# INTERACTIVE WATER STORAGE FOR BUIKSLOTERHAM

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# DELTA INTERVENTIONS

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# PREFACE

This MSc thesis is the result of the work I have done the last 10 months. It was created as a part of the Delta Interventions graduation studio and done in collaboration with the AMS institute.

The thesis is a result of my own personal interest, which have been developed the previous year of my MSc education and during my BSc. I have learned a lot in this process, but mostly I have discovered that I would like to expand this knowledge and learn more about sustainable design. I hope this thesis gives you, the reader, inspiration and that you enjoy reading it.

Of course, this thesis would not have been possible without the help of some people. First I would very much like to thank my mentors, Kristel and Frits, who have helped and inspired me throughout the entire process. Kristel, thank you very much for being such a good mentor. Not only do I always get the feeling that your knowledge in terms of water management and sustainable design must be endless, you made me feel like all my questions where relevant and pushed me towards investigating all the options in my design process. And you helped me organize my thoughts on paper and in writing, which is always a challenge for me. Frits, thank you for pushing me out of my comfort zone. Without you, my sketching equipment would still be forgotten at the back of a closet. You helped me discover alternative ways of design and showed me that the way I know is not always the best way.

And I would also like to thank my fellow students, friends and family. Especially through the last months of the process, I needed all of you for input, discussions, distractions and 'gezelligheid'.

Let this thesis be an inspiration to the possibilities of sustainable design, so that together we can create a generation that gives back to the planet.

Lisanne Viergever

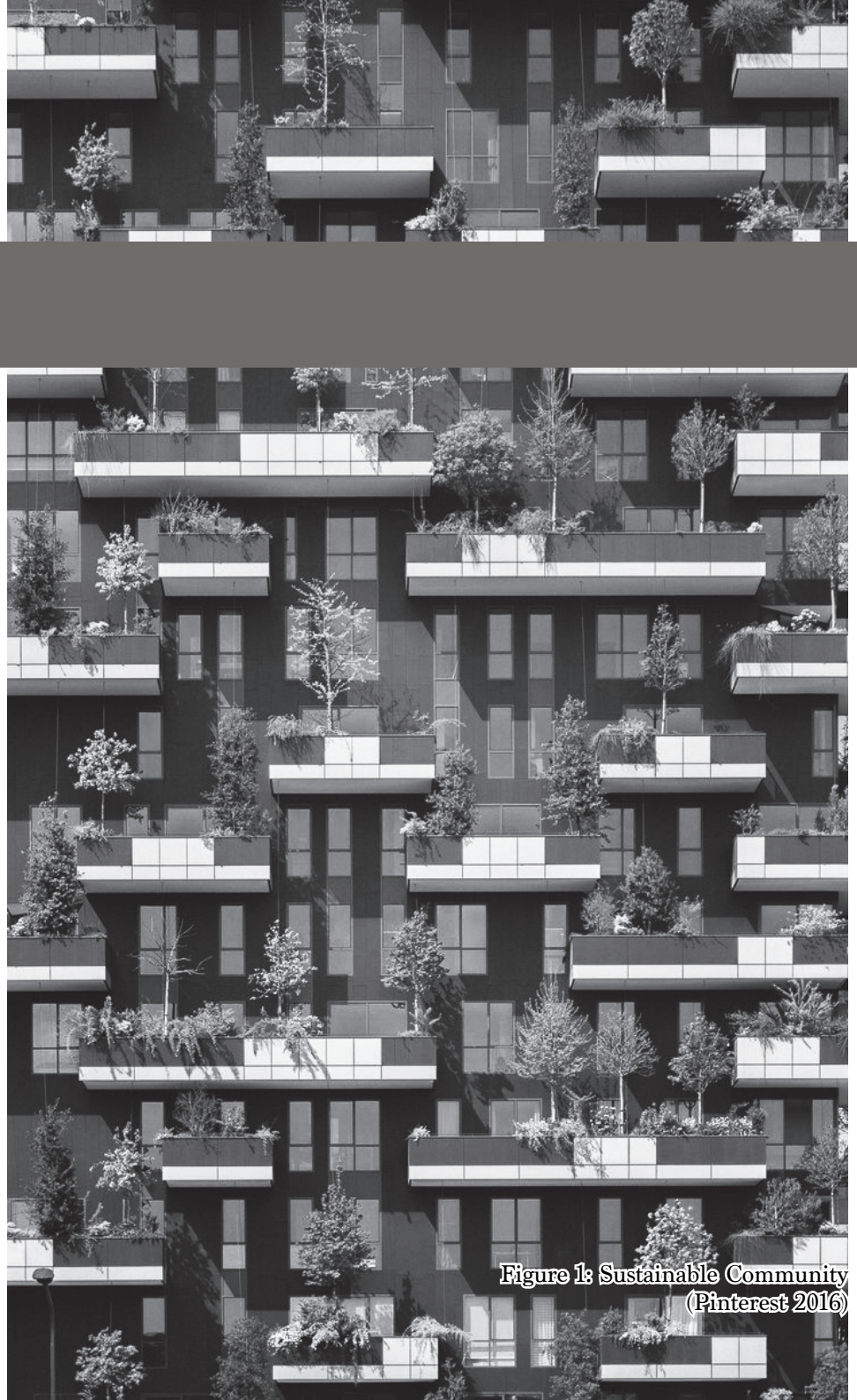


Figure 1: Sustainable Community (Pinterest 2016)


Figure 2: Humans in Danger
(Google 2016)

# ABSTRACT

With climate change changing the world, literally, delta landscapes become more vulnerable. At the same time, delta landscapes become more densely populated every year, creating an uncertain environment for high density urban areas. In the Netherlands, cities are facing treats from the sea level rising, heat stress and increasing amounts of rain fall. The high density combined with the hardening of surfaces in city areas, leaving little open green space with permeable soil, creates problems for cities in times of heavy rain fall.

Amsterdam is one of those cities, developing as the biggest metropolitan area of the Netherlands. The city of Amsterdam wants to solve the problems with rain water management, while at the same time developing as a smart, innovative, sustainable metropolitan area. Buiksloterham is a key area in this aspect, functioning as a test ground for sustainable neighborhood development.

To create a more sustainable way of water management, the thesis aims for Buiksloterham to become self-sufficient in water use. Storing rain water, re-using rain and grey water and creating high quality water are key factors for achieving this. The design creates 3 separate systems, one for black water which is cleansed by using a living machine. After the black water has been cleansed, it joins the grey water system. This system gathers all the grey water from the households in the neighborhood, circulates this and passes it through helofyte filters for cleansing. Then this water joins the clean water system, a system that is created for a larger part of Amsterdam North. This system is connected to the households, so that the households can re-use the rain water and cleansed grey water to create a circular structure.

In order to create more sustainable awareness for the inhabitants of Buiksloterham and make the area function as a sustainable water community, it is important for the inhabitants of Buiksloterham to experience water (visual, audial, touch and smell), to have a say in the way water is managed in the area, to have influence on the way water is managed and to have responsibility over this system. To achieve this, water storage is applied through every scale. On the small scale, changeable objects are added to the public space, integrated with water storage, so that the inhabitants can influence their public space. This creates an ambition in Buiksloterham, that closely connects the inhabitants of the area to the sustainable way of water management. It also creates the possibility for the inhabitants to adjust, add and change the system according to their wishes.

The combination of these two aspects, the technical water management part of the societal part which creates a sustainable community, creates an opportunity for both Buiksloterham and Amsterdam, to develop itself as an example of a new way of life, a more connected, interactive urban fabric with the environment and an example of high dense sustainable urban development.

key words: **water management, rain water management, rain water re-use, sustainable community, sustainable urban fabric, interactive design**

# INTRODUCTION

Climate change is changing the world, literally. Temperatures are rising, climates are changing, rain is increasing and snow is melting. The average European land temperature is already up 1.3C. To stop this rapid increase, the UN World Commission on Environment and Development has created a strategy to protect vulnerable landscapes, such as delta areas.

The Netherlands is one of those delta areas. With it dense population, it faces high treat from climate change. The next decade the Netherlands will face an increase in winter precipitation, river flow and risk of river and coastal flooding (European Commision, 2013). It is predicted by the meteorological institute of the Netherlands, the KNMI, that in the next 70 years it will see an increase in rainfall by 7%. It will also be possible that there are longer periods of draught, which results into a water shortage, reduced water quality and salination. The temperature in the Netherlands will increase by about 4C average, with higher maximum temperatures (Koninklijk Nederlands Meteorologisch Instituut, 2014). Growth of the population and the possibilities for economic activities, in combination with climate change, make the delta area of the Netherlands vulnerable (H. Meyer, 2015).

Since the report from the UN World Commission on Environment and Development was published in 1987, the concept of sustainable development has become an important aspect of worldwide developments. It views the future development of cities in such a way that they 'meet the needs of the present without compromising the ability of future generations to meet their own needs'. The report brought such a change, that a completely different strategy for spatial planning of the urban fabric was necessary (Allmendinger, 2002).

But it's not only because of climate change that the way we design our cities has changed. Over the past 50 years we have seen an increased movement from thinking of the city as separate systems, to thinking of the city as a complex system. This way of thinking calls for a more flexible approach to the design of the city. The environment of the city plays a much bigger role in this type of approach. The complex city theory makes it possible for cities to become more flexible, allowing them to react to unforeseen circumstances (Allmendinger, 2002). For cities to develop in a sustainable way, it is necessary for urban planners to give priority to the concerns of sustainable development (Naess, 2001). But what makes it so that the inhabitants of the city will be aware of sustainability?

We have seen from studies that knowledge and awareness does not directly lead to pro-environmental behavior. This is because people need a direct experience, to adjust their behavior. People are not that likely to change their behavior, unless they see immediate results. But the effects of non-environmentally friendly behavior are usually promoted in a 10-year+ timeframe, which keeps it very distant. That, combined with people's social norms, cultural traditions, customs and attitudes, makes it very hard to promote pro-environmental behavior for people (A. Kollmuss, 2002). One of the ways to bring pro-environmental behavior closer to the inhabitants of the city, is the direct urban structure they live in. Neighborhoods are as important as any other element in the urban system, and they can be seen as the frontline in the battle for sustainability (Choguill, 2008).

Figure 3: Coastal Cities
(Google 2016)

# PROBLEM STATEMENT

WORLDWIDE

The population of the planet is increasing rapidly. In 2100, the worldwide population is predicted to be between 11-16 billion people. Not only are there more people on the planet, people also live longer. This increase in population calls for worldwide urbanization, which results in the most attractive areas of the planet becoming more densely populated. The coastal areas are the most popular areas for this urbanization, which leads to a rapid development of cities in vulnerable delta landscapes (United Nations Population Fund, 2017).

Not only is the worldwide population changing, the planet itself is changing too. In 2011 the average temperature was 0.5C above what it should be at that time (Koninklijk Nederlands Meteorologisch Instituut, 2012). This increase in temperature increases drought worldwide. The sea level rises with 3.4 mm/year. And extreme events are more than twice as likely to happen on a yearly base (NASA, 2017).

This climate change will also have effect on economic developments, causing damages but also creating opportunities. Technological developments will become more and more integrated in people's everyday lifestyle (Global Business Policy Council, 2015), especially in the life of metropolitan citizens (United Nations Population Fund, 2017).

Worldwide, the challenge in the next 50 years will be to deal with the growth in population, in a sustainable way. Cities in vulnerable areas will increase in size, in these areas a balance between men and nature has to be sought.

PEOPLE

PLANET

PROFIT

NATIONAL

In the Netherlands, we also see an increase in population. From 2015-2016 there was a growth of 0.5 %, which is expected to continue over the next 50 years. The population of the Netherlands is mostly concentrated in the Randstad area, the cities here are rapidly growing and increasing in density. The population of the Netherland also sees an increased number of elderly people, due to increased lifespan and decrease in new-borns (Centraal Bureau voor de Statistiek, 2016).

Climate change is also influencing the Netherlands. But, contrary to most of the world, the Netherlands is expected to have an increase in rainfall, and an excess amount of fresh water. The treat comes from too much water, instead of not enough. This creates an interesting opportunity for the Netherlands (Koninklijk Nederlands Meteorologisch Instituut, 2014). Challenges lie in dealing with the increase in rain fall, temperature rise, sea level rise, decreasing biodiversity and the water quality (Centraal Bureau voor de Statistiek, 2016).

Sustainable development creates economic opportunities in the Netherlands, which focusses its investments on technology and the knowledge economy.

For the Netherlands, sustainable rain proof development of the Randstad area will be key in the next 50 years. This will not only provide with extra safety for the inhabitants of the area, it will also create economic opportunities and stimulate the knowledge economy of the country.

PEOPLE

PLANET

PROFIT

AMSTERDAM

Amsterdam is the biggest metropolitan area of the Netherlands. With that comes that it's also one of the fastest growing cities. Amsterdam is an attractive city for self-employees and small businesses. The city has a high demand of so called third-workspace environments, like shops, restaurants, parks and public spaces. The people of Amsterdam enjoy a flexible lifestyle with plenty of room for flexible work spaces and hours, sports, long lunches with good quality food and a green outdoor feeling of the public space the spend their time in. They travel mostly by bicycle and public transport. There is also an increased demand for electric cars. The people of Amsterdam show an interest in their city, they wish to help improve their living environment by inhabitant initiatives (Gemeente Amsterdam, Bureau Onderzoek en Statistiek, 2014).

The green structure of Amsterdam is decreasing with the growth of the city, while there is an increasing demand for green public space by the inhabitants of the city (Gemeente Amsterdam, Bureau Onderzoek en Statistiek, 2014). The city also faces problems with rain water discharge due to the high density. And the high density also contributes to the heat stress of the city (Koninklijk Nederlands Meteorologisch Instituut, 2014). The city of Amsterdam aims towards new sustainable residential areas, where flexibility, waste-, water- and energy management are integrated into the neighbourhood (Gemeente Amsterdam, 2011).

Amsterdam wants to be internationally recognized as a sustainable, innovative, smart metropolitan area. They aim to achieve this by investing in a healthy economy for sustainable development, knowledge infrastructure and new built neighbourhoods. Further they aim to increase their economy by creating more the tourism, opportunities for small businesses, third place work environments, cultural experiences and luxury lifestyle possibilities. The businesses in Amsterdam should aim to be flexible, allowing their employees to create and adapt their work and private life, to further benefit from each other (Gemeente Amsterdam, 2011).

The challenge for Amsterdam lies in developing the city, increasing its density, while at the same time proving more green and public space for the inhabitants. In order for the inhabitants of Amsterdam to lead the sustainable lifestyle they aspire, the city needs to sustainably create high quality outdoor space, so that people can live outside as much as inside.

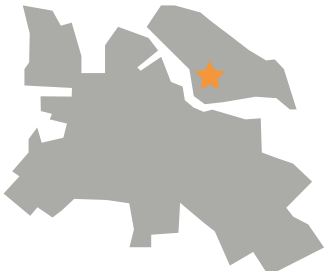



Figure 4: Analysis in Maps
Green strucute 2015, 2025 expected, 2025 prefered
Flood chance 2015, expected 2025, 2025 prefered
Made by the Autor, based on (Edugis, 2015)




Figure 5: Analysis in Maps
Infrastrcture 2015, Air pollution 2015, Hard Surfaces 2015
Average house size 2015, Traffic pollution 2015, Density 2015
Made by the Autor, based on (Edugis, 2015)

BUIKSLOTERHAM

Amsterdam has appointed Buiksloterham as a test location for sustainable development. It is located in the North of Amsterdam, at the IJ-shore. It is an old industrial area that is now mainly abandoned (Gemeente Amsterdam, 2009). The municipality wishes for Buiksloterham to become a circular, sustainable area. The objectives for the area include:

- Buiksloterham is energy self-sufficient with a fully renewable energy supply.
- Buiksloterham is a zero waste neighbourhood, with a near 100% circular flow.
- Buiksloterham is rainproof and has a near 100% resource recovery from waste water.
- Infrastructure is maximally-used and local mobility has zero emissions.

When looking at those objectives in a bit more detail, for water it means they wish to:

- Manage all rainwater above ground with the capacity to handle heavy peak rainfall without flooding.
- Reduce domestic & commercial water demand by 25%.
- Intelligent drinking water use.
- Separate wastewater.

(Gemeente Amsterdam, 2015).

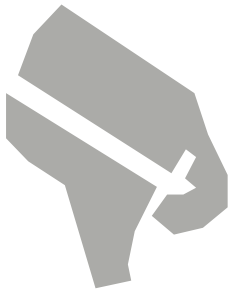
But when looking at the other objectives they have set for themselves, for example the ones for energy and waste management, the objectives for water are a little unimaginative and uninspiring. Modern understanding of circularity and the Netherlands strong history with water management offer more possibilities to develop the area sustainable in terms of rain water use. When taking into account the wish from the municipality to become 'the smartest and most innovative water site of the Netherlands' (Gemeente Amsterdam, 2015), the thesis aims to set higher goals for Buiksloterham in terms of rain water storage and use.

The location is perfect; it is a sustainable based community where participants are already aware and interested in sustainable development. It is located in the biggest metropolitan area of the Netherlands, that has already expressed the wish to become very innovative in their water use. This creates an opportunity for Buiksloterham.

For Buiksloterham the municipality wants to create a work-residential area, with a lot of room for small businesses, temporary businesses and residential areas. It will be a high-density area. The people that live in the area will be traveling mostly by public transport and bicycle. The area is appointed to be develop as a sustainable neighbourhood. The area should have plenty of third place office environments, as well as lots of outdoor green spaces, public spaces with room for inhabitants to initiate their own activities and ideas.

With the high density area that Amsterdam aims to create in Buiskloterham, rain water discharge and heat stress need to be take into account in the design. The area is also located at a connecting point for possible green structures, which will help with the biodiversity of the area as well.

Buiksloterham will be designed towards small or medium size businesses, with





room for self-employees and a combined work-living environment. The wish of the municipality to create a sustainable neighbourhood in Buiksloterham creates a possibility for profit as well. Businesses that are located in the area should have sustainability as part of their identity, so the sustainable image of the neighbourhood is only increased. This will also strengthen the area economically.

For Buiksloterham, the challenge is to combine a high density work/residential area with a sustainable development. It should become an example for sustainable city development in the Netherlands.

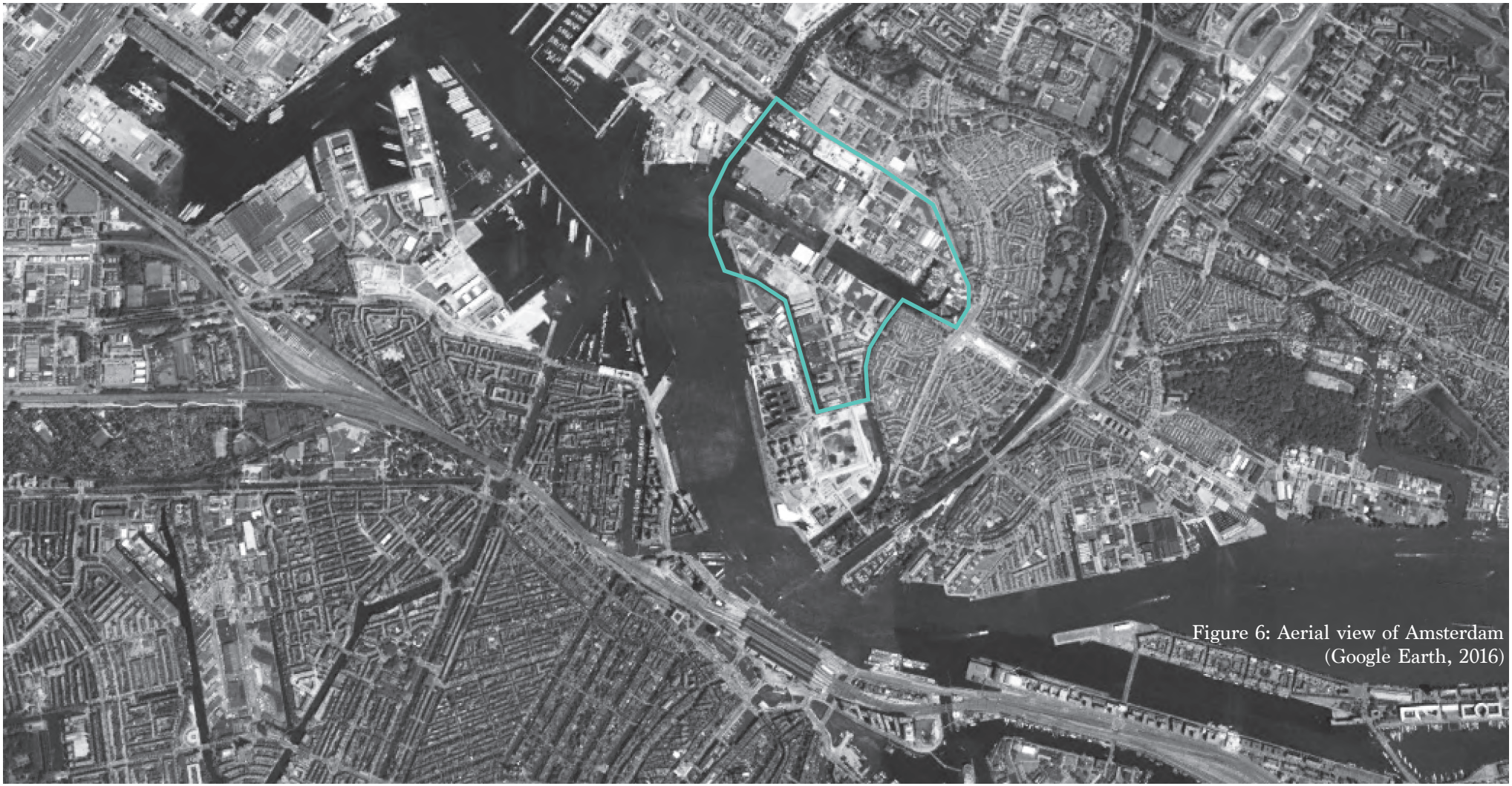


Figure 6: Aerial view of Amsterdam (Google Earth, 2016)

## CITY OF THE FUTURE

For Amsterdam to develop sustainable, it needs to look at where it wants to be in the future. Amsterdam wants to develop itself as a smart, innovative, sustainable metropolitan area. It has to find solutions for the growing demand in housing space, the increased demand for high quality public space and the balance with the environment. For Amsterdam, the city of the future means a sustainable city, which sets an example for the rest of the Netherlands. It has to focus on public transport, electric transport and bicycle transport. The city needs to have high quality green space, good third-workspaces, plenty of public spaces and a flexible day-night rhythm.

It needs to pay attention to the green structure of the city and create new green structures. For the city to stay habitable in the future, it needs to be able to deal with an increase in rain water. The city of Amsterdam also wants to identity as a smart, innovative, water city and look towards re-using rain water as much as possible. Amsterdam aims towards new sustainable residential areas, where flexibility, waste-, water- and energy management are integrated into the neighbourhood (Gemeente Amsterdam, 2011).

This graduation thesis aims to create a first step in the transformation of the city of Amsterdam. The thesis creates a design for Buiksloterham, one of the sustainable, innovative test locations of Amsterdam, that focusses on sustainable rain water management while creating a sustainable community at the same time.

Figure 7: Buiksloterham
Made by Author

# RESEARCH FRAMEWORK

This chapter will explain the framework used to create the thesis. It starts with the research questions that form the base of the research, then the objectives for the thesis are explained. These are followed by the methodology, the theoretical background and the societal & scientific relevance.

RESEARCH QUESTIONS

The thesis is formed around the main question:

**How can a flexible interactive water storage system be designed to help Buiksloterham prepare for climate change?**

As well as increase sustainable awareness through neighbourhood participation through the different scales?

This question can be answered by looking at the different sub-parts of the question. For the thesis we look at climate change, the water sytem, water storage, the area of Buiksloterham, the city of Amsterdam and the sustainable community.

*Climate change: What problems is Buiksloterham going to face because of climate change?*

For the climate change issues that influence the plan it will look at the general problems that come from climate change, what these problems mean for Amsterdam and what they mean for Buiksloterham.

*Water storage: What is the best water storage method for Buiksloterham?*

The thesis looks at the current water storage methods, how they are applicable in Buiksloterham and how they help create sustainable awareness. Then the methods are adjusted, to see if they can be made interactive and if so, what extra benefits this adds for Buiksloterham. The flexibility of the methods will be taken into account as well.

*Buiksloterham: How can we combine the use of a water storage system to sustainable awareness in a way that adds an attractive identity to the Buiksloterham living environment?*

When designing for Buiksloterham, the existing elements of Buiksloterham need to be analysed in order to understand the starting point of the project. The current problems and opportunities of the neighbourhood need to be made visible, as well as the identity it has now and the identity that would be preferable for the area in the future.

*Amsterdam: How can Amsterdam benefit from the design of Buiksloterham?*

Buiksloterham's water storage will have an impact on the entire city of Amsterdam as well. For the design, it needs to become clear in what way, and the possibilities the design offers for the entire city. Also, the design needs to be evaluated on whether or not it could be implemented in a different location.

*Sustainable awareness: How does water storage create sustainable awareness in Buiksloterham?*

When the design has to increase sustainable awareness, first it needs to become clear what sustainable awareness currently is, in relation to water. And it needs to become clear what the sustainable awareness of the current and future inhabitants of Buiksloterham is. This will then be related to the different design choices, so that the methods are picked that also benefit the sustainable awareness of the neighbourhood.

RESEARCH OBJECTIVES

The end goal of the thesis is the develop a design for Buiksloterham that offers enough water storage possibilities to meet the demands for grey water reuse (washing machine, toilet, garden) for every inhabitant and employee in the area, while at the same time creating an attractive environment in the Buiksloterham area. This will be done by the design of a flexible, interactive system, that can respond both top down and bottom up. This system will help the inhabitants of the city gain sustainable awareness and responsibility, allowing them to decide for themselves when and where they want to store rainwater. The system will also relieve some of the water stress on the city of Amsterdam.

Objectives:

- Buiksloterham becomes self-sufficient in water use
- Water becomes part of the identity of Buiksloterham
- The Buiksloterham area functions as a sustainable water community
- Buiksloterham re-uses rainwater
- Buiksloterham re-uses grey water
- Buiksloterham has a good water quality and improves the current rain and grey water quality
- The water storage in Buiksloterham is flexible
- The water storage in Buiksloterham is interactive
- The water storage in Buiksloterham is applied through the different scales

**Buiksloterham becomes self-sufficient in water use.**

The official definition of an area being self-sufficient is that it can maintain itself without outside aid (Merriam-Webster dictionary, 2016). For water use this means that Buiksloterham has no need to import water from the municipality, with the exception for tap water. There should be enough water for every inhabitant (60,5L per person/per day) and employee (40L per person/per day) (WMD Water, 2014). In order to do this, Buiksloterham needs to be able to store water in the area, create a circular system, re-use grey water and rain water and create a good water quality in this system. Connected objectives: re-use rainwater, re-use grey water and create a good water quality.

**Water becomes part of the identity of Buiksloterham.**

In order for water to become a recognizable and memorable part of Buiksloterham, it's important water plays on all the senses on the users of the public space of Buiksloterham. People should be able to see, hear, smell, touch and, if they want to, taste the water when they are in the public space. Water should therefore be a design element in the public space. Also, in order to further enhance the relation with the water, all houses should be connected (visually or physically) to the water system. And, to enhance the relationship between the neighbourhood and water, water storage should be an element that inhabitants can decide on together.

**The area functions as a sustainable water community.**

A community is often described as a group of people in a particular area that have a common goal (Merriam-Webster dictionary, 2016). A sustainable water community can therefore be described as a group of people that have the sustainable use of water as their common goal. In Buiksloterham this can be accomplished by having the inhabitants work together on water storage, connect all the households to the water system, have households share water storage and re-using grey- and rainwater.

*Re-use rain water.*

Rain water that falls on the Buiksloterham area will be used in the households and businesses located in the area, for all functions that demand water with an exception of the ones that can only be met with tap water.

*Re-use grey water.*

Grey water that comes from the households and businesses in Buiksloterham should be used again in the area.

*Good water quality.*

In order to re-use rainwater and grey water in the Buiksloterham area, the water should have a good quality. The rain- and grey water will be cleaned in the

area itself, with the use of helophyte filters. When this is not possible due to the nature of the pollution (for example when it has been in contact with the ground water), the possibility of on side mechanical cleaning should be considered. There should be m2 reserved for the helophyte filters (4m2 per person) in the area (Stichting Medume, 2016). And the water should be able to flow.

*Flexible water storage.*

Flexibility in design is one of the key aspects of designing sustainably, as explained by the complex system theory. The water storage system in Buiksloterham must be able to resist the expected climate changes, as well as function throughout the entire season. Therefore; the water system needs to be designed through the different scales, functioning on all scale levels. It needs to be designed in a way that it functions just as well in extreme water levels (wet vs dry). And it needs to be able to handle an expected 5%-10% increase in rainfall, as expected by the KNMI.

*Interactive water storage.*

As explained in the theoretical framework, people are more willing to adjust their behaviour when they see results/changes immediately and when they can influence things. Water storage is more likely to stimulate sustainable behaviour, when it can react to the wishes of the inhabitants. In order to achieve this, the system needs to be able to have a flexible water level, function both wet and dry, respond to the wishes of the inhabitants (with an overrule possibility by the municipality in times of expected great water stress) and allow people to decide together on the water storage.

*Water storage will be applied through the different scales.*

In order to be as interactive as possible and encourage people to work together, as well as create a strong connection in the area with water, the system works best when it is applied and visible in all scales. Water storage methods should be created for all scales, able to respond to the wishes of different people. And it should all be connected together in one system.

*Relieve heat-stress.*

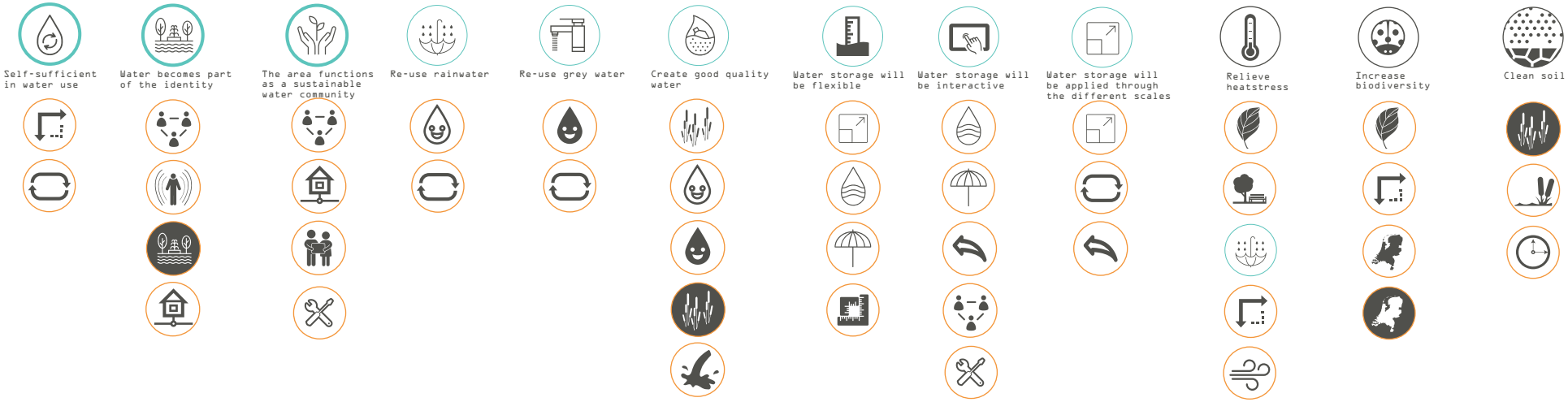
The design of Buiksloterham will combine the design of the water storage system with as many measurements against heat-stress as possible. These are to create open areas, so that the wind can flow through the area. To create green space, in order to create shadow and air. To re-use the rain-water in the area and to use green roofs and facades.

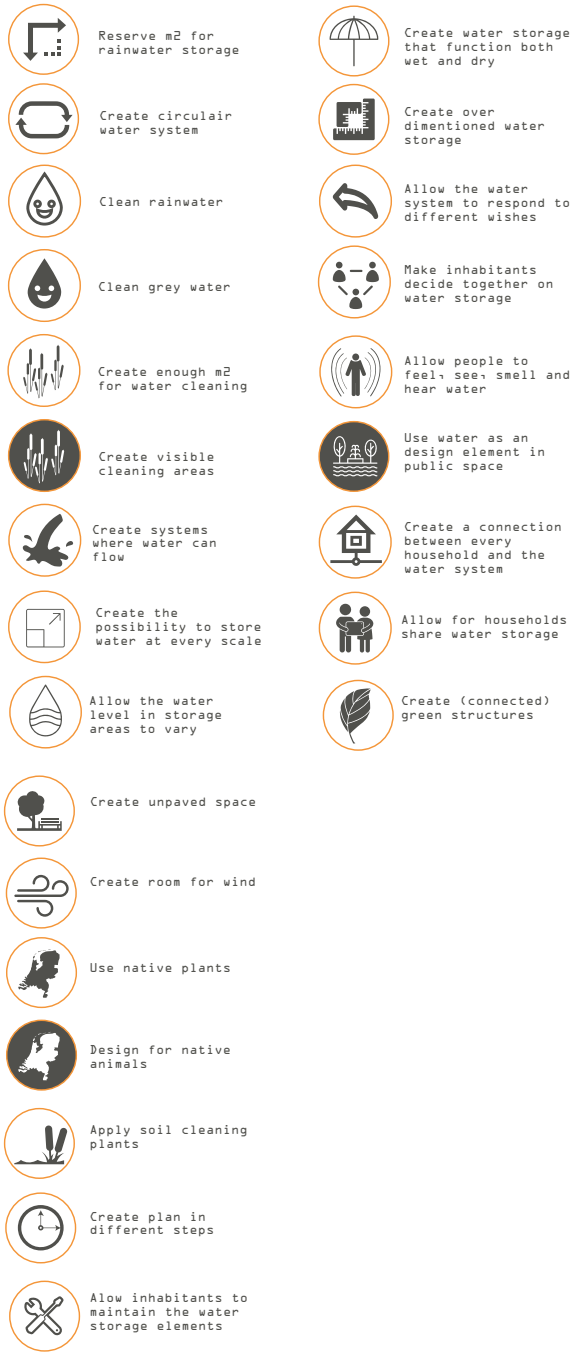
*Increase biodiversity*

The design will also help increase the biodiversity in the area, through the design of the water storag system. In order to achieve this it needs to reserve space for green- and water areas. And the area will be designed with native plants, for native wildlife.

*Better the soil condition*

The design will also strive to better the soil condition by the use of plants and trees. This will be done in steps, and primarely in the green structures that are to be formed in the area.


Self-sufficient in water use
Water becomes part of the identity
The area functions as a sustainable water community
Re-use rainwater
Re-use grey water
Create good quality water
Water storage will be flexible
Water storage will be interactive
Water storage will be applied through the different scales
Relieve heatstress
Increase biodiversity
Clean soil




METHODOLOGY

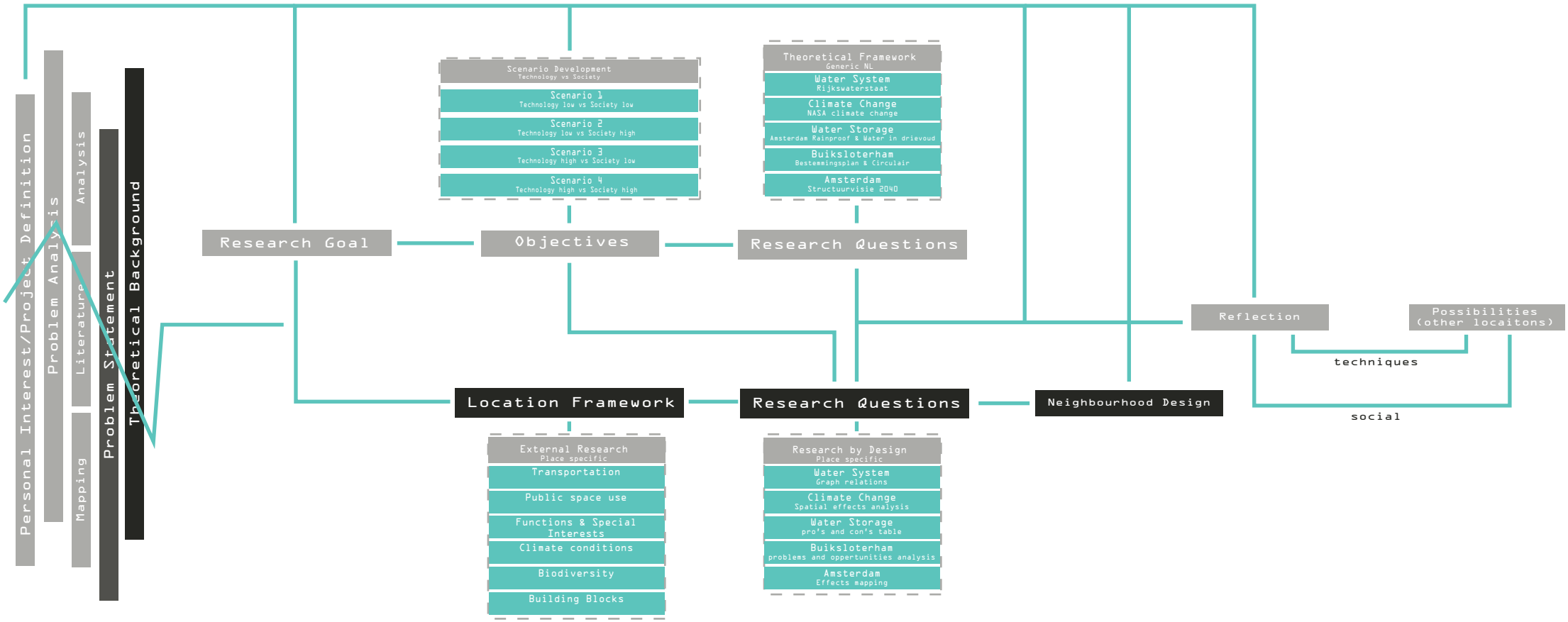
The diagram shows the different methods and techniques, and their relation, that are used for this graduation project. The project starts with a personal interest, a problem statement and theoretical background that together form the research goal and questions.

The theoretical background looks at 4 different theories; the complex system theory, the existing methods on how to design with this complex system, the people, planet and profit theory and how the interactive part of the design objective relates to the psychology of the people. The research goals, formed based upon the previous steps, are further determined and investigated by both the research questions and the objectives set for the thesis. The research questions are based upon various theories, plans by the municipality, techniques and climate data. These are then applied to the location to see what their effects are on the Buiksloterham area. The objectives are set by the goal, and are the elements that are needed to achieve this goal. With the help of scenario development, 4 different extremes are created. These extremes are then tested to see how well they meet the objectives (and the research questions). Together with the applied data from the research questions, they will form the base for the actual neighbourhood design.

