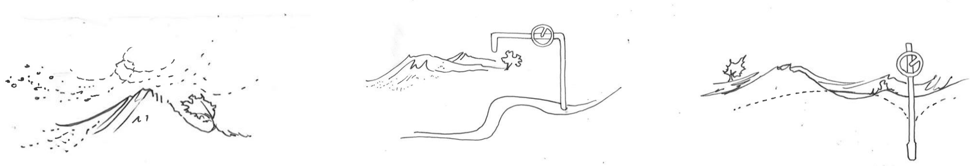


Figure 27.
The interventions

Since 1982, some improvements have already been made. Meijendel and Berkheide are protected sites, under the Natura2000 regulations (DUNEA Duin & Water, n.d.g.), and the pre-dune filtration phases at Berg Ambacht and Brakel have reduced the nutrient load on the dune ecosystems significantly (DUNEA Duin & Water, n.d.d.). On a trip to the Dunea facilities, guides explained that more attention is given to the seepage areas in which the original dune slack habitats have a chance of returning (L. Vos, personal communication, May 15th 2026). However, because of the constant balance between infiltration and extraction, very little fluctuations exist in the current groundwater level, making a full return difficult.

One other effect of drinking water extraction in the Meijendel dune landscape has to be mentioned. Its function as a drinking water production landscape has protected the landscape from urban invasion (Croin Michielsen, 1974). The current drinking water company, Dunea, plays a very nurturing role in the relationship between landscape and company. Dunea is not only focussed on the continuation of drinking water extraction, but also on the general health and dynamics of the landscape (DUNEA Duin & Water, n.d.c). Plans for a water transition are progressing slowly which means this might also be the time to make more radical steps in restoring original dune dynamics and habitats within this transition process. The proposed interventions by Van der Meulen (1982) can be an inspiration for how a system transition can make space for dune dynamics and processes, so that dune specific habitats can return.

1.4 ~~Industrial~~ Landscape

The dunes occupy a distinct position within the infrastructural network of drinking water sourcing, filtration, and distribution in South Holland. Pipelines run under the surface of the dune landscape, invisible to the coastal resident but for the Dunea public taps with which they can fill their water bottles. Several viewing platforms dot the map on top of the tallest dunehills, from which people can catch a glimpse of the infiltration lakes. Information on the Meijendel vegetation, formation, birds and predators can be read on plaques. Some sentences are given to the fact that the lakes and water tower play a part in the production of drinking water.

Unlike conventional industrial landscapes, which are typically characterised by concrete, steel, and visible extraction, the river-dune system is a system with a largely imperceptible industrial infrastructure. It operates through the subsurface hydrological processes of sand filtration, subsurface water extraction, post-dune filtration and the subsurface transport of the finished drinking water product. Unsurprisingly, the public does not recognize the dune landscape as a productive landscape. The western coastal dunes are widely valued and visited as a landscape, and yet their role as a critical node in regional drinking water infrastructure remains obscured.

This apparent contradiction can be explained by the conceptual and spatial separation of landscape and infrastructure (Bélanger, 2017). However, within this specific context, that separation is illogical. The infrastructure does not simply pass through the landscape, but is part of an industrial system which utilizes dune processes. Therefore, the dunes cannot be understood as an urban-supporting landscape without understanding what is extracted from them. Yet this is precisely what happens: the infrastructural system remains unseen, undermining any sense of accountability for the spatial and ecological effects of resource extraction.

The mental detachment of brownfields as remote and obscure places risks the extensive appropriation and overextraction of these landscapes (Flaquer, n.d.). When landscapes of extraction are hidden, the physical and ecological implications on the landscape also remain unseen (Flaquer, n.d.). Especially in the case of industrialisation of the Dutch dune landscape, many dune processes, like sand drifts and a dynamic groundwater table, have been stabilized or halted. This resulted in the disappearance of natural dynamics, accompanied by a decrease of specie and conditional diversity in the dune area (Van der Meulen, 1982). However, the ecological degradation due to extraction has been such a painfully slow process, it remained largely unnoticed by human perception and memory. By now, coastal inhabitants suffer from a kind of amnesia where they perceive the dunes as the epitome of nature, even though the landscape is straying further from its natural state.

When the utilization of a landscape is obscure, the question becomes whether humans will take accountability when extraction becomes overextraction. Within the current urgency of increasing water scarcity, water companies are trying to responsibly respond in the shape of a sustainable transition (UvA and VEWIN, 2026). A sustainable transition, however, necessitates a change of approach when designing infrastructure.

Modern man-made infrastructure, by definition, works and delivers until it ages and decays, and inevitably fails (Bélanger, 2017). Merging landscape and infrastructure is a way to counteract the temporary and disruptive qualities of contemporary infrastructure. As Bélanger (2017, p.113) states, catastrophes like floods and resource shortages mark the 'fragility of this invisible background' of contemporary urban life which has yet to reach its 100th birthday (Bélanger, 2017, p. 113). The water infrastructure of the future should be adaptive enough to respond to both water surpluses and shortages, which is only possible through a 'cooperation' with local landscape structures. In this thesis, I interpret Bélangers term of 'landscape infrastructure' as a new infrastructure which is always in a mutually giving interaction with nature. What form 'landscape infrastructure' can take within this context will be explained further in paragraph 2.3.

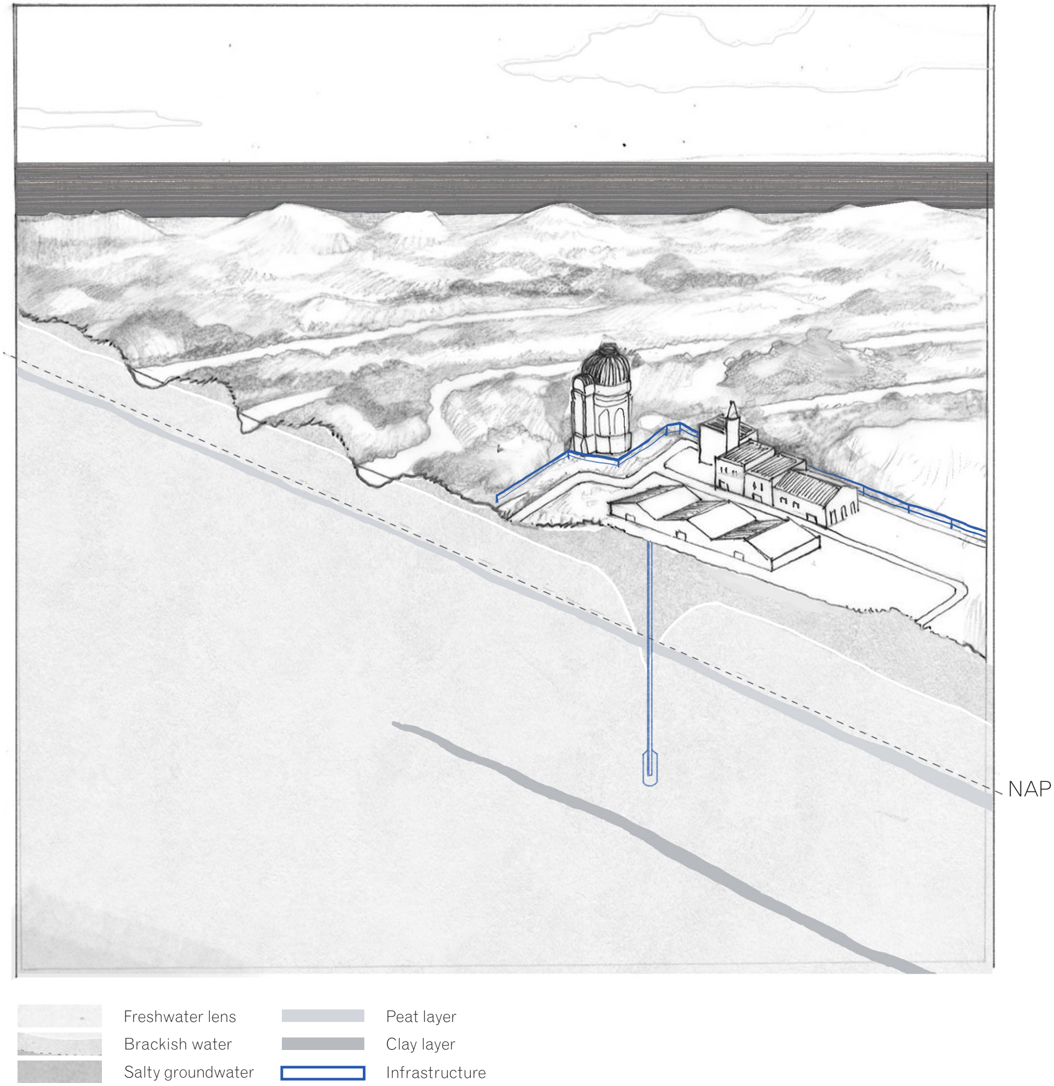


Figure 28.
Scenario 3 of a drastically changed drinking water system. One where dune water dynamics are reintroduced and salty water is kept at bay.

Figure 29.
Instead of watching from a distance, people can again approach dune creeks. They will not drink water which is not from a tap, but feeling the dune creek is normal.

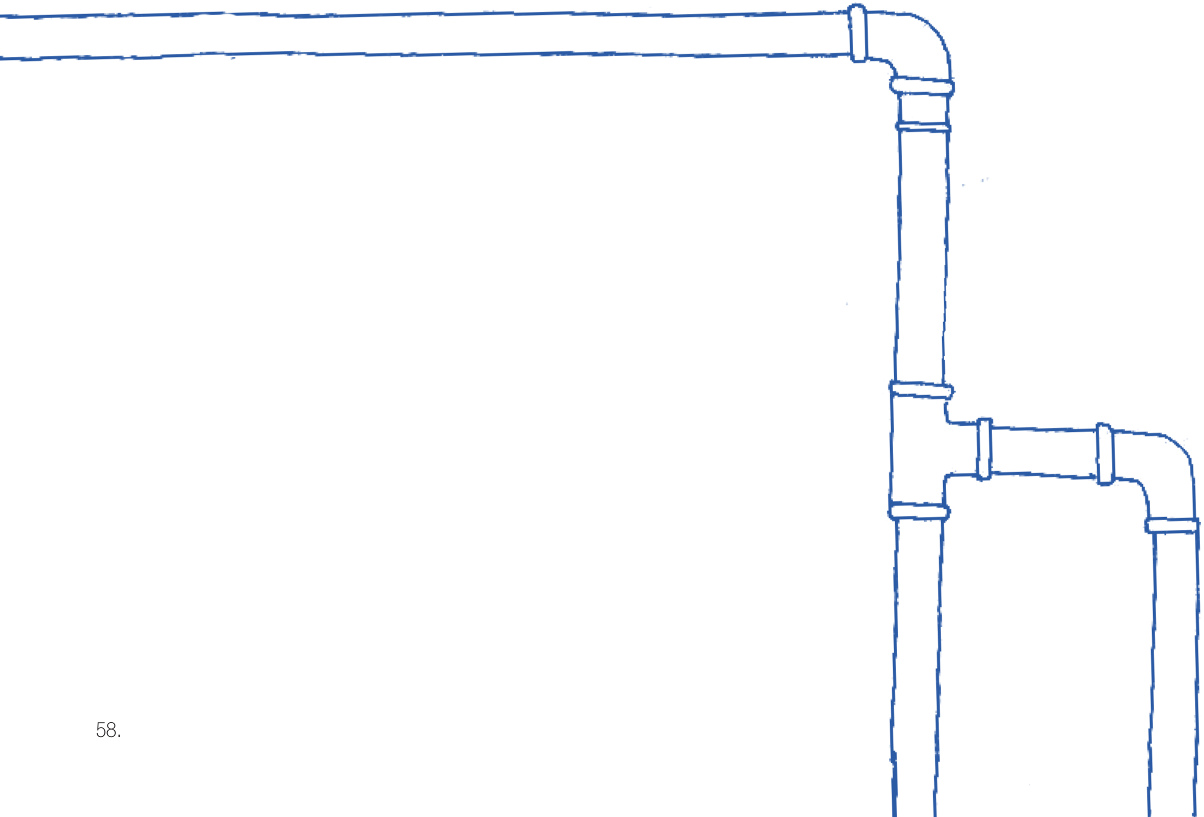
One thing which can be established now is that a sustainable transition of water infrastructure is not possible without public recognition of the places which provide drinking water. People cannot see the infrastructures which transport their drinking water, and people do not interact with the natural processes which filter it. Public recognition could be the leverage to rebalance the river dune system and respond to water scarcity sustainably. Within the next decade, the river-dune system will undergo a drastic transformation, which has not fully taken shape yet. Within this transition, we should not remove humans even further from the productive landscapes which sustain them, but that we should instead involve them as witnesses and even participants in drinking water landscapes. It is time to think beyond what we can take from this industrial landscape, and understand that it is a living landscape. In order to achieve this, natural water processes have to be spatially translated, encountered and understood on the human scale. First, however, the threats on the larger system have to be analysed.

Chapter 2.

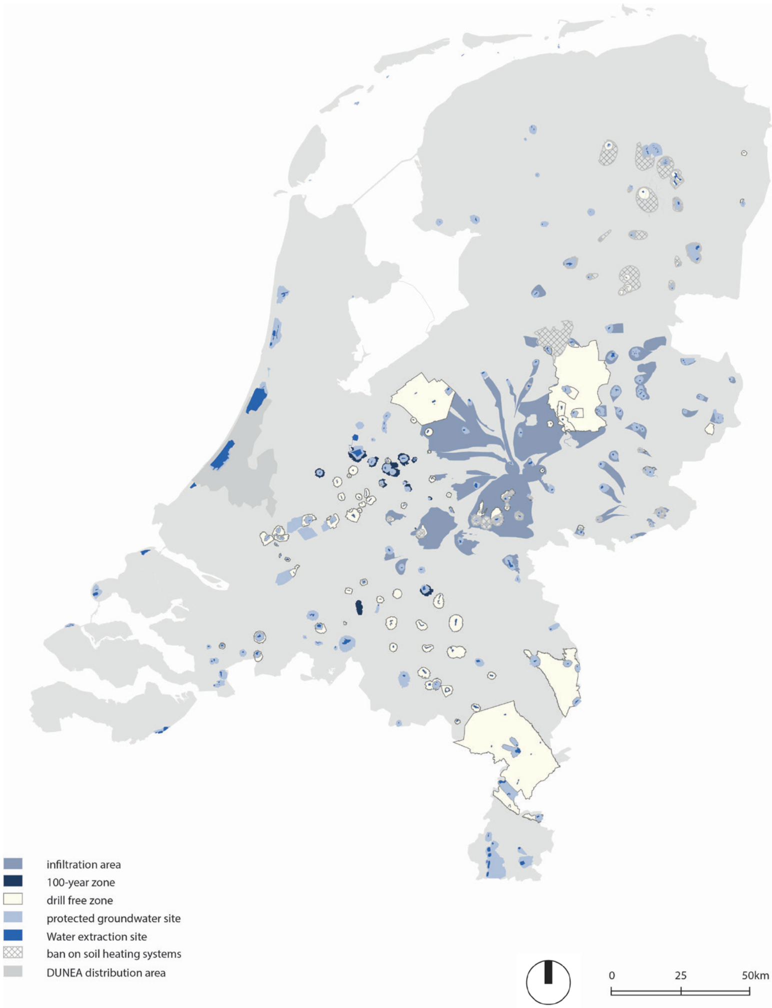
water circularity.

'More than just steel, cement, and asphalt infrastructure therefore forms distinctively complex, urban ecologies, a vast and immense landscape of biophysical and geospatial systems, an expansive field of resources, services and agents that together support the landscape of contemporary economies."

— Bélanger, 2017, p. 46 in Landscapes as Infrastructure.



2.1 The journey of a drinking drop



Map 4.
Drinking water landscapes in the Netherlands. By the author. Adapted from Atlas Leefomgeving

The dune system was the first centralized drinking water distribution system in the Netherlands (Loen, 2020). Now, drinking water production and distribution have spread over the country, with most drinking water companies in the Netherlands using groundwater as a source for drinking water. Map 4 shows the groundwater protection sites, infiltration areas and water extraction sites, making this a map of drinking water landscapes in the Netherlands. The river-dune system is but one piece of the puzzle.

To ensure the quality of groundwater across the country, rules and restrictions apply in 100-year zones and groundwater protection sites. Drill-free zones prohibit the perforation of clay layers in the soil, to protect the integrity of freshwater storage. Water infiltration areas are mostly on the sandy soils, in the Veluwe as well as in the coastal dunes. As the case in the Veluwe, water extraction sites are generally quite small compared to the area of infiltration. In the coastal dunes, however, which are located in the highly urbanized Randstad, the infiltration area is limited and the whole site is swallowed by water extraction.

The Meijendel coastal dunes as the drinking water landscape of South Holland are providing 1.3 million people with high quality drinking water daily. As the population continues growing, 1.6 million people will be dependent on this drinking water landscape by 2040 (DUNEA Duin & Water, n.d.b), with a necessary increase of 10 billion litres of drinking water per year extra by 2030 (DUNEA Duin & Water, n.d.a). The river dune system will somehow have to adapt to respond to the increase in the demand. First, however, a deeper understanding of how the modern system operates is fundamental in order to propose change.

The current system starts in the Afgedamde Maas, a river branch of the Maas, and has been in use as the source of the river-dune system since 1976. This river branch is twelve kilometres long and has a slow current, which is beneficial for the water quality (DUNEA Duin & Water, n.d.d.). Dunea reduces the phosphate content in the river by adding iron sulphate and oxygen. After intake in Brakel, the water is passed through microfilters to remove excess organic material in both spring and summer (DUNEA Duin & Water, n.d.d.).

After a thirty-kilometre journey through pipelines, the water reaches Berg Ambacht: the pre-dune filtration station. Here, the water passes the first sand filters which include UV, zone and hydroperoxide, which eliminate microcontaminants, pesticides and hormone-disrupting substances (DUNEA Duin & Water, n.d.d.). In recent years, ageing of the population and increasing drought have increased the concentration of microcontaminants like medicine residues in our water (DUNEA Duin & Water, n.d.d.). Due to the threat of these contaminants, which are harmful for drinkers as well as the dune landscape, Dunea has developed a new filtration technique to remove them. The new installation GOBAM is active since 2017 and has increased the filtration capacity to 2000 cubic metres water per hour (DUNEA Duin & Water, n.d.e.). Two pipelines transport this water from Berg Ambacht to the dune area between Monster and Katwijk.

The water passes underneath the dune hills, through the pipelines, and ends up in the infiltration lakes. There, the water starts its hurried journey to sink through the lakebed. The infiltrating river water has slowly invaded the realm of infiltrated rainwater. This realm is a collection of rainwater which has infiltrated the sandy soil of the dune landscape since the formation of the younger dunes, 500-800 years ago (Croin Michielsen, 1974). Now, rainwater and riverwater are assembled into a huge freshwater lens, which reaches to 120 meters below surface level. Individual water particles are not sinking down in a straight line, until a time in which they are pumped up again. Instead, the two-month period the water lives in the soil is spent in constant movement; up, down, left, right, along with subterranean currents drawing the water to the depths, to below the seabed or back to the surface (Croin Michielsen, 1974). After a two-month passage, the unwanted bacteria and viruses have been naturally removed, and the water is drawn back into pipelines and filters (DUNEA Duin & Water. n.d.d.).

