

# A Landscape based Approach to the Transformation of the seven Weirs in the Dutch Part of the River Meuse

**Master:** Architecture Urbanism and Building Sciences  
**Track:** Landscape Architecture  
**Graduation Studio:** Flowscapes;  
**Graduation Lab:** Landscape Architecture Principles  
**Student:** Wout de Joode  
**Date:** 19-06-2024

**1st mentor:** Prof.Ir. Eric Luiten  
**2nd mentor:** Prof.Ing. Mark Voorendt  
**Delegate of the Board of Examiners:** Angela Rout



Veur ik goan, wil ik noa de Maas toe  
Efkes stoan doa, woar ut water mich al kent

...

Want hie bin ik geboare  
An de oevers in ut zand  
Kiek aling mer noa mien spoare  
Ik heb getroaie op dit land  
Ik weet zeker dat ut **landschap** das se  
gans die leave zies dich makt

Before I go, I want to visit the Meuse  
For a while, where the water knows me

...

Because I was born here,  
At the river banks in the sand,  
Only looking at my traces  
I have trampled on this land  
I am sure that the **landscape** you see  
your whole life makes up your person

Noa de Maas toe, Frans Pollux (2021)

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# Preface

Before you lies the master thesis: "A Landscape-based Approach to the Transformation of the seven Weirs in the Dutch Part of the River Meuse." This report is written as a requirement for graduating the master landscape architecture at Delft University of Technology. I have written this thesis during the academic year 2023/2024.

My thesis report is written for everyone interested in landscape architecture combined with civil engineering. By integrating these two professions a new perspective for the weir system in the river Meuse is presented.

I would like to thank my first supervisor Prof. ir. Eric Luiten. As a landscape architect he advised and supported me during this project through feedback on things such narrative, design and much more. I would also like to thank my second supervisor Prof.ing. Mark Voorendt. As a civil engineer he helped me to look critically on the civil infrastructure, whilst having a critical eye on the report structure, and scientific methodology. Next to that I also would like to thank others who helped me with writing this thesis through providing data and by commenting on my work.

Finally I want to thank the readers of this report, I hope you enjoy reading it.

Wout de Joode,  
Rotterdam, June 12, 2024



# Glossary

## Weir

A weir is a dam with an adjustable height situated in a river. Its main function is to increase the upstream water level, to make shipping during low river discharges possible. There are 46 weirs in the river Maas, from which seven in The Netherlands. The weirs work in combination with ship locks and fish passes.



Figure 2: Weir Borgharen (By author)



Figure 3: Ship lock Sambeek (Rijkswaterstaat)

## Ship lock

A ship lock is a passage in rivers where ships can pass, even though there is a different water level on each side. A ship travels into the lock chamber, in which water can flow to match the water level on the other side. Since the natural water flow is stopped, the ship locks work in combination with weirs.

## River Dam

A river dam is a structure in a river which raises the water level, and keeps water upstream. It is fixed in its position, which means that the dam cannot be raised or lowered. They are most prevalent in areas where rivers are relatively narrow and not used as waterways for boats.



Figure 4: Jubilee river dam (Cox 2009)



Figure 5: Fish pass Linne (By author)

**Fish pass**

A fish pass is a side stream parallel to the river at the location of a weir building. The goal of a fish pass is to facilitate a passage for migratory fish upstream, because the natural river flow is blocked by the weir. In the river Meuse, all seven weirs have their own fish pass directly next to the weir.

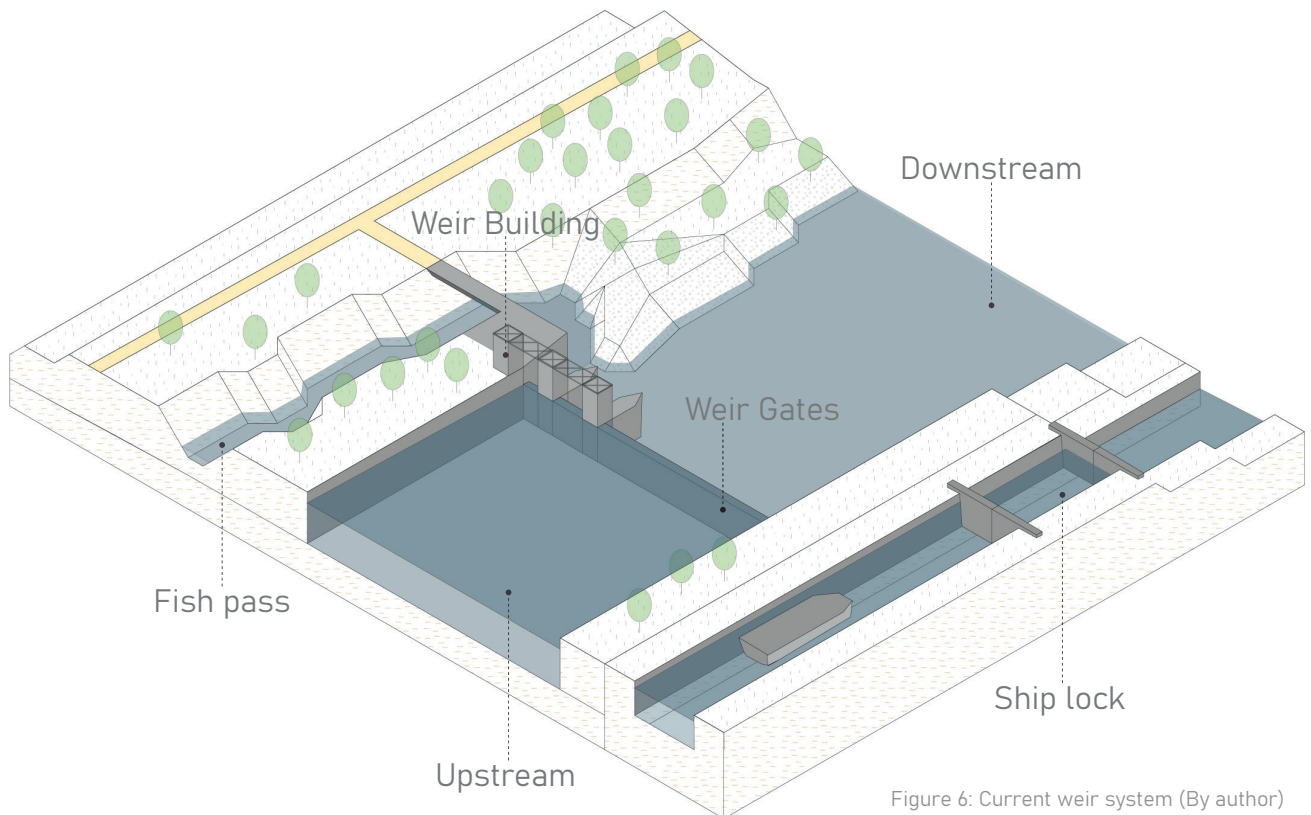



Figure 6: Current weir system (By author)

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# 1. Introduction

As an introduction to the thesis, first the personal motivation behind this topic is elaborated in 1.1 Motivation. Next in 1.2 Context, the context of the weirs in the river Meuse is discussed, including history and an analysis of the problem. This context leads to 1.3 Research question, where the goals of this thesis are specified. In 1.4 Methodology the means to reach this goal are explained through a step by step approach.

# 1.1 Motivation

As a master graduation student in Landscape Architecture I have implemented knowledge from my bachelor studies of Civil Engineering into my graduation project. A second motivation for this project is my fascination for the landscape of Limburg.

After achieving my bachelor degree in Civil Engineering I did not start my career or master studies on that matter. I discovered and developed a passion for design, which led to the master track Landscape Architecture. During the course of the Landscape programme I found out that my switch from Civil Engineering to Landscape Architecture was not that strange after all. The two professions are closely related in many projects, and I could use basic knowledge I had gained during my bachelor programme in many projects. During my graduation year I have continued that trend, and I have worked on a project in which both landscape architects and civil engineers should be involved. This combination of professions results in my landscape based design approach, in which civil engineering and nature based designs come together.

I grew up in the South of Limburg, a unique part of the Dutch landscape. While the focus of my studies was primarily on the west of the Netherlands, I did not have the chance to work on a project in Limburg. For me as a landscape architect, it is important to work on a project where the landscape is familiar. I believe that problems can be solved best by working with local communities. People who actually lived on the land for years know the landscape best, and can read the landscape best when needed.

*“Landscape associates people and place. Danish landskab, German landschaft, Dutch landschap, and Old English landscape combine two roots. “Land” means both a place and the people living there. Skabe and schaffen mean “to shape”*

(Whiston Spirn, 1998)

‘Land’ in the word landscape is not only a geographical location, as Whiston Spirn explains in the book ‘The language of Landscape’. It is also about people living there. These people live on the land, and they also care for the land, which makes them expert in reading the landscape; knowing what the landscape does and why. This is key to solving current problems we are facing in the landscape right now. This problem in the landscape around river Meuse is uncovered in the next section 1.2 Context.



Civil Engineering and Landscape Architecture are inseparable in many projects, especially the weir renovation project in the river Meuse.



Figure 8: Author in park Boscherveld (Van Schijndel, 2023)

# 1.2 Context

In this section the context of the river Meuse and its weirs is addressed. First some general information on the full length of the river is provided. Secondly there is some background information on the history of the river. Next the current imbalance of natural ecosystems through industrialisation of the landscape is discussed through an example. Lastly the current problem regarding the Dutch weirs that the Department of Waterways and Public Works faces is stated.

The Meuse originates in Plateau de Langres in France, 409 meters above normal Amsterdam level (NAP). It flows north through the Ardennes nature reserve into Belgium, where it enters a fully canalized riverbed. It enters the Netherlands around Maastricht, and flows through the south of the Netherlands to eventually reach the North Sea. The Meuse is a rain river, which means the water level is determined by the amount of rainfall in the catchment area of the river. This causes the water level to fluctuate heavily throughout the seasons, with maximum water levels during winter, and minimum water levels during summer.

In total there are 46 big infrastructure works in the Meuse which obstruct natural flow of the river. These structures are dams and weirs, constructed to make shipping on the river possible year-round, because the water could be too shallow in summer periods.

Upstream in France the river is very shallow and narrow. The first obstructions in the river are small dams to increase water levels locally. In Belgium, around the Euregion Maas-Rijn the infrastructure is much bigger. Harbours and weirs are more frequent. When the river enters The Netherlands, the river is situated 46 meters above NAP, and only has a relatively low amount of descending left to do. This means that weirs are less frequent in The relatively flat Netherlands.

Borgharen



Linne



Roermond



Belfeld



Sambeek



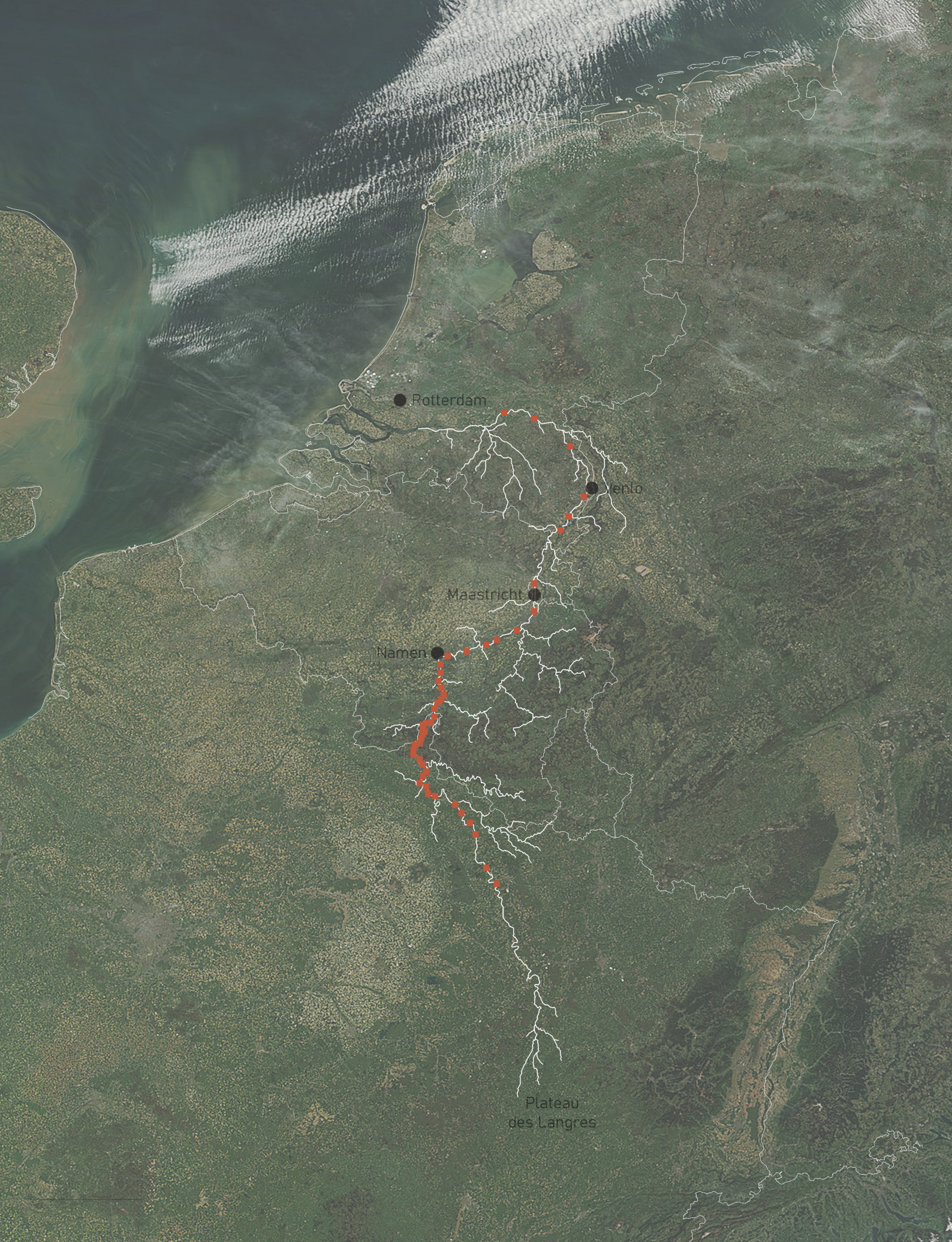
Grave



Lith



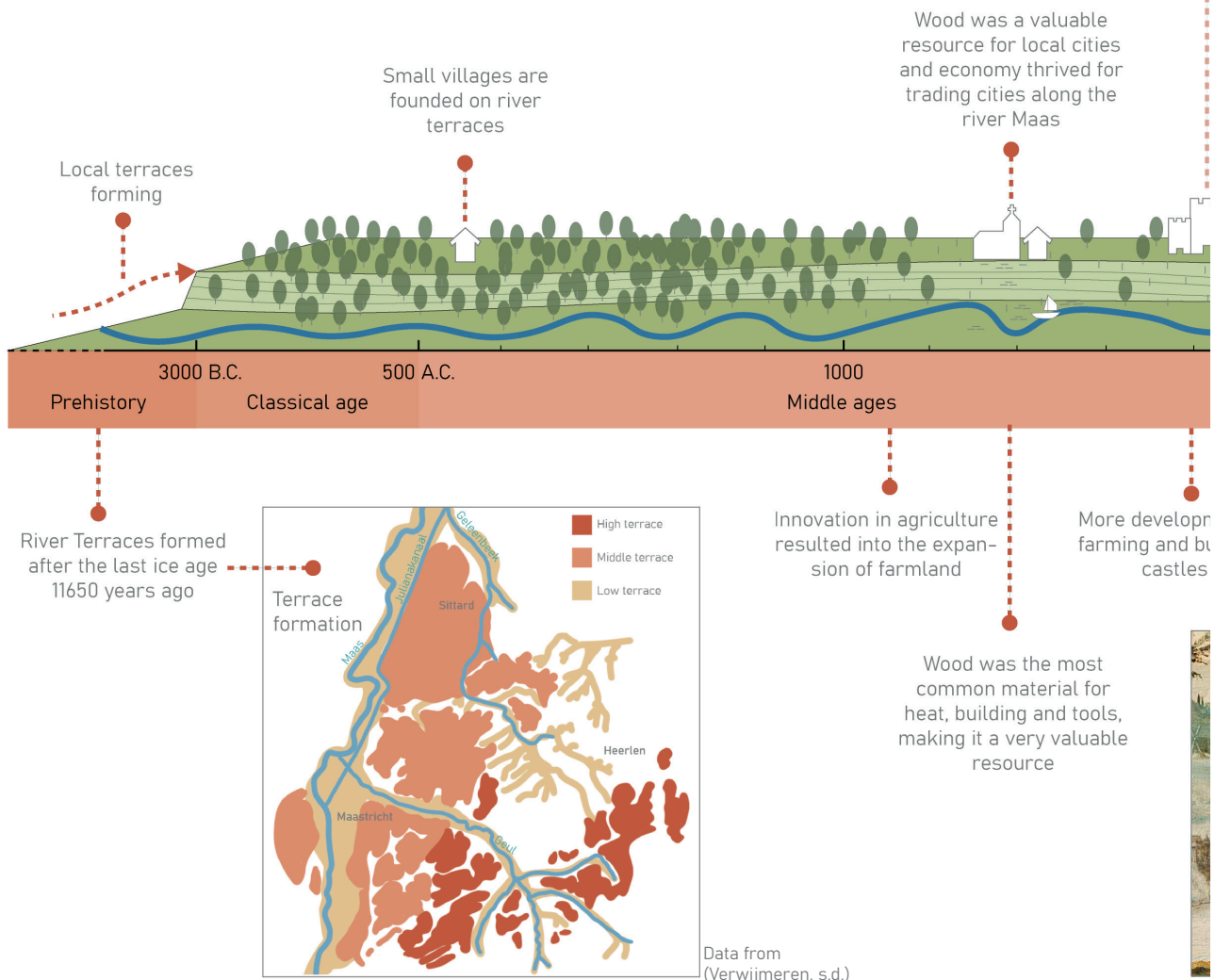
Figure 9: The seven Dutch weirs in an international context (By author)



When the river Meuse was formed thousands of years ago after the last ice age, the Meuse Terraces as we know them today were formed. These terraces are visible in the landscape, especially in the south of Limburg. These elevated parts in the landscape close to the river were used as settlements for the first ever villages, because the river brought water and fertility, while the terraces functioned as a natural barrier against floods.

The settlements around the river thrived, and during the middle ages this prosperity was enhanced because of wood shipping. Many forests around the river were cut down for the most valuable building material; wooden logs. This prosperity lead into construction of castles and monasteries along the river, most of them still visible today. The river Meuse quickly transformed from a natural river into a waterway used for shipping.

In the new age, the value of wood started to diminish, because of the uprising of other materials like stone coal. This stone coal was found in the south of Limburg, relatively close to the river. To make the most use of this valuable trading resource, the water level of the Meuse had to be controlled to make shipping possible year-round. This was done by constructing the seven weirs as we know them nowadays. Next to that, several canals were constructed to create a more efficient shipping route.



The extraction of stone coal stopped in 1974. Nowadays the river Meuse is still used for shipping, mainly for building materials and resources such as sand and gravel.

balance of the natural system in place is distorted. When taking from the landscape, it should be considered how to give back, and create a human ecosystem that thrives not only for human purposes.

As seen through the timeline of the river, humans have been interacting with the river and its landscape ever since they arrived. Materials used by mankind were brought by the river, wood, sand and gravel, directly or indirectly. The problem with exploiting landscapes for their resource is that the

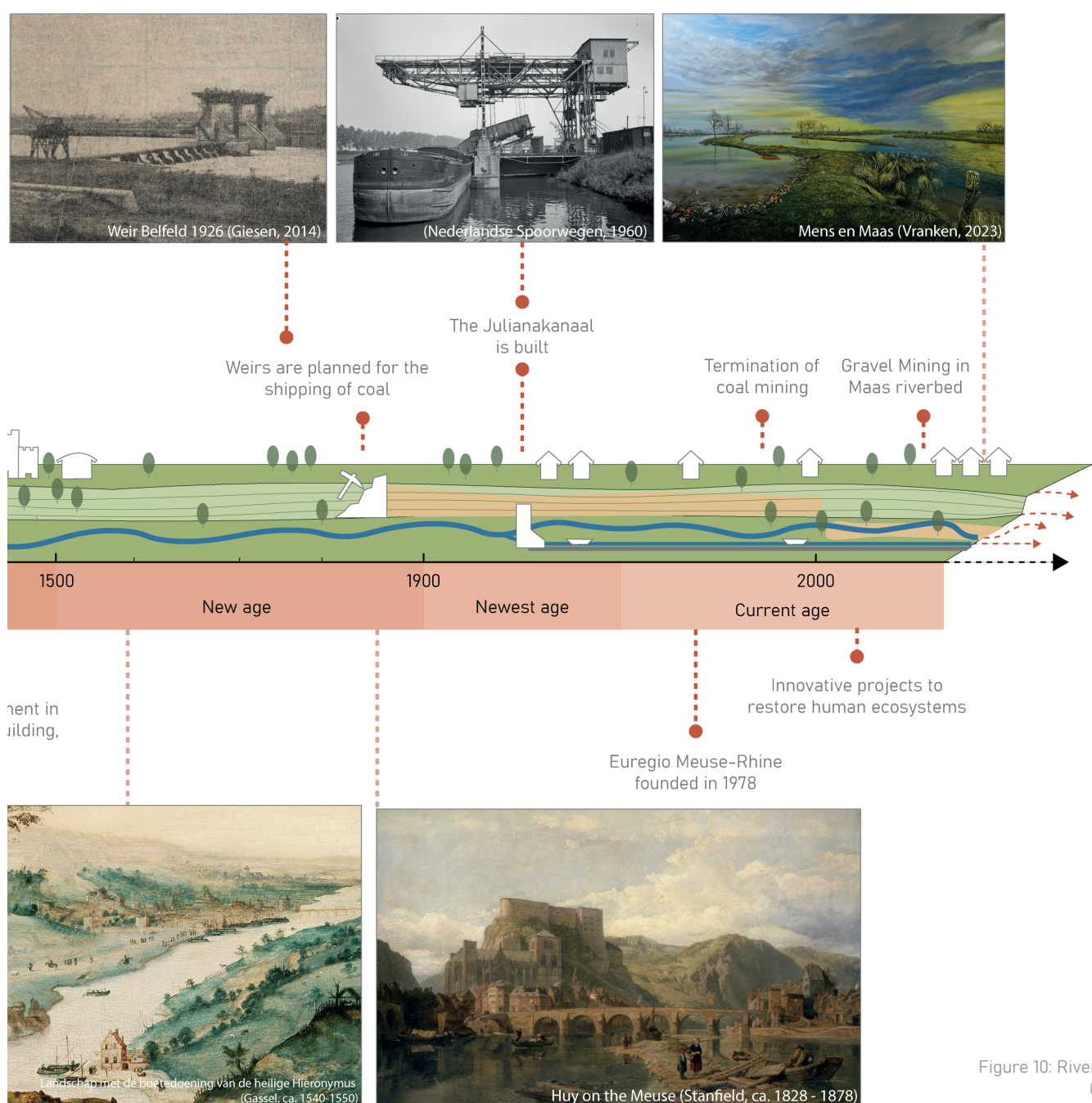


Figure 10: River Meuse timeline (By author, 2023)

This brings us to the state of neglect of the natural landscape and ecosystems around the Meuse. The landscape has reached a tipping point after constructing the seven weirs over a hundred years ago, which caused imbalance in ecosystems. Not only in the Netherlands, but all around the world this ignorance of ecosystems was a trend in big scale civil works, during this age of modernity in the early twentieth century. A clear example of this is shown in Human Ecosystems, written by Lyle in 1969. The San Elijo Lagoon near San Diego is a case where humans interfered with the function of the landscape, as seen in Figure 11: San Elijo Lagoon. The lagoon is an intricate ecosystem, dependent on water supply through ocean tides. The construction of a railroad, blocking the natural water flow, proves the ignorance of humans on natural functions for species in this landscape. This resulted into a big habitat loss for local species and regional

species such as migratory birds. Even the smallest intervention can have an impact on the biggest scale (Lyle, 1969).

