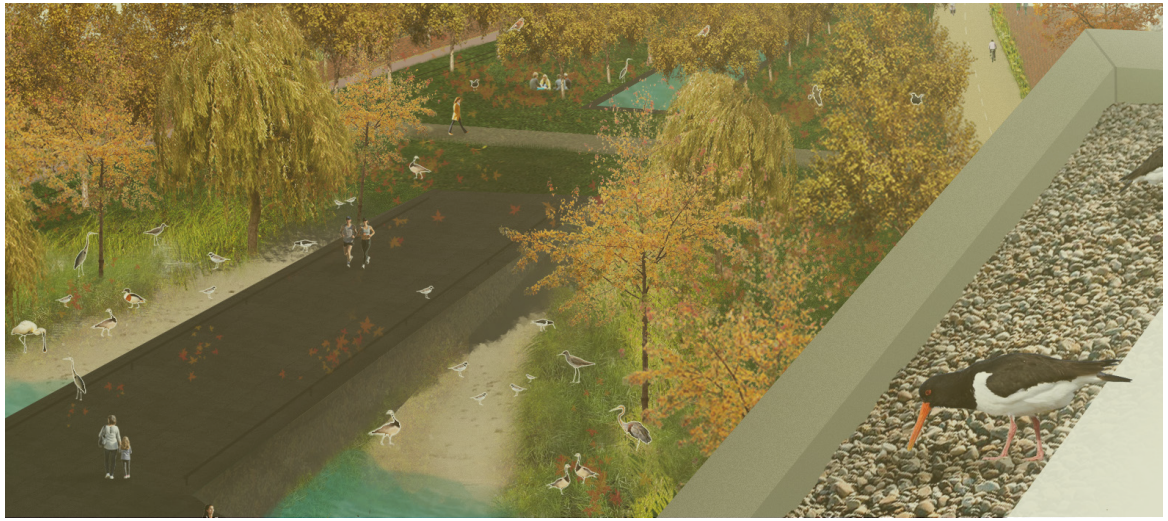

ROTTERDAM AS
URBAN TIDESCAPE

Transforming Westblaak-Blaak, Rotterdam into a resilient and dynamic public space for people and animals alike, whilst contributing to the mobility transition and restoring biodiversity; all through the unique tidal characteristics of the Nieuwe Maas

Ivo Brands 4376870
Delft University of Technology – 10 January 2022
MSc Landscape Architecture – Flowscapes: Urban Ecology & Eco-Cities

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MASTER OF SCIENCE
Landscape Architecture

GRADUATION STUDIO
Flowscapes

GRADUATION LAB
Urban Ecology & Eco-Cities

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LANDSCAPE ARCHITECTURE

ABSTRACT
The increasing popularity of the city of Rotterdam has resulted in a number of spatial and ecological challenges. Public space is already scarce north of the Nieuwe Maas, with demand increasing due to densification, and the large amount of paved surface results in heat stress. Despite harbour functions having shifted from the city centre towards the North Sea, quays within the centre remain paved; creating a hard boundary between people and river. Additionally, main city boulevards are intersected by the traffic barrier of Westblaak-Blaak, which contains eight lanes of car traffic and subsequently results in dangerous and unattractive intersections (e.g. Eendrachtsplein). Furthermore, natural habitat loss has resulted in a biodiversity crisis affecting the entire ecosystem.

This research project, *Rotterdam as Urban Tidescape*, explores the potential of exploiting the unique tidal characteristics of the Nieuwe Maas within an urban design for Westblaak-Blaak, Rotterdam, with the goal of transforming it into a resilient and dynamic public space for people and animals alike, whilst contributing to the mobility transition and restoring biodiversity.

Through the design process, researching an integral solution to the aforementioned challenges, it was found that incorporating tidal nature within the urban area would benefit people in a variety of ways (e.g. providing healthier public space, creating unique experiences, and reducing heat stress). Natural gradients as a result of tidal cycles provide an array of animals with more and unique (tidal) habitats, which contributes to countering the biodiversity crisis. By adding to the mobility transition of Rotterdam through a significant reduction of (the surface for) car traffic, the resulting freed up space can be transformed into a healthier urban environment - from rooftop to underwater.

With the unique tidal habitats, the migration of animals, and the increasing salinity of the river water over time, Westblaak-Blaak has the potential to become a resilient and dynamic hotspot which evolves along the day, throughout the seasons, and over the years. Key findings have been collected into an Urban Tidescape Toolkit for reference within similar urban landscape design assignments, and an overview of essentially endangered red-listed and icon species along with their respective habitats has been enclosed.

ACKNOWLEDGEMENTS

This report is the result of my graduation project during the Master of Science Landscape Architecture at the TU Delft. The project is part of the Urban Ecology & Eco-Cities lab with the Flowscapes graduation studio.

I would like to express great appreciation and gratitude to my first mentor and supervisor, ir. Frits van Loon, for his guidance during the project. During our meetings he often challenged me to look into different approaches, and to question my own findings and ideas. I would also like to thank ir. Leo van den Burg, my second mentor, for his additional guidance and not uncommonly out-of-the-box ideas. Along with critical feedback, both have continuously provided me with valuable suggestions and interesting insights, and their experience has helped me give (re)direction to the research and shape the design.

During my research on species and habitats, I also received advice from dr.ir. Nico Tillie. I would like to acknowledge and thank him for sharing his knowledge with me. I also thank my teachers and the tutors throughout my studies.

Ultimately, I would like to express a big thank you to my parents, brother, and friends for their ongoing support and words of encouragement, and for looking after me. Thanks also to my mother for her help with the handdrawings of the selected species. And to my Flowscapes graduation companions - in particular Dorien Tulp, Farnoosh Bazrafkan and Emmanouela Armoutaki, whom I have spent the majority of time with - thank you for the many memorable moments at BK City, the various libraries, and beyond - we'll meet again!

INDEX

1

INTRODUCTION

From fascination to research methodology

I. FASCINATION

Throughout my time at the Faculty of Architecture I have been interested in bringing nature, in the broad sense of the word, into my designs. It started with buildings in dunes or grass on rooftops early in the bachelor programme, and concepts became more refined during the master. Since being introduced to and learning more about tidal parks, I've become quite passionate about the topic. During a great internship in 2019, for the municipality of Rotterdam, I was able to work on the subject for real.

From a young age, I often used to go to the sea and forest. Being out in nature and visiting different environments for a while was always great. Besides my connection with the area of Rotterdam itself, my fascination for tidal parks is based on the fact that they are unique to this area within the Netherlands, and because I think the potential of such parks is extensive. During a busy day at work for instance, who wouldn't want to relax for a moment and have lunch in a park that's always different? There are birds and other animals to see that are usually not found within an urban area, the city becomes cooler and more liveable, and the biodiversity is enriched - the potential is all there for Rotterdam in the shape of the Nieuwe Maas. The various existing plans for tidal parks mainly focus on the south of Rotterdam, but there is also potential for the historic harbour basins in the north. Westblaak-Blaak currently is a car-dominated traffic connection which abruptly separates the Rotte river from the Nieuwe Maas, and acts as a barrier for Rotterdammers and tourists traversing the city by foot or bike.

Clearly, the Urban Ecology & Eco-Cities lab within the Flowscapes graduation studio at the TU Delft was an obvious choice for me in order to investigate solutions and try to achieve a resilient and dynamic environment for people and animals in the north of Rotterdam; using the unique tidal qualities of the Nieuwe Maas.

Figure 1: *Spotting spoonbills and geese on the gradients at Tij, a design by RO&AD in Stellendam, Netherlands.*

II. PROBLEM STATEMENT

Due to the increasing popularity of the city of Rotterdam, by both domestic and foreign visitors (Rotterdam Partners, 2019), the city is facing a number of social, spatial and ecological challenges. In order to provide solutions for already occuring issues, as well as avoiding more pressing situations in the near future, the following challenges will need to be addressed.

Figure 2: *The increasing popularity of Rotterdam results in more tourists and inhabitants (Van den Broek & NBTC, 2018).*

LACK OF GREEN ENVIRONMENTS

THE ISSUE: Currently, residents of the Rotterdam city centre and older city districts have the least access to public green, despite making for one of the most densely populated areas of the city. The Kralingse Bos in the north, as well as the western area of the city centre (the Westersingel, Museum District and Het Park), make up mostly all of the green area in the city north of the river. With the exception of a small grass surface next to the Laurenskerk, the Coolsingel, Binnenrotte, Blaak and Maritiem District contain virtually no green surface at all.

TOWARDS A SOLUTION: Both people and animals would benefit from more, and more different types, of green for a healthier public space, which could act as green corridors and ecological stepping stones throughout the city.

POOR CONNECTION WITH THE RIVERS

THE ISSUE: Whilst water is often nearby in the form of the Rotte and Nieuwe Maas, all quays are paved, and thus no sensible connection with the water is present. In a questionnaire by the municipality of Rotterdam (2019a), 39% of the Rotterdammers indicated they would like to see more destinations along the river, 32% wants more nature, and 30% wants more leisure space. Half of the Rotterdammers never visits the river for recreation.

TOWARDS A SOLUTION: The significant amount of Rotterdammers never visiting the river could be reduced by creating more destinations along the river, and reducing the presence of barriers such as hard quays and traffic.

EXCESSIVE TRAFFIC

THE ISSUE: On top of the lack of destinations along the river, there is another reason why the Nieuwe Maas is not the hotspot for the city it could be. Tourists arriving from the Rotterdam Centraal and Rotterdam Blaak train stations are met with the Westblaak-Blaak traffic connection as they move south towards the river. It cuts all the main city boulevards (Westersingel, Coolsingel and Binnenrotte) and results in busy and dangerous intersections. Westblaak-Blaak acts as a barrier, preventing both tourists and Rotterdammers from pleasantly arriving at the Nieuwe Maas, or even going there at all.

Additionally, there is multi-lane car traffic on the quays right along the Nieuwe Maas, such as the Boompjes and Maasboulevard, further opposing people's safety and experience, and public destinations on these quays (e.g. swimming pool Tropicana) have disappeared.

TOWARDS A SOLUTION: In accordance with the mobility transition aims of the municipality (Gemeente Rotterdam, 2020a), various measures could be implemented. These include the reduction of the number of car lanes and maximum speed within the city centre, in order to increase safety, reduce omissions and noise pollution, and make for an overall better quality of public space – with a focus on bike, pedestrian and other (future) slow-speed movement flows.

DENSIFICATION: PRESSURE ON SPACE

THE ISSUE: In order to house the increasing number of inhabitants, the city of Rotterdam is densifying. The municipality aims to add an additional 50.000 homes by 2040 (Gemeente Rotterdam, 2019a). In e.g. the Maritiem District, various high-rise apartment buildings have already been completed, with more projects under construction or planned. All these new inhabitants will need to make use of the already scarce (green) public space.

II. PROBLEM STATEMENT *(cont.)*

TOWARDS A SOLUTION: The space freed up in order to reduce the number of traffic lanes for cars can be transformed into attractive and healthy public space. This benefits the current inhabitants, whom already lack access to such space, as well as the future inhabitants and tourists.

RESILIENCE: CLIMATE ADAPTATION

THE ISSUE: Climate adaptation measures should be implemented in order to make for a future-proof city. As stated, a significant amount of Rotterdam is paved, which heats up the city and results in flooding during heavy rainfall. Due to climate change, these issues are to become even more pressing in the future. Measures need to be taken with regards to sea level rise, heavier rainfall and draught, and the reduction of the urban heat island effect (Gemeente Rotterdam, 2019b). Another aspect of climate change is salinisation, endangering freshwater areas (International Architecture Biennale Rotterdam, 2020).

TOWARDS A SOLUTION: In order to adapt Rotterdam with regards to the aforementioned climate-related challenges, paved areas such as excessive traffic lanes could be transformed using more natural materials and vegetation, allowing stormwater to be stored and drained more evenly and reducing urban heat island effects for a cooler and more pleasant climate in the city; amongst a range of a smaller-scale solutions on building level.

THE BIODIVERSITY CRISIS

THE ISSUE: There is also an urgent need for a recovery of the biodiversity in Rotterdam: in the sustainability score by Het PON & Telos (2020), the municipality of Rotterdam ranks on a poor number 353 out of 355 municipalities with regards to the ecological capital in 2020.

High biodiversity is of the utmost importance for a healthy environment: with the biodiversity lowered and ecosystems under pressure due to an imbalance in species, issues arise related to the production of oxygen, decomposition of dead organisms, pollination of plants including agricultural crops, water purification, and even plagues and pandemics (Biodiversiteit.NL, n.d.).

TOWARDS A SOLUTION: Due to its tidal nature, the Nieuwe Maas has great potential when it comes to creating the conditions for a variety of habitats that will offer a living environment for (unique and/or endangered) species. The river could, and should, contribute to a revitalised biodiversity in the Rotterdam region.

III. OBJECTIVE

The proposed solutions to different challenges regarding the city of Rotterdam, as outlined in the problem statement, altogether suggest the potential and benefits of creating more healthy public space, a range of habitats, and reducing car traffic. The Nieuwe Maas could be an interesting component as the backbone of a unique integral solution to all aforementioned aspects. The fact that it is the only remaining tide-influenced river in the Dutch delta area makes it conceivable to recover biodiversity, provide for the high demand for public space, contribute the mobility transition, and adapt Rotterdam to a changing climate. This research project aims to connect the challenges related to pressure on public space, the mobility transition, and biodiversity challenges, rather than regarding them as separate or contrary objectives. In addition, it would reconnect the people of Rotterdam to their river, through a healthy and attractive hotspot for people and animals alike in the historic city centre.

This research project, *Rotterdam as Urban Tidescape*, explores the potential of tidal river the Nieuwe Maas, and its qualities regarding the transformation of the city centre of Rotterdam into a more resilient, attractive and biodiverse environment. These various aspects stimulate an integral design solution, alongside tools for creating dynamic public space in a tidal environment, and an overview of species related to their habitats. The project was conducted through the eye of the landscape architect.

IV. RESEARCH QUESTION

MAIN RESEARCH QUESTION
How could the unique tidal characteristics of the Nieuwe Maas be exploited in order to transform Westblaak-Blaak, Rotterdam into a resilient and dynamic public space for people and animals alike, whilst contributing to the mobility transition and restoring biodiversity?

SUB-QUESTION 1.1
What are the characteristics and benefits of a tidal river?

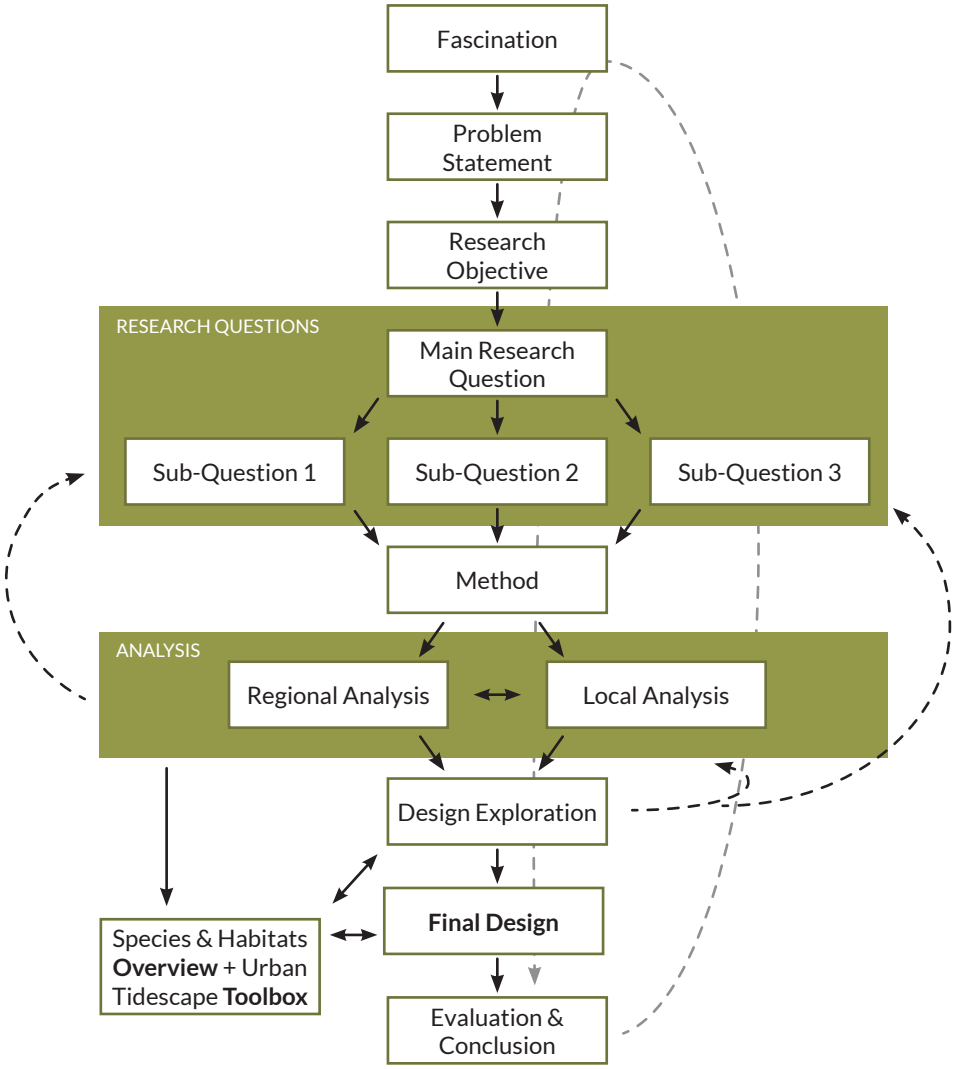
SUB-QUESTION 1.2
How could these benefits result in unique and dynamic public space?

SUB-QUESTION 2
What are the possibilities for reducing car use in order to contribute to the mobility transition in Rotterdam?

SUB-QUESTION 3.1
Which types of habitats will contribute to recovering the biodiversity in Rotterdam, and which endangered/tidal species are expected to benefit from such habitats?

SUB-QUESTION 3.2
How could these habitats be incorporated in urban planning with an ever-changing environment as the result?

v. APPROACH



Rotterdam is becoming an increasingly attractive city and as a result will continue to grow. As more extensively outlined in the problem statement, the city faces various challenges with regards to not only densification and its subsequent pressure on already scarce public space, but also concerning the ongoing mobility transition, the poor state of the biodiversity, climate adaptation, and the living environment and experience of both inhabitants and tourists.

Both the economic and spatial development of Rotterdam were largely influenced by the habours, which were present as early as 1350 (Port of Rotterdam, n.d.). Nowadays, however, the historic harbours located in the centre of Rotterdam have lost their harbour functions, which has resulted in deserted quays and empty water surfaces. Through this project, the possibilities of solving the various challenges outlined in the problem statement are explored. The goal is a design solution true to the character of the place, which provides a solution to the various challenges and provides both people and animals, Rotterdammers and tourists, a dynamic, lively and attractive place to enjoy a moment away from the often hectic city life, whether it's relaxing in a park, strolling over attractive boulevards, or just being on the quest for something exciting.

The diagram to the left explains the setup of the research project. Through the design process, new questions and insights arise which then lead to further reading and/or analysis. The specific design area in Rotterdam is based on the context of the research lab, as well as analysis, yet the design is not an isolated solution; it should provide a function within the larger scale of Rotterdam and have impact outside of the design area boundaries.

In addition to the design, the following products are included for reference in similar urban tidal design projects:

- an overview of habitats, linked to a list of potential (endangered/icon) species likely to visit such habitats;
- a toolbox comprising measures for creating urban tidal experiences.

VI. METHODOLOGY

CONTEXT: URBAN ECOLOGY & ECO-CITIES

This research project is part of the Flowscapes graduation studio at the TU Delft. Within the studio, it is part of the Urban Ecology & Eco-Cities graduation lab, which centers around the (re)introduction of ecological principles into urban design, in order to achieve ecologically healthy cities also known as eco-cities. Specifically, the research lab seeks to provide answers to the following question (Tillie, 2020):

How can we translate the eco-city principles plus the biodiversity and ecological challenges into (site-specific) spatial design, spatial quality and spatial experience?

Within the lab, these challenges are explored in the context of Rotterdam, the Netherlands; the works produced are also to be exhibited during the Ecocity World Summit. Hence, the location and various decisions made in the research approach are resulting from this framework.

SCIENTIFIC RELEVANCE

Within the scientific framework of landscape architecture theory, the graduation project deals with various themes. It seeks to build on existing principles, as described by Allan Ruff (1982, as cited in Swaffield, 2002), related to improving life quality within the city and making for an optimal relationship between people and other components of the natural environment. Ruff's principles to achieve this include working with nature, having biological factors determine the design, regarding landscape as process with no final design, and bringing a landscape as close as one's front door. In addition to these existing points, the conditions in Rotterdam and the tidal quality of the Nieuwe Maas could provide for new principles with regards to landscape experience and spatial quality within the city, whilst also taking into account species other than human beings through principles of ecology. The definition of ecology by Vink et al. (2017, p. 31) is, not coincidentally, closely related to the themes outlined by Ruff: it is the science that studies the relationship between living organisms and their interaction with their environment.

With regards to sustainable landscapes, the project is related to various principles as outlined by Michael Hough (1990, as cited in Swaffield, 2002), such as knowing the place, concerning the regional identity which relates to the physical and social environment, and maintaining a sense of history; related to the protection of natural history - or in this project rather the *recovery* of natural history. The graduation project is also especially related to the aesthetics of ecology, as the attention for a multitude of habitats has a significant impact on the spatial design.

Figure 3: *Illustrative image of an eco-city (Ecocity World Summit, 2020).*

2

DEVELOPMENTS IN SOUTH HOLLAND

Evolution of the landscape, emergence of the harbour, reconstruction, the car; (re)defining moments

I. THE LANDSCAPE OF SOUTH HOLLAND

Influence of the delta dynamics (1100)

Characteristic for the origins and developments within Rotterdam throughout history is the location; partially in and partially next to a river delta, through which the large rivers flow from and towards the North Sea through an estuary.

The area north of what is currently known as the Nieuwe Maas is comprised of mudflats (*wadden*), which eventually became a swamp forest in which a peat area has developed on the soil. From this area, creeks and small water streams reach the larger rivers. One of these is the Rotte, as shown in figure 4. South of the Nieuwe Maas, an area comprised of islands is found, cut through by river brances and creeks. Due to tidal cycles, the extensive area floods twice a day. This results in an overall cohesive system of sea, rivers, creeks and marshes (Palmboom, 1990, p. 15).

Besides influence from the sea, there is also influence from the river dynamics: a more gentle stream in the summer, against a turbulent stream during winter time. Disruptive events like heavy storms further impact the layout of the area (Palmboom, 1990, pp. 15-16).

Figure 4: *Situation in the estuary around 1100, with the locations of future cities annotated (drawn by author; based on Palmboom, 1990, p. 14).*

II. INITIAL HUMAN DEVELOPMENTS

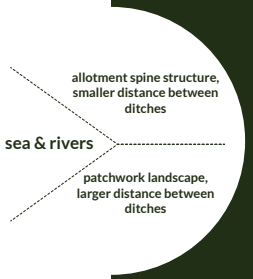
Dike consolidation and land subvision (1200-1580)

Both the exploitation and embankment processes shape the colinisation of the landscape. Through parallel ditches, the wilderness is drained and made suitable for land use. This process however leads to the peat mass shrinking, and thus to the lowering of the soil level. Dikes and quays therefore are necessary interventions in order to ensure safety for inhabitants of the area (Palmboom, 1990, p. 19).

Overall, the embankment process takes place along the main rivers. The peat rivers Rotte and Schie become disconnected from tidal influences, nature and biodiversity, and lose their open connection with the Maas. Behind the dams, cities such as Rotterdam, Schiedam and Vlaardingen start to develop (Palmboom, 1990, pp. 19-20).

North of the Maas, the embankment process takes up a relatively short period of time, merely 80 years. The landscape south of the Maas sees a more turbulent and longer timespan of 300 years. These varying developments have resulted in significantly different landscapes north and south of the Maas (Palmboom, 1990, pp. 19-20), as shown in figure 5.

Figure 5: *Situation in the estuary around 1200-1580, with the develloping cities annotated (drawn by author; based on Palmboom, 1990, p. 14).*



III. A LANDSCAPE SHAPED ALONG RIVERS

Complex allotments and a structure along allotment spines (1200-1580)

North of the Maas, in the peat area, a structure of fine ditches can be found. Water and land levels are nearly the same. The allotments are placed along ribbons, with perpendicular ditches attached, resulting in a herringbone structure (Palmboom, 1990, p. 23). See figure 6.

The sharp curve in the Maas at the height of Rotterdam makes for a complex situation regarding allotments. Various allotment spines (*waaiers*) come together; nowadays the complexity is still visible in the urban structure of Rotterdam. Additionally, intensive use and the burning of peat (for e.g. industrial use) has resulted in soil subsidence in the backlands, resulting in lakes. Such soils were redistributed but now with a regular pattern unrelated to the original allotment spines, which means the retained, old structures have now become more meaningful (Palmboom, 1990, p. 24).

Due to a clay soil in the south, the distance between ditches is larger and drainage leads to less soil subsidence. There is no continuity between adjacent areas, in contrary to the clear structures in the north; instead it is a patchwork landscape (*lappendeken*) with ring structures rather than ribbons.

The new landscape and its structure of lots (*kavels*), ditches and roads is resilient as it not only takes care of drainage and transportation, but it also has a range of possible uses; from grassland and allotment gardens to factories and urban settlements. Densification thus takes place along the ribbons, and not solely around the city triangle (*stadsdriehoek*) (Palmboom, 1990, p. 27). The overall conclusion that can be drawn from this is that the urbanised landscape was shaped along historical structures.

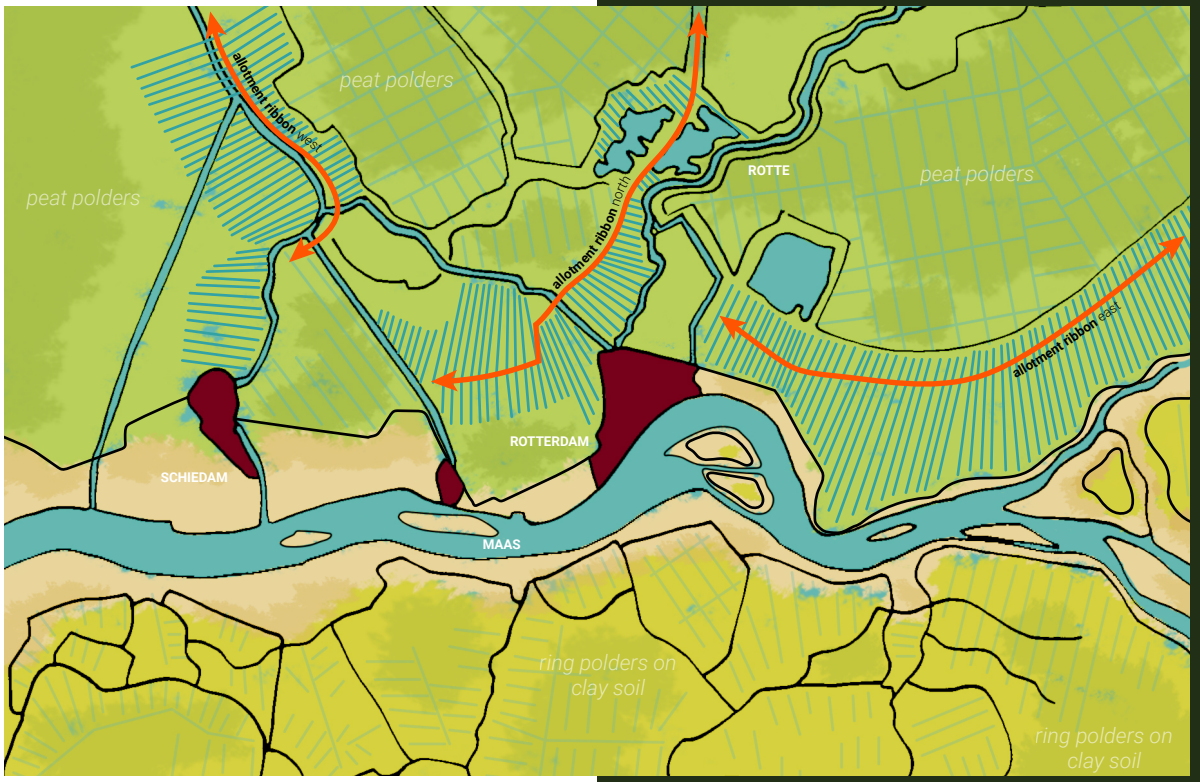


Figure 6: *The shaping of allotments along spines, and the differences in landscape between north and south of the Maas around 1200-1580 (drawn by author; based on Palmboom, 1990, p. 22).*

IV. DEVELOPMENT OF THE HARBOUR

History of the port of Rotterdam and its shift towards the sea

Around 1250, the original dam of Rotterdam was established (Port of Rotterdam, n.d.). Currently known as the Hoogstraat, the dam closed the connection between the Rotte and the Maas and subsequently became an area of trade. It appeared a useful area to transfer goods from larger ships into smaller river boats.

WATERSTAD

As a result of the municipality's decision circa 1575 to fortify the city, in order to protect ships and goods, the harbour capacity was increased (Van Ast, 2019, p. 20). The western part of the fort is known as Blaak; nowadays a car-heavy traffic connection, it was originally a waterway connecting Leuvehaven and Oudehaven.

In a timespan of merely 10 years, the following harbours were constructed: Leuvehaven (1604), Wijnhaven (1613), Scheepmakershaven (1613), Glashaven (1614) and Bierhaven (1614) (Port of Rotterdam, n.d.). Trade and shipping increased rapidly with the establishment of the Dutch East India Company (*Verenigde Oost-Indische Compagnie*).

The area, entitled Waterstad, became the heart of enthusiastic trade in herring, wine, beer, and was the centre point of industries such as shipwrights. It was the flourishing centre of merchant city Rotterdam (Van Ast, 2019, p. 15); of great significance for city life and economy.

FROM WATERWEG TO MAASVLAKTE

Due to industrialisation and the related increase in amount and dimensions of ships, capacity became a pressing issue. Hydraulic engineer Pieter Caland was commissioned to come up with a solution and so he designed the Nieuwe Waterweg (Port of Rotterdam, n.d.). In 1864, the construction commenced. The Nieuwe Waterweg marked the beginning of a shift of harbour functions towards the North Sea, as indicated on figure 7.