But the neighbourhood design is also influenced by other, external factors. These are elements like transportation, the use of public space, climate change, biodiversity, functions in the area and the ground condition. The scenario's form a base to start with, with the objectives and research questions as a way to test them and see what works best. From this base, an actual design needs to be created. In this step, it is important to see how the rest of the design functions, looking into the daily life of the (imaginative) inhabitant.

This design process will eventually be reflected on, to determine the parts that are location specific and the parts of the design that could also be implemented on other locations. This will then relate itself to possibilities for the city of Amsterdam as a whole, which will have a feedback loop to the design itself. We will

split this reflection in parts, to see how the aspects of the design are transferable. It might also be possible to look at a bigger scale, such a transferability to the rest of NL, EU and other delta landscape regions.



## THEORETICAL FRAMEWORK

There are a few theories that underline the importance for flexible and interactive sustainable design. The first one explains the need to need for flexible design of the urban fabric, based on the complex system theory, described by P. Allmendinger and M. Scheffer. The second theory, by F. van de Ven and S. Tjallingii, forms a guideline how to deal with this complexity in design principles, indicating different approaches and when best to use them. Also, there is another paper by S. Tjallingii that follows on these approaches, explaining the guiding principle models. Then we quickly look at the three pillars of sustainable design; people, planet and profit, as described by A. Bayley and T. Strange. The last will delve more into the way we can connect people to sustainable development, by neighbourhood participation, explaining the need for interactivity. This will be based on theories develop by A. Kollmus, C. Choguill and a very helpful Youtube video.

### *The city as a complex system*

Throughout all aspects of urban planning and design, over the last 50 years or so we can see a shift of focus. Before this transition period, cities used to be seen as a collection of different systems. It was acknowledged that there is a connection between the different systems that form the city, but they were all approached separately. The focus of the design was on one system in its entirety, forming a very set plan for its developments. This approach leaves very little space for unforeseen side effects, changes and circumstances. It was approached more in a way that the design should be so resilient and firm, that it would still function in the same way even though circumstances have changed. But nowadays we are in a transition phase to a different way of thinking about the urban fabric. We are moving away from the system thinking approach, seeing the city more as a collection of elements we can't all control. This theory is describes as thinking of the city as a complex system. The systems that forms the city are still recognized as their own system, with its own characteristics and dynamics, but it also shows the interaction the different systems have with each other and the external influences on the city. And it determines a constant interactive connectivity between all subsystems of the city, that together form the whole of the urban fabric (Allmendinger, 2002). This way of thinking forces the urban planner to let go of (illusions of) control, determining flexibility and adaptivity

Figure 8; Complex City (Google, 2016)

as some of the main driving forces of future design. It shows the non-linear and unpredictable nature of societal, economic and environmental changes. A city should focus on robustness, the ability to protect itself to changes, resilience, when a system can recover quickly from change, and adaptivity, so that it can adapt itself to changing circumstances (Scheffer, 2009). The complex system theory indicates the need for flexible design, in order to allow the urban fabric to become more robust, resilient and adaptive.

*From complexity to design*

While thinking of the urban fabric as a complex and unpredictable system sounds great in theory, it poses a massive challenge for urban planners and designers to translate this complexity and unpredictability to a physical design. F. van de Ven and S. Tjallingii talk about 3 different methods that can help translate the complexity of design, especially designing with water, while not losing it at the same time. The 3 methods are: the target imagine approach, the guiding principle approach and the negotiations approach. In practise we see that an urban plan or design often starts with one of these 3 principles.

The target image approach centralized around the problem of the design objective. From there they set goals for the future of the urban water system, which becomes the driving force behind the project. Multiple scenarios can be used to test different principles, ending up with the one that best approaches the target goals. Important for this approach is that the goals set for the future are clear, unambiguously and distinct. It directs a very rational approach, bordering on a technical approach. Interactivity and flexibility are found in a more modern version of this approach, but again more as a technical approach to the problem.

With the guiding principle approach a toolbox is created for urban planners that want to design in an interactive way, to achieve a solution for water management and urban development. A leading idea and direction of search are the leading elements through the design process. The design process focusses on choosing a guiding principle and combining this to the location and its context. To help the process, guiding models have been developed that can be chosen to the specific condition of the location, that can be used alone or in combination with each other. One of the mayor benefits of this approach is that complex problems stay complex, they aren't simplified down, but rather encourage the urban designer to work with the systems the way they are. Flexibility, in this approach, comes from a different usage of the guiding principles on different occasions.

And the negotiations approach choses the interactive participation of the different stakeholders as its main focus point. Urban planning or design is seen as a transaction between the different stakeholders of the project. The planning process should be open to discussion and input for every participant of the project. To make this possible, the location, the themes and the procedure of the project have to be set form the beginning. Flexibility is hidden in participation, because it allows the design to adapt to the wishes of the different stakeholders from the begging of the process. The question is whether or not this flexibility is still achievable after the design is completed.

F. van de Ven and S. Tjallingii have tested these theories based on 2 different models and after a comparison between the two they can recommend the use of the target image approach in a situation where there is a clear problem and a unambiguous solution, for example polluted canals, or, in more complex situations, more abstract problems and solutions, for example self-regulating water systems. The guiding principle approach is best when the need for improvement has become clear for many parties, but there is a lot of insecurity about the exact goals and means. An example of this would be measurements to guard ourselves to the consequences of climate change. And the negotiations principle is best used when there is either a lack of knowledge, indifference or tensions caused by the water management.

Based on this, for the project it would be most likely to use a combination of the guiding principle approach and the target image approach, starting with the guiding principle approach (S. Tjallingii, 2005).

*Guiding principle models*

The guiding theme of the project would be to create a flexible, interactive water storage system for Buiksloterham, that also helps Buiksloterham prepare for and gain from climate change and increases sustainable awareness through

neighbourhood participation. To help the design we will look at the guiding models developed by S. Tjallingii.

All models want to hold water and keep it clean, but have different methods of achieving this. The first base model, the cascade model, gradually releases the rain water flow in one direction. Rain water is held on rooftops, streets and in gardens. This model is mostly used in high density areas (like the center of Amsterdam). The infiltration model stores water in the ground water. This model is mostly used in urban landscape areas. Notice that, since the rain water in this model joins the ground water, the quality of the ground water becomes a very important factor. And the last model, the circulation model, guides the rain water to fresh water storage areas, where it is being cleaned, and then again brought back to the urban fabric. This model also works as seasonal storage. It is often used in the urban landscape, mostly in newer developed areas (Tjallingii, 2011). The cascade model and the circulation model are the best fit for the location of Buiksloterham, mainly because of the quality of the ground water in Buiksloterham. With these guiding principles, more concrete goals can be created for the neighbourhood, flowing more into a target image approach. The concrete goals will be set for the water storage aspect of the neighbourhood, mentioning how much water should be stored, and in what way. Scenarios testing will help determine how to best achieve this, as well as showing other problems and opportunities that arise with the different scenarios.

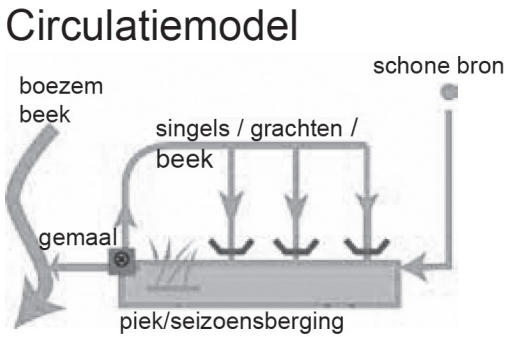
*People, planet, profit*

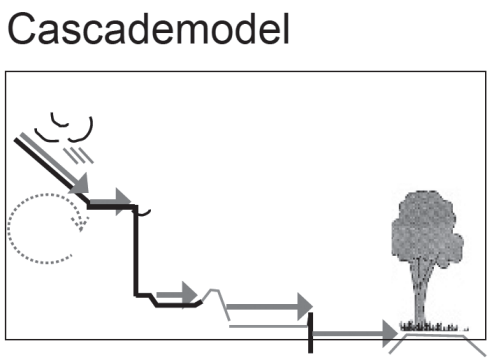
Sustainable development is described as development (growth or progress) that meets the needs of the present without compromising the ability of future generations to meet their needs. At the heart of this sustainable development are three so called pillars; people, planet and profit. Mankind depends on the environment, planet, and the services it provides in order to maintain our way of life. At the same time, the stability and success of societies relies on a healthy and productive population. When designing there needs to be an understanding of these three components, and the way they are connected together (A. Bayley, 2008).

*Interactivity and inhabitants*

With all the data, we have on climate change, still about 25% of the population does not believe in climate change. We respond more strongly to treats that are personal, abrupt, immoral and affect us now. In that way, climate change is the perfect problem, it's a gradual impersonal thing that always happens in the future. Our brains will come up will all kinds of excuses, why we should not act today. Due to our brain's optimism bias, climate change stays very far away from us, not allowing it to affect us (It's Okay to be Smart, 2014). We have seen from studies in the 1970's that knowledge and awareness does not directly lead to pro-environmental behaviour. This is because people need a direct experience, to adjust their behaviour, instead of an indirect experience, as is usually the case with climate change. People are also not that likely to change their behaviour, unless they see immediate results. But the effects of non-environmentally friendly behaviour are usually promoted in a 10-year+ timeframe, which keeps it very distant. That combined with people's social norms, cultural traditions, customs and attitudes, makes it very hard to promote pro-environmental behaviour for people (A. Kollmuss, 2002).

One of the ways to bring pro-environmental behaviour closer to the inhabitants of the city, is the direct urban structure they live in. Neighbourhoods are as important as any other element in the urban system, and they can be seen as the frontline in the battle for sustainability. Sustainability can be split in 4 different categories; economic sustainability, social sustainability, technical sustainability and environmentally sustainable. In order for a neighbourhood to function in a sustainable way, all these 4 categories need to be sustainable and work together in



balance (Choguill, 2008). In order to get people to work sustainable, we need to give them a direct experience, direct personal connection, direct results and fit it with our social conformity (It's Okay to be Smart, 2014). Creating awareness through an interactive system could help here, since the interactive part of the design gives people responsibility, a communal experience, direct visual results and a personal gain. This are all elements that direct to people on a closer, more direct and personal level. Which is why they will be more motivated to do something, changing their behaviour to a more sustainable way. With that, it could be argued that interactivity in design is key to creating a sustainable community.

## RELEVANCE

### *Societal Relevance*

As mentioned in the introduction, climate change creates problems for cities in delta areas. The Netherlands is one of those areas. In the next 70 years, the KNMI has predicted an increase in rainfall of about 7%, a sea level rise of 80 cm, reduced water quality, salination, temperature rise by 4C and longer periods of draught (Koninklijk Nederlands Meteorologisch Instituut, 2014).

For cities in the Netherlands this means that they will have to deal with a higher stress on their sewage system, due to the increase in rainfall. This while over the past 3 years there have been multiple occasions on which the sewage system already failed to cope with the rainfall. It also means that they have to increase their flood defences (Tooms, 2017). The increase in temperature will mean that heat-stress in cities will become more dangerous. And the longer periods of draught might cause a shortage in fresh water supplies. Rain water becomes a problem because most cities are not designed to hold, let alone use, the rain water that fall on their surfaces.

We could reduce the stress on the sewage system due to increased rain fall, keep the water quality, keep the fresh water and lower the heat-stress by storing and re-using rain water.

### *Scientific Relevance*

As mentioned in the theoretical framework, we need to start building our cities in a more flexible, adaptive and sustainable way. The complex city theory mentions that we need to look at the sustainability of the whole of the system (Allmendinger, 2002). For delta cities, water management is key to their future and success. For the Netherlands, this means not only flood defences, but also especially rain water management. All over the Netherlands, cities are now adjusted and redesigned so that they can better cope with the increasing amount of rainfall.

With the design of the city, sustainability becomes more and more important. Not only in the design but also in the use of the city. In Scandinavia, we already see examples of cities that are (partly) designed to work with the water, allowing for space. Interesting projects here are the Vinge Delta, in Vinge, Denmark (Arch Daily, 2014), the Western Harbour of Mälmo, Sweden (Urban Green-Blue Grids; for sustainable and resillient cities, 2015) and the design of Nørrebro in Copenhagen, Denmark (Arch Daily, 2016). We see here that water formed an inspiration for the designers, both technically and aesthetically, to make sure the area functions both in very dry but also in the very wet seasons.

But what we often lack in urban design, is the link to the people. When looking at the tree pillars of sustainability, we design with planet and profit, with maybe even an emphasis on the planet part, but the ideas we construct fail to reach the inhabitants of the city (A. Bayley, 2008). This thesis includes them by creating an interactive design that can respond to the wishes of the inhabitants of the area and the municipality of the city.

# RESEARCH

This chapter focusses on the research part of the thesis. As explained in the methodology, the thesis is a combination of more generic research, which then is applied to the location to form a place specific design. The chapter first talks about the watersystem, then the water storage methods are explained, followed by the development of the grid, the relation between public and private and the social part of the thesis. It ends with a more concrete explaination of self-sufficiency in water use.

WATERSYSTEM

To understand the water system of Buiksloterham, it's important to first look at the bigger scale, towards the water system of the Amsterdam metropolitan area.

Amsterdam is situated at het IJ (-0.41 NAP). This river connects the North Sea, salt water (-0.34 NAP) with the IJsselmeer, sweet water (-0.41 NAP). From het IJ flow many side rivers towards the polder systems of North and South Holland. The boezem system of the polders of Amsterdam (-0.91 NAP) separates in many different smaller stream systems, forming the entire water system of the region of Amsterdam.

The IJ is disconnected from both the North Sea and the IJsselmeer with 2 boat locks. In case of the North Sea this boat lock also functions to maintain the difference in water level, however small it might be. The main function of these 2 boat locks is to guard the IJ from the treat coming from both places in case of sea level rise due to climate change, storms and heavy rainfall. Het IJ and its side canals also aren't directly connected. There are 7 boat locks and 2 pumps that form a barrier between het IJ and the boezem's towards the different polder systems. Those barriers function both as a means to maintain the ~0.50 m height difference and as a safety measure. In case one of the 2 main boat locks of het IJ fails, the land behind it is still protected by the smaller boat locks (Rijkswaterstaat, 2016).

The system of Buiksloterham is a lot less complicated then the bigger system. Buiksloterham has 3 canals, which are all directly connected to het IJ. Buiksloterham is located outside the primary flood defence system, as it was created artificially by spewing sand in the river. This means that the ground water in Buiksloterham is influenced directly by the water that comes from het IJ. This water is of poor quality, and cannot be used in household systems. When storing rain water in Buiksloterham, a separation has to be made between the stored water and the ground water (Rijkswaterstaat, 2016).

For the neighbourhood, we have to deal with 3 different kinds of water. Rain water, which has a good quality and can be used in households for non-tap water functions. Grey water, the water that comes from the households but is only slightly polluted. And black water. This water comes from showers or toilets and is very polluted.

To be able to use this water, there are 3 separate systems, each with their own cleansing method. The diagram shows the relation between the systems.

The main system is the clean rain water system. Rain water will gather in this system. This system is spread over a larger area of Amsterdam North and will create the possibility for other neighbourhoods to also re-use rain water. The diameter of the canal will be 1-3-1m, offering space for cleansing by helofyte filters and allowing enough space for maintenance of the canal. Large areas for seasonal storage are connected to this system. The system has a lock at the connection to het IJ, to make an overflow of water from Amsterdam North into het IJ possible. A mill provides power to keep the system circulation. This system will fluctuate mostly due to seasonal changes, being influences less on a daily basis and more by the amount of rain water.

Figure 8: Aerial picture of the regio of Amsterdam (Google Earth, 2016)

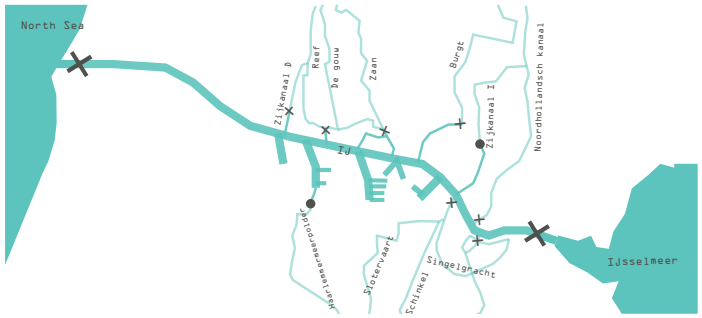



Figure 10: Schematic of the regio of Amsterdam's water system made by Author

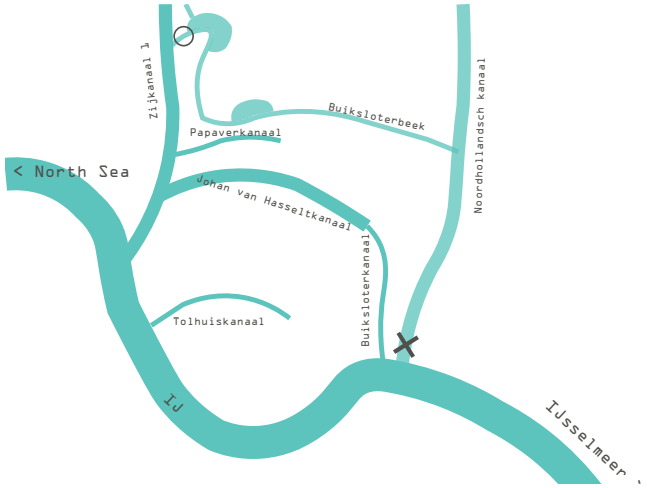



Figure 11: Schematic of Buiksloterham's water system made by Author

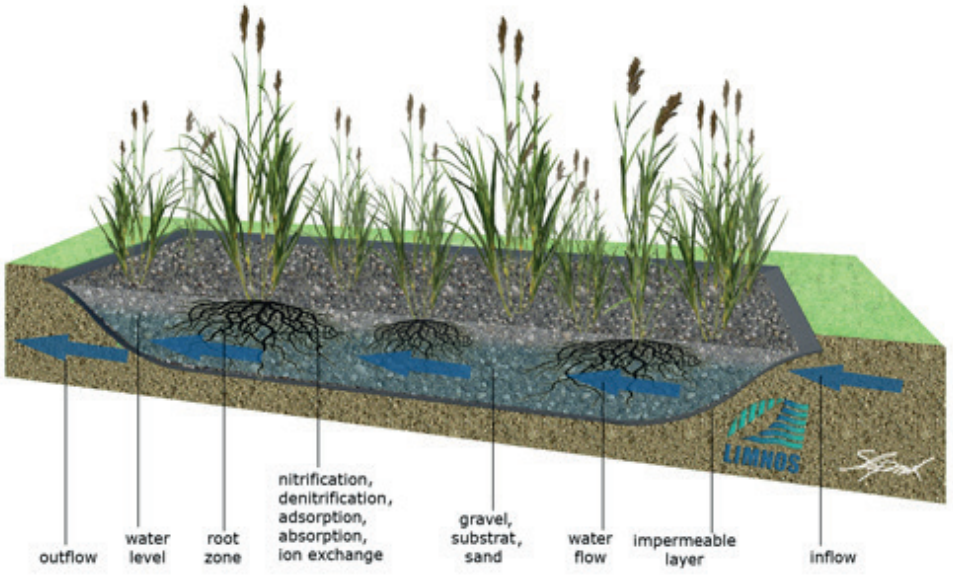

Figure 12: Schematic of Buiksloterham's dyke system made by Author

The grey water system collects all the grey water from the households in Buiksloterham. The grey water gathers in the couryards of the building blocks, where it is cleansed with a constructed wetland. After that, the cleansed grey water flows into a smaller, visible clean water system before joining the large system.

The black water system is invisible, it gathers the black water from households underground. It transports this water towards a hydroponic living machine green house, where it will be cleansed. After it has been cleaned, it will join the grey water system before joining the clean water system.

A hydroponic living machine consists of several tanks, which are filled with a textile material and covered with vegetation. It is supported on racks and aerated by bubble diffusers that create the needed oxygen for the cleansing treatment. The roots of the vegetation provide a good living environment for microbial growth, white the vegetation itself also functions as a habitat for insects and other organisms. Shale aggregate is added to the mix, which creates a natural biofilter that creates bacteria that prevent odors (Living Machine Systems, 2011).


Figure 13: Schematic of new water system
Made by Author



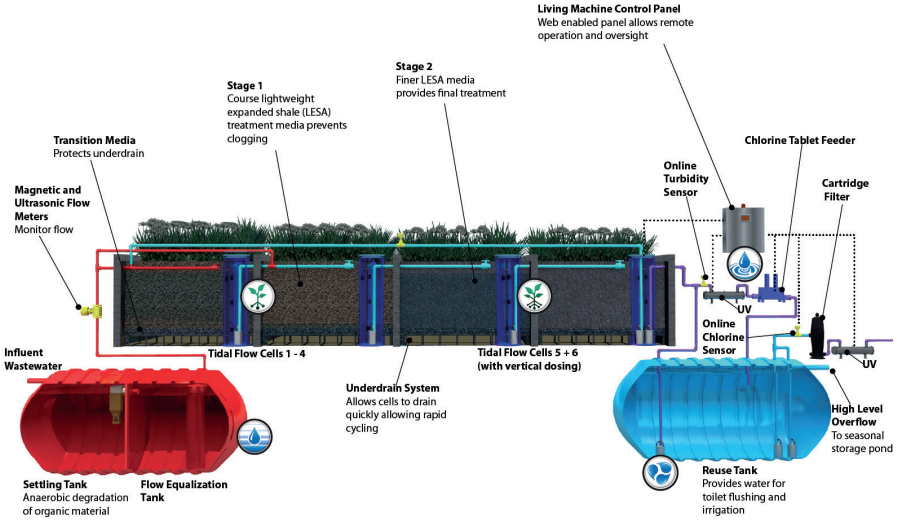




Figure 14: Schematic of constructed wetland & living machine by case study (Living Machine Systems, 2011)

WATER STORAGE

For Buiksloterham there are several water storage methods that can be made available throughout the different scales. The water storage methods are chosen for their capacity, visibility, possibility to apply in the existing soil conditions, flexibility and added benefits. For a more detailed explanation of all the water storage methods that are possible for Buiksloterham, see Appendix 2: Water Storage Methods. To see different methods of how they can be applied in several water systems, see Appendix 1: Scenario's.

For the Buiksloterham area the most effective water storage methods are rain water ponds, intensive green roofs, water roofs, water squares, rain water barrels, urban waterways, seasonal storage, water holding planters, water walls, storage under buildings and underground storage.

The next part will briefly discuss the different water storage methods that are applicable in Buiksloterham, with pictures to illustrate on the next page.

A rain water ponds temporarily store water. They should have a depth of at least 1.5m. And it can be combined with helofyte filters.

An intensive green roof is a green roof with various types of plants, which means that it can hold quite a bit of rainwater. They store the rainwater in the substrate layer. It also increases the quality of the water.

A water roof is a roof that is designed so that rain water can be stored on top of it.

A water square is a lowered square that can hold rain water. The rain water flows from elsewhere in the area to this square. It combines water storage with other daily urban life.

A rain barrel is a barrel that can store rainwater. It is connected to the drainpipe from the roof. They can store up to 200L per barrel. They are easy to apply, and might not be able to store the most water but they highly increase sustainable water awareness. Rain barrels can also be integrated in the outdoor space furniture.

Urban waterways are oversized open gutters. They are concrete structures where rain water can be stored. The rain water is gathered there from the surrounding area. They can be combined with rocks, plants and other elements to make them look more interesting and increase the water quality.

Seasonal storage is an area where the excess of water from the winter period can be stored until it needs to be used in summer. They also create extra storage for peak rainfall periods. They can be combined with helophyte filters as well, increasing the water quality. Or they can be created with nature friendly shores, to increase the biodiversity.

Water holding planters are planters that are closed at the bottom and filled with gravel (underneath the soil and the plants). They have a drainage pipe that is connected to the regular sewage system.

A water wall is a wall that is made with blocks, which are hollow, that can store rain water.

Storage under buildings can be created in different ways. One can store water in the basement, create a water storage area in unused space or form a water reservoir underneath the structure of the building.

Underground storage is created much in the same way as storage under buildings, by creating a reservoir underground (Pötz, 2016).

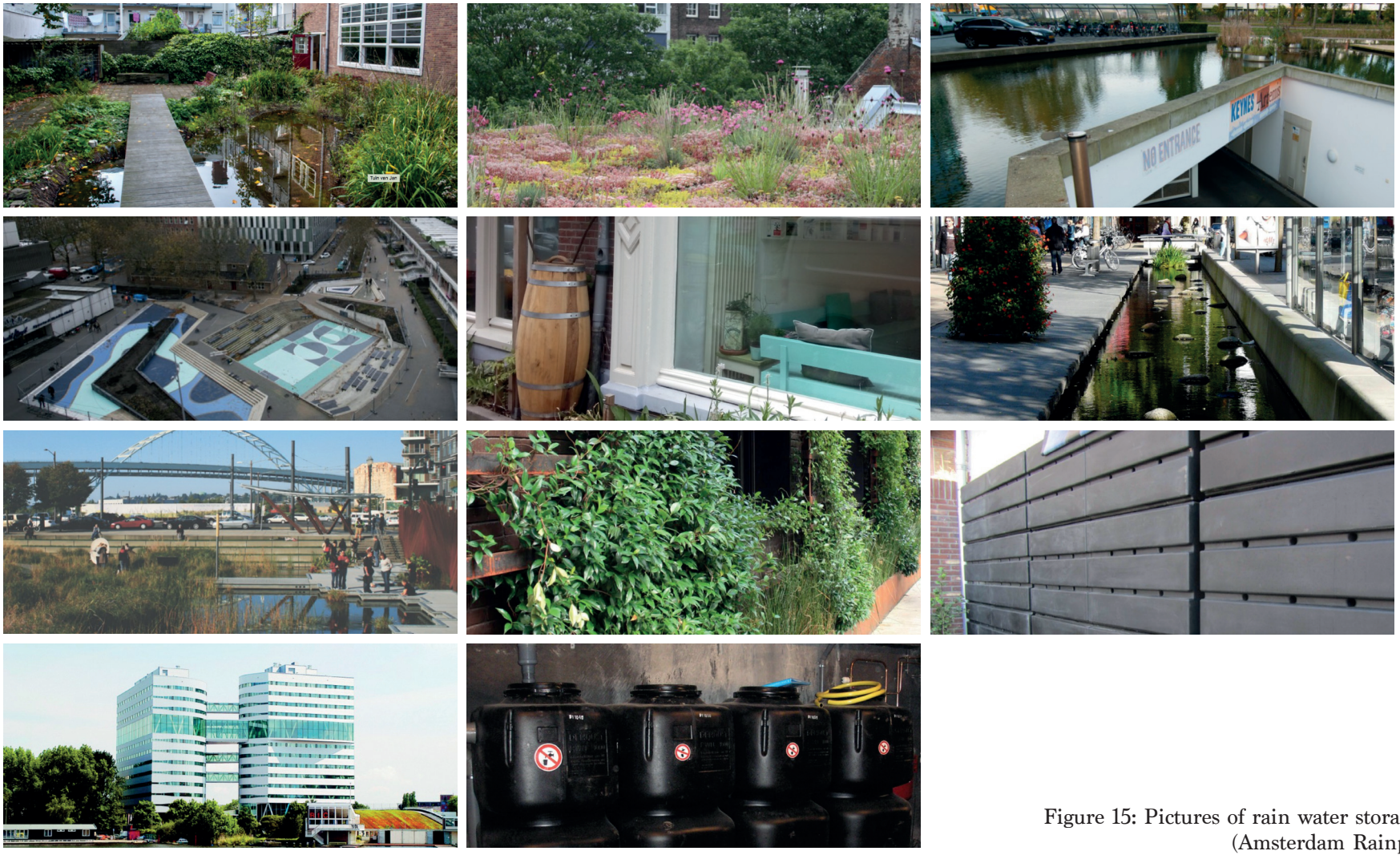



Figure 15: Pictures of rain water storage methods (Amsterdam Rainproof, 2017)

GRID DEVELOPMENT

In order to achieve a high density, fitting in the future vision of Amsterdam North, an urban grid is developed for the area. The measurements of this grid depend on the width and height of the building blocks and streets. For the area, a density of 1,5-3 FSI is desired (Gemeente Amsterdam, 2009). This means that the area will consist of low rise blocks, medium rise blocks and high rise points. Looking at the examples set by Berghauser, this gives a starting point of a grid of 100-50m (M. Berghauser Pont, 2009).

The building blocks for Buiksloterham provide the possibility for multiple type of buildings to be created within the parameters. To determine a more precise measurement for the building blocks, and to get a grip on the number of houses in a building block, a general study is done (Birkhäuser, 2015). This creases a measurement for the building blocks of 94x45x11-15m. Note, the study is only to determine a flexible measurement for the building blocks in order to create the grid. A combination of these type of buildings in one building block is also possible.

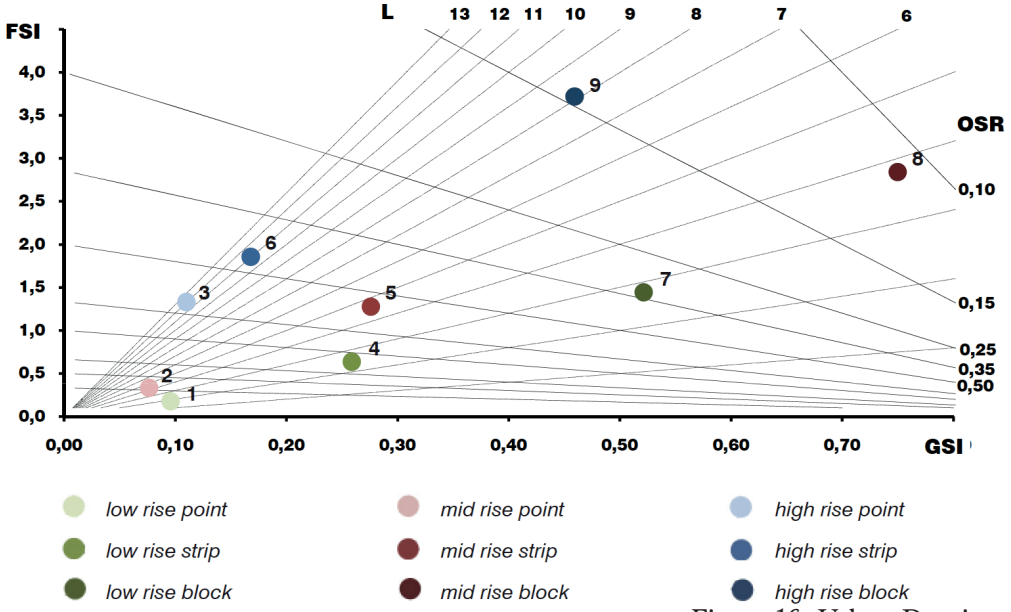



Figure 16: Urban Density (M. Berghauser Pont, 2009)

Then, for the streets, the thesis looks to the climate circumstances. In order to determine the amount of sunsine in streets and courtyards, a sun study is done. The diagram alternates the height of the building blocks with the width of the streets. The diagram shows the areas that will receive sunshine in winter, summer and September/March (halfway) (Bouwkunde TU Delft, 2010). This creates a grid which is based on streets that vary between 12-15-18m wide.

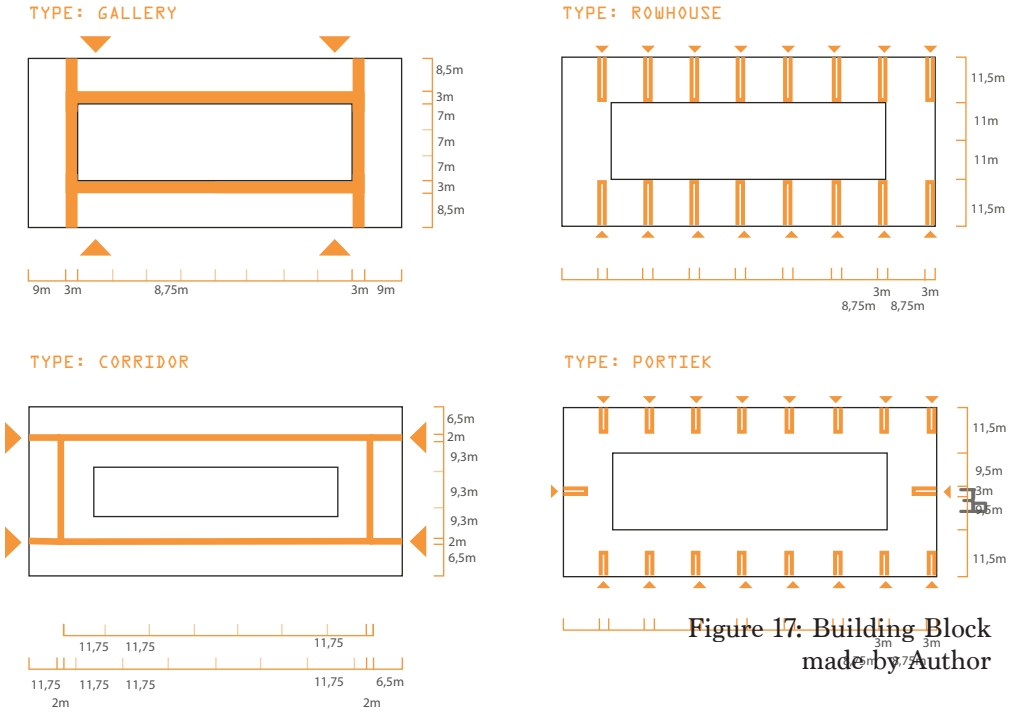



Figure 17: Building Block made by Author

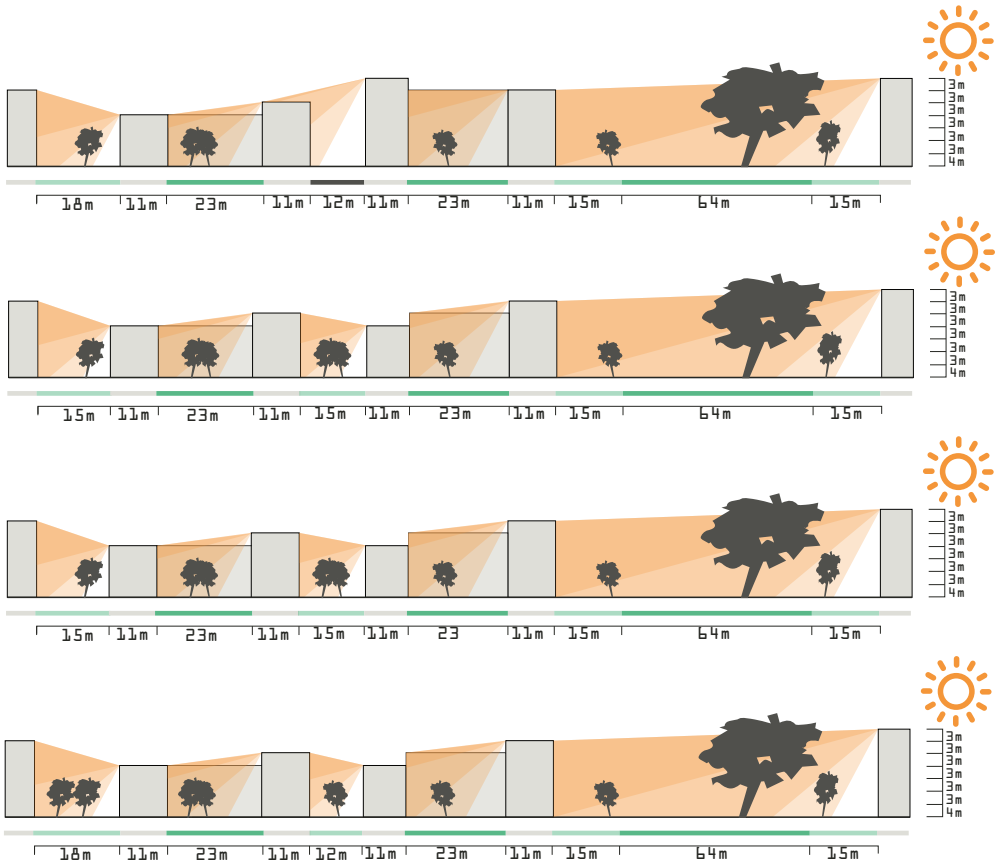



Figure 18: Sunshine made by Author

PUBLIC/PRIVATE

With the grid determined, the width of the street developed and the height of the building blocks know, it becomes possible to look at the street in further detail. To break the uniformity of the grid, the streets have different levels of accessibility. This creates a difference in the public or private atmosphere of the streets. Which in turn also creates a public and a private side for the building blocks. In order for the neighbourhood to stay accessible, the area will be suited for public transport, bicycles, pedestrians and cars. The focus on the design will be on public transport and bicycles and pedestrian transport, in order to promote a more sustainable lifestyle and to give the streets are more public space function.

The figure on the next page shows a section with multiple streets. The first row is the section, with underneat a bar in different orange shades. The darker the orange, the more public the street is. The second row shows the borders between public/semi-private/private. The third row combines the two, showing the borders and the transitions between public and private.