*“The truth is that human beings have been designing ecosystems for some twelve thousand years now, ever since they first learned how to cultivate plants. Through all these millennia, they have been habitually, even compulsively, changing the world’s landscape.”*

(Lyle, 1969)

As Lyle said in 1969, the world’s landscape has been altered by humans for centuries, resulting into biodiversity loss. Humans should learn from previous mistakes in projects, and be actively involved in transformation of these landscapes into healthy human ecosystems, where species thrive of the functions the landscape has to offer (Lyle, 1969).

The San Elijo Lagoon near San Diego is a clear example of a human intervention that caused problems for the tidal ecosystem. The important tidal influence is blocked off by a railway constructed over 125 years ago. In the present projects are developing aiming to restore this unique ecosystem.

Figure 11: San Elijo Lagoon  
(Marathon Construction Corporation, 2020)



This example of designing without considering the natural ecosystem links back to the weir construction in the river Meuse. When constructing the weirs in the river Meuse in the 1920's, there was little to no regard of preserving ecosystems. The focus was clear back then; raising the water level so that shipping would be possible. Unfortunately, this had a drastic impact on life in and around the river. The landscape of rare and location-specific species had been eradicated. Nowadays the same mistake is bound to happen. Currently the weirs need replacement, which is a perfect time to set an example for the future, embracing ecosystems. The weirs cannot be dismantled in the foreseen future, while shipping still has a big economic benefit (Van Woerden, 2023). However, different solutions to the weir system can be explored, to maintain the higher water levels, and provide passages and habitats for all species.

In this thesis alternative options to transform the weirs are explored, both beneficial for natural processes, people's experience and landscape differentiation. This is referred to as a landscape based approach, an approach where nature based solutions and civil engineering solutions are integrated.

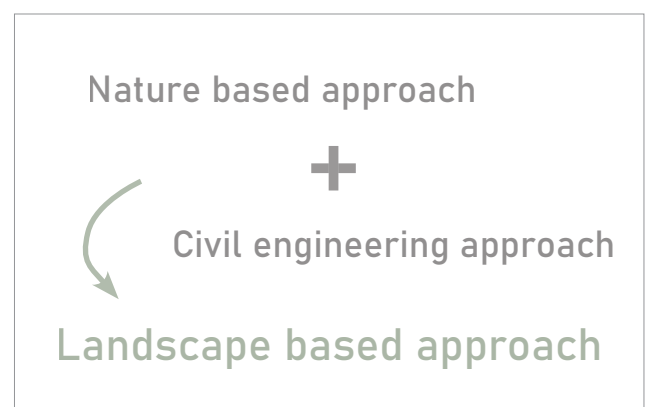


Figure 12: Hambeek in Roermond (By author, 2024)

Landscape based approaches are a combination of nature based approach and a civil engineering approach. Nature based solutions are inspired by nature, bringing more natural and diverse features into landscapes in locally adapted interventions (European commission, 2023). Nature based solutions can be used as means to reach a rewilded landscape in which biodiversity gets put on the first place. However, in the river Meuse, most of the river system has evolved into a cultural waterway where transforming back to wilderness is not desirable. Simply removing the weir system to bring back the natural flow of the river is not possible because of many implications such as changes in the current ground water table which can lead to flooding of houses along the river (Van Woerden, 2023).

Recent technologies and innovative research is needed when addressing these big civil projects. It is not possible to return back to nature's original state without reading the current landscape and realising what the effects of nature based solutions for rewilding will bring. This tones down the definition of nature based solutions.

A landscape based approach is more comprehensive, integrating different professions to reach a desirable landscape for both nature and culture. Currently the opportunity is there to implement such a landscape based approach, since the seven weirs need to be renovated in the upcoming future.



The one responsible for this renovation is the Department of Waterways and Public Works (Rijkswaterstaat), a Dutch governmental organization responsible for designing, constructing maintaining and managing infrastructure facilities. One of their tasks is assessing the technical status of the Dutch weirs, and renovating them if necessary. The technical lifespan of all weirs in the Dutch part of the river Meuse is almost over, which means the technical structures need to be replaced to guarantee safety. The current plans of the weir renewal are based solely on a civil engineering approach, as it appears from the strategy to replace and reinstall the weirs as they were built over hundred years ago. The guiding design principles will be effectivity of shipping and high water safety, even though the weirs as they are implemented nowadays cause problems for human and nature.

*“The guiding principles while constructing the Meuse system around 1900 were water safety and shipping. These guiding principles are unchanged during the 20th century and still form the base of decision making revolving replacing the weirs.”*

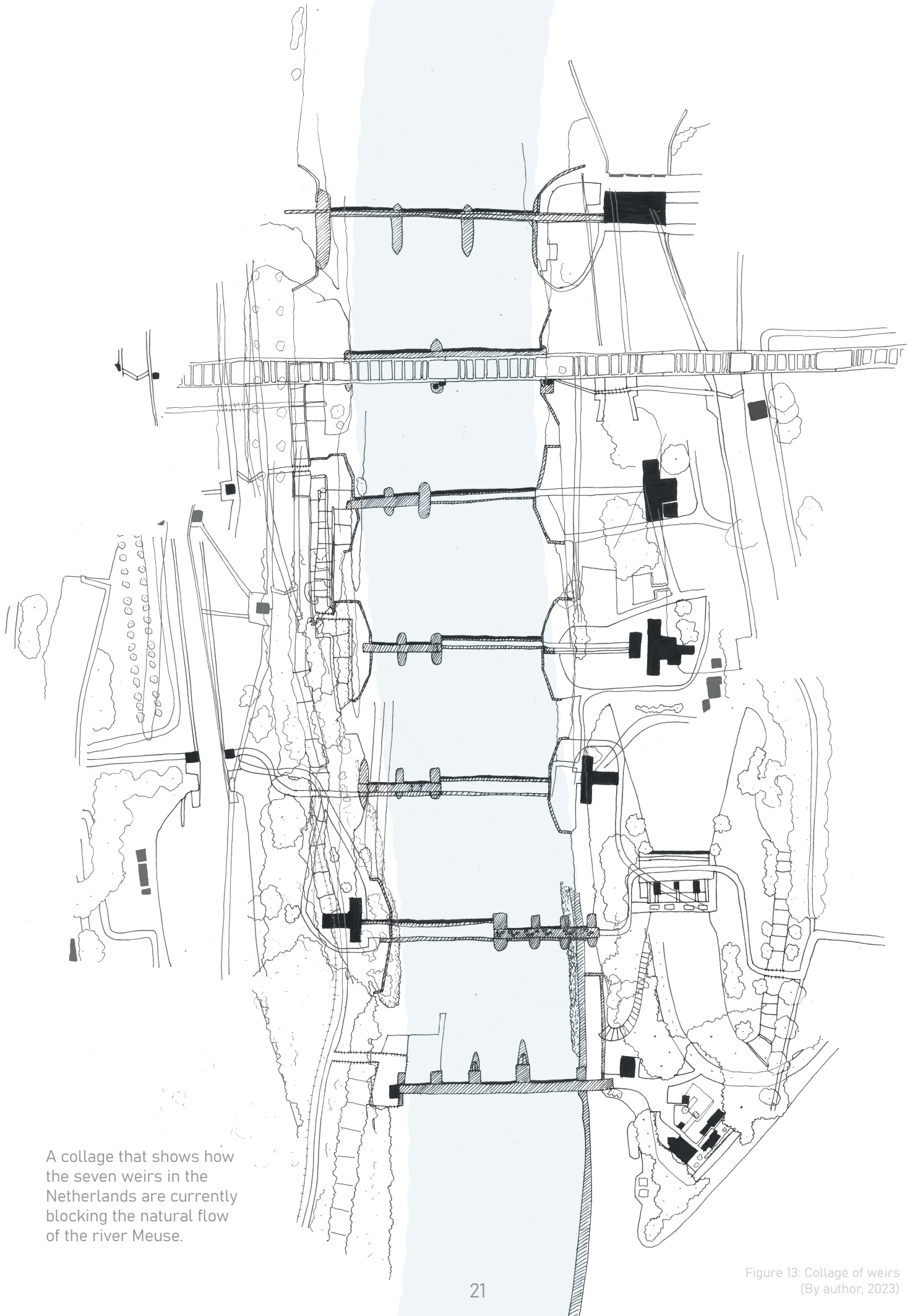
Translated from  
(The Department of Waterways  
and Public Works 2023)

As The Department of Waterways and Public Works stated in 2023, the current program to renew the weir structures is based on safety and shipping. Most of the renovation in the near future is already planned. For example, weir Linne already has construction scheduled the upcoming three years, renovating the valves, trusses and powertrains (The Department of Waterways and Public Works, 2024).

The problem with the weir-approach to make shipping possible year-round is that natural processes are heavily impacted by this system of wall-like structures in the river. Because the Meuse is divided into fragments with weirs on both ends, the river looks nothing like its original natural state of many years ago. This leads to habitat loss for unique species. Unique species are necessary to maintain a healthy and robust ecosystem.

A more human oriented problem is the lack of functions that the area surrounding the weirs fulfil. Smart usage of available space is one of the biggest challenge the Netherlands face, since most of the land is built and densely populated.

From these problems revolving the weir system together with the context of the river Meuse the research question of this thesis is formed in the next section 1.3 Research question.



A collage that shows how the seven weirs in the Netherlands are currently blocking the natural flow of the river Meuse.

Figure 13: Collage of weirs  
(By author, 2023)

# 1.3 Research question

As mentioned in section 1.2 Context, the Meuse's weirs have to be replaced or transformed in the upcoming future. A research question is formulated and three sub-questions elaborate the landscape based elements of this approach. By answering these, this thesis gives a new perspective for the future of the Meuse's weirs. The answer of the research question is given through research and design.

How can the series of the Meuse's weirs be replaced or transformed through a **landscape based** approach?

How are the weirs disrupting biotic and abiotic natural processes currently and how can these barriers be mitigated throughout the river when renovating the weirs?

How to replace or transform the series of weirs coherently, standardising the functionality of the design, but still considering each individual landscape features?

What will the transformed weirs look like, dealing with the spatial aspects of the current weirs and their surrounding landscape?

Landscape based

Natural processes

Differentiation

Experience



# 1.4 Methodology

Answering the research question and sub questions is done following five steps. These steps have not always followed up chronologically during the process, but are intertwined, and executed with feedback loops back to previous steps, as illustrated in Figure 15: Methodology scheme. The different steps can be divided into two categories: Research and Design. On top of that, the relation between the different methods and the research questions is shown.

## 1. Landscape analysis

First of all, the current landscape of the river Meuse and its environment is analysed to answer how the weirs are disrupting the biotic and abiotic processes in the river. This is done by literature research on the river to collect data. Next to that, the sites are visited to grasp the atmosphere of the weir locations and to take photographic material. All these findings are documented in section 2. Landscape Analysis.

## 2. Landscape diagnosis

The findings of the analyses are concluded in section 3. Landscape diagnosis. A vision on the river Meuse is formed in which the current barriers are mitigated through transforming

the current weirs. Next to that, a catalogue of eight landscape elements is introduced which complements the current river Meuse in experiential value based on the landscape analysis.

## 3. Creating conceptual approach

Based on the landscape diagnosis, a design for a new transformed weir is elaborated in section 4 Conceptual approach. This is one standardised design which has to be integrated in every specific weir location. The concept is based on the corridor approach which uses landscape structures, such as the river Meuse, as an armature that can create conditions to stimulate ecological and social interaction (Nijhuis, 2019). Landscape architectural theory on design is used to form a strategy to create a thought-out design on a smaller scale. Messy Ecosystems, Orderly Frames (Iverson Nassauer, 1995) is used as a main reference.

## 4. Application to large scale design

For all seven weirs in the Dutch part of the river Meuse a big scale design plan is made, implementing landscape elements from the catalogue introduced in the landscape diagnosis, and integrating the design concept in the local topography. For each weir location different landscape elements are fulfilled by a critical assessment. This way, the transformation of

How can the series of the Meuse's weirs be replaced or transformed through a **landscape based** approach?

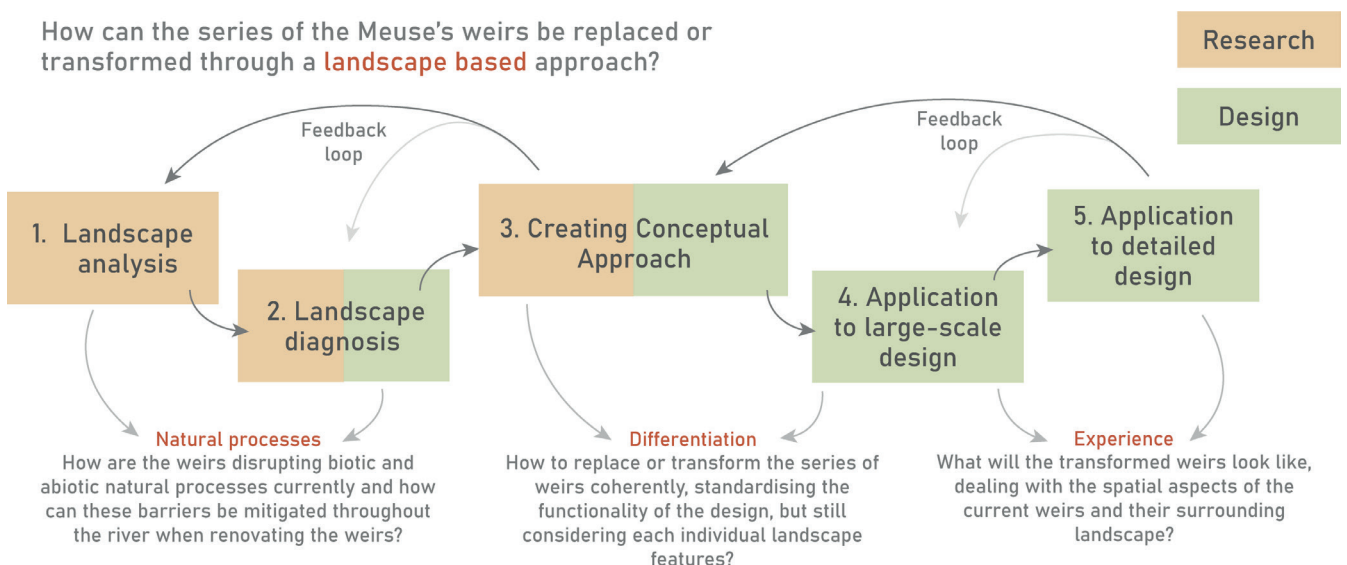


Figure 15: Methodology scheme (By author, 2024)

the series of weirs is done by standardising the design, but still considering each individual weirs' landscape features.

**5. Detailed design**

For the weir locations Borgharen and Roermond the theory on spatiality is used to create a detailed design including plans, sections and visualizations. This illustrates how the transformed weirs could look in the future, dealing with the spatial aspects of the current weirs and their surrounding landscape. These two design location can be used as an example of the other five weirs.

The four lenses Scale continuum, Processes, Palimpsest and Atmosphere play an important part in the design process of the graduation lab Landscape Architecture Principles, with a focus on scale continuum. When landscaping through scales in step 4 and 5 of the methodology, three different levels of modification will be considered: Control, influence and effect. Next to that, when classifying and elaborating landscape architectural projects through scale continuum, three categories can be used as a tool. Pars pro toto, cause and effect and copy paste (Luiten, 2023). An intervention can be part of a whole, it can have an impact on a scale bigger than design scale itself, or it can be implemented on multiple places. While the transformation of the weirs in a river can relate with all of these categories, the most fitting is cause and effect. An intervention in a river always brings changes, both upstream and downstream. These effects have to be considered while addressing the river system. The three categories of scale continuum tools will be evaluated in a personal reflection.

During the design four different scale levels are used, from zoomed-out to zoomed-in, to create a design for the landscape around the weir system of the river Meuse from a big scale to a small scale. When evaluating the new weir designs in section 7. Conclusion. These four scales are used to elaborate on cause and effect on different scale levels.

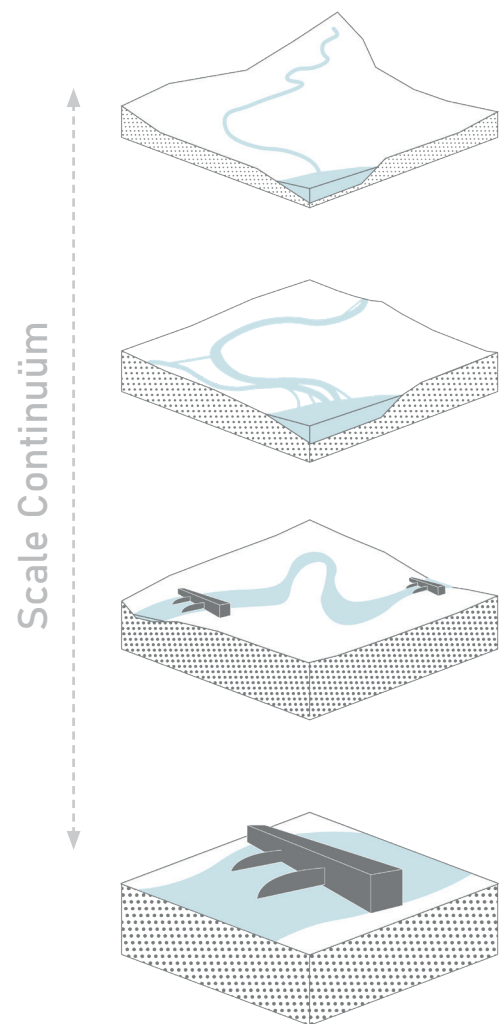


Figure 16: Weirs through scales (By author, 2023)

Different scale levels in which the river Meuse and their weirs have been observed; international, national, regional and local.

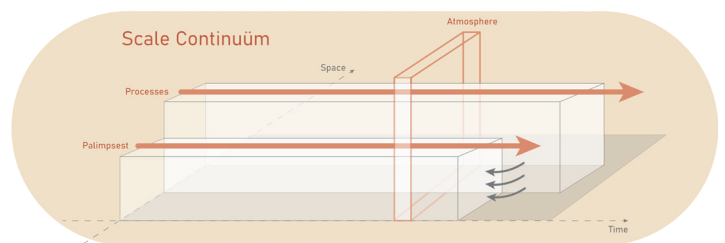


Figure 17: Four lenses (By author, 2023)

A personal view on the four lenses used in this graduation lab. Processes move forward through time, while leaving remains in the form of palimpsest. Atmosphere can be captured in a specific time period, where processes and palimpsest can be observed. Scale continuum is the overarching lens in which the other three can be observed through different scale levels.



# 2. Landscape analysis

In this chapter the soil condition, water system, ecological quality and people's experience is analysed. With that comes a better understanding of the landscapes and their current opportunities. The results of this analysis are summarized in section 3. Landscape Diagnosis, and afterwards used as a base for redesigning the seven weirs in the river Meuse.



## 2.1 Soil condition

The fundamentals of every landscape is situated beneath the surface, in the soil. In this section the different ground types the Meuse flows through are elaborated. Next to that, the relevance of the horsts and rifts in the landscape is explained

The river Meuse is a unique river in the Netherlands in terms of soil types it flows through (Figure 18: Soil map and diagram). From south to north the soil consists of limestone and loam, gravel, sand and clay. All of these soil types are a result of the natural process of sedimentation of the river Meuse. It can be seen as a palimpsest of the river. All of the soil types have their own characteristics, which leads to a differentiated spectrum of biodiversity all throughout the river. Some soil types are heavily mined and have caused massive changes in the landscape.

Rifts and horsts are cracks and movements of tectonic plates. It might not be immediately visible to the naked eye, but these elevated, or valley-like landscapes affect the characteristics of the soil, vegetation and behaviour of the river.

### Limestone and loam

On the border with Belgium, where the Meuse flows into our country, the soil consists of limestone and loam. Limestone can be very diverse, and the type most commonly found in the South of the Netherlands is a chalk rock type, marl. The flow of rivers carved sharp edges into this particular landscape with relatively steep edges. The marl is a valuable resource which has been used over centuries. Romans used it to increase fertility on agricultural soils. In the Middle Ages the resource was a valuable building material. Later the marl was used for cement industry.