In 1931, the construction of the Merwehaven was finished, with the Botlek following in 1960. The Europoort opened 1964, further extending the harbour towards the North Sea, and Maasvlakte and Maasvlakte 2 were finished in respectively 1973 and 2013 (Port of Rotterdam, n.d.). The following page, 17, provides an overview. With the size of ships further increasing, the old harbours in the city centre lost their function as main trade areas.

CITY CENTRE HARBOURS IN THE 2020s

Whereas originally Waterstad was a lively and cultural trade area, greatly contributing to the prosperity of Rotterdam, over time harbours such as Glashaven were removed, and Blaak lost its water and became a dense traffic area. Harbour functions have moved away. The result is an area in the city centre with deserted quays, a hard connection between land (or indeed, people) and water, with only little space for biodiversity or activities on the water.

Figure 7: *Birdview of the Nieuwe Maas flowing through urbanised Rotterdam (www.marcovermeulen.eu, n.d.; edited).*

IV. DEVELOPMENT OF THE HARBOUR *(cont.)*

A timelapse from Waterstad to Maasvlakte 2

Figure 9: *Shift of the harbour functions and expansion towards the west (drawn by author).*

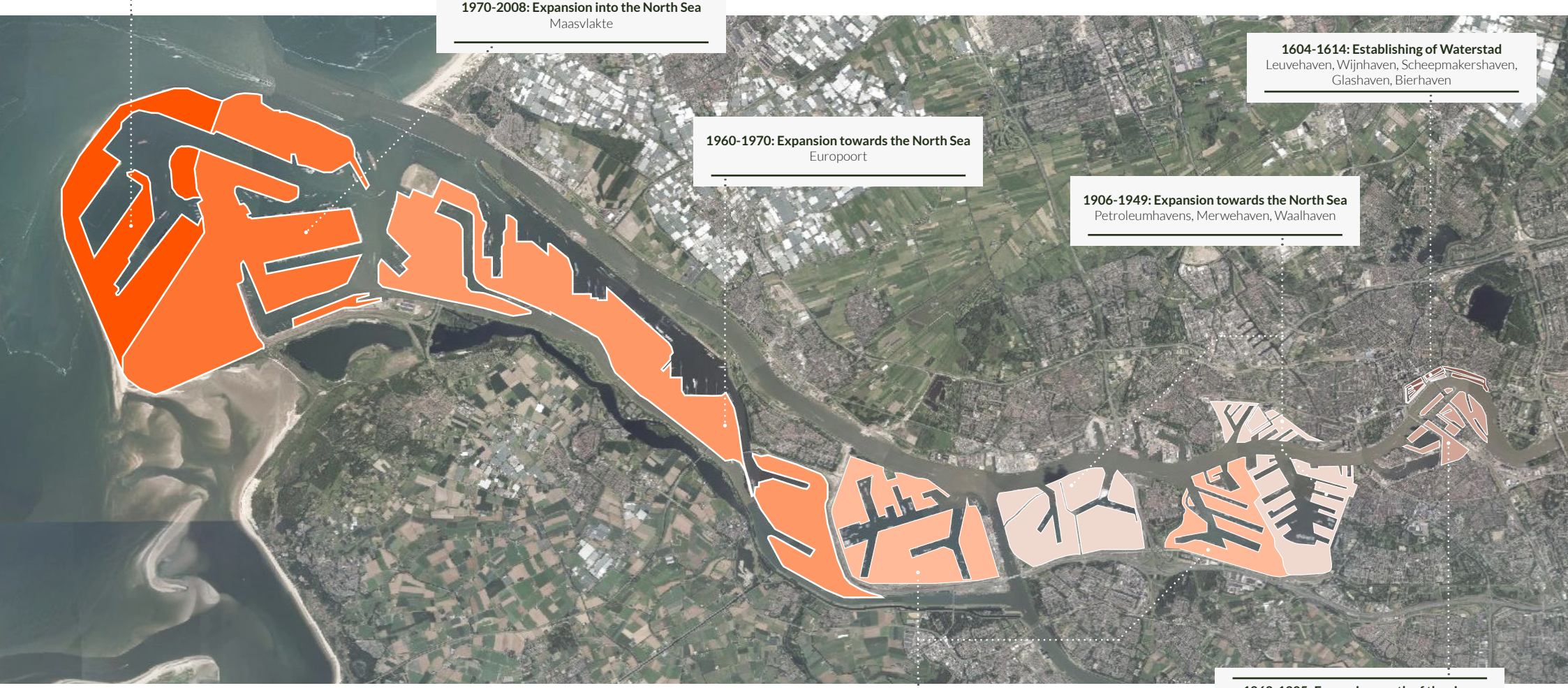


Figure 8: *Overview map of the harbour development of Rotterdam, from 1604 up till present day (drawn by author; dates retrieved from https://www.portofrotterdam.com/).*

v. DESTRUCTION, RECONSTRUCTION, AND THE CAR

The long-term consequences of the redevelopment plan

Along with the developments in the harbour, and the resulting densification along the river due to the increasing number of jobs, came the intensification of the traffic network. Edges along the allotment spines were designated as main transportation lines: Schiekade, Linker Rottekade, Rechter Rottekade, Goudsesingel and the Coolsingel. The latter two also became the two most important boulevards of the city, coming together in Hofplein which, as a result, by accident had become the centre of vivid city life (Palmboom, 1990, p. 28).

BOMBING OF ROTTERDAM

During the German bombing during World War II, on 14 May 1940, the entire situation changed. Nearly the entire city triangle was destroyed with 800 to 900 people losing their lives (Brandgrens, n.d.). Figure 10 shows the extent of the city fires that resulted from the attack. Adjacent city areas were severely damaged as well. The city of Rotterdam lost its vivid centre, or indeed its heart. A memorial statue was revealed in 1953, entitled *De verwoeste stad*, designed by Ossip Zadkine. It is located on Plein 1940. See figures 11 and 12.

REDEVELOPMENT OF THE CITY: BASISPLAN

The city redevelopment plan, known as the Basisplan, would become the basis for the post-war city. Due to the urgent need for housing following the bombing, old structures within the landscape were largely disregarded, and the rise of larger-scale harbour and traffic developments instead found their place in the Basisplan. The plan coincided with the Nieuwe Zakelijkheid, an urban development at the time that seeked to ignore historic references in the design process (Palmboom, 1990, p. 57). The network lies parallel to the Nieuwe Maas; main streets are oriented either perpendicular or parallel to the river. This was done to minimise the impact of other rivers, including the Rotte, on the shape of the network (Palmboom, 1990, p. 58). The city centre was relocated from Hofplein towards the west of the Coolsingel, and the Nieuwe Maas was used as a reference for the grid; the Rotte, which was already disconnected from the Nieuwe Maas even before the bombing, was largely disregarded during the urban redevelopment of Rotterdam.

EMERGENCE OF THE CAR

Through the Basisplan, the city was established as a car city. Rotterdam became known for its high amount of cars. The city was well connected, but at the cost of attractive (green) public space, poor biodiversity, heat stress and traffic incidents. To illustrate: during a count of the number of people crossing the Coolsingel in 2008 - before the transformation - it turned out that people no longer crossed the street at all due to the high traffic count (Fontein, 2021).

Figure 10: *Extent of city fires, the 'brandgrens', resulting from the German bombing (drawn by author, data retrieved from https://brandgrens.nl/navigator).*

Figure 11: *The city centre of Rotterdam heavily damaged following the bombing in 1940 (HH/SV-Bilderdienst, n.d.).*

Figure 12: De verwoeste stad, *a memorial statue by Ossip Zadkine on Plein 1940 (photo by author).*

v. DESTRUCTION, RECONSTRUCTION, AND THE CAR *(cont.)*

The long-term consequences of the redevelopment plan

THE CONSEQUENCES STILL FELT TODAY

A number of negative consequences of the Nieuwe Zakelijkheid way of thinking, though arguably logical at the time, are still prominent as of today:

- The main city boulevards perpendicular to the river are interrupted by high-traffic boulevards parallel to the river, resulting in dangerous intersections along all of the boulevards. From north to south, and from east to west, everyone traversing the city will have to cross them (see figure 15);
- For tourists arriving from the Rotterdam Centraal train station, the way to the river is unattractive and not an appealing route to take, as it is interrupted by at least two of said intersections. There also is a lack of destinations at the river front, further taking away incentive;
- The current high amount of mobilised traffic not only makes for unsafe situations for humans and animals, it also produces both air and noise pollution;
- The large surface of asphalted high-speed traffic lanes contributes to the urban heat island effect, which means a warmer rather than cooler city. If nothing would be done, this effect will increase due to higher temperatures as a result of climate change. It has also resulted in loss of natural habitat for a large amount of species. Reducing the number of traffic lanes will open up potential to transform these areas into green or blue space, improving both spatial quality as well as biodiversity.

The ongoing mobility transition aims to reduce the amount of traffic and traffic lanes within the city as will be outlined in chapter 4.

The Basisplan was to make Rotterdam the 'city along the river' through a continuous system of main roads in the form of a rectangular system of boulevards across the city, as shown in figure 15. The goal: making the city clear and straightforward from a spatial perspective, as well as creating a better flowing infrastructure. This was done by connecting the aforementioned east and west allotment spines (Palmboom, 1990, p. 58). As previously outlined, nearly the entirety of quays form a hard edge between land and water. Hence, it can be argued that Rotterdam in fact is not a city along the river, but rather next to the river. Transformations are happening however, making for a softer connection between land and water, as will be further outlined in the upcoming chapters. Rotterdam should be on its way to indeed become the 'city along the river'.

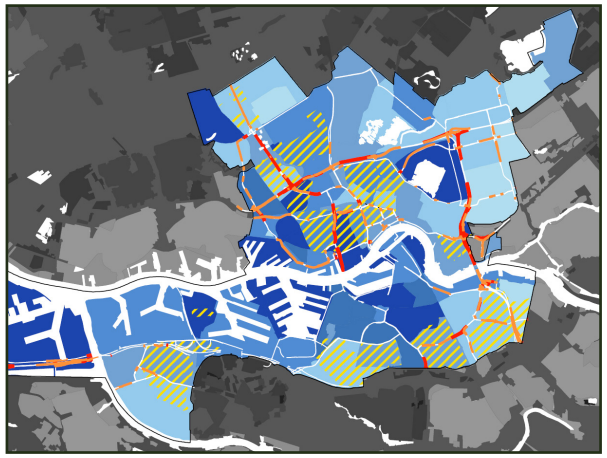
Figure 13: *The Coolsingel in 1928, one of large new city boulevards providing space for busy street life (Van Leer, 1928).*

Figure 14: *The Coolsingel in 1962, as part of the Basisplan, providing broad space for the car and thus reducing space for pedestrians (Stadsarchief Rotterdam, n.d.).*

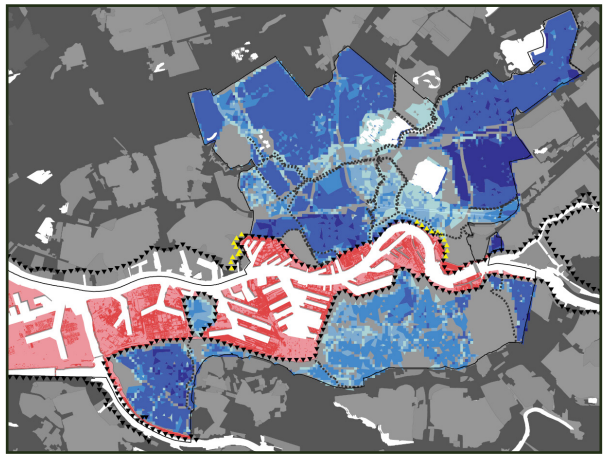
Figure 15: *Map of the present-day car infrastructure, and dangerous intersections resulting from the Basisplan (drawn by author).*

VI. EFFECTS OF CLIMATE CHANGE

These various climate-related challenges should also be taken into account within the urban transformation

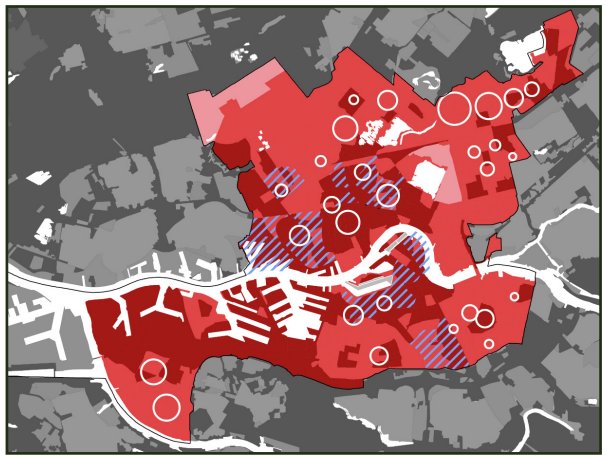


HEAVIER RAINFALL

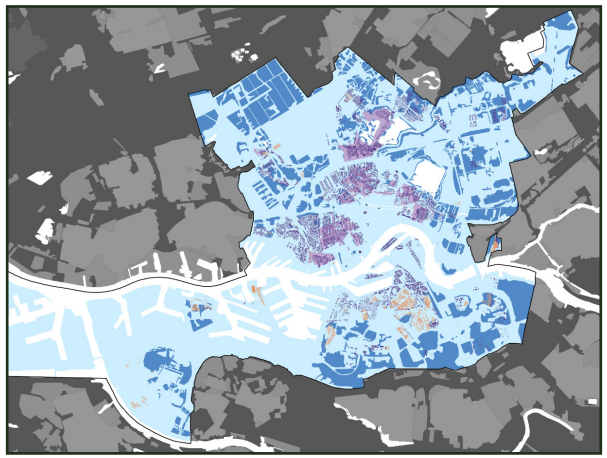


INCREASED RISK OF FLOODING DUE TO RAINFALL AND SEA LEVEL RISE

EXTENSIVE PERIODS OF DROUGHT



HEAT, ALSO RESULTING FROM THE URBAN HEAT ISLAND



GROUNDWATER LEVELS AFFECTING FOUNDATIONS

SOIL SUBSIDENCE

Figure 16: *Maps outlining the various climate-related challenges Rotterdam faces (Gemeente Rotterdam, 2019b).*

VII. ROTTERDAM'S (RE)DEFINING MOMENTS

Timeline of the traditionally drastic events demanding specific urban transformations

URBAN ISSUES & CONSEQUENCES

The Singelplan	Major City Expansion	The Basisplan	Car Invasion	Connecting North & South	Major City Transformation
1842	within 150 years	1946	emerging around 1960	1996	answering to ongoing challenges
Increasing **pollution** of the streets and waters within the city centre due to lack of a sewage system	Drastic **expansion of the harbours**, accelerated by industrialisation; **decrease in the amount of habitats**	14 May 1940: **bombing** of Rotterdam by Germany during World War II	Rotterdam is well connected through the Basisplan; **car use increases** substantially	Harbour functions shifting towards the sea; **two disconnected areas** are now to be redeveloped	Large amount of paved surface, causing city **heat** and a **biodiversity crisis** due to habitat loss
Lack of clean drinking water and **heavy stench**	Space needed for the **housing** of harbour workers; on e.g. the quays **city life flourishes**	Nearly **total destruction** of the Rotterdam city centre; housing and infrastructure	Boulevards of the plan offer broad space for cars, that **dominate traffic** and hinder public functions	Opening of the **Erasmus Bridge**, a new landmark for the city of Rotterdam	**Climate change**-related challenges, e.g. heavier rainfall, risk of flooding, and increased heat
					Traffic situation untenable; **car-dominated streets** make for safety/liveability concerns and **pollution**
					Ongoing **city growth**, further increasing demand for already **scarce attractive public space**

URBAN (RE)DEFINITIONS

Figure 17: *Map of the Singelplan by Willem Nicolaas Rose, 1842 (www.heemraadssingel.nl, n.d.).*

Figure 18: *Flourishing city life in Rotterdam, 1930 (Stadsarchief Rotterdam, n.d.).*

Figure 19: *Map of the Basisplan by Cornelis van Traa, 1946 (Stadsarchief Rotterdam, n.d.).*

Figure 20: *Car traffic jam at 's-Gravendijkwal, Rotterdam (Hollandse Hoogte & Rozing, n.d.).*

Figure 21: *Opening of the Erasmus Bridge (NOS, 1996).*

Figure 22: *Impression of a future resilient Rotterdam with spaces for people and animals (De Urbanisten, 2015).*

3

WATER SYSTEM, TIDES & POTENTIAL OF TIDAL NATURE

What are the characteristics and benefits of a tidal river? SQ1.1

How could these benefits result in unique and dynamic public space? SQ1.2

I. ROTTERDAM WATER SYSTEM

Two rivers coming together in the centre of urbanised Rotterdam

In order to investigate the potential of the tidal river Nieuwe Maas within the urban Rotterdam city centre area, the current water system should first be analysed. The local tidal character and climate-induced aspects such as sea level rise and salinisation, are also outlined in this chapter. The next page, 24, provides an overview map.

NIEUWE MAAS

The Nieuwe Maas is a distributary of the Rhine and discharges freshwater towards the North Sea, generally during low tide. From the North Sea land inwards, saltwater intrudes the fresh-water, which results in a brackish water type around the urban centre of Rotterdam. The heavier saltwater intrudes underneath the lighter freshwater of the river (Gemeente Rotterdam et al., 2005, p. 28).

ROTTE

The Rotte is a connection between the dense city centre and the surroundings landscapes. The length of 18 km makes the river an attractive cycling route along the adjacent lakes and parks. South of the A20 however, the Rotte is no longer to be recognised by adjacent nature, and in the city centre it is hidden under the urban tissue (Gemeente Rotterdam & DELVA Landscape Architects, 2016, p. 16).

Both spatially and eco-hydrologically however, there are distinguishable segments along the Rotte, which differ in the use of space, urban context, programme, and water system (Gemeente Rotterdam & DELVA Landscape Architects, 2016, p. 14). The Rotte therefore has potential to entail a variety of habitats which benefits not only the experience of people, but also provides space for animals, plants and insects.

WHERE NIEUWE MAAS MEETS ROTTE

The most northern point of the Leuvehaven in Waterstad marks the meeting point of the brackish Nieuwe Maas river with the freshwater Rotte river. On this location, the Leuvekolk, there is currently no connection between the Maas and the Rotte.

In addition to salinisation due to sea level rise, as will be outlined in the next paragraph, the saline sea water is also able to travel further inland due to the deepening of the Nieuwe Waterweg. In 2020, a freshwater inlet between the Maas and Rotte was established at the Leuvekolk (Stichting Landschapsfonds Hof van Delfland, 2020). During periods of freswhater discharge through the Maas, the inlet can open and freshwater will enter the Rotte. This allows fish to migrate in case of an added a fish pass, provides freshwater for agriculture areas along the Rotte during periods of draught, and in the city centre it is especially here were the water quality is likely to increase. Before the inlet was opened, water commonly stood still at this point of the river (and the adjacent area of the Rotte from Leuvekolk to the A20 highway) which resulted in poor water quality and an unpleasant smell, to the point it became known as a 'dirty shameful corner' (*vieze schaamhoek*) within the city (De Vliegh, 2020), see figure 23.

PUMPING STATION OOSTPLEIN

With no open connection at the Leuvekolk, excessive water from the Rotte can in the centre of Rotterdam only be discharged into the Nieuwe Maas (to ultimately end up in the North Sea) through a pumping station located at Oostplein. At this location, the water of the Rotte is pumped up for over 2 meter, and then passes through an underground pipe, ultimately ending up in the Nieuwe Maas at Boerengat, 200 meter to the south (Wikimapia, n.d.). With the aforementioned inlet at the Leuvekolk opened in 2020, there is to be less stationary water in the centre of the city, and thus a better water quality as well as a reduction of smell issues. Due to the flowing water animals, plants and fish species will thrive as a result. This will in turn make for a more pleasant public space.

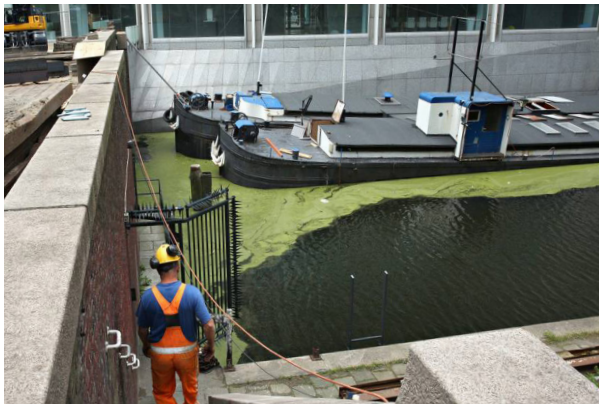


Figure 23: *Still water at the Leuvekolk has resulted in poor water quality, smell and an unpleasant view (Donders, 2020).*

I. ROTTERDAM WATER SYSTEM *(cont.)*

An overview map of the water system in the north of Rotterdam

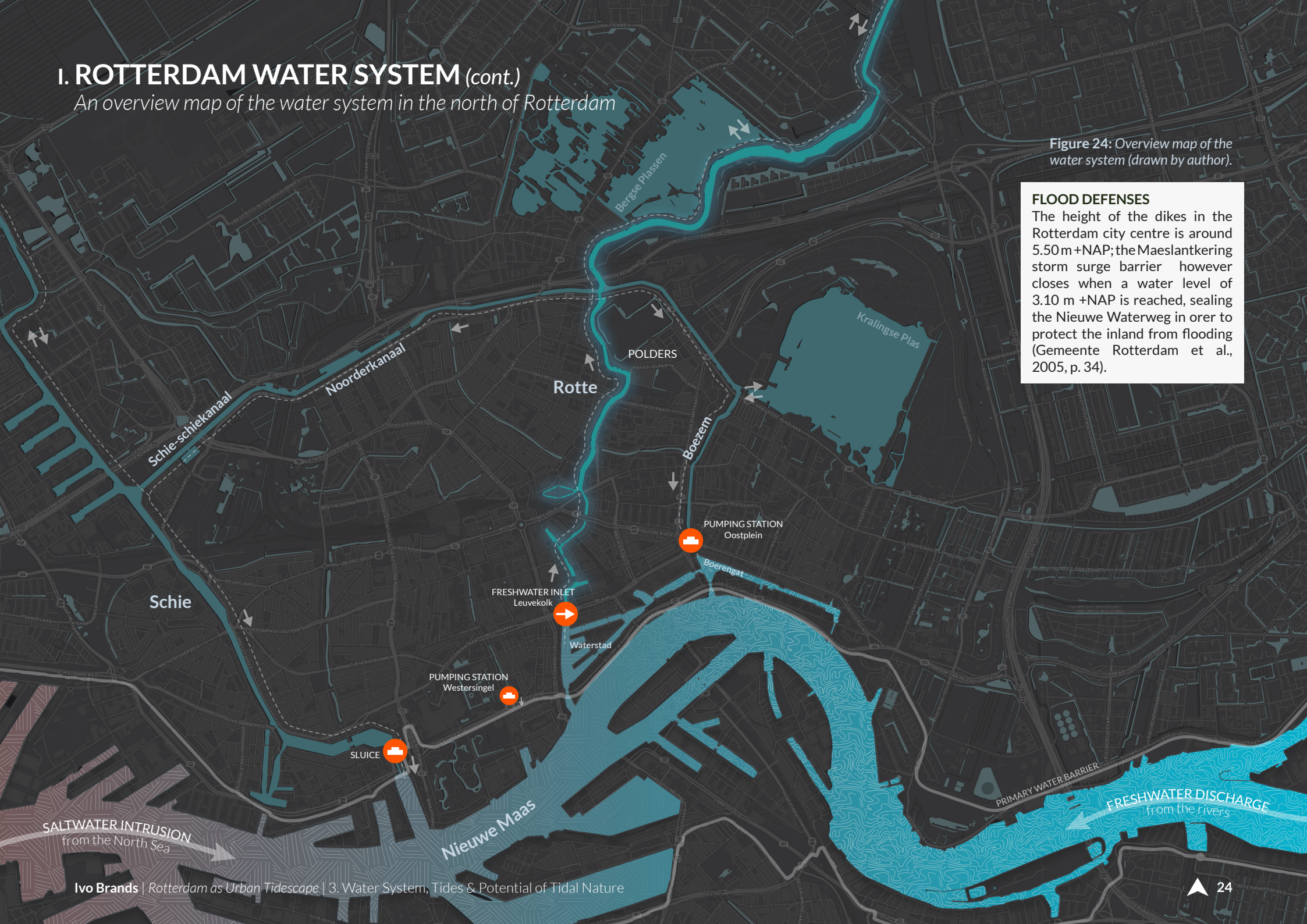


Figure 24: *Overview map of the water system (drawn by author).*

FLOOD DEFENSES

The height of the dikes in the Rotterdam city centre is around 5.50 m +NAP; the Maeslantkering storm surge barrier however closes when a water level of 3.10 m +NAP is reached, sealing the Nieuwe Waterweg in orer to protect the inland from flooding (Gemeente Rotterdam et al., 2005, p. 34).

II. SHIFT OF THE TIDES

The phenomenon of tides and the influences of climate change

GRAVITY AND THE EARTH'S ROTATION

Sir Isaac Newton stated in 1687 that tides are resulting from the gravitational attraction of the sun and moon on the oceans of the earth (Sumich, J.L., 1996, as cited in National Oceanic and Atmospheric Administration, n.d.). Tides are the fluctuation of water levels caused by those gravitational forces, in combination with the rotation of the earth. Ebb and flow, respectively low and high water levels, are notable at coastal and delta areas.

EFFECTS ON THE WATER LEVEL

The exact position of the moon has an effect on mean high water (MHW; *gemiddeld hoogwater*) and mean low water (MLW; *gemiddeld laagwater*): during spring tide (*springtij*) and neap tide (*doodtij*) the differences between ebb and flow are bigger and smaller, respectively. Additionally, the wind has an effect on the tides; a western storm combined with spring tide results in extreme water levels at the Dutch coastal area (Gemeente Rotterdam et al., 2005, p. 28).

WATER LEVELS IN ROTTERDAM

The Nieuwe Maas is in open connection with the North Sea. Along the coast, the impact of the sea is bigger than at the banks of adjacent rivers; impact and the corresponding tidal effects decrease further upstream the river. The difference between MHW and MLW at the height of the Rotterdam city centre is nonetheless still significant: 1.50 m - an interesting factor to incorporate within urban/landscape design. MHW and MLW are respectively 1.15 m +NAP and 0.35 m -NAP (Gemeente Rotterdam et al., 2005, p. 28). Due to the constant character of the movements of the earth and the moon, the ebb and flow rhythm is constant as well. With a tidal cycle taking 12 hours and 25 minutes, both ebb and flow occur twice every 24 hours and 50 minutes; slightly over twice per day (Rijkswaterstaat, n.d.).

SEA LEVEL RISE

With climate change causing an increase of the amount of meltwater, which is the water released due to the melting of snow and ice, water levels will continue to rise for the coming decades (Le Bars, 2019). See figure 25. The most recent prognosis is a sea level rise of 1.1 m in 2100 (Le Bars, 2019; based on the IPCC publication *Special Report on the Ocean and Cryosphere in a Changing*). This would result in estimated water levels in Rotterdam of 2.25 m +NAP and 0.75 m +NAP during respectively MHW and MLW. The numbers are estimates, and due to an increase in extreme weather events as a result of climate change, such as extreme rainfall, water levels are likely to increase even further.

CURRENT WATER LEVELS:
Mean High Water: 1.15 m +NAP
Mean Low Water: 0.35 m -NAP

ESTIMATED SEA LEVEL RISE IN 2100:
1.1 m
(Le Bars, 2019; based on the IPCC publication *Special Report on the Ocean and Cryosphere in a Changing*)

ESTIMATED WATER LEVELS IN 2100:
Mean High Water: 2.25 m +NAP
Mean Low Water: 0.75 m +NAP

TIDES IN THE NETHERLANDS:
A tidal cycle takes 12 hours and 25 minutes: both ebb and flow occur just over twice per 24 hours.

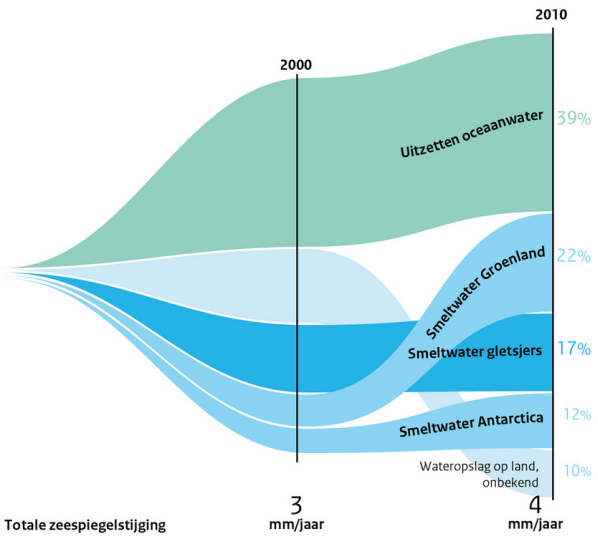


Figure 25: *Contributions to sea level rise (Le Bars, 2019).*

III. WHY INTEGRATE TIDAL NATURE IN URBAN DESIGN?

The uniqueness and potential of tidal nature in the Netherlands

CHARACTERISTICS OF TIDAL NATURE

The tidal zone is found at the edges of a water body, where the level of the surrounding landscape is higher than the water levels. Due to the cycles of high and low water, there is a portion of the zone that is dry during low tide, but wet during high tide: the intertidal zone. The differentiation in habitats resulting from this cycle generally results in a larger variety in species and a dynamic environment. Urban tidal parks therefore offers residents access to nature, and the river, at their doorstep or for instance during their lunch break if they work in the area. It offers unique and lively green-blue public space, and expanding public space into the river of course means the pressure on public space elsewhere is reduced. The unique experience that is the result will get more Rotterdammers to the waterfront, and have a great impact on climate adaptation and especially on restoring biodiversity. With tidal parks, densification, climate adaptation and ecological recovery go hand in hand.

NATURAL GRADIENTS

The tidal changes result in a large variety of animals and planting types distributed over a natural gradient. It starts on the bottom with species that need a lot of water, because these are underwater most of the time. It works up towards various species that deal with less water. All species attract their own birds, create specific shallow areas for fish, or offer nesting space for insects (reeds, for example). This is also related to how saline or fresh the water in the area is. Enlarging the surface area of this kind of gradient will greatly contribute to biodiversity recovery, as right now there is near to none at all; hard quays still dominate the street profile at the Nieuwe Maas in Rotterdam. Figure 26 shows that the tidal cycle happens twice a day in Rotterdam; the tidal difference is 1.50 meter as outlined on the previous page. These aspects makes it interesting to exploit the tidal character of the river in urban design. Due to the notable shifting in tides along the day, and the gradients that will emerge under the right conditions - softening quays - unique experiences can be created for people along and in the water of Rotterdam.