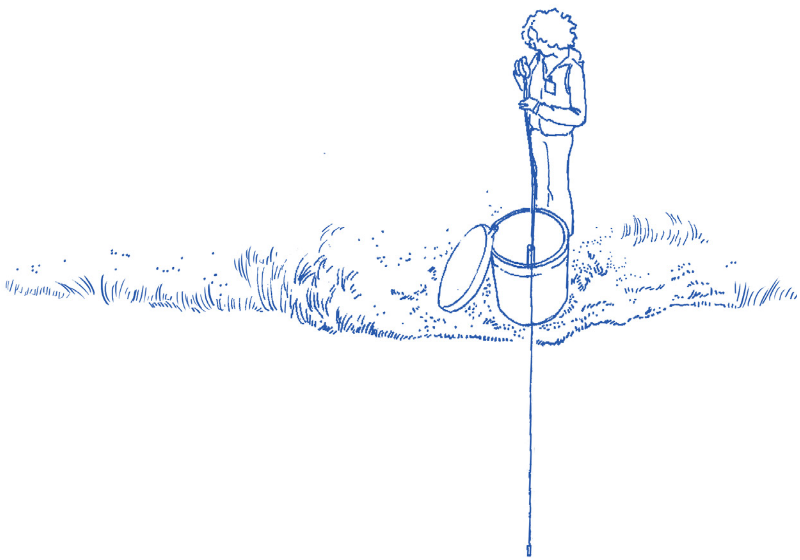


Figure 30.
The author manually measuring the depth of the groundwater in a monitoring well.

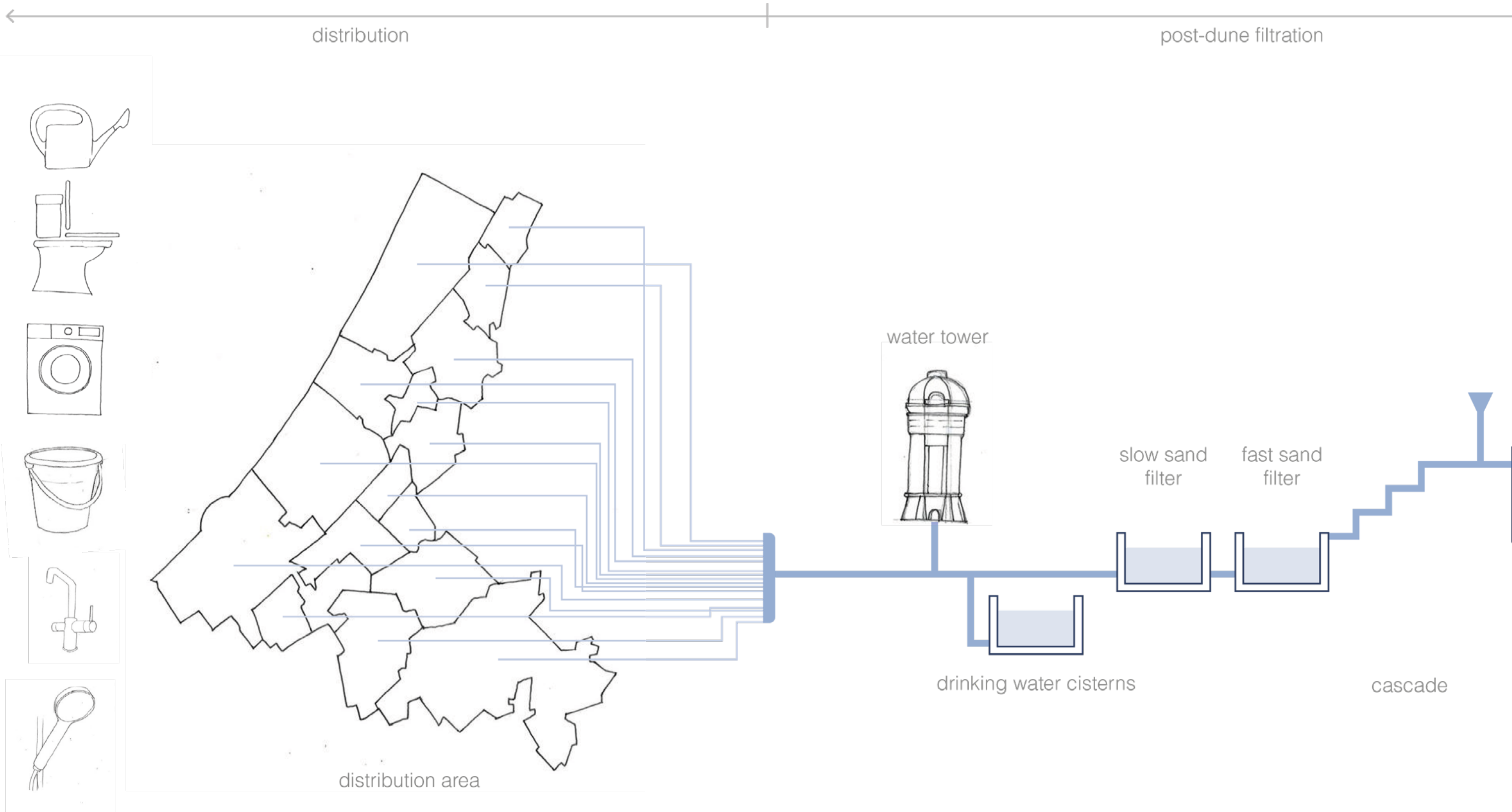
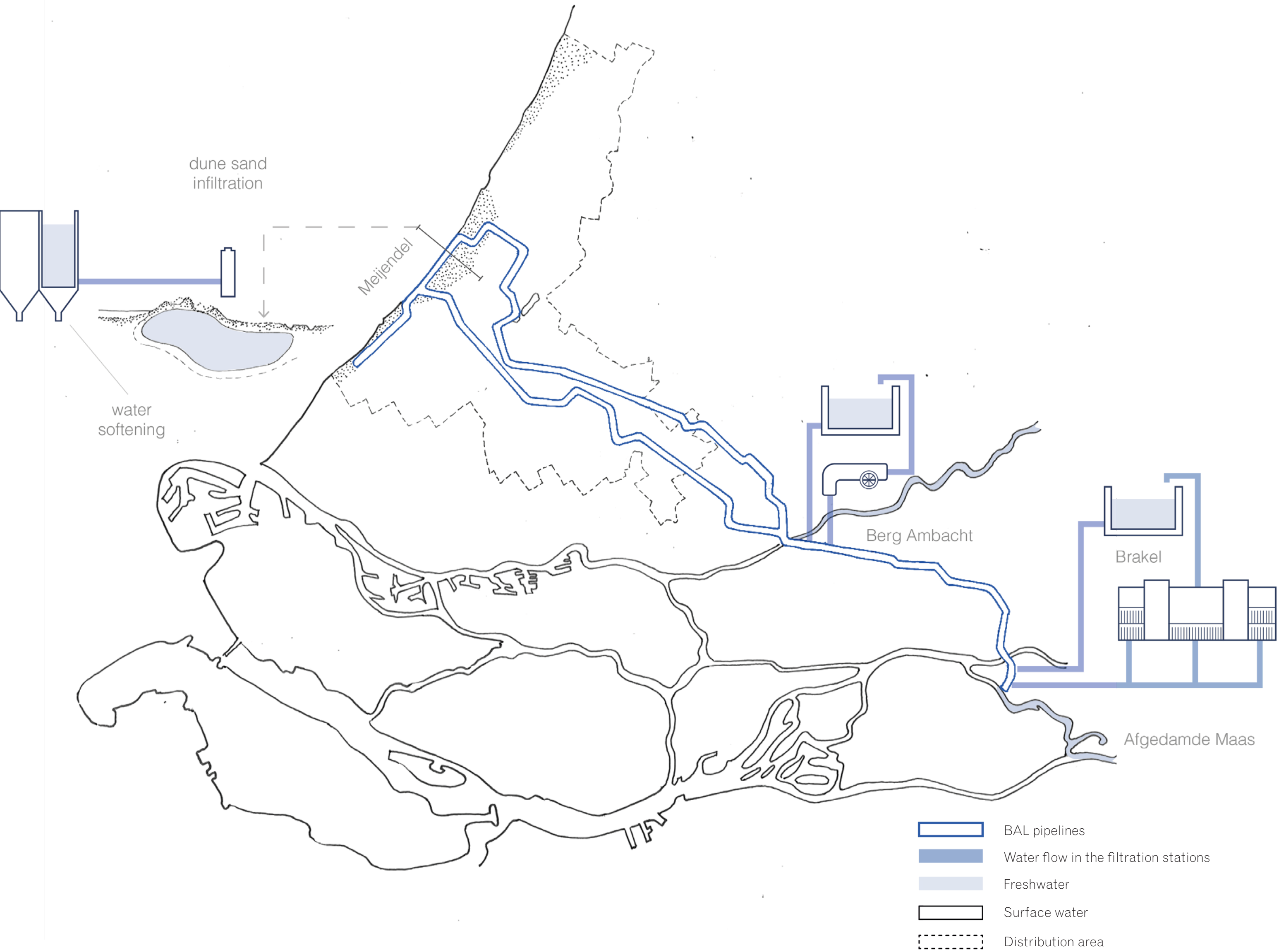


Figure 31. The current, centralized, river-dune system.

The water extracted from the dune sand is still brown and has a distasteful scent (DUNEA Duin& Water, 2023). This means the water is safe to drink, but not yet to the aspired quality which is fit for consumers. The water is led through the final, post-dune, filtration stage which clears the water of all colour, scent and taste. This post filtration stage includes water softening, carbon dosage to remove the taste, cascades for aeration, and a last stage of sand filters (DUNEA Duin & Water, n.d.d.). On a visit to the Dunea facilities, the guide stated that the dunes made the water safe (veilig), water softening made the water friendly (vriendelijk), and the carbon dosage and aeration made the water delicious (verrukkelijk) (L. Vos, personal communication, May 15th 2026). After these phases, the water is stored in 'reinwaterkleders', or clean water cisterns. Then, using the pressure created by the water tower, water is distributed to consumers. This way water is available even in the case of a power outage (DUNEA Duin & Water, n.d.d.).

dune filtration

sourcing and transportation



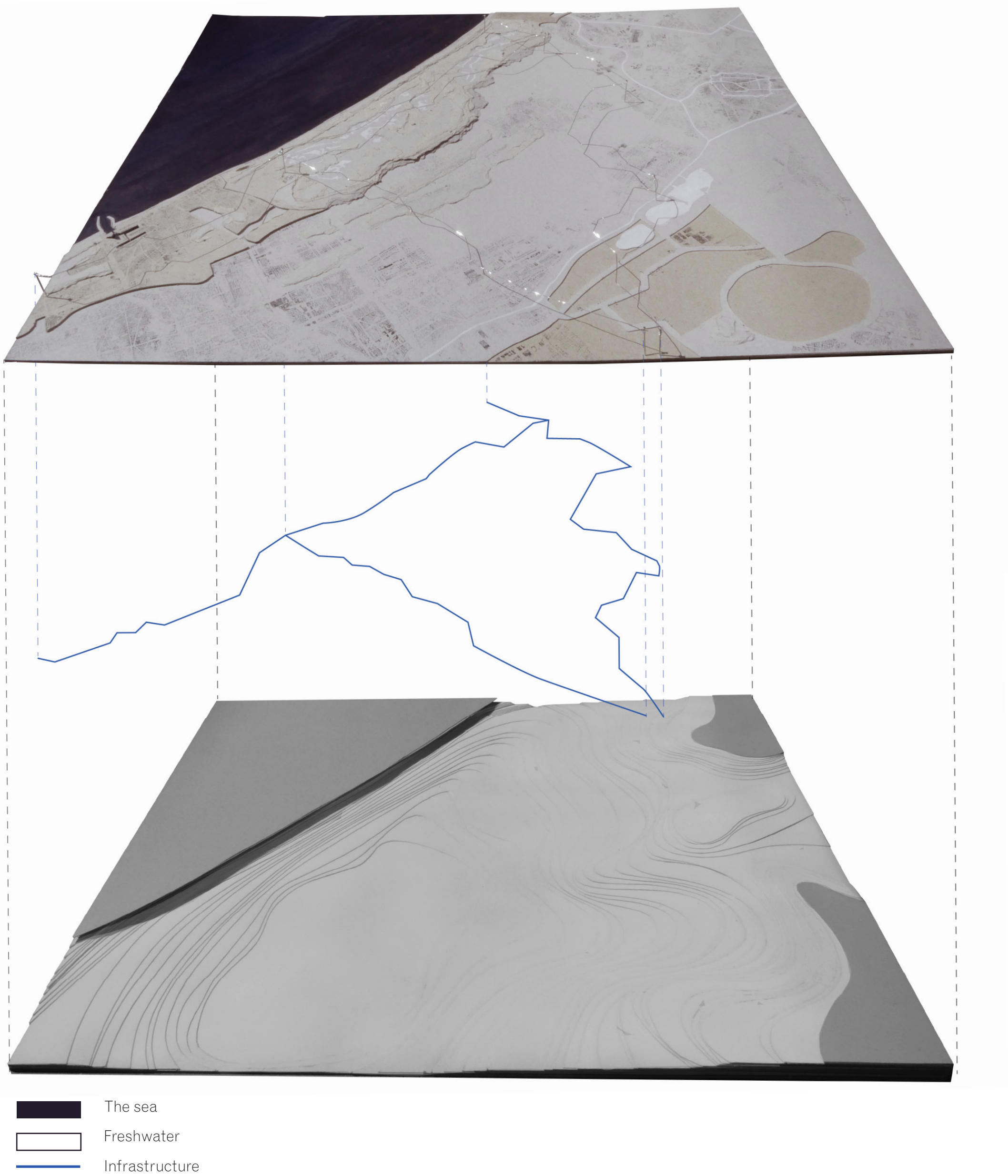


Figure 32. An exploration model (1:30.000) on the subterranean infrastructure, linked with the surface landscape and the sub-surface freshwater lens.

In order to map this extensive system and the infrastructural relations between the subterranean freshwater lens, the pipelines, and the surface landscapes, a three-dimensional model was constructed (see figure 32.).

In the model, the topography of the entire dune landscape is visible. The hills of th Younger Dunes, the sand ridges in the Old Dunes, all the way to the polders behind the Vlietlanden. The subterranean layer visualises the depth of the freshwater lens. Even though most water infiltrates in the sandy soils of the Younger Dunes, the freshwater lens is deepest around 4 kilometres from the coast, under the Old Dunes. The freshwater saltwater interface comes up again around the threshold between Old Dunes and polder, where salinisation occurs.

The pipelines come in from the South East, pass the Vlietlanden and continue to the coastline where they transfer the water into the infiltration lakes. In the model, the pipelines are represented by wire, which cast a shadow on the landscape surface on the location they are buried. In figure 32, the blue infrastructural are drawn to make it more clear in this report. Only by combining the surface and section of the system, combining infrastructure and landscape structures, is a system like this comprehensible.

2.2 Water scarcity as a catalyst for transition

In January 2026, Vewin (association of drinking water companies) and UvW (Union of waterboards) published a water manifesto, in which they plead for the government to take action in the face of growing water scarcity. Publishing such a manifesto is a cry for help on this issue, which regardless of its urgency remains largely unnoticed.

The Dutch water system is failing due to climate change causing periods of excessive rainfall and periods of drought (UvW and VEWIN, 2026). Periods of drought in the summer and spring put extreme pressure on drinking water systems, because the demand for water grows whilst the supply of water dwindles. Simultaneously, excessive rainfall in autumn and winter is testing the limits of our water storage capacity, leading to the risk of flooding and the inclination to pump all water out. There is enough water to go by, but not in the right place at the right time (UvW and VEWIN, 2026). Additionally, the drinking water sources which we have now in the form of both groundwater and surface water are exposed to an increasing amount of industrial, agricultural and domestic pollution. Both the dwindling quality and quantity of water is putting the drinking water supply of 8 million households in the Netherlands at risk (UvW and VEWIN, 2026).

Vewin and UvW start the manifesto specifically with a concise list of goals. Three of five items are focussed on the landscape and the restoration of natural areas:

(2) Spatial design guided by water and soil.
(3) Restoration of the water balance with a robust water system capable of handling periods of both too much and too little water.
(5) Initiating nature restoration through water interventions and utilizing the connecting role of water in other societal challenges.

This list emphasizes the fact that clean water is not possible without healthy landscapes. Within the context of growing water scarcity, VEWIN and UvW (2026) plead for the protection of freshwater sources, an increase in water storage landscapes, stricter rules regarding water pollution, more action to improve surface water quality, and more action to raise public awareness to include consumers in decreasing the use of potable water. Landscape architecture is precisely the discipline to deal with the spatial and natural challenges within such a large, complex system.

Figure 33.
The dune landscape under pressure due to water scarcity.