### Gravel

The first weir, Borgharen can be seen as the transition zone from limestone to gravel. The Meuse's gravel originates from upstream sediment. It is only found in the south part of the Netherlands because closer to the estuary, the river flow speed is too low to carry the gravel pieces farther. The gravel has been used throughout history for roads and later for concrete. In recent year gravel has been dug out to create more flood areas for the river.

The gravel soil type is unique in The Netherlands and brings a valuable amount of biodiversity. In between Borgharen and Linne the Meuse can flow closely to its original streambed. This part of the river is called 'Grensmaas'.

### Sand

Following up the gravel soil layer, there is a large part of sandy soil in the riverbed. Many high water protection projects are carried out in this area, such as excavation for water retention and dyke fortification.

### Clay

The last subsoil of the river Meuse before it flows into the North Sea is clay. River clay has the characteristic of being barely permeable, which means it has no use in crop agriculture. The brown river clay however has been used a lot in bricks, hence many brick factories are located near the river estuaries.

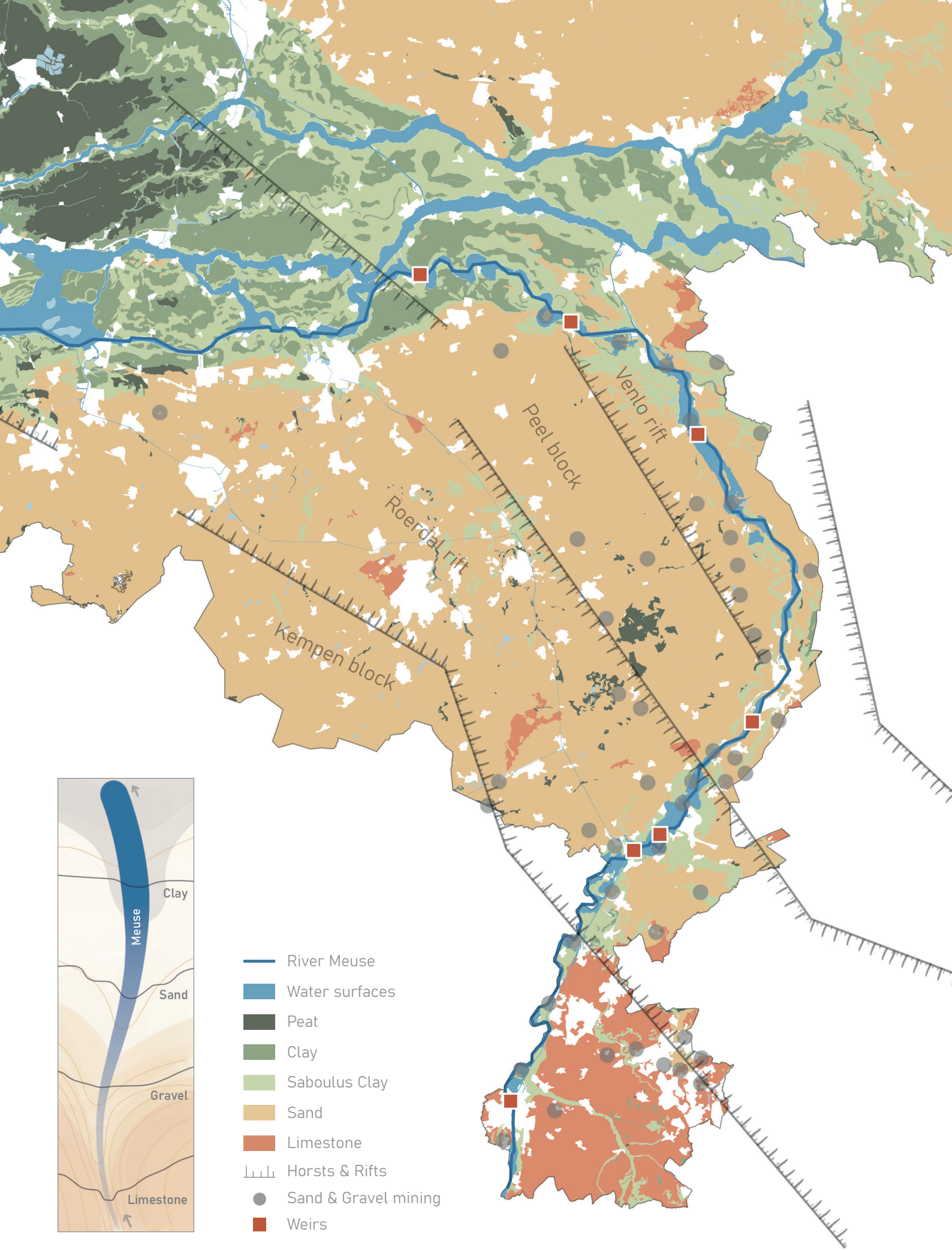


Figure 18: Soil map and diagram (By author, 2023)



## 2.2 Water system

The seven weirs in the river Meuse are indispensable for economical shipping. Downsides of this wall-like structures in the river are often overlooked. Flow speed, water quality and as a consequence natural processes have been heavily impacted for the last hundred years.

The Rijkswaerwegen (Dutch waterways with shipping function, shown in red in Figure 20: Water map) currently still have a big economical influence, and cannot be lifted in the upcoming future (Van Woerden, 2023). Most shipping in the river Meuse originates or ends in the port of Rotterdam where it will be distributed further. Venlo and Maastricht are still two big hubs in the Dutch part of the river Meuse, connecting to the Euregion Rhine-Meuse in Germany and Belgium. Most of the shipping route follows the natural meanders of the river Meuse, however some channels were constructed to make the shipping process more efficient. The biggest channel is the Julianakanaal, a 36-kilometre-long waterway from Maastricht to Linne. By isolating the shipping from the natural river meanders, there are two separated but parallel waterbodies.

By separating the economical shipping, the natural meandering river has developed into an interesting biodiverse place called Grensmaas (Meuse Border). The Grensmaas is still influenced by the weir-controlled water level, however can flow 'freely' for 48 kilometres. This means that water levels are the most fluctuant in this part of the river. This has led to a biodiverse gradient on riverbanks.

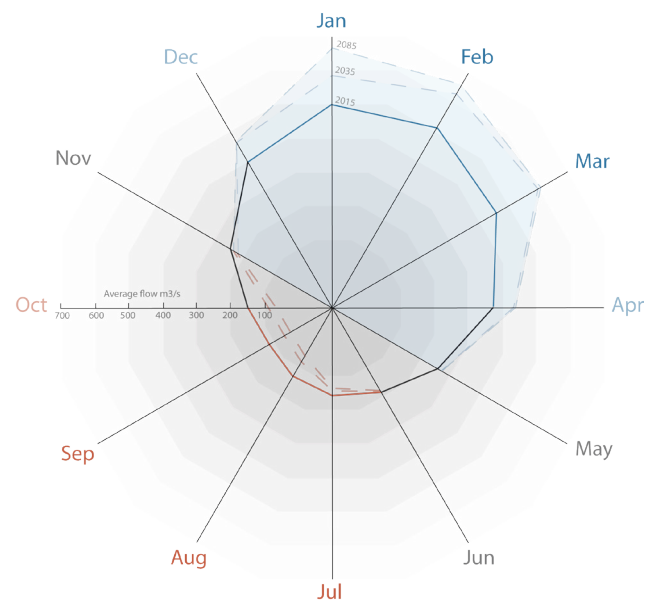
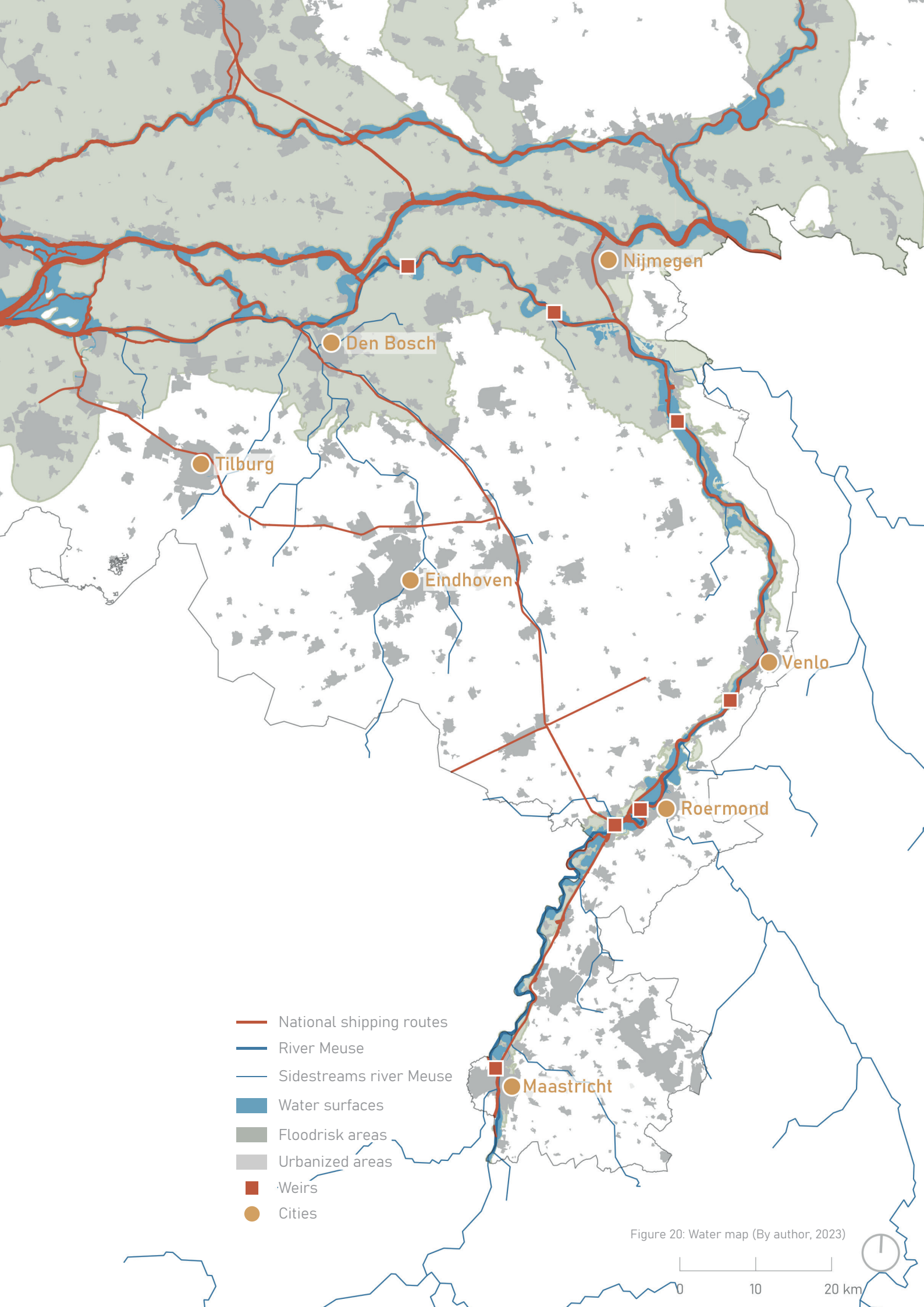


Figure 19: Water discharge diagram (By author, 2024)

In this diagram the water discharge throughout the year is shown. On top of that the difference of water discharge from 2015 to 2085 is shown. In the future there will be more extreme high water levels, but also more droughts. Based on data from (Waterpeilen, 2016).

The introduction of the seven weirs in the river has caused long term effects on the water quality, and as a consequence has impacted biodiversity. The average flow speed of the river is much lower than before the intervention when the river could flow freely. Because of the weir structures in place, the slope gradient of the river is smaller. At every weir location, the water falls with high speed, but throughout the whole compartmented river the water flow speed is on average lower. On average this has caused depletion in oxygen in the water.

Other problems which lead to lower water quality in the river Meuse are: higher water temperatures which makes it harder for oxygen to be absorbed in the water, low water discharge which increases the share of waste in the river relatively and algae bloom (Klink, Bij de Vate, 1996).



- National shipping routes
- River Meuse
- Sidestreams river Meuse
- Water surfaces
- Floodrisk areas
- Urbanized areas
- Weirs
- Cities

Figure 20: Water map (By author, 2023)



# 2.3 Ecological quality

**Weirs in the river Meuse can be seen as barriers mitigating natural processes that would normally happen in a free flowing river system. Fish migration is one of these processes, and is analysed in this chapter. Next to that, the connectivity from the river to regional nature areas is addressed.**

Habitats of fish in the river Meuse are drastically decreasing by the normative compartmentalised riverbeds with low water quality. As mentioned in the water analysis, the oxygen flow over the course of the river is minimal, damaging fish populations which only thrive in water with high oxygen levels. As a measure to prevent the extinction of native unique fish species, several fish passes were constructed. Each weir in the Dutch part of the river Meuse currently has one of these fish passes, the last one being constructed in 2008. A fish pass is a dug out trench that functions as a side channel. Fish that migrate upstream can pass through this stream, while the weir function is still intact. Unfortunately, through monitoring from Rijkswaterstaat, it can be concluded that many fish species are not or only sporadically in the river Meuse (Vriese, F.T. et al., 2021). Through this monitoring research, oxygen depletion and compartmentalisation it can be concluded that the streaming habitat and connectivity of river Meuse need to be improved to support specific fish species.

As mentioned in the historical analysis, the river Meuse has created and evolved its surrounding landscape for over thousands of years. In this timeline relatively recently mankind interfered with this natural river system. Agriculture, Industrial functions and towns and cities have enclosed the river, without considering ecosystems and natural processes that occur in the landscape. This has led to fragmented and isolated nature areas, as seen in Figure 22. Nature network map and diagram. The link between the river and its surrounding valuable landscape is lost through an urban barrier. By cutting off this link with urban barriers, several habitats have lost its connection to the river Meuse, which has a negative impact in the natural ecosystem.

In this diagram the amount of Dutch freshwater fish species is illustrated next to the native and red list species. It can be seen that a considerable amount of native species is threatened and on the red list. Three focus species are selected based on habitat and occurrence in the river Meuse. Data from (Observation international, 2024).

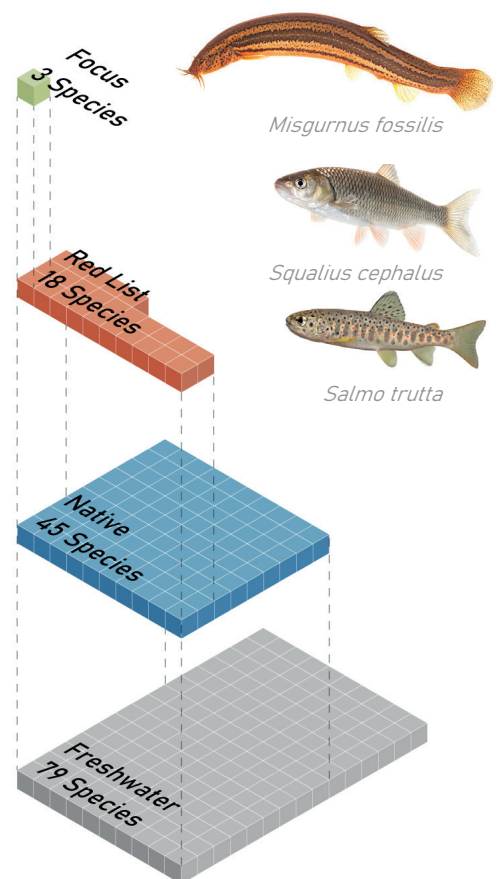


Figure 21: Fresh water fish species (By author, 2024)

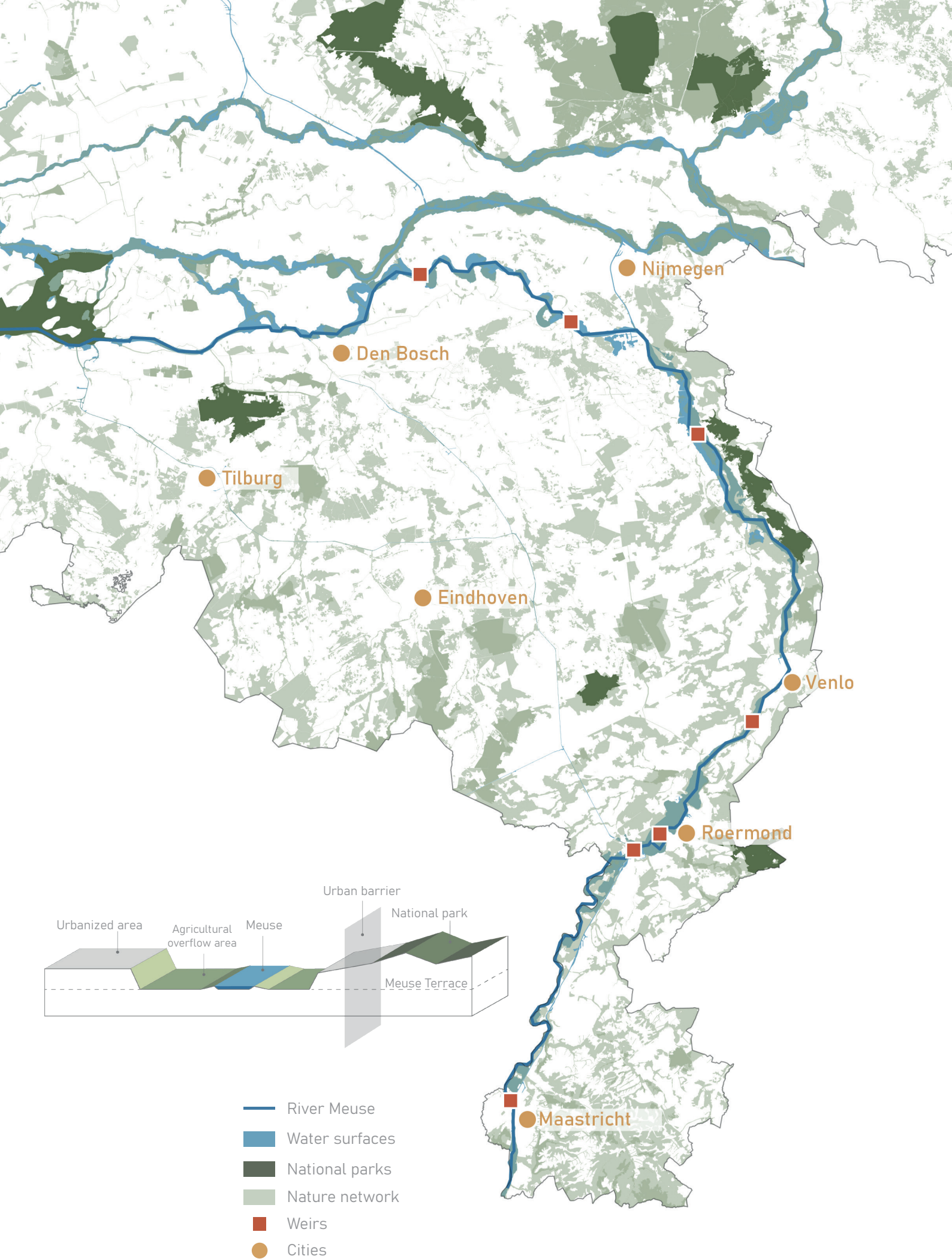


Figure 22: Nature network map and diagram (By author, 2023)



# 2.4 People's Experience

When visiting the seven weirs of the river Meuse, two main findings were consistent at every weir location. On one hand, the weirs feel distant or closed off for humans, on the other there are many slow traffic networks along the river.

The seven weirs are very inconsistent in terms of access for people. Several of the weirs are closed off with fencing (Belfeld, Lith) while others have a dated sign where people are instructed to not enter the area (Grave, Roermond). Others are accessible (Linne, Borgharen, Sambeek), however most are situated in a remote area on dead ends. This immediately brings an industrial, neglected atmosphere around the weirs (Figure 23: Collage of weirs as barriers for humans).

On most locations when arriving on bike paths or trails close to the weir there are several signs guiding different routes. However, since the weirs are very remote, it is hard for local people to find a short walking trail that is interesting (Belfeld).

One overarching bike trail is called the Maasroute. A 481 kilometres long route in which people can follow the Meuse upstream from the estuary near Hoek van Holland all the way to Maastricht where the river enters The Netherlands. The route follows the river as closely as possible, however only at Grave and Linne the weirs can be experienced and crossed (Figure 24: Collage of routing).

In these images of the surroundings of the weirs it shows that weirs are not only a barrier in the river, but also across the river. Some of the Dutch weirs are fenced off for people which creates an unpleasant atmosphere. Others are not properly maintained, or look like an industrial site.