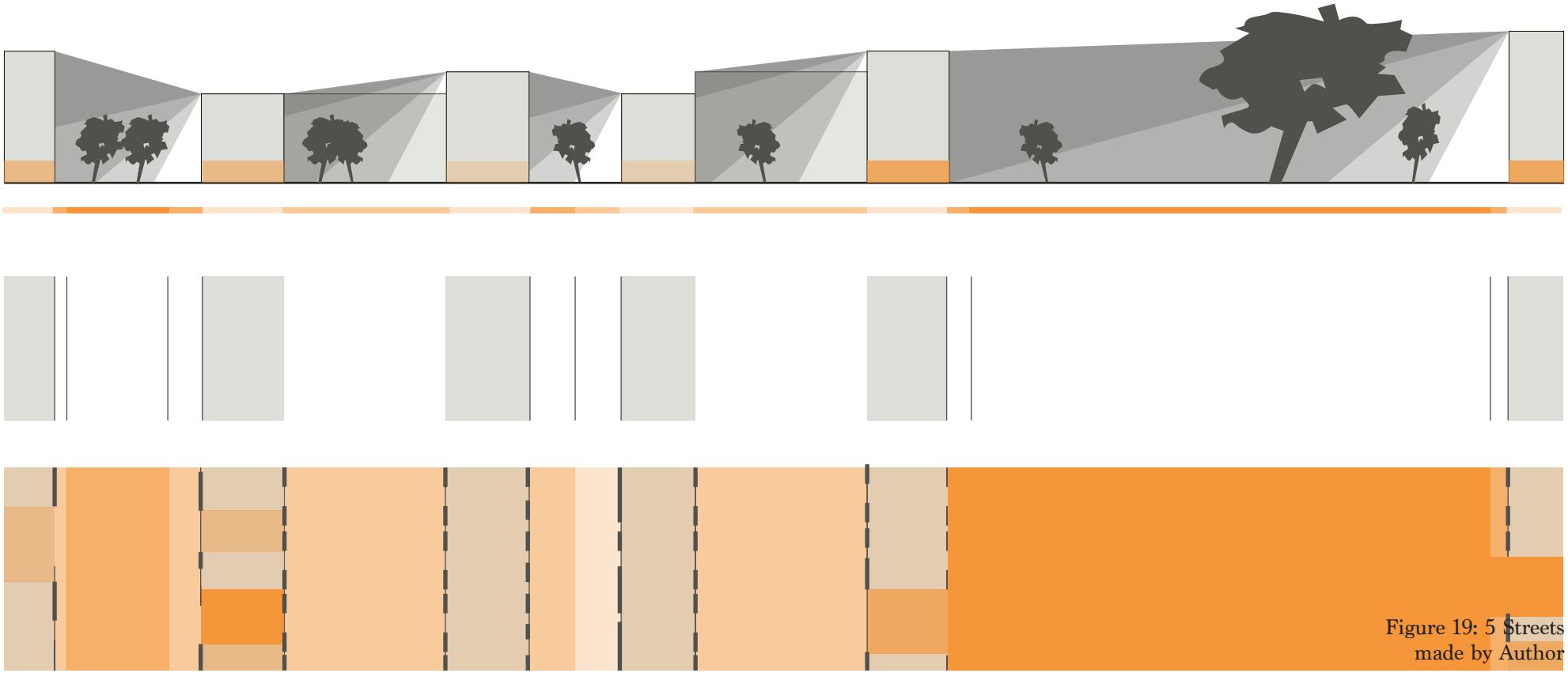


Figure 19: 5 Streets made by Author

There are 5 different streets typologies:

- Green axes. These streets connect all the important areas in the neighbourhood. They offer space for pedestrians, cyclists and public transport. The relationship between building block and street is very direct in these areas, making it interesting for businesses, restaurants & bars and other public functions to locate on those streets. The green axes have the grey water system running through them, connecting the main streets of the area with water storage visually.
- North-South connections large. These streets are public as well. They offer room for pedestrians and cyclists and, sometimes, public transport. The connection between building blocks and the street is less direct here, offering space for a semi-private lane where the building blocks are more private.
- North-South connections small. These streets are more private then the previous two. They offer a shared space for pedestrians and cyclists. But it encourages a connection between the building blocks and the street. This is the street where can play, people can sit outside to BBQ or have a drink with their friends. The street offers space for a semi-private area, to ease the connection from building block to street. It also has room for terraces. And in the connection with the East-West green streets, a square is created. The building block opens up to this square, to create a community within the neighbourhood.

- The East-West green streets. These streets are comparable to the North-South small streets. They have the same type of spaces. These streets also have the grey water system running through them.
- The East-West car streets. To increase the accesability of the area, there are streets which are accesable by cars. These streets are small and have are closed to the building blocks. There is room for pedestrians, but there is no semi-private space. There is room for side parking next to the street on both sides (San Francisco Planning Department, 2010). To create a barrier between the road and the pedestrians that use this street, hedges are placed next to the parking spaces.

These different streets ask for a different relation with the building blocks.

The first picture shows the relationship between building block and the green axes. There is a direct connection between building block and the public space, creating a very harsh transition. There are no balconies on these streets.

The second picture shows that the North-South large connection is similar to the green axes, but the main difference is the semi-private space to create a softer transition between building block and street. There are small balconies on these streets.

The North-South small streets are more informal, they have a strong relationship between building block and street. And it offers space for a semi-private transition, but still with a clear boundary. There are balconies on this side of the building block, to connect the outdoor spaces.

The East-West green streets are comparable to the North-South Small streets, but with a less distinct border between semi-private and public.

The East-West car streets have a harsh line between the building block and the street. The balconies here are possible, creating a more safe athmosphere in the streets because it enlarges the visibility into the streets. The ground floor of the buildings will not be used residentially, but as an entrance into the building or creating room for small scale public functions.

Figures 20: Building blocks (Pinterest, 2017)

SOCIAL STUDIES

To see what the thesis needs in terms of social design, the thesis looks at how to build a general sustainable community. The neighbourhood has to look socially sustainable and safe, houses should allow for neighbours to interact, high quality public space and give residents a voice. From the theoretical framework we have learned that people need to feel responsible, see results and see benefits.

There are a few elements that can add this to the design of the neighbourhood.

First, for the sustainable look, the area is inspired by green urban neighbourhoods as shown in the picture.

To allow for the neighbours to interact, there should be semi-private space connected to the building blocks and the entrances of the building should encourage neighbours to interact. Small entrances work better in this case, since a larger scale entrance to a building leads to anonymity.

The public spaces of the neighbourhood use design elements that bring inhabitants together, but also gives the feeling of extra attention to the detailing of the public space due to the look of materials. For more information on the materials, see Appendix 5; Materials. The public space in the area has been designed for several target groups and their wishes.

And residents are given a voice by creating the possibility for water storage elements to fluctuate in water level, directed by the wish of the residents (Smart Cities DIVE, 2012).

The area is desgined for a varied group of people; elderly, children, businesses, recreative users, families, single partent families, singles, couples, restaurants, sporters and the elements needed for clean water.

With the target groups, the public space in the neighbourhood should be visible, have wifi, restaurants, bathrooms, sitting areas, shopping areas, parks, open spaces and parking spaces.



Figure 21: Target Groups
made by Author

Figures 22: ReGen Village
(ReGen Village, 2014)

Figures 23: Material
& Atmosphere
(Pinterest, 2017)

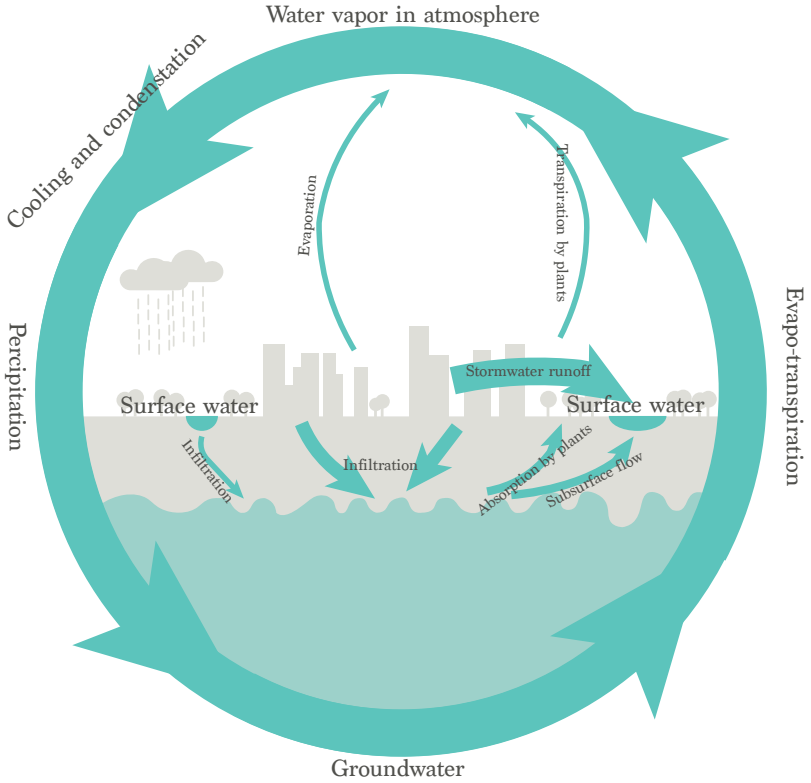
SELF-SUFFICIENT

To be able to be self-sufficient in water use, the neighbourhood needs to be able to maintain itself without water coming in from outside of the area. The water circle consists of 3 types of water; ground water, surface water and vaporized water. For Buiksloterham, we will leave the ground water alone as much as possible. Because of the quality, it cannot be re-used in households. In order to keep the landscape in Buiksloterham, all the rain water that will fall on soft surfaces will be allowed to drain into the ground. This will keep the ground water level stable, making sure plants can survive and the ground condition remains stable (Naess, 2001).

The area is 100 HA in total, 1.000000 m2. Of this, 63 HA, 630.000 m2, is hard surface and 37 are soft surfaces. Of the soft surfaces, 9 HA, 90.000 m2, is surface water (of various depths). Buiksloterham will have a total of 15.000 inhabitants and 8.000 employees.

Inhabitants use 120 L water a day, of this 50 L has to be tap water quality, and therefore has to be imported from outside the area. Employees use 60 L a day in the area of which 10 L has to come from outside the area due to the quality (WMD Water, 2014). This creates a total demand of ((50x0,001x15000) + (50x0,001x8000)) = 1150 m3 water/day. Per day, 9 mm/m2 of water is evaporated. That translates to 9 x 0,001 x 90000 = 810 m2 water/day. The average water depth in the area is 2,78m. This means 1150/2,75 = 418 m2 of water is needed per day by the users of Buiksloterham and 810/2,75 = 295 m2 is evaporated every day (Lenntech, 2016). Because, even in the Netherlands, it does not rain every day and to compensate for the evaporation, the entire area will have more than 810 m2 for the grey water system. In 2014, the longest dry period was 15 days in a row (Koninklijk Nederlands Meteorologisch Instituut, 2014). Because 50% is evaporated every day, this can be related to 15 x 1,5 = 23 days. That means, in order to be self-sufficient, the grey water system has to be able to store 22 x (810 – 418) + 810 = 9.434 m2 of water. The grey water system is influenced greatly by the day and night rhythm of the users of the Buiksloterham area and therefore it will fluctuate during the day as well as being influenced by periods of rain.

To be self-sufficient, the rain water that falls on the area needs to be stored. A maximum rain fall has to be able to be stored completely, both to relieve stress on the sewage system of Amsterdam but mostly to keep that rain water for later use. For the maximum rain fall the heavy rain of June 2014 will be the starting point. This was measured 141mm/m2 in Rotterdam (Koninklijk Nederlands Meteorologisch Instituut, 2014). We add 10% to that to adjust according to predicted climate change (Koninklijk Nederlands Meteorologisch Instituut, 2014). This is 141 x 0,001 x 630000 x 1x 110 = 99.710 m3 of rain water = 99.710.000 L. This water will be stored in the clean water system and the seasonal storage areas. These areas will fluctuate over the year, being (almost) empty in dry periods and full in wet periods.



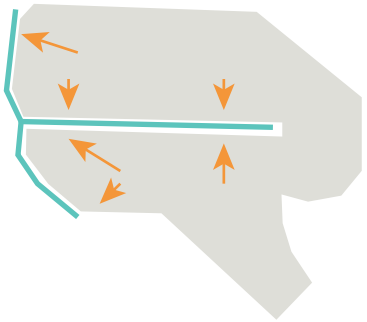
The figure below shows, from left to right, a respresentation of the m2 of the total area, the hard surfaces, the soft surfaces, the water surfaces, the grey water system minimum and the rain water system minimum.

# DESIGN APPROACH

The Design Approach chapter takes the elements from the Research chapter and applies them to Buiksloterham to create a location specific design. It starts with the design approach for the area, then the watersystem, then the water storage and how they are integrated in the design. To illustrate further, 4 zoom-in areas are shown and explain; a square, a park, a green axis and the streets. Then it looks to the social aspect of the design. And it ends with the self-sufficiency of the neighborhood.

DESIGN APPROACH

For the area, a guide is created to create the design. This guide is a set of rules, that link design steps to the objectives set in the Research Objectives. This guide explains the approach to the design, showing how why the different elements of the design are designed in this way. The guide, that starts on the next page, shows a schematic of where/how the element can be found in the design, with a brief explanation and a mention of the Research Objectives (RO) that are influenced by this design step.



## WATERFRONT

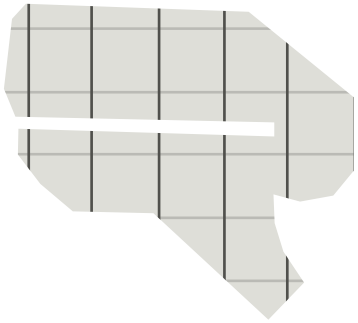
From the inside of the area the user is directed outwards, towards the waterfronts.

RO: Water Identity

## SQUARES

The important connections, between either the green axes and the waterfront or the green axes together, are emphasized by squares.

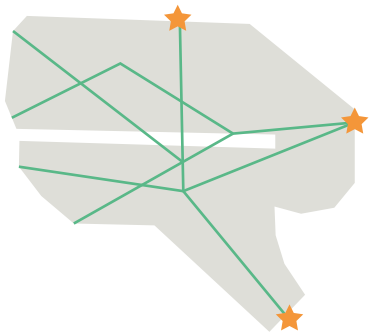
RO: Water Identity



## NORTH-SOUTH

The grid is devided in two directions. The North-South direction has the emphasis, as to guide the user towards the waterfront in the middle of the area.

RO: Water Identity



## ENTRANCES

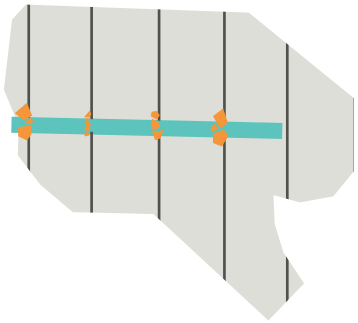
The entrances into the area are on the green axes and are combined with water to show the water identity of the area.

RO: Water Identity

## PARKS

The other crossing between green axes are visualized by parks.

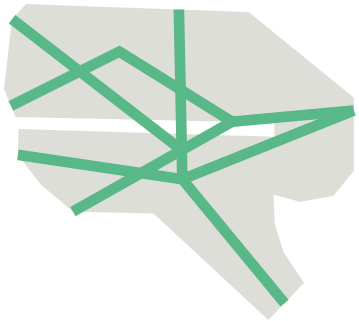
RO: Biodiversity, Heat stress



## N-S CONNECTION

At the important N-S lanes, the water will be bridged so the connection is not lost.

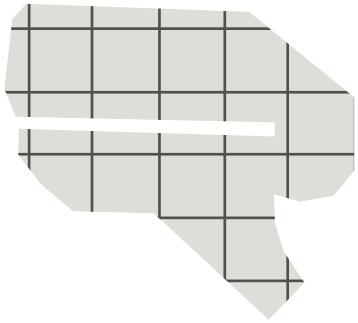
RO: Water Identity



## AXES

To break the grid and guide towards the waterfront, green axes are added.

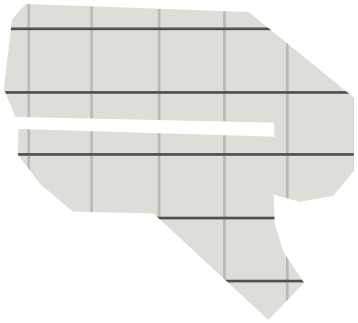
RO: Water Identity, Biodiversity, Heat stress



## GRID

To achieve a high density, an urban grid is applied to the area. The grid is filled with open building blocks to create outdoor green space for the inhabitants.

RO: Sustainable Community



## EAST-WEST

The East-West connection is designed more private, to create a more intimate athmosphere between building blocks.

RO: Sustainable Community

## MATERIALS

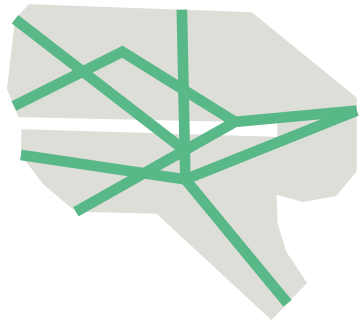
The materials used in the area are sustainable and are a mix of a natural atmosphere and a modern look.

RO: Self-Sufficient, Rainwater, Grey Water, Flexible, Interactive, Through Scales

## STREETS

The streets follow the grid pattern and the green axes. There are 5 different profiles used in the area.

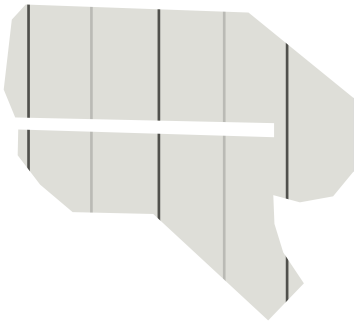
RO: Sustainable Community



## GREEN AXES

The green axes offer room for public transport, a cycling lane, a pedestrian lane, green areas, public spaces and water storage. In combination with squares and parks they are connected to these.

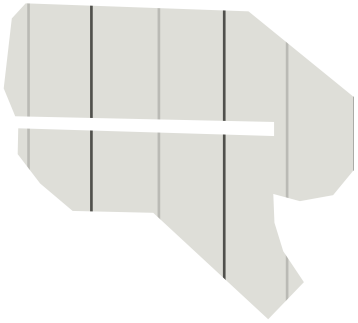
RO: Water Identity, Sustainable Community, Self-Sufficient, Through Scales, Biodiversity, Heat Stress



## N-S BIG

The N-S Streets alternate in size. The Big streets are 18m wide and are designed for the public. They offer room for a cycling lane, pedestrian lane, green areas, public spaces and water storage.

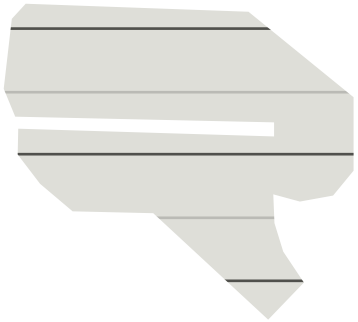
RO: Water Identity, Self-Sufficient, Through Scales, Biodiversity, Heat Stress



## N-S SMALL

The small N-S streets are 12 m wide and are designed for the inhabitants. They offer room for a pedestrian lane, green space, (semi)private public space and water storage.

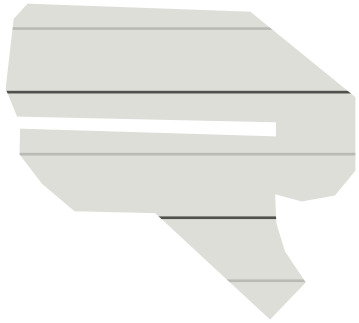
RO: Water Identity, Sustainable Community, Self-Sufficient, Through Scales, Biodiversity, Heat stress



## E-W GREEN

The E-W streets are 15m wide and alternate in use. Half of them are designed for the inhabitants and form private green streets focussed on pedestrians, they are comparable to the N-S Small streets.

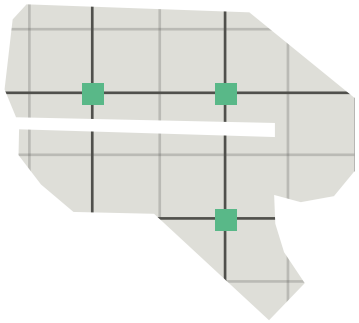
RO: Water Identity, Sustainable Community, Self-Sufficient, Through Scales, Biodiversity, Heat Stress



## E-W CAR

The other E-W streets are destined for car traffic, to allow them into the area to increase the accessibility . The focus is on the other streets.

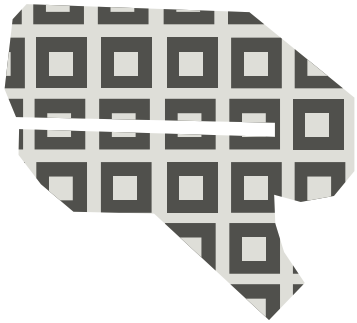
RO: Sustainable Community



## E-W/N-S

The crossings of the E-W green streets and the N-S small streets, the more private streets, form a green square designed for the inhabitants of the surrounding building blocks.

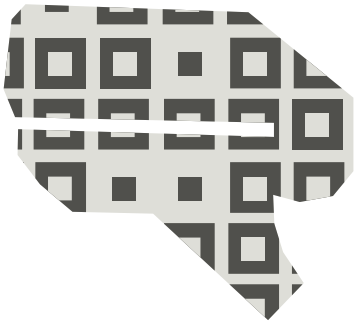
RO: Sustainable Community



## BUILDING BLOCK

The building blocks have a size of 45x94x(11-15)m and offer the possibility for different styles of appartment buildings. They also house small/medium sized buisinessed.

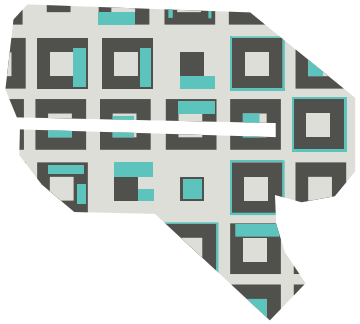
RO: Sustainable Community



## BUILDING BLOCK

The building blocks are alternated with high towers. Both have a density of 2,0-3,5 FSI

RO: Sustainable Community



## BUILDING BLOCK

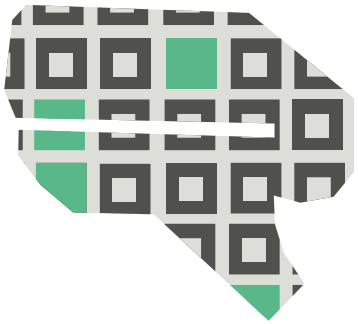
The building blocks offer enough water storage to fulfill the need of it's inhabitants.

RO: Water Identity, Self-Sufficient, Through Scales

## WATER STORAGE

The squares and parks offer room for visible water storage. To meet the demand of the inhabitants and increase capacity, underground storage is applied.

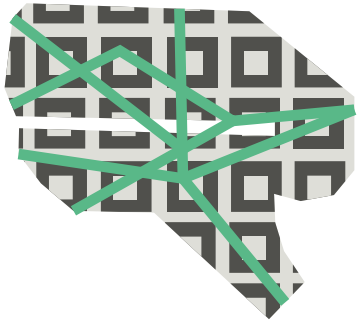
RO: Self-Sufficient, Flexible, Interactive, Through Scales



## BUILDING BLOCK

One in every 9 gridblocks is a park.

RO: Self-Sufficient, Flexible, Interactive, Through Scales, Biodiversity, Heat stress



## BUILDING BLOCK

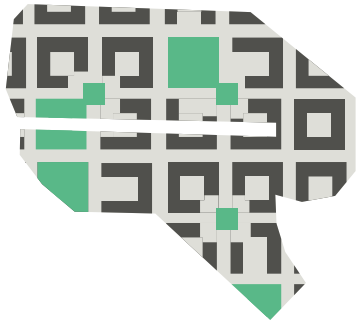
The building blocks give way to the green axes.

RO: Water Identity

## WATER STORAGE

The streets offer possibility to store water.

RO: Self-Sufficient, Flexible, Interactive, Through Scales



## BUILDING BLOCK

The building blocks open towards the parks and the green squares on the street crossings.

RO: Sustainable Community, Biodiversity, Heat Stress

## PLANTS

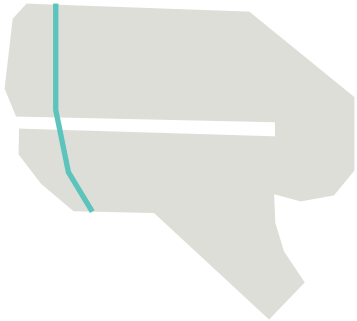
The plants used in the area are the ones from the plant-encyclopedia developed for this area.

RO: Biodiversity, Water Quality, Soil Quality

## WATER SYSTEM

The area uses 3 seperate systems for clean water, grey water and black water.

RO: Self-Sufficient, Water Quality



## WATER SYSTEM

The clean water system flows through a bigger part of Amsterdam North. It gathers rain water and household water after its been cleaned. The water is cleansed by helofyte filters. Seasonal storage is added to this system.

RO: Self-Sufficient, Water Quality, Sustainable Community

## WATER SYSTEM

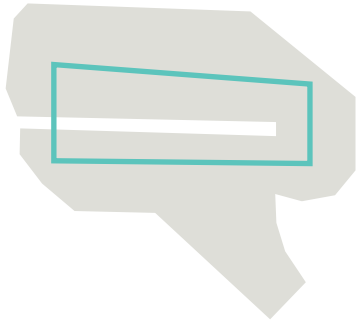
The grey water system gathers the grey household water. It flows through the E-W Green streets and the green axes. Cleansing is done by helofyte filters.

RO: Self-Sufficient, Water Quality, Sustainable Community

## WATER SYSTEM

The black water system gathers the black water from the households underground. It is then transported to a living machine cleansing system, after which it joins the grey water system.

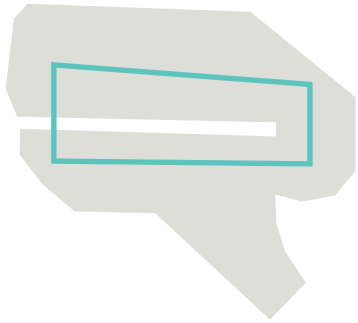
RO: Self-Sufficient, Water Quality



## WATER SYSTEM

A circular system is created to allow the water in the area to flow. Water Storage Elements are connected to this larger system.

RO: Water Quality



## WATER SYSTEM

The circular system has a 1-3-1m profile, to allow for helofyte filters and cleaning of the water. The 3m part is at least 1m deep.

RO: Water Quality

WATER STORAGE SYSTEM

The water storage system consists of 3 parts, as explained earlier. The clean water system runs through a larger part of Amsterdam North, so that new developments there can also re-use the clean water. It is combined with large seasonal storages.

The maps show these systems. The first map shows the water systems that are above ground, so the clean water system and the grey water system.

The clean water system connects to this grey water system at several points. Locks can be opened to let water flow from the grey system into the clean system. The clean system crosses the canal coming from het IJ several times, this will be done by creating underground pipes to let the water flow through. The clean water system uses natural shores, allowing the water level to vary throughout the year. The building blocks are connected to the clean water system by an underground sewage system, allowing the clean water to be used in the households. To prevent the ground water from polluting the clean water system, a clay layer is added to the bottom of this system, creating a barrier.

The grey water system uses the building blocks, for cleansing, after which it flows into a smaller clean water system. This system uses the green axes and the E-W Green streets to connect to all the households. Because they are visible in the most important streets, the green axes, this increases the sustainable awareness. In the park areas, the grey water system makes loops, to create extra m2 for cleansing by helofyte filters. It also connects to the living machine green house, where it gathers the cleaned water from the black water system. This system is materialized in concrete, creating an urban waterway. Decorative elements like rocks and plants are added to these waterways, to give it a more interesting look. The water level in these urban waterways varies through the day, being at its peak when there are the most people in the area. The building blocks are connected to the constructed wetland with an underground sewage system, that gathers all the grey water from the building block into the constructed wetland.

The second map shows the underground sewage system.

The black water system is part of this. The E-W car streets are used for the black water sewage pipes. This system brings the black water to the two living machine greenhouses, so that the sewage pipes do not have to cross het IJ. After the water has been cleaned in the living machines, it joins the grey water system.

The section illustrates this further, the white lines underground are the sewage pipes for the clean water system, and the grey line underground is the line for the grey water going to the grey water system. The thick dark grey line is the clay under the clean water system.

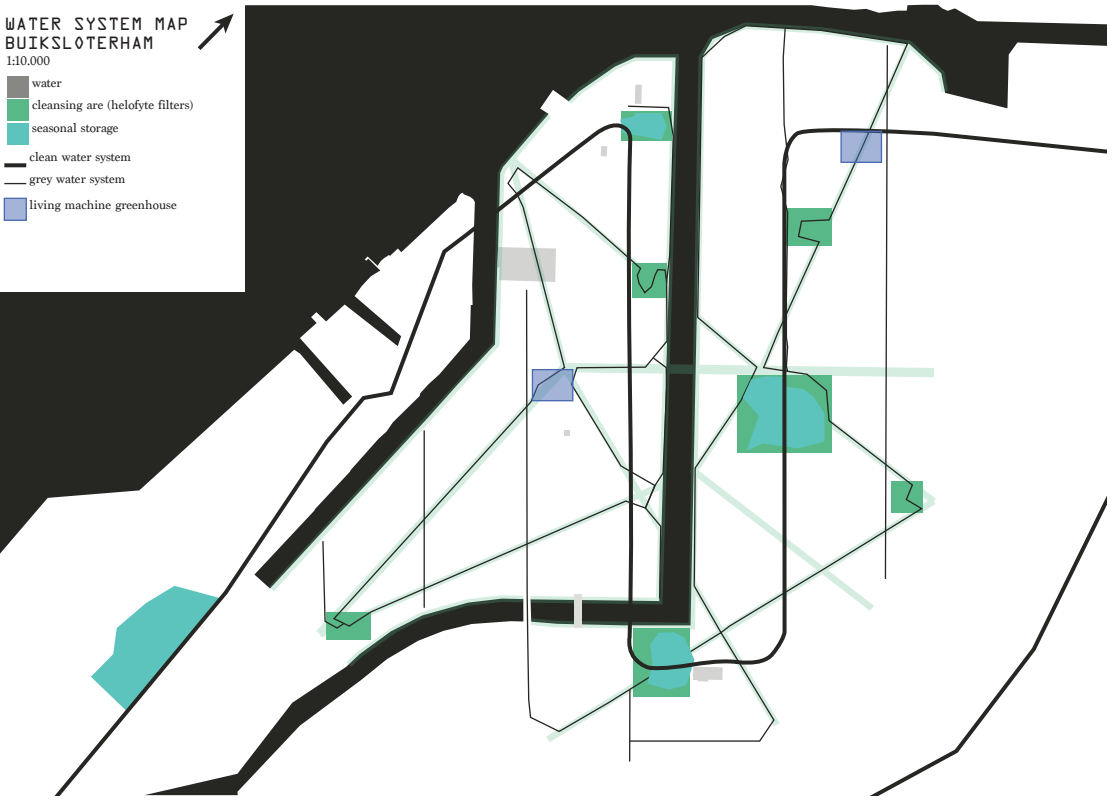



Figure 24: Water System
made by Author


Figure 25: Sewage System
made by Author

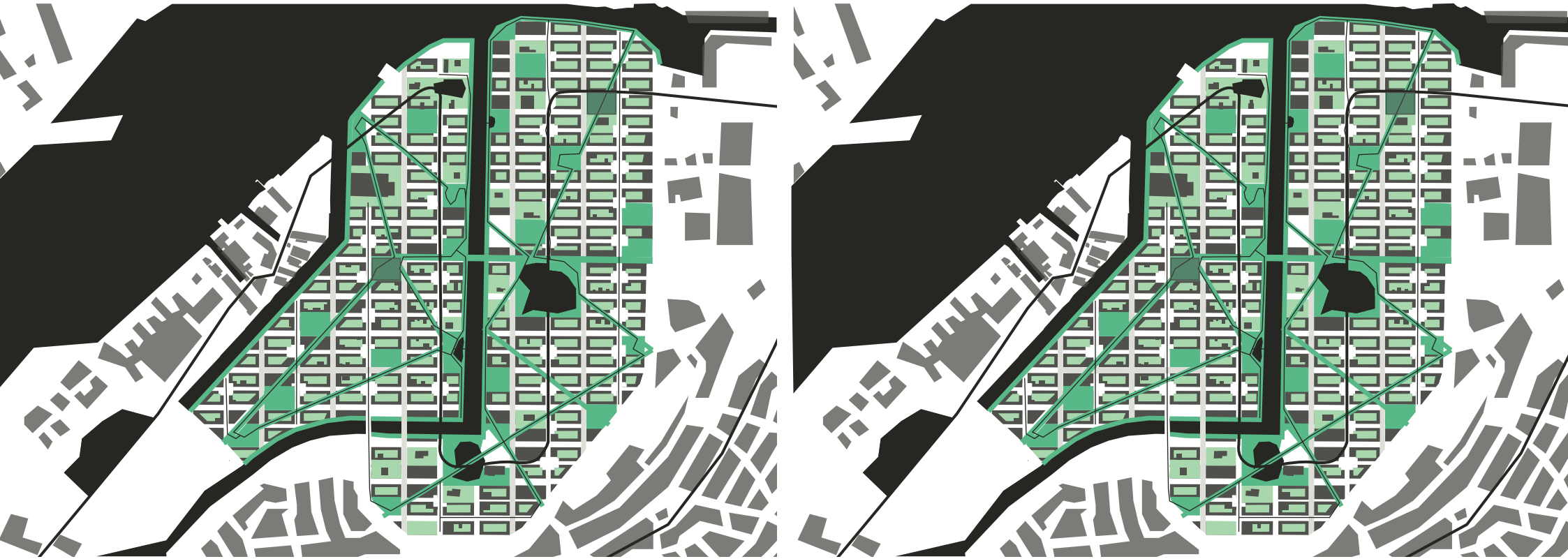


Figure 26: Site Plan
made by Author

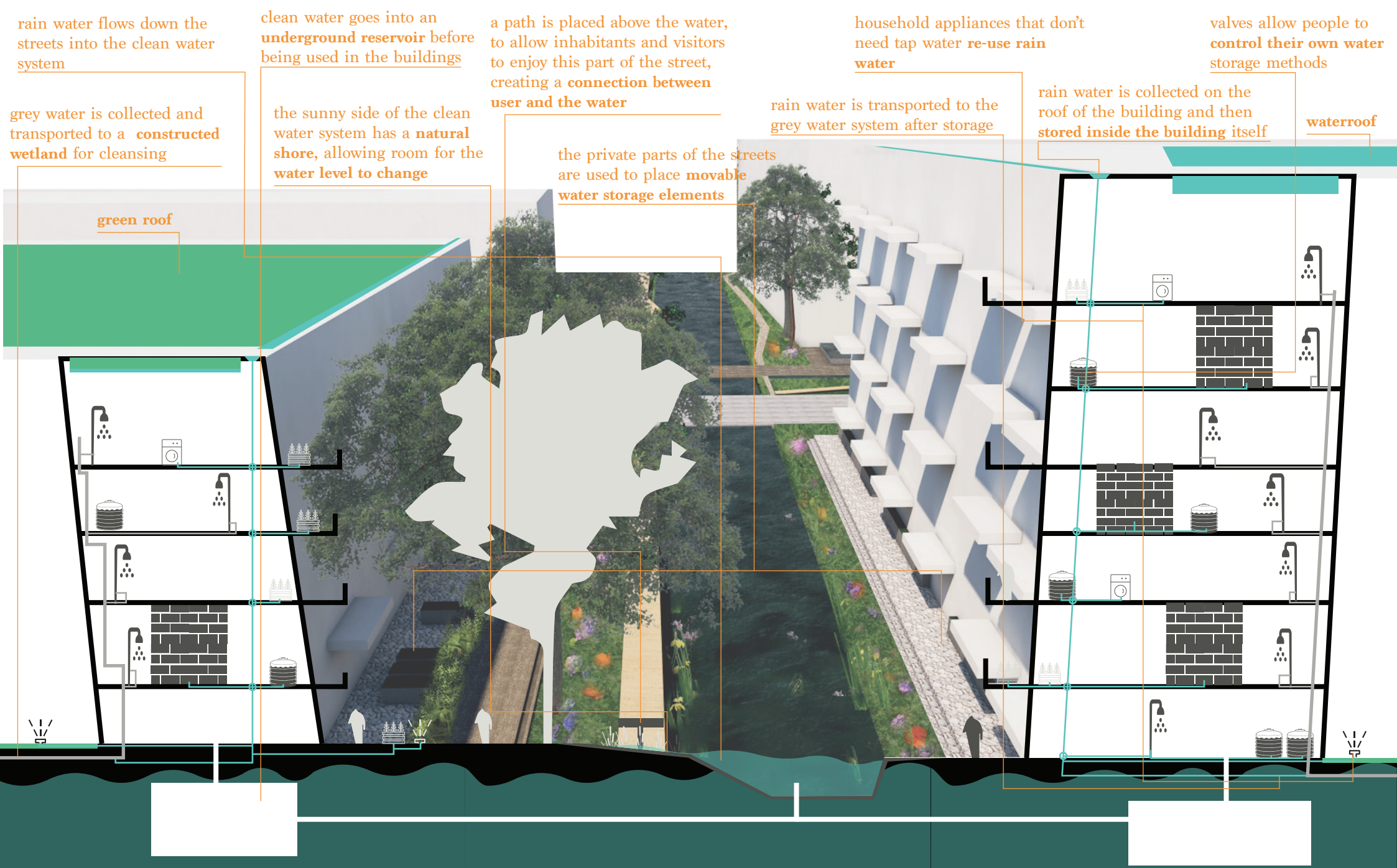



Figure 27: Section E-W Green Street
made by Author

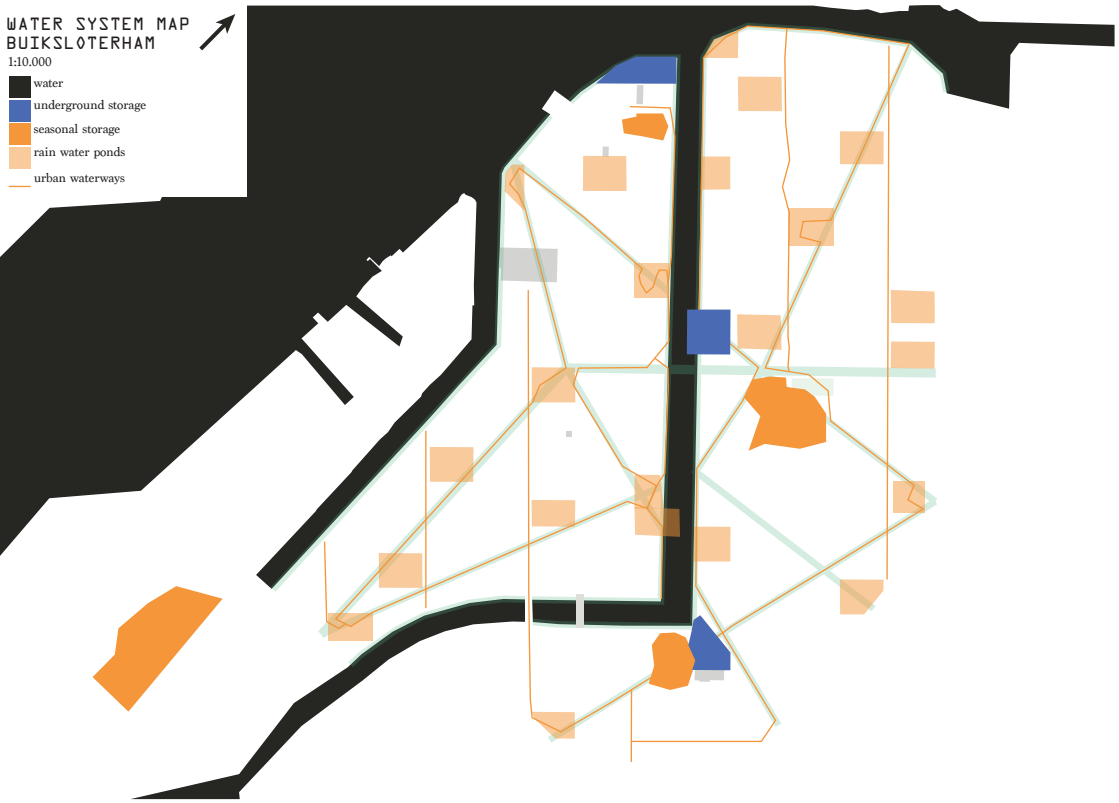
## WATER STORAGE ELEMENTS

The water storage elements that are applicable to Buiksloterham can be divided in 3 scales; public large, public small, private.