2.3 Rethinking infrastructure

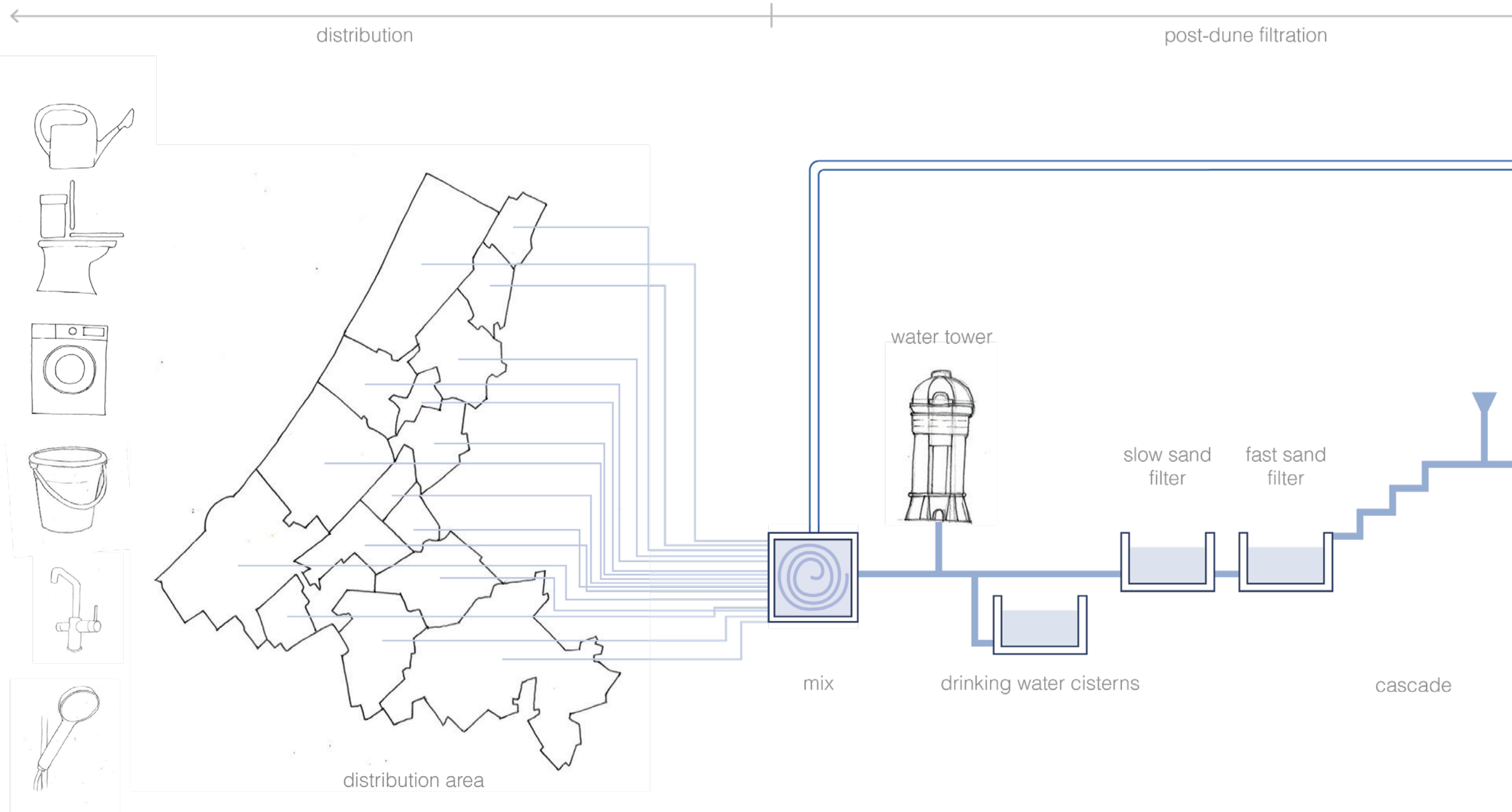
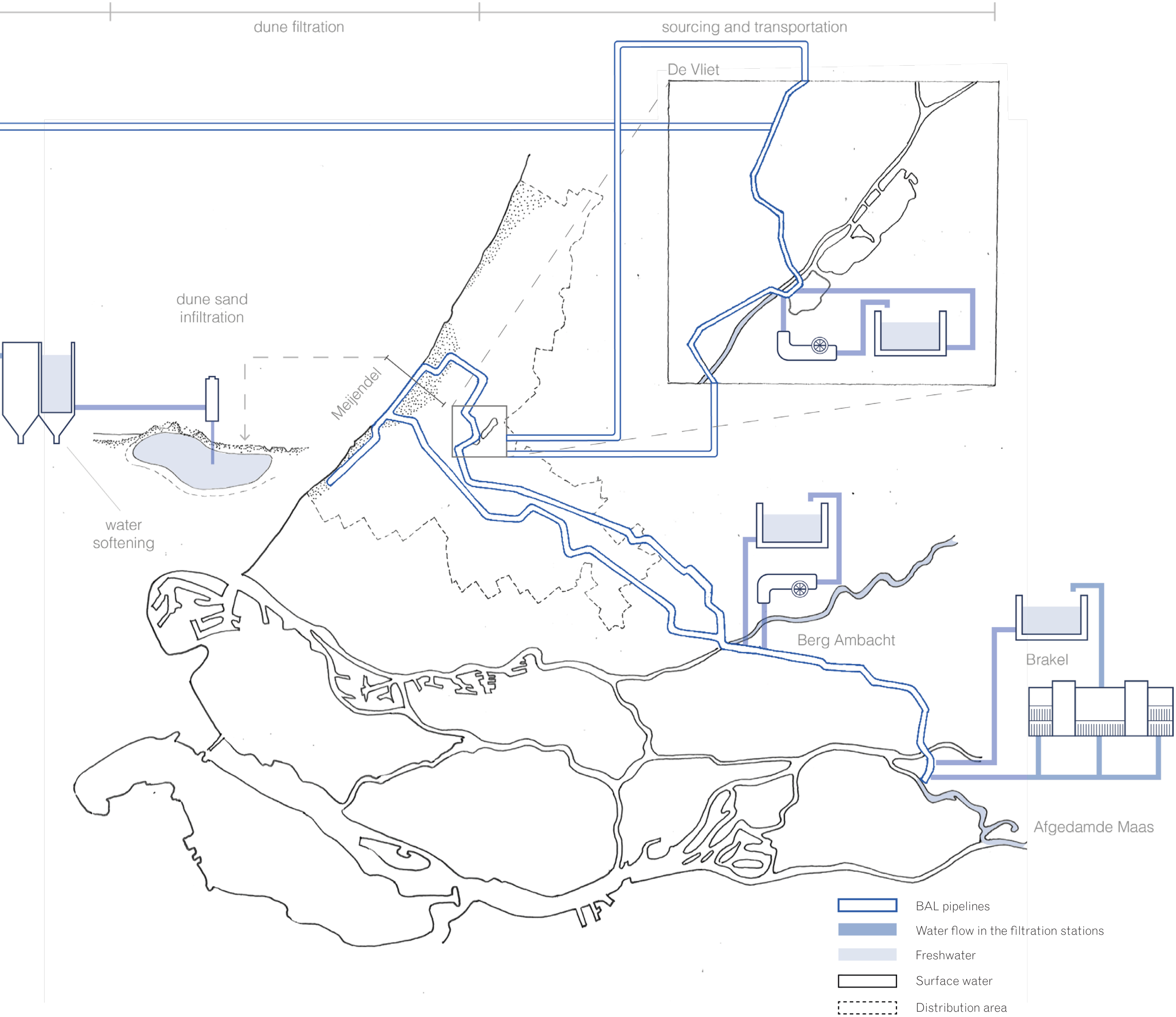


Figure 34. The extended, centralized, river-dune system.

Dunea is aiming for a resilient drinking water system of the future, which involves clean freshwater sources and conscious and sustainable water use. Like all water companies in the Netherlands, they will be running into supply issues due to water shortages within the next 10 years (DUNEA Duin & Water, n.d.a). In their search for ways to respond to increasing water scarcity, Dunea collaborated with the province of South-Holland, the municipalities and the waterboards to find new sources of drinking water. Options on the table included extracting and filtering brackish water, extracting and filtering seawater and freshwater from de Vliet as a regional emergency source (DUNEA Duin & Water, n.d.a). In September 2024, they announced that the Vliet as a new regional source will become the backbone of this transformation (DUNEA Duin & Water, n.d.a). This intervention is a step towards water localisation, and minimising the distance between the water source, filtration landscape and consumers.



dune filtration
sourcing and transportation
De Vliet
dune sand
infiltration
Meijendel
water
softening
Berg Ambacht
Brakel
Afgedamde Maas
BAL pipelines
Water flow in the filtration stations
Freshwater
Surface water
Distribution area

For a sustainable transition of the river-dune system, this thesis formulates an argument for a more radical localisation of water access, which utilizes local waterways with water storage and self-cleaning capacities.

As established in paragraph 1.4, modern day water infrastructures are inflexible and unable to respond to the extreme weather conditions caused by climate change. The urban water system, a network of pipelines and treatment plants, is one with little room for adaptivity (Van Roon, 2007). In case drought, the system is not resilient enough keep up with the growing demand. In case of flooding, the system is not far-sighted enough to store water safely for emergency use in cases of drought. Additionally, this system facilitates the widespread use of drinking water for non-potable purposes (Van Roon, 2007). It is an immense expense to go through the whole process of sourcing, three stages of filtering and distributing drinking water, just to flush it down the toilet (Van Roon, 2007). This is especially wasteful when we think of the pressure on the dune landscape to produce all this drinking water, when extraction is already at capacity. As established in paragraph 1.3, the pressure on the dune landscape has to be relieved by reducing the amount of extraction instead of increasing it. Decentralisation and localisation of water access, storage and treatment have the potential to decrease drinking water extraction in the dune landscape, minimising the risk of flooding in periods of heavy rainfall. The implementation of partial water decentralisation — with centralized drinking water distribution and local rainwater harvesting and water reuse for non-potable use — is only possible through public education on the new system (Van Roon, 2007). The transformation to a new system based on conscious water use also has the potential to draw attention to productive water landscapes like the dunes.

For river-dune system in particular, it can be argued that the most important reason to decentralize water access is that the capacity limit of the western dune landscape to produce clean water is reached. The western dune landscape is a Natura2000 area, which means it is protected from a certain level of overextraction (L. Vos, personal communication, April 16th 2026). Trying to respond to increasing drinking water demands using the current infrastructure, would exceed the limits listed in the Natura2000 regulations (L. Vos, personal communication, April 16th 2026). Increasing the capacity of the system is not possible, because it can lead to a more destructive impact on the dune landscape. Instead, we need to decrease the amount of drinking water extracted from the dune landscape by localising water access.

When we look at the bottlenecks of the current system and identify water access localisation as a way to relieve pressure on these points, the selection of the Vliet as the new regional source can become the first step to more radical localisation. As of right now, the proposal states the Vliet as a additional source of water, which will be filtered alternatively using membrane filtration instead of dune infiltration. To summarise, this proposal circumvents the Natura2000 limitations by industrialising to dune capacity and designing a whole parallel system to fill the gaps of drinking water demands. Alternatively, complete water localisation of water access for non-potable use could relieve the pressure on the river-dune system, which will then be responsible solely for drinking water production. This decrease in drinking water demands offers an opportunity to start extracting less from the dune landscape, and instead have it function as the dynamic landscape and freshwater aquifer storage it used to be.

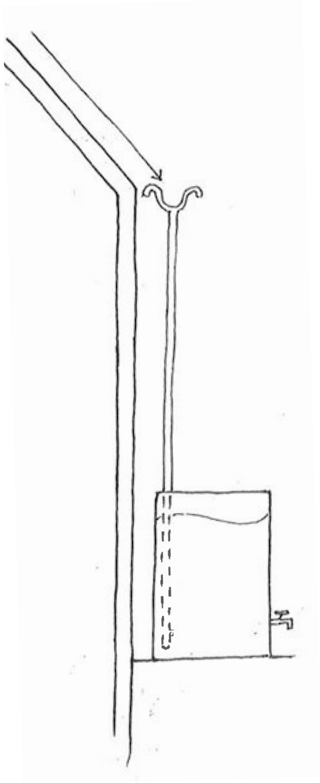


Figure 35. Simple interventions, like a rainwater tank which stores water from rooftops, are the first step to larger water localisation.

The small circular infrastructures that make up this localised network of grey water and rainwater access, storage, and treatment is a new local landscape infrastructure. Local collection, reclamation and redistribution of all water types strengthen water cycles in local landscapes, which can reduce cost and ecological impact (Van Roon, 2007). When designed properly, the development of local water cycles can even enhance local ecology and biodiversity. However, this transition needs consumer participation through consumer education in order to include all actors in reducing potable water demand and work with alternative water sources for non-potable use (Van Roon, 2007).

2.4 Making landscape infrastructure

Combining the needs of the dune landscape and the needs of society is a challenge where the demands for less extraction and more freshwater collide. This challenge will be spatially addressed in this paragraph. To summarise:

Challenges of the dune landscape: Extraction has caused ecological degradation in the dune landscape. Specifically, dune habitats have disappeared due to the loss of dynamic processes, which are caused by drinking water extraction and river water infiltration.

Needs of the dune landscape: To counteract drought, a decrease in freshwater extraction is necessary. The reintroduction of dune dynamics, including a dynamic groundwater level and sand drifting can promote the creation of new dune slack habitats.

Challenges of the drinking water companies and waterboards: Weather extremes caused by climate change are testing the limits of or water systems. Periods of drought cause increasing issues of water scarcity, whilst water from excessive rainfall in different seasons cannot be stored properly. Additionally, the water which we do have suffers from increasing pollution.

Needs of the drinking water companies and waterboards: A sustainable transition to adaptive water system to respond to increasing water scarcity. Adaptive means that the system can store water in seasons of excessive rainfall, in order to use that water in seasons of excessive drought. The quality of surface water would also have to be protected and, where possible, improved.

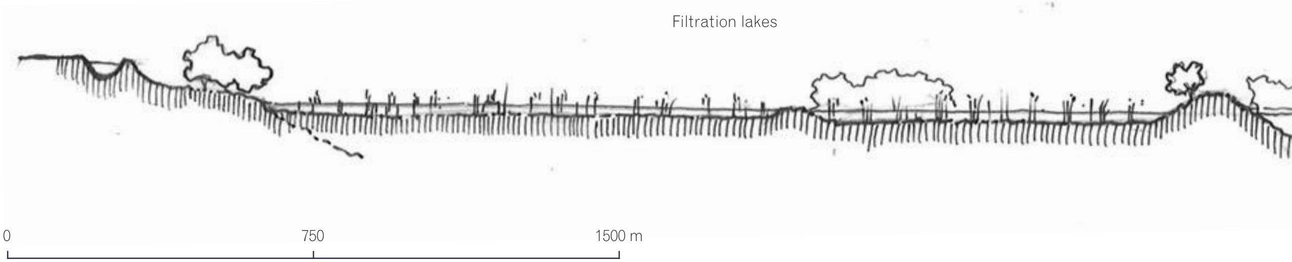
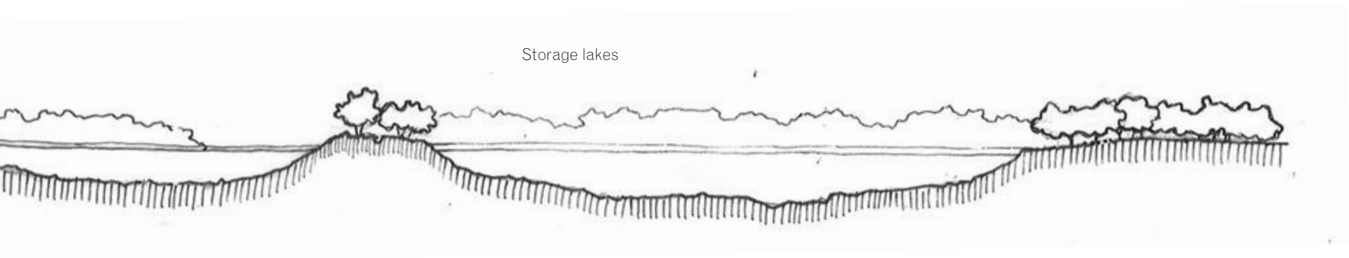


Figure 36. Section A-A' of the new Vlietlanden water filtration and storage landscape. The depth of the lakes is exaggerated for visualisation purposes.

To address these challenges and align the interventions, some elements of the vision will need to be explained in order to understand the full scope. For the sake of clarity, a strategy for the location of water sourcing will be explained first.

The source strategy is an adjusted version of the regional Vliet plans. This adjusted strategy extends and uses the Vlietlanden landscape as a water filtration and storage landscape. The Vogelplas Starrevaart and the new shallow lake clean surface water by a large surface area of helophyte filters, which will be a functionality on top of standard Dunea filtering practices. These two lakes will not be accessible to humans, but will function as an extended landscape for the 'Vogelplas Starrevaart', and host a wide variety of birds. Species like *Limosa limosa, Tringa erytropus, Plegadis falcinellus, Mareca penelope, Anas acuta* and *Alcedo atthis* (Birding places, 2023) will see their habitat grow.

From there, the water will flow into the main Vlietland lakes, which were created through sand excavation. Sand excavated lakes are incredibly deep, meaning they are perfectly suited to store large amounts of freshwater. Additionally, the depth of these lakes (up to 34 metres) is very beneficial for water quality due to temperature stratification (Osté et al, 2011). The water which has been filtered in the Vogelplas Starrevaart will not lose its quality in the Vlietland lakes.



Map 5.
The Vlietlanden as a water filtration and storage landscape.

At the end of this Vlietlanden journey, the water can be taken in by Dunea to be filtered further before the water is transported to the dune landscape. Here, the strategy will again diverge from the official plans. As explained, the official plans see the Vliet as an alternative, additional source which uses roughly the same infrastructure as the existing system, but will be taken out before the phase of dune infiltration. According to the original plans, the same amount of water in the BAL (Berg Ambacht Leidingen) pipelines which entered at the Vliet, will be diverted and filtered alternatively (see diagram 4). This method can ensure enough water for periods of drought but will not exceed the Natura2000 limitations.

The alternative strategy proposes to slowly increase the share of Vlietwater and slowly decrease the share of Afgedamde Maas water in the BAL pipelines, letting the clean water from the regional Vliet slowly take over the river-dune system. This Vliet-Meijendel system is regional and circular, which is less dependent on kilometres of pipelines and extensive chemical filtering (see diagram 5). In diagram 6, the total amount of water entering the dune infiltration has also decreased. The next parts of this strategy explain how this is possible.

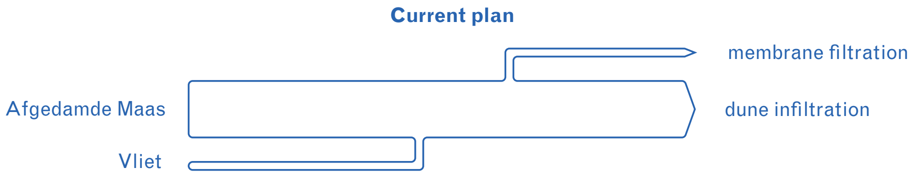


Diagram 4.
Current plan.

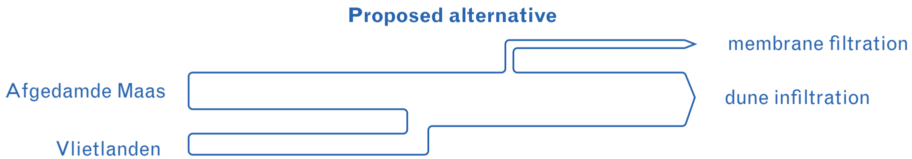


Diagram 5.
A slow manipulation of water flows into the Dutch dunes.

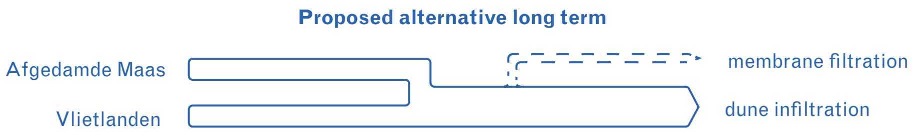


Diagram 6.
The long term manipulation of water flows into the Dutch dunes.