Figure 23: Collage of weirs as barriers for humans (By author, 2024) (Grave, Belfeld, Borgharen, Roermond)

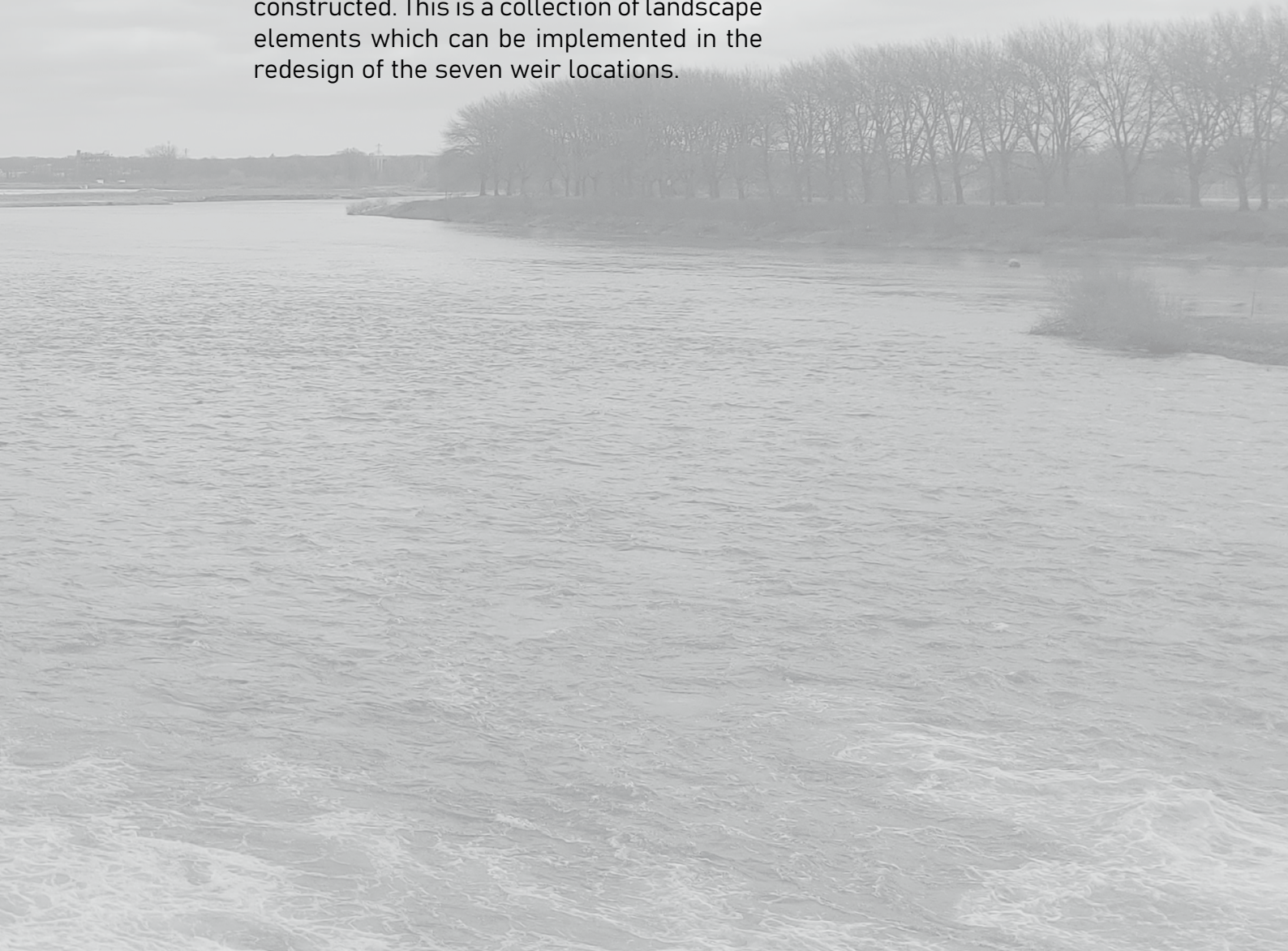


Figure 24: Collage of routing (By author, 2024) (Linne, Linne, Roermond, Grave, Linne)



# 3. Landscape diagnosis

The landscape analysis findings are summarised in the landscape diagnosis. This results into a vision for the Dutch part of the river Meuse. Based on the diagnosis and river Meuse vision, a landscape catalogue is constructed. This is a collection of landscape elements which can be implemented in the redesign of the seven weir locations.



# 3.1 River Meuse vision

First the analyses from section 2: Landscape analysis are summarised. From those findings, the vision for river Meuse on a national level is concluded. A landscape based approach is used as a guideline.

In the previous section, the landscape surrounding the weirs of the river Meuse has been analysed in terms of soil conditions, water system, ecological qualities and people's experience. When diagnosing this landscape, it has been concluded that many processes in the weir areas are being blocked, mitigating the ecological and recreative qualities around the river. Sedimentation, fish migration, green corridors and recreative connections are not functioning optimally and they should be more involved when redesigning the seven weirs to create an inclusive landscape.

In the upcoming future, the river Meuse should function as an example of how rivers can embrace natural processes instead of pressuring them through barriers. By removing the weirs and implementing a landscape based river dam, processes such as fish migration and sedimentation can be brought to balance again. Next to that, it can bring more interest to the area to improve people's experience. More in-depth information about this new landscape based river dam is elaborated in section 4.2 Conceptual approach.

In Figure 25: Meuse vision the Meuse can be seen as a corridor, a blue-green backbone for the ecosystem in the surrounding landscape. Outwards from this central corridor, several side streams connect to the high-value natura 2000 areas.

The focus species of fish from section 2.4 Ecological quality are illustrated on the vision map on their natural habitat. The *Salmo trutta* in the south part of the river, in fast flowing side streams connected to the river Meuse. The *Squalius cephalus* in the Grensmaas area, in a gravel and fast water flow habitat. The *Misgurnus fossilis* in the north part of the Meuse in a clay soil habitat. When the weirs are transformed these three species are monitored and used as an indicator to see how the fish species behave on the intervention in the new river Meuse dam system.

The series of seven weirs in the Dutch part of the river Meuse is a unique system in which seven locations are all working together while being many kilometres apart from each other. Transforming all seven weirs gives an opportunity to create a standardised design, applicable to every weir location. However, every location is different in terms of topography, soil conditions and experience, which means differentiation is necessary. Differentiating in experience is done by creating a catalogue with seven landscape elements, applicable in the surroundings of the weirs. Some elements might be great for one location, while others can be irrelevant for the other location. This catalogue is constructed in section 3.2 Landscape catalogue.

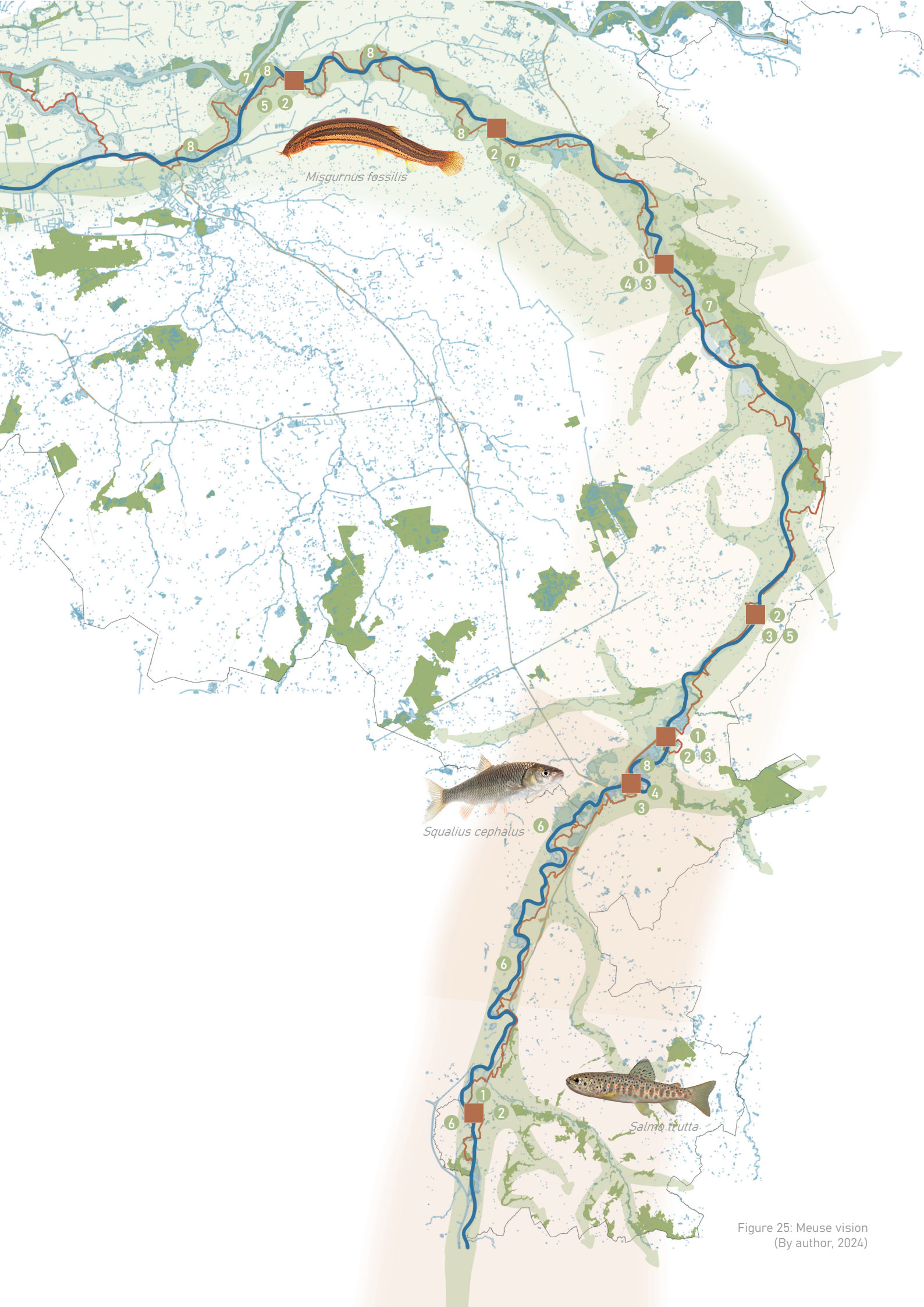


Figure 25: Meuse vision  
(By author, 2024)

## 3.2 Landscape catalogue

Resulting from the landscape vision, a catalogue with landscape elements is constructed, applicable in the design phase of the project. These elements are elaborated in this section. Not all landscape elements can be implemented on every weir location. Therefore, section 2. Landscape analysis functions as a foundation on decision making which element to implement where. In section 4 Large scale design the application and selection of these elements per weir location is shown.

The landscape catalogue is constructed to create a guideline for improving people's experience around the weir areas. Some of them also have an added ecological value. The seven landscape elements are 1. Elevated paths, 2. Building transformation, 3. Recreational banks, 4. Fishing spots, 5. Canoe route, 6. Flood forests, and 7. Old meanders (See Figure 26: Landscape catalogue).

### 1. Elevated paths

Elevated pathways are a great way to improve the routing in the weir area, since many current paths have a dead end according to section 2.4 People's experience. Most weirs are located in flood areas, which means non-elevated paths will be flooded occasionally.

### 2. Building transformation

As mentioned in section 2.4 People's experience, current weir maintenance buildings create an industrial atmosphere and look abandoned. When redesigning the weirs, the current weir buildings are not needed anymore. More about this in section 4. Floodable river dam. By removing the buildings and transforming them into viewpoints of the area it will increase the experiential value, while mitigating the industrial atmosphere.

### 3. Recreational banks

Recreational banks are lacking, which is a missed opportunity in these unique weir areas. When redesigning the weirs, elements such as soft banks, grassy fields, benches and other facilities can be implemented.

### 4. Fishing spots

As mentioned in section 3.1 Landscape vision, native fish species play an important part in the redesign of the weirs in river Meuse. Fishing spots can seem contradictory to improving fish migration, however by regulating fishing on designated areas, the fish population can be monitored. With this valuable data, the migration of native fish species can be monitored, while controlling the invasive fish population.

### 5. Canoe route

Most parts of the river Meuse are used as a waterway for shipping, as mentioned in section 2.2 Water system. This means a canoe routes are not possible there. The few parts where these routes can be established should be used to create a boost in experiential value in the area,

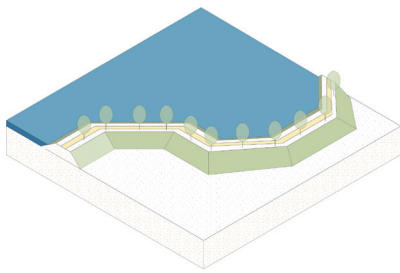
### 6. Flood forests

As mentioned in section 2.3 ecological qualities the important corridors connecting the river to nature areas are currently not present. Section 1.2 Context showed that in history the area surrounding river Meuse was full of forests. These forests were so called 'Ooibossen' with a high ecological value. In current times these forests are rare, and through restoring these forests, old ecosystems can be re-established.

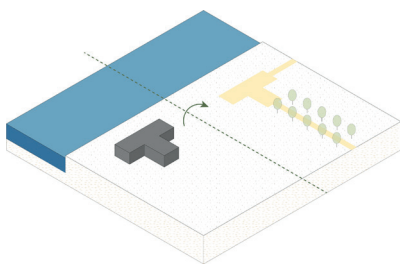
### 7. Old meanders

Since the river Meuse has been canalised, the natural process of meandering has been halted. By restoring these old meanders, the river can reclaim more of its old streambed, improving ecological qualities and water retention.

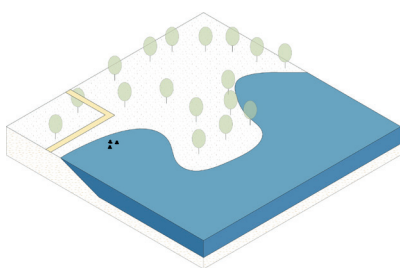
1 Elevated paths



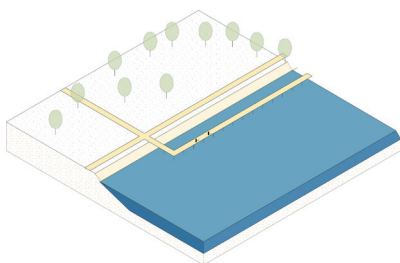
2 Building transformation



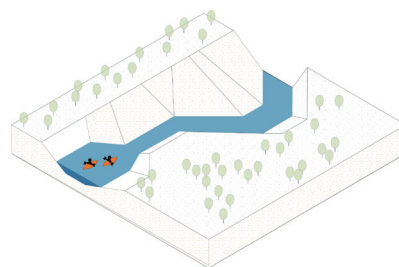
3 Recreational banks



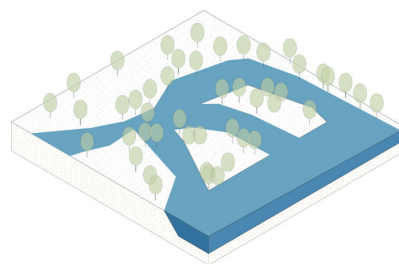
4 Fishing spots



5 Canoe route



6 Flood forests



7 Old meanders

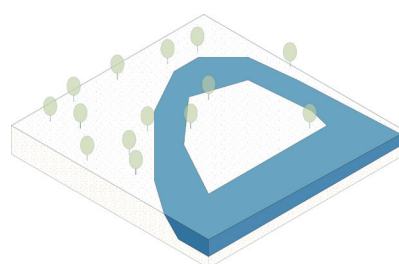


Figure 26: Landscape catalogue (By author, 2024)



# 4. Conceptual approach

Based on the landscape diagnosis, a design for a new transformed weir is elaborated in this section. This is one standardised design which will be integrated in every specific weir location. The concept is formulated in section 4.1 Weir as nexus. In section 4.2 Floodable river dam, the technicalities of the concept are addressed. Finally in section 4.3 Design approach the used landscape design strategy is explained.

# 4.1 Weir as nexus

The transformation of the seven weirs of the river Meuse is all about the balance between differentiating and standardising. The analyses showed that every weir has its own unique site conditions regarding soil and its surrounding landscape. Through research and site visits these unique identifying aspects of the landscape are discovered for every weir. However, these differentiating aspects of the weirs should be implemented in a standardised renovation approach, to emphasise and improve the visual connection between all seven locations. This visual connection is necessary to understand the big scale story of the river Meuse at every weir location. In this chapter the standardised design is explained.

A current weir in the river Meuse can be seen as a nexus; A central or focal point in a series of connections. Every weir is their own central or focal point in the series of seven, connected by the water of the river Meuse. In the concept, Weir as a nexus, next to the water, the surroundings of the weir also function as a nexus, for nature and culture. In order to transform the site into a central point for both nature and culture, several ecological and recreational conditions should be met.

- Ecological: Weir without mitigating natural processes
- Ecological: Crossable weir area for nature, connecting to a nature network
- Recreational: Crossable weir area for people, mitigating industrial atmosphere
- Recreational: Recreative heritage integrated network in Maasroute.

These nexus transformations are achieved by implementing the following three interventions at every weir location:

## 1. Weir gate removal

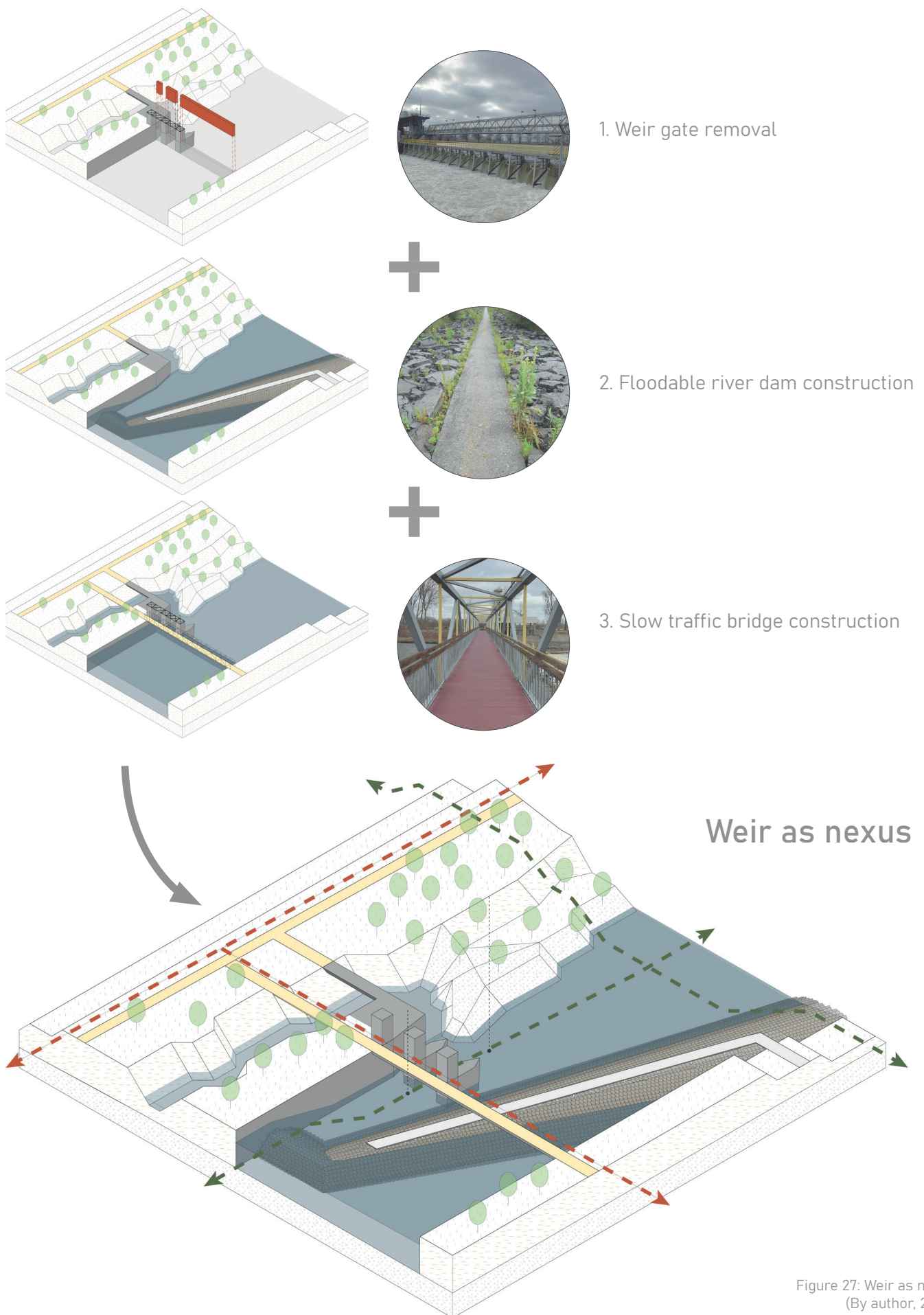
The analyses made clear that the current weirs obstruct natural processes such as fish migration. By removing weir gates, (the buildings can still be valuable monumentally or culturally) fish migration is again possible through weir areas. Next to being crossable for fish, the average flow speed of water will be higher over the course of the river Meuse, because the river is less compartmentalised which increases oxygen levels and thus water quality. The improvement of fish migration can be monitored through the three fish species mentioned in 2.3 Ecological qualities. However, this intervention of removing weir gates on its own causes problems for shipping, which is why step two is implemented.

## 2. Floodable river dam construction

A lengthways angled river dam is constructed as a substitute for the current weirs. The water will be kept upstream by the intricate shape of the system. In section 4.2 Floodable river dam this innovative solution is further elaborated.

## 3. Slow traffic bridge construction

Finally, the areas can be described as unpleasant with an industrial atmosphere. Making the weir crossable for people, and adding functions will help mitigate this negative image the weirs have currently. By making the weirs crossable, the current slow traffic (bike and pedestrian) network including the Maasroute can be rerouted, adding value in experience and heritage by crossing the river Meuse at all seven weir locations.



# 4.2 Floodable river dam

The biggest intervention at all seven weir location is the construction of a floodable river dam in order to stop the mitigation of natural processes. This intervention will act as a replacement for the current weir system, and thus the weir gates need to be dismantled.

The floodable river dam concept is formed by Hans Brinkhof (Rijkswaterstaat Zuid-Nederland), JanJaap Tiemersma and Ron Agtersloot. The main driving force behind this concept is the improvement of fish pass ability and the creation of fish habitats for unique species (Deltares, 2021). On top of that, the dam is more robust, and would need only little maintenance compared to the current weirs (Agtersloot, 2024). The floodable river dam concept is in an early stage and much research needs to be done to implement such. One point for further research is the slight increase of the upstream water level, which has a big impact on shipping. Next to that, the water table cannot be raised or lowered manually. On top of that, the difference in sediment behaviour and stacking ice sheets during cold winters could cause problems, blocking off the floodable river dam. Experts on specific fish species are needed to research the new passage method, and habitats. The costs of the construction of the new dam should be investigated, and compared with the annual costs of the current weirs (Deltares, 2021). In this thesis the placement of the floodable river dams in their surrounding landscape is investigated.