UNIQUE IN THE NETHERLANDS

On the larger scale, a tidal park may appear small on first glance, but it could play a significant role as part of the ecological corridor and river structure. It is so to say a stepping stone, see figure 27, necessary for flocks of birds to find shelter and food during their migration; for fish to find food and shallow water to rest, or places to lay eggs. Due to their relationship with tidal differences (high water, low water), these parks cannot be created everywhere. In fact, the Nieuwe Maas is the only river in the Netherlands that still has an open connection with the North Sea and so it is the only river in the Netherlands where tidal nature could be possible. The realisation of tidal nature in the urban area of Rotterdam is therefore not just a unique opportunity in regards to recovering ecology, creating a dynamic park for people, and uplift the economic value in order to enable densification, it will uplift the river system as a whole.

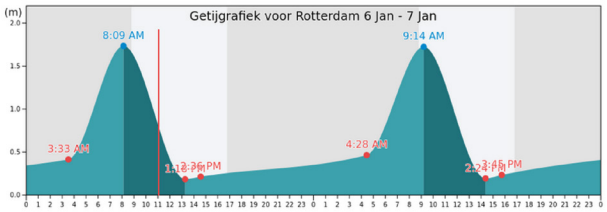


Figure 26: *Tidal graph for the Nieuwe Maas on a day in the centre of Rotterdam (www.tideschart.com, 2021).*

POTENTIAL IN THE NORTH

The ecological strength of the city of Rotterdam should be in the river, yet this is not currently the situation. Through a tidal park, all the aforementioned issues can be addressed integrally. A tidal park will also contribute to climate adaptation, as tidal parks are cooler places. A variety of plans has been worked on by the municipality, and various projects in the south are ongoing, however the busy city centre in the north remains disconnected from the tidal features of the river, despite providing a large stretch of space available.

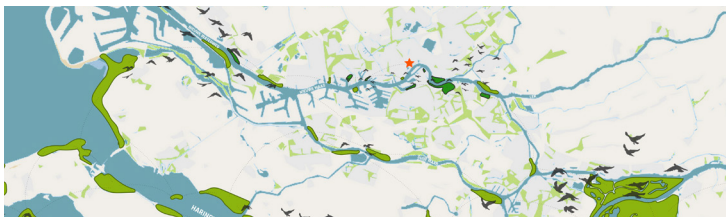


Figure 27: *A tidal park is a stepping stone within the delta area, from the Biesbosch to the North Sea (drawn by author).*

IV. TIDAL PARKS IN THE SOUTH OF ROTTERDAM

Existing and planned parks incorporating tidal nature for a dynamic environment

There is a small number of tide-influenced areas in the centre of Rotterdam, such as Eiland van Brienenoord and Quarantaineterrein. Additionally, there is a number of plans in varying phases of development. Three prime examples are Feyenoord City, Rijnhaven and Maashaven. All five aforementioned areas are located at the south of the river, however, whilst the most dense area of the city, and indeed the city centre, are located north of the river.

The following examples further illustrate the potential of incorporating tidal characteristics into the transformation of northern city boulevards, particularly Westblaak-Blaak.

EILAND VAN BRIENENOORD

Entitled a 'jewel of nature' within a city (ARK Natuurontwikkeling, n.d.), Eiland van Brienenoord partially floods during high tide. A range of habitats, from wet to dry, attracts a variety of (endangered) plants and animals. See figure 28. The richness in nature makes the area interesting for birdwatchers, for children looking to play and discover animals, for joggers, et cetera. The tidal island is loved by Rotterdammers; it even has its own fan page entitled *Vrienden van het Eiland van Brienenoord* (Friends of the Eiland van Brienenoord) (Rijnmond, 2021b). The tide-influenced areas are concentrated at the east, with tidal areas currently being developed on other parts of the island. Ecologist Johan de Bijl from Rijkswaterstaat states that "everything will be in bloom in a few years," and underlines that the area is one of only three areas in the Netherlands with a fresh-saline gradient (Rijnmond, 2021a).

RIJNHAVEN

In March 2020, the masterplan for a tidal park in Rijnhaven was presented by the municipality of Rotterdam. See figure 29. The large-scale project, done in corporation with Barcode Architects, BGSV, and landscape architect Robbert de Koning, sees the transformation of the now-empty Rijnhaven basin into a floating city park involving trees, boardwalks, terraces, and swimming pool. It also provides a contribution to the demand for housing in Rotterdam by providing 2.000-2.500 houses (Gemeente Rotterdam, 2020b). Besides the new residents of the area, tidal park Rijnhaven should provide park space for adjacent neighbourhoods lacking in such space, such as Afrikaanderwijk, and become a hotspot along the river for employees, tourists and animals.

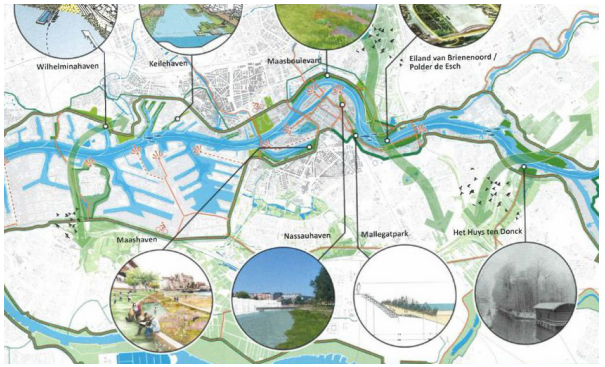


Figure 30: *A selection of tidal park plans within the Rotterdam port area (Rotterdam Duurzaam, 2016).*

Figure 29: *The masterplan for tidal park Rijnhaven (Gemeente Rotterdam, 2020b).*

Figure 28: *A highland cattle grazing on Eiland van Brienenoord (Zuid-Hollands Landschap, n.d.).*

v. OVERVIEW OF TIDAL NATURE BENEFITS

Overview of the benefits of incorporating tidal nature in urban design

It could be argued that the ecological strength of the city should be enhanced by the river. The Nieuwe Maas is not currently exploited to its potential though. Through a tidal urban environment along the Nieuwe Maas, a unique option for Rotterdam, the aforementioned challenges can all be addressed integrally. Various plans for the south have been worked on, but despite the high amount of paved quays in e.g. Waterstad, there have been no plans for the dense centre area of Rotterdam. In order to solve the previously outlined challenges in Rotterdam, the benefits of a tidal park north of the Maas are significant, and thus it is suggested to also involve the north of Rotterdam within the vision for tidal urban environments.

This chapter aimed to answer the first third of the research question. Throughout the chapter, the characteristics of the tidal river and arguments for tidal nature have been outlined. A conclusive overview of urban tidal nature benefits is listed to the right.

- Tidal gradients **bring nature into the urban environment**, and thus provide it to people that may otherwise not get to experience such nature as easily, or at all;
- With the Nieuwe Maas as the only remaining tide-influenced river within the Netherlands, a tidal park in the historic Rotterdam city centre has the potential to become a **new city symbol**;
- The **uplifting of the economic value** of the area will contribute to enabling densification;
- Providing for **new public space** north of the river, an area where public space is in demand not only due to densification, but also because it is already scarce;
- As previously outlined, half of the Rotterdammers never visits the river for recreation, and there is demand by Rotterdammers for **more public space destinations** (e.g. lunchrooms or bars) and **routes along the Nieuwe Maas** - a tidal park can provide for this demand and connect people with their river;
- New housing would be built on less than 500 m from the river;
- The **unique tidal landscape will become an experience**, an attraction in the centre of Rotterdam, where people experience the tidal cycles and are able to do all kinds of activities, e.g. spotting tidal bird species;
- Urban tidal areas can be **well connected with existing pedestrian and cycling routes**, as well as with public transport such as the tram, and make for a more natural stop in an otherwise urban route;
- The **amount of habitats** for endangered, red-listed, icon and tidal species **will increase**;
- The richness in habitats within the natural gradient of a tidal park will contribute to a **recovery of the biodiversity**;
- Quays and floating elements offer possibilities for **underwater nature**, also establishing non-gradient areas as useful habitats for a variety of fish species;
- A tidal park in the centre of Rotterdam will be a **new stepping stone in the Dutch delta area** network of ecological stepping stones; it will be of significance to migrating animals and strengthen the ecological network;
- Tidal parks are cooler parks; a reduction of paved surface and more green will contribute to **reducing the urban heat island effect**;
- People **experience the effects of climate change** due to the salination process, which affects the habitats in the area over the years as they transform into saltwater habitats; with the gradients at the Rotte protected from salinisation, also freshwater habitats will be maintained.

4

MOBILITY TRANSITION & TRANSFORMATION POTENTIAL

What are the possibilities for reducing car use in order to contribute to the mobility transition in Rotterdam? SQ2

I. BOULEVARDS INTERSECTED BY WESTBLAAK-BLAAK

Characteristics of the intersected main city boulevards

The aforementioned Basisplan has resulted in various boulevards perpendicular to the Nieuwe Maas, and intersected by Westblaak-Blaak before reaching the Nieuwe Maas (or, if coming from the river side, before reaching the city centre). The characteristics of and issues related to the three main boulevards in the centre of Rotterdam will be outlined.

The **WESTERSINGEL** is a main city boulevard in the centre of Rotterdam. With the Rotterdam Centraal Station as the start point in the north, this boulevard is the first glance of Rotterdam for people arriving by train. With regards to ecology, this boulevard contains the most vegetation out of the major city boulevards in Rotterdam, providing a cooling function as well as a habitat for various animals, and two sections of the singel include a water body in the middle with a grass bank at respectively one or both sides. In the middle, Eendrachtsplein is located, a traffic-heavy intersection with Westblaak-Blaak. The square is designated a 'black spot' which indicates a traffic point with over six accidents involving injuries occurring in three years (Molenaar, 2018); the municipality states it is looking for solutions.

The **COOLSINGEL** is the most central city boulevard in the centre, originating from Hofplein, leading towards the Erasmus Bridge and thus connecting the northern city centre to the south of Rotterdam across the Nieuwe Maas. It is regarded as a key portion within the city axis (*stadsas*): the central connection from Schiekade to Zuidplein, north to south, right through the city centre of Rotterdam (Gemeente Rotterdam, 2020b). Unlike the Westersingel, the Coolsingel does not contain any significant vegetation apart from trees, of which 99% however are the same species, the Platanus × hispanica. This specific tree (and the fact that there is no diversity in tree species) does not significantly contribute to a healthy biodiversity (Hiemstra, 2018), as will be further outlined in the next chapter.

Through a count of people crossing the Coolsingel in 2008, it turned out that people no longer crossed the street at all due to the heavy car traffic across four lanes (Fontein, 2021). The Coolsingel was recently transformed, between 2018 and 2021, with car traffic reduced from four to two lanes, opening up more space for cyclists and pedestrians.

In contrary to the two aforementioned boulevards, the **BINNENROTTE** is mainly focused on pedestrians and cyclists, and houses the biggest market of the city on Tuesdays and Saturdays. Whilst traffic-related issues are much less of a problem here, the large amount of paved surface contributes to the urban heat island effect and due to no variety in habitats also contributes to a poor biodiversity.

In conclusion, none of the boulevards currently offer an uninterrupted way from the train station or city centre towards the Nieuwe Maas. Their common disruptor: perpendicular traffic lane Westblaak-Blaak and the resulting intersections. Reducing traffic on Westblaak-Blaak would contribute to improving safety whilst traversing the city from centre to river and vice versa, and the freed up space can be transformed into attractive public space with room for both people and animals, enhancing people's experience and stimulating visits to the Nieuwe Maas.

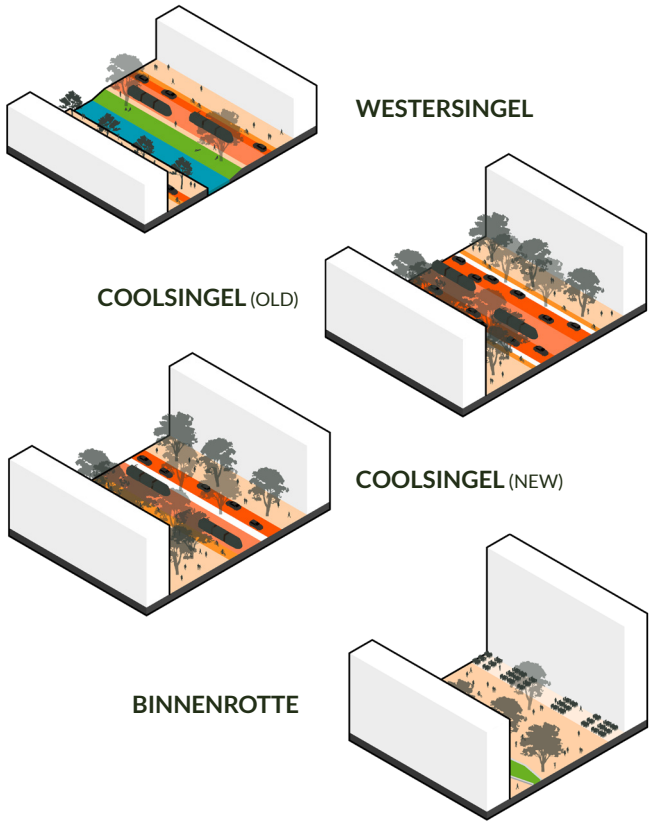
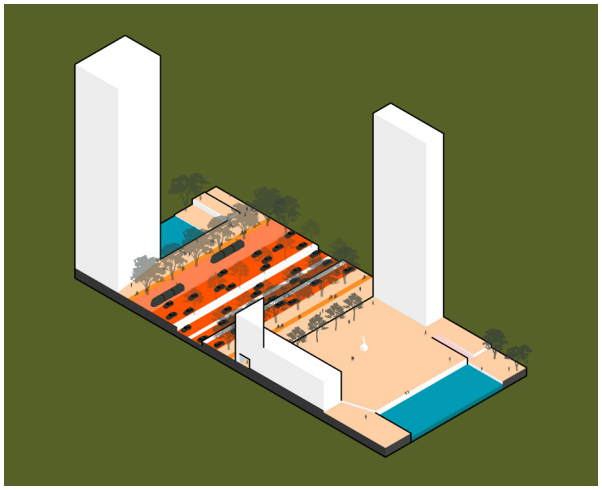


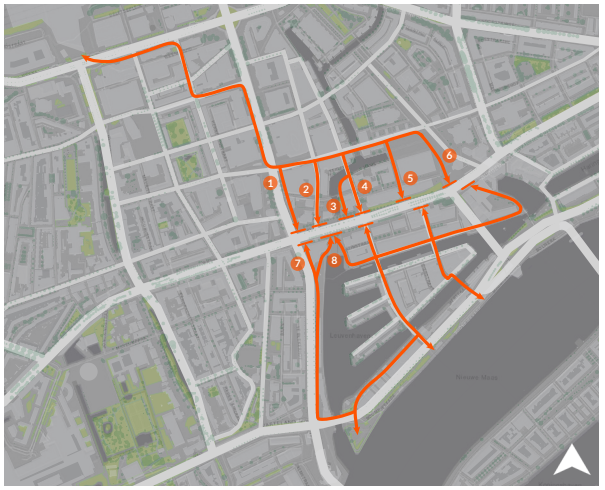
Figure 31: *Typologies of the main boulevards in the city centre; traffic intensity marked with orange (drawn by author).*

II. ARRIVING AT WESTBLAAK-BLAAK

Approaching the traffic-dominated boulevard from a range of directions

The three outlined boulevards, Westersingel, Coolsingel and Binnerotte, as well as a number of smaller streets, are all intersected by Westblaak-Blaak. Figure 32 shows the visual and spatial situation for people arriving at the traffic-heavy boulevard. The photographs are to indicate that the road acts as a barrier from all directions, both spatially and visually. Overall, it can be concluded that the boulevard is dominated by traffic, is very monotonous in habitats and barely offers public space functions. The area greatly focuses on movement flows, and there is no incentive to stay. The city experience is halted here.





1. ROTTERDAM CENTRAAL - WEENA - LIJNBAAN - STADHUISPLEIN - COOLSINGEL - BLAAK

2. KORTE HOOGSTRAAT - BLAAK

3. LEUVEKOLK - BLAAK

4. KEIZERSTRAAT - BLAAK

5. DS. JAN SCHARPSTRAAT - BLAAK

6. BLAAK MARKT - BLAAK

7/8. LEUVEHAVEN + PLEIN 1940 - BLAAK

Figure 32: *Approaching Blaak from a variety of directions (photos taken; birdview and map drawn by author).*

III. USE OF THE QUAYS

Space for traffic, but what about people, animals and the river?

As explained in the previous chapter, the quays have lost their original meaning due to the disappearnce of harbour functions from the area. Remaining are hard quays, with no ecologically beneficial gradients. In fact, 100% of the quays in the area pictured to the right is paved. See figures 33 and 34. For people, this results in a poor connection with the river; tides are barely notable and there is always a distance to the water. Car traffic is present as well. The other way around: the Nieuwe Maas herself has also lost her ability to flow freely. The introduction of tidal gradients would result in an increased number of habitats for animals, which would greatly contribute to the biodiversity and experience.

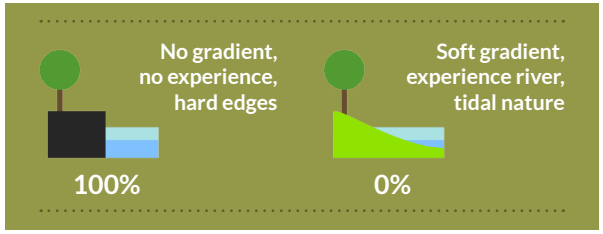


Figure 33: *Distribution of hard and soft quays.*

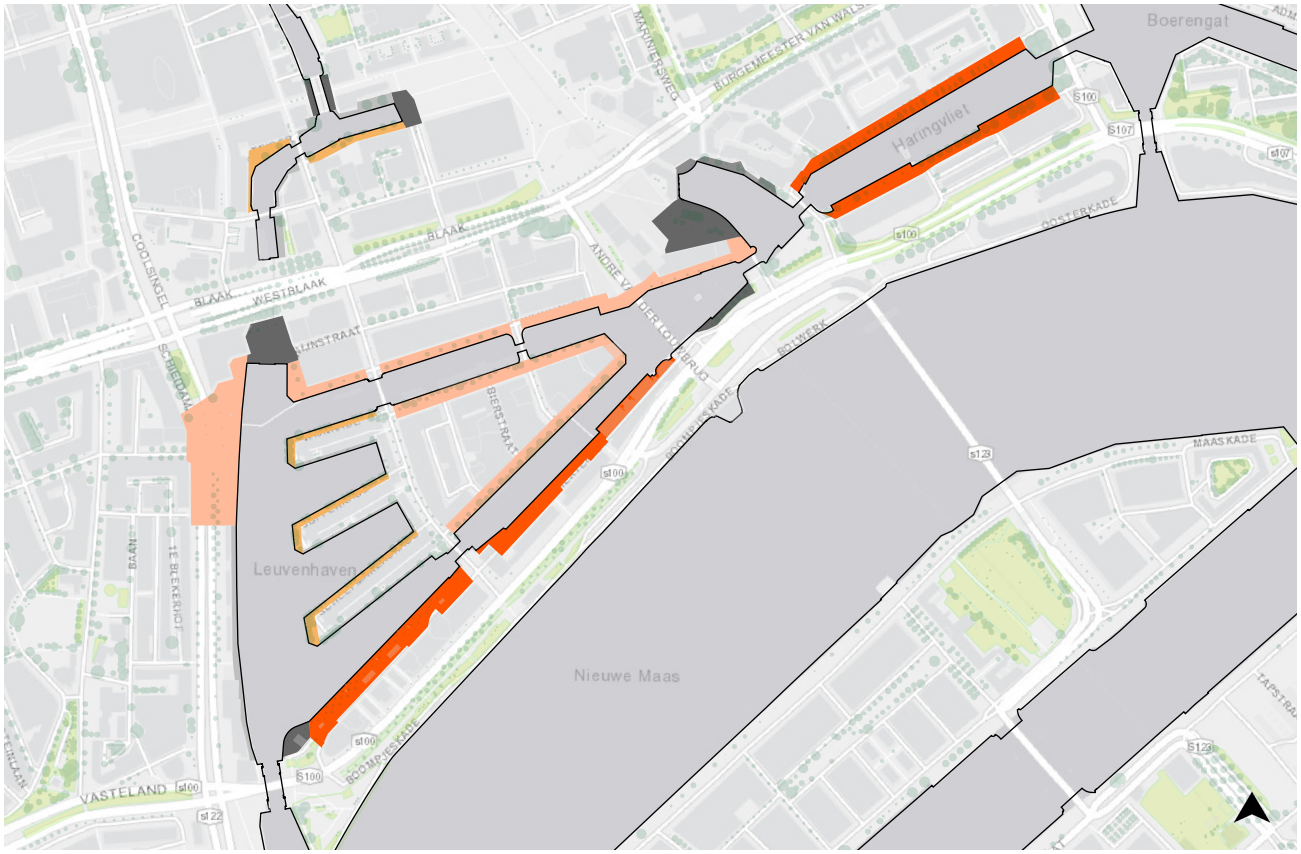
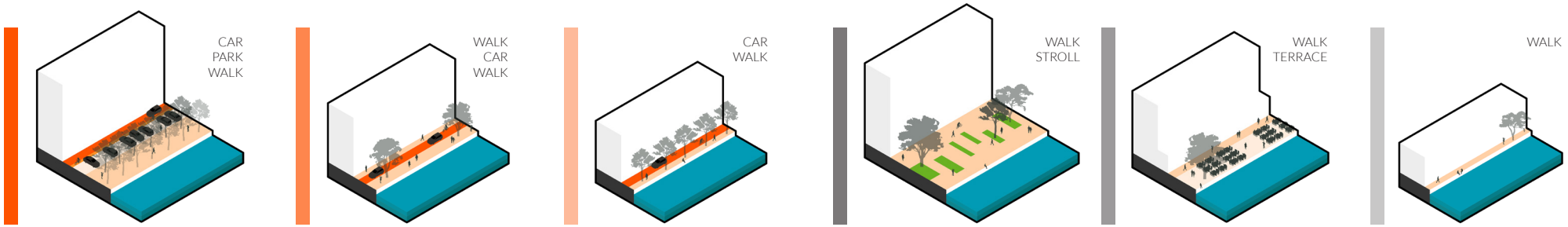


Figure 34: *Current usage of the quays in the centre of Rotterdam (map and birdviews drawn by author).*



IV. TOWARDS A SOLUTION

Plans to transform the boulevards by the municipality of Rotterdam

Plans by the municipality of Rotterdam in order to transform the traffic-dominated boulevards of the city into a more attractive and green public space, or 'city lounge', are being worked on continuously in order to create a city centre with places to stay and meet, and for leisure. The transformed Coolsingel was opened in April 2021 and features only two of the original four traffic lanes, putting focus on public transport and biking through a widened cycling lane.

MOBILITY TRANSITION

This plan fits within the goals of the city of Rotterdam with regards to the ongoing mobility transition, as outlined by the municipality (Gemeente Rotterdam, 2020a):

- Rotterdam contains a variety of public/ development areas with high noise and air pollution levels, such as Blaak and Weena, and measures should be taken to reduce both these issues (p. 6);
- Rotterdam should become better protected against the effects of climate change, which is achieved through more green and blue (also in combination), better accessible green and blue, and the use of other materials (p. 6);
- By transforming the mobility network into a cleaner and better system, the 18.000 new houses in 2022, and 50.000 in 2040, can be made accessible (p. 4), which facilitates the growth of the city.

The points outlined above would contribute to a more attractive, greener, and healthier city for current as well as future inhabitants. Public space is the area where people meet, work and stay, and is also the calling card of the city (Gemeente Rotterdam, 2020a, p. 7). Interestingly, the list of potential locations by the municipality (namely Schouwburgplein, Alexanderknoop, Maashaven, Hofbogen and the 'green lung' from Westblaak to Hofplein) does not include Blaak, despite this being one of the most traffic-dominated areas in the centre - containing eight and at some point as much as ten adjacent traffic lanes - and *the* location with potential to realise the 'green and blue' space the municipality aims for due to the river.

INCREASING SPACE FOR SLOWER TRAFFIC

With regards to mobility, the main goal is more space for pedestrians, bicycles and public transport. These traffic flows are to be the centre point in new policies. This means more space should be designated to attractive green routes for walking, strolling, and staying, for public transportation stops, and with the rise of biking, for royal cycle lanes. Generally, the infrastructure in the city centre should entail more space for slower traffic (Gemeente Rotterdam, 2020a, p. 9). This makes sense within the drastic increase of cyclists, and the decrease of car ownership, see figures 35 and 36. With car use reduced within the city centre, the intensity on the public transportation network will also increase, which should be facilitated (Gemeente Rotterdam, 2020a, p. 11). See figure 37.

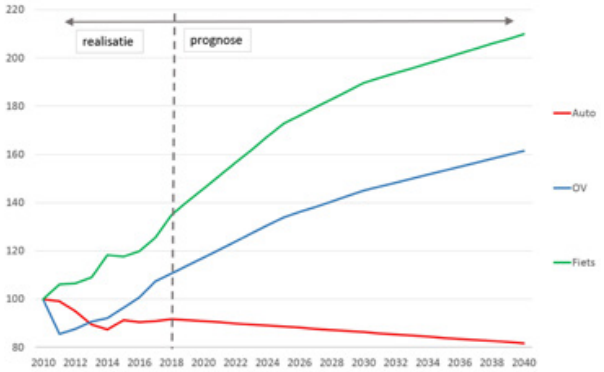


Figure 35: *Mobility developments in the Rotterdam city centre (Gemeente Rotterdam, 2020a, p. 9).*

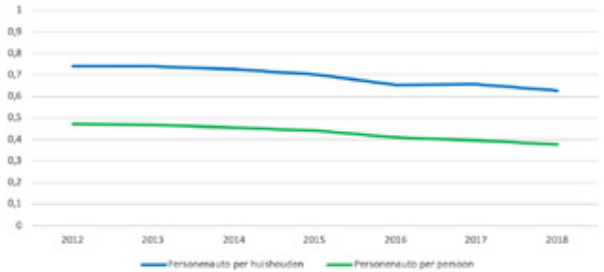


Figure 36: *Decrease in car ownership in the Rotterdam city centre (Gemeente Rotterdam, 2020a, p. 9).*

Figure 37: *Intensity of the public transportation network; Blaak annotated (Gemeente Rotterdam, 2020a, p. 11).*

IV. TOWARDS A SOLUTION *(cont.)*

Plans to transform the boulevards by the municipality of Rotterdam

REDUCING CARS IN THE CITY CENTRE

A large portion of the cars in the city centre actually has no business being there, state Annemieke Fontein and Emiel Arends from the municipality of Rotterdam (Liukku, 2020). Offering car traffic on the main boulevards a different route could result in a reduced intensity of just 40% to 70% of the current amount of car traffic during rush hour (Gemeente Rotterdam, 2020a, p. 12). Figure 38 shows that 30-40% of car traffic on Westblaak concerns short rides of less than 5 km. P+R hubs outside of the centre with a good connection to public transport will be constructed at the border of the city in order to facilitate the car reduction and stimulate the use of public transport in the centre. The ambition is a limit of 30 km/h on the city axis and city boulevards (Gemeente Rotterdam, 2020a, pp. 21-23).

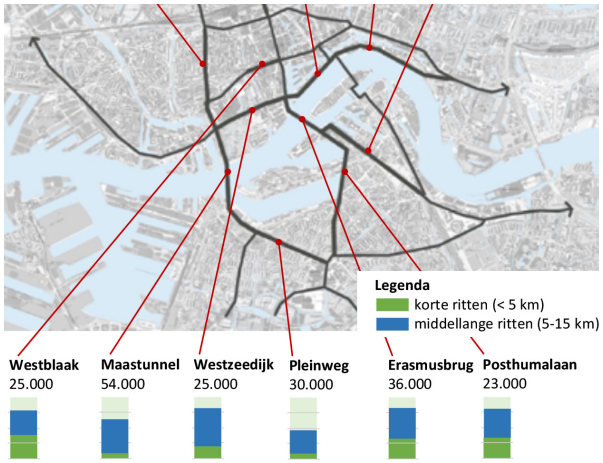


Figure 38: *Distribution of short and medium range car rides on city boulevards (Gemeente Rotterdam, 2020a, p. 12).*

SUFFICIENT SPACE FOR CYCLISTS

The aforementioned transformation of the Coolsingel reduced car traffic lanes by 50%, going from four to two lanes. As a result, more space could be given to pedestrians and cyclists. In the months following the opening of the transformed Coolsingel, the 4.50 m wide cycle road was deemed in fact not wide enough by the Fietsersbond (Keunen, 2021) due to the high intensity of use. Additionally, as argued by the Fietsersbond, having separated cycle lanes, rather than a single lane, should be preferred in order to avoid safety issues regarding people looking to cross the cycle path.

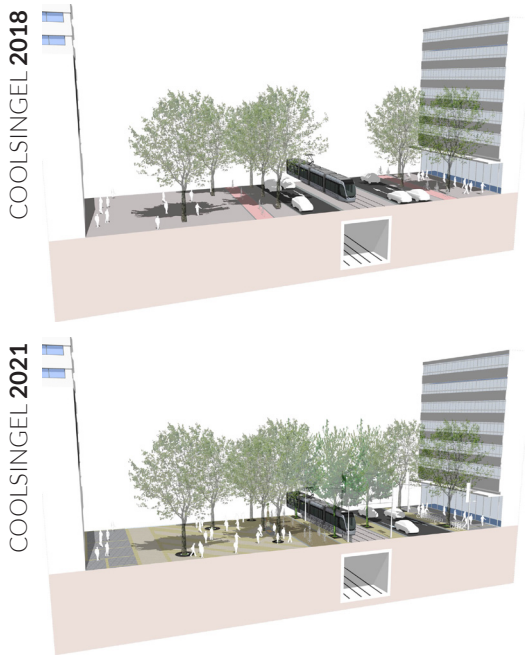


Figure 39: *Situation on the Coolsingel, respectively before and after the transformation (Gemeente Rotterdam, 2021).*

Figure 40: *Impression of the Blaakpark launched by Emiel Arends in September 2019 (Liukku & Mulders, 2019).*

v. TRANSFORMATION OF WESTBLAAK-BLAAK

The plan by the municipality and potential for incorporating the Nieuwe Maas

With regards to the various new city projects within Rotterdam, Annemieke Fontein (Head of Landscape Architecture at the municipality of Rotterdam), explains the necessity of adapting the city to climate change, as well as the importance of creating more green public space due to the current shortage, ongoing densification and various transitions such as the mobility transition. She outlines 7 projects, one of which concerns Westblaak.