The elements that can be applied on a large public scale, parks, squares, throughout the neighborhood, are; rain water ponds, urban waterways, seasonal storage and underground storage. Underground storage is not necessarily needed for the area, since the m2 created without underground storage are enough to foresee the need of the inhabitants of Buiksloterham. However, in order to make the area more flexible and to create an excess of fresh water for economic purposes, they are created underneath the squares in Buiksloterham. The map shows which elements can be found where in the design.

In the smaller scale public areas, streets, there are urban waterways, water holding planters and rain water ponds. The streets are used more for visibility and circulation, then for capacity. In order to increase the sustainable awareness of the users of Buiksloterham, visibility of water and water storage is key. Visible water also creates a stronger water identity for Buiksloterham. The map again shows which elements can be found where. The streets also have open gutters, they are not a water storage element but they do increase the water identity and the sustainable awareness because of the visibility of the water. The water storage elements don't just store water, they form borders in the streets to separate public from private and to create an easier transition from building block into public street. The smaller water storage elements are connected to the grey water system, so that they can discharge their water into the larger system. Because water might get polluted (cars, trash) in these elements, it first goes into the grey water system before joining the clean water system.

For the building blocks, the private scale, the available storage elements are intensive green roofs, water roofs, rain water ponds, water holding planters, water barrels and water walls. The last 3 of those can be applied in every household and inhabitants can choose for themselves if they want to use one of these methods or not. Of course, it is encouraged by creating space in the architectural design for these methods. The building blocks use at least one of the first 3 methods.




Figures 28: Public; large water storage elements
made by Author

Figures 29: Site Plan
made by Author

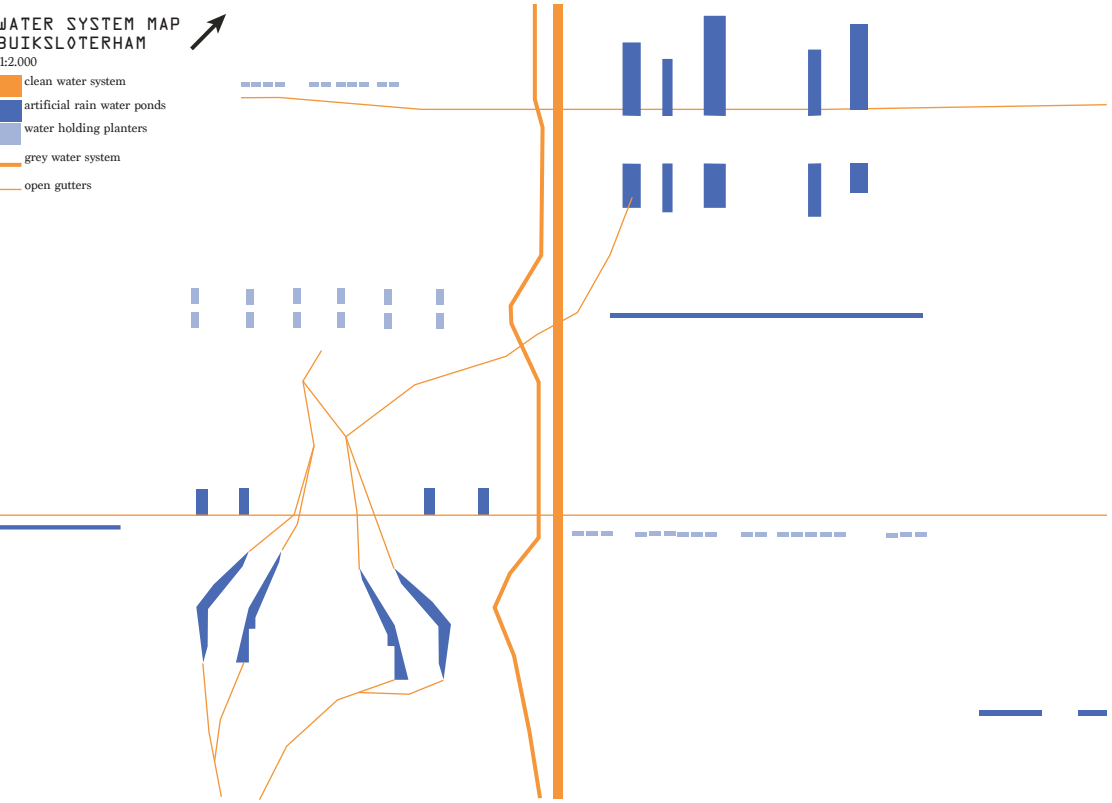



Figure 30: Public; small water storage elements made by Author

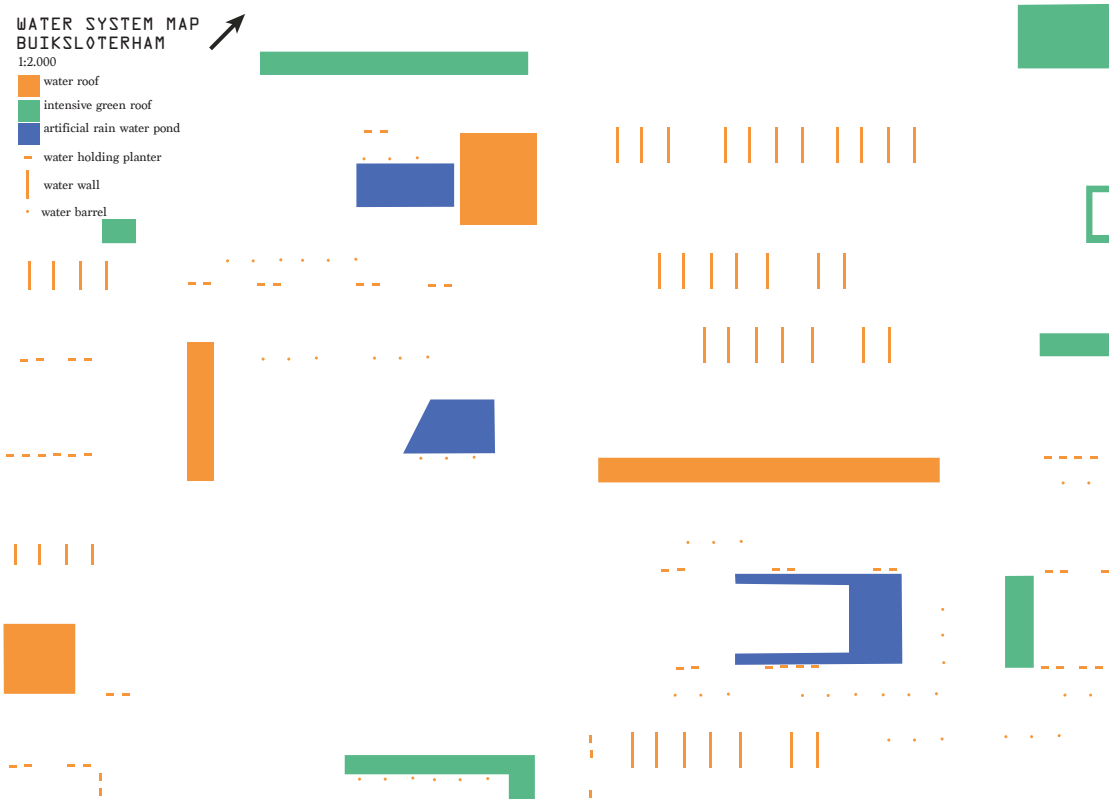
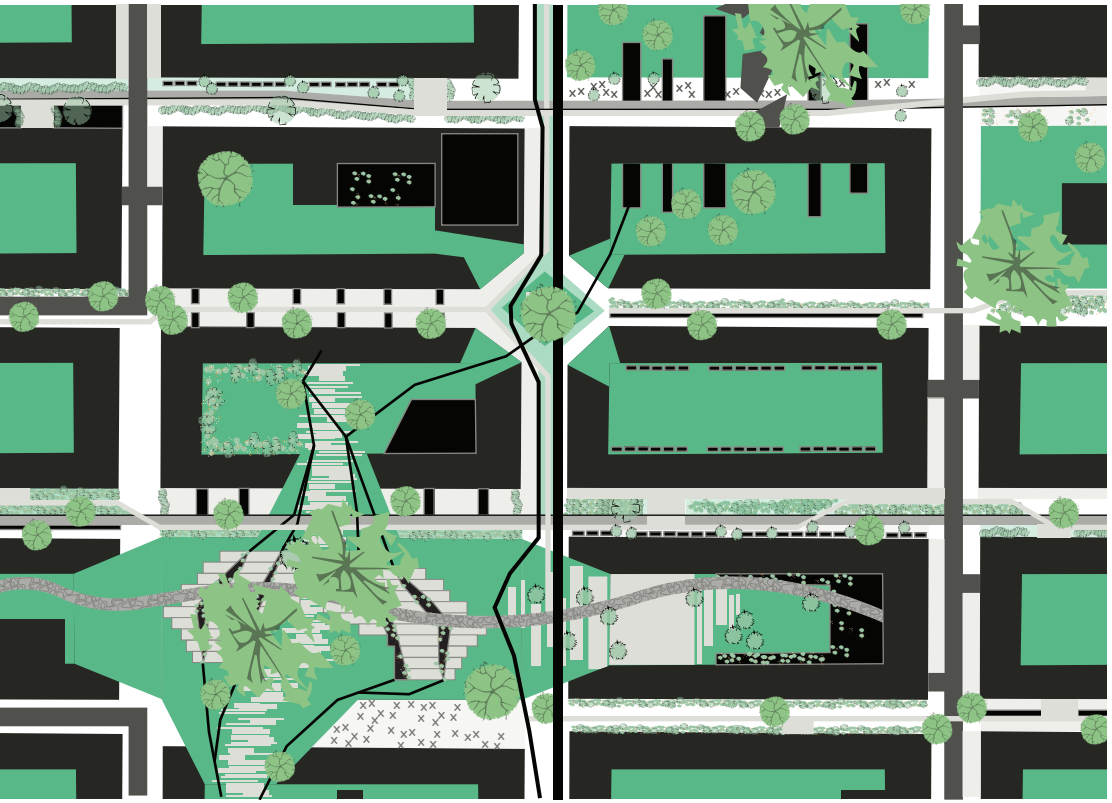
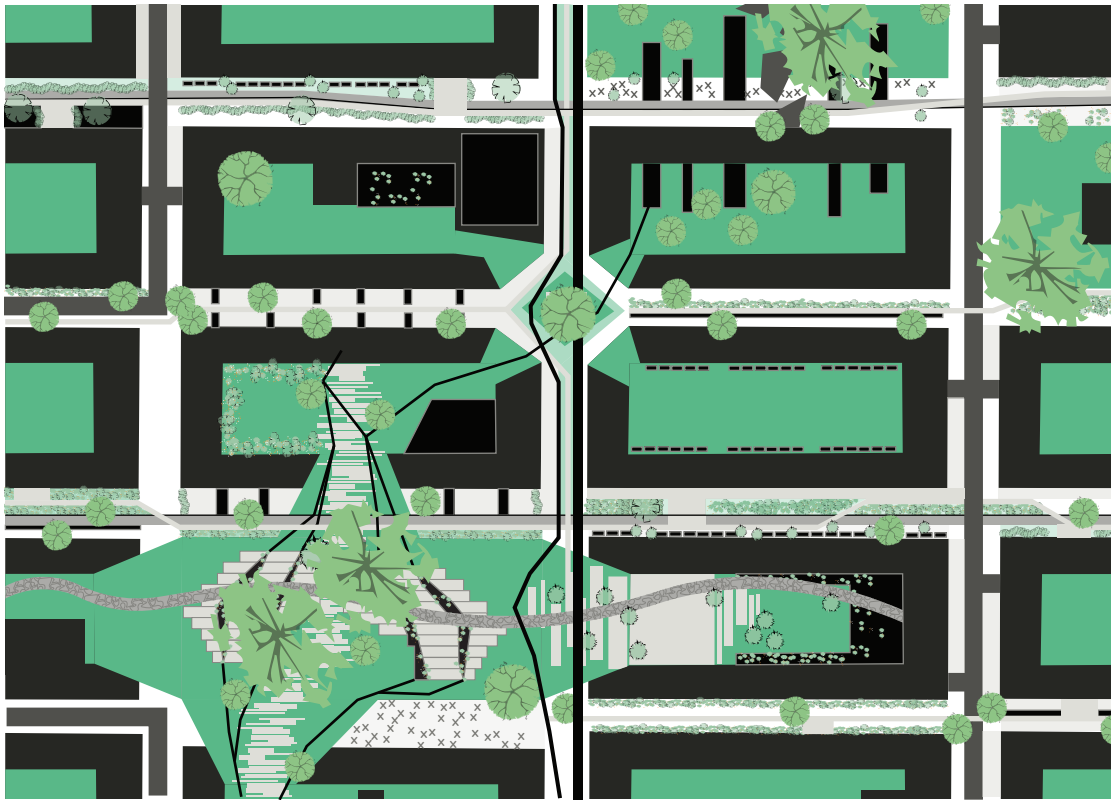



Figure 31: Private water storage elements made by Author





Figures 32: Street plan
made by Author

ZOOM IN; SQUARE

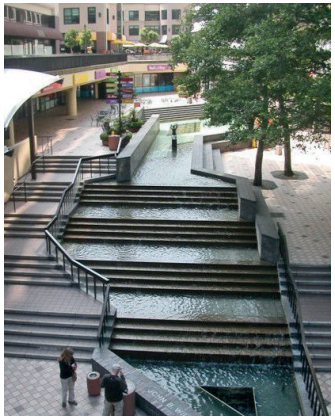
The squares are an important element in the design of the entire area, they combine public space with water storage. The green axis leads towards the square. To increase the water awareness, the main entrance to the square is a staircase over the water. This staircase combines the green axis, the waterfront park and the square. The stairs have water running down at the side as well, to create a stronger relationship with the water.

The fragmented visualization connects the different parts of the area together. The stairs enter into the static part of the square. Space is reserved here for restaurants, the building block next to this part of the square should have a very strong relationship with the square. The shapes represent different materials, to create a more interesting atmosphere. Some parts are elevated, to create different heights and create the feeling of smaller spaces. The water storage element in this part serves as a barrier between the green axis running through the square and this part of the square. On the other side of the green part of the square is a more flexible area. The large artificial rain water pond is flexible and can be completely drained of water. This can be done in order to create a larger flat surface, for example when there is a festival, exposition or other activity on the square.

The green axis running over the square connects the green axis at the top, the park and the water front park. There is a bicycle lane running through that, connecting the bicycle lane from the top green axis and the bicycle lane in the water front park.

The water front park has a natural Dutch landscape, using native plants to create a water park. There are platforms next to a pedestrian path, these platforms can be used for people to sit and relax, but also have a pick nick, sunbathe and other relaxing activities.

The square is cut in two parts, but the continuing fragmented shapes tie everything together. Water runs through this park and is visible in every part, so that the visitors and inhabitants of Buiksloterham are constantly reminded of the relationship with the water.

Figures 33: Square materialization
(Pinterest, 2017)

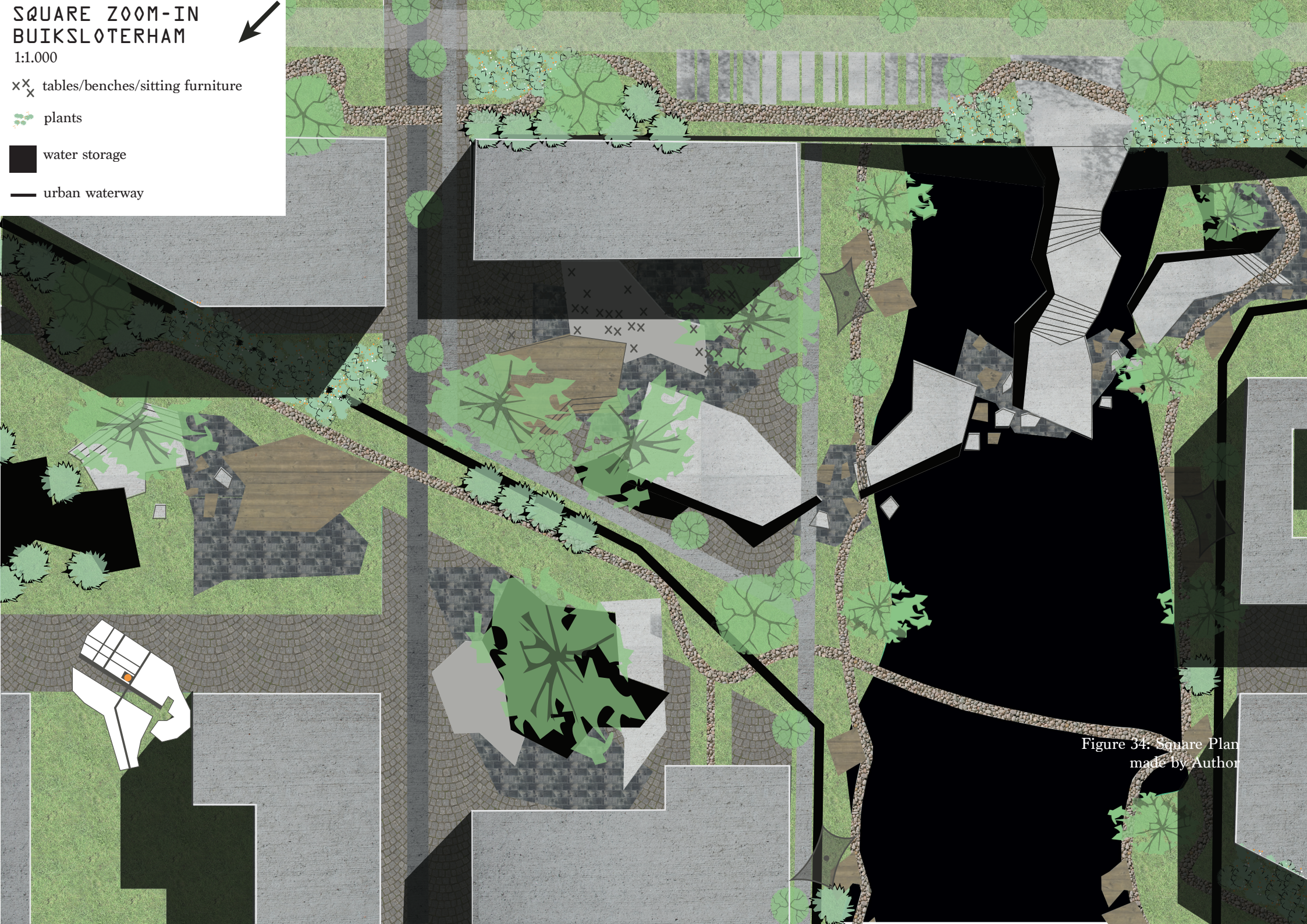
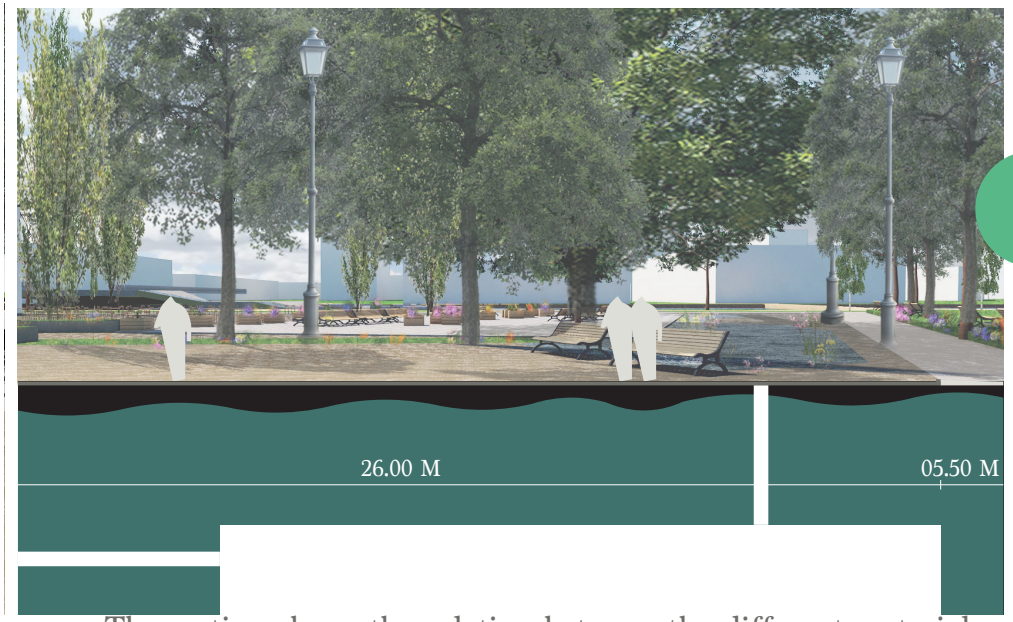



Figure 34: Square Plan
made by Author



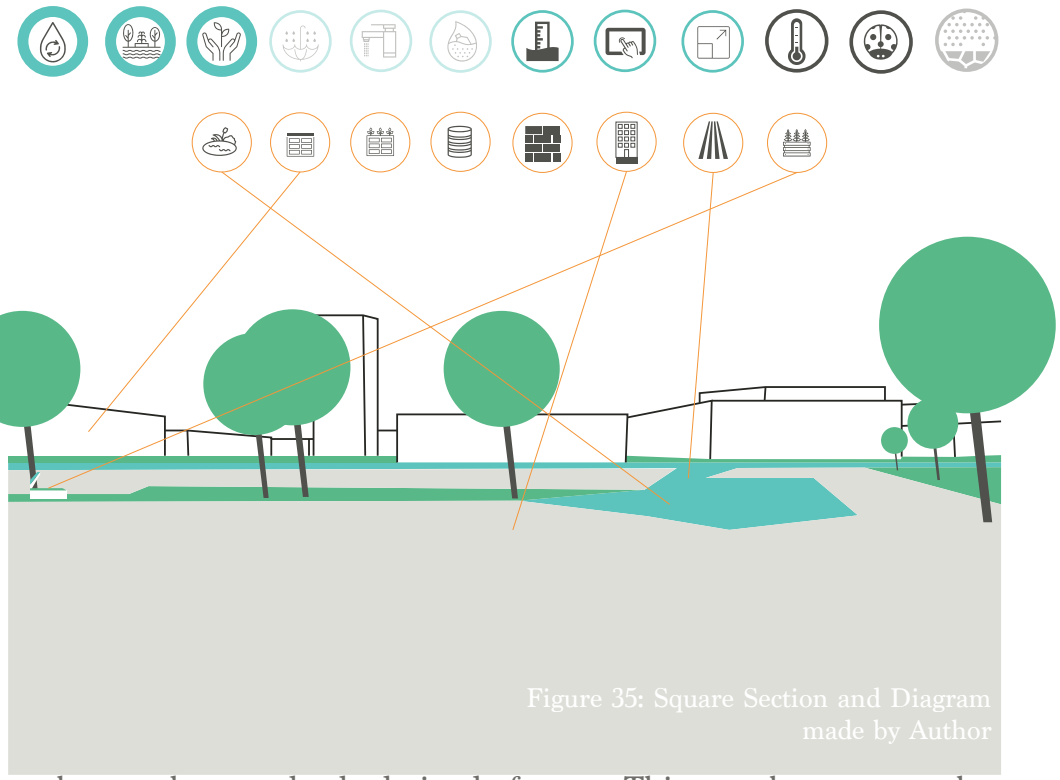



Figure 35: Square Section and Diagram made by Author

The section shows the relation between the different materials of the square. The diagram explains further the water storage methods used in this area of the design. The square itself offers room for buildings with intensive green roofs, underground storage, waterways and water holding planters. The last are interesting because they can be moved to places as the users of the area wish. Further, the area has larger water storage areas, which are connected to the urban waterways, that can be completely drained of water. This way the space can be used differently when needed.

Figure 36: Square Impression
made by Author

ZOOM IN; PARK

The parks are also a part of the design where there is a very strong relation between creating a community and having a sustainable relation with water.

The parks offer space for helofyte filters that can clean the grey water system. A layer of clay is placed underneath the canals in the park, to prevent the ground water from mixing with the grey water. The park uses native plants from the Netherlands, and creates a relaxing, natural feeling outdoor space for the inhabitants of Buiksloterham. A building is placed in this park, that can be used for flexible activities in the neighborhood.

The fragmented shapes are visible in this park again, to create a connection between the water front park and the green axis running next to the park. Other parks may use different shapes, but it will still be a fragmented look. For an example, the green axis on the top of the square zoom in shows a more rectangular fragmented shape.

Figures 37: Park materialization
(Pinterest, 2017)

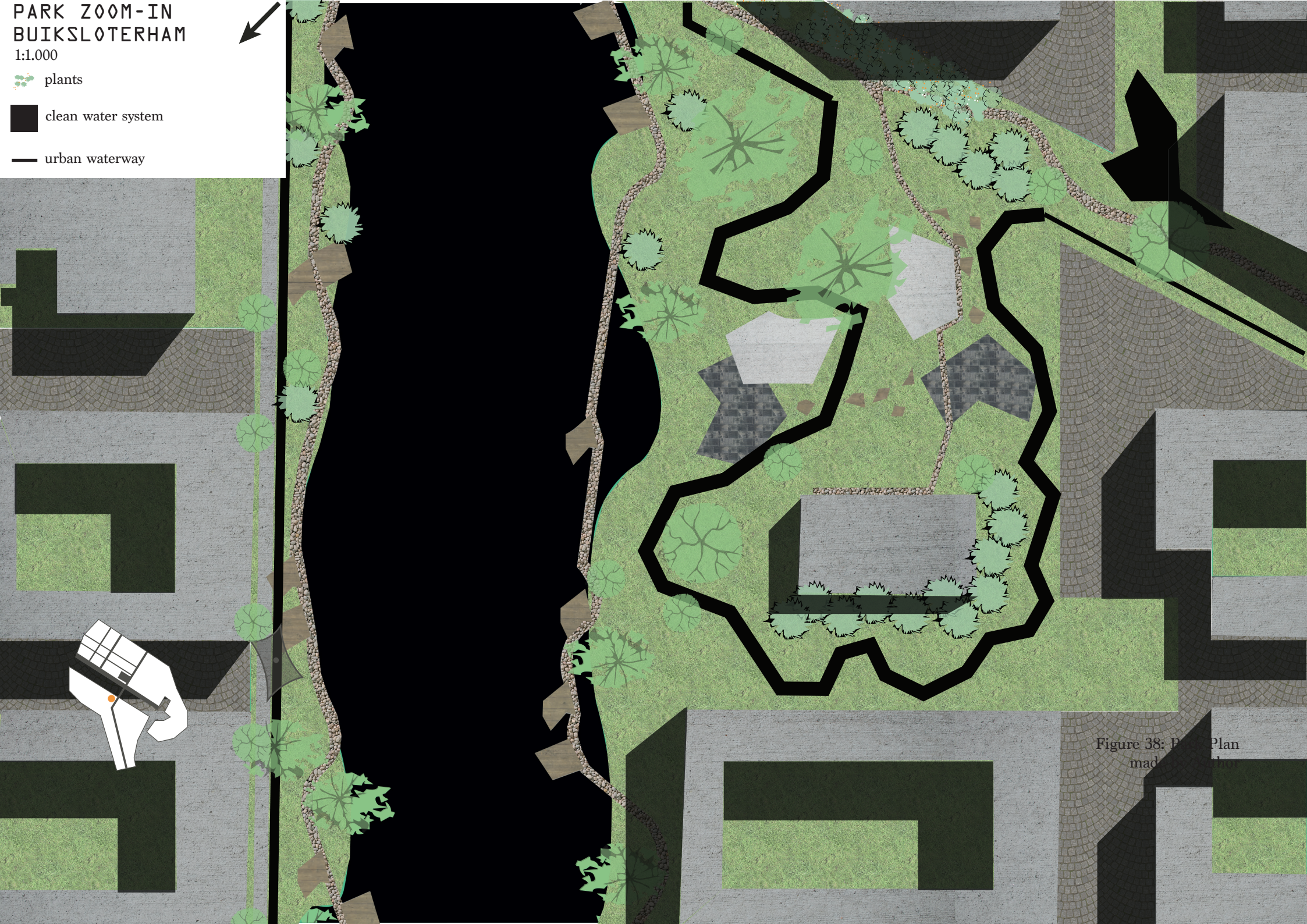
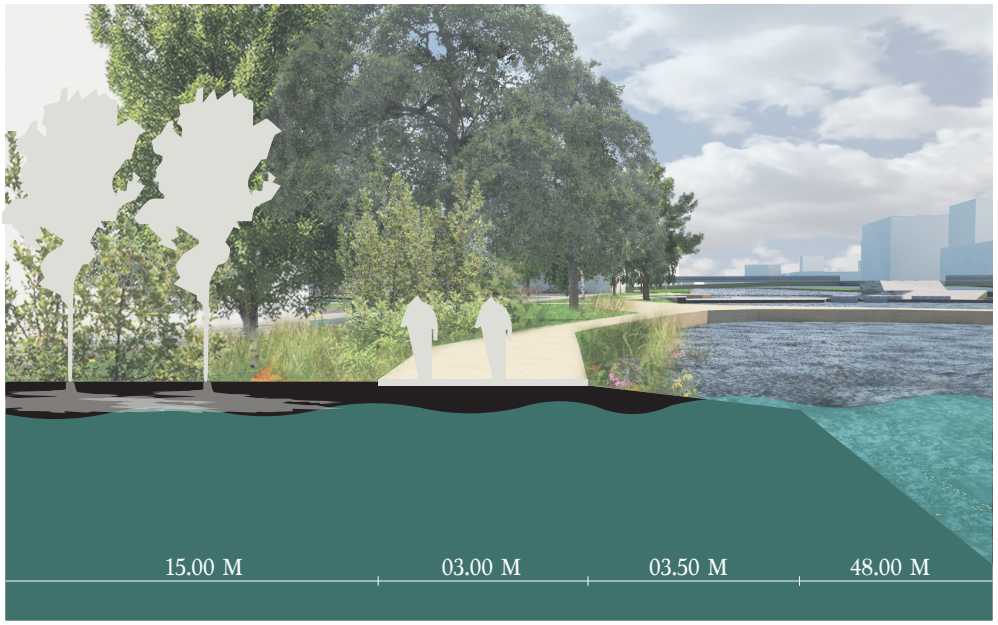



Figure 38: P Plan
mad



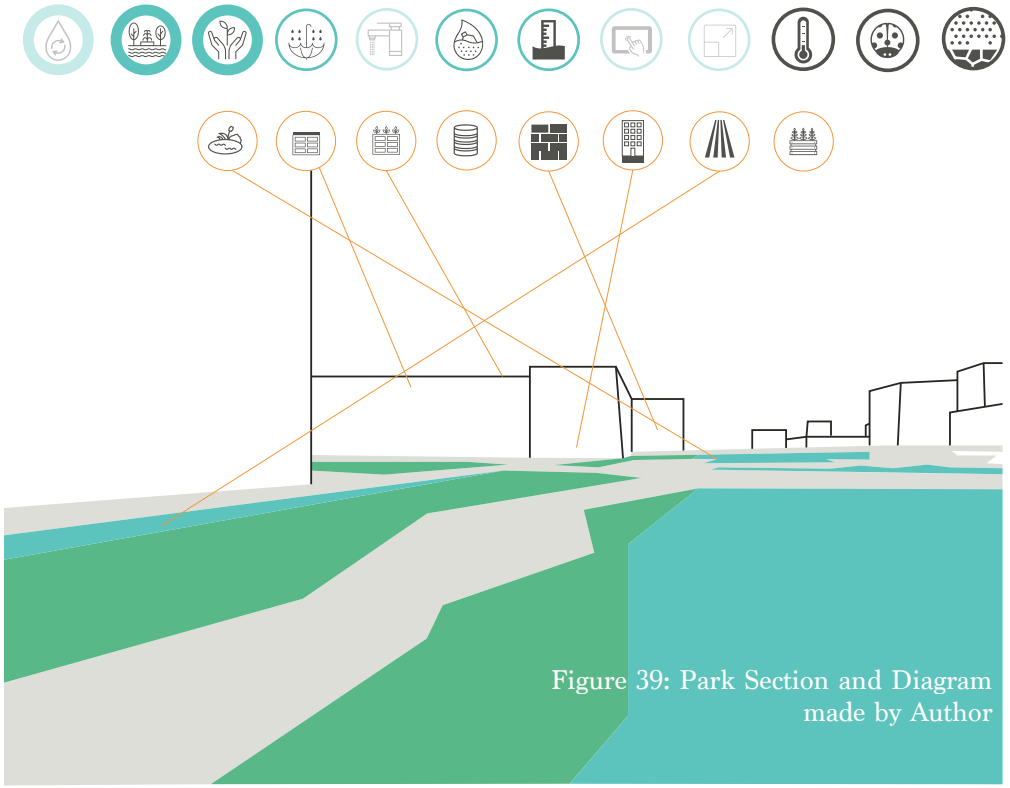



Figure 39: Park Section and Diagram made by Author

The section shows the relation between the park and the water. The park is designed to create a strong water identity for the area. The diagram shows the water storage methods used for this part of the design. The area is less interactive then the square, but offers room for a lot of change in the waterlevel and creating a different landscape through the different seasons.

Figure 40: Park Impression
made by Author

ZOOM IN; STREETS

The map shows a residential area of the design. There are 5 different streets, and the relationship between them becomes visible here. The different type of streets have different type of materializations.

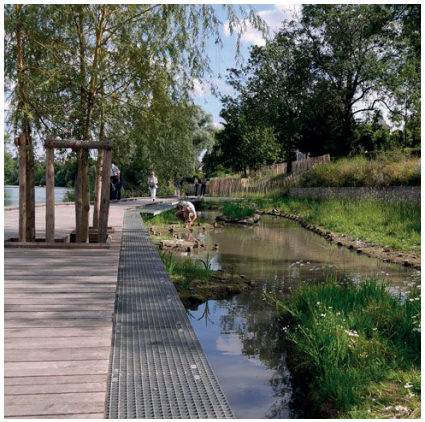
The building blocks open up towards the parks and the green squares. To enhance the relationship between the courtyards of the building blocks and the public green spaces, the shapes used in both areas continue and stay the same. Next to the parks there is the possibility to create a terrace next to the building blocks, with some tables and sitting areas.

There are a few elements that create a boundary between the building blocks and the streets. Plants are used as a natural barrier, open gutters and the urban water ways are a barrier between different parts of the streets, different materials also show a difference in use and furniture can be placed at strategic parts to create a boundary as well.

The parks in these areas are more private and very connected to the building blocks. It is possible for inhabitants to adjust and readjust these areas over time.

Elements like green houses, vegetable gardens, furniture, temporary terraces and sports equipment can be added. To allow inhabitants to change their living environment over time, benefits the connection between inhabitant and environment.



Figures 41: Street materialization
(Pinterest, 2017)

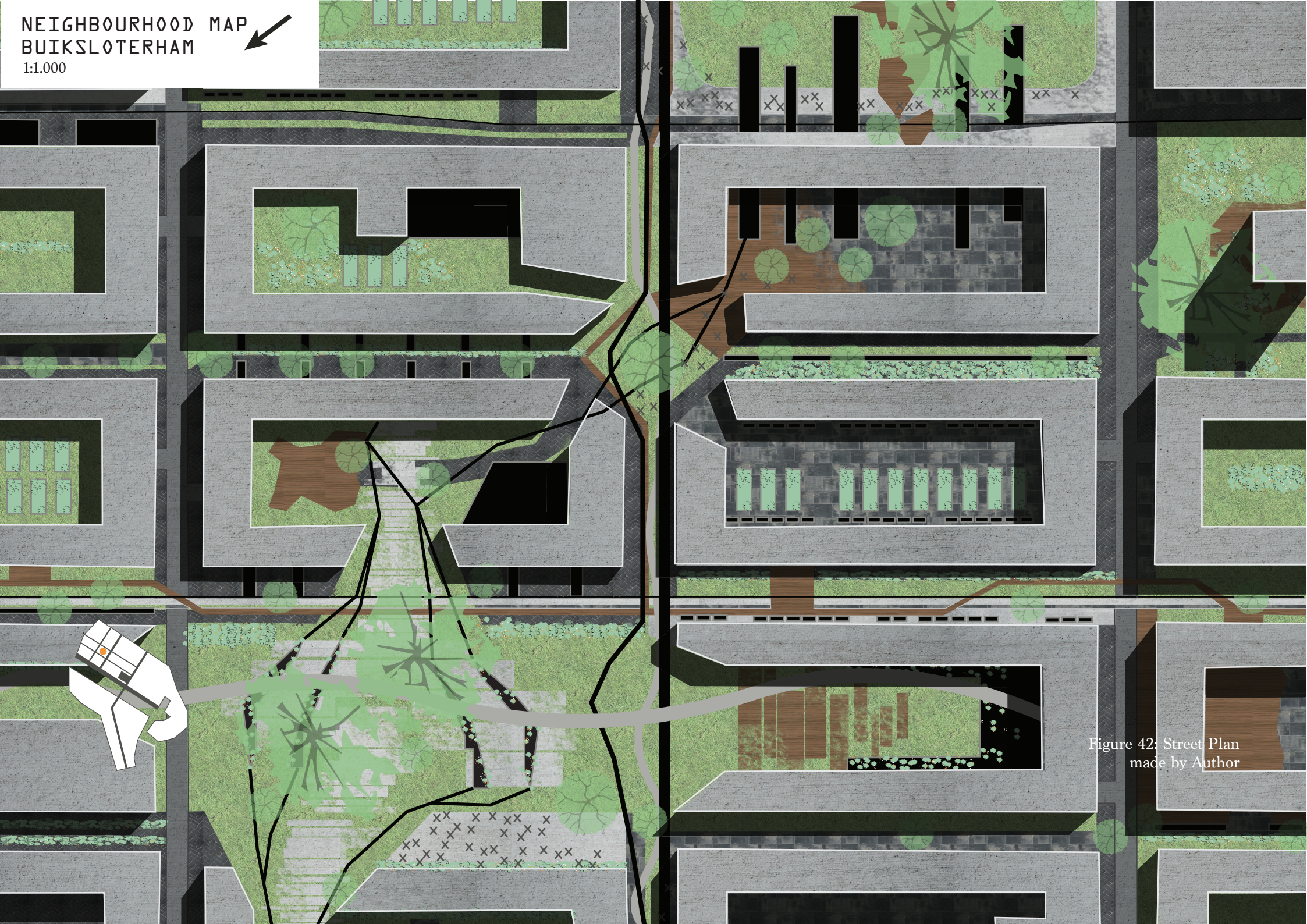



Figure 42: Street Plan
made by Author

ZOOM-IN; STREETS

The design has 5 different street types, which can be seen in relation to each other in the previous zoom in.