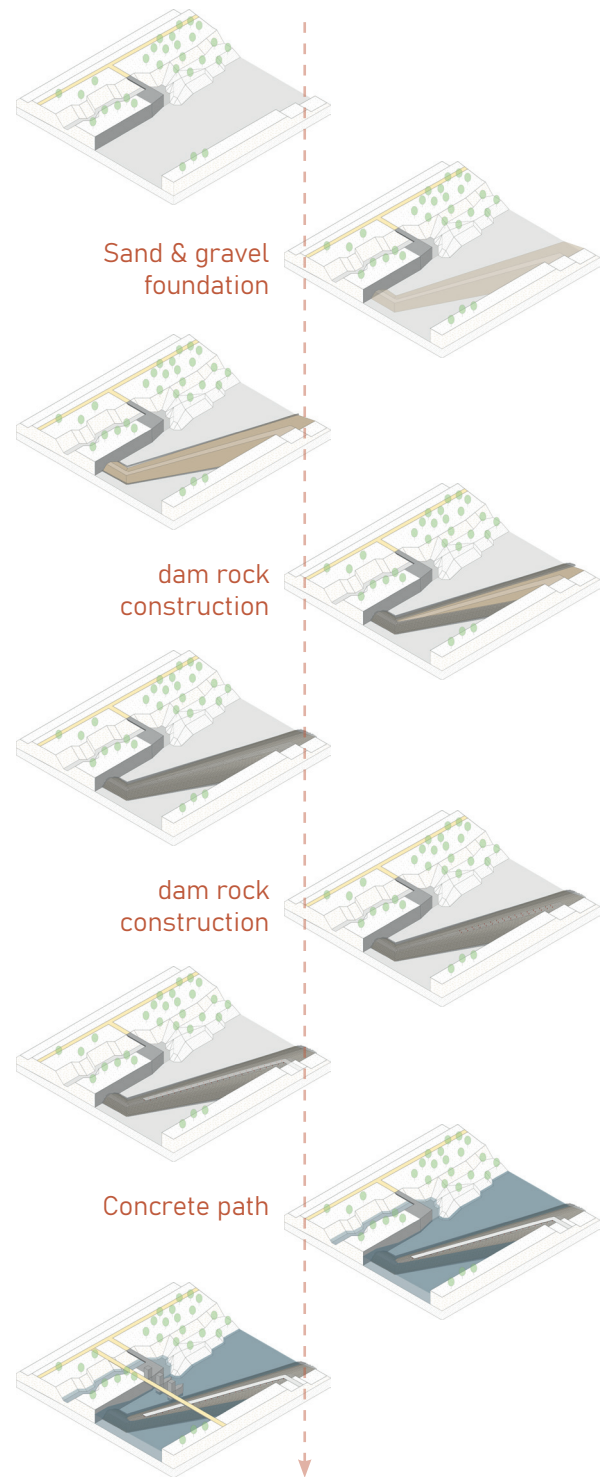


Figure 28: Floodable river dam materials (By author, 2024)

Several conditions of the river dam concept have a big influence in the placement in the landscape. Certain aspects have been estimated and calculated, to make a complete landscape design of the area.

- As illustrated in Figure 28: Floodable river dam materials, the shape of the floodable river dam is not a horizontal barrier like a weir. The shape follows the course of the river, but it is slanting slightly which makes the construction lengthy. Next to that, the lengthy shape is sloped, which means it can regulate water levels naturally. When water levels are high, most of the structure will be flooded. When water levels are low, most of the structure is dry. (See Figure 29: Seasonal water level)

- The length of the floodable river dam in this landscape design is around 500 meters. This value is derived from the first technical design drawings (Van Schee, Brinkhof, 2020).
- The material of the river dam has properties which make water push up when it is placed in the shape of the design. In this standardised design proposal, sturdy rocks found in the Meuse region are used in order to construct this floodable river dam. On top of a base layer of gravel and sand, rocks are added with a minimal diameter of 0,5 meters to prevent floating (calculation based on De Heer, 2020). These rocks are piled up to resemble the shape shown in Figure 28: Floodable river dam materials.

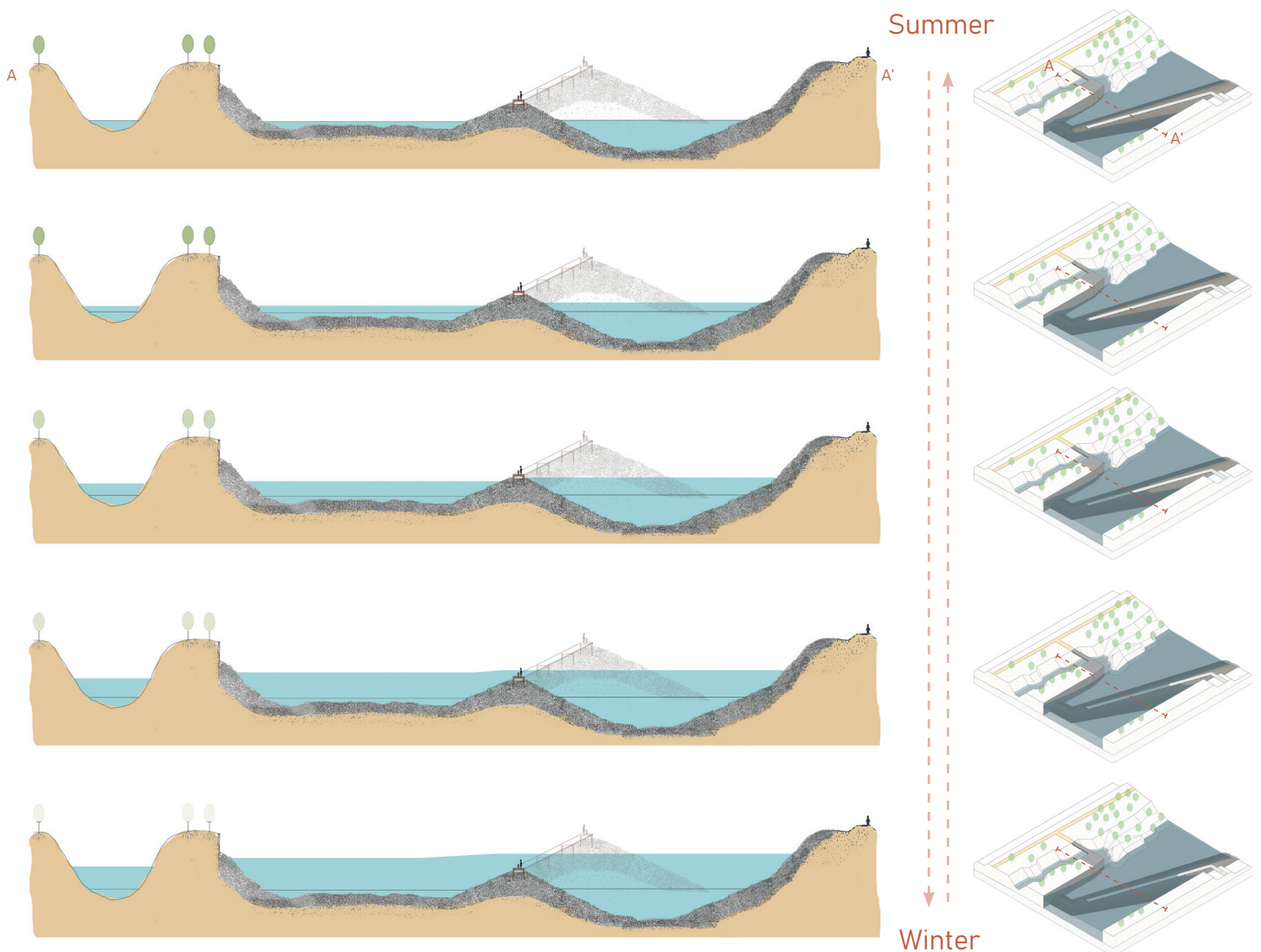
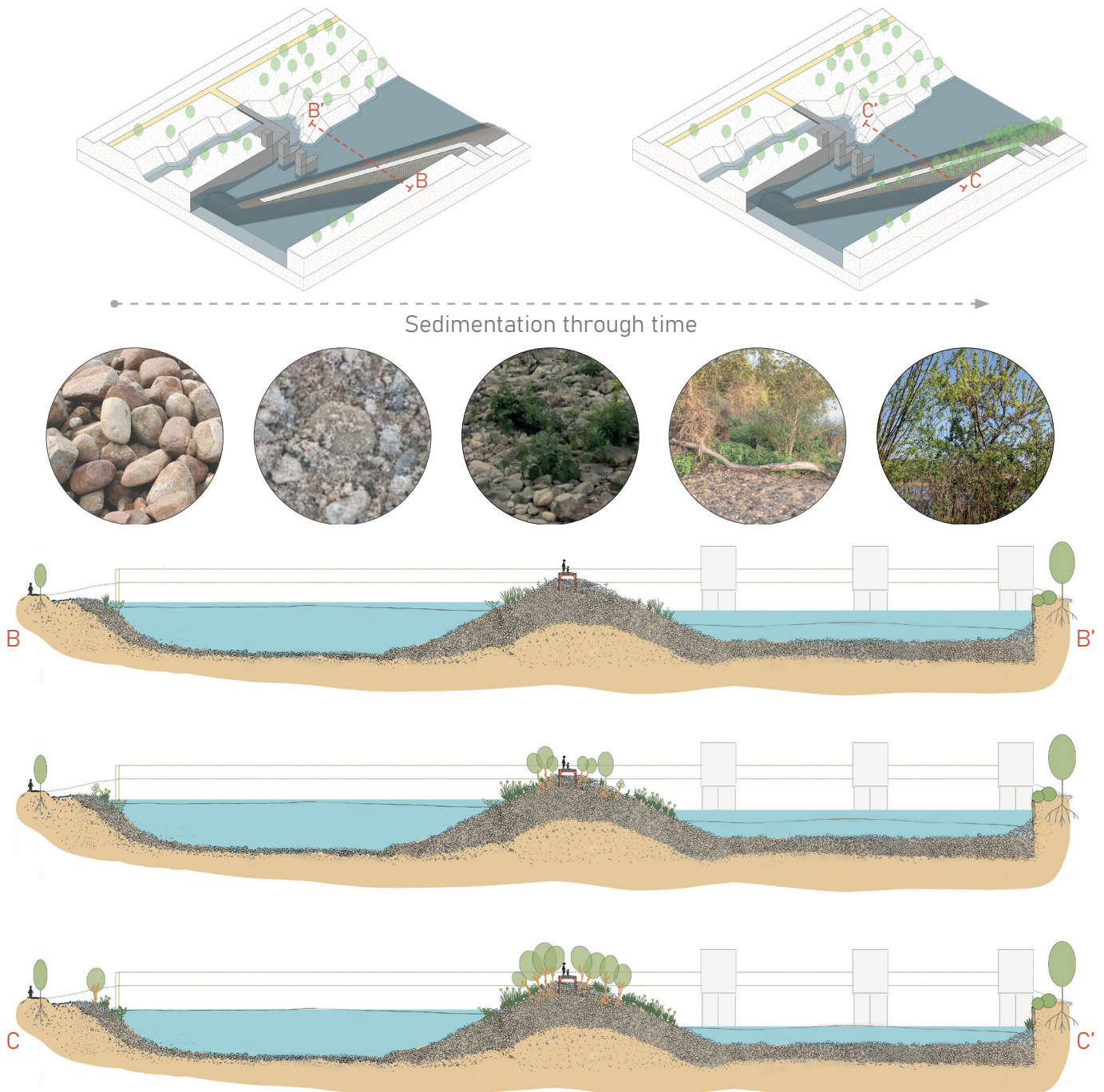


Figure 29: Seasonal water level (By author, 2024)

- On top of this rock pile there will be pathing in a straight line, constructed from concrete and old materials from the weir gates. Maintenance on concrete pathing is kept low, and this material can easily withstand periodic flooding. The weir gates are implemented below the concrete in order to support and elevate the pathing. The pathing on the floodable river dam is entirely usable during dry summer months, but during winter the pathing is mostly flooded.
- As a reference for this concrete path on rock material the transformation of Maurice Rose Airfield in Frankfurt am Main, Germany is used. Redesigned by Gnüchtel Triebswetter Landschaftsarchitekten (GLT), this old airfield is now accessible for people. Old asphalt from runways is deconstructed into a rocky material, where vegetation growth can occur spontaneously. A thin strip of old asphalt is kept as a pathway



Floodable river dam construction, on top of weir gate removal and bridge construction will change the landscape immediately after implementation. These three interventions will also help elevating the landscape to a new level through time.

As mentioned before, the sedimentation behaviour of the river at the weir locations will change when the floodable river dam is in place. At first, the dam will consist of rocks with many gaps in between. Periodically sediment will settle in these gaps, solidifying the positioning of the dam,

whilst adding soil material for several types of vegetation. In the first years this will lead to growth of small aquatic plants. After years of sediment collection more and bigger species can grow on the floodable river dam. Bushes and small trees can get their roots into this large deposit of sediment between the rocks, and solidify the dam even more. This process of evolving continues, and the river dam once consisting of only rocks will merge with the surrounding landscape when vegetation starts to spread over. The most common vegetation on the river dam will consist of the species below.

Floodable river dam vegetation species



*Nuphar lutea*



*Ceratophyllum demersum*



*Phragmites australis*



*Salix alba*



*Alnus glutinosa*



Figure 31: Maurice Rose Airfield (Bravo Bordas, 2018)

## 4.3 Design strategy

When implementing the conceptual approach at every weir location, a strategy for detailed design should be discussed. In this section the approach for designing on a smaller scale whilst respecting both ecosystems and recreative value is elaborated.

To determine how to design this landscape inviting for nature but also aesthetic for humans is a topic discussed in *Messy Ecosystems, Orderly Frames* (Nassauer, 1995). Ecological quality has a tendency to look messy and not aesthetically pleasing. Think for example of a front yard. People tend to prefer well-maintained, structured gardens. On the other hand, people tend to dislike messy and wild gardens, where weeds are thriving. This can cause problems when elaborating a design which has a purpose of increasing ecological quality. To comprehend these messy landscapes, it is better to put them in orderly frames (Nassauer, 1995). A different understanding of aesthetically pleasing landscapes could help in transforming landscapes for the better.

A project in which this design method is used is the Park am Gleisdreieck in Berlin, Germany, designed by Atelier LOIDL. In figure it can be seen that the grass is well maintained, while the railroad track and its curbs function as an orderly frame for the messy ecosystem that is evolving in between the tracks. On the second figure the well maintained path, elevated and bordered with hard edges is a stark contrast between the messy forest ecosystem next to it.

During the site visits from [section 2.4 People's experience](#), this contrast between messy ecosystems and orderly frames was found near weir Sambeek, figure... The well maintained hedgerow functions as an orderly frame in front of the more wilder and messy vegetation growth.

The principle of designing with orderly frames around messy ecosystems is something that is used in [section 6. Detailed design](#). Hedgerows are used as an orderly frame while the floodable river dam functions as messy ecosystem.



Figure 32: Maurice Rose Airfield vegetation (Bravo Bordas, 2018)



Figure 33: Park am Gleisdreieck rail (Börner, s.d.)

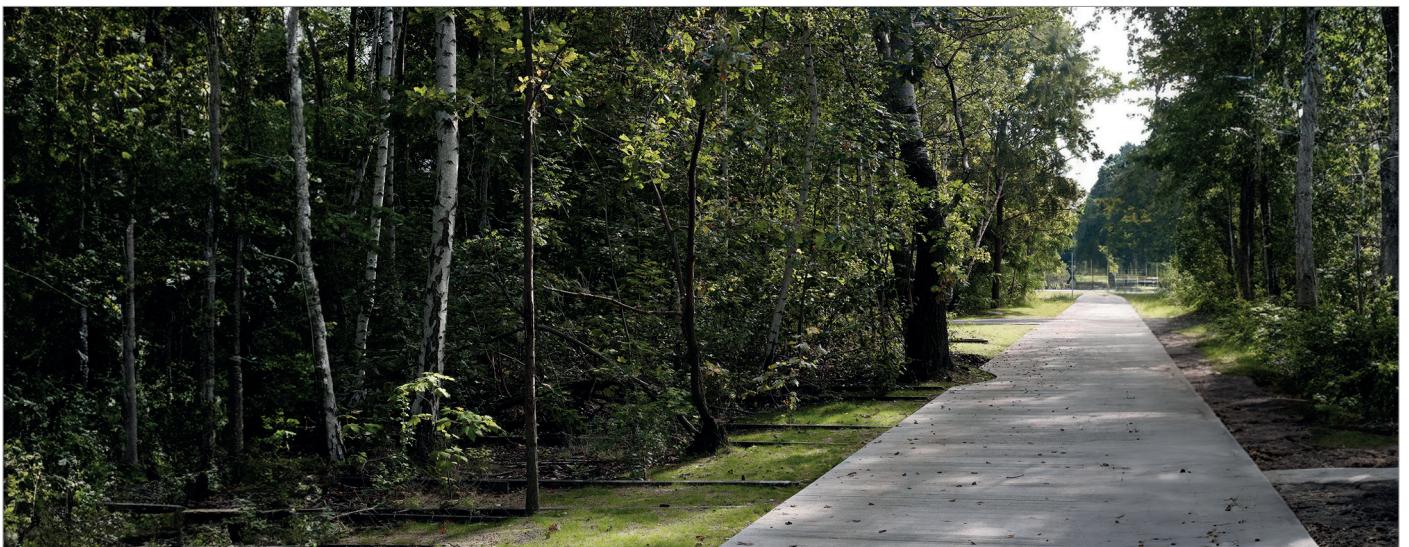


Figure 34: Park am Gleisdreieck path edge (Atelier LOIDL, s.d.)



Figure 35: Hedgerow in Sambeek (By author, 2024)



# 5. Large-scale design

This section is all about integrating the conceptual approach in a large scale landscape. Section 4. Conceptual approach is used as a base for all seven designs. Landscape elements from the catalogue in section 3. Landscape diagnosis are used to differentiate between the designs in every location. All seven weirs, Borgharen, Linne, Roermond, Belfeld, Sambeek, Grave and Lith are explained, starting with the first weir in Dutch river Meuse, Borgharen.



# 5.1 Borgharen

The weir in Borgharen is an outlier in the weir sequence, because downstream there is the natural flowing river Grensmaas. This river is the only natural part of the river Meuse. Cargo ships pass through the Julianakanaal on the east side of the river. There are two side rivers of river Meuse in close proximity of the Borgharen weir, the Jeker and the Geul. The Geul is an important corridor to the Heuvelland, for both recreation and biodiversity. The weir can be connected to this important landscape.

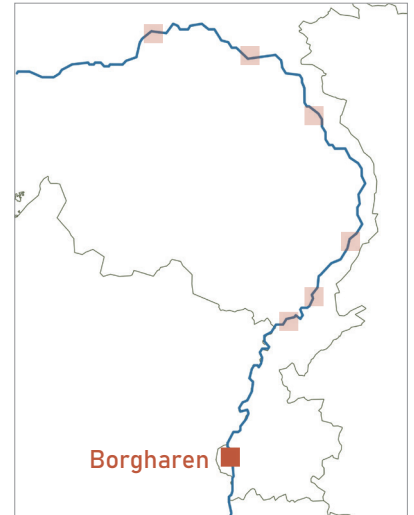


Figure 36: Weir Borgharen location (By author, 2023)



Figure 37: Weir Borgharen context (By author, 2023)



Figure 38: Weir Borgharen (By author, 2023)

The landscape elements added to Borgharen to elevate the experience around the weir area are hedge landscape, elevated paths and canoe route. As seen in the current situation plan of the site area, the Borgharen weir is on the west side connected to nature area Boscherveld. In contrast there is a big industrial site located north-east of the weir. As mentioned in 2.4 People's experience, these industrial areas mitigate natural processes and a pleasant human atmosphere.

By expanding the hedge landscape next to pathing on the north and south side of the weirs, people are guided towards the weir connections, creating a pleasant experience. On top of that, the hedges function as corridors for wildlife to the valuable Heuvelland landscape.



Figure 39: Park Boscherveld (Van Schijndel, 2023)



Figure 40: Castle Borgharen (Kasteelborgharen, 2023)



Figure 41: Map and diagram Borgharen current situation (By author, 2024)

Addition of paths in park Boscherveld is necessary to create a functional path system year-round. Not only cyclists from the Maasroute bike trail can cross this area now, but also local inhabitants have a new hiking route on a smaller scale. This new path loop in park Boscherveld can easily be connected with both the heritage of the old weir buildings, and castle Borgharen, north of the weir.

Lastly, a canoe route is installed at weir Borgharen, because it is the only weir which leads into a recreative river, instead of a canalised river for shipping. This makes Borgharen the best choice for a new canoe hub, starting at the weir location. Around the weir the former fish pass can be used for one canoe route, while the main floodable river dam can also be used as another. More detail about this can be found in section 6.1 Borgharen detail.