POTENTIAL ON WESTBLAAK

According to Fontein, there is much potential for new public services and amenities on Westblaak, but it is currently not possible to intervene due to sound and air pollution. More space can be achieved by reducing the number of traffic lanes from four to two. She explains this space can be used for e.g. storing water and reducing heat stress, while adding a considerable amount of green and places to stay. It also makes it easier to cross Westblaak when going from one city district to another.

The transformation of Westblaak as proposed in the lecture by Fontein (2021) is not a contained stand-alone project, but rather it is part of the transformation of various areas in Rotterdam. In particular, it is part of the 'green lung', a green connection from Hofplein to Westblaak. The investments may not seem worth it as clearly compared to housing projects, as acknowledged by Fontein, but they will turn out to be successful in other ways in the long run: through the health benefits of green space, reduced polution, more spaces for people to stay and move, and through inciting investments (e.g. housing, cafes).

Figure 40 on the previous page shows the transformation plan for the Blaakpark launched by Emiel Arends, urban designer at the municipality of Rotterdam, in September 2019 (Liukku & Mulders, 2019). An interpretation of the park drawn by the author is seen in figure 41 below. Due to excessive noise levels, 70 db against the facades rather than the 63 db maximum, housing and school functions are respectively only possible with additional insulation measures and not allowed at all. By reducing the number of car traffic lanes from four to two, this problem can be resolved and the freed up surface area can be transformed into green public space functions; especially in the northern part of the park.

ROOM FOR THE NIEUWE MAAS

The plan for Westblaak offers much potential and would transform the area into a green and attractive public space, as opposed to the traffic-heavy street it is currently. Westblaak extends towards the east into Blaak; the latter appears to have even more potential than the proposed plan outlines, due to its adjacent ends of both the Rotte and the Nieuwe Maas. Introducing tidal nature, with all its benefits as extensively outlined in the previous chapter, would make the transformation of Westblaak-Blaak a dynamic and unique public hotspot - it should indeed be considered an additional 8th city project on its own.

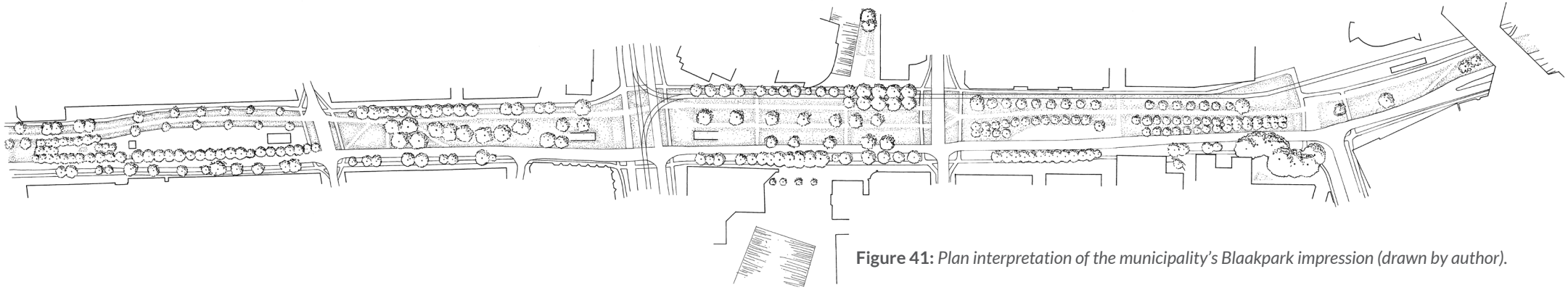


Figure 41: *Plan interpretation of the municipality's Blaakpark impression (drawn by author).*

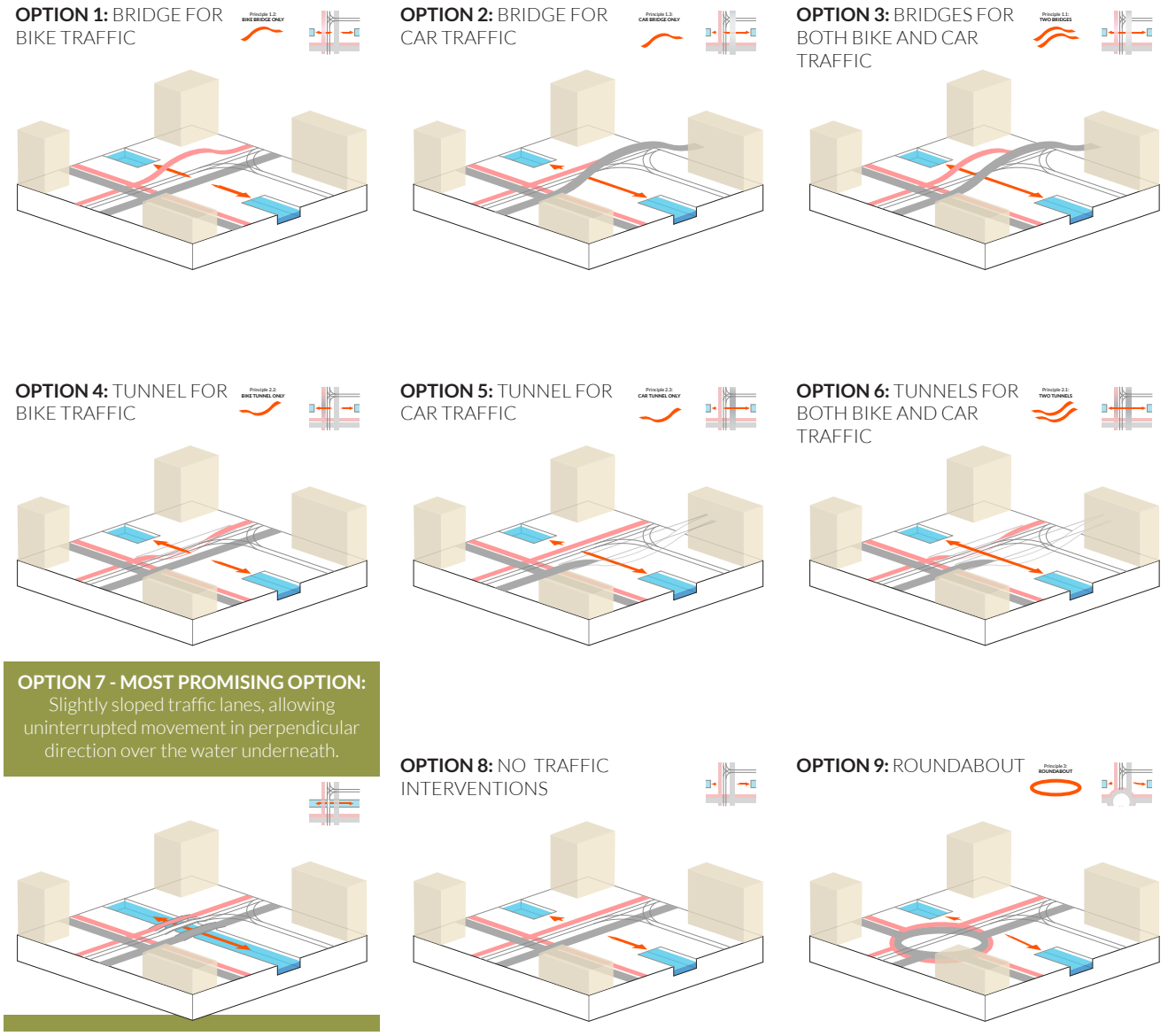
VI. IMPROVING THE INTERSECTIONS ALONG WESTBLAAK-BLAAK

Exploration of transformation options on the boulevard intersections

In order to reduce or remove traffic barriers, solutions should be found for the interrupted traffic flows through the various intersections. In order to achieve a high level of safety, the intersections should be designed in order to minimise the impact of traffic flows interrupted by crossing, or by diverging flows of different speeds (vehicles, pedestrians, bicyles). The design should pay attention to the following points related to minimising the potential for crashes between the various flows: minimising the number of conflict points, simplifying the conflict areas, limiting the frequency of conflicts, and limiting the severity of conflicts (Pande & Wolshon, 2016, pp. 322-323).

With these points in mind, the experiments outlined in figure 42 were conducted in order to investigate how the movement flows of slower traffic in the direction along the Westblaak-Blaak could be realised with as least interruptions as possible. The intersection Coolsingel-Blaak was explored due to this intersection being the location where pedestrian, car, bike, and the tram intersect from various directions. The already existing tunnel structure (*tunnelbak*), now heavily used by car traffic, offers opportunities. It could be given a new function, serving as a main tidal boulevard for pedestrian flows along Westblaak-Blaak. The construction of slightly sloping bridges will allow vehicular and bike traffic from perpendicular streets. The tram, already there, fits within the aims of the mobility transition and will be maintained.

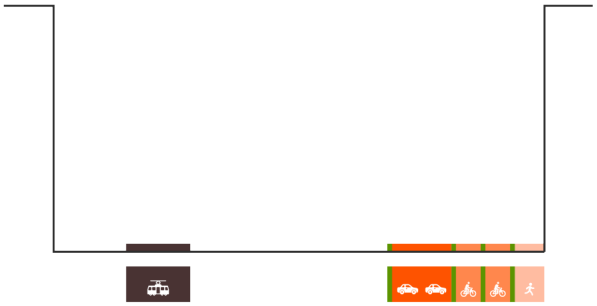
Figure 42: *Exploration of options on improving the intersections along Westblaak-Blaak (drawn by author).*



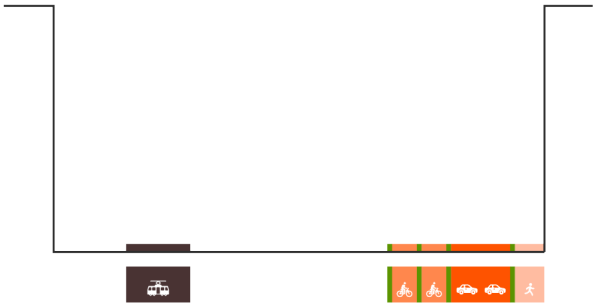
VII. IMPROVING THE STREET PROFILES ALONG WESTBLAAK-BLAAK

Reducing car traffic and focusing on walking, cycling and public transport

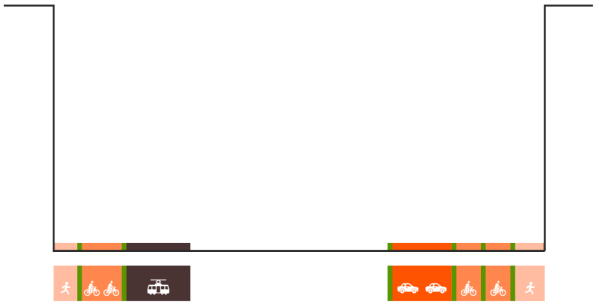
OPTION 1: 2 CAR LANES + 2 BIKE LANES; CARS CLOSER TO CENTRE



OPTION 2: 2 CAR LANES + 2 BIKE LANES; BIKES CLOSER TO CENTRE



OPTION 3: OPTION 1 WITH ADDED NECESSARY BIKE LANE IN THE NORTH



OPTION 4 - MOST PROMISING OPTION: WIDE BIKE LANE WITH CARS AS GUEST USERS

Figure 43: *Exploration of options on reducing car traffic and increasing slower traffic flows on Westblaak-Blaak (drawn by author).*

In addition to the outlined transformation of the intersections, options were drawn in order to explore the possibilities for future traffic flows, as well as the space for public functions, on Westblaak-Blaak. See figure 43. Due to the use of the tunnel structure as outlined on the previous page, the four roads in the middle have been taken out for all options. Remaining are four other roads along the buildings (two on each side). By removing two lanes entirely, and transforming the other two in a royal cycling path of 6 m (2 x 3 m), with cars allowed at low speeds and solely as guests, the least amount of space will be used for traffic. This opens up the possibilities for experiencing tidal nature within the tunnel structure, meanwhile ensuring the plan will fit well within the ongoing mobility transition.

5

RECOVERING BIODIVERSITY THROUGH EXPANDING HABITATS

Which types of habitats will contribute to recovering the biodiversity in Rotterdam, and which endangered/tidal species are expected to benefit from such habitats? SQ3.1

How could these habitats be incorporated in urban planning with an ever-changing environment as the result? SQ3.2

I. TOWARDS A BIODIVERSE ROTTERDAM

The necessity of recovering the biodiversity within the urban environment of Rotterdam

BIODIVERSITY: NATURE IN BALANCE

The variety of species on earth keep nature in balance, together they shape a productive and lively nature; this is called biodiversity (Biodiversiteit.NL, n.d.). Variation in species should be considered in the broadest sense of the word; think about animals, plants, grass, sand, and indeed humans. When biodiversity is disturbed, for instance due to the disappearance of a certain animal, this affects other animals in the chain as well (e.g. the disappeared animal's prey or predator) and thus it impacts the entire food cycle.

For a lively and productive nature, there needs to be a balance in species. It makes for clean water, fertile soil and a stable climate. It also produces the materials for food, clothing and medicine, and enables agriculture (Biodiversiteit.NL, n.d.). Ecosystems comprise the species and the physical environment with which they interact; they provide oxygen production, contribute to the decomposition of dead animals and plants, enable the pollination of plants such as agricultural crops, and contribute to water purification and pest control (Biodiversiteit.NL, n.d.). For people, these are unmistakably critical factors, as biodiversity is the driving force behind our food, building/raw materials, medicine and clothing.

The necessary or preferred conditions for the physical living environment differ per species. Ecosystems with a larger range of living environments, known as habitats, offer conditions for a larger number of species to be able to live there, which in turn contributes to the biodiversity. Providing new habitats, or reintroducing lost habitats, could thus contribute to regenerating the ecological strength of a city and help achieving higher biodiversity.

CURRENT STATE OF THE BIODIVERSITY

The ecological capital of Rotterdam was measured in a sustainability score by Het PON & Telos (2020) and compared to 354 other municipalities in the Netherlands. Out of the 355 municipalities, Rotterdam ranks 353. This underlines the urgent need for recovering the biodiversity in Rotterdam. The amount of habitats is limited, as illustrated on the next page. A large portion of the urban tissue is paved, with natural habitats limited to mostly grass, or traditional parks. Also trees play a part in biodiversity; not only the amount of different trees contributes, but also the type of trees.

TREE SPECIES ON THE COOLSINGEL

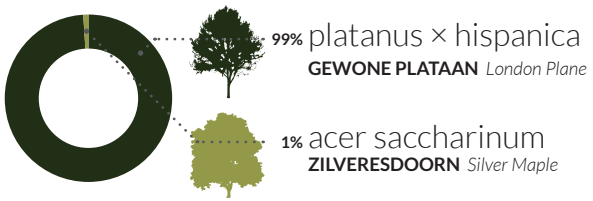


Figure 44: *Distribution of tree species on the Coolsingel (drawn by author; data retrieved from https://data.overheid.nl/dataset/6098-bomen-rotterdam).*

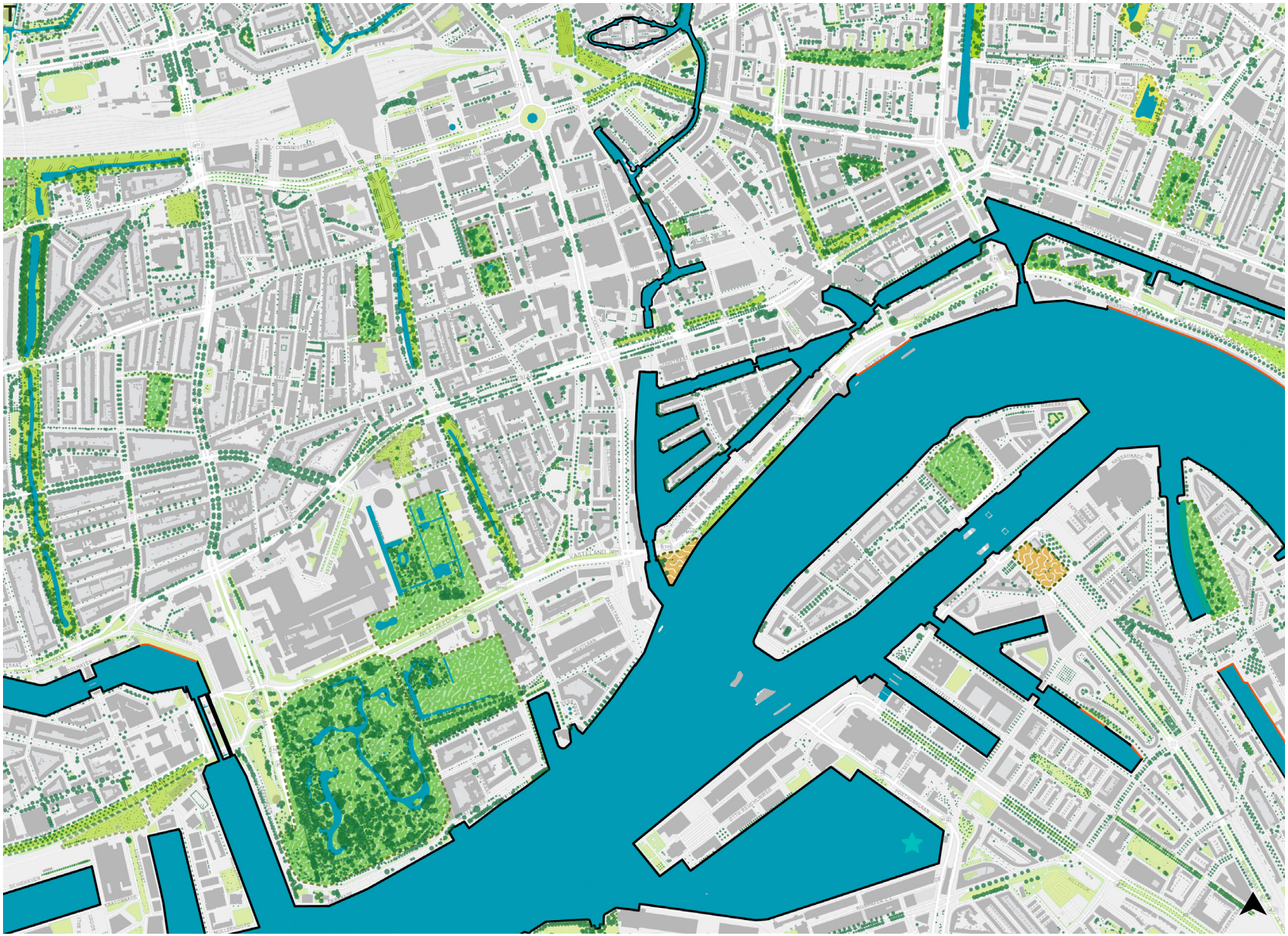
For instance, the *Platanus × hispanica* is known to have an insignificant meaning as a nector source for insects, as a pollen source for insects, or as a food source for birds. Additionally, it ranks among the highest in disadventageous properties in the research conducted by Hiemstra (2018). Yet, it is widely found in Rotterdam; 99% of the trees on the Coolsingel are this *Platanus × hispanica*. See figure 44.

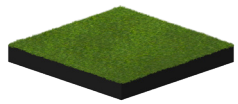
HABITATS AS THE STARTING POINT

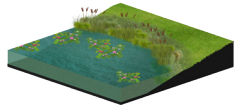
As outlined in chapter 3, there is a range of benefits attached to introducing tidal nature into urban design, one of which is the ability to achieve a high number of habitats of which each will attract specific species, e.g. different kinds of birds, fish, mammals, plants, et cetera. As outlined in the previous paragraphs, high biodiversity is of the utmost importance for a healthy urban environment and for a balanced ecosystem. Therefore, creating the conditions for a range of habitats, both tidal and non-tidal, will attract the maximum feasible number of species, including endangered and unique species in the Netherlands. This will make it possible for Rotterdam to become a biodiverse hotspot within the region, and establish the area as a significant ecological stepping stone within the larger picture.

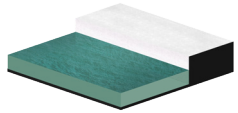
II. CURRENT HABITATS WITHIN THE CENTRE OF ROTTERDAM

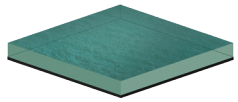
Current availability and distribution of habitats







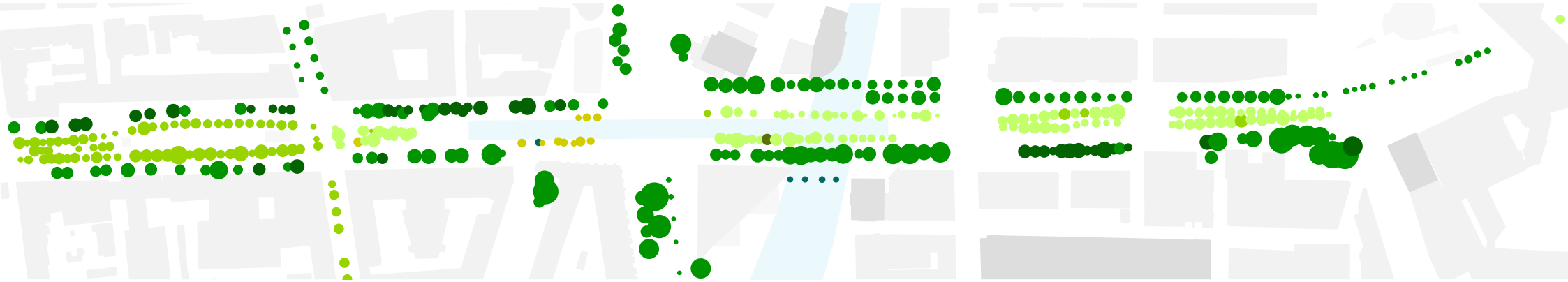




Please refer to page 42 for the proposed new habitats, and to page 43 for clarification.

III. CURRENT DISTRIBUTION OF TREES

A total of 7 tree species is found across the entirety of Westblaak-Blaak



Platanus × hispanica

BENEFICIAL CHARACTERISTICS

HEAT ISLAND REDUCTION	★★★	NECTAR SOURCE *for Insects*	☆☆☆☆
ENDURES WET PERIODS	★☆☆	POLLEN SOURCE *for Insects*	☆☆☆☆
ENDURES DRY PERIODS	★★☆	CAPTURES NO_x/O_3	★★★★★
FOOD SOURCE *for Birds*	☆☆☆	SECURES CO_2	★★★★★

DISADVANTAGEOUS CHARACTERISTICS

ALLERGENICITY	⚠⚠⚠	VOC EMISSION	⚠⚠⚠

Acer pseudoplatanus

BENEFICIAL CHARACTERISTICS

HEAT ISLAND REDUCTION	★★★	NECTAR SOURCE *for Insects*	★★★★★
ENDURES WET PERIODS	☆☆☆	POLLEN SOURCE *for Insects*	★★☆☆☆
ENDURES DRY PERIODS	☆☆☆	CAPTURES NO_x/O_3	★★★★★
FOOD SOURCE *for Birds*	☆☆☆	SECURES CO_2	★★★★★

DISADVANTAGEOUS CHARACTERISTICS

ALLERGENICITY	⚠⚠⚠	VOC EMISSION	⚠⚠

Tilia × europaea

BENEFICIAL CHARACTERISTICS

HEAT ISLAND REDUCTION	★★★	NECTAR SOURCE *for Insects*	★★★★★
ENDURES WET PERIODS	☆☆☆	POLLEN SOURCE *for Insects*	★★☆☆☆
ENDURES DRY PERIODS	☆☆☆	CAPTURES NO_x/O_3	★★★☆☆
FOOD SOURCE *for Birds*	☆☆☆	SECURES CO_2	★★★★★

DISADVANTAGEOUS CHARACTERISTICS

ALLERGENICITY	⚠	VOC EMISSION	⚠⚠

Platanus orientalis

BENEFICIAL CHARACTERISTICS

HEAT ISLAND REDUCTION	★★★	NECTAR SOURCE *for Insects*	☆☆☆☆
ENDURES WET PERIODS	☆☆☆	POLLEN SOURCE *for Insects*	☆☆☆☆
ENDURES DRY PERIODS	☆☆☆	CAPTURES NO_x/O_3	★★★★★
FOOD SOURCE *for Birds*	★★★	SECURES CO_2	★★★★★

DISADVANTAGEOUS CHARACTERISTICS

ALLERGENICITY	⚠⚠⚠	VOC EMISSION	⚠⚠⚠

Quercus robur

BENEFICIAL CHARACTERISTICS

HEAT ISLAND REDUCTION	★★★	NECTAR SOURCE *for Insects*	☆☆☆☆
ENDURES WET PERIODS	☆☆☆	POLLEN SOURCE *for Insects*	★★★☆☆
ENDURES DRY PERIODS	★☆☆	CAPTURES NO_x/O_3	★★★★★
FOOD SOURCE *for Birds*	★★★	SECURES CO_2	★★★★★

DISADVANTAGEOUS CHARACTERISTICS

ALLERGENICITY	⚠⚠	VOC EMISSION	⚠⚠⚠

Tilia cordata

BENEFICIAL CHARACTERISTICS

HEAT ISLAND REDUCTION	★★★	NECTAR SOURCE *for Insects*	★★★★★
ENDURES WET PERIODS	☆☆☆	POLLEN SOURCE *for Insects*	★★☆☆☆
ENDURES DRY PERIODS	☆☆☆	CAPTURES NO_x/O_3	★★★☆☆
FOOD SOURCE *for Birds*	☆☆☆	SECURES CO_2	★★★★★

DISADVANTAGEOUS CHARACTERISTICS

ALLERGENICITY	⚠	VOC EMISSION	⚠⚠

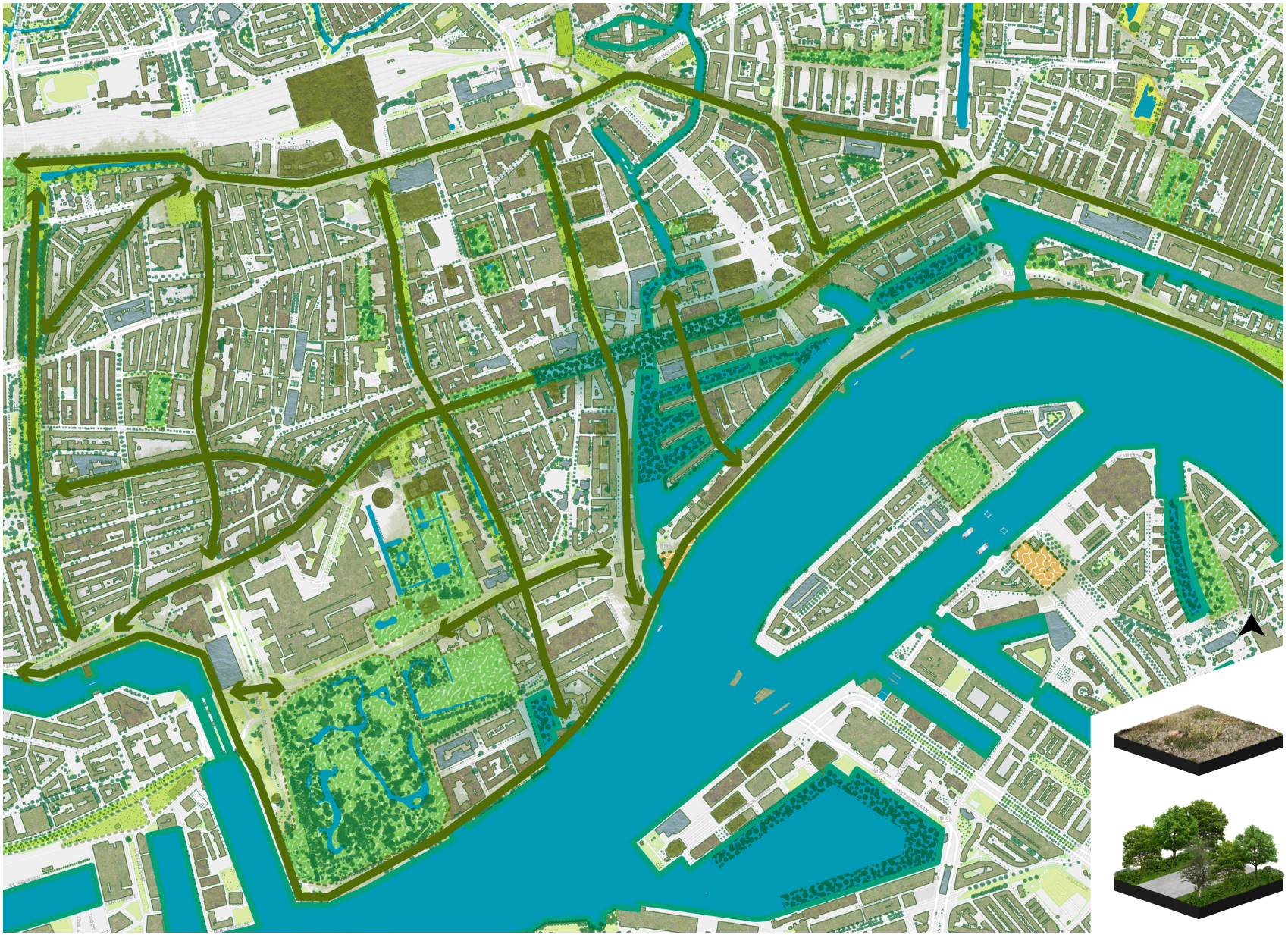
Tilia × europaea 'Euchlora'

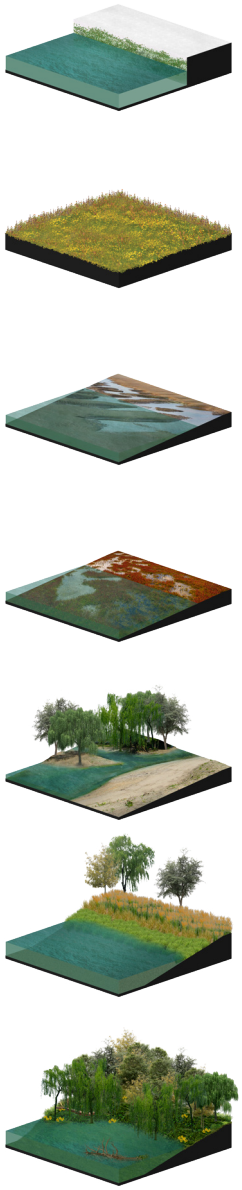
Only seven different tree species are found in the area; of which a high percentage is the Platanus. This tree has few benefits for urban ecology. Improvements should be made by gradually replacing such trees with more beneficial species.