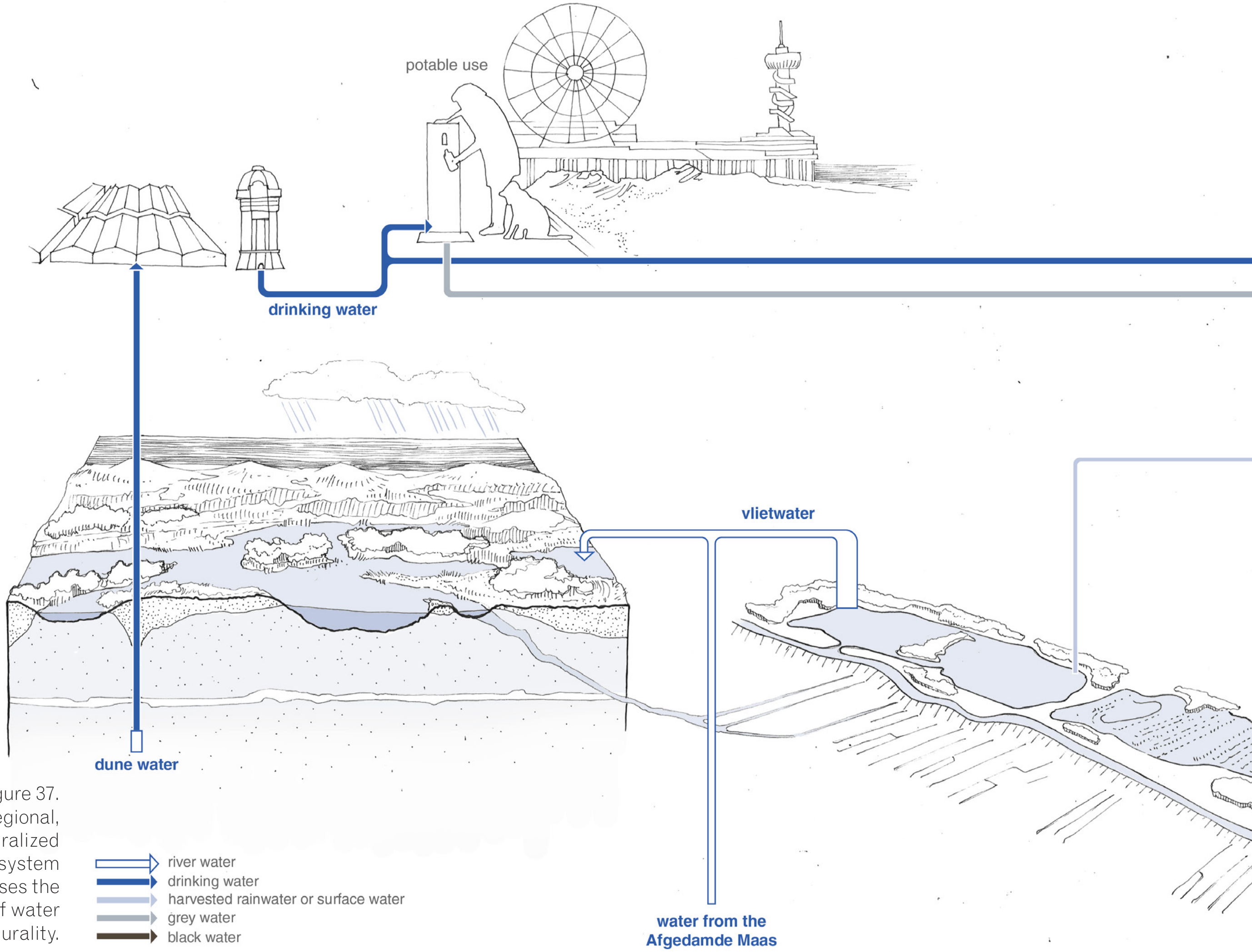
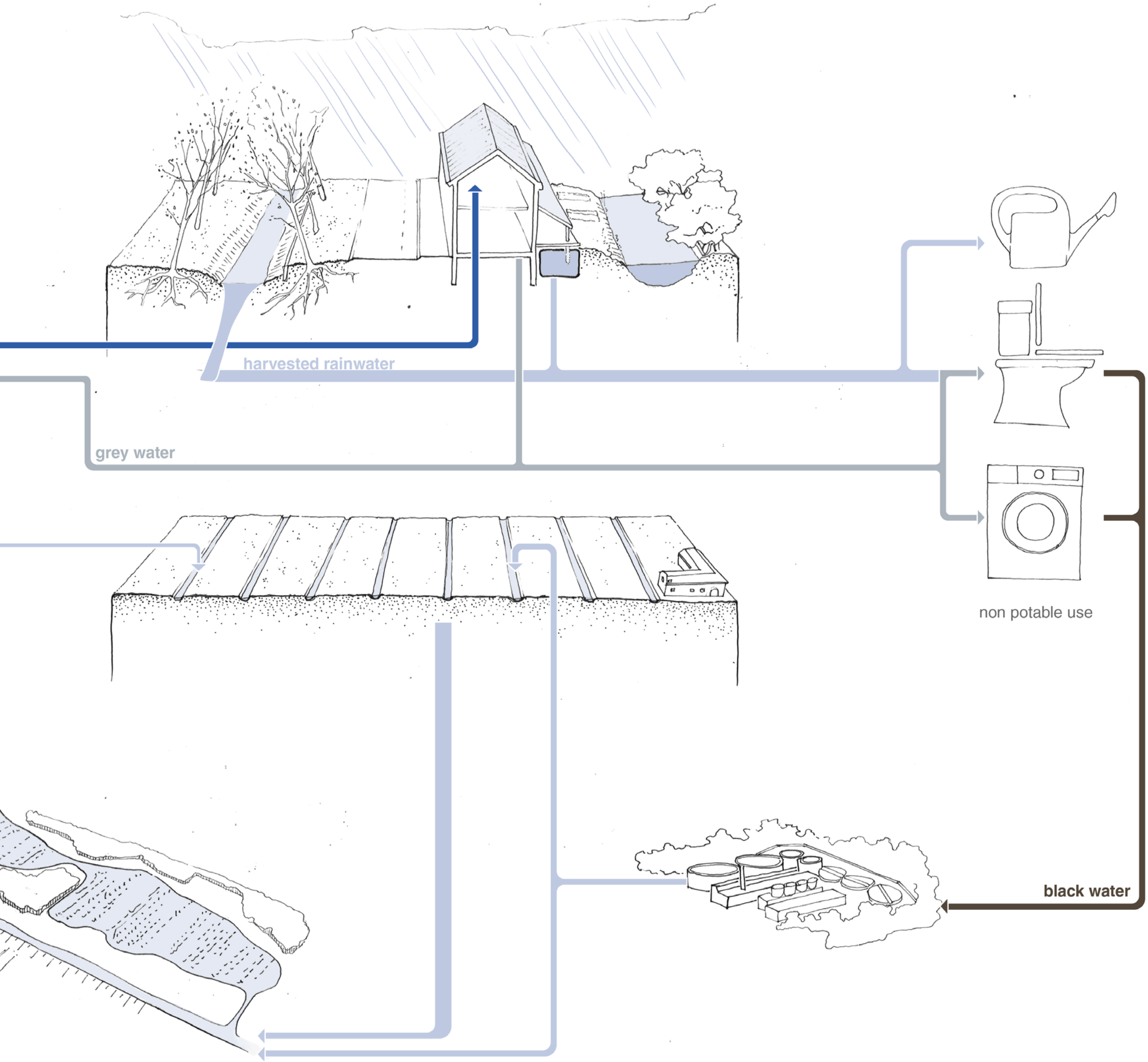
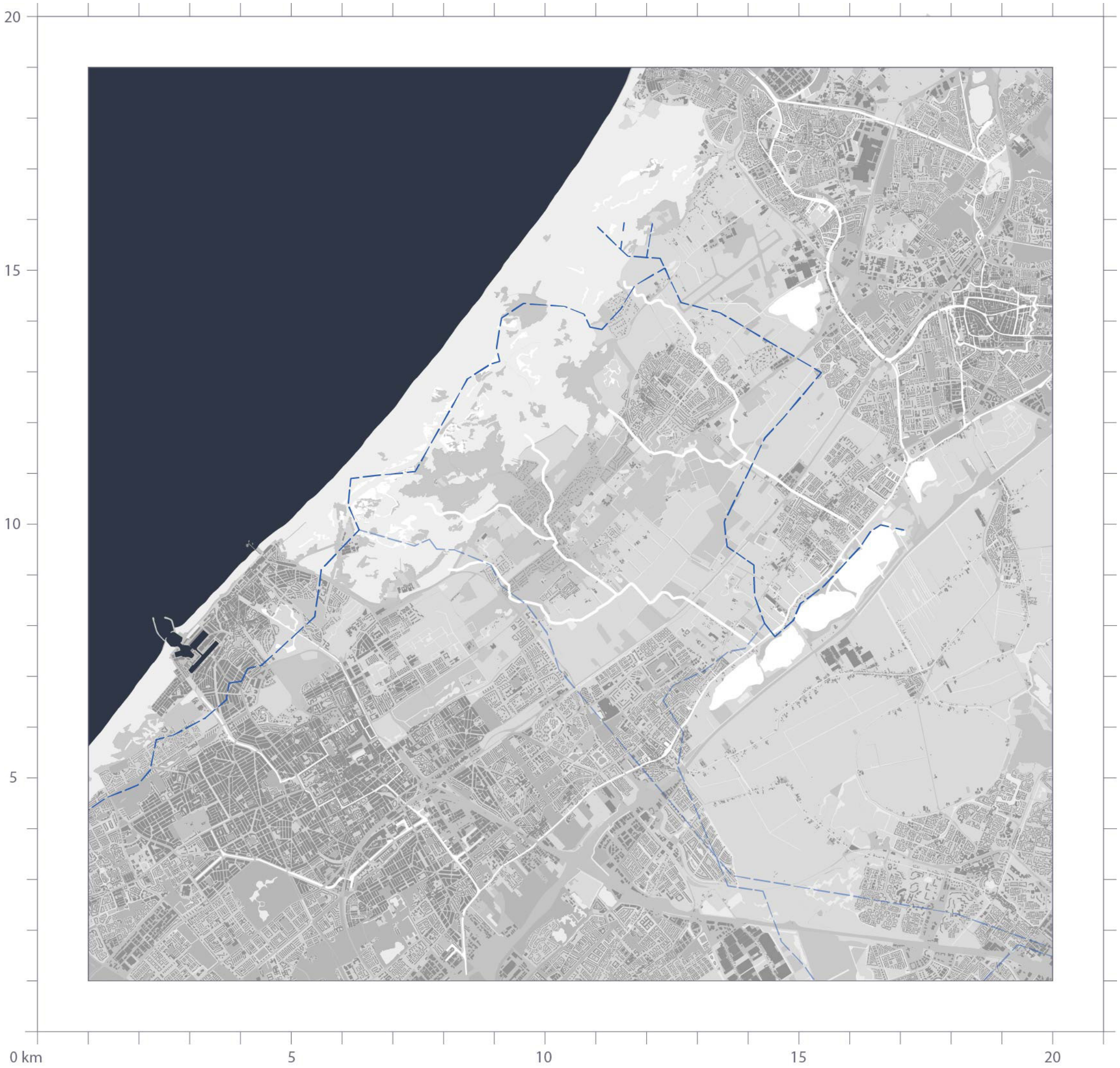


Figure 37.
A regional, decentralized water system which uses the concept of water plurality.

In this system drawing we see a representation of a regional landscape infrastructure which is made up of several water flows of localised water access. The localised network of grey water and rainwater access, storage, and treatment provide a water supply for non-potable uses. The dunewater is drinking water and will be exclusively spent as such. Other water flows



will provide the demand for non-potable water use. This results in a reduced flow into the dune landscape. The Vlietlanden as a water filtration and storage landscape will provide the bulk of the water which infiltrates the dune landscape. Within this transition, water plurality returns.



Map 6.
Vision map.

- The sea
- Freshwater
- Younger dunes
- Open grasslands
- Forest
- Dune creeks
- Built environment
- Pipelines

Water scarcity is not only a problem for water companies and consumers, but for landscape structures as a whole. To counteract the consequences of climate change, larger scale rainwater harvesting will also be implemented in cases of heavy rainfall, which can be used in cases of heavy drought. Next to seasonal water storage on the landscape surface, the dune landscape will provide subsurface seasonal storage. A dune infiltration system of a permanent balance between water infiltration and extraction will be replaced by an irregular regime, where over time, the freshwater lens can start growing. Seasonal and irregular storage in the freshwater lens will reintroduce dune dynamics and provide water in cases of emergency. As shown in map 6 and diagrams 38-40, the water dynamics in the dunes reintroduce dune slacks and dune creeks.

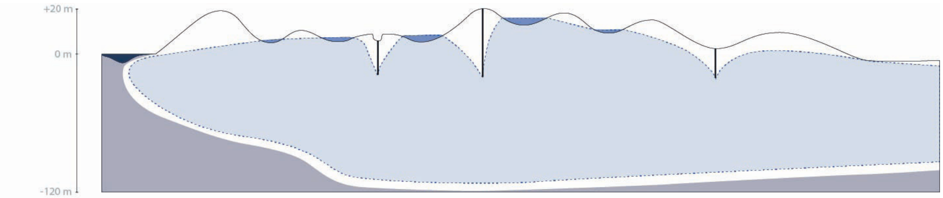


Figure 38.
Current situation.

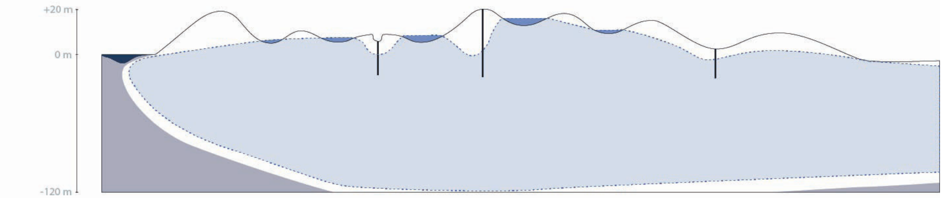


Figure 39.
Freshwater lens starts growing.

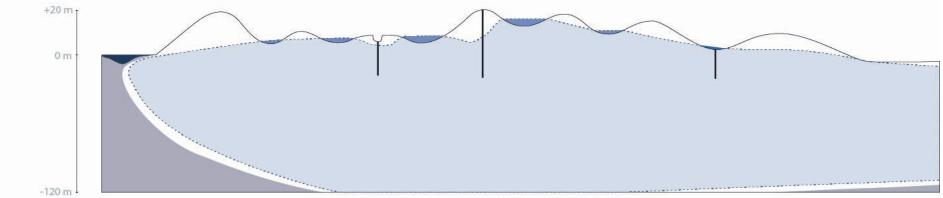
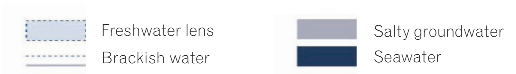


Figure 40.
Groundwater meets the surface.

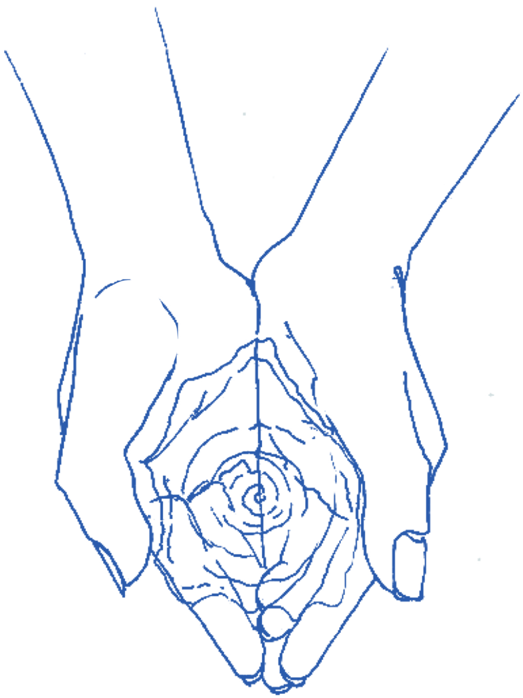


Chapter 3.

water relationality.

'Transformation is also a means of communicating by working on our physical surroundings that make it possible to internalise an awareness of human interaction with the nature we are rooted in and on which we depend so heavily.'

— Braae, 2015, p. 309 in Beauty Redeemed: Recycling Post-Industrial Landscapes



3.1 A reintroduction to (drinking water) landscapes

The landscape infrastructural strategy of the Vliet-Meijendel area proposes a radical change of water access and distribution: releasing pressure on the centralized river-dune drinking water system by decentralizing non-potable water flows and preparing the regional landscape for seasonal water storage. But as stated by Van Roon (2007) the separation of water flows and qualities for different uses necessitates developer- and consumer education. A system like this cannot be implemented blindly, but has to slowly take root in the minds of humans.

A shift towards infrastructure based on landscape structures and processes is a landscape architectural challenge. Where static infrastructure ages and breaks, landscapes operate through natural processes of growth, infiltration, erosion and decay. These can be cultivated rather than merely managed (Bélanger, 2017). A design approach that aligns with these processes, rather than suppressing them, introduces balance and adaptability into what would otherwise be a purely technical system. The discipline of Landscape Architecture should actively engage with productive landscapes as an integral part of the designed environment, bridging the gap between civil engineering and ecology. Landscapes are limitless and thus a landscape architectural approach operates across all scales, from the territorial logic of the water network to the spatial conditions of a single site. The first two chapters covered a systemic approach to address the full scale of the system in transition. Yet, it is my view that only by designing through all these scales that productive landscapes can become both functionally integrated and publicly appreciated. Within the context of making landscape infrastructure, a landscape designer can translate the natural processes of water infiltration, filtration and movement into an experiential space. This way, designers can transform abstract infrastructure into physical places which can foster a meaningful relationship between coastal dwellers and their drinking water landscape.