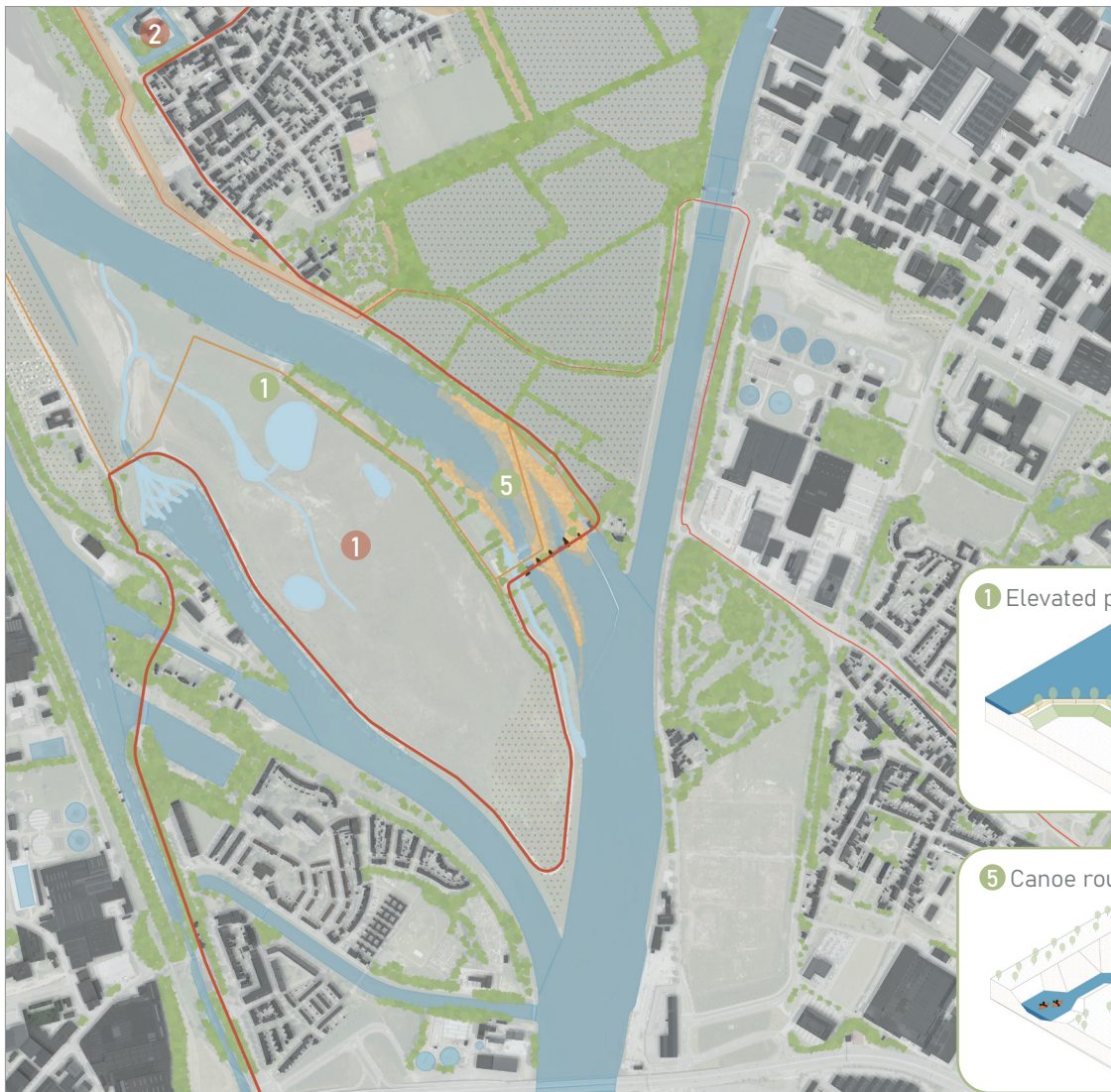
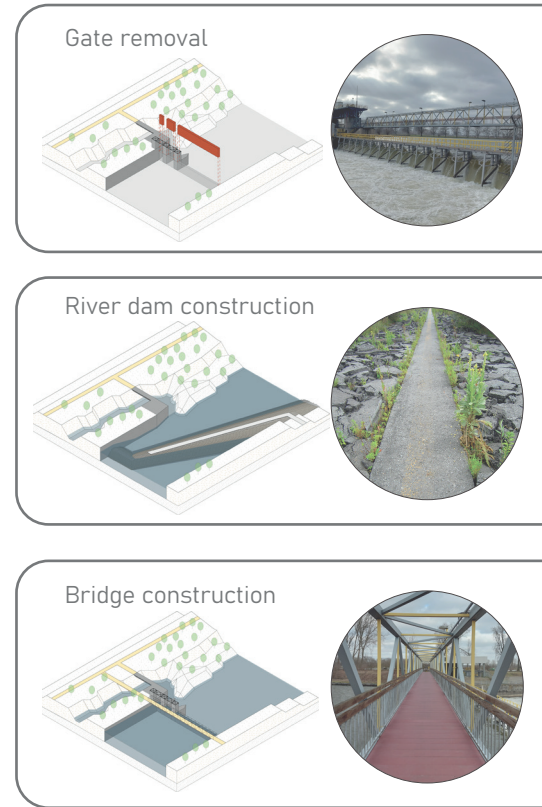


Figure 42: Map and diagrams Borgharen new situation (By author, 2024)

# 5.2 Linne

The second weir in the sequence is Linne. The biggest difference between Linne and most other weirs is that a slow traffic traverses the weir. Because of this, many routes already cross the river Meuse at this connection hub.

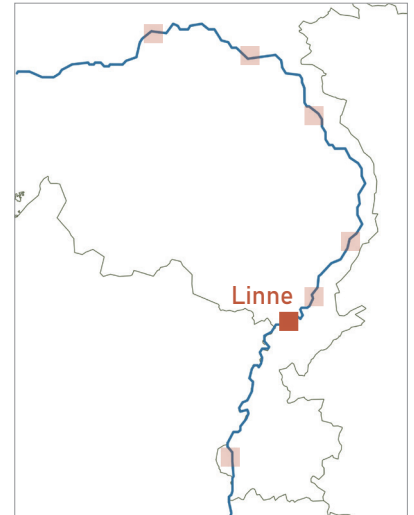


Figure 43: Weir Linne location (By author, 2023)

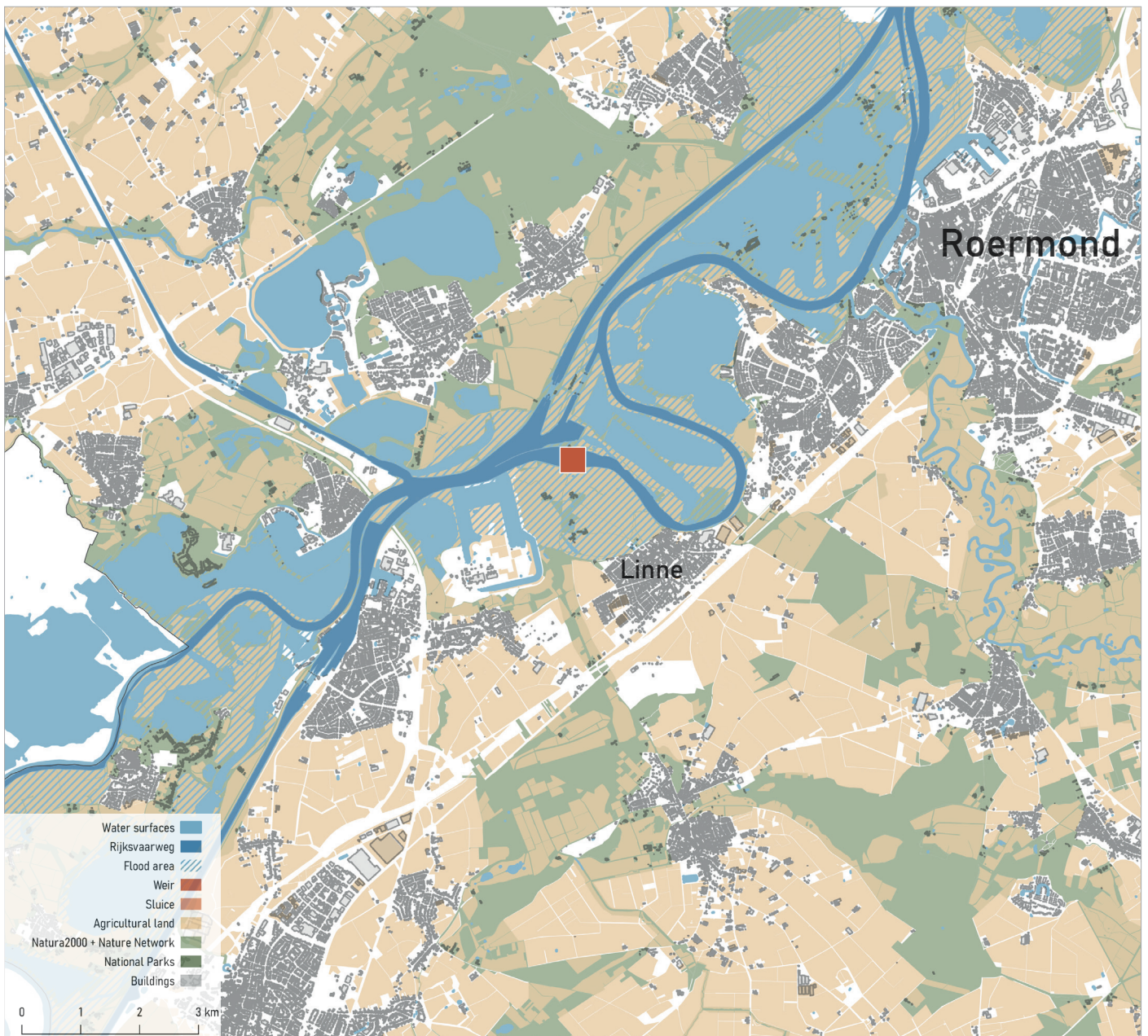


Figure 44: Weir Linne context (By author, 2023)



Figure 45: Weir Linne (By author, 2024)

The landscape elements added to weir Linne are transformation of weir building and recreational bank. Since weir Linne already has a slow-traffic bridge currently (Figure 48: Map and diagram Linne current situation) the bridge construction from the conceptual approach is not necessary.

By implementing the new river dam, the building is not needed anymore, and can be transformed. To elevate the experience at weir Linne, the weir building is transformed into an information centre including several facilities such as a small restaurant and toilets. Currently the building is in a central location, close to the weir and bridge location. It will function as a stop for cyclists of the Maasroute, or as a destination during summer for local people from villages in close surroundings.



Figure 46: Atmosphere Linne (Henrifloor)



Figure 47: Ship lock Linne (Rijkswaterstaat, 2021)

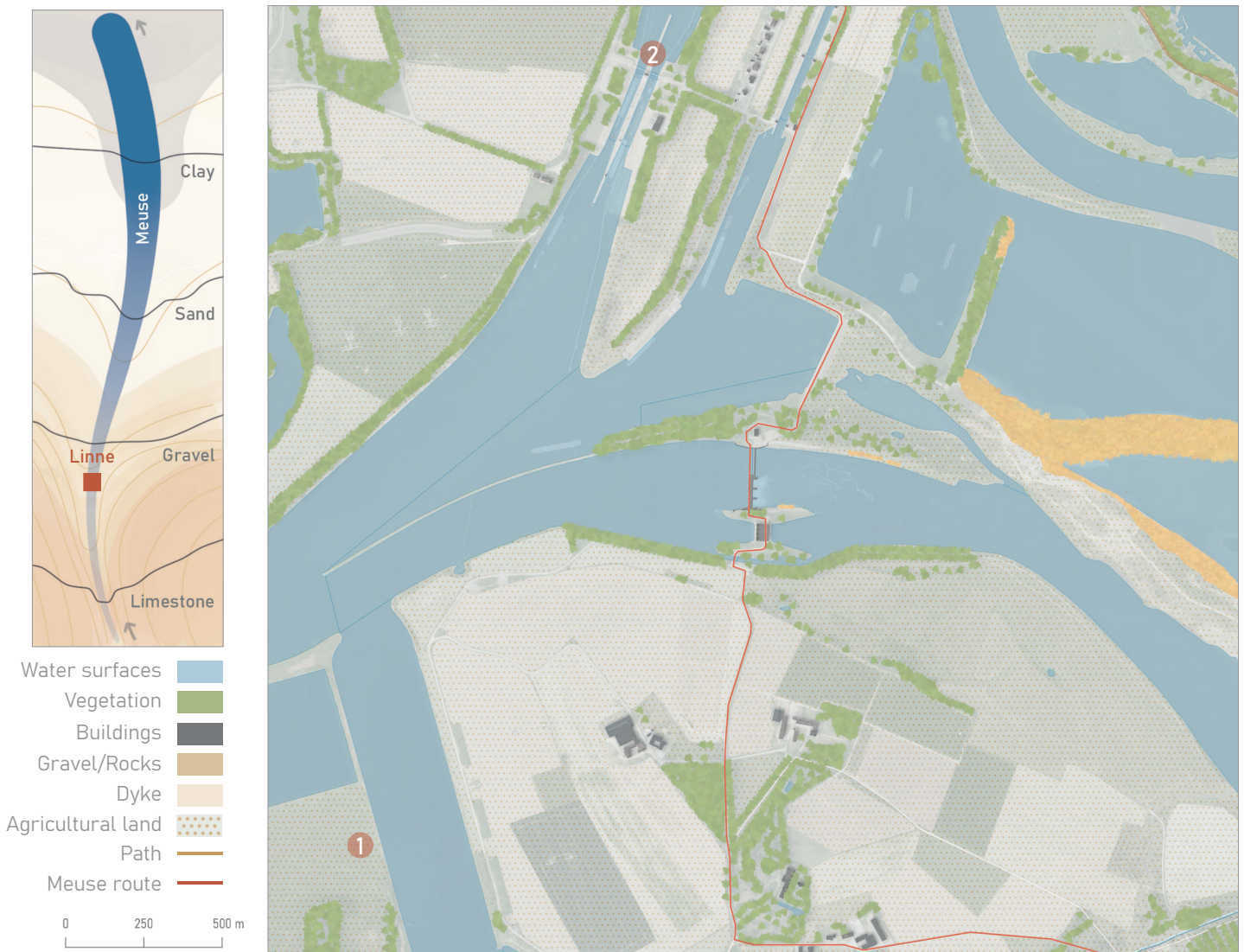


Figure 48: Map and diagram Linne current situation (By author, 2024)

In addition to these new facilities in the old weir building, the banks around the new river dam are transformed to be more inviting for people. The surroundings of weir Linne have many small bays and banks for people to experience the landscape close to river Meuse. Trees are added for more inviting shady places during summer, rock formations and grass plains are used to create more hospitable areas, and finally benches and pathing are added.

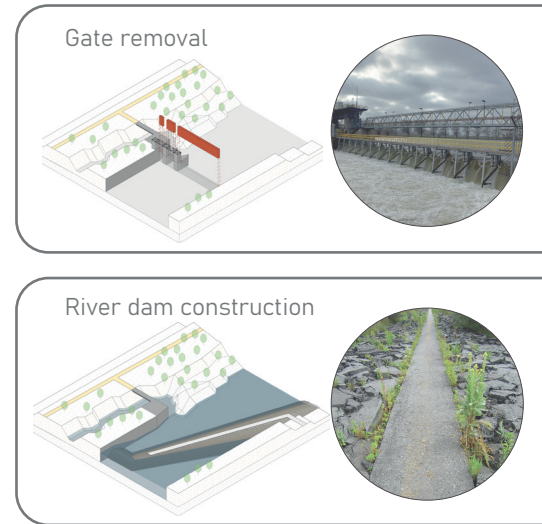


Figure 49: Map and diagrams Linne new situation (By author, 2024)

# 5.3 Roermond

Roermond follows up weir Linne relatively soon. The weir is located close to the city of Roermond, and located in a big flood area called Stadsweide Roermond (Figure 54: Stadsweide Roermond). South of Roermond there is an important corridor to the natura 2000 landscape Meinweg. This corridor is a blue-green network of the rivers Roer and Hambeek.

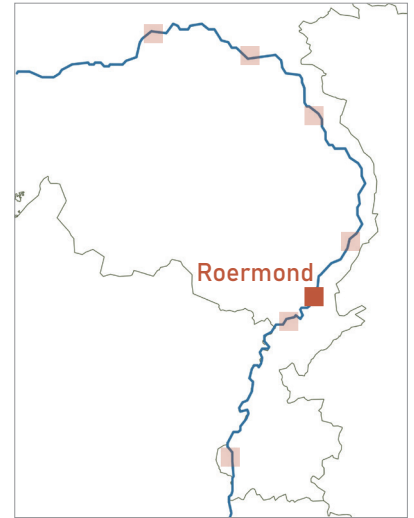


Figure 50: Weir Roermond location (By author, 2023)

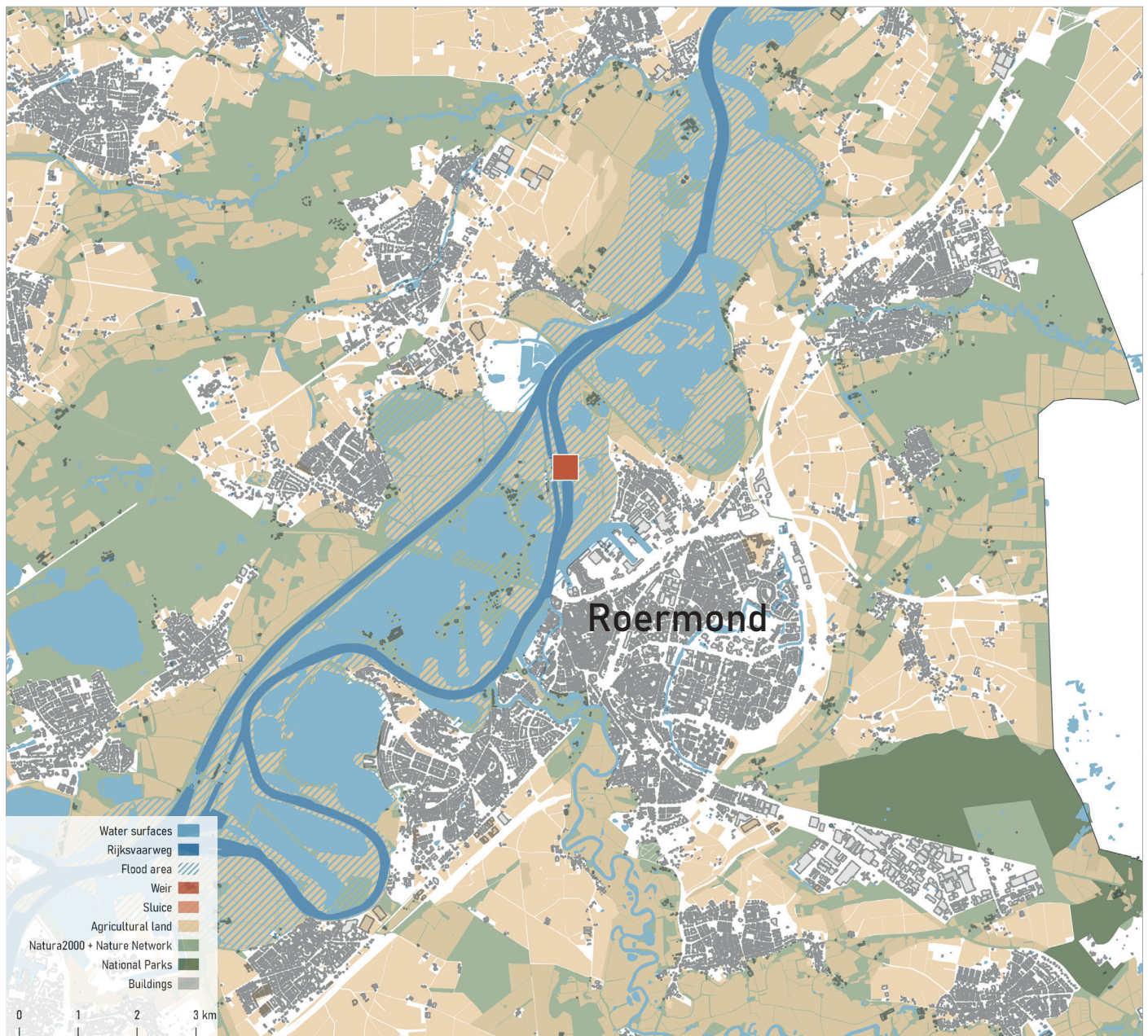


Figure 51: Weir Roermond context (By author, 2023)



Figure 52: Weir Roermond (By author, 2024)

Next to the three additions of the conceptual approach, three landscape elements are added around weir Roermond: hedge landscape, elevated paths and building transformation.

Hedge landscape is added as a functional tool to close off the old weir building area with dense shrub-like vegetation. This is necessary because of activity of beavers in the area (Figure 53: Beaver activity). The hedges are firstly implemented in combination with fencing, but when the hedges have gotten strong enough through time, the fences can be removed. The hedges also have a guiding function for visitors of the area by bike or by foot.

Elevated paths are added to make sure the paths including the new Maasroute are above the water level year-round. Next to this practicality, the elevated paths elevate the experience with better views on the floodable river dam, old weir buildings and the nature area Stadswede Roermond.



Figure 53: Beaver activity (By author, 2024)



Figure 54: Stadswede Roermond (By author, 2024)



Figure 55: Map and diagram Roermond current situation (By author, 2024)

Lastly, the old weir building next to the bridge is transformed. Because the weir building is directly on the place where east-west pathing meets the north pathing it is decided to remove the building in its entirety. More detail about the transformation of this area can be read in section 6.2 Detail Roermond.

The beaver has been extinct in The Netherlands for 150 years until they were brought back in 1988 with big success. Currently they roam everywhere in the country, mostly along rivers. In this image you can see how beavers are tearing down the big trees in Stadsweide Roermond. They are considered a big problem in this area. This raises the question if currently people actually want to rewild the 'human' landscape.

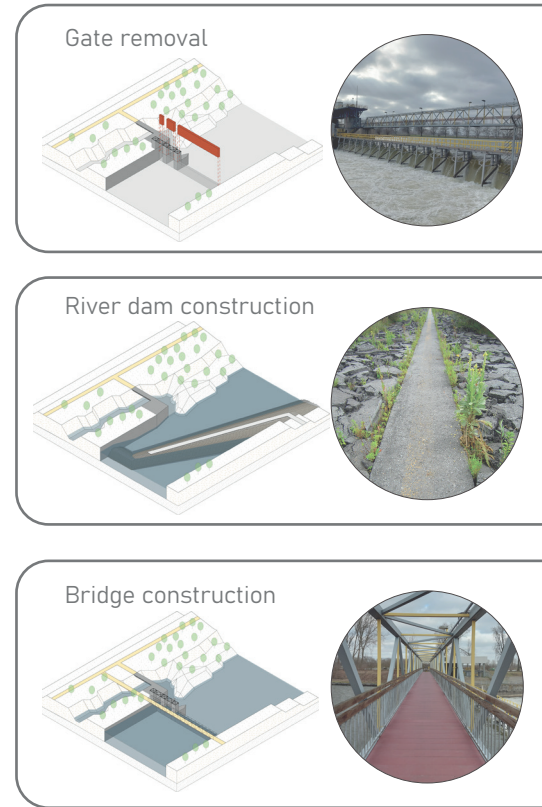


Figure 56: Map and diagrams Roermond new situation (By author, 2024)

# 5.4 Belfeld

The fourth weir in the Dutch part of the river Meuse is Belfeld. The soil is gradually becoming sandier in this area and the water flow speed is getting slower. The weir is located next to the village Belfeld, close to the city of Venlo. As seen on the map there are no nature areas and floodplains directly east of the weir area.