Data: *Hiemstra, 2018.*

IV. PROPOSED NEW HABITATS WITHIN THE CENTRE OF ROTTERDAM

Suggested additional tidal and non-tidal habitats, as well as ecological corridors





Please refer to the next page for clarification.

v. POTENTIAL TIDAL AND NON-TIDAL HABITATS

Existing and suggested habitats with potential for an ecologically diverse and attractive city

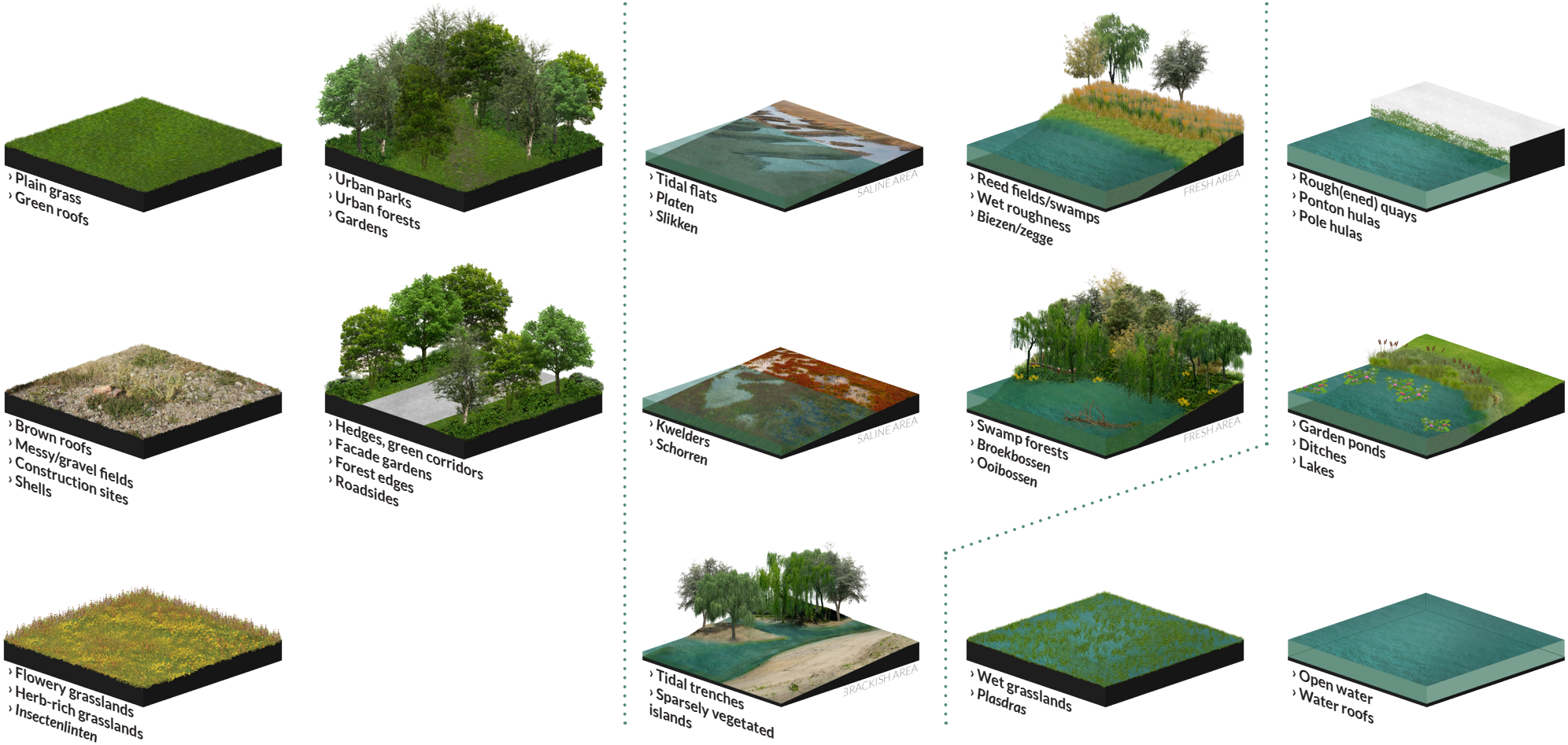
The following are habitats fit for achieving a large variety of species. This includes more common animals but also red-listed and icon species. Introducing new habitats will enrich the biodiversity of Rotterdam, whilst at the same time offering people more variety in natural environments in the urban area. The habitats are ranked from dry to tidal to wet.

Please refer to the appendix for a comprehensive list of flora and fauna related to the below habitats.

DRY HABITATS

TIDAL HABITATS
from Saline to Brackish to Fresh

WET HABITATS

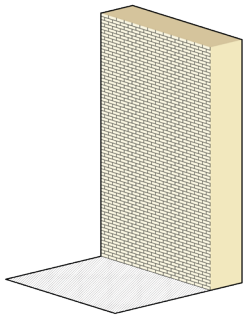


VI. VERTICAL HABITATS

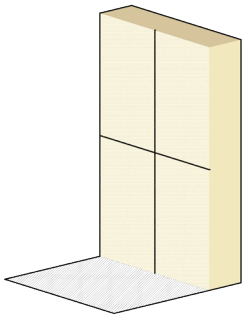
Expanding the ecological zone from surfaces to facades

Throughout the urban environment, a variety of facades and materials can be distinguished. In the Westblaak-Blaak area, four types are especially prominent. As displayed below, the boulevard contains brick walls, various types of walls covered with natural stones (both glazed and rough), and glazing. With the exception of possible bird/bat nesting box stones, these walls are currently not part of the ecological zone of the city. Through various green/living wall solutions, however, building facades throughout the area, and indeed the city, could become ecologically meaningful - offering food and shelter for animals - whilst also making for a more diverse and attractive view for residents and visitors.

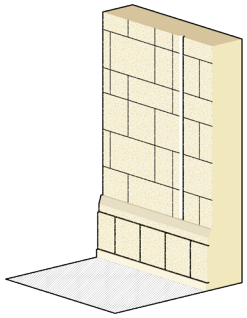
The following types of facades on Westblaak-Blaak are distinguished. To the right, various solutions with regards to realising vertical habitats are explained. The next page, 45, offers an overview concluding promising, possible, and less plausible combinations.



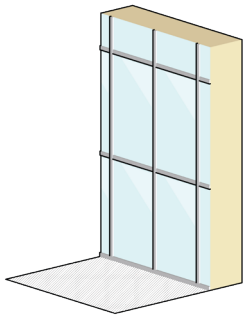
BRICK WALL



NATURAL STONE (GLAZED) WALL



NATURAL STONE (ROUGH) WALL



GLAZING

ECOLOGICALLY MEANINGFUL FACADES

Designing for an attractive and biodiverse city does not stop at the building edges. Besides flat surfaces such as the soil and roofs, the facades of the surrounding (existing) buildings should play a role as well. Various types of greenery aimed to vertical surfaces are available, as outlined below. Each of those have characteristics that may or may not fit with specific building types.

PLANTING ON
CONSTRUCTION FRAME

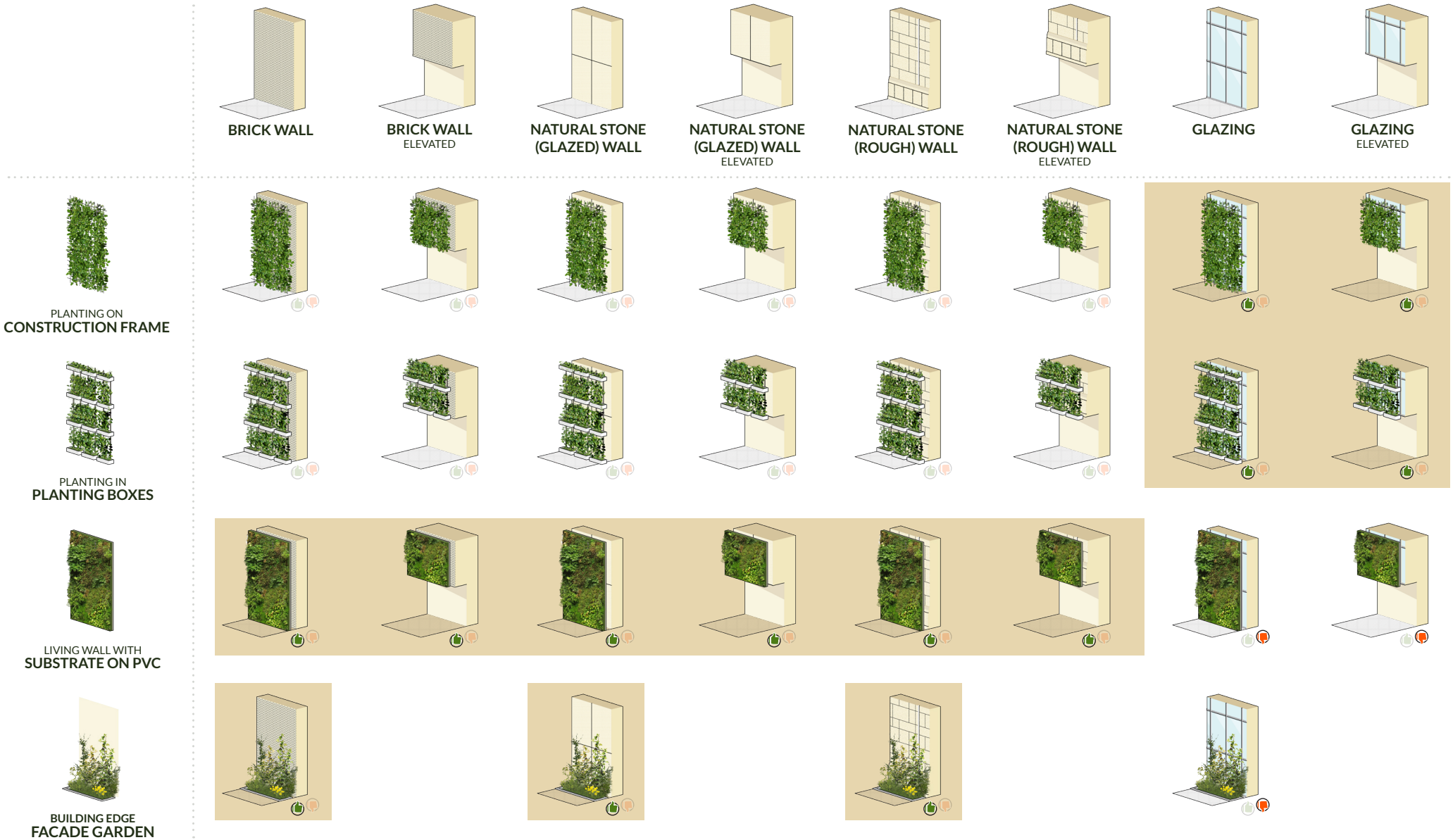
PLANTING IN
PLANTING BOXES

LIVING WALL WITH
SUBSTRATE ON PVC

BUILDING EDGE
FACADE GARDEN

VI. VERTICAL HABITATS *(cont.)*

Overview of various vertical habitat options in relation to different facade types



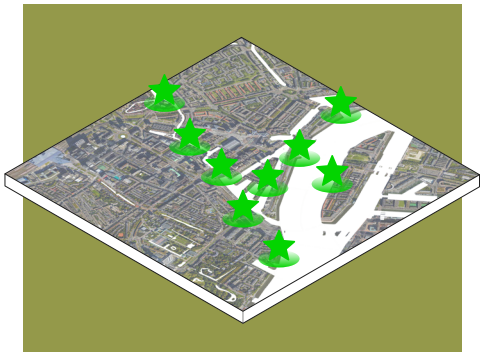
6

WESTBLAAK-BLAAK 3.0

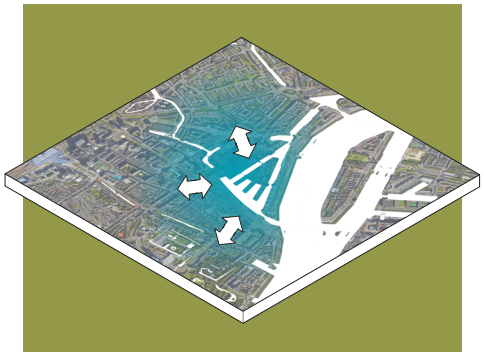
Translating gained knowledge into a resilient urban transformation with space for people and animals

I. DESIGN GOALS

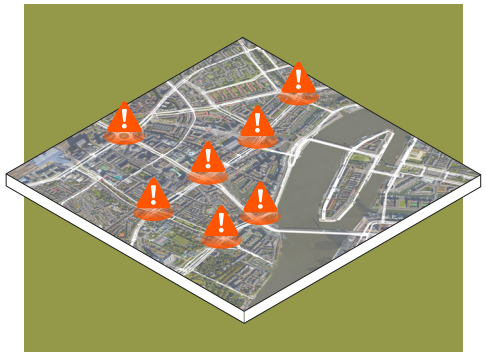
As concluded from the conducted research



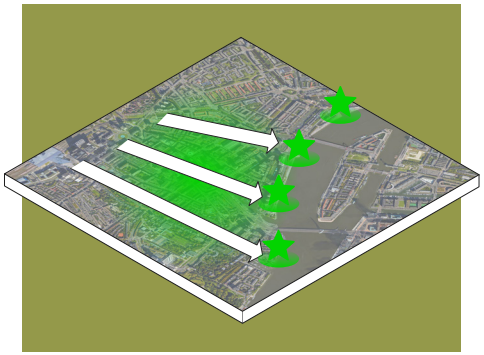
Establishing the Nieuwe Maas as dynamic public space, with a range of destinations and habitats where people, flora and fauna can meet



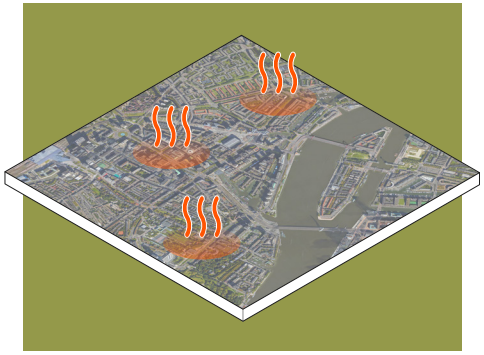
Better connecting the district and the Rotte to the city centre; enhancing accessibility



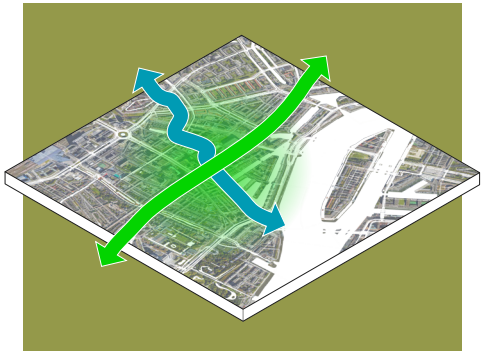
Reducing mobilised traffic on boulevards, and Westblaak-Blaak intersections, freeing up space for a healthier and more attractive urban environment



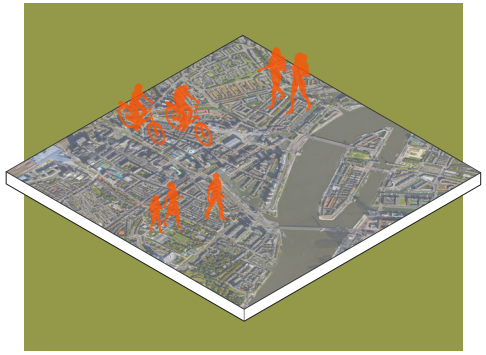
Transforming intersections will provide for easier, safer and more gradual access to destinations along the river, connecting city and the Nieuwe Maas



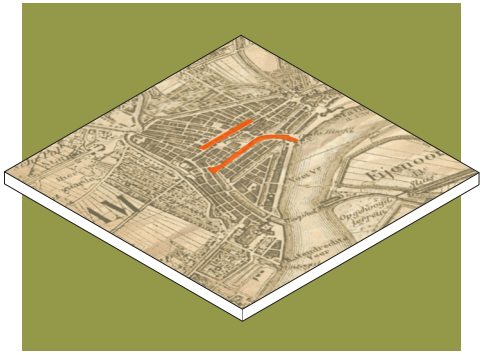
Adapting to climate-related challenges, such as a reduction of paved surface to reduce the urban heat island effect and areas for stormwater storage



Introducing various types of nature into the dense urban tissue; utilising unique tidal qualities through a network of ecological corridors



Contributing to the ongoing mobility transition through drastically reducing car use and increasing space for pedestrians, cyclists, and public transport



Reintroducing elements from the historic cultural landscape, e.g. the original Rotte dam and the original charachter of Blaak

II. DESIGN CONCEPT

Experiencing the Nieuwe Maas, literally, within the centre of Rotterdam

PATTERNS & MATERIALS from the Rotterdam Area

ABSTRACTING THE SHAPE of the Nieuwe Maas & Maintaining Historic Identity

Reflecting Harbours & Tidal Zones

Bringing Back the **BLINK OF BLAAK**

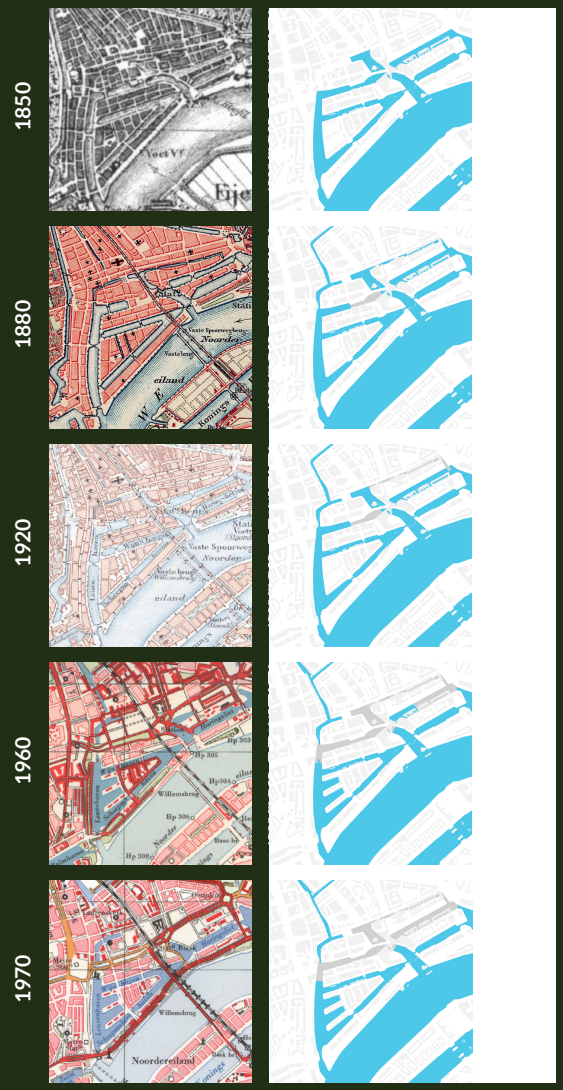
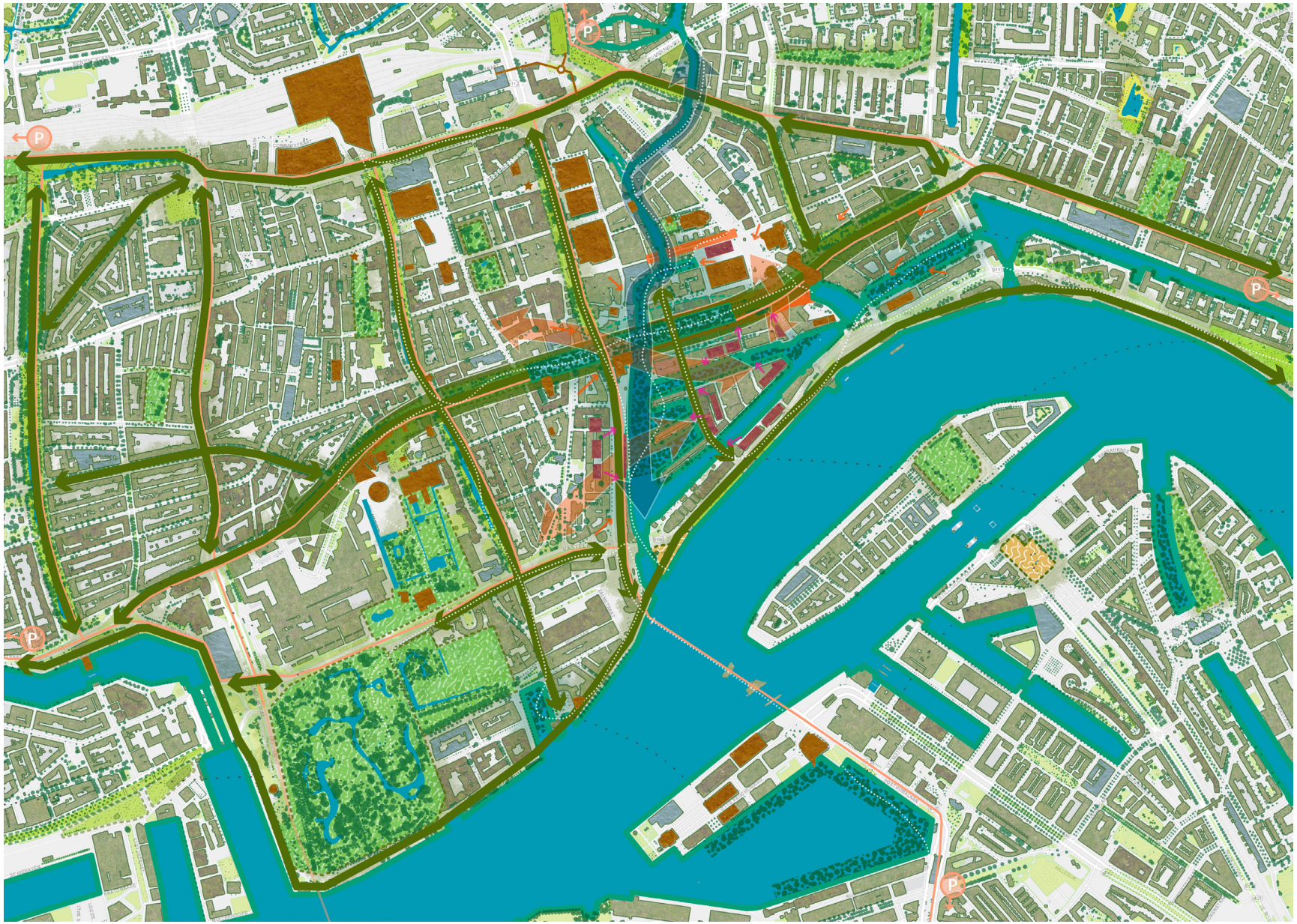


Figure 45: *Maps showing how the harbour basin and water at Blaak disappeard over time (www.topotijdreis.nl, n.d.; edited).*

III. VISION MAP

Towards a resilient and connected city centre through the ecological strength of corridors and rivers



1:10.000

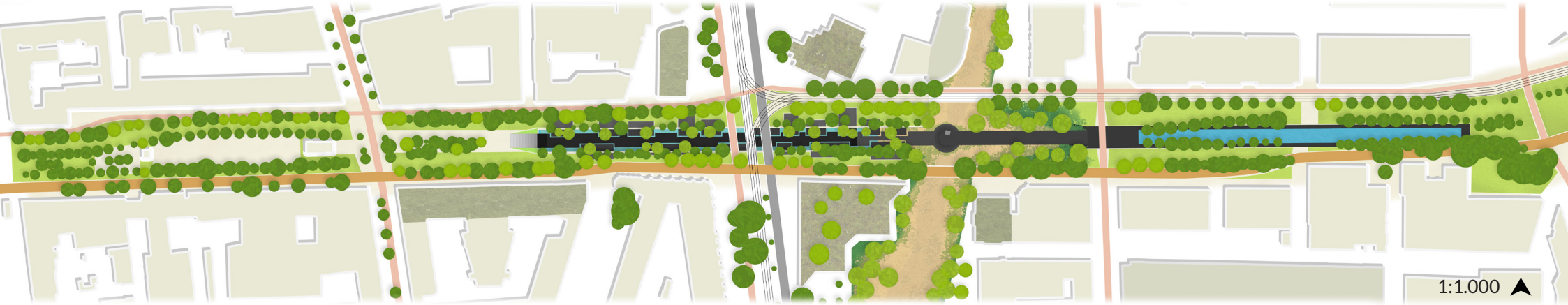
IV. VISION BIRDVIEW

Spatial overview of the suggested urban transformation

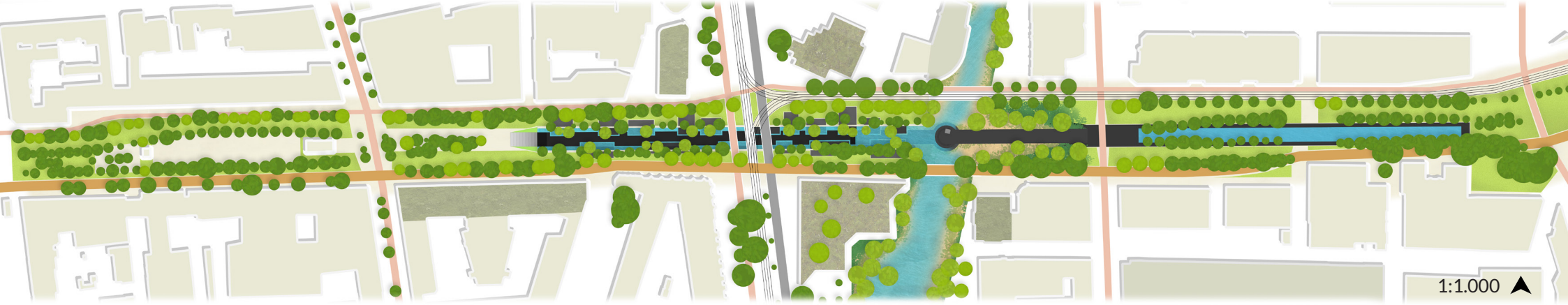
v. MASTERPLAN 2022

From an enclosed to a free-flowing Nieuwe Maas

MEAN LOW WATER SITUATION



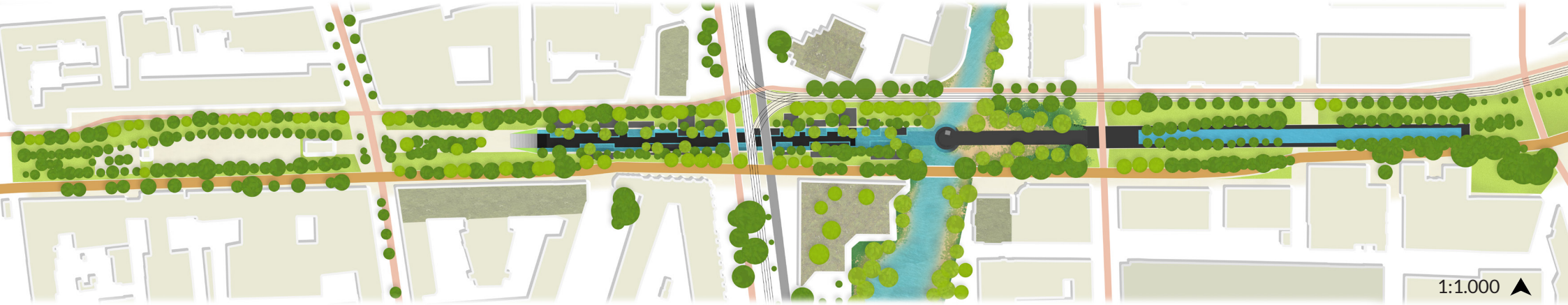
MEAN HIGH WATER SITUATION



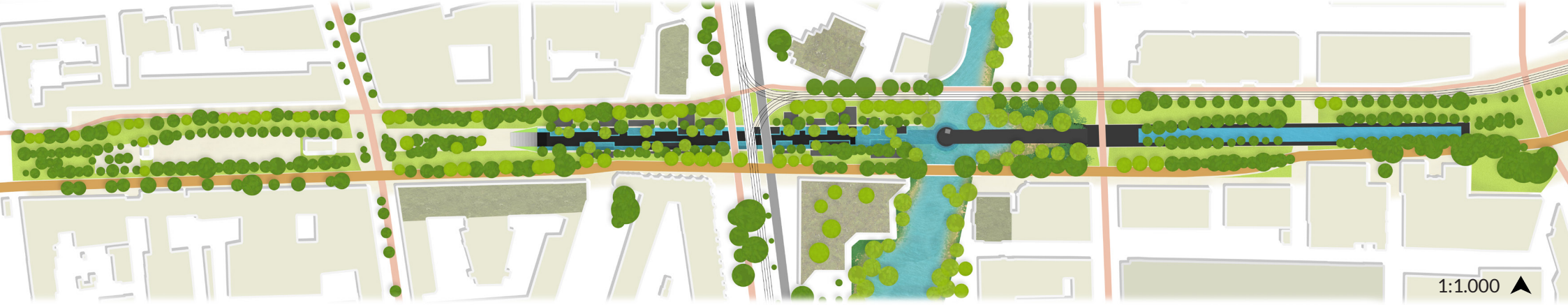
VI. MASTERPLAN 2100

A free-flowing Nieuwe Maas, with 1.1 m rise in sea level

MEAN LOW WATER SITUATION



MEAN HIGH WATER SITUATION



VII. ADVANTAGEOUS TREE PLAN

The introduction of specific trees would increase experience and offer ecological benefits

Populus × canescens 'De Moffart'

BENEFICIAL CHARACTERISTICS

HEAT ISLAND REDUCTION	★★★	NECTAR SOURCE *for Insects*	★★★☆
ENDURES WET PERIODS	☆☆☆	POLLEN SOURCE *for Insects*	★★★☆
ENDURES DRY PERIODS	★☆☆	CAPTURES NO_x/O_3	★★★★★
FOOD SOURCE *for Birds*	☆☆☆	SECURES CO_2	★★★★★