According to Braae (2015) a ‘fundamental and expanding acknowledgement that our planets resources are limited’ is essential for a sustainable future, which can only happen when the active physical places of resource extraction are acknowledged, and thus recognized and appreciated. Systemic redesign and circularity can rebalance the hydrological system in theory, but in reality, public awareness of local productive landscapes

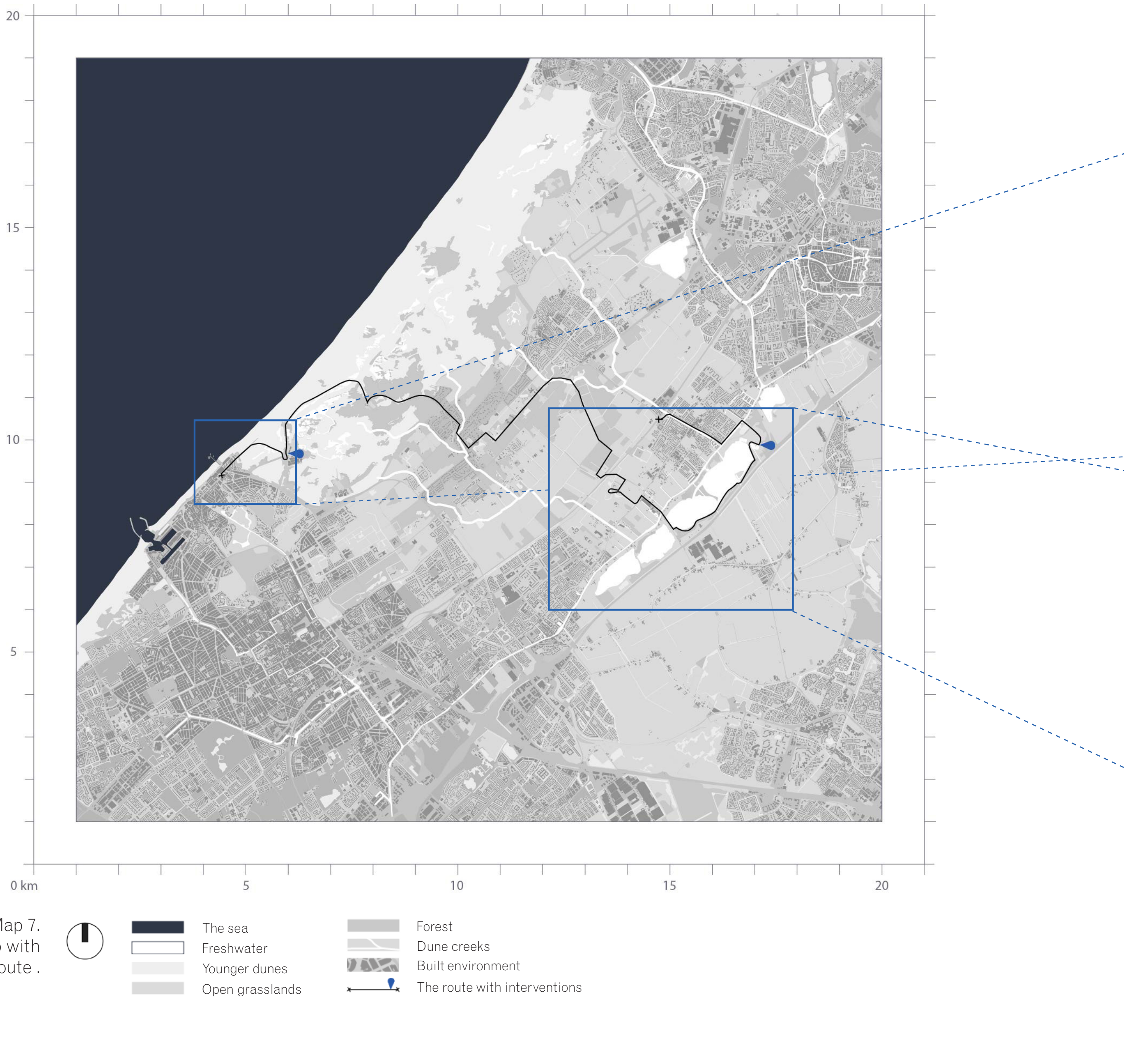
Figure 41.
Current human interventions in Meijendel, which draw attantion to what happened in the past. Interventions in this thesis, however, will draw attention to what is happening now.

is a necessary condition to achieve the goal of sustainable water use in the future. The aim of this thesis to use an intervention of translation to enable people to reconnect the landscapes that sustain them. This is also formulated by Braae (2015) in her conclusion on how to reintegrate industrial landscapes:

> *Transformation is also a means of communicating by working on our physical surroundings that make it possible to internalise an awareness of human interaction with the nature we are rooted in and on which we depend so heavily. (p.309).*

This next chapter is an attempt to design the human-scale, physical surroundings within the system and integrate human-water interactions to nurture a relationship between the coastal residents and the drinking water landscape they depend on so heavily. The design assignment as formulated in the introduction reads as follows:

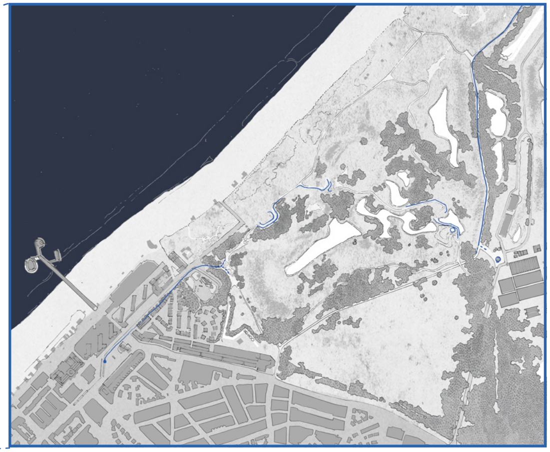
To design interventions in the industrial freshwater extraction landscapes of the Dutch dunes and at the intake area of water that foster a meaningful reconnection between the contemporary coastal dwellers and their freshwater source.



Map 7.
Vision map with
route .

3.2 A complete dune landscape experience

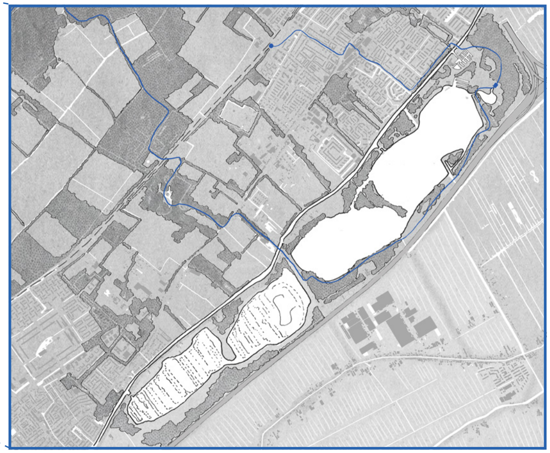
The explicit design interventions which serve to facilitate a renewed relationship between coastal residents and their drinking water landscape will be located in the Oostduinpark near the water tower and in the north of the Vlietlanden. These interventions represent mere moments in a system.



Oostduinpark

Figure 42. Locating the Oostduinpark.

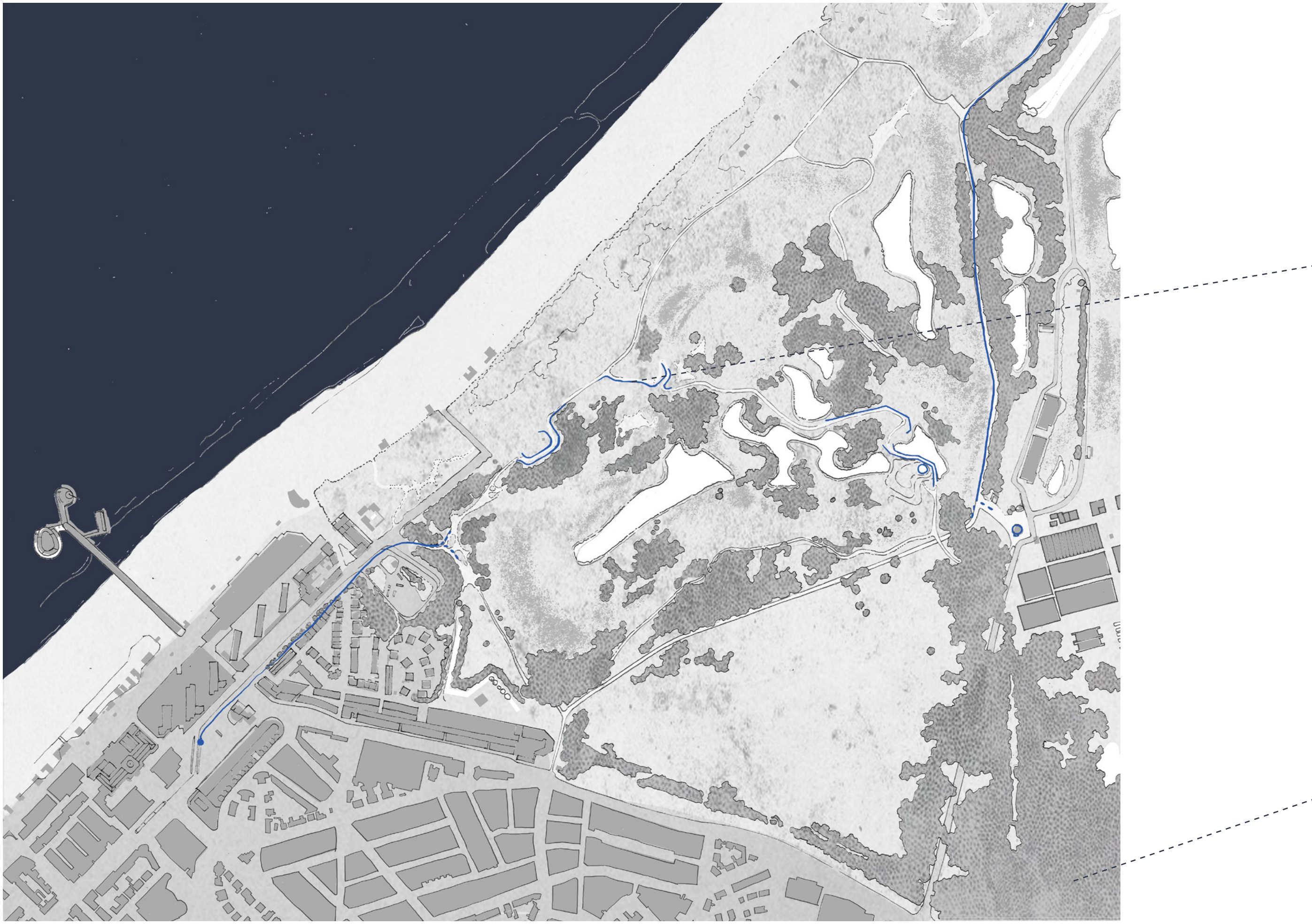
The system itself will be represented in the form of a route, which will start at the train station of Voorschoten and end at the tram stop Kurhaus in Scheveningen. The hike is roughly 25 kilometres long. This means it is not a casual, recreational walk, but rather a full day activity. It serves as an additional story to the designed interventions, which follows the entire dune landscape and regional dune drinking water system.



Vlietlanden

Figure 43. Locating the Vlietlanden.

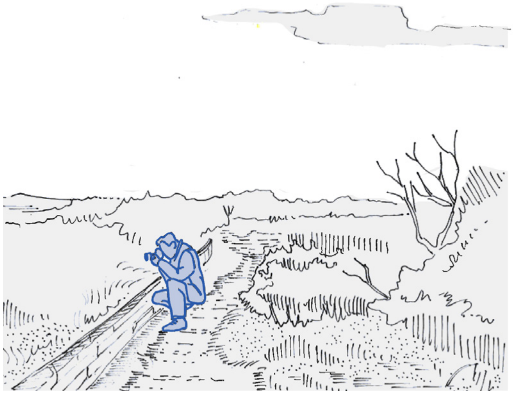
The dune landscape is larger than the Younger Dunes, and the route runs from the coast in the Oostduinpark, all the way through historic estates to the Vlietlanden. On the way, hikers encounter many different waterlines. The are an example of the diversity that can be found in the entire dune landscape.



Map 8.
Opening up the
Oostduinpark.

0 250 500 m

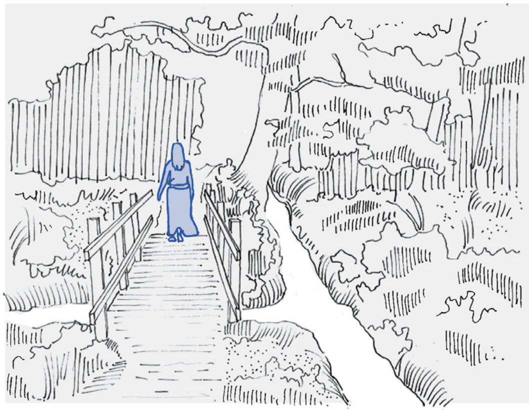
The sea
Freshwater
Built environment
Forest
Dune vegetation
Sand
Start or end of the route
Interventions
Explorative route



the coastal dunes

In the Oostduinpark, the rough dune landscape can be experienced in full. Instead of fences, low ha-has border the sandy paths. These encourage a playful exploration of the dune landscape without allowing full access to the nature reserve.

Figure 44.
The coastal dunes.



the dune creeks

In the dune forests on the edge of the Younger and Old Dunes, dune creeks flow into the hinterland. On this part of the route, the path follows a dune creek. Hikers walk in the direction of the water flow, down to Wassenaar.

Figure 45.
The dune creeks.

Map 9.
A route through
the Vlietlanden.

het molenpad

The route through the Old Dunes is varied, from forests to open pastures. 'Het molenpad' is a path InDesign waterways of the grasslands, with willows bordering the path. It is a long, uninterrupted line, with no possible turns until you reach the end.

Figure 46.
Het molenpad.

between the beeches

From there, hikers follow the route through several historic estates, characteristic for the Old Dunes. There, they pass though lanes lines with full grown beeches and oaks. After exploring estate Duivenvoorde, the route continues around the Vlietlanden, and ends in Voorschoten.

Figure 47.
Between the beeches.

3.3 Precedent: The ENCI quarry

From the narrative of an entire landscape route, we return to the explicit design interventions. The inspiration for designing a translation of the impact of industry on productive landscapes arose from a project I visited in October 2025. The Luikerweg viewing platform of the ENCI quarry in Maastricht is an impressive example of design emphasising the physical remnants of extraction.

I experienced the design in reverse to the intended order, which turned out to make an impression. Instead of starting at the viewing point, the walk started in the pit of the quarry, next to the factory. The reverse route slowly approaches the quarry cliffs, which contain several enormous openings. On the side and on top of the cliffs, visitors can catch a glimpse of the viewing platform (figure 51.). When they reach the cliffs, a platform guides the visitor into a cavern (figure 50.) to walk around a column and step outside again, only to climb the stairs all the way up the cliffs (figure 49.). After a climb of 50 metres, visitors reach the viewing platform which watches over the entire abandoned quarry (figure 48.).

The signs of extraction in the drinking water landscape of the coastal dunes are way less dramatic than in the ENCI quarry, yet the approach and result can teach us something about identifying the key components of extraction and visualising them. For the ENCI quarry, the sheer plunge of cliffs 50 metres high, is a clear experiential design of the amount of extraction in this site. In the Dutch coastal dunes, other key elements of the production process have to be translated into spaces which foster a meaningful connection between coastal dwellers and their freshwater. For the dune drinking water system, those elements will be the spatial translation of natural water filtration processes and water infrastructure in the drinking water landscapes.

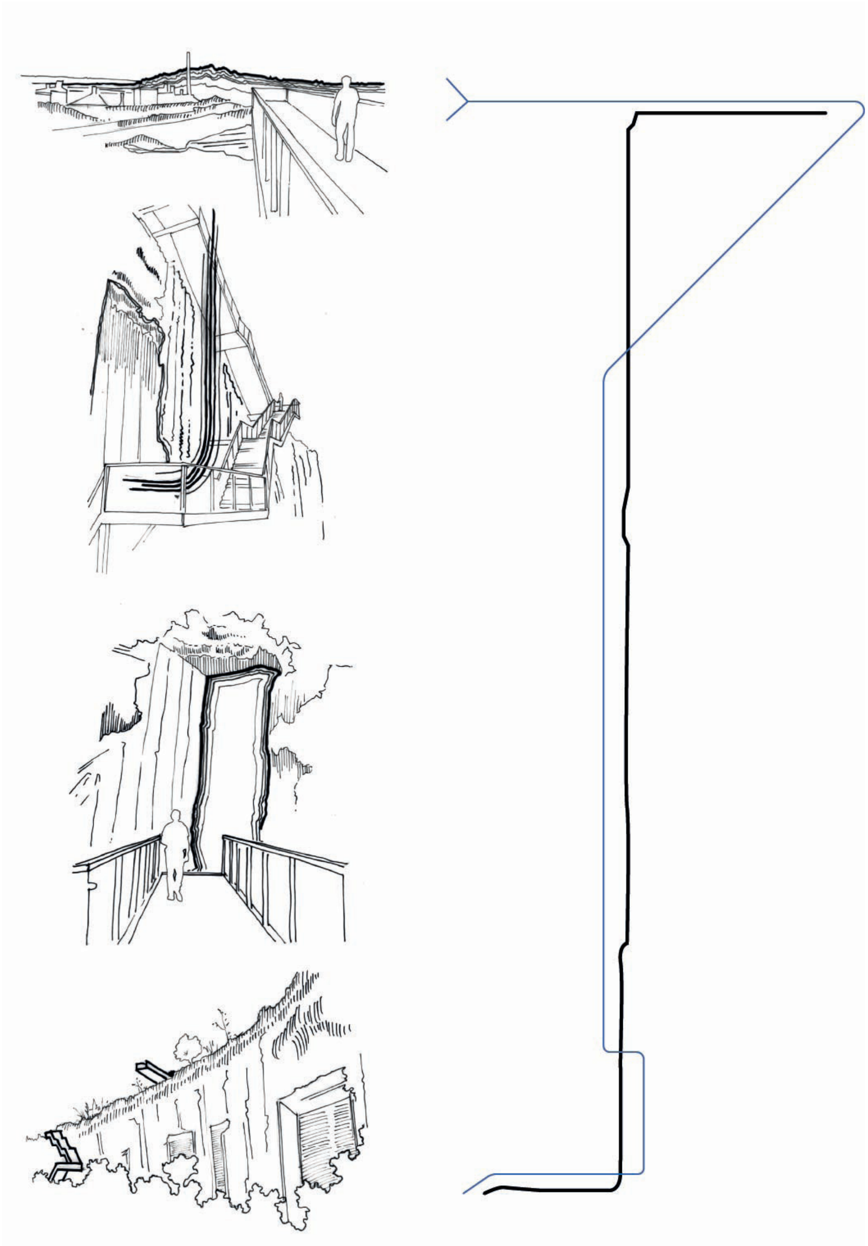


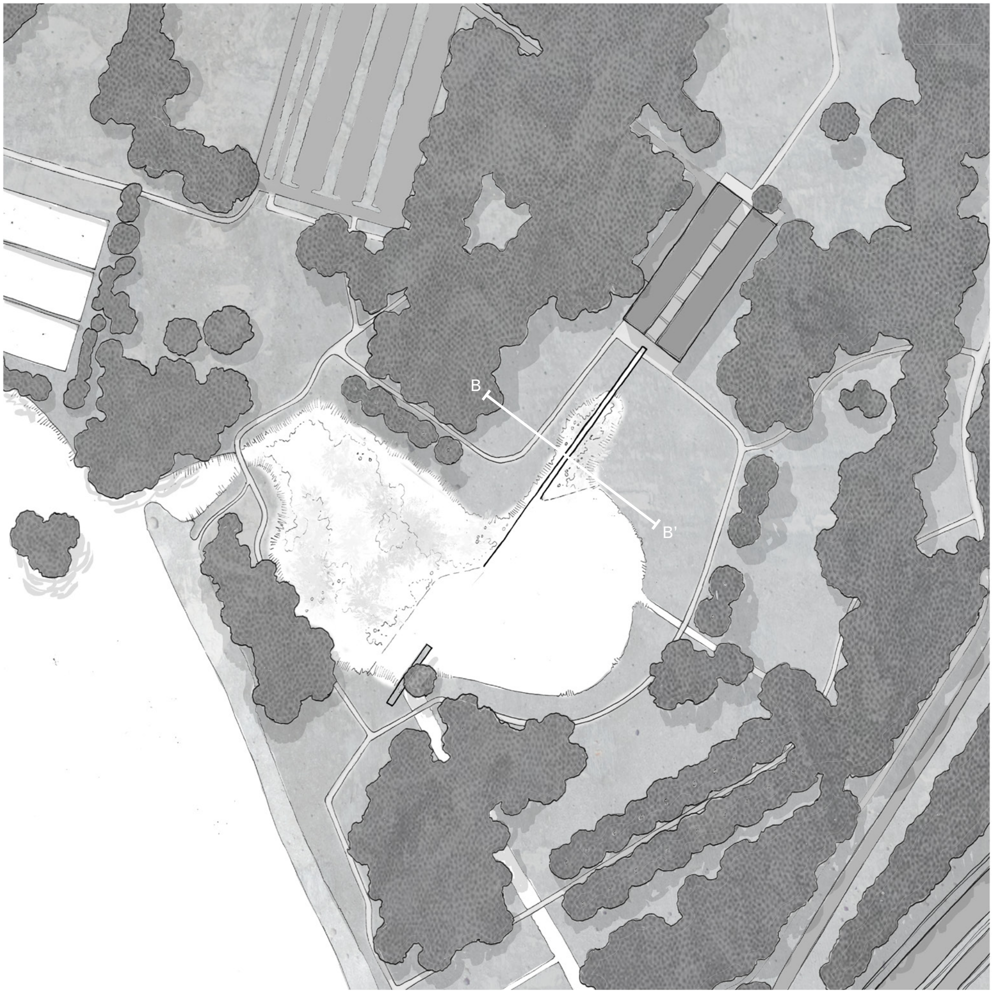
Figure 48.
The viewing platform.