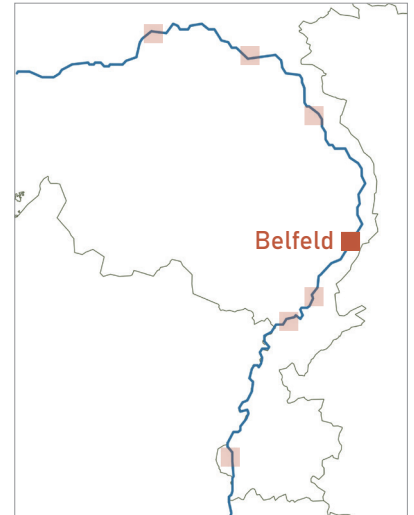


Figure 57: Weir Belfeld location (By author, 2023)

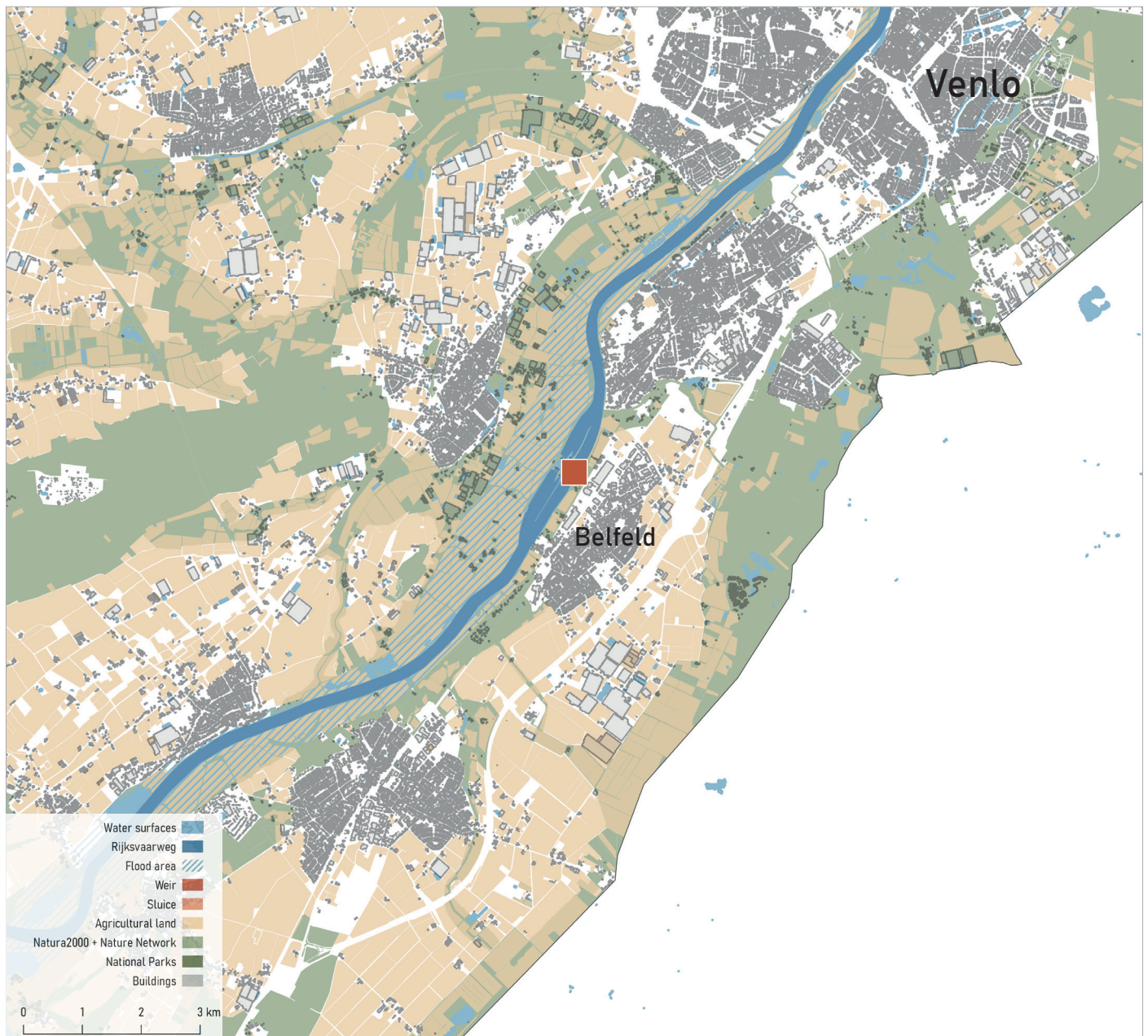


Figure 58: Weir Belfeld context (By author, 2023)



Figure 59: Weir Belfeld (By author, 2024)

Weir Belfeld is a location primarily for local people, since there is not much room for nature areas or other facilities to attract tourists. As experienced during the site visits, the pathing along the river is used by local people. A problem is the lack of routing for these local short walks. People walk up and down in the same straight line along the river, which gives an opportunity to create a better experience when installing the floodable river dam. The landscape elements added in Belfeld are therefore elevated paths, building transformation and fishing spots.

An elevated pathing on the island between the ship lock and the river dam adds a new loop for local walks. In this loop the moveable river dam can be experienced from up close. South of the river dam the elevated path will cross the water as a bridge.



Figure 62: Map and diagram Belfeld current situation (By author, 2024)

The building next to the weir will be transformed into a small park for people to have a break, sit down or relax. Currently the building is blocking pathing all around the area (Figure 60: Atmosphere Belfeld). Removing these barriers and the building will create a new entrance for the weir area where people are invited instead of being kept out of the area in general.

On the elevated paths, north-west of the river dam several fishing spots are implemented. It is necessary to monitor the fish population after the changes in the weir system. Fishing can provide data, while also adding recreational value for people.

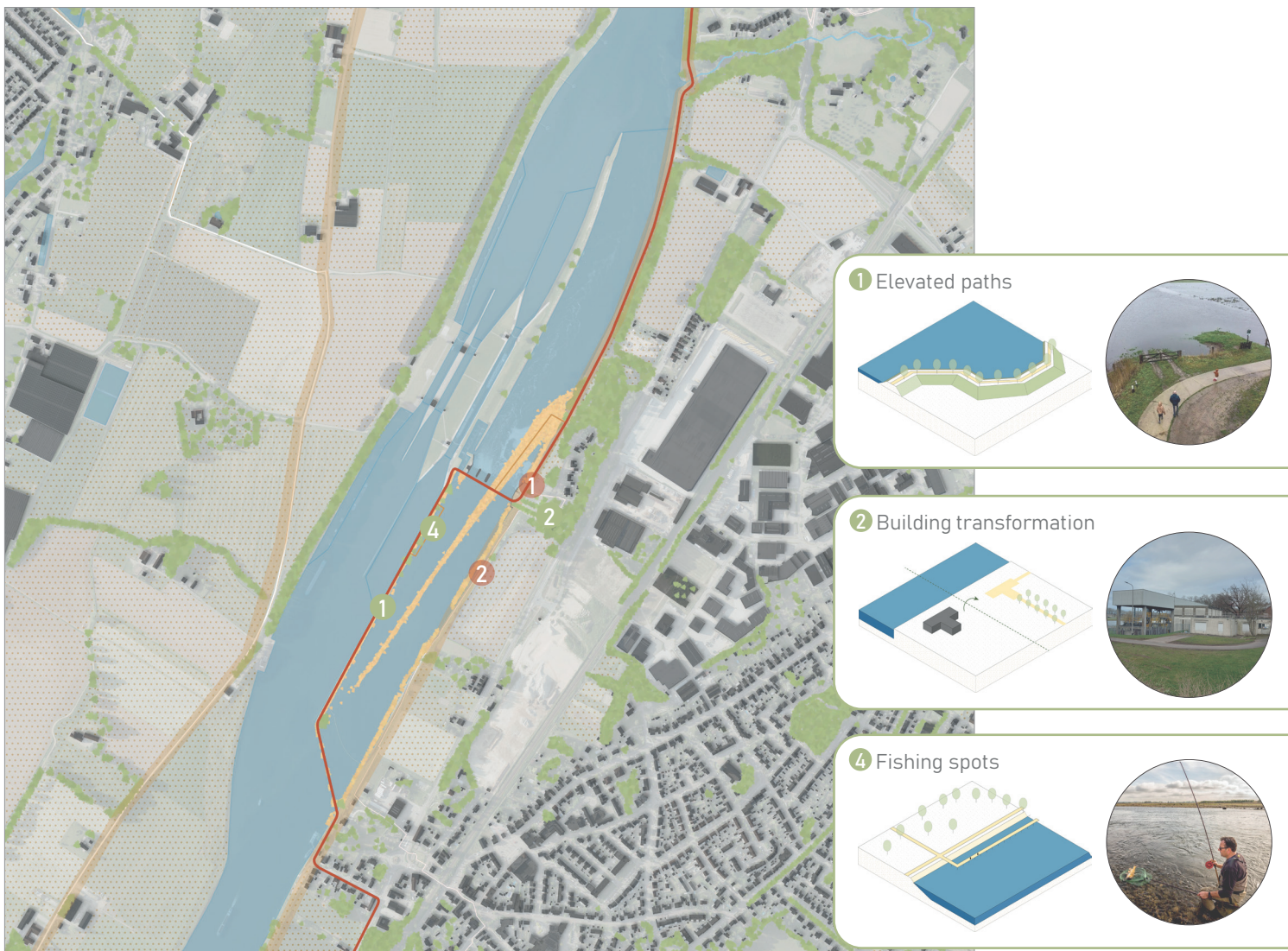
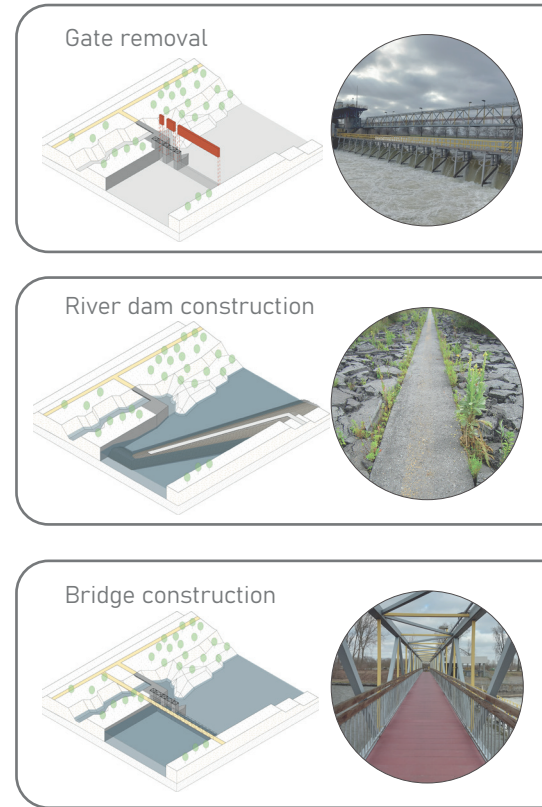


Figure 63: Map and diagrams Belfeld new situation (By author, 2024)

# 5.5 Sambeek

Weir Sambeek is located in between two high value landscapes: Maasduinen and Maasheggen. Maasduinen is a natura 2000 area and can clearly be seen on the map east of the weir. Maasheggen is a collection of different hedgerows with native shrub species. These hedges divide agricultural plots and function as corridor for wildlife. The Maasheggen are cultural heritage, and have been around for centuries because the firm shrub species can withstand floods (Unesco).

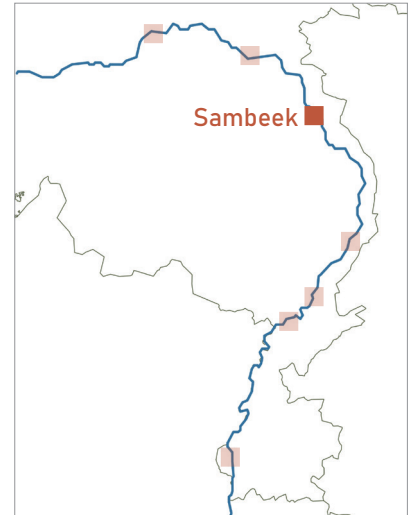


Figure 64: Weir Sambeek location (By author, 2023)



Figure 65: Weir Sambeek context (By author, 2023)



Figure 66: Weir Sambeek (By author, 2024)

Weir Sambeek already has a big entrance in the spatial form of a tree lane at the north side (Figure 6: Weir Sambeek entrance). The downside is that this road leads to a dead end. Implementing the river dam, including slow-traffic bridge will give purpose to this entrance and invite more people to this unique location. Other landscape elements to elevate people's experience at location Sambeek are the hedge landscape, building transformation and recreational banks.

As mentioned in this section, the connection between Maasheggen and Maasduinen is important for both biodiversity and people's experiences. By adding more native hedges to divide agricultural plots the Maasheggen landscape is mimicked. These hedges act as corridor between weir location and Maasheggen, but also between weir location and Maasduinen. The hedges guide hikers and cyclists towards the new river dam.



Figure 69: Map and diagram Sambeek current situation (By author, 2024)

The entrance path leads to the weir building, which is not needed anymore when the weir gates are removed. The building will be removed and can be transformed just like the building in Roermond. More detail about that transformation in section 6.2 Roermond detail.

Recreational banks are added along the upstream edge of the river. At this location there will be several viewpoints towards the floodable river dam, old weir buildings and the cultural hedge landscape.

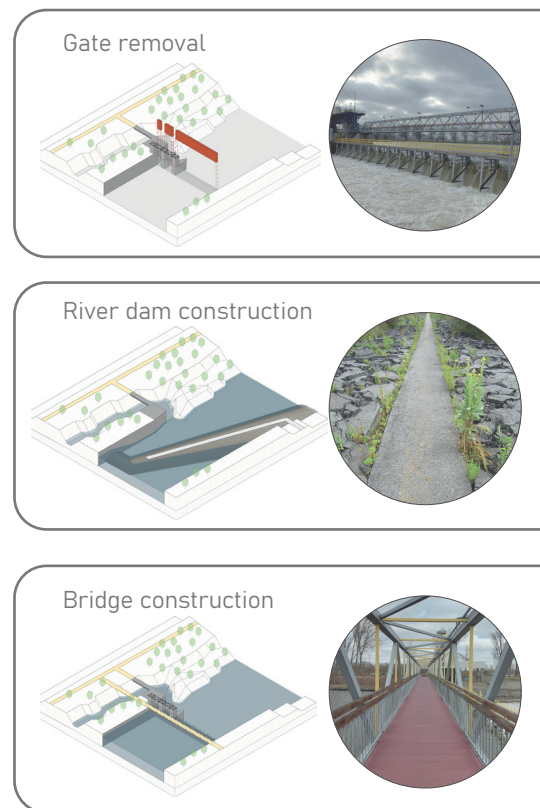


Figure 70: Map and diagrams Sambeek new situation (By author, 2024)

# 5.6 Grave

Weir Grave is the only weir where a bridge for fast and slow traffic is built. Car drivers, cyclists and pedestrians can all cross the river, using the John S. Thompson bridge, named after the lieutenant who liberated the surrounding area in 1944. (Remery, 2021). The bridge does not only cross the weir, but also the parallel ship locks. This means the weir is built high above the water. Ships need to be able to pass underneath. This also results into much grassland underneath the bridge in dry seasons (Figure 73: weir Grave).

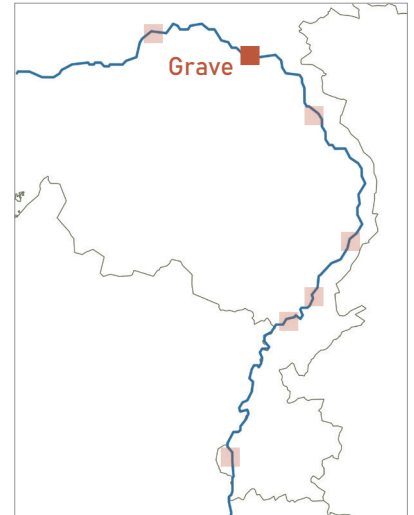


Figure 71: Weir Grave location (By author, 2023)

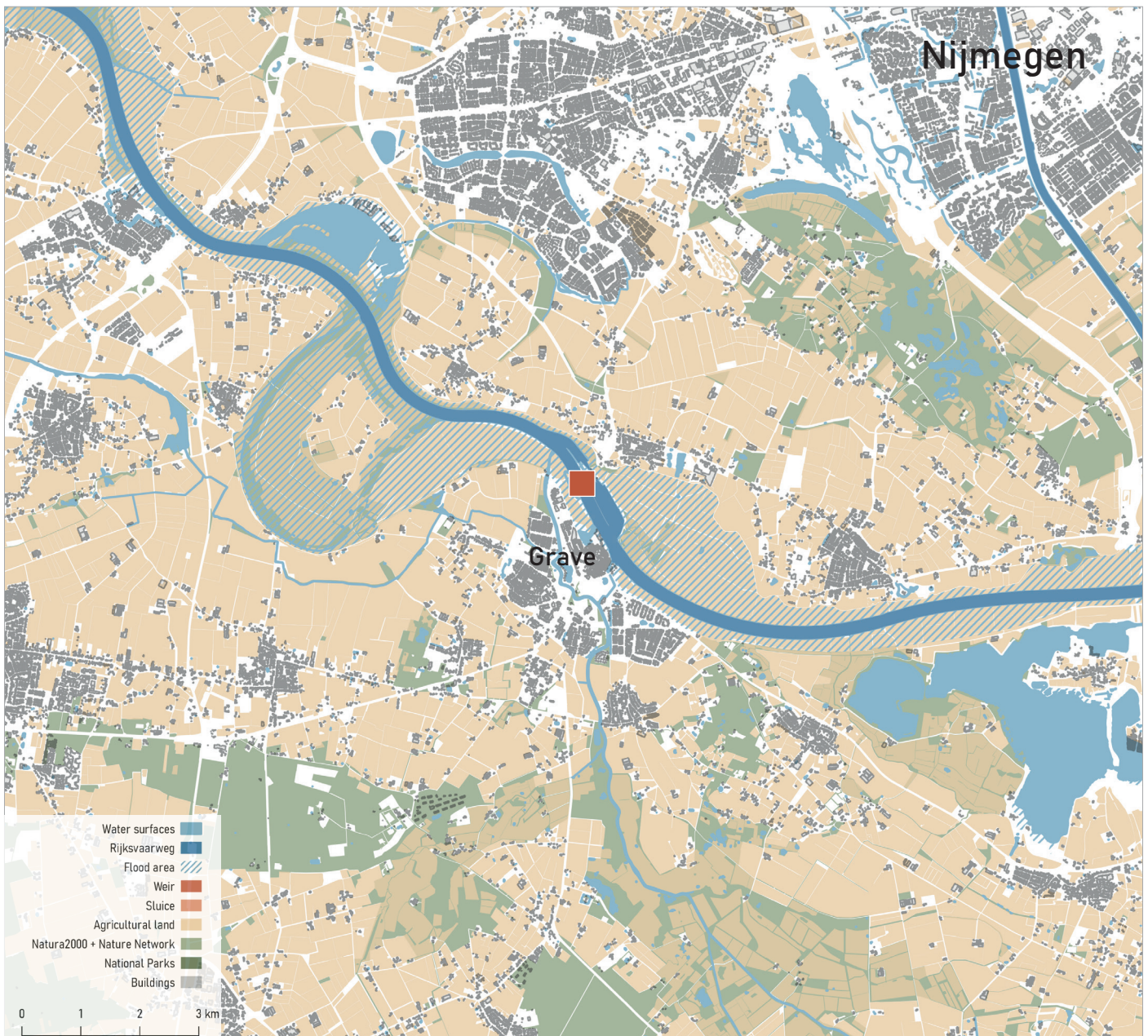


Figure 72: Weir Grave context (By author, 2023)



Figure 73: Weir Grave (By author, 2024)

The bridge construction from the conceptual approach is not necessary in the case of Grave. Other landscape elements added are elevated paths and flood forests.

A certain type of flood forest called 'Ooibos' can be implemented in the area of Grave. These forests consist of *Salix alba* and *Alnus glutinosa* and are the fastest growing forests of Europe. These forests are native to floodplains in The Netherlands, however nearly all have disappeared through time. Certain areas such as Koningssteen and Millingerwaard have restored these old forests, and are one of the most biodiverse landscapes in the river landscape.

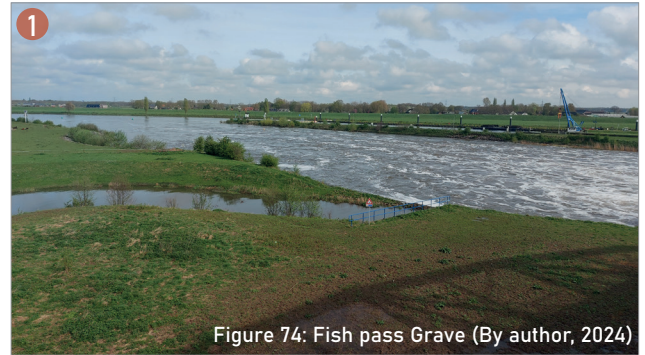


Figure 74: Fish pass Grave (By author, 2024)



Figure 75: Weir Grave 2 (By author, 2024)



Figure 76: Map and diagram Grave current situation (By author, 2024)

Next to that they are a sight for people to see, and people can experience the landscape as it was before the flood forests disappeared.

Grave has the opportunity to transform the agricultural plots with much flood risk into these flood forests as illustrated on the map in Figure 77: Map and diagrams Grave new situation. Trough time the expansion of the forest can be monitored and admired from the John S. Thompson bridge.

The flood forest is not only visible from above. People can experience this unique landscape on elevated paths through the forest area.

The bridge in Grave is not only used by people. Many birds use the steel beam construction as a nesting location. Safer nest options for birds will be available when the flood forest is added.