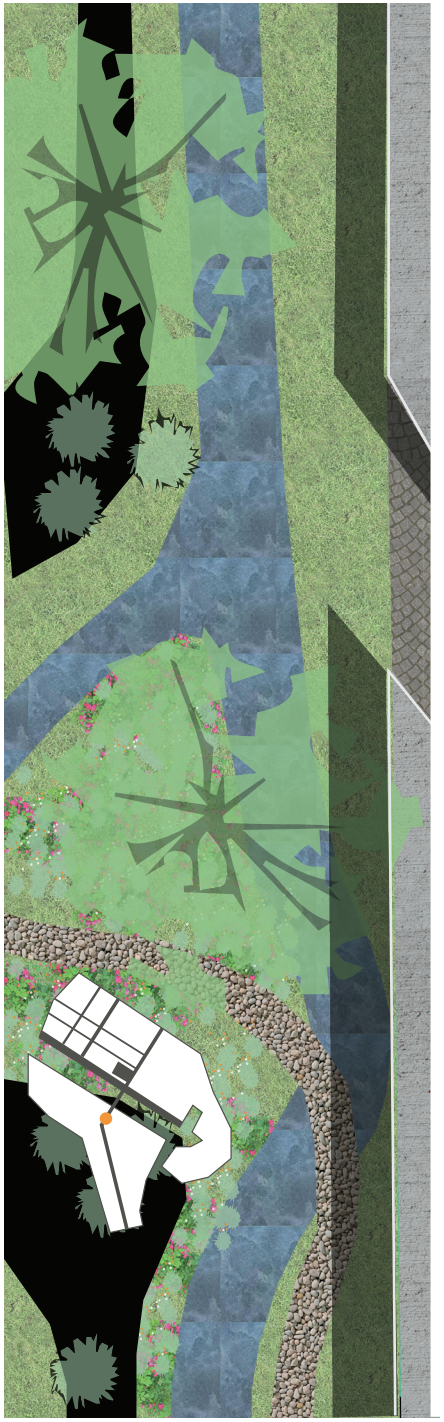
The green axis has a luxe, green modern feel to it. The materialization is both modern and luxe, like the blue marble path, and more organic, as the pebble path. In The green axis, there is room for different green areas, with flowers, grasses, bushes and trees of different heights. There is also room for the clean water system. There is no semi-private structure that separates the buildings from the green axis. At the place this section was made, the buildings are residential more than public functions. So, the buildings in this area are closed to the axis. In other, more public parts, terraces can be created next to the buildings and connected to the path, to form a relation between the building block and the green axis. The grey water from the building joins the grey water system in the green axis through a sewage pipe underground.

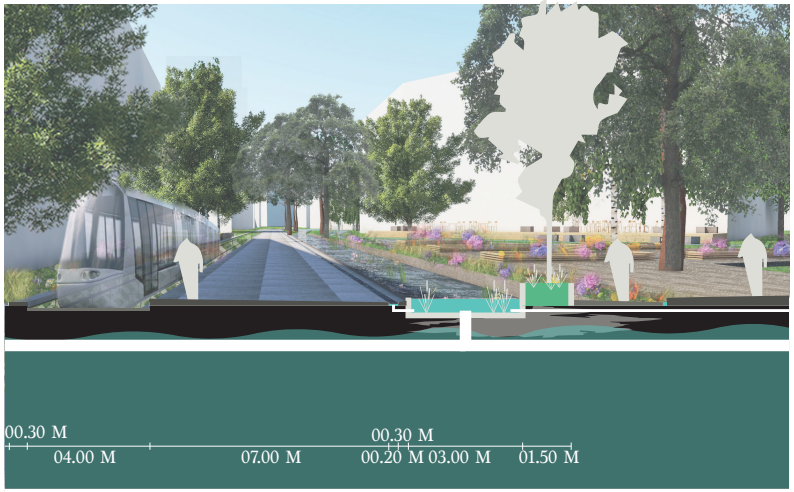
The North-South Big street is also inspired by modern luxurious materials, the blue marble is used in this street, but most of the materials have a more casual feeling to them. The street uses two different types of brick and one type of wood. To create a boundary between the street and the building blocks, furniture is placed along the building (the brown squares) as well as water holding planters. Flowers are added next to an open water gutter, to further separate public from semi-private. The street uses mostly grasses with some flowers, roughly the same height, and trees, all the same height, for plants.

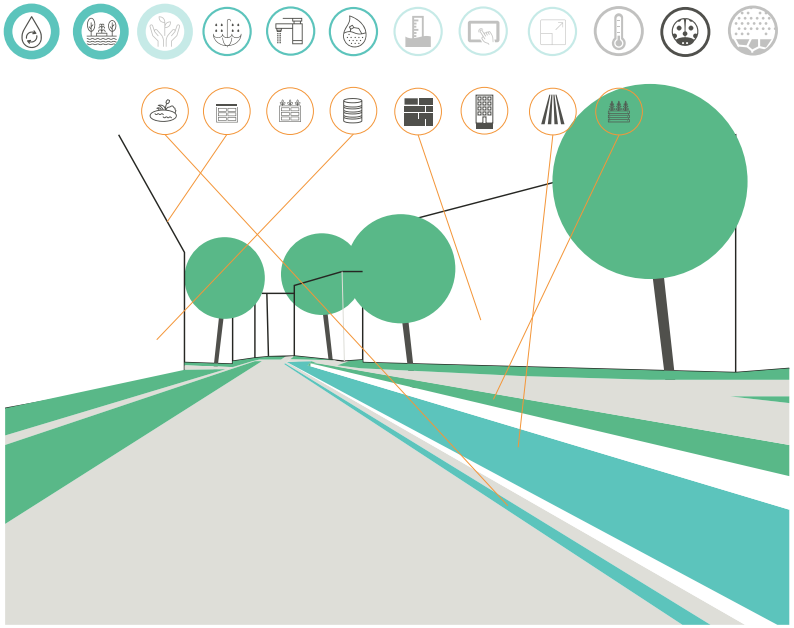
The North-South Small streets have a more private, organic feel. The entire street is materialized from the same bricks. A lane of plants and a large water holding tray is added to create semi-private areas next to the building blocks. Benches and tables are added to these semi-private areas, to encourage visitors of Buiksloterham to stay in the middle of the road. This street uses smaller plants and bushes and small trees. The large water tray is connected to the grey water system.

The East-West green streets have a very green, natural feeling to them. A large part of these streets is materialized in grass, the rest is small bricks. The water system creates a barrier between public and semi-private. The pebble path fits in with the organic feeling of the street. Benches and tables are again placed in the semi-private areas to encourage visitors to stay in the middle of the road. The grey water system runs through these streets, and the building blocks are connected to this system by underground sewage pipes.

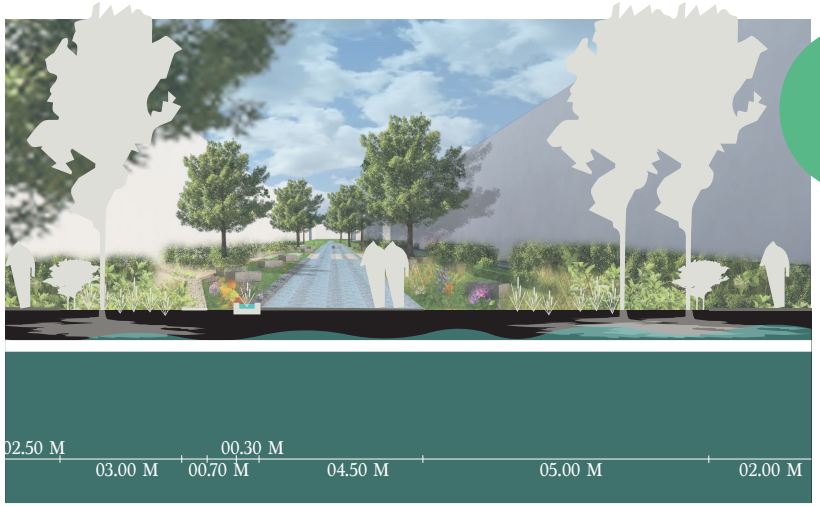
The East-West car streets use two different materials to indicate the road and the pedestrian path. Side parking is added to these streets in semi-permeable material. Under these streets is the black water system, a large sewage pipe runs under these streets towards the living machine greenhouse. The building blocks are connected to this system with underground sewage pipes.

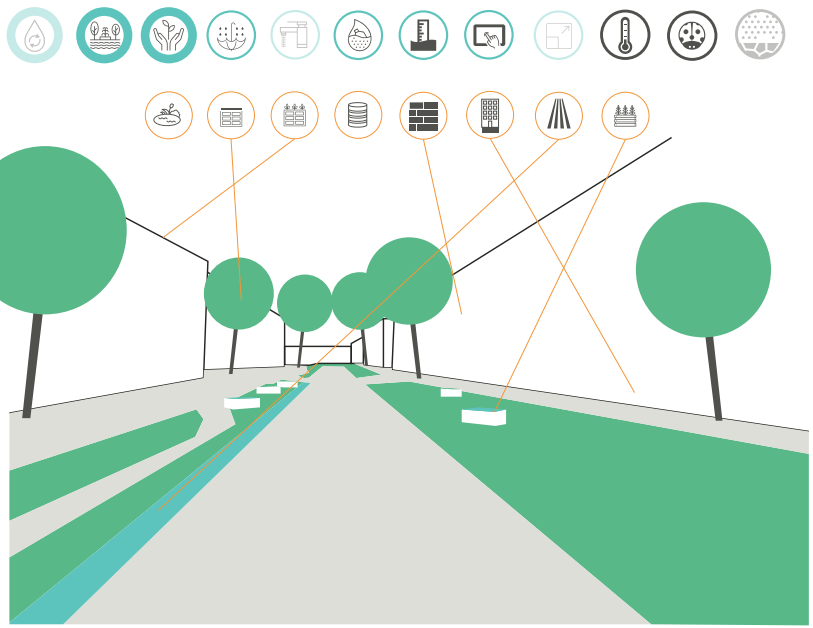




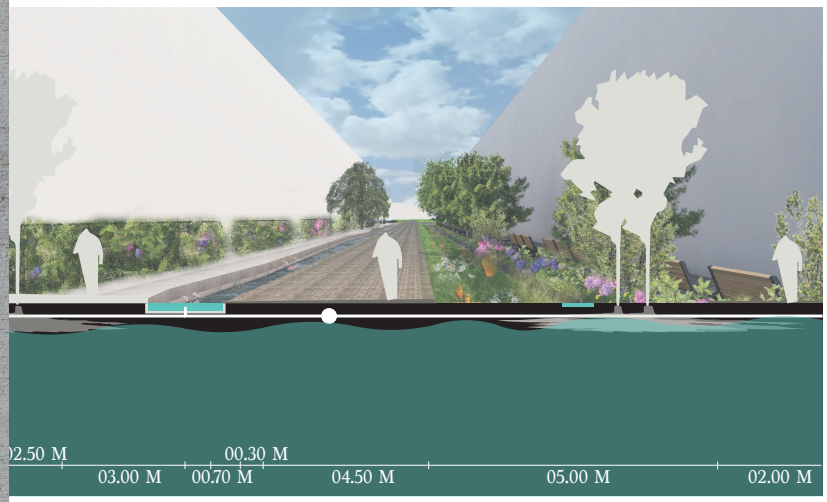



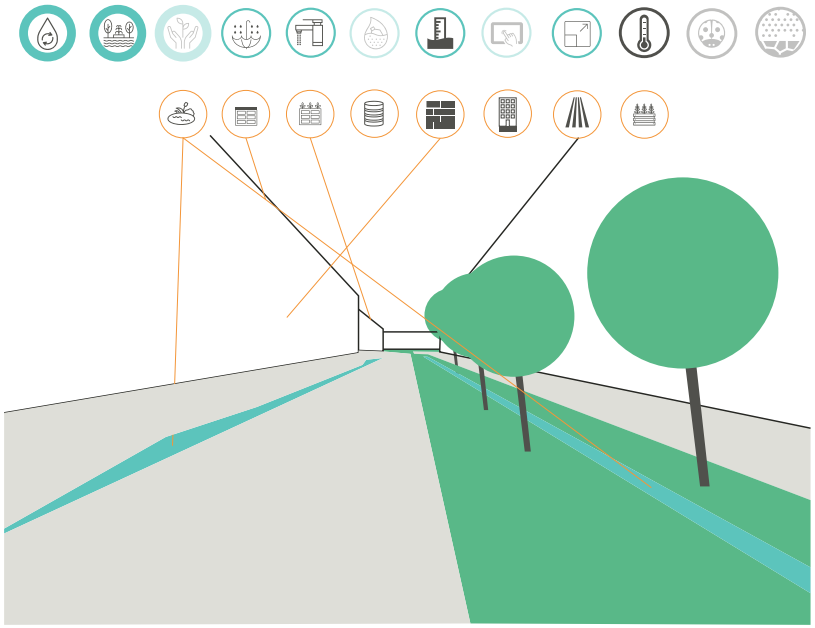
Figures 43: Green Axis Plan, Section, Diagram, Impression Wet, Impression Dry made by Author



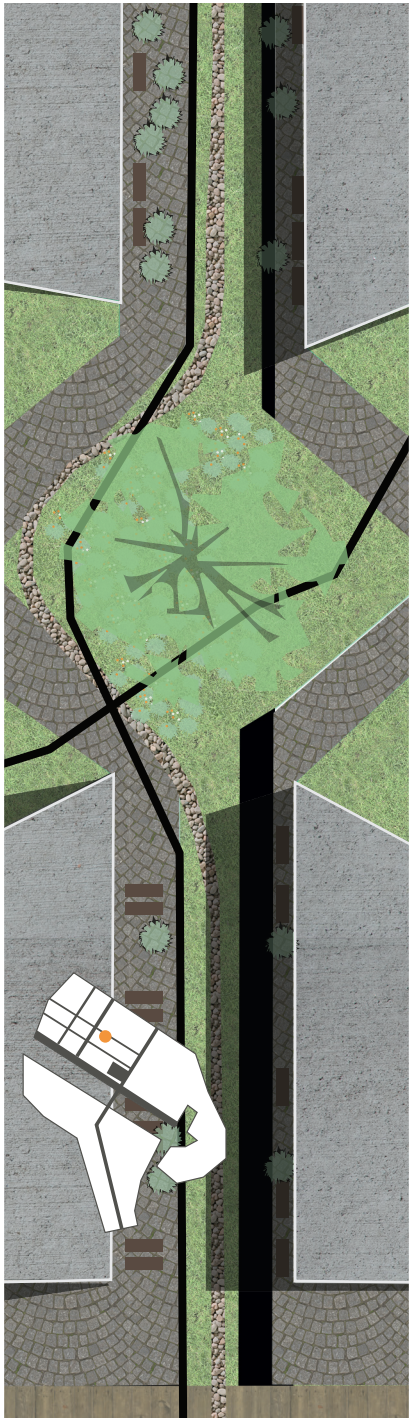



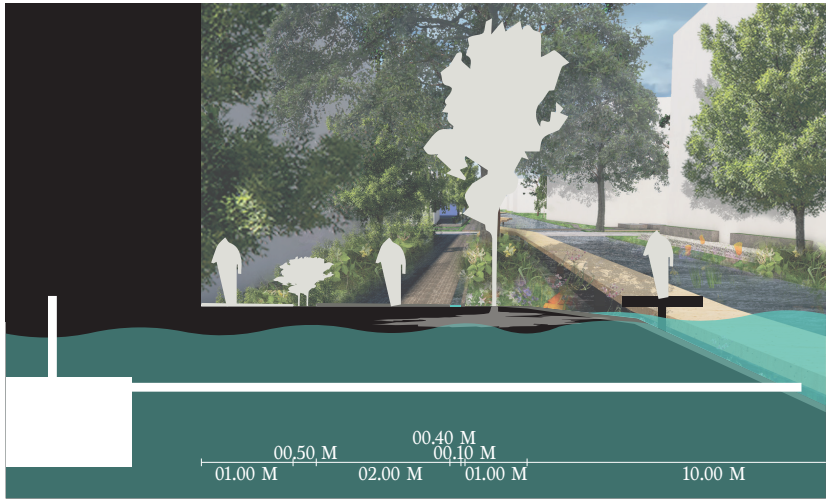
Figures 44: North-South BIG, Section, Diagram, Impression Wet, Impression Dry made by Author



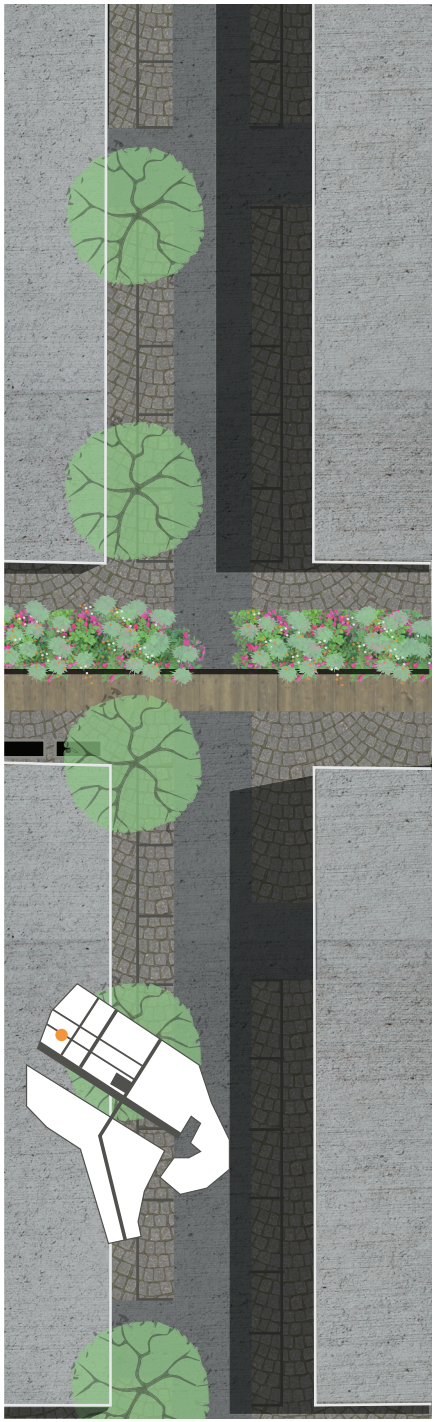



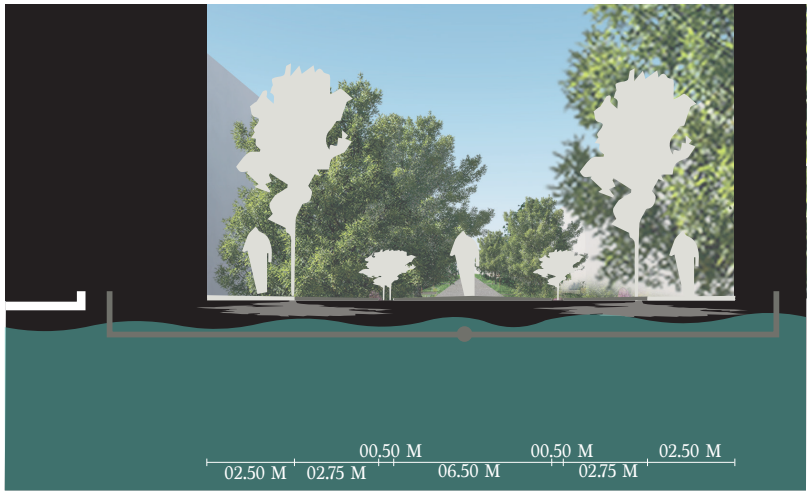
Figures 45: North-South SMALL, Section, Diagram, Impression Wet, Impression Dry made by Author

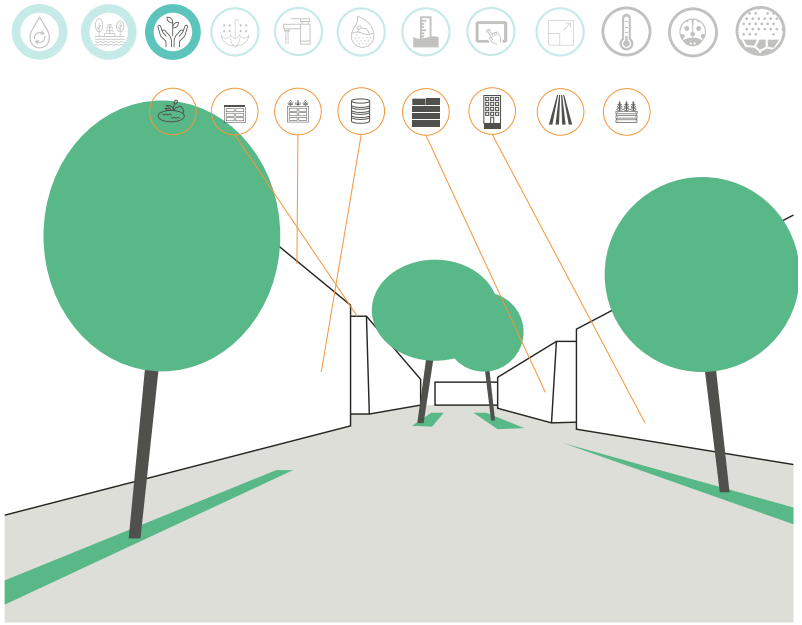





Figures 46: East-West GREEN, Section, Diagram, Impression Wet, Impression Dry made by Author





Figures 47: East-West CAR, Section, Diagram, Impression Wet, Impression Dry made by Author

SOCIETAL DESIGN

For the social part of the design, the thesis has already explained that there are multiple scales of water storage elements that can be influenced. The social part of the design only influences the grey- and clean water system. Since the black water system happens underground and goes directly to the living machine greenhouse for cleansing, and because you cannot re-use black water anyways, it has no added benefit to make this system interactive.

The social part works with these scales, each scale representing the wishes of more people. Each scale has different water storage methods available to them. Some of these water storage methods are not only interactive in terms that they can very in water level at any time, they are also interactive in the fact that they can be moved around by the inhabitants. This plays a large role in inhabitant participation, because this movability in the objects allows for people to co-design the space they use.

The water holding planters and water barrels are the most movable objects, but sitting elements are made movable aswell and can be integrated with extra space for water storage. These elements are small enough for people to move them by themselves, but play a huge role in the use of the space because they allows for people to create a sitting area or can be used as barriers.

By adding this to the design you encourage people to adjust the space as they see fit, with elements that store water. This encouragement makes that people become more invested in their public space, because they are closer connected to it. This in term will create a bigger connection to the entire system.

The goal is, that by adding these small changeable elements, the inhabitants will be encouraged to add elements themselves to the public space that they find important. Inhabitants could start adding elements like greenhouses, for urban farming and waste management, small windmills, for sustainable energy, BBQ's, to get together with the neighbourhood or even a small outdoor library.

Figure 48: Aquaponics wi

SELF-SUFFICIENT

The starting point for the area was to have 90.000 m2 of surface water. The actual design has almost 150.000 m2 of surface water. For the inhabitants to use, the area needs about 9.500 m2 of water to be available for use in the clean water system and for storage in the grey water system. The grey water system has a capacity of 18.000 m2. For the clean water system, in total the area needs 9.500 m2 + 33.000 m2 (for the peak rain fall), which is about 34.000 m2. The design has 38.000 m2 available for that.

The self-sufficiency of the area does not just come from the capacity. Because of the social system, the interaction with the inhabitants and the flexibility of the system, the total area is capable to withstand change. The social system also inspires a knowledge infrastructure, set up by the inhabitants of the area and passed on to new generations. This creates a different form of self-sufficiency. The area can change, and the inhabitants will want it to change. They can keep educating themselves and adding more elements to the system. In the future, new water storage techniques can be integrated into the water storage system. Other ways of sustainable living can also be integrated to the neighborhood. By creating knowledge and passing on knowledge, the neighborhood stays flexible and can keep working towards achieving their ever-changing goals.

Figure 49: Schematic of m2 surface area, hard surface, soft surface, water surface, daily demand of water, peak rain fall made by Author

# EVALUATION

To reflect upon the project and the process, this chapter looks towards the results for Buiksloterham, Amsterdam, the transferability of the project, the people planet profit triangle and a general reflection on the process of the graduation thesis.

## RESULTS FOR BUIKSLOTERHAM

The design is tested with the plan developed by the municipality of Amsterdam. Since the area is currently under construction, with a lot of empty plots and construction sites, the current situation is not comparable to the design. The thesis is tested by the objectives.

The area has self-sufficiency in water use as one of the 3 main objectives. That is why the imported water amount is less than half in the thesis. Because it is not possible to fulfill the entire water need with rain water and re-used grey water, due to the quality, it is not possible to create complete self-sufficiency. In the future, this might change when cleansing methods get better and the quality of rain water and re-used grey water can meet the quality of tap water. Self-sufficiency has as a side effect that the area, because it stores all rain water that falls on hard surfaces, that it has no added stress to the sewage system.

The second main objective is to create a water identity for the area. All the parks and important public spaces in the thesis where designed with the water identity and visibility of the water in mind. This results in a strong relationship with the water in all of these places. Because this relationship comes from the most important structural elements, the street pattern, the waterfront visibility, the water system structure and the large water storage areas, the smaller elements can change in the future, but the main structure will stay intact and continue to give the neighborhood its water identity.

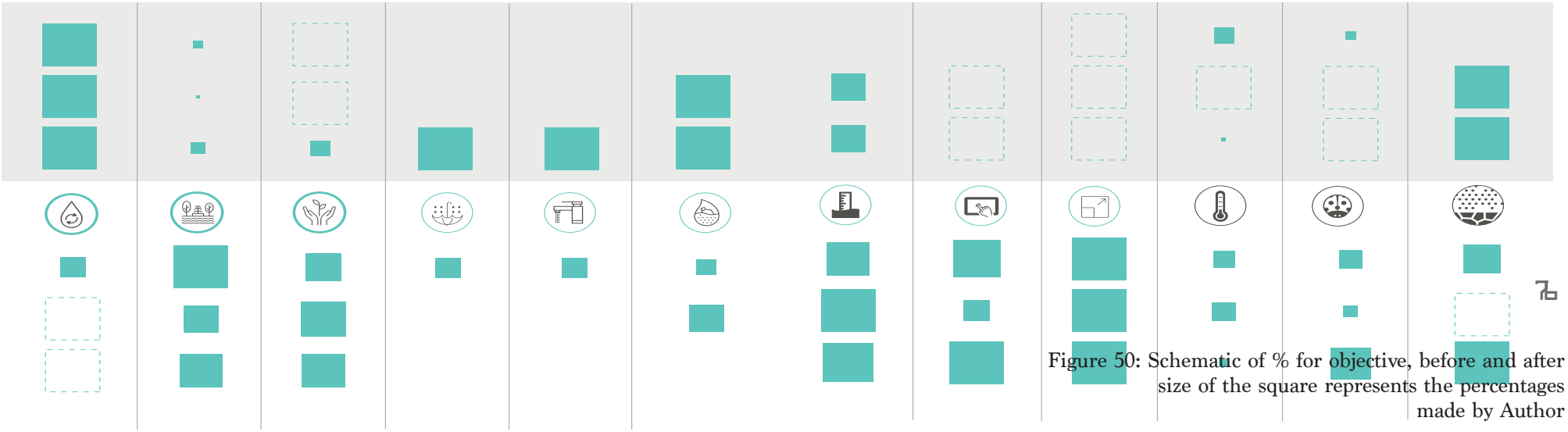


Figure 50: Schematic of % for objective, before and after
size of the square represents the percentages
made by Author

The 3rd main objective is to create a sustainable community. By creating integrated elements of sustainable design and allowing the inhabitants to participate, the thesis develops itself as a sustainable community. Water is, of course, the main goal in this sustainable community. But through a knowledge network, inhabitants are encouraged to add different elements of sustainability into the neighborhood.

When looking at the other objectives, it becomes visible that the need for imported water decreases with 53%. The other 47% comes from tab water, which needs to be mechanically treated. The water system created in the neighborhood focusses on using natural cleansing methods in order to better and maintain the water quality, so that indeed only the tap water needs to be mechanically treated. The water storage is made flexible and interactive on every scale, so that most of the water storage elements fit these objectives as well. Due to capacity, it is not possible to make every water storage element interactive.

The thesis has rougly the same HA for soft surface and open surface, but it adds green roofs to hold back the heat island effect. By using native plants, the thesis increases the biodiversity of Buiskloterham and creates possibilities for Amsterdam. Due to the nature of the soil pollution, the soil has to be cleansed before building starts, this cannot be done by natural cleansing methods. But, the thesis applies natural cleansing by plants in order to maintain the soil condition.

The self-sufficiency of the area does not just come from the capacity. Because of the social system, the interaction with the inhabitants and the flexibility of the system, the total area is capable to withstand change. The social system also inspires a knowledge infrastructure, set up by the inhabitants of the area and passed on to new generations. This creates a different form of self-sufficiency. The area can change, and the inhabitants will want it to change. They can keep educating themselves and adding more elements to the system. In the future, new water storage techniques can be integrated into the water storage system. Other ways of sustainable living can also be integrated to the neighborhood. By creating knowledge and passing on knowledge, the neighborhood stays flexible and can keep working towards achieving their ever-changing goals.

One of the possible, more unforseen sideeffect of the design is that, by focussing the design of the neighbourhood on rain water and climate change, the area has a very green, more village like athmosphere. This is something that not a lot of neighbourhoods in the center of Amsterdam have. An area like this, with a lot of safe outdoor space, is interesting for other target groups than you would normally find in city centers, like families with smaller children and elderly people. By focussing the design on rain water, the area becomes more usable for a wider group of people, making the center of Amsterdam more accesable.

Also, by creating a green-blue neighbourhood, the area possesses a calm athmosphere, which is further enhanced by the fact that most of the streets are without cars, which offers health benefits to both the inhabitants and the users of Buiksloterham in terms of stress related illnesses and airpollution related illnesses.

RESULTS FOR AMSTERDAM

The thesis shows results for Amsterdam in two different ways. The first comes from the fact that the thesis aims to create a water self-sufficient neighborhood in Amsterdam. This means that the area needs 53% less tap water every day then a generic neighborhood. Buiksloterham saves 1150000 L water every day. The water system of Buiksloterham also creates the possibility to store an excess of rain water from elsewhere in the area, since it has space to store a peak rainfall on the area + extra. There is 4.000 m2 = 12.000m3 = 12.000.000L extra room in the Buiksloterham area, where the municipality of Amsterdam could store excess rain water. Buiksloterham also relieves the stress on the sewage system, since the rain fall discharge is stored in the area itself and the grey- and black water from the area is reused.

The second way comes from the ambition of the municipality of Amsterdam to use Buiksloterham as a test location for sustainable development. The city of Amsterdam could gain a lot of knowledge from the Buiksloterham area. Not just in (rain) water management, but also in how to create a sustainable community that educates and trains itself.

TRANSFERABILITY

The transferability of the project in its entirety is limited, it can only be applied in cities that have an excess amount of rain water and aim to create a sustainable city. But, when the thesis is broken down by its objectives, parts are transferable. Self-sufficiency in water use is most transferable to cities with an excess of rain water, since the amount of rain fall should be enough to fulfill part of the daily need. A water identity is also best applied to cities with a lot of water, because then it enhances the natural relation with the environment. A sustainable community is, of course, applicable for every city that wishes to develop sustainably. Small scale projects can also be started in cities that do not have this goal, but when applied on a large city wide scale, it automatically creates the wish of a city to be sustainable. There a very few sustainable communities that do not aim to be sustainable.

Flexible water storage, interactive water storage and storage throughout the different scales can be easily applied in all cities that want to invest in sustainable development. Because it is an extra investment and knowledge is needed, this will not be a choice made for cities that don't reach towards sustainable development. Re-using rain water is most transferable to cities with a lot of rain water, because it gets very hard to re-use rain water when there is very little. The ground water, soil condition and vegetation also use rain water, and when there is little rain water, using this rain water might result into other problems. Re-using grey water, creating a good water quality, relieving heat stress, increasing biodiversity and improving on the soil conditions are objectives that can be applied in any location in the world. Of course, conditions may vary and the outcome might be different. But these are goals that can be achieved anywhere in the world.

PEOPLE, PLANET, PROFIT

The thesis aims more towards the planet side of the triangle. It looks close to the environment of Amsterdam and the problems climate change creates for the area. From a planet perspective, the project also offers the possibility to add different elements to this design. This could be waste management, energy management or urban farming. The green structure in the design connects possible larger green structures through Amsterdam North. The native plants applied in the project also form opportunities for the surrounding areas. The seeds of these plants will travel to the surrounding area, possibly improving the biodiversity in those areas as well.

The sustainable community development of the thesis ties the plan to the people of the triangle. The thesis is highly connected with the inhabitants of the area by creating flexible and interactive stories. This gives the inhabitants the means to change their own environment. The design also promotes for people to work together on several aspects of the water system. But, because of the way the area is designed, it

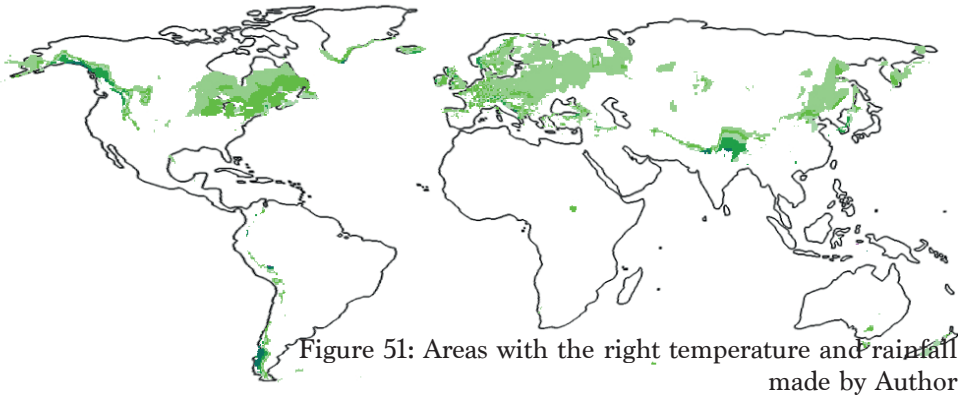


Figure 51: Areas with the right temperature and rainfall made by Author

it is a pleasing place to live for everyone. Even if sustainable living is not high on your priority list. The car streets make all the building blocks accessible by car, improving the accessibility of the neighborhood. There is a lot of public space, with different levels of privacy. The different street types also crease the possibility for children to play outside without the chance of them being interrupted by cars.


Figure 52: Schematic of transferability made by Author

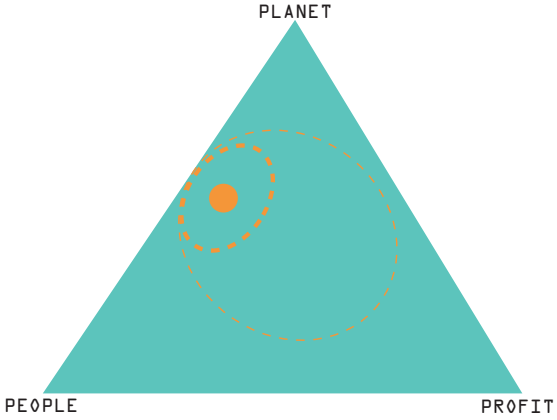



Figure 53: People, planet, profit made by Author

The profit part is relatively unexplored in the thesis. But looking at the project from a profit perspective, there are opportunities. The first opportunity comes from the possibility to store excess rain water. The demand in fresh water is increasing every year and the Netherlands is one of the few countries that has an excess of this resource (Koninklijk Nederlands Meteorologisch Instituut, 2012). By creating more storage for fresh water then the area needs, it creates the possibility for export. This can create business opportunities for Amsterdam and possibly the rest of the Netherlands. Economic opportunities for the inhabitants and business in the area also come from the amount of water they use. They use less tap water, so the costs will be lower. If they store enough water, they could even sell water back to the grid, earning money. The knowledge infrastructure that is promoted in the area could also form an economic opportunity for starting businesses. The area allows for those new businesses to test their theories in the area. For the city of Amsterdam, Buiksloterham could even grow to an international example of sustainable living, helping Amsterdam to create a new sustainable brand.

REFLECTION

For my graduation thesis, I set out to create a more sustainable way of life. Water management, especially in terms of rain water and re-using water, was my main focus in this aspect. With the Delta Interventions studio, I think the subject fits very well. With climate change, the Netherlands will have continued and increasing stress from rain water and I believe it's very important to give this problem an integrated approach in our urban environment. The teachers from the studio all had vast amounts of knowledge and in that way, I am very happy that I chose Delta Interventions to graduate in.

However, I do feel like the approach of the Delta Interventions study was not my cup of tea. It is very studio based, I feel like the setup of the studio limited can limit you. In the first few weeks, there seems to be a very set way of doing this. This may help you get started, but when you like to find your own way through a project this can feel very constricting. The setup of the Delta Interventions studio was one of the reasons why I chose not to join the San Francisco group. The other reason was that I already had my basic subject, interactive rain water management, in mind when I started the graduation process. I felt, and still do, that the subject is better suited for the Netherlands then it is for San Francisco.

The choice to not pick San Francisco resulted in me not having much to do with the Delta Interventions studio. The lectures at the beginning of the year where helpful. But since so many students chose San Francisco, everything was very much applied to that location. I felt that in order to stay connected to the Delta Interventions group I had do to work that did not really relate well to what I was doing for my personal project. This is why I chose not to be part of the group work for the Delta Interventions studio, since the group work was based on San Francisco entirely, and resulted in my project losing the connection with most of the studio. I still feel like the subject fits in Delta Interventions, since it is about interventions in the urban fabric in a delta located area. I do however think it would be better for me to join a different research group, just because the setup of the project did not relate to my personal preference of working and because I felt like the group work of the studio held no added benefits for my project.

In my project, I think that there is a strong relationship between research and design. As a personal, I can be quite structural and straight to the point. That can sometimes result in a project which is only research based and from there directly translated to a design. My second mentor, Frits, pushed me out of my comfort zone in this area. He asked me to do design as well as research, allowing the design to become a form of research. This way, the project became an interactive process between the two. This is visible in the methodology. The research starts with setting research questions and objectives, to test the outcome of the design process by. Then one the one hand there is the more analytical approach to the objectives, which

are tested by scenarios, and theoretical framework. And then there is the design approach on the other side, which looks at location specific problems and how to solve those in the location. These are related to each other and come together in a plan, that consists of a plan that explains how to build the area, a plan of how the inhabitants interact with each other and examples on how to design key areas in the total plan.

The project has both a technical and a social approach. It fits in the ambition of the municipality of Amsterdam to develop Buiksloterham as an innovative sustainable neighbourhood. It also helps Amsterdam to set an example in sustainable water management. But the project not only creates a new way of using and re-using (rain)water, it also encourages inhabitants to participate. This participation creates a strong relationship between the neighbourhood and the inhabitants, giving them responsibilities and influence on what is happening in their surroundings. This creates a bigger drive for people to adjust their lifestyle to a more sustainable way of life. I feel that the project not only creates a more sustainable living environment in a high density urban area, but it also sets an example of how to live sustainably in a metropolitan area.

I do feel like, because the project approaches both a technical and a social aspect, that the technical aspect gained the upper hand at the end. This is, I think, because of my personal preference and the fact that an area has to first be created in a good way. After that, it becomes easier to dive into the way people live there. Ideally, this would be two different projects. The social part of the design deserved more attention, it has more options and possibilities that I was able to explore at this point. There are many things that can be added to what I have delivered for the social part of this design. I do however feel like the type of approach was right, because the social part has been integrated from the beginning. This makes it compliment the design. That being said, I do feel like somebody else can pick up where I left and improve on the social part of the plan.