Figure 49.
Climbing the cliffs.

Figure 50.
Entering the cavern.

Figure 51.
Approaching the cliffs.

Diagram 5. The climb and result.



Map 10.
De Vlietvijver.

0 50 100 m

Freshwater
Buildings
'Open' pipeline
Water plants
Forest
Grasslands
Sand

3.4 De Vlietvijver

The first explicit intervention is at the new source of the dune drinking water system: the Vlietlanden. The Vlietlanden will become the new water filtration and storage landscape and the intervention is meant to both spatially translate the water filtration processes and visualise the moment where the water is drawn into the systems infrastructure.

As explained in the regional strategy, the Vlietlanden will both filter water using a helophyte filtering system in the shallow lakes, and store water in the deeper lakes. The Vlietvijver intervention is located at the end of this process, in a smaller lake intended for swimming and recreating. This smaller lake is shallow, with a large area of water planting which refer back to the helophyte lakes. The planting is separated from swimmers by simple beams. These are mostly submerged, but still recognizable as a boundary.

From this swimming pond the water is drawn into a straight line right to the pumping station, where it will enter the drinking water system. This line serves as a visual representation of the beginning of infrastructure. Additionally, it is a sight-line and thus visual connection between the pumping station and the storage lakes. This line continues as a route through the pumping station. Breaking open this building is a physical representation of drawing people into the system.

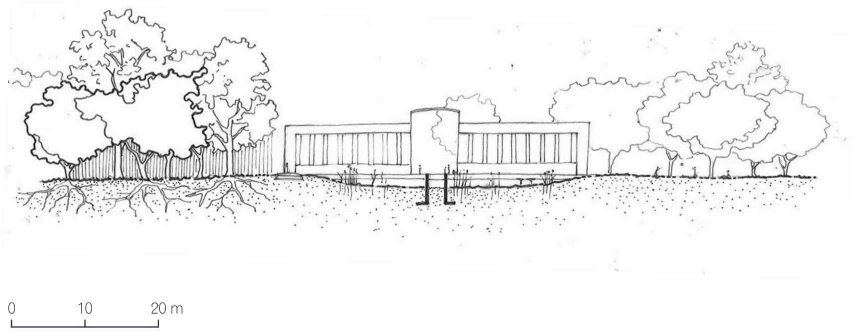
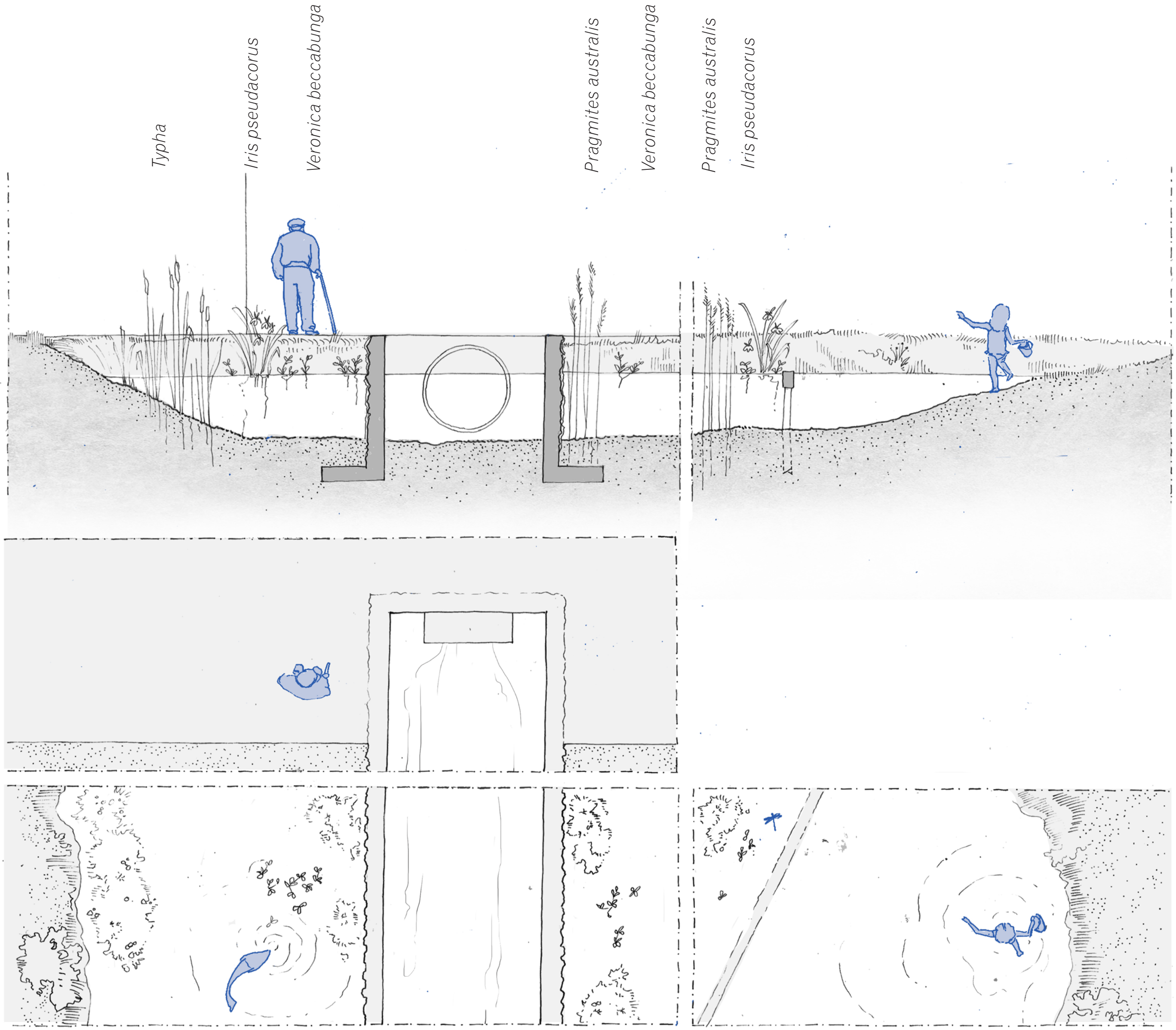


Figure 52.
Section B-B'



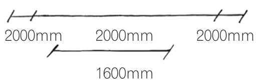


Figure 53.
Detail of the 'open' pipeline. 1:50 scaled to 1:100.

The ‘open’ pipeline

The line through which the Vlietwater enters the system is an ‘open pipeline’ which runs from the lake to the Dunea pumping station (see map 10 on page 92). This open pipeline is drawn in detail in figure 53. The line itself is a line of clear water running in-between the plants which have filtered it. Then the line encounters land, where it continues to the Dunea pumping station. At the pumping station the water is drawn into a river-dune pipeline, which explicitly symbolises the entry to the subterranean pipeline network.

Plants beneficial to water quality are also included in the detail: *Pragmites australis, Typha, Iris Pseudacorus* and *Veronica beccabunga*. Although visible from the swimming pond, humans are separated from the filter by beams. The swimming pond itself is an ideal place for recreation and interaction with water. The site is already used as a swimming spot, but the intervention adds a layer of visibility to what is now part of a landscape infrastructural system.

There is a large distance between the moment of the water entering the system in the Vlietlanden and the moment it enters the dune lakes and ends up at the water tower. This means that for visitors who either walk the route or visit each site separately, some compositional elements in combination with material use have to mark these places as one and the same system. The similarities will be explained in the detail of the second intervention on figure 61 on page 102.

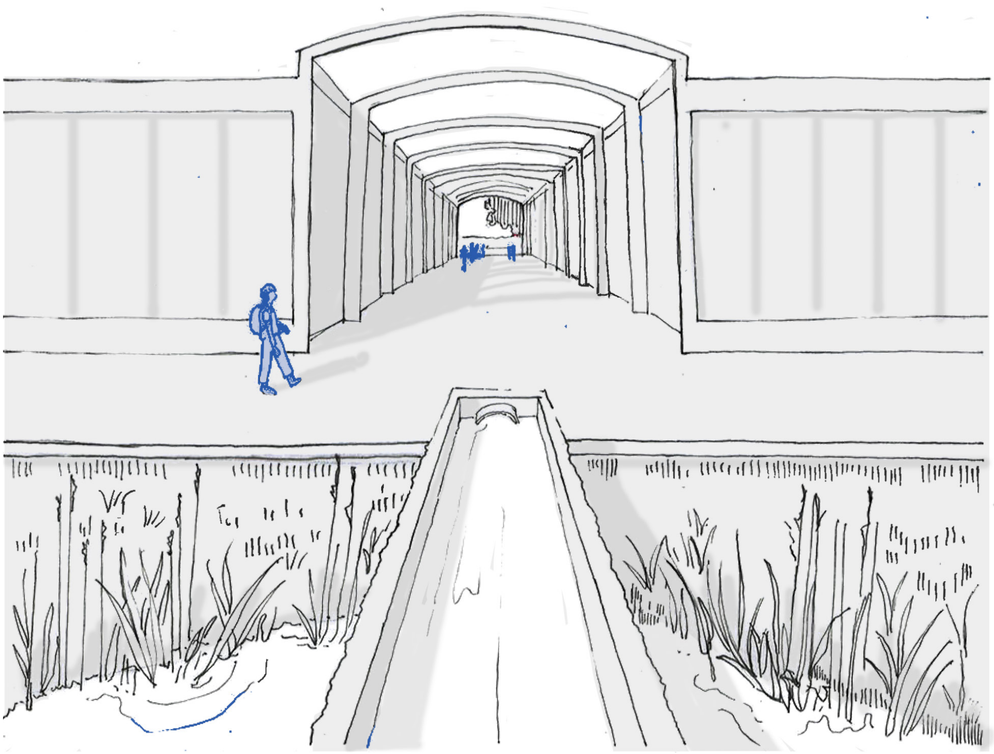


Figure 54.
Breaking open the
pumping station.

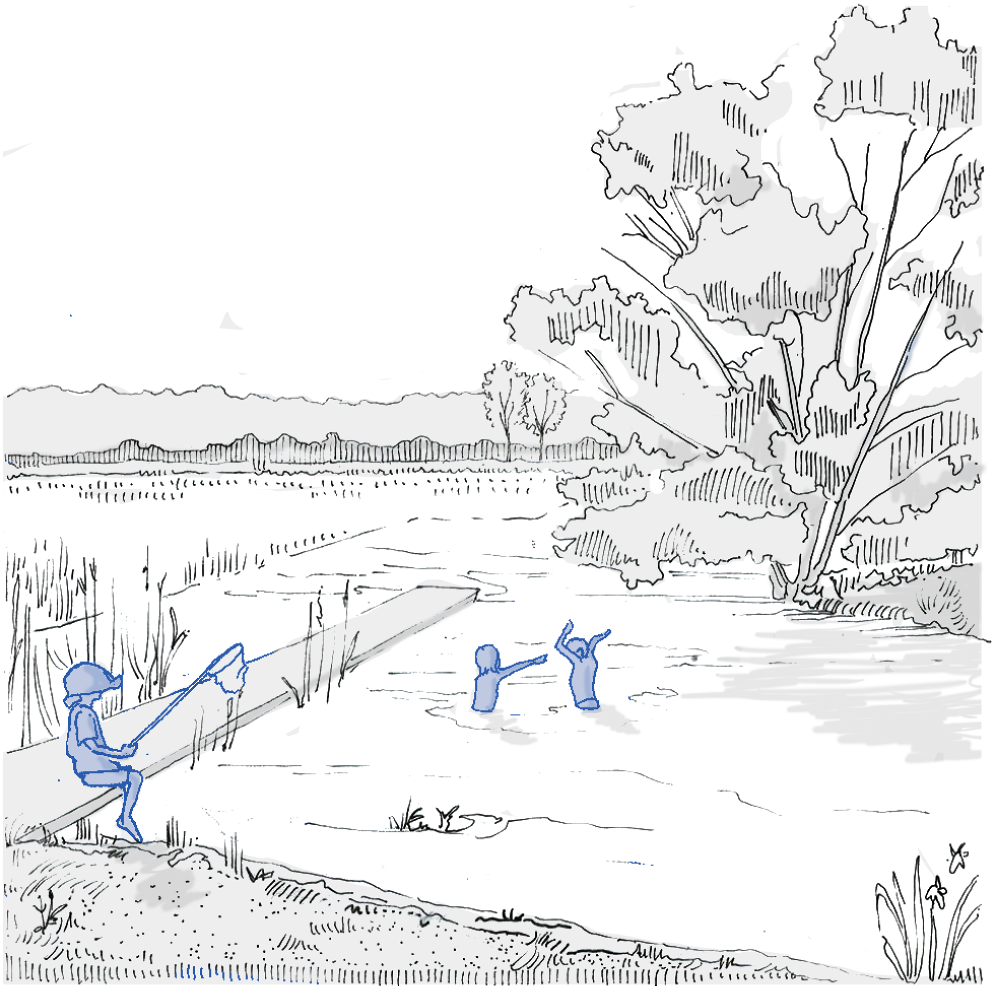
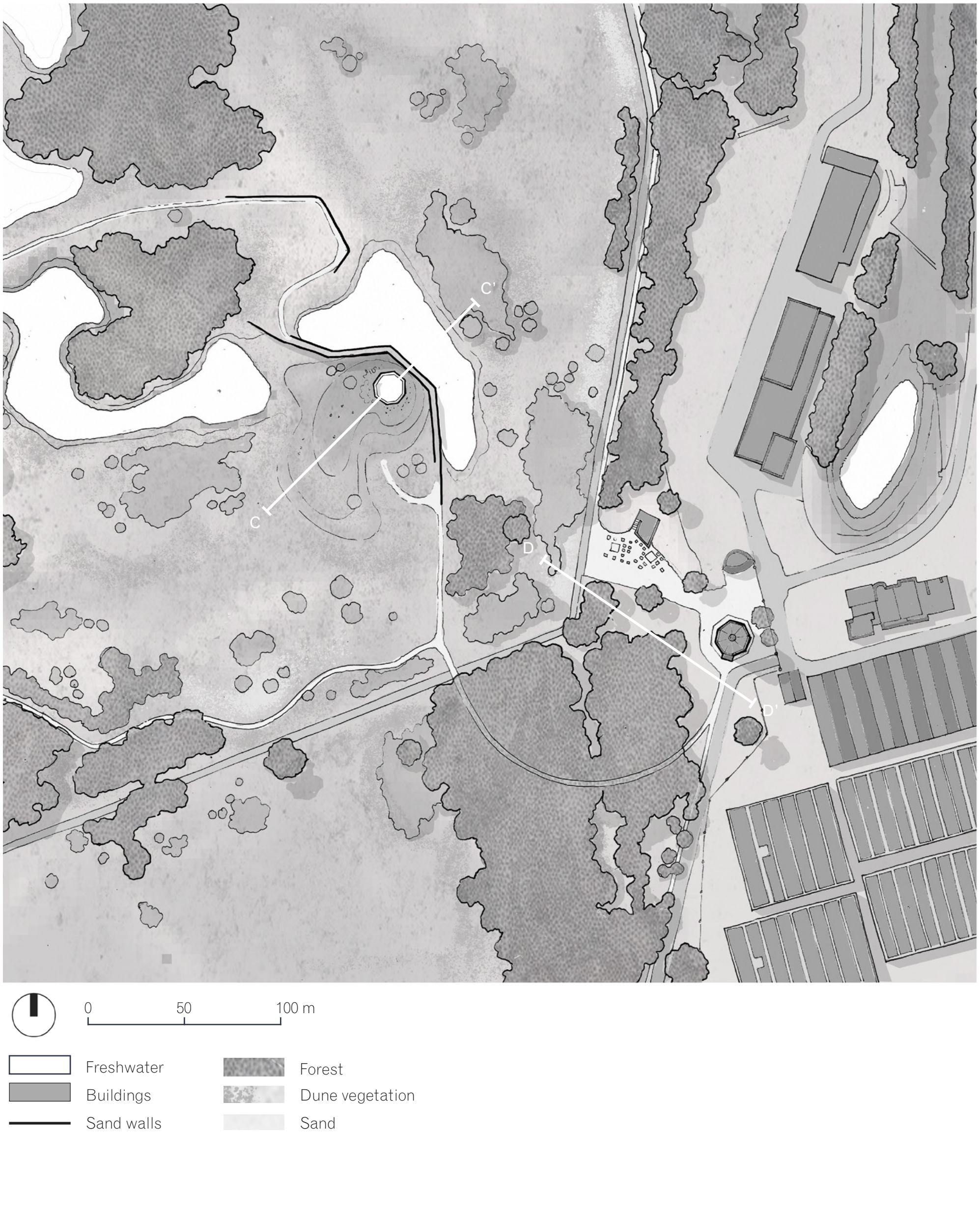


Figure 55.
Swimming and recreating.



Map 11.
Onder de
watertoren.

3.5 Onder de Watertoren

The second intervention is located ‘underneath the water tower’. It is the counterpart of the Vlietvijver, because this is where the water comes up from the pipelines to infiltrate into the dune landscape.