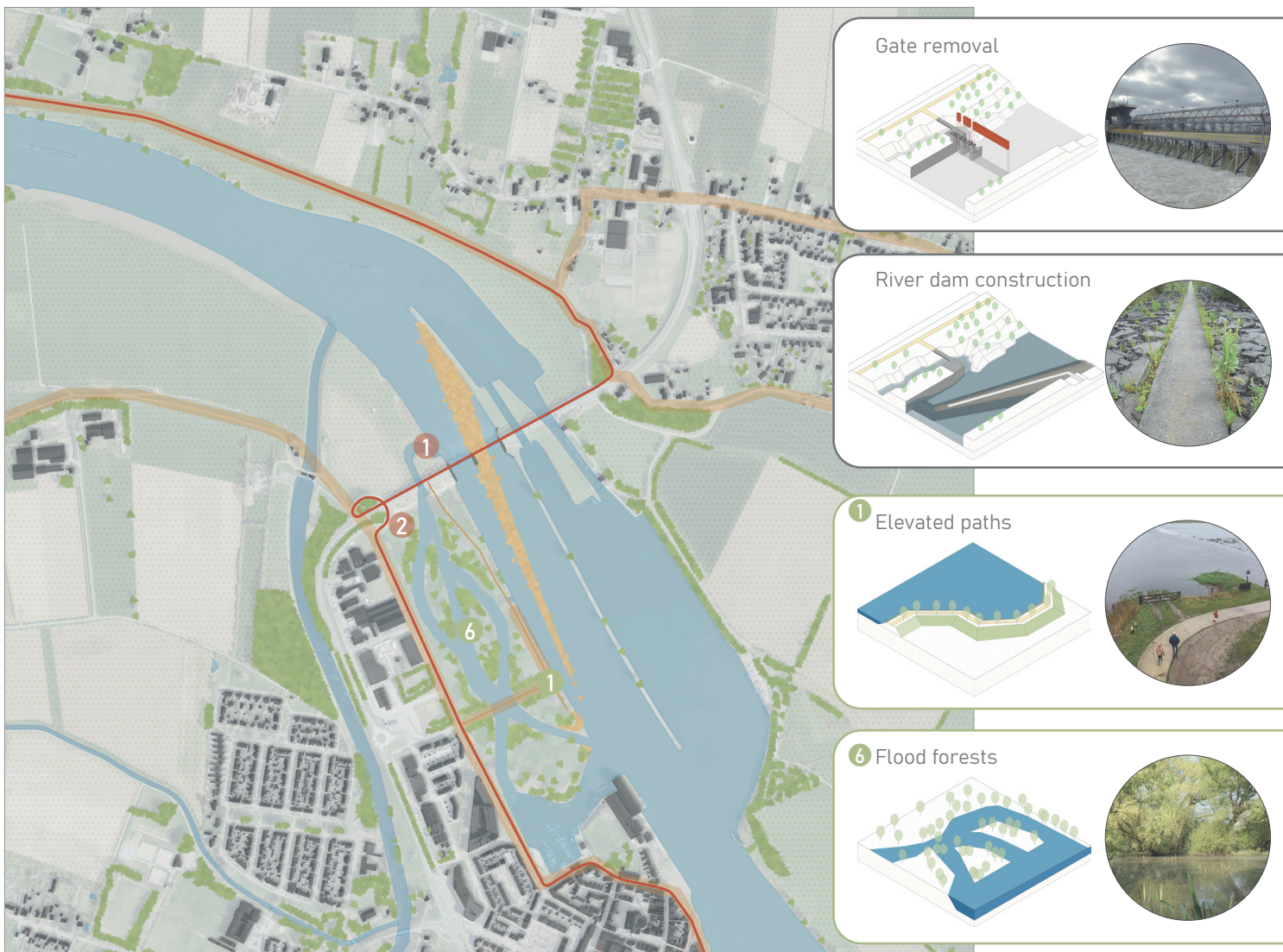


Figure 77: Map and diagrams Grave new situation (By author, 2024)

# 5.7 Lith

The last weir before river Meuse flows freely towards the estuary in the North Sea is in Lith. The soil of the river at this stage consists of mostly clay. Many old meanders are visible in this part of the river (Figure 79: Weir Lith context). Some of these old meanders are agricultural fields, while others are nature areas.

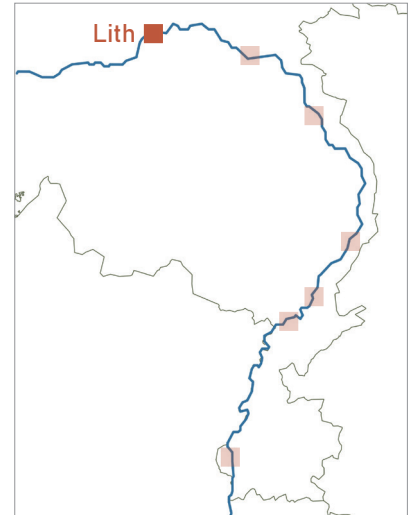


Figure 78: Weir Lith location (By author, 2023)



Figure 79: Weir Lith context (By author, 2023)



Figure 80: Weir Lith (By author, 2024)

Lith has much potential in providing a new experience in the landscape, because of the old meander north of the weir. The landscape elements used for transforming the area are elevated paths, fishing spots, flood forests and old meanders.

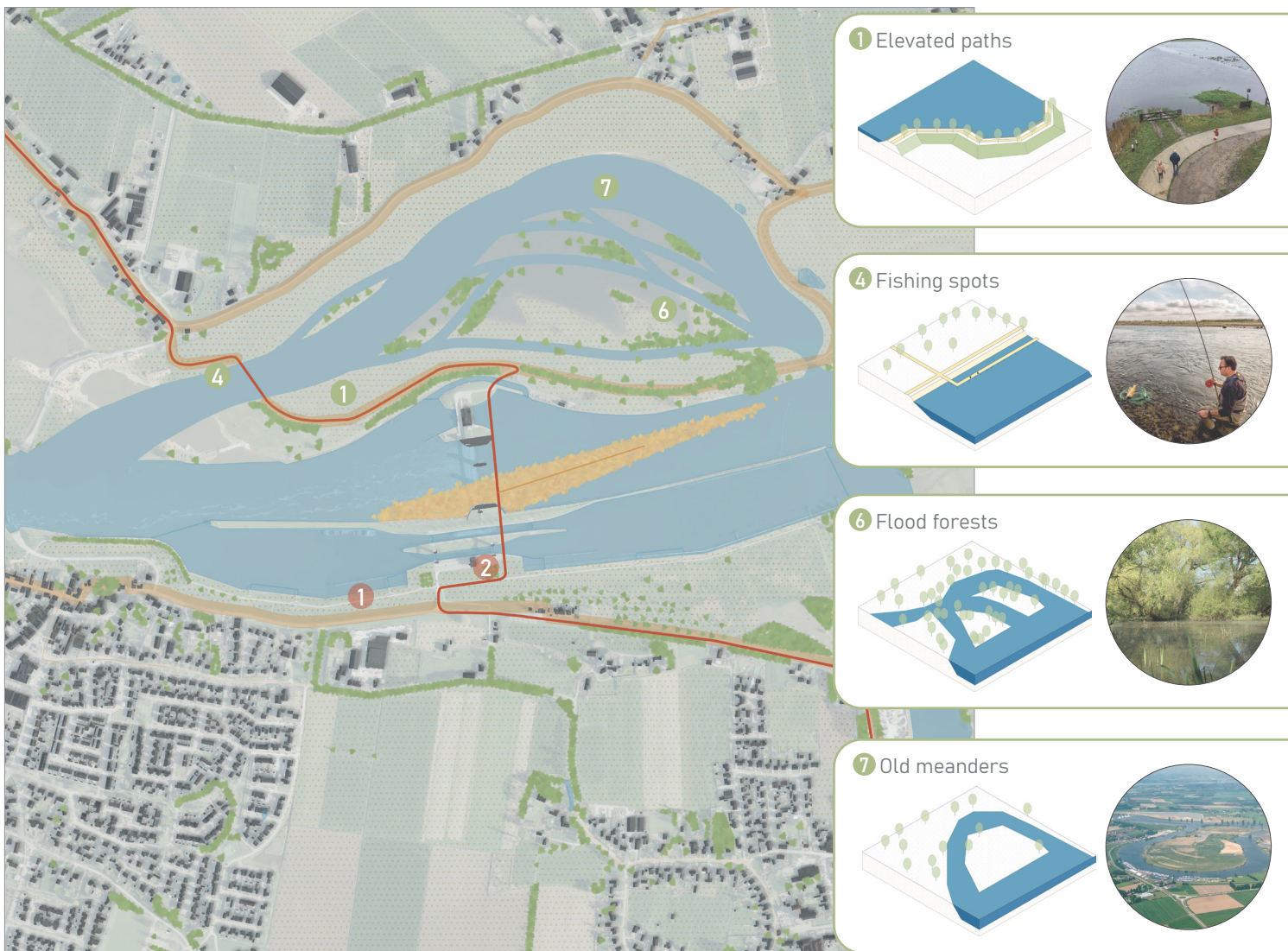
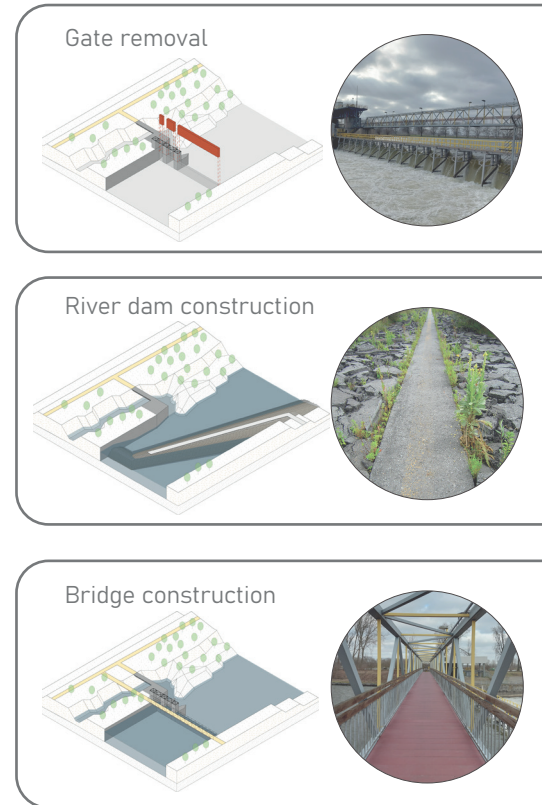
Restoring old meanders is the main focus in this design. Previous meander restoration in the east-neighbouring Hemelrijkse Waard can be continued in the area north of Lith. This brings much potential for biodiversity and people's experience around the area of the new floodable river dam.



Elevated paths are used to cross these restored meanders. The bridge crossing the old weir, river dam and ship lock can be accessed year-round.

Fishing spots are added at the north side of the old meanders. Just as in Belfeld, the monitoring of fish in the river is important to evaluate the effects of the floodable river dam.

The restoration of the meander brings an opportunity to revitalise the area with flood forests, just like in Grave.





# 6. Detailed design

In section 6.1 and 6.2 two zoom-ins on the locations Borgharen and Roermond are elaborated. These two locations are chosen, because currently they have much transformation potential by transforming the weir and by adding the slow-traffic bridge and elements from the landscape catalogue.



# 6.1 Detail Borgharen

In Figure 86: Detail Borgharen a more zoomed-in plan of the floodable river dam is shown. The thoughts behind the plan are explained in this section. Next to that several visual references Figure 87: Canoe route Grensmaas and visualisations Figure 88: Visualisations Borgharen are used to give an image of how the weir and its surroundings look like after the intervention of the floodable river dam.

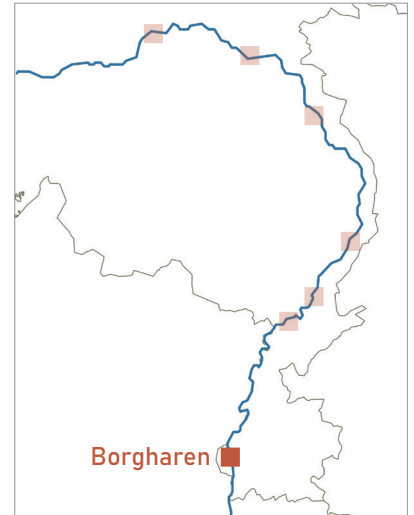


Figure 85: Weir Borgharen location (By author, 2023)



Figure 86: Detail Borgharen (By author, 2024)

The detailed design uses the strategy elaborated in section 4.3 Design strategy. Messy ecosystems, orderly frames is used to frame the 'messy' weir with a structured hedgerow along the elevated pathway, which can be seen in the plan in Figure 86: Detail Borgharen. The river dam south of this hedgerow will require no maintenance, and vegetation will spread all over through time. In contrast the pathing north of the hedgerow will be maintained to keep an orderly frame for the wild river dam.

As mentioned in 5.1 Borgharen, this location is suited for expanding the canoe route in the Grensmaas area. The wild river around the river dam will create many exiting fast streams which creates a unique experience. Some rocks are added perpendicular in the river to create rapids.



Figure 87: Canoe route Grensmaas (Kano Maastricht)



Figure 88: Visualisations Borgharen (By author, 2024)

# 6.2 Detail Roermond

A second detail design is given in this section. In Figure 90: Detail Roermond a more zoomed-in plan is shown. The same approach of the messy ecosystems orderly frames is used as a base. Next to that several visual references Figure 91: Reference path and visualisations Figure 92: Visualisations Roermond give an example of how this area can transform with the addition of the floodable river dam.

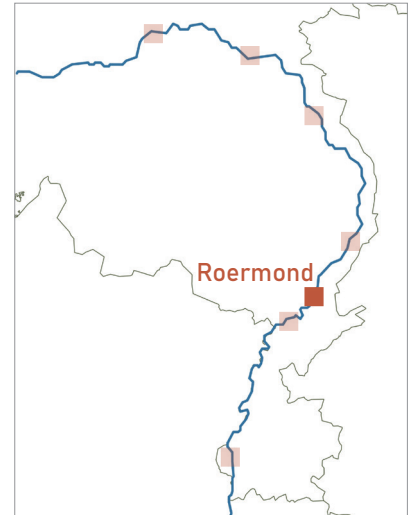


Figure 89: Weir Borgharen location (By author, 2023)



Figure 90: Detail Roermond (By author, 2024)

Just as in Borgharen, the hedgerows are used to create these orderly frames, and the river dam functions as messy ecosystem. The main aspect in which the designs differentiate is the transformed old weir building in Roermond.

The weir building on the river bank is not needed anymore, because heavy maintenance is not necessary when the floodable river dam is installed. The building will transform into a viewpoint where visitors and people en route can have a rest and experience the floodable river dam from an elevated platform. As a relic, the iconic T-shape of the building and re-used concrete elements are kept in the design, while the function of the building is different. On and

around this building, the area is well maintained and bordered with a hedgerow, to keep the contrast between the messy ecosystem and the orderly frame. The re-use of weir buildings can be applied at more weir locations, while the functions can differentiate every time.

In the visualisations it can be seen how the concrete pathing is elevated on top of the floodable river dam. Old beams of the removed weir gates are used as material to elevate the path. The old weir gates are reused sustainably, while it creates a better view experience for visitors.



# 7. Conclusion

A complete conclusion of the project is stated in this section. First the sub-questions from section 1.3 Research question are answered. With those answers the main question is answered

**How are the weirs disrupting biotic and abiotic natural processes currently and how can these barriers be mitigated throughout the river when renovating the weirs?**

Currently the weirs in the river Meuse are obstructing natural processes. In section 2.4 Ecological quality the effect of the weirs on fish species is elaborated. Current weirs can obstruct fish migration due to the small fish passes which cannot always be found by fish. The barrier can be mitigated by removing the weirs entirely, creating a free passage for fish upstream. However, the removal of weirs would cause shipping to be impossible on river Meuse. It is unthinkable in the upcoming years to remove shipping in the river, so other solutions are needed. One of these other solutions is the floodable river dam. The idea and design principles of the floodable river dam are elaborated in section 3.1 conceptual approach.

**How to replace or transform the series of weirs coherently, standardising the functionality of the design, but still considering each individual landscape features?**

A standardised concept of the floodable river dam is elaborated in section 3.2 Conceptual approach. This concept is applied at every weir location, which makes for a coherent, standardised system. In section 2. Landscape analysis many differences between the landscapes of the seven weirs are pointed out. A catalogue of seven landscape elements is used to amplify these individual features or add missing features. The catalogue is constructed in section 3.1 River Meuse vision. By using the landscape elements from the catalogue the seven designs have all differentiated from the standard design.

**What will the transformed weirs look like, dealing with the spatial aspects of the current weirs and their surrounding landscape?**

Sections and isometric views of the floodable river dam in section 4.2 Floodable river dam give an idea of how this new system can look. Section 6.1 Detail Borgharen and 6.2 Detail Roermond show how the new dams look in combination with the old weirs and the surrounding landscape. By creating a contrast in a messy ecosystem on the floodable river dam and a hedgerow as orderly frame, the landscape is understandable for people, while still having much ecological value.

**How can the series of the Meuse's weirs be replaced or transformed through a landscape based approach?**

Next to the current civil engineering approach of Rijkswaterstaat, stated in section 1.2 Context, there are other ways to transform the series of weirs in the river Meuse. By combining a nature based solution with a civil engineering solution a landscape based solution can arise. The floodable river dam concept is such a landscape based solution which could change the future of retaining water upstream in a river. If researched further and applied in a real-life situation the next steps to a working floodable river dam system is made.

The weirs of the river Meuse are currently already scheduled for renovation with a civil engineering approach. Rijkswaterstaat has decided, and has chosen for the safe option of renovating the weirs to the same shape as they were a hundred years ago, focussing on shipping and safety. Without big changes in civil engineering approaches, the amount of functional natural processes will only decline which will lead to an ever increase of habitat and biodiversity loss.



## 8. Reflection

My approach going into the graduation project was based on the Landscape Architecture Principles. I wanted to look into my project through the lens scale continuum, from biggest scale to a small, detailed scale. For me that meant a general analysis of the entire river Meuse, the river on a National scale, on compartment scale in between weirs, and on zoom-in scale per weir location. This approach worked for me, because it made me aware of problems in the river on a big scale, and how this resulted into interventions, or more problems downstream. For example, on the biggest scale of the river Meuse it was found that many unique native species are disappearing. The cause of this problem can be found on the zoom-in scale; many fish migration routes are blocked through barriers in the river.

It made sense to me to work from biggest scale, to small scale. After my seven local interventions I want to look back to the bigger picture, and reflect on how my intervention could have impact on this scale. By creating the seven floodable river dams in the Meuse natural processes are no longer blocked by the weirs. Fish can pass the river year round, and sedimentation is more balanced on a local scale. Next to that, by creating more pathing and redirecting existing routes, people will be drawn more to the river Meuse. The industrial setting that the weirs are built in will disappear. The dams will be a nexus, connecting through and along the river.

One of the downsides of the floodable river dam is the increased water level upstream during normal water flow. This impacts urban areas with houses and harbours,

which could lead to economic problems. This would be something to look into when doing further research into the floodable river dam system.

Another thing to consider is the impact scale of the intervention. In my design I focussed on the seven weirs in the Netherlands. Because this directly impacts the estuary of the river Meuse, it is safe to say the intervention would have a positive impact for migratory fish from ocean, all the way into the river across the country. The problem however is the amount of weirs in the upstream part of the river Meuse. To fully assist native fish populations in the river, the whole streambed from France to the Netherlands should be improved. Since the landscape is very different in the upstream areas, the local interventions cannot be copies of the floodable river dams in my project.

There is a knowledge gap when designing on a big scale. The more you dive into a project the more questions pop up. By designing and drawing more details I came across more of these intricate details which would have big consequences for my design. For example, the fluctuation of the water level of the river Meuse. It was known to me what the minimum and maximum water level was in the river. However I completely neglected the timespan of high and low water levels. I found out that almost five months of the year the river has a high water level, in contrary to the lowest water level, which is only present during the two driest months. This has a big impact on spatial design, and routing along the floodable river dams. Some designed elements are flooded most of the year, while others need to be dry for the entire year-cycle.

Most of the time I followed up on feedback from my mentors after critically thinking about the matter. My biggest challenge was the actual spatial design and composition. I tried to put in meaning into the design, before composition. My mentor helped me with realising this, and I decided to design more from a logical perspective, trying to complement the current landscape.

Looking back on the scale continuum focus of my graduation lab landscape architecture principles I can conclude that scale has played an inseparable role during my project. Pars pro toto, copy paste and cause and effect are all used during this project as a tool for understanding and designing the landscape. One weir is pars pro toto of the whole weir system. One weir cannot work without all the other weirs, therefore the series of weirs in the river Meuse can be seen as a system. Copy paste is applied when implementing the standardised design in each individual locations' landscape. Next to that several landscape elements from the catalogue in section 3.1 River Meuse vision are copy pasted on different weir locations. Cause and effect has always been a big influence in reading the landscape, since one intervention in the river has effects both upstream and downstream.

To conclude I think I evolved as a landscape designer throughout this graduation project. A main struggle for me personally is the graphical representation of what I want to show. Through trial and error, I finally discovered a personal style for this project which I am happy with. The process of the detailed drawing can be seen in Figure 93: Drawing progress.

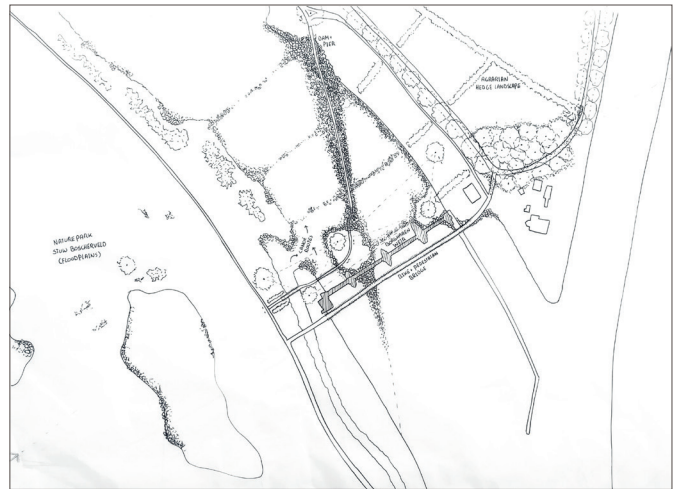


Figure 93: Drawing progress (By author, 2024)

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