In some ways, a year is too much. I got lost along the way, not knowing what to do next, now knowing what to expect of such a long process and feeling like I could endlessly go over every part of the thesis and it would still not be good enough for a year's worth of products. In other ways, a year is not nearly enough. Like I said, I feel like I got stuck on the technical part of the design too much, which leaves opportunities for the social part of the design that I did not investigate. I feel like the thesis is a first step to building sustainable cities, getting the technical right and knowing that it works better when it is balanced with people's daily life. But I hope this thesis will be an inspiration to others, and I challenge them to create a plan which greatly improves mine.

Figure 54: Rain
(Google, 2016)

# CONCLUDING

RESEARCH QUESTIONS

Rain water management will be one of the main topic for high density urban areas in the Netherlands for the next 50 years. The thesis shows one way to approach this problem, while creating opportunities at the same time. The thesis was formed around the question:

**How can a flexible, interactive, water storage system be designed to help Buiksloterham prepare for climate change, as well as increase sustainable awareness through neighborhood participation through different scales?**

To answer this question, we first look at the sub-parts.
First, for the water system, the thesis has designed a separated clean-, grey and black water system. These 3 systems circulate through the neighborhood and each have their own sewage system and cleansing methods. The system has enough capacity to fulfill the daily need, the peak rain fall and more.

Climate change will cause Buiksloterham to experience heavier rain falls, which where taken into account for the design of the water system. Climate change also creates higher temperatures for Buiksloterham, creating a heat island effect. This is limited by forming enough open- and green spaces in the area. Climate change can also decrease the biodiversity of the area, which the thesis counteracts by re-introducing the native biodiversity in the landscape.

The water storage methods that are suitable for Buiksloterham should have a balance between capacity, visibility, flexibility, added benefits and the negatives of the method. The water storage methods that are suitable for Buiksloterham are (artificial) rain water ponds, intensive green roofs, water roofs, rain water barrels, urban waterways, seasonal storage, water holding planters, water walls, storage under buildings and underground storage. These methods provide the possibility for water storage on every scale, with different levels of flexibility and interaction, while at the same time creating enough capacity to fulfill the water need.

The materialization of the public space is done with the water storage methods integrated into them. The public spaces offer a variety of materials and atmosphere, ranging from more luxurious and modern for the large public spaces, to more organic and private for the small public spaces. All of these public spaces have a visible part of the water storage system and water system in them. This creates a strong relationship between inhabitant, environment and water in all the public spaces.

The evaluation shows that the design of Buiksloterham helps Amsterdam in two different ways. First, it relieves stress on the sewage system, relieves stress on the demand of fresh water and creates the possibility to store an excess of rain water in Buiksloterham. The second way comes from the ambition of the municipality of Amsterdam to use Buiksloterham as a test location for sustainable development. The city of Amsterdam could gain a lot of knowledge from the Buiksloterham area. Not just in (rain) water management, but also in how to create a sustainable community that educates and trains itself.

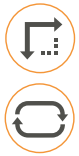
And the last sub question was formed around the sustainable awareness part of the research question. By relating water storage and the water system visibly in the public space of the area, the neighborhood identifies itself with water. By creating this visibility, the inhabitants of Buiksloterham start to see results of what they do, which encourages a change towards sustainable behavior. Also, by allowing inhabitants to determine what happens with the water storage and by giving them the responsibility of the water storage element and their maintenance, the inhabitants get a sense of responsibility over the water storage system. This also promotes sustainable behavior.

All of these parts form the design of Buiksloterham. The water system is the base around this design, all of the other systems are created with this base system in mind. The design formed by the thesis looks closely to what is possible in Buiksloterham and relates this to creating a sustainable community through every step of the way. The thesis prepares Buiksloterham for climate change, with the flexibility and extra capacity in the system. By visualizing the water system and the water storage element at every scale, and creating responsibility the area starts to behave as a sustainable community.

## RESEARCH OBJECTIVES

The thesis reached all of the objectives set. Although, 100% self-sufficiency is not achievable at this point, due to the quality difference in rain water and tap water. Also, it is not possible to have all the water storage systems be flexible, some need to have water in them at all time, like the urban waterways of the grey water system, or interactive, there is no reason for underground storage to be interactive. A good water quality is achievable, but only when made sure that the stored water does not come in contact with the ground water. The ground water cannot be cleansed, since it is in direct contact with het IJ. For the biodiversity, it is not possible to use only native plants, since the areas surrounding Buiksloterham do use foreign plants. And last, for the soil condition, the thesis only offers the possibility to maintain the soil condition. Due to the pollution in the area, cleansing naturally is not possible.

Self-sufficient in water use



Water becomes part of the identity

The area functions as a sustainable water community

Re-use rainwater

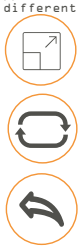
Re-use grey water

Create good quality water

Water storage will be flexible

Water storage will be interactive

Water storage will be applied through the different scales



Relieve heatstress

Increase biodiversity

Clean soil

RECOMMENDATIONS

The first recommendation, is to separate the technical part and the social part of the design in two separate project. I do believe that solving them both creates a very integrated design. But, there are more possibilities to the social aspect of the design than the ones investigated for the thesis.

The second recommendation is to the architect. It would be beneficial to the project when the houses designed for the neighborhood are integrated with water as much as possible, to really bring water storage into the private scale as well.

Also, for the building blocks to form their own neighborhood, and to create a connection between some building blocks as well, to create a community within a neighborhood.

For the roof scape of the area, looking into the possibility to create smaller communities within the neighborhood would strengthen the sustainable community aspect of the thesis.

Combining the design with the stakeholders of the area can create more possibilities and a better integrated design as well.

And last, it would be very interesting to see how my approach can be broken down into sustainable typologies. This could be an example for a water integrated typology, energy, waste, urban farming, social design can be added to this as well. And then it would be interesting to see how these typologies can be combined together.

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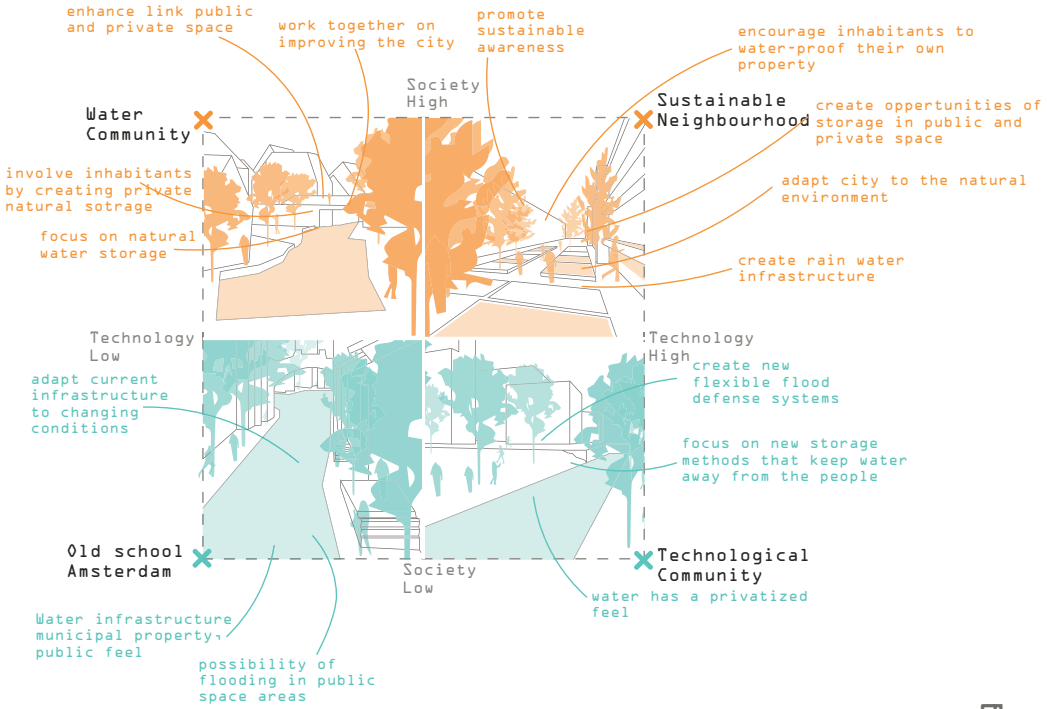
# APPENDIX 1; SCENARIO'S

SCENARIO APPROACH

In order to test the different methods and elements that are important for the design, 4 different scenarios are created to test 4 different extremes. The outcome of these scenarios is a sketch design, that can be tested against the objectives and research questions set for the thesis.

The first scenario, scenario 0, is a zero-point scenario, it is based on a technology low – society low framework, meaning that the storage methods used are basic and that there is no neighbourhood participation possibility in the design. This scenario is to see how we can create a water self-sufficient neighbourhood. The second scenario, scenario 1, is based on a technology low – society high framework. It uses mainly natural means of water storage, but encourages people to live in close relationship to the water. The design of scenario 2 focusses on a technology high – society low framework. It uses integrated water storage methods together with the possibility of parts of the area to be flooded. But there are no means of water storage on the small scale, only on the large, and the methods that are used are non-interactive methods. The last scenario, scenario 3, is based on a technology high – society high framework. It looks towards integrated storage methods throughout all scale, adding water storage at as many places as possible and using interactive methods in order to get people as involved with the water storage system as possible.



## HYPOTHETICAL SCENARIO

What we want to create is a neighbourhood that is self-sufficient in water use, identifies with water and functions as a sustainable water community (see the research goals).

In order for the neighbourhood to be self-sufficient in water use, we should have enough storage to fulfil the daily water need. This can be described by the formula total m3 per day = L/per day x 1000 = ((60,5 x number of inhabitants) + (40 x number of employees)) x 1000. This will then be related to m2 by the possible depth that can be created for the different storage options, for example an underground storage reservoir may be 5m deep, but an above ground storage surface may only be 0.10m deep. Ideally there should be more m3 of storage available then the daily need, in order to compensate for dry periods. The average dry period in the Netherlands is 3 days and the longest dry period in 2014 was 15 days (KNMI, 2014).

The formula described above is only what the people and employees in the neighbourhood use on a daily basis, but I order to be a true self-sufficient water neighbourhood, there should be no added stress to the sewage system of Amsterdam in case of rainfall. This means that the neighbourhood should offer enough storage possibility to completely store a peak rainfall. This can be described by the formula, which is based on the peak rainfall of July 2014, m3 total storage = m3 of daily water use + m3 of peak rainfall = ((60,5 x number of inhabitants) + (40 x number of employees)) + (141x10.000=1.410.000m3) (based on a peak rainfall of 141 mm).

In order for the neighbourhood to identify with water people need to be able to see, touch, hear and/or smell water in both private and public areas of the neighbourhood. Water storage should be made possible both public and private and people should be able to decide on this storage both alone and together.

And when the neighbourhood functions as a sustainable water community there should be the common goal to use water sustainably. This goal should be accomplished by the possibility to have inhabitants works together of water storage, connecting all the households to the water system, have households share water storage and have people re-use rain- and grey water.

## GENERIC DATA

| | |
|---|---|
| Housing: | 10.000 inhabitants |
| Businesses: | 5.000 employees |
| Water: | 20 HA |
| Public space: | 11 HA |
| Green space: | 08 HA |
| Possible storage: | 200.000 m3 |

Representation of data in %
made by Author

## SCENARIO 1: OLD SCHOOL AMSTERDAM

The first scenario, scenario 1, is developed to fulfil in the required m3 of rain water storage needed to be able to deliver the required rain water to every household in the designed area. But this is done in a way that it least impacts the further design of the area, so that it becomes a zero perspective to test the other scenario's against.

Therefore, for scenario 1, the water storage in the area is mainly underground. There will be storage underground and underneath buildings. The buildings in the area are connected to these underground storage reservoirs, which makes it possible to re-use the rain water in the households and businesses of the area. Above ground, rain water ponds and wadi's could be created to lower the stress on the sewage system and underground storage system. They also have an added benefit of improving the water quality when combined with helophyte filters. The design of the area is inspired by the street pattern of the historical Amsterdam housing, but instead of water structures, the design uses green structures. The inspiration for the aesthetical part of the design is that of a green urban village, creating a high density urban atmosphere but with green all throughout.

The sustainability in this design comes from the re-use of rain water and the added green structure to Amsterdam North to increase biodiversity and heat stress. Possibilities for interactivity and neighbourhood participation in this model are very low.

## GENERIC DATA

| | |
|---|---|
| Housing: | 9.500 inhabitants |
| Businesses: | 5.000 employees |
| Water: | 23 HA |
| Public space: | 11 HA |
| Green space: | 08 HA |
| Possible water storage: | 200.000 m3 |

Representation of data in %
made by Author

## RESERACH QUESTIONS (IN SHORT)

Watersystem

Direct connection het IJ: Direct connection stays

Flood defence: This design does not add additional flood defence to protect the area from flood risk from het IJ

Heavy rain stress: The design does prove a solution to store heavy rainfall and relieve stress on the sewage system. It does this by creating underground reservoirs for rain water storage, that can store all the rain water of a peak rainfall.

Climate change

Heavy rainfall: The design offers the possibility to store all water of a heavy rainfall, with extra m3 of storage to allow for an increase in rain.
Heat stress: The green structure of the area may relieve heat stress, but the orientation of the design prohibits wind from flowing through the area, because it is not designed towards the main direction of the wind and there is are very little large open spaces.
Increased flood risk: The design does not create additional flood defences.
Longer dry periods: By storing all the rain water the design becomes more resilient to longer dry periods.

Water storage

Visible water storage: There is no visible water storage in the design.

Interactive water storage: The storage methods used in this scenario do not lend themselves to become interactive.
Flexible storage: The methods used are flexible, they function just as well when dry as when wet.
Storage throughout scales: In this scenario, water storage is mainly on the large scale. There are no methods that can be used to storage water on the smaller scale.

Buiksloterham

Visible water: There is no visible water storage. The rain water ponds and the cannel that already flows through the area are the only visible water elements in the design.
Water in public space: Again, there is very little visible water in the design of this scenario.
Connect houses with water: There is no direct visible connection between the housing in the area and the water structure.

Amsterdam

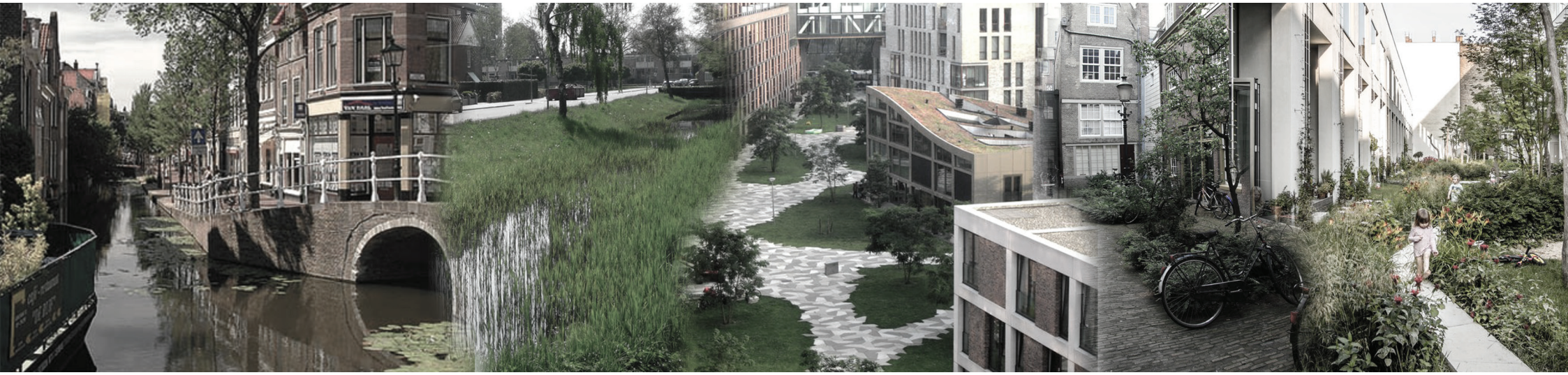
Self-sufficient in water use: The area is capable of storing enough water so that it becomes self-sufficient.
Relieve stress on the sewage system: Because there is so much storage, the stress on the sewage system coming from the Buiksloterham area will be significantly lower. All the rain water will go to the underground
reservoirs, not the sewage system.
Transferability of the technology: The methods used can be applied everywhere.
Transferability of the social aspects: This scenario does not apply any of the social aspects that increase sustainable awareness. Therefore, they are also not transferable, because they are not in the model.

Sustainable awareness

Connecting people: The model does not create an opportunity for people to work together on the water storage system.
Feedback from the municipality: Because the water storage system in scenario 0 is not interactive, it cannot reply to feedback coming from the municipality.
Connection houses with water: There is no visible connection between the houses and the water structure.
Storage through scales: The design only creates storage opportunities

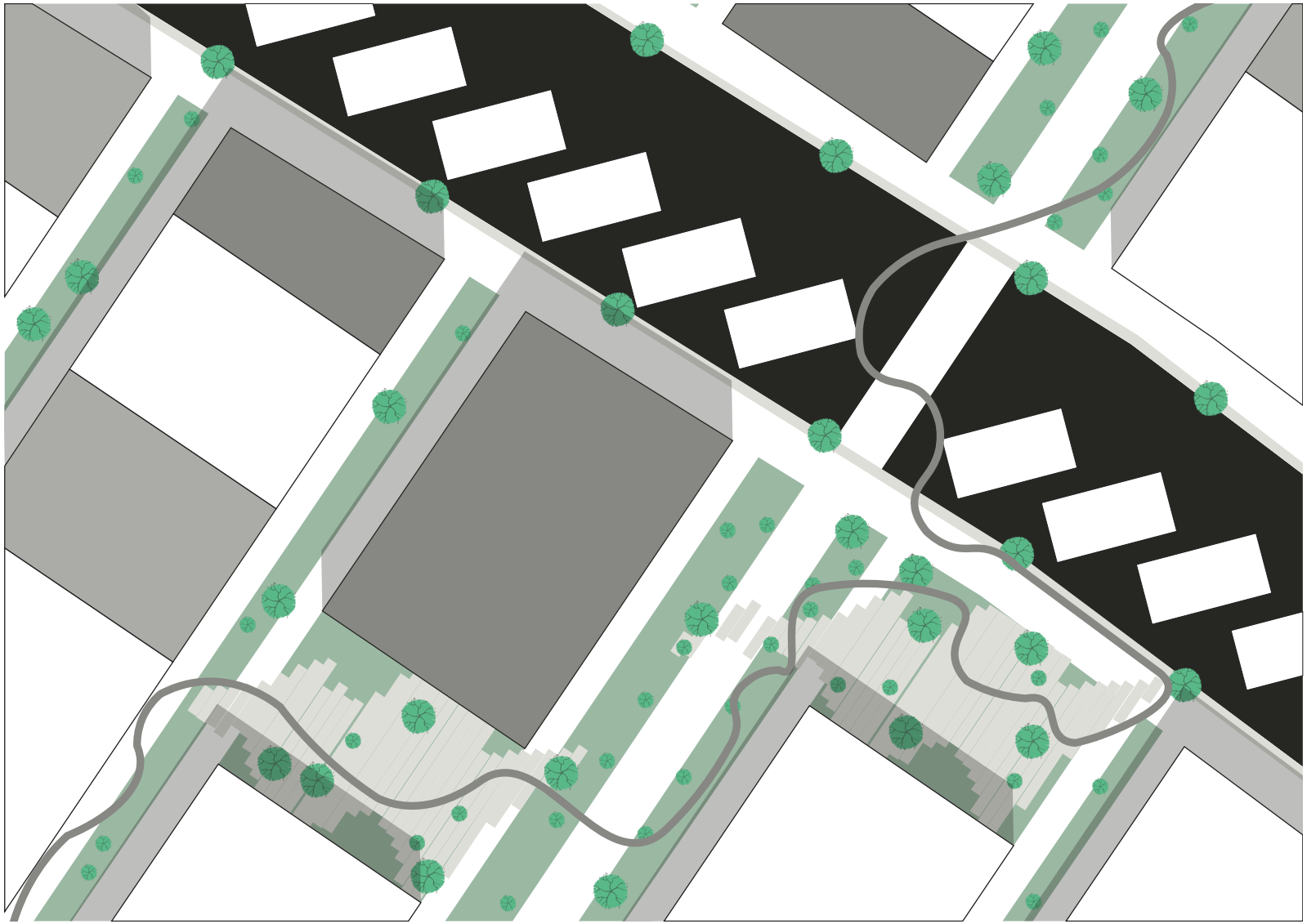
on a large scale.

Scenario 0 may fulfil the wish to have a water self-sufficient Buiksloterham design, but it does not do well for the objectives set for the thesis. It does however give us a nice place to start, since we now know that it is possible to become self-sufficient in water use. We can now see how the other objectives relate to this, by testing it in the next 3 scenarios'.



Impression of the athmosphere for Scenario 1

Plan 1:10.000



Plan 1:1.000

DESIGN

The design of scenario 0 is based upon the cannel houses in Amsterdam, the size of the houses determined by a comparable block, just outside of the center of Amsterdam. The blocks will be between 3-6 layers high, creating a high density area. The streets in the middle are wide, one way streets. In the middle, instead of having a cannel, is a green structure. The green structure leading visually towards the cannel in the middle of the area. The blocks also house some small businesses, allowing for the
oppertunity to create mixed work-living housing. On the east, next to het IJ is a big park and square, forming the center of the area. This connectes to the NDSM-werf at the east of the location. Living boats are situated in the cannel in the middle, to further enhance the relation between the area and the center of Amsterdam.

Looking at the zoom-in it becomes clear that space has been left open in between the blocks to create a green area for the inhabitants of the Buiksloterham area. These green spaces are connected together by means of a flowing route, which also connects with the green structure in the middle of every street. This route also flows towards the cannel in the middle of the area, directing people there. The streets next to the cannel in the
middle will form a river boulevard area, with a pathway next to the riverside which is framed by trees.

THE METHODS

Scenario 0 uses rainwater ponds, wadi's, storage under buildings and underground storage to store rain water. The storage methods are connected to the houses by pipes underground. Most of the methods are applied on the larger scales.

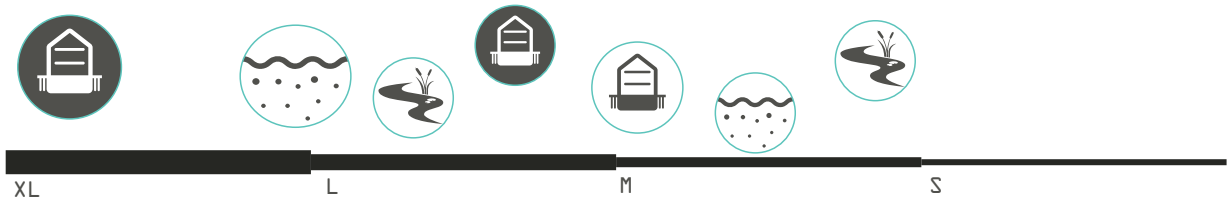
Rainwater ponds

Wadi

Storage under buildings

Underground storage

## THE METHODS

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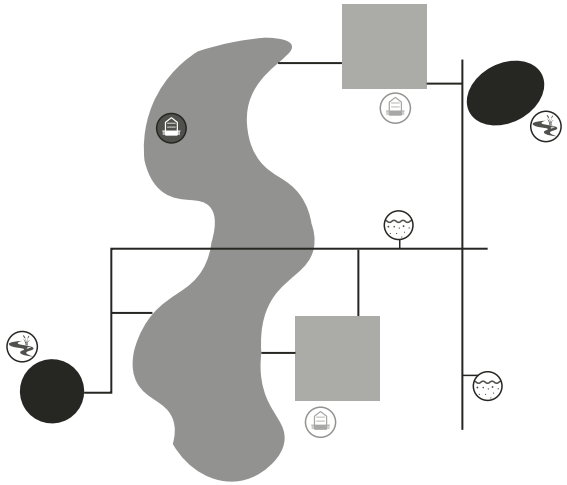


## THE PRINCIPLE

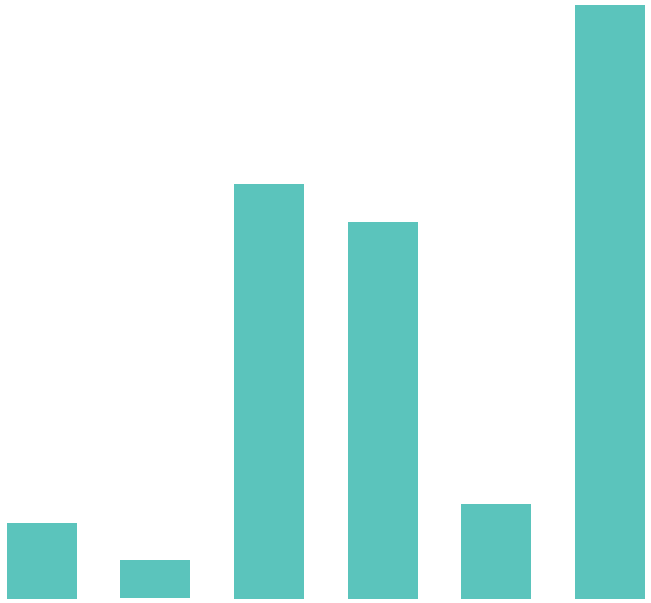
## SCENARIO 2: WATER COMMUNITY

The second scenario, scenario 2, is based on creating as much connection between the daily life of the inhabitants and water. It is designed in such a way that every housing block is surrounded by water and the public space areas are surrounded and/or on the water. Rain water storage are mostly natural storage methods, such as the use of wadi's, rain water ponds and relief to store water in the different areas. There is the possibility for houses to use rain barrels to store their own rain water, to further increase the connection between the inhabitants and the water. Important in this model is the condition of the ground water. The soil in the area is heavily polluted, which means so is the ground water. With the storage methods chosen for the design, the rain water will come in contact with the ground water, after which it cannot be used any more in the households. In this model, either the areas where rain water is stored need to be separated from the soil with a foil, or the soil needs to be cleaned.

The sustainability in this design comes from the living with water aspect, allowing for lots of storage and movement of the water in the area. In this scenario lots of permeable soil, soft surfaces and green space is created. This also helps increase the biodiversity, relieve heat stress and improve the soil conditions.

## GENERIC DATA

| | |
|---|---|
| Housing: | 4.000 inhabitants |
| Businesses: | 1.000 employees |
| Water: | 33 HA |
| Public space: | 21 HA |
| Green space: | 04 HA |
| Possible water storage: | 660.000 m3 |



Representation of data in %
made by Author

## RESEARCH QUESTIONS (IN SHORT)

### Watersystem

Direct connection het IJ: The direct connection between het IJ and the water in the area can be severed in this model.
Flood defence: This design does add additional flood defence to protect the area from flood risk from het IJ
Heavy rain stress: The design does prove a solution to store heavy rainfall and relieve stress on the sewage system. It does this by creating flexible floodable areas.

### Climate change

Heavy rainfall: The design offers the possibility to store all water of a heavy rainfall, with extra m3 of storage to allow for an increase in rain.
Heat stress: The green structure of the area relieves the heat stress and there is a lot of open space in the area.
Increased flood risk: The design creates additional flood defence by separating the area from het IJ.
Longer dry periods: By storing all the rain water the design becomes more resilient to longer dry periods.

### Water storage

Visible water storage: Water is stored all through the public spaces in the area, creating highly visible water storage.
Interactive water storage: The storage methods used in this scenario do not lend themselves to become interactive, with exception of the rain barrels.
Flexible storage: The methods used are flexible, they function just as well when dry as when wet.
Storage throughout scales: In this scenario, there is a connection between the storage methods on every scale, going from small scale storage
interventions on the private level to large scale public storage methods.

### Buiksloterham

Visible water: All storage methods used in this model are visible.
Water in public space: The public space in this design is used for water storage, creating public space that can either be (partly) flooded or public space that is on the water.
Connect houses with water: There is a visible connection between the houses and the water.

### Amsterdam

Self-sufficient in water use: The area is capable of storing enough water so that it becomes self-sufficient.
Relieve stress on the sewage system: Because there is so much storage, the stress on the sewage system coming from the Buiksloterham area will be significantly lower. All the rain water will go to the lowest parts of the area, flooding more and more parts of the neighborhood.
Transferability of the technology: The methods used can be applied everywhere as long as the design of the area allows for water to flow flexible through the intended area and parts of the area can be flooded from time to time.

Transferability of the social aspects: This model creates an environment that is very dependable on the weather and very flexible. This means that the inhabitants will have to be willing to live with these circumstances. Schooling of inhabitants on the importance of this way of water storage can be needed.

Sustainable awareness

Connecting people: The model encourages the inhabitants of a building block to work together on water storage.
Feedback from the municipality: Because the water storage system in scenario 1 is not interactive, it cannot reply to feedback coming from the municipality. The rain barrels are to small scale to be of importance to the municipality when it is in need of water storage.
Connection houses with water: There is a visible connection between the houses and the water structure.
Storage through scales: The design creates storage possibilities for every scale level.

Scenario 2 creates a residential area where the inhabitants will have to live closely to the water. The inhabitants will be forced to give up functioning parts of their public space for weeks, when the water level is high and parts will be flooded. It creates a new way of living with water, forming a water village in the center of Amsterdam.

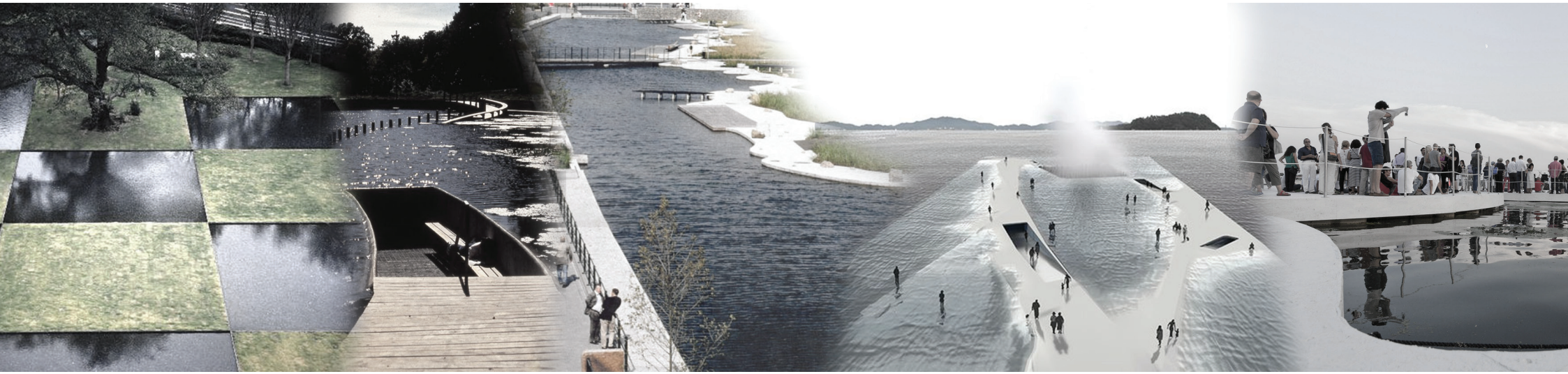
DESIGN

The design of scenario 1 is was inspired by Giethoorn, a small village in the Netherlands where they have no streets, only rivers. Everybody moves there by boats. This living with water idea was what inspired this design. The houses are blocks, with a small green area in the middle which is only meant for the inhabitants of the blocks. The public space is all part of the water storage system, it all can be flooded. The streets are highers then the green surrounding them, so that they remain dry and people can still move through the area in wet periods. The other public space areas, parks and squares for example, are all allowed to be flooded. Functions in these areas will be designed in such a way that they function both wet and dry. All throughout the neighbourhood are little flowing rivers, made by simply digging out the soil so that the water will naturally flow towards these lowers parts.

In the zoom-in we see one of the squares. It becomes clear that the square is surrounded by little rivers and streams, that can grow in size
depending on how much rain fall there is. Parts of the square itself can also be flooded. There is a slightly elevated route going through the area, which will always remain dry.

THE METHODS

Scenario 1 uses rain water ponds, rain barrels, relief, infiltration barrels, urban waterways, seasonal storage and wadi's. The storage systems are all connected by the small rivers, which form a circulair system. The rain barrels allow people to participate in the storage process on a private scale.

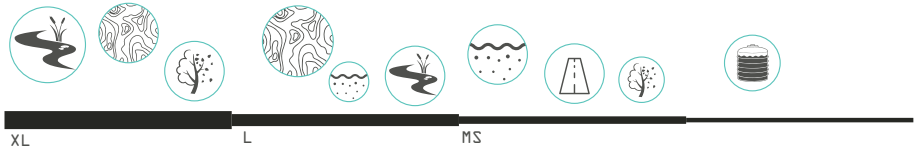


Impression of the athmosphere for Scenario 2

Plan 1:10.000

Plan 1:1.000


## THE METHODS

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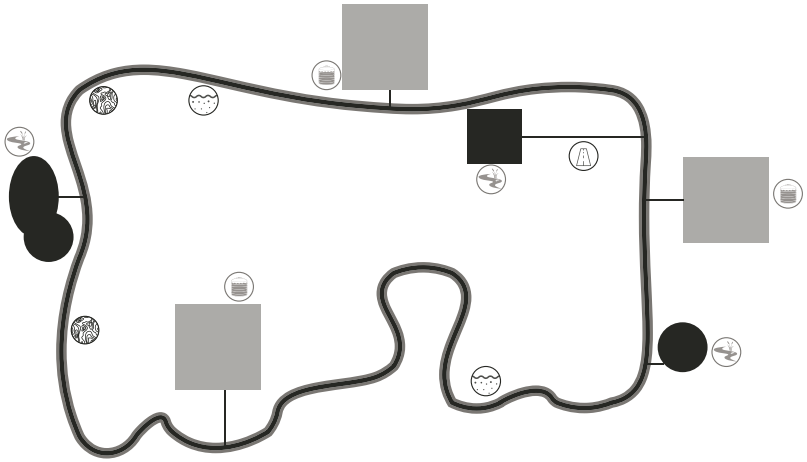

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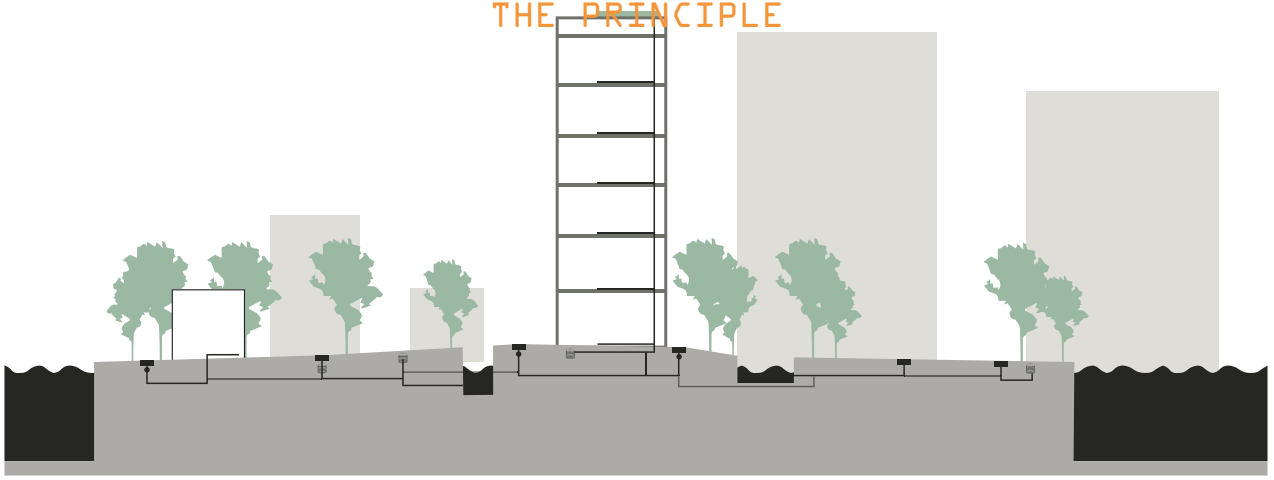
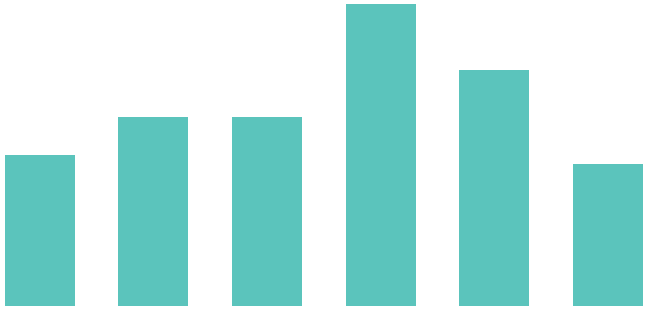


## SCENARIO 3: TECHNOLOGICAL COMMUNITY

Scenario 3 is formed by creating 3 different levels in the area, of which the highest is in the middle. These 3 levels all have a river at the edge, where water can naturally flow into. When the highest level is full, it overflows into the level below and so onwards. At the lowest level the water will simply flow into het IJ. The levels have small rivers going through it as well, connecting them together. Each ring is connected to its own set of other water storage methods. And to the housing blocks on that level. It used a combination of natural storage methods and more integrated ones. The inhabitants of the area are not that involved, most of the methods chosen are non-interactive, and they focus on the larger scales. The public space is where most of the water storage elements are situated.

## GENERIC DATA

| | |
|---|---|
| Housing: | 8.000 inhabitants |
| Businesses: | 5.000 employees |
| Water: | 20 HA |
| Public space: | 18 HA |
| Green space: | 11 HA |
| Possible water storage: | 145.000 m3 |



Representation of data in %
made by Author

## RESEARCH QUESTIONS (IN SHORT)

### Watersystem

Direct connection het IJ: The direct connection between het IJ and the water in
the area can be severed in this model, but with the possibility to overflow into het IJ.
Flood defence: Additional flood defence is added by heightening the area.
Heavy rain stress: This scenario relieves stress on the sewage system, because all rain water can be stored in the area itself.
Heavy rainfall: The design has enough room to store all the rain water of a heavy rainfall, but it does not leave room for a lot more.
Heat stress: The green structure of the area relieves the heat stress and there is a lot of open space in the area.

### Climate change

Increased flood risk: The design creates additional flood defence by separating the area from het IJ and heightening the area itself.
Longer dry periods: It is possible to store all rain water, but there isn't room for a lot extra when there has been a peak rainfall or a long wet
period. So, it is possible to store rain water for dry periods, but not as much as scenario 0 & 1.

Water storage
Visible water storage: Water is stored all through the public spaces in the area, creating highly visible water storage. And water is also stored on the private level, further increasing the visibility.
Interactive water storage: The storage methods used are interactive, although not all of the large-scale water storage methods are interactive.
Flexible storage: The methods used are flexible, they function just as well when dry as when wet.
Storage throughout scales: In this scenario, there is a connection between the storage methods on every scale, going from small scale storage
interventions on the private level to large scale public storage methods.