DISADVANTAGEOUS CHARACTERISTICS

ALLERGENICITY	⚠⚠⚠	VOC EMISSION	⚠⚠⚠

Salix alba 'Belders'

BENEFICIAL CHARACTERISTICS

HEAT ISLAND REDUCTION	★★★	NECTAR SOURCE *for Insects*	★★★☆
ENDURES WET PERIODS	★★☆	POLLEN SOURCE *for Insects*	★★☆☆
ENDURES DRY PERIODS	★★☆	CAPTURES NO_x/O_3	★★★☆
FOOD SOURCE *for Birds*	☆☆☆	SECURES CO_2	★★★★★

DISADVANTAGEOUS CHARACTERISTICS

ALLERGENICITY	⚠⚠⚠	VOC EMISSION	⚠⚠⚠

Acer saccharinum

BENEFICIAL CHARACTERISTICS

HEAT ISLAND REDUCTION	★★★	NECTAR SOURCE *for Insects*	★★★☆
ENDURES WET PERIODS	★☆☆	POLLEN SOURCE *for Insects*	★★☆☆
ENDURES DRY PERIODS	★★☆	CAPTURES NO_x/O_3	★★★★★
FOOD SOURCE *for Birds*	☆☆☆	SECURES CO_2	★★★★★

DISADVANTAGEOUS CHARACTERISTICS

ALLERGENICITY	⚠⚠⚠	VOC EMISSION	⚠⚠☆

Robinia pseudoacacia 'Nyirségi'

BENEFICIAL CHARACTERISTICS

HEAT ISLAND REDUCTION	★★☆	NECTAR SOURCE *for Insects*	★★★★★
ENDURES WET PERIODS	☆☆☆	POLLEN SOURCE *for Insects*	★☆☆☆
ENDURES DRY PERIODS	☆☆☆	CAPTURES NO_x/O_3	★★★★★
FOOD SOURCE *for Birds*	★★★	SECURES CO_2	★★★★★

DISADVANTAGEOUS CHARACTERISTICS

ALLERGENICITY	⚠☆☆	VOC EMISSION	⚠⚠⚠

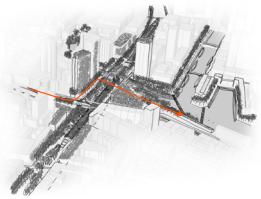
- **MAINTAINED ON LOCATION**
- **MINOR MOVEMENT** (<5 m)
- **RELOCATION** (>5 m)
- **NEWLY PLANTED**

Data: *Hiemstra, 2018.*

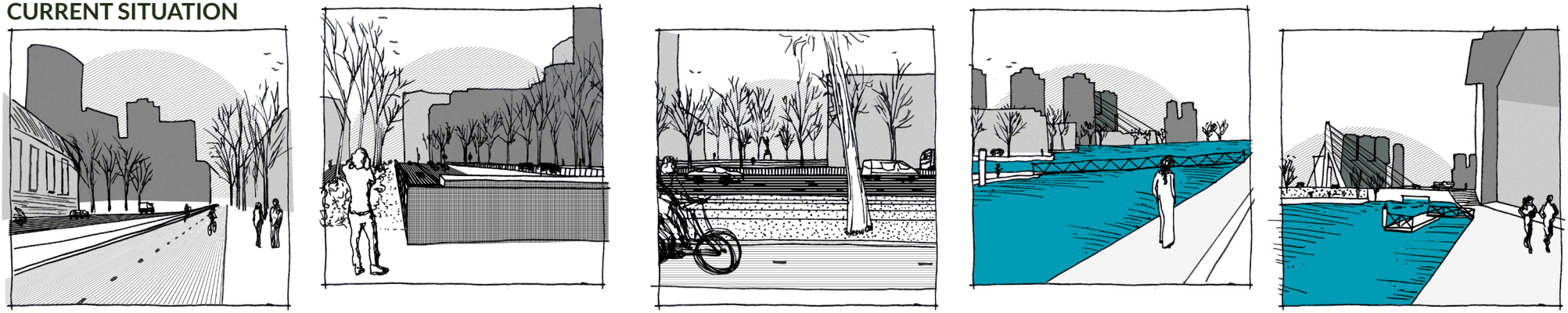
The current trees, as previously outlined, can be maintained; if they are over time replaced with more beneficial species. The existing 'gaps' and free space as a result of the mobility transition can be filled up with the more advantageous species outlined above. These offer more habitats for birds and insects, as well as bringing back the 'glance' to Blaak through reflection of the leaves. Especially wet-enduring species are located in the centre (tidal) part of the area. Through a larger variety in species, both experience and ecology are enhanced.

VIII. IMPROVED EXPERIENCE WHEN CROSSING WESTBLAAK-BLAAK

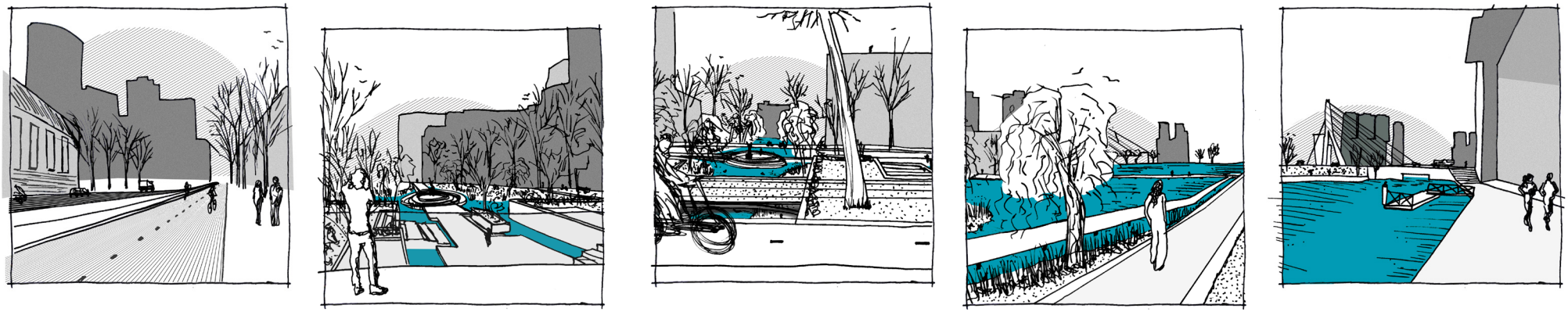
Sequence sketching the current situation and how this could be improved through implementing tidal features



CURRENT SITUATION

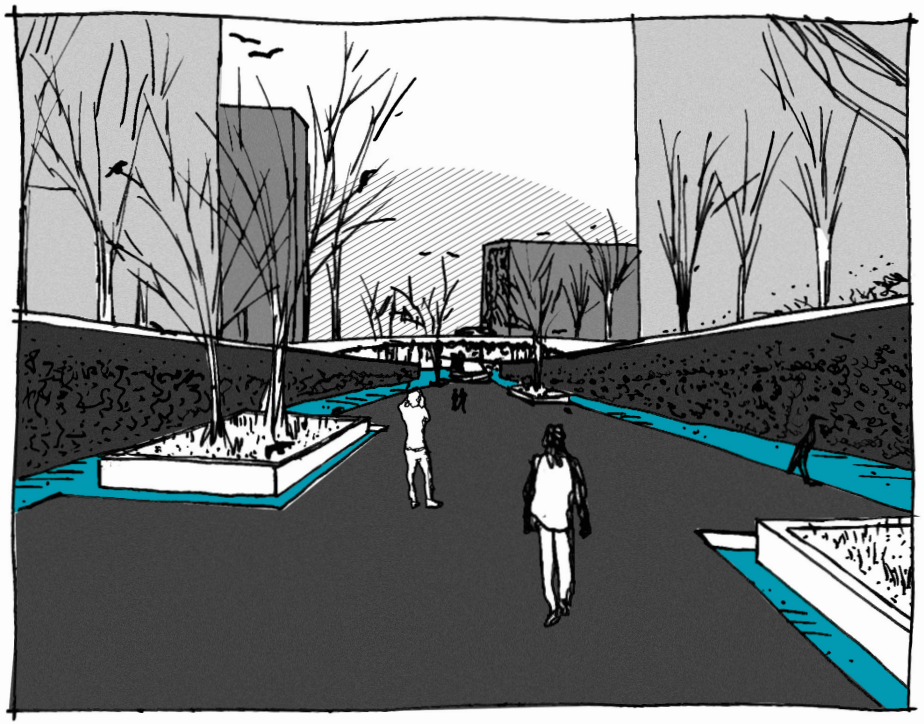


IMPROVED SITUATION

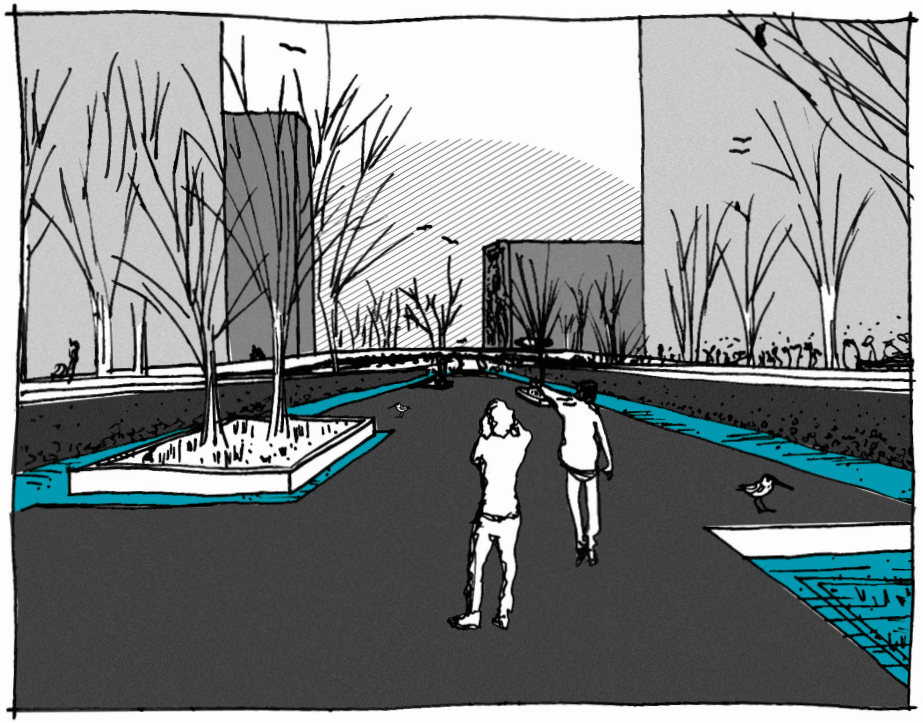


IX. EXPERIENCING THE FLOATING BOULEVARD

Sketches showing the experience on the tide-influenced boulevard, with floating and (dis)appearing fixed elements



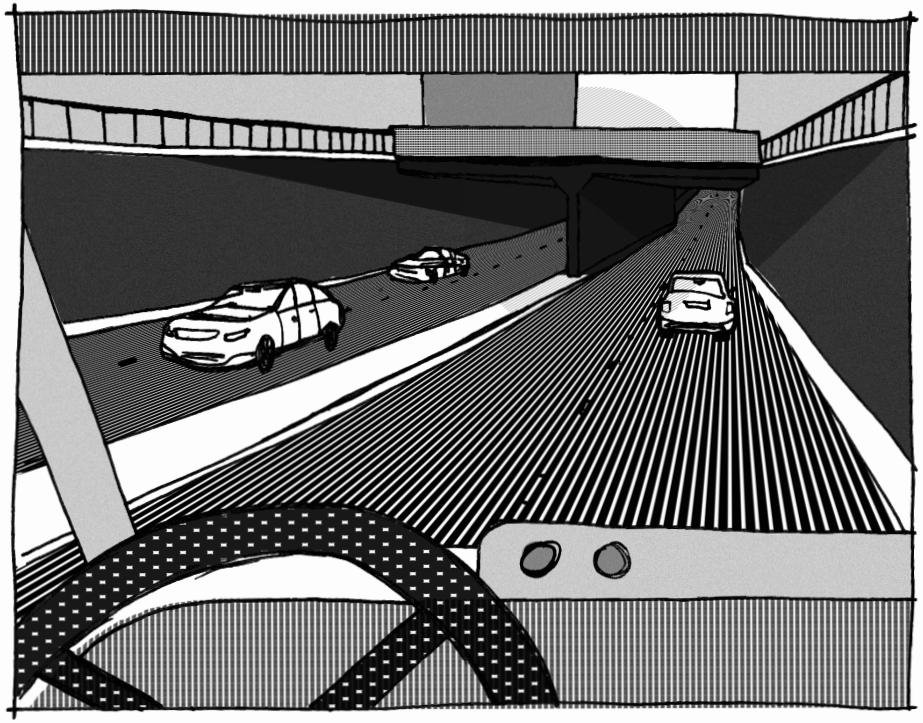
MEAN LOW WATER SITUATION



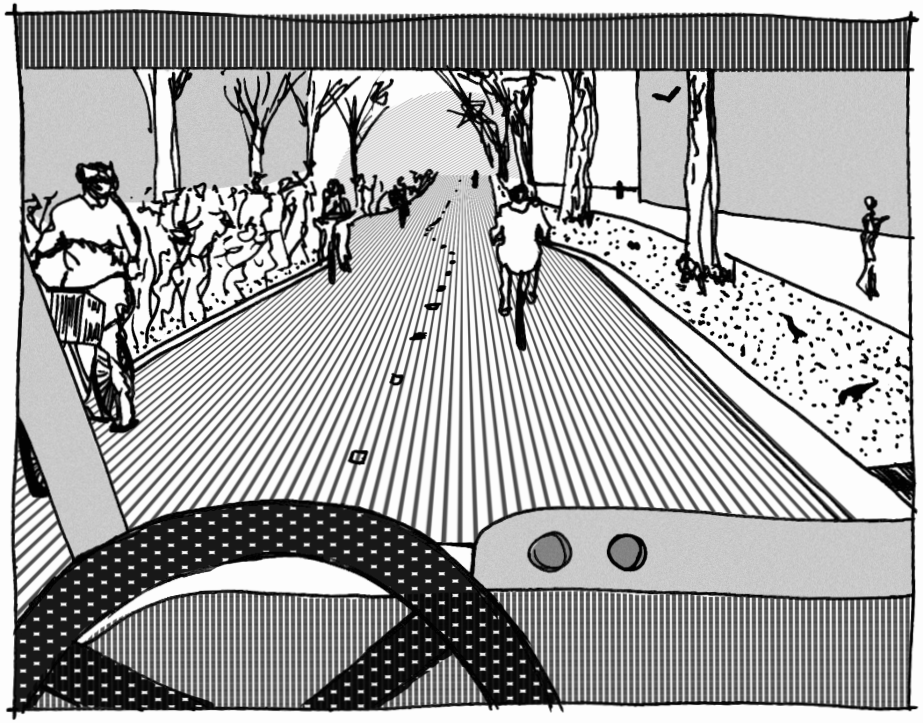
MEAN HIGH WATER SITUATION

x. EXPERIENCING WESTBLAAK-BLAAK AS A CAR DRIVER

Sketches showing the removal of traffic from the tunnel, retaining just a guest role for cars on the south side



CURRENT SITUATION

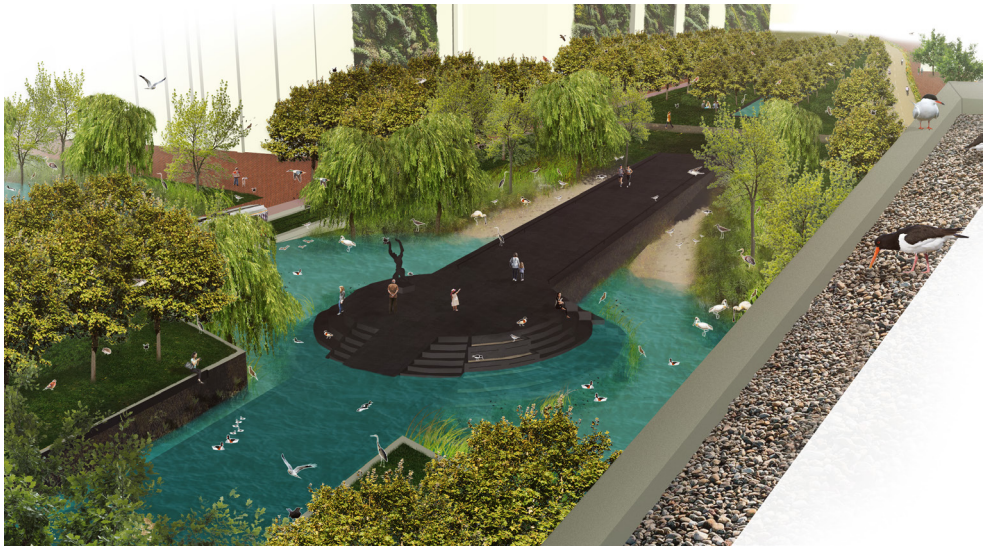


IMPROVED SITUATION

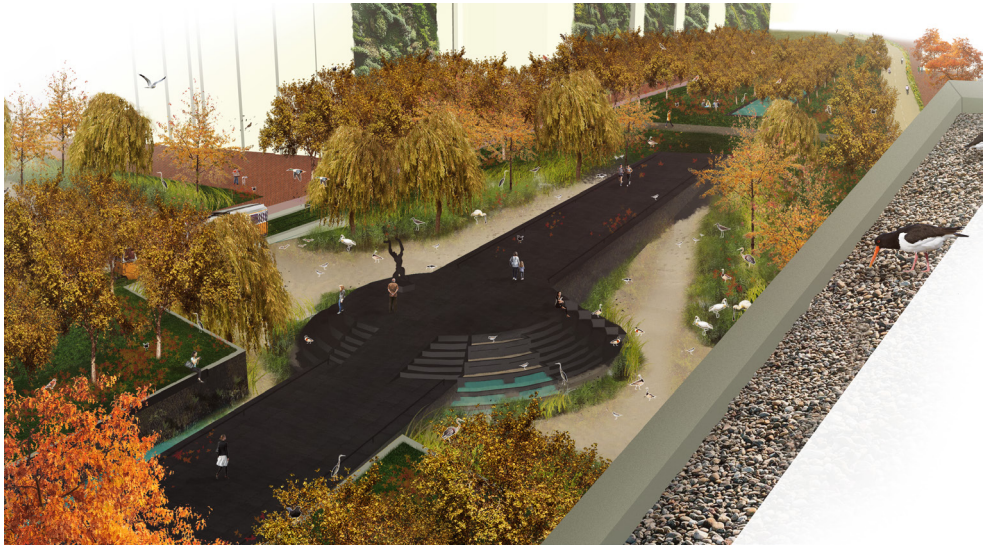
XI. AN EXPERIENCE SHAPED THROUGH THE TIDES

The tide-influenced centre changes with the tides, as seen from the Maritime Museum rooftop terrace

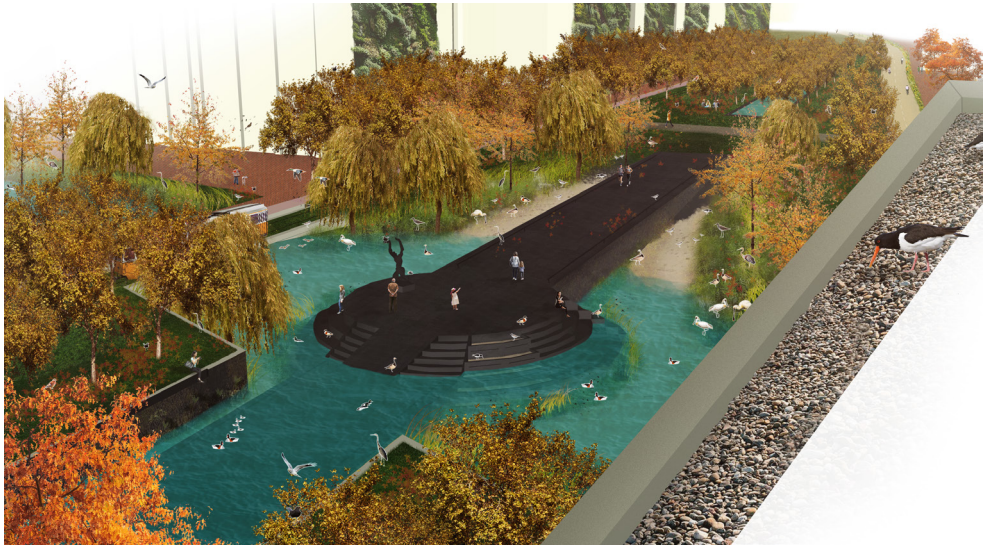
MEAN LOW WATER SITUATION SPRING



MEAN HIGH WATER SITUATION SPRING



MEAN LOW WATER SITUATION AUTUMN

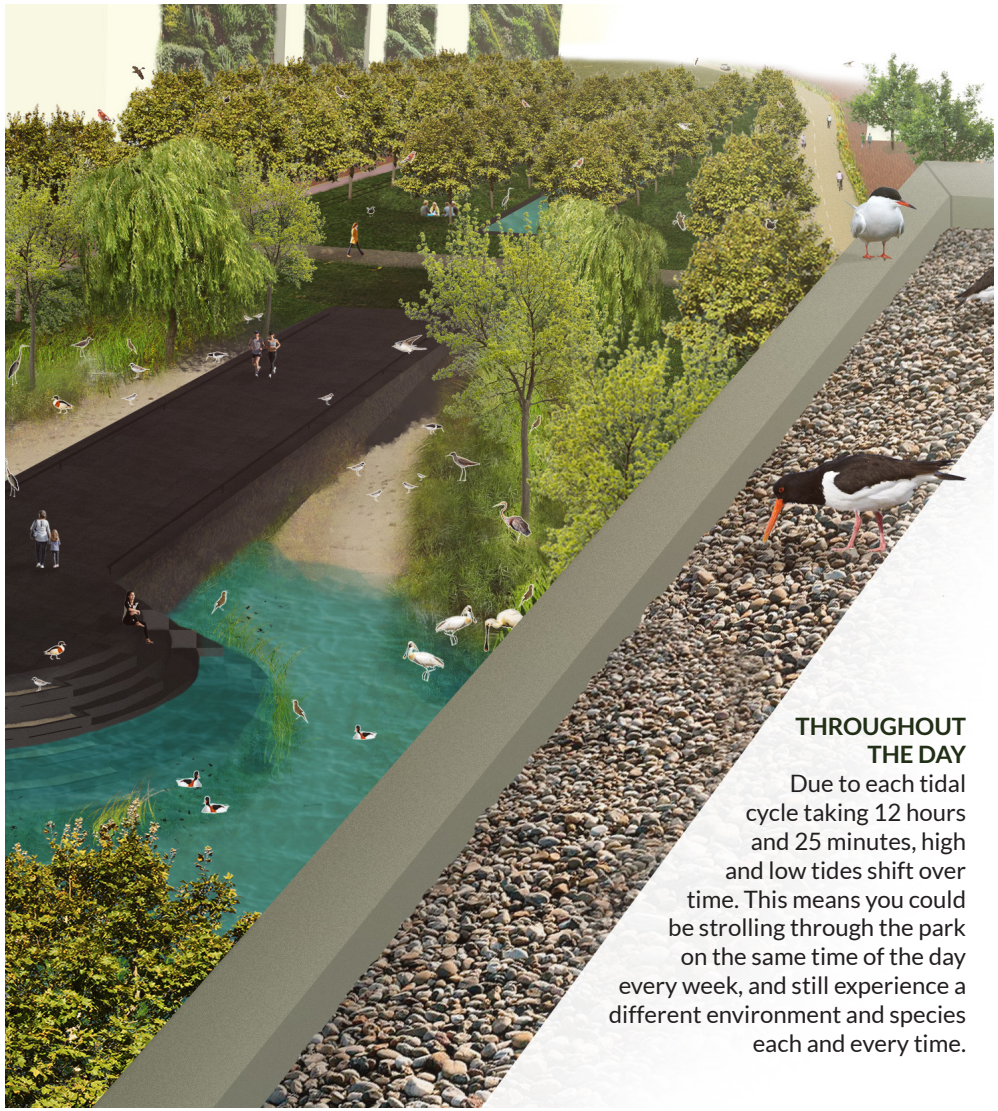


MEAN HIGH WATER SITUATION AUTUMN

XII. WESTBLAAK-BLAAK ON A SPRING DAY

The tide-influenced centre on a spring day, as seen from the Maritime Museum rooftop terrace

MEAN LOW WATER SITUATION
encountered at 14:00 on a Monday

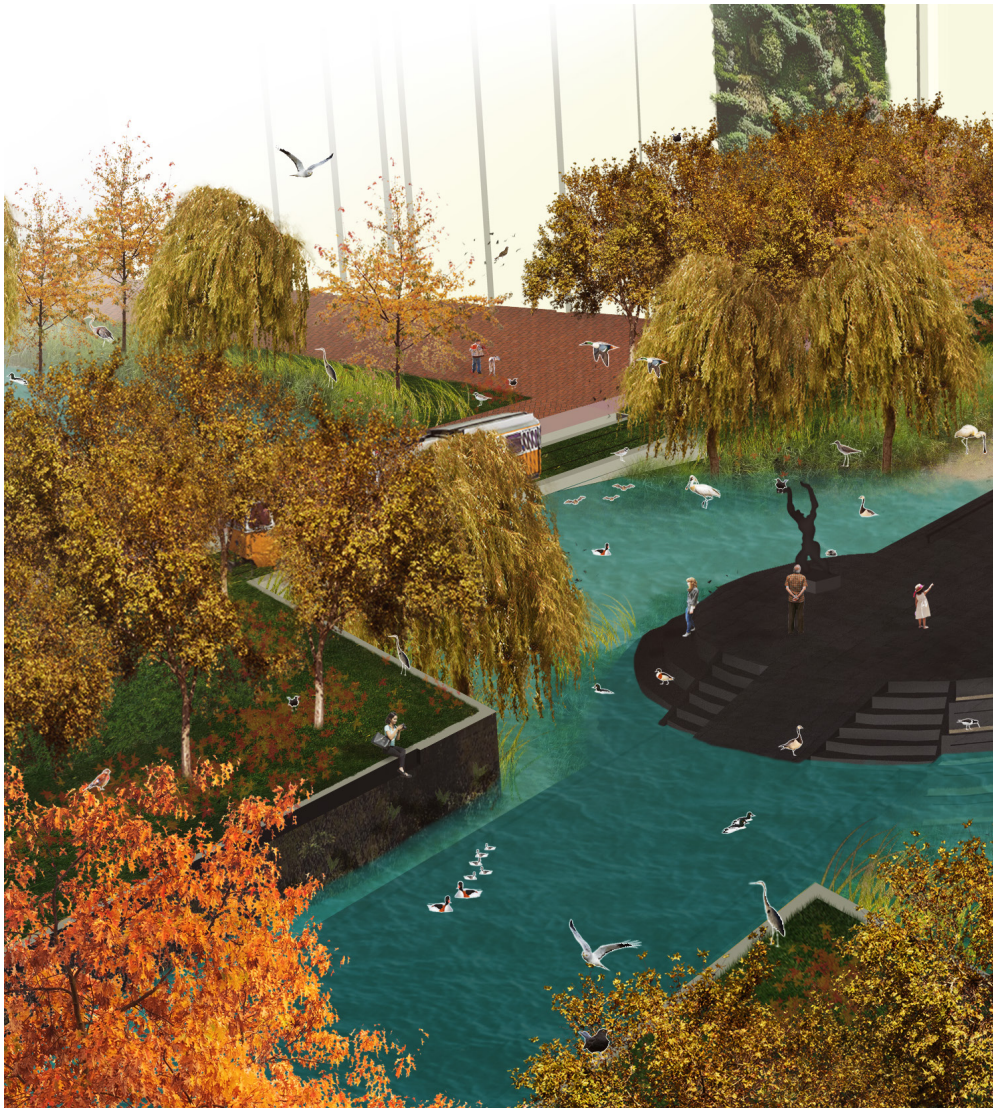


THROUGHOUT THE DAY
Due to each tidal cycle taking 12 hours and 25 minutes, high and low tides shift over time. This means you could be strolling through the park on the same time of the day every week, and still experience a different environment and species each and every time.