The design is a dug dune slack, right next to an infiltration lake. The dune slack comes in sight when visitors stand on top of the dune hill. Then they follow the route which leads them right in-between the lake and slack, using the same materiality of the ‘open’ pipeline in the Vlietvijver. In the deepest part of the dune slack one can see the contours of the water tower, marking this place as part one of the design. Here, visitors descend into the dune landscape to experience its water filtration processes. This will be explained further on page 102-104.

Visitors have already caught a glimpse of the water tower, but now the route continues until they are standing at its foot. The intervention at the water tower is meant to symbolise the leaks in the current water system. This concept will be further elaborated on on page 106-107.

Right next to the water tower is a cafe, now called ‘Onder de Watertoren’ (underneath the water tower), where visitors of the Meijendel area can take a break.

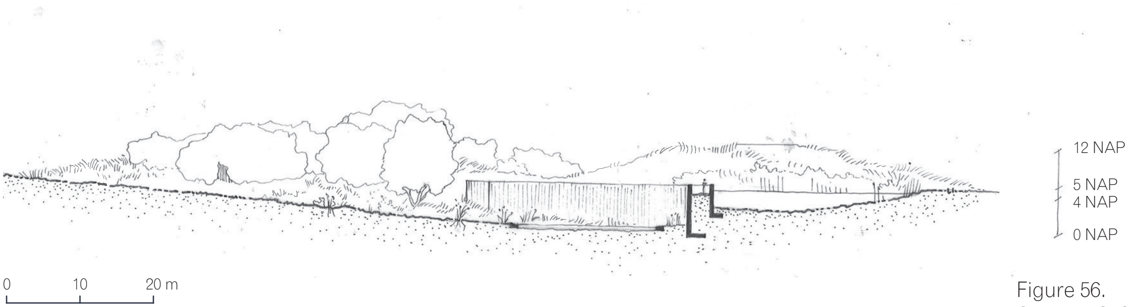


Figure 56.
Section C-C’. The dune slack and sand wall.

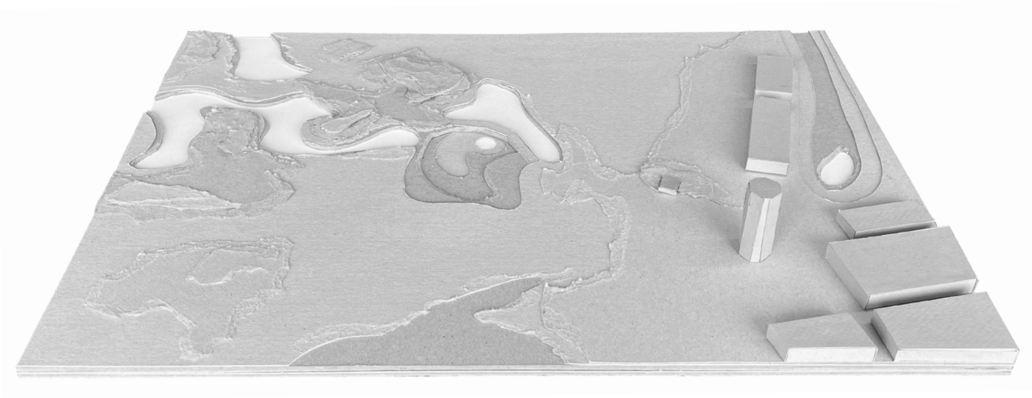
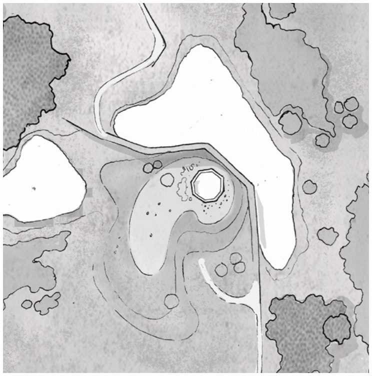


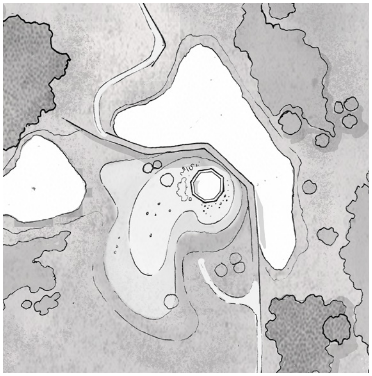
Figure 57.
An exploration model on the topography of the intervention landscape.

The design of the dune slack is not purely meant for the facilitation of human understanding of natural filtration processes. The digging of dune slacks is one of Van der Meulens (1982) suggested interventions to reintroduce dune dynamics and habitats.

As can be seen in figure 57 the lowest part of the area between the water tower and the hills was chosen to create a dune slack habitat. Unlike the infiltration lakes, this depression will not be filled artificially. Groundwater can move freely, once the regional strategy. The fluctuations in the groundwater table reintroduce the dune slack species which have been lost in the process of industrialisation.



level 1 (0,5 meter)



level 2 (2 metres)

level 3 (4 metres)

The regional strategy introduces dune dynamics by increasing freshwater storage in the dune landscape and implementing periodic imbalances between water infiltration and water extraction.

These fluctuations mean that the dune slack can lay dry, but also that water can rise up several levels. Because the water regime is so irregular, the dune slack is quite deep (4 metres under the walkway). As the water regime is slowly restored to its natural dome shape, the water can reach up to the same level as neighbouring infiltration lakes.

Level two and three are a drastic rise in water level. For the short term, fluctuation between a dry slack and level one is likely. This fluctuation will reintroduce dune slack species and will be beneficial to some amphibian species, like the *Lissotriton vulgaris* (see figure 61, on page 102.).

Figure 58.
Level 1: The groundwater starts fluctuating.

Figure 59.
Level 2: The groundwater starts rising as the freshwater lens restores.

Figure 60.
Level 3: Even the dune lakes have fluctuating levels due to groundwater.

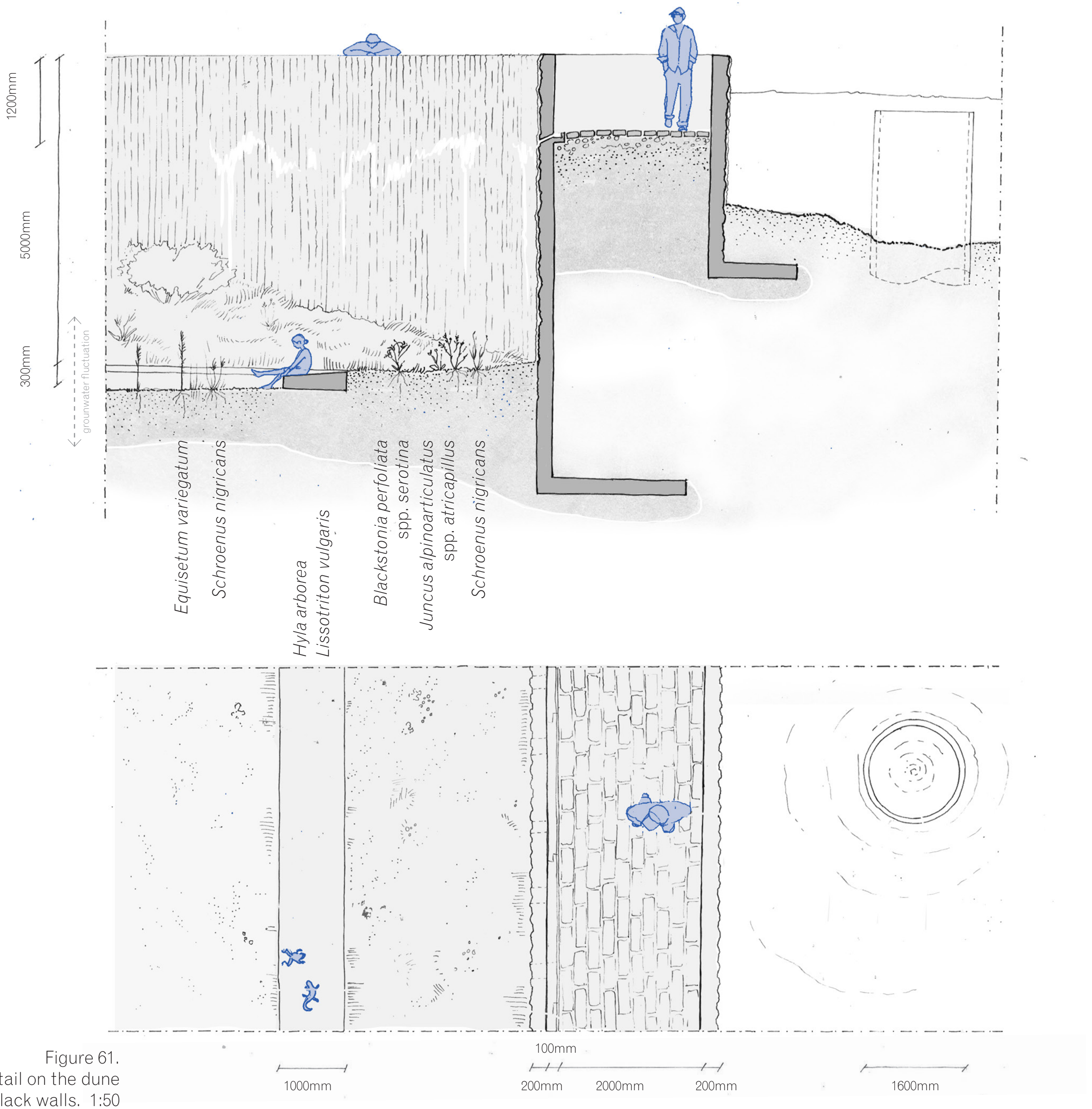


Figure 61.
Detail on the dune slack walls. 1:50 scaled to 1:100.

The sand wall

Part of the route is the walkway between the dune slack and the infiltration lake. This walkway has the same compositional design and materiality as the 'open' pipeline in the Vlietvijver. However, where that line contained water flowing into the system, this line contains people who observe the system around the walkway. On the one side, visitors are walking close to the water level of the lake. Underneath the surface of the water they can see the circular outline of the pipeline delivering Vlietwater to the dune landscape.

On the other side, the visitors can see the dune slack. The dune slack intervention serves to facilitate a renewed relationship between people and the drinking water landscape through the visualisation of sand infiltration. Sand infiltration is the dune natural process which makes the dune landscape such an attractive drinking water landscape in the Netherlands. The sand filters freshwater and stores it in large quantities right underneath the surface.

The filtration process occurs when freshwater seeps through the sandy soil. Because the filtration process is occurring underneath the dune surface, it is hard to visualise. To make the subterranean process experiential for humans, seepage of water is created along the wall of the dune slack. The wall is made of textured concrete, referring to the sand particles in the soil. Through strategically placed, irregular openings in the wall, water from the rainwater drain drips along the concrete. The rainwater in the drain is collected on the surface of the walkway. The effect of rainwater seeping through the soil can be seen on figure 62 on page 104.

The sand wall is best observed when standing at its foot. From there, the slowly dripping excess rainwater is sketching a pattern on the concrete, all the way ‘through’ the soil (see figure 62.). The placement of the dune slack in regard to the water tower is visible in figure 63, as well as the restored water table which will periodically flood the dune slack.

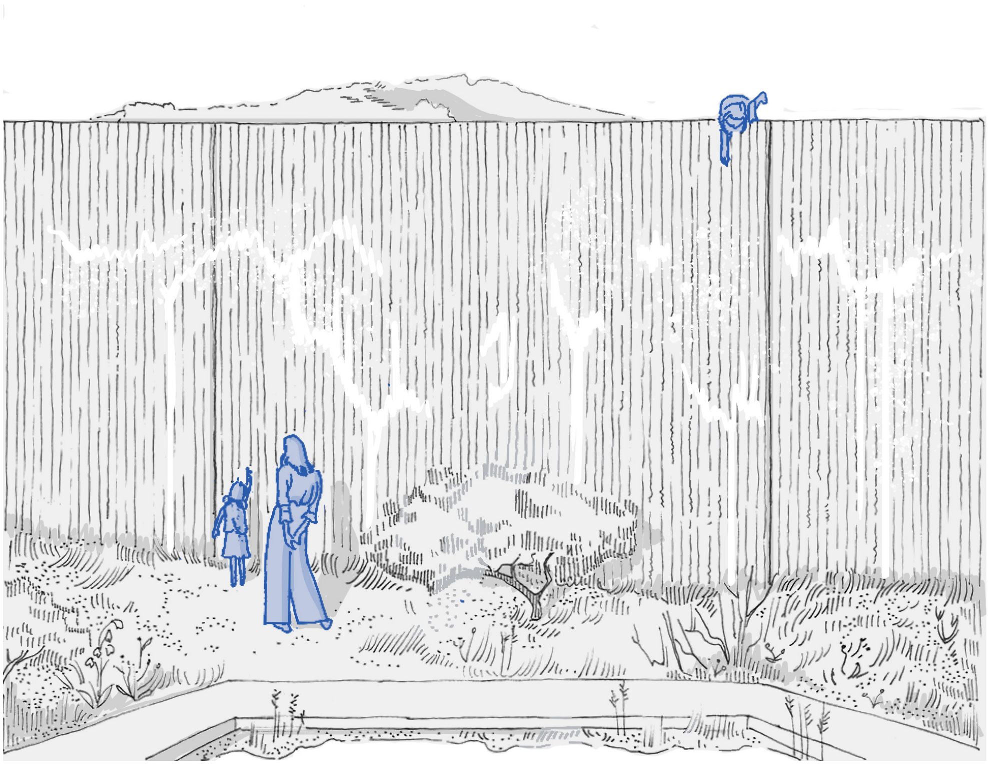


Figure 62. Water seeping along the sand wall.

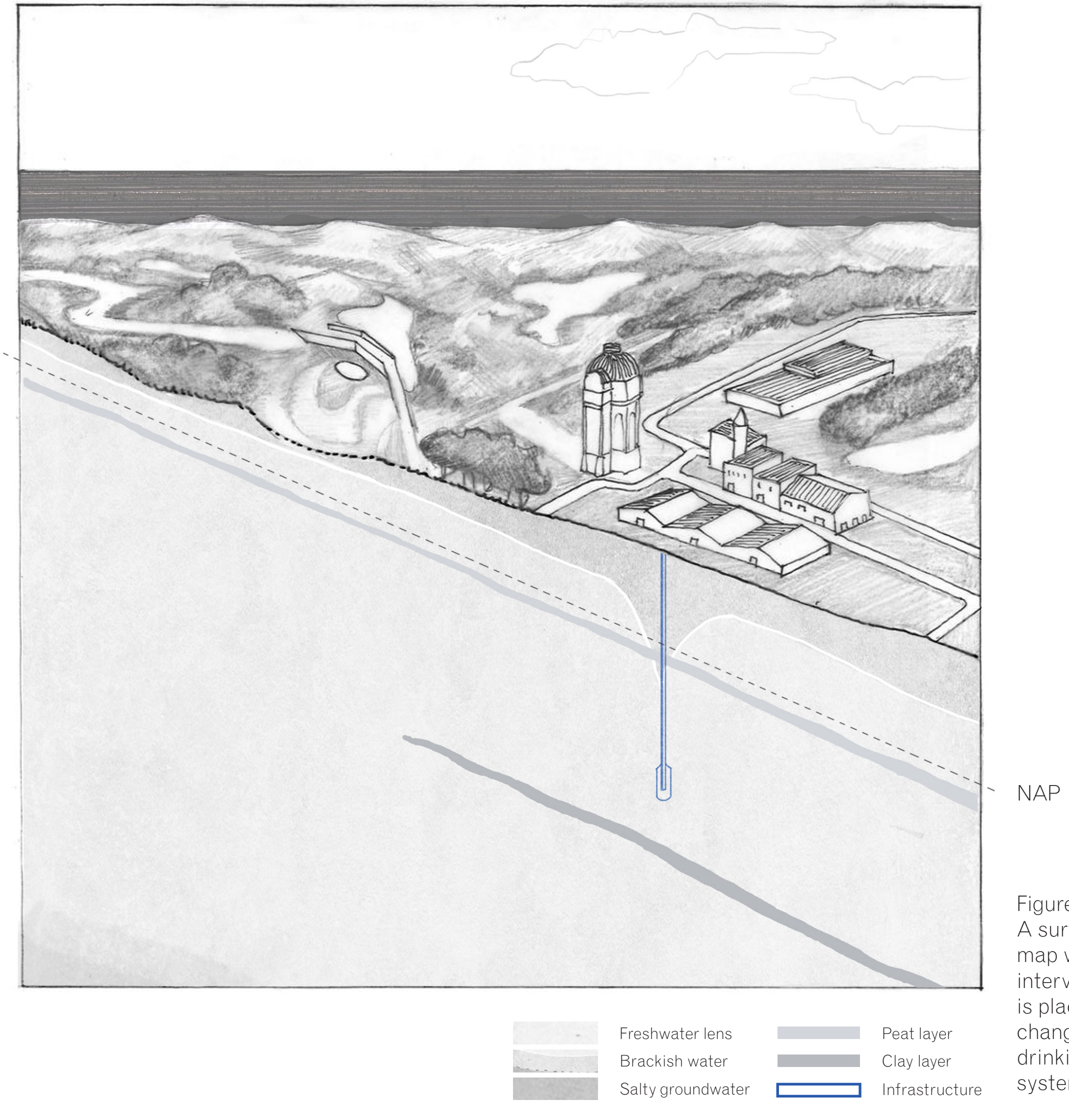


Figure 63.
A surface soil map where the intervention is placed in a changed dune drinking water system.