Buiksloterham
Visible water: All storage methods used in this model are visible.
Water in public space: Water storage is also integrated in the public space in such a way that it does not limit the function of the public space.
Connect houses with water: There is a visible connection between the houses and the water.

Amsterdam
Self-sufficient in water use: The area is capable of storing enough water so that it becomes self-sufficient.
Relieve stress on the sewage system: There is enough storage to store a peak rain fall, so in most cases this scenario will relieve the stress on the sewage system. But there is not a lot of room for much extra rain water, so it will not take away all the stress on the sewage system.
Transferability of the technology: The methods used can be applied in all designs where it is possible to heighten parts of the area, creating different levels.
Transferability of the social aspects: This model has water storage mostly on the large scale, with not a lot of interference from the inhabitants of the area. Awareness in this model will come from visibility and closeness of the water in public space, which could be applied everywhere where it rains enough so that the water is visible most of the year.

Sustainable awareness
Connecting people: The parts of the design of the water storage system that are interactive are both on the small and the large scale. On the large scale, decisions will have to be made by multiple people on how to proceed. In this way it does connect the inhabitants of the area together, but in reality this will only be a select group of people.
Feedback from the municipality: The larger scale interventions could be influenced by the wishes of the municipality. However, because there is
limited amount of water storage, the questions is if this is relevant, since the municipality cannot store excess rain water on the location after a heavy rain fall (since the water storage elements will be completely full already).
Connection houses with water: There is a visible connection between

the houses and the water structure.
Storage through scales: The design creates storage possibilities for every scale level.

Impression of the athmosphere for Scenario 3

Plan 1:10.000

Plan 1:1.000

DESIGN

The design of this scenario was inspired by floodable areas and Ankorpark in Mälmo, Sweden. The idea is that is looks like a natural green area with streams flowing through it, in these streams rain water can gather. These streams flow all throughout the neighbourhood. The area in the middle is higher, so that from that point rain water will automaticly flow towards to lower levels, there there is a higher capacity to store rain water.

In the zoom-in it becomes visible that there is a rover that flows all along the cannel in the middle of the area. This is the final ring, the one of the lowest level. It is seperated from het IJ, but with the possibility to overflow the excess rain water into the cannels connecting this ring river and het IJ. The design is inspired by the edgy formation that water forms in rock. The round shapes of the paths cut through these edgy shapes. The path connectes the North bank and the South bank together. The North bank has a park on it, because this is the side with the most sun. People can walk all along this edge through the park next to the canal. The square in the zoom-in is partly a water square, to increase the m3 of water storage in the area.

THE METHODS

This scenario used rain water ponds, intensive green roofs, relief, infiltration barrels, water squares, urban waterways, seasonal storage, water roofs and wadi's. All of the storage elements are focussed on the large scale, except infiltration barrels which could be applied on the smallest scale.

Rainwater ponds

Intensive green roof

Relief

Infiltration barrels

Watersquares

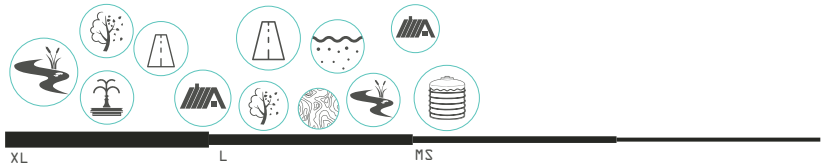
Urban waterways

Seasonal storage

Water roofs

Wadi

## THE METHODS

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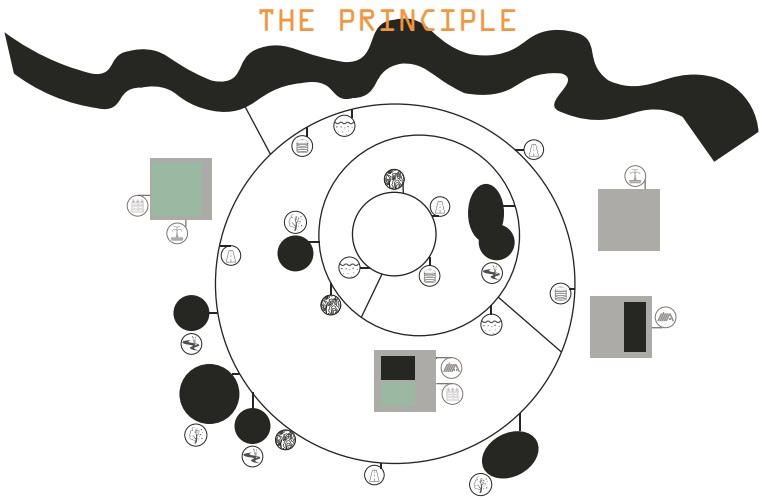

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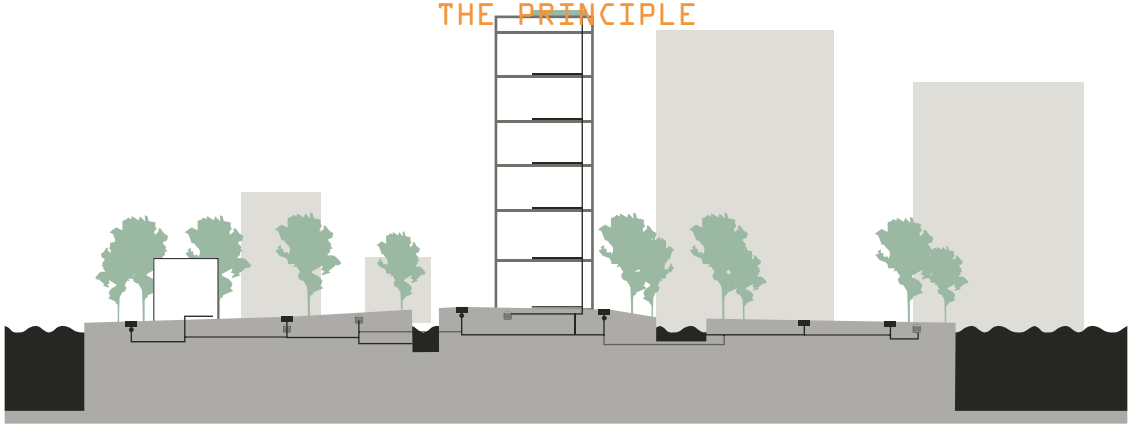
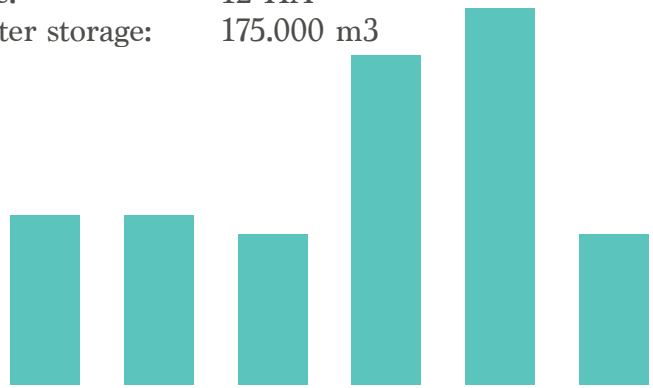


SCENARIO 4: SUSTAINABLE COMMUNITY

Scenario 4 is inspired by the design of the Western harbour area of Mälmo, Sweden. The goal is to integrate water storage at every scale as much as possible, with a focus on the small scale and using as many interactive water storage methods as possible. The design also aims to show as many of these storage methods as possible, so that both visitors and inhabitants of the area are confronted with rain water storage in all the public space areas. Water storage is integrated here with elements like water holding planters, green roofs, water roofs, water walls, but also large scale elements like rain water ponds, urban water ways and seasonal storage.

GENERIC DATA

| | |
|---|---|
| Housing: | 9.000 inhabitants |
| Businesses: | 4.500 |
| Water: | 18 HA |
| Public space: | 19 HA |
| Green space: | 12 HA |
| Possible water storage: | 175.000 m3 |



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made by Author

GENERIC DATA

| | |
|---|---|
| Housing: | 10.000 inhabitants |
| Businesses: | 5.000 employees |
| Water: | 20 HA |
| Public space: | 11 HA |
| Green space: | 08 HA |
| Possible storage: | 200.000 m3 |

RESERACH QUESTIONS (IN SHORT)

Watersystem

Direct connection het IJ: The direct connection between het IJ and the water in the area can be severed in this model.
Flood defence: No additional flood defence is added.
Heavy rain stress: This scenario relieves stress on the sewage system, because all rain water can be stored in the area itself.
Heavy rainfall: The design has enough room to store all the rain water of a heavy rainfall, but it does not leave room for a lot more.
Heat stress: The green structure of the area relieves the heat stress but
there are too little open spaces for the wind to flow freely.

Climate change

Increased flood risk: The design creates no additional flood defence.
Longer dry periods: It is possible to store all rain water, but there isn't room for a lot extra when there has been a peak rainfall or a long wet
period. So, it is possible to store rain water for dry periods, but not as

much as scenario 0 & 1.

Water storage

Visible water storage: Water is stored all through the public spaces in the area, creating highly visible water storage. And water is also stored on the private level, further increasing the visibility.
Interactive water storage: Most of the storage methods used can be made interactive, every inhabitants of the area should be able to participate in this model.
Flexible storage: The methods used are flexible, they function just as well when dry as when wet.
Storage throughout scales: In this scenario, there is a connection between the storage methods on every scale, going from small scale storage
interventions on the private level to large scale public storage methods.

Buiksloterham

Visible water: All storage methods used in this model are visible.
Water in public space: Water storage is also integrated in the public space in such a way that it does not limit the function of the public space.
Connect houses with water: There is a visible connection between the houses and the water.

Timeframe

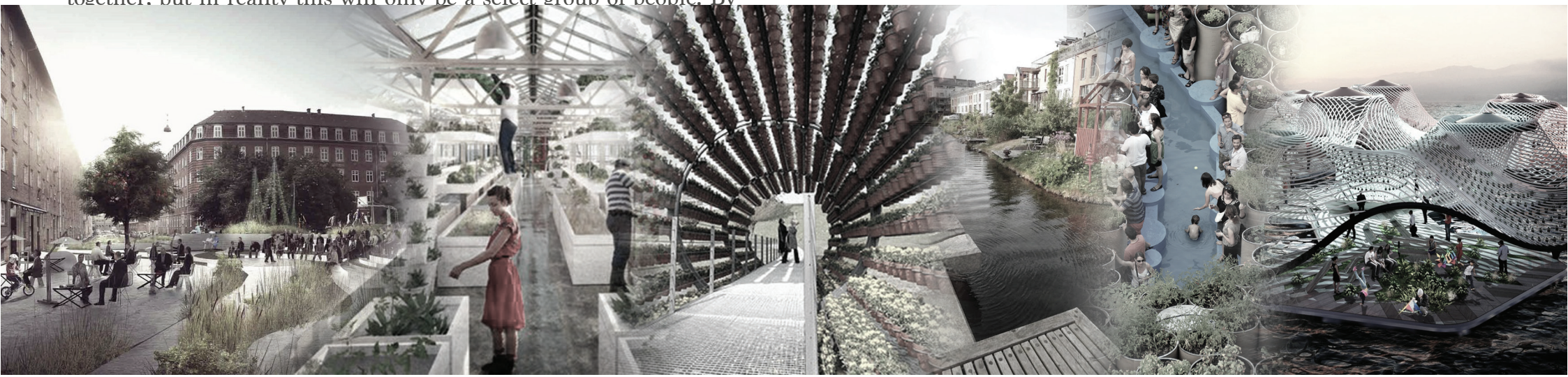
Day-night dependency: There are small-scale storage methods, these will vary throughout the day.
Seasonal variation: The water storage elements will vary through the season; they will probably be full in winter and then towards summer they will empty more and more.
Lifespan: The elements created for water storage have a life span of about 50-100 years. In 50 years, they might be outdated. They are natural storage methods, which could become very inefficient compared to new develop technologies. And the methods used now that depend on technology will be outdated in about 25 years. The methods need to be applied in a flexible way, with the possibility to change them in the future.

Amsterdam

Self-sufficient in water use: The area is capable of storing enough water so that it becomes self-sufficient.
Relieve stress on the sewage system: There is enough storage to store a peak rain fall, so in most cases this scenario will relieve the stress on the sewage system. But there is not a lot of room for much extra rain water, so it will not take away all the stress on the sewage system.
Transferability of the technology: The methods used can be applied in most urban areas, given that they have enough space to be executed.
Transferability of the social aspects: The methods used can be applied in most high-density areas, but a willingness of the inhabitants to participate in living sustainable is preferable. If not, then further education might be necessary to convince inhabitants of the importance of the system.

Sustainable awareness

Connecting people: The parts of the design of the water storage system that are interactive are both on the small and the large scale. On the large scale, decisions will have to be made by multiple people on how to proceed. This way, it does connect the inhabitants of the area together, but in reality this will only be a select group of people. By



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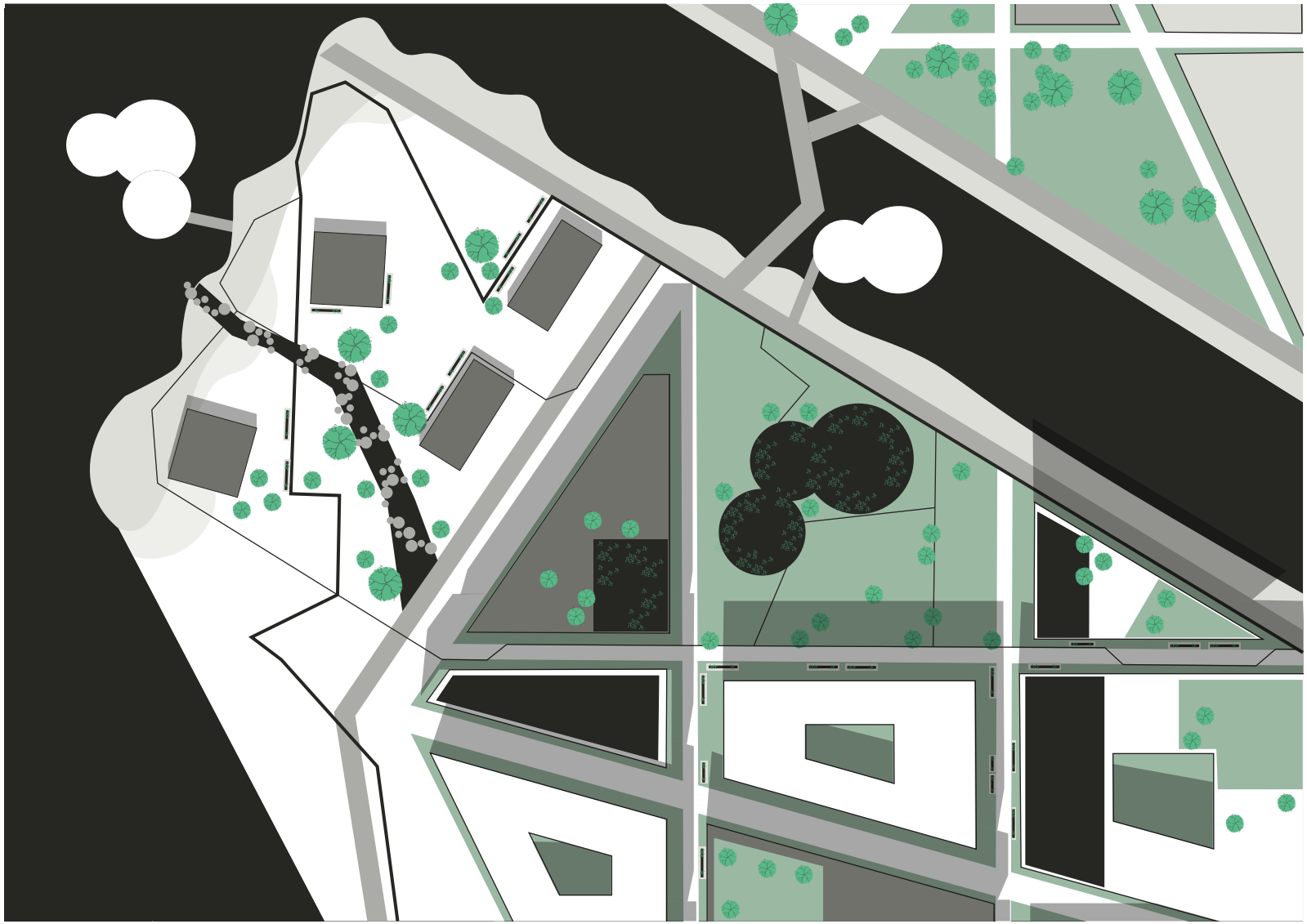


Plan 1:1.000

## DESIGN

The design of this scenario was inspired by the Western harbour area in Mälmo, Sweden. The goal is to integrate rain water storage as much as possible in the design of the area, both private and public. The cannal from het IJ will become a center point in the area, creating large public spaces next to it. These public spaces have forms of water storage integrated through it. Throughout the neighbourhood all the urban waterways form a flowing circle, where helophyte filteres can be added to improve on the quality of the rain water. The buildings can be equipped with water roofs or green roofs. The grid structure of the area is directed at the sun, so that the streets will have the sun in them during the afternoon. Water is an element of design all throughout this scenario.

## THE METHODS

This scenario used rain water ponds, intensive green roofs, water holding planters, infiltration barrels, water squares, urban waterways, rain barrels, water roofs and water walls. These are storage methods that run through the different scales and can react to wishes of inhabitants and the
municipality.

Rainwater ponds

Intensive green roof

Rainbarrels

Infiltration barrels

Watersquares

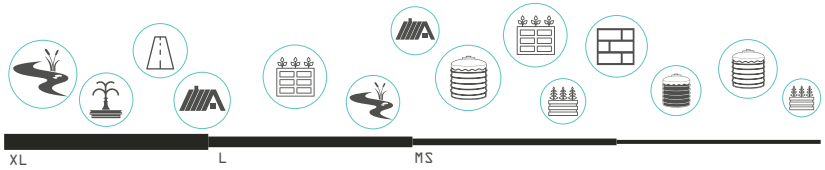
Urban waterways

Water holding planters

Water roofs

Water walls

## THE METHODS

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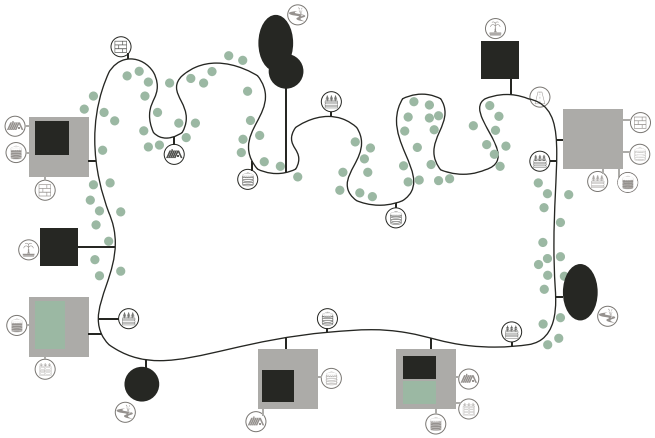

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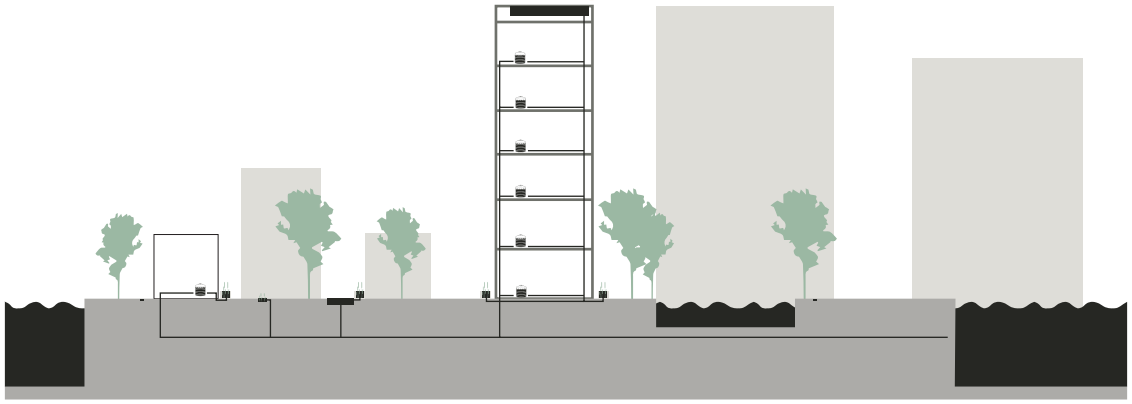


SCENARIO COMPARISSON

The first scenario was to test a zero point, to see what is needed to create a water self-sufficient neighbourhood. Scenario 1, aims to test how people can integrate their daily lives with water in their direct environment. Scenario 1 looks at natural ways of water storage that can be integrated into a modern day high density urban area. The last scenario, scenario 4, looks at water storage methods that can be made interactive and tries to apply those in as many ways possible.

The first and second scenario do not live up to the objectives set for the thesis very well. They both fail to meet the 3 main criteria. The first scenario, the zero point, only meets 3 of the objectives, of which two are external ones. However, what is interesting, they do have a much higher storage capacity then the last two scenarios. This means that they could have a more significant contribution to the whole of the Amsterdam system. The last two scenarios, at the moment, lack this, which is a missed oppertunity.

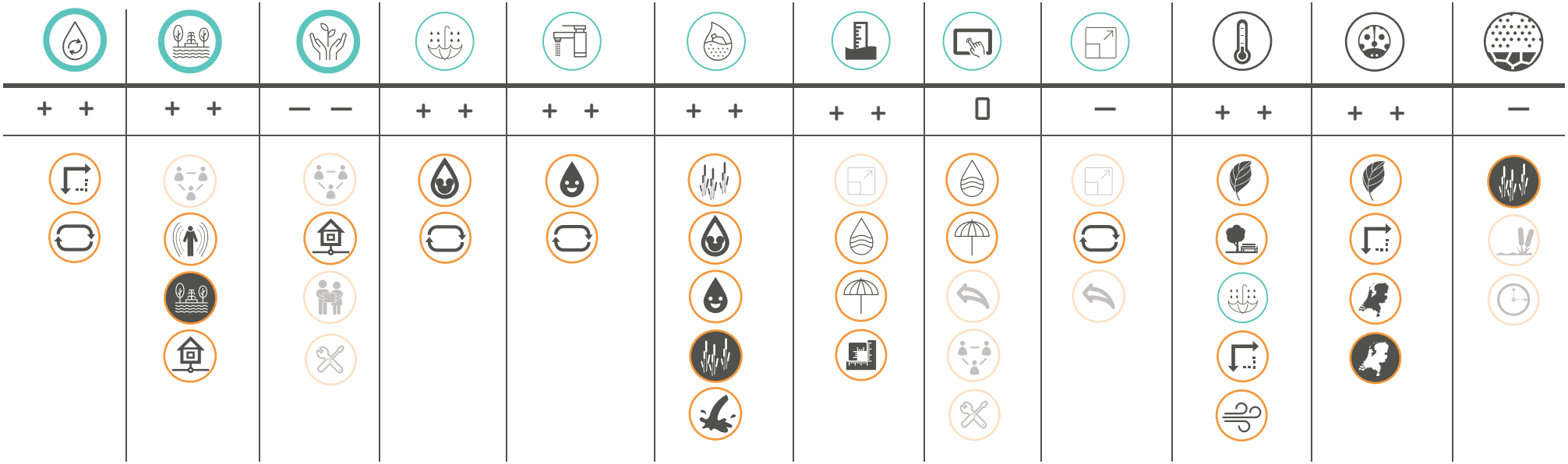
The third scenario scores a lot higher then the first two. But creating a sustainable neighbourhood, interactive water storage and water storage throughout the scales is still lacking in this model.

The last scenario, scenario 4, does quite well on the objectives. It does however need to pay more attention to re-using grey water and creating better soil conditions.

When looking at the research question we see the same pattern, the first two scenarios don't solve all the problems. The last two almost do, but in the next step more attention needs to be paid to flood defences, interactive water storage, storage throughout the scales and the social aspects of the design. In general, scenario 4 does quite well, but still leaves room improvement on flood defence and the social aspects of integrated water storage.

The recommendation for the next step is to look at scenario 2, take some of the elements from scenario 3 and add these to the system of scenario 4. The design will have to look towards the scenario 1 and scenario 2 to see how the capacity for rain water storage can increase. For the next step, the scenario also has to be translated to a realistic design. The models that are now created are sketches, models to calculate and see effects of different storage concepts. For the actual design this concept needs to be translated to reality, combining it with elements like transport, daily life functions, social use of public space, landscape and the environment.

All scenarios have good points, for the best design of an interactive flexible water storage system for Buiksloterham, they need to be combined and integrated all throughout the design.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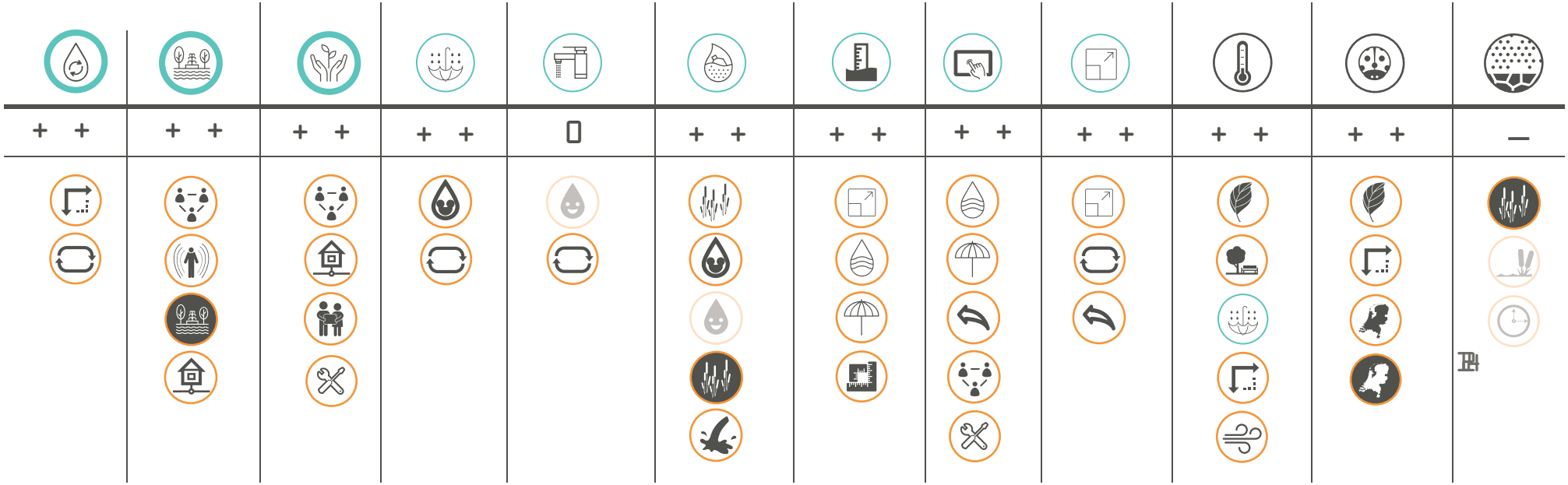
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# APPENDIX 2; WATER STORAGE METHODS

In order to see what the best storage methods are for Buiksloterham, first the thesis will examine all the methods currently available for rain water storage. Then the different scenario's will test to see which methods work in what circumstances, to see which are the best match for Buiksloterham.

Note, the methods are all from the book: Green-blue grids; Manual for Resilient cities 2016). By Hiltrud Pötz.

*Rainwater pond*

Rain water ponds temporarily store rain water. They can be connected to a system that determines when it's going to rain, so that the pond is only emptied just before rainfall. The depth of the pond should preferably be 1.5m or more, to ensure a good water quality. The pond can b
e combined with plants, like helophyte filters, to further improve the water quality. Then the water needs to flow through the pond, which means it needs to be connected to a circulating system. If needed, they can be lined with a water proof foil, to prevent filtration of the water into the ground.
Apply when: When there is a high ground level, it needs to be applied with the water proof foil. There are no other criteria.
Added benefits: improves the water quality, the biodiversity and relieves heat stress.
Negatives: Maintenance is needed.
Possibility to become interactive: Yes.
Flexibility: Medium.
Visibility: High

*Intensive green roof*

An intensive green roof is a green roof with various types of plants, which means that it can hold quite a bit of rainwater. They store the
rainwater in the substrate layer. It also increases the quality of the water.
Apply when: The roofs of a building are constructed to bear a higher load then usual (more than 1kN/m2). Or additional constructive measurements are taken to bear the higher load.
Added benefits: improves water quality, biodiversity and relieves heat stress.
Negatives: Construction needs to be tested to see if it's strong enough and maintenance is needed.
Possibility to become interactive: No
Flexibility: Low.
Visibility: Low.

Wadi

Intensive green roof

*Relief*

Relief, a difference in height, creates different areas where one can overflow with water while the high parts remain dry. This can create a landscape that is capable of overflowing once in a while, without doing damage to the buildings, the infrastructure, the inhabitants etc.
Apply when: When it's possible that some parts of the area overflow with rain water once in a while.
Added benefits: Increases the water quality and it's a natural solution to water storage.
Negatives: When the rain water comes in contact with the ground water it's no longer usable and parts of the area can't be used when they are flooded.
Possibility to become interactive: No.
Flexibility: High.
Visibility: High.

*Infiltration barrels*

These are plastic barrels that are placed underground, that are connected to a pipe. This pipe gathers the water from above the ground and then it transports through this pipe towards the barrels. From the bottom of the barrels the water can be, slowly, released towards the ground again.
Apply when: Anywhere under the ground, above the ground water level.
Added benefits: Little.
Negatives: They need to be placed above the ground water level.
Possibility to become interactive: Yes.
Flexibility: High.
Visibility: Low.

*Water squares*

A water square is a lowered square that can hold rain water. The rain water flows from elsewhere in the area to this square. It combines water storage with other daily urban life.
Apply where: High density urban areas.
Added benefits: Can be created with non-permeable street coating, like concrete or asphalt.
Negatives: Very high in maintenance, every time the square is used as water storage it needs to be completely cleaned.
Possibility to become interactive: Yes
Flexibility: High.
Visibility: High.

*Urban waterways*

Urban waterways are in theory like oversized open gutters. They are concrete structures where rain water can be stored. The rain water is gathered there from the surrounding area. They can be combined with rocks, plants and other elements to make them look more interesting and increase the water quality.
Apply when: In urban areas where there is space, the width is preferably >1m.
Added benefits: Increases the water quality.
Negatives: There needs to be attention in the design process for both

Garden roof

the wet and the dry extreme, to make sure it's still aesthetic even when completely dry.
Possibility to become interactive: Yes
Flexibility: High.
Visibility: High.

*Seasonal storage*

Seasonal storage is an area where the excess of water from the winter period can be stored until it needs to be used in summer. They also create extra storage for peak rainfall periods. They can be combined with helophyte filters as well, increasing the water quality. Or they can be created with nature friendly shores, to increase the biodiversity.
Apply when: Anywhere where a large area (>/=50m2) for water storage can be made available.
Added benefits: Functions as peak rainfall storage as well, increased the water quality and biodiversity and it relieves heat stress.
Negatives: Loose the use of large area for a long period of time.
Possibility to become interactive: Yes.
Flexibility: High.
Visibility: High.

*Water roof*

A water roof is a roof that is designed so that rain water can be stored on top of it.
Apply when: The construction of a roof can bear a load of minimum 1kN/m2.
Added benefits: The water also keeps the temperature of the building underneath it down.
Negatives: Because the water level fluctuates, this temperature also fluctuates.
Possibility to become interactive: Yes.
Flexibility: High.
Visibility: High.

*Wadi*

A Wadi is a ditch or small stream that is filled with gravel or sand. This way the Wadi can both hold and filter the rain water. The water flows from buildings and streets into the Wadi. Plants can be added to the Wadi to increase the water quality and the appearance.
Apply when: A Wadi is most effective with a low ground water level, but it could be applied elsewhere as well. It works best with a permeable soil.
Added benefits: Increases the water quality, the biodiversity and relieves heat stress.
Negatives: They are high in maintenance and maintenance costs.
Possibility to become interactive: No.
Flexibility: High.
Visibility: Medium.

*Storage under buildings*

Storage under buildings can be created in different ways. One can store water in the basement, create a water storage area in unused space or form a water reservoir underneath the structure of the buil-

ding.
Apply when: The construction of the buildings is strong enough.
Added benefits: Easy storage without effect on the public space.
Negatives: Expensive and usually the water does not flow in these r eservoirs.
Possibility to become interactive: Yes.
Flexibility: High.
Visibility: Low.

*Water holding planters*

Water holding planters are planters that are closed at the bottom and filled with gravel (underneath the soil and the plants). They have a drainage pipe that is connected to the regular sewage system.
Apply when: High density urban areas.
Added benefits: Creates a better water quality and increases the biodiversity.
Negatives: The planters need to be made at least 1m high in order to store water. Mostly made out of concrete.
Possibility to become interactive: Yes
Flexibility: High.
Visibility: Low.

*Underground storage*

Underground storage is created much in the same way as storage under buildings, by creating a reservoir underground.
Apply when: There is enough space in the subsoil for underground storage.
Added benefits: Easy method for storage without effect on the public space.
Negatives: Expensive and the water doesn't flow in these reservoirs. Also, it might not be possible to build high structures on top of these reservoirs.
Possibility to become interactive: Yes.
Flexibility: High.
Visibility: Low.

*Water walls*

A water wall is a wall that is made with blocks, which are hollow, that can store rain water.
Apply when: A non-constructive wall can be made out of these blocks.
Added benefits: Easy to integrate in households.
Negatives: When used indoor they can create cold-bridges.
Possibility to become interactive: Yes.
Flexibility: High.
Visibility: Low.

*Rain barrels*

A rain barrel is a barrel that can store rainwater. It is connected to the drainpipe from the roof. They can store up to 200L per barrel. They are easy to apply, and might not be able to store the most water but they highly increase sustainable water awareness.
Apply when: Possible for every household, but it needs to be connected to the sewage system.
Added benefits: Very cheap solution.

Negatives: They don't store a lot of water and they can freeze in winter.
Possibility to become interactive: Yes
Flexibility: High
Visibility: High

*Garden roof*

A garden roof is a green roof on which you can walk, sit, dance, run etc. It needs a heavier construction then the other types of green roofs.
Apply when: The roofs of a building are constructed to bear a higher load then usual (more than 1,5kN/m2). Or additional constructive measurements are taken to bear the higher load.
Added benefits: improves water quality, biodiversity and relieves heat stress.
Negatives: Construction needs to be tested to see if it's strong enough and maintenance is needed.
Possibility to become interactive: No
Flexibility: Low.
Visibility: Low.

*Polder roof*

A polder roof is a green roof with an added substrate layer to increase the capability to store rainwater.
Apply when: The roofs of a building are constructed to bear a higher load then usual (more than 1kN/m2). Or additional constructive measurements are taken to bear the higher load.
Added benefits: improves water quality, biodiversity and relieves heat stress.
Negatives: Construction needs to be tested to see if it's strong enough and maintenance is needed.
Possibility to become interactive: No
Flexibility: Low.
Visibility: Low.

*Infiltration areas with storage*

Infiltration areas are unpaved areas where the rain water can be temporarily stored. They are lowered about 30 cm from the ground level. Gutters can lead the rain water from buildings and streets to these infiltration areas where, in time, the water simply seeps into the ground.
Apply when: There is a low ground water level and the soil type makes filtration into the ground possible.
Added benefits: Increases the water quality.
Negatives: They can't be walked on and not all soil types are suited.
Possibility to become interactive: No
Flexibility: High.
Visibility: High

When looking at the Buiksloterham area, most of these storage methods can be applied. The ones with the need for a low ground water
level might be more difficult, since the ground water level at Buiksloterham is at -0.50m. When using these methods, extra measures need to be taken in order to make sure they still work (Pötz, 2016).

The different scenario's will use varying combinations of the storage methods, depending on the technologies they use, the visibility, flexibility and possibility to be made interactive.