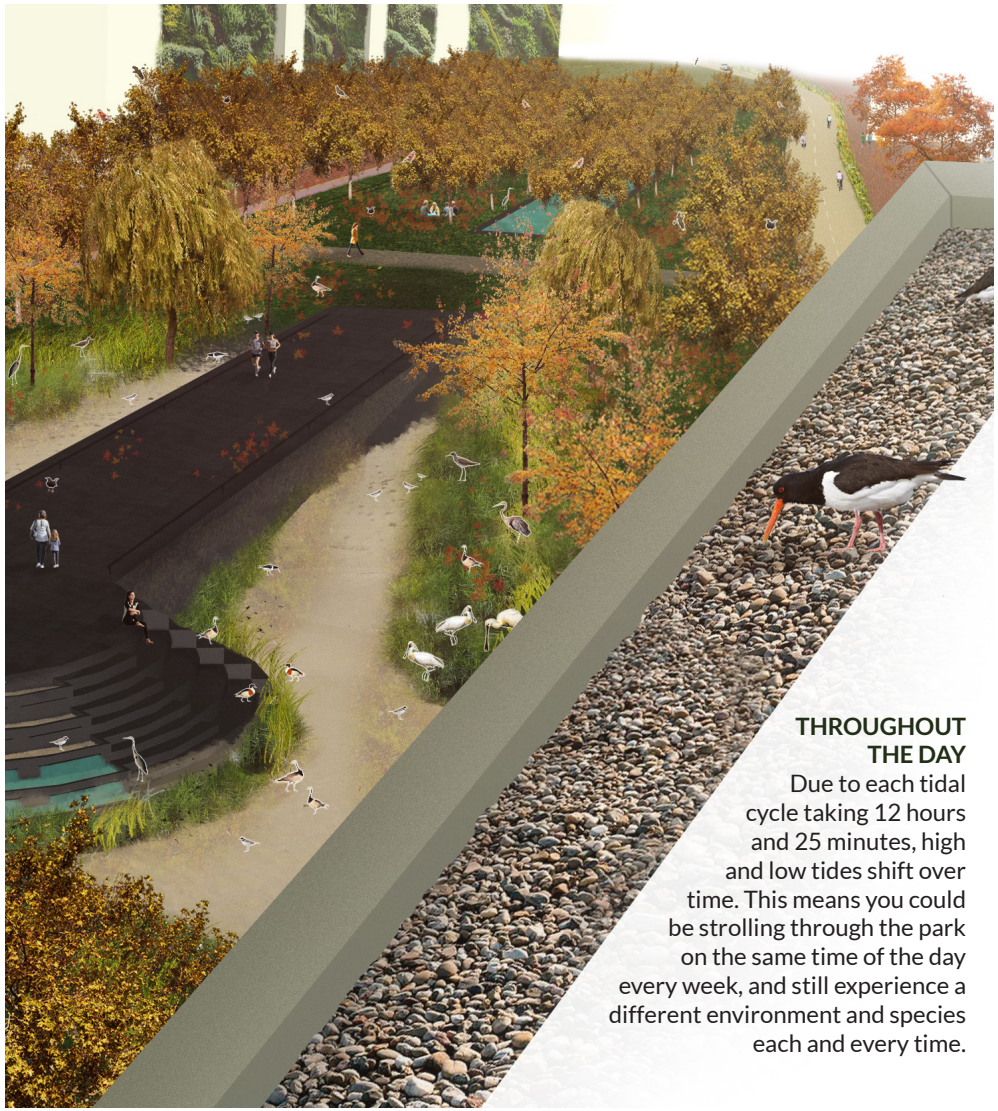
MEAN HIGH WATER SITUATION
encountered at 14:00 on Monday, a week later

XIII. WESTBLAAK-BLAAK ON AN AUTUMN DAY

The tide-influenced centre on an autumn day, as seen from the Maritime Museum rooftop terrace



MEAN LOW WATER SITUATION
encountered at 14:00 on a Monday

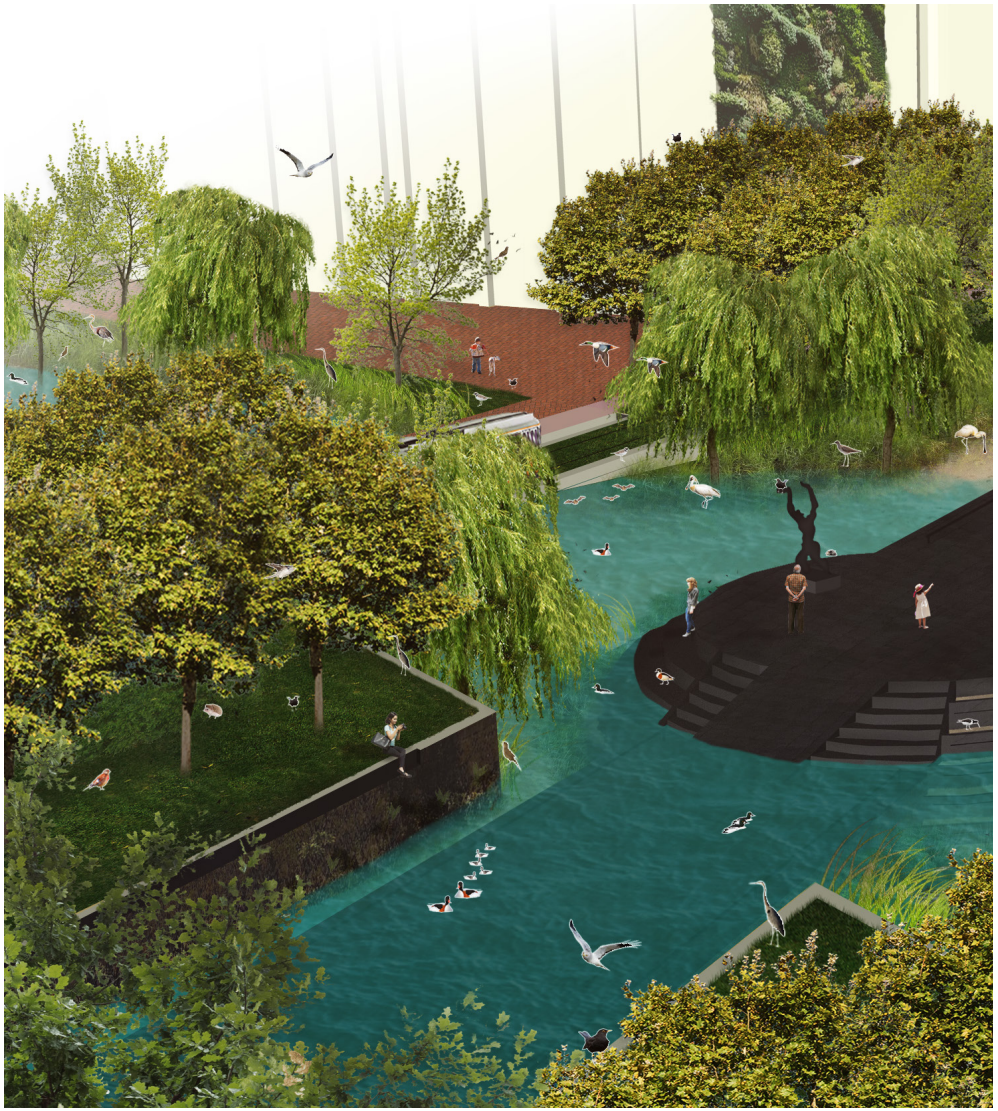


THROUGHOUT THE DAY
Due to each tidal cycle taking 12 hours and 25 minutes, high and low tides shift over time. This means you could be strolling through the park on the same time of the day every week, and still experience a different environment and species each and every time.

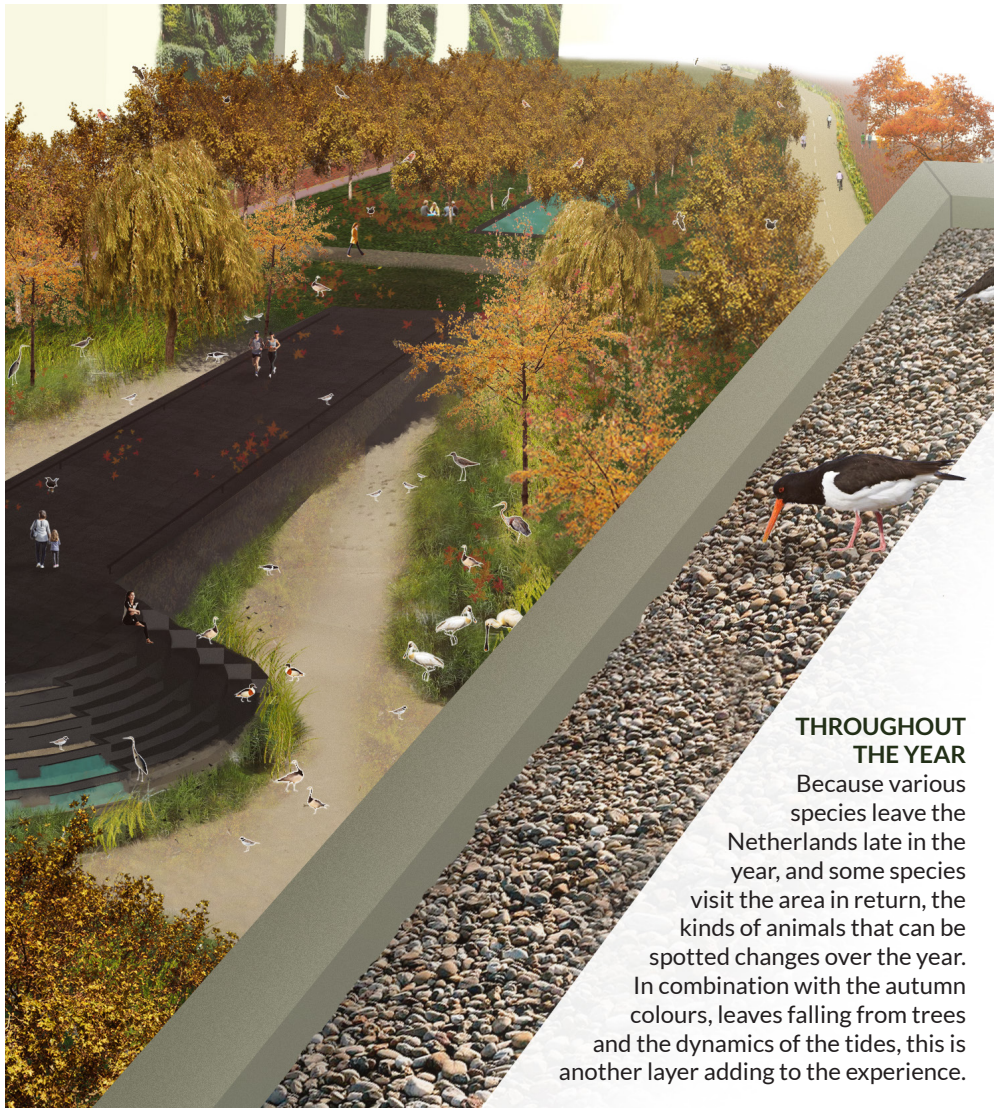
MEAN HIGH WATER SITUATION
encountered at 14:00 on Monday, a week later

XIV. WESTBLAAK-BLAAK THROUGHOUT THE SEASONS

The tide-influenced centre over the year, as seen from the Maritime Museum rooftop terrace



MEAN HIGH WATER SITUATION
encountered on a day in spring

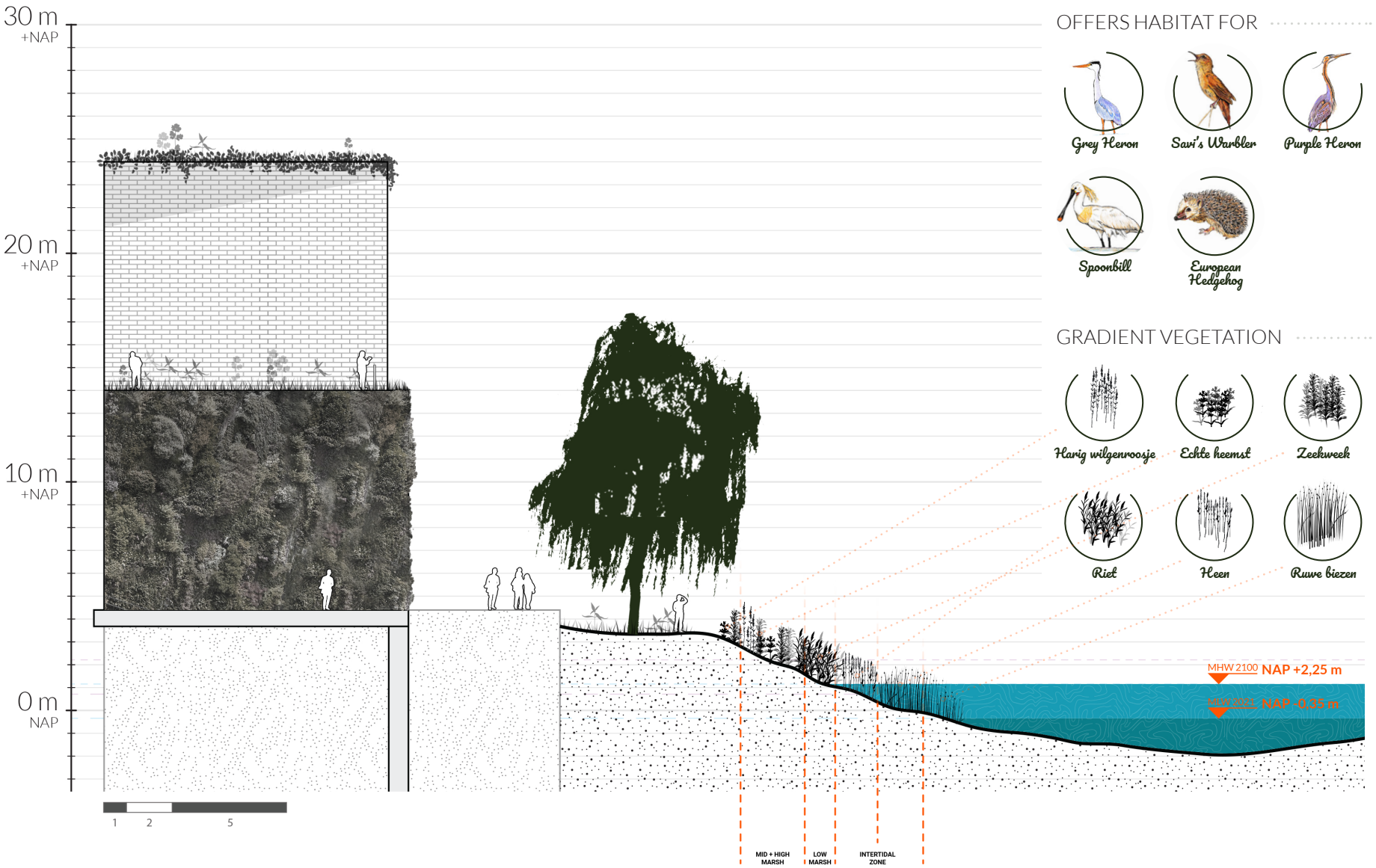


THROUGHOUT THE YEAR
Because various species leave the Netherlands late in the year, and some species visit the area in return, the kinds of animals that can be spotted changes over the year. In combination with the autumn colours, leaves falling from trees and the dynamics of the tides, this is another layer adding to the experience.

MEAN LOW WATER SITUATION
encountered on a day in autumn

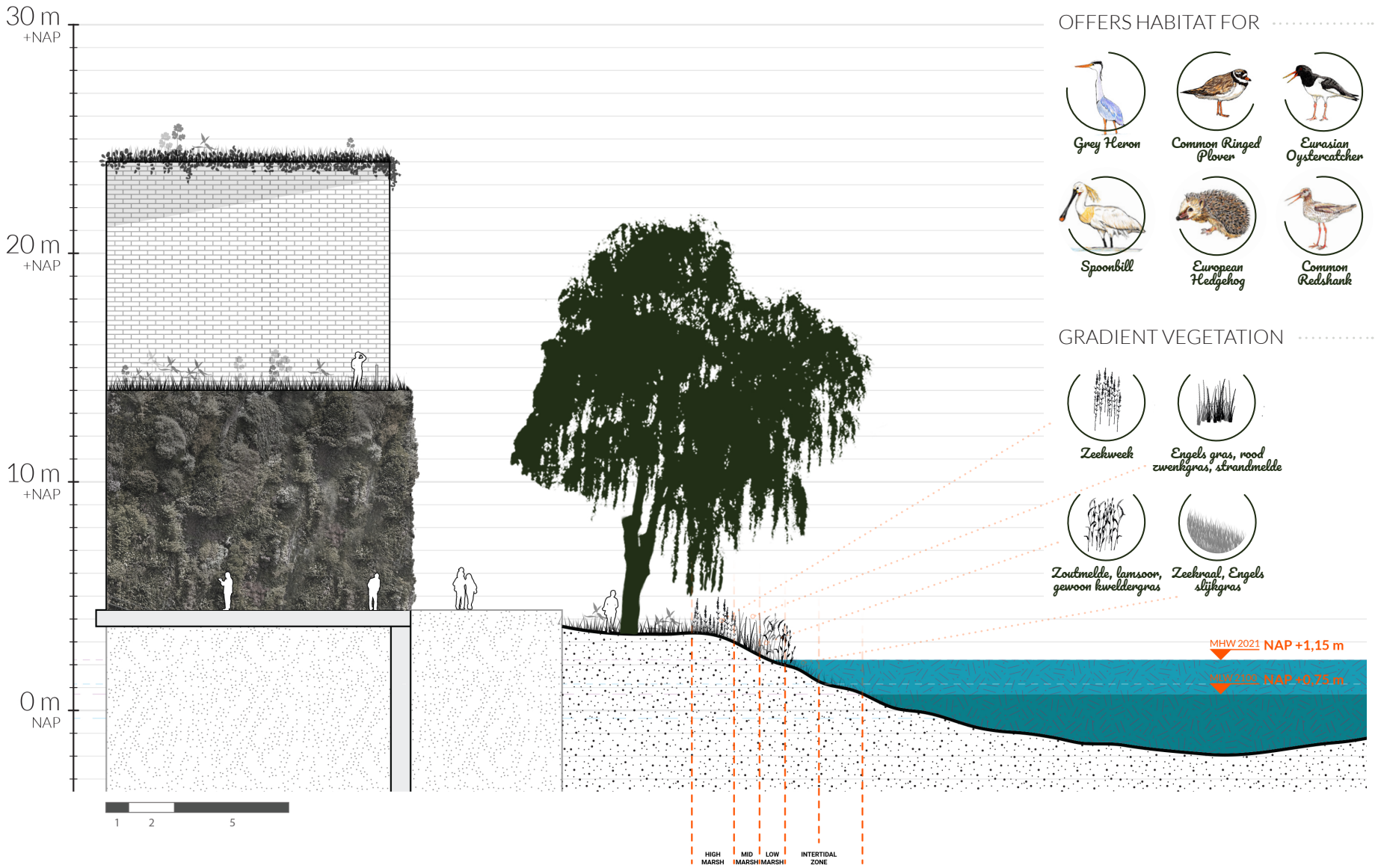
xv. TIDAL GRADIENT 2022

Comprising fresh-brackish tidal habitats



XVI. TIDAL GRADIENT 2100

Habitats are becoming more saline over time

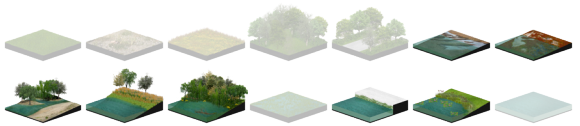


XVII. HIGHLIGHTED SPECIES

The following is a mix of both common and red-listed species, which amongst other can be spotted on the previous pages

Grey Heron

PREFERRED HABITATS

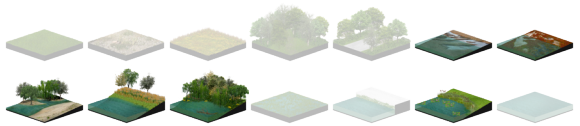


MOST LIKELY SPOTTED IN

JAN **FEB** **MAR** **APR** **MAY** **JUN** **JUL** **AUG** **SEP** **OCT** **NOV** **DEC**

Spoonbill

PREFERRED HABITATS



MOST LIKELY SPOTTED IN

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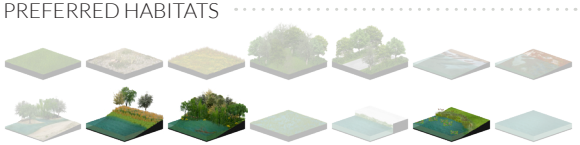
Savi's Warbler

PREFERRED HABITATS



MOST LIKELY SPOTTED IN

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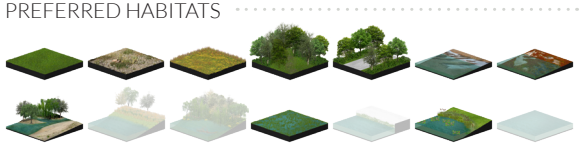
Eurasian Oystercatcher

PREFERRED HABITATS



MOST LIKELY SPOTTED IN

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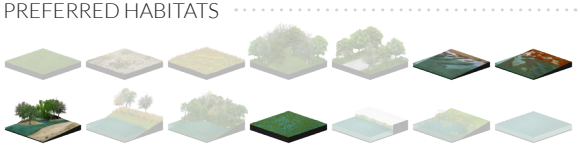
Common Ringed Plover

PREFERRED HABITATS

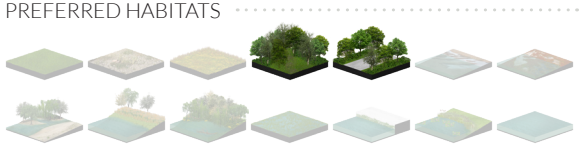


MOST LIKELY SPOTTED IN

JAN FEB MAR APR **MAY** JUN JUL **AUG** **SEP** **OCT** NOV DEC

European Hedgehog

PREFERRED HABITATS

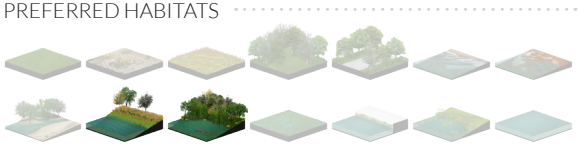


MOST LIKELY SPOTTED IN

JAN FEB MAR APR MAY **JUN** **JUL** **AUG** **SEP** **OCT** NOV DEC

Purple Heron

PREFERRED HABITATS



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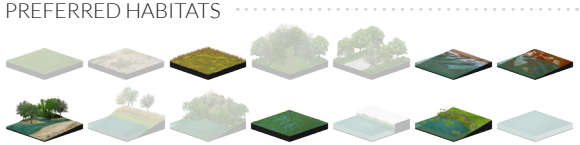
Common Redshank

PREFERRED HABITATS



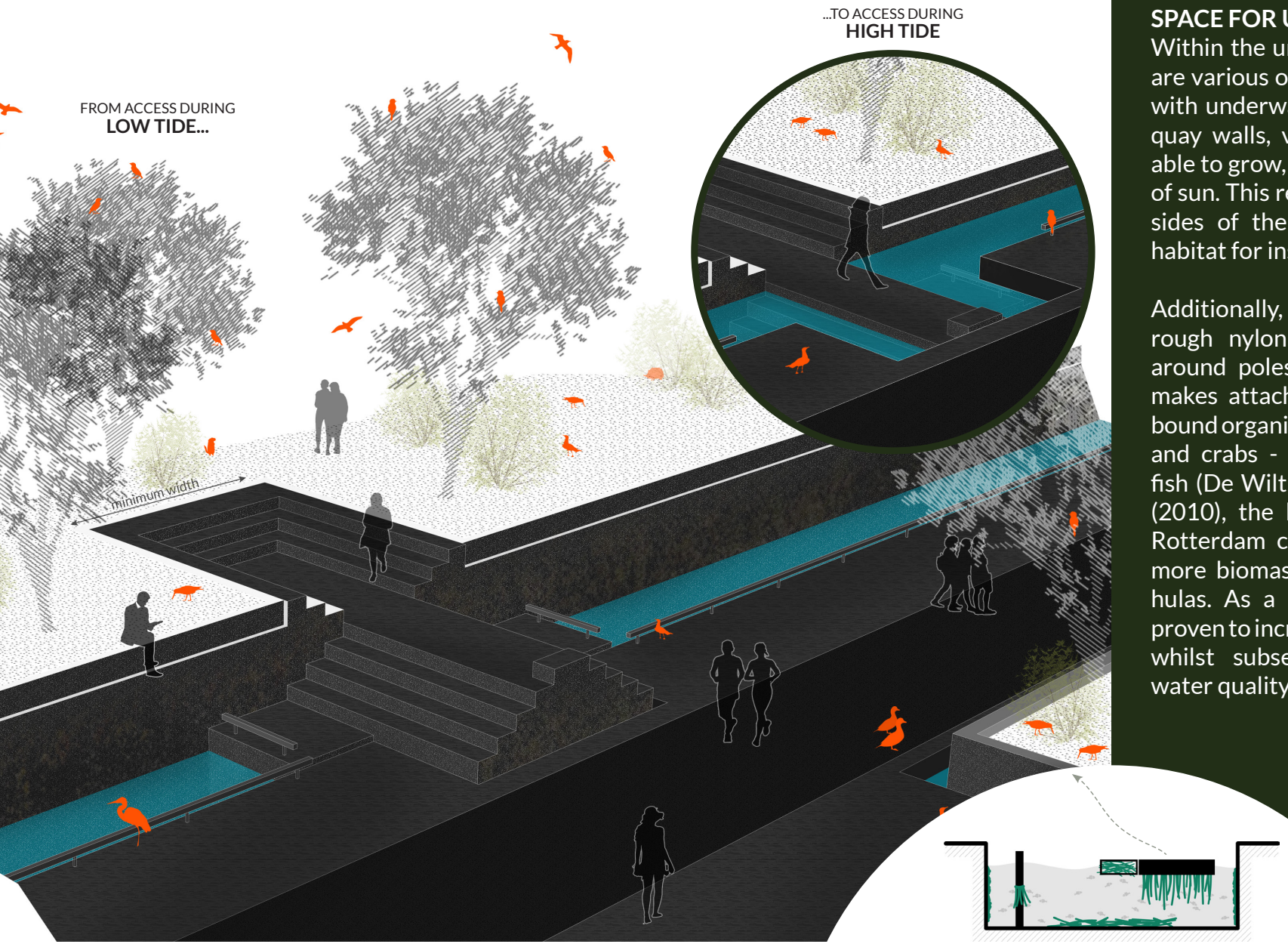
MOST LIKELY SPOTTED IN

JAN FEB MAR **APR** **MAY** **JUN** JUL AUG SEP OCT NOV DEC

Please refer to the appendix for a comprehensive list of flora and fauna related to the specific habitats.

XVIII. ENTERING THE DYNAMIC BOULEVARD

Entrances and exits of the floating walkway within the former tunnel structure



VARYING MEASURES FOR
UNDERWATER NATURE

SPACE FOR UNDERWATER NATURE

Within the urban area of Rotterdam, there are various options to enhance biodiversity with underwater measures. By roughening quay walls, various types of ferns will be able to grow, also depending on the amount of sun. This results in varying views on both sides of the tunnel structure as well as habitat for insects.

Additionally, the hula is a construction of rough nylon threads placed underwater around poles or underneath pontoons. It makes attachment possible for substrate-bound organisms and attracts algae, shrimps and crabs - and subsequently freshwater fish (De Wilt, 2017). According to Paalvast (2010), the hulas placed in Scheurhaven, Rotterdam contained up to twenty times more biomass compared to poles without hulas. As a result, these structures have proven to increase biodiversity and biomass, whilst subsequently resulting in better water quality (Paalvast, 2017).

7

CONCLUSION & DISCUSSION

Answering the research question and reflecting on the project

I. CONCLUSION & DISCUSSION

Concluding on the project findings and reflecting on the outcome

Throughout the project *Rotterdam as Urban Tidescape*, and thus as outlined in this report, knowledge on the topics of tidal nature, the vision for Rotterdam with regards to the urban environment and mobility, and the significance of certain habitats in order to provide living space for various (endangered) species has been researched. Gained knowledge has eventually been incorporated into a transformation design for Westblaak-Blaak. The main research question was set up as follows:

How could the unique tidal characteristics of the Nieuwe Maas be exploited in order to transform Westblaak-Blaak, Rotterdam into a resilient and dynamic public space for people and animals alike, whilst contributing to the mobility transition and restoring biodiversity?

The structure of the project was outlined in chapter 1, with analysis and background information following in chapter 2. Answers to the research question were explored through analysis and design, as outlined in chapters 3 to 6. The main findings will be concluded in the following paragraphs, followed by discussion and reflection. Key findings with regards to designing the urban tidescape are collected in a toolbox, provided on the following page. These measures, or tools, can be used for reference within urban landscape design assignments concerned with creating urban tidal experiences in similar environments.

THE RIVER AS UNIQUE PUBLIC SPACE

With regards to the water system around the centre of Rotterdam, it was found that the tidal character of the Nieuwe Maas is unique within the Netherlands; in fact the Nieuwe Maas is the only remaining river with an open connection to the North Sea. Due to the historic harbour functions, which have shifted towards the sea, essentially all of the quays within the centre are still paved; a hard boundary providing people little connection with the river. The difference in high and low tide is 1.50 m however; with natural river banks, this condition would allow attractive natural gradients to develop.

Incorporating tidal nature would benefit current and future residents as well as tourists by bringing nature into the urban environment, whilst also upping the economic value of the area enabling the ongoing densification, providing the necessary public space, improving pedestrian and cycling routes, and making for a new city symbol for Rotterdam. Heat stress will be reduced due to the reduction of asphalt and hard materials. Animals, such as endangered birds and fish, will be provided with new habitats, which will contribute to the recovery of the currently poor biodiversity of Rotterdam. This includes a number of tidal species such as the spoonbill and purple heron, but also more common species such as the Eurasian Oystercatcher, and a number of fish, mammals and endangered insects. A list outlining mainly tidal, endangered and icon species is found within the appendix.

FROM CAR CITY TO DYNAMIC HOTSPOT

In essence, the three main city boulevards in the centre of Rotterdam all lead towards the river. They are however all intersected by the barrier formed by Westblaak-Blaak, a high-traffic boulevard which contains eight lanes of car traffic. The resulting intersections have proven dangerous, with Eendrachtsplein marked as a 'black spot', and they are unattractive places to stay. Car traffic is also present on the quays within Waterstad, further establishing the car within the urban living environment of the city centre. In order to turn the tide with regards to traffic, the ongoing mobility transition within Rotterdam sees a focus on slower traffic forms (walking, cycling, public transport), and by taking out the car lanes, the freed up space can be transformed into a healthier environment.

The Westblaak transformation plan by the municipality will greatly improve the boulevard. It does however appear there is more potential for the area at Blaak, where the ends of both the Rotte and the Nieuwe Maas come together. By giving a second life to the tunnel structure at Blaak (currently used for four lanes of car traffic) in the form of a tidal boulevard on the water of the Nieuwe Maas itself - literally bringing the river into the city - together with the aformentioned tidal nature benefits Blaak has the potential to become a dynamic hotspot, changing every day, through the seasons, and over the years.

I. CONCLUSION & DISCUSSION *(cont.)*

Concluding on the project findings and reflecting on the outcome

BIODIVERSE THROUGH THE SCALES

As a result of the loss of natural habitats due to expansion of the harbour and urbanisation, the diversity of species in Rotterdam has greatly decreased over time. This disturbance of the ecosystem impacts all flora and fauna, and thus it also affects human beings. For instance, it affects oxygen production, pollination of plants (including agricultural crops), water purification, and pest control. High potential for restoring the ecological strength for the city of Rotterdam could be found within the Nieuwe Maas. By transforming hard quays into natural gradients, the now contained river will be able to flow freely again, resulting in tidal habitats within the city centre which offer space for a large variety of common, endangered and icon species, and thus contributing to a recovery of the biodiversity.

In addition to the tidal habitats, the conditions for more habitats can be established by considering the city as a gradient landscape, from underwater to rooftop. Currently, a large amount of surface is paved and the natural areas are limited to traditional parks and grass. By implementing softer surfaces and also incorporating the facades and rooftops of buildings into urban design, the number of existing habitats can be greatly expanded. In addition, ecologically beneficial trees should be planted, and underwater nature such as rough quay walls or hulas underneath floating pontons can further contribute to an ecologically healthy Rotterdam.