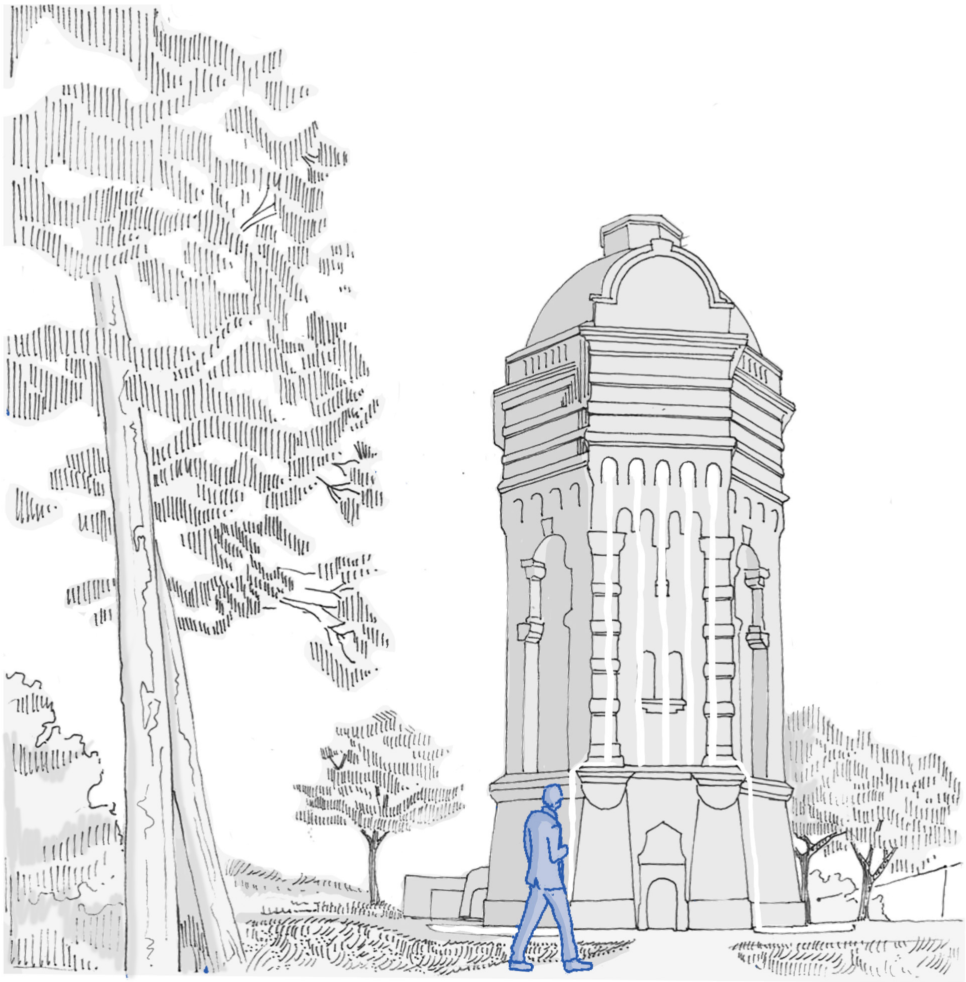


Figure 64.
The watertower is leaking.

De huilende watertoren

The last moment of the route occurs at the foot of the water tower. Visitors move from the dune slack to a densely forested path and emerge to see the immense structure in full. Now becomes visible what they could not notice from a distance: the drops leaking from five perfectly spaced holes high above the entrance. From this perspective they look like tears.

This intervention is dependant on the development of the system. Right after implementation, the water tower will be leaking to symbolise that the system itself is still 'leaking'. A system which is still wasting water on non-potable use puts pressure on the dune landscape. As the pressure releases, the amount of water dripping from the water tower will decrease until at one point it stops 'crying'.

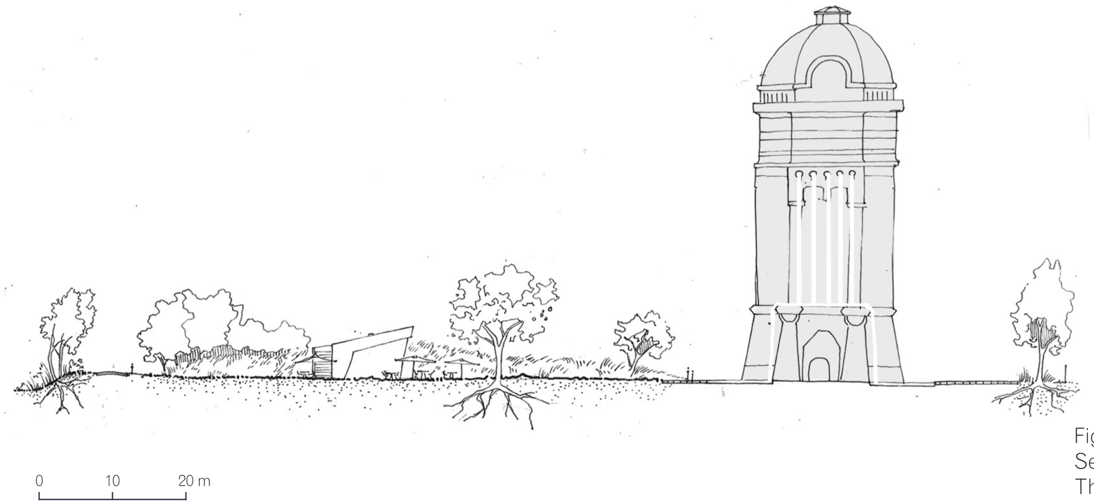


Figure 65.
Section D-D'.
The watertower is leaking.

Conclusions.

Freshwater is becoming more and more scarce, the results of climate change are wreaking havoc on Dutch water systems and still inhabitants spend very little time thinking about where their drinking water comes from. Not only will the drinking water system need to transition in order to respond sustainably to water scarcity, coastal dwellers will need to transform into water stewards instead of water consumers. Thus, the research question was as follows:

How can landscape architectural strategies mediate a renewed relationship between contemporary coastal inhabitants and sources of freshwater within the drinking water extraction landscape of the Dutch dune system?

This thesis is an attempt to internalise awareness of the importance and value of drinking water landscapes in the minds of coastal inhabitants through a systemic regional strategy and a design translation of water filtration processes in public spaces. To properly translate water filtration processes in an experiential design as part of a regional freshwater strategy, bottlenecks had to be identified.

The centralization of drinking water production and distribution and the loss of water plurality have removed humans as participants of the system, leading to an unseen continuation of extraction in a slowly degrading dune system. The removal of people in the drinking water system poses a problem now, 150 years later, where water scarcity and extreme weather conditions apply significant pressure on an obscure, buried, rigid infrastructural system which does not have the adaptability to respond sustainably. The lost concept of water plurality, where consumers are active participants, offers inspiration for a smaller network of water access infrastructures which include people as participants in the water system. Such a system necessitates understanding of different water sources, qualities and uses, which shows a potential to nurture human appreciation for drinking water landscapes. The regional freshwater strategy is a modern interpretation on how and why this concept can be implemented in a new form of infrastructure: landscape infrastructure. In this case, the strategy makes use of regional water structures, like the Vlietlanden as a water filtration and storage landscape for the river-dune system, to close infrastructural water systems locally. No longer will drinking water be spent for all water purposes, but exclusively for potable use. Rainwater harvesting will be reintroduced, as both crisis storage in case of heavy rainfall and as a new water source for non-potable use in households.

A separation of water flows and qualities will be accompanied by experiential design interventions which have the ultimate goal of rooting people into their drinking water production landscape. Two interventions (one at the source of freshwater and one at the dune filtration site) will translate natural water filtration processes into physical places which facilitate human-water interactions. The transformation of space to facilitate physical interaction with water can nurture care, understanding and appreciation of the specific landscape it is located in. Only care, understanding and appreciation can transform coastal residents into dune caretakers who participate in the a transformed dune drinking water system.

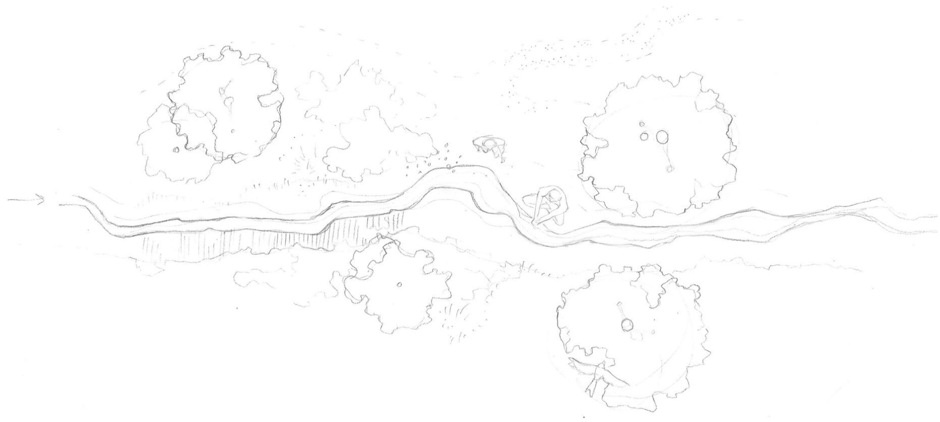


Figure 66. Drawing interaction with a duinrel.

Discussion.

Throughout the project, the dune drinking water system has been approached from a landscape architectonic point of view. Research, strategy and design are focussed on improving the conditions for the landscapes involved, and finding a symbiotic relationship between humans and productive landscape. However, since the topic of drinking water systems is extensive, the results contain certain limitations.

Some of the elements that were addressed slightly stray outside the bounds of the design discipline, demanding a stretch of knowledge and research techniques. Landscape architecture remains a design discipline in the built environment, which means research and design sites often demand infrastructural or hydrological input. However, in the case of this thesis, complete accuracy of conclusions based on the infrastructural or hydrological analyses cannot be guaranteed. In case of the regional strategy, which proposes a partial decentralization of the water distribution system, no specific quantities of water flows are addressed to quantify the new system. Additionally, the assumption is made that pressure on the dune landscape can decrease by decentralizing non-potable water flows, which is also not measured. These alternative proposals remain conceptual and theoretical.

Likewise, making changes in the irregular water regime in the dunes can make it hard to predict results. That means the intervention ‘Onder de Watertoren’ also contains assumptions in the design result. As stated at the beginning of this report, this thesis was not conducted for Dunea, but done using public sources on the dune landscape and drinking water infrastructure. The author is no expert, meaning that information can accidentally be faulty or wrongly interpreted.

Furthermore, the thesis is based on the statement that the drinking water landscape of the Dutch dunes is an example of obscure, or nearly invisible, infrastructure. This statement is based on theories discussing similar trends in the development of industry and infrastructure in the built environment, by Braae (2015) and Bélanger (2017) specifically. However, applying those theories of obscurity, invisibility and under appreciation on the South Holland dune landscape has been based on site observations. No interviews have been undertaken to get to the bottom of public awareness of the dune drinking water landscape in the coastal regions. However, whenever the topic of this thesis came up in informal conversations, the standard response was: ‘Who is going to drink dune water?’. This led me to suspect that the theories about the obscurity of productive landscapes and infrastructure are applicable on this case.

Further research on this topic is already being conducted by involved parties since the challenges regarding water scarcity are increasing in urgency. Although this thesis is far from the conventional way of approaching such challenges, inspiration can be drawn from historic, symbiotic examples. Water localisation, based on water plurality, might seem less governable, but it is fact a way to collaborate with local landscape structures. Additionally, residents will have to be involved in order to decrease the amount of drinking water consumption for non-potable uses. Non-conventional might be the way to convince them to change their water consumption habits.

Reflection.

The process of this thesis has been a constant struggle in finding balance between a systemic and experiential approach. The term 'struggle' is not meant negatively, but rather as an educative challenge to dive into a topic which is so multifaceted. Although this graduation year was an experiment in terms of university planning, this project was my first chance to spend time to discover what I want to research, read, and conceptualise. It was a first experience in having full-time freedom in applying my disciplinary interests, allowing for trial and error in finding which topics are really relevant in the attempt to make a spatial experience of a landscape architectural system.

Instead of specifically and thematically defined learning goals, the goal for a thesis is to independently prove that you are adept at the discipline. For example, drinking water infrastructure as a topic can be approached in many different ways. An appropriate approach to get to the bottom of a sustainable drinking water transition would be to analyse and strategise systemically, including stakeholders. Instead, in this thesis I was completely free to apply themes of awareness and water relationality onto a very specific topic, and explain precisely why I thought that was relevant. Because of that freedom, I find I have developed a sense of independence when working on a project which I did not know I was missing. Aside from being able to apply academic skills, sharpen my design ideas and expand my knowledge base as a landscape designer, that sense of independence is the most important of what I will take with me.

Acknowledgements.

First and foremost, I would like to thank my tutors, Inge Bobbink and Mieke Vink for their valuable guidance during this project. Inge, thank you for making me understand and believe that I could make much more of this project than I initially thought and to challenge me to step out of my comfort zone. And Mieke, thank you for your kind, accurate and valuable insights which helped me considerably along my way to make a infrastructural system tactile. I feel like you both challenged me to think though all layers of this topic and asked exactly the right questions at the right moments. Your input and guidance have greatly contributed to my enjoyment of writing this thesis.

Whom I would also like to thank for making this thesis year the best ending to five years in Delft, are my fellow students and friends: Roger, Isidora, Roderick, Geeske, Evelien, Emma, Pratipal, Daan, Jesper, Tijn and Franka. Every day, I looked forward to working at the faculty with you. And even though we are now very much wishing the deadlines are over, I am going to miss our daily routine.

For helping me understand the complex system of drinking water in Meijendel I would very much like to thank Loeki Vos, Strategic Geohydrologist at Dunea, whom I got into contact with through Wim Drossaert (also thank you Wim!). Answering my many ignorant questions kindly and accurately was worth much more than you might think. I also very much appreciate the invitation to the Dunea facilities. It was incredibly fun to see in real life what I had spent so many months reading about.

Lastly, I would like to thank my friends, family and Thomas, who voluntarily put up with my insistent working and distracted thinking when I randomly got an idea. You didn't really know what I was doing, but you helped me by just being there.

Floor Klapwijk
Delft, May 2026

Glossary.

Dune landscape

The sandy coastal landscape is a hilly border between the sea and the hinterland. The dune landscape had been formed by natural processes of sand drifting, sedimentation, and coastal erosion (Neefjes, 2018). In natural conditions, a freshwater lens formed in the dune soils, which welled up in the form of dune slacks and dune creeks (Spek, 2025).

Duinbeek

See '*duinrel*'.

Duinrel

A '*duinrel*' or '*duinbeek*' is a creek, either dug or naturally occurring, which transports excess clear dune water inland. These creeks appear during a high groundwater table, and disappear once that table lowers (Spek, 2025).

Dune slack

A naturally occurring depression in the Younger and Older Dunes, which creates a humid environment. These depressions are humid because of the seasonal groundwater fluctuation, causing a gradient of different vegetation types which thrive on moist and nutrient poor conditions. Due to the extraction of drinking water, the groundwater table has lowered, causing dune slacks to disappear. Dune slacks are also known as dune valleys. (Van der Meulen, 1982)

Duinwater

Duin -Water. *Duinen* means

dunes. Duinwater, a word for drinking water from the dunes, was in common use before the centralization of drinking water distribution (Croin Michielsen, 1974). The word itself indicates an awareness of the source of the water, and which water sources and qualities could be used for what function. Duinwater is one of the most clear and clean water-sources in the history of the Netherlands (Loen, 2020).

Drinking water

A first degree human necessity. Due to the excessive amount of pollution in water bodies today, it is usually necessary to decontaminate or filter the water in some way. Drinking water, as the name implies, should be safe to drink.

Groundwater

One of the three main sources of drinking water (Loen, 2020).

Rainwater

One of the three main sources of drinking water (Loen, 2020).

Surface water

One of the three main sources of drinking water (Loen, 2020).

Infiltration lake

Instead of periodically flooded dune slacks, coastal dunes in the Netherlands which are used for drinking water production are covered by infiltration lakes. These lakes are filled with fresh river water. (DUNEA Duin & Water, n.d.d.)

Infrastructure	'*The basic system of essential services that support a city, a region, a country.*' (Bélanger, 2017, p.113)
Non-potable water	In this thesis, I use the term 'non-potable' water to indicate water which has not been treated to the same standards as drinking water, and thus is not safe to drink. It is, however, safe for other non-potable uses, like flushing the toilet.
Potable water	See 'drinking water'.
Productive Landscape	Within this thesis, the term productive landscape is used to describe all landscapes which are utilized for the generation or production of resources. This is a broad concept, which means that also other, more specific term are used in this context:
Industrial Landscape	Industrial landscapes can take many different forms. However, in this project the term is used for productive landscape which also include certain structures for manufacturing or processing.
Landscape of extraction	A landscape of extraction is a landscape where specific resources are extracted. In these territories, nature is 'constantly being reorganized' in order to continue extraction processes (Flaquer, n.d.).

River-dune system

The river-dune system is a Dutch drinking water production system, where riverine water is transported to the coastal dune landscape to infiltrate into the dune sands.
The dunes filter the water. After infiltration the water is extracted, goes through post-treatment processes and is finally distributed to consumers. (DUNEA Duin & Water, n.d.d.)

Water Circularity

In this thesis the concept of water circularity means closing water flow circles regionally. In this case, storing, filtering and reusing water contribute to water circularity.

Water Obscurity

Lifting water obscurity is the basis this project. In this thesis the term is used to signal the apparent detachment between coastal residents and their drinking water landscapes.

Water Plurality

'*Different types of water were available through different infrastructures, for different purposes and with wide local variety*.' (Pierik, 2024, p. 245)

Water Quality

What defines drinking water is it's quality, being clean enough to drink safely by earths species. The power of the dunes in the context of this project is its ability to cleanse water of unwanted bacteria and viruses.

Water Relationality

The relationality of water is about the interdependence between water, landscapes and people.

Water Singularity

This term in the thesis explains the trend of industrialisation and unification of infrastructures to provide resource extraction and distribution on as large a scale as humanly possible. However, as far as 'humanly' possible might not be the best solution, instead we should look at the resources and regenerative qualities landscapes naturally provide. In that case, downscaling will be the next step of industrialisation.

Watertoren

(= water tower) A water tower is a very visible and architectural piece of water distribution infrastructure. The water tower has height, and contains a lot of water storage, which provides the pressure for water distribution. Water towers are still visible all over the Netherlands, though not all are still in use. The Scheveningen water tower is still operational and can provide water pressure in case of a power outage (DUNEA Duin & Water, n.d.d.).

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Graphics

Figure 4: Hooimeijer, F. L., Kuzniecow Bacchin, T., Iorio, L., Kothuis, B. L. M., & van Stel, A. (Eds.) (2021). Drawing what is beneath the surface reveals the unseen despoliation of the Earth in the pursuit of extraction and settlement, write Rania Ghosn and El Hadi Jazairy of Design Earth. [Image]

Figure 11. - 19., 28., 63: By the author. Information on subterranean infrastructure adapted from the article by Draak (2012). Later corrected using DUNEA Duin & Water (2019).

Figure 9., 31., 34: By the author. Information adapted from DUNEA Duin & Water (n.d.b), DUNEA Duin & Water (n.d.d.).

Map 1: Heightmap. By the author. Adapted from AHN5 (2023) data via Geotiles.nl.

Map 2: Freshwater lens ‘depthmap’. By the author. Adapted from ‘*Ligging grensvlak tussen zoet en zout grondwater*’ by Rijkswaterstaat & Detares & Arcadis & Hydrologic & Ministerie van Infrastructuur (2024) via Klimaateffectatlas.nl.

Map 3. Soil map. By the author. Adapted from BRO (2025) data via pdok.nl.

Map 4. Drinking water landscapes in the Netherlands. By the author. Adapted from '*Grondwater beschermingsgebieden rondom bronnen voor drinkwater*' by Rijksinstituur voor Volksgezonheid en milieu (2026), via Atlasleefomgeving.nl.

Map 6. Vision map. By the author. Adapted from Bestand Bodemgebruik 2017 by CBS, via pdok.nl, and Top10NL, via pdok.nl.

Map 7. Vision map with route. By the author. Adapted from Bestand Bodemgebruik 2017 by CBS, via pdok.nl, and Top10NL, via pdok.nl.

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