Pictures: (Amsterdam Rainproof, 2017)

# APPENDIX 2; PLANTS

LEGEND


Shape of tree/plant


Suited for wet ground


Suited for high and low temperatures


Benefitial to ecology


Origins from the Netherlands


Leaf tree


Pine tree


Looses leaves in winter


Suited for polluted ground


Cleaning to polluted ground


Suited for urban environment


Flower colour

SQ In design applied on squares
WP In design applied in water park
GP In design applied in green park
GA In design applied on green axis
ST In design applied in streets
BB In design applied in building blocks
WS In design applied in water storage areas

## FRAXINUM EXCELSIOR - GEWONE ES
25-30 M

SQ WP GP GA ST BB WS

## POPULUS NIGRA - ZWARTE POPULIER
25-30 M

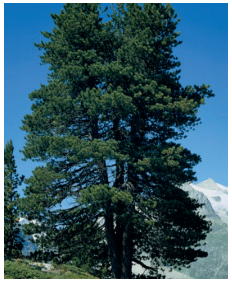
SQ WP GP GA ST BB WS

## ALNUS GLUTINOSA - ZWARTE ELS
15-20 M

SQ WP GP GA ST BB WS

## SALIX BABYLONICA - TREURWILG
12-15M

SQ WP GP GA ST BB WS



## PINUS CEMBRA - ALPENDEN
10-15 M

SQ WP GP GA ST BB WS

## QUERCUS ROBUR - ZOMEREIK
25-30 M

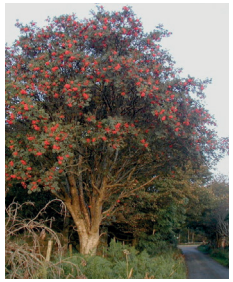
SQ WP GP GA ST BB WS

## SALIX PENTANDRA - LAURIERWILG
10-15 M

SQ WP GP GA ST BB WS

## PLATANUS X HISPANICA - GEWONE PLATAAN
20-35 M

SQ WP GP GA ST BB WS



## SORBUS AUCUPARIA - GEWONE LIJSTERBES
8-12 M

SQ WP GP GA ST BB WS

## CLETHRA ALNIFOLIA - SCHIJNELS

1.8-2.0 M

SQ
WP
GP
GA
ST
BB
WS

## HYDRANGEA INVOLUCRATA - HORTENSIA

1.8-2.2 M

SQ
WP
GP
GA
ST
BB
WS

## SAMBUCUS NIGRA - GEWONE VLIER

3.0-4.0 M

SQ
WP
GP
GA
ST
BB
WS

## LONICERA PERICLYMENUM - WILDE KAMPERFOELIE

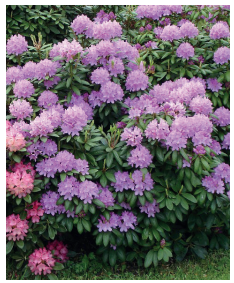
4.0-6.0 M

SQ
WP
GP
GA
ST
BB
WS

## SKIMMIA JAPONICA - SKIMMIA

0.5-0.6 M

SQ
WP
GP
GA
ST
BB
WS



## ROSEUM ELEGANS - RODODENDRON

2.5-3.5 M

SQ
WP
GP
GA
ST
BB
WS

## CRAAEGUS LAEVIGATA - TWEESTIJLIGE MEIDOORN

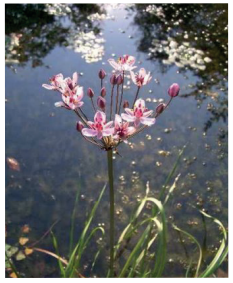
4.5-5.5M

SQ
WP
GP
GA
ST
BB
WS

## SAGITTARIA SAGITTIFOLIA - PIJLKRUID

0.4-0.6 M

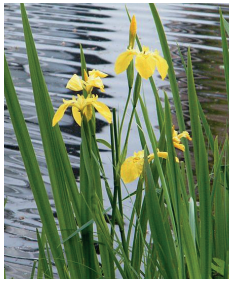
SQ
WP
GP
GA
ST
BB
WS



## BUTOMUS UMBELLATUS - ZWANENBLOEM

0.8-1.0 M

SQ
WP
GP
GA
ST
BB
WS



## IRIS PSEUDACORUS - GELE LIS

0.8-1.0 M

SQ
WP
GP
GA
ST
BB
WS

## TYPHA LATIFOLIA - GROTE LISDODDE

1.8-2.0 M

SQ
WP
GP
GA
ST
BB
WS

## PERSICARIA BISTORTA - ADDERWORTEL

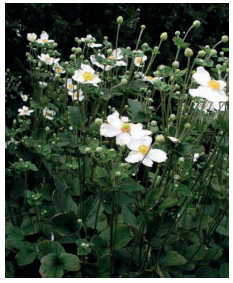
0.3-0.5 M

SQ
WP
GP
GA
ST
BB
WS

## AJUGA REPTANS - KRUIPEND ZENEGROEN

0.1-0.2 M

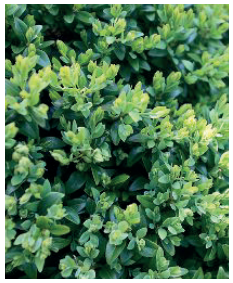
SQ
WP
GP
GA
ST
BB
WS



## ANEMONE HUPEHENSIS - HERFSTANEMOON

0.6-1.2 M

SQ
WP
GP
GA
ST
BB
WS



## PACHYSANDRA TERMINALIS - BUXUS

0.1-0.2 M

SQ
WP
GP
GA
ST
BB
WS

## SEDUM SPECTABILE - VETKRUID

0.4-0.6 M

SQ
WP
GP
GA
ST
BB
WS

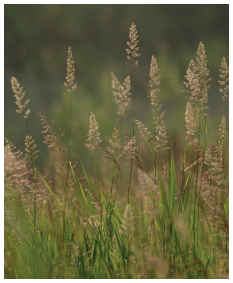
## ATHYRIUM FILIX-FEMINA - WIJFJESVAREN

0.4-0.5 M

SQ
WP
GP
GA
ST
BB
WS

PANICUM VIRGATUM - VINGERGRAS
1.0-1.2 M

SQ
WP
GP
GA
ST
BB
WS



PHALARIS ARUNDINACEA - RIETGRAS
1.0-1.5 M

SQ
WP
GP
GA
ST
BB
WS

ACHILLEA MILLEFOLIUM - DUIZENDBLAD
0.5-0.6 M

SQ
WP
GP
GA
ST
BB
WS

SAGINA SUBULATA - PRIEMVETMUUR
0.0-0.1 M

SQ
WP
GP
GA
ST
BB
WS

HERNIARIA GLABRA - KAAL BREUKKRUID
0.0-0.1 M

SQ
WP
GP
GA
ST
BB
WS

# APPENDIX 3; MATERIALS

## STONE PAVING

200x300x35

WP SQ GA BB ST WS

## STONE PAVING

190x90x65

WP SQ GA BB ST WS

## STONE PAVING

190x90x65

WP SQ GA BB ST WS

## STONE PAVING

175x82x50

WP SQ GA BB ST WS

## PLASTIC PAVING

150X300X65

WP SQ GA BB ST WS

## CONCRETE PAVING

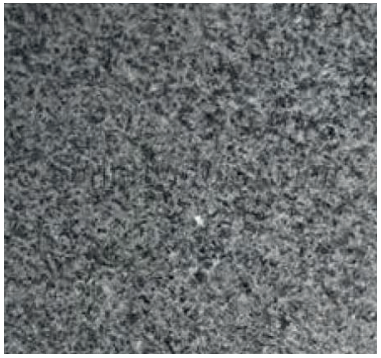
150X300X65

WP SQ GA BB ST WS

## MARBLE PAVING

200x400x35

WP SQ GA BB ST WS



## GRANITE TILE

800x800x32

WP SQ GA BB ST WS

## GRANITE TILE

800x800x32

WP SQ GA BB ST WS

## SIAM STONE TILE

600x600x35

WP SQ GA BB ST WS

## CONCRETE TILE

800x800x32

WP SQ GA BB ST WS

## CONCRETE TILE

600x600x85

WP SQ GA BB ST WS

## GRANITE TILE

600x300x32

WP SQ GA BB ST WS

## PEBBLES

XXxXXxXX

WP SQ GA BB ST WS

## EUROPEAN OAK

100x360x22

WP SQ GA BB ST WS

## FRENCH OAK

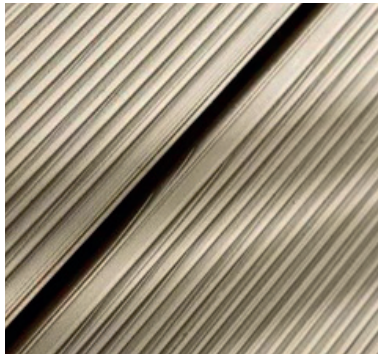
100x360x22

WP SQ GA BB ST WS

## DOUGLAS FIR

110x380x22

WP SQ GA BB ST WS



## COMPOSIT WOOD

100x350x22

WP SQ GA BB ST WS

## THERMAL TREATED OAK

110x380x22

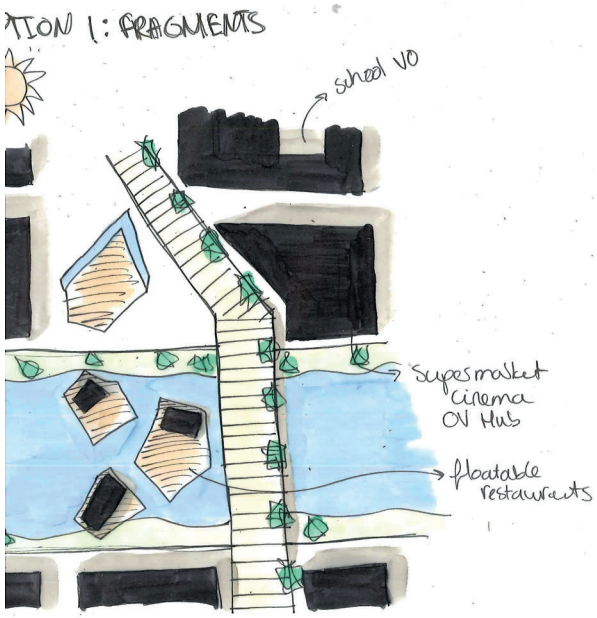
WP SQ GA BB ST WS

## THERMAL TREATED MIXED WOOD

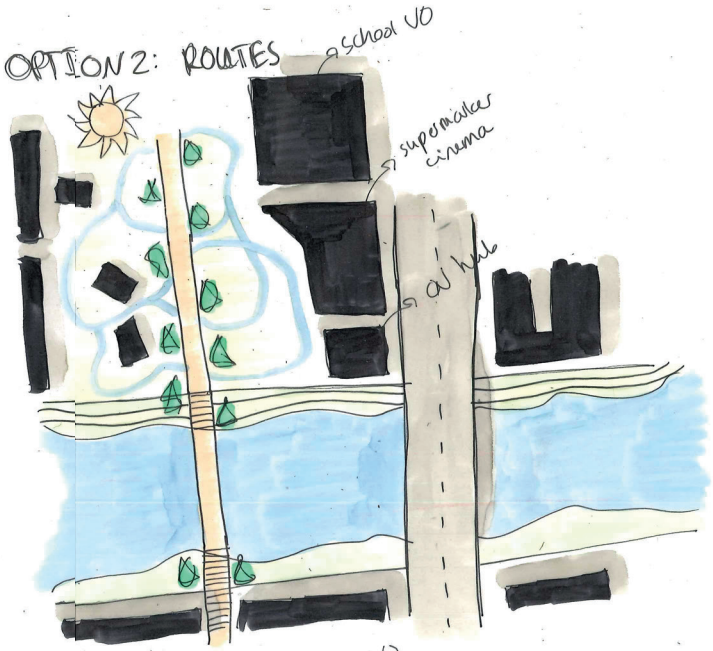
110x380x22

WP SQ GA BB ST WS

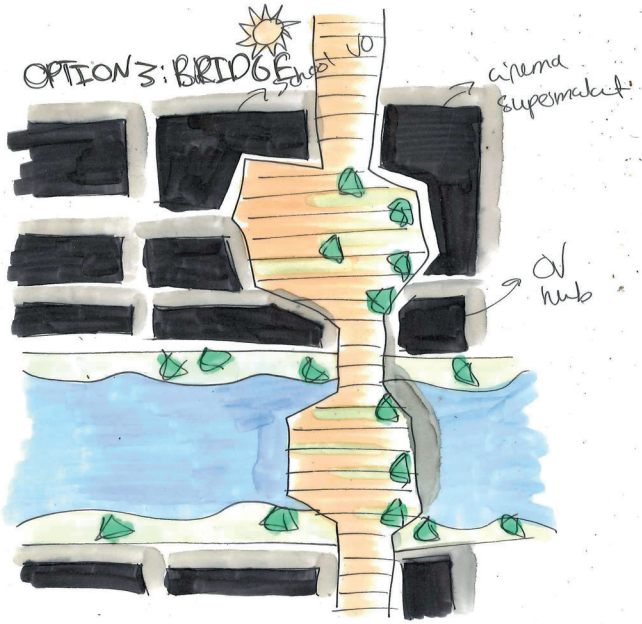
# APPENDIX 3; SKETCHING




idge connection N2
ragments form second connection?
hat functions on water?
orks with rain/storm/wind?
stra water storage on square and bridge

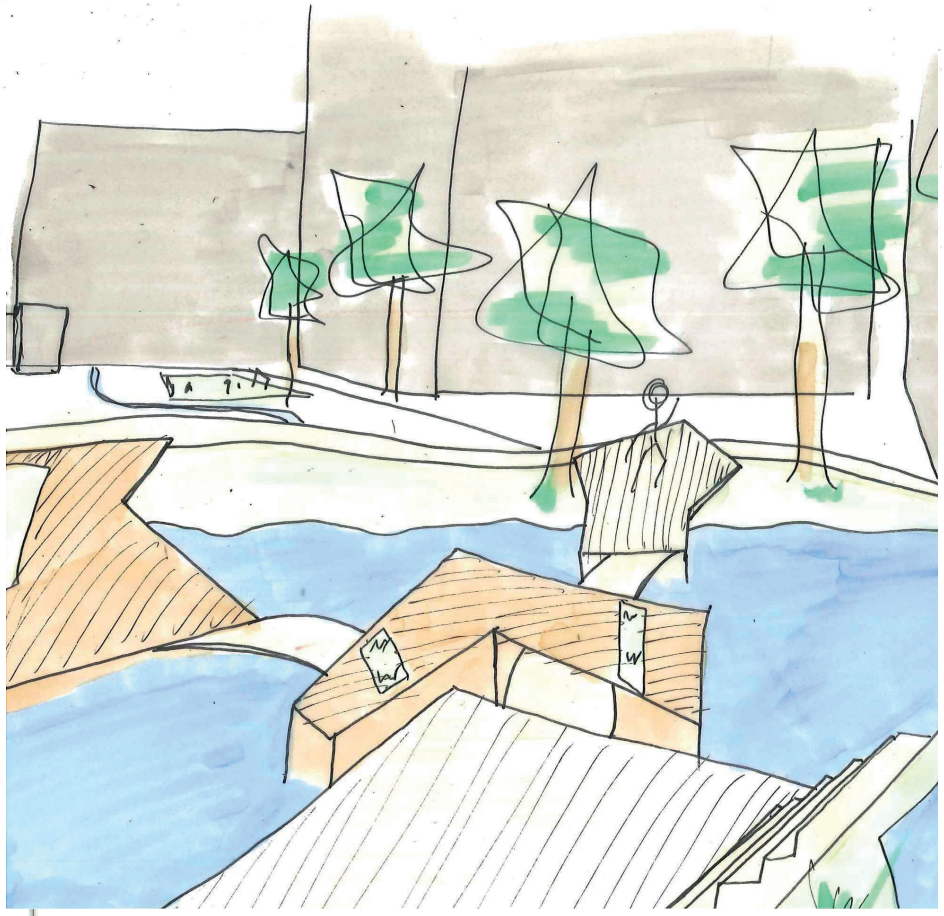


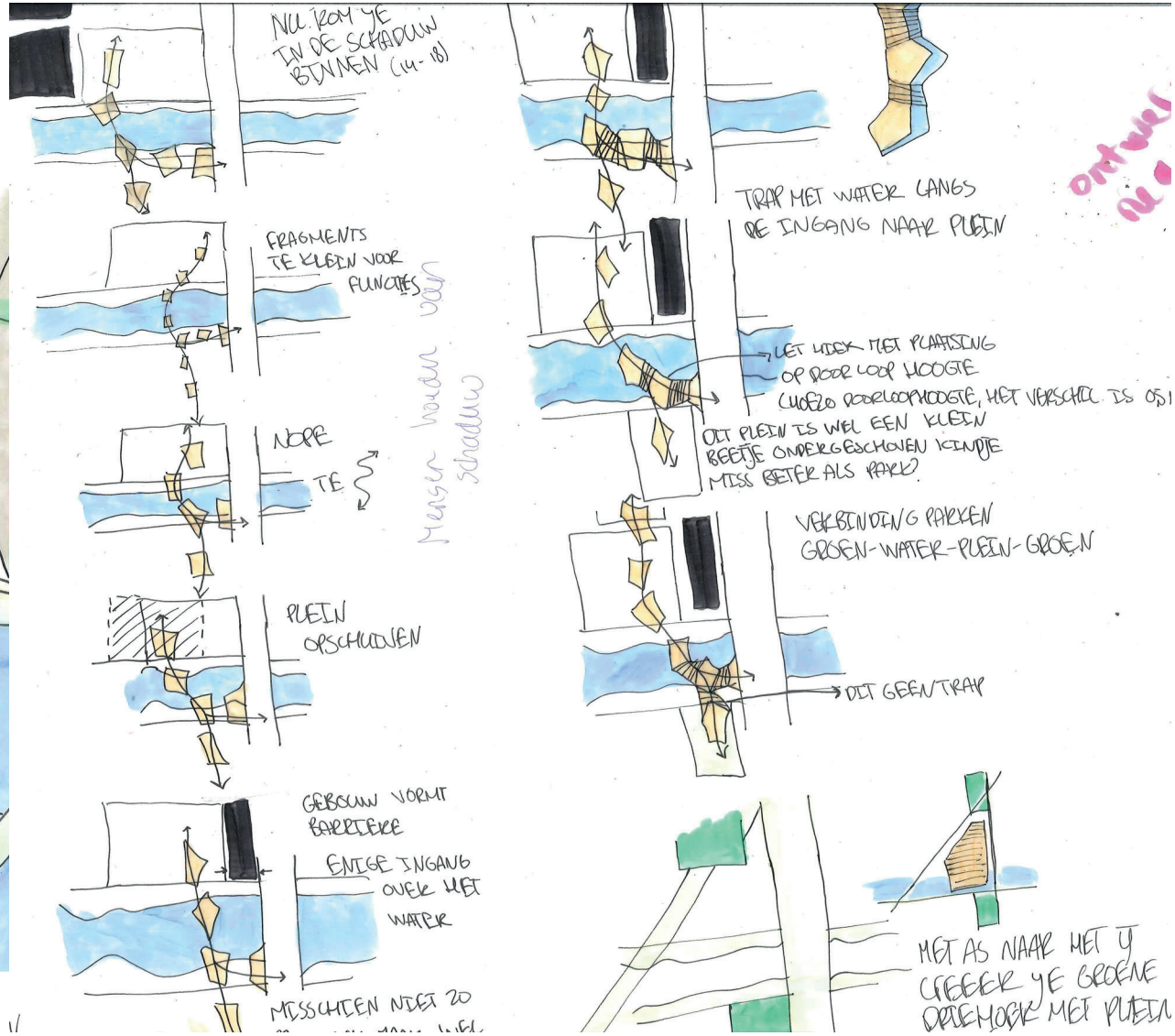

- Route connection N2
- Contact water by walking over
- Route could be like NY high line/ blue green line going through neighborhood
- Bridge for car connection
- Buildings facing square / route
- Car route is secondairy route

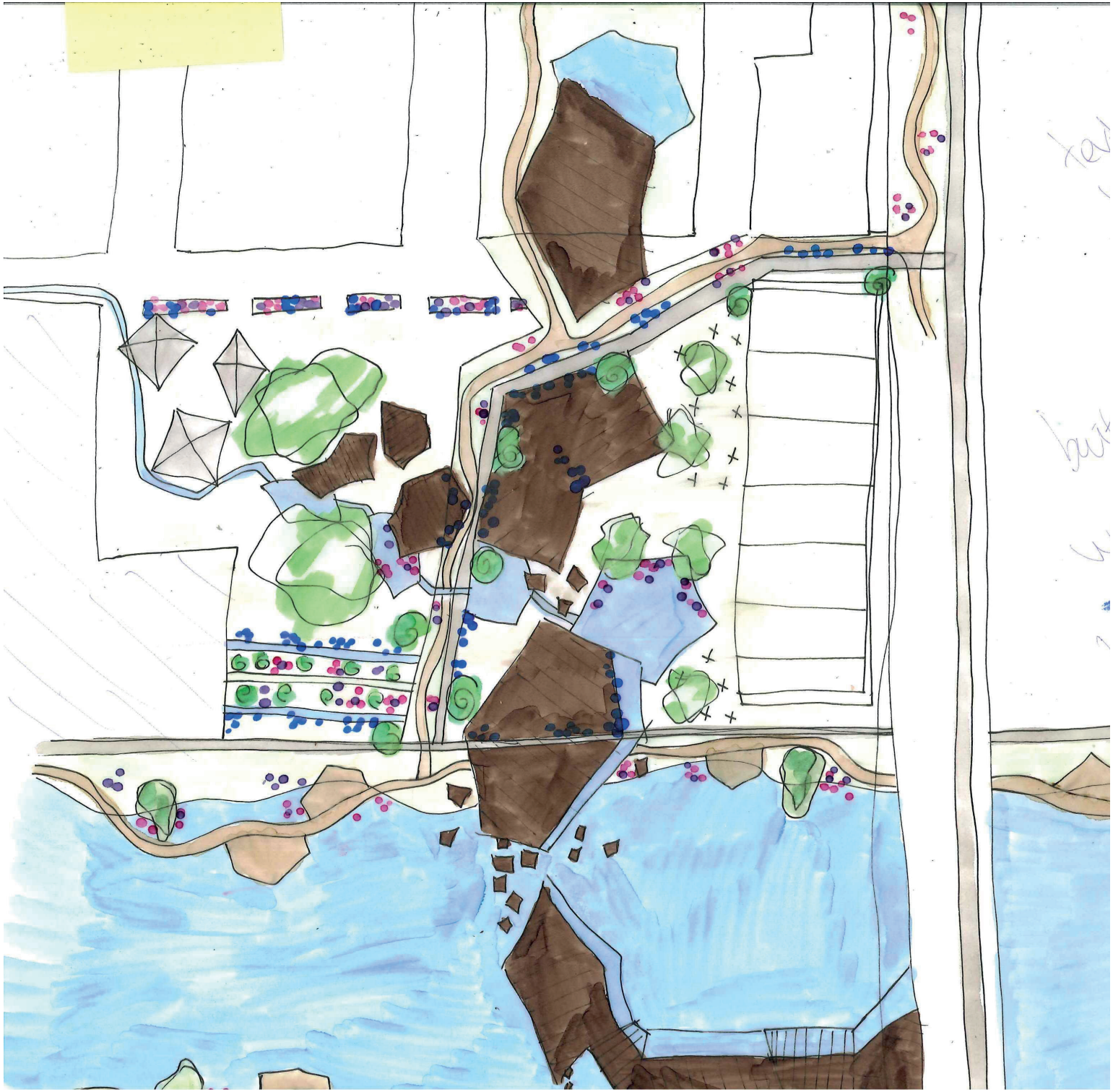


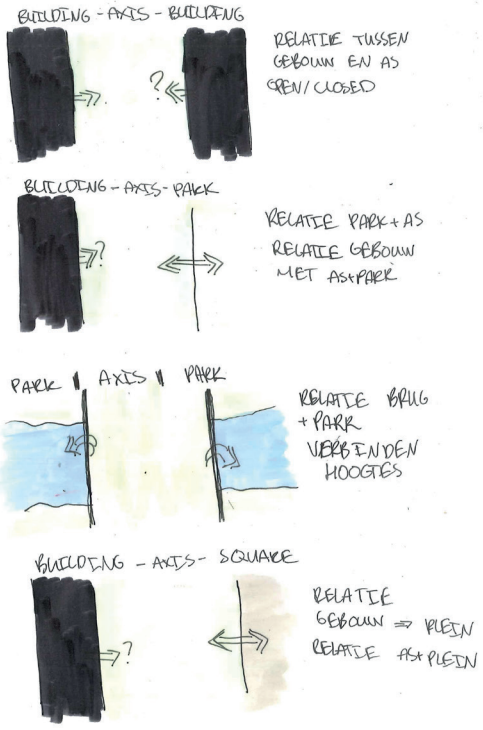

- Bridge = square
- functions in buildings
- More seperated functions/ buildings vs open space
- Bridge = green blue line
- Bridge = water storage

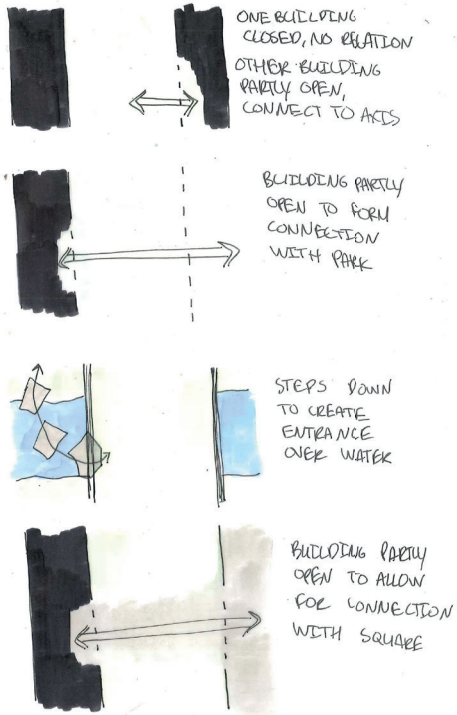
Plus en min

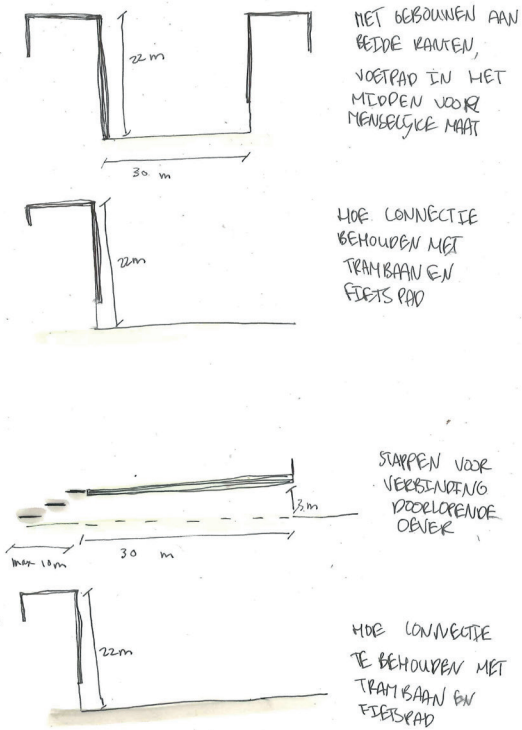


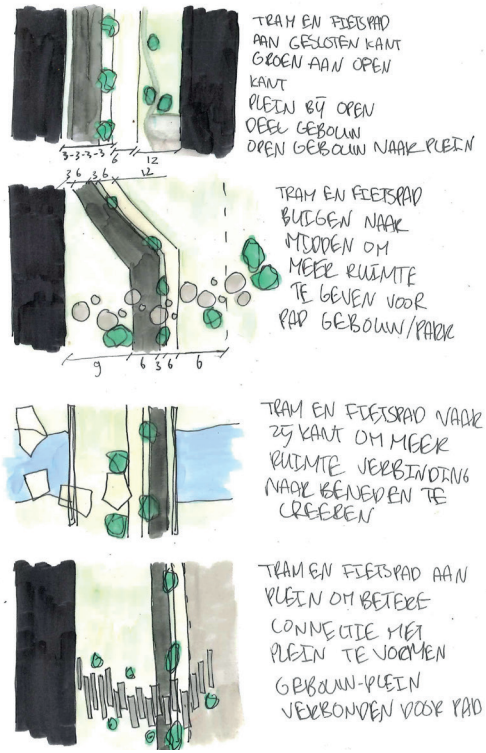

NU. ROM YE IN DE SCHADUW BINNEN (14-18)
FRAGMENTS TE KLEIN VOOR FUNCTIES
NOPE
TE
PLEIN OPSCHUIVEN
GEBOUW VORMT BARRIERE
ENIGE INGANG OVER HET WATER
MISSCHIEN NIET 20
TRAP MET WATER LANGS DE INGANG NAAR PLEIN
LET HIER MET PLAATSING OP ROOD LOOP HOOGTE
DIT PLEIN IS WEL EEN KLEIN BEETJE ONDERGESCHOVEN KINDJE MISS BETER ALS PARK?
VERBINDING PARKEN GROEN-WATER-PLEIN-GROEN
DIT GEEN TRAP
MET AS NAAR MET Y CREEER YE GROENE DRIEHOEK MET PLEIN

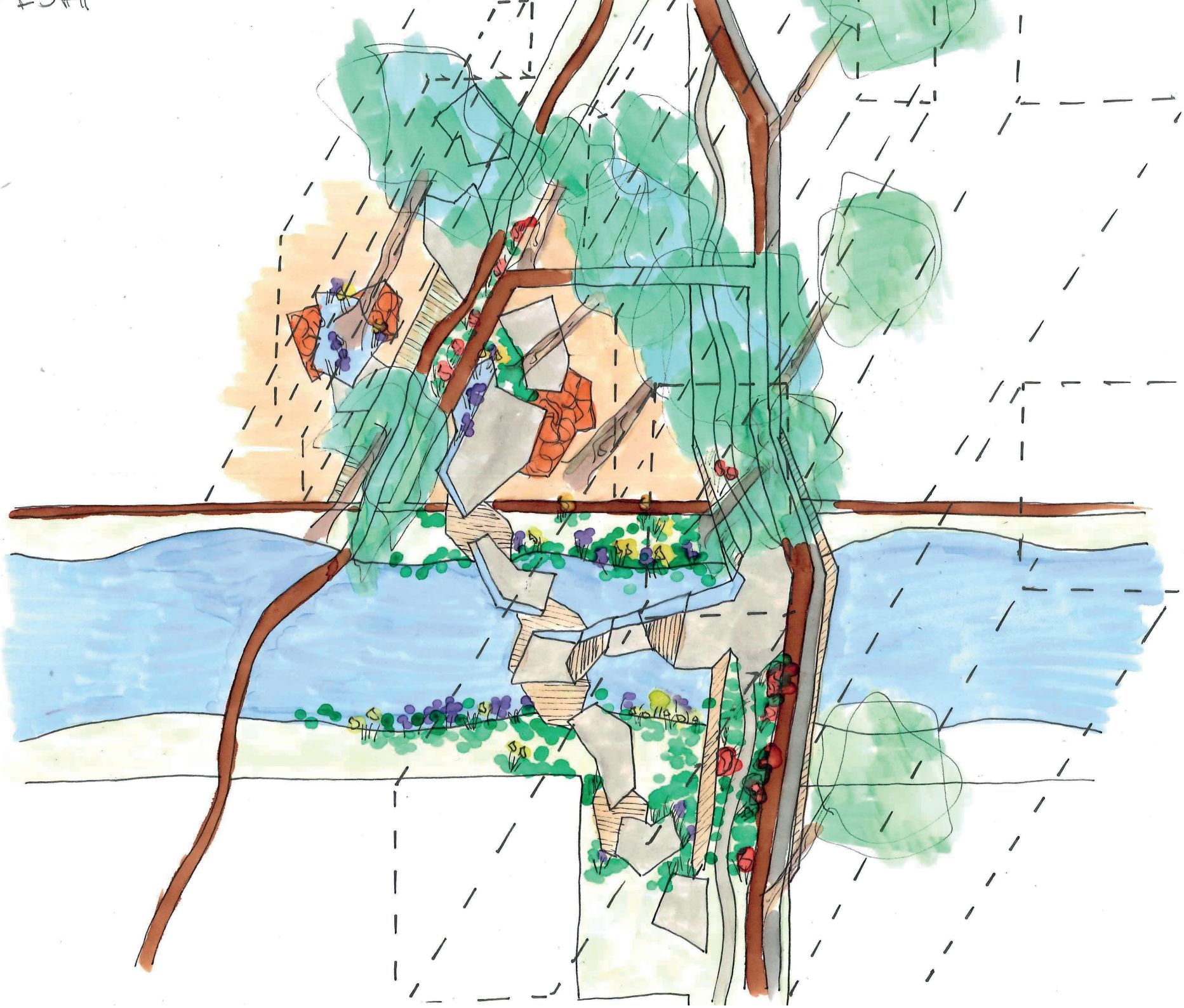



BUILDING - AXIS - BUILDING
RELATIE TUSSEN GEBOUW EN AS OPEN/CLOSED
BUILDING - AXIS - PARK
RELATIE PARK + AS
RELATIE GEBOUW MET AS+PARK
PARK AXIS PARK
RELATIE BRUG + PARK VERBINDEN HOOGTES
BUILDING - AXIS - SQUARE
RELATIE GEBOUW ⇒ PLEIN
RELATIE AS+PLEIN


ONE BUILDING CLOSED, NO RELATION
OTHER BUILDING PARTLY OPEN, CONNECT TO AXIS
BUILDING PARTLY OPEN TO FORM CONNECTION WITH PARK
STEPS DOWN TO CREATE ENTRANCE OVER WATER
BUILDING PARTLY OPEN TO ALLOW FOR CONNECTION WITH SQUARE


22 m
30 m
MET GEBOUWEN AAN BEIDE KANTEN, VOETPAD IN HET MIDDEN VOOR MENSELIJKE MAAT
22m
HOE CONNECTIE BEHOUDEN MET TRAMBAAN EN FIETSPAD
1,3m
max 10m
30 m
STAPPEN VOOR VERBINDING DOORLOPENDE OEVER
22m
HOE CONNECTIE TE BEHOUDEN MET TRAMBAAN EN FIETSPAD


TRAM EN FIETSPAD AAN GESLOTEN KANT GROEN AAN OPEN KANT
PLEIN BIJ OPEN OEVER GEBOUW
OPEN GEBOUW NAAR PLEIN
TRAM EN FIETSPAD BUIGEN NAAR MIDDEN OM MEER RUIMTE TE GEVEN VOOR PAD GEBOUW/PARK
TRAM EN FIETSPAD VAAK ZIJ KANT OM MEER RUIMTE VERBINDING NAAR BENEDEN TE CREEREN
TRAM EN FIETSPAD AAN PLEIN OM BETERE CONNECTIE MET PLEIN TE VORMEN
GEBOUW-PLEIN VERBONDEN DOOR PAD



## CONCRETES

- EBB

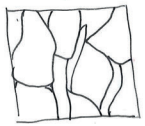
- REGENWATER STAAT IN LAGERE PELEN

- RAINAWAY GARDEN ROTTERDAM
- RESILIENT MATERIAL

- GEOSTEEN

- TEXTURIZED CONCRETE
- DURABLE
- CHEAP
- LARGE COLOUR RANGE

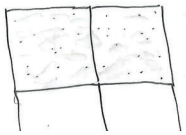
- HUGGING CLAYROLLS



- RELIËF VOOR REGENWATER

- 50×50 cm
- DURABLE

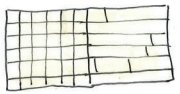
- ARDEX ARDURAPID



- LICHT GEMÊLEERD OF CLEAN TE VERKRIJGEN
- CONCRETE TILES
- DURABLE
- SMOOTH TEXTURES

## BRICK & STONE

- CLASSIC STONE



- RELIEF

- TEXTURED
- DURABLE
- FABRICATED IN PANELS
- LARGE VARIETY

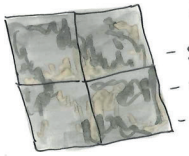
- PEBBELS

- GOOD PERMEABILITY
- NATURAL LOOK
- DURABLE
- WEATHER RESISTANT

- FIBERSTONE → NERO MARQUINA

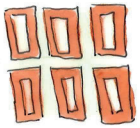
- MARBEL STRUCTURE (ZWART)
- CHEAPER
- DURABLE
- WEATHER RESISTANT

- STAVONA



- GREY TILES WITH SLIGHT COLOUR VARIATION
- SMOOTH TEXTURE
- WEATHER RESISTANT
- DURABLE

- PERMEABLE BRICKS



- HIGH PERMEABILITY
- NATURAL LOOK
- WEATHER RESISTANT

- COBBELSTONES

- NATURAL LOOK
- DURABLE
- WEATHER RESISTANT
- MANY COLOURS

(cradle) groene functie inrichting

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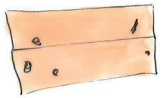
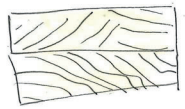
permeabiliteit

- CYPRESS



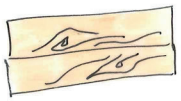
- GEEN/WEINIG ZICHTBARE NERF
- OPVALLENDE RONDE 'HART' IN HOUT
- ROODBRUINE KLEUR
- GESCHIKT VOOR BUITEN

- DOUGLAS FIR



- OPVALLENDE NERF
- LICHT HOUT
- VERWEERT GRIJS

- BLACK LOCUST



- OPVALLEND HART/NERF PATROON
- DURABLE
- LICHTE KLEUR

- IPE

- DONKERDER HOUT
- KLEURVERSCHILLEN
- WEINIG OPVALLENDE NERF
- DURABLE
- WEATHERS LIGHT GREY

- EUROPEAN LARCH

- OPVALLENDE NERF
- LICHTE KLEUR

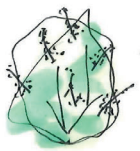
WATER PARK

PLEIN

GROENE AS

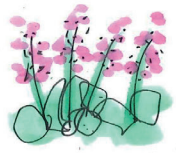

Goud Beik Framed Fietspad
Zomer Eik als hotse mega boom op plein
bloembakken met Adderwortel, Lingergras
Waterspuare met Pijlkruid, Zwanenbloem, Gele Lis, Rietgras
Squares → Grote bomen, struiken als scheiding, bloembakken en water met veel kleur
Wilder stukje met kruidig & wijfjesvaren
Verblijfsplekje omlijst met boeren hortensia's
kruidig omlijst fietspad
Bloemenveld met Adderwortel & kruipend zenegroen & Lingras
waterbakken met wat Gele Lis & Rietgras & Zwanebloemen
Struikenveld met boerenhortensia & Schijn Elis
Natuurlijk ogend waters/ wetlands park idee
Met de N kant iets meer open ivm connectie plein
Mensen kunnen hier relaxen in een wetlands park
Hemelwater beging

sboom
* 10-20 m
* witheems
* rood blad
* goed bij water

- Schijnels

* 1,5-2m
* goed bij water
* witte pluimbloemen
* witheems

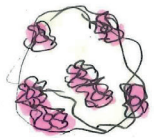
- Pijlkruid

* 0,10-1 m
* groeit in water
* wit met paarse bloem
* inheems

- Adderwortel

* 0,3-1 m
* roze bloem
* goed met
* inheems

esdoorn

* 12-15 m
* witheems
* goed bij water
* meerstammig

- Bosen hortensia

* 0,5 - 1,5 m
* witheems
* roze, wit of blauwe bloemen
* goed water & stad

- Zwanebloem

* 0,5 - 1,2m
* groeit in water
* wit met roze bloemen
* inheems

- kruipend Zenegroen

* 0,4 - 0,5
* paarse
* goed
* inheem

- Wijfjesvaren

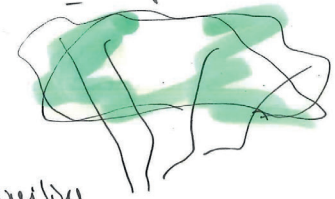
* 0,3-0,5 m
* inheems
* goed m

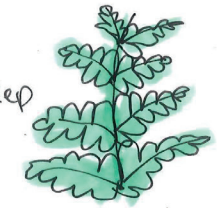
- Gele lis

* 0,8 - 1 m
* groeit naast water
* gele bloem
* inheems

Plantaan
weinig ecologisch

* 35 m hoog
* goed bij water
* stadsboom
* goed tegen luchtverontreiniging
* inheems Fout

- Spoorkruid

* 3-6 m
* meerstammig
* inheems
* goed water

- Adelaarsvaren

* 0,5 - 1m
* inheems

- Lisdodde

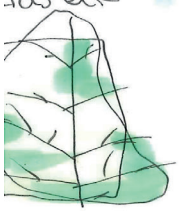
* 1-2m
* water max 15 diep
* groeit in water
* sigaars pluim
* inheems

- Moeashyacint

* 0,3 - 1 m
* groeit naast water
* paarse bloem
* Brede bladeren
* witheems

- Daglelie

* 0,3 - 0,5 m
* witheems
* rood, roze wit
* goed bij

ras eik

* 20 m hoog
* goed bij water
* witheems
* breed onderkant

- Gewone Vlier

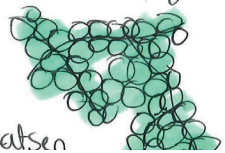
* 3-5 m
* witte bloemen met zwarte bessen
* goed biodiversiteit
* goed water
* inheems

de Lijster bes

* 10 m
* witheems
* goed bij water

- Wilde kamperfoelie

* 2-10 m
* grote witte bloemen
* goed water

- Penning kruid

* 0,10 - 0,6 m
* inheems
* kruipplant

- Vingergras

* 0,05-
* goed
* zuive