On a larger scale, a variety of migrating birds and fish also benefits from the richness in habitats at Westblaak-Blaak. The area would become an ecological stepping stone within the Dutch delta area, whilst at the same time becoming an attractive, resilient and dynamic public space for Rotterdammers and visitors.

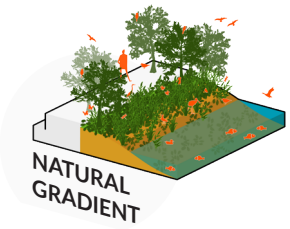
ABOUT THE DESIGN PROCESS

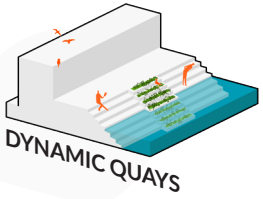
Through the lens of landscape architecture, my aim initially was to create a tidal park in the centre of Rotterdam. During earlier courses within the master of Landscape Architecture, I was introduced to the topic of tidal parks and quickly had become inspired to go deeper into it during my graduation project. Looking back, the project has seen a clear shift and expansion in concept, ultimately narrowed down to the presented result. In the weekly meetings with my supervisor Frits van Loon, and more or less biweekly meetings with my second mentor Leo van den Burg, I would explain what I had been working on and a conversation would follow. I've always seeked to implement feedback into my project; over time, the concept of tidal parks has shifted from a goal to a means for instance. The aim of the project has broadened because of this, although I believe the main goal was still achieved: creating a dynamic public space in Rotterdam and restoring biodiversity in order to create a pleasant space for people and animals. All in all, the project has been quite educational and very inspiring.

II. URBAN TIDESCAPE TOOLKIT

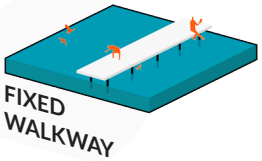
Resulting from the design and research in Rotterdam

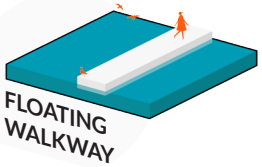
ORDERED GRADUALLY FROM **EXPERIENCING THE TIDES** TO **BIODIVERSITY RECOVERY & CLIMATE**


NATURAL GRADIENT

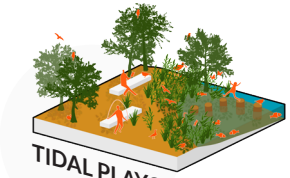

DYNAMIC QUAYS

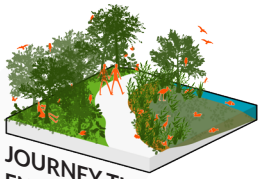

TIDE-RELATED EVENTS

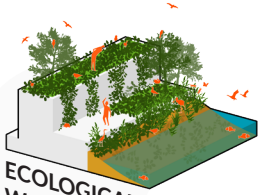

FIXED WALKWAY

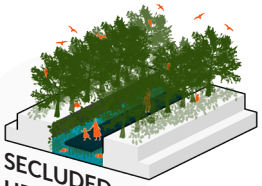

FLOATING WALKWAY

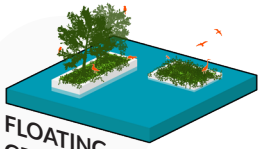

A SPACE FOR WATER ACTIVITIES

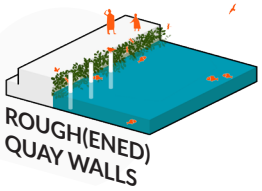

TIDAL PLAYGROUND


JOURNEY THROUGH ENVIRONMENTS

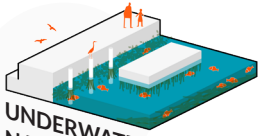

ECOLOGICAL ZONE FROM WATER TO ROOF

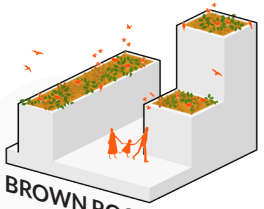

SECLUDED URBAN WORLD

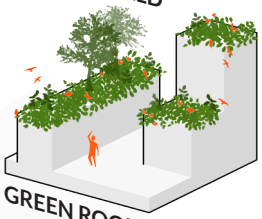

FLOATING GREEN

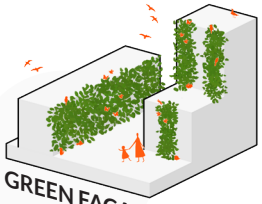

ROUGH(ENED) QUAY WALLS


RICHNESS IN HABITATS, RICHNESS IN SPECIES

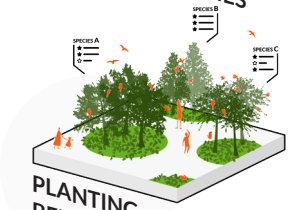

UNDERWATER NATURE

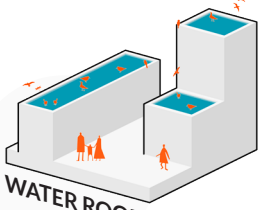

BROWN ROOFS

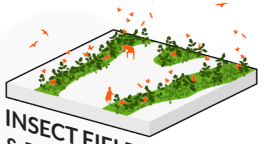

GREEN ROOFS

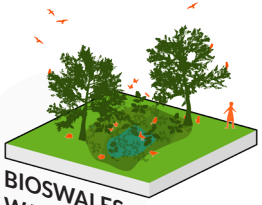

GREEN FACADES

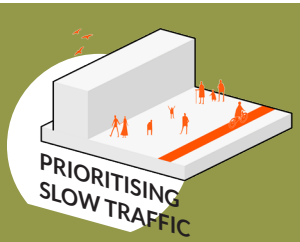

WATER STORAGE & COOLING ELEMENTS

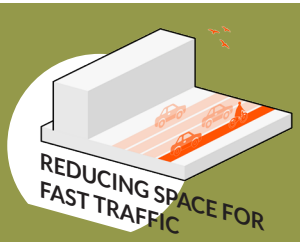

PLANTING BENEFICIAL TREES


WATER ROOFS


INSECT FIELDS & RIBBONS


BIOSWALES & WATER STORAGE


PRIORITISING SLOW TRAFFIC


REDUCING SPACE FOR FAST TRAFFIC

POLICY MEASURES

ALLOWING SUCH TRANSFORMATIONS IN THE URBAN AREA

8

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A

appendix

MEANING OF THE ICONS

SPOTTED AT **EILAND VAN BRIENENOORD**

SPOTTED AT **TIENDGORZEN**

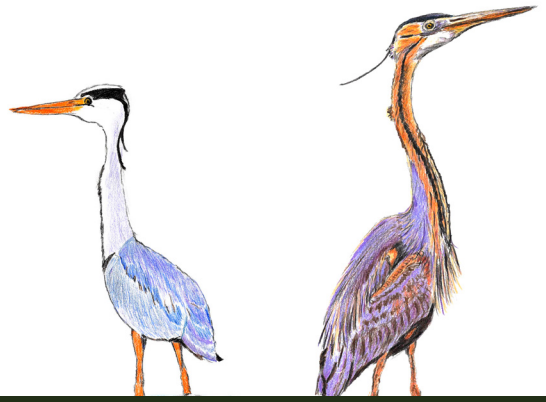
SPOTTED AT **GORS LANDHOEVE**

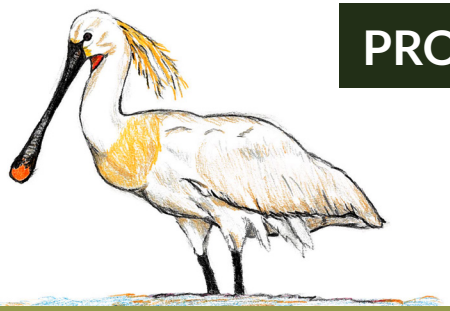
SPOTTED AT **KLEIN PROFIJT**

ENDANGERED RED-LISTED SPECIES

SOUTH HOLLAND ICON SPECIES

Please refer to the appendix references list on page 80 for the respective sources.



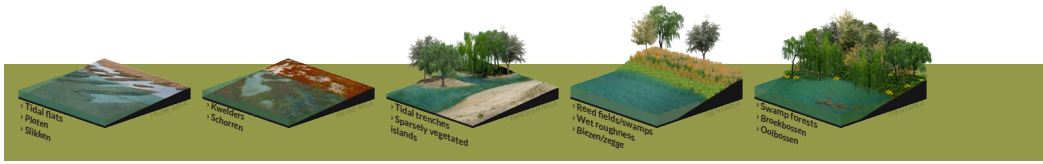


PROMISING SPECIES & THEIR RESPECTIVE HABITATS

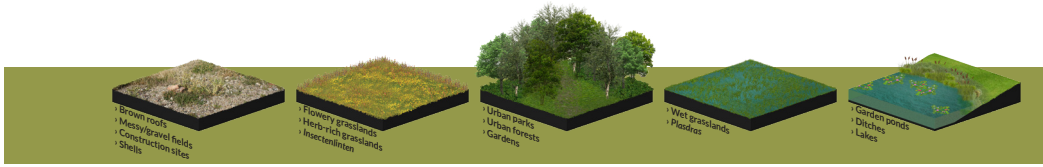
60 birds, 21 fish, 13 mammals, 8 amphibians, 21 insects and 20 plants

I. BIRDS & THEIR HABITATS

List of expected species related to their respective habitats

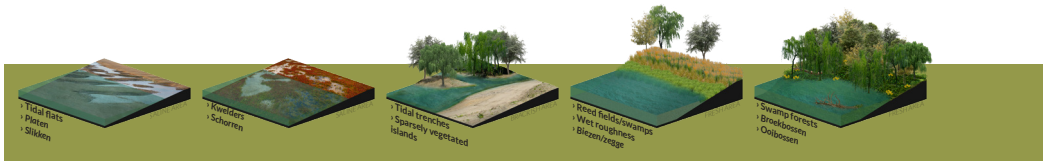


SPECIES												
AALSCHOLVER	*Great Cormorant*	*PHALACROCORAX CARBO* [3]			✓		✓		✓		✓		
BAARDMAN	*Bearded Reedling*	*PANURUS BIARMICUS* [2,3]							✓				
BERGEEND	*Common Shelduck*	*TADORNA TADORNA* [2,3]	✓		✓		✓		✓				✓
BLAUWBORST	*Bluethroat*	*LUSCINIA SVECICA* [1,3]				✓			✓			✓	✓
BLAUWE KIEKENDIEF	*Hen Harrier*	*CIRCUS CYANEUS* [2,3]			✓	✓			✓				
BLAUWE REIGER	*Grey Heron*	*ARDEA CINEREA* [2,3]	✓		✓		✓		✓			✓	✓
BONTBEKPLEVIER	*Common Ringed Plover*	*CHARADRIUS HIATICULA* [2,3]	✓	✓	✓		✓			✓			
BONTE STRANDLOPER	*Dunlin*	*CALIDRIS ALPINA* [2,3]	✓		✓		✓			✓			
BRANDGANS	*Barnacle Goose*	*BRANTA LEUCOPSIS* [1,2,3]	✓		✓		✓		✓			✓	
BRILDUIKER	*Common Goldeneye*	*BUCEPHALA CLANGULA* [2,3]						✓					✓
BRUINE KIEKENDIEF	*Western Marsh Harrier*	*CIRCUS AERUGINOSUS* [2,3]							✓			✓	
BUIZERD	*Common Buzzard*	*BUTEO BUTEO* [2,3]				✓		✓				✓	
DWERGSTERN	*Little Tern*	*STERNULA ALBIFRONS* [2,3]	✓	✓	✓		✓						
GIERZWALUW	*Common Swift*	*APUS APUS* [1,3]						✓					
GOUDPLEVIER	*European Golden Plover*	*PLUVIALIS APRICARIA* [2,3]	✓		✓	✓							
GROENE SPECHT	*Eurasian Green Woodpecker*	*PICUS VIRIDIS* [2,3]				✓		✓					
GROTE KAREKIET	*Great Reed Warbler*	*ACROCEPHALUS ARUNDINACEUS* [2,3]							✓				
GROTE STERN	*Sandwich Tern*	*STERNA SANDVICENSIS* [1,3]	✓		✓		✓						
GRUTTO	*Black-Tailed Godwit*	*LIMOSA LIMOSA* [1,2,3]				✓				✓			
HUISMUS	*House Sparrow*	*PASSER DOMESTICUS* [1,2,3]		✓				✓					
IJSVOGEL	*Common Kingfisher*	*ALCEDO ATTHIS* [2,3]					✓	✓	✓			✓	✓
KEMPHAAN	*Ruff*	*CALIDRIS PUGNAX* [2,3]	✓		✓	✓	✓			✓		✓	✓
KLEINE KAREKIET	*Eurasian Reed Warbler*	*ACROCEPHALUS SCIRPACEUS* [2,3]							✓			✓	✓
KLEINE PLEVIER	*Little Ringed Plover*	*CHARADRIUS DUBIUS* [2,3]		✓		✓		✓					✓
KLEINE ZILVERREIGER	*Little Egret*	*EGRETTA GARZETTA* [2,3]	✓		✓		✓		✓			✓	✓
KLEINE ZWAAN	*Bewick's Swan*	*CYGNUS BEWICKII* [1,3]								✓			✓
KLUUT	*Pied Avocet*	*RECURVIROSTRA AVOSETTA* [1,2,3]	✓		✓		✓						
KNEU	*Common Linnet*	*LINARIA CANNABINA* [2,3]		✓		✓		✓					
KOEKOEK	*Common Cuckoo*	*CUCULUS CANORUS* [2,3]				✓		✓	✓			✓	✓
KOKMEEUW	*Black-Headed Gull*	*CHROICOCEPHALUS RIDIBUNDUS* [2,3]	✓	✓	✓	✓	✓	✓	✓			✓	✓

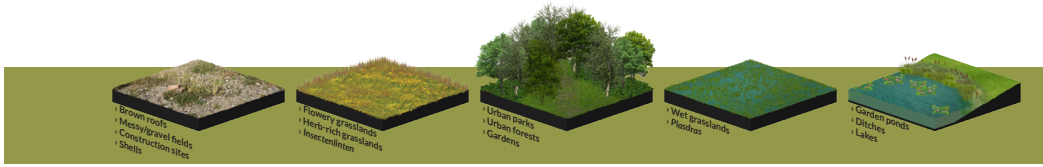


I. BIRDS & THEIR HABITATS *(cont.)*

List of expected species related to their respective habitats



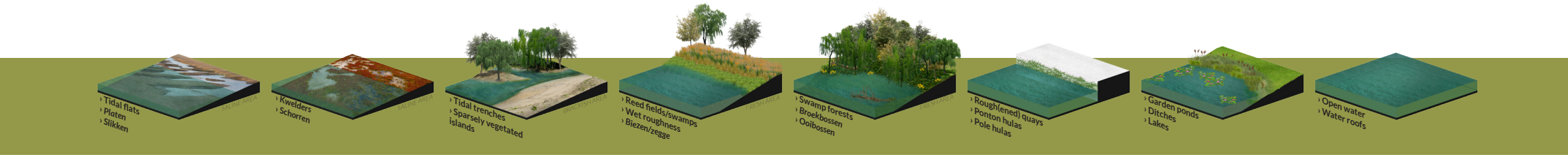
SPECIES											
KRAKEEND	*Gadwall* MARECA STREPERA [2,3]				✓	✓		✓			✓
KUIFEEND	*Tufted Duck* AYTHYA FULIGULA [2,3]					✓					✓
LEPELAAR	*Eurasian Spoonbill* PLATALEA LEUCORODIA [2,3]	✓		✓		✓		✓		✓	✓
MEERKOET	*Eurasian Coot* FULICA ATRA [2,3]					✓		✓	✓	✓	✓
⊛ **MEREL**	*Common Blackbird* TURDUS MERULA [1,3]				✓		✓			✓	
OEVERLOPER	*Common Sandpiper* ACTITIS HYPOLEUCOS [2,3]					✓					✓
⊛ **PATRIJS**	*Grey Partridge* PERDIX PERDIX [1,3]				✓						✓
PIJLSTAART	*Northern Pintail* ANAS ACUTA [2,3]	✓		✓		✓					✓
⊛ **PURPERREIGER**	*Purple Heron* ARDEA PURPUREA [1,3]							✓		✓	
PUTTER	*European Goldfinch* CARDUELIS CARDUELIS [2,3]		✓		✓		✓				
RIETGORS	*Common Reed Bunting* EMBERIZA SCHOENICLUS [2,3]			✓	✓			✓		✓	✓
RIETZANGER	*Sedge Warbler* ACROCEPHALUS SCHOENOBAENUS [2,3]					✓		✓		✓	
⊛ **ROERDOMP**	*Eurasian Bittern* BOTAURUS STELLARIS [1,2,3]							✓		✓	
ROODBORST	*European Robin* ERITHACUS RUBECULA [2,3]				✓		✓				
SCHOLEKSTER	*Eurasian Oystercatcher* HAEMATOPUS OSTRALEGUS [2,3]	✓	✓	✓	✓	✓	✓		✓		✓
SLOBEEND	*Northern Shoveler* SPATULA CLYPEATA [2,3]					✓		✓	✓		✓
SMIENT	*Eurasian Wigeon* MARECA PENELOPE [2,3]								✓		✓
SNOR	*Savi's Warbler* LOCUSTELLA LUSCINIOIDES [2,3]							✓		✓	✓
SPOTVOGEL	*Icterine Warbler* HIPPOLAIS ICTERINA [2,3]				✓		✓				
SPRINKHAANZANGER	*Common Grasshopper Warbler* LOCUSTELLA NAEVIA [2,3]					✓		✓		✓	✓
STORMMEEUW	*Mew Gull* LARUS CANUS [2,3]	✓	✓	✓		✓					
TURELUUR	*Common Redshank* TRINGA TOTANUS [2,3]	✓		✓	✓	✓			✓		✓
VISDIEF	*Common Tern* STERNA HIRUNDO [2,3]	✓	✓	✓		✓			✓	✓	✓
WATERSNIP	*Common Snipe* GALLINAGO GALLINAGO [2,3]			✓				✓	✓	✓	✓
WINTERTALING	*Eurasian Teal* ANAS CRECCA [2,3]			✓		✓			✓	✓	✓
WULP	*Eurasian Curlew* NUMENIUS ARQUATA [2,3]	✓		✓	✓	✓			✓		
ZILVERMEEUW	*European Herring Gull* LARUS ARGENTATUS [2,3]	✓	✓	✓		✓					✓
ZILVERPLEVIER	*Grey Plover* PLUVIALIS SQUATAROLA [2,3]	✓		✓		✓			✓		
ZOMERTALING	*Garganey* SPATULA QUERQUEDULA [2,3]			✓						✓	✓
⊛ **ZWARTE STERN**	*Black Tern* CHLIDONIAS NIGER [1,3]							✓		✓	✓



II. FISH & THEIR HABITATS

List of expected species related to their respective habitats

	SPECIES	
	AAL/PALING	*European Eel* ANGUILLA ANGUILLA [4,5]
!	**ALVER**	*Common Bleak* ALBURNUS ALBURNUS [2,6,7]
★	**ATLANTISCHE STEUR**	*Atlantic Sturgeon* ACIPENSER STURIO [1,4,5]
★	**ATLANTISCHE ZALM**	*Atlantic Salmon* SALMO SALAR [1,4,5,8]
★	**BITTERVOORN**	*European Bitterling* RHODEUS AMARUS [1]
	BOT	*European Flounder* PLATICHTHYS FLESUS [5,8]
	BRASEM	*Common Bream* ABRAMIS BRAMA [2]
	DIKLIPHARDER	*Thicklip Grey Mullet* CHELON LABROSUS [8]
	DRIEDOORNIGE STEKELBAARS	*Three-Spined Stickleback* GASTEROSTEUS ACULEATUS ACULEATUS [2,4,5]
	DUNLIPHARDER	*Thinlip Grey Mullet* CHELON RAMADA [5]
	ELFT	*Allis Shad* ALOSA ALOSA [4,5]
!	**FINT**	*Twaite Shad* ALOSA FALLAX [4,5,6,7]
	MEERVAL	*Wels Catfish* SILURUS GLANIS [8]
!	**NOORDZEEHOUTING**	*Houting* COREGONUS OXYRINCHUS [4,5,6,7]
!	**RIVIERPRIK**	*River Lamprey* LAMPETRA FLUVIATILIS [4,5,6,7]
	ROOFBLEI	*Asp* ASPIUS ASPIUS [2]
!	**SPIERING**	*European Smelt* OSMERUS EPERLANUS [4,5,6,7]
	TIENDOORNIGE STEKELBAARS	*Ten-Spined Stickleback* PUNGITIUS PUNGITIUS [2]
	ZEEFOREL	*Sea Trout* SALMO TRUTTA TRUTTA [4,5]
!	**ZEEPRIK**	*Sea Lamprey* PETROMYZON MARINUS [4,5,6,7,8]
	ZWARTBEKGRONDEL	*Round Goby* NEOGOBIUS MELANOSTOMUS [2]



III. MAMMALS & AMPHIBIANS & THEIR HABITATS

List of expected species related to their respective habitats

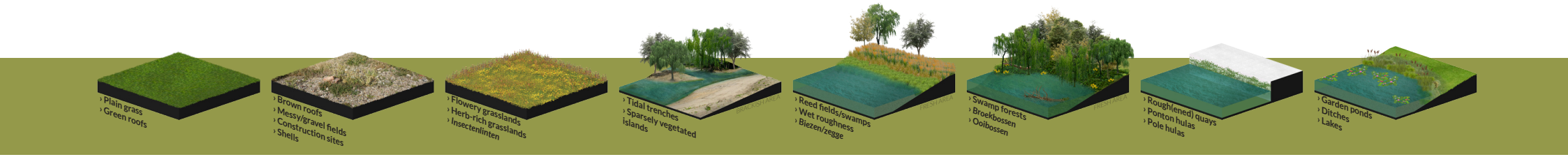
SPECIES		
BEVER	*Eurasian Beaver*	*CASTOR FIBER* [1,2,8,10,12]
DWERGMUIS	*Eurasian Harvest Mouse*	*MICROMYS MINUTUS* [2,10]
EEKHOORN	*Eurasian Red Squirrel*	*SCIURUS VULGARIS* [10,11]
EGEL	*European Hedgehog*	*ERINACEUS EUROPAEUS* [1,10,11]
GEWONE DWERGVLEERMUIS	*Common Pipistrelle*	*PIPISTRELLUS PIPISTRELLUS* [2,10]
HAAS	*European Hare*	*LEPUS EUROPAEUS* [2,9,10]
KONIJN	*European Rabbit*	*ORYCTOLAGUS CUNICULUS* [2,9,10]
MEERVLEERMUIS	*Pond Bat*	*MYOTIS DASYCNEME* [1,10]
NOORDSE WOELMUIS	*Tundra Vole*	*ALEXANDROMYS OECONOMUS ARENICOLA* [1,2,9,10]
OTTER	*Eurasian Otter*	*LUTRA LUTRA* [1,10]
ROSSE WOELMUIS	*Bank Vole*	*MYODES GLAREOLUS* [2,10]
RUIGE DWERGVLEERMUIS	*Nathusius's Pipistrelle*	*PIPISTRELLUS NATHUSII* [2,10]
VELDMUIS	*Common Vole*	*MICROTUS ARVALIS* [2,10]

SPECIES NAME		
ALPENWATERSALAMANDER	*Alpine Newt*	*ICHTHYOSAURA ALPESTRIS* [13]
BASTAARDKIKKER	*Edible Frog*	*PELOPHYLAX KLEPTON ESCULENTUS* [13]
BRUINE KIKKER	*Common Frog*	*RANA TEMPORARIA* [13]
GEWONE PAD	*Common Toad*	*BUFO BUFO* [2,13]
KAMSALAMANDER	*Great Crested Newt*	*TRITURUS CRISTATUS* [13]
KLEINE WATERSALAMANDER	*Smooth Newt*	*LISSOTRITON VULGARIS* [2,13]
MEERKIKKER	*Marsh Frog*	*PELOPHYLAX RIDIBUNDUS* [13]
POELKIKKER	*Pool Frog*	*PELOPHYLAX LESSONAE* [13]

IV. INSECTS & THEIR HABITATS

List of expected species related to their respective habitats

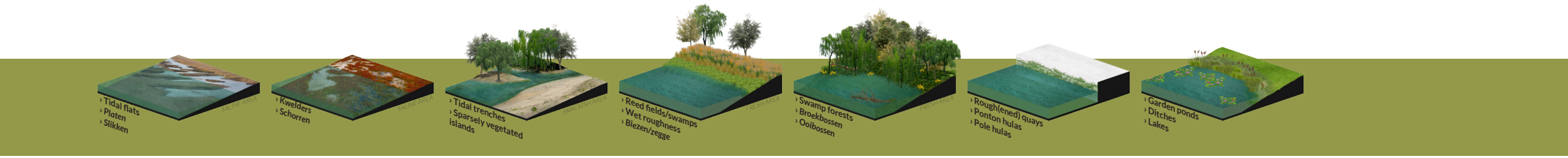
	SPECIES		
⍟	**ARGUSVLINDER**	*Wall Brown*	*LASIOMMATA MEGERA* [1,16]
!	**BOSHOMMEL**	*Shrill Carder Bee*	*BOMBUS SYLVARUM* [14,15,19]
🦗	**BRAMENSPRINKHAAN**	*Dark Bush-Cricket*	*PHOLIDOPTERA GRISEOAPTERA* [2,20]
🦗 !	**BRUIN BLAUWTJE**	*Brown Argus*	*ARICIA AGESTIS* [2,16,17]
!	**BRUINE VUURVLINDER**	*Sooty Copper*	*LYCAENA TITYRUS* [16,17]
	DONKERE BIJ	*European Dark Bee*	*APIS MELLIFERA MELLIFERA* [15]
!	**GEELSTAARTKLAVERZANDBIJ**	*European Legume Miner Bee*	*ANDRENA WILKELLA* [14,15,19]
!	**GEVLEKTE GLANSLIBEL**	*Yellow-Spotted Emerald*	*SOMATOCHLORA FLAVOMACULATA* [16,18]
⍟	**GLASSNIJDER**	*Hairy Dragonfly*	*BRACHYTRON PRATENSE* [1,16]
!	**GOUDEN SLAKKENHUISBIJ**	*Gold-Fringed Mason Bee*	*OSMIA AURULENTA* [14,15]
! ⍟	**GROENE GLAZENMAKER**	*Green Hawker*	*AESHNA VIRIDIS* [1,16,18]
!	**GROTE KEGELBIJ**	*Large Sharp-Tail Bee*	*COELIOXYS CONOIDEA* [14,15]
🦗	**KLEINE ROODOOGJUFFER**	*Small Red-Eyed Damselfly*	*ERYTHROMMA VIRIDULUM* [2,16]
🦗	**LANTAARNTJE**	*Blue-Tailed Damselfly*	*ISCHNURA ELEGANS* [2,16]
!	**ORANJE ZANDOOGJE**	*Gatekeeper*	*PYRONIA TITHONUS* [16,17]
	RIVIERROMBOUT	*River Clubtail*	*STYLURUS FLAVIPES* [8,16]
🦗	**SINT-JACOBSVLINDER**	*Cinnabar Moth*	*TYRIA JACOBAEAE* [2,16]
🦗	**VROEGE GLAZENMAKER**	*Green-Eyed Hawker*	*AESHNA ISOCELES* [2,16]
⍟	**WEIDEHOMMEL**	*Early Bumblebee*	*BOMBUS PRATORUM* [1,15]
! ⍟	**ZANDHOMMEL**	*Veteran Bumblebee*	*BOMBUS VETERANUS* [1,14,15]
	ZWARTE HEIDELIBEL	*Black Darter*	*SYMPETRUM DANAE* [8,16]



v. RIVER BANK/AQUATIC PLANTS & THEIR HABITATS

List of expected species related to their respective habitats

SPECIES		
DRIEKANTIGE BIES	*Triangular Club-Rush*	*SCHOENOPLECTUS TRIQUETER* [2,20,21]
DRIJVEND FONTEINKRUID	*Floating Pondweed*	*POTAMOGETON NATANS* [2,20]
GEVLEUGELDSTERRENKROOS	*Pond Water-Starwort*	*CALLITRICHE STAGNALIS* [2,20]
GEWIMPERDLANGBAARDGRAS	*Long-Bearded Grass*	*VULPIA CILIATA SUBSP. CILIATA* [2,20,21]
GLANZIGE HOORNBLOEM	*Common Mouse-Ear Chickweed*	*CERASTIUM FONTANUM SUBSP. HOLOSTEOIDES* [2,20,21]
GOUDKNOPJE	*Buttonweed*	*COTULA CORONOPIFOLIA* [2,20]
GROTE KAARDEBOL	*Wild Teasel*	*DIPSACUS FULLONUM* [2,20]
HEELBLAADJES	*Common Fleabane*	*PULICARIA DYSENTERICA* [2,20]
MOERASKRUISKRUID	*Fen Ragwort*	*JACOBAEA PALUDOSA* [2,20,21]
MOERASSTREEPZAAD	*Marsh Hawk's-Beard*	*CREPIS PALUDOSA* [2,20]
PITRUS	*Soft Rush*	*JUNCUS EFFUSUS* [2,20]
RIETORCHIS	*Southern Marsh-Orchid*	*DACTYLORHIZA MAJALIS SUBSP. PRAETERMISSA* [1,20]
RODE OGENTROOST	*Red Bartsia*	*ODONTITES VERNUS SUBSP. SEROTINUS* [2,20,21]
RODE WATEREREPRIJS	*Pink Water-Speedwell*	*VERONICA CATENATA* [2,20]
SCHEDEFONTEINKRUID	*Sago Pondweed*	*POTAMOGETON PECTINATUS* [2,20]
SPINDOTTERBLOEM	*Marsh-Marigold*	*CALTHA PALUSTRIS SUBSP. ARANEOSA* [1,2,20]
WATERGENTIAAN	*Fringed Water-Lily*	*NYMPHOIDES PELTATA* [2,20]
WATERPEPER	*Water Pepper*	*PERSICARIA HYDROPIPER* [2,20]
ZEEGROENE RUS	*Hard Rush*	*JUNCUS INFLEXUS* [2,20]
ZOMERKLOKJE	*Summer Snowflake*	*LEUCOJUM AESTIVUM* [2,20,21]



VI. BIBLIOGRAPHY APPENDIX

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The bibliography on this page references the annotations in the appendix only; the main report references list can be found on page 69